# LT1937K WHITE LED STEP-UP CONVERTER

June 2006 – revised May 2012

## FEATURES

- Inherently matched LED current.
- High efficiency 84% (typ.).
- Drives up to four LEDs from 3.2-volt supply.
- Drives up to six LEDs from a 5-volt supply.
- 36V rugged bipolar switch.
- Fast switching frequency 1.2MHz.
- Uses tiny 1mm-tall Inductors.
- Requires only 0.22µF output capacitor.

## DESCRIPTION

The LT1937K circuit is a step-up DC/DC converter specifically designed to drive white LEDs with a constant current. The device can drive two, three or four LEDs in series from a Li-Ion cell. The series connection of the LEDs provides identical LED currents resulting in uniform brightness and eliminating the need for ballast resistors. The output capacitor can be as small as 0.22µF, saving space versus alternative solutions. A low 95mV feedback voltage minimizes power loss for a better efficiency.

## APPLICATIONS

- Cellular phones.
- PDAs, handheld computers.
- Digital cameras.
- MP3 players.
- GPS receivers.

## TYPICAL APPLICATION

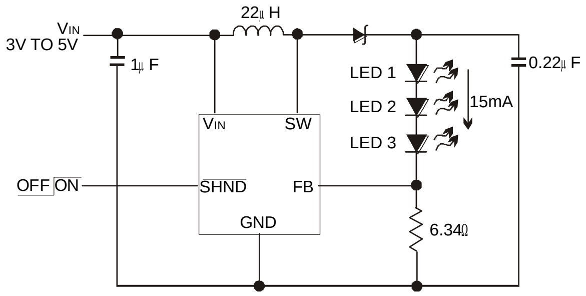
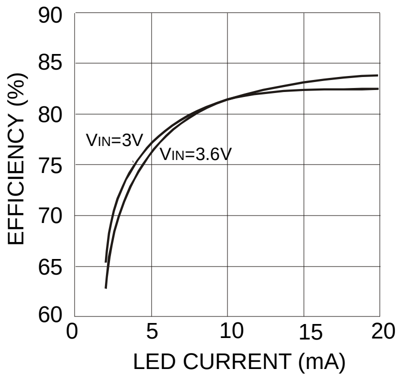



Fig.1. Li-Ion powered driver for three white LEDs

## CONVERSION EFFICIENCY

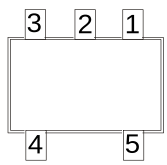



## ABSOLUTE MAXIMUM RATINGS (Note 1)

| | | | |
|---|---|---|---|
| Input voltage ($V_{IN}$) | 10V | Operating temperature range | –40°C to 85°C |
| SW voltage | 36V | Maximum junction temperature | 125°C |
| FB voltage | 10V | Storage temperature range | –65°C to 150°C |
| $\overline{\text{SHDN}}$ voltage | 10V | Lead temperature (soldering, 10 sec) | 300°C |

**Note 1:** **ABSOLUTE MAXIMUM RATINGS** are those values beyond which the life of the device may be impaired.

## PIN FUNCTIONS
**Top View**




| PIN | NAME | DESCRIPTION |
|---|---|---|
| 1 | SW | Switch. (Minimize the trace area at this pin to reduce EMI.) |
| 2 | GND | Ground. Connect directly to local ground plane. |
| 3 | FB | Feedback. The reference voltage is 95 mV.<br>(Calculate the resistor value according to the formula: $R_{FB} = 95mV/I_{LED}$.) |
| 4 | $\overline{\text{SHDN}}$ | Shutdown. (Connect to 1.5V or higher to enable device, and to 0.4 V or less to disable device.) |
| 5 | $V_{IN}$ | Input supply. (Must be locally bypassed.) |

## ELECTRICAL CHARACTERISTICS

($T_A$ = 25°C, $V_{IN}$ = 3V, $V_{\overline{SHDN}}$ = 3V, unless otherwise noted.)

| PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---|---|---|---|---|---|
| Minimum operating voltage | | 2.5 | | | V |
| Maximum operating voltage | | | | 10 | V |
| Feedback voltage | $I_{SW}$ = 100mA, Duty Cycle = 66% | 86 | 95 | 104 | mV |
| FB pin bias current | | 10 | 45 | 100 | nA |
| Supply current | $\overline{SHDN}$ = 0V | | 1.9<br>0.1 | 2.5<br>1.0 | mA<br>μA |
| Switching frequency | | 0.8 | 1.2 | 1.6 | MHz |
| Maximum duty cycle | | 85 | 90 | | % |
| Switch current limit | | | 320 | | mA |
| Switch $V_{CESAT}$ | $I_{SW}$ = 250mA | | 350 | | mV |
| Switch leakage current | $V_{SW}$ = 5V | | 0.01 | 5 | μA |
| $\overline{SHDN}$ voltage High | | 1.5 | | | V |
| $\overline{SHDN}$ voltage Low | | | | 0.4 | V |
| $\overline{SHDN}$ pin bias current | | | 65 | | μA |

**LT1937K**

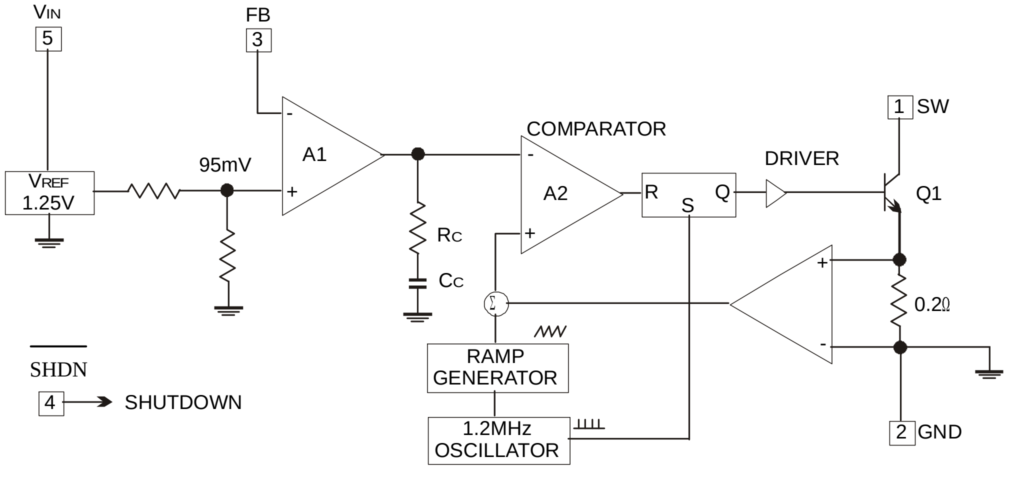



Fig.2. Block diagram

## OPERATION

The LT1937K circuit uses a constant frequency, current mode control scheme to provide excellent line and load regulations. Its operation can be best understood by referring to the block diagram in Fig.2. At the start of each oscillator cycle, the SR latch is set turning on the power switch Q1. A voltage proportional to the switch current is added to a stabilizing ramp and the resulting sum is fed into the positive terminal of the PWM comparator A2. When this voltage exceeds the level at the negative input of A2, the SR latch is reset turning off the power switch. The level at the negative input of A2 is set by the error amplifier A1, and is simply an amplified version of the difference between the feedback voltage and the reference voltage of 95mV. In this manner, the error amplifier sets the correct peak current level to keep the output in regulation. If the error amplifier’s output increases, more current is delivered to the output; if it decreases, less current is delivered.

**Minimum output current**

LT1937K can regulate three series-connected LEDs at low output currents down to approximately 4mA from a 4.2V supply, without pulse skipping, using the same external components as specified for 15mA operation. As the current is further reduced, the device will begin skipping pulses. This will result in some low frequency ripple, although the LED current remains regulated on an average basis down to zero.

## APPLICATION INFORMATION

**Inductor selection**

A 22mH inductor is recommended for most LT1937K applications. Although the small size and high efficiency are major concerns, the inductor should have low core losses at 1.2MHz and low DCR (copper wire resistance). Some inductors in this category with small sizes are listed in Table 1.

**Table 1. Recommended Inductors**

| Part number | DCR, Ohm | Current rating, mA | Manufacturer |
|---|---|---|---|
| LQH3C220 | 0.71 | 250 | Murata |
| ELJPC220KF | 4.0 | 160 | Panasonic |
| CDRH3D16-220 | 0.53 | 350 | Sumida |
| LB2012B220M | 1.7 | 75 | Taiyo Yuden |
| LEM2520-220 | 5.5 | 125 | Taiyo Yuden |

**Capacitor selection**

A small size of ceramic capacitors makes them ideal for LT1937K applications. The X5R and X7R types are recommended because they retain their capacitance over wider voltage and temperature ranges than other types such as Y5V or Z5U. The input capacitor at 1μF and the output capacitor at 0.22μF. are sufficient for most LT1937K applications. The recommended ceramic capacitor manufacturers are Taiyo Yuden, AVX, Murata, and Kemet.

**Diode selection**

Schottky diodes, with their low forward voltage drop and fast reverse recovery, are the ideal choices for LT1937K applications. The forward voltage drop of a Schottky diode represents the conduction losses in the diode, while the diode capacitance ($C_T$ or $C_D$) represents the switching losses. For selecting a diode, both forward voltage drop and diode capacitance need to be considered. Schottky diodes with higher current ratings usually have lower forward voltage drop and larger diode capacitance, which can cause significant switching losses at the 1.2MHz switching frequency of the LT1937K. A Schottky diode rated at 100mA to 200mA is sufficient for most LT1937K applications. Some recommended Schottky diodes are listed in Table 2.

**Table 2. Recommended Schottky Diodes**

| Part number | Forward current, mA | Voltage drop, V | Diode capacitance, pF | Manufacturer |
|---|---|---|---|---|
| CMDSH-3 | 100 | 0.58 at 100mA | 7.0 at 10V | Central |
| CMDSH2-3 | 100 | 0.49 at 200mA | 15 at 10V | Central |
| BAT54 | 200 | 0.53 at 100mA | 10 at 25V | Zetex |

**LED current control**

The LED current is controlled by the feedback resistor (R1 in Fig.1). The feedback reference is 95mV. The LED current is 95mV/R1. In order to have an accurate LED current, precision resistors are preferred (1% is recommended). The formula and Table 3 for R1 selection are shown below. R1 = 95mV/$I_{LED}$

**Table 3. R1 Resistor Value Selection**

| $I_{LED}$, mA | R1, Ohm |
|---|---|
| 5 | 19.1 |
| 10 | 9.53 |
| 12 | 7.87 |
| 15 | 6.34 |
| 20 | 4.75 |

**Open-circuit protection**

In the cases of an output open-circuit, when the LEDs are disconnected from the circuit or the LEDs fail, the feedback voltage will be zero. The LT1937K will then switch at a high duty cycle resulting in a high output voltage, which may cause the SW pin voltage to exceed its maximum 36V rating. A zener diode can be used at the output to limit the voltage on the SW pin (Fig.3). The zener voltage should be larger than the maximum forward voltage of the LED string. The current rating of the zener should be larger than 0.1mA.

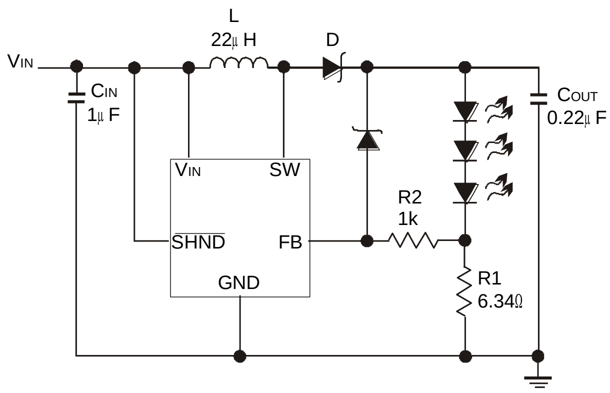



Fig.3. LED driver with the open-circuit protection

**Dimming control**

There are some different types of the dimming control in the circuit:

1. Using a PWM Signal to $\overline{\text{SHDN}}$ Pin

With the PWM signal is applied to the $\overline{\text{SHDN}}$ pin, the LT1937K is turned on or off by the PWM signal. The LEDs operate at either zero or full current. The average LED current increases proportionally with the duty cycle of the PWM signal. A zero-percent duty cycle will turn off the LT1937K and corresponds to zero LED current. A 100-percent duty cycle corresponds to a full current. The typical frequency range of the PWM signal is 1kHz to 10kHz. The magnitude of the PWM signal should be higher than the minimum SHDN voltage high.

2. Using a DC Voltage

For some applications, the preferred method of brightness control is a variable DC voltage to adjust the LED current. The dimming control using a DC voltage is shown in Fig.4. As the DC voltage increases, the voltage drop on R2 increases and the voltage drop on R1 decreases. Thus, the LED current decreases. The selection of R2 and R3 will make the current from the variable DC source much smaller than the LED current and much larger than the FB pin bias current. For the $V_{DC}$ range from 0V to 2V, the selection of resistors in Fig.4 enables the dimming control of LED current from 0mA to 15mA.

3. Using a filtered PWM signal

The filtered PWM signal can be considered as an adjustable DC voltage. It can be used to replace the variable DC voltage source in the dimming control. The circuit is shown in Fig.5.

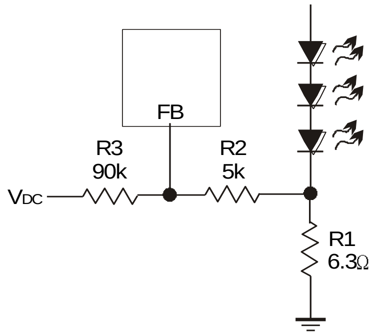



Fig.4. The dimming control using a DC Voltage

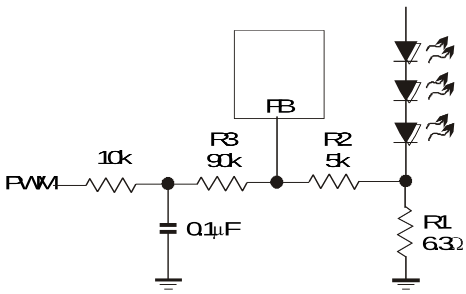
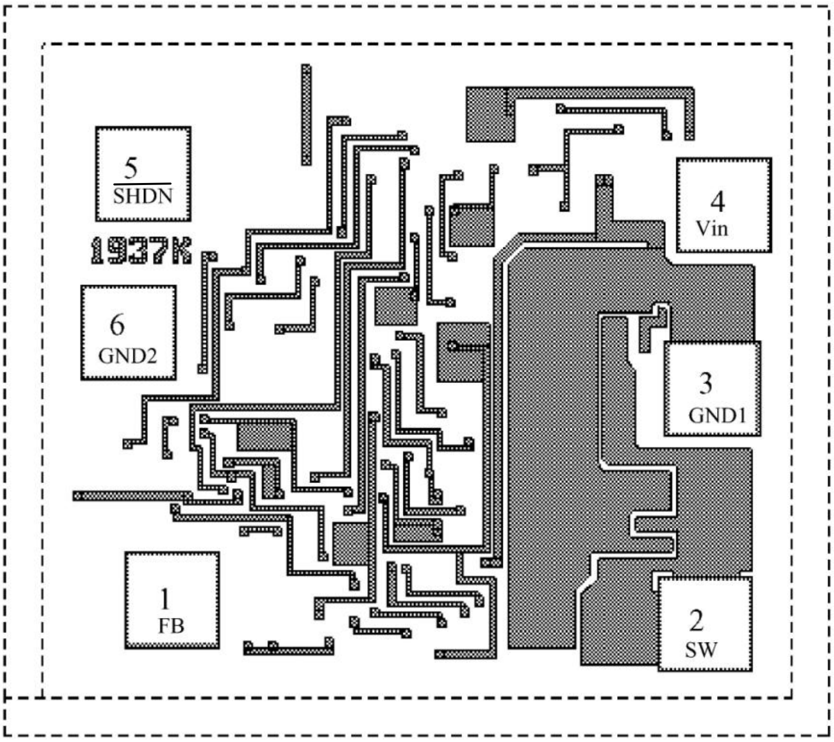



Fig.5. The dimming control using a filtered PWM signal

## PAD LOCATION AND COORDINATES



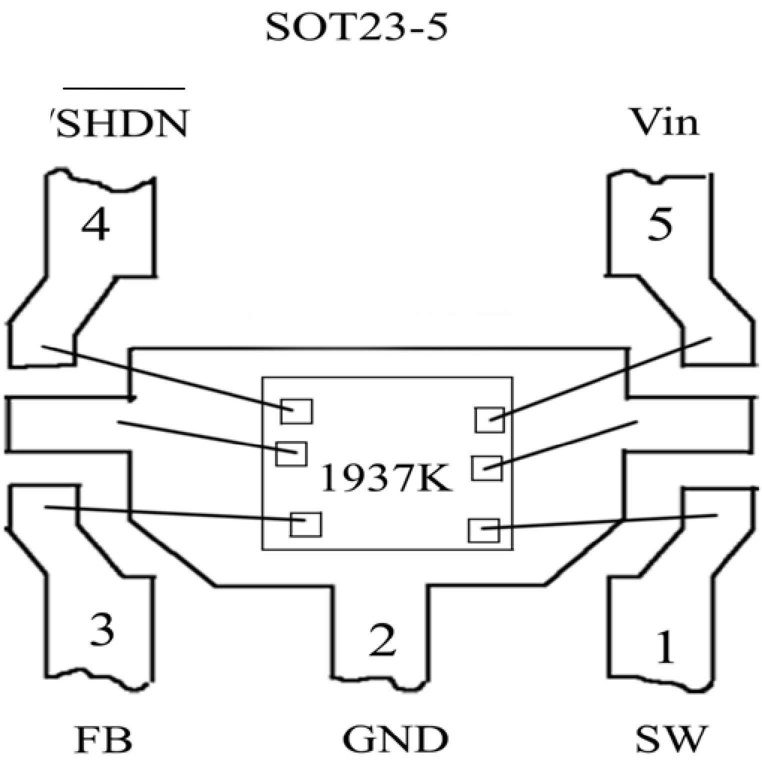

Chip size: 0.87mm x 0.77mm

| Pad | Name | Pad center coordinates, μm X - Y | Pad size, (μm) |
|---|---|---|---|
| 1 | FB | 176 - 144 | 100 x 100 |
| 2 | CW | 740 - 118 | 100 x 100 |
| 3 | GND1 (Note 1) | 747 - 367 | 100 x 100 |
| 4 | $V_{IN}$ | 760 -561 | 100 x 100 |
| 5 | SHDN | 145 - 593 | 100 x 100 |
| 6 | GND2 (Note 1) | 130 - 426 | 100 x 100 |

Note 1: For a 5-pin package the pads numbered 3 and 6 must be connected to the GND pin

# BONDING DIAGRAM

**Bottom view**




The appearance complies with the requirements of the company standards.