



Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

General Description

The MAX1817 is a compact, high-efficiency, dual-output step-up converter for portable devices that provides both the main logic supply and the LCD bias. The device operates from an input voltage of +1.5V to +5.5V, allowing the use of 2- or 3-cell alkaline batteries, or 1-cell lithium-ion (Li+) batteries.

The MAX1817's main regulator supplies 125mA at either a preset 3.3V or an adjustable 2.5V to 5.5V output voltage with up to 88% efficiency. A 0.1μA shutdown state also minimizes battery drain. The MAX1817's secondary step-up converter provides the LCD bias voltage and is adjustable up to +28V.

Other features include a fast switching frequency to reduce the size of external components and a low quiescent current to maximize battery life. Both outputs can be independently shut down for improved flexibility.

The MAX1817 is supplied in a compact 10-pin μ MAX package. The MAX1817 evaluation kit (MAX1817EVKIT) is available to speed up design.

Applications

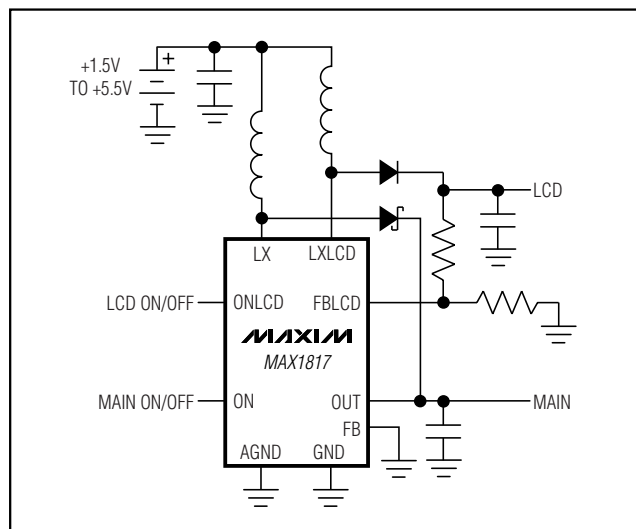
Organizers/Translators

PDAs

MP3 Players

GPS Receivers

Typical Operating Circuit



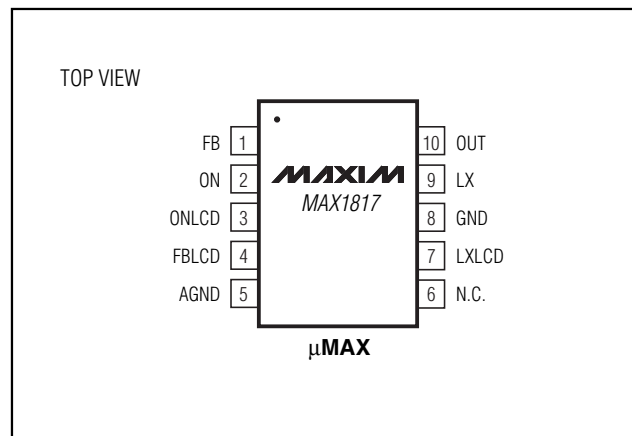
Features

- ◆ **Dual Step-Up Converter in a Tiny 10-Pin μ MAX Package**
- ◆ **Main Output**
 - Up to 125mA Load Current
 - Fixed 3.3V or Adjustable 2.5V to 5.5V
 - Up to 88% Efficiency
 - Internal Switch
- ◆ **LCD Output**
 - Up to 28V for LCD Bias
 - Internal Switch
- ◆ **Input Voltage Range +1.5V to +5.5V**
- ◆ **Minimal External Components Required**
- ◆ **0.1 μ A Logic-Controlled Shutdown**
- ◆ **Low 15 μ A Quiescent Supply Current**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX1817EUB	-40°C to +85°C	10 µMAX

Pin Configuration



MAX 1817



Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

ABSOLUTE MAXIMUM RATINGS

OUT to GND-0.3V to +6V
 ON, ONLCD, FB, FBLCD, LX to GND-0.3V to ($V_{OUT} + 0.3V$)
 LXLCD to GND-0.3V to +30V
 AGND to GND-0.3V to +0.3V
 Continuous Power Dissipation ($T_A = +70^\circ\text{C}$)
 10-Pin μMAX (derate 5.6mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$)444mW
 LXLCD, LX Maximum Current0.5A_{RMS}

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

($V_{ON} = V_{ONLCD} = V_{OUT} = +3.3V$, FB = GND, $T_A = 0^\circ\text{C}$ to +85 $^\circ\text{C}$, unless otherwise noted. Typical values are at $T_A = +25^\circ\text{C}$.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
GENERAL					
Input Voltage Range		1.5		5.5	V
Startup Voltage	$R_{LOAD} = 35\Omega$		1.5		V
	$R_{LOAD} = \infty$, $V_{FB} = 1.35V$		1.2	1.55	
Quiescent Current from OUT (Main Only)	$V_{FB} = V_{FBLCD} = 1.35V$, $V_{ONLCD} = 0$		5	10	μA
Quiescent Current from OUT	$V_{FB} = V_{FBLCD} = 1.35V$		15	30	μA
Shutdown Quiescent Current	$V_{ON} = V_{ONLCD} = 0$		0.1	1	μA
MAIN OUTPUT					
OUT Undervoltage Lockout	V_{OUT} rising, $V_{FB} = 1.35V$		2.2	2.4	V
	V_{OUT} falling, $V_{FB} = 1.35V$	1.95	2.15		
Fixed-Mode Output Voltage	$V_{FB} \leq 45mV$	3.14	3.3	3.47	V
Adjustable-Mode FB Regulation Voltage		1.20	1.25	1.30	V
FB Input Bias Current	$V_{FB} = 1.35V$			50	nA
FB Dual Mode™ Threshold		45	75	105	mV
Output Voltage Adjustment Range		2.5		5.5	V
Maximum LX On-Time	$V_{FB} = 0.5V$	2.4	5	7.5	μs
Zero Crossing Comparator Threshold ($V_{LX} - V_{OUT}$)		0	20	40	mV
Zero Crossing Comparator Backup Timer	$V_{FB} = +0.5V$	22	45	70	μs
Line Regulation	$I_{OUT} = 100mA$, $V_{IN} = +2V$ to +3V		1.6		%
Load Regulation	$V_{IN} = +2.5V$, $I_{LOAD} = 10mA$ to 100mA		1.6		%
LX On-Resistance	$V_{OUT} = 3.3V$, $I_{LX} = 100mA$		0.35	0.65	Ω
LX Current Limit		0.5	0.75	1.05	A

Dual Mode is a trademark of Maxim Integrated Products.

Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

MAX1817

ELECTRICAL CHARACTERISTICS (continued)

($V_{ON} = V_{ONLCD} = V_{OUT} = +3.3V$, $FB = GND$, $T_A = 0^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted. Typical values are at $T_A = +25^{\circ}C$.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
LX Leakage Current	$V_{ON} = GND$, $V_{LX} = 5.5V$		0.1	1	μA
ON Input Low Voltage	$1.8V < V_{OUT} < 5.5V$, $V_{FB} = 0.5V$			400	mV
ON Input High Voltage	$1.8V < V_{OUT} < 5.5V$, $V_{FB} = 0.5V$	1.6			V
ON Input Bias Current				1	μA
LCD OUTPUT					
LXLCD Voltage				28	V
LXLCD On-Resistance	$V_{OUT} = 3.3V$, $I_{LXLCD} = 100mA$		1.1	2.0	Ω
LXLCD Current Limit		0.28	0.5	0.7	A
LXLCD Leakage Current	$V_{LXLCD} = 28V$, $V_{ONLCD} = 0$		0.1	1	μA
FBLCD Regulation Voltage		1.20	1.25	1.30	V
FBLCD Input Bias Current	$V_{FBLCD} = 1.35V$			50	nA
LCD Line Regulation	$I_{LOAD} = 5mA$, $V_{IN} = +2V$ to $+3V$		0.1		%
LCD Load Regulation	$I_{LOAD} = 1mA$ to $5mA$, $V_{IN} = +2.5V$		0.5		%
Maximum LXLCD On-Time		4	9	14	μs
Minimum LXLCD Off-Time	$V_{FBLCD} \geq 1.2V$	0.5	1	1.5	μs
	$V_{FBLCD} \leq 0.7V$	2.4	5	7.5	
ONLCD Input Low Voltage	$2.5V < V_{OUT} < 5.5V$			400	mV
ONLCD Input High Voltage	$2.5V < V_{OUT} < 5.5V$	1.6			V
ONLCD Input Bias Current				1	μA

ELECTRICAL CHARACTERISTICS

($V_{ON} = V_{ONLCD} = V_{OUT} = +3.3V$, $FB = GND$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted.) (Note 1)

PARAMETER	CONDITIONS	MIN	MAX	UNITS
GENERAL				
Input Voltage Range		1.5	5.5	V
Startup Voltage	$R_{LOAD} = \infty$, $V_{FB} = 1.35V$		1.7	V
Quiescent Current from OUT (Main Only)	$V_{FB} = V_{FBLCD} = 1.35V$, $V_{ONLCD} = 0$		10	μA
Quiescent Current from OUT	$V_{FB} = V_{FBLCD} = 1.35V$		30	μA
Shutdown Quiescent Current	$V_{ON} = V_{ONLCD} = 0$		1	μA
MAIN OUTPUT				
OUT Undervoltage Lockout	V_{OUT} rising, $V_{FB} = 1.35V$		2.4	V
	V_{OUT} falling, $V_{FB} = 1.35V$	1.95		
Fixed-Mode Output Voltage	$V_{FB} \leq 45mV$	3.14	3.47	V
Adjustable-Mode FB Regulation Voltage		1.20	1.30	V
FB Input Bias Current	$V_{FB} = 1.35V$		50	nA

Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

ELECTRICAL CHARACTERISTICS (continued)

($V_{ON} = V_{ONLCD} = V_{OUT} = +3.3V$, $FB = GND$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted.) (Note 1)

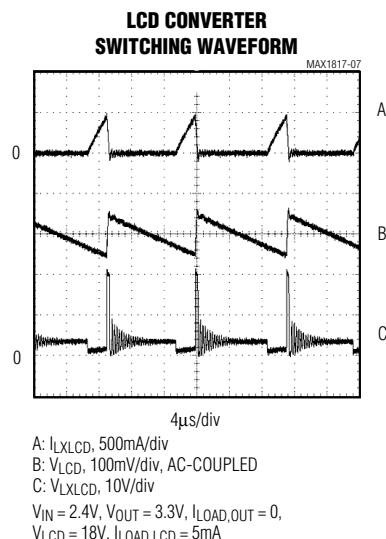
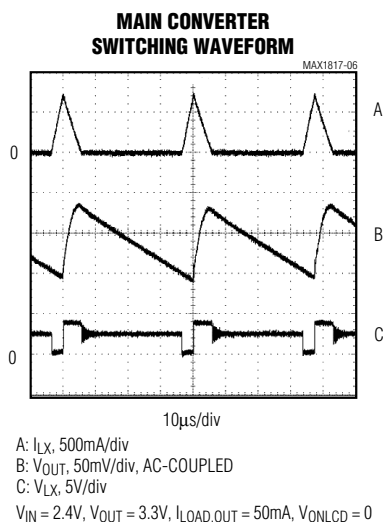
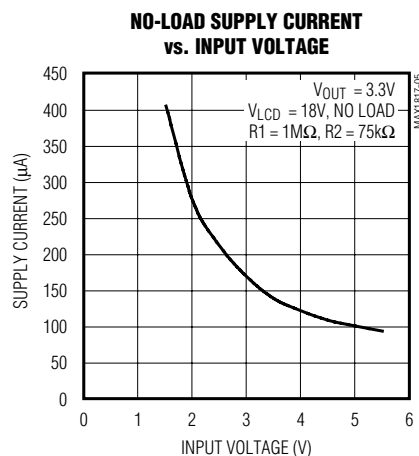
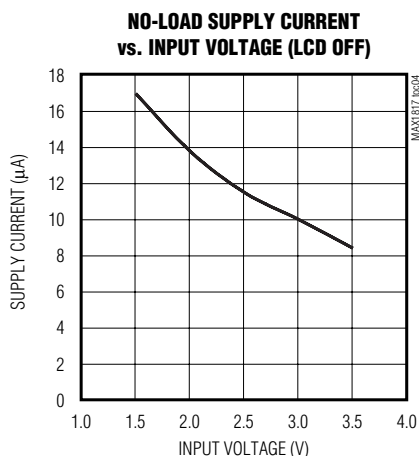
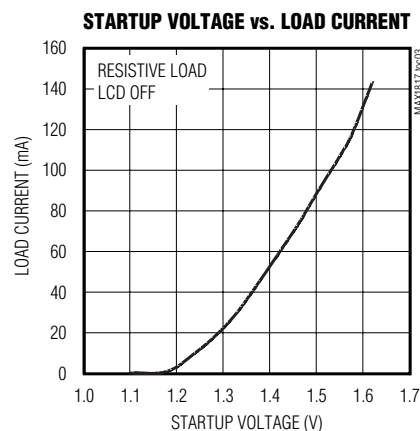
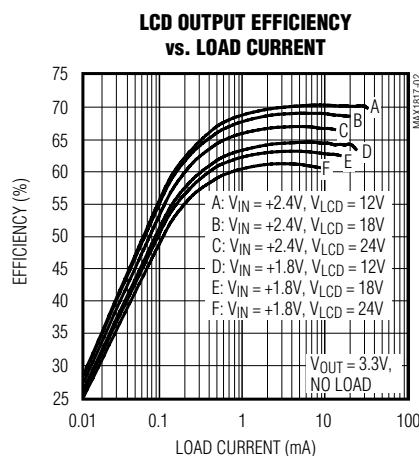
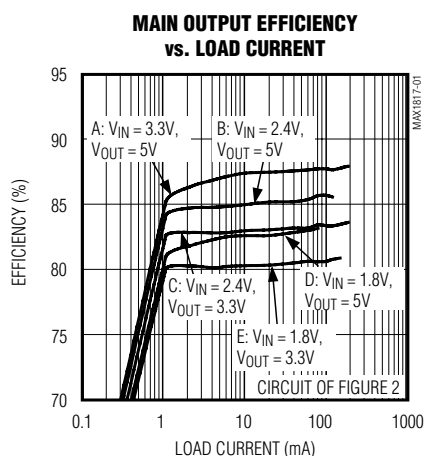
PARAMETER	CONDITIONS	MIN	MAX	UNITS
FB Dual Mode Threshold		45	105	mV
Output Voltage Adjustment Range		2.5	5.5	V
Maximum LX On-Time	$V_{FB} = 0.5V$	2.4	7.5	μs
Zero Crossing Comparator Threshold ($V_{LX} - V_{OUT}$)		0	40	mV
Zero Crossing Comparator Backup Timer	$V_{FB} = 0.5V$	22	70	μs
LX On-Resistance	$V_{OUT} = 3.3V$, $I_{LX} = 100mA$		0.65	Ω
LX Current Limit		0.42	1.05	A
LX Leakage Current	$V_{ON} = GND$, $V_{LX} = 5.5V$		1	μA
ON Input Low Voltage	$1.8V < V_{OUT} < 5.5V$, $V_{FB} = 0.5V$		400	mV
ON Input High Voltage	$1.8V < V_{OUT} < 5.5V$, $V_{FB} = 0.5V$	1.6		V
ON Input Bias Current			1	μA
LCD OUTPUT				
LXLCD Voltage			28	V
LXLCD On-Resistance	$V_{OUT} = 3.3V$, $I_{LXLCD} = 100mA$		2	Ω
LXLCD Current Limit		0.25	0.7	A
LXLCD Leakage Current	$V_{LXLCD} = 28V$, $V_{ONLCD} = 0$		1	μA
FBLCD Regulation Voltage		1.20	1.30	V
FBLCD Input Bias Current	$V_{FBLCD} = 1.35V$		70	nA
Maximum LXLCD On-Time		4	14	μs
Minimum LXLCD Off-Time	$V_{FBLCD} \geq 1.2V$	0.5	1.5	μs
	$V_{FBLCD} \leq 0.7V$	2.2	7.5	
ONLCD Input Low Voltage	$2.5V < V_{OUT} < 5.5V$		400	mV
ONLCD Input High Voltage	$2.5V < V_{OUT} < 5.5V$	1.6		V
ONLCD Input Bias Current			1	μA

Note 1: Specifications to $-40^{\circ}C$ are guaranteed by design and not production tested.

Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

Typical Operating Characteristics

(Circuit of Figure 3, $T_A = +25^\circ\text{C}$, unless otherwise noted.)

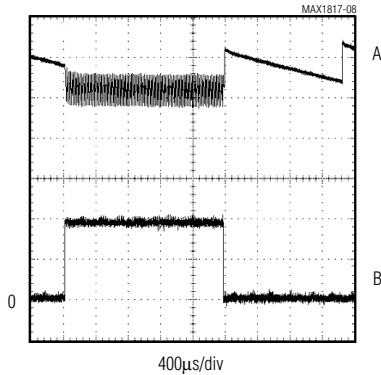


Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

Typical Operating Characteristics (continued)

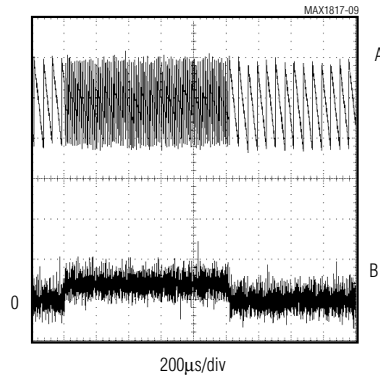
(Circuit of Figure 3, $T_A = +25^\circ\text{C}$, unless otherwise specified)

MAIN LOAD TRANSIENT RESPONSE



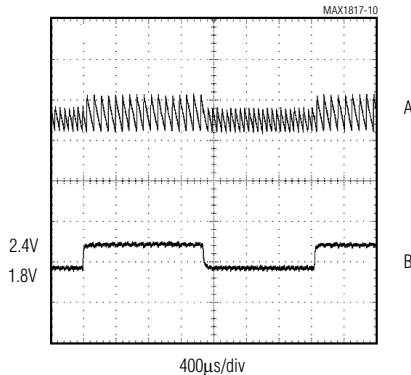
A: V_{OUT} , 100mV/div, AC-COUPLED
B: $I_{LOAD, OUT}$, 50mA/div
 $V_{IN} = 2.4\text{V}$, $V_{OUT} = 3.3\text{V}$

LCD LOAD TRANSIENT RESPONSE



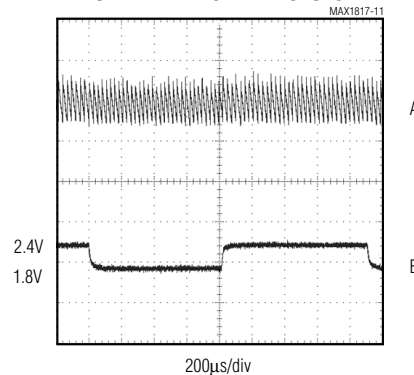
A: V_{LCD} , 50mV/div, AC-COUPLED
B: $I_{LOAD, OUT}$, 10mA/div
 $V_{IN} = 2.4\text{V}$, $V_{OUT} = 3.3\text{V}$ (NO LOAD), $V_{LCD} = 18\text{V}$

MAIN LINE TRANSIENT RESPONSE



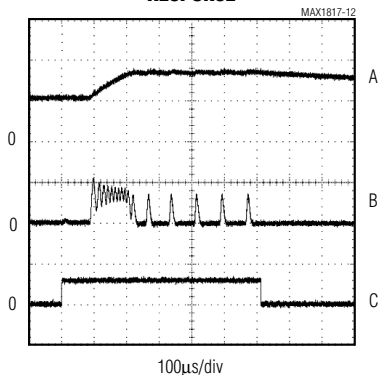
A: V_{OUT} , 100mV/div, AC-COUPLED
B: V_{IN} , 1V/div
 $V_{OUT} = 3.3\text{V}$, $I_{LOAD, MAIN} = 20\text{mA}$, $V_{ONLCD} = 0$

LCD LINE TRANSIENT RESPONSE



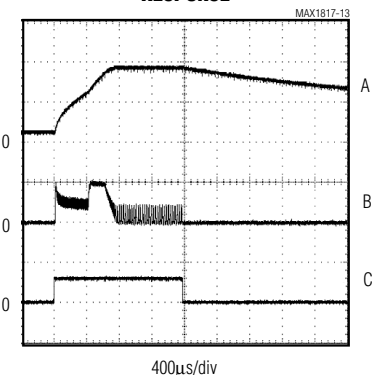
A: V_{LCD} , 100mV/div, AC-COUPLED
B: V_{IN} , 1V/div
 $V_{OUT} = 3.3\text{V}$ (NO LOAD), $V_{LCD} = 18\text{V}$, $I_{LOAD, LCD} = 2\text{mA}$

MAIN OUTPUT TURN-ON/TURN-OFF RESPONSE



A: V_{OUT} , 2V/div
B: I_{IN} , 500mA/div
C: V_{ON} , 5V/div
 $V_{IN} = 2.4\text{V}$, $R_{LOAD, MAIN} = 165\Omega$, $V_{ONLCD} = 0$

LCD OUTPUT TURN-ON/TURN-OFF RESPONSE



A: V_{LCD} , 10V/div
B: I_{IN} , 200mA/div
C: V_{ONLCD} , 5V/div
 $V_{IN} = 2.4\text{V}$, $V_{OUT} = 3.3\text{V}$ (NO LOAD), $R_{LOAD, LCD} = 9\text{k}\Omega$

Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

Pin Description

MAX1817

PIN	NAME	FUNCTION
1	FB	Main Output Feedback Input. Connect FB to GND for fixed 3.3V main output. For other output voltages, use a resistive voltage-divider to set the output voltage. The feedback regulation voltage is 1.25V at FB.
2	ON	Main Step-Up Converter On/Off Control. Connect ON to OUT for automatic startup. Connect ON to GND to put the IC into shutdown mode.
3	ONLCD	LCD Output On/Off Control. Connect ONLCD to OUT to enable the LCD output. Connect ONLCD to GND to disable the LCD output. The main output must be $\geq 2.4V$ to enable the LCD output.
4	FBLCD	LCD Output Feedback Input. Use a resistive voltage-divider from the LCD output to FBLCD to set the voltage. The feedback regulation voltage is 1.25V at FBLCD.
5	AGND	Analog Ground. Connect AGND to GND as close to the IC as possible.
6	N.C.	No Connection. Not internally connected.
7	LXLCD	LCD Output Switching Node. Drain of the internal N-channel MOSFET that drives the LCD output. Connect an external inductor and rectifier to LXLCD.
8	GND	Power Ground. Connect GND to AGND as close to the IC as possible.
9	LX	Main Output Switching Node. Drain of the internal N-channel MOSFET that drives the main output. Connect an external inductor and rectifier to LX.
10	OUT	Main Step-Up Converter Output. OUT is used to measure the output voltage in fixed mode (FB = GND) and is the internal bias supply input to the IC. When shut down (ON = ONLCD = GND), OUT is high impedance, drawing 1 μA (max).

Detailed Description

The MAX1817 dual step-up converter is designed to supply the main power and LCD bias for low-power, hand-held devices. The MAX1817's main step-up converter includes a 0.35 Ω N-channel power MOSFET switch and provides a fixed 3.3V or adjustable 2.5V to 5.5V output at up to 125mA from an input as low as 1.5V. The MAX1817's LCD bias step-up converter includes a high-voltage 1.1 Ω power MOSFET switch to support as much as 5mA at 28V (Figure 1). During startup, the MAX1817 extends the LCD MOSFET switch minimum off-time, limiting surge current. Both converters require an inductor and external rectifier.

The MAX1817 runs in bootstrap mode, powering the IC from the main step-up converter's output. Independent logic-controlled shutdown for the main and LCD step-up converters reduces quiescent current to 0.1 μA .

Main Step-Up Converter

The MAX1817 main step-up converter runs from a +1.5V to +5.5V input voltage and produces a fixed 3.3V or adjustable 2.5V to 5.5V output voltage as well as

biasing the internal control circuitry. The MAX1817 switches only as often as is required to supply sufficient power to the load. This allows the converter to operate at lower frequencies at light loads, improving efficiency.

The control scheme maintains regulation when the error amplifier senses the output voltage is below the feedback threshold, turning on the internal N-channel MOSFET and initiating an on-time. The on-time is terminated when the 0.75A current limit is reached or when the maximum on-time is reached. The N-channel MOSFET remains off until the inductor current drops to 0, forcing discontinuous inductor current. At the end of a cycle, the error comparator waits for the voltage at FB to drop below the regulation threshold, at which time another cycle is initiated.

The main step-up converter uses a startup oscillator to allow it to start from an input voltage as low as +1.2V. This is necessary since the control circuitry is powered from the step-up converter output (OUT). When the voltage at OUT is below the OUT undervoltage lockout, a fixed 50% duty cycle drives the internal N-channel MOSFET, forcing the main output voltage to rise. Once

Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

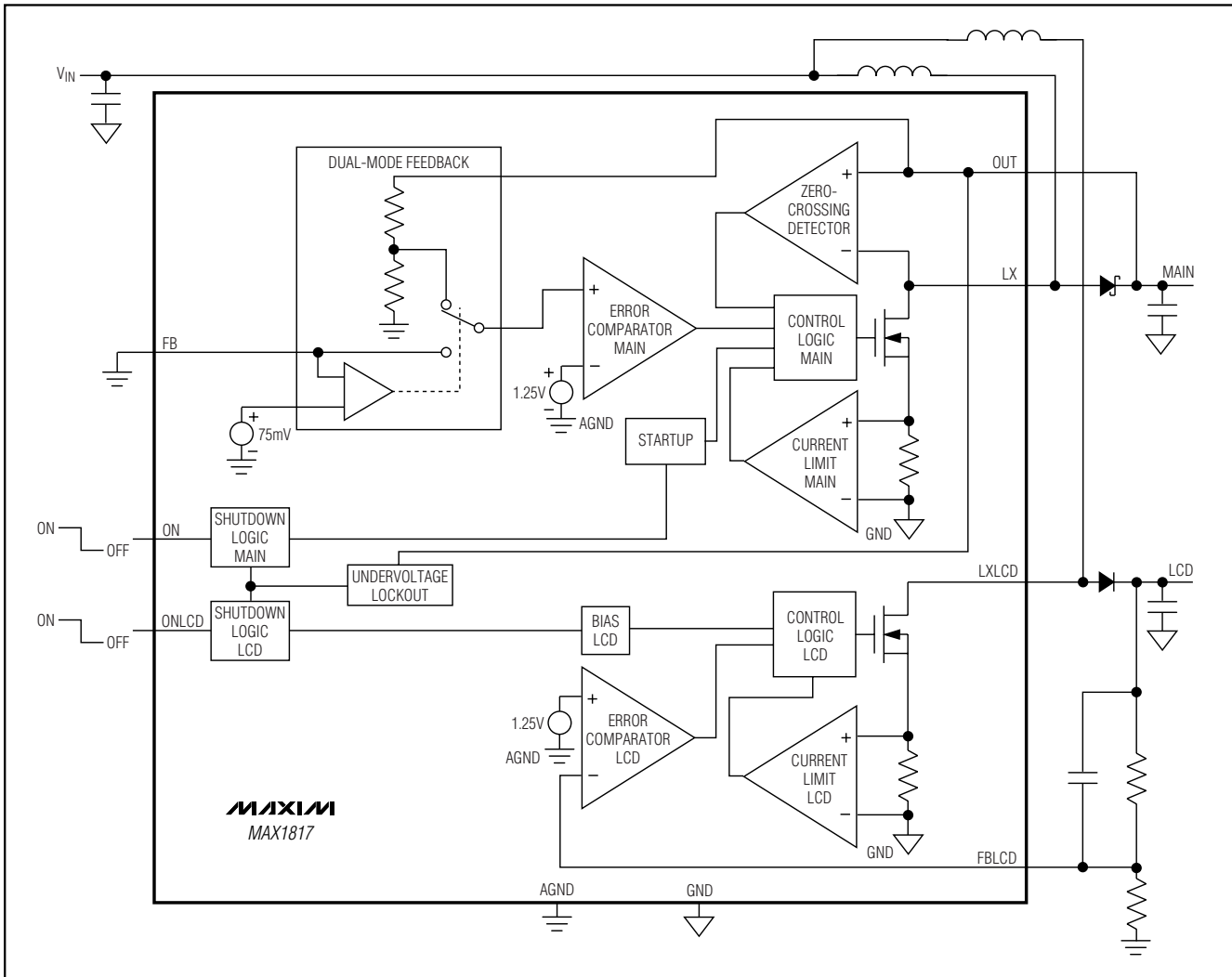


Figure 1. MAX1817 Simplified Functional Diagram

the output voltage rises above the undervoltage threshold, the control circuitry is enabled, allowing proper regulation of the output voltage.

LCD Step-Up Converter

The MAX1817's LCD step-up converter generates an LCD bias voltage up to 28V by use of a 500mA, 1.1 Ω internal N-channel switching MOSFET (Figure 1). The LCD step-up converter control circuitry is powered from the main step-up converter output (OUT), so the voltage at OUT must be above the OUT undervoltage lockout voltage for the LCD step-up converter to operate.

During startup, the MAX1817 extends the minimum off-time to 5 μ s for V_{FBLCD} voltages <0.9V, limiting initial surge current. The LCD step-up converter features an independent shutdown control, ONLCD.

The LCD step-up converter features a minimum-off-time, current-limited control scheme. A pair of one-shots that set a minimum off-time and a maximum on-time governs the duty cycle. The switching frequency can be up to 500kHz and depends upon the load, and input and output voltages.

MAX 1817



Design Procedure

Setting the Main Output Voltage

$$R3 = R4 [(V_{OUT} / V_{FB}) - 1]$$

Shutdown: ON and ONLCD

Setting the LCD Output Voltage

$$R1 = R2 [(V_{LCD} / V_{FBLCD}) - 1]$$

A logic low at ONLCD shuts down the LCD step-up converter, and LXLCD enters a high-impedance state. The LCD output remains connected to the input through the inductor and output rectifier, holding it to one diode drop below the input.

Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

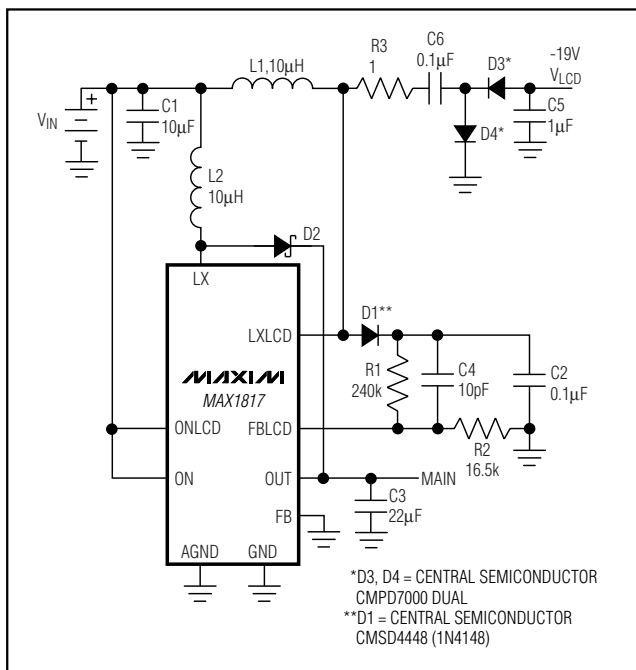


Figure 4. Negative Voltage for LCD Bias

Using a Charge Pump to Make Negative LCD Output Voltage

The MAX1817 can generate a negative LCD output by adding a diode-capacitor charge-pump circuit (D3, D4, and C6) to the LXLCD pin as shown in Figure 4. FBLCD is driven through a resistive voltage-divider from the positive output, which is not loaded, allowing a very small capacitor value at C2. For best stability and lowest ripple, the time constant of the R1 + R2 series combination and C2 should be near that of C5 and the effective load resistance. Output load regulation of the negative output degrades compared to the standard positive output circuit and may rise at very light loads. If this is not acceptable, reduce the resistance of R1 and R2, while maintaining their ratio, to effectively preload the output with a few hundred μA . This is why the R1 and R2 values shown in Figure 4 are lower than typical values for a positive-output design. When loaded, the magnitude of the negative output voltage is slightly lower (closer to ground by approximately a diode forward voltage) than the voltage on C2.

Applications Information

Inductor Selection

The MAX1817's high switching frequency allows the use of small surface-mount inductors. The 10 μ H values

shown in Figure 3 are recommended for most applications, although values between $4.7\mu\text{H}$ and $47\mu\text{H}$ are suitable. Smaller inductance values typically offer a smaller physical size for a given series resistance, allowing the smallest overall circuit dimensions. Larger inductance values exhibit higher output current capability, but larger physical dimensions.

Circuits using larger inductance values may start up at lower input voltages and exhibit less ripple, but they may provide reduced output power. This occurs when the inductance is sufficiently large to prevent the maximum current limit from being reached before the maximum on-time expires. The inductor's saturation current rating should be greater than the peak switching current. However, it is generally acceptable to bias most inductors into saturation by as much as 20%, although this may slightly reduce efficiency.

For best efficiency, select inductors with resistance no greater than the internal N-channel FET resistance in each step-up converter.

For maximum output current, choose L such that:

$$L < [(V_{IN} \times t_{ON}) / I_{PEAK}]$$

where t_{ON} is the maximum switch on-time (5 μ s for main step-up converter) or 9 μ s for LCD step-up converter) and I_{PEAK} is the switch peak current limit (0.75A for the main step-up converter, or 0.5A for the LCD step-up converter). With this inductor value, the maximum output current the main converter is able to deliver is given by:

$$I_{OUT(MAX)} = 0.5 \times I_{PEAK} / (1 + t_{ON} / t_{OFF})$$

where $t_{ON} / t_{OFF} = (V_{OUT} + V_D - V_{IN}) / (V_{IN} - V_{ON})$, V_{IN} and V_{OUT} are the input and output voltages, V_D is the Schottky diode drop (0.3V typ), and $V_{ON} = I_{PEAK} \times R_{ON}$, where R_{ON} is the switch on-resistance.

For $V_{IN} = 1.5V$ and $V_{OUT} = 3.3V$, with a minimum I_{PEAK} value of $0.5A$, and $V_{ON(MAX)}$ given by $(0.5) \times (0.65) = 0.325V$, the available output current that the converter can provide is at least $90mA$.

For larger inductor values, I_{PEAK} is determined by:

$$I_{PF\Delta K} = [(V_{IN} \times t_{ON}) / L]$$

External Rectifiers

The high maximum switching frequency of the MAX1817 requires a high-speed rectifier. Schottky diodes such as the Motorola MBR0530 or the Nihon EP05Q03L are recommended. To maintain high efficiency, the average current rating of the Schottky diode should be greater than the peak switching current. A junction diode such as the Central Semiconductor CMPD4448 can be used for the LCD output with little

Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

loss in efficiency. Choose a reverse breakdown voltage greater than the output voltage.

Input Bypass Capacitor

The input supplies high currents to the inductors and requires local bulk bypassing close to the inductors. A low equivalent series resistance (ESR) input capacitor connected in parallel with the battery will reduce peak battery currents and input-reflected noise. Battery bypassing is especially helpful at low input voltages and with high-impedance batteries (such as alkaline types). Benefits include improved efficiency and lower useful end-of-life voltage for the battery. A single 10 μ F low-ESR surface-mount capacitor is sufficient for most applications.

Output Bypass Capacitors

For most applications, use a small surface-mount 22 μ F or greater ceramic capacitor on the main converter output, and a 1 μ F or greater ceramic capacitor on the LCD output. For small ceramic capacitors, the output ripple voltage is dominated by the capacitance value. If tantalum or electrolytic capacitors are used, the ESR of the capacitors dominates the output ripple voltage. Decreasing the ESR reduces the output ripple voltage and the peak-to-peak transient voltage.

LCD Compensation

The MAX1817's LCD step-up converter feedback requires a small 4.7pF feed-forward capacitor for the typical application circuit. Circuits with adjustable V_{OUT}

(main converter) from 2.5V to 5.5V may require a larger value LCD feed-forward capacitor to prevent multipulsing of the LCD converter. Larger feed-forward capacitors slightly degrade load regulation, so choose the smallest value capacitor that provides stability.

Layout Considerations

The MAX1817's high-frequency operation makes PC board layout important for optimal performance. Use separate analog and power ground planes. Connect the two planes together at a single point as close as possible to the IC. Use surface-mount components where possible. If leaded components are used, minimize lead lengths to reduce stray capacitance and keep the components close to the IC to minimize trace resistance. Where an external voltage-divider is used to set output voltage, the traces from FB or FBLCD to the feedback resistors should be extremely short (less than 0.2in or 5mm) to minimize coupling from LX and XLCD. Refer to the MAX1817 evaluation kit for a full PC board example.

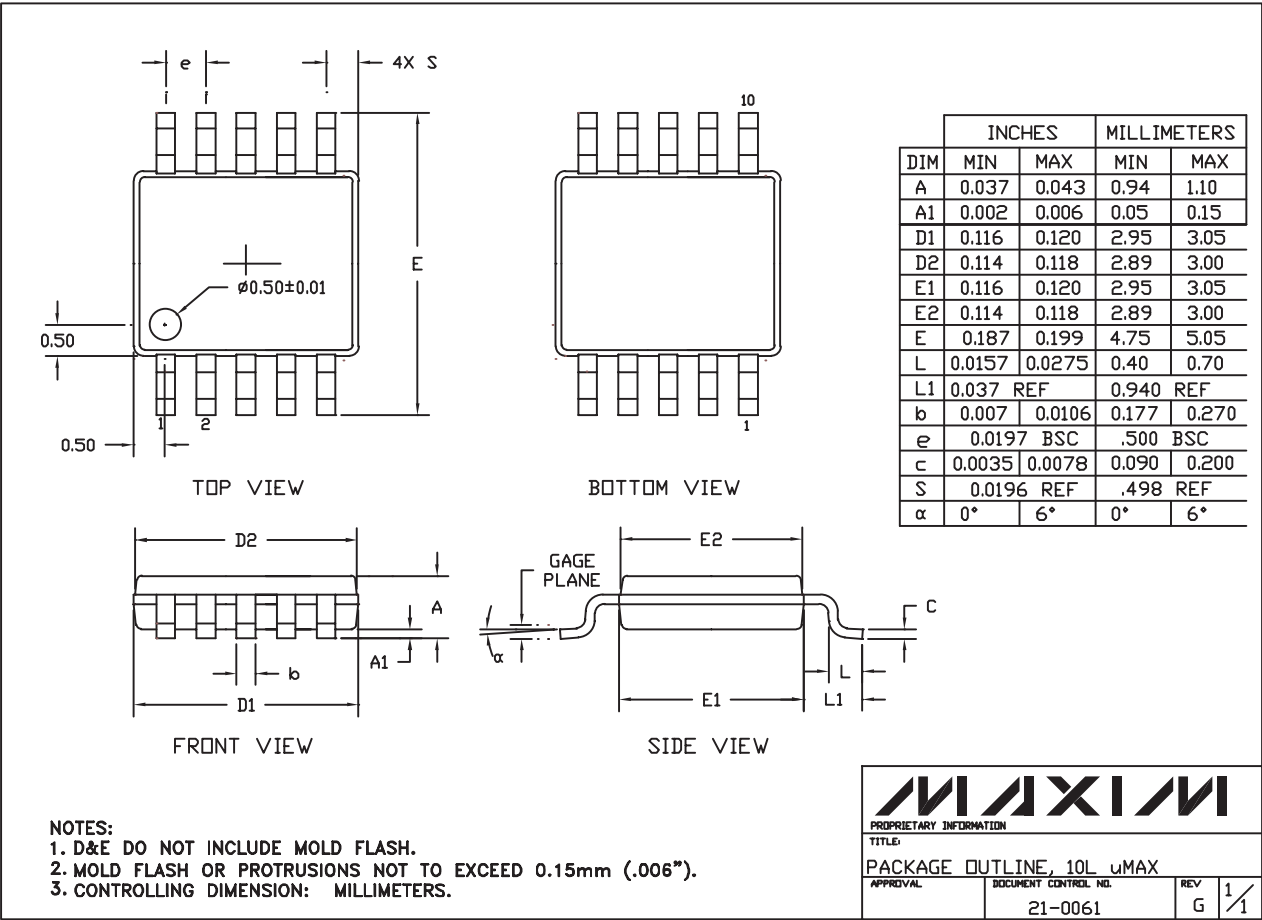
Chip Information

TRANSISTOR COUNT: 2785

PROCESS: BiCMOS

Compact, High-Efficiency, Dual-Output Step-Up DC-DC Converter

Package Information



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12 Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600