

**DESCRIPTION**

The LX1745 is a compact high efficiency step-up boost regulator for driving white or color LEDs in LCD lighting applications while supplying the necessary LCD bias voltages with an additional two integrated boost converters.

Designed for maximum efficiency and featuring a psuedo-hysteretic PFM topology (that decreases output voltage ripple), the LX1745 minimizes system cost and condenses layout area making it ideal for PDA, smart-phone, and digital camera applications.

While the LCD Bias generation is implemented using an internal N-Channel MOSFET for LCD Bias generation, the LED driver utilizes an external N-Channel MOSFET in order to maintain maximum efficiency along with flexible power requirements..

The LX1745's control circuitry is optimized for portable systems with a shutdown current of less than 1 $\mu$ A. The input voltage range of 1.6V to 6.0 allows for a wide selection of system battery voltages and start-up is

guaranteed at a  $V_{IN}$  equal to 1.6V with sustained operation as low as 1.1V.

The maximum LED drive current is easily programmed using one external current sense resistor in series with the LEDs. In this configuration, LED current provides a feedback signal to the FB pin, maintaining constant current regardless of varying LED forward voltage ( $V_F$ ). Depending on the MOSFET selected, the LX1745 is capable of achieving an LED drive in excess of 1.0W.

The LX1745 provides simple dynamic adjustment of the LED drive current (0% to 100% full range dimming) and the LCD Bias output voltages (up to  $\pm 15\%$  typ) through separate IC interfaces. Each interface has an internal RC filter allowing designers to make these adjustments via a direct PWM input signal or an analog reference signal. Further, any PWM amplitude is easily accommodated using a single external resistor.

The LX1745 is available in the low-profile 20-Pin TSSOP.

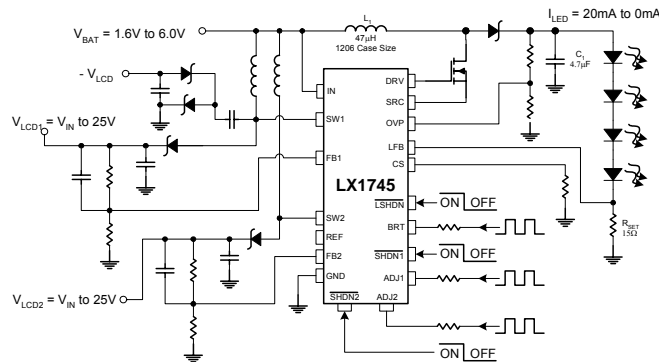
**KEY FEATURES**

- > 90% Maximum Efficiency
- Low Quiescent Supply Current
- Externally Programmable Peak Inductor Current Limit For Maximum Efficiency
- Logic Controlled Shutdown
- < 1 $\mu$ A Shutdown Current
- Dynamic Output LED Current and Two LCD Bias Voltage Adjustments Via Analog Reference Or Direct PWM Input
- 20-Pin TSSOP Package

**APPLICATIONS**

- Pagers
- Smart Phones
- PDAs
- Handheld Computers
- General LCD Bias Applications
- LED Driver

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

**PRODUCT HIGHLIGHT**


LX1745 Evaluation Board

**PACKAGE ORDER INFO**

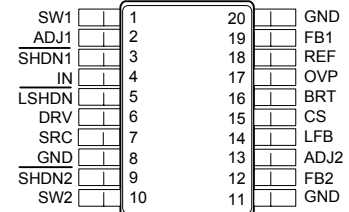
|            |   |
|------------|---|
| $T_A$ (°C) | <b>PW</b> Plastic TSSOP                                   |
|            | 20-Pin<br>RoHS Compliant / Pb-free<br>Transition DC: 0442 |
| -40 to 85  | <b>LX1745CPW</b>  |

Note: Available in Tape & Reel. Append the letters "TR" to the part number. (i.e. LX1745CPW-TR)

**ABSOLUTE MAXIMUM RATINGS**

|   |                          |
|---|--------------------------|
| Supply Input Voltage .....  | -0.3V to 7V              |
| Feedback Input Voltage ( $V_{FBx}$ ) .....  | -0.3V to $V_{IN} + 0.3V$ |
| Shutdown Input Voltage ( $V_{SHDNx}$ ) .....  | -0.3V to $V_{IN} + 0.3V$ |
| PWM Input Amplitude (ADJx, BRT) .....   | -0.3V to $V_{IN} + 0.3V$ |
| Analog Adjust Input Voltage ( $V_{ADJx}$ , $V_{BRT}$ ) .....                                | -0.3V to $V_{IN} + 0.3V$ |
| SRC Input Current .....   | 500mA <sub>RMS</sub>     |
| Operating Temperature Range .....   | -40°C to 85°C            |
| Maximum Operating Junction Temperature .....  | 150°C                    |
| Storage Temperature Range .....   | -65°C to 150°C           |
| RoHS / Pb-free Peak Package Solder Reflow Temperature<br>(40 second maximum 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.  
x denotes respective pin designator 1, 2, or 3

**PACKAGE PIN OUT**


**PW PACKAGE**  
(Top View)

RoHS / Pb-free 100% Matte Tin Lead Finish

**THERMAL DATA**
**PW Plastic TSSOP 20-Pin**

|   |               |
|---|---------------|
| <b>THERMAL RESISTANCE-JUNCTION TO AMBIENT, <math>\theta_{JA}</math></b> | <b>90°C/W</b> |
|---|---------------|

Junction Temperature Calculation:  $T_J = T_A + (P_D \times \theta_{JA})$ .

The  $\theta_{JA}$  numbers are guidelines for the thermal performance of the device/pc-board system. All of the above assume no ambient airflow.

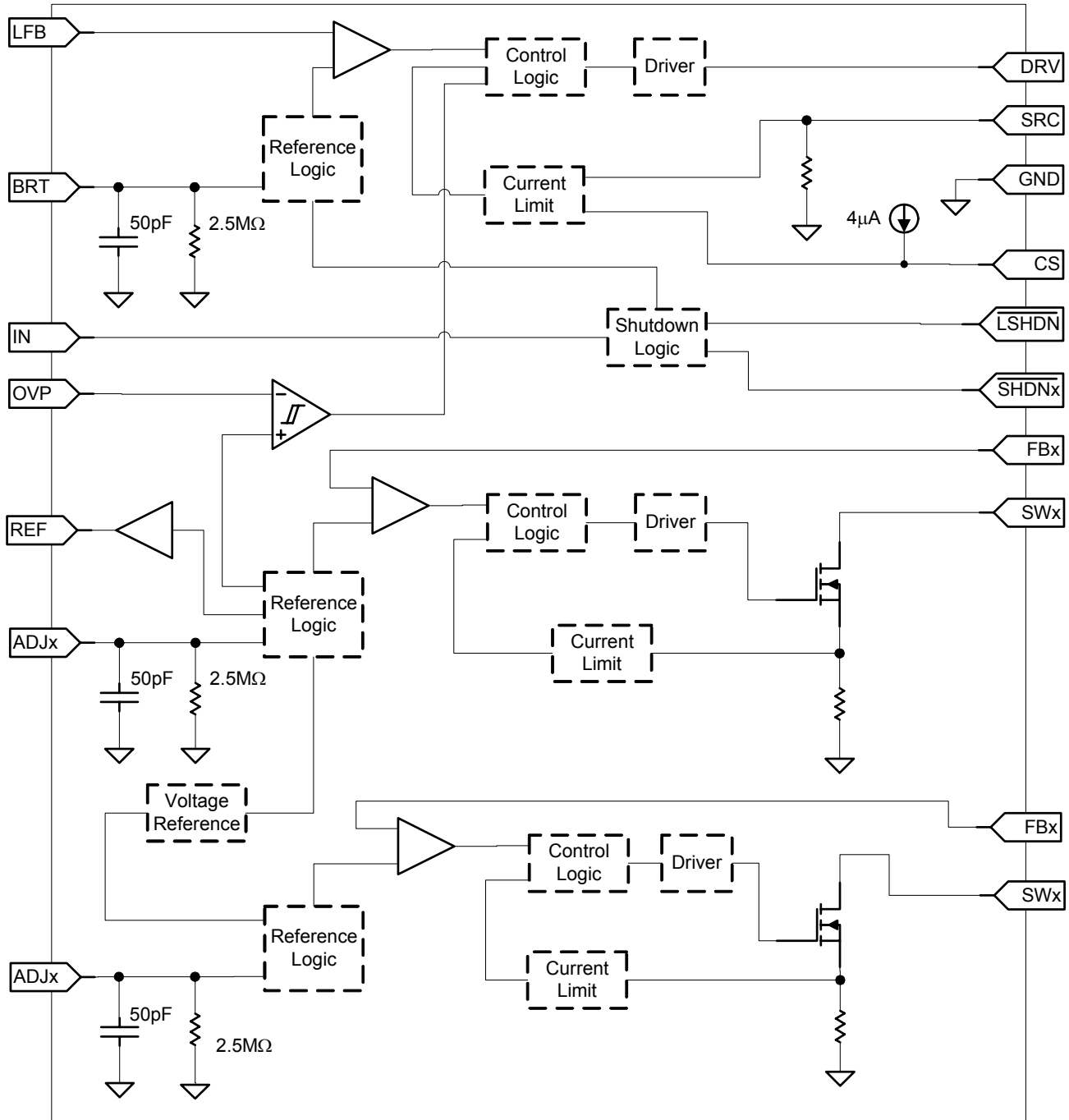
**FUNCTIONAL PIN DESCRIPTION**

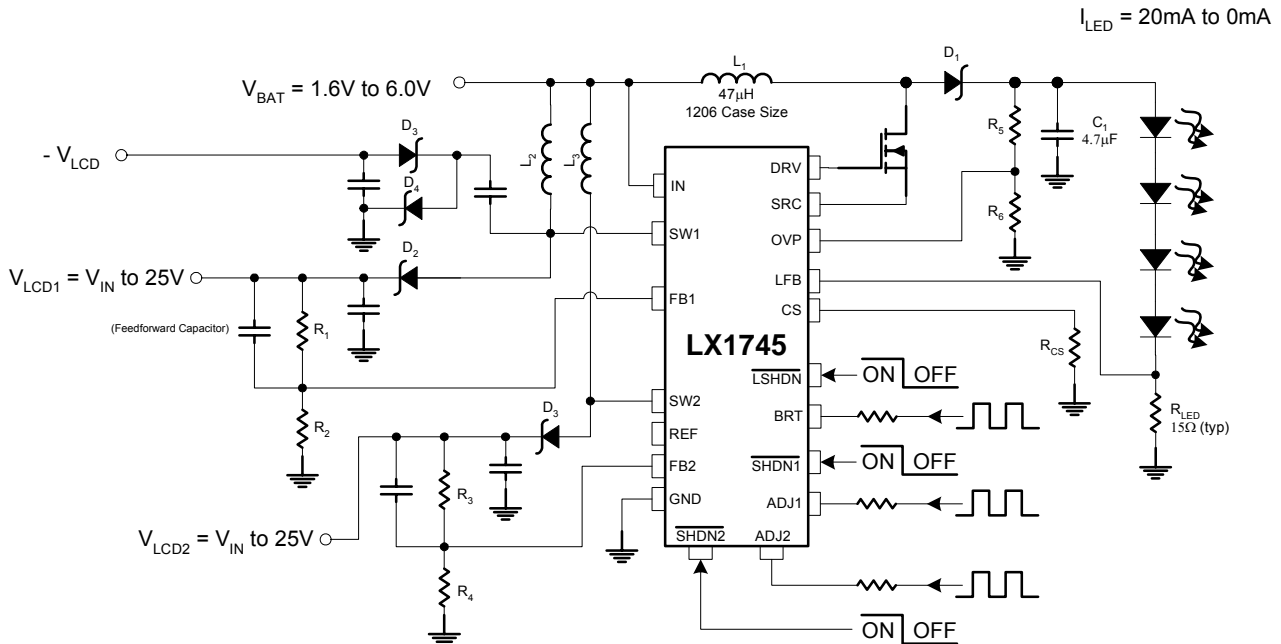
| Name               | Description   |
|--------------------|---|
| IN                 | Unregulated IC Supply Voltage Input – Input range from +1.6V to 6.0V. Bypass with a 1 $\mu$ F or greater capacitor for operation below 2.0V.  |
| DRV                | LED MOSFET Gate Driver – Connects to an external N-Channel MOSFET.  |
| SRC                | LED MOSFET Current Sense Input - Connects to the External N-Channel MOSFET Source.  |
| OVP                | Over Voltage Programming Pin – Connects to a resistor divider between the output load and GND to set the maximum output voltage. OVP has a voltage threshold of 1.2V  |
| LFB                | LED Current Feedback Input – Connects to a current sense resistor between the LED output load and GND to set the LED drive current.   |
| GND                | Common terminal for ground reference.   |
| BRT                | LED Dimming Signal Input – Provides the internal reference, via an internal filter and gain resistor, allowing for a dynamic output LED current adjustment that corresponds to the PWM input signal duty cycle. Either a PWM signal or analog voltage can be used. The actual BRT pin voltage range is from $V_{IN}$ to GND. Minimize the current sense resistor power dissipation by selecting a range for $V_{BRT} = 0.0V$ to 0.5V. |
| REF                | Buffered Reference Output – Connected to the internal bandgap reference voltage of 1.2V.  |
| SWx                | LCD Bias Inductor Switch Connection – Internally connected to the drain of a 28V N-channel MOSFET. SW is high impedance in shutdown.  |
| FBx                | Feedback Input – Connect to a resistive divider network between the output and GND to set the output voltage between $V_{CC}$ (IN) and 25V. The feedback threshold is 1.29V.  |
| ADJx               | LCD Bias Adjustment PWM Signal Input – Connect to an RC filter allowing for dynamic output voltage adjustment $>\pm 15\%$ , corresponding to a varying duty cycle. Either a PWM signal or analog voltage can be used. The ADJ input voltage range is from 0.9V to $V_{IN}$ DC. The ADJx pin should be connected to ground when the internal reference is used.  |
| $\overline{LSHDN}$ | LED Driver Active-Low Shutdown Input – A logic low shuts down the LED driver circuitry and reduces the supply current by 60 $\mu$ A (Typ). Pull $\overline{LSHDN}$ high for normal operation.   |
| $\overline{SHDNx}$ | LCD Bias Active-Low Shutdown Input – A logic low shuts down the LCD Bias circuitry and reduces the supply current by 60 $\mu$ A (Typ). Pull $\overline{SHDNx}$ high for normal operation.   |
| CS                 | Current-Sense Amplifier Input – Connecting a resistor between CS and GND sets the peak inductor current limit.  |

**ELECTRICAL CHARACTERISTICS**

Unless otherwise specified, the following specifications apply over the operating ambient temperature  $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$  except where otherwise noted and the following test conditions:  $V_{IN} = 3\text{V}$ ,  $\overline{\text{LSHDN}} = V_{IN}$ ,  $\overline{\text{SHDN1}} = V_{IN}$ ,  $\overline{\text{SHDN2}} = V_{IN}$

| Parameter                                | Symbol                        | Test Conditions   | LX1745 |       |          | Units                        |
|--|-------------------------------|---|--------|-------|----------|------------------------------|
|  |                               |   | Min    | Typ   | Max      |                              |
| <b>LED DRIVER</b>                        |                               |   |        |       |          |                              |
| LFB Threshold Voltage                    | $V_{LFB}$                     | $V_{BRT} = 100\text{mV}$  | 85     | 100   | 115      | mV                           |
|  |                               | $V_{BRT} = 20\text{mV}$   | 5      | 20    | 35       |                              |
| LFB Input Bias Current                   | $I_{LFB}$                     | $V_{LFB} = 100\text{mV}$  | -100   |       | 100      | nA                           |
| BRT Input Voltage Range                  | $V_{BRT}$                     |   | 0      |       | $V_{IN}$ | V                            |
| BRT Input Bias Current                   | $I_{BRT}$                     | $BRT = 100\text{mV}$  |        |       | 60       | nA                           |
| LED Driver Shutdown Input Bias Current   | $I_{\overline{\text{SHDN1}}}$ | $0.0\text{V} \leq \overline{\text{SHDN1}} \leq V_{IN}$  | -100   |       | 100      | nA                           |
| Current Sense Bias Current               | $I_{CS}$                      |   |        | 4     |          | $\mu\text{A}$                |
| Switch Peak Current                      | $I_{PK}$                      | $R_{CS} = 0\text{k}\Omega$  |        | 170   |          | mA                           |
|  |                               | $R_{CS} = 2\text{k}\Omega$  |        | 210   |          |                              |
| DRV Sink/Source Current                  |                               | $V_{IN} = 5\text{V}$ , $V_{DRV} = 3\text{V}$  | 85     | 100   |          | mA                           |
| DRV On-Resistance                        | $R_{DRV(ON)}$                 | $V_{CC} = 5\text{V}$  |        | 12    | 15       | $\Omega$                     |
| Maximum Switch On-Time                   | $t_{ON}$                      | $V_{FB} = 1\text{V}$  |        |       | $\infty$ | $\mu\text{S}$                |
| Minimum Switch Off-Time                  | $t_{OFF}$                     | $V_{FB} = 1\text{V}$  | 200    | 300   | 410      | nS                           |
| OVP Threshold Voltage                    | $V_{OVP}$                     |   | 1.15   | 1.21  | 1.26     | V                            |
| Reference Voltage                        | $V_{REF}$                     |   | 1.186  | 1.21  | 1.234    | V                            |
| <b>LCD BIAS</b>                          |                               |   |        |       |          |                              |
| Output Voltage Range                     | $V_{OUT}$                     |   |        |       | 25       | V                            |
| FBx Threshold Voltage                    | $V_{FB}$                      |   | 1.166  | 1.190 | 1.214    | V                            |
| FBx Input Current                        | $I_{FB}$                      | $V_{FB} = 1.4\text{V}$  |        |       | 200      | nA                           |
| LCD Bias Shutdown Input Bias Current     | $I_{\overline{\text{SHDNx}}}$ | $\overline{\text{SHDNx}} = \text{GND}$  |        |       | 100      | nA                           |
| Peak Inductor Current                    | $I_{LIM}$                     | $T_A = +25^{\circ}\text{C}$   |        | 330   |          | mA                           |
| Internal NFET On-resistance              | $R_{DS(ON)}$                  | $I_{SW} = 10\text{mA}$ , $T_A = +25^{\circ}\text{C}$ , $V_{IN} = 5\text{V}$   |        | 1.1   |          | $\Omega$                     |
| Switch Pin Leakage Current               | $I_{LEAK}$                    | $V_{SW} = 25\text{V}$   |        |       | 1.0      | $\mu\text{A}$                |
| Switch On-Time                           | $t_{ON}$                      | $V_{FB} = 1\text{V}$  |        |       | $\infty$ | $\mu\text{s}$                |
| Switch Off-Time                          | $t_{OFF}$                     | $V_{FB} = 1\text{V}$  | 150    |       | 400      | ns                           |
| ADJx Input Voltage Range                 | $V_{ADJx}$                    |   | 0.9    |       | 1.5      | V                            |
| ADJx Input Bias Current                  | $I_{ADJx}$                    |   |        | 0.3   | 1.0      | $\mu\text{A}$                |
| <b>ENTIRE REGULATOR</b>                  |                               |   |        |       |          |                              |
| Operating Voltage                        | $V_{IN}$                      | Recommended Operating Range   | 1.6    |       | 6.0      | V                            |
| Minimum Start-up Voltage                 |                               | $T_A = +25^{\circ}\text{C}$   |        |       | 1.6      | V                            |
| Start-up Voltage Temperature Coefficient | $\kappa$                      |   |        | -2    |          | $\text{mV}/^{\circ}\text{C}$ |
| Shutdown High Input Voltage              | $V_{\overline{\text{SHDNx}}}$ | $V_{IN} = 2\text{V}$  | 1.6    |       |          | V                            |
| Shutdown Low Input Voltage               | $V_{\overline{\text{SHDNx}}}$ | $V_{IN} = 2\text{V}$  |        |       | 0.4      | V                            |
| Quiescent Current                        | $I_Q$                         | $V_{FBx} = 1.4\text{V}$ , $V_{LFB} > V_{BRT} - 0.1\text{V}$   |        | 200   | 320      | $\mu\text{A}$                |
|  |                               | $V_{FBx} = 1.4\text{V}$ , $V_{LFB} > V_{BRT} - 0.1\text{V}$ , $V_{\overline{\text{LSHDN}}} < 0.4\text{V}$                               |        | 0.35  | 1        |                              |
|  |                               | $V_{FBx} = 1.4\text{V}$ , $V_{LFB} > V_{BRT} - 0.1\text{V}$ , $V_{\overline{\text{SHDN1}}} < 0.4\text{V}$                               |        | 140   | 220      |                              |
|  |                               | $V_{FBx} = 1.4\text{V}$ , $V_{LFB} > V_{BRT} - 0.1\text{V}$ , $V_{\overline{\text{SHDN2}}} < 0.4\text{V}$                               |        | 80    | 120      |                              |
|  |                               | $V_{\overline{\text{SHDN1}}} < 0.4\text{V}$ , $V_{\overline{\text{SHDN2}}} < 0.4\text{V}$ , $V_{\overline{\text{LSHDN}}} < 0.4\text{V}$ |        | 0.35  | 1        |                              |

**SIMPLIFIED BLOCK DIAGRAM**

**Figure 1 – Simplified Block Diagram**

**APPLICATION CIRCUITS**

**Figure 2 – LED Driver with Full-Range Dimming plus LCD Bias With Contrast Adjustment Via PWM Input**

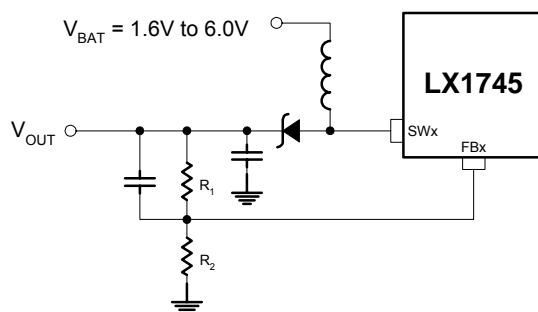
**APPLICATION NOTE**
**FUNCTIONAL DESCRIPTION**

The LX1745 is a triple output Pulse Frequency Modulated (PFM) boost converter that is optimized for large step-up voltage applications like LCD biasing and LED drive.

Operating in a pseudo-hysteretic mode with a fixed switch “off time” of 300ns, converter switching is enabled when the feedback voltage ( $V_{FB}$ ) falls below the bandgap reference voltage or the ADJ pin voltage managed by the reference logic block (see Block Diagram). When this occurs, the feedback comparator activates the switching logic, pulling the gate of the power MOSFET high. This in turn connects the boost inductor to ground causing current to flow building up the energy stored in the inductor. The output remains “on”, until the inductor current ramps up to the peak current level set either by the CS pin programming resistor ( $R_{CS}$ ) in the case of the LED driver or by an internal reference threshold for the LCD bias outputs. During this switch cycle, the load is powered from energy stored in the output capacitor. Once the peak inductor current value is achieved, the driver output is turned off, for the fixed off-time period of 300ns, allowing a portion of the energy stored in the inductor to be delivered to the load causing output voltage to rise at the input to the feedback circuit. If the voltage at the feedback pin is less than the internal reference at the end of the off-time period, the output switches the power MOSFET “on” and the inductor charging cycle repeats until the feedback pin voltage is greater than the internal reference. Typical converter switching behavior is shown in Figure 14.

**LCD BIAS – OUTPUT VOLTAGE PROGRAMMING**

Selecting the appropriate values for LCD Bias output voltage divider (Figure 3), connected to the feedback pin, programs the output voltage.


**Figure 3 – LCD Bias Output Voltage**

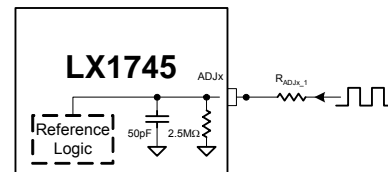
Using a value between 40k $\Omega$  and 75k $\Omega$  for  $R_2$  works well in most applications.  $R_1$  can be determined by the following equation (where  $V_{REF} = 1.19V$  nominal):

$$R_1 = R_2 \frac{V_{OUT} - V_{REF}}{V_{REF}} \quad \text{eq. 1}$$

**LCD BIAS – OUTPUT VOLTAGE ADJUSTMENT**

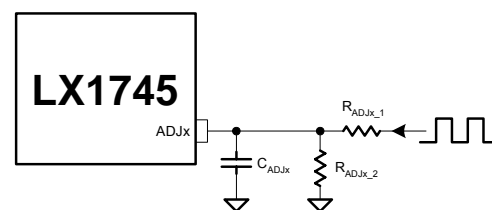
The LX1745 allows for the dynamic adjustment of each of the voltage outputs via an adjustment pin (ADJx). Any voltage applied to the adjustment pin(s) works in conjunction with the internal reference logic. The LX1745 will automatically utilize the internal reference when no signal is detected or when the adjustment signal voltage is below approximately 0.6V.

Each of these pins includes an internal 50pF capacitor to ground (Figure 4) that works with an external resistor to create a low-pass filter. This allows a direct PWM ( $f_{PWM} \geq 100KHz$ ) signal input to be used for the voltage adjustment signal. (Consequently a DC bias signal can also be used).


**Figure 4 – LCD Bias Adjustment Input**

Different PWM signal levels can be accommodated by selecting a value for  $R_{PWM}$  such that the filtered  $V_{ADJx}$  value is equal to the reference voltage (eq. 2)

$$V_{ADJx} = V_{PWM} \cdot \text{Duty Cycle} \cdot \left( \frac{2.5M\Omega}{2.5M\Omega + R_{PWM\_1}} \right) \quad \text{eq. 2}$$


**Figure 5 – LCD Bias Adjustment Input Filter**

Ideally the resultant ripple on the ADJx pin should be approximately 1% or 40dB down from the nominal reference. When using a PWM with a frequency that is

**APPLICATION NOTE**

less than 100kHz, an external filter capacitor will be needed (Figure 5). The value of  $C_{PWM}$  is easily calculated based on the PWM frequency and  $R_{PWM\_1}$  using the following equation.

$$C_{PWM} = \frac{50}{\pi \cdot f_{PWM} \cdot R_{PWM\_1}} \quad \text{eq. 3}$$

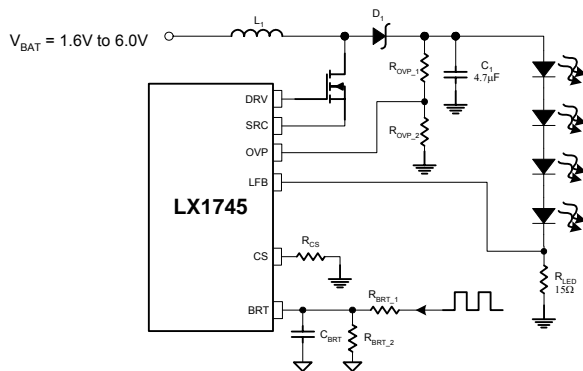
where

$$R_{PWM\_1} \ll 2.5M\Omega \quad \text{eq. 4}$$

**LED DRIVER – OUTPUT CURRENT PROGRAMMING**

Maximum LED current is easily programmed by choosing the appropriate value for  $R_{LED}$  (Figure 6). It is recommended that a minimum value of  $15\Omega$  be used for this resistor in order to prevent noise coupling issues on the feedback line. Although, alternate values can be calculated using the following equation:

$$R_{LED} = \frac{V_{BRTx(MAX)}}{I_{LED(MAX)}} \quad \text{eq. 5}$$



**Figure 6 – LED Current Programming**

**LED DRIVER – LED BRIGHTNESS ADJUSTMENT**

The LX1745 features a full range dimming LED driver. LED current regulation is accomplished by using the applied BRT pin voltage as the LED current reference. This reference voltage, in conjunction with the LED current setting resistor ( $R_{LED}$ ), sets the LED output current.

Dimming can be accomplished in one of two ways: by applying a variable DC voltage, or by varying the duty cycle (DC) of a PWM control signal, directly to the BRT pin.

It is recommended that a maximum signal voltage of

300mV ( $V_{BRT}$ ) be used in order to minimize dissipative losses in the LED current sense resistor ( $R_{LED}$ ).

Like the LCD bias adjustment (ADJx) pins, the BRT pin is connected to an internal 50pF capacitor to ground that works with an external resistor to create a low-pass filter, allowing the BRT pin to driven directly by a PWM signal whose frequency is greater than 100kHz. When this pin is driven by a PWM signal whose frequency is less than 100kHz, an external filter capacitor is needed. This capacitor is selected such that the ripple component of the resultant voltage on the BRT pin is less than 10% of the nominal input voltage.

For PWM frequencies greater than 100kHz, the external BRT input resistor is calculated using the following equation.

$$R_{BRT\_1} = 2.5M\Omega \cdot \left( \frac{V_{PWM(DC_{MAX})} - V_{BRT(MAX)}}{V_{BRT(MAX)}} \right) \quad \text{eq. 6}$$

where  $V_{BRT}$  is the selected maximum LED current sense feedback threshold.

For PWM frequencies less than 100kHz, the external BRT input resistors and filter capacitor (Figure 4) are calculated using the following equations.

$$R_{BRT\_1} = R_{BRT\_2} \cdot \left( \frac{V_{PWM(DC_{MAX})} - V_{BRT(MAX)}}{V_{BRT(MAX)}} \right) \quad \text{eq. 7}$$

where  $R_{BRT\_2}$  is selected and  $V_{BRT(MAX)}$  is the selected maximum LED current sense feedback threshold.

$$C_{BRT} = \frac{5}{\pi \cdot f_{PWM}} \cdot \left( \frac{R_{BRT\_1} + R_{BRT\_2}}{R_{BRT\_1} \cdot R_{BRT\_2}} \right) \quad \text{eq. 8}$$

where  $V_{RIPPLE}$  is selected to be 10% of  $V_{BRT}$ , and  $f_{PWM}$  is the PWM signal frequency.

**DIODE SELECTION**

A Schottky diode is recommended for most applications (e.g. Microsemi UPS5817). The low forward voltage drop and fast recovery time associated with this device supports the switching demands associated with this circuit topology. The designer is encouraged to consider the diode's average and peak current ratings with respect to the application's output and peak inductor current requirements. Further, the diode's reverse breakdown voltage characteristic must be capable of withstanding a



**APPLICATION NOTE**

negative voltage transition that is greater than the output voltage.

**POWER MOSFET SELECTION**

The LX1745 can source up to 100mA of gate current. An logic level N-channel MOSFET with a low turn on threshold voltage, low gate charge and low  $R_{DS(ON)}$  is required to optimize overall circuit performance.

**OVER VOLTAGE PROTECTION PROGRAMMING**

Since the output of the LED Driver is a current mode configuration, it may be desirable to protect the output from an over-voltage condition in the event the load is removed or not present.

The LX1745 includes an over voltage monitor that is easily programmed with two external resistors (Figure 6). This feature eliminates the need for a Zener Diode clamp on the output.

Programming is accomplished by first selecting  $R_{OVP\_2}$  and then calculating  $R_{OVP\_1}$  using the following equation.

$$R_{OVP\_1} = R_{OVP\_2} \frac{V_{OVP} - V_{REF}}{V_{REF}} \quad \text{eq. 9}$$

where  $V_{OVP}$  is the desired maximum voltage on the output. This voltage should be selected to accommodate the maximum forward voltage of all the LEDs, over temperature, plus the maximum feedback voltage. Conversely, it may also be selected according to the maximum  $V_{DS}$  voltage of the output MOSFET.

**INDUCTOR CURRENT LIMIT PROGRAMMING**

Setting of the peak inductor current limit is an important aspect of the PFM constant off-time architecture; it determines the maximum output power capability and has a marked effect on efficiency.

It is recommended that the peak inductor current be set to approximately two times the expected maximum DC input current. This setting will minimize the inductor size, the input ripple current, and the output ripple voltage. Care should be taken to use inductors that will not saturate at the peak inductor current level. The desired peak inductor current can be estimated by the following equation:

$$I_{PK} = 2 \cdot \frac{P_{OUT}}{\eta \cdot V_{IN}} \quad \text{eq. 10}$$

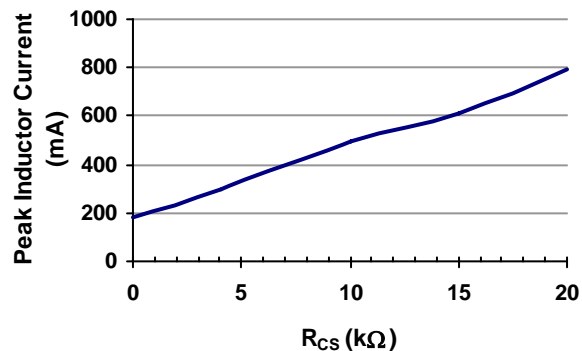
where  $P_{OUT}$  is the total output power,  $\eta$  is the expected conversion efficiency, and  $V_{IN}$  is the input voltage.

From the calculated desired  $I_{PK}$  an  $R_{CS}$  resistance value

can be chosen from the following equation:

$$R_{CS} \cong \frac{I_{PK} - 0.185}{30 \cdot 10^{-6}} \quad \text{eq. 11}$$

which is taken from the following graph (Figure 7).



**Figure 7 – Peak Current Programming Resistor**

This graph characterizes the relationship between peak inductor current, the inductance value, and the  $R_{CS}$  programming resistor.

**INDUCTOR SELECTION**

An inductor value of 47μH has been shown to yield very good results. Choosing a lower value emphasizes peak current overshoot, effectively raises the switching frequency, and increases the dissipative losses due to increased currents.

**OUTPUT CAPACITOR SELECTION**

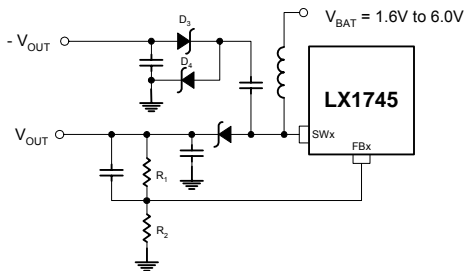
Output voltage ripple is a function of the several parameters: inductor value, output capacitance value, peak switch current, load current, input voltage, and the output voltage. All of these factors can be summarized by the following equation:

$$V_{RIPPLE} \cong \left( \frac{L \cdot I_{PK} \cdot I_{OUT}}{C_{OUT}} \right) \left( \frac{1}{V_{IN} - (V_{SW} + V_L)} + \frac{I_{PK} \cdot I_{OUT}}{V_{OUT} + V_F - V_{IN}} \right) \quad \text{eq. 12}$$

where  $V_L$  is the voltage drop across the inductor,  $V_F$  is the forward voltage of the output catch diode, and  $V_{SW}$  is the voltage drop across the power switch.  $V_L + V_{SW}$  can be approximated at 0.4V and  $V_F$  can be approximated at 0.4V.

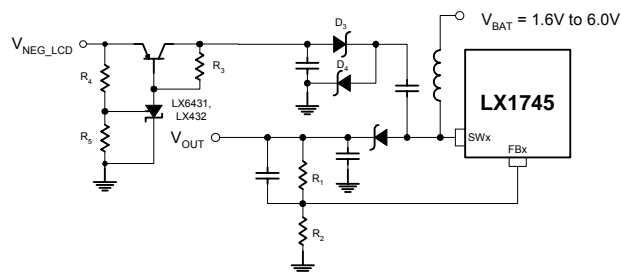
**APPLICATION NOTE**
**NEGATIVE LCD BIAS GENERATION**

For applications that require it, a negative bias can be easily generated using an inductorless charge pump consisting of only four additional discrete components (Figure 8).


**Figure 8 – Negative Bias Generation**

This negative output is a mirror of the positive output voltage. However, it is unregulated.

If a regulated negative bias is desired then this is also possible with some additional components. A low current shunt regulator (LX6431 or LX432) and a bipolar pass element can form a simple negative voltage LDO (Figure 9).


**Figure 9 – Regulated Negative Bias**

$R_3$  is sized to meet the minimum shunt current required for regulation while  $R_4$  and  $R_5$  are calculated. If  $R_5$  is selected to be 100k $\Omega$  then  $R_4$  is calculated using the following equation:

$$V_{\text{NEG\_LCD}} = V_{\text{REF}} \cdot \left( 1 + \frac{R_4}{R_5} \right) \quad \text{eq. 13}$$

where  $V_{\text{REF}}$  is a -2.5V in the case of the LX6431.

**FEED-FORWARD CAPACITANCE**

Improved efficiency and ripple performance can be

achieved by placing a feed-forward capacitor across the feedback resistor connected to the output (Figure 2). A recommended value of 1nF should be used.

**PCB LAYOUT**

Minimizing trace lengths from the IC to the inductor, diode, input and output capacitors, and feedback connection (i.e. pin 3) are typical considerations. Moreover, the designer should maximize the DC input and output trace widths to accommodate peak current levels associated with this circuit.

| SHDN | SHDN2 | SHDN1 | LCD1 | LCD2 | LED |
|------|-------|-------|------|------|-----|
| 0    | 0     | 1     | 1    | 0    | 0   |
| 0    | 1     | 1     | 1    | 1    | 0   |
| 1    | 0     | 1     | 1    | 0    | 1   |
| 1    | 1     | 1     | 1    | 1    | 1   |
| 1    | 1     | 0     | 0    | 0    | 0   |
| 0    | 1     | 0     | 0    | 0    | 0   |
| 1    | 0     | 0     | 0    | 0    | 0   |
| 0    | 0     | 0     | 0    | 0    | 0   |

**Table 1 – Enable Logic**

**EVALUATION BOARD**
**Table 2: Input and Output Pin Assignments**

| Name  | Input/Output Range | Description   |
|-------|--------------------|---|
| VIN   | 0 to 6V            | Main power supply for outputs.  |
| GND   | 0V                 | Common ground reference.  |
| ADJ1  | 0 to VIN-100mV     | Apply a DC voltage or a PWM voltage to this pin to adjust the LCD1 output voltage. PWM inputs should be greater than 120Hz.                           |
| ADJ2  |                    | Apply a DC voltage or a PWM voltage to this pin to adjust the LCD2 output voltage. PWM inputs should be greater than 120Hz.                           |
| SHDN  | 0 to VIN           | Pulled up to VIN on board (10K $\Omega$ ), Ground to inhibit the LED driver output (VOUT).  |
| SHDN1 |                    | Pulled up to VIN on board (10K $\Omega$ ), Ground to inhibit the VLCD1.   |
| SHDN2 |                    | Pulled up to VIN on board (10K $\Omega$ ), Ground to inhibit the VLCD2.   |
| VLCD1 | $\leq 25V$         | Output voltage test point. Programmed for 18V output, adjustable up to 25V.   |
| -VLCD | $\geq -25V$        | Output voltage mirror of VLCD1  |
| VLCD2 | $\leq 25V$         | Output voltage test point. Programmed for 22V output, adjustable up to 25V.   |
| VOUT  | $\leq 25V$         | LED drive voltage probe point.  |
| FDBK  | 0 to VIN           | LED current sense feedback.   |
| BRT   | 0 to 350mV         | Apply a DC voltage or a PWM voltage to this pin to adjust the LED current. PWM inputs should be greater than 120Hz with a DC portion less than 350mV. |
| REF   | 1.19V Typ.         | Buffered IC reference output.   |

*Note: All pins are referenced to ground.*

**EVALUATION BOARD**
**Table 3: Jumper Position Assignments**

| Jumper | Position | Function  |
|--------|----------|---|
| JU1    | N/A      | Remove the factory installed jumper and insert a 4~6cm wire loop (optional) to observe the inductor current waveform using a current probe. |
| JU2    | N/A      |   |
| JU3    | N/A      |   |
| JU4    | N/A      | Remove jumper to test open-circuit over-voltage protection implemented with R1 and R2   |

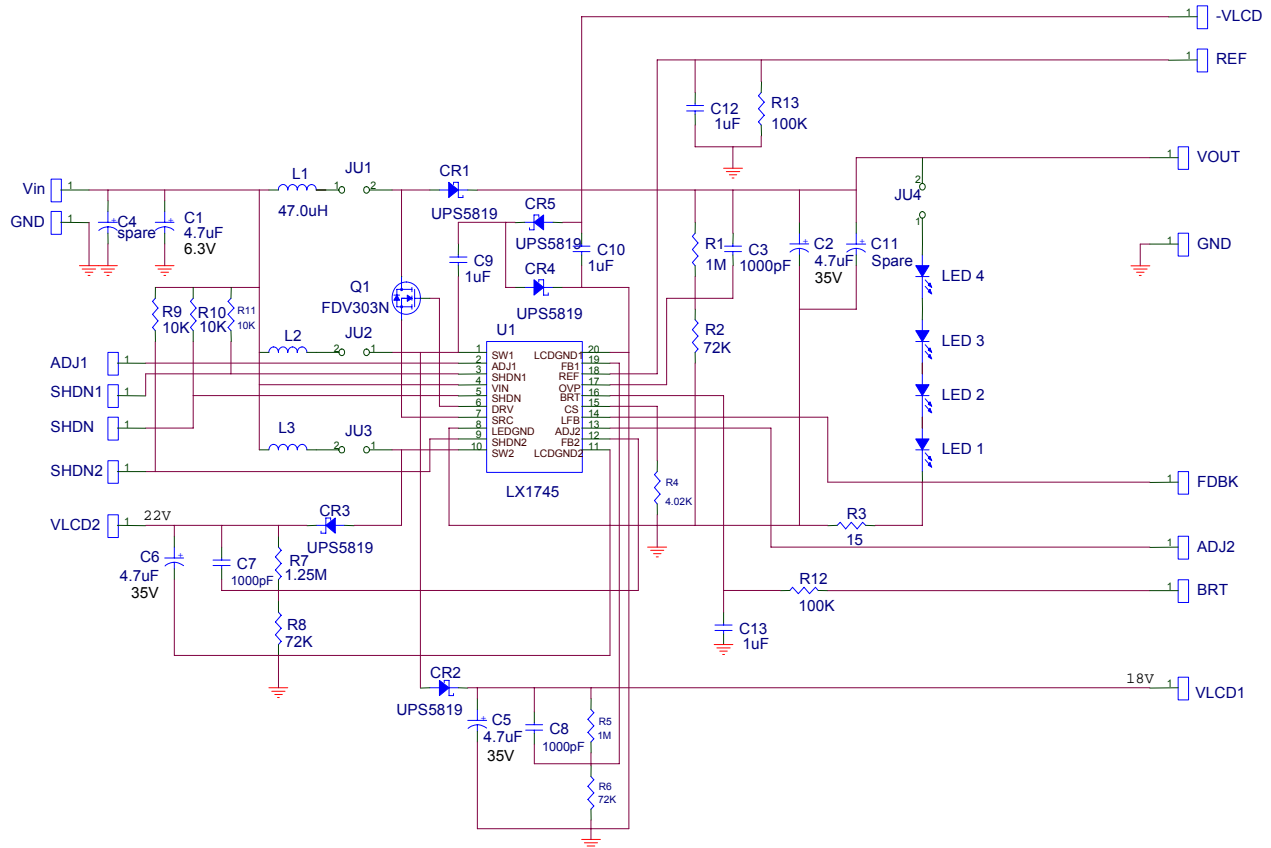
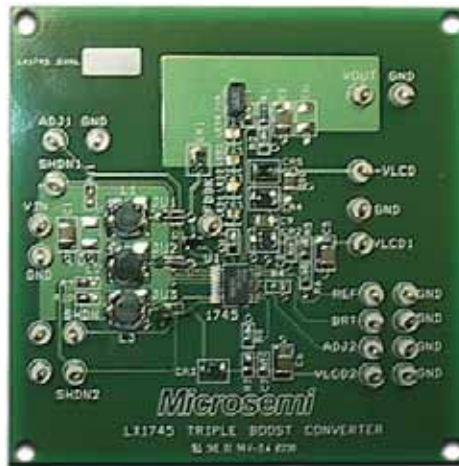
*Note: All pins are referenced to ground.*

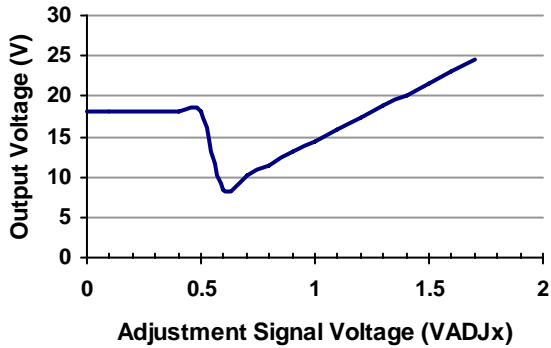
**Table 4: Factory Installed Component List**

| Ref                     | Part Description                                |
|-------------------------|---|
| C1                      | CAPACITOR, 4.7 $\mu$ F, 1210, 6.3V              |
| C2, C5, C6              | CAPACITOR, 4.7 $\mu$ F, 1210, 35V               |
| C3, C7, C8              | CAPACITOR, 1000pF, 0805, 35V                    |
| C4, C11                 | CAPACITOR, (SPARE), See Note 1                  |
| C9, C10, C12, C13       | CAPACITOR, 1 $\mu$ F, 0805, 35V                 |
| CR1, CR2, CR3, CR4, CR5 | Microsemi UPS5819, SCHOTTKY, 1A, 40V, POWERMITE |
| LED1, LED2, LED3, LED4  | Microsemi UPWLEDxx, LED, Optomite               |
| L1, L2, L3              | INDUCTOR, 47 $\mu$ H, 480mA, SMT                |
| Q1                      | FDV303N MOSFET, 30V, SOT-23                     |
| R1, R5                  | RESISTOR, 1M, 1/16W, 0805                       |
| R2, R6, R8              | RESISTOR, 75K, 1/16W, 0805                      |
| R3                      | RESISTOR, 15, 1/16W, 0805                       |
| R4                      | RESISTOR, 4.02K, 1/16W, 0805                    |
| R7                      | RESISTOR, 1.25M, 1/16W, 0805                    |
| R9, R10, R11            | RESISTOR, 10K, 1/16W, 0805                      |
| R12, R13                | RESISTOR, 100K, 1/16W, 0805                     |
| U1                      | Microsemi LX1745CPW BOOST CONTROLLER            |

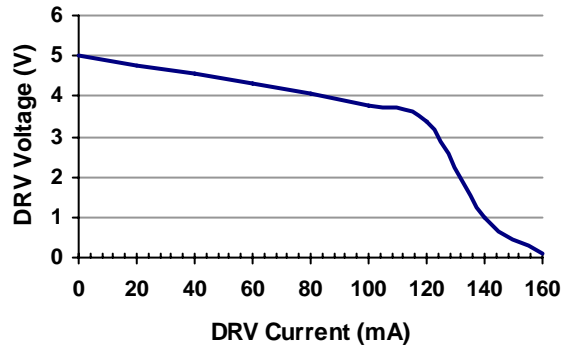
**Notes**

1. Use these locations to insert additional input and/or output capacitance.

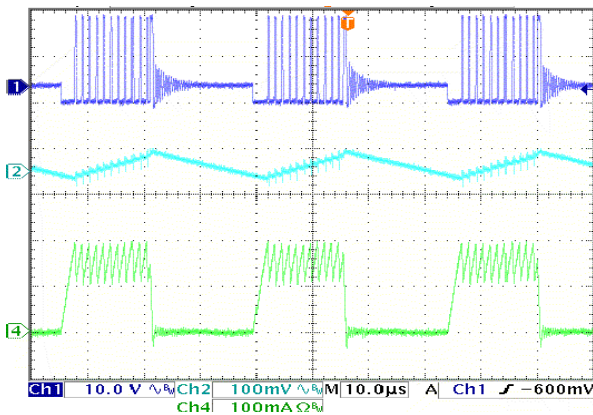
**EVALUATION BOARD**

**Figure 10 – LX1745EVAL Evaluation Board Schematic**

**Figure 11 – LX1745EVAL Evaluation Board**

**VOUT VERSUS VADJ**

**Figure 12 – Output Voltage Vs. Adjustment Signal Threshold**

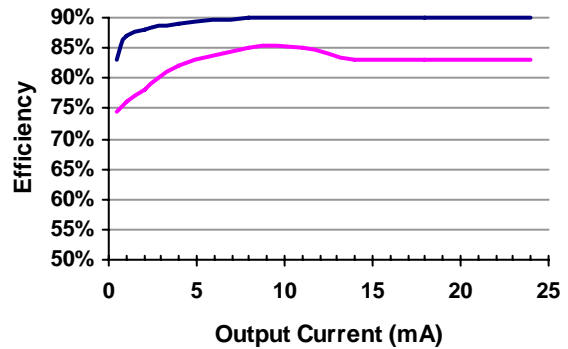
**Note:** The LX1745 uses the internal voltage reference until the VADJ signal exceeds 0.5V (typ).

**GATE DRIVE**

**Figure 13 – Gate Drive Voltage Vs. Drive Current**

$V_{IN} = 5V$ ,  $T_A = 25^\circ C$

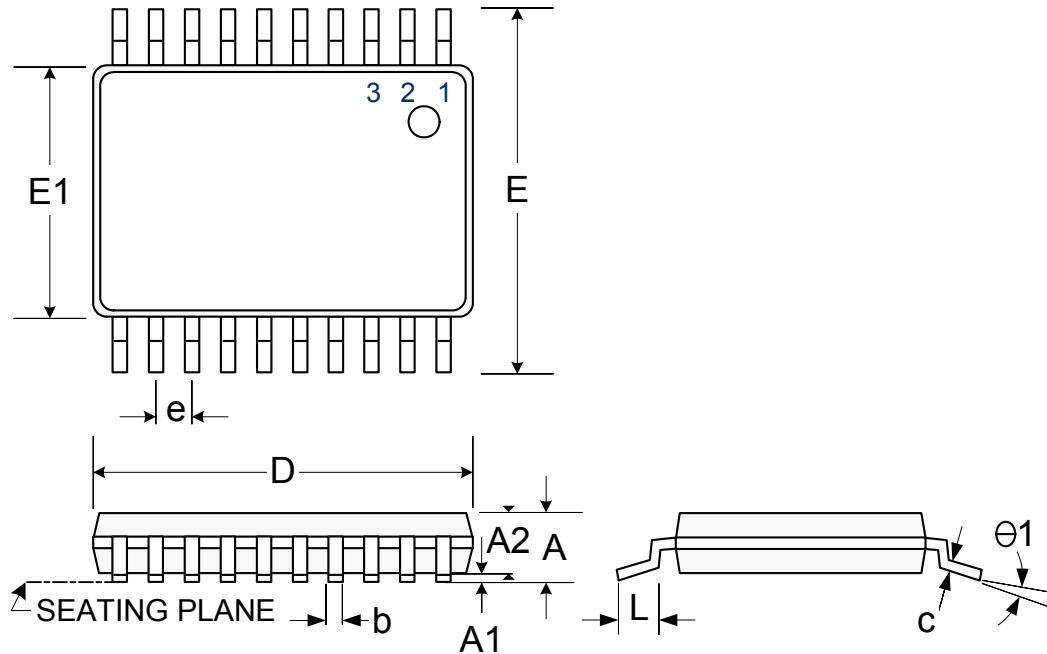
**WAVEFORM**

**Figure 14 – Typical Switching Waveform**

**CH1** – SWx Voltage, **CH2** – Output Voltage, **CH3** – Inductor Current  
 $V_{IN} = 3.6V$ ,  $V_{OUT} = 18V$ ,  $I_{OUT} = 9mA$

**EFFICIENCY**

**Figure 15 – LED Driver (Upper) and LCD Bias Efficiency**

$V_{IN} = 5V$ , Four LEDs,  $L = 47\mu H$ ,  $R_{CS} = 4k\Omega$

$V_{IN} = 3.6V$ ,  $V_{OUT} = 5.5V$ ,  $L = 47\mu H$

**PACKAGE DIMENSIONS**
**PW 20-Pin Thin Small Shrink Outline Package (TSSOP)**


| Dim | MILLIMETERS |      | INCHES    |       |
|-----|-------------|------|-----------|-------|
|     | MIN         | MAX  | MIN       | MAX   |
| A   | -           | 1.10 | -         | 0.043 |
| A1  | 0.05        | 0.15 | 0.002     | 0.006 |
| A2  | 0.80        | 1.05 | 0.031     | 0.041 |
| b   | 0.19        | 0.30 | 0.007     | 0.012 |
| c   | 0.09        | 0.20 | 0.004     | 0.008 |
| D   | 6.40        | 6.60 | 0.252     | 0.260 |
| E   | 6.25        | 6.55 | 0.246     | 0.258 |
| E1  | 4.30        | 4.50 | 0.169     | 0.177 |
| e   | 0.65 BSC    |      | 0.026 BSC |       |
| L   | 0.45        | 0.75 | 0.018     | 0.030 |
| θ1  | 0°          | 8°   | 0°        | 8°    |
| *LC | -           | 0.10 | -         | 0.004 |

\* Lead Coplanarity

**Note:** Dimensions do not include mold flash or protrusions; these shall not exceed 0.155mm(.006") on any side. Lead dimension shall not include solder coverage.



LX1745

Triple Output Boost – LED Driver / LCD Bias

PRODUCTION DATASHEET

NOTES

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