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# MAXIM

## 0.8A, Low-Noise, 1MHz, Step-Up DC-DC Converter

MAX1760

### General Description

The MAX1760 is a high-efficiency, low-noise, step-up DC-DC converter intended for use in battery-powered wireless applications. It maintains exceptionally low quiescent supply current (100 $\mu$ A) despite its high 1MHz operating frequency. Small external components and a tiny 10-pin  $\mu$ MAX package make this device an excellent choice for small hand-held applications requiring the longest possible battery life.

The MAX1760 uses a synchronous-rectified pulse-width-modulation (PWM) boost topology to generate 2.5V to 5.5V outputs from a wide range of input sources, such as 1 to 3 alkaline or NiCd/NiMH cells or a single lithium-ion (Li+) cell. Maxim's proprietary Idle-Mode™ circuitry significantly improves efficiency at light load currents while smoothly transitioning to fixed-frequency PWM operation at higher load currents to maintain excellent full-load efficiency.

Low-noise, forced PWM mode is available for applications requiring constant-frequency operation at all load currents. The MAX1760 may also be synchronized to an external clock to protect sensitive frequency bands in communications equipment. Analog soft-start and adjustable current limit permit optimization of efficiency, external component size, and output voltage ripple.

### Applications

Digital Cordless Phones	PCS Phones
Wireless Handsets	Hand-Held Instruments
Palmtop Computers	Personal Communicators
Two-Way Pagers	

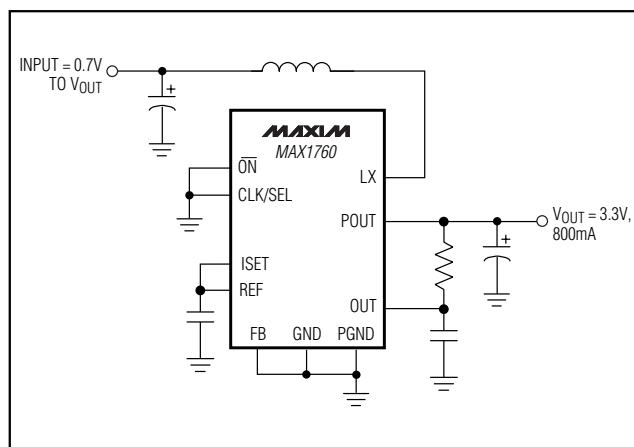
### Features

- ◆ Up to 94% Efficiency
- ◆ 0.7V to 5.5V Input Range
- ◆ Up to 800mA Output
- ◆ Fixed 3.3V Output (or adj from 2.5V to 5.5V)
- ◆ PWM Synchronous Rectified Topology
- ◆ Low-Noise, Constant Frequency Operation (1MHz)
- ◆ 0.1 $\mu$ A Logic-Controlled Shutdown
- ◆ Synchronizable Switching Frequency
- ◆ Adjustable Current Limit
- ◆ Adjustable Soft-Start
- ◆ 10-Pin  $\mu$ MAX Package

### Ordering Information

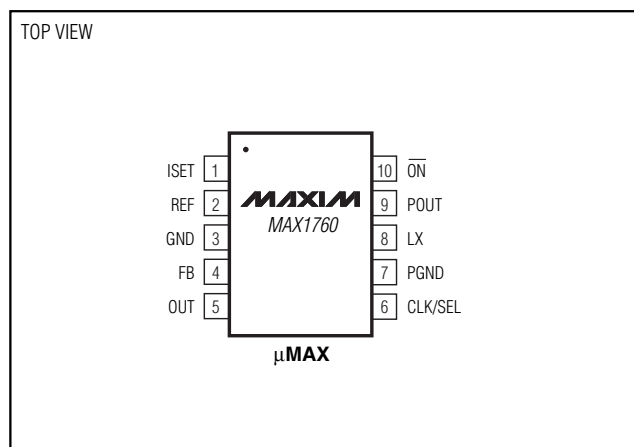
PART	TEMP. RANGE	PIN-PACKAGE
MAX1760EUB	-40°C to +85°C	10 $\mu$ MAX

### Typical Operating Circuit



Idle Mode is a trademark of Maxim Integrated Products.

### Pin Configuration



MAXIM

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# 0.8A, Low-Noise, 1MHz, Step-Up DC-DC Converter

## ABSOLUTE MAXIMUM RATINGS

$\overline{\text{ON}}$ , OUT, CLK/SEL to GND ..... -0.3V to +6V  
 PGND to GND .....  $\pm 0.3\text{V}$   
 LX to PGND ..... -0.3V to ( $V_{\text{POUT}} + 0.3\text{V}$ )  
 POUT to OUT .....  $\pm 0.3\text{V}$   
 REF, FB, ISET, POUT to GND ..... -0.3V to ( $V_{\text{OUT}} + 0.3\text{V}$ )

Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )  
     10-Pin  $\mu\text{MAX}$  (derate 5.6mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 444mW  
 Operating Temperature Range .....  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$   
 Junction Temperature .....  $+150^\circ\text{C}$   
 Storage Temperature Range .....  $-65^\circ\text{C}$  to  $+150^\circ\text{C}$   
 Lead Temperature (soldering, 10s) .....  $+300^\circ\text{C}$

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.

## ELECTRICAL CHARACTERISTICS

(CLK/SEL =  $\overline{\text{ON}}$  = FB = PGND = GND, ISET = REF, OUT = POUT,  $V_{\text{OUT}} = 3.6\text{V}$ ,  $T_A = 0^\circ\text{C}$  to  $+85^\circ\text{C}$ . Typical values are at  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DC-DC CONVERTER</b>					
Input Voltage Range (Note 1)			0.7	5.5	V
Minimum Startup Voltage (Note 2)	$I_{\text{LOAD}} < 1\text{mA}$ , $T_A = +25^\circ\text{C}$		0.9	1.1	V
Temperature Coefficient of Startup Voltage	$I_{\text{LOAD}} < 1\text{mA}$		-2.3		mV/ $^\circ\text{C}$
Frequency in Startup Mode	$V_{\text{OUT}} = 1.5\text{V}$	125	500	1000	kHz
Internal Oscillator Frequency	CLK/SEL = OUT	0.8	1	1.2	MHz
Oscillator Maximum Duty Cycle (Note 3)		80	86	90	%
External Clock Frequency Range		0.5		1.2	MHz
Output Voltage	$V_{\text{FB}} < 0.1\text{V}$ , CLK/SEL = OUT, includes load regulation for $0 < I_{\text{LX}} < 0.55\text{A}$	3.17	3.3	3.38	V
FB Regulation Voltage	Adjustable output, CLK/SEL = OUT, includes load regulation for $0 < I_{\text{LX}} < 0.55\text{A}$	1.215	1.240	1.270	V
FB Input Leakage Current	$V_{\text{FB}} = 1.35\text{V}$		0.01	100	nA
Load Regulation	CLK/SEL = OUT, no load to full load ( $0 < I_{\text{LX}} < 1.0\text{A}$ )		-1.5		%
Output Voltage Adjust Range		2.5		5.5	V
Output Voltage Lockout Threshold (Note 4)	Rising edge	2.00	2.15	2.30	V
ISET Input Leakage Current	$V_{\text{ISET}} = 1.25\text{V}$		$\pm 0.01$	$\pm 50$	nA
Supply Current in Shutdown	$V_{\text{ON}} = 3.6\text{V}$		0.1	5	$\mu\text{A}$
No-Load Supply Current (Note 5)	CLK/SEL = GND		100	185	$\mu\text{A}$
No-Load Supply Current Forced PWM Mode	CLK/SEL = OUT		2.5		mA
<b>DC-DC SWITCHES</b>					
POUT Leakage Current	$V_{\text{LX}} = 0$ , $V_{\text{OUT}} = 5.5\text{V}$		0.1	10	$\mu\text{A}$
LX Leakage Current	$V_{\text{LX}} = V_{\text{ON}} = V_{\text{OUT}} = 5.5\text{V}$		0.1	10	$\mu\text{A}$
Switch On-Resistance	N-channel		0.15	0.28	$\Omega$
	P-channel		0.25	0.45	
N-Channel Current Limit		1.0	1.25	1.6	A
P-Channel Turn-Off Current	CLK/SEL = GND	20	60	120	mA

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## ELECTRICAL CHARACTERISTICS (continued)

(CLK/SEL =  $\overline{\text{ON}}$  = FB = PGND = GND, ISET = REF, OUT = POUT,  $V_{\text{OUT}} = 3.6\text{V}$ ,  $T_A = 0^\circ\text{C}$  to  $+85^\circ\text{C}$ . Typical values are at  $T_A = +25^\circ\text{C}$  unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>REFERENCES</b>					
Reference Output Voltage	$I_{\text{REF}} = 0$	1.230	1.250	1.270	V
Reference Load Regulation	$-1\mu\text{A} < I_{\text{REF}} < 50\mu\text{A}$		5	15	mV
Reference Supply Rejection	$2.5\text{V} < V_{\text{OUT}} < 5\text{V}$		0.2	5	mV
<b>LOGIC INPUTS</b>					
CLK/SEL Input Low Level	$2.5\text{V} \leq V_{\text{OUT}} \leq 5.5\text{V}$		$(0.2)V_{\text{OUT}}$		V
CLK/SEL Input High Level	$2.5\text{V} \leq V_{\text{OUT}} \leq 5.5\text{V}$	$(0.8)V_{\text{OUT}}$			V
$\overline{\text{ON}}$ Input Low Level (Note 6)	$1.1\text{V} \leq V_{\text{OUT}} \leq 1.8\text{V}$			0.2	V
	$1.8\text{V} \leq V_{\text{OUT}} \leq 5.5\text{V}$			0.4	
$\overline{\text{ON}}$ Input High Level (Note 6)	$1.1\text{V} \leq V_{\text{OUT}} \leq 1.8\text{V}$	$V_{\text{OUT}} - 0.2$			V
	$1.8\text{V} \leq V_{\text{OUT}} \leq 5.5\text{V}$	1.6			
Input Leakage Current	CLK/SEL, $\overline{\text{ON}}$		0.01	1	$\mu\text{A}$
Minimum CLK/SEL Pulse Width			200		ns
Maximum CLK/SEL Rise/Fall Time			100		ns

## ELECTRICAL CHARACTERISTICS

(CLK/SEL =  $\overline{\text{ON}}$  = FB = PGND = GND, ISET = REF, OUT = POUT,  $V_{\text{OUT}} = 3.6\text{V}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted.) (Note 7)

PARAMETER	CONDITIONS	MIN	MAX	UNITS
<b>DC-DC CONVERTER</b>				
Output Voltage	$V_{\text{FB}} < 0.1\text{V}$ , CLK/SEL = OUT, includes load regulation for $0 < I_{\text{LX}} < 0.55\text{A}$	3.17	3.38	V
FB Regulation Voltage	Adjustable output, CLK/SEL = OUT, includes load regulation for $0 < I_{\text{LX}} < 0.55\text{A}$	1.215	1.270	V
Internal Oscillator Frequency	CLK/SEL = OUT	0.75	1.2	MHz
Oscillator Maximum Duty Cycle (Note 3)		80	90	%
Output Voltage Lockout Threshold (Note 4)	Rising edge	2.00	2.30	V
Supply Current in Shutdown	$V_{\text{ON}} = 3.6\text{V}$		5	$\mu\text{A}$
No-Load Supply Current (Note 5)	CLK/SEL = GND		185	$\mu\text{A}$
<b>DC-DC SWITCHES</b>				
Switch On-Resistance	N-channel		0.28	$\Omega$
	P-channel		0.45	
N-Channel Current Limit		1.0	1.6	A
<b>REFERENCE</b>				
Reference Output Voltage	$I_{\text{REF}} = 0$	1.230	1.270	V

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## ELECTRICAL CHARACTERISTICS (continued)

(CLK/SEL =  $\overline{\text{ON}}$  = FB = PGND = GND, ISET = REF, OUT = POUT,  $V_{\text{OUT}} = 3.6\text{V}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted.) (Note 7)

PARAMETER	CONDITIONS	MIN	MAX	UNITS
<b>LOGIC INPUTS</b>				
CLK/SEL Input Low Level	$2.5\text{V} \leq V_{\text{OUT}} \leq 5.5\text{V}$		$(0.2)V_{\text{OUT}}$	V
CLK/SEL Input High Level	$2.5\text{V} \leq V_{\text{OUT}} \leq 5.5\text{V}$	$(0.8)V_{\text{OUT}}$		V
$\overline{\text{ON}}$ Input Low Level (Note 6)	$1.1\text{V} \leq V_{\text{OUT}} \leq 1.8\text{V}$		0.2	V
	$1.8\text{V} \leq V_{\text{OUT}} \leq 5.5\text{V}$		0.4	
$\overline{\text{ON}}$ Input High Level (Note 6)	$1.1\text{V} \leq V_{\text{OUT}} \leq 1.8\text{V}$	$V_{\text{OUT}} + 0.2$		V
	$1.8\text{V} \leq V_{\text{OUT}} \leq 5.5\text{V}$	1.6		
Input Leakage Current	CLK/SEL, $\overline{\text{ON}}$		1	$\mu\text{A}$

**Note 1:** Operating voltage—since the regulator is bootstrapped to the output, once started the MAX1760 will operate down to 0.7V input.

**Note 2:** Startup is tested with the circuit shown in Figure 6.

**Note 3:** Defines maximum step-up ratio.

**Note 4:** The regulator is in startup mode until this voltage is reached. Do not apply full load current until the output exceeds 2.3V.

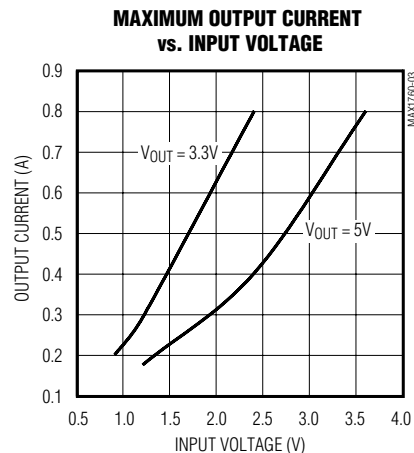
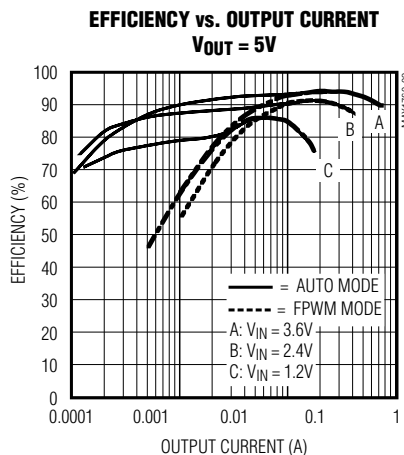
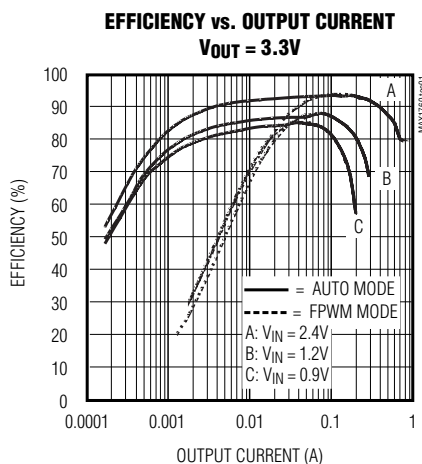
**Note 5:** Supply current into the OUT pin. This current correlates directly to the actual battery-supply current, but is reduced in value according to the step-up ratio and efficiency.

**Note 6:**  $\overline{\text{ON}}$  has a hysteresis of approximately  $0.15 \times V_{\text{OUT}}$ .

**Note 7:** Specifications to  $-40^\circ\text{C}$  are guaranteed by design and not production tested.

## Typical Operating Characteristics

(Circuit of Figure 2,  $V_{\text{IN}} = 2.4\text{V}$ ,  $V_{\text{OUT}} = 3.3\text{V}$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



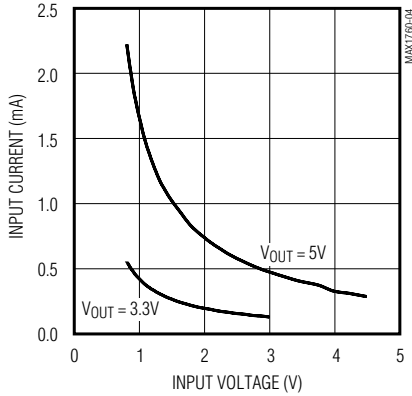
# 0.8A, Low-Noise, 1MHz, Step-Up DC-DC Converter

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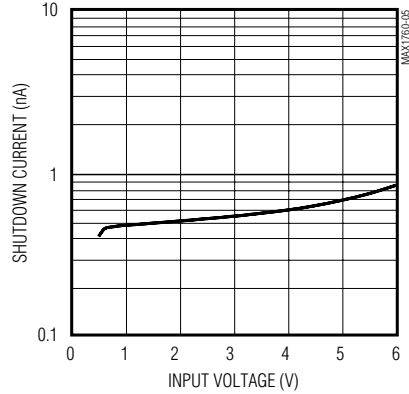
## Typical Operating Characteristics (continued)

(Circuit of Figure 2,  $V_{IN} = 2.4V$ ,  $V_{OUT} = 3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

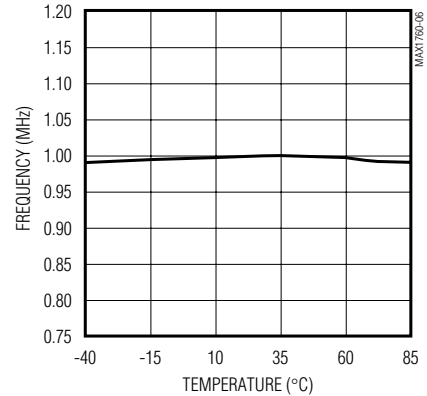
**NO-LOAD BATTERY CURRENT  
vs. INPUT VOLTAGE**



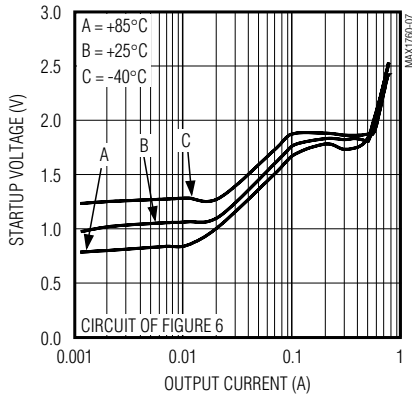
**TOTAL SHUTDOWN CURRENT  
( $I_{LX} + I_{OUT}$ ) vs. INPUT VOLTAGE**



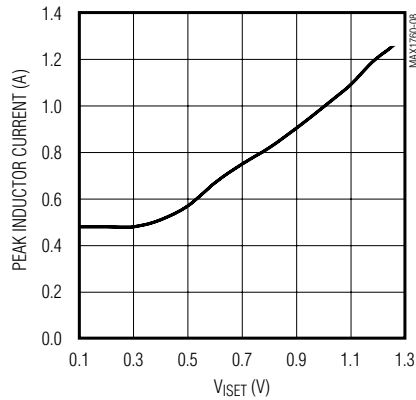
**INTERNAL OSCILLATOR  
FREQUENCY vs. TEMPERATURE**



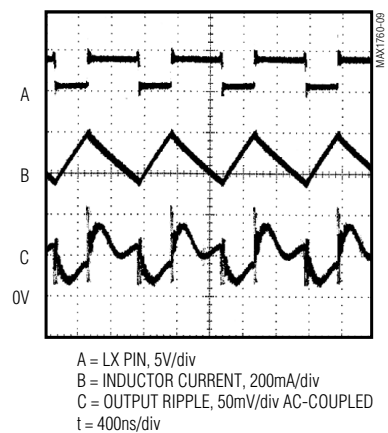
**STARTUP VOLTAGE  
vs. OUTPUT CURRENT**



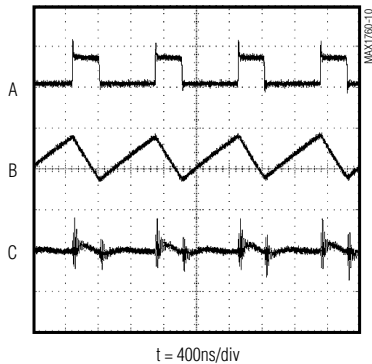
**PEAK INDUCTOR CURRENT vs.  $V_{ISET}$**



**HEAVY-LOAD SWITCHING WAVEFORMS**

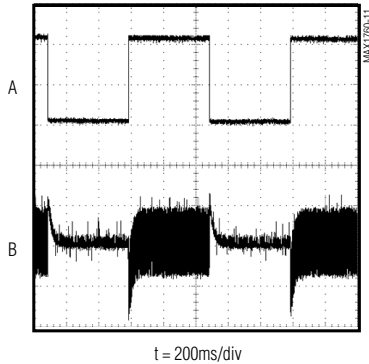


**LIGHT-LOAD SWITCHING WAVEFORMS**



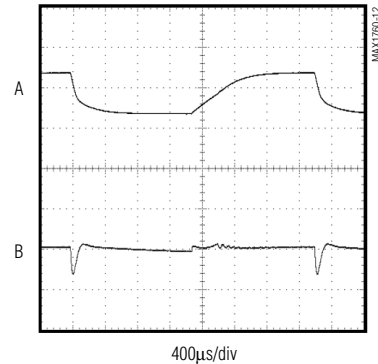
A = LX PIN, 5V/div  
B = INDUCTOR CURRENT, 200mA/div  
C = OUTPUT RIPPLE, 50mV/div, AC-COUPLED

**LOAD-TRANSIENT RESPONSE**



$V_{IN} = 1.1V$ ,  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 0$  AND  $0.2A$   
A =  $I_{OUT}$ , 100mA/div  
B =  $V_{OUT}$ , 50mV/div, AC-COUPLED

**LINE-TRANSIENT RESPONSE**

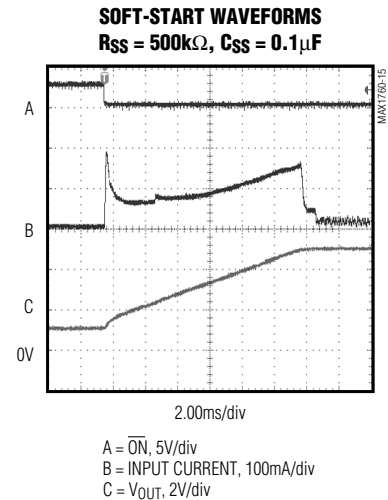
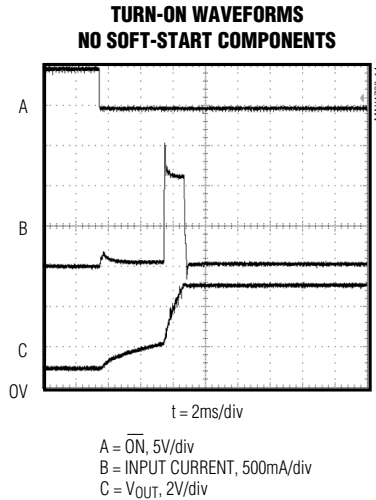
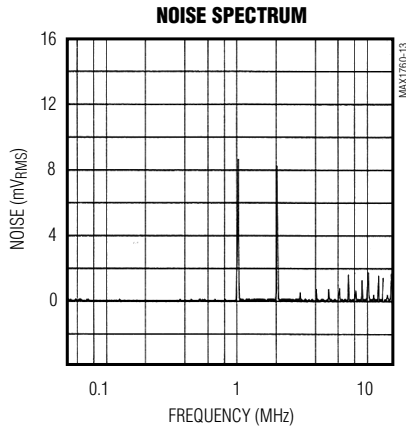


$V_{IN} = 2.4V$  TO  $1.4V$ ,  $I_{OUT} = 70mA$   
A =  $V_{IN}$ , 1V/div  
B =  $V_{OUT}$ , 5mV/div, AC-COUPLED

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## Typical Operating Characteristics (continued)

(Circuit of Figure 2,  $V_{IN} = 2.4V$ ,  $V_{OUT} = 3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pin Description

PIN	NAME	FUNCTION
1	IS $\overline{E}T$	N-Channel Current-Limit Control. For maximum current limit, connect to REF. To reduce current, supply a voltage between REF and GND by means of a resistive voltage-divider. If soft-start is desired, connect a capacitor from IS $\overline{E}T$ to GND. When $\overline{ON} = \text{high}$ , or $V_{REF} < 80\%$ of nominal value, an on-chip 100k $\Omega$ switched resistor discharges this pin to GND.
2	REF	1.250V Voltage Reference Bypass. Connect a 0.22 $\mu F$ ceramic bypass capacitor to GND. Up to 50 $\mu A$ of external load current is allowed.
3	GND	Ground. Connect to PGND with short trace.
4	FB	DC-DC Converter Feedback Input. To set fixed output voltage of +3.3V, connect FB to ground. For adjustable output of 2.5V to 5.5V, connect to a resistive divider from OUT to GND. FB set point = 1.24V.
5	OUT	IC Power, Supplied from the Output. Bypass to GND with a 0.68 $\mu F$ ceramic capacitor, and connect to POUT with a series 4.7 $\Omega$ resistor (Figure 2).
6	CLK/SEL	Clock Input for the DC-DC Converter. Also serves to program operating mode of switcher as follows: <b>CLK/SEL = LO:</b> Normal operation—operates at a fixed frequency, automatically switching to low-power mode if load is minimized. <b>CLK/SEL = HI:</b> Forced PWM mode—operates in low-noise, constant-frequency mode at all loads. <b>CLK/SEL = Clocked:</b> Forced PWM mode with the internal oscillator synchronized to CLK in 500kHz to 1200kHz range.
7	PGND	Source of N-Channel Power MOSFET Switch
8	LX	Inductor Connection
9	POUT	Power Output. P-channel synchronous-rectifier source.
10	$\overline{ON}$	Shutdown Control Input. When $\overline{ON} = \text{high}$ , the IC is in shutdown. Connect $\overline{ON}$ to GND for normal operation.

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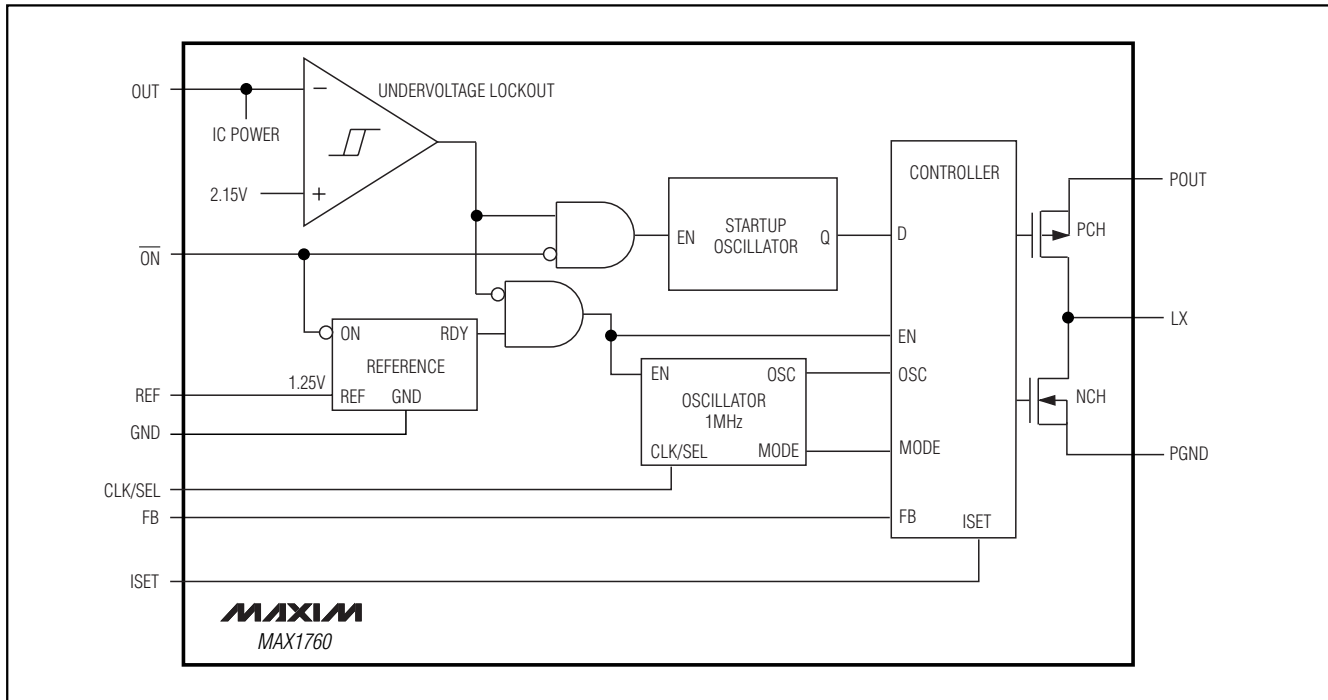


Figure 1. Functional Diagram

## Detailed Description

The MAX1760 is a highly efficient, low-noise power supply for portable RF and hand-held instruments. It combines a boost switching regulator, N-channel power MOSFET, P-channel synchronous rectifier, precision reference, and shutdown control (Figure 1).

The DC-DC converter boosts a 1-cell to 3-cell battery voltage input to a fixed 3.3V or adjustable voltage between 2.5V and 5.5V. An external Schottky diode is required for output voltages greater than 4V. The MAX1760 guarantees startup with an input voltage as low as 1.1V and remains operational down to an input of just 0.7V. It is optimized for use in cellular phones and other applications requiring low noise and low quiescent current for maximum battery life. It features fixed-frequency operation at medium and heavy loads, but at light loads, switches only as needed for optimum efficiency. This device is also capable of constant-frequency (1MHz), low-noise PWM operation at all load currents, or frequency-synchronized PWM operation when connected to an external clock. Table 1 lists some typical outputs. Shutdown reduces quiescent current to just 1μA. Figure 2 shows the standard application circuit for the MAX1760.

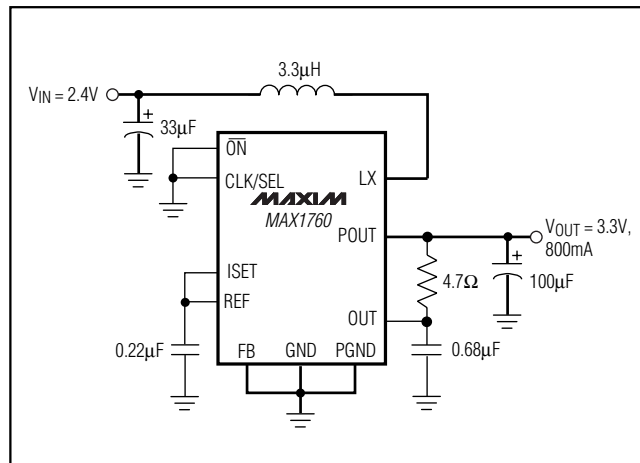


Figure 2. Standard Application Circuit

## Step-Up Converter

During DC-DC converter operation, the internal N-channel MOSFET switch turns on for the first part of each cycle, allowing current to ramp up in the inductor and store energy in a magnetic field. During the second part of each cycle, the MOSFET turns off and inductor current flows through the synchronous rectifier to the

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**Table 1. Typical Available Output Current**

NUMBER OF NiCd/NiMH CELLS	INPUT VOLTAGE (V)	OUTPUT VOLTAGE (V)	OUTPUT CURRENT (mA)
1	1.2	3.3	350
2	2.4	3.3	800
	2.4	5.0	500
3	3.6	5.0	750

**Table 2. Selecting the Operating Mode**

CLK/SEL	MODE	FEATURES
0	Normal Operation	High efficiency at all loads. Fixed frequency at all but light loads.
1	Forced PWM	Low noise, fixed frequency at all loads.
External Clock 500kHz to 1.2MHz	Synchronized PWM	Low noise, fixed frequency at all loads.

output filter capacitor and the load. As the energy stored in the inductor is depleted, the current ramps down and the synchronous rectifier turns off. At light loads, the device operates at fixed frequency or only as needed to maintain regulation, depending on the CLK/SEL setting (Table 2).

### Normal Operation

Pulling CLK/SEL low selects the MAX1760's normal operating mode. In this mode, the device operates in PWM when driving medium-to-heavy loads, and automatically switches to PFM if the load requires less power. PFM operation allows higher efficiency than PWM under light load conditions.

### Forced PWM Operation

When CLK/SEL is high, the MAX1760 operates in a low-noise PWM-only mode. During forced PWM operation, the MAX1760 switches at a constant frequency (1MHz), and modulates the MOSFET switch pulse width to control the power transferred per cycle to regulate the output voltage. Switching harmonics generated by fixed-frequency operation are consistent and easily filtered. See the Noise Spectrum plot in the *Typical Operating Characteristics*.

### Synchronized PWM Operation

The MAX1760 can be synchronized in PWM mode to an external frequency of 500kHz to 1.2MHz by applying an external clock signal to CLK/SEL. This allows interference to be minimized in wireless applications. The synchronous rectifier is active during synchronized PWM operation.

### Synchronous Rectifier

The MAX1760 features an internal, P-channel synchronous rectifier to enhance efficiency. Synchronous rectification provides 5% improved efficiency over similar nonsynchronous boost regulators. In PWM mode, the synchronous rectifier is turned on during the second half of each switching cycle. In low-power mode, an internal comparator turns on the synchronous rectifier when the voltage at LX exceeds the boost regulator output, and turns it off when the inductor current drops below 60mA. When setting output voltages greater than 4V, an external 0.5A Schottky diode must be connected in parallel with the on-chip synchronous rectifier.

### Low-Voltage Startup Oscillator

The MAX1760 uses a CMOS, low-voltage startup oscillator for a 1.1V guaranteed minimum startup input voltage. At startup, the low-voltage oscillator switches the N-channel MOSFET until the output voltage reaches 2.15V. Above this level, the normal boost-converter feedback and control circuitry take over. Once the device is in regulation, it can operate down to 0.7V input since internal power for the IC is bootstrapped from the output through OUT. Do not apply full load until the output exceeds 2.3V.

### Shutdown

The MAX1760 has a shutdown mode that reduces quiescent current to 0.1μA. During shutdown (ON = high), the reference and all feedback and control circuitry are off. During shutdown, the output voltage is one diode drop below the input voltage.



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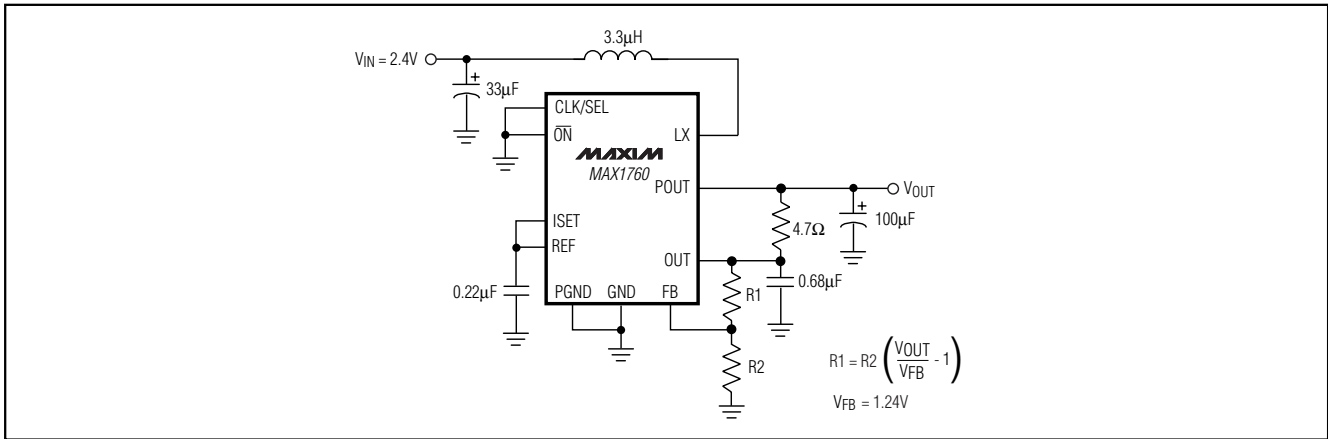


Figure 3. Connecting Resistors for External Feedback

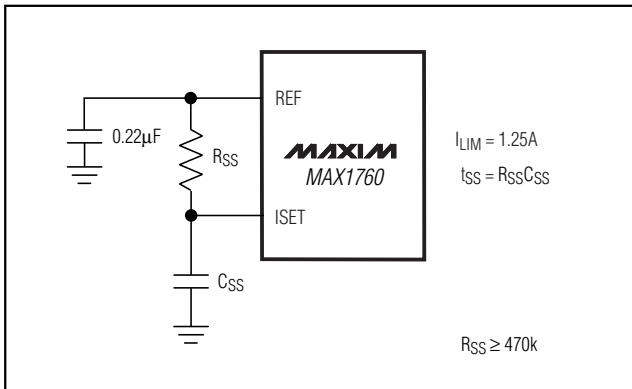


Figure 4. Soft-Start with Maximum Switch Limit Current

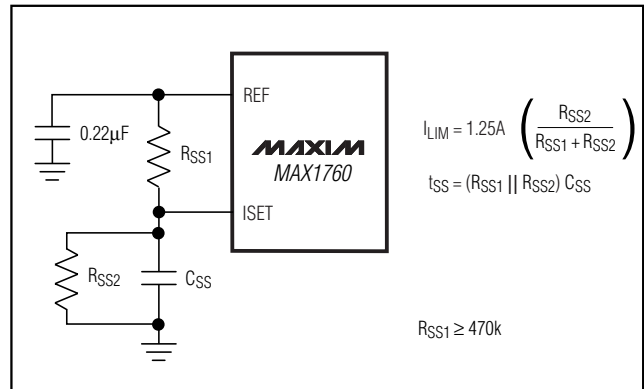


Figure 5. Soft-Start with Reduced Switch Current Limit

## Reference

The MAX1760 has an internal 1.250V  $\pm 1\%$  reference. Connect a 0.22µF ceramic bypass capacitor from REF to GND within 0.2in (5mm) of the REF pin. REF can source up to 50µA of external load current.

## Design Procedure

### Setting the Output Voltages

For a fixed 3.3V output, connect FB to GND. To set other output voltages between 2.5V and 5.5V, connect a resistor voltage-divider to FB from OUT to GND (Figure 3). The input bias current into FB is  $< 20\text{nA}$ , allowing large-value divider resistors without sacrificing accuracy. Connect the resistor voltage-divider as close to the IC as possible, within 0.2in (5mm) of FB. Choose R2 of 270kΩ or less, then calculate R1 using:

$$R1 = R2 \left( \frac{V_{OUT}}{V_{FB}} - 1 \right)$$

where  $V_{FB}$ , the boost-regulator feedback set point, is 1.24V.

### Setting the Switch Current Limit and Soft-Start

The ISET pin adjusts the inductor current limit and implements soft-start. With ISET connected to REF, the inductor current limits at 1.25A. With ISET connected to a resistive divider set from REF to GND, the current limit is reduced according to:

$$I_{LIM} = 1.25A \left( \frac{V_{ISET}}{1.25V} \right)$$

Implement soft-start by placing a resistor from ISET to REF and a capacitor from ISET to GND. In shutdown, ISET is discharged to GND through an on-chip 100kΩ resistor. At power-up, ISET is 0V and the LX current is zero. As the capacitor voltage rises, the current increases and the output voltage rises. The soft-start

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**Table 3. Component Selection Guide**

PRODUCTION METHOD	INDUCTORS	CAPACITORS	DIODES
Surface Mount	Coilcraft DS3316P	AVX TPS series	EIC SB series
	Coilcraft LPT3305	Kemet T510 series	Motorola MBR0520L
	Sumida CDRH5D18	Sanyo POSCAP series	—
	Sumida CD43	—	—

**Table 4. Component Suppliers**

SUPPLIER	PHONE
AVX	USA: 843-448-9411
Coilcraft	USA: 847-639-6400
EIC	USA: 916-941-0712
Kemet	USA: 810-287-2536
Motorola	USA: 408-629-4789 Japan: 81-45-474-7030
Sumida	USA: 847-956-0666 Japan: 011-81-3-3667-3302

**Note:** Please indicate that you are using the MAX1760 when contacting these component suppliers.

time constant is:

$$t_{SS} = R_{SS}C_{SS}$$

where  $R_{SS} \geq 470k$ .

Placing a capacitor across the lower resistor of the current-limiting resistive divider provides both current-limit and soft-start features simultaneously (Figures 4 and 5).

## Inductor Selection

The MAX1760's high switching frequency allows the use of a small 3.3μH surface-mount inductor. The chosen inductor should generally have a saturation current rating exceeding the N-channel switch current limit; however, it is acceptable to bias the inductor current into saturation by as much as 20% if a slight reduction in efficiency is acceptable. Lower current-rated inductors may be used if ISET is employed to reduce the peak inductor current (see *Setting the Switch Current Limit and Soft-Start*). For high efficiency, choose an inductor with a high-frequency ferrite core material to reduce core losses. To minimize radiated noise, use a toroid or shielded inductor. See Table 3 for suggested components and Table 4 for a list of component suppliers. Connect the inductor from the battery to the LX pin as close to the IC as possible.

## External Diode

For output voltages greater than 4V, an external Schottky diode must be connected from LX to POUT, in parallel with the on-chip synchronous rectifier (Figure 6). The diode should be rated for 0.5A. Representative devices are Motorola MBR0520L, Nihon EP05Q03L, or generic 1N5817. This external diode is also recommended for applications that must start with input voltages at or below 1.8V. The Schottky diode carries current during startup and after the synchronous rectifier turns off; thus, its current rating only needs to be 500mA. Connect the diode as close to the IC as possible. Do not use ordinary rectifier diodes; their slow switching speeds and long reverse-recovery times render them unacceptable. For circuits that do not require startup with inputs below 1.8V, and have an output of 4V or less, no external diode is needed.

## Input and Output Filter Capacitors

Choose input and output filter capacitors that will service the input and output peak currents with acceptable voltage ripple. Choose input capacitors with working voltage ratings over the maximum input volt-

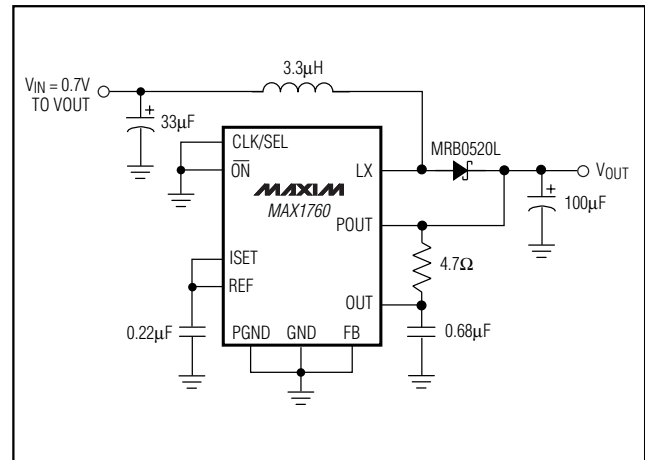


Figure 6. Connection with External Schottky Diode for Output Voltages Greater than 4V, or to Assist Low-Voltage Startup

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age, and output capacitors with working voltage ratings higher than the output.

The input filter capacitor reduces peak currents drawn from the input source and also reduces input switching noise. The input voltage source impedance determines the required value of the input capacitor. When operating directly from one or two NiMH cells placed close to the MAX1760, use a single 33 $\mu$ F low-ESR input filter capacitor. With higher impedance batteries, such as alkaline and Li+, a higher value input capacitor may improve efficiency.

The output filter capacitor reduces output ripple voltage and provides the load with transient peak currents when necessary. For the output, a 100 $\mu$ F, low-equivalent-series-resistance (ESR) capacitor is recommended for most applications.

Sanyo POSCAP, Panasonic SP/CB, and Kemet T510 are good low-ESR capacitors. Low-ESR tantalum capacitors offer a good tradeoff between price and performance. Do not exceed the ripple current ratings of tantalum capacitors. Avoid aluminum electrolytic capacitors; their high ESR typically results in higher output ripple voltage.

### Other External Components

Two ceramic bypass capacitors are required for proper operation. Bypass REF to GND with 0.22 $\mu$ F. Also,

bypass OUT to GND with a 0.68 $\mu$ F ceramic capacitor, and connect OUT to POUT with a 4.7 $\Omega$  resistor. Each of these components should be placed as close to its respective IC pins as possible, within 0.2in (5mm). Table 4 lists suggested suppliers.

### Layout Considerations

High switching frequencies and large peak currents make PC board layout a critical part of design. Poor design will cause excessive EMI and ground bounce, both of which can cause instability or regulation errors by corrupting the voltage and current feedback signals.

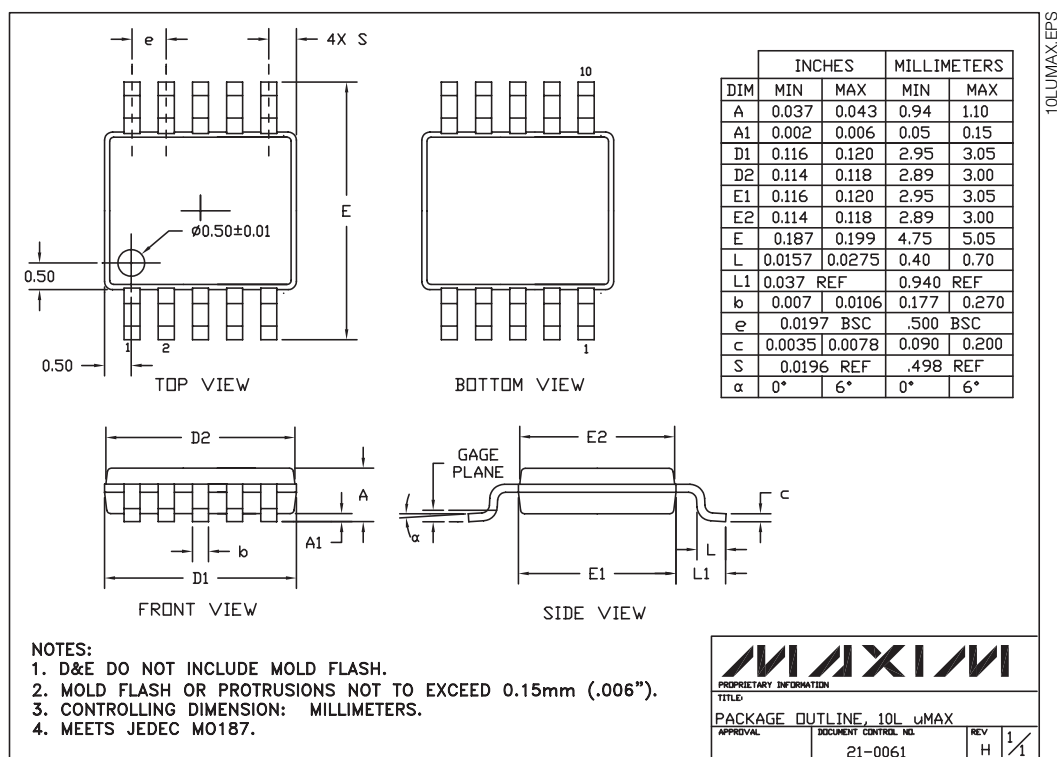
Power components—such as the inductor, converter IC, filter capacitors, and output diode—should be placed as close together as possible, and their traces should be kept short, direct, and wide. Keep the voltage feedback network very close to the IC, within 0.2in (5mm) of the FB pin. Keep noisy traces, such as those from the LX pin, away from the voltage feedback network and guarded from them using grounded copper. Refer to the MAX1760 EV kit for a full PC board example.

### Chip Information

TRANSISTOR COUNT: 1361

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## Package Information



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