# SP1937
# DC-DC Step-Up Converter for White LED

## APPLICATION INFORMATION

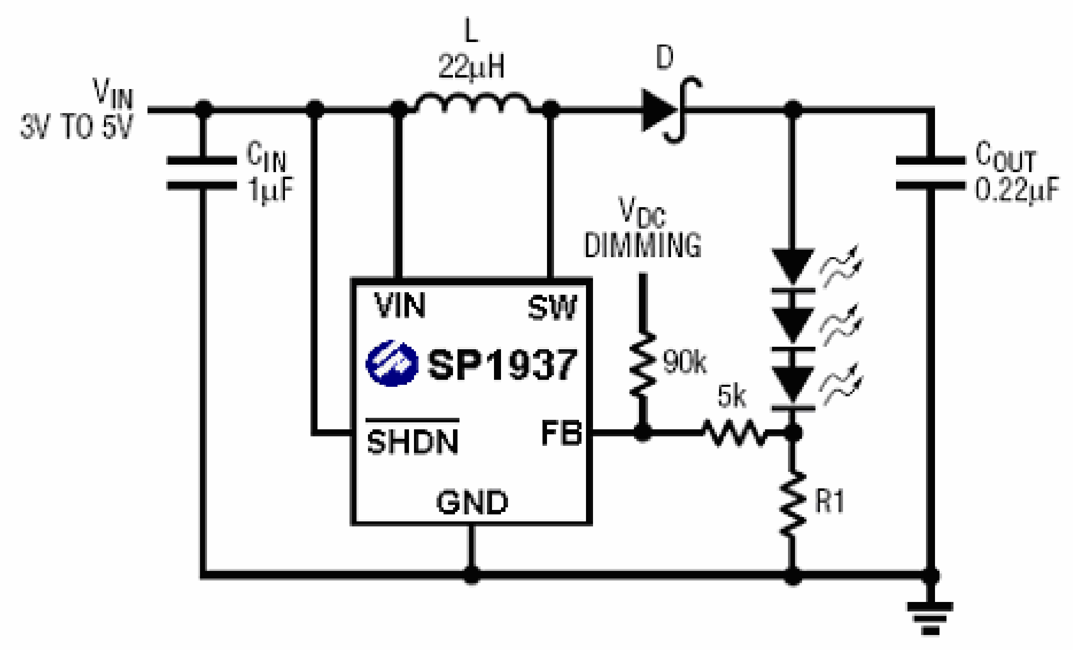


**Fig.1 SP1937 Application Diagram**

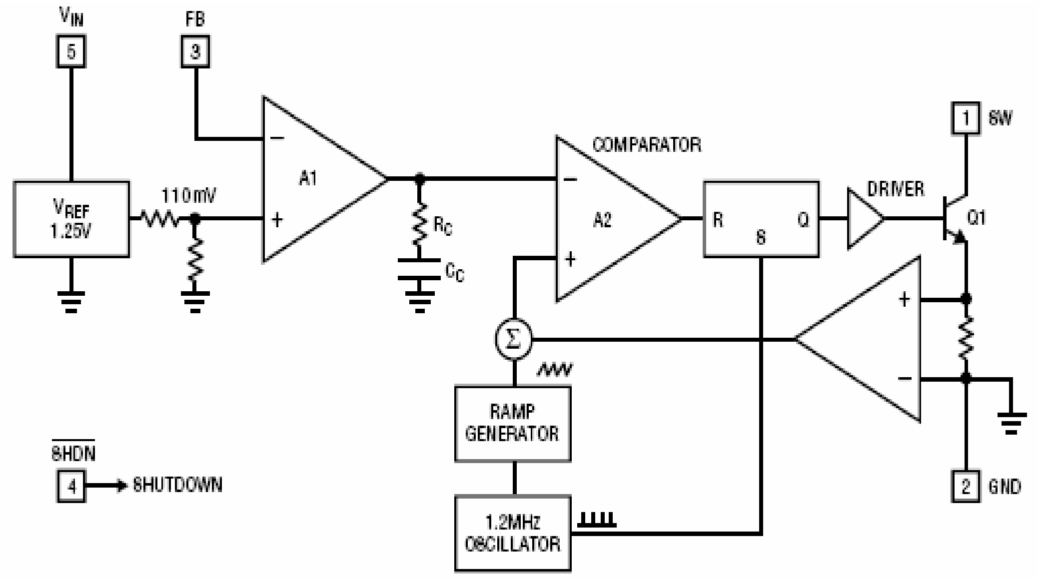


**Fig.2 SP1937 Block Diagram**

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The SP1937 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 2. 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 110mV. 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 SP1937 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 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 photo in Figure 3 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 300W resistor across the inductor, although this will degrade efficiency.

**Inductor Selection**

A 22mH inductor is recommended for most SP1937 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).

**CH1: VCC / CH2: Vsw / CH3: Inductor current**

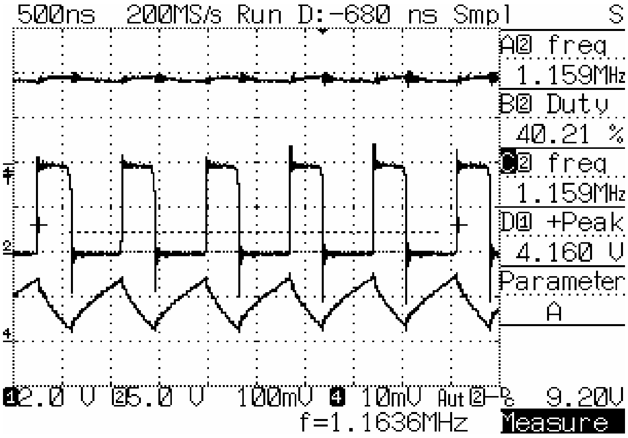


**Fig.3 : Vin=3.75V ; Vout=8.957V ; Iout=14.698mA**

**Capacitor Selection**

The small size of ceramic capacitors makes them ideal for SP1937 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 1mF input capacitor and a 0.22mF output capacitor are sufficient for most SP1937 applications.

**Diode Selection**

Schottky diodes, with their low forward voltage drop and fast reverse recovery, are the ideal choices for SP1937 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 SP1937. A Schottky diode rated at 100mA to 200mA is sufficient for most SP1937 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 110mV/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)**

**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 SP1937 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 22V 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.

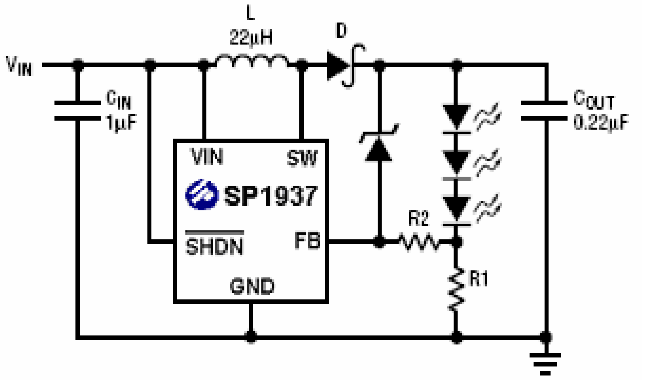


**Fig.4 : LED Driver with Open-Circuit Protection**

**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 SP1937 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 LT1937 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

**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 Figure.5 . 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 5 gives dimming control of LED current from 0mA to 15mA.

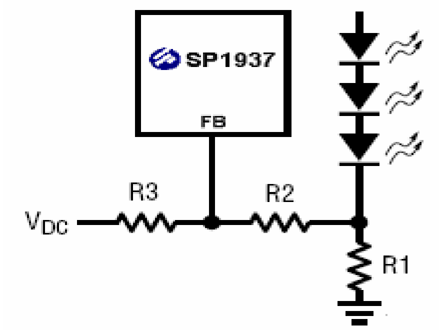


**Fig.5 : Dimming Control Using a DC Voltage**

**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 6.

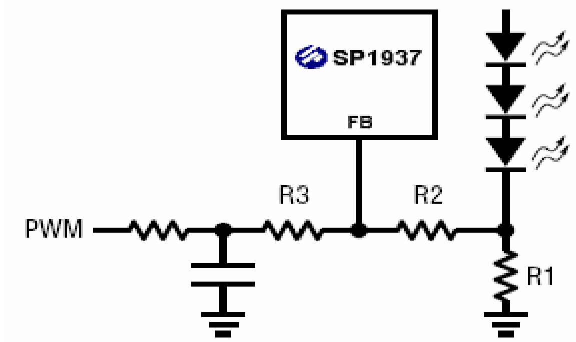


**Fig.6 : Dimming Control Using a Filtered PWM Signal**

**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 7. 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.

**Start-up and Inrush Current**
To achieve minimum start-up delay, no internal soft-start circuit is included in SP1937. When first turned on without an external soft-start circuit, inrush current is about 200mA. If soft-start is desired, the recommended circuit are shown in Figure 8. If both

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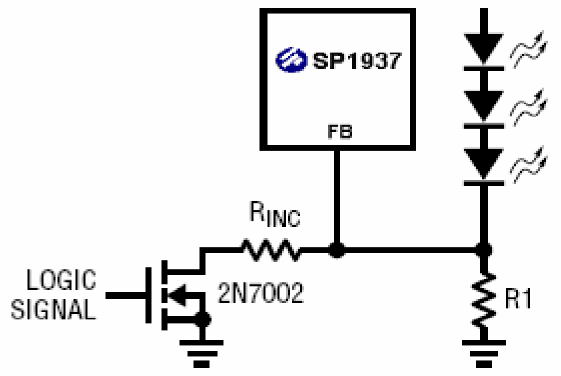



**Fig.7 : Dimming Control Using a Logic Signal**

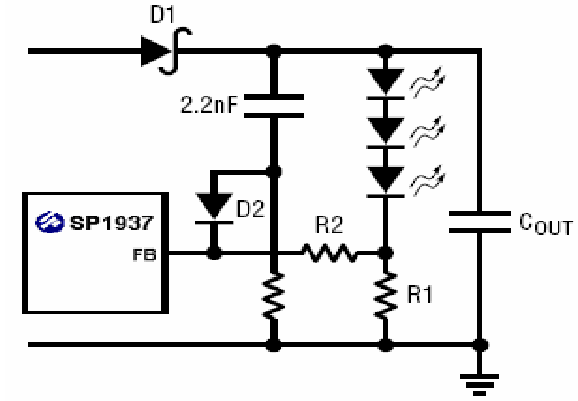


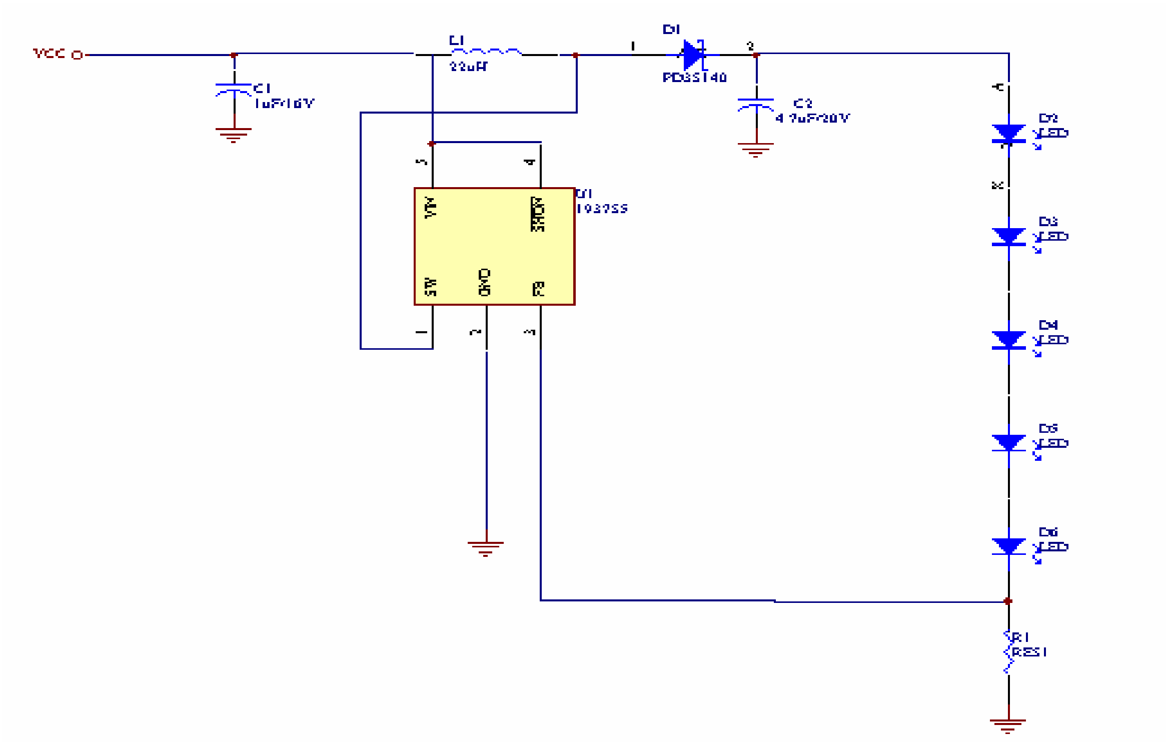

**Fig.8 : Recommended Soft-Startup Circuit**

soft-start and dimming are used, a 10kHz PWM signal on SHDN is not recommended. Use a lower frequency or implement dimming through the FB pin as shown in Figures 5, 6 or 7.

**Board Layout Consideration**

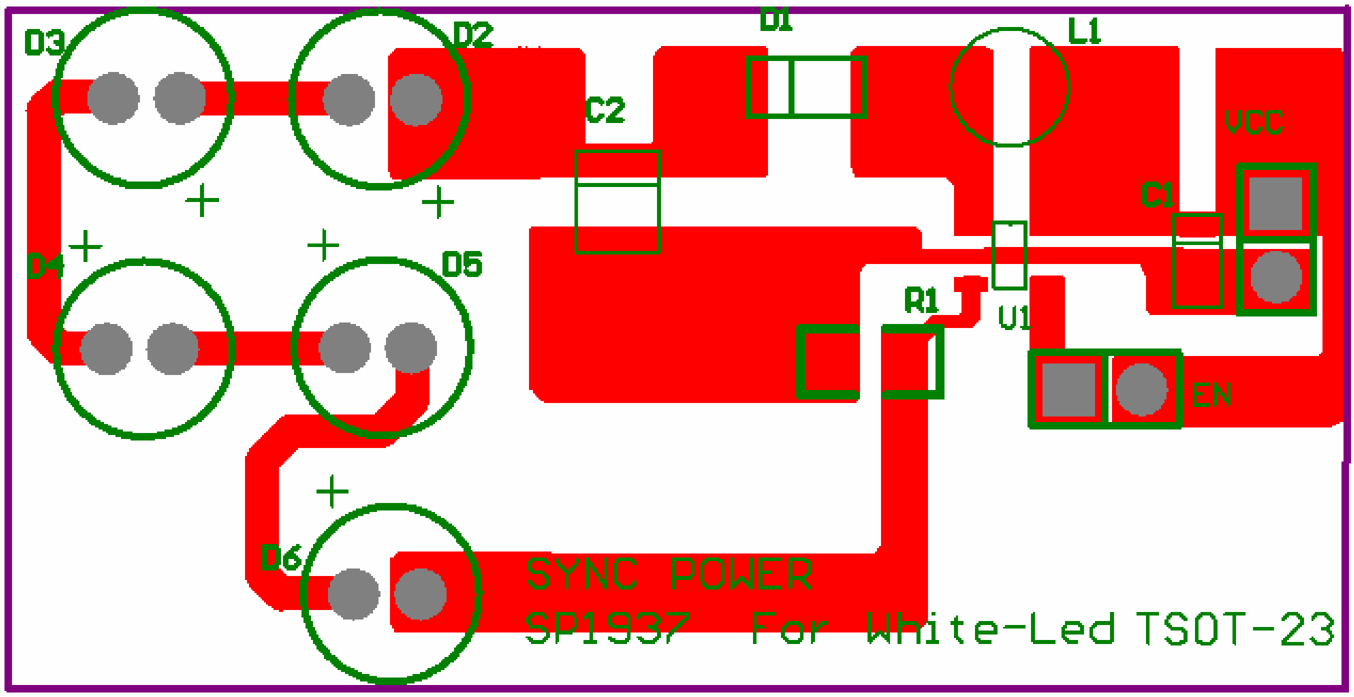
As with all switching regulators, careful attention must be paid to the PCB board layout and component placement. To maximize efficiency, switch rise and fall times are made as short as possible. To prevent electromagnetic interference (EMI) problems, proper layout of the high frequency switching path 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 inter plane 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 PCB Layout.

## Application Circuit

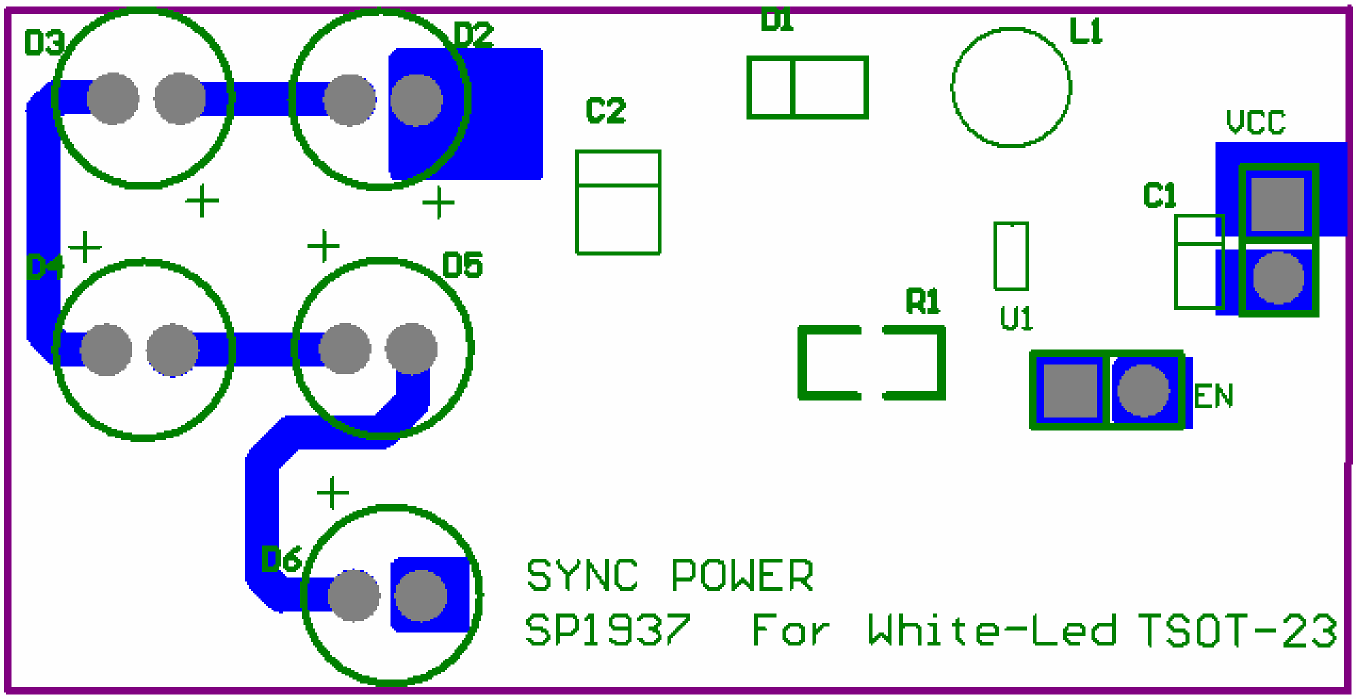


**PCB Layout Diagram ( SOT-23-5L )**

**TOP**




**BOTTOM**



# SP1937
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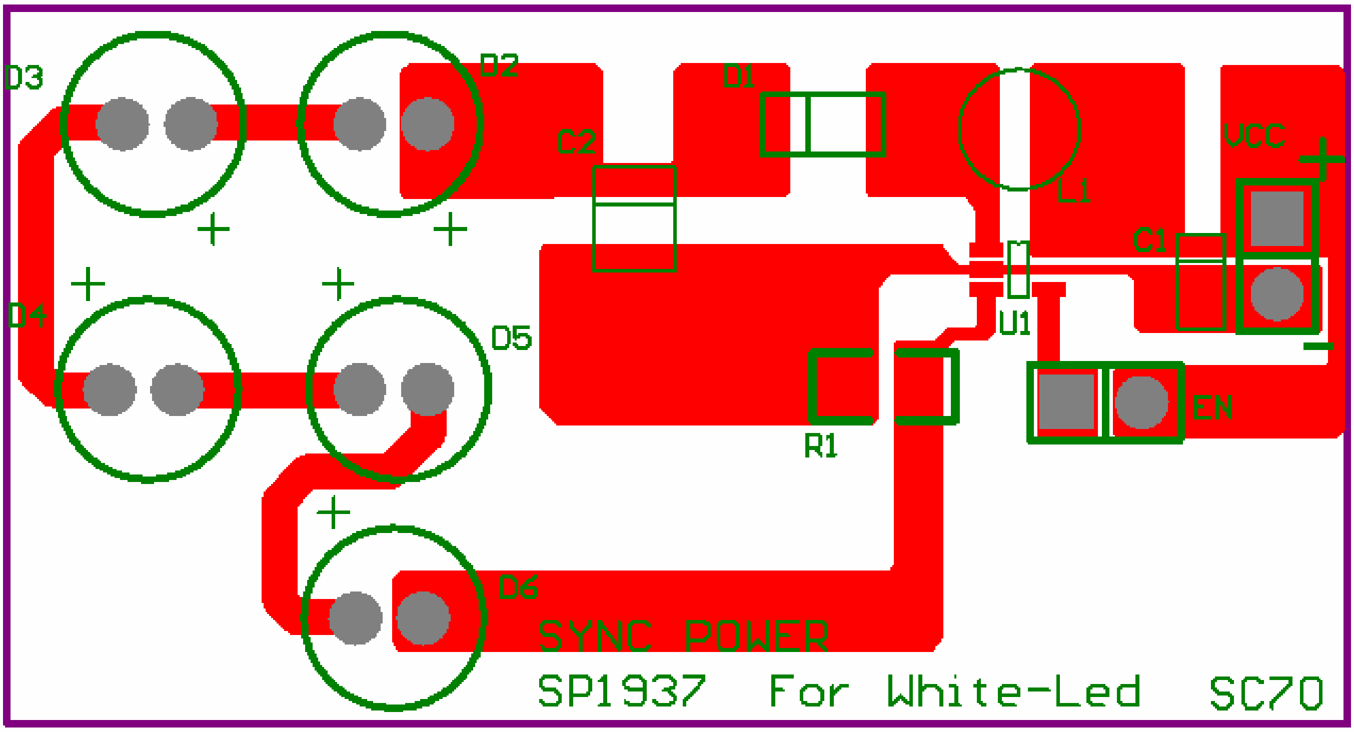
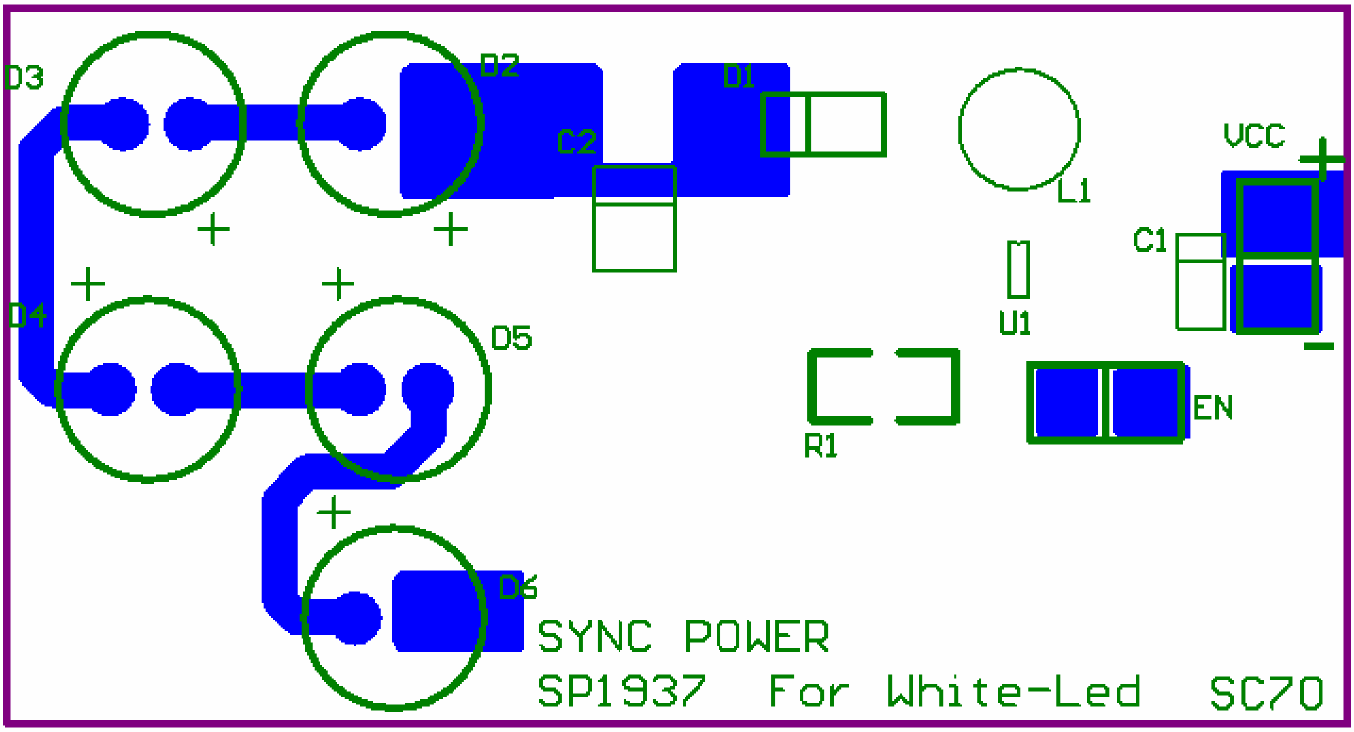
**PCB Layout Diagram ( SOT-353 )**

**TOP**




**BOTTOM**



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