

High-Voltage Micropower Boost Converter with 50mA Input Current Limit

MAX77291

General Description

The MAX77291 is a low-quiescent-current boost (step-up) DC-DC converter with a 100mA peak inductor current limit and True Shutdown™. True Shutdown disconnects the output from the input with no forward or reverse current. The output voltage is set with an external resistor-divider. The output voltage can be widely varied between 5.5V and 20V.

The MAX77291 is available in a 6-bump, 0.4mm pitch, wafer-level package (WLP).

Applications

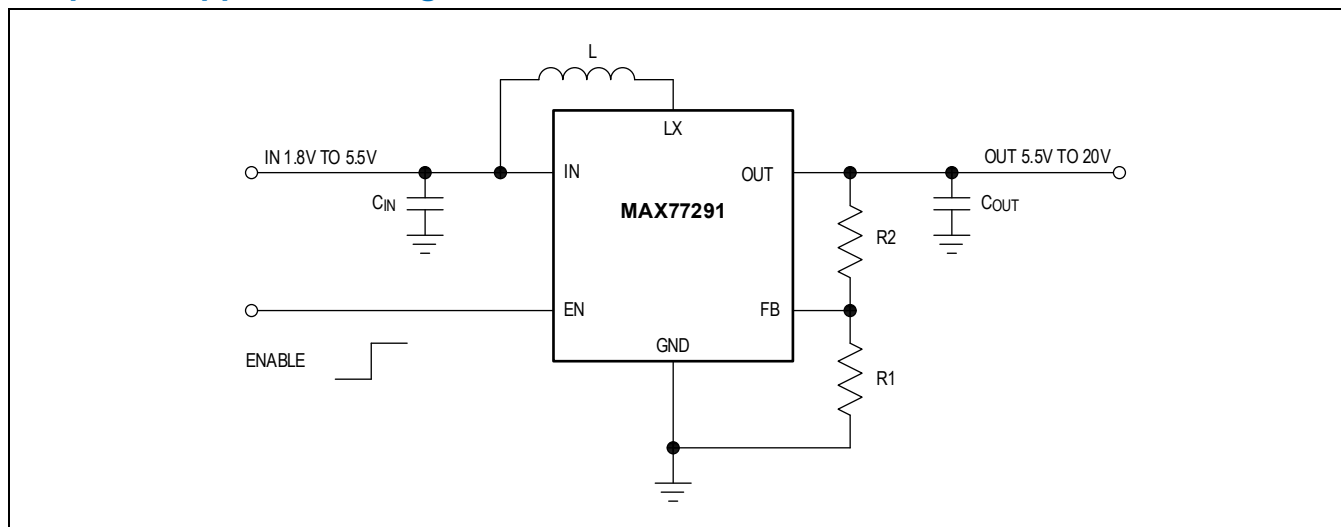
- Primary Cell Portable Systems
- Battery-Powered Medical Equipment
- Tiny, Low-Power Internet of Things (IoT) Sensors
- Low-Power Wireless Communication Products
- Secondary-Cell Portable Systems

Features and Benefits

- 28 μ A Quiescent Supply Current from Input
- Output Short Circuit Protection
- Overtemperature Protection
- True Shutdown Mode
 - 13nA Shutdown Current
 - No Reverse Current from OUT
- 90% Peak Efficiency
- 1.8V to 5.5 V Input Range
- 5.5V to 20V Output Voltage Range
- 100mA Peak Inductor Current Limit
- 1.27mm x 0.87mm 6-Bump WLP (3 x 2, 0.4mm Pitch) Package
- -40°C to +125°C Temperature Range

[Ordering Information](#) appears at end of data sheet.

Simplified Application Diagram



True Shutdown is a trademark of Maxim Integrated Products, Inc.

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Absolute Maximum Ratings

EN, IN to GND	-0.3V to +6V	Operating Temperature Range	-40°C to +125°C
FB to GND	-0.3V to +6V	Maximum Junction Temperature	+150°C
OUT, LX to GND	-0.3V to +22V	Storage Temperature Range	-40°C to +150°C
LX RMS Current	-0.7A to +0.7A	Soldering Temperature Reflow	+260°C
Continuous Power Dissipation ($T_A = +70^\circ\text{C}$) (Derate 10.51mW/°C above +70°C)	840mW	Lead Temperature (Soldering, 10 Seconds)	+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

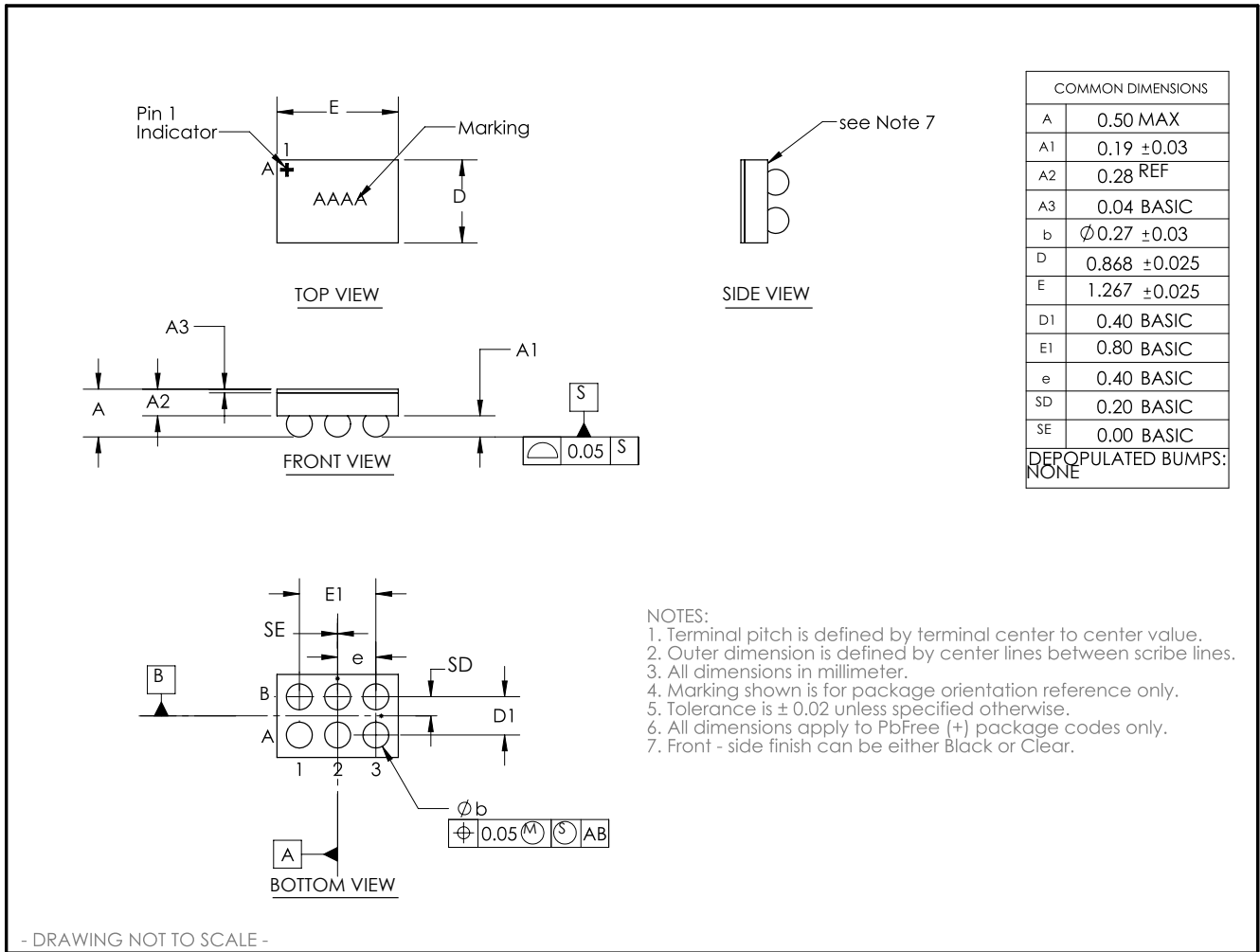
Package Information

Package Code	N60N1+1S
Outline Number	21-100577
Land Pattern Number	Refer to Application Note 1891
Thermal Resistance, Four Layer Board:	
Junction-to-Ambient (θ_{JA})	95.15°C/W
Junction-to-Case Thermal Resistance (θ_{JC})	N/A

For the latest package outline information and land patterns (footprints), go to [Packaging Index](#). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [Thermal Characterization of IC Packages](#).

Packaging Information (continued)



Electrical Characteristics

(V_{IN} = 3.6V, V_{EN} = 3.6V, V_{OUT} = 12V, T_J = -40°C to +125°C, typical values are at T_J = +25°C, unless otherwise noted ([Note 1](#).)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range	V _{IN}	Guaranteed by input UVLO		1.8		5.5	V
UVLO	V _{UVLO}	V _{IN} rising		1.7		1.8	V
UVLO Hysteresis	V _{HYS}				100		mV
Output Voltage Range	V _{OUT}	For V _{IN} < V _{OUT} target, guaranteed by I _{Q_OUT}		5.5		20	V
Feedback (FB) Accuracy	ACC	V _{FB} falling, when in Discontinuous Conduction Mode (DCM) (Note 2)		-1.25		+1.25	%
Output Load Regulation	ACC _{LOAD_REG}	10mA < I _{IN} < 50mA			1		%
Quiescent Supply Current Into IN	I _{Q_IN}	Not switching, V _{OUT} = 104% of regulation	T _J = +25°C		28	45	μA
Quiescent Supply Current Into OUT	I _{Q_OUT}	Not switching, V _{OUT} = 104% of regulation	T _J = +25°C		3.5	25	μA
Shutdown Current into IN	I _{SD_IN}	V _{EN} = 0V	T _J = +25°C		13	200	nA
LX Leakage Current	I _{LX_LEAK}	V _{IN} = 5.5V, V _{LX} = 5.5V, V _{OUT} = 0, V _{EN} = 0	T _J = +25°C		10	500	nA
Startup Time	t _{SU}	V _{OUT} = 12V			2.4		ms
Inductor Peak Current Limit	I _{PEAK}	V _{IN} = 2.5V to 5.5 V, (Note 3)	T _J = -40°C to 125°C	90	100	110	mA
LX Maximum On-Time	t _{ON_MAX}	V _{IN} = 3.6V, V _{LX} = 5.0V, V _{OUT} = 0			3.4		μs
N-Channel On-Resistance	R _{DSON}	V _{IN} = 3.6V			450	900	mΩ
P-Channel On-Resistance	R _{DSON}	V _{IN} = 3.6V			320	450	mΩ
Diode Forward Voltage	V _f	V _{IN} = 3.6V, I _{LX} = 100mA			0.4		V
FB Leakage	I _{FB_LEAK}	V _{FB} = 1.25V	T _J = +25°C		0.5	100	nA
Overtemperature Lockout Threshold	T _{OTLO}	T _J rising, 15°C typical hysteresis			+165		°C
Enable Voltage Threshold	V _{IL}	V _{IN} = 1.8V to 5.5 V, when LX stops switching, EN falling		400	750		mV
	V _{IH}	V _{IN} = 1.8V to 5.5 V, EN rising			820	1400	
Enable Input Leakage	I _{EN_LEAK}	V _{EN} = 0V to 5.5 V	T _J = +25°C		0.5	100	nA

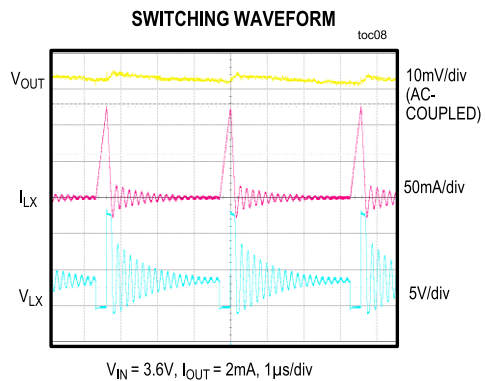
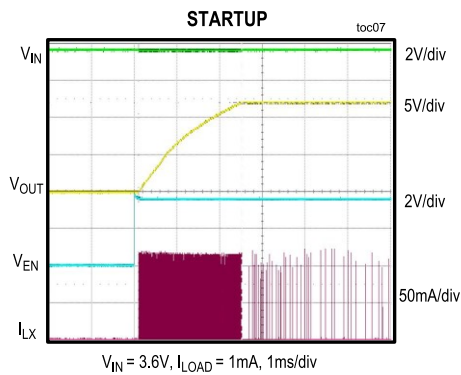
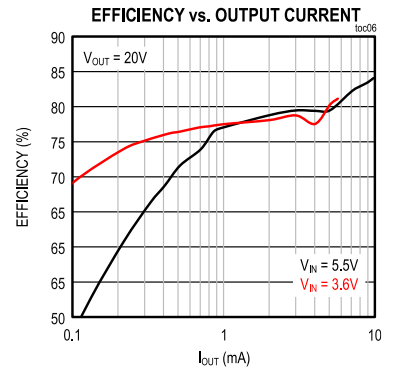
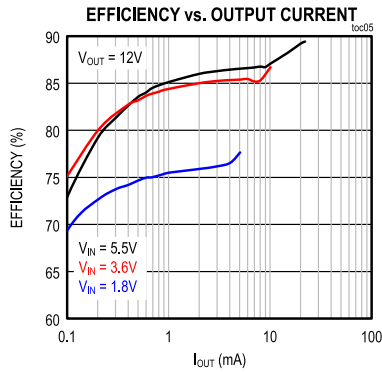
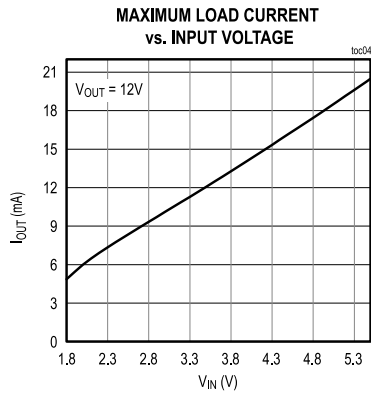
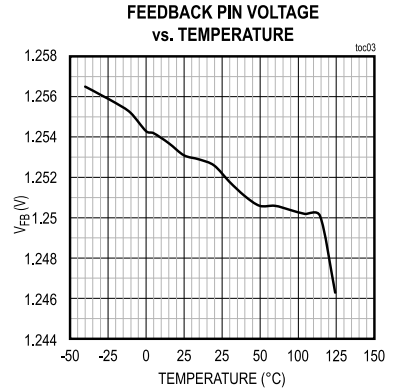
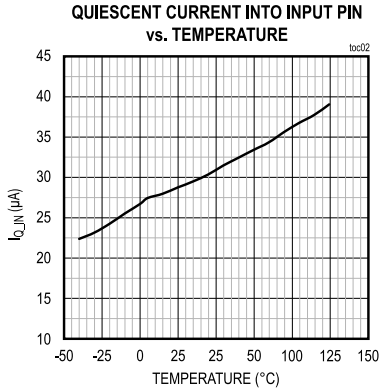
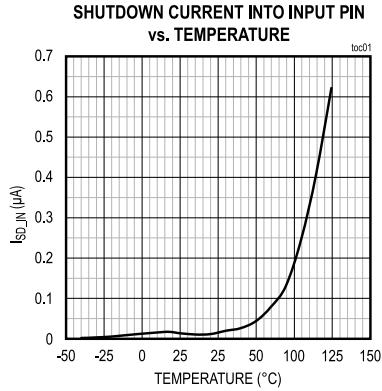
Note 1: Limits are 100% production tested at T_J = +25°C. Limits over the operating temperature range are guaranteed through correlation using statistical quality control (SQC) methods.

Note 2: Output accuracy does not include load, line, or ripple.

Note 3: This is a static measurement. The actual peak current limit depends upon V_{IN} and the inductor due to propagation delays.

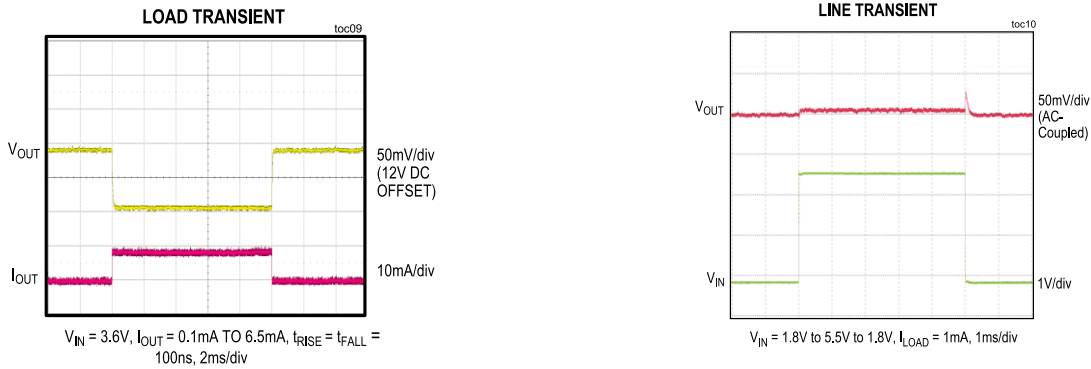
Typical Operating Characteristics

($V_{IN} = 3.6V$, $V_{OUT} = 12V$, $T_A = +25^\circ C$, $C_{IN} = 22\mu F$, $C_{OUT} = 4.7\mu F$, $L = 10\mu H$, unless otherwise noted.)

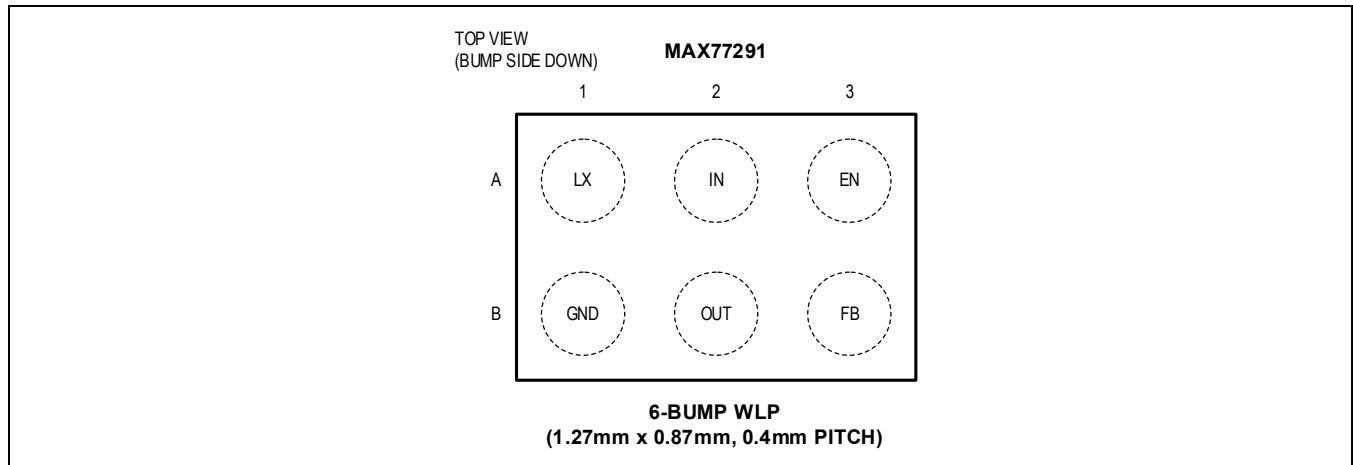


Typical Operating Characteristics (continued)

($V_{IN} = 3.6V$, $V_{OUT} = 12V$, $T_A = +25^{\circ}C$, $C_{IN} = 22\mu F$, $C_{OUT} = 4.7\mu F$, $L = 10\mu H$, unless otherwise noted.)



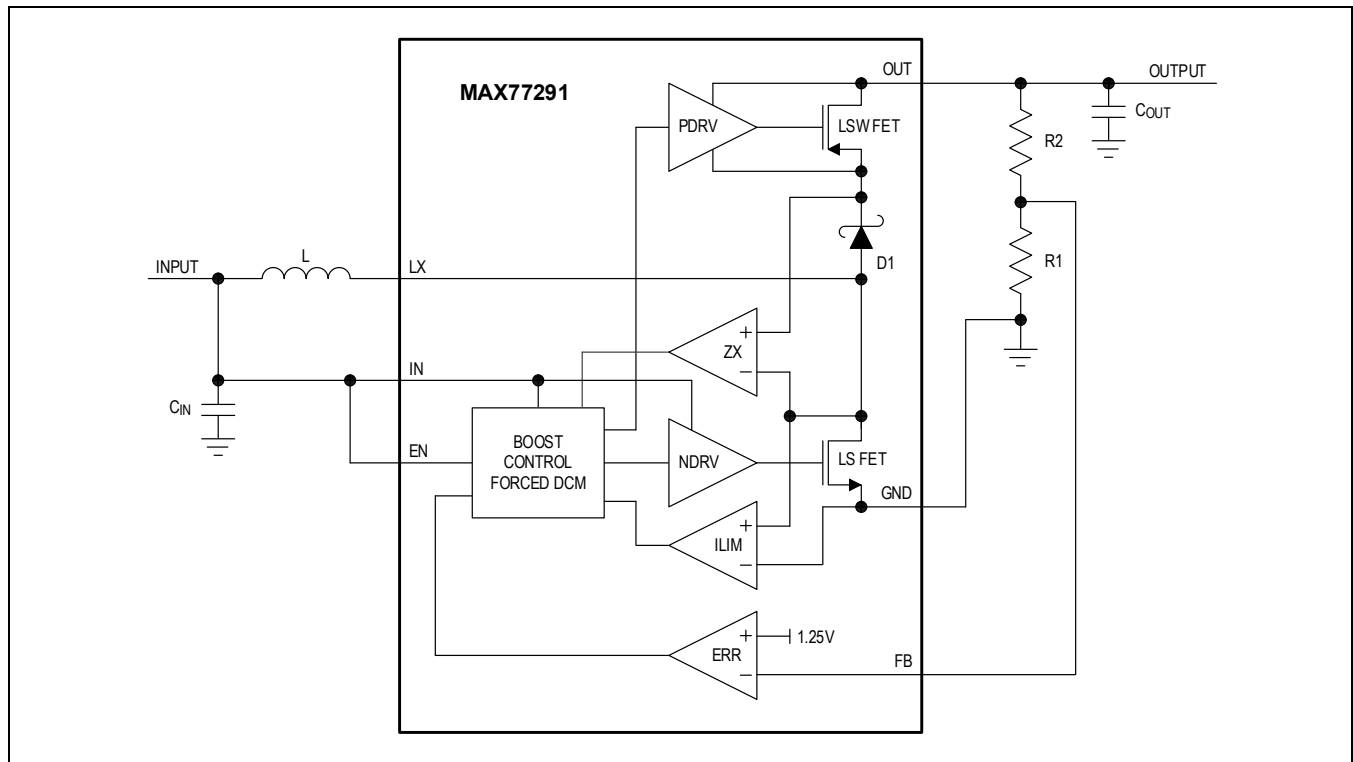
Pin Configuration



Pin Descriptions

PIN	NAME	FUNCTION
A1	LX	Switching Node. Connect the inductor from IN to LX.
A2	IN	Input Supply. Connect to a voltage between 1.8V and 5.5 V and bypass with a 22μF ceramic capacitor from IN to GND.
A3	EN	Enable Input, Active-High. Force this pin high to enable the converter. Force this pin low to disable the converter and enter shutdown. If the enable feature is unused, short this pin to IN.
B3	FB	Feedback. Connect to the center point of a resistor-divider from OUT to GND to set the output voltage.
B2	OUT	Output. Connect the ceramic capacitor between the OUT and GND pins.
B1	GND	Power Ground. Connect to the system GND plane.

Functional Diagram



Detailed Description

The MAX77291 is a low quiescent-current boost (step-up) DC-DC converter with a 100mA peak inductor current limit and True Shutdown. True Shutdown disconnects the output from the input with no forward or reverse current. The output voltage is set with an external resistor-divider. The MAX77291 offers low quiescent current, small total solution size, and high efficiency throughout the entire load range. The MAX77291 is a highly integrated boost converter designed for applications requiring high voltage, and tiny solution sizes, such as sensor modules. It integrates a power switch, power diode, and output load switch. It can output 5.5V to 20V from a 1.8V to 5.5 V input supply range. The load switch is turned off under shutdown mode, truly disconnecting the load from the input voltage, thus minimizing the leakage current during shutdown mode. The device operates in a discontinuous conduction mode of operation. The device features short-circuit and thermal protection.

The MAX77291 employs a power-save mode with pulse frequency modulation (PFM) to improve efficiency. The on-time is determined by a peak inductor current limit of 100mA. Once the inductor current hits its limit, the on-time is terminated, and the power diode is forward-biased. During the off-time, the charge is transferred to output capacitance, causing its voltage to rise. The off-time is terminated once the inductor current ramps down to zero; the load is supplied by the output capacitor, and the output voltage declines. When the FB voltage falls below the reference voltage, the device initiates the on-time again to bring the output voltage up. The MAX77291 clamps the average input current to a maximum of 50mA.

Undervoltage Lockout

An undervoltage lockout (UVLO) circuit is implemented to ensure proper behavior while the input voltage supply is ramping up or down. The UVLO enables the operation of the converter when the input voltage ramps above the typical UVLO threshold of 1.75V (V_{UVLO}). A hysteresis of 100mV (V_{UVLO_HYS}) assures that the device does not stop regulation due to a small V_{IN} transient. Once V_{IN} drops below $V_{UVLO} - V_{UVLO_HYS}$, the converter is disabled.

Enable and Disable

When V_{IN} is above the UVLO rising threshold and the EN pin is pulled high ($V_{EN} > V_{IH}$), the MAX77291 is enabled. When the EN pin is pulled low ($V_{EN} < V_{IL}$), the MAX77291 goes into shutdown mode. While in shutdown mode, the device provides the isolation between the input and output. In this mode, 13nA current is consumed from V_{IN} . If the enable feature is not used, the pin should be connected to IN.

Startup

This feature provides a way to limit the inrush current drawn from the supply upon startup. The MAX77291 startup begins when the EN pin is pulled high above its V_{IH} level, after which the output voltage starts to rise. The device limits the amount of charge transferred to the output per cycle by enforcing the 100mA peak inductor current limit during the startup.

Output Short-Circuit Protection

The MAX77291 limits the output current whenever the output voltage drops below the input voltage. This function protects the devices when the output is shorted to ground. When the V_{OUT} is shorted to ground, the peak inductor current remains limited to 100mA and a 1.5 μ s off-time is enforced. Upon recovery from the short-circuit event, the MAX77291 ramps the output to regulation, maintaining constant input current.

Thermal Shutdown

The MAX77291 goes into thermal shutdown once the junction temperature exceeds +165°C. When the junction temperature drops below the thermal shutdown temperature threshold, less the hysteresis, typically to the +150°C level, the device starts operating again.

Applications Information

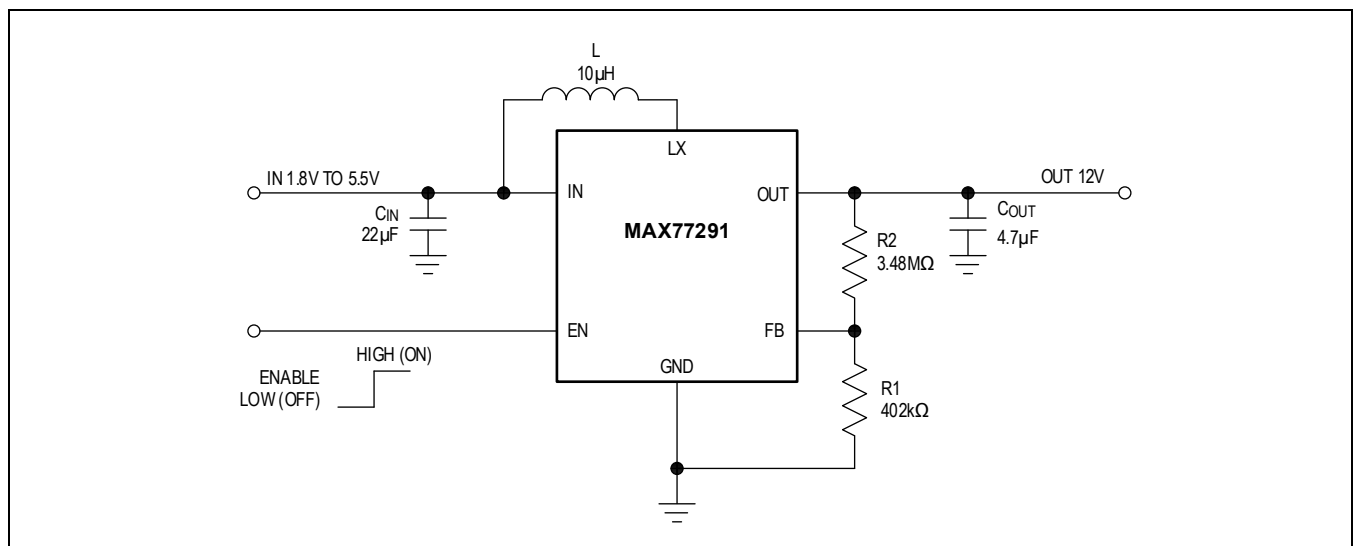


Figure 1. Application Diagram

Design Procedure

Programming Output Voltage

The MAX77291 programs V_{OUT} using an external resistor-divider. By selecting the external resistor-divider R1 and R2, the output voltage is programmed to the desired value. When the output voltage is regulated, the typical voltage at the FB pin is 1.25V.

$$R2 = ((V_{OUT} / V_{FB}) - 1) \times R1$$

Where

- V_{OUT} is the desired output voltage

- V_{FB} is the internal reference voltage at the FB pin, 1.25V (typ)

For the best accuracy, R1 is recommended to have a value smaller than 475k Ω to ensure that the current flowing through it is significantly larger than the FB pin bias current. Additionally, using R1 values that are lower increases immunity against noise injection. The advantage of using the higher value R1 is the reduction of quiescent current for achieving the highest efficiency at light load currents.

Inductor Selection

Because the selection of the inductor affects steady-state operation, transient behavior, and loop stability, the inductor is the most important component in power regulator design. There are three important inductor specifications to pay attention to inductor value, saturation current, and DC resistance (DCR). The MAX77291 is designed to work with inductor values between 4.7 μ H and 15 μ H.

Table 1. Inductor Value Recommendation

V_{OUT} (V)	L (μ H)
5.5V to 7V	4.7
7V to 14V	10
14V to 20V	15

Input and Output Capacitor Selection

Input capacitors reduce current peaks from the input supply and increase efficiency. For the input capacitor, a ceramic capacitor is recommended because they have the lowest equivalent series resistance (ESR), smallest size, and lowest cost. Other capacitor types can be used as well, but they can have larger ESR. The biggest downside of ceramic capacitors is their capacitance derating with higher DC bias; therefore, at minimum, a standard 22 μ F ceramic capacitor (12 μ F effective capacitance) is recommended at the input for all applications. Refer to the capacitor data sheet for proper DC bias, AC ripple, and temperature capacitance derating.

The output capacitor is mainly selected to meet the requirements for output ripple and loop stability. This ripple voltage is related to the capacitance and equivalent series resistance (ESR). The ESR impact on the output ripple must be considered. Refer to the capacitor data sheet for ESR information. Effective capacitance is a function of bias, ageing, temperature, and AC signal, so proper derating must be considered. Always use a margin on the voltage rating to ensure adequate capacitance at the required output voltage. The recommended effective output capacitor is 4 μ F at 12V output and 6 μ F at 20V output.

Layout Guidelines

As with all switching power supplies, especially those running at a high switching frequency, special attention needs to be paid to the printed circuit board (PCB) layout. If the board is not carefully laid out, the regulator could suffer from instability, noise problems, and inefficiency. To prevent radiation of high-frequency noise (EMI) due to fast switching edges, proper layout of the high-frequency switching paths is essential. Minimize the length and area of all traces connected to the LX pin, and always use a ground plane under the switching regulator. The most critical current path for a boost converter is through the rectifier power diode and output capacitor, and then back through the GND connection. This high-current path contains nanosecond rise and fall time switching edges and should be kept as short as possible. Therefore, the output capacitor needs to be connected as close to the OUT and GND pins as possible to reduce parasitic overshoot at the LX and OUT. The input capacitor connections to IN and GND need to be short to reduce supply voltage ripple. Route the output voltage sensing away from the inductor and LX switching node to minimize noise and magnetic interference. The inductor and LX node need to be separated from the feedback pin and its resistor-divider network by the device itself and component placement clearance. The inductor should be placed on the opposite side of the feedback pin and its resistive-divider network. The resistor-divider ground reference needs to have a Kelvin connection back to the GND pin. Maximize the size of the ground metal on the component side to help with thermal dissipation. Use a ground plane with several vias connecting to the component-side ground to further reduce noise interference on sensitive circuit nodes. It is recommended to refer to the [MAX77291 EV kit](#) layout.

Ordering Information

PART NUMBER	TEMP RANGE	PIN-PACKAGE	FEATURES
MAX77291ANT+	-40°C to +125°C	1.27mm x 0.87mm 6-Bump WLP	100mA Inductor Peak Current, Enable Input, Externally Adjustable Outputs

+Denotes a lead (Pb)-free/RoHS-compliant package.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	04/24	Initial release	—

