Tel: 886-2-66296288
Fax: 886-2-29174598
URL: http://www.princeton.com.tw

DESCRIPTION

The PT6937 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. Series connection of the LEDs provides identical LED currents resulting in uniform brightness and eliminating the need for ballast resistors. The PT6937 switches at 1.2MHz, allowing the use of tiny external components. The output capacitor can be as small as 0.22µF, saving space and cost versus alternative solutions. A low 95mV feedback voltage minimizes power loss in the current setting resistor for better efficiency.
The PT6937 is available in a low profile SOT package.

FEATURES

- Inherently Matched LED Current
- High Efficiency: 84% Typical
- Drives Up to Four LEDs from a 3.2V Supply
- Drives Up to Six LEDs from a 5V Supply
- Fast 1.2MHz Switching Frequency
- Uses Tiny 1mm Tall Inductors
- Requires Only 0.22µF Output Capacitor
- Low Profile SOT Packaging

APPLICATIONS

- Cellular Phones
- PDAs, Handheld Computers
- Digital Cameras
- MP3 Players
- GPS Receivers

BLOCK DIAGRAM

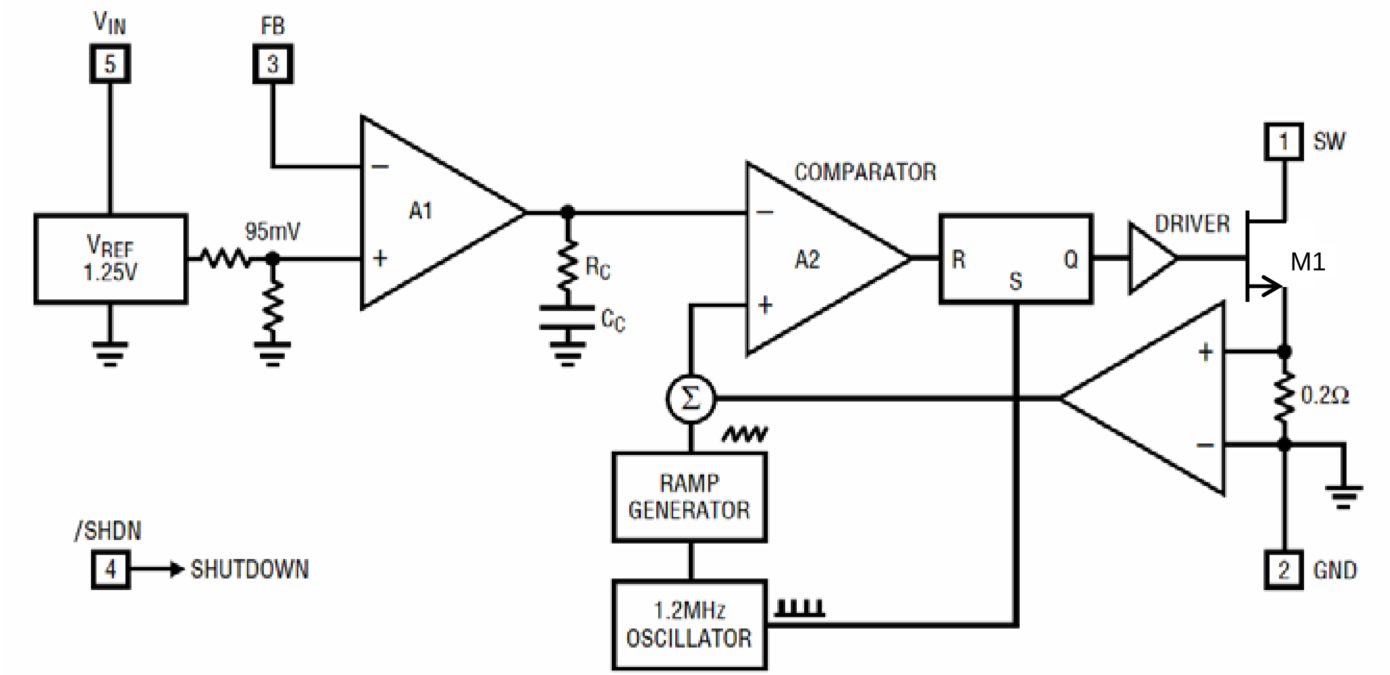
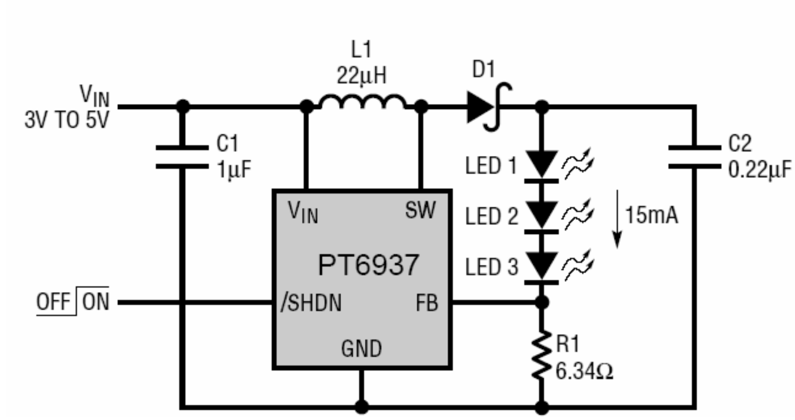
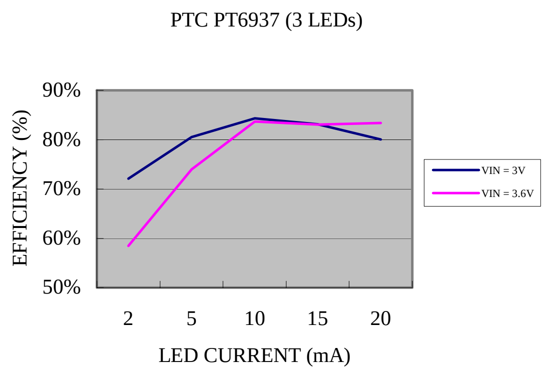


Figure 1: Block Diagram

TYPICAL APPLICATION





D1：FAIRCHILD 1N5819
L1：3L Electronic Corp. SMTSDR322520C-220K

Figure 2: Li-Ion Powered Driver for Three White LEDs

PIN DESCRIPTION

Pin Name	Description	Pin No.
SW	Switch Pin. Connect inductor/diode here. Minimize trace area at this pin to reduce EMI.	1
GND	Ground Pin. Connect directly to local ground plane.	2
FB	Feedback Pin. Reference voltage is 95mV. Connect cathode of lowest LED and resistor here. Calculate resistor value according to the formula: RFB = 95mV/ILED	3
/SHDN	Shutdown Pin. Connect to 1.5V or higher to enable device; 0.4V or less to disable device.	4
VIN	Input Supply Pin. Must be locally bypassed.	5

FUNCTIONAL DESCRIPTION

The PT6937 uses a constant frequency, current mode control scheme to provide excellent line and load regulation. Operation can be best understood by referring to the block diagram in Figure 1. At the start of each oscillator cycle, the SR latch is set, which turns 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

The PT6937 can regulate three series LEDs connected 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. The image below details circuit operation driving three white LEDs at a 4mA load. Peak inductor current is less than 50mA and the regulator operates in discontinuous mode, meaning the inductor current reaches zero during the discharge phase. After the inductor current reaches zero, the switch pin exhibits ringing due to the LC tank circuit formed by the inductor in combination with switch and diode capacitance. This ringing is not harmful; far less spectral energy is contained in the ringing than in the switch transitions. The ringing can be damped by application of a 300Ω resistor across the inductor, although this will degrade efficiency.

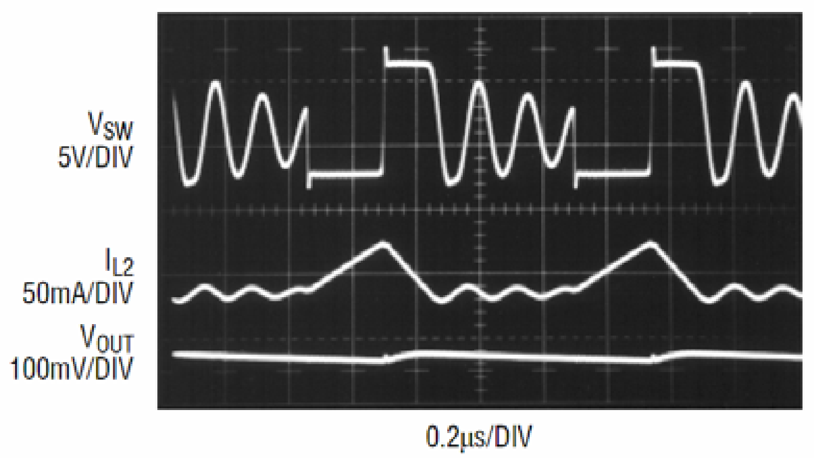


Figure 3: Switching Waveforms at ILED = 4mA, VIN = 3.6V

APPLICATION INFORMATION

INDUCTOR SELECTION

A 22μH inductor is recommended for most PT6937 applications. Although small size and high efficiency are major concerns, the inductor should have low core losses at 1.2MHz and low DCR (copper wire resistance).

CAPACITOR SELECTION

The small size of ceramic capacitors makes them ideal for PT6937 applications. 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. A 1μF input capacitor and a 0.22μF output capacitor are sufficient for most PT6937 applications.

DIODE SELECTION

Schottky diodes, with their low forward voltage drop and fast reverse recovery, are the ideal choices for PT6937 applications. The forward voltage drop of a Schottky diode represents the conduction losses in the diode, while the diode capacitance (CT or CD) represents the switching losses. For diode selection, 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 PT6937. A Schottky diode rated at 100mA to 200mA is sufficient for most PT6937 applications.

LED CURRENT CONTROL

The LED current is controlled by the feedback resistor (R1 in Figure 1). The feedback reference is 95mV. The LED current is 95mV/R1. In order to have accurate LED current, precision resistors are preferred (1% is recommended). The formula and table for R1 selection are shown below.

R1 = 95mV/ILED (1)

ILED (mA)	R1 (Ω)
5	19.1
10	9.53
12	7.87
15	6.34
20	4.75

OPEN-CIRCUIT PROTECTION

In the cases of output open circuit, when the LEDs are disconnected from the circuit or the LEDs fail, the feedback voltage will be zero. The PT6937 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 (Figure 4). 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.

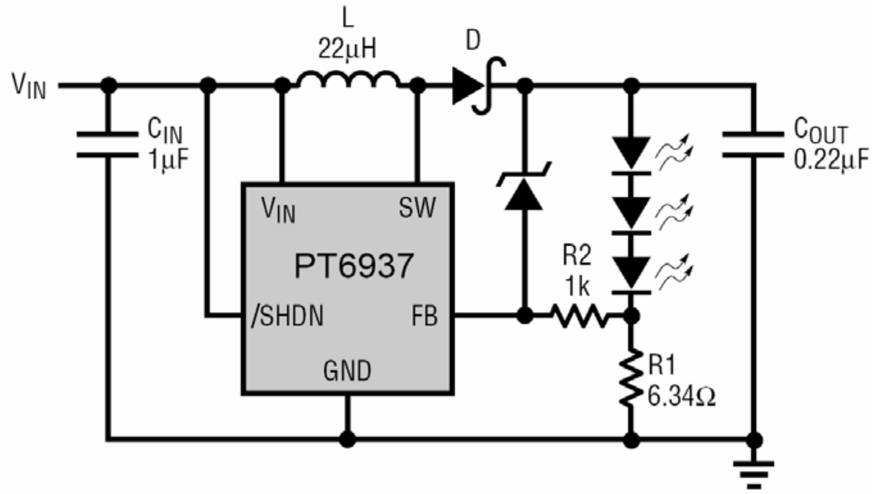


Figure 4: LED Driver with Open-Circuit Protection

DIMMING CONTROL

There are four different types of dimming control circuits:

1. Using a PWM Signal to /SHDN Pin
   With the PWM signal applied to the /SHDN pin, the PT6937 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 0% duty cycle will turn off the PT6937 and corresponds to zero LED current. A 100% duty cycle corresponds to 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. The switching waveforms of the /SHDN pin PWM control are shown in the Figures 5 and 6 below.

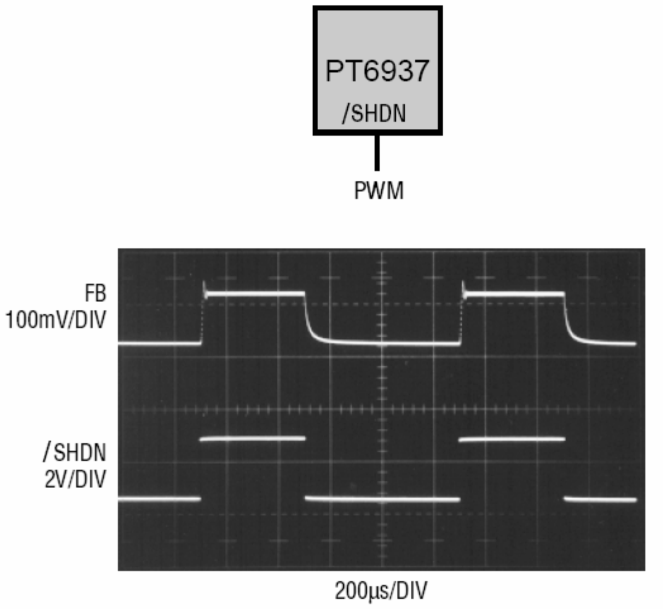


Figure 5: PWM Dimming control Using the /SHDN Pin (1kHz)

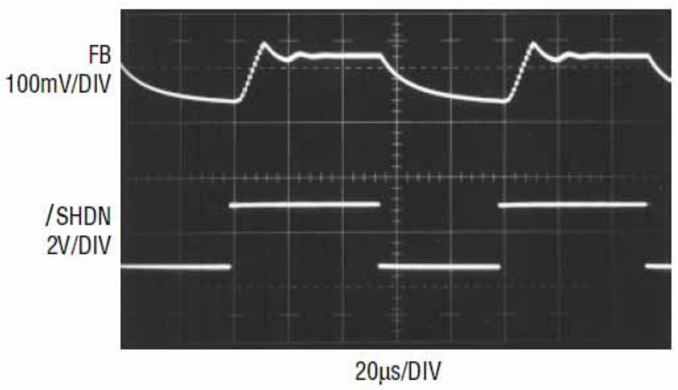


Figure 6: PWM Dimming control Using the /SHDN Pin (10kHz)

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 the figure below. 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 VDC range from 0V to 2V, the selection of resistors in Figure 7 gives 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 dimming control. The circuit is shown in Figure 8.

4. Using a Logic Signal
   For applications that need to adjust the LED current in discrete steps, a logic signal can be used as shown in Figure 9. R1 sets the minimum LED current (when the NMOS is off). RINC sets how much the LED current increases when the NMOS is turned on. The selection of R1 and RINC follows formula (1) and Table 4.

START-UP AND INRUSH CURRENT

To achieve minimum start-up delay, no internal soft-start circuit is included in PT6937. When first turned on without an external soft-start circuit, inrush current is about 200mA as shown in Figure 10. If soft-start is desired, the recommended circuit and the waveforms are shown in Figures 11 and 12. If both soft-start and dimming are used, a 10 kHz PWM signal on /SHDN is not recommended. Use a lower frequency or implement dimming through the FB pin as shown in Figures 7, 8 or 9.

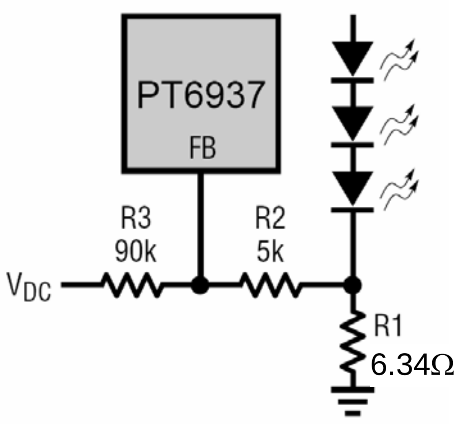


Figure 7: Dimming Control Using DC Voltage

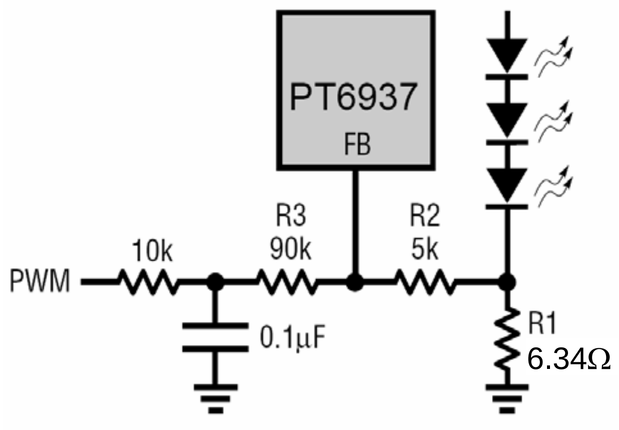


Figure 8: Dimming Control Using a Filtered PWM Signal

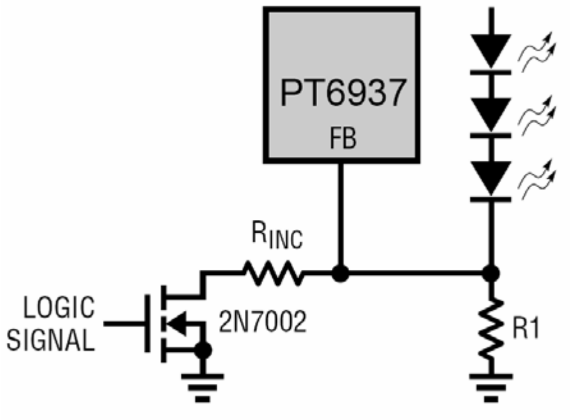


Figure 9: Dimming Control Using a Logic Signal

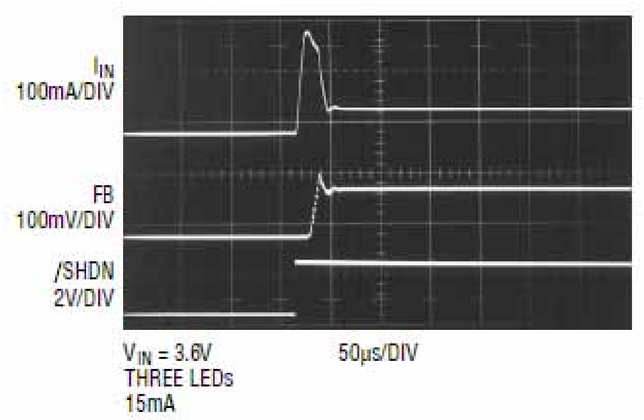


Figure 10: Start-Up Waveforms Without Soft-Startup Circuit

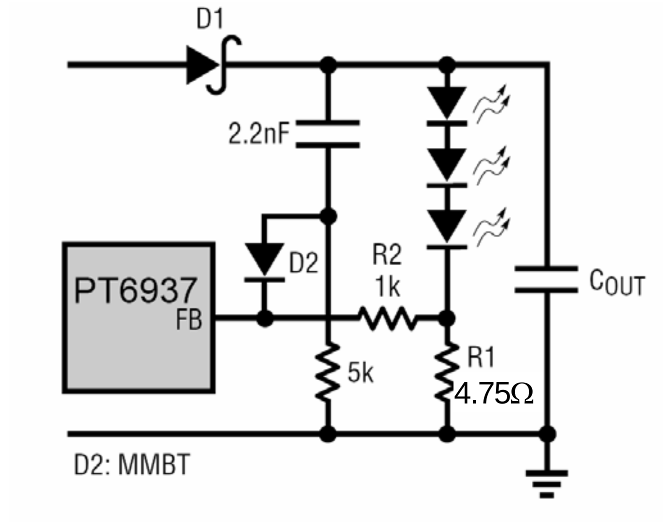


Figure 11: Recommended Soft-Startup Circuit

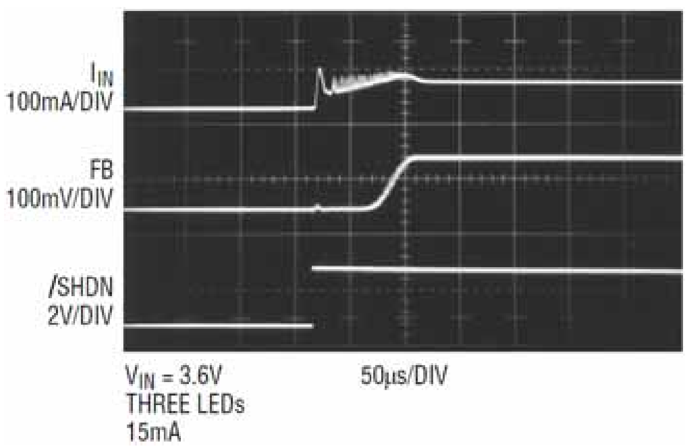
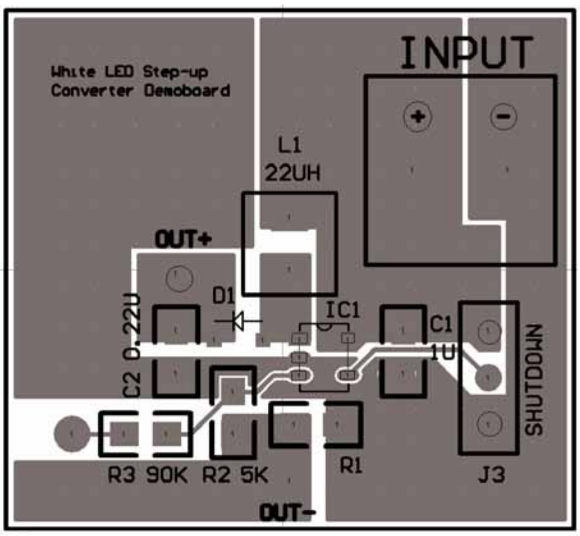


Figure 12: Soft-Startup Waveforms

BOARD LAYOUT CONSIDERATION

As with all switching regulators, careful attention must be paid to the PCB board layout and component placement. To maximize efficiency, switch rise and fall times are made as short as possible. To prevent electromagnetic interference (EMI) problems, proper layout of the high frequency switching path is essential. The voltage signal of the SW pin has sharp rise and fall edges. Minimize the length and area of all traces connected to the SW pin and always use a ground plane under the switching regulator to minimize interplane coupling. In addition, the ground connection for the feedback resistor R1 should be tied directly to the GND pin and not shared with any other component, ensuring a clean, noise-free connection. Recommended component placement is shown in Figure 13.

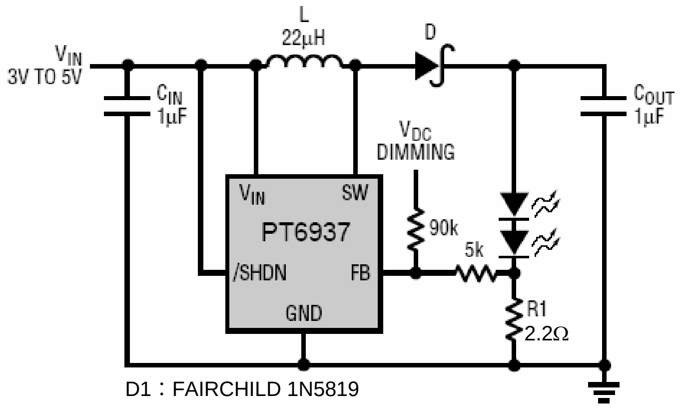


(SOT-23 Package)

Figure 13: Recommended Component Placement

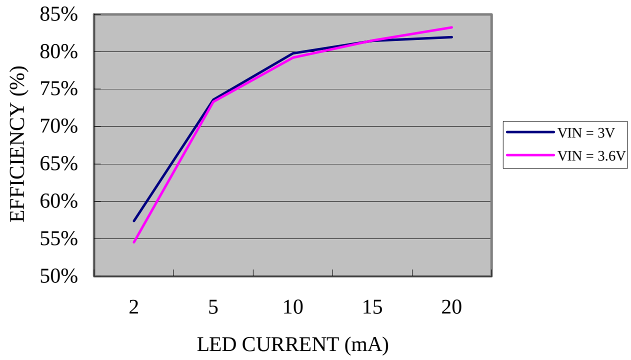
TYPICAL APPLICATIONS

Li-Ion to Two White LEDs

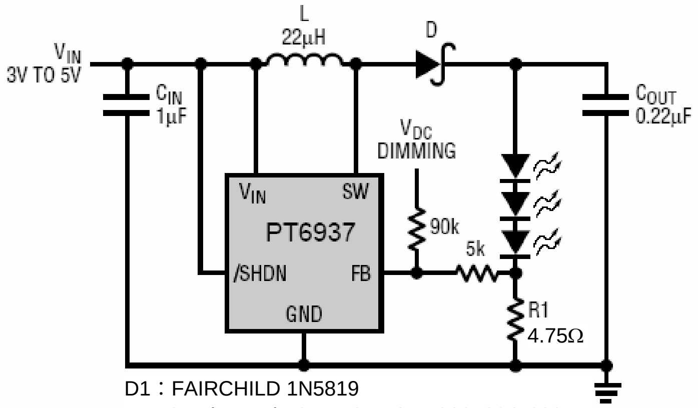


D1：FAIRCHILD 1N5819
L1：3L Electronic Corp. SMTSDR322520C-220K

PTC PT6937 (2 LEDs)

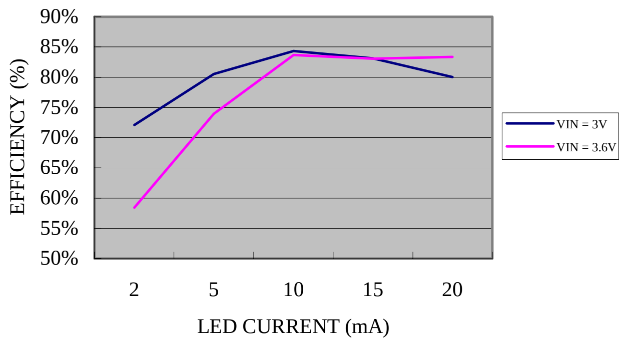


Li-Ion to Three White LEDs

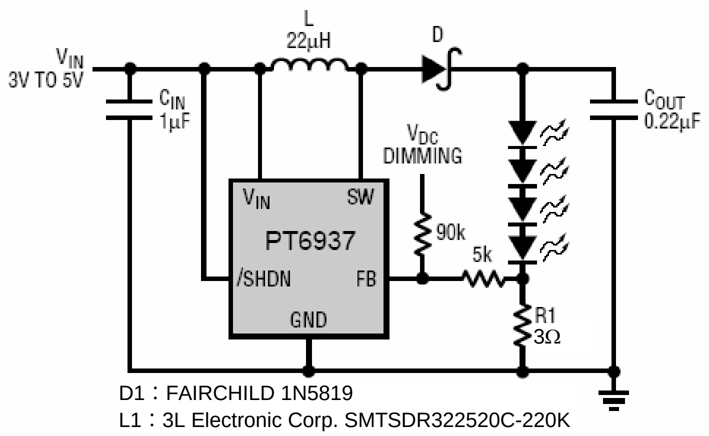


D1：FAIRCHILD 1N5819
L1：3L Electronic Corp. SMTSDR322520C-220K

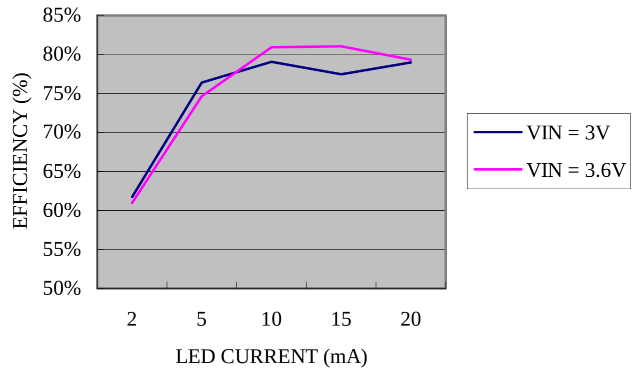
PTC PT6937 (3 LEDs)



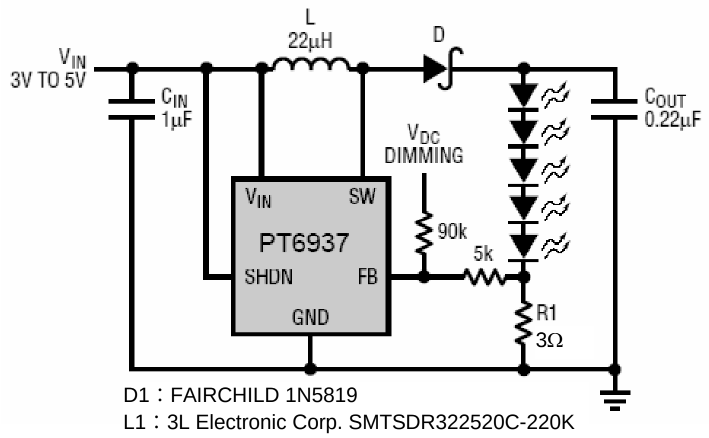
Li-Ion to Four White LEDs



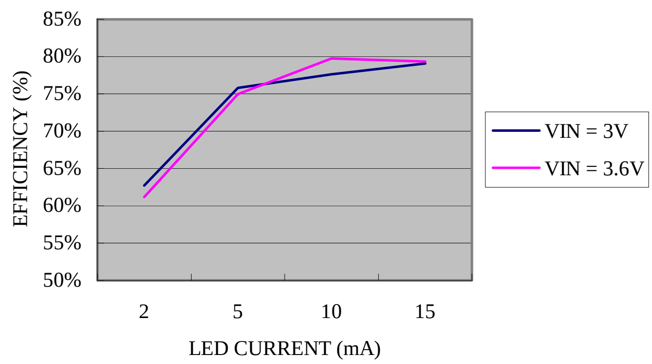
PTC PT6937 (4 LEDs)



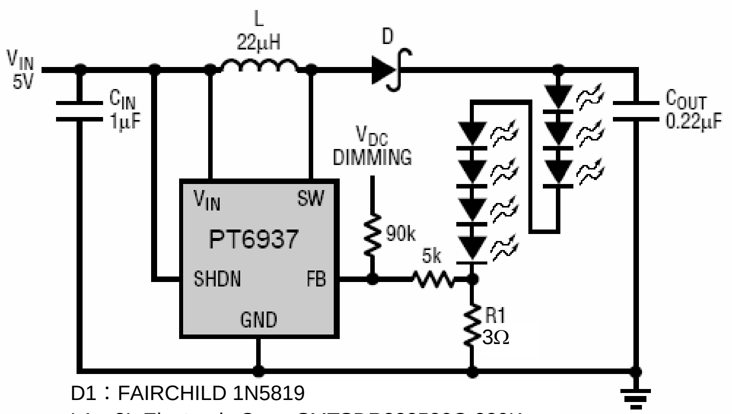
Li-Ion to Five White LEDs



PTC PT6937 (5 LEDs)

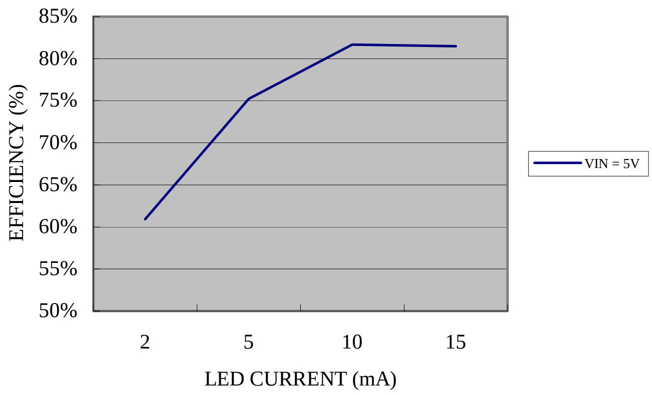


5V to Seven White LEDs

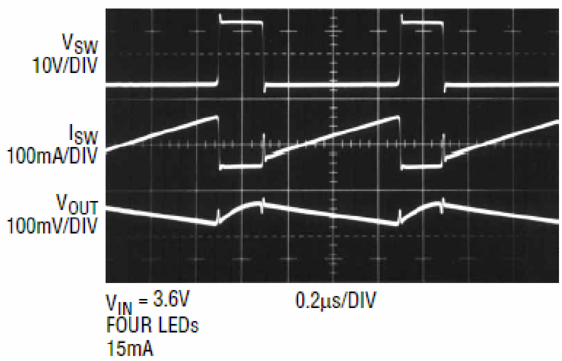


D1：FAIRCHILD 1N5819
L1：3L Electronic Corp. SMTSDR322520C-220K

PTC PT6937 (7 LEDs)



Switching Waveforms



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ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Ratings	Unit
Input Voltage	VIN	5	V
SW Voltage		36	V
FB Voltage		5	V
/SHDN Voltage		5	V
Operating Temperature		-40 to +85	°C
Storage Temperature		-65 to +150	°C
Maximum Junction Temperature		125	°C
Lead Temperature (Soldering, 10 sec.)		300	°C

Note: Absolute Maximum Ratings are those values beyond which the life of the device may be impaired.

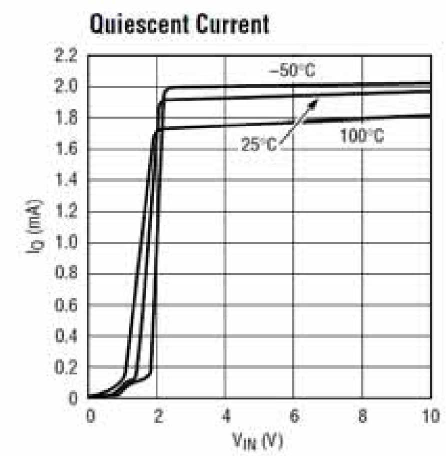
ELECTRICAL CHARACTERISTICS

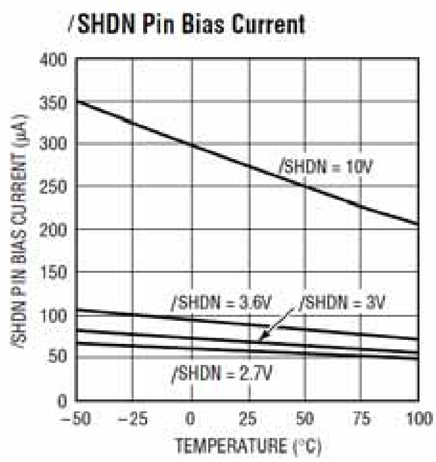
TA = 25°C, VIN = 3V, V /SHDN = 3V, unless otherwise noted.

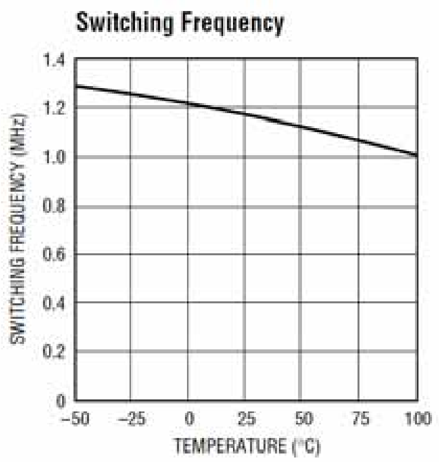
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Minimum Operating Voltage		2.5			V
Maximum Operating Voltage				5	V
Feedback Voltage	ISW = 100mA, Duty Cycle = 66%	86	95	104	mV
FB Pin Bias Current		10	45	100	nA
Supply Current	 /SHDN = 0V		0.75 0.1	1.2 1.0	mA µA
Switching Frequency		0.8	1.2	1.6	MHz
Maximum Duty Cycle		85	90		%
Switch Current Limit			320		mA
Switch VCESAT	ISW = 250mA		350		mV
Switch Leakage Current	VSW = 5V		0.01	5	µA
/SHDN Voltage High		1.5			V
/SHDN Voltage Low				0.4	V
/SHDN Pin Bias Current			20		µA

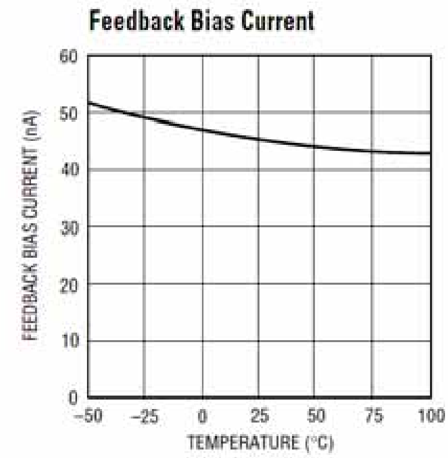
Note: The PT6937 is guaranteed to meet specifications from 0°C to 70°C. Specifications over the –40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

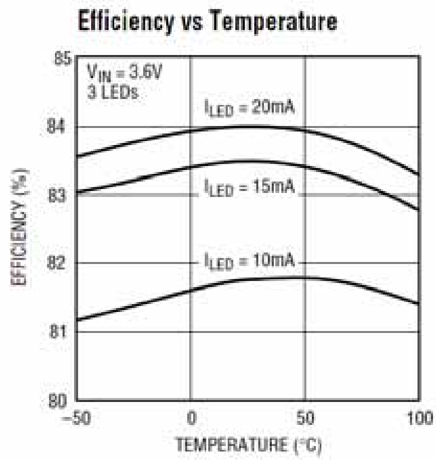
TYPICAL PERFORMANCE CHARACTERISTICS

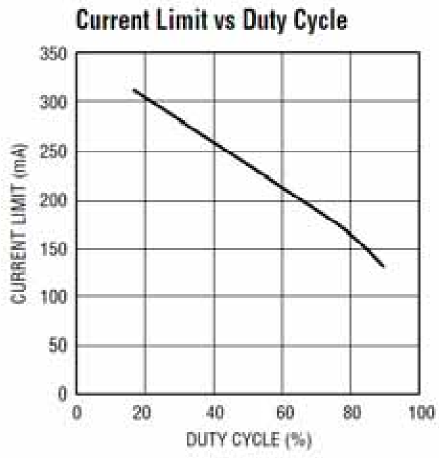










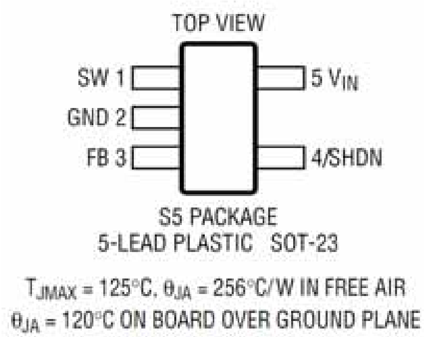


ORDER INFORMATION

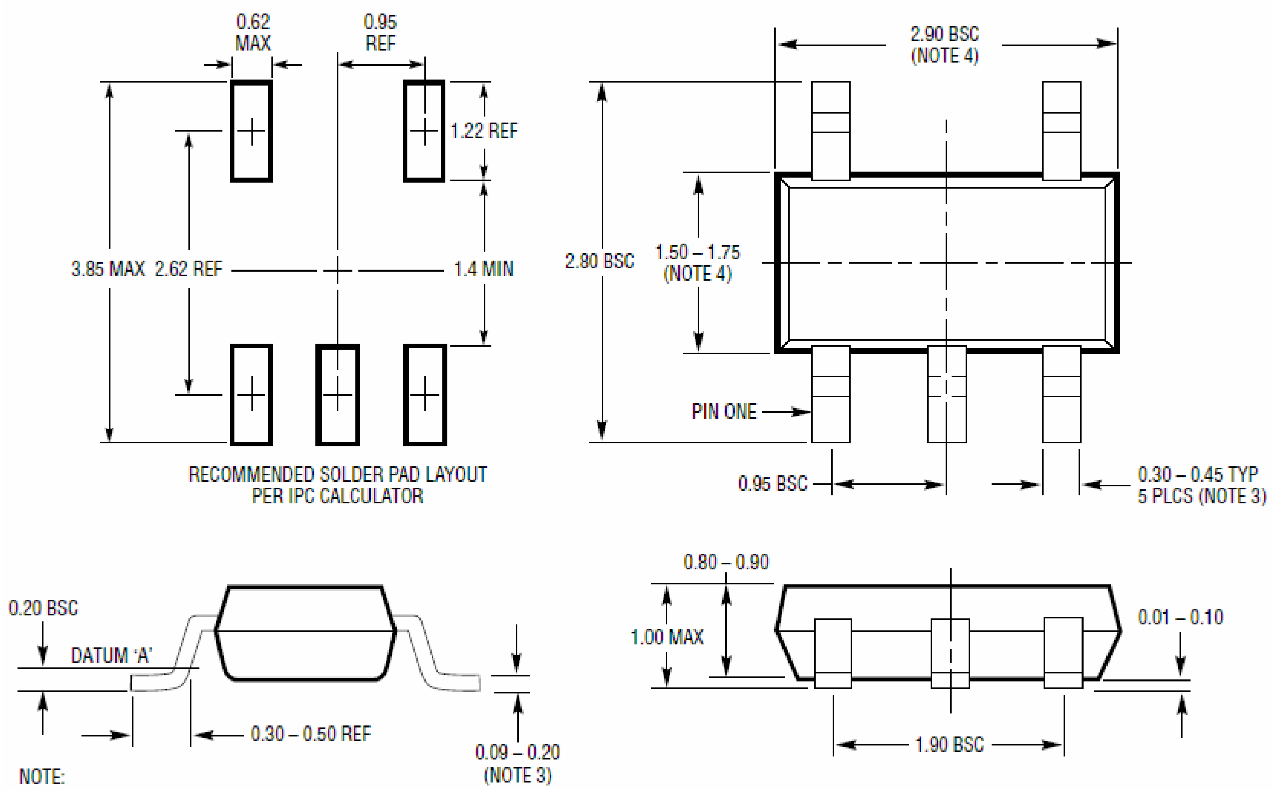
Order Part Number	Package	Top Code
PT6937	SOT Package	PT6937

Tel: 886-2-66296288
Fax: 886-2-29174598
URL: http://www.princeton.com.tw

PACKAGE INFORMATION



S5 Package
5-Lead Plastic SOT-23



NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
2. DRAWING NOT TO SCALE
3. DIMENSIONS ARE INCLUSIVE OF PLATING
4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
5. MOLD FLASH SHALL NOT EXCEED 0.254mm
6. JEDEC PACKAGE REFERENCE IS MO-193

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REVISION HISTORY

Date	Revision #	Reference #	Remarks
February 20, 2004	01	PT6937 ref1.0	New spec.
March 17, 2004	02	PT6937 ref1.1	Req: 040308