Built-In OVP White LED Step-Up Converter in Tiny Package

Description

The FP6737/A is a step-up DC/DC converter specifically designed to drive white LEDs with a constant current. The device can drive two to seven LEDs in series from a Li-Ion cell. Series connection of the LEDs provides identical LED current resulting in uniform brightness and eliminating the need for ballast resistors. The FP6737/A switches at 1.2MHz, allowing the use of tiny external components. The output capacitor can be as small as 0.22μF for saving space and cost versus alternative solutions. A low 250mV/104mV feedback voltage minimizes power loss in the current setting resistor for better efficiency.

The FP6737/A is available in low profile SOT-23-6 and TSOT-23-6 packages.

Features

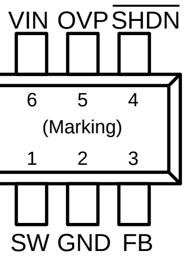
- Inherently Matched LED Current
- High Efficiency: 87%
- Drives up to Seven LEDs from a 3.2V Supply
- 33V Internal Switch
- Fast 1.2MHz Switching Frequency
- Use Tiny 1mm Tall Inductors
- Need only 0.22μF Output Capacitor
- Low Profile SOT-23-6 and TSOT-23-6 Packages
- Built-In Open Circuit Protection
- Over Voltage Protection
- RoHS Compliant

Applications

- Cellular Phone
- Digital Camera
- MP3 Player
- GPS Receiver
- PDA, Handheld Computer

Pin Assignments

S6 Package (SOT-23-6)



S9 Package (TSOT-23-6)

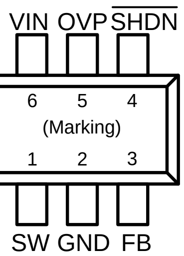
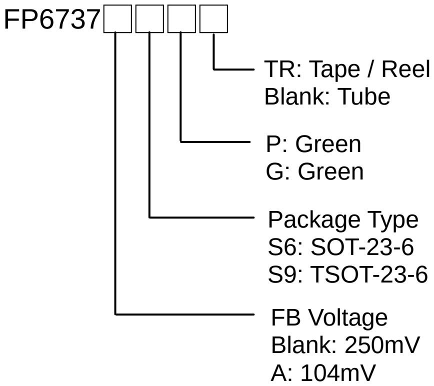


Figure 1. Pin Assignment of FP6737/A

Ordering Information



SOT-23-6 Marking

Part Number	Product Code
FP6737S6P	**C4**
FP6737AS6G	**aV=**

TSOT-23-6 Marking

Part Number	Product Code
FP6737S9P	**C1**
FP6737AS9G	**aW=**

Typical Application Circuit

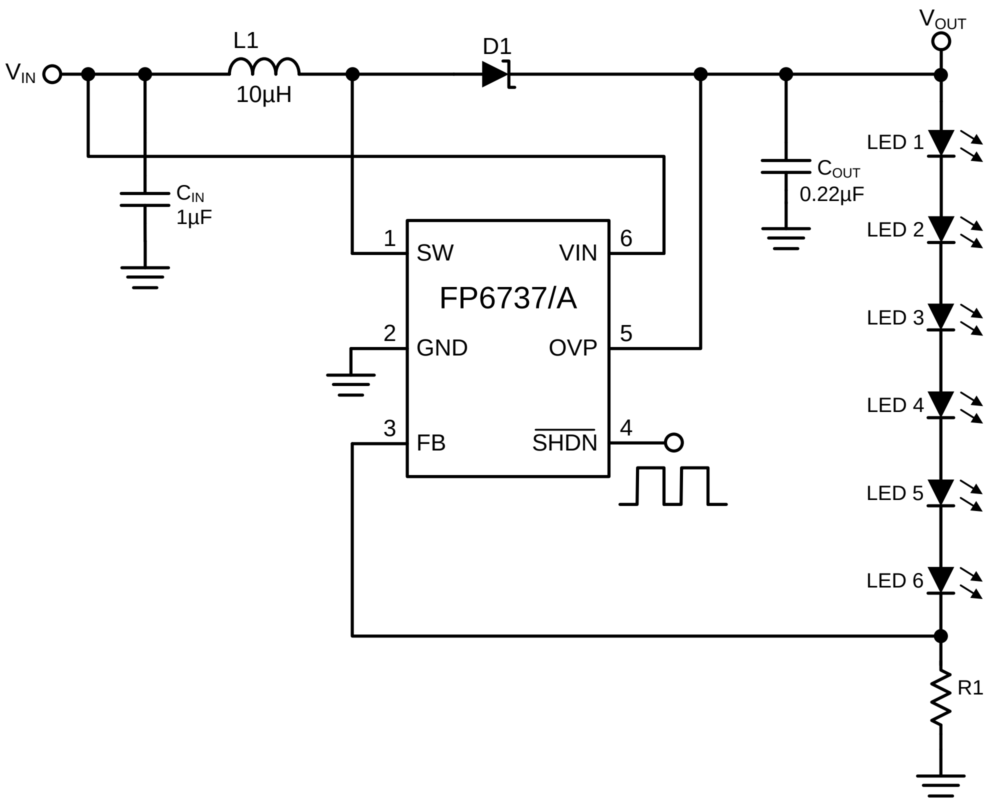


Figure 2. Typical Application Circuit of FP6737/A

Functional Pin Description

Pin Name	Pin Function
SW	Switch Pin. Connect inductor/diode here. Minimize trace area at this node to reduce EMI.
GND	Ground Pin. Connect to local ground plane directly.
FB	Feedback Pin. Connect cathode of the lowest LED and resistor here. Calculate resistor value according to the formula: $R_{FB}=V_{FB}/I_{LED}$
$\overline{\text{SHDN}}$	Shutdown Pin. Force 1.5V or higher voltage to enable the device; force 0.4V or lower voltage to disable the device.
OVP	Over-Voltage Protection Sensing Input Pin. The function will be triggered when the trip point reaches 28V. Leave it unconnected to disable this function.
VIN	Input Supply Pin. Must be locally bypassed.

Block Diagram

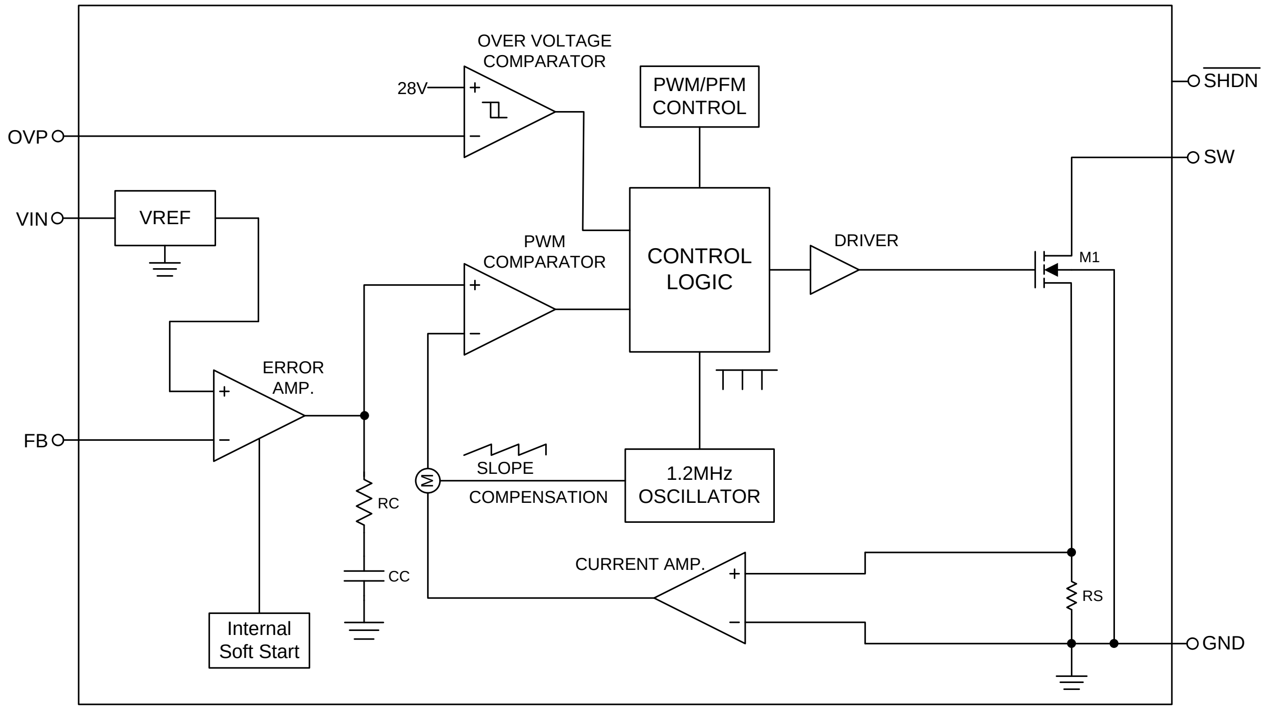


Figure 3. Block Diagram of FP6737/A

Absolute Maximum Ratings

- Supply Input Voltage (VIN) --- +6V
- SW, OVP Voltage --- +33V
- FB Voltage --- +6V
- $\overline{\text{SHDN}}$ Voltage --- +6V
- Power Dissipation @T_A=25ºC, SOT-23-6/TSOT-23-6 (P_D) --- +0.4W
- Package Thermal Resistance SOT-23-6/TSOT-23-6 (θ_{JA}) --- +250ºC/W
- Maximum Junction Temperature (T_J) --- +150ºC
- Storage Temperature Range (T_S) --- -65ºC to +150ºC
- Lead Temperature (Soldering, 10 sec.) (T_{LEAD}) --- +260ºC

Note 1：Stresses beyond those listed under “Absolute Maximum Ratings" may cause permanent damage to the device.

Recommended Operating Conditions

- Input Voltage (V_{IN}) -- +2.5V to +5.5V
- Operating Temperature Range -- -40ºC to +85ºC

Electrical Characteristics

(V_{IN}=3V, $V_{\overline{SHDN}}$=3V, T_A=25ºC, unless otherwise specified)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input Voltage Range	V_{IN}		2.5		5.5	V
Supply Current	I_{IN}	Switching		0.7	1.5	mA
		Non switching		50	100	µA
		$V_{\overline{SHDN}}$=0V		0.1	1	
ERROR AMPLIFIER						
Feedback Voltage	V_{FB}	FP6737	237	250	263	mV
		FP6737A	94	104	114	
FB Input Bias Current	I_{FB}	V_{FB}=250mV		1		nA
OSCILLATOR						
Switching Frequency	f_{OSC}		0.9	1.2	1.5	MHz
Maximum Duty Cycle	D		85	90		%
POWER SWITCH						
Switch Current Limit (Note 2)	I_{LIM}			350		mA
Switch On Resistance	$R_{DS(ON)}$			1	5	Ω
Switch Leakage Current	$I_{SW(OFF)}$	V_{SW}=33V		0.1	1	µA
CONTROL INPUT						
$\overline{SHDN}$ Voltage High	V_{IH}	ON	1.5			V
$\overline{SHDN}$ Voltage Low	V_{IL}	OFF			0.4	V
OVER VOLTAGE PROTECTION						
OVP Input Resistance (Note 2)	R_{OVP}			1.2		MΩ
OVP Threshold	V_{OVP}	1V Hysteresis typical	25	28	31	V

Note 2：Guarantee by design.

Typical Performance Curves

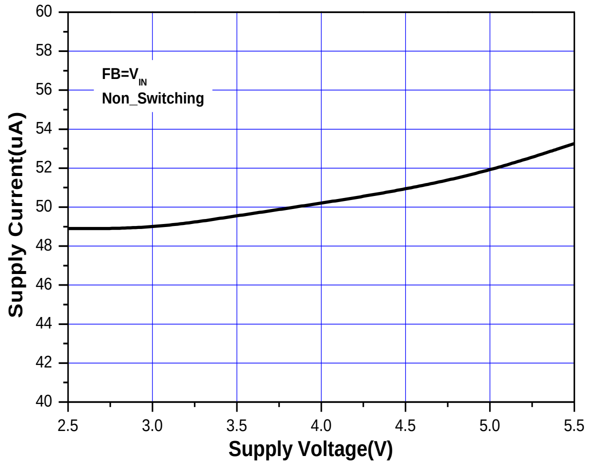


Figure 4.Supply Current vs. Supply Voltage

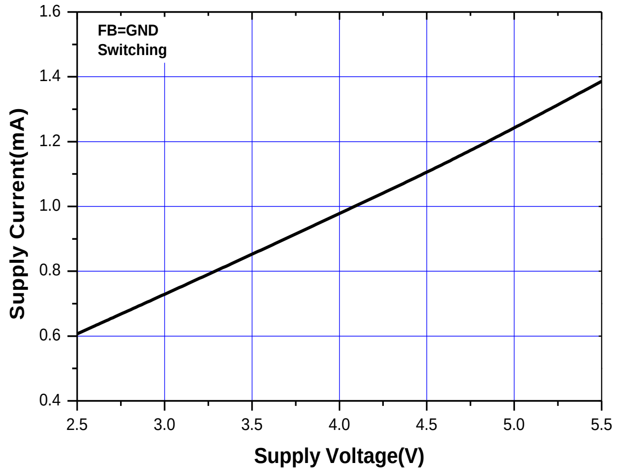


Figure 5.Supply Current vs. Supply Voltage

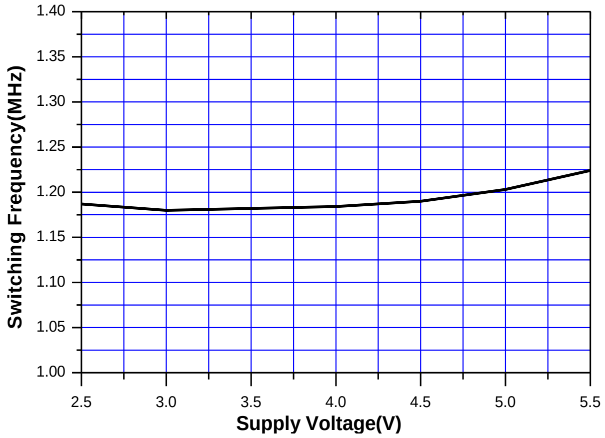


Figure 6. Switching Frequency vs. Supply Voltage

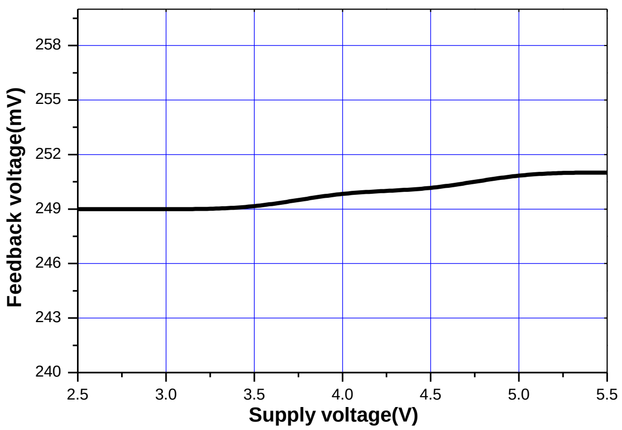


Figure 7. Feedback Voltage vs. Supply Voltage

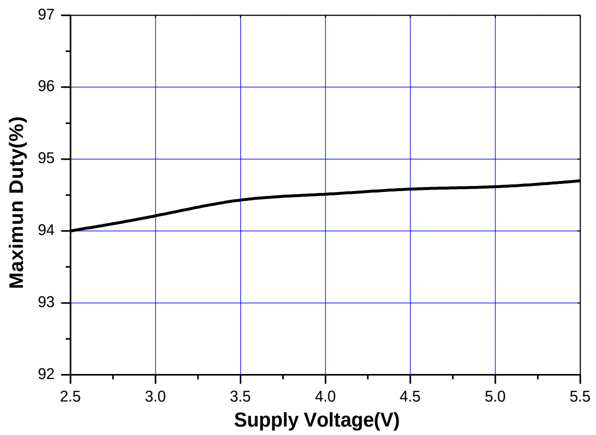


Figure 8. Maximum Duty vs. Supply Voltage

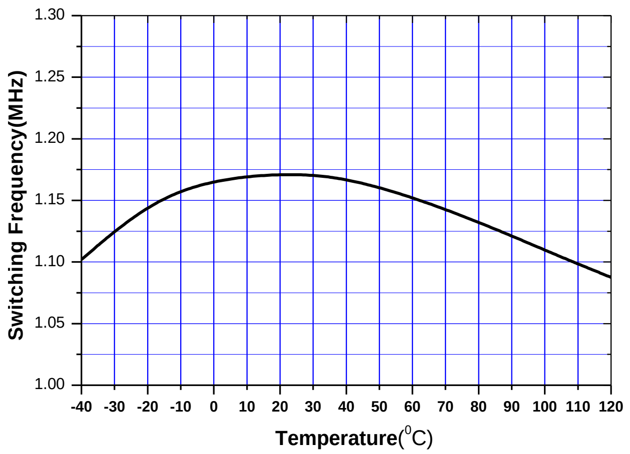


Figure 9. Switching Frequency vs. Temperature

Typical Performance Curves (Continued)

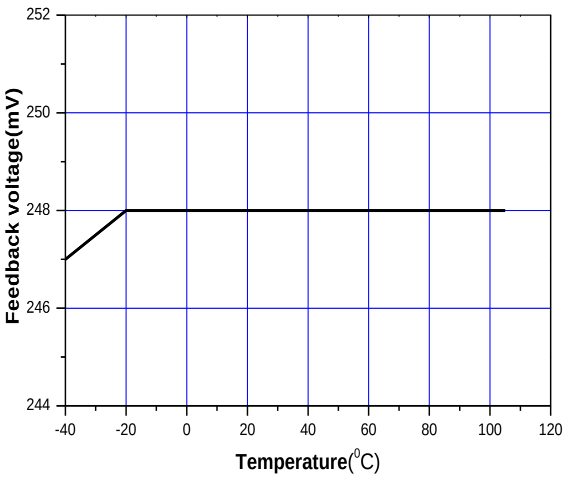


Figure 10. Feedback Voltage vs. Temperature

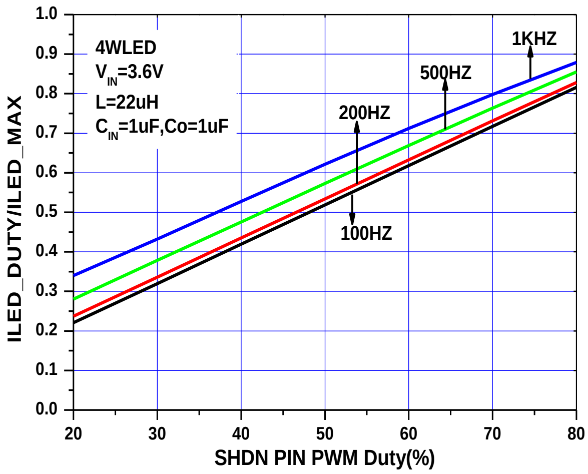


Figure 11. Dimming Control by Shutdown PIN

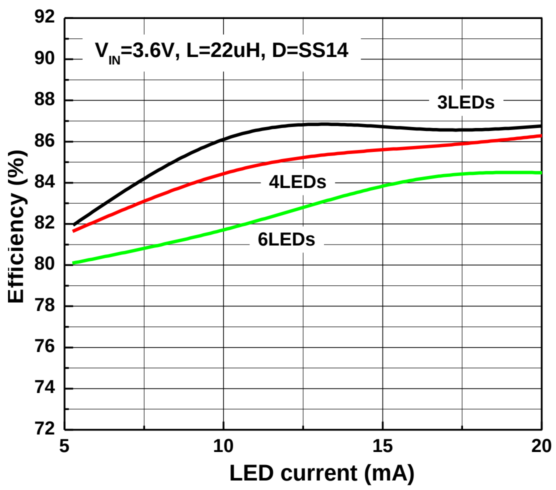


Figure 12. Efficiency vs. LED Current

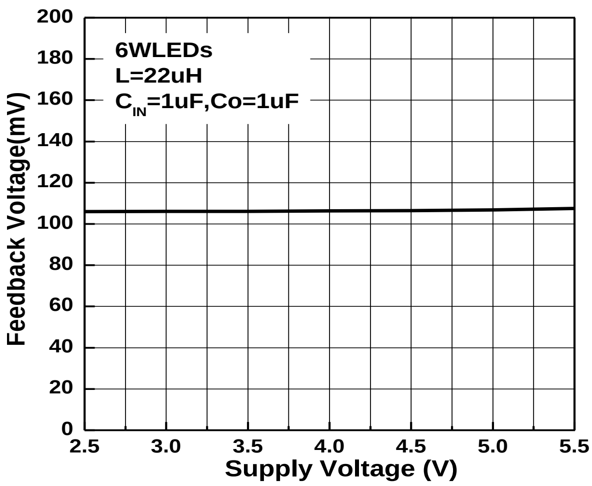


Figure 13. Feedback Voltage vs. Supply Voltage

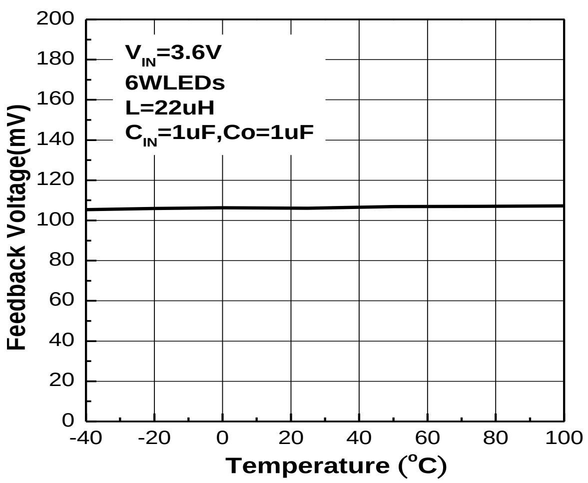


Figure 14. Feedback Voltage vs. Temperature

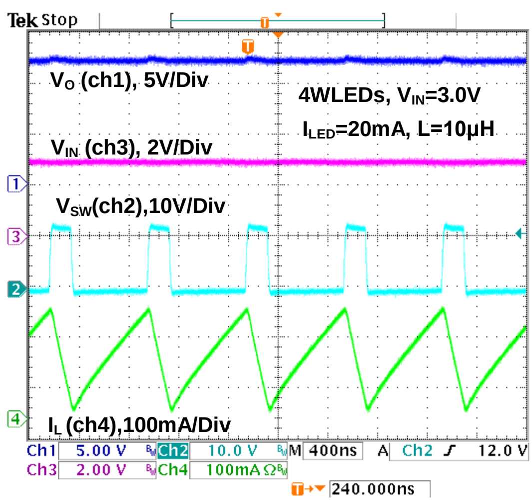


Figure 15. Operation Waveform

Typical Performance Curves (Continued)

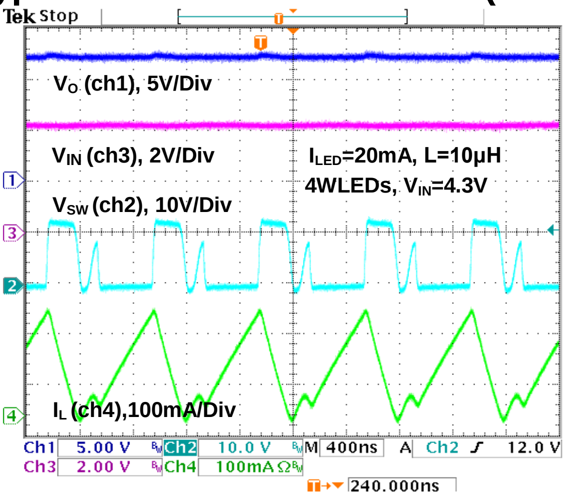


Figure 16. Operation Waveform

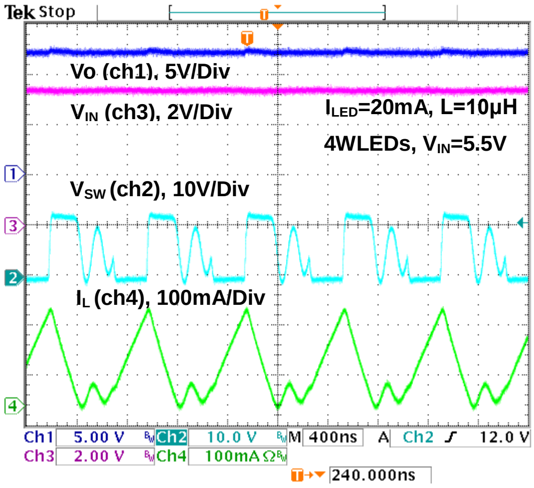


Figure 17. Operation Waveform

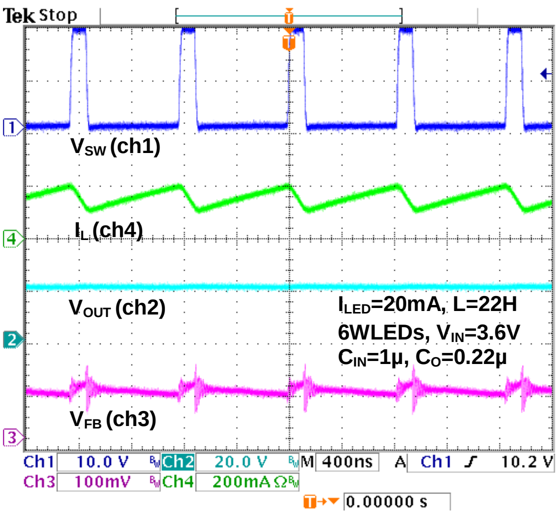


Figure 18. Operation Waveform

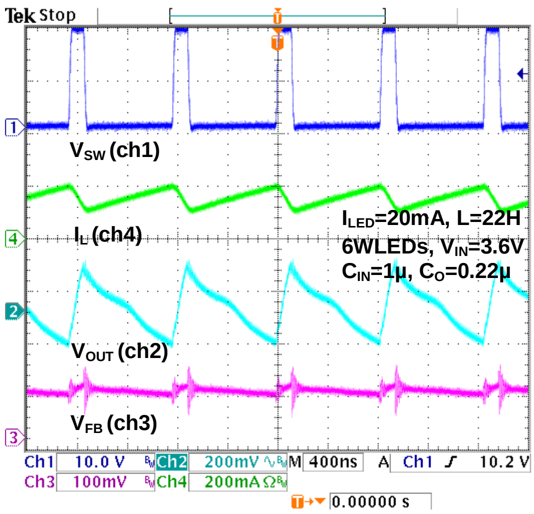


Figure 19. Operation Waveform

Application Information

Inductor Selection

A 10μH inductor is recommended for most FP6737/A 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 FP6737/A applications. X5R and X7R types are recommended because they retain their capacitance over wider voltage and temperature ranges better than other types such as Y5V or Z5U. A 1μF input capacitor and a 0.47μF output capacitor are sufficient for most FP6737/A applications.

Diode Selection

The Schottky diodes, with their low forward voltage drop and fast reverse recovery, are the ideal choices for FP6737/A 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 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 1MHz switching frequency of the FP6737/A. A Schottky diode rated at 100mA to 400mA is sufficient for most FP6737/A applications.

LED Current Control

The LED current is controlled by the feedback resistor (R1 in Figure 20). The FP6737 feedback reference is 250mV and the FP6737A feedback reference is 104mV. The LED current is V_{FB}/R1. In order to have accurate LED current, precision resistors are preferred (1% is recommended). The formula and table for R1 selection are shown as below.

Version	Feedback Reference Voltage V_{FB}(V)	LED Current Setting I_{LED}(A)
FP6737	0.25	0.25/R1
FP6737A	0.104	0.104/R1

Table 1. R1 Resistor Value Selection

Over Voltage Protection

The FP6737/A has an internal open-lamp protection circuit. In the cases of output open circuit, when the LEDs are disconnected from the circuit or the LEDs fail open circuit, the over-voltage function will monitor the output voltage through SW pin to protect the converter against. The LED strings open will cause N-MOS to switch with a maximum duty cycle and come out output over-voltage. This may cause the SW voltage exceeds its maximum rating then damages built-in N-MOS. In the state, the OVP protection circuitry will be triggered if output voltage exceeds 25V (min.). The FP6737/A will then stop switching. The FP6737/A will automatically recover normal operation until SW is under 24V (1V hysteresis).

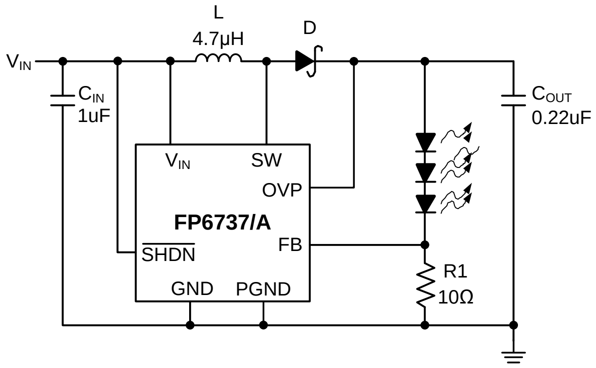


Figure 20. LED Driver with Open-Circuit Protection

Dimming Control

The LED current can be modulated by a DC voltage, PWM signal or a filtered PWM signal.

(1) Using a PWM Signal

With the PWM signal applied to the $\overline{SHDN}$ pin, the FP6737/A 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 FP6737/A and corresponds to zero LED current. A 100% duty cycle corresponds to full current. The typical frequency range of the PWM signal is 200Hz to 5kHz. The magnitude of the PWM signal should be higher than the minimum $\overline{SHDN}$ voltage.

Application Information (Continued)

(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 21. 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 FP6737, the VDC ranges from 1.75V to 2.75V, and for FP6737A, the VDC ranges from 0.144V to 1.144V, the selection of resistors in Figure 21 gives dimming control of LED current from 0mA to 20mA.

V_{DC} (FP6737)	I_{LED}
1.75V	20mA
2.25V	10mA
2.75V	0mA

Table 2. DC Voltage vs. LED Current

V_{DC} (FP6737A)	I_{LED}
0.144V	20mA
0.644V	10mA
1.144V	0mA

Table 3. DC Voltage vs. LED Current

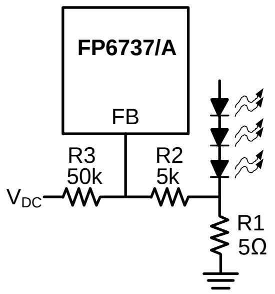


Figure 21. Dimming Control Using a DC Voltage

(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 22.

(4) Using a Logic Signal

For applications which need to adjust the LED current in discrete steps, a logic signal can be used as shown in Figure 23. R1 sets the minimum LED current (when the NMOS is off). RSET 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 FP6737/A. When first turned on without an external soft-start circuit, inrush current is about 200mA. If soft-start is desired, the recommended circuit is shown in Figure 24. If both soft-start and dimming are used, a 5kHz PWM signal on $\overline{SHDN}$ is not recommended. Use a lower frequency or implement dimming through the FB pin as shown in Figures 21, 22 or 23

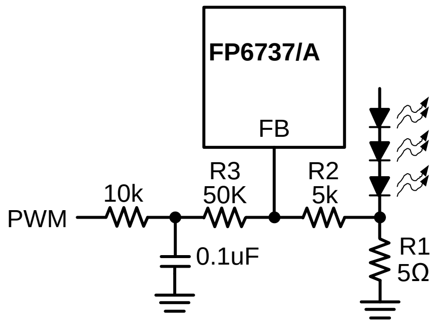


Figure 22. Dimming Control Using a Filtered PWM Signal

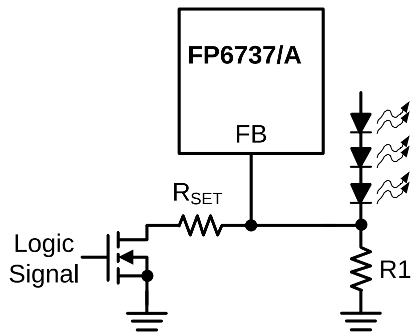


Figure 23. Dimming Control Using a Logic Signal

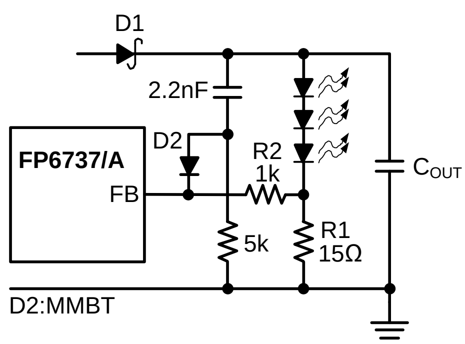
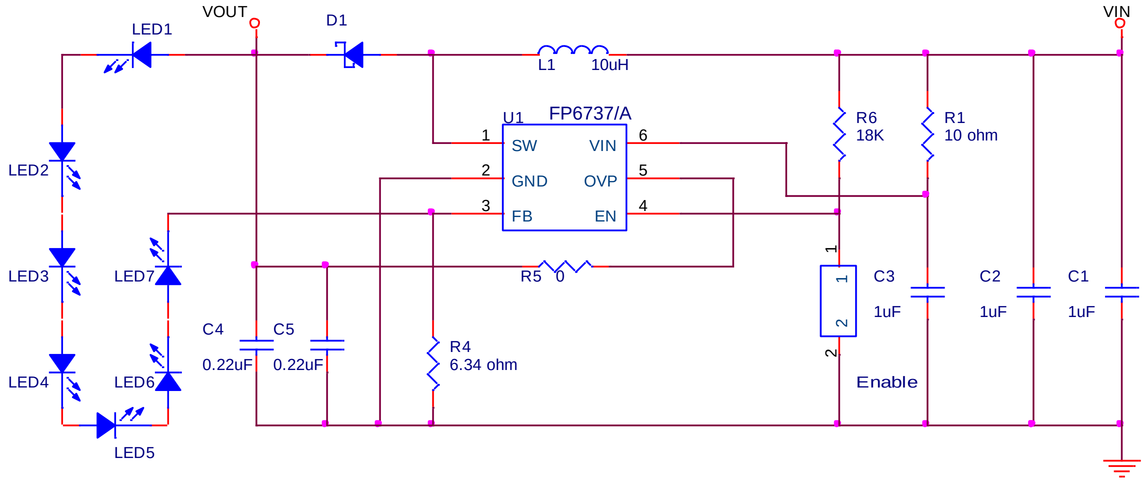


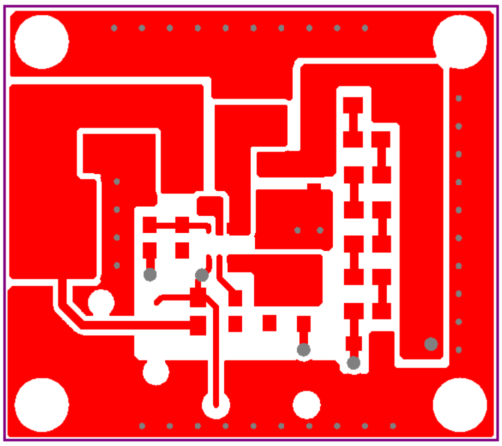
Figure 24. Recommended Soft-Startup Circuit

Demo Board Circuit & Layout

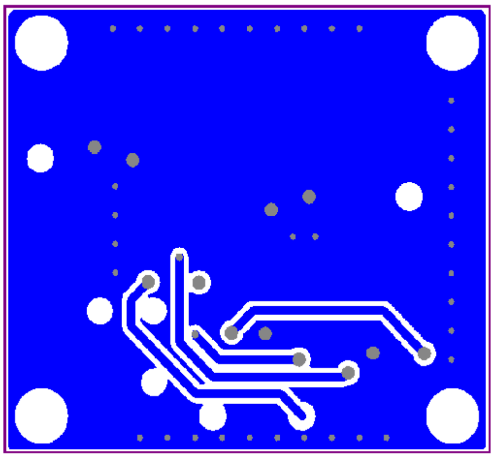
SOT-23-6 Package



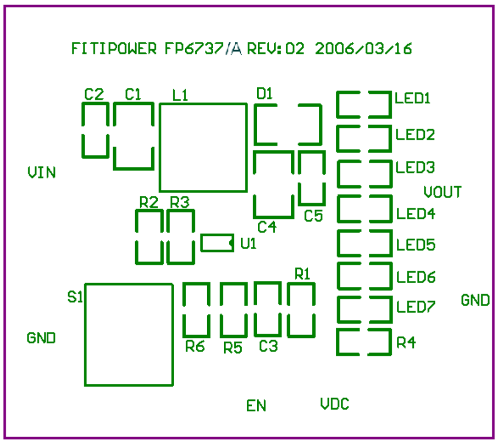
Top Side (SOT-23-6 Package)



Bottom Side (SOT-23-6 Package)

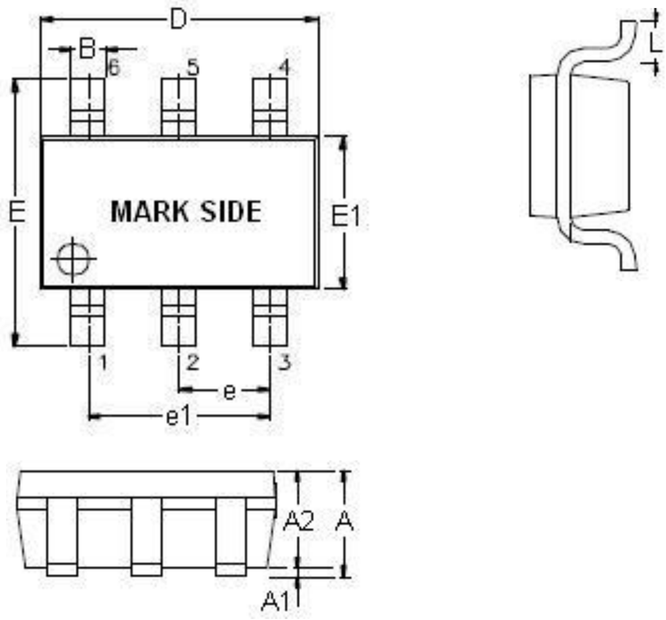


Component Placement(SOT-23-6 Package)



Outline Information

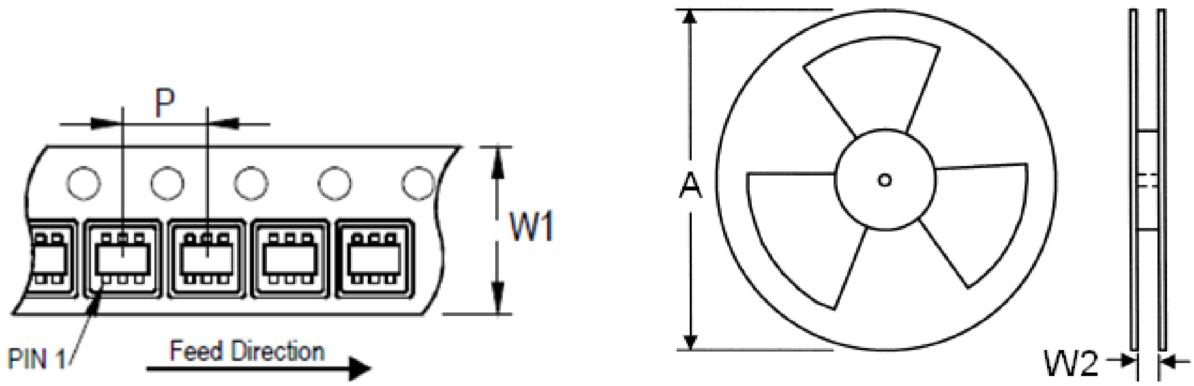
SOT-23-6 Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
B	0.30	0.50
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.70
e	0.90	1.00
e1	1.80	2.00
L	0.30	0.60

Note：Followed From JEDEC MO-178-C.

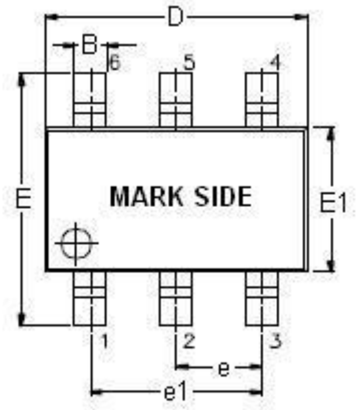
Carrier dimensions

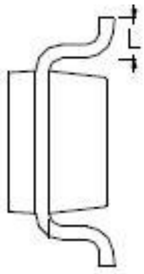


Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
8	4	7	180	8.4	300~1000	3,000

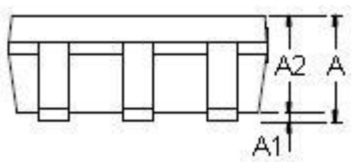
Outline Information (Continued)

TSOT-23-6 Package (Unit: mm)

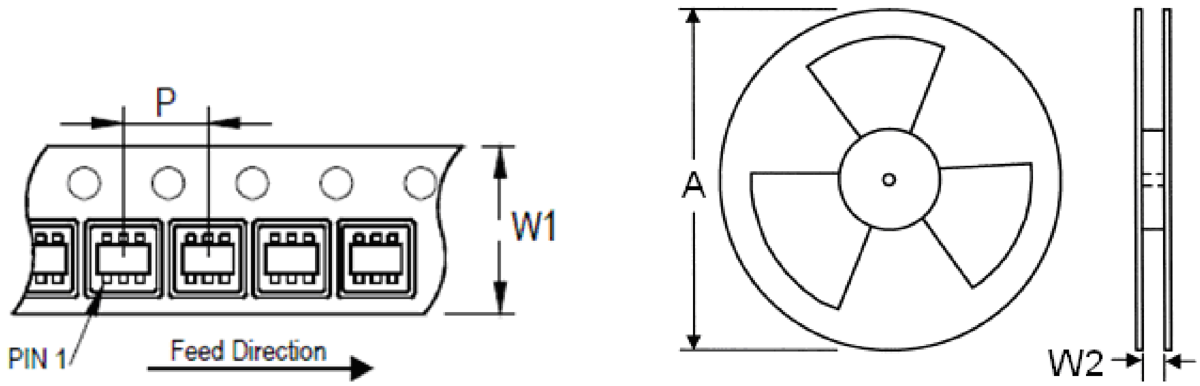




SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.70	1.10
A1	0.00	0.10
A2	0.70	1.00
B	0.30	0.50
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.70
e	0.90	1.00
e1	1.80	2.00
L	0.30	0.60



Carrier dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
8	4	7	180	8.4	300~1000	3,000