



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

**MAX1760/MAX1760H**

## General Description

The MAX1760/MAX1760H are high-efficiency, low-noise, step-up DC-DC converters intended for use in battery-powered wireless applications. They combine low quiescent supply current (100µA) with a high 1MHz operating frequency. Small external components and tiny 10-pin TDFN and µMAX® packages make this device an excellent choice for small hand-held applications. The MAX1760 is activated by a logic-low ON signal while the MAX1760H is activated by a logic-high ON input.

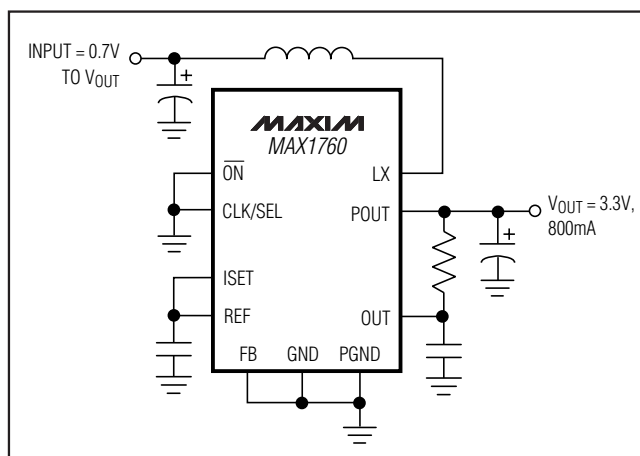
Both devices use a synchronous-rectified pulse-width-modulation (PWM) boost topology to generate 2.5V to 5.5V outputs from a wide range of inputs, such as 1 to 3 alkaline or NiCd/NiMH cells or a single lithium-ion (Li+) cell. Proprietary Idle-Mode™ circuitry significantly improves light-load efficiency and smoothly transitions to fixed-frequency PWM operation at higher load currents.

Low-noise, forced-PWM mode is available for applications requiring constant-frequency operation at all load currents. PWM operation can 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       | Handheld Instruments   |
| Palmtop Computers       | Personal Communicators |
| Two-Way Pagers          |                        |

## Typical Operating Circuit



µMAX is a registered trademark of Maxim Integrated Products, Inc.  
Idle Mode is a trademark of Maxim Integrated Products, Inc.

## Features

- ◆ Up to 94% Efficiency
- ◆ 0.7V to 5.5V Input Range
- ◆ Up to 800mA Output
- ◆ Fixed 3.3V Output (or Adjustable from 2.5V to 5.5V)
- ◆ PWM Synchronous-Rectified Topology
- ◆ Low-Noise, Constant-Frequency Operation (1MHz)
- ◆ 0.1µA Logic-Controlled Shutdown
- ◆ Synchronizable Switching Frequency
- ◆ Adjustable Current Limit
- ◆ Adjustable Soft-Start
- ◆ 10-Pin µMAX Package
- ◆ 10-Pin 3mm x 3mm TDFN Package

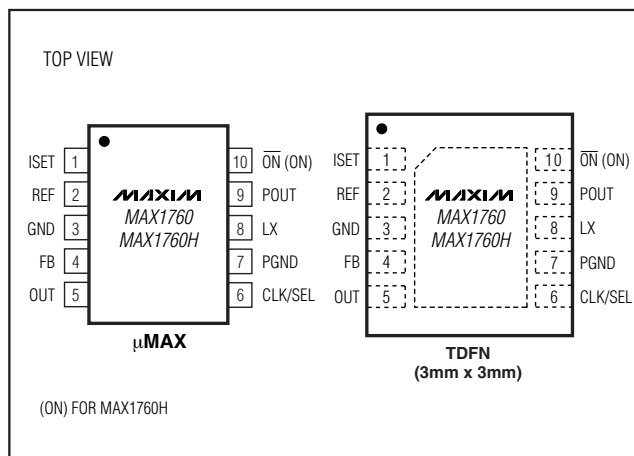
## Ordering Information

| PART        | PIN-PACKAGE | ON LOGIC | PKG CODE |
|-------------|-------------|----------|----------|
| MAX1760ETB  | 10 TDFN-EP* | Low      | T1033-1  |
| MAX1760EUB  | 10 µMAX     | Low      | U10-2    |
| MAX1760HETB | 10 TDFN-EP* | High     | T1033-1  |
| MAX1760HEUB | 10 µMAX     | High     | U10-2    |

\*EP = Exposed paddle.

**Note:** All devices are specified over the -40°C to +85°C operating temperature range.

## Pin Configurations



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

## ABSOLUTE MAXIMUM RATINGS

ON,  $\overline{\text{ON}}$ , 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 ( $T_A = +70^\circ\text{C}$ )  
 Single-Layer Board:  
   10-Pin  $\mu\text{MAX}$   
     (derate 5.6mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 444mW

10-Pin TDFN-EP (derate 18.5mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 1482mW  
 Multilayer Board:  
   10-Pin  $\mu\text{MAX}$  (derate 8.8mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 707mW  
   10-Pin TDFN-EP (derate 24.4mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 1951mW  
 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 = 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                    | $I_{\text{LOAD}} < 1\text{mA}$ , $T_A = +25^\circ\text{C}$ (Note 2)                                                 |       | 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                   | $V_{\text{FB}} = 1.35\text{V}$ ( $T_A = +25^\circ\text{C}$ , MAX1760ETB, MAX1760HETB)                               |       | 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           | Rising edge (Note 4)                                                                                                | 2.00  | 2.15       | 2.30     | V                    |
| ISET Input Leakage Current                 | $V_{\text{ISET}} = 1.25\text{V}$ ( $T_A = +25^\circ\text{C}$ , MAX1760ETB, MAX1760HETB)                             |       | $\pm 0.01$ | $\pm 50$ | nA                   |
| Supply Current in Shutdown                 | $V_{\text{ON}} = 3.6\text{V}$ , $V_{\text{ON}} = 0\text{V}$                                                         |       | 0.1        | 5        | $\mu\text{A}$        |
| No-Load Supply Current                     | CLK/SEL = GND (Note 5)                                                                                              |       | 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                       | $V_{\text{LX}} = 0$ , $V_{\text{OUT}} = 5.5\text{V}$ ( $T_A = +25^\circ\text{C}$ , MAX1760ETB, MAX1760HETB)         |       | 0.1        | 10       | $\mu\text{A}$        |
| LX Leakage Current                         | $V_{\text{LX}} = V_{\text{OUT}} = 5.5\text{V}$ , in shutdown ( $T_A = +25^\circ\text{C}$ , MAX1760ETB, MAX1760HETB) |       | 0.1        | 10       | $\mu\text{A}$        |

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

MAX1760/MAX1760H

## ELECTRICAL CHARACTERISTICS (continued)

(CLK/SEL = FB = PGND = GND, ISET = REF, OUT = POUT, V<sub>OUT</sub> = 3.6V, T<sub>A</sub> = 0°C to +85°C. Typical values are at T<sub>A</sub> = +25°C, unless otherwise noted.)

| PARAMETER                                            | CONDITIONS                                                                             | MIN                    | TYP   | MAX                    | UNITS |
|------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------|-------|------------------------|-------|
| Switch On-Resistance                                 | N-channel                                                                              |                        | 0.15  | 0.28                   | Ω     |
|                                                      | 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    |
| <b>REFERENCES</b>                                    |                                                                                        |                        |       |                        |       |
| Reference Output Voltage                             | I <sub>REF</sub> = 0                                                                   | 1.230                  | 1.250 | 1.270                  | V     |
| Reference Load Regulation                            | -1μA < I <sub>REF</sub> < +50μA                                                        |                        | 5     | 15                     | mV    |
| Reference Supply Rejection                           | 2.5V < V <sub>OUT</sub> < 5V                                                           |                        | 0.2   | 5                      | mV    |
| <b>LOGIC INPUTS</b>                                  |                                                                                        |                        |       |                        |       |
| CLK/SEL Input Low Level                              | 2.5V ≤ V <sub>OUT</sub> ≤ 5.5V                                                         |                        |       | 0.2 x V <sub>OUT</sub> | V     |
| CLK/SEL Input High Level                             | 2.5V ≤ V <sub>OUT</sub> ≤ 5.5V                                                         | 0.8 x V <sub>OUT</sub> |       |                        | V     |
| ON, $\overline{\text{ON}}$ Input Low Level (Note 6)  | 1.1V ≤ V <sub>OUT</sub> ≤ 1.8V                                                         |                        |       | 0.2                    | V     |
|                                                      | 1.8V ≤ V <sub>OUT</sub> ≤ 5.5V                                                         |                        |       | 0.4                    |       |
| ON, $\overline{\text{ON}}$ Input High Level (Note 6) | 1.1V ≤ V <sub>OUT</sub> ≤ 1.8V                                                         | V <sub>OUT</sub> - 0.2 |       |                        | V     |
|                                                      | 1.8V ≤ V <sub>OUT</sub> ≤ 5.5V                                                         | 1.6                    |       |                        |       |
| Input Leakage Current                                | CLK/SEL, $\overline{\text{ON}}$ , ON (T <sub>A</sub> = +25°C, MAX1760ETB, MAX1760HETB) |                        | 0.01  | 1                      | μA    |
| Minimum CLK/SEL Pulse Width                          |                                                                                        |                        | 200   |                        | ns    |
| Maximum CLK/SEL Rise/Fall Time                       |                                                                                        |                        | 100   |                        | ns    |

## ELECTRICAL CHARACTERISTICS

(CLK/SEL = FB = PGND = GND, ISET = REF, OUT = POUT, V<sub>OUT</sub> = 3.6V, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted.) (Note 7)

| PARAMETER                        | CONDITIONS                                                                                      | MIN   | MAX   | UNITS |
|----------------------------------|-------------------------------------------------------------------------------------------------|-------|-------|-------|
| <b>DC-DC CONVERTER</b>           |                                                                                                 |       |       |       |
| Output Voltage                   | V <sub>FB</sub> < 0.1V, CLK/SEL = OUT, includes load regulation for 0 < I <sub>LX</sub> < 0.55A | 3.17  | 3.38  | V     |
| FB Regulation Voltage            | Adjustable output, CLK/SEL = OUT, includes load regulation for 0 < I <sub>LX</sub> < 0.55A      | 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 | Rising edge (Note 4)                                                                            | 2.00  | 2.30  | V     |
| Supply Current in Shutdown       | V <sub>ON</sub> = 3.6V                                                                          |       | 5     | μA    |
| No-Load Supply Current           | CLK/SEL = GND (Note 5)                                                                          |       | 185   | μA    |
| <b>DC-DC SWITCHES</b>            |                                                                                                 |       |       |       |
| Switch On-Resistance             | N-channel                                                                                       |       | 0.28  | Ω     |
|                                  | P-channel                                                                                       |       | 0.45  |       |

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

## ELECTRICAL CHARACTERISTICS (continued)

(CLK/SEL = FB = PGND = GND, ISET = REF, OUT = POUT, V<sub>OUT</sub> = 3.6V, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted.) (Note 7)

| PARAMETER                                            | CONDITIONS                           | MIN                    | MAX                    | UNITS |
|------------------------------------------------------|--------------------------------------|------------------------|------------------------|-------|
| N-Channel Current Limit                              |                                      | 1.0                    | 1.6                    | A     |
| <b>REFERENCE</b>                                     |                                      |                        |                        |       |
| Reference Output Voltage                             | I <sub>REF</sub> = 0                 | 1.230                  | 1.270                  | V     |
| <b>LOGIC INPUTS</b>                                  |                                      |                        |                        |       |
| CLK/SEL Input Low Level                              | 2.5V ≤ V <sub>OUT</sub> ≤ 5.5V       |                        | 0.2 × V <sub>OUT</sub> | V     |
| CLK/SEL Input High Level                             | 2.5V ≤ V <sub>OUT</sub> ≤ 5.5V       | 0.8 × V <sub>OUT</sub> |                        | V     |
| ON, $\overline{\text{ON}}$ Input Low Level (Note 6)  | 1.1V ≤ V <sub>OUT</sub> ≤ 1.8V       |                        | 0.2                    | V     |
|                                                      | 1.8V ≤ V <sub>OUT</sub> ≤ 5.5V       |                        | 0.4                    |       |
| ON, $\overline{\text{ON}}$ Input High Level (Note 6) | 1.1V ≤ V <sub>OUT</sub> ≤ 1.8V       | V <sub>OUT</sub> + 0.2 |                        | V     |
|                                                      | 1.8V ≤ V <sub>OUT</sub> ≤ 5.5V       | 1.6                    |                        |       |
| Input Leakage Current                                | CLK/SEL, $\overline{\text{ON}}$ , ON |                        | 1                      | μA    |

**Note 1:** Operating voltage—since the regulator is bootstrapped to the output, once started, the MAX1760 operates 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.

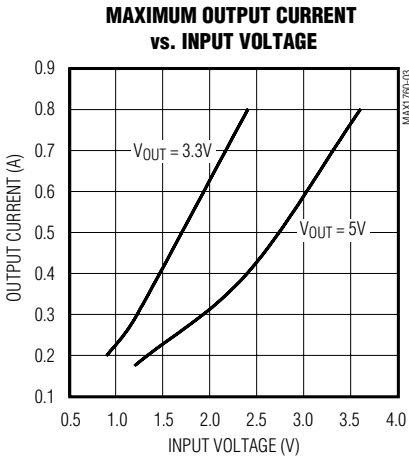
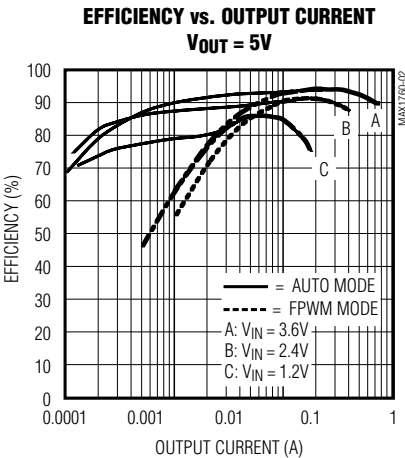
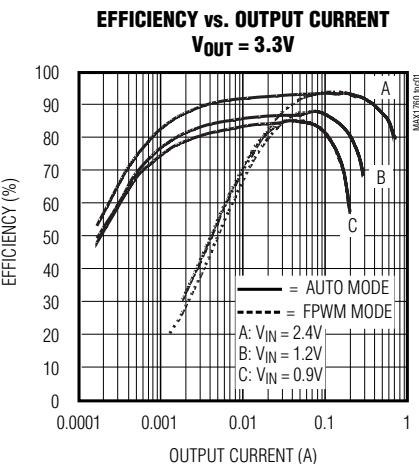
**Note 5:** Supply current into the OUT pin. This current correlates directly to the actual battery-supply current, but is reduced in value according to the step-up ratio and efficiency.

**Note 6:**  $\overline{\text{ON}}$  (MAX1760) and ON (MAX1760H) have a hysteresis of approximately 0.15 × V<sub>OUT</sub>.

**Note 7:** Specifications to -40°C are guaranteed by design and not production tested.

## Typical Operating Characteristics

(Circuit of Figure 2, V<sub>IN</sub> = 2.4V, V<sub>OUT</sub> = 3.3V, T<sub>A</sub> = +25°C, unless otherwise noted.)



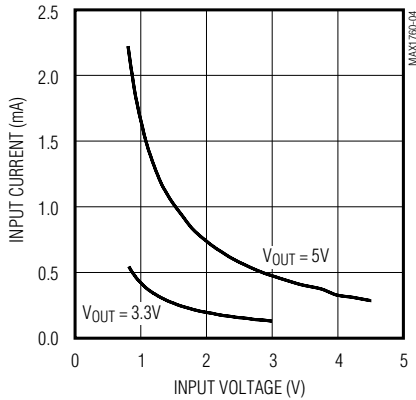
# 0.8A, Low-Noise, 1MHz, Step-Up DC-DC Converter

MAX1760/MAX1760H

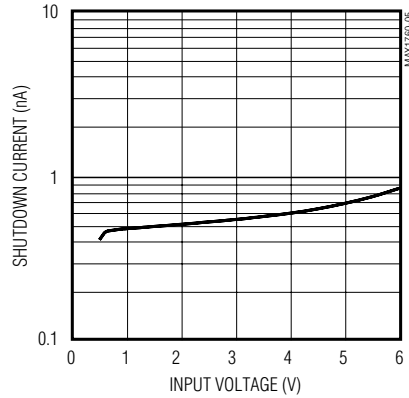
## Typical Operating Characteristics (continued)

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

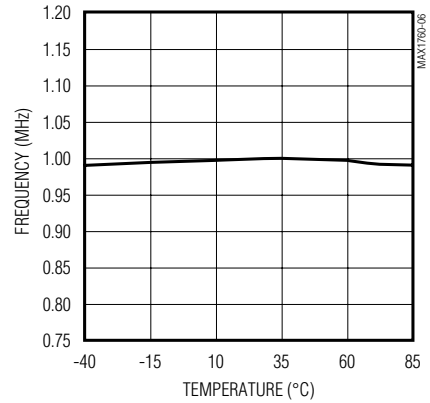
**NO-LOAD BATTERY CURRENT vs. INPUT VOLTAGE**



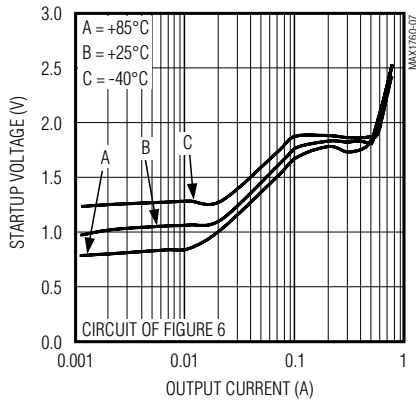
**TOTAL SHUTDOWN CURRENT ( $I_{LX} + I_{OUT}$ ) vs. INPUT VOLTAGE**



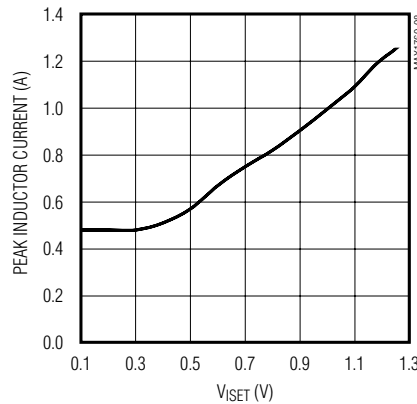
**INTERNAL OSCILLATOR FREQUENCY vs. TEMPERATURE**



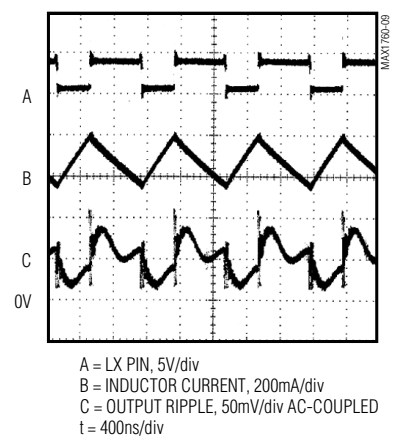
**STARTUP VOLTAGE vs. OUTPUT CURRENT**



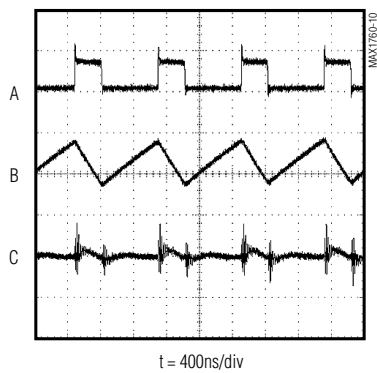
**PEAK INDUCTOR CURRENT vs.  $V_{ISET}$**



**HEAVY-LOAD SWITCHING WAVEFORMS**

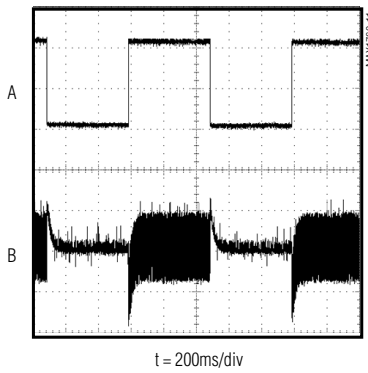


**LIGHT-LOAD SWITCHING WAVEFORMS**



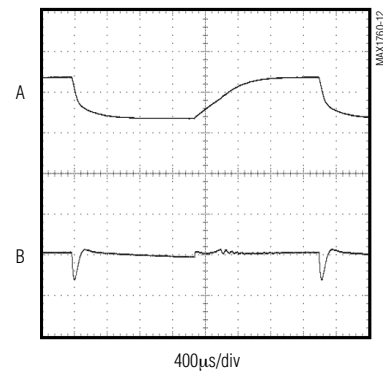
A = LX PIN, 5V/div  
B = INDUCTOR CURRENT, 200mA/div  
C = OUTPUT RIPPLE, 50mV/div, AC-COUPLED

**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**

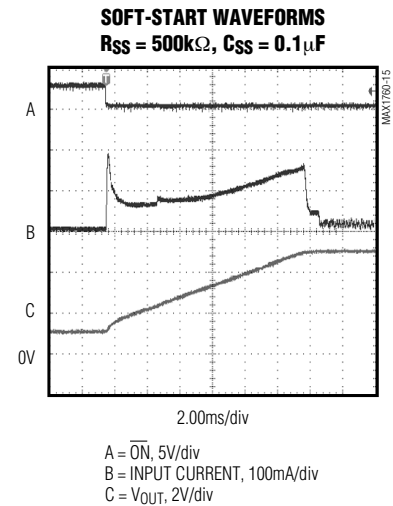
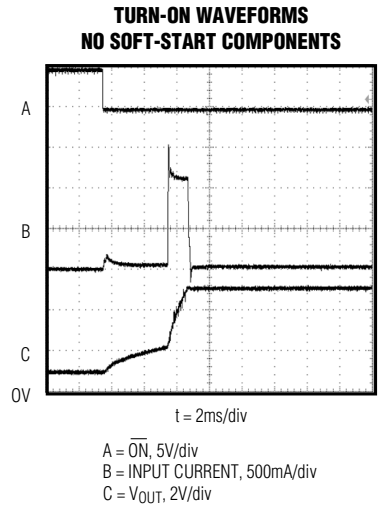
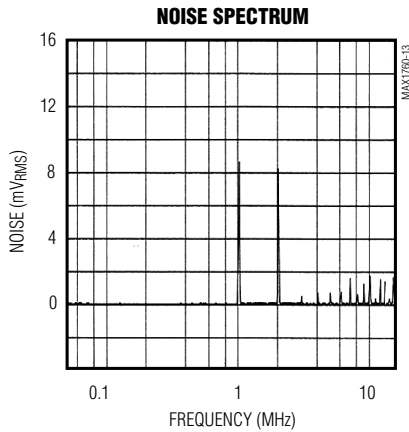


$V_{IN} = 2.4V$  TO  $1.4V$ ,  $I_{OUT} = 70mA$   
A =  $V_{IN}$ , 1V/div  
B =  $V_{OUT}$ , 5mV/div, AC-COUPLED

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

## 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 <sub>ET</sub> | 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 ISET 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:<br><b>CLK/SEL = LO:</b> Normal operation—operates at a fixed frequency, automatically switching to low-power mode if load is minimized.<br><b>CLK/SEL = HI:</b> Forced-PWM mode—operates in low-noise, constant-frequency mode at all loads.<br><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  | $\overline{ON}$  | MAX1760 Enable Input. When $\overline{ON}$ is low, the IC is on. Connect to GND for normal operation.                                                                                                                                                                                                                                                                                                                                                                     |
|     | ON               | MAX1760H Enable Input. When ON is high, the IC is on. Connect to OUT for normal operation.                                                                                                                                                                                                                                                                                                                                                                                |
| —   | EP               | Exposed Paddle (TDFN Package Only). Internally connected to GND. Connect to a large ground plane to maximize thermal dissipation. Do not use as sole ground connection.                                                                                                                                                                                                                                                                                                   |

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

MAX1760/MAX1760H

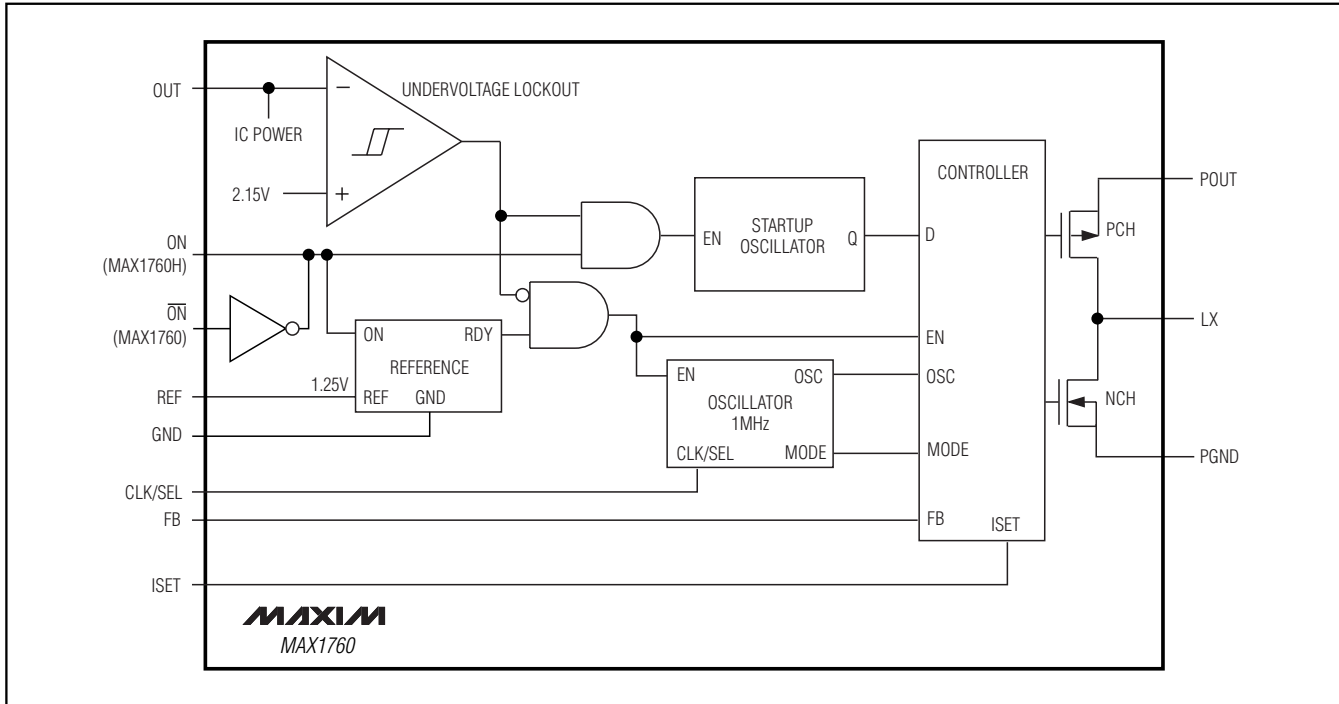


Figure 1. Functional Diagram

## 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.

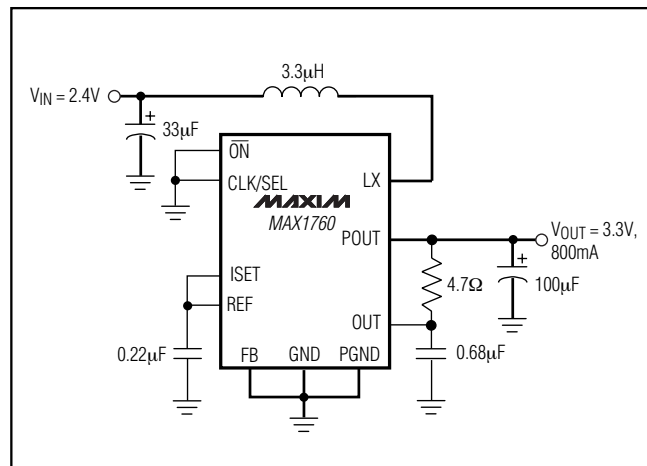


Figure 2. Standard Application Circuit

## 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

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

**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<br>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 on MAX1760, ON = low on MAX1760H), the reference and all feedback and control circuitry are off. During shutdown, the output voltage is one diode drop below the input voltage.

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

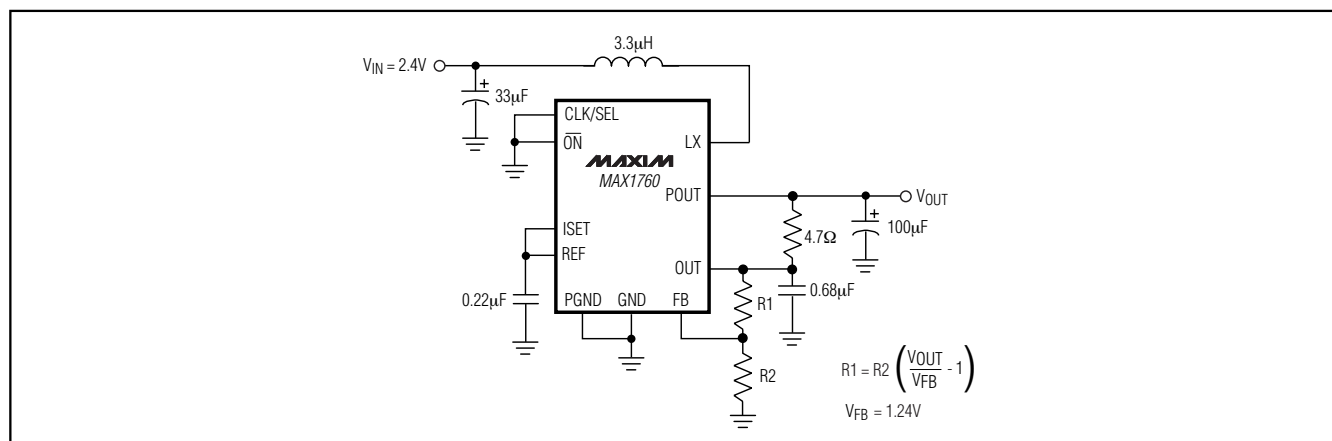


Figure 3. Connecting Resistors for External Feedback

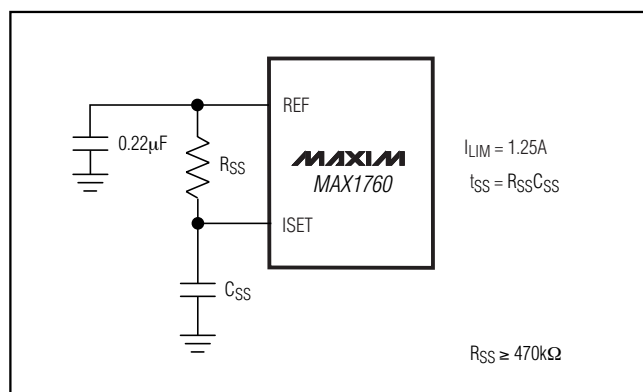


Figure 4. Soft-Start with Maximum Switch Limit Current

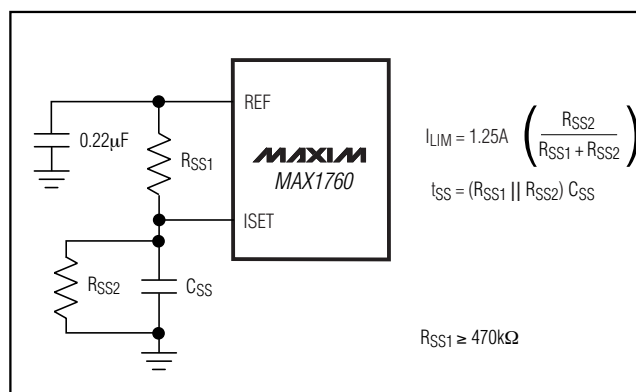


Figure 5. Soft-Start with Reduced Switch Current Limit

## Reference

The MAX1760 has an internal  $1.250\text{V} \pm 1\%$  reference. Connect a  $0.22\mu\text{F}$  ceramic bypass capacitor from REF to GND within 0.2in (5mm) of the REF pin. REF can source up to  $50\mu\text{A}$  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  $270\text{k}\Omega$  or less, then calculate R1 using:

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

where  $V_{\text{FB}}$ , 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:

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

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  $100\text{k}\Omega$  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     | TOKO type D52LC  | AVX TPS series      | EIC SB series     |
|                   | TOKO type D518LC | Kemet T510 series   | Motorola MBR0520L |
|                   | Sumida CDRH5D18  | Sanyo POSCAP series | —                 |
|                   | Sumida CDRH4D28  | —                   | —                 |

**Table 4. Component Suppliers**

| SUPPLIER | PHONE                                          |
|----------|------------------------------------------------|
| AVX      | USA: 843-448-9411                              |
| EIC      | USA: 916-941-0712                              |
| Kemet    | USA: 810-287-2536                              |
| Motorola | USA: 408-629-4789<br>Japan: 81-45-474-7030     |
| Sumida   | USA: 847-956-0666<br>Japan: 011-81-3-3667-3302 |
| TOKO     | USA: 847-297-0070                              |

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

time constant is:

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

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

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

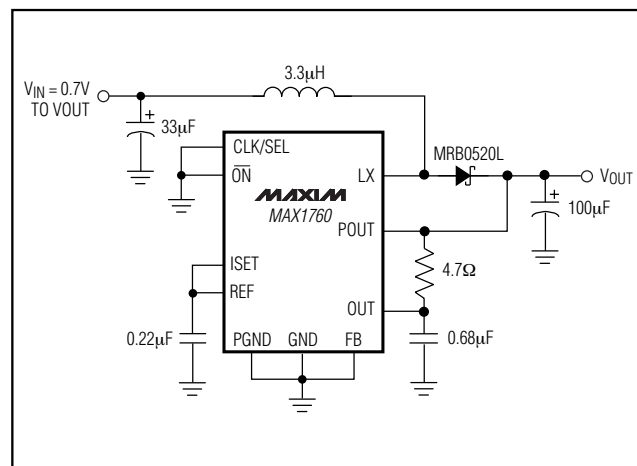
The MAX1760's high switching frequency allows the use of a small 3.3 $\mu$ H surface-mount inductor. The chosen inductor should generally have a saturation current rating exceeding the N-channel switch current limit; however, it is acceptable to bias the inductor current into saturation by as much as 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 the *Setting the Switch Current Limit and Soft-Start* section). 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

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

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 PCB layout a critical part of design. Poor design causes 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 evaluation kit for a full PCB example.

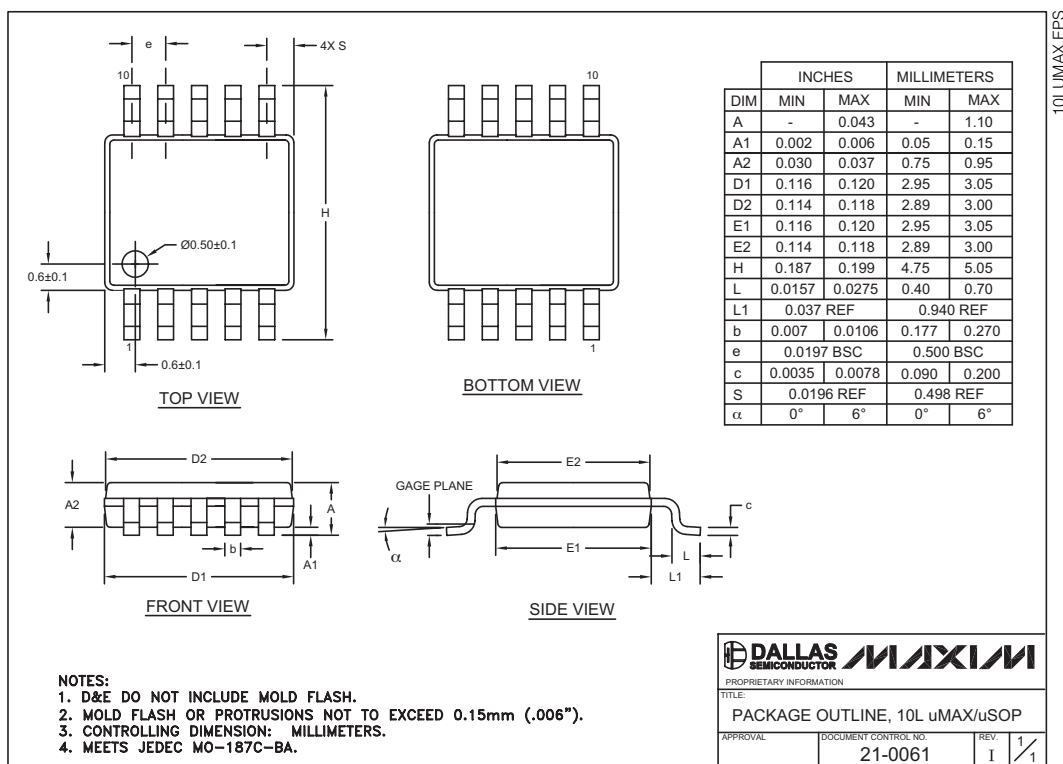
### Chip Information

TRANSISTOR COUNT: 1361

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

## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

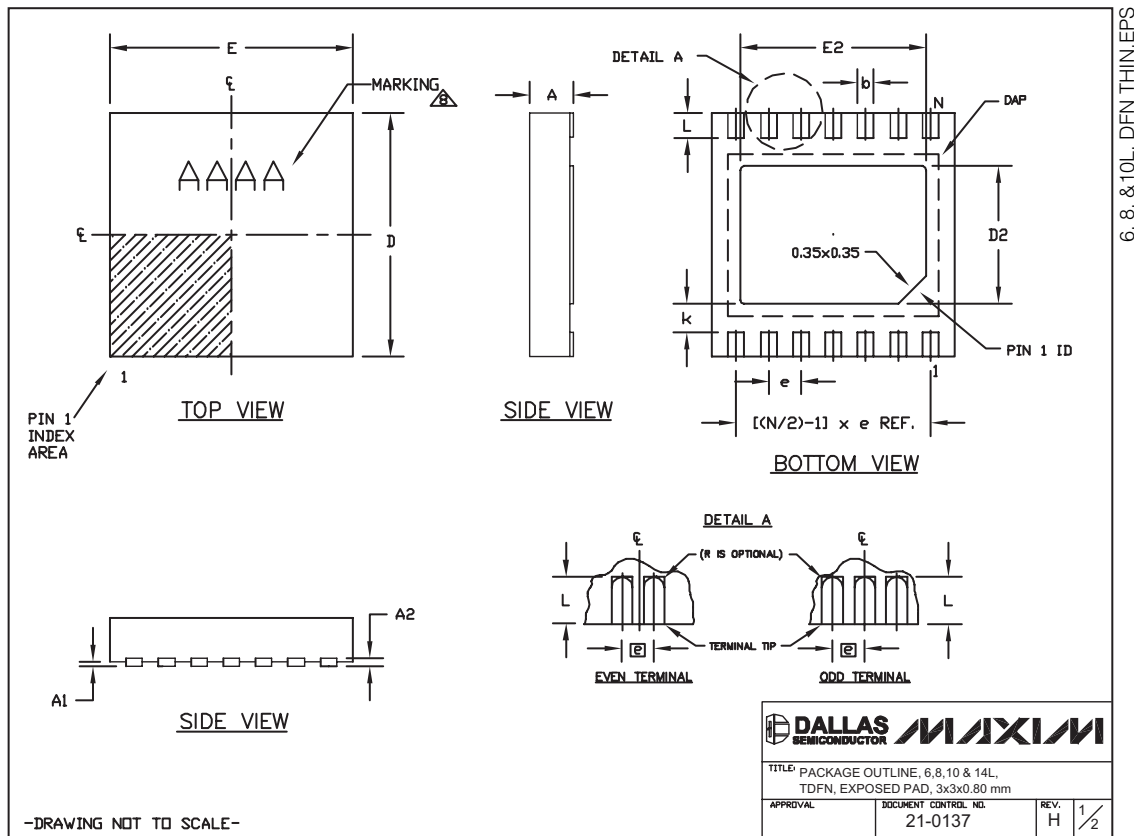


10L uMAX/EPs

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

## Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)



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

## Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

| COMMON DIMENSIONS |           |      |
|-------------------|-----------|------|
| SYMBOL            | MIN.      | MAX. |
| A                 | 0.70      | 0.80 |
| D                 | 2.90      | 3.10 |
| E                 | 2.90      | 3.10 |
| A1                | 0.00      | 0.05 |
| L                 | 0.20      | 0.40 |
| k                 | 0.25 MIN. |      |
| A2                | 0.20 REF. |      |

| PACKAGE VARIATIONS |    |           |           |          |                |           |               |  |
|--------------------|----|-----------|-----------|----------|----------------|-----------|---------------|--|
| PKG. CODE          | N  | D2        | E2        | e        | JEDEC SPEC     | b         | [(N/2)-1] x e |  |
| T633-1             | 6  | 1.50±0.10 | 2.30±0.10 | 0.95 BSC | MO229 / WEEA   | 0.40±0.05 | 1.90 REF      |  |
| T633-2             | 6  | 1.50±0.10 | 2.30±0.10 | 0.95 BSC | MO229 / WEEA   | 0.40±0.05 | 1.90 REF      |  |
| T833-1             | 8  | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC   | 0.30±0.05 | 1.95 REF      |  |
| T833-2             | 8  | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC   | 0.30±0.05 | 1.95 REF      |  |
| T833-3             | 8  | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC   | 0.30±0.05 | 1.95 REF      |  |
| T1033-1            | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF      |  |
| T1033-2            | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF      |  |
| T1433-1            | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | ----           | 0.20±0.05 | 2.40 REF      |  |
| T1433-2            | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | ----           | 0.20±0.05 | 2.40 REF      |  |

### NOTES:

1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
  2. COPLANARITY SHALL NOT EXCEED 0.08 mm.
  3. WARPAGE SHALL NOT EXCEED 0.10 mm.
  4. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
  5. DRAWING CONFORMS TO JEDEC MO229, EXCEPT DIMENSIONS "D2" AND "E2", AND T1433-1 & T1433-2.
  6. "N" IS THE TOTAL NUMBER OF LEADS.
  7. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
- ▲ MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.

-DRAWING NOT TO SCALE-

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| <b>TITLE:</b> PACKAGE OUTLINE, 6,8,10 & 14L,<br>TDFN, EXPOSED PAD, 3x3x0.80 mm       |                                        |
| <b>APPROVAL</b>                                                                      | <b>DOCUMENT CONTROL NO.</b><br>21-0137 |
| <b>REV.</b><br>H                                                                     | <b>2</b> / <b>2</b>                    |

## Revision History

Pages changed at Rev 3: 1, 2, 6, 11, 14

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