Tiny Package, High Performance, Constant Current Switching Regulator for 10X White LED

General Description

The uP6003 is a compact high-efficiency step-up converter with integrated switch specifically designed to drive up to ten white LEDs in series. Series connection of the LEDs provides identical current resulting in uniform brightness. Fixed 1.0 MHz operation allows smallest output ripple and external component size. With high conversion efficiency and small package, the uP6003 is suitable for portable devices which PCB area is especially concerned.

The uP6003 features over-voltage protection against open-LED situation. A single pin provides shutdown and accurate LED dimming control. Other features includes internal soft start, internal compensation, over-current protection, and over temperature protection.

The uP6003 is available in TSOT23-6L package.

Features

- **Drive Up to Ten White LEDs from 3V Supply**
  - **Wide VIN Range from 2.5V to 5.5V**
  - **Internal Soft-Start**
- **One Pin Shutdown and Dimming Control**
  - **Wide Range for PWM Dimming (100Hz to200kHz)**
  - **Under Voltage Protection**
- **Over-Temperature and Over-Voltage Protection**
- **Integrated 1.2A, 0.7Ω Switch**
- **Internal Compensation**
- **Small TSOT23-6L Package**
- **RoHS Compliant and Halogen Free**

Applications

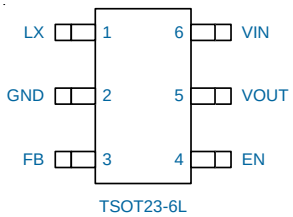
- **White LED Supply for Backlight Displays**
  - **Cellular Phones**
  - **PDSs, Handheld Computers**
  - **Digital Cameras**
  - **MP3 Players**
  - **GPS Receivers**
  - **Camcorders**

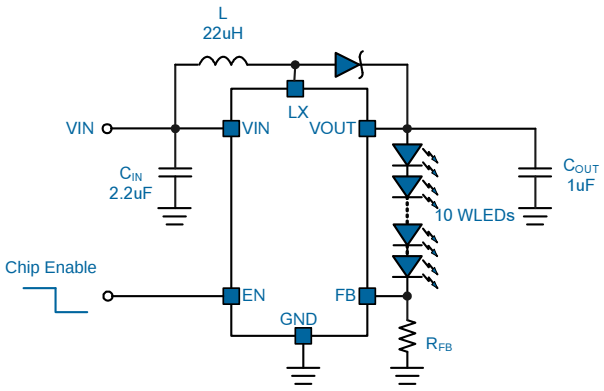
Ordering Information

Order Number	Package Type	Top Marking
uP6003AMT6	TSOT23-6L	N54

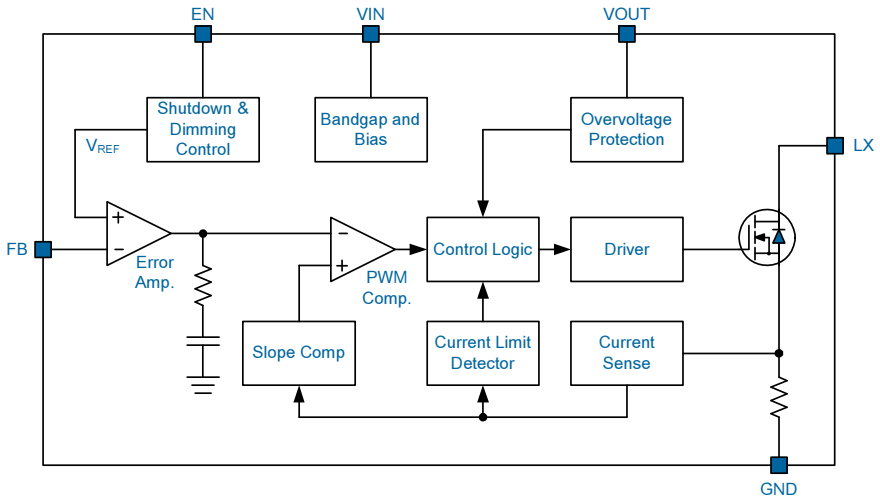
Note: uPI products are compatible with the current IPC/ JEDEC J-STD-020 requirement. They are halogen-free, RoHS compliant and 100% matte tin (Sn) plating that are suitable for use in SnPb or Pb-free soldering processes.

Pin Configuration & Typical Application Circuit





Functional Block Diagram



Functional Pin Description

Pin No.	Pin Name	Pin Function
1	LX	**Internal Switch Output.** The pin is the drain of internal NMOSFET. Connect this pin to the boost inductor and anode of external Schottky diode.
2	GND	**Ground.** Ties the pin directly to the cathode terminal of C_{IN} and C_{OUT} and ground plane with the lowest impedance. All small-signal and feedback components should connect to this pin.
3	FB	**Current Feedback.** This pin is the inverting-input of error amplifier. The LED current is sensed through a series resistor and regulated to internal reference voltage.
4	EN	**Shutdown and Dimming Control.** Pulling this pin low shuts down the converter and reduces its supply current down to 0.1uA. This pin receives pluses for LED dimming control (see the related section.)
5	VOUT	**Output Voltage.** Connect this pin directly to the output voltage. This pin is monitored for output overvoltage protection against open-LED. A minimum 1uF X5R or X7R ceramic capacitor is required.
6	VIN	**Power Supply Input.** Input voltage that supplies current to the output voltage and powers the internal control circuit. Bypass input voltage with a minimum 2.2uF X5R or X7R ceramic capacitor.

Functional Description

The uP6003 is a compact high-efficiency step-up converter with integrated switch specifically designed to drive up to 10 WLEDS in series. Series connection of the LEDs provides identical LED current resulting in uniform brightness. Fixed 1.0MHz operation allows smallest output ripple and external component size. With high conversion efficiency and small package, the uP6003 is suitable for portable devices where PCB area is especially concerned.

Power on Reset

The uP6003 continuously monitor supply input voltage at VIN pin for power on reset (POR). Once the rising POR threshold is exceeded, the uP6003 sets itself to active state and is ready to accept chip enable command. The POR threshold is typically 2.2V at V_{IN} rising with 0.1V hysteresis.

Enable/Disable

Pulling the EN pin higher than 1.4V enables the device and initiate its soft start cycle. Pulling the EN pin lower than 0.4V disables the device and reduces it shutdown current less than 1uA. When the EN pin pulls low, the uP6003 does not shuts down immediately but reduces the LED current gradually.

Soft Start

The uP6003 limits the in-rush current at start-up by increasing the current limit. This prevents unwanted shutdown otherwise may be triggered by voltage drop due to large inrush current.

LED Current Regulation

The uP6003 operates in a constant-frequency, slope-compensated peak-current-mode control to regulate the LED current. The LED current is sensed at FB pin by a current sensing resistor (R_{FB}): $V_{FB} = R_{FB} \times I_{LED}$. The error amplifier compares the feedback voltage with internal 0.3V reference and compensates the error signal to get current command level.

The internal NMOSFET turns on at the beginning of each switching cycle and lets the inductor current ramp up linearly. The NMOSFET turns off when the inductor current reaches the current command level. The uP6003 modulates on-time of NMOSFET by changing the current command to regulate the LED current.

Dimming Control

The uP6003 receives a PWM signal at EN pin for LED brightness control. The PWM signal is flatted by internal low pass filter to get a reference voltage that is proportional to the duty cycle of the PWM signal. The uP6003 does not turn off as the EN pin is pulled high or low as shown in the Typical Operation Characteristics section. This eliminates inrush current and audio noise that may occurs in convention PWM dimming control.

The PWM frequency range from 100Hz to 200kHz is acceptable and yield linear brightness control.

Current Limit Function

The uP6003 features cycle-by-cycle current to prevent the device from damage due over current that might be result from of abnormal operation.

The uP6003 turns off the NMOSFET when its current exceeds the current limit of 1.2A typical, preventing the indcutor current from continuously ramping up. The NMOSFT is turned on at next switching cycle. This minimizes the power dissipation and components stresses under over load and short-circuits conditions.

Over Voltage Protection

The over voltage protection prevents damage to uP6003 during high output voltage conditions. When the output voltage is higher than Threshold Limit, the converter stops switching and the output voltage decays. Switching would be turned on again when the voltage of the OVP pin drops below the below the lower hysteresis limit.

Over Temperature Protection

The excessive internal dissipation of thermal protection will malfunction uP6003. The junction over-temperature threshold is 160^{O}C with 30^{O}C of temperature hysteresis. The output voltage resumes when the over temperature fault condition is removed.

Absolute Maximum Rating

(Note 1)

Supply Input Voltage, V_{IN} ---------- -0.3V to +6V
LX, VOUT Pin Voltage ---------- -0.3V to +50V
Other Pins ---------- -0.3V to +6V
Storage Temperature Range ---------- -65°C to +150°C
Junction Temperature ---------- 150°C
Lead Temperature (Soldering, 10 sec) ---------- 260°C
ESD Rating (Note 2)
HBM (Human Body Mode) ---------- 2kV
MM (Machine Mode) ---------- 200V

Thermal Information

Package Thermal Resistance (Note 3)
TSOT23 -6L θ_{JA} ---------- 250°C/W
TSOT23 -6L θ_{JC} ---------- 100°C/W
Power Dissipation, P_D @ T_A = 25°C
TSOT23 -6L ---------- 0.4W

Recommended Operation Conditions

(Note 4)

Operating Junction Temperature Range ---------- -40°C to +125°C
Operating Ambient Temperature Range ---------- -40°C to +85°C
Supply Input Voltage, V_{IN} ---------- +2.8V to +5.5V

Electrical Characteristics

(V_{IN} = 3.7V, C_{IN} = 2.2uF, C_{OUT} = 1uF, I_{OUT} = 20mA, L = 22uH, T_A=25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supply Current						
Supply Voltage Range	V_{IN}		2.5	--	5.5	V
Power On Reset Threshold	V_{IN}	V_{IN} Rising	2.0	2.2	2.45	V
Power On Reset Hysteresis	ΔV_{IN}		--	0.1	--	V
Quiescent Current	I_Q	V_{EN} = 5V, V_{FB} = 1.5V, I_{OUT} = 0mA, (No Switching)	--	200	300	uA
Supply Current	I_{IN}	FB = 0V, Switching	--	1	2	mA
Shutdown Current	I_{SHDN}	V_{EN} = 0V	--	1	4	uA
Reference						
Reference Voltage	V_{FB}		0.285	0.3	0.315	V
Line Regulation		V_{IN} = 3.0V ~ 4.3V	--	1	--	%
Dimming Control Accuracy		PWM duty cycle > 20% at 20kHz	--	5	--	%
Minimum Dimming Duty			5	--	100	%

Electrical Characteristics

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Oscillator						
Switching Frequency Range	f_{OSC}		0.8	1	1.2	MHz
Maximum Duty Cycle		V_{FB} = 0.25V	90	92	--	%
Power Switch and Diode						
$R_{DS(ON)}$ Switch	$R_{DS(ON)}$	I_{LX} = 100mA	--	0.7	1.2	Ω
Logic Input						
EN Logic Low Threshold	V_{IL}	V_{IN} = 2.8V to 5.5V, Shutdown	--	--	0.4	V
EN Logic High Threshold	V_{IH}	V_{IN} = 2.8V to 5.5V, Enable	1.4	--	--	V
EN Sink Current	I_{IH}		--	--	1	uA
PWM Frequency for Dimming			0.1	--	200	kHz
Shutdwon Delay			--	20	--	ms
Protection						
Over Voltage Protection Level			42	46	50	V
Current Limit Level	I_{LX}		1	1.2	--	A
Thermal Shutdwon Temperature	T_{SHDN}	By design	--	160	--	°C
Thermal Shutdown Hysteresis	ΔT_{SHDN}	By design	--	30	--	°C

Note 1. Stresses listed as the above *Absolute Maximum Ratings* may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

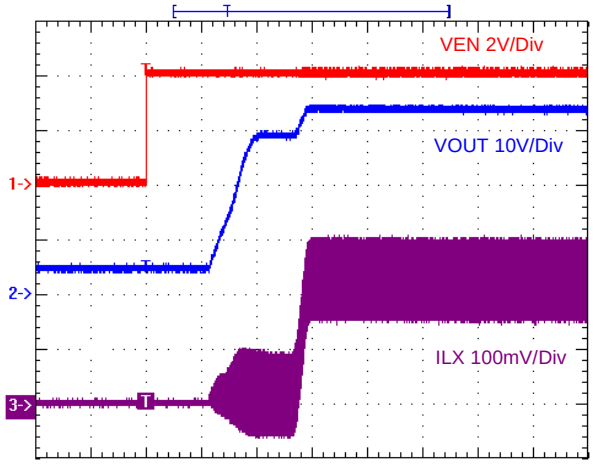
Note 2. Devices are ESD sensitive. Handling precaution recommended.

Note 3. θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

Note 4. The device is not guaranteed to function outside its operating conditions.

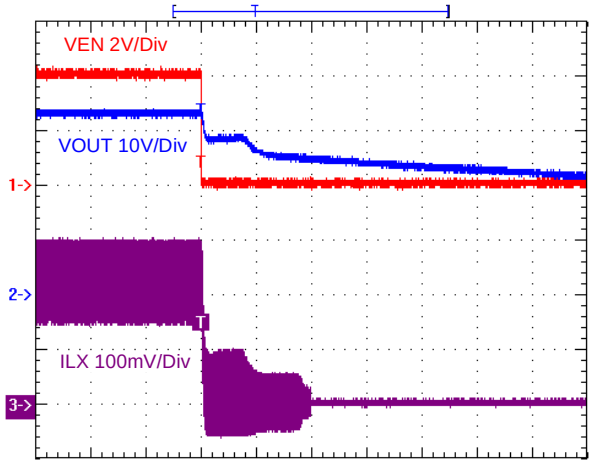
Typical Operation Characteristics

Power On from EN



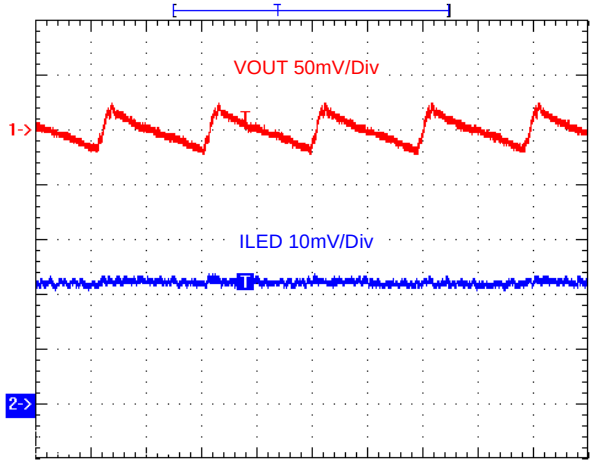
2ms/Div
10WLED, I_{LED} = 20mA, V_{IN} = 3.7V

Power Off from EN



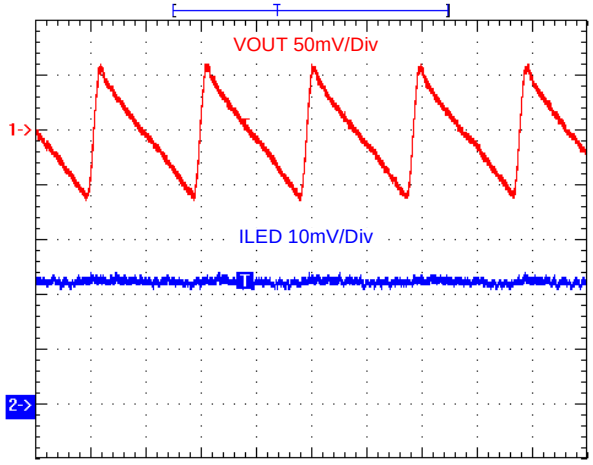
10ms/Div
10WLED, I_{LED} = 20mA, V_{IN} = 3.7V

Ripple



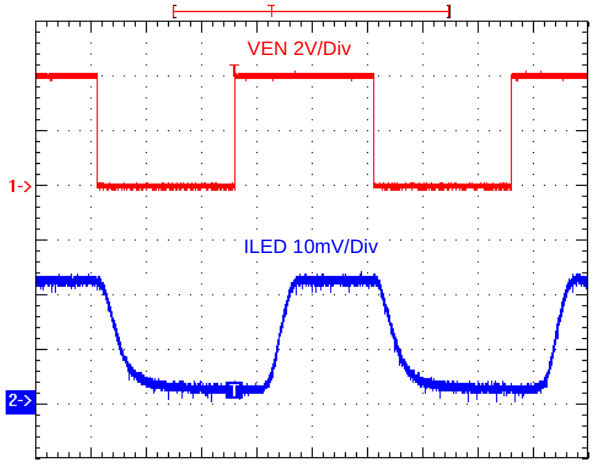
500ns/Div
V_{IN} = 3.7V, I_{LED} = 20mA, C_{OUT} = 1uF

Ripple



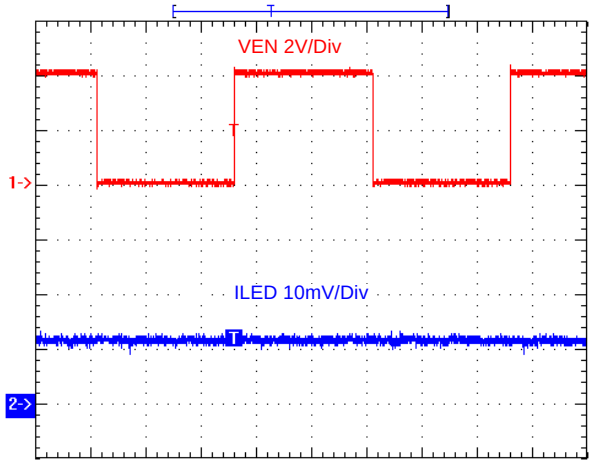
500ns/Div
V_{IN} = 3.7V, I_{LED} = 20mA, C_{OUT} = 0.22uF

PWM Dimming from EN



1ms/Div
V_{IN} = 3.7V, I_{LED} = 20mA, F_{DIM} = 200Hz

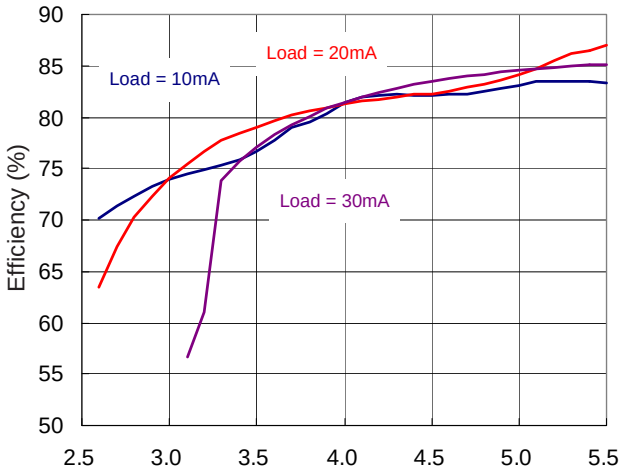
PWM Dimming from EN



10us/Div
V_{IN} = 3.7V, I_{LED} = 20mA, F_{DIM} = 20kHz

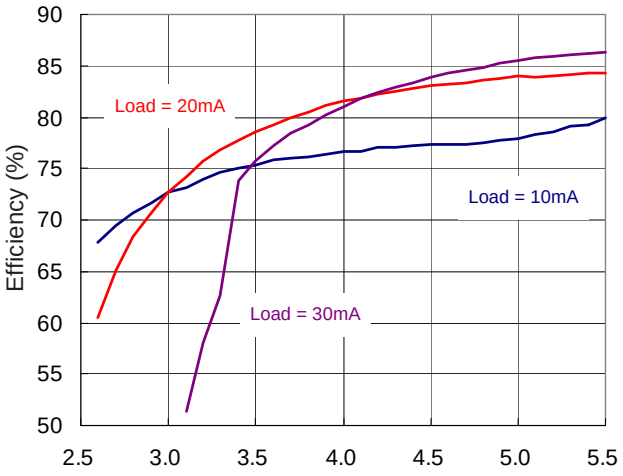
Typical Operation Characteristics

Efficiency vs. Input Voltage



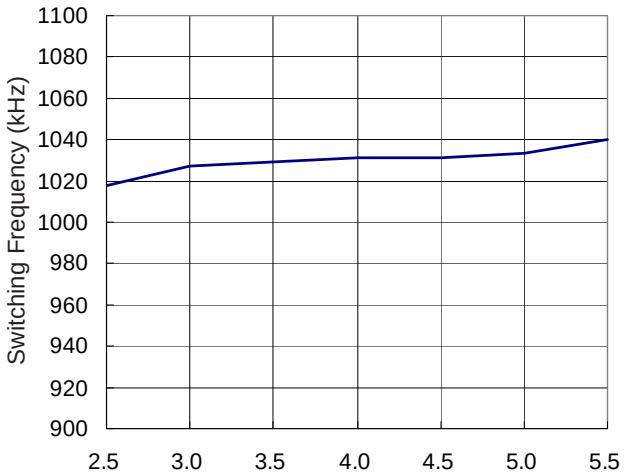
10WLED, L = 10uH

Efficiency vs. Input Voltage



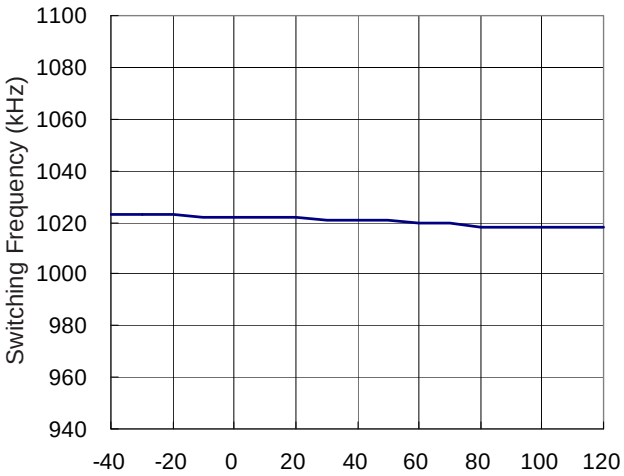
10WLED, L = 22uH

Switching Frequency vs. Input Voltage



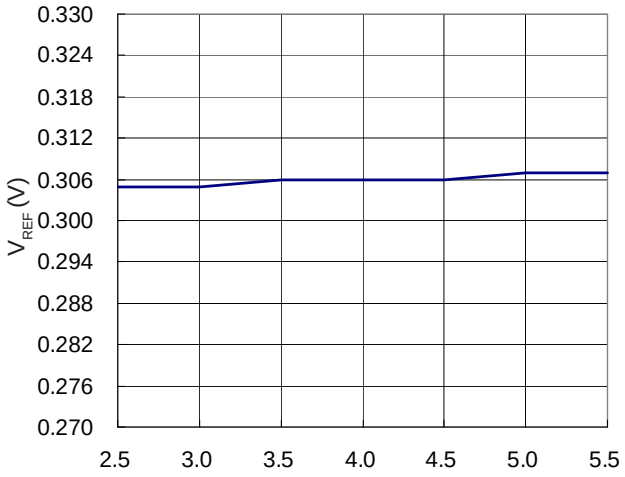
No Load

Switching Frequency vs. Temperature



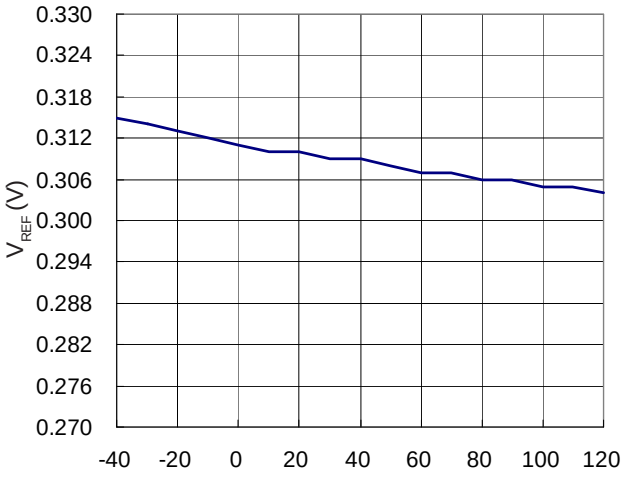
VIN = 3.7V, No Load

V_{REF} vs. Input Voltage



No Load

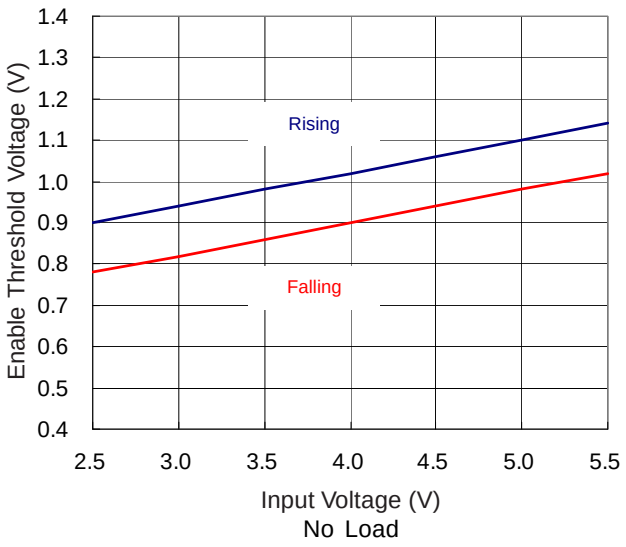
V_{REF} vs. Input Temperature



V_{IN} = 3.7V, No Load

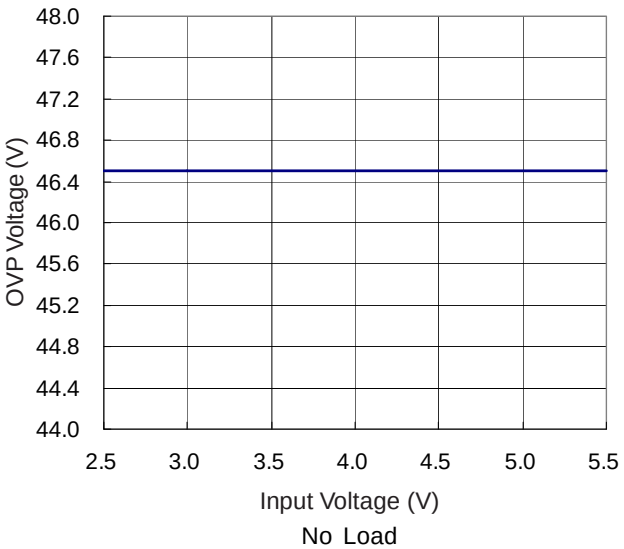
Typical Operation Characteristics

Enable Threshold vs. Input Voltage



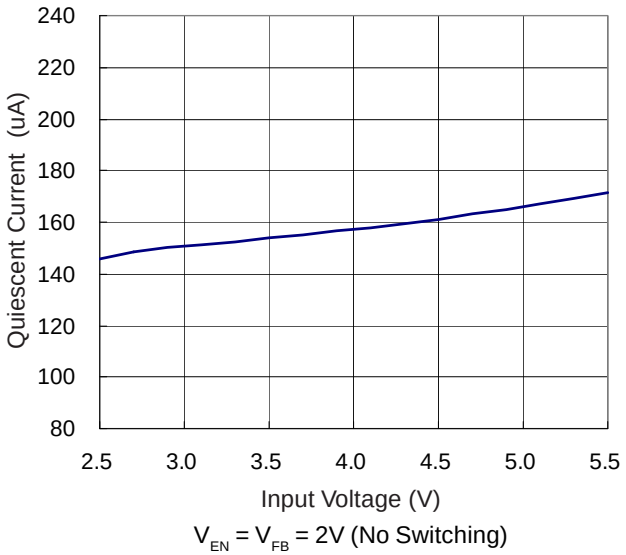
No Load

OVP Voltage vs. Input Voltage



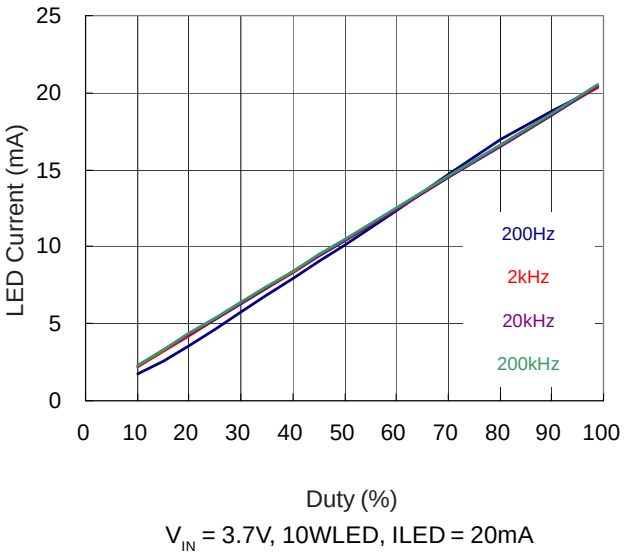
No Load

Quiescent Current vs. Input Voltage



$V_{EN} = V_{FB} = 2V$ (No Switching)

LED Current vs. Duty



V_{IN} = 3.7V, 10WLED, ILED = 20mA

Component Selection

External component selection begins with inductor value selection based on the considerations of the output voltage, output current, and the maximum/minimum input voltages. Catch diode and input/output capacitors can be selected according to the inductor value L.

Inductor Selection

Inductor selection should consider the inductor value, rated current, DCR, size, core material, and cost. The inductor value is selected based on the consideration of inductor ripple current. The recommended value of inductor for 10 WLEDs applications is from 10uH to 22uH. The inductor should have low core loss at 1MHz and low DCR for better efficiency. The inductor saturation current rating should be considered to cover the inductor peak current.

Layout Consideration

For best performance of the uP6003, the following guidelines must be strictly followed.

1. Input and output capacitors should be placed close to the IC and connected to ground plane to reduce noise coupling.

2. The GND should be connected to a strong ground plane for heat sinking and noise protection.

3. Keep the main current traces as short and wide as possible.

4. LX node of DC-DC converter is with high frequency voltage swing. It should be kept at a small area.

5. Place the feedback components as close as possible to the IC and keep away from the noisy devices.

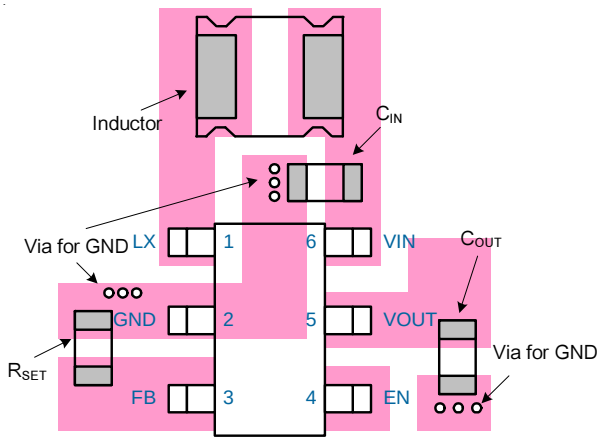


Figure 1. TSOT23 - 6L Layout Reference

Maximum Output Current vs. Output Voltage

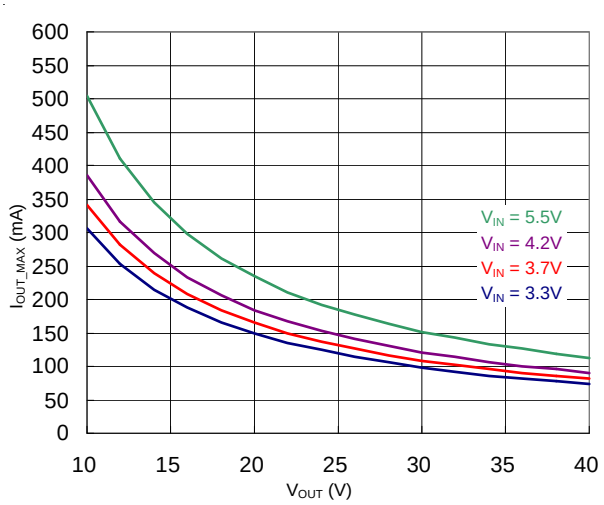


Figure 2. Maximum Output Current vs. Output Voltage

$$I_{OUT(MAX)} = (1-D)\times\eta\times(I_{LX} - \frac{1}{2}\times\frac{V_{IN}}{F_{OSC}\times L}\times D)$$

Calculation conditions:

L = 10uH, F_{OSC} = 1MHz, η = 0.85, I_{LX} = 1.2A

Multi-strings Application

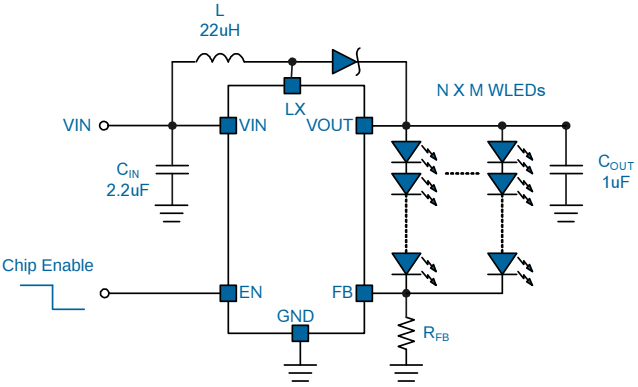
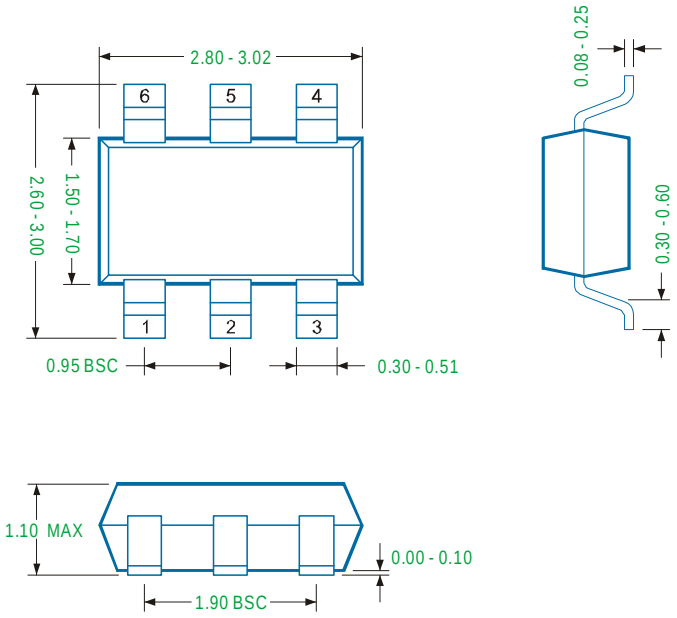


Figure 3. Application for Driving nxm WLEDs

Please considering the Maximum Output Current vs. Output Voltage relationship when used for nxm WLEDs application.

Package Information

TSOT23-6L



Note

1. Package Outline Unit Description:
   BSC: Basic. Represents theoretical exact dimension or dimension target
   MIN: Minimum dimension specified.
   MAX: Maximum dimension specified.
   REF: Reference. Represents dimension for reference use only. This value is not a device specification.
   TYP. Typical. Provided as a general value. This value is not a device specification.
2. Dimensions in Millimeters.
3. Drawing not to scale.
4. These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm.

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