



# 12V/15V or Adjustable, High-Efficiency, Low I<sub>Q</sub>, Step-Up DC-DC Converters

MAX761/MAX762

## General Description

The MAX761/MAX762 step-up switching regulators provide high efficiency over a wide range of load currents, delivering up to 150mA. A unique, current-limited pulse-frequency-modulated (PFM) control scheme gives the devices the benefits of pulse-width-modulated (PWM) converters (high efficiency with heavy loads), while using less than 110µA of supply current (vs. 2mA to 10mA for PWM converters). The result is high efficiency over a wide range of loads.

The MAX761/MAX762 input voltage range is 2V to 16.5V. Output voltages are preset to 12V (MAX761) and 15V (MAX762), or they can be set with two external resistors. With a 5V input, the MAX761 guarantees a 12V, 150mA output. Its high efficiency, low supply current, fast start-up time, SHDN controlling capability, and small size make the MAX761 ideal for powering flash memory.

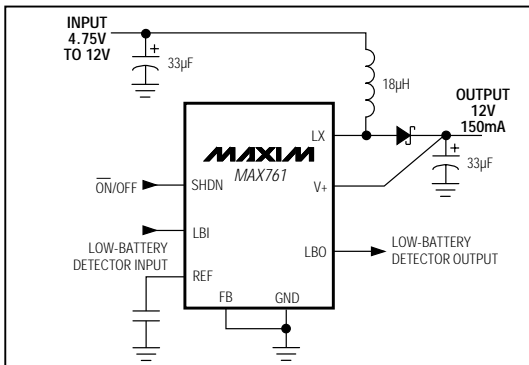
The MAX761/MAX762 have an internal 1A power MOSFET, making them ideal for minimum-component, low- and medium-power applications. These devices use tiny external components, and their high switching frequencies (up to 300kHz) allow for small surface-mount magnetics.

For increased output drive capability or higher output voltages, use the MAX770–MAX773, which are similar in design to the MAX761/MAX762, but drive external power MOSFETs. For stepping up to 5V, see the MAX756/MAX757 and MAX856–MAX859 data sheets.

## Applications

- Flash Memory Programming
- PCMCIA Cards
- Battery-Powered Applications
- High-Efficiency DC-DC Converters

## Typical Operating Circuit



## Features

- ◆ High Efficiency for a Wide Range of Load Currents
- ◆ 12V/150mA Flash Memory Programming Supply
- ◆ 110µA Max Supply Current
- ◆ 5µA Max Shutdown Supply Current
- ◆ 2V to 16.5V Input Voltage Range
- ◆ 12V (MAX761), 15V (MAX762) or Adjustable Output
- ◆ Current-Limited PFM Control Scheme
- ◆ 300kHz Switching Frequency
- ◆ Internal, 1A, N-Channel Power FET
- ◆ LBI/LBO Low-Battery Comparator

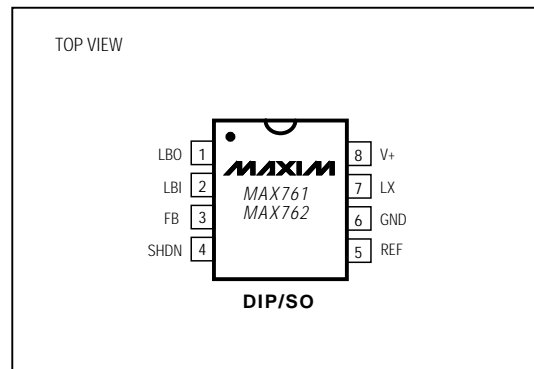
## Ordering Information

| PART      | TEMP. RANGE     | PIN-PACKAGE   |
|-----------|-----------------|---------------|
| MAX761CPA | 0°C to +70°C    | 8 Plastic DIP |
| MAX761CSA | 0°C to +70°C    | 8 SO          |
| MAX761C/D | 0°C to +70°C    | Dice*         |
| MAX761EPA | -40°C to +85°C  | 8 Plastic DIP |
| MAX761ESA | -40°C to +85°C  | 8 SO          |
| MAX761MJA | -55°C to +125°C | 8 CERDIP**    |
| MAX762CPA | 0°C to +70°C    | 8 Plastic DIP |
| MAX762CSA | 0°C to +70°C    | 8 SO          |
| MAX762C/D | 0°C to +70°C    | Dice*         |
| MAX762EPA | -40°C to +85°C  | 8 Plastic DIP |
| MAX762ESA | -40°C to +85°C  | 8 SO          |
| MAX762MJA | -55°C to +125°C | 8 CERDIP**    |

\* Contact factory for dice specifications.

\*\* Contact factory for availability and processing to MIL-STD-883.

## Pin Configuration



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## ABSOLUTE MAXIMUM RATINGS

|  |                           |
|--|---------------------------|
| Supply Voltage $V_+$ to GND  | -0.3V to 17V              |
| REF, LBO, LBI, SHDN, FB  | -0.3V to ( $V_+ + 0.3V$ ) |
| LX   | -0.3V to 17V              |
| LX Peak Current  | 1.5A                      |
| LBO Current  | 5mA                       |
| Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )               |                           |
| Plastic DIP (derate 9.09mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) | 727mW                     |
| SO (derate 5.88mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ )          | 471mW                     |
| CERDIP (derate 8.00mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ )      | 640mW                     |

### Operating Temperature Ranges:

|                                     |   |
|-------------------------------------|---|
| MAX76_C_A                           | $0^\circ\text{C}$ to $+70^\circ\text{C}$    |
| MAX76_E_A                           | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |
| MAX76_MJA                           | $-55^\circ\text{C}$ to $+125^\circ\text{C}$ |
| Junction Temperatures:              |   |
| MAX76_C_A/E_A                       | $+150^\circ\text{C}$                        |
| MAX76_MJA                           | $+175^\circ\text{C}$                        |
| Storage Temperature Range           | $-65^\circ\text{C}$ to $+160^\circ\text{C}$ |
| Lead Temperature (soldering, 10sec) | $+300^\circ\text{C}$                        |

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

( $V_+ = 5V$ ,  $I_{LOAD} = 0mA$ ,  $C_{REF} = 0.1\mu F$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , typical values are at  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

| PARAMETER                 | SYMBOL     | CONDITIONS  | MIN  | TYP    | MAX    | UNITS   |      |
|---------------------------|------------|---|--|--------|--------|---------|------|
| Supply Voltage            | $V_+$      | Figure 2, bootstrapped  | 2  |        | 16.5   | V       |      |
|                           |            | Figure 3 or 5 with external resistors.                                    | MAX76_C/E  | 3      |        |         | 16.5 |
|                           |            |   | MAX76_M  | 3.1    |        |         | 16.5 |
| Minimum Operating Voltage |            | Figure 2, bootstrapped  |  | 1.7    |        | V       |      |
| Minimum Start-Up Voltage  |            | Figure 2, bootstrapped  |  | 1.7    | 2.0    | V       |      |
| Supply Current            |            | $V_+ = 16.5V$ , normal operation, SHDN = 0V, non-bootstrapped             |  | 88     | 110    | $\mu A$ |      |
|                           |            | Figure 2, MAX761, $V_{IN} = 5V$ , SHDN = 0V, normal operation             |  | 300    |        |         |      |
| Shutdown Current          |            | $V_+ = 10.0V$ , shutdown mode, SHDN = $V_+$                               |  | 1      | 5      | $\mu A$ |      |
| Output Voltage (Note 1)   | $V_{OUT}$  | Figure 2, MAX761, bootstrapped  | $0mA \leq I_{LOAD} \leq 75mA$ , $3V \leq V_+ \leq 12V$     | 11.52  | 12.0   | 12.48   | V    |
|                           |            |   | $0mA \leq I_{LOAD} \leq 150mA$ , $4.75V \leq V_+ \leq 12V$ | 11.52  | 12.0   | 12.48   |      |
|                           |            | Figure 2, MAX762, bootstrapped  | $0mA \leq I_{LOAD} \leq 50mA$ , $3V \leq V_+ \leq 15V$     | 14.4   | 15.0   | 15.6    |      |
|                           |            |   | $0mA \leq I_{LOAD} \leq 100mA$ , $4.75V \leq V_+ \leq 15V$ | 14.4   | 15.0   | 15.6    |      |
| Peak Current at LX        | $I_{PEAK}$ | See Figure 4b   | 0.75   | 1.0    | 1.25   | A       |      |
| Maximum Switch-On Time    | $t_{ON}$   |   | 6  | 8      | 10     | $\mu s$ |      |
| Minimum Switch-Off Time   | $t_{OFF}$  |   | 1.0  | 1.3    | 1.6    | $\mu s$ |      |
| Load Regulation           |            | Figure 2, $0mA \leq I_{LOAD} \leq 200mA$ , bootstrapped                   |  | 0.0042 |        | %/mA    |      |
| Line Regulation           |            | Figure 2, $4V \leq V_{IN} \leq 6V$ , bootstrapped                         |  | 0.08   |        | %/V     |      |
| Efficiency                |            | Figure 2, bootstrapped, $V_{OUT} = 12V$ , $60mA \leq I_{LOAD} \leq 120mA$ |  | 86     |        | %       |      |
| Reference Voltage         | $V_{REF}$  | MAX76_C   | 1.4700   | 1.50   | 1.5300 | V       |      |
|                           |            | MAX76_E   | 1.4625   | 1.50   | 1.5375 |         |      |
|                           |            | MAX76_M   | 1.4550   | 1.50   | 1.5450 |         |      |

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MAX761/MAX762

## ELECTRICAL CHARACTERISTICS (continued)

( $V_+ = 5V$ ,  $I_{LOAD} = 0mA$ ,  $C_{REF} = 0.1\mu F$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , typical values are at  $T_A = +25^\circ C$ , unless otherwise noted.)

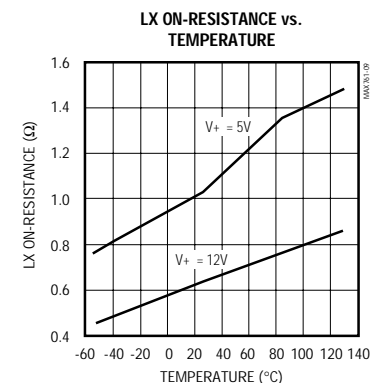
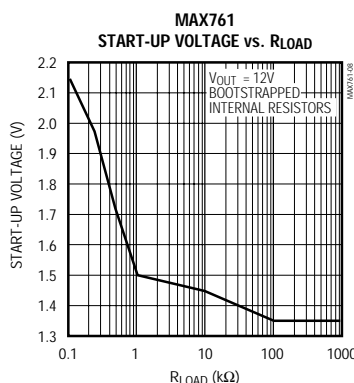
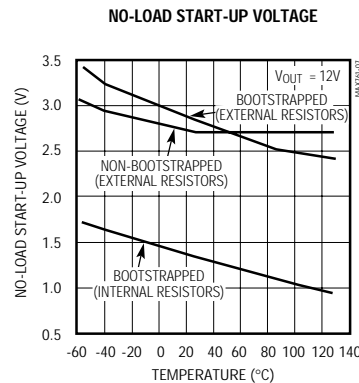
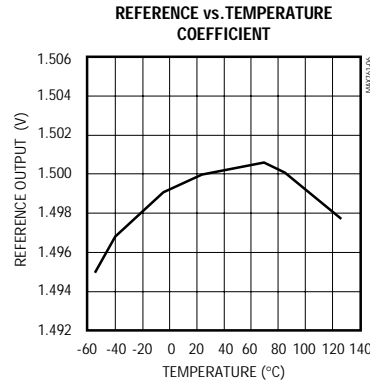
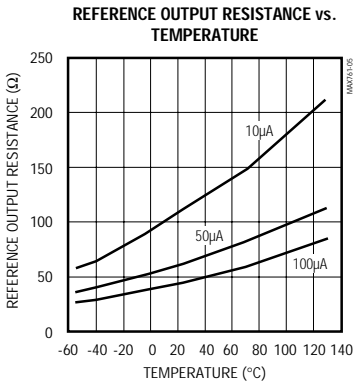
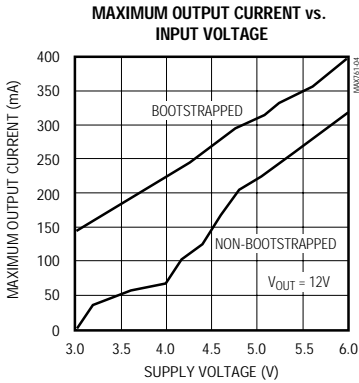
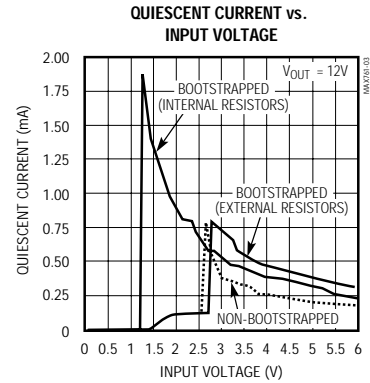
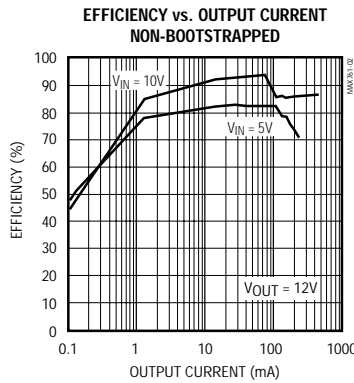
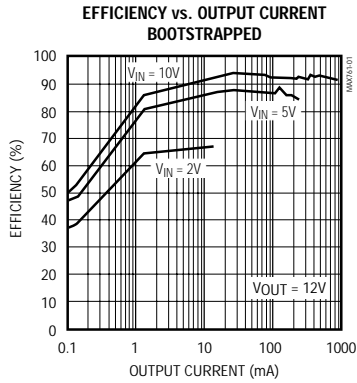
| PARAMETER                 | SYMBOL   | CONDITIONS                           | MIN       | TYP    | MAX    | UNITS     |   |
|---------------------------|----------|--------------------------------------|-----------|--------|--------|-----------|---|
| Reference Load Regulation |          | $0\mu A \leq I_{LOAD} \leq 100\mu A$ | MAX76_C/E |        | 10     | mV        |   |
|                           |          |                                      | MAX76_M   |        | 15     |           |   |
| Reference Line Regulation |          | $3.0V \leq V_+ \leq 16.5V$           |           | 30     | 100    | $\mu V/V$ |   |
| LX Leakage Current        |          | $V_+ = 16.5V$ ,<br>$LX = 17V$        | MAX76_C   | -5     | 5      | $\mu A$   |   |
|                           |          |                                      | MAX76_E   | -10    | 10     |           |   |
|                           |          |                                      | MAX76_M   | -30    | 30     |           |   |
| FB Leakage Current        | $I_{FB}$ | MAX76_C                              | -20       | 20     | nA     |           |   |
|                           |          | MAX76_E                              | -40       | 40     |        |           |   |
|                           |          | MAX76_M                              | -60       | 60     |        |           |   |
| Voltage Trip Point        | $V_{FB}$ | MAX76_C                              | 1.4700    | 1.50   | 1.5300 | V         |   |
|                           |          | MAX76_E                              | 1.4625    | 1.50   | 1.5375 |           |   |
|                           |          | MAX76_M                              | 1.4550    | 1.50   | 1.5450 |           |   |
| LX On Resistance          |          | $V_+ > 5.0V$                         |           | 1.0    | 2.2    | $\Omega$  |   |
| SHDN Input High Voltage   | $V_{IH}$ | $2.0V \leq V_+ \leq 16.5V$           | 1.6       |        |        | V         |   |
| SHDN Input Low Voltage    | $V_{IL}$ | $2.0V \leq V_+ \leq 16.5V$           |           |        | 0.4    | V         |   |
| SHDN Leakage Current      |          | $V_+ = 16.5V$ , SHDN = 0V or $V_+$   | -1        |        | 1      | $\mu A$   |   |
| LBI Threshold Voltage     |          | LBI falling                          | MAX76_C   | 1.4700 | 1.50   | 1.5300    | V |
|                           |          |                                      | MAX76_E   | 1.4625 | 1.50   | 1.5375    |   |
|                           |          |                                      | MAX76_M   | 1.4550 | 1.50   | 1.5450    |   |
| LBI Hysteresis            |          |                                      |           | 20     |        | mV        |   |
| LBI Leakage Current       |          | $V_+ = 16.5V$ , $V_{LBI} = 1.5V$     | -20       |        | 20     | nA        |   |
| LBO Leakage Current       |          | $V_+ = 16.5V$ , $V_{LBO} = 16.5V$    | -1        |        | 1      | $\mu A$   |   |
| LBO Voltage               | $V_{OL}$ | $V_+ = 5.0V$ , $I_{SINK} = 1mA$      |           |        | 0.4    | V         |   |
| LBI to LBO Delay          |          | Overdrive = 5mV                      |           | 2.5    |        | $\mu s$   |   |

**Note 1:** See *Typical Operating Characteristics* for output current capability versus input voltage. Guarantees based on correlation to switching on and off times, on-resistance, and peak-current ratings.

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## Typical Operating Characteristics

(Circuit of Figure 2,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

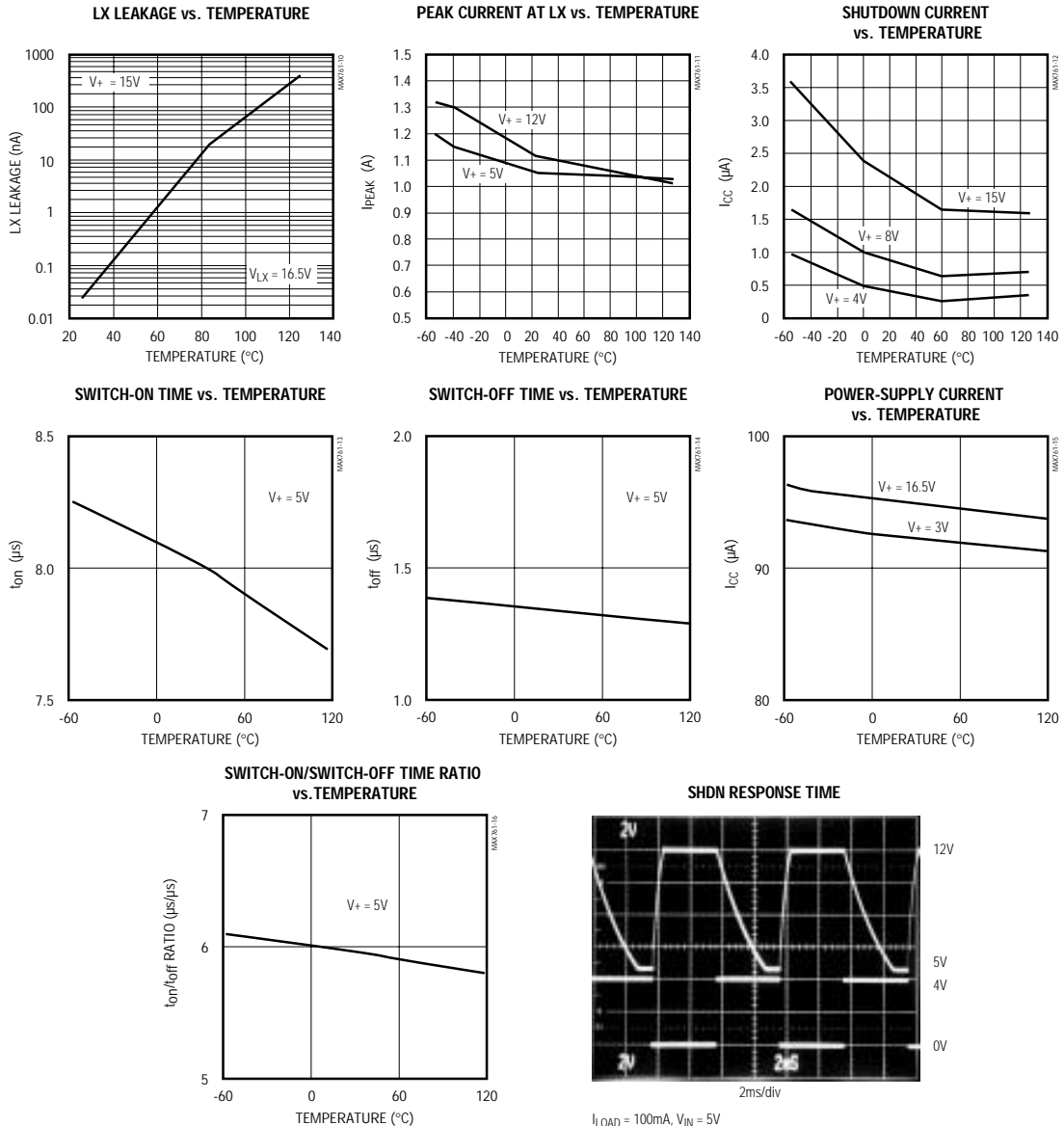


# 12V/15V or Adjustable, High-Efficiency, Low $I_Q$ , Step-Up DC-DC Converters

## Typical Operating Characteristics (continued)

(Circuit of Figure 2,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

MAX761/MAX762

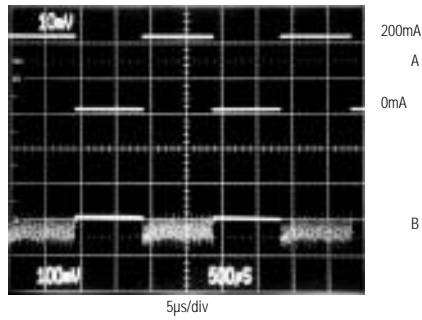


# 12V/15V or Adjustable, High-Efficiency, Low $I_Q$ , Step-Up DC-DC Converters

## Typical Operating Characteristics (continued)

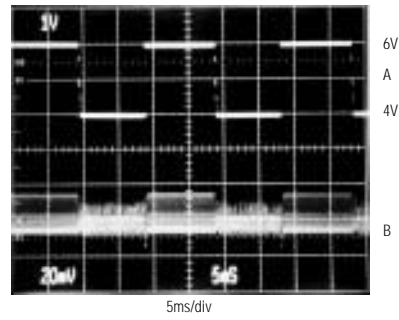
(Circuit of Figure 2,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

**LOAD-TRANSIENT RESPONSE**



A:  $I_{LOAD}$ , (0mA to 200mA)  
 B:  $V_{OUT}$ , AC COUPLED, 100mV/div  
 $V_{IN} = 5V$ ,  $V_{OUT} = 12V$

**LINE-TRANSIENT RESPONSE**



A:  $V_{IN}$  (4V to 6V)  
 B:  $V_{OUT}$ , AC COUPLED, 20mV/div  
 $I_{OUT} = 50mA$ ,  $V_{OUT} = 12V$

## Pin Description

| PIN | NAME | FUNCTION  |
|-----|------|---|
| 1   | LBO  | Low-battery output is an open-drain output that goes low when LBI is less than 1.5V. Connect to $V+$ through a pull-up resistor. Leave LBO floating if not used.  |
| 2   | LBI  | Input to the internal low-battery comparator. Tie to GND or $V+$ if not used.   |
| 3   | FB   | Feedback input. For fixed-output bootstrapped operation, connect FB to GND. For adjustable-output bootstrapped operation, connect a resistor divider between $V+$ , FB and GND. For non-bootstrapped operation, there is no fixed-output option. Connect a resistor divider network between $V_{OUT}$ , FB and GND. See <i>Bootstrapped/Non-Bootstrapped Modes</i> section. |
| 4   | SHDN | Active-high TTL/CMOS logic-level input. In shutdown mode ( $SHDN = V+$ ), the internal switch is turned off and the output voltage equals $V+$ minus a diode drop (due to the DC path from the input to the output). Tie to GND for normal operation.   |
| 5   | REF  | 1.5V reference output that can source 100 $\mu\text{A}$ for external loads. Bypass with 0.1 $\mu\text{F}$ or larger capacitor.  |
| 6   | GND  | Ground  |
| 7   | LX   | Drain of the internal N-channel FET. LX has an output resistance of 1 $\Omega$ and a peak current limit of 1A.  |
| 8   | $V+$ | Power-supply input. In bootstrapped mode, $V+$ is also the output voltage sense input.  |

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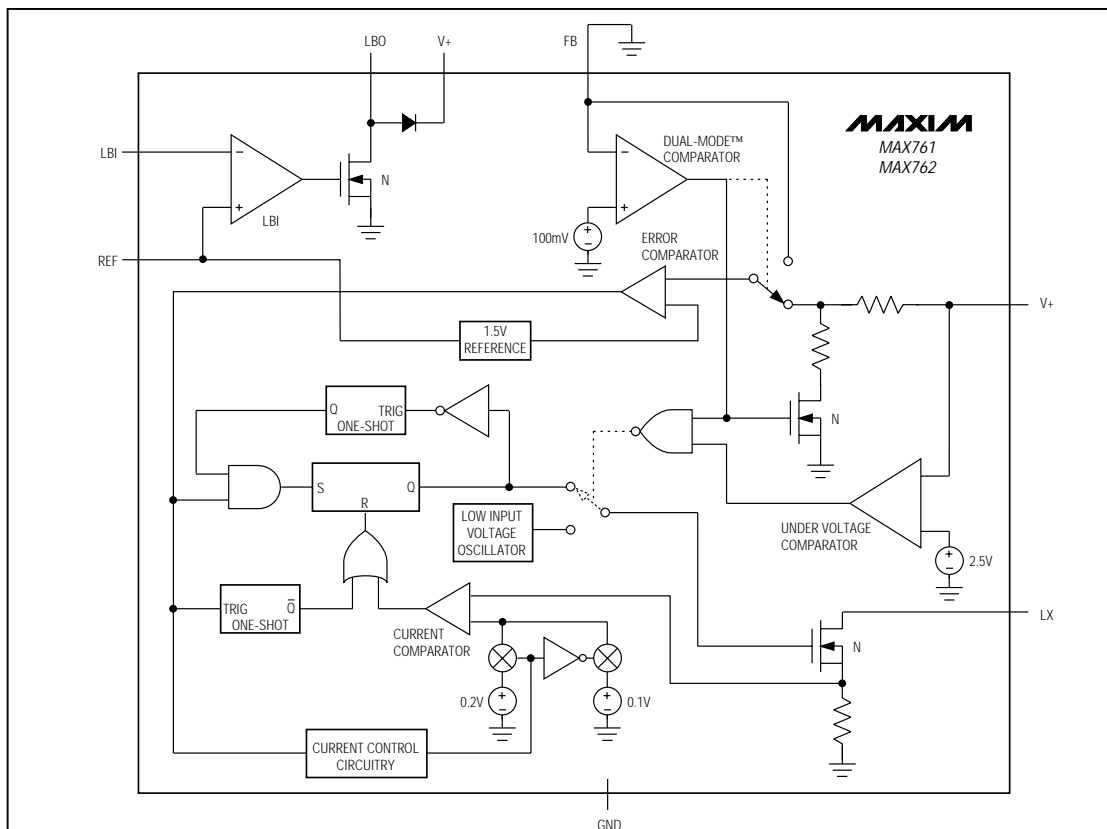


Figure 1. Simple Block Diagram

## Detailed Description

### Operating Principle

The MAX761/MAX762 BiCMOS step-up switch-mode power supplies provide fixed outputs of 12V and 15V, respectively. They have a unique control scheme that combines the advantages of pulse-frequency modulation (low supply current) and pulse-width modulation (high efficiency at high loads). The internal N-channel power MOSFET allows 1A peak currents, increasing the output current capability over previous pulse-frequency-modulation (PFM) devices. Figure 1 shows the MAX761/MAX762 block diagram.

The MAX761/MAX762 offer three main improvements over prior solutions: (1) the converters operate with tiny surface-mount inductors (less than 5mm diameter)

because of their 300kHz switching frequency, (2) the current-limited PFM control scheme allows 86% efficiencies over a wide range of load currents, and (3) the maximum supply current is only 110 $\mu$ A.

### Bootstrapped/Non-Bootstrapped Modes

Figures 2 and 3 show the standard application circuits for bootstrapped and non-bootstrapped modes. In bootstrapped mode, the IC is powered from the output ( $V_{OUT}$ ). In other words, the current needed to power the bootstrapped circuit is different from the  $V_+$  current the chip consumes. The voltage applied to the gate of the internal N-channel FET is switched from  $V_{OUT}$  to ground, providing more switch-gate drive and increasing the efficiency of the DC-DC converter compared with non-bootstrapped operation.

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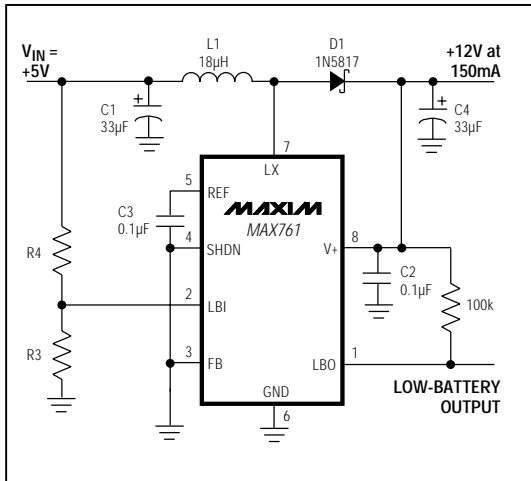


Figure 2. Bootstrapped Operating Circuit

In non-bootstrapped mode, the IC is powered from the supply voltage,  $V_{IN}$ , and operates with minimum supply current. Since the voltage applied to the gate of the internal FET is reduced, efficiency declines with low input voltages. **Note: In non-bootstrapped mode, there is no fixed-output operation; external resistors must be used to set the output voltage.** Use 1% external feedback resistors when operating in non-bootstrapped mode (Figure 3).

Use bootstrapped mode when  $V_{IN}$  is below approximately 4V. For  $V_{IN}$  between 4V and 6V, the trade-off is lower supply current in non-bootstrapped mode versus higher output current in bootstrapped mode (see *Typical Operating Characteristics*).

### Pulse-Frequency Modulation (PFM) Control Scheme

The MAX761/MAX762 use a proprietary current-limited PFM control scheme. This control scheme combines the ultra-low supply current of pulse-skipping PFM converters with the high full-load efficiency characteristic of current-mode pulse-width-modulation (PWM) converters. It allows the devices to achieve high efficiency over a wide range of loads, while the current-sense function and high operating frequency allow the use of tiny external components.

As with traditional PFM converters, the internal power MOSFET is turned on when the voltage comparator senses the output is out of regulation (Figure 1). However, unlike traditional PFM converters, switching is accomplished through the combination of a peak cur-

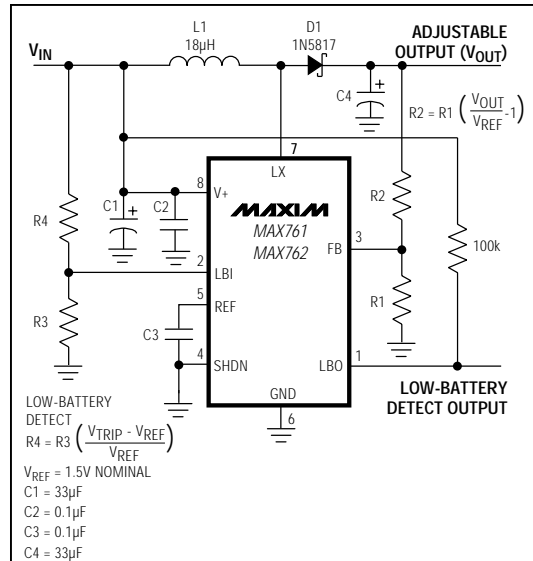


Figure 3. Non-Bootstrapped Operating Circuit

rent limit and a pair of one-shots that set the maximum on-time ( $8\mu s$ ) and minimum off-time ( $1.3\mu s$ ) for the switch. Once off, the minimum off-time one-shot holds the switch off for  $1.3\mu s$ . After this minimum time, the switch either (1) stays off if the output is in regulation, or (2) turns on again if the output is out of regulation.

The MAX761/MAX762 also limit the peak inductor current, allowing the devices to run in continuous-conduction mode (CCM) and maintain high efficiency with heavy loads (Figure 4a). This current-limiting feature is a key component of the control circuitry. Once turned on, the switch stays on until either (1) the maximum on-time one-shot turns it off ( $8\mu s$  later), or (2) the current limit is reached.

To increase light-load efficiency, the current limit for the first two pulses is set to half the peak current limit. If those pulses bring the output voltage into regulation, the voltage comparator holds the MOSFET off, and the current limit remains at half the peak current limit. If the output voltage is still out of regulation after two pulses, the current limit for the next pulse is raised to the full current limit of 1A (Figure 4b).

### Internal vs. External Resistors

When external feedback resistors are used, an internal undervoltage lockout system prevents start-up until  $V+$  rises to about 2.7V. When external feedback resistors are



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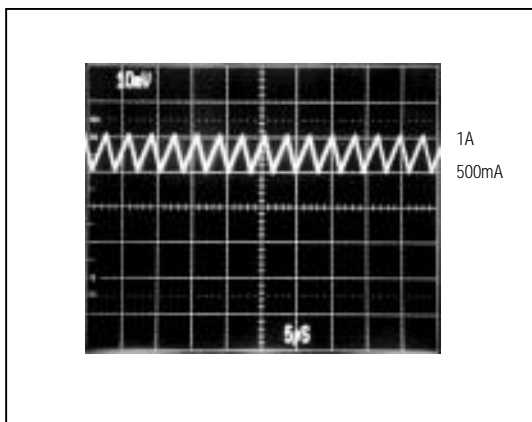


Figure 4a. CCM, Heavy Load Current Waveform (500mA/div)

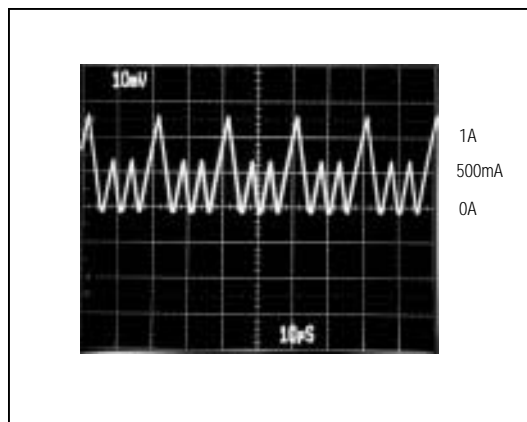


Figure 4b. Light/Medium Load Current Waveform (500mA/div)

used in a bootstrapped circuit (Figure 5), undervoltage lockout prevents start-up at low input voltages; but once started, operation can continue down to a lower voltage that depends on the load.

There is no undervoltage lockout when the internal feedback resistors are used (Figure 2), and special circuitry guarantees start-up at 2.0V. The start-up circuitry fixes the duty cycle at 50% until  $V_+$  is driven to 2.5V, above which the normal control system takes over.

### Shutdown Mode

The MAX761/MAX762 enter shutdown mode when SHDN is high. In this mode, the internal biasing circuitry is turned off (including the reference) and  $V_{OUT}$  equals  $V_+$  minus a diode drop (due to the DC path from the input to the output). In shutdown mode, the supply current drops to less than 5 $\mu$ A. SHDN is a TTL/CMOS logic level input. Connect SHDN to GND for normal operation. LBO is high impedance during shutdown.

### Modes of Operation

When delivering high output currents, the MAX761/MAX762 operate in CCM. In this mode, current always flows in the inductor, and the control circuit adjusts the switch's duty cycle on a cycle-by-cycle basis to maintain regulation without exceeding the switch-current capability. This provides excellent load-transient response and high efficiency.

In discontinuous-conduction mode (DCM), current through the inductor starts at zero, rises to a peak value, then ramps down to zero on each cycle. Although efficiency is still excellent, the switch waveforms contain

ringing (the inductor's self-resonant frequency). This ringing is normal and poses no operational problems.

### Low-Battery Detector

The MAX761/MAX762 provide a low-battery comparator that compares the voltage on LBI to the 1.5V reference voltage. When the LBI voltage is below  $V_{REF}$ , LBO (an open-drain output) goes low. The low-battery comparator's 20mV of hysteresis adds noise immunity, preventing repeated triggering of LBO. Use a resistor-divider network between  $V_+$ , LBI, and GND to set the desired trip voltage  $V_{TRIP}$  (Figure 3). When SHDN is high, LBI is ignored and LBO is high impedance. The value of resistor R3 should be no larger than 500k $\Omega$  to ensure the LBI leakage current does not cause inaccuracies in  $V_{TRIP}$ .

### Design Procedure

#### Setting the Output Voltage

The MAX761/MAX762's output voltage can be adjusted from 5V to 16.5V using external resistors R1 and R2 configured as shown in Figures 3 and 5. For adjustable-output operation, select feedback resistor R1 in the 10k $\Omega$  to 250k $\Omega$  range. Higher R1 values within this range give lowest supply current and best light-load efficiency. R2 is given by:

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

where  $V_{REF} = 1.5V$ .

**Note: Tie FB to GND for fixed-output operation (bootstrapped mode only).**

## 12V/15V or Adjustable, High-Efficiency, Low $I_Q$ , Step-Up DC-DC Converters

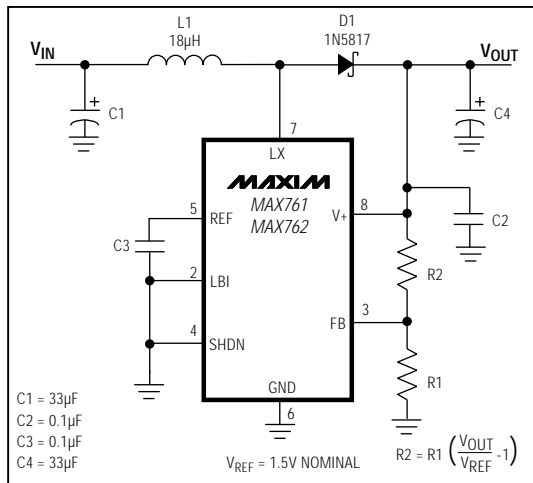


Figure 5. Bootstrapped Operation with Adjustable Output

### Selecting the Inductor (L)

In both CCM and DCM, practical inductor values range from 10µH to 50µH. If the inductor value is too low, the current in the coil will ramp up to a high level before the current-limit comparator can turn off the switch. The minimum on-time for the switch ( $t_{ON(min)}$ ) is approximately 2.5µs, so select an inductance that allows the current to ramp up to  $I_{LIM}/2$  in no less than 2.5µs. Choosing a value of  $I_{LIM}/2$  allows the half-size pulses to occur, giving higher light-load efficiency and minimizing ripple. Hence, calculate the minimum inductance value as:

$$L \geq \frac{(V_{IN(max)})(t_{ON(min)})}{I_{LIM}/2}$$

OR

$$L \geq (V_{IN(max)})(5)$$

where  $V_{IN(max)}$  is in volts and L is in microhenries.

The coil's inductance need not satisfy this criterion exactly, as the circuit can tolerate a wide range of values. Larger inductance values tend to produce physically larger coils and increase the start-up time, but are otherwise acceptable. Smaller inductance values allow the coil current to ramp up to higher levels before the switch can turn off, producing higher ripple at light loads. In general, an 18µH inductor is sufficient for most applications ( $V_{IN} \leq 5V$ ). An 18µH inductor is appropriate for input voltages up to 3.6V, as calculated above. However, the same 18µH coil can be used with input voltages up to 5V with only small increases in peak current, as shown in Figures 4a and 4b.

Inductors with a ferrite core or equivalent are recommended. The inductor's incremental saturation-current rating should be greater than the 1A peak current limit. It is generally acceptable to bias the inductor into saturation by approximately 20% (the point where the inductance is 20% below the nominal value). For highest efficiency, use a coil with low DC resistance, preferably under 100mΩ. To minimize radiated noise, use a toroid, a pot core, or a shielded coil.

Table 1 lists inductor types and suppliers for various applications. The listed surface-mount inductors' efficiencies are nearly equivalent to those of the larger through-hole inductors.

### Diode Selection

The MAX761/MAX762's high switching frequency demands a high-speed rectifier. Use a Schottky diode with a 1A average current rating, such as a 1N5817. For high-temperature applications, use a high-speed silicon diode, such as the MUR105 or the EC11FS1. These diodes have lower high-temperature leakage than Schottky diodes (Table 1).

### Capacitor Selection

#### Output Filter Capacitor

The primary criterion for selecting the output filter capacitor (C4) is low effective series resistance (ESR). The product of the inductor current variation and the output filter capacitor's ESR determines the amplitude of the high-frequency ripple seen on the output voltage. A 33µF, 16V Sanyo OS-CON capacitor with 100mΩ ESR typically provides 100mV ripple when stepping up from 5V to 12V at 150mA.

Because the output filter capacitor's ESR affects efficiency, use low-ESR capacitors for best performance. The smallest low-ESR SMT tantalum capacitors currently available are the Sprague 595D series. Sanyo OS-CON organic semiconductor through-hole capacitors and Nichicon PL series also exhibit very low ESR. Table 1 lists some suppliers of low-ESR capacitors.

#### Input Bypass Capacitors

The input bypass capacitor, C1, reduces peak currents drawn from the voltage source, and also reduces noise at the voltage source caused by the MAX761/MAX762's switching action. The input voltage source impedance determines the size of the capacitor required at the V+ input. As with the output filter capacitor, a low-ESR capacitor is recommended. For output currents up to 250mA, 33µF (C1) is adequate, although smaller bypass capacitors may also be acceptable. Bypass the IC separately with a 0.1µF ceramic capacitor, C2, placed close to the V+ and GND pins.

# 12V/15V or Adjustable, High-Efficiency, Low I<sub>O</sub>, Step-Up DC-DC Converters

MAX761/MAX762

## Reference Capacitor

Bypass REF with a 0.1μF capacitor. REF can source up to 100μA.

## Setting the Low-Battery Detector Voltage

To set the low-battery detector's falling trip voltage (V<sub>TRIP</sub>), select R3 between 10kΩ and 500kΩ (Figures 2 and 3), and calculate R4 as follows:

$$R4 = R3 \left[ \frac{V_{TRIP} - V_{REF}}{V_{REF}} \right]$$

where V<sub>REF</sub> = 1.5V.

The rising trip voltage is higher because of the comparator's hysteresis of approximately 20mV, and can be calculated by:

$$V_{TRIP}(\text{rising}) = (V_{REF} + 20\text{mV})(1 + R4/R3).$$

Connect a high-value resistor (larger than R3 + R4) between LBI and LBO if additional hysteresis is required.

Connect a pull-up resistor (e.g., 100kΩ) between LBO and V<sub>OUT</sub>. Tie LBI to GND or V+ and leave LBO floating if the low-battery detector is not used.

## Applications Information

### Layout Considerations

Proper PC board layout is essential because of high current levels and fast switching waveforms that radiate noise. Minimize ground noise by connecting GND, the input bypass-capacitor ground lead, and the output filter-capacitor ground lead to a single point (star ground configuration). Also minimize lead lengths to reduce stray capacitance, trace resistance, and radiated noise. The traces connected to FB and LX, in particular, must be short. Place bypass capacitor C2 as close as possible to V+ and GND.

**Table 1. Component Suppliers**

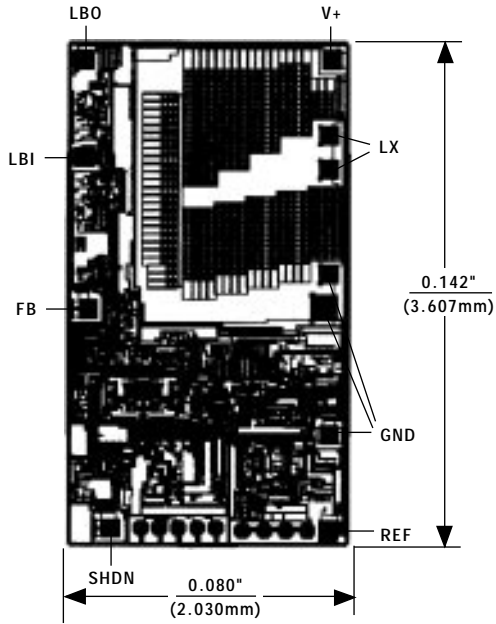
| PRODUCTION METHOD      | INDUCTORS  | CAPACITORS   | DIODES                        |
|------------------------|--|--|-------------------------------|
| Surface Mount          | Sumida<br>CD54-180 (22μH)<br><br>Coiltronics<br>CTX 100-series | Matsuo<br>267 series   | Nihon<br>EC10 series          |
| Miniature Through-Hole | Sumida<br>RCH855-180M  | Sanyo<br>OS-CON series<br>Low-ESR organic<br>semiconductor                           | Motorola<br>1N5817,<br>MUR105 |
| Low-Cost Through-Hole  | Renco<br>RL 1284-18  | Nichicon<br>PL series<br>Low-ESR electrolytics<br><br>United Chemi-Con<br>LXF series |                               |

|                 |         |                |                    |
|-----------------|---------|----------------|--------------------|
| Coiltronics     | (USA)   | (407) 241-7876 | FAX (407) 241-9339 |
| Matsuo          | (USA)   | (714) 969-2491 | FAX (714) 960-6492 |
| Matsuo          | (Japan) | 81-6-337-6450  | FAX 81-6-337-6456  |
| Nichicon        | (USA)   | (708) 843-7500 | FAX (708) 843-2798 |
| Nihon           | (USA)   | (805) 867-2555 | FAX (805) 867-2556 |
| Renco           | (USA)   | (516) 586-5566 | FAX (516) 586-5562 |
| Sanyo           | (USA)   | (619) 661-6835 | FAX (619) 661-1055 |
| Sanyo           | (Japan) | (0720) 70-1005 | FAX (0720) 70-1174 |
| Sumida          | (USA)   | (708) 956-0666 |                    |
| Sumida          | (Japan) | 81-3-607-5111  | FAX 81-3-607-5144  |
| United Chem-Con | (USA)   | (714) 255-9500 | FAX (714) 255-9400 |

# 12V/15V or Adjustable, High-Efficiency, Low $I_Q$ , Step-Up DC-DC Converters

MAX761/MAX762

Chip Topography



TRANSISTOR COUNT: 492;  
SUBSTRATE CONNECTED TO V+.

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