19-1586; Rev 0; 7/00

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.

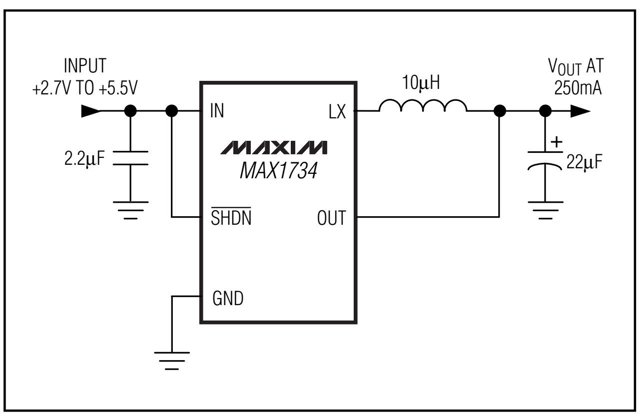
Applications

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

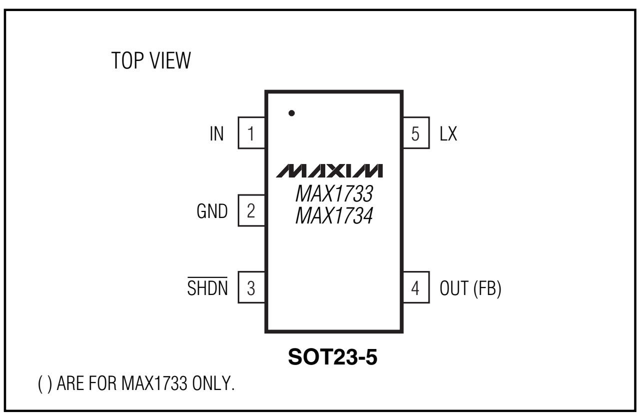
PART	TEMP. RANGE	PIN-PACKAGE
MAX1733EUK-T	-40°C to +85°C	5 SOT23-5
MAX1734EUK_ _-T	-40°C to +85°C	5 SOT23-5

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_{OUT} (V)	TOP MARK
MAX1733EUK	Adjustable	ADKY
MAX1734EUK18	1.8	ADKW
MAX1734EUK15	1.5	ADKX

Pin Configuration



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

ABSOLUTE MAXIMUM RATINGS

IN, $\overline{SHDN}$ to GND ....-0.3V to +6V
OUT, FB, LX to GND ....-0.3V to (V_{IN} + 0.3V)
OUT Short Circuit to GND ....Continuous
Continuous Power Dissipation (T_A = +70°C)
5-Pin SOT23 (derate 7.1mW/°C above +70°C)............571mW
Operating Temperature Range ....-40°C to +85°C
Junction Temperature ....+150°C
Storage Temperature Range ....-65°C to +150°C
Lead Temperature (soldering, 10s) ....+300°C

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

ELECTRICAL CHARACTERISTICS

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

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

ELECTRICAL CHARACTERISTICS

(V_{IN} = +2.7V to +5.5V, $\overline{SHDN}$ = IN, **T_A = -40°C to +85°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	µA
Shutdown Supply Current	I_{SHDN}	$\overline{SHDN}$ = GND		4	µA
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	µA
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	µA
$\overline{SHDN}$ 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	µA
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	Ω
		I_{LX} = -50mA, V_{IN} = 5.5V		1.1	
Rectifier On-Resistance	R_{ONN}	I_{LX} = -50mA, V_{IN} = 3.0V		2	Ω
		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	µA
LX Reverse Leakage Current	$I_{LXLK,R}$	IN unconnected, V_{LX} = 5.5V, $\overline{SHDN}$ = GND		5	µA
Minimum On-Time	$t_{ON(MIN)}$		0.25	0.55	µs
Minimum Off-Time	$t_{OFF(MIN)}$		0.25	0.55	µs

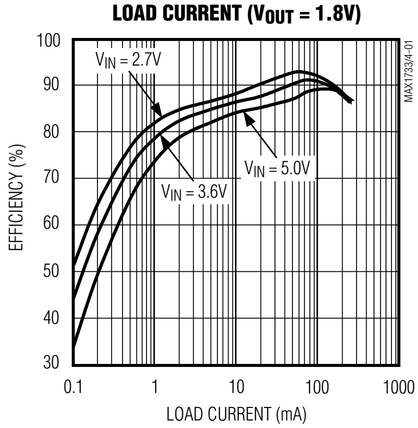
Note 1: All devices are 100% production tested at T_A = +25°C. Limits over the operating temperature range are guaranteed by design.

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

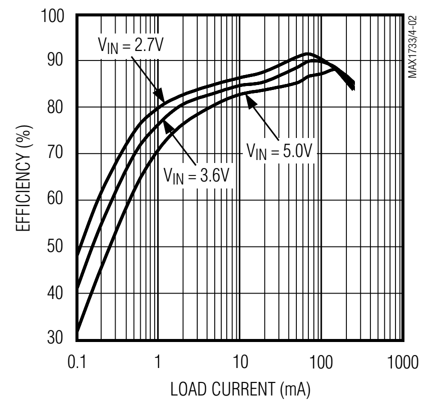
Typical Operating Characteristics

(C_{IN} = 2.2µF ceramic, C_{OUT} = 22µF tantalum, L = 10µH, unless otherwise noted.)

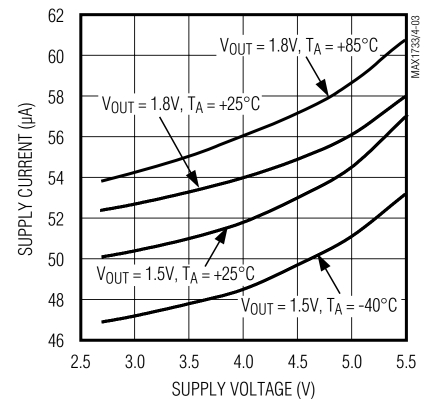
EFFICIENCY vs. LOAD CURRENT (V_{OUT} = 1.8V)



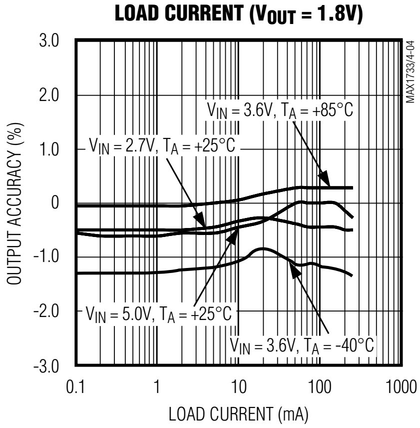
EFFICIENCY vs. LOAD CURRENT (V_{OUT} = 1.5V)



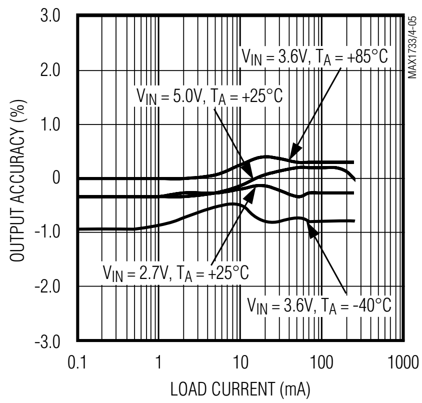
NO-LOAD SUPPLY CURRENT vs. SUPPLY VOLTAGE



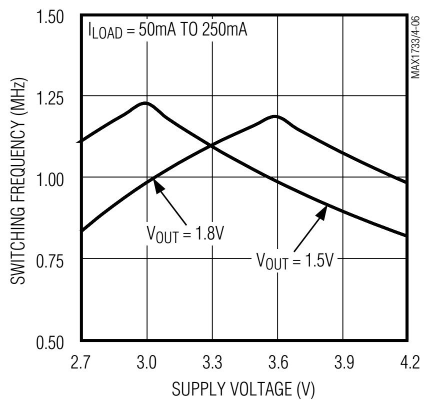
OUTPUT ACCURACY vs. LOAD CURRENT (V_{OUT} = 1.8V)



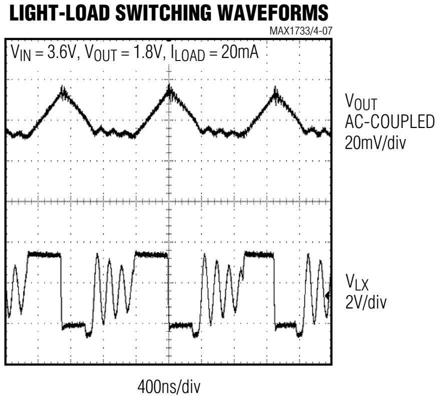
OUTPUT ACCURACY vs. LOAD CURRENT (V_{OUT} = 1.5V)



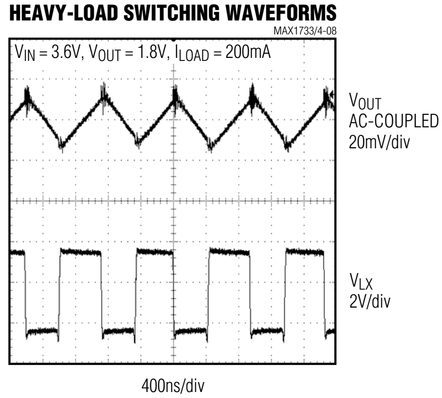
SWITCHING FREQUENCY vs. SUPPLY VOLTAGE



LIGHT-LOAD SWITCHING WAVEFORMS



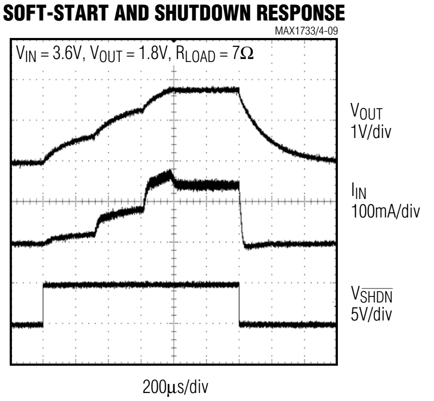
HEAVY-LOAD SWITCHING WAVEFORMS



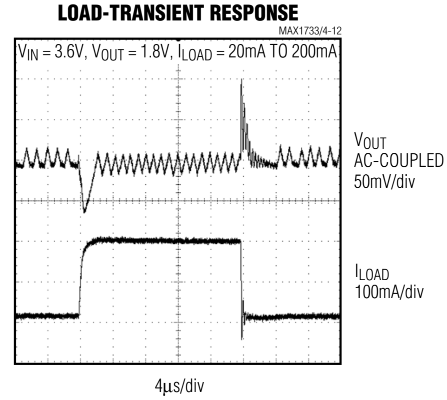
Typical Operating Characteristics (continued)

(C_{IN} = 2.2µF ceramic, C_{OUT} = 22µF tantalum, L = 10µH, unless otherwise noted.)

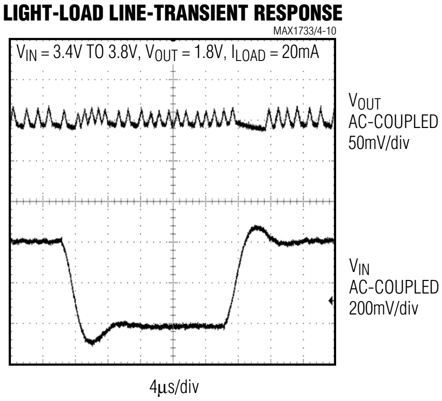
SOFT-START AND SHUTDOWN RESPONSE



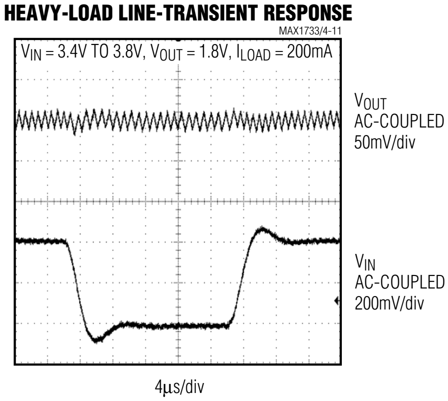
LOAD-TRANSIENT RESPONSE



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	$\overline{SHDN}$	Active-Low Shutdown Input. Connect $\overline{SHDN}$ 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

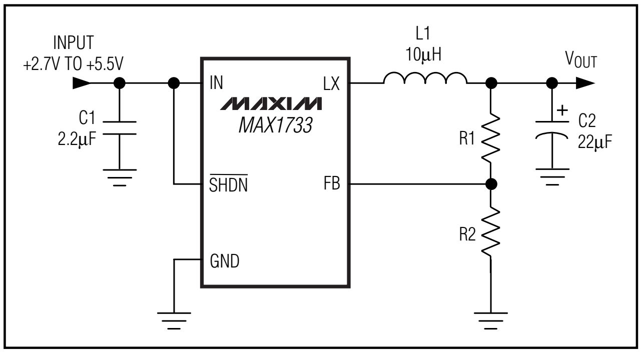


Figure 1. MAX1733 Typical Application Circuit

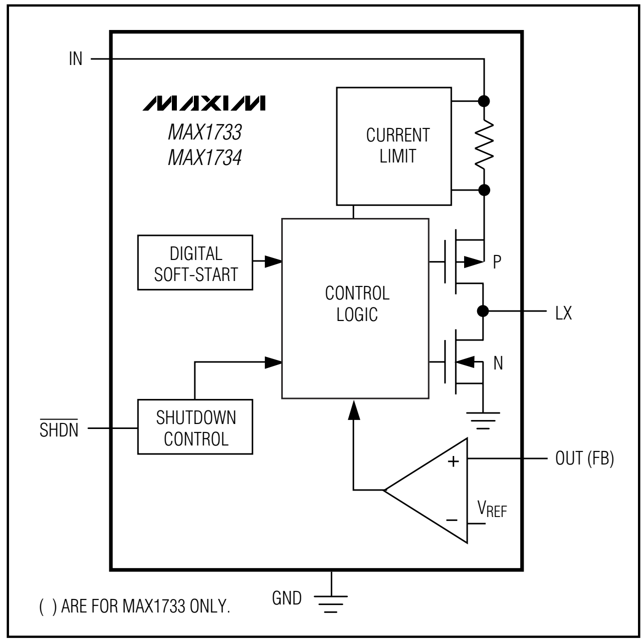


Figure 2. Simplified Functional Diagram

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

Shutdown Mode

Connecting $\overline{SHDN}$ 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 $\overline{SHDN}$ 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

Table 1. Suggested Inductors

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

Table 2. Suggested Capacitors

CAPACITOR TYPE	MANUFACTURER	PART NUMBER
Tantalum (22µF)	Taiyo Yuden	LMK212BJ225MG
Ceramic (2.2µF)	AVX	TAJA226M006R

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:

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	847-956-0702
	Japan	81-3-3607-5111	81-3-3607-5144
Taiyo Yuden		408-573-4150	408-573-4159

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

Tables 2 and 3 list some suggested capacitors and suppliers.

Using Ceramic C_{OUT} 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.

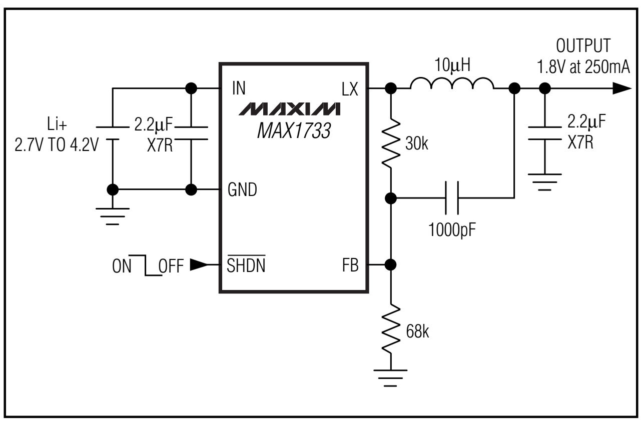


Figure 3. Using a Ceramic Output Capacitor with the MAX1733

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

Layout Considerations

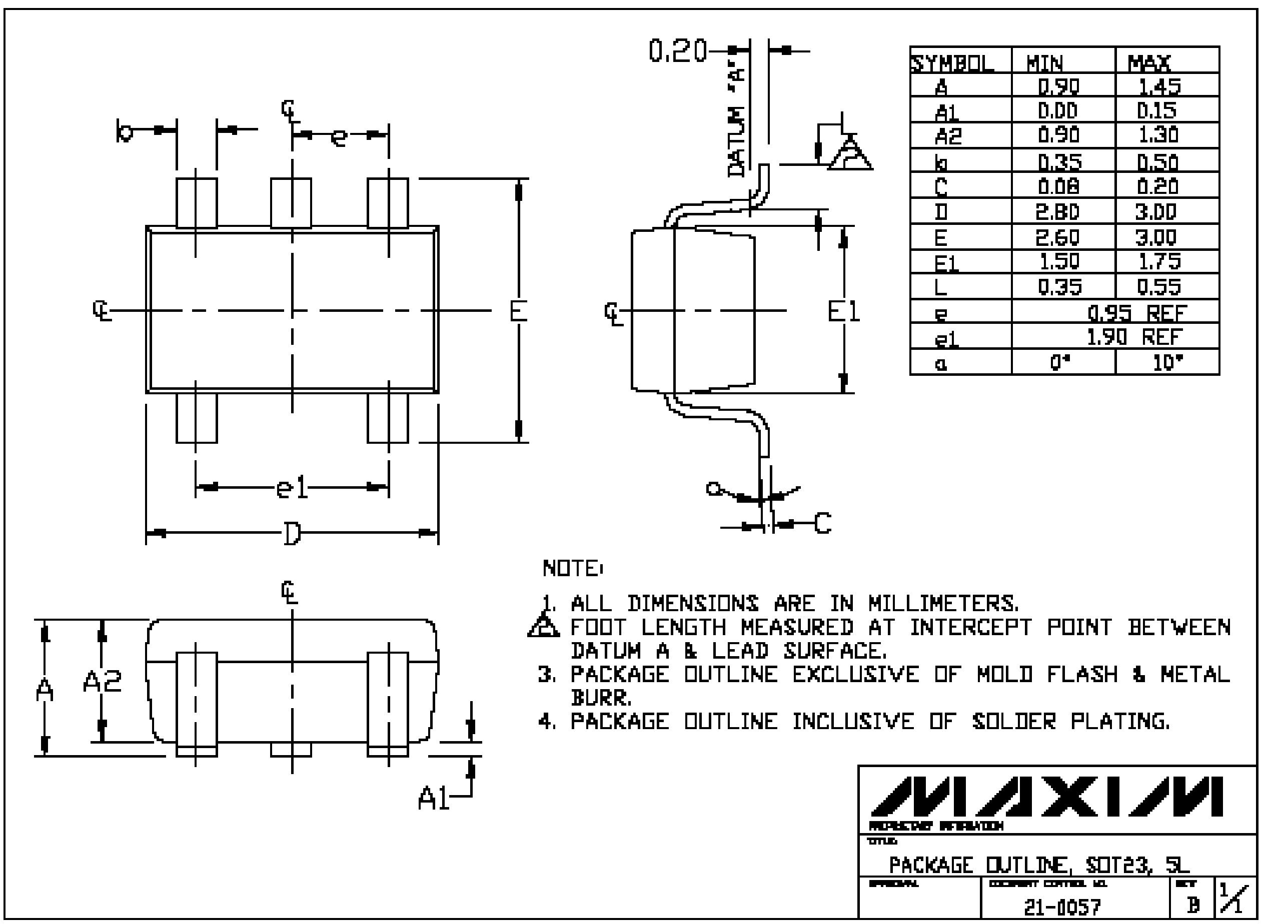
High switching frequencies make PC board layout a very important part of design. Good design minimizes excessive EMI on the feedback paths and voltage gradients in the ground plane, both of which can result in instability or regulation errors. Connect the inductor, input filter capacitor, and output 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 voltage-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



SYMBOL	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.35	0.50
C	0.08	0.20
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.75
L	0.35	0.55
e	0.95 REF	
e1	1.90 REF	
α	0°	10°

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.