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INTEGRATED PRODUCTS

High Current PFM Boost Converter

PRODUCTION DATA SHEET

DESCRIPTION

The LX1732 is a compact, high efficiency, step-up DC-DC boost regulator implemented in a BiCMOS process technology. This device features variable frequency operation and a built in N-channel MOSFET power switch for optimal functioning in low voltage portable systems.

Start-up operation is guaranteed from 1.1V inputs (at light load) and the input voltage can be as low as 0.7V after start-up. This attribute allows the LX1732 to operate in an extended power-savings mode, supplying (data) critical system components, even after battery capacity no longer supports normal operation.

The output voltage programming range of 2.2V to 5V, requires only two external resistors via the feedback pin (see Figure 1.0). Output load currents of up to 200mA are achievable and the internal MOSFET is capable of switching up to a 1A current limit. Quiescent current during operation is 200µA (max) and in shutdown-mode drops to a mere 1µA thus maximizing overall battery life-time.

The LX1732 features a low battery-detect circuitry that alerts system power management of low input voltages thus allowing portable systems to enter a power-savings mode (e.g., to protect data)

IMPORTANT: For the most current data, consult *MICROSEMI*'s website: **http://www.microsemi.com**

KEY FEATURES

- 88% Efficiency
- 200µA Quiescent Current
- 0.1µA Logic Shutdown
- Low-Battery Detector
- 8-Pin MSOP Package

APPLICATIONS/BENEFITS

- Pagers
- Wireless Phones
- Hand-Held Computers
- PDAs
- RF Tags
- Two-cell Alkaline Battery Applications
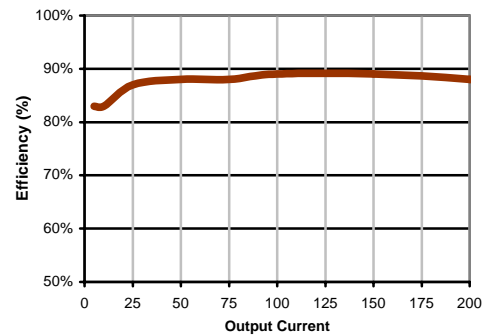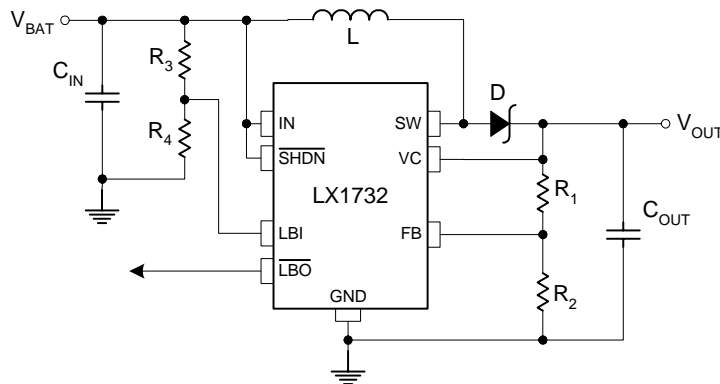- Single-cell Lithium Ion 5V Boost

PRODUCT HIGHLIGHT

Figure 1 – LX1732 General Circuit Topology and Typical Efficiency Performance

PACKAGE ORDER INFO

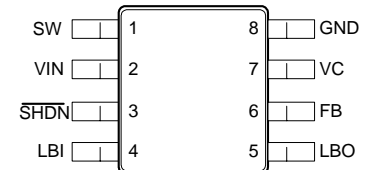| T_A (°C)	DU Plastic MSOP 8-Pin
	RoHS Compliant / Pb-free Transition DC: 0432
0 to 70	**LX1732CDU**

Note: Available in Tape & Reel. Append the letters "TR" to the part number. (i.e. LX1732CDU-TR)

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ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V_{IN}) ....-0.3V to 7.0V
Output Voltage (V_C) ....-0.3V to 7.0V
Switch Voltage (V_{SW}) ....-0.3V to 7.0V
Shutdown Input Voltage ($V_{\overline{SHDN}}$) .... -0.3V to (V_C + 0.3V)
Low Battery Detect Output ($V_{\overline{LBO}}$) .... -0.3V to (V_C + 0.3V)
Low Battery Detect Input Voltage (V_{LBI}) .... -0.3V to (V_C+ 0.3V)
Feedback Input Voltage (V_{FB}) .... -0.3V to (V_C+ 0.3V)
Switch Current (I_{LX})... 1.0A$_{RMS}$
Operating Temperature Range .... 0°C to 70°C
Operating Junction Temperature.. 150°C
Storage Temperature Range..-65°C to 150°C
Peak Package Temp for Solder Reflow (40 second max. exposure) .... 260°C (+0, -5)

Note: Exceeding these ratings could cause damage to the device. All voltages are with respect to Ground. Currents are positive into, negative out of specified terminal.

PACKAGE PIN OUT

Pin		Pin
SW	1	8	GND
VIN	2	7	VC
$\overline{SHDN}$	3	6	FB
LBI	4	5	LBO

DU PACKAGE
(Top View)

RoHS / Pb-free 100% Matte Tin Lead Finish

THERMAL DATA

DU **Plastic MSOP 8-Pin**

THERMAL RESISTANCE-JUNCTION TO AMBIENT, θ_{JA}	**206°C/W**
THERMAL RESISTANCE-JUNCTION TO CASE, θ_{JC}	**39°C/W**

Junction Temperature Calculation: $T_J = T_A + (P_D \times \theta_{JC})$.
The θ_{JA} numbers are guidelines for the thermal performance of the device/pc-board system. All of the above assume no ambient airflow.
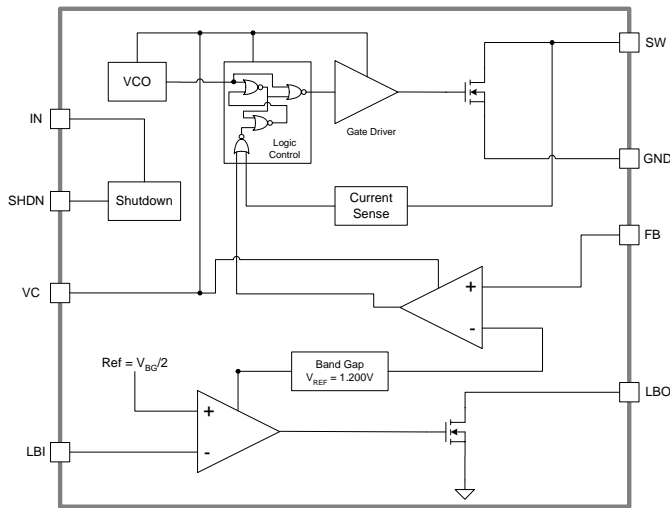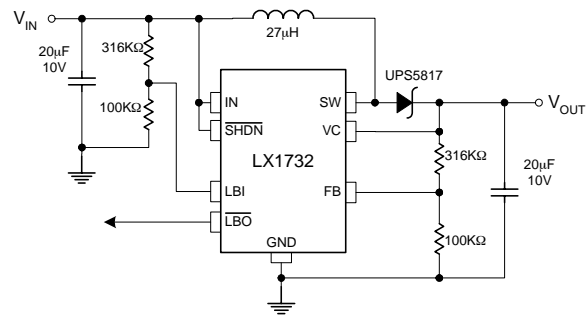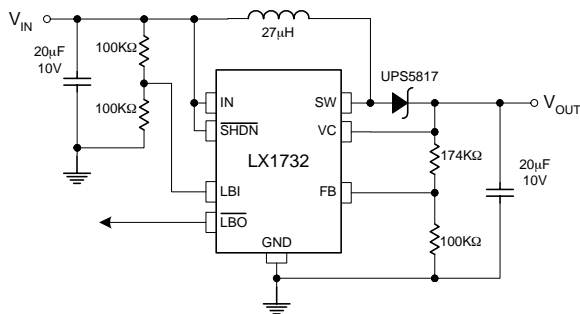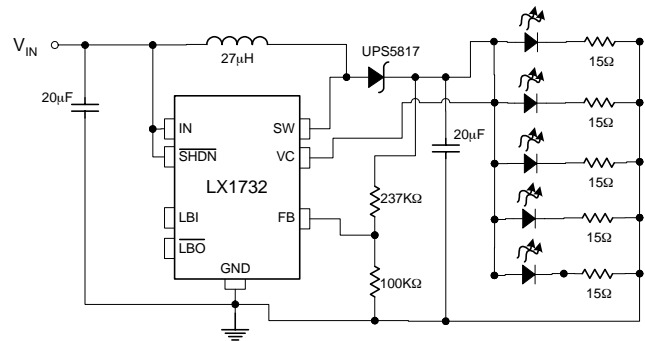
FUNCTIONAL PIN DESCRIPTION

NAME	DESCRIPTION
IN	Unregulated IC Supply Voltage Input – Input range from +1.1V to 5.5V. Bypass with a 4.7μF or greater capacitor.
FB	Control pin for output voltage programming. Connect this pin to a resistive divider network between the output and GND to obtain an output voltage between 2.0V and 5.5V.
$\overline{SHDN}$	Active-Low Shutdown Input – A logic low shuts down the device and reduces the supply current to 0.1μA. Connect $\overline{SHDN}$ to V_{CC} for normal operation.
SW	Inductor Switching Connection – Internally connected to the drain of an N-channel MOSFET.
VC	Output voltage control pin: Connect this pin to the circuit load and cathode of the switching diode.
GND	Common terminal for ground reference.
LBI	Low Battery Detect Comparator Input – Connect to a resistive divider network between the V_{CC} and GND to set the Low Battery Detect trip point. The LBI threshold is 0.6V.
$\overline{LBO}$	Low Battery Detect Comparator Output – Open drain comparator output. This output is pulled low when V_{LBI} is less than 0.6V. $\overline{LBO}$ is high impedance during shutdown.

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ELECTRICAL CHARACTERISTICS

Unless otherwise specified, the following specifications apply over the operating ambient temperature $0°C \leq T_A \leq 70°C$ except where otherwise noted and the following test conditions: $V_{IN} = 2V$, $V_{OUT} = 3.3V$, $R_{LOAD} = 3k\Omega$, $V_{\overline{SHDN}} = 2V$

Parameter	Symbol	Test Conditions	LX1732 Min	LX1732 Typ	LX1732 Max	Units
PFM Regulator						
Operating Voltage	V_{IN}		1.1		5.5	V
Minimum Operating Voltage	V_{IN}	$I_{OUT} \cong 1mA$		0.7		V
Minimum Start-up Voltage		$T_A = +25°C$; $I_{OUT} < 10mA$			1.1	V
Start-up Voltage Temperature Coefficient	κ_{SU}			-2		mV/°C
Output Voltage Range	V_{OUT}		2.2		5.5	V
Steady State Output Current	I_{OUT}	$V_{OUT} = 3.3V$: GBNT	250			mA
		$V_{OUT} = 5V$: GBNT	100			
Internal N-FET On-resistance	$R_{DS(ON)}$	$I_{LX} = 100mA$		0.2	1.0	Ω
Switch Current Limit	I_{SW}		0.47		1.0	A
Switch Pin Leakage Current	I_{LEAK}	$V_{LX} = 5.5V$, $V_{OUT} = 5V$			1.0	μA
Oscillator Frequency	f_{OSC}	$V_{FB} = 1V$; $T_A = +25°C$	65	100	135	kHz
Duty Cycle	D	$V_{FB} = 1V$; $T_A = +25°C$	65	75	85	%
Operating Current	I_Q	(into VC pin)			200	μA
Error Amplifier						
Voltage Feed Back Threshold	V_{FB}	$T_A = +25°C$	1.170	1.200	1.230	V
Voltage Feed Back Input Current	I_{FB}	$V_{FB} = 1.4V$			300	nA
Shutdown Circuit						
$\overline{SHDN}$ Input Bias Current	I_{SHDN}	$\overline{SHDN}$ = GND			100	nA
$\overline{SHDN}$ High Input Voltage	V_{SHDN}		$V_{IN}/2$			V
$\overline{SHDN}$ Low Input Voltage	V_{SHDN}				0.4	V
Shutdown Operating Current	I_Q	$\overline{SHDN}$ = GND			1	μA
Low Battery Detect						
Low Battery Detect Output Voltage	$V_{\overline{LBO}}$	$V_{LBI} = 0V$, $I_{\overline{LBO}} = -1mA$			0.5	V
Low Battery Detect Output Leakage Current	$I_{\overline{LBO}}$	$V_{LBI} = V_{IN}$, $V_{\overline{LBO}} = 5V$			1	μA
Low Battery Threshold	V_{LBT}		0.54		0.71	V
Hysteresis	V_{HLBT}	$T_A = +25°C$		80		

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APPLICATION CIRCUITS

Figure 2 – LX1732 Block Diagram

Figure 3 – V_{OUT} = 5.0V; I_{OUT} = 150mA and V_{LBI} = 2.5V

Figure 4 – V_{OUT} = 3.2V; I_{OUT} = 250mA and V_{LBI} = 1.2V

Figure 5 – LX1732 driving 5 white LEDs in parallel where $V_{OUT} \geq 3.6V$; I_{OUT} = 100mA.

APPLICATIONS

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APPLICATION NOTE

FUNCTIONAL DESCRIPTION

The LX1732 implements a constant on-time and off-time PFM architecture that can deliver a 5.0V output and over 150mA of continuous output current. The free-running oscillator and logic-circuit initiate the internal MOSFET switching cycle during power-up via the VC pin (see block diagram in Figure 2)). The current passing through the LX pin is detected by the I-sense circuit and compared with the feedback voltage status via the logic circuit. The internal limit for the peak current is set at 1000mA (max). The MOSFET switch remains on for the on-time duration or until the I-sense detects the maximum peak current, or when the feedback threshold voltage is detected at the FB pin. The feedback threshold voltage is set by an external resistor divider network and compared with the internal reference voltage. The LX1732 implements a non-load isolated shutdown mode using an input-voltage referenced signal level via the SHDN pin. Connect this pin to the input supply rail if the shutdown feature is not required. The LX1732 features a low-battery detection circuit that allows for sensing of the input voltage supply. If the supply voltage at LBI drops below the internal reference voltage, the internal MOSFET (open-drain) sinks current to GND.

OUTPUT VOLTAGE PROGRAMMING

Resistors R1 and R2 of Figure 1 program the output voltage. An optional 1000pF capacitor is recommended across R1 to improve the transient response and reduce output voltage ripple (see Figure 7). The value of R2 should be less than 250KΩ. The value of R1 can be determined using the following equation where VREF is found in the ELECTRICAL CHARACTERISTICS TABLE:

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

DESIGN EXAMPLE:

Let R2 equal 100K and the required VOUT equal to 5.0V.

$$R1 = 100K\left[\left(\frac{5V}{1.20}\right) - 1\right] = 316.6K\Omega$$

DIODE SELECTION

A Schottky diode is recommended for use with the LX1732 because it provides fast switching and superior reverse recovery performance. The Microsemi UPS5817 (20V @ 1A) makes an effective choice for most applications.

LOW BATTERY DETECTION PROGRAMMING

Program the Low Battery Detect voltage threshold by selecting values for resistors R3 and R4 (see Figure 1) using the formula below. Use a value of less than 250KΩ for R4 to minimize threshold error due to the internal comparator's offset current. The value of R3 can be determined using the following equation.

$$R3 = R4\left[\left(\frac{V_{LOW\,BATT}}{V_{REF}}\right) - 1\right]$$

The LBO pin's open drain output requires a pull up resistor (i.e., 100K typ.) to drive external CMOS logic circuits. Connect the LBI pin to ground and omit resistors R3 and R4 when the Low Battery Detect function is not implemented.

DESIGN EXAMPLE:

Let R3 equal 100K and the required LB threshold equal to 2.5V.

$$R3 = R100\left[\left(\frac{2.5V}{0.6V}\right) - 1\right] = 316K\Omega$$

CAPACITOR SELECTION

To minimize ripple voltage, output capacitors in the range of 10uF to 100uF with a low series resistance (ESR) are recommended. Multi-layer ceramic capacitors with X5R or X7R dielectric make an effective choice because they feature small size, very low ESR, a temperature stable dielectric, and can be connected in parallel to increase capacitance. Other low ESR capacitors such as solid tantalum, specialty polymer, or organic semiconductor, make effective choices provided that the capacitor is properly rated for the output voltage and ripple current. Finally, choose an input capacitor of sufficient size to effectively decouple the input voltage source impedance (e.g., $C_{IN} \geq 47\mu F$).

LAYOUT CONSIDERATIONS

The high peak currents and switching frequencies present in DC/DC converter applications require careful attention to device layout for optimal performance. Basic design rules include: (1) maintaining wide traces for power components (e.g., width > 50mils); (2) place C_{IN}, C_{OUT}, the Schottky diode, and the inductor close to the LX1732; (3) minimizing trace capacitance by reducing the etch area connecting the SW pin to the inductor; and (4) minimizing the etch length to the LBI and FB pins to reduce noise coupling into these high impedance sense inputs. Other considerations include placing a 0.1uF capacitor between the LX1732 VOUT pin and GND pin to reduce high frequency noise and decoupling the VIN pin using a 0.1uF capacitor.

APPLICATIONS

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APPLICATION INFORMATION

INDUCTOR SELECTION

A smaller value inductor tends to have a smaller package size. Also using a smaller value inductor can reduce output voltage ripple. The inductor value must be large enough to maintain a reasonable level of inductor current ripple (during a burst period) since this will increase the DC output power capability of the converter. The ripple current can be estimated as:

$$L \approx \frac{V_{IN}}{\Delta I_L \times f_{SW}} \times \left(1 - \frac{V_{IN}}{V_{OUT} + V_{FWD}}\right)$$

THERMAL CONSIDERATIONS

Calculating maximum power dissipation for a given operating condition is achieved using the following relationship:

$$P_D(max) = [T_J(max) - T_A(max)]/\Theta_{JA}$$

The maximum device junction temperature is specified at 150°C and the 8 pin MSOP package thermal resistance is 206°C/W. The LX1732 operates within specified parameters up to a maximum ambient temperature of 70°C. The maximum power dissipation achievable under these constraints is (150°C - 70°C)/ 206°C/W = 0.38W and increases to 0.58W at a device ambient temperature of 30°C. Designers should pay close attention to PCB design, device thermal coupling, proximity to other active components, and access to airflow in applications that require the device to operate close to the maximum junction temperature.

CIRCUIT DESIGN EXAMPLE

Example 1

V_{IN} = 3.0; V_{OUT} = 5.0V±5%; I_{OUT} = 150mA (max); Efficiency > 80%; $V_{OUT(ripple)}$ < 100mV.

Step 1: Program the output voltage. This value was already determined in the example on page 5 as 316kΩ.

Step 2: Determine an appropriate inductor value. Determine the inductor that will result in a ripple current of 200mA. Assuming a diode forward voltage drop of 350mV and a nominal switching frequency of 130KHz, based on the equation above : L = 51uF; use 47uF standard value.

Step 3: Determine output capacitance. The value of the output capacitor effects output voltage ripple and transient performance. The ripple voltage on the output (ignoring ESR) is the summation of the comparator overdrive voltage, the voltage undershoot (which usually occurs during the first switch "on" time) and overshoot that occurs at the end of the burst when the stored energy in the inductor is delivered to the output capacitor. An approximation of the output ripple voltage is given by this relationship:

- $\Delta V_{OUTpp} = \{(I_{OUT}*t_{ON}) / C_{OUT}\} + \{0.5*(L / C_{OUT})*(I_{PEAK} - I_{OUT})^2 / (V_{OUT} - V_{IN})\} + I_{PEAK}* ESR_C + 10mV.$

Based upon this equation, making the output capacitor large, the inductor value small, and the peak current small will help reduce ripple. Figure 14 shows I_{PEAK} equal to 400mA for a 150mA load condition.. Two 100μF tantalum capacitors were placed in-parallel at the output. The total ESR_C is approximately 0.10Ω. The estimated ripple voltage based upon these values is calculated to be 59mV. The actual ripple measured in Figure 14 is less than 40mV. Variation in t_{ON}, actual ESR_C and C_{OUT} contribute to the error associated between the measured and calculated value.

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EVALUATION BOARD

OVERVIEW

The LXE1732 evaluation board is available from *Microsemi* for assessing overall circuit performance. The evaluation board, shown in Figure 6, is 3 by 3 inches (i.e., 7.6 X 7.6cm) square and factory calibrated for optimal performance over a wide load range. Circuit designers can easily modify output voltage to suit their particular application. Moreover, inductor, capacitors, and diode are easily swapped out to promote design verification of a circuit that maximizes efficiency and minimizes cost for a wide variety of applications. The input and output connections are described in Table 1.

ELECTRICAL CONNECTIONS

Apply the DC input voltage directly to the VIN pin and connect the test load to the VOUT pin. The output voltage is factory programmed at 3.0V, however, the user may adjust this value by changing the R1 and R2 values accordingly. Install a wire loop at JU1 to close the circuit connection and to examine the inductor current using a suitable current probe.

The LX1732 exhibits a low quiescent current ($I_Q <$ 1μA: typ) during shutdown mode. This pin is pulled-up to VIN via a 10K resistor. Grounding the SHDN test point shuts down the IC however, the load is still capable of drawing current through the inductor & diode circuit path.

Hence, V_{OUT} during shutdown will be approximately the input voltage minus the inductor and diode forward voltage drop.

The LXE1732 evaluation board provides an easy and cost effective solution for evaluation of the LX1732. The factory installed component list for the evaluation board is provided in Table 2 and the schematic is shown in Figure 7.

Figure 6 – LX1732 Evaluation Board

Table 1: Input and Output Pin Assignments

Pin Name	Allowable Range	Description
VIN	0 to 6V	Input power supply connection.
LBI	V ≤ VIN	Low Battery Input voltage threshold sense pin: Programmed for 0.93V nominal.
LBO	N/A	Low Battery Output voltage: Connect a DVM to LBO to observe voltage.
/SHDN	0 to VIN	Ground to inhibit the LX1732
VOUT	V > VIN	Programmed for 3.0V nominal output, adjustable via R1 and R2.
GND	0V	Circuit Ground

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EVALUATION BOARD (CONTINUED)

Table 2: Factory Installed Component

Ref	Description / Part No. / Supplier
CR1	Schottky Diode; 1N5817; (**Microsemi**)
C1	0.01µF 50VCeramic Capacitor; (various)
C2	0.1µF 50VCeramic Capacitor; (various)
C3	100µF, 6.3V Tantalum Capacitor; (various)
C4	100µF, 6.3V Tantalum Capacitor; (various)
C5	100µF, 6.3V Tantalum Capacitor; (various)
C6	100µF, 6.3V Tantalum Capacitor; (various)
L1	47µH Inductor – shielded; (various)
R1	392KΩ Resistor; (various)
R2	255KΩ Resistor; (various)
R3	150KΩ Resistor; (various)
R4	270KΩ Resistor; (various)
R5	50Ω Resistor; (various)
R6	100KΩ Resistor; (various)
U1	Boost Controller IC; LX1732CDU; (**Microsemi**)

Note: The minimum part set for a working power supply consists of: U1, L1, CR1, C3, C5, R1, R2
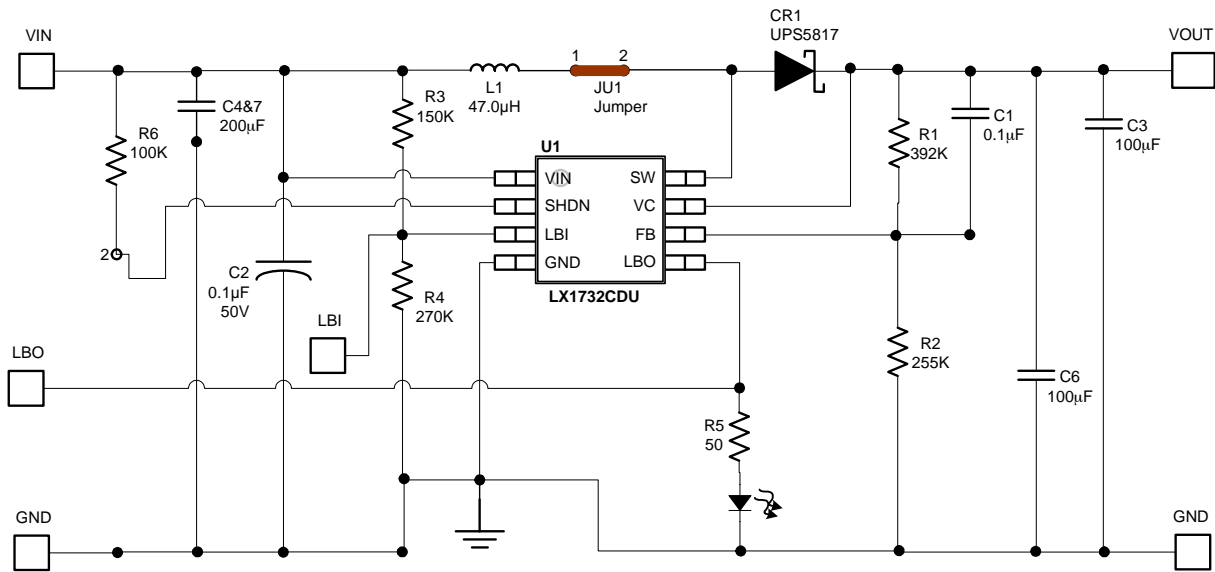
EVALUATION BOARD (CONTINUED)

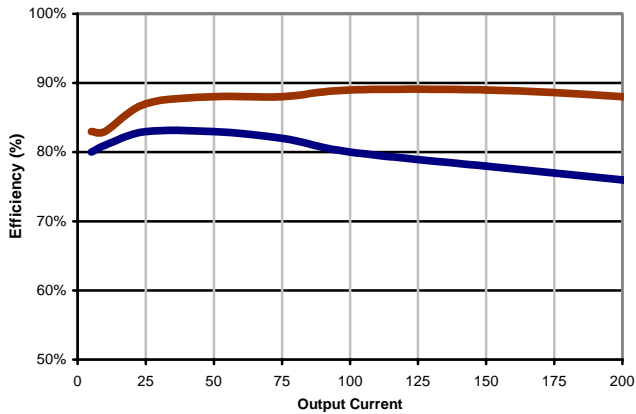**Figure 7** – LXE1732: LX1732 Evaluation Board Schematic

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CHARACTERISTIC CURVES

Figure 8 – Efficiency vs. Output Current (mA)
Top: V_{IN} = 3.0V, V_{OUT} = 5.0V, L1 = 47.0μH; Bottom: V_{IN} =
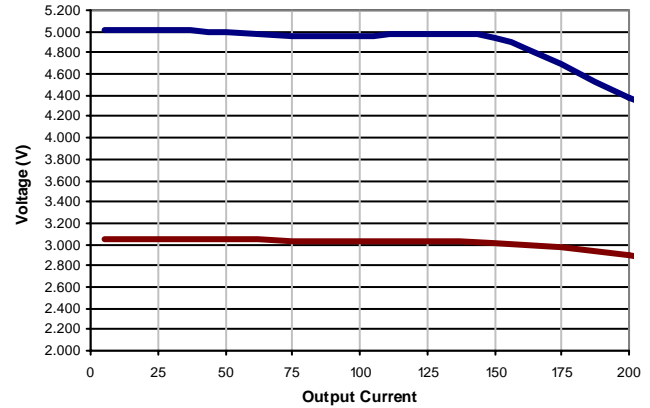1.5V, V_{OUT} = 3.0, L1 = 47.0μH.

Figure 9 – Line Regulation vs. Output Current (mA)
Configuration: Top: V_{IN} = 3.0V, V_{OUT} = 5.0V, Bottom: V_{IN} =
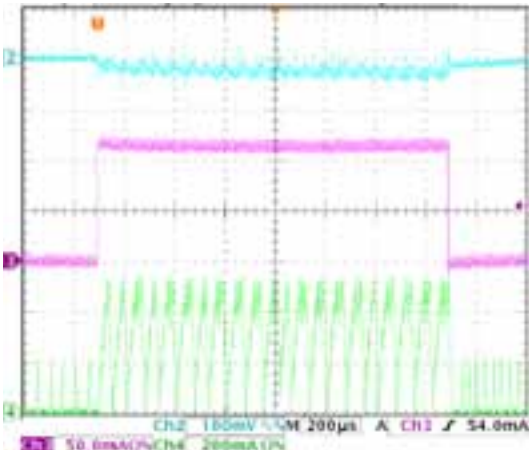1.5V, V_{OUT} = 3.0V

Figure 10: Step Load Response
Configuration: V_{IN} = 1.5V; CH2: V_{OUT} = 3.0V; CH3 I_{LOAD} =
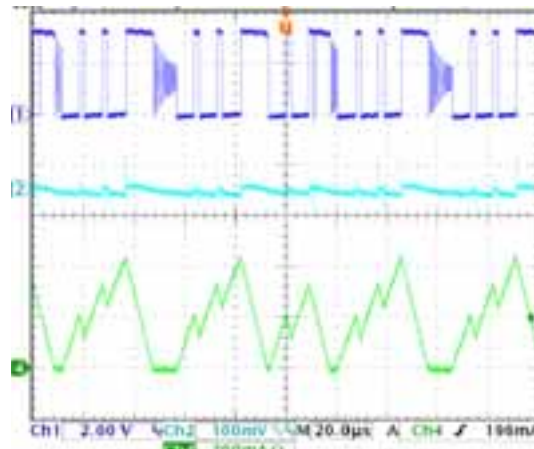5mA to 110mA; CH4: I_L

Figure 11 – Switching Waveforms: **CH2** = V_{OUT}, **CH1** = SW
pin, **CH4** = Inductor Current where I_{OUT} = 75mA; V_{IN} = 1.5V;
V_{OUT} = 3.0V; L = 47μH; C_{OUT} = 200μF

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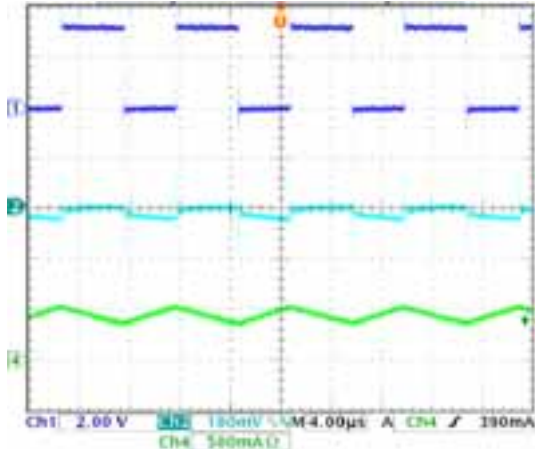
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CHARACTERISTIC CURVES

Figure 12– Switching Waveforms: **CH2** = V$_{OUT}$, **CH1** = SW pin, **CH4** = Inductor Current where I$_{OUT}$ = 240mA; V$_{IN}$ = 2.0V; V$_{OUT}$ = 3.0V; L = 47μH; C$_{OUT}$ = 200μF
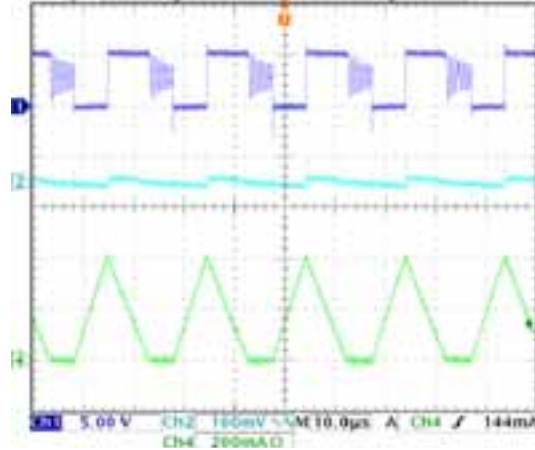

Figure 13 – Switching Waveforms: **CH2** = V$_{OUT}$, **CH1** = SW pin, **CH4** = Inductor Current where I$_{OUT}$ = 80mA; V$_{IN}$ = 3.0V; V$_{OUT}$ = 5.0V; L = 47μH; C$_{OUT}$ = 200μF
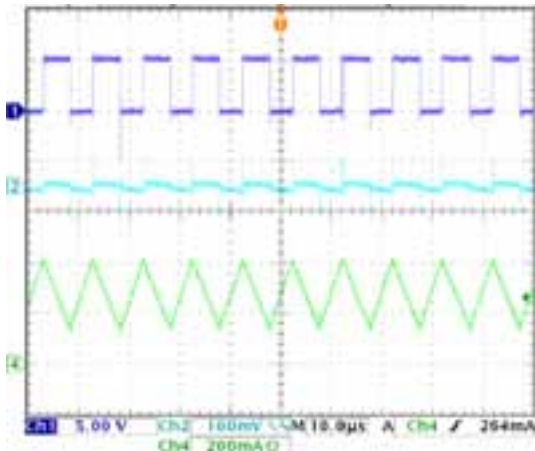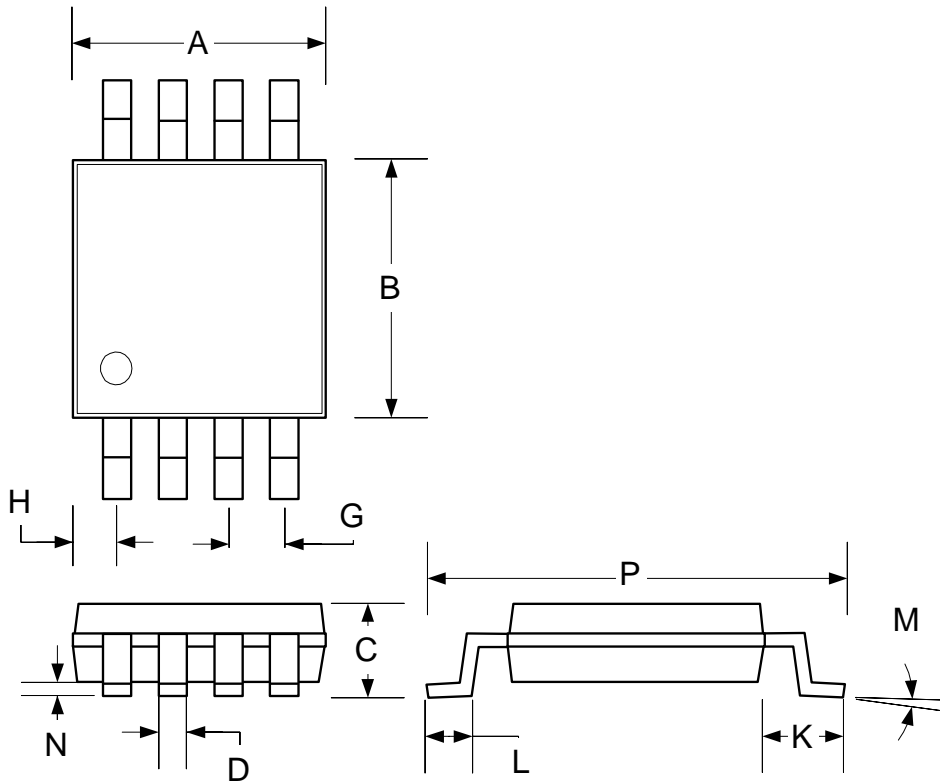

Figure 14– Switching Waveforms: **CH2** = V$_{OUT}$, **CH1** = SW pin, **CH4** = Inductor Current where I$_{OUT}$ = 150mA; V$_{IN}$ = 3.0V; V$_{OUT}$ = 5.0V; L = 47μH; C$_{OUT}$ = 200μF

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PACKAGE DIMENSIONS

DU **8-Pin Miniature Shrink Outline Package (MSOP)**

Dim	MILLIMETERS		INCHES	
	MIN	**MAX**	**MIN**	**MAX**
A	2.85	3.05	.112	.120
B	2.90	3.10	.114	.122
C	–	1.10	–	0.043
D	0.25	0.40	0.009	0.160
G	0.65 BSC		0.025 BSC	
H	0.38	0.64	0.015	0.025
J	0.13	0.18	0.005	0.007
K	0.95 BSC		0.037 BSC	
L	0.40	0.70	0.016	0.027
M	3°		3°	
N	0.05	0.15	0.002	0.006
P	4.75	5.05	0.187	0.198

Note: Dimensions do not include mold flash or protrusions; these shall not exceed 0.155mm(0.006") on any side. Lead dimension shall not include solder coverage.

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