

1.5µA IQ, Step-Up DC-DC Converters in TSOT

General Description

The MAX1722/MAX1723/MAX1724 compact, high-efficiency, step-up DC-DC converters are available in tiny, 5-pin TSOT packages. They feature an extremely low 1.5µA quiescent supply current to ensure the highest possible light-load efficiency. Optimized for operation from one to two alkaline or nickel-metal-hydride (NiMH) cells, or a single Li+ cell, these devices are ideal for applications where extremely low quiescent current and ultra-small size are critical.

Built-in synchronous rectification significantly improves efficiency and reduces size and cost by eliminating the need for an external Schottky diode. All three devices feature a 0.5Ω N-channel power switch. The MAX1722/MAX1724 also feature proprietary noise-reduction circuitry, which suppresses electromagnetic interference (EMI) caused by the inductor in many step-up applications. The family offers different combinations of fixed or adjustable outputs, shutdown, and EMI reduction (see *Selector Guide*).

Applications

| | |
|------------------------------|-------------------------------------|
| Pagers | Single-Cell Battery-Powered Devices |
| Remote Controls | |
| Remote Wireless Transmitters | Low-Power Hand-Held Instruments |
| Personal Medical Devices | MP3 Players |
| Digital Still Cameras | Personal Digital Assistants (PDA) |

Features

- ◆ Up to 90% Efficiency
- ◆ No External Diode or FETs Needed
- ◆ 1.5µA Quiescent Supply Current
- ◆ 0.1µA Logic-Controlled Shutdown
- ◆ ±1% Output Voltage Accuracy
- ◆ Fixed Output Voltage (MAX1724) or Adjustable Output Voltage (MAX1722/MAX1723)
- ◆ Up to 150mA Output Current
- ◆ 0.8V to 5.5V Input Voltage Range
- ◆ 0.91V Guaranteed Startup (MAX1722/MAX1724)
- ◆ Internal EMI Suppression (MAX1722/MAX1724)
- ◆ TSOT Package (0.9mm typ Height)

Ordering Information

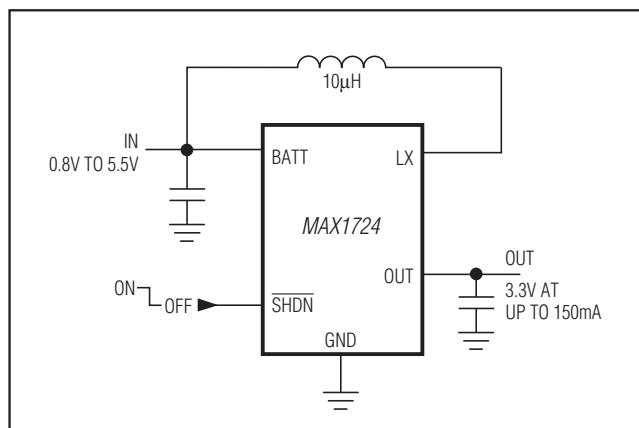
| PART | TEMP RANGE | PIN-PACKAGE | TOP MARK |
|----------------|----------------|-------------|----------|
| MAX1722EZK+T+ | -40°C to +85°C | 5 TSOT | ADQF |
| MAX1723EZK+T | -40°C to +85°C | 5 TSOT | ADQG |
| MAX1724EZK27+T | -40°C to +85°C | 5 TSOT | ADQH |
| MAX1724EZK30+T | -40°C to +85°C | 5 TSOT | ADQI |
| MAX1724EZK33+T | -40°C to +85°C | 5 TSOT | ADQJ |
| MAX1724EZK50+T | -40°C to +85°C | 5 TSOT | ADQK |

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

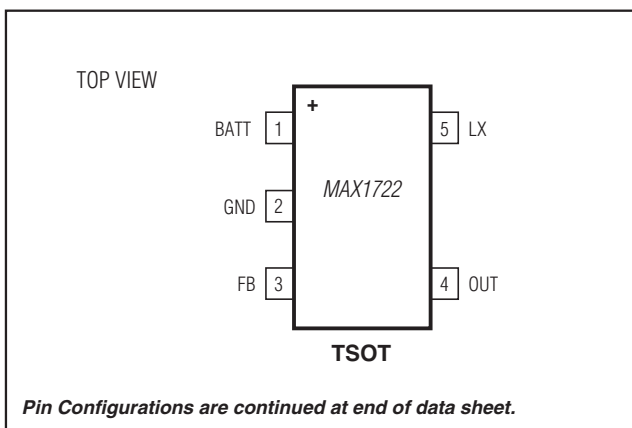
T = Tape and reel.

Selector Guide appears at end of data sheet.

Typical Operating Circuit



Pin Configurations



For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maximintegrated.com.

MAX1722/MAX1723/MAX1724

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ABSOLUTE MAXIMUM RATINGS

OUT, SHDN, BATT, LX to GND-0.3V to +6V
 FB to GND-0.3V to (V_{OUT} + 0.3V)
 OUT, LX Current.....1A
 Continuous Power Dissipation (T_A = +70°C)
 5-Pin Thin SOT (derate 2.7mW/°C above +70°C) ..219.10mW

Operating Temperature Range-40°C to +85°C
 Junction Temperature.....+150°C
 Storage Temperature Range.....-65°C to +150°C
 Soldering Temperature
 Lead(Pb)-free packages.....+260°C
 Packages containing lead(Pb).....+240°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_{BATT} = 1.2V, V_{OUT} = 3.3V (MAX1722/MAX1723), V_{OUT} = V_{OUT(NOM)} (MAX1724), SHDN = OUT, R_L = ∞, T_A = 0°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---------------------|---|-------------------------------|-------|-------|-------|-------|
| Minimum Input Voltage | | MAX1722/MAX1724 | | 0.8 | | | V |
| Operating Input Voltage | V _{IN} | T _A = +25°C | MAX1722/MAX1724 | 0.91 | | 5.5 | V |
| | | | MAX1723 (Note 2) | 1.2 | | 5.5 | |
| Minimum Startup Input Voltage | | T _A = +25°C, R _L = 3kΩ | MAX1722/MAX1724 | | 0.83 | 0.91 | V |
| | | | MAX1723 (Note 2) | | 0.87 | 1.2 | |
| Output Voltage | V _{OUT} | MAX1724EZK27 | T _A = +25°C | 2.673 | 2.7 | 2.727 | V |
| | | | T _A = 0°C to +85°C | 2.633 | | 2.767 | |
| | | MAX1724EZK30 | T _A = +25°C | 2.970 | 3.0 | 3.030 | |
| | | | T _A = 0°C to +85°C | 2.925 | | 3.075 | |
| | | MAX1724EZK33 | T _A = +25°C | 3.267 | 3.3 | 3.333 | |
| | | | T _A = 0°C to +85°C | 3.218 | | 3.383 | |
| | | MAX1724EZK50 | T _A = +25°C | 4.950 | 5.0 | 5.050 | |
| | | | T _A = 0°C to +85°C | 4.875 | | 5.125 | |
| Output Voltage Range | V _{OUT} | MAX1722/MAX1723 | | 2 | | 5.5 | V |
| Feedback Voltage | V _{FB} | MAX1722/MAX1723 | T _A = +25°C | 1.223 | 1.235 | 1.247 | V |
| | | | T _A = 0°C to +85°C | 1.210 | | 1.260 | |
| Feedback Bias Current | I _{FB} | MAX1722/MAX1723 | T _A = +25°C | | 1.5 | 20 | nA |
| | | | T _A = +85°C | | 2.2 | | |
| N-Channel On-Resistance | R _{DS(ON)} | V _{OUT} forced to 3.3V | | | 0.5 | 1.0 | Ω |
| P-Channel On-Resistance | R _{DS(ON)} | V _{OUT} forced to 3.3V | | | 1.0 | 2.0 | Ω |
| N-Channel Switch Current Limit | I _{LIM} | V _{OUT} forced to 3.3V | | 400 | 500 | 600 | mA |
| Switch Maximum On-Time | t _{ON} | | | 3.5 | 5 | 6.5 | µs |
| Synchronous Rectifier Zero-Crossing Current | | V _{OUT} forced to 3.3V | | 5 | 20 | 35 | mA |
| Quiescent Current into OUT | | (Notes 3, 4) | | | 1.5 | 3.6 | µA |
| Shutdown Current into OUT | | MAX1723/MAX1724 (Notes 3, 4) | T _A = +25°C | | 0.01 | 0.5 | µA |
| | | | T _A = +85°C | | 0.1 | | |
| Quiescent Current into BATT | | MAX1722/MAX1724 (Note 4) | T _A = +25°C | | 0.001 | 0.5 | µA |
| | | | T _A = +85°C | | 0.01 | | |

MAX1722/MAX1723/MAX1724

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ELECTRICAL CHARACTERISTICS (continued)

(V_{BATT} = 1.2V, V_{OUT} = 3.3V (MAX1722/MAX1723), V_{OUT} = V_{OUT(NOM)} (MAX1724), $\overline{\text{SHDN}}$ = OUT, R_L = ∞, T_A = 0°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|-----------------|--|------------------------|-------|-----|-------|
| Shutdown Current into BATT | | MAX1724 (Note 4) | T _A = +25°C | 0.001 | 0.5 | µA |
| | | | T _A = +85°C | 0.01 | | |
| $\overline{\text{SHDN}}$ Voltage Threshold | V _{IL} | MAX1723/MAX1724 | 75 | 400 | | mV |
| | V _{IH} | MAX1723/MAX1724 | | 500 | 800 | |
| $\overline{\text{SHDN}}$ Input Bias Current | | MAX1723/MAX1724, V _{SHDN} = 5.5V | T _A = +25°C | 2 | 100 | nA |
| | | | T _A = +85°C | 7 | | |

ELECTRICAL CHARACTERISTICS

(V_{BATT} = 1.2V, V_{OUT} = 3.3V (MAX1722/MAX1723), V_{OUT} = V_{OUT(NOM)} (MAX1724), $\overline{\text{SHDN}}$ = OUT, R_L = ∞, T_A = -40°C to +85°C, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---------------------|---------------------------------|-------|-----|-------|-------|
| Output Voltage | V _{OUT} | MAX1724EZK27 | 2.633 | | 2.767 | V |
| | | MAX1724EZK30 | 2.925 | | 3.075 | |
| | | MAX1724EZK33 | 3.218 | | 3.383 | |
| | | MAX1724EZK50 | 4.875 | | 5.125 | |
| Output Voltage Range | V _{OUT} | MAX1722/MAX1723 | 2 | | 5.5 | V |
| Feedback Voltage | V _{FB} | MAX1722/MAX1723 | 1.200 | | 1.270 | V |
| N-Channel On-Resistance | R _{DS(ON)} | V _{OUT} forced to 3.3V | | | 1.0 | Ω |
| P-Channel On-Resistance | R _{DS(ON)} | V _{OUT} forced to 3.3V | | | 2.0 | Ω |
| N-Channel Switch Current Limit | I _{LIM} | V _{OUT} forced to 3.3V | 400 | | 620 | mA |
| Switch Maximum On-Time | t _{ON} | | 3.5 | | 6.5 | µs |
| Synchronous Rectifier Zero-Crossing Current | | V _{OUT} forced to 3.3V | 5 | | 35 | mA |
| Quiescent Current into OUT | | (Notes 3,4) | | | 3.6 | µA |
| $\overline{\text{SHDN}}$ Voltage Threshold | V _{IL} | MAX1723/MAX1724 | 75 | | | mV |
| | V _{IH} | MAX1723/MAX1724 | | | 800 | |

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

Note 2: Guaranteed with the addition of a Schottky MBR0520L external diode between LX and OUT when using the MAX1723 with only one cell, and assumes a 0.3V voltage drop across the Schottky diode (see Figure 3).

Note 3: Supply current is measured with an ammeter between the output and OUT pin. This current correlates directly with actual battery supply current, but is reduced in value according to the step-up ratio and efficiency.

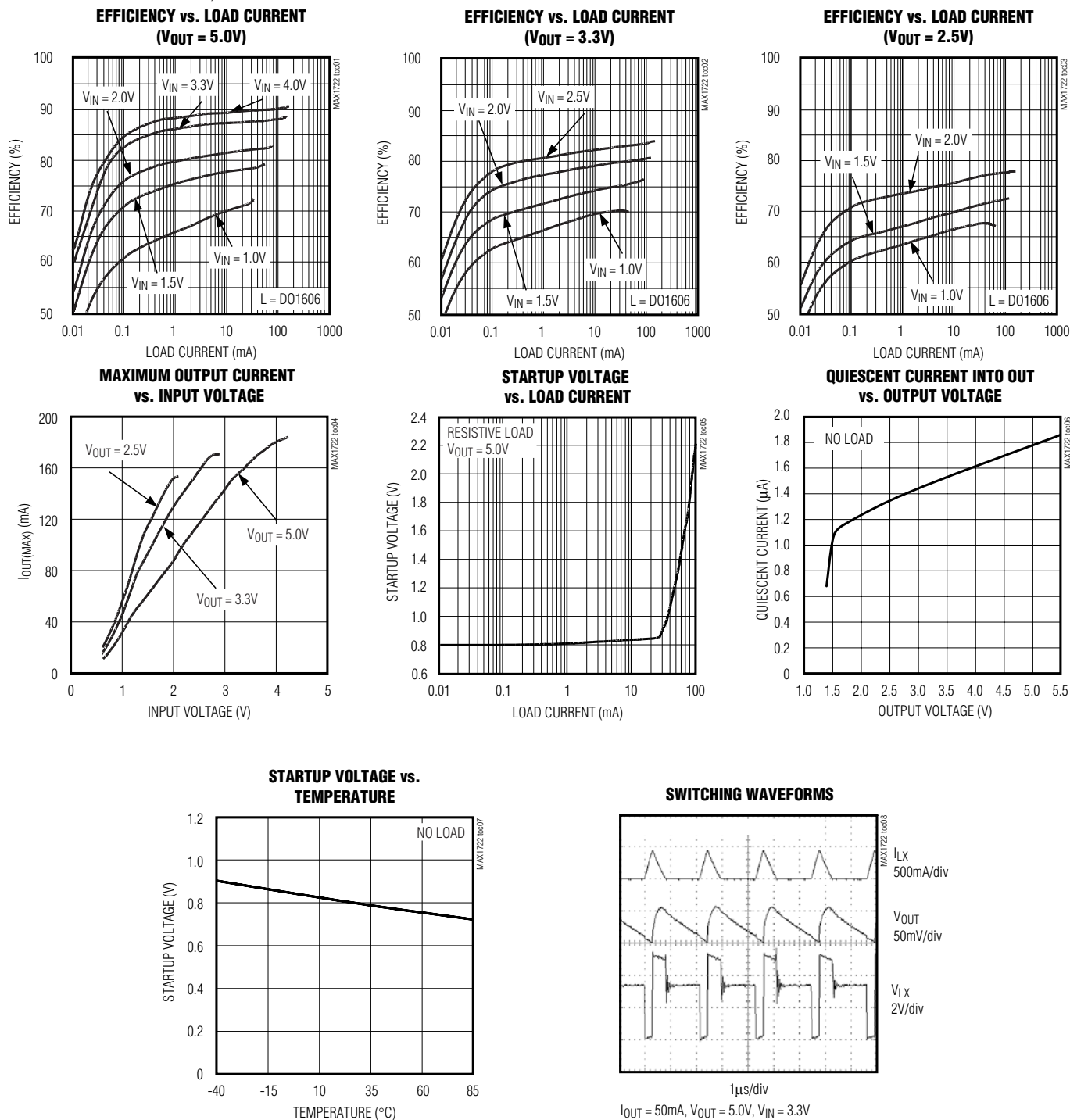
Note 4: V_{OUT} forced to the following conditions to inhibit switching: V_{OUT} = 1.05 × V_{OUT(NOM)} (MAX1724), V_{OUT} = 3.465V (MAX1722/MAX1723).

MAX1722/MAX1723/MAX1724

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Typical Operating Characteristics

(Figure 3 (MAX1723), Figure 7 (MAX1722), Figure 8 (MAX1724), $V_{BATT} = V_{IN} = 1.5V$, $L = 10\mu H$, $C_{IN} = 10\mu F$, $C_{OUT} = 10\mu F$, $T_A = +25^\circ C$, unless otherwise noted.)

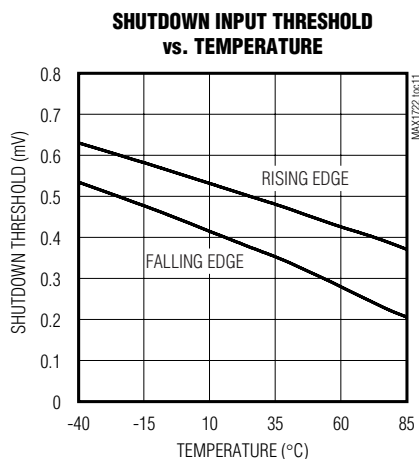
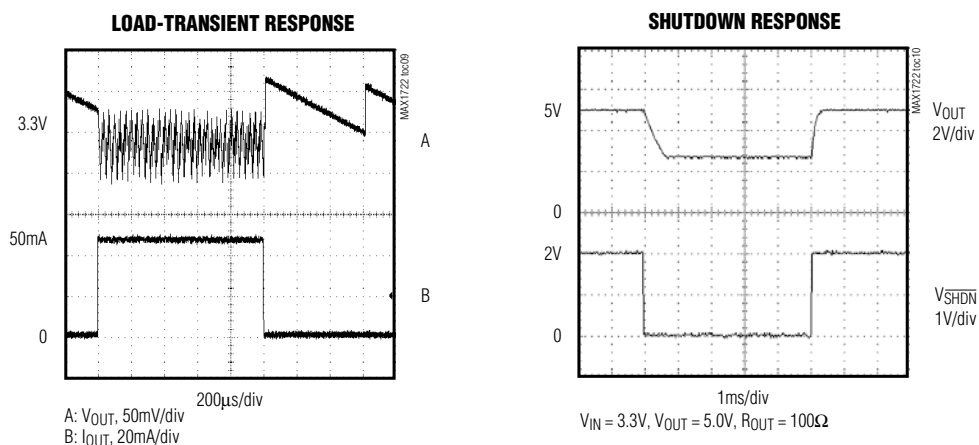


MAX1722/MAX1723/MAX1724

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Typical Operating Characteristics (continued)

(Figure 3 (MAX1723), Figure 7 (MAX1722), Figure 8 (MAX1724), $V_{BATT} = V_{IN} = 1.5V$, $L = 10\mu H$, $C_{IN} = 10\mu F$, $C_{OUT} = 10\mu F$, $T_A = +25^\circ C$, unless otherwise noted.)



Pin Description

| PIN | | | NAME | FUNCTION |
|---------|---------|---------|-------------------|---|
| MAX1722 | MAX1723 | MAX1724 | | |
| 1 | — | 1 | BATT | Battery Input and Damping Switch Connection |
| — | 1 | 3 | \overline{SHDN} | Shutdown Input. Drive high for normal operation. Drive low for shutdown. |
| 2 | 2 | 2 | GND | Ground |
| 3 | 3 | — | FB | Feedback Input to Set Output Voltage. Use a resistor-divider network to adjust the output voltage. See <i>Setting the Output Voltage</i> section. |
| 4 | 4 | 4 | OUT | Power Output. OUT also provides bootstrap power to the IC. |
| 5 | 5 | 5 | LX | Internal N-channel MOSFET Switch Drain and P-Channel Synchronous Rectifier Drain |

MAX1722/MAX1723/MAX1724

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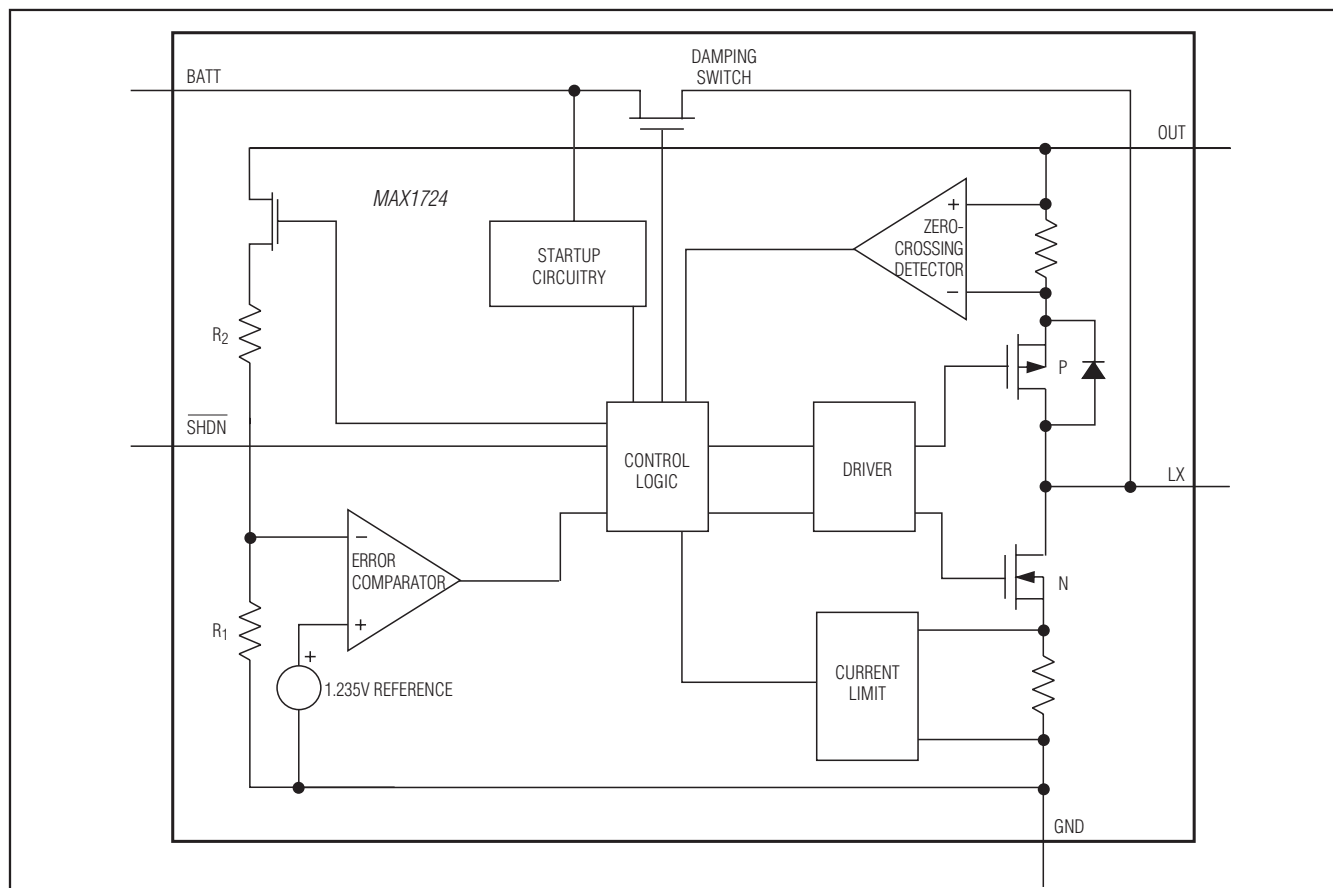


Figure 2. MAX1724 Simplified Functional Diagram

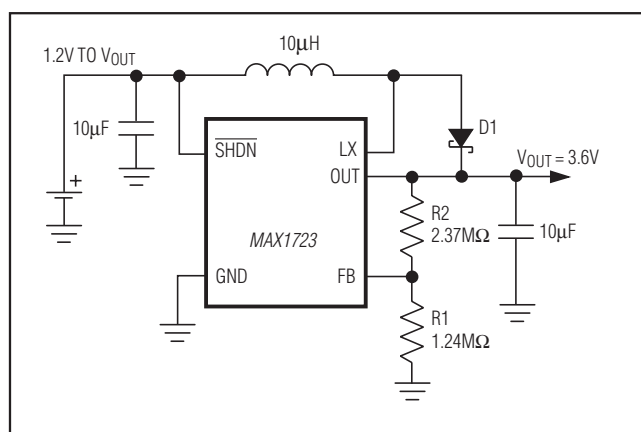


Figure 3. MAX1723 Single-Cell Operation

up voltage is a function of load current (see *Typical Operating Characteristics*). This circuit is powered from the BATT pin for the MAX1722/MAX1724, guaranteeing startup at input voltages as low as 0.91V. The MAX1723

lacks a BATT pin; therefore, this circuit is powered through the OUT pin. Adding a Schottky diode in parallel with the P-channel synchronous rectifier allows for startup voltages as low as 1.2V for the MAX1723 (Figure 3). The external Schottky diode is not needed for input voltages greater than 1.8V. Once started, the output maintains the load as the battery voltage decreases below the startup voltage.

Shutdown (MAX1723/MAX1724)

The MAX1723/MAX1724 enter shutdown when the SHDN pin is driven low. During shutdown, the body diode of the P-channel MOSFET allows current to flow from the battery to the output. V_{OUT} falls to approximately $V_{IN} - 0.6V$ and LX remains high impedance. Shutdown can be pulled as high as 6V, regardless of the voltage at BATT or OUT. For normal operation, connect SHDN to the input.

MAX1722/MAX1723/MAX1724

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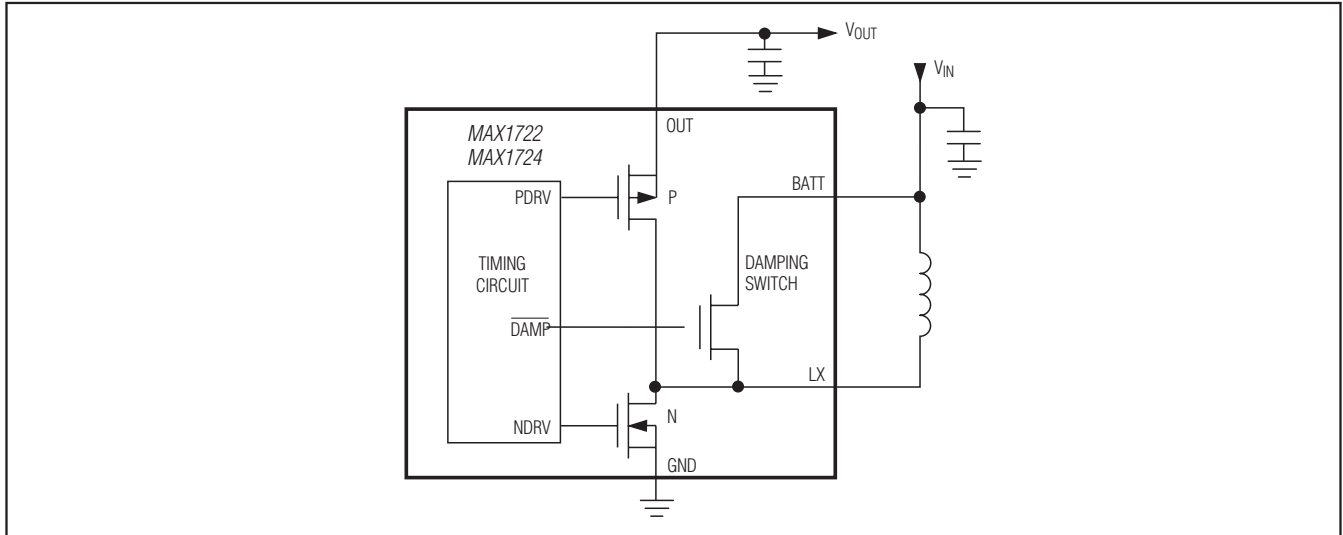


Figure 4. Simplified Diagram of Damping Switch

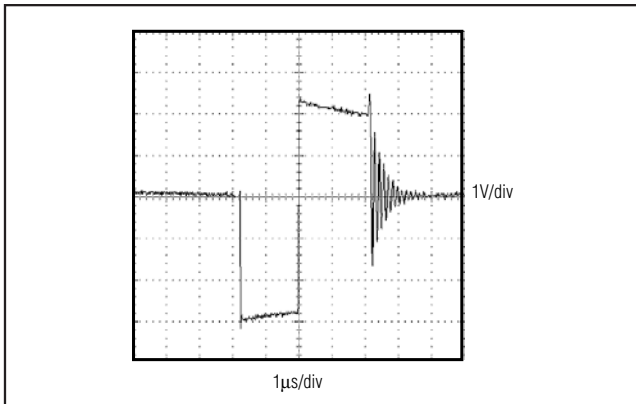


Figure 5. LX Ringing Without Damping Switch (MAX1723)

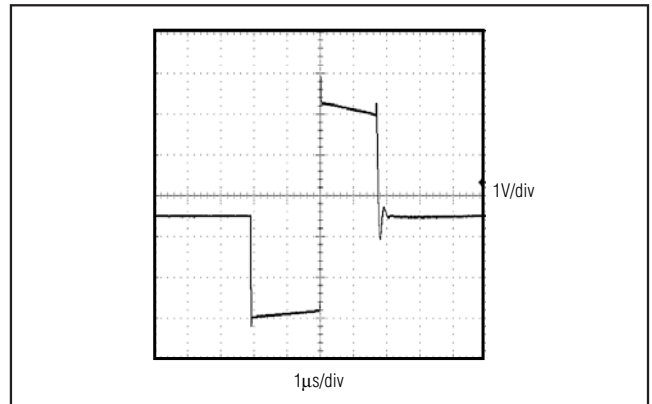


Figure 6. LX Ringing With Damping Switch (MAX1722/MAX1724)

BATT/Damping Switch (MAX1722/MAX1724)

The MAX1722/MAX1724 include an internal damping switch (Figure 4) to minimize ringing at LX and reduce EMI. When the energy in the inductor is insufficient to supply current to the output, the capacitance and inductance at LX form a resonant circuit that causes ringing. The damping switch supplies a path to quickly dissipate this energy, suppressing the ringing at LX. This does not reduce the output ripple, but does reduce EMI with minimal impact on efficiency. Figures 5 and 6 show the LX node voltage waveform without and with the damping switch, respectively.

Design Procedure

Setting the Output Voltage (MAX1722/MAX1723)

The output voltage can be adjusted from 2V to 5.5V using external resistors R1 and R2 (Figure 7). Since FB leakage is 20nA (max), select feedback resistor R1 in the 100kΩ to 1MΩ range. Calculate R2 as follows:

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

where $V_{FB} = 1.235V$.

MAX1722/MAX1723/MAX1724

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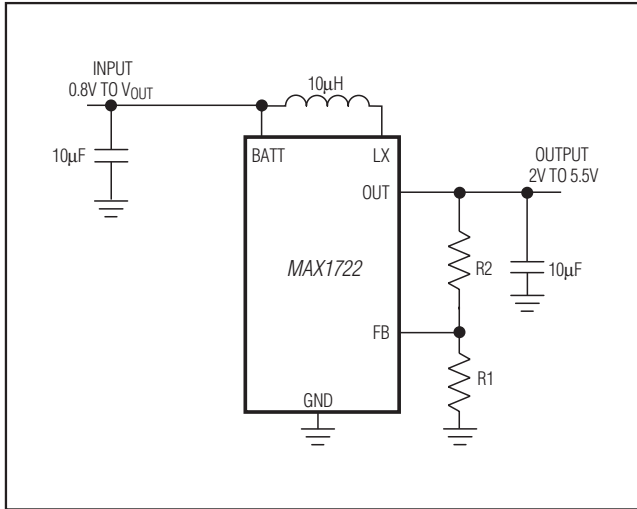


Figure 7. Adjustable Output Circuit

Inductor Selection

The control scheme of the MAX1722/MAX1723/MAX1724 permits flexibility in choosing an inductor. A 10μH inductor value performs well in most applications. Smaller inductance values typically offer smaller physical size for a given series resistance, allowing the smallest overall circuit dimensions. Circuits using larger inductance values may start up at lower battery voltages, provide higher efficiency, and exhibit less ripple, but they may reduce the maximum output current. This occurs when the inductance is sufficiently large to prevent the maximum current limit (I_{LIM}) from being reached before the maximum on-time ($t_{ON(MAX)}$) expires.

Table 1. Suggested Inductors and Suppliers

| MANUFACTURER | INDUCTOR | PHONE WEBSITE |
|---------------------------------|--|--|
| Coilcraft | DO1608 Series DO1606 Series | 847-639-2361 www.coilcraft.com |
| Murata | LQH4C Series | 770-436-1300 www.murata.com |
| Sumida | CDRH4D18 Series CR32 Series CMD4D06 Series | 847-545-6700 www.sumida.com |
| Sumitomo/ Daidoo Electronics | CXLD140 Series | +81 (06) 6355-5733 www.daidoo.co.jp |
| Toko | 3DF Type D412F Type | 847-297-0070 www.toko.com |

For maximum output current, choose the inductor value so that the controller reaches the current-limit before the maximum on-time is triggered:

$$L < \frac{V_{BATT} t_{ON(MAX)}}{I_{LIM}}$$

where the maximum on-time is typically 5μs, and the current limit (I_{LIM}) is typically 500mA (see *Electrical Characteristics* table).

For larger inductor values, determine the peak inductor current (I_{PEAK}) by:

$$I_{PEAK} = \frac{V_{BATT} t_{ON(MAX)}}{L}$$

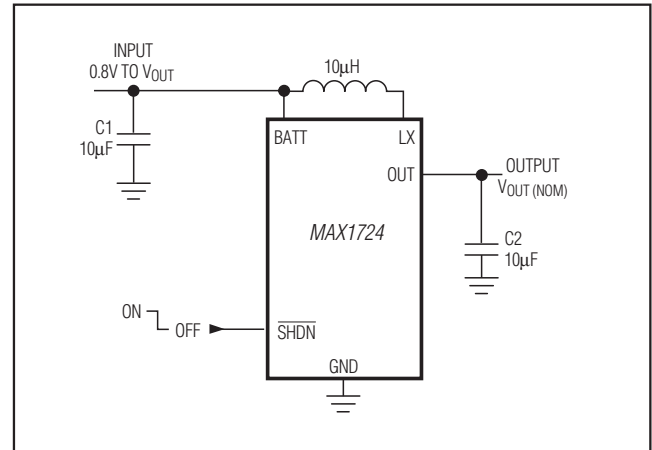


Figure 8. MAX1724 Standard Application Circuit

The inductor's incremental saturation current rating should be greater than the peak switching current. However, it is generally acceptable to bias the inductor into saturation by as much as 20%, although this will slightly reduce efficiency. Table 1 lists suggested inductors and suppliers.

Maximum Output Current

The maximum output current depends on the peak inductor current, the input voltage, the output voltage, and the overall efficiency (η):

$$I_{OUT(MAX)} = \frac{1}{2} I_{PEAK} \left(\frac{V_{BATT}}{V_{OUT}} \right) \eta$$

MAX1722/MAX1723/MAX1724

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Table 2. Suggested Surface-Mount Capacitors and Manufacturers (C1 and C2)

| MANUFACTURER | CAPACITOR VALUE | DESCRIPTION | PHONE WEBSITE |
|----------------|-----------------|--|---------------------------------|
| AVX | 1μF to 10μF | X7R Ceramic | 843-448-9411 www.avxcorp.com |
| | 10μF to 330μF | TAJ Tantalum Series TPS Tantalum Series | |
| Kemet | 1μF to 22μF | X5R/X7R Ceramic | 864-963-6300 www.kemet.com |
| | 10μF to 330μF | T494 Tantalum Series | |
| | 68μF to 330μF | T520 Tantalum Series | |
| Sanyo | 33μF to 330μF | TPC Polymer Series | 408-749-9714 www.secc.co.jp |
| Taiyo Yuden | 33μF to 330μF | X5R/X7R Ceramic | 800-368-2496 www.t-yuden.org |
| TDK | 1μF to 10μF | X7R Ceramic | 847-803-6100 www.tdk.com |
| Vishay Sprague | 10μF to 330μF | 594D Tantalum Series 595D Tantalum Series | 203-452-5664 www.vishay.com |

For most applications, the peak inductor current equals the current limit. However, for applications using large inductor values or low input voltages, the maximum on-time limits the peak inductor current (see *Inductor Selection* section).

Capacitor Selection

Choose input and output capacitors to supply the input and output peak currents with acceptable voltage ripple. The input filter capacitor (C_{IN}) reduces peak currents drawn from the battery and improves efficiency. Low equivalent series resistance (ESR) capacitors are recommended. Ceramic capacitors have the lowest ESR, but low ESR tantalum or polymer capacitors offer a good balance between cost and performance.

Output voltage ripple has two components: variations in the charge stored in the output capacitor with each LX pulse, and the voltage drop across the capacitor's ESR caused by the current into and out of the capacitor:

$$V_{RIPPLE} = V_{RIPPLE(C)} + V_{RIPPLE(ESR)}$$

$$V_{RIPPLE(ESR)} \approx I_{PEAK} R_{ESR}(C_{OUT})$$

$$V_{RIPPLE(C)} \approx \frac{1}{2} \left(\frac{L}{(V_{OUT} - V_{BATT})C_{OUT}} \right) (I_{PEAK}^2 - I_{OUT}^2)$$

where I_{PEAK} is the peak inductor current (see *Inductor Selection* section). For ceramic capacitors, the output voltage ripple is typically dominated by $V_{RIPPLE(C)}$. For example, a 10μF ceramic capacitor and a 10μH inductor typically provide 75mV of output ripple when stepping up from 3.3V to 5V at 50mA. Low input-to-output voltage differences (i.e. two cells to 3.3V) require higher output capacitor values.

Capacitance and ESR variation of temperature should be considered for best performance in applications with wide operating temperature ranges. Table 2 lists suggested capacitors and suppliers.

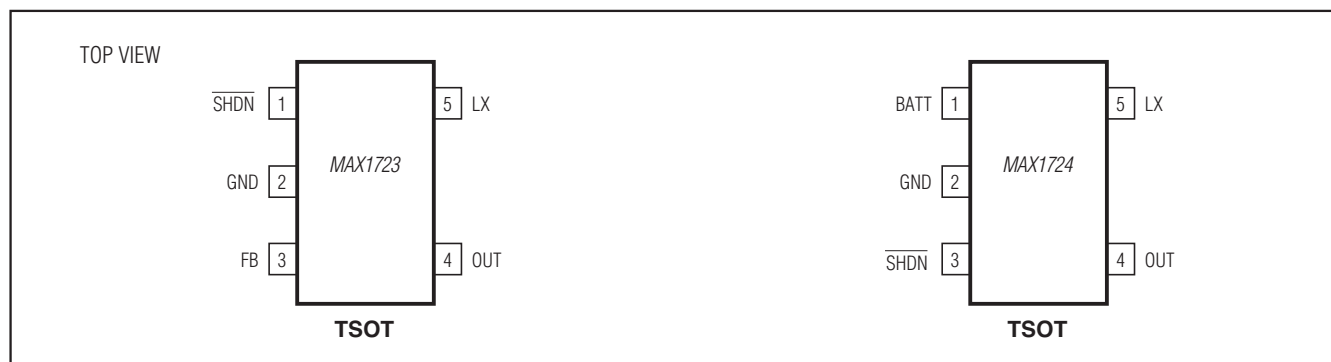
PC Board Layout Considerations

Careful PC board layout is important for minimizing ground bounce and noise. Keep the IC's GND pin and the ground leads of the input and output capacitors less than 0.2in (5mm) apart using a ground plane. In addition, keep all connections to FB (MAX1722/MAX1723 only) and LX as short as possible.

MAX1722/MAX1723/MAX1724

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Pin Configurations (continued)



Selector Guide

| PART | OUTPUT (V) | SHDN | LX DAMPING |
|--------------|------------|------|------------|
| MAX1722EZK | Adjustable | No | Yes |
| MAX1723EZK | Adjustable | Yes | No |
| MAX1724EZK27 | Fixed 2.7 | Yes | Yes |
| MAX1724EZK30 | Fixed 3.0 | Yes | Yes |
| MAX1724EZK33 | Fixed 3.3 | Yes | Yes |
| MAX1724EZK50 | Fixed 5.0 | Yes | Yes |

Package Information

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

| PACKAGE TYPE | PACKAGE CODE | OUTLINE NO. | LAND PATTERN NO. |
|--------------|--------------|-------------------------|-------------------------|
| TSOT | Z5+1 | 21-0113 | 90-0241 |

MAX1722/MAX1723/MAX1724

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Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|-----------------|---------------|---|---------------|
| 0 | 7/01 | Initial release | — |
| 1 | 9/12 | Added lead-free and tape-and-reel designations and added soldering temperatures | 1, 2 |
| 2 | 5/13 | Corrected package and thermal information in <i>Feature, Ordering Information, Absolute Maximum Ratings, Pin Configuration, and Package Information</i> | 1, 2, 11 |



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[MAX1724EZK27-T](#) [MAX1724EZK30-T](#) [MAX1724EZK33-T](#) [MAX1722EZK-T](#) [MAX1724EZK50-T](#) [MAX1724EVKIT](#)