

DESCRIPTION

The MP2313 is a high frequency synchronous rectified step-down switch mode converter with built-in internal power MOSFETs. It offers a very compact solution to achieve 1A continuous output current over a wide input supply range with excellent load and line regulation.

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

Full protection features include OCP and thermal shut down.

The MP2313 requires a minimum number of readily available standard external components and is available in a space saving TSOT23-8 package.

FEATURES

- Wide 4.5V to 24V Operating Input Range
- 1A Load Current
- 110mΩ/50mΩ Low Rds(on) Internal Power MOSFETs
- Low Quiescent Current
- High Efficiency Synchronous Mode Operation
- Fixed 2MHz Switching Frequency
- AAM Power Save Mode
- Internal Soft Start
- OCP Protection and Hiccup
- Thermal Shutdown
- Output Adjustable from 0.8V
- Available in a TSOT23-8 package

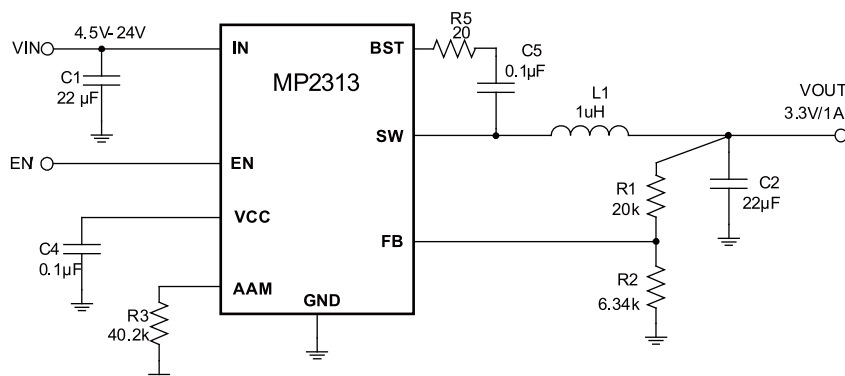
APPLICATIONS

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

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

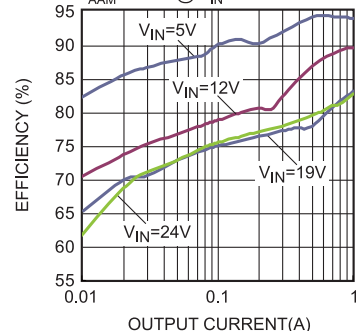
"MPS" and "The Future of Analog IC Technology" are registered trademarks of Monolithic Power Systems, Inc.

TYPICAL APPLICATION



Efficiency vs. Output Current

$V_{OUT}=3.3V$, $L=1\mu H$, $I_{OUT}=0.01A$ to $1A$
 $R_{AAM}=40.2k$ @ $V_{IN}=12V$ to $24V$,
 $R_{AAM}=80.6k$ @ $V_{IN}=5V$



ORDERING INFORMATION

Part Number*	Package	Top Marking
MP2313GJ	TSOT23-8	See Below

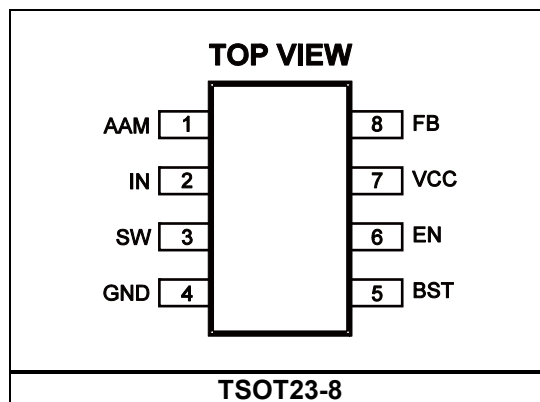
* For Tape & Reel, add suffix -Z (e.g. MP2313GJ-Z);

TOP MARKING

| AMBY

AMB: product code of MP2313GJ;
Y: year code;

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS ⁽¹⁾

V_{IN}	-0.3V to +28V
V_{SW}	-0.3V (-5V<10ns) to +28V (30V <10ns)
V_{BST}	V_{SW} +6V
All Other Pins ⁽²⁾	-0.3V to +6V
Continuous Power Dissipation (T_A =+25°C) ⁽³⁾ ...	1.25W
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 to 24V
Output Voltage V_{OUT}	0.8V to V_{IN} *Dmax
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) About the details of EN pin's ABS MAX rating, please refer to Page 10, EN control section.
- 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 will cause excessive die temperature, and the regulator will 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

$V_{IN} = 12V$, $T_A = 25^{\circ}C$, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Supply Current (Shutdown)	I_{IN}	$V_{EN} = 0V$			1	μA
Supply Current (Quiescent)	I_q	$V_{EN} = 2V$, $V_{FB} = 1V$, AAM=0.5V		0.2		mA
		$V_{EN} = 2V$, $V_{FB} = 1V$, AAM=5V		0.7		
HS Switch On Resistance	HS_{RDS-ON}	$V_{BST-SW}=5V$		110		m Ω
LS Switch On Resistance	LS_{RDS-ON}	$V_{CC}=5V$		50		m Ω
Switch Leakage	SW_{LKG}	$V_{EN} = 0V$, $V_{SW} = 12V$			1	μA
Current Limit	I_{LIMIT}	Duty Cycle=40%	2.5	3.5		A
Oscillator Frequency	f_{SW}	$V_{FB}=750mV$	1700	2000	2400	kHz
Fold-back Frequency	f_{FB}	$V_{FB}<400mV$		0.3		f_{SW}
Maximum Duty Cycle	D_{MAX}	$V_{FB}=700mV$	78	83		%
Minimum On Time ⁽⁶⁾	$T_{ON\ MIN}$			35		ns
Feedback Voltage	V_{FB}	$T_A=25^{\circ}C$	786	798	810	mV
Feedback Current	I_{FB}	$V_{FB}=820mV$		10	50	nA
EN Rising Threshold	$V_{EN\ RISING}$		1.2	1.4	1.6	V
EN Hysteresis	$V_{EN\ HYS}$		80	150	220	mV
EN Input Current	I_{EN}	$V_{EN}=2V$		2		μA
		$V_{EN}=0$		0		nA
VIN Under Voltage Lockout Threshold-Rising	$INUV_{Vth}$		3.7	3.9	4.1	V
VIN Under Voltage Lockout Threshold-Hysteresis	$INUV_{HYS}$			650		mV
VCC Regulator	V_{CC}			4.9		V
VCC Load Regulation		$I_{CC}=5mA$		1.5		%
Soft-Start Period	T_{SS}	V_{OUT} from 10% to 90%	0.8	1.5	2.2	ms
Thermal Shutdown ⁽⁶⁾				150		$^{\circ}C$
Thermal Hysteresis ⁽⁶⁾				20		$^{\circ}C$
AAM Source Current	I_{AAM}		5.6	6.2	6.8	μA

Notes:

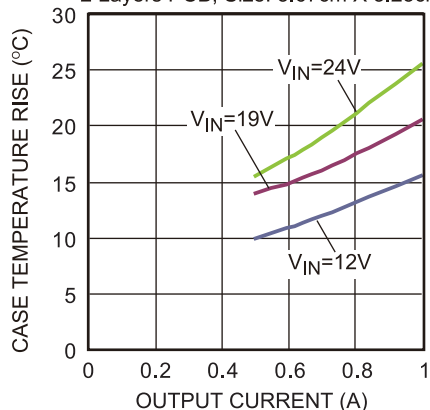
6) Guaranteed by design

TYPICAL CHARACTERISTICS

$V_{IN} = 19V$, $V_{OUT} = 3.3V$, $L = 1\mu H$, $T_A = 25^\circ C$, unless otherwise noted.

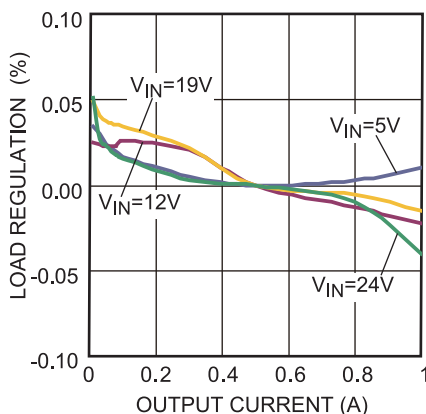
Case Temperature Rise vs. Output Current

$V_{OUT} = 3.3V$, $I_{OUT} = 0.5A$ to $1A$,
2 Layers PCB, Size: 3.67cm X 3.25cm



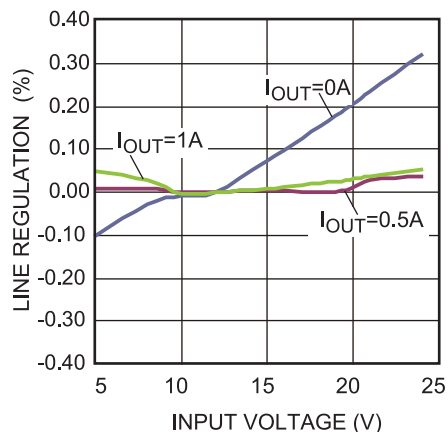
Load Regulation

$V_{IN} = 5V$ to $24V$, $I_{OUT} = 0.1A$ to $1A$

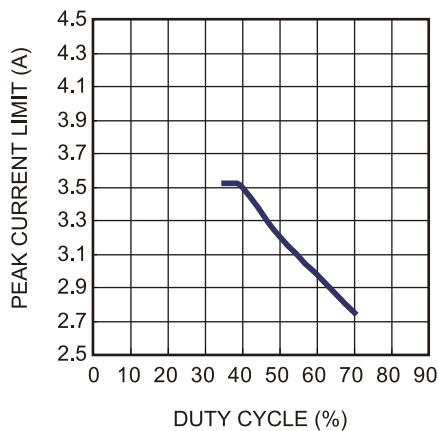


Line Regulation

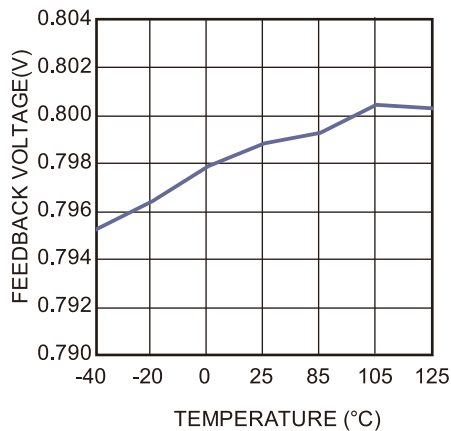
$V_{IN} = 5V$ to $24V$, $I_{OUT} = 0A$ to $1A$



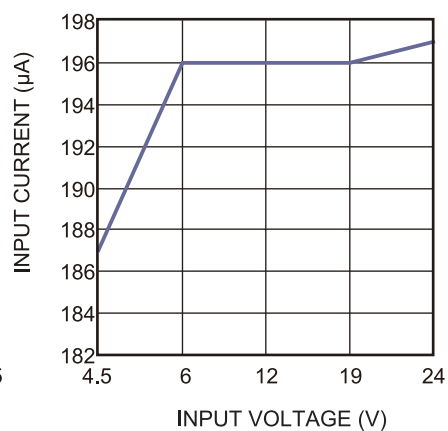
Peak Current Limit vs. Duty Cycle



Feedback Voltage vs. Temperature



Enabled Supply Current vs. Input Voltage

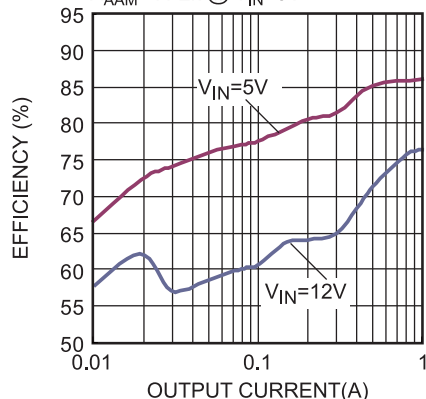


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 19V$, $V_{OUT} = 3.3V$, $L = 1\mu H$, $T_A = 25^\circ C$, unless otherwise noted.

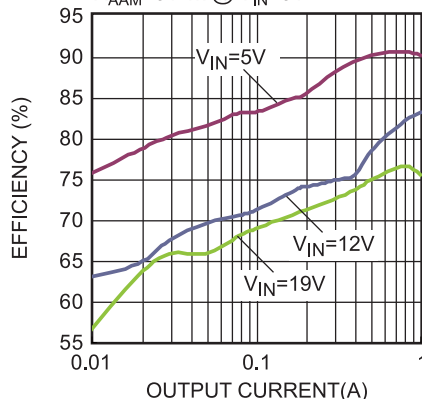
Efficiency vs. Output Current

$V_{OUT}=1.2V$, $L=0.68\mu H$, $I_{OUT}=0.01A$ to $1A$
 $R_{AAM}=19.1k$ @ $V_{IN}=12V$,
 $R_{AAM}=41.2k$ @ $V_{IN}=5V$



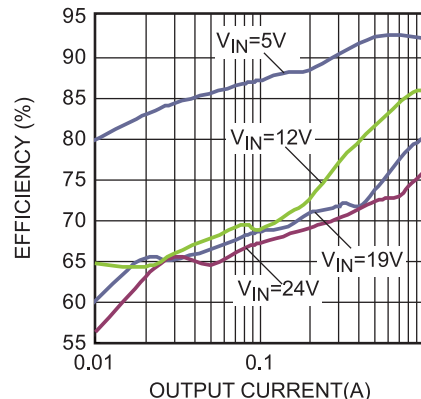
Efficiency vs. Output Current

$V_{OUT}=1.8V$, $L=0.82\mu H$, $I_{OUT}=0.01A$ to $1A$
 $R_{AAM}=32.4k$ @ $V_{IN}=12V$ to $19V$
 $R_{AAM}=51.1k$ @ $V_{IN}=5V$



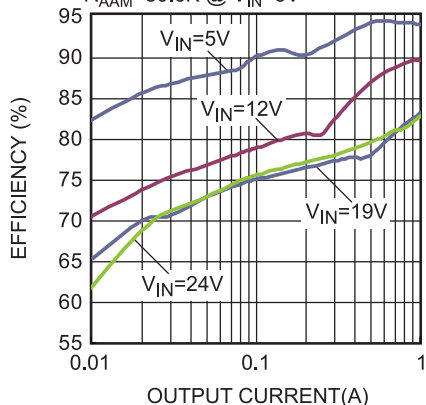
Efficiency vs. Output Current

$V_{OUT}=2.5V$, $L=0.82\mu H$, $I_{OUT}=0.01A$ to $1A$
 $R_{AAM}=28.7k$ @ $V_{IN}=12V$ to $24V$,
 $R_{AAM}=63.4k$ @ $V_{IN}=5V$



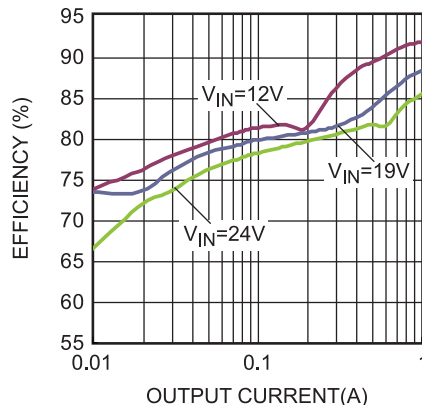
Efficiency vs. Output Current

$V_{OUT}=3.3V$, $L=1\mu H$, $I_{OUT}=0.01A$ to $1A$
 $R_{AAM}=40.2k$ @ $V_{IN}=12V$ to $24V$,
 $R_{AAM}=80.6k$ @ $V_{IN}=5V$



Efficiency vs. Output Current

$V_{OUT}=5V$, $L=1.5\mu H$, $I_{OUT}=0.01A$ to $1A$
 $R_{AAM}=54.9k$ @ $V_{IN}=12V$ to $24V$

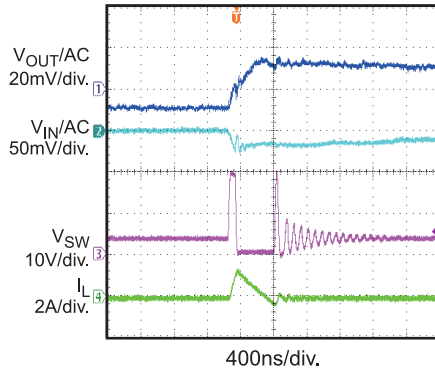


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 19V$, $V_{OUT} = 3.3V$, $L = 1\mu H$, $T_A = 25^\circ C$, unless otherwise noted.

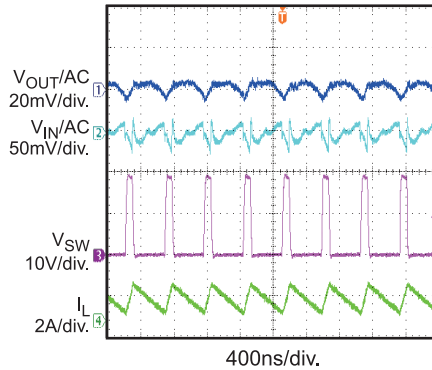
Input/Output Ripple

$I_{OUT} = 0A$



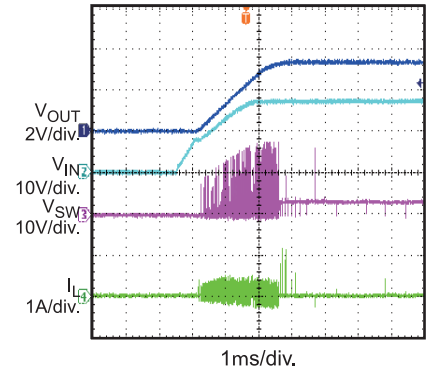
Input/Output Ripple

$I_{OUT} = 1A$



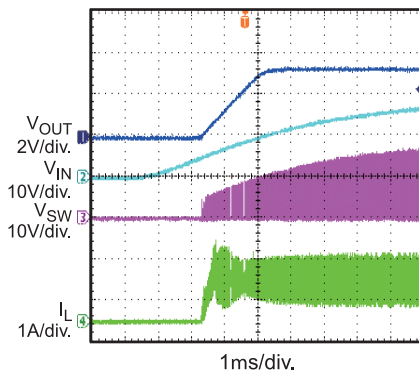
Startup through Input Voltage

$I_{OUT} = 0A$



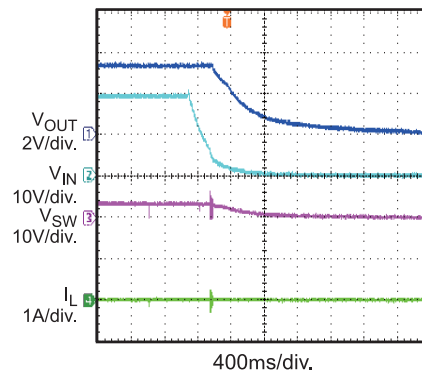
Startup through Input Voltage

$I_{OUT} = 1A$



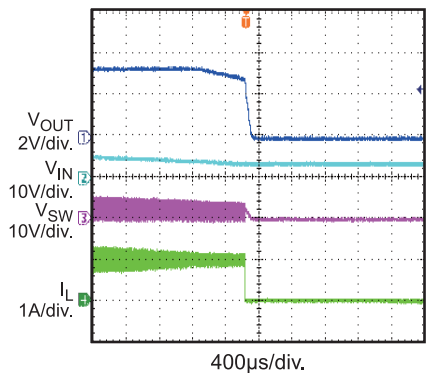
Shutdown through Input Voltage

$I_{OUT} = 0A$



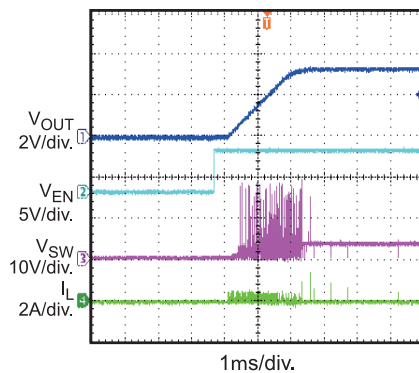
Shutdown through Input Voltage

$I_{OUT} = 1A$



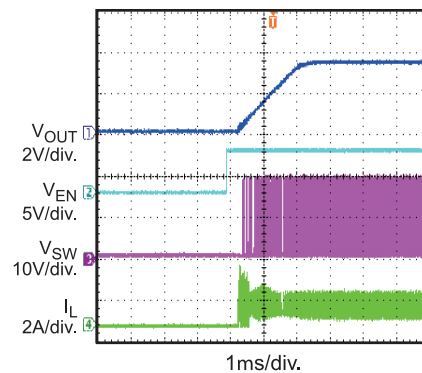
Startup through Enable

$I_{OUT} = 0A$



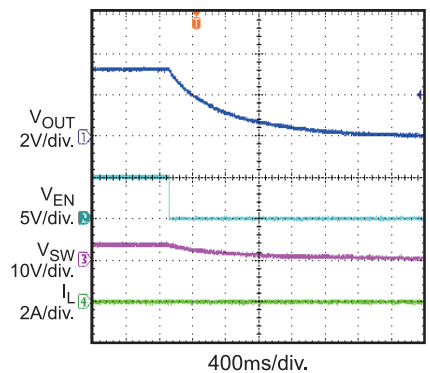
Startup through Enable

$I_{OUT} = 1A$



Shutdown through Enable

$I_{OUT} = 0A$

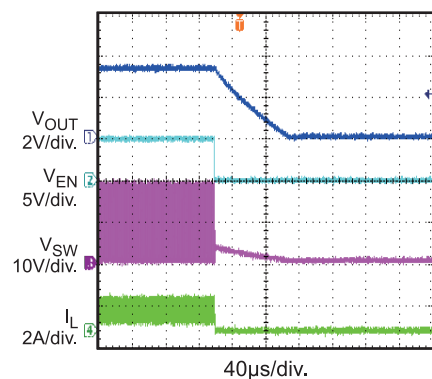


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 19V$, $V_{OUT} = 3.3V$, $L = 1\mu H$, $T_A = 25^\circ C$, unless otherwise noted.

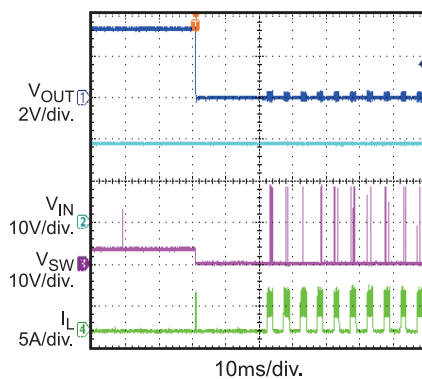
Shutdown through Enable

$I_{OUT} = 1A$



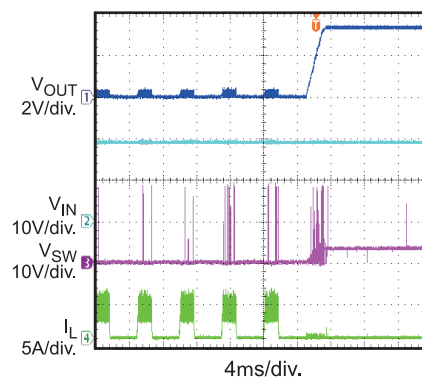
Short Circuit Entry

$I_{OUT} = 0A$



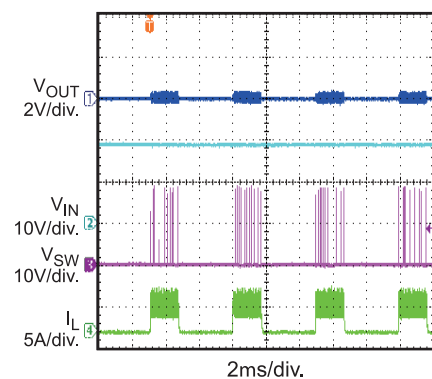
Short Circuit Recovery

$I_{OUT} = 0A$



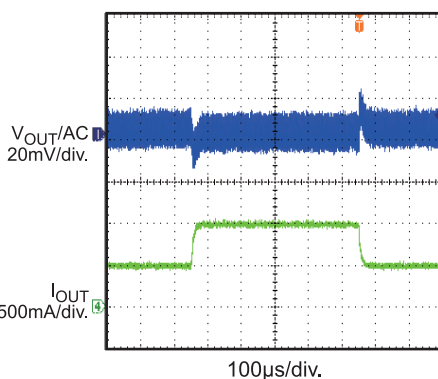
Short Circuit Steady

$I_{OUT} = 0A$



Load Transient

$I_{OUT} = 0.5A$ to $1A$, $2.5A/\mu s$



PIN FUNCTIONS

Package Pin #	Name	Description
1	AAM	A resistor is connected from AAM pin to ground to set a AAM voltage force MP2313 into non-synchronous mode when load is small. Drive AAM pin high (=VCC) or float AAM pin will force MP2313 into CCM.
2	IN	Supply Voltage. The MP2313 operates from a +4.5V to +24V input rail. C1 is needed to decouple the input rail. Use wide PCB trace to make the connection.
3	SW	Switch Output. Use wide PCB trace to make the connection.
4	GND	System Ground. This pin is the reference ground of the regulated output voltage. For this reason care must be taken in PCB layout. Suggested to be connected to GND with copper and vias.
5	BST	Bootstrap. A capacitor and a 20Ω resistor connected between SW and BST pins are required to form a floating supply across the high-side switch driver.
6	EN	EN=1 to enable the MP2313.
7	VCC	Bias Supply. Decouple with 0.1μF-0.22μF cap. And the capacitance should be no more than 0.22μF
8	FB	Feedback. An external resistor divider from the output to GND, tapped to the FB pin, sets the output voltage. To prevent current limit run away during a short circuit fault condition the frequency fold-back comparator lowers the oscillator frequency when the FB voltage is below 400mV.

FUNCTION BLOCK DIAGRAM

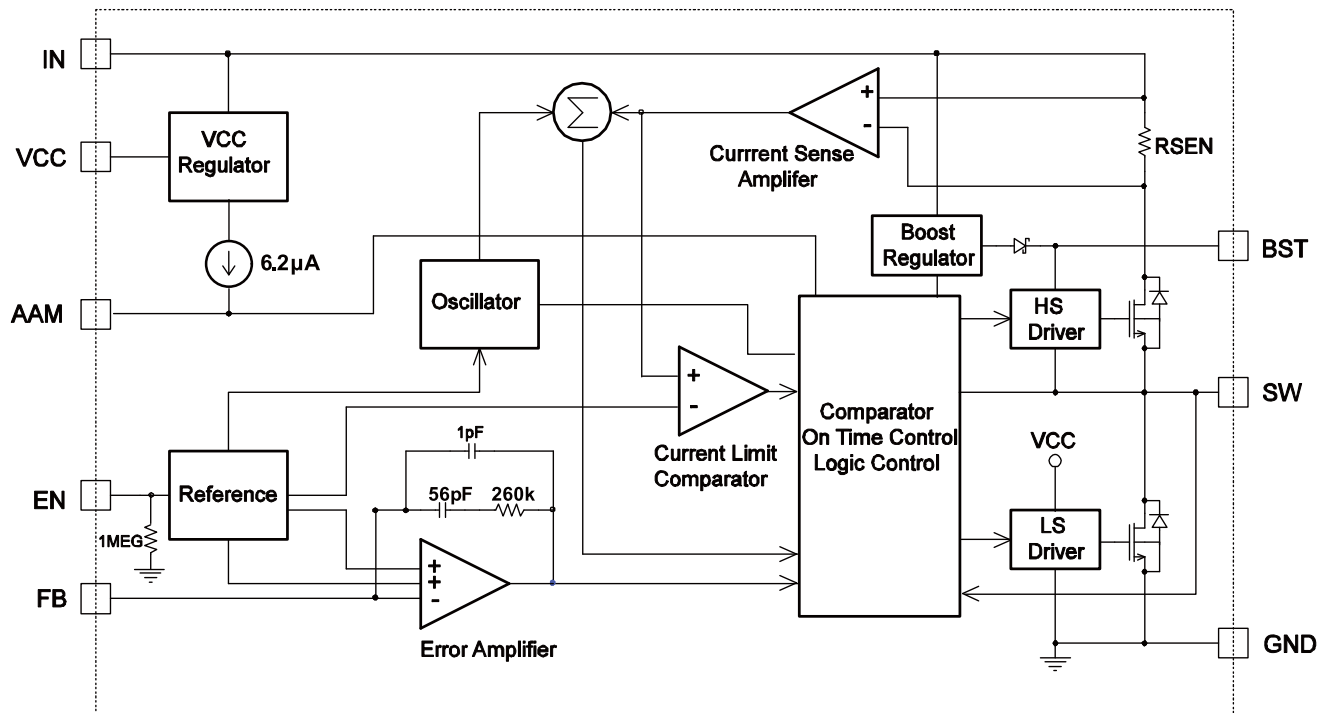


Figure 1: Functional Block Diagram

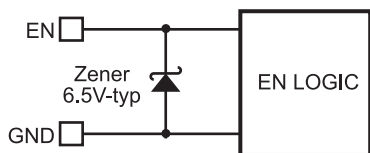


Figure 3: 6.5V Zener Diode Connection

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) is implemented to protect the chip from operating at insufficient supply voltage. The MP2313 UVLO comparator monitors the output voltage of the internal regulator, VCC. The UVLO rising threshold is about 3.9V while its falling threshold is consistent 3.25V.

Internal Soft-Start

The soft start is implemented to prevent the converter output voltage from overshooting during start up. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V. The soft-start period lasts until the voltage on the soft-start capacitor exceeds the reference voltage of 0.8V. At this point the reference voltage takes over. The soft-start time is internally set to be around 1.5ms.

Over-Current-Protection and Hiccup

The MP2313 has cycle-by-cycle over current limit when the inductor current peak value exceeds the set current limit threshold. Meanwhile, output voltage starts to drop until FB is below the Under-Voltage (UV) threshold, typically 50% below the reference. Once a UV is triggered, the MP2313 enters hiccup mode to periodically restart the part. This protection mode is especially useful when the output is dead-short to ground. The average short circuit current is greatly reduced to alleviate the thermal issue and to protect the regulator. The MP2313 exits the hiccup mode once the over current condition is removed.

Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from operating at exceedingly high

temperatures. When the silicon die temperature is higher than 150°C, it shuts down the whole chip. When the temperature is lower than its lower threshold, typically 130°C, the chip is enabled again.

Floating Driver and Bootstrap Charging

The floating power MOSFET driver is powered by an external bootstrap capacitor. This floating driver has its own UVLO protection. This UVLO's rising threshold is 2.2V with a hysteresis of 150mV. The bootstrap capacitor voltage is regulated internally by VIN through D1, R5, C5, L1 and C2 (Figure 4). If (VIN-VSW) is more than 5V, U2 will regulate M3 to maintain a 5V BST voltage across C5.

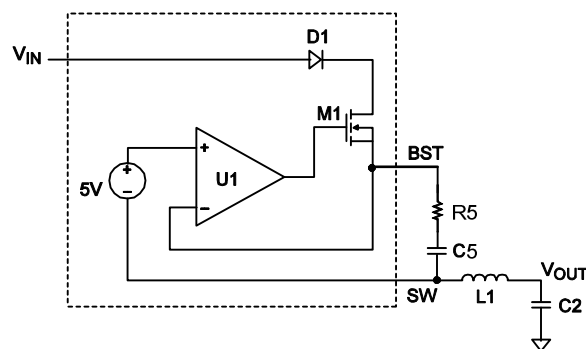


Figure 4: Internal Bootstrap Charging Circuit

Startup and Shutdown

If both V_{IN} and EN are higher than their appropriate thresholds, the chip starts. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries.

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

APPLICATION INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

The external resistor divider is used to set the output voltage (see Typical Application on page 1). The feedback resistor R1 also sets the feedback loop bandwidth with the internal compensation capacitor (see Typical Application on page 1). R2 is then given by:

$$R2 = \frac{R1}{\frac{V_{OUT}}{0.798V} - 1}$$

The feedback network is as Figure 5 shows.

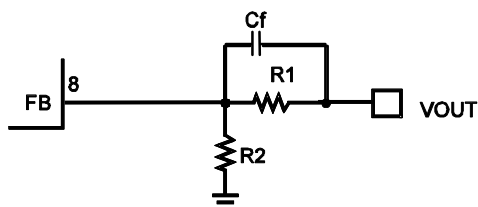


Figure 5: Feedback Network

Table 1 lists the recommended feedback resistors value for common output voltages.

Table 1—Resistor Selection for Common Output Voltages

V _{OUT} (V)	R1 (kΩ)	R2 (kΩ)	Cf (pF)	L(μH)
1.05	80.6	255	12	0.68
1.2	80.6	160	12	0.68
1.8	40.2	31.6	12	0.82
2.5	40.2	18.7	12	0.82
3.3	20	6.34	22	1
5	20	3.74	22	1.5

Selecting the Inductor

A 0.47μH to 4.7μH inductor with a DC current rating of at least 25% percent higher than the maximum load current is recommended for most applications. For highest efficiency, the inductor DC resistance should be 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 inductor current to be approximately 30% of the maximum load current. The maximum inductor peak current is:

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

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency.

Setting the AAM Voltage

The AAM voltage is used to setting the transition point from AAM to PWM. It should be chosen to provide the best combination of efficiency, stability, ripple, and transient.

If the AAM voltage is set lower, then stability and ripple improves, but efficiency during AAM mode and transient degrades. Likewise, if the AAM voltage is set higher, then the efficiency during AAM and transient improves, but stability and ripple degrades. So the optimal balance point of AAM voltage for good efficiency, stability, ripple and transient should be found out.

Adjust the AAM threshold by connecting a resistor from AAM pin to ground. Take Figure 6 as reference. An internal 6.2μA current source charges the external resistor.

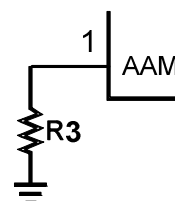


Figure 6: AAM Network

Generally, R3 is then given by:

$$V_{AAM} = R3 \times 6.2\mu A$$

The optimized AAM can be got from Figure 7.

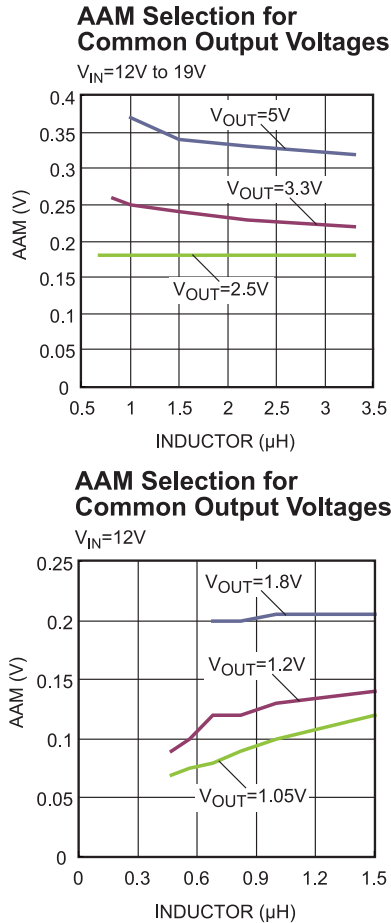


Figure 7: AAM Selection for Common Output Voltages

Selecting the Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 22μF capacitor is sufficient.

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

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

The worse case condition occurs at $V_{IN} = 2V_{OUT}$, where:

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

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

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple caused by capacitance can be estimated by:

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

Selecting the Output Capacitor

The output capacitor (C2) is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

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

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

In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

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

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

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

The characteristics of the output capacitor also affect the stability of the regulation system. The MP2313 can be optimized for a wide range of capacitance and ESR values.

External Bootstrap Diode

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

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

In these cases, an external BST diode is recommended from the VCC pin to BST pin, as shown in Figure 8.

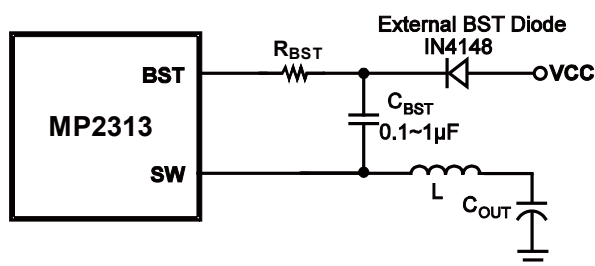


Figure 8: Add Optional External

Bootstrap Diode to Enhance Efficiency

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

PC Board Layout⁽⁶⁾

PCB layout is very important to achieve stable operation. Please follow these guidelines and take Figure 9 as reference.

- 1) Keep the connection of input ground and GND pin as short and wide as possible.
- 2) Keep the connection of input capacitor and IN pin as short and wide as possible.

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

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

Notes:

- 6) The recommended layout is based on the Figure 10 Typical Application circuit on the page 16.

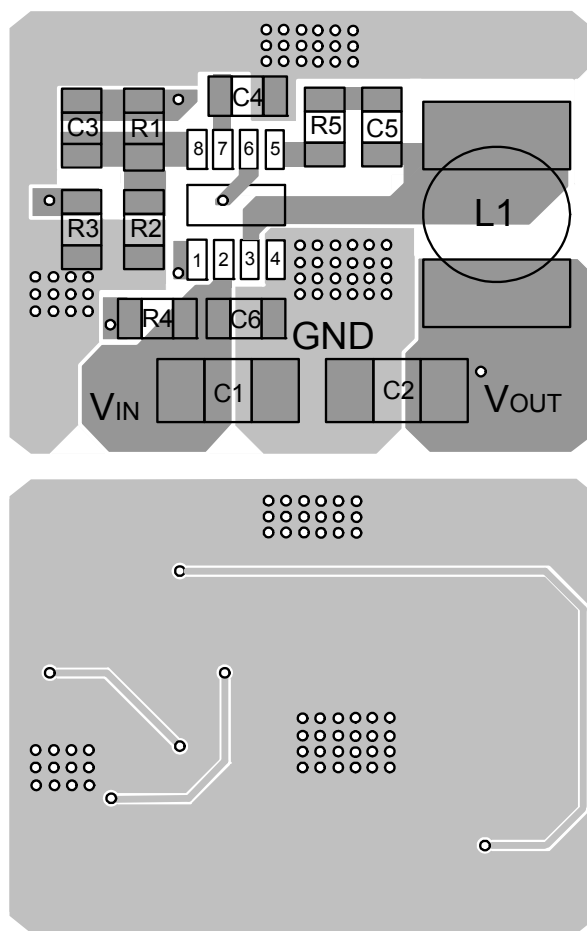


Figure 9: Sample Board Layout

Design Example

Below is a design example following the application guidelines for the specifications:

Table 2: Design Example

V_{IN}	19V
V_{OUT}	3.3V
I_O	1A

The detailed application schematics are shown in Figures 10 through 15. The typical performance and circuit waveforms have been shown in the Typical Performance Characteristics section. For more device applications, please refer to the related Evaluation Board Datasheets.

TYPICAL APPLICATION CIRCUITS

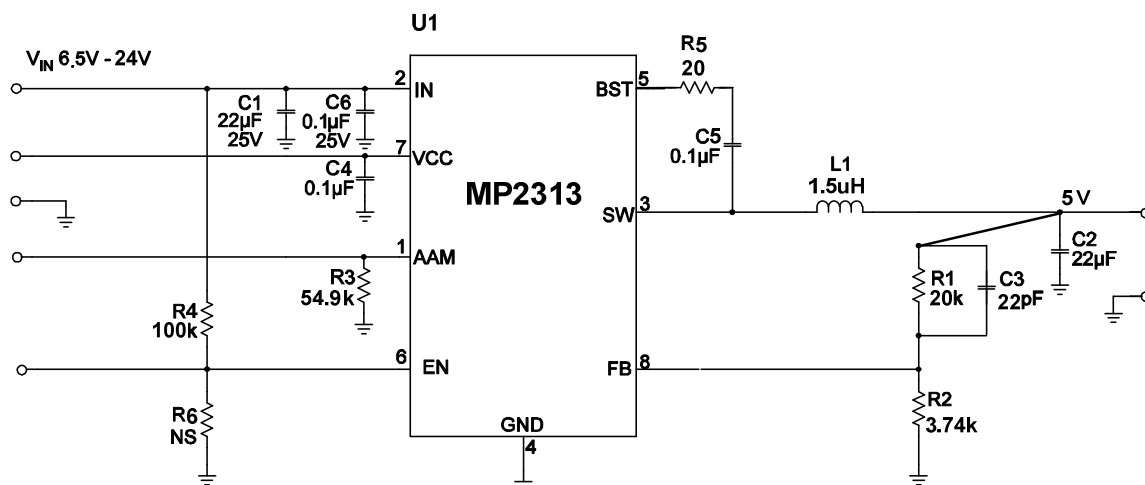


Figure 10: $V_{IN}=19V$, $V_{OUT}=5V$, $I_{OUT}=1A$

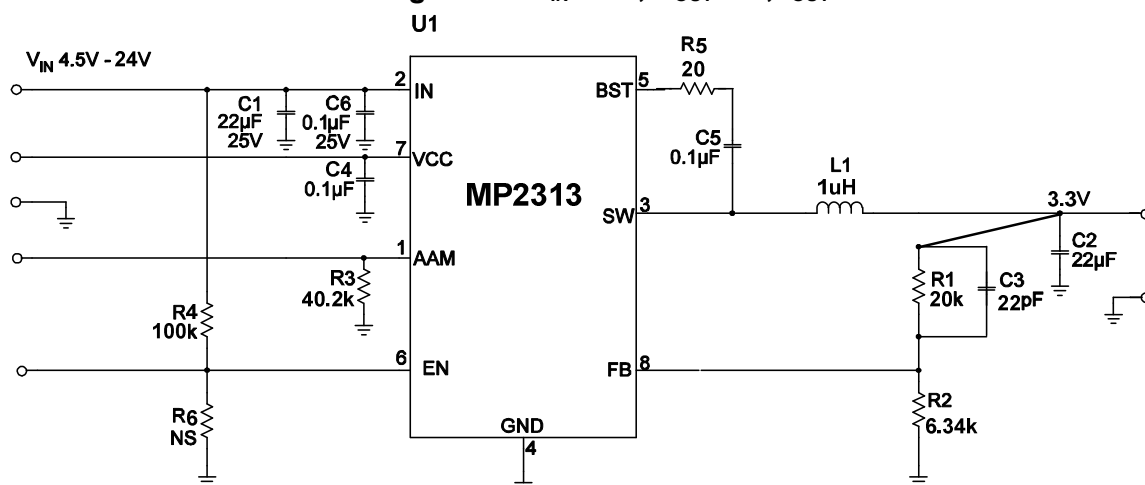


Figure 11: $V_{IN}=19V$, $V_{OUT}=3.3V$, $I_{OUT}=1A$

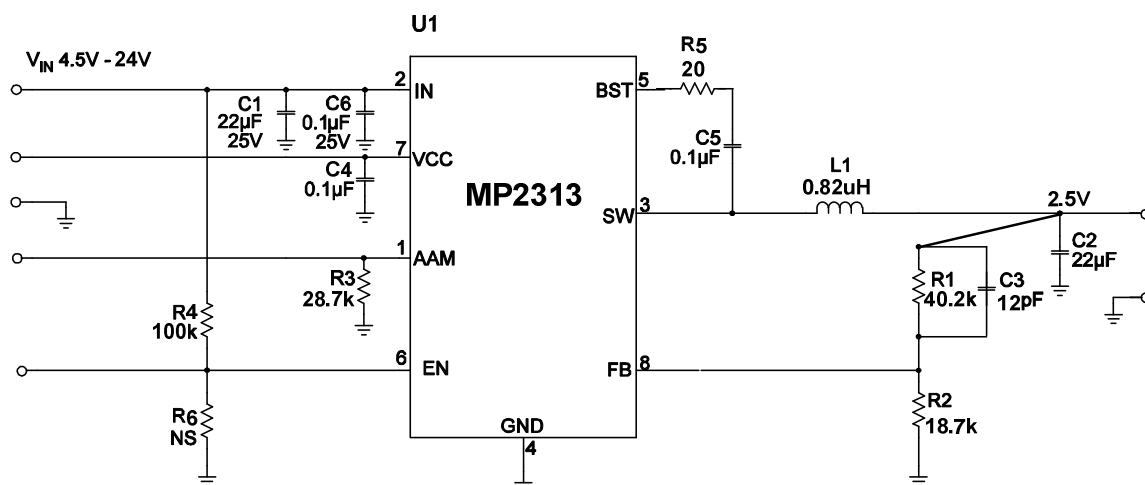


Figure 12: $V_{IN}=19V$, $V_{OUT}=2.5V$, $I_{OUT}=1A$

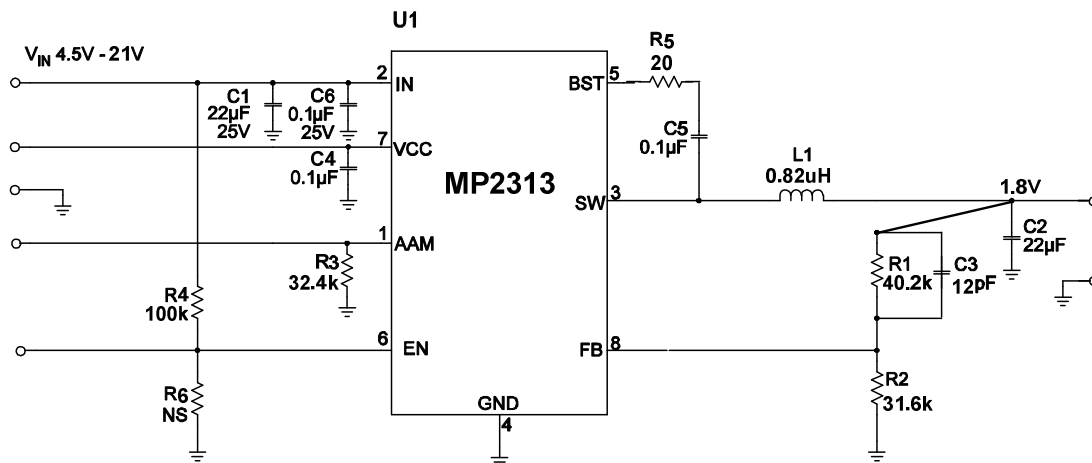


Figure 13: $V_{IN}=12V$, $V_{OUT}=1.8V$, $I_{OUT}=1A$

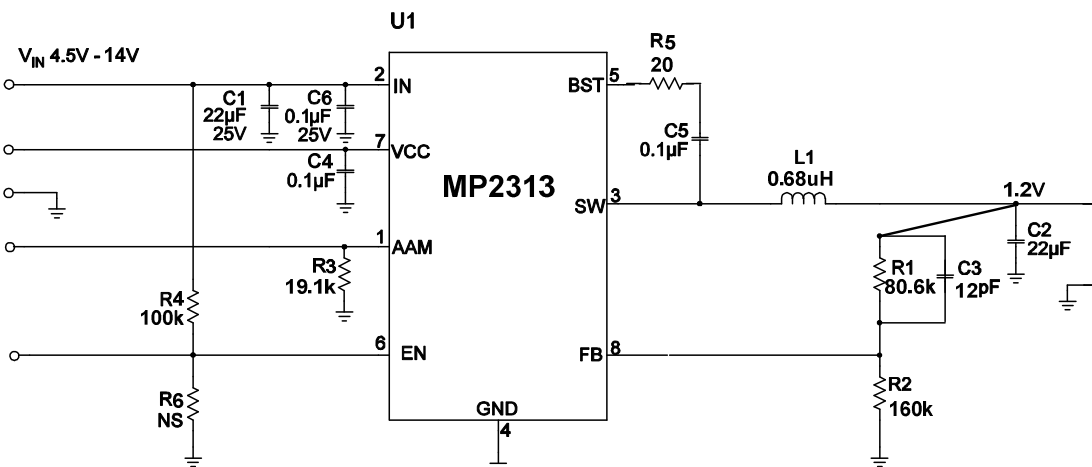


Figure 14: $V_{IN}=12V$, $V_{OUT}=1.2V$, $I_{OUT}=1A$

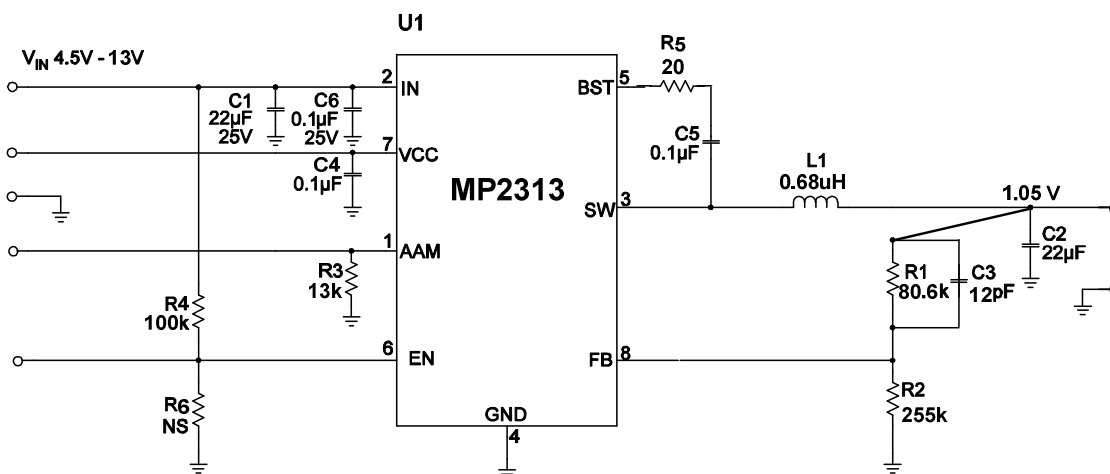
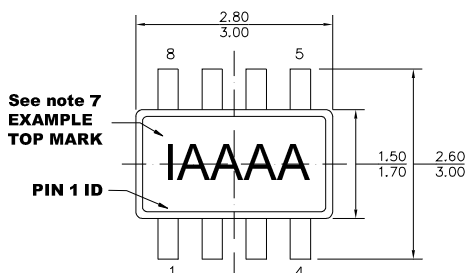


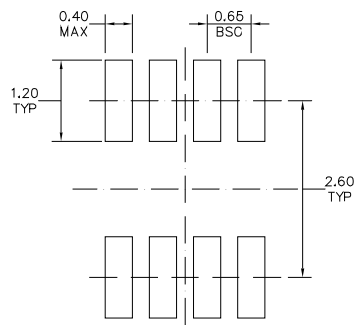
Figure 15: $V_{IN}=12V$, $V_{OUT}=1.05V$, $I_{OUT}=1A$

PACKAGE INFORMATION

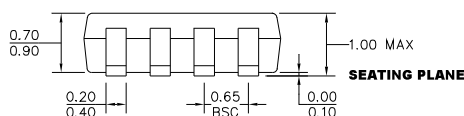
TSOT23-8



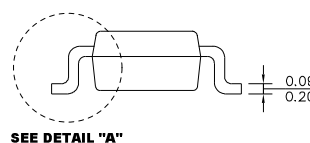
TOP VIEW



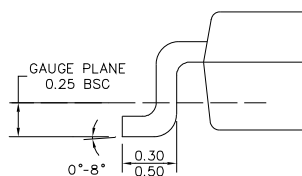
RECOMMENDED LAND PATTERN



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)

NOTICE: The information in this document is subject to change without notice. Users should warrant and guarantee that third party Intellectual Property rights are not infringed upon when integrating MPS products into any application. MPS will not assume any legal responsibility for any said applications.