

**MAXIM**

# Low-Voltage, Step-Down DC-DC Converters in SOT23

## General Description

The MAX1733/MAX1734 step-down DC-DC converters deliver over 250mA to outputs as low as 1.25V. These converters use a unique proprietary current-limited control scheme that achieves over 90% efficiency. These devices maintain extremely low quiescent supply current (40µA), and their high 1.2MHz (max) operating frequency permits small, low-cost external components. This combination of features makes the MAX1733/MAX1734 excellent high-efficiency alternatives to linear regulators in space-constrained applications.

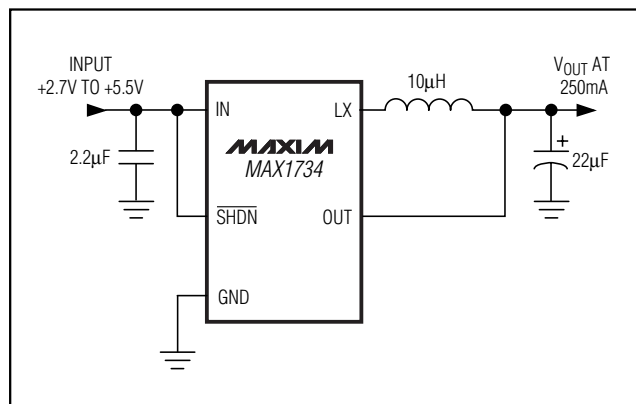
Internal synchronous rectification greatly improves efficiency and eliminates the external Schottky diode required in conventional step-down converters. Both devices also include internal digital soft-start to limit input current upon startup and reduce input capacitor requirements.

The MAX1733 provides an adjustable output voltage (1.25V to 2.0V). The MAX1734 provides factory-preset output voltages (see *Selector Guide*). Both are available in space-saving 5-pin SOT23 packages.

## Applications

Cellular, PCS, and Cordless Telephones  
PDAs, Palmtops, and Handy-Terminals  
Battery-Powered Equipment

## Typical Operating Circuit



## Features

- ◆ 250mA Guaranteed Output Current
- ◆ Synchronous Rectifier for Over 90% Efficiency
- ◆ Tiny 5-Pin SOT23 Package
- ◆ 40µA Quiescent Supply Current
- ◆ 0.01µA Logic-Controlled Shutdown
- ◆ Up to 1.2MHz Switching Frequency
- ◆ Fixed 1.8V or 1.5V Outputs (MAX1734)
- ◆ Adjustable Output Voltage (MAX1733)
- ◆ ±1.5% Initial Accuracy
- ◆ 2.7V to 5.5V Input Range
- ◆ Soft-Start Limits Startup Current

## Ordering Information

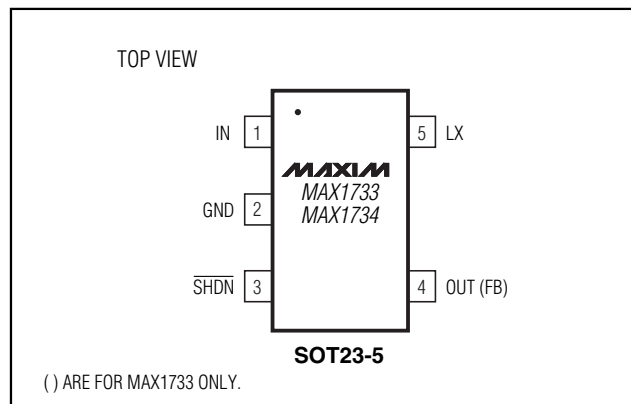
| PART          | TEMP. RANGE    | PIN-PACKAGE |
|---------------|----------------|-------------|
| MAX1733EUK-T  | -40°C to +85°C | 5 SOT23-5   |
| MAX1734EUK_-T | -40°C to +85°C | 5 SOT23-5   |

**Note:** The MAX1734 offers two output voltages. See the *Selector Guide*, then insert the proper designator into the blanks above to complete the part number.

## Selector Guide

| PART         | V <sub>OUT</sub> (V) | TOP MARK |
|--------------|----------------------|----------|
| MAX1733EUK   | Adjustable           | ADKY     |
| MAX1734EUK18 | 1.8                  | ADKW     |
| MAX1734EUK15 | 1.5                  | ADKX     |

## Pin Configuration

**MAXIM**

Maxim Integrated Products 1

For free samples and the latest literature, visit [www.maxim-ic.com](http://www.maxim-ic.com) or phone 1-800-998-8800.  
For small orders, phone 1-800-835-8769.

MAX1733/MAX1734

# Low-Voltage, Step-Down DC-DC Converters in SOT23

## ABSOLUTE MAXIMUM RATINGS

IN,  $\overline{\text{SHDN}}$  to GND ..... -0.3V to +6V  
 OUT, FB, LX to GND ..... -0.3V to ( $V_{\text{IN}} + 0.3\text{V}$ )  
 OUT Short Circuit to GND ..... Continuous  
 Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )  
 5-Pin SOT23 (derate 7.1mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) ..... 571mW

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

( $V_{\text{IN}} = +2.7\text{V}$  to  $+5.5\text{V}$ ,  $\overline{\text{SHDN}} = \text{IN}$ ,  $T_A = 0^\circ\text{C}$  to  $+85^\circ\text{C}$ . Typical values are at  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

| PARAMETER                                   | SYMBOL                       | CONDITIONS                                                                                     | MIN   | TYP   | MAX   | UNITS         |
|---------------------------------------------|------------------------------|------------------------------------------------------------------------------------------------|-------|-------|-------|---------------|
| Input Voltage Range                         | $V_{\text{IN}}$              |                                                                                                | 2.7   |       | 5.5   | V             |
| Startup Voltage                             | $V_{\text{START}}$           |                                                                                                |       |       | 2.0   | V             |
| UVLO Threshold                              | $V_{\text{UVLO}}$            | $V_{\text{IN}}$ rising                                                                         |       | 1.85  | 1.95  | V             |
|                                             |                              | $V_{\text{IN}}$ falling                                                                        | 1.55  | 1.65  |       |               |
| UVLO Hysteresis                             |                              |                                                                                                |       | 200   |       | mV            |
| Quiescent Supply Current                    | $I_{\text{IN}}$              | No switching, no load (FB/OUT above trip point)                                                |       | 40    | 70    | $\mu\text{A}$ |
| Shutdown Supply Current                     | $I_{\text{SHDN}}$            | $\overline{\text{SHDN}} = \text{GND}$                                                          |       | 0.01  | 4     | $\mu\text{A}$ |
| Output Voltage Range (MAX1733)              | $V_{\text{OUT}}$             |                                                                                                | 1.25  |       | 2.0   | V             |
| Output Voltage Accuracy (MAX1734)           |                              | $I_{\text{OUT}} = 0$ , $T_A = +25^\circ\text{C}$                                               | -1.5  |       | +1.5  | %             |
|                                             |                              | $I_{\text{OUT}} = 0$ to 250mA                                                                  | -3    |       | +3    |               |
| Load Regulation                             |                              | $I_{\text{OUT}} = 0$ to 250mA                                                                  |       | 0     |       | %/mA          |
| Line Regulation                             |                              | $V_{\text{IN}} = 2.7\text{V}$ to $5.5\text{V}$                                                 |       | 0     |       | %/V           |
| OUT Sense Current (MAX1734)                 |                              | $V_{\text{OUT}} = V_{\text{REG}}$ , $V_{\text{IN}} = V_{\overline{\text{SHDN}}} = 5\text{V}$   |       | 4     | 8     | $\mu\text{A}$ |
| FB Feedback Threshold (MAX1733)             | $V_{\text{FB}}$              | $T_A = +25^\circ\text{C}$ , $V_{\text{IN}} = 3.6\text{V}$                                      | 1.231 | 1.250 | 1.269 | V             |
|                                             |                              | $V_{\text{IN}} = 3.6\text{V}$                                                                  | 1.220 |       | 1.280 |               |
| FB Leakage Current (MAX1733)                | $I_{\text{FB}}$              | $V_{\text{FB}} = 1.5\text{V}$                                                                  |       | 0.001 | 0.2   | $\mu\text{A}$ |
| $\overline{\text{SHDN}}$ Input High Voltage | $V_{\text{IH}}$              | $2.7\text{V} < V_{\text{IN}} < 5.5\text{V}$                                                    | 1.6   |       |       | V             |
| $\overline{\text{SHDN}}$ Input Low Voltage  | $V_{\text{IL}}$              | $2.7\text{V} < V_{\text{IN}} < 5.5\text{V}$                                                    |       |       | 0.4   | V             |
| $\overline{\text{SHDN}}$ Leakage Current    | $I_{\overline{\text{SHDN}}}$ | $\overline{\text{SHDN}} = \text{GND}$ or $\text{IN}$                                           |       | 0.001 | 1     | $\mu\text{A}$ |
| High-Side Current Limit                     | $I_{\text{LIMP}}$            |                                                                                                | 300   | 425   | 535   | mA            |
| Low-Side Current Limit                      | $I_{\text{LIMN}}$            |                                                                                                | 200   | 325   | 430   | mA            |
| High-Side On-Resistance                     | $R_{\text{ONP}}$             | $I_{\text{LX}} = -50\text{mA}$ , $V_{\text{IN}} = 3.0\text{V}$                                 |       | 0.7   | 1.4   | $\Omega$      |
|                                             |                              | $I_{\text{LX}} = -50\text{mA}$ , $V_{\text{IN}} = 5.5\text{V}$                                 |       | 0.5   | 1.1   |               |
| Rectifier On-Resistance                     | $R_{\text{ONN}}$             | $I_{\text{LX}} = -50\text{mA}$ , $V_{\text{IN}} = 3.0\text{V}$                                 |       | 1.0   | 2     | $\Omega$      |
|                                             |                              | $I_{\text{LX}} = -50\text{mA}$ , $V_{\text{IN}} = 5.5\text{V}$                                 |       | 0.8   | 1.6   |               |
| Rectifier Off-Current Threshold             | $I_{\text{LXOFF}}$           |                                                                                                |       | 40    |       | mA            |
| LX Leakage Current                          | $I_{\text{LXLEAK}}$          | $V_{\text{IN}} = 5.5\text{V}$ , $V_{\text{LX}} = 0$ to $V_{\text{IN}}$                         |       | 0.1   | 5     | $\mu\text{A}$ |
| LX Reverse Leakage Current                  | $I_{\text{LXLK,R}}$          | $\text{IN}$ unconnected, $V_{\text{LX}} = 5.5\text{V}$ , $\overline{\text{SHDN}} = \text{GND}$ |       | 0.1   | 5     | $\mu\text{A}$ |
| Minimum On-Time                             | $t_{\text{ON(MIN)}}$         | $V_{\text{IN}} = 3.6\text{V}$                                                                  | 0.28  | 0.4   | 0.5   | $\mu\text{s}$ |
| Minimum Off-Time                            | $t_{\text{OFF(MIN)}}$        | $V_{\text{IN}} = 3.6\text{V}$                                                                  | 0.28  | 0.4   | 0.5   | $\mu\text{s}$ |

# Low-Voltage, Step-Down DC-DC Converters in SOT23

MAX1733/MAX1734

## ELECTRICAL CHARACTERISTICS

( $V_{IN} = +2.7V$  to  $+5.5V$ ,  $\overline{SHDN} = IN$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted.) (Note 1)

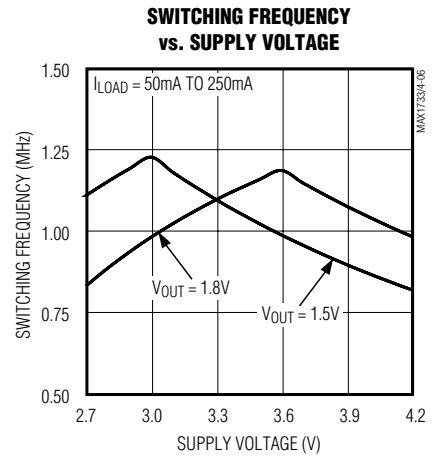
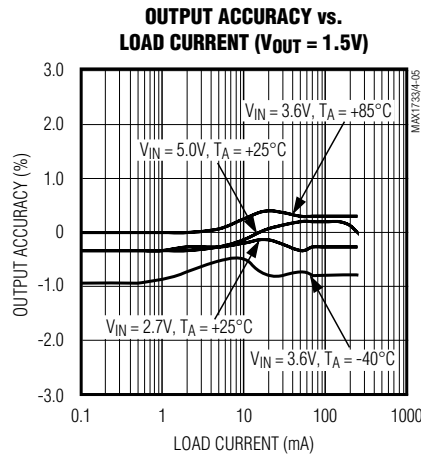
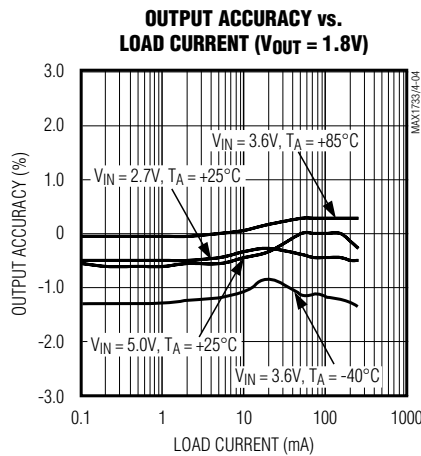
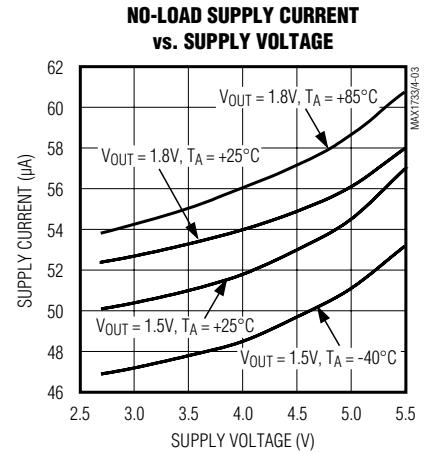
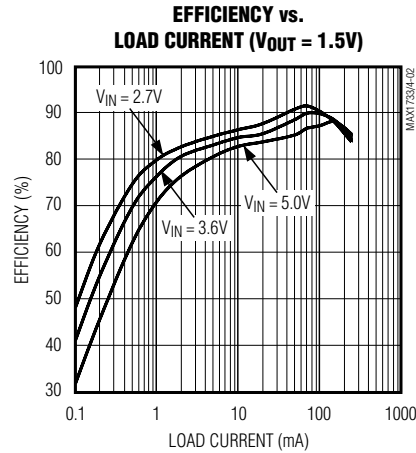
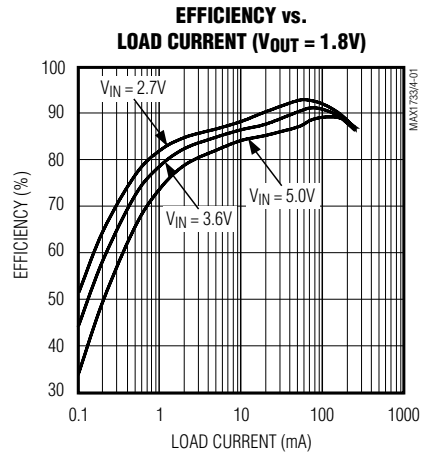
| PARAMETER                            | SYMBOL                | CONDITIONS                                                  | MIN   | MAX   | UNITS    |
|--------------------------------------|-----------------------|-------------------------------------------------------------|-------|-------|----------|
| Input Voltage Range                  | $V_{IN}$              |                                                             | 2.7   | 5.5   | V        |
| Startup Voltage                      | $V_{START}$           |                                                             |       | 2.0   | V        |
| UVLO Threshold                       | $V_{UVLO}$            | $V_{IN}$ rising, 200mV typical hysteresis                   |       | 1.95  | V        |
|                                      |                       | $V_{IN}$ falling                                            | 1.55  |       |          |
| Quiescent Supply Current             | $I_{IN}$              | No switching (FB/OUT above trip point)                      |       | 70    | $\mu A$  |
| Shutdown Supply Current              | $I_{SHDN}$            | $\overline{SHDN} = GND$                                     |       | 4     | $\mu A$  |
| Output Voltage Range (MAX1733)       | $V_{OUT}$             |                                                             | 1.25  | 2.0   | V        |
| Output Voltage Accuracy (MAX1734)    |                       | $I_{OUT} = 0$ to 250mA                                      | -3    | +3    | %        |
| OUT Sense Current (MAX1734)          | $I_{OUT}$             | $V_{OUT} = V_{REG}$ , $V_{IN} = V_{\overline{SHDN}} = 5V$   |       | 8     | $\mu A$  |
| FB Feedback Threshold (MAX1733)      | $V_{FB}$              | $V_{IN} = 3.6V$                                             | 1.210 | 1.280 | V        |
| FB Leakage Current (MAX1733)         | $I_{FB}$              | $V_{FB} = 1.5V$                                             |       | 0.2   | $\mu A$  |
| $\overline{SHDN}$ Input High Voltage | $V_{IH}$              | $2.7V < V_{IN} < 5.5V$                                      | 1.6   |       | V        |
| $\overline{SHDN}$ Input Low Voltage  | $V_{IL}$              | $2.7V < V_{IN} < 5.5V$                                      |       | 0.4   | V        |
| $\overline{SHDN}$ Leakage Current    | $I_{\overline{SHDN}}$ | $\overline{SHDN} = GND$ or $IN$                             |       | 1     | $\mu A$  |
| High-Side Current Limit              | $I_{LIMP}$            |                                                             | 300   | 565   | mA       |
| Low-Side Current Limit               | $I_{LIMN}$            |                                                             | 200   | 430   | mA       |
| High-Side On-Resistance              | $R_{ONP}$             | $I_{LX} = -50mA$ , $V_{IN} = 3.0V$                          |       | 1.4   | $\Omega$ |
|                                      |                       | $I_{LX} = -50mA$ , $V_{IN} = 5.5V$                          |       | 1.1   |          |
| Rectifier On-Resistance              | $R_{ONN}$             | $I_{LX} = -50mA$ , $V_{IN} = 3.0V$                          |       | 2     | $\Omega$ |
|                                      |                       | $I_{LX} = -50mA$ , $V_{IN} = 5.5V$                          |       | 1.6   |          |
| LX Leakage Current                   | $I_{LXLEAK}$          | $V_{IN} = 5.5V$ , $V_{LX} = 0$ to $V_{IN}$                  |       | 5     | $\mu A$  |
| LX Reverse Leakage Current           | $I_{LXLK,R}$          | $IN$ unconnected, $V_{LX} = 5.5V$ , $\overline{SHDN} = GND$ |       | 5     | $\mu A$  |
| Minimum On-Time                      | $t_{ON(MIN)}$         |                                                             | 0.25  | 0.55  | $\mu s$  |
| Minimum Off-Time                     | $t_{OFF(MIN)}$        |                                                             | 0.25  | 0.55  | $\mu s$  |

**Note 1:** All devices are 100% production tested at  $T_A = +25^{\circ}C$ . Limits over the operating temperature range are guaranteed by design.

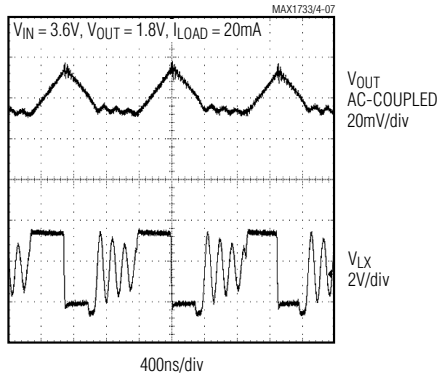
# Low-Voltage, Step-Down DC-DC Converters in SOT23

## Typical Operating Characteristics

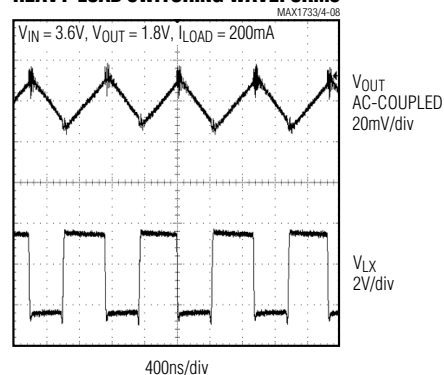
( $C_{IN} = 2.2\mu\text{F}$  ceramic,  $C_{OUT} = 22\mu\text{F}$  tantalum,  $L = 10\mu\text{H}$ , unless otherwise noted.)



### LIGHT-LOAD SWITCHING WAVEFORMS



### HEAVY-LOAD SWITCHING WAVEFORMS

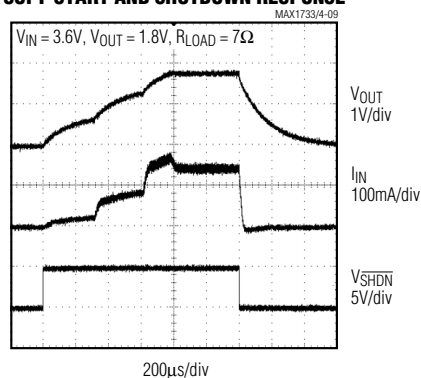


# Low-Voltage, Step-Down DC-DC Converters in SOT23

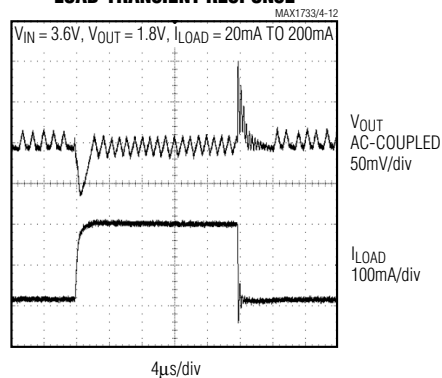
## Typical Operating Characteristics (continued)

( $C_{IN} = 2.2\mu\text{F}$  ceramic,  $C_{OUT} = 22\mu\text{F}$  tantalum,  $L = 10\mu\text{H}$ , unless otherwise noted.)

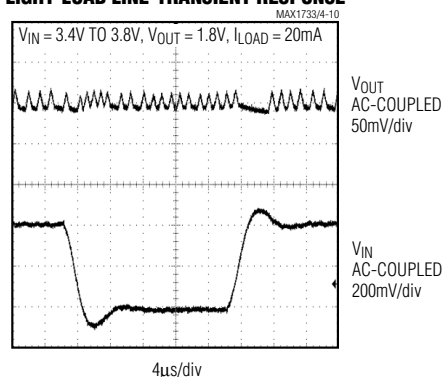
**SOFT-START AND SHUTDOWN RESPONSE**



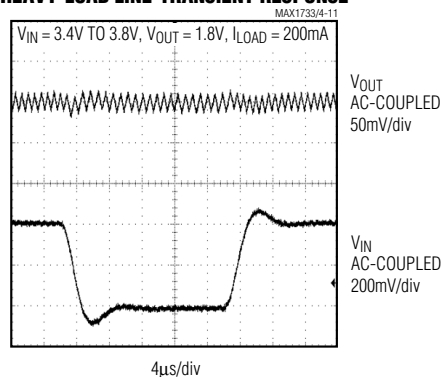
**LOAD-TRANSIENT RESPONSE**



**LIGHT-LOAD LINE-TRANSIENT RESPONSE**



**HEAVY-LOAD LINE-TRANSIENT RESPONSE**



## Pin Description

| PIN | NAME                     | FUNCTION                                                                                                                                                              |
|-----|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | IN                       | Supply Voltage Input. Input range from +2.7V to +5.5V. Bypass with a 2.2μF ceramic capacitor to GND.                                                                  |
| 2   | GND                      | Ground                                                                                                                                                                |
| 3   | $\overline{\text{SHDN}}$ | Active-Low Shutdown Input. Connect $\overline{\text{SHDN}}$ to IN for normal operation. In shutdown, LX becomes high impedance and quiescent current drops to 0.01μA. |
| 4   | FB                       | MAX1733 Voltage Feedback Input. FB regulates to 1.25V nominal. Connect FB to an external voltage-divider between the output voltage and GND.                          |
|     | OUT                      | MAX1734 Voltage Sense Input. OUT is connected to an internal voltage-divider.                                                                                         |
| 5   | LX                       | Inductor Connection                                                                                                                                                   |

# Low-Voltage, Step-Down DC-DC Converters in SOT23

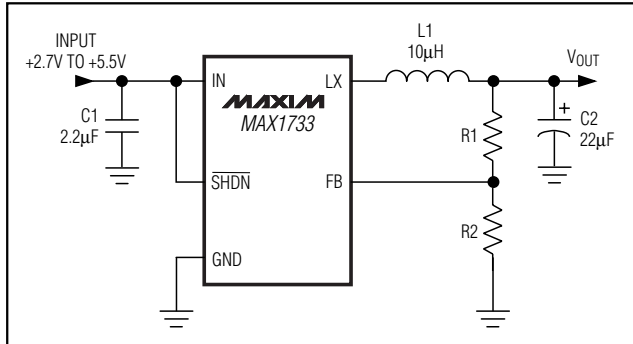


Figure 1. MAX1733 Typical Application Circuit

## Detailed Description

The MAX1733/MAX1734 step-down DC-DC converters deliver over 250mA to outputs as low as 1.25V. They use a unique proprietary current-limited control scheme that maintains extremely low quiescent supply current (40µA), and their high 1.2MHz (max) operating frequency permits small, low-cost external components. Figure 2 is a simplified functional diagram.

### Control Scheme

The MAX1733/MAX1734 use a proprietary, current-limited control scheme to ensure high-efficiency, fast transient response, and physically small external components. This control scheme is simple: when the output voltage is out of regulation, the error comparator begins a switching cycle by turning on the high-side switch. This switch remains on until the minimum on-time of 400ns expires and the output voltage regulates or the current-limit threshold is exceeded. Once off, the high-side switch remains off until the minimum off-time of 400ns expires and the output voltage falls out of regulation. During this period, the low-side synchronous rectifier turns on and remains on until either the high-side switch turns on again or the inductor current approaches zero. The internal synchronous rectifier eliminates the need for an external Schottky diode.

This control scheme allows the MAX1733/MAX1734 to provide excellent performance throughout the entire load-current range. When delivering light loads, the high-side switch turns off after the minimum on-time to reduce peak inductor current, resulting in increased efficiency and reduced output voltage ripple. When delivering medium and higher output currents, the MAX1733/MAX1734 extend either the on-time or the off-time, as necessary to maintain regulation, resulting in

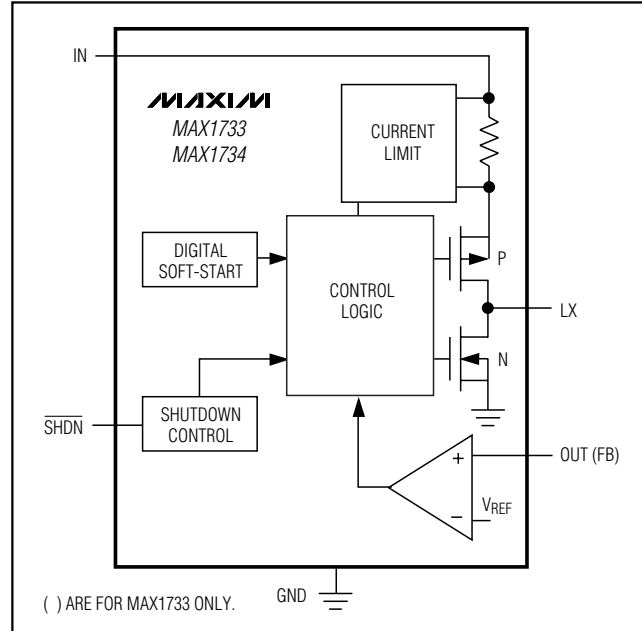


Figure 2. Simplified Functional Diagram

nearly constant frequency operation with high efficiency and low output voltage ripple.

### Shutdown Mode

Connecting  $\overline{\text{SHDN}}$  to GND places the MAX1733/MAX1734 in shutdown mode and reduces supply current to 0.01µA. In shutdown, the control circuitry, internal switching MOSFET, and synchronous rectifier turn off and LX goes high impedance. Connect  $\overline{\text{SHDN}}$  to IN for normal operation.

### Soft-Start

The MAX1733/MAX1734 have internal soft-start circuitry that limits current draw at startup, reducing transients on the input source. Soft-start is particularly useful for higher impedance input sources, such as Li+ and alkaline cells. Soft-start is implemented by starting with the current limit at 25% of its full current value and gradually increasing it in 25% steps until the full current limit is reached. See Soft-Start and Shutdown Response in the *Typical Operating Characteristics* section.

## Design Information

### Setting the Output Voltage (MAX1733)

Select an output voltage for the MAX1733 by connecting FB to a resistive divider between the output and

# Low-Voltage, Step-Down DC-DC Converters in SOT23

MAX1733/MAX1734

**Table 1. Suggested Inductors**

| INDUCTOR VALUE<br>(μH) | MANUFACTURER | PART<br>NUMBER |
|------------------------|--------------|----------------|
| 10                     | Sumida       | CR43-100       |
|                        |              | CDRH4D18-100   |
| 10                     | Coilcraft    | DT1608C-103    |

**Table 2. Suggested Capacitors**

| CAPACITOR<br>TYPE  | MANUFACTURER | PART<br>NUMBER |
|--------------------|--------------|----------------|
| Tantalum<br>(22μF) | Taiyo Yuden  | LMK212BJ225MG  |
| Ceramic<br>(2.2μF) | AVX          | TAJA226M006R   |

**Table 3. Component Suppliers**

| COMPANY     | PHONE        | FAX            |
|-------------|--------------|----------------|
| AVX         | 843-946-0238 | 843-626-3123   |
| Coilcraft   | 847-639-6400 | 847-639-1469   |
| Kemet       | 408-986-0424 | 408-986-1442   |
| Murata      | 814-237-1431 | 814-238-0490   |
| Sumida      | USA          | 847-956-0666   |
|             | Japan        | 81-3-3607-5111 |
| Taiyo Yuden | 408-573-4150 | 408-573-4159   |

$$I_{RMS} = \frac{I_{OUT} \left[ V_{OUT} (V_{IN} - V_{OUT}) \right]^{1/2}}{V_{IN}}$$

Tables 2 and 3 list some suggested capacitors and suppliers.

GND (Figure 1). Choose R2 to be less than 50kΩ:

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

where  $V_{REF} = 1.25V$ .

## Inductor Selection

The MAX1733/MAX1734 are optimized to use a 10μH inductor over the entire operating range. A 300mA rated inductor is enough to prevent saturation for output currents up to 250mA. Saturation occurs when the inductor's magnetic flux density reaches the maximum level the core can support and inductance falls. Choose a low DC-resistance inductor to improve efficiency. Tables 1 and 3 list some suggested inductors and suppliers.

## Capacitor Selection

The MAX1733/MAX1734 require output voltage ripple (approximately 30mVp-p) for stable switching behavior. Use a 10μF to 47μF tantalum output capacitor with about 200mΩ to 300mΩ ESR to provide stable switching while minimizing output ripple. Choose input and output capacitors to filter inductor currents for acceptable voltage ripple. The input capacitor reduces peak currents and noise at the voltage source. Input capacitors must meet the input ripple requirements and voltage rating. Use the following equation to calculate the maximum RMS input current:

## Using Ceramic Cout with MAX1733

The circuit of Figure 3 is designed to allow the use of ceramic output capacitors with the MAX1733. Feedback is derived from the LX pin instead of the output to remove the effects of phase lag in the feedback loop. Compared to the standard applications circuit, there are three benefits: 1) availability of ceramic vs. tantalum; 2) size of 2.2μF 0805 vs. 22μF A-case; 3) output ripple less than 10mVp-p vs. greater than 30mVp-p. Increase the output capacitance to 4.7μF to further reduce the output ripple. Note that this circuit exhibits load regulation equal to the series resistance of the inductor multiplied by the load current. This small amount of load regulation is helpful in reducing overshoot of the output voltage during load transients.

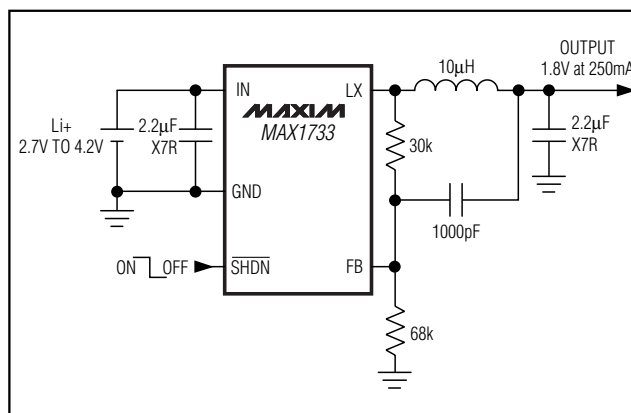


Figure 3. Using a Ceramic Output Capacitor with the MAX1733

# Low-Voltage, Step-Down DC-DC Converters in SOT23

## Layout Considerations

High switching frequencies make PC board layout a very important part of design. Good design minimizes excessive EMI on the feedback paths and voltage gradients in the ground plane, both of which can result in instability or regulation errors. Connect the inductor, input filter capacitor, and output filter capacitor as close to the device as possible, and keep their traces short, direct, and wide. Connect their ground pins at a single common node in a star ground configuration. The external voltage-feedback network should be very close to the FB pin, within 0.2 inches (5mm). Keep noisy traces, such as the LX trace, away from the volt-

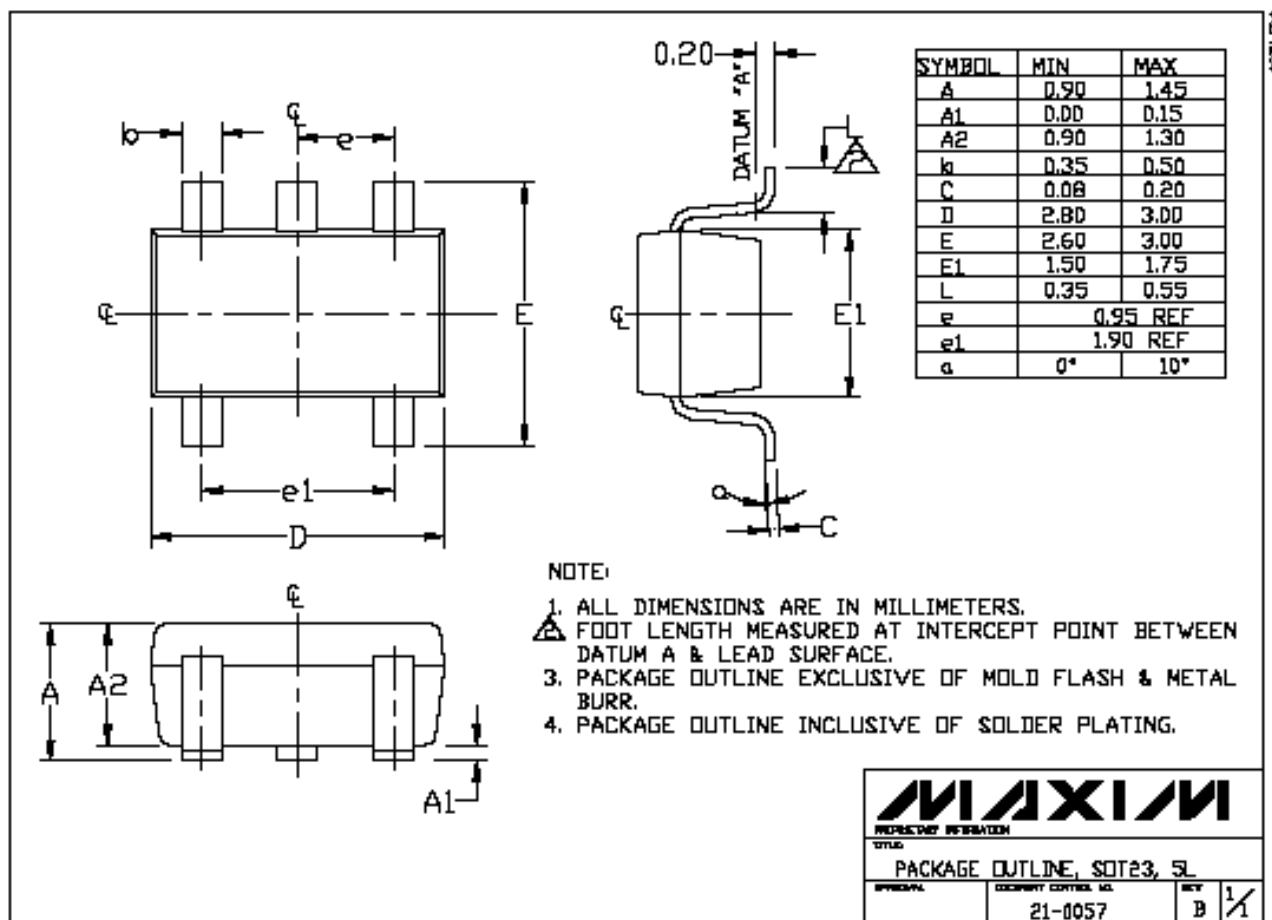
age-feedback network; also keep them separate, using grounded copper. The MAX1733/MAX1734 evaluation kit data sheet includes a proper PC board layout and routing scheme.

## Chip Information

TRANSISTOR COUNT: 1190

PROCESS: BiCMOS

## Package Information



Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

8 \_\_\_\_\_ **Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600**

© 2000 Maxim Integrated Products

Printed USA

**MAXIM** is a registered trademark of Maxim Integrated Products.