MP2235S

High-Efficiency, 3 A, 16 V, 800 kHz Synchronous Step-Down Converter

DESCRIPTION

The MP2235S is a high-frequency, synchronous, rectified, step-down, switch-mode converter with built-in power MOSFETs. It offers a compact solution to achieve a 3 A continuous output current with excellent load and line regulation over a wide input supply range. The MP2235S has synchronous mode operation for 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 (TSD).

The MP2235S requires a minimal number of readily available, standard, external components and is available in a space-saving 8-pin TSOT23 package.

FEATURES

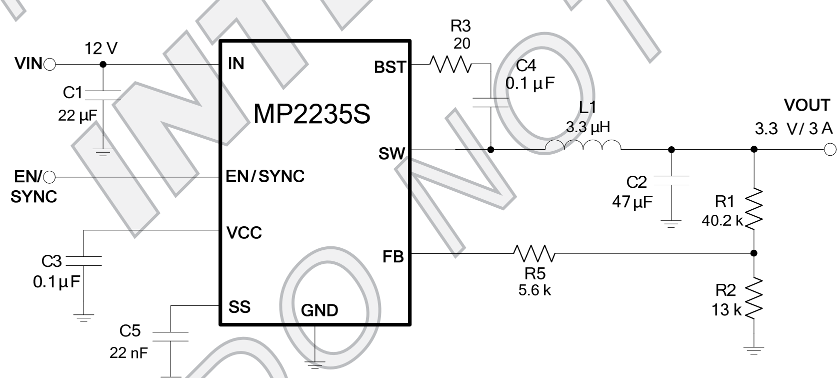
- Wide 4.5 V to 16 V Operating Input Range
- 120 mΩ/50 mΩ Low $R_{DS(ON)}$ Internal Power MOSFETs
- High-Efficiency Synchronous Mode Operation
- Fixed 800 kHz Switching Frequency
- Synchronizes from a 300 kHz to a 2 MHz External Clock
- Power-Save Mode at Light Load
- External Soft-Start
- Over-Current Protection and Hiccup
- Thermal Shutdown
- Output Adjustable from 0.804 V
- Available in a 8-pin TSOT-23 Package

APPLICATIONS

- Notebook Systems and I/O Power
- Digital Set-Top Boxes
- Flat-Panel Televisions and Monitors
- Distributed Power Systems

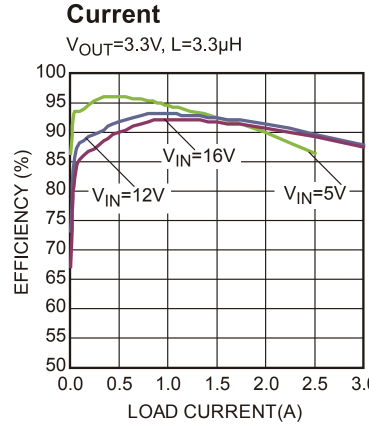
All MPS parts are lead-free, halogen-free, and adhere to the RoHS directive. For MPS green status, please visit the MPS website under Quality Assurance.

TYPICAL APPLICATION



Efficiency vs. Load Current

V_{OUT}=3.3V, L=3.3µH



ORDERING INFORMATION

Part Number*	Package	Top Marking
MP2235SGJ	TSOT23-8	*See Below*

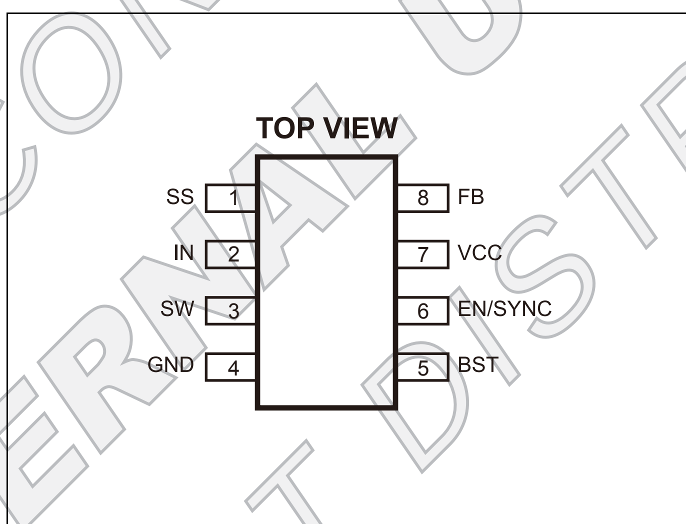
* For Tape & Reel, add suffix –Z (e.g. MP2235SGJ–Z)

TOP MARKING

|AQAY

AQA: Product code of MP2235SGJ
Y: Year code

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS [1]

V_{IN} ....-0.3 V to 17 V
V_{SW}.........-0.3 V (-5 V for <10 ns) to 17 V (19 V for < 10 ns)
V_{BST} .... V_{SW} + 6 V
All other pins .... -0.3 V to 6 V [2]
Continuous power dissipation (T_A = +25°C) [3]
.... 1.25 W
Junction temperature ....150°C
Lead temperature ....260°C
Storage temperature.................. -65°C to 150°C

Recommended Operating Conditions [4]

Supply voltage (V_{IN}) ....4.5 V to 16 V
Output voltage (V_{OUT}).........0.804 V to V_{IN} x D_{MAX}
Operating junction temp. (T_J)... -40°C to +125°C

Thermal Resistance [5]

	θ_{JA}	θ_{JC}	
TSOT23-8	100	55	°C/W

NOTES:

1) Exceeding these ratings may damage the device.
2) For additional details on the absolute maximum rating of EN, please refer to the “Enable/SYNC Control” section on page 12.
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) The device is not guaranteed to function outside of its operating conditions.
5) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

V_{IN} = 12 V, T_J = -40°C to + 125°C(6), typical value is tested at T_J = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Supply current (shutdown)	I_{IN}	V_{EN} = 0 V, T_J= + 25°C			1	μA
		V_{EN} = 0 V, T_J = -40°C to + 125°C			5	μA
Supply current (quiescent)	I_q	V_{EN} = 2 V, V_{FB} = 1 V		0.5	1	mA
HS switch on resistance	HS_{RDS-ON}	V_{BST-SW} = 5 V		120		mΩ
LS switch on resistance	LS_{RDS-ON}	V_{CC} = 5 V		50		mΩ
Switch leakage	SW_{LKG}	V_{EN} = 0 V, V_{SW} = 12 V or 0 V			1	μA
Current limit	I_{LIMIT}	Under 40% duty cycle	4	5		A
Oscillator frequency	f_{SW}	V_{FB} = 0.75 V, T_J = + 25°C	620	800	900	kHz
		V_{FB} = 0.75 V, T_J = -40°C to +125°C	550	800	900	kHz
Foldback frequency	f_{FB}	V_{FB} < 400 mV		0.5		f_{SW}
Maximum duty cycle	D_{MAX}	V_{FB} = 700 mV		92		%
Minimum on time(7)	τ_{ON_MIN}			40		ns
Sync frequency range	f_{SYNC}		0.3		2	MHz
Feedback voltage	V_{FB}	T_J = 25°C	788	804	820	mV
		T_J = -40°C to +125°C	784	804	824	mV
Feedback current	I_{FB}	V_{FB} = 830 mV		10	50	nA
EN rising threshold	V_{EN_RISING}		1	1.4	1.8	V
EN hysteresis	$V_{EN\_Hysteresis}$			150		mV
EN input current	I_{EN}	V_{EN} = 2 V		2		μA
		V_{EN} = 0 V		0		μA
EN turn-off delay	EN_{td-off}			10		μs
VIN under-voltage lockout threshold—rising	$INUV_{Vth}$		3.5	3.9	4.3	V
VIN under-voltage lockout threshold—hysteresis	$INUV_{HYS}$			700		mV
VCC regulator	V_{CC}		4.6	5	5.4	V
VCC load regulation		I_{CC} = 5 mA		2		%
Soft-start current	I_{SS}		8	11	14	μA
Thermal shutdown (7)				150		°C
Thermal hysteresis (7)				20		°C

NOTES:

6) Not tested in production. Guaranteed by over-temperature correlation.

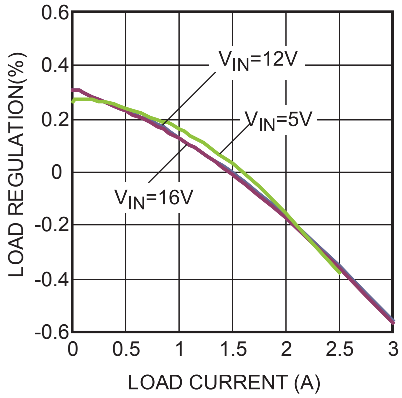
7) Guaranteed by design.

TYPICAL CHARACTERISTICS

Performance waveforms are tested on the evaluation board of the design example section.
V_{IN} = 12 V, V_{OUT} = 3.3 V, L = 3.3 µH, T_A = 25°C, unless otherwise noted.

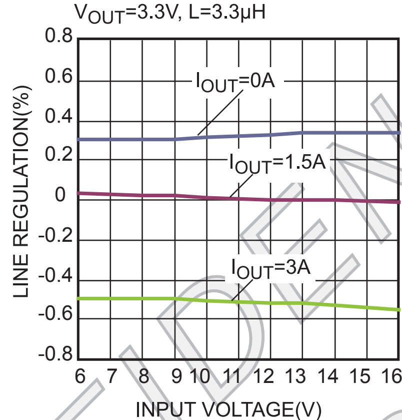
Load Regulation

V_{OUT}=3.3V, L=3.3µH

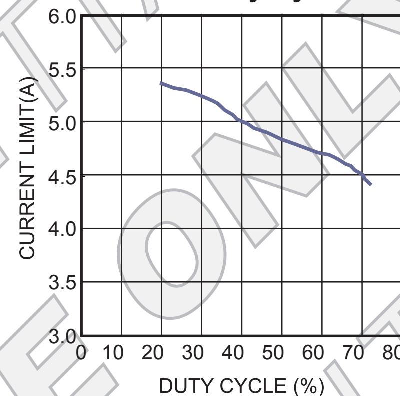


Line Regulation

V_{OUT}=3.3V, L=3.3µH

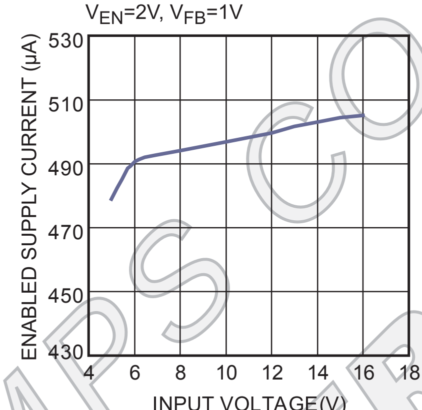


Inductor Peak Current Limit vs. Duty Cycle



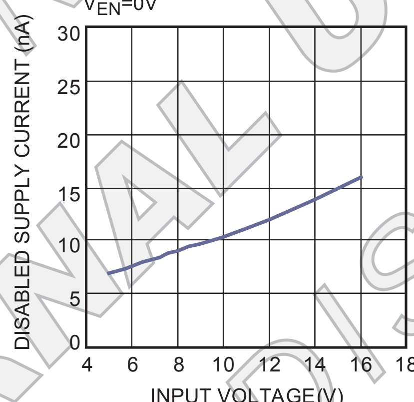
Enabled Supply Current vs. Input Voltage

V_{EN}=2V, V_{FB}=1V

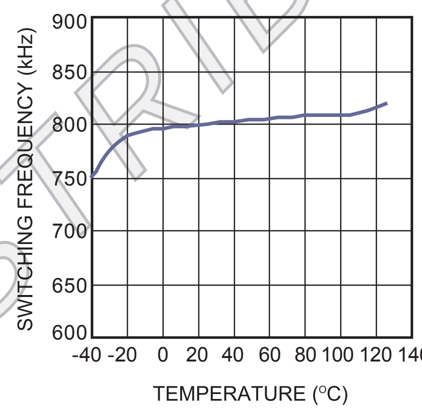


Disabled Supply Current vs. Input Voltage

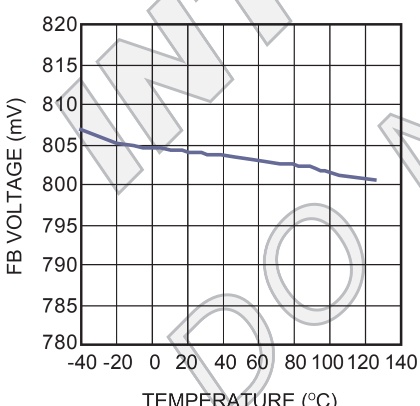
V_{EN}=0V



Switching Frequency vs. Temperature



FB Voltage vs. Temperature

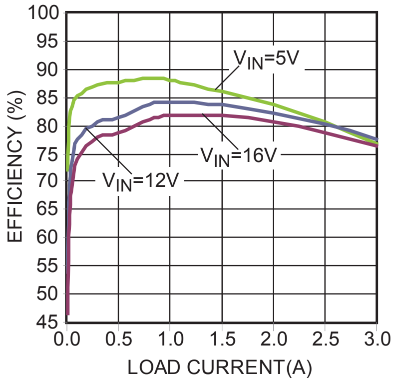


TYPICAL PERFORMANCE CHARACTERISTICS

Performance waveforms are tested on the evaluation board of the design example section.
V_{IN} = 12 V, V_{OUT} = 3.3 V, L = 3.3 µH, T_A = 25°C, unless otherwise noted.

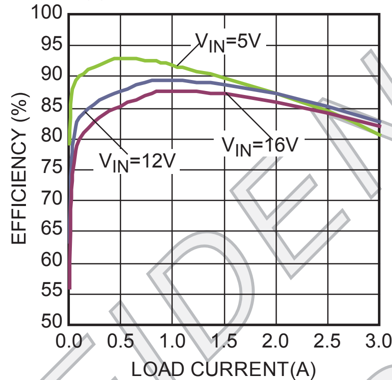
Efficiency vs. Load Current

V_{OUT}=1.2V, L=1µH



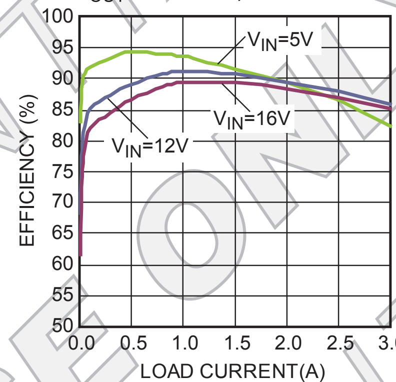
Efficiency vs. Load Current

V_{OUT}=1.8V, L=2.2µH



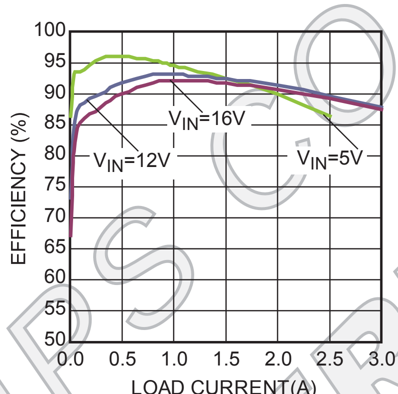
Efficiency vs. Load Current

V_{OUT}=2.5V, L=2.2µH



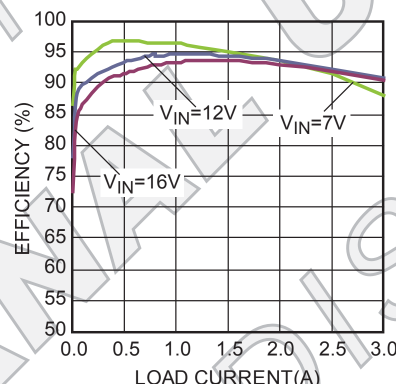
Efficiency vs. Load Current

V_{OUT}=3.3V, L=3.3µH



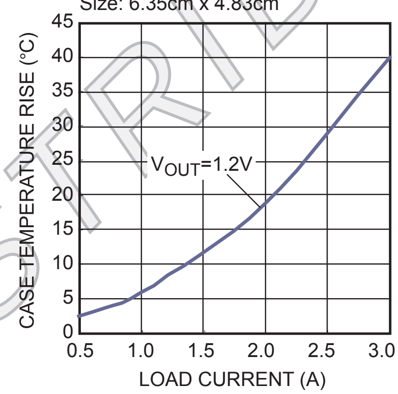
Efficiency vs. Load Current

V_{OUT}=5V, L=3.3µH



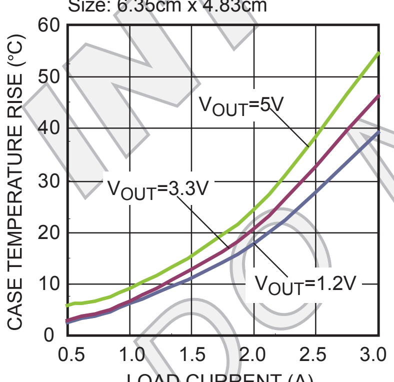
Case Temperature Rise vs. Load Current

V_{IN}=5V, 2 Layers PCB,
Size: 6.35cm x 4.83cm



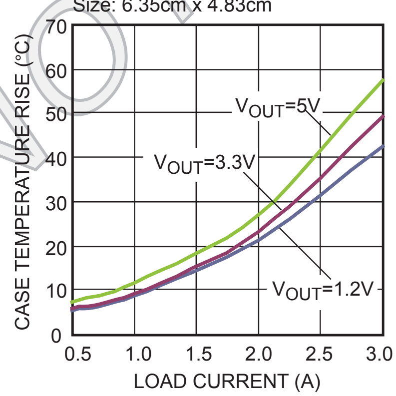
Case Temperature Rise vs. Load Current

V_{IN}=12V, 2 Layers PCB,
Size: 6.35cm x 4.83cm



Case Temperature Rise vs. Load Current

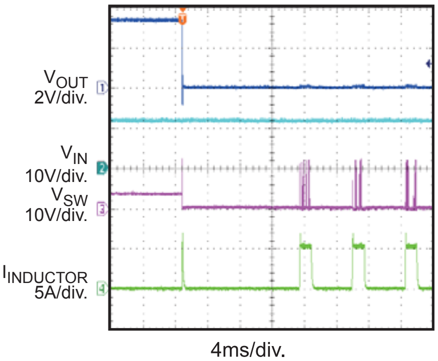
V_{IN}=16V, 2 Layers PCB,
Size: 6.35cm x 4.83cm



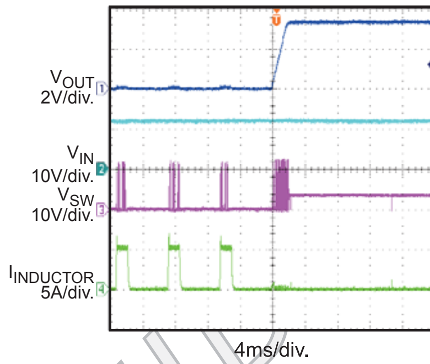
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Performance waveforms are tested on the evaluation board of the design example section.
V_{IN} = 12 V, V_{OUT} = 3.3 V, L = 3.3 µH, T_A = 25°C, unless otherwise noted.

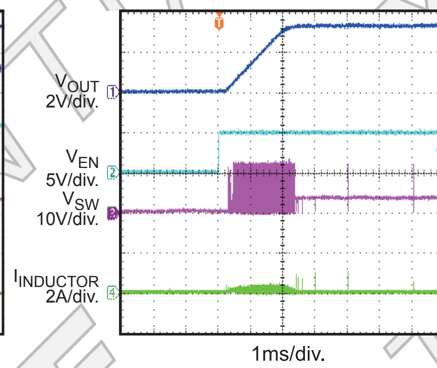
Short Entry
I_{OUT}=0A



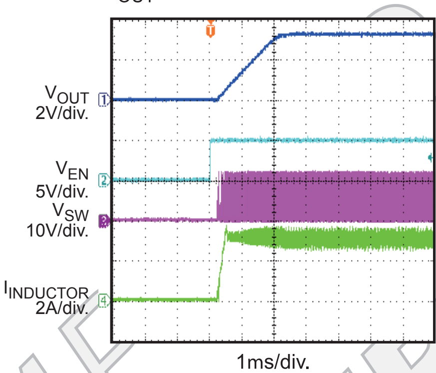
Short Recovery
I_{OUT}=0A



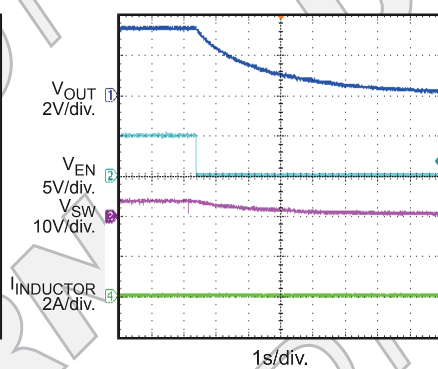
Start-Up through Enable
I_{OUT}=0A



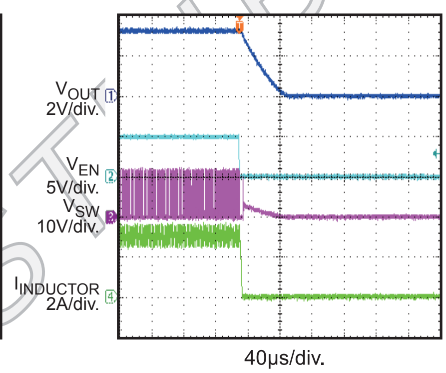
Start-Up through Enable
I_{OUT}=3A



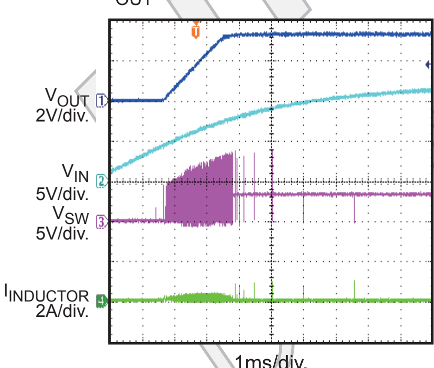
Shutdown through Enable
I_{OUT}=0A



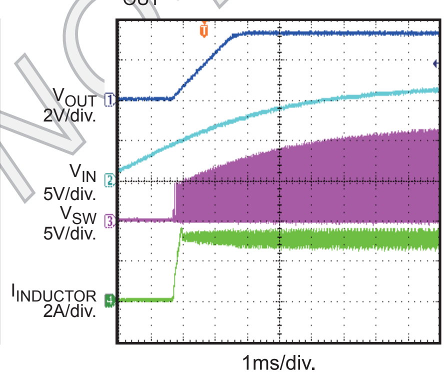
Shutdown through Enable
I_{OUT}=3A



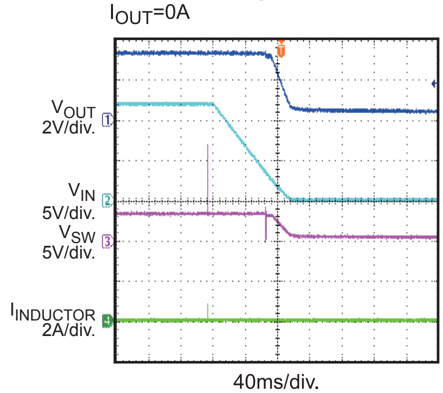
Start-Up through Input Voltage
I_{OUT}=0A



Start-Up through Input Voltage
I_{OUT}=3A



Shutdown through Input Voltage
I_{OUT}=0A

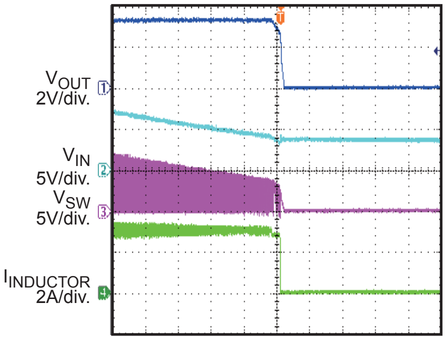


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

Performance waveforms are tested on the evaluation board of the design example section.
V_{IN} = 12 V, V_{OUT} = 3.3 V, L = 3.3 μH, T_A = 25°C, unless otherwise noted.

Shutdown through Input Voltage

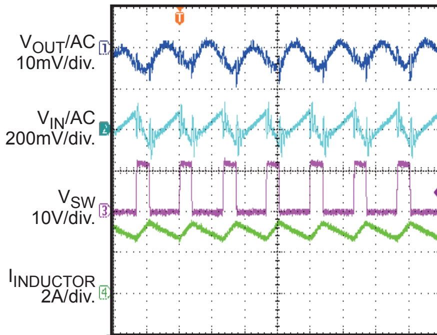
I_{OUT}=3A



400μs/div.

Input / Output Ripple

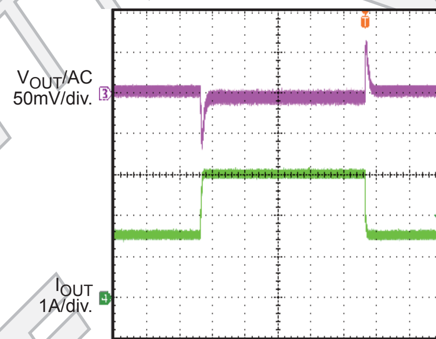
I_{OUT}=3A



1μs/div.

Load Transient Reponse

I_{OUT}=1.5A to 3A



200μs/div.

PIN FUNCTIONS

Package Pin #	Name	Description
1	SS	**Soft start**. Connect an external capacitor to program the soft-start time for the switch mode regulator.
2	IN	**Supply voltage.** IN supplies power for the internal MOSFET and regulator. The MP2235S operates from a +4.5 V to +16 V input rail. IN requires a low ESR and low-inductance capacitor (C1) to decouple the input rail. Place the input capacitor very close to IN and connect it with wide PCB traces and multiple vias.
3	SW	**Switch output.** Connect SW to the inductor and bootstrap capacitor. SW is driven up to V_{IN} by the high-side switch during the PWM duty cycle on time. The inductor current drives SW negative during the off time. The on resistance of the low-side switch and the internal body diode fixes the negative voltage. Connect SW using wide PCB traces and multiple vias.
4	GND	**System ground.** GND is the reference ground of the regulated output voltage. PCB layout requires extra care. For best results, connect to GND with copper and vias.
5	BST	**Bootstrap.** Requires a capacitor connected between SW and BST to form a floating supply across the high-side switch driver.
6	EN/SYNC	**Enable.** EN=high to enable the MP2235S. Apply an external clock to change the switching frequency. For automatic start-up, connect EN to V_{IN} with a 100 kΩ resistor.
7	VCC	**Internal 5 V LDO output.** VCC powers the driver and control circuits. Decouple with a 0.1 µF to 0.22 µF capacitor. Do NOT use a capacitor ≥0.22 µF.
8	FB	**Feedback.** Connect FB to the tap of an external resistor divider from the output to GND to set the output voltage. The frequency foldback comparator lowers the oscillator frequency when the FB voltage is below 400 mV to prevent current limit runaway during a short-circuit fault. Place the resistor divider as close to FB as possible. Avoid placing vias on the FB traces.

FUNCTIONAL BLOCK DIAGRAM

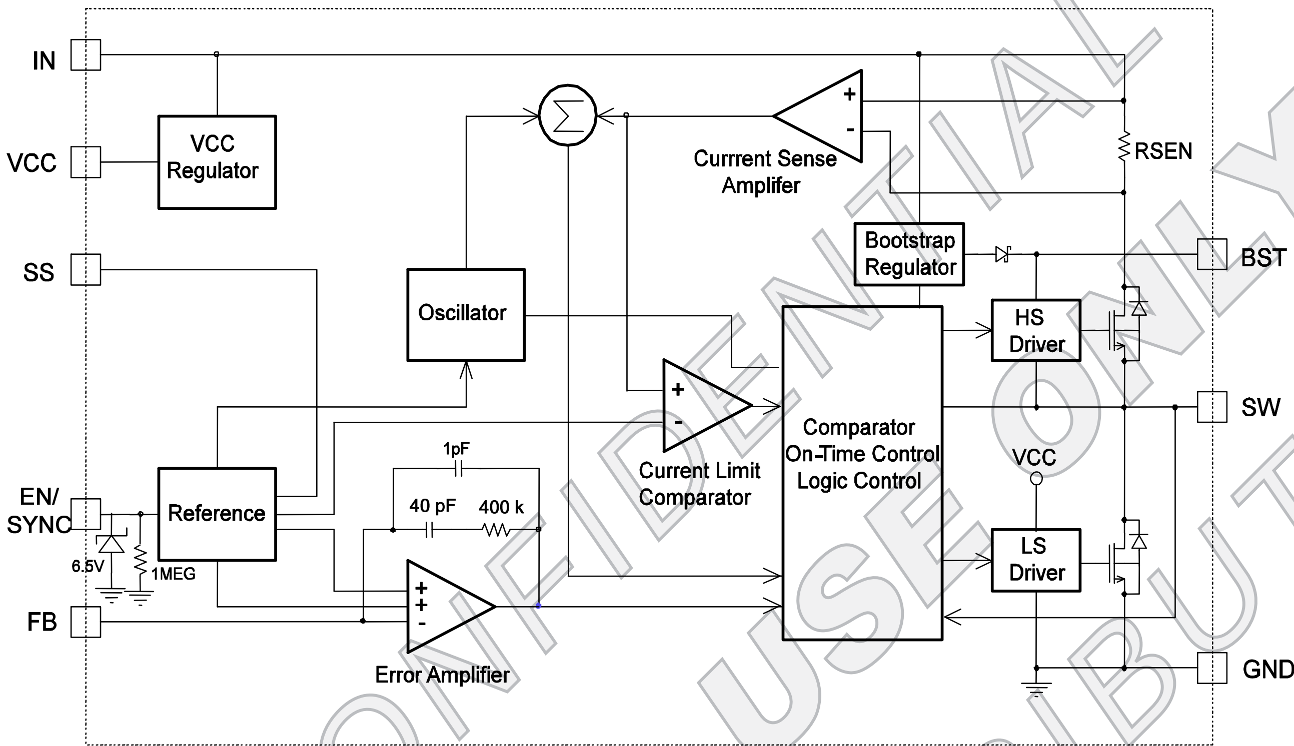


Figure 1—Functional block diagram

OPERATION

The MP2235S is a high-frequency, synchronous, rectified, step-down, switch-mode converter with built-in power MOSFETs. It offers a compact solution that achieves a 3 A continuous output current with excellent load and line regulation over a 4.5 V to 16 V input supply range.

The MP2235S has three working modes: advanced asynchronous modulation (AAM) mode, discontinuous conduction mode (DCM), and continuous conduction mode (CCM). The load current increases as the device transitions from AAM mode to DCM to CCM.

AAM Control Operation

In a light-load condition, the MP2235S works in advanced asynchronous modulation (AAM) mode (see Figure 2). The V_{AAM} is an internal fixed voltage when the input and output voltages are fixed. V_{COMP} is the error-amplifier output (which represents the peak inductor-current information). When V_{COMP} is lower than V_{AAM}, the internal clock is blocked. This causes the MP2235S to skip pulses, achieving the light-load power save. Refer to AN032 for additional details.

The internal clock re-sets every time V_{COMP} is higher than V_{AAM}. Simultaneously, the high-side MOSFET (HS-FET) turns on and remains on until $V_{ILsense}$ reaches the value set by V_{COMP}.

The light-load feature in this device is optimized for 12 V input applications.

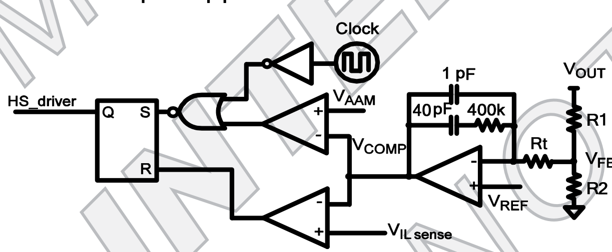


Figure 2—Simplified AAM control logic

DCM Control Operation

The V_{COMP} ramps up as the output current increases. When its minimum value exceeds V_{AAM}, the device enters discontinuous conduction mode (DCM). In DCM, the internal clock initiates the PWM cycle, the HS-FET turns on and remains on until $V_{ILsense}$ reaches the value set by V_{COMP} (after a period of dead time), and the low-side MOSFET (LS-FET) turns on and remains on until the inductor-current value decreases to zero. The device repeats the same operation in every clock cycle to regulate the output voltage (see Figure 3).

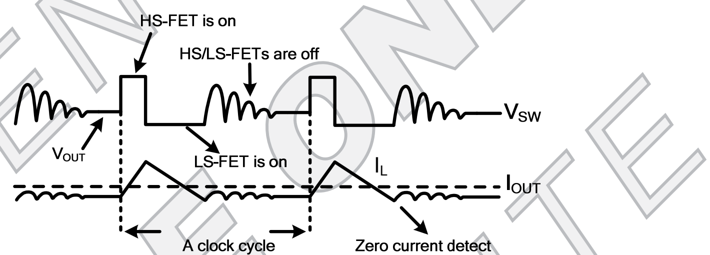


Figure 3—DCM control operation

CCM Control Operation

The device enters continuous conduction mode (CCM) from DCM once the inductor current no longer drops to zero in a clock cycle. In CCM, the internal clock initiates the PWM cycle, the HS-FET turns on and remains on until $V_{ILsense}$ reaches the value set by V_{COMP} (after a period of dead time), and the LS-FET turns on and remains on until the next clock cycle begins. The device repeats the same operation in every clock cycle to regulate the output voltage.

If $V_{ILsense}$ does not reach the value set by V_{COMP} within 92 percent of one PWM period, the HS-FET is forced off.

Internal Regulator

A 5 V internal regulator powers most of the internal circuitries. This regulator takes V_{IN} and operates in the full V_{IN} range. When V_{IN} exceeds 5 V, the output of the regulator is in full regulation. When V_{IN} is less than 5 V, the output decreases, and the part requires a 0.1 µF ceramic decoupling capacitor.

Error Amplifier (EA)

The error amplifier compares the FB voltage to the internal 0.804 V reference (V_{REF}) and outputs a current proportional to the difference between the two. This output current then charges or discharges the internal compensation network to form the COMP