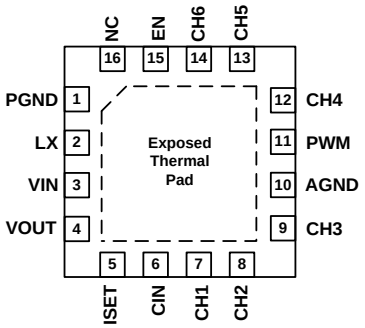
6 – Channel LED Driver

FEATURES

- **Wide input range from 2.7V to 24V**
- **Integrated 2.7A/40V boost converter FET**
- **Built-in loop compensation and soft-start**
- **Six programmable current sinks**
  - **Current up to 30mA per channel**
  - **PWM dimming from 100Hz to 30kHz**
  - **Ultra low dimming cycle 0.005% @ 100Hz dimming frequency**
  - **2.5% current matching**
  - **3% current accuracy**
- **Protection:**
  - **LED string open/short detection**
  - **Overvoltage protection**
  - **Overcurrent protection**
  - **Overtemperature protection**
- **Thin 3x3 mm 16-lead WQFN package**
- **Rohs compliant and 100% Lead(Pb)-Free/Green**

QFN-16PIN CONFIGURATION



APPLICATIONS

- **Notebook/Ultrabook/Tablet PC Display Backlight**
- **Car Navigator/Entertainment Display Backlight**
- **Flash light or utility light**

DESCRIPTION

The ANX6923 is a highly compact white LED driver especially optimized for thin-film transistor (TFT) liquid crystal displays (LCDs) backlight. The chip can drive up to six strings of LEDs and up to ten LEDs in series per string. Wide input voltage range from 2.7V to 24V makes ANX6923 well suited for applications ranging from a one-cell lithium-ion battery tablet PC to a full-size notebook PC.

The ANX6923 offers a built-in high efficiency current mode boost converter. The six integrated current sink regulators provide high precision current regulation and matching for LED currents up to 30mA. The feedback loop senses LED current sink voltages and compensates for the non-uniformity of the LED forward voltage accumulated on the LED strings. To minimize the power loss, the output voltage of the boost converter is automatically adjusted by monitoring the highest forward voltage of the LED strings. An unused LED channel can be disabled by connecting the channel to ground.

The ANX6923 controls LED dimming through the pulse-width-modulation (PWM) method. The LED current is turned on and off in response to the duty cycle and frequency applied at the PWM pin.

The ANX6923 features several protection functions including overcurrent protection (OCP), overtemperature protection (OTP), overvoltage protection (OVP), and LED string open and short detection. Once the device is turned on, the soft-start function raises the output voltage gradually to avoid voltage overshoot and inrush current. If one string opens, the LED open detection circuit detects this fault and excludes this current sink from the regulation loop. All other strings continue to work normally.

ORDERING INFORMATION

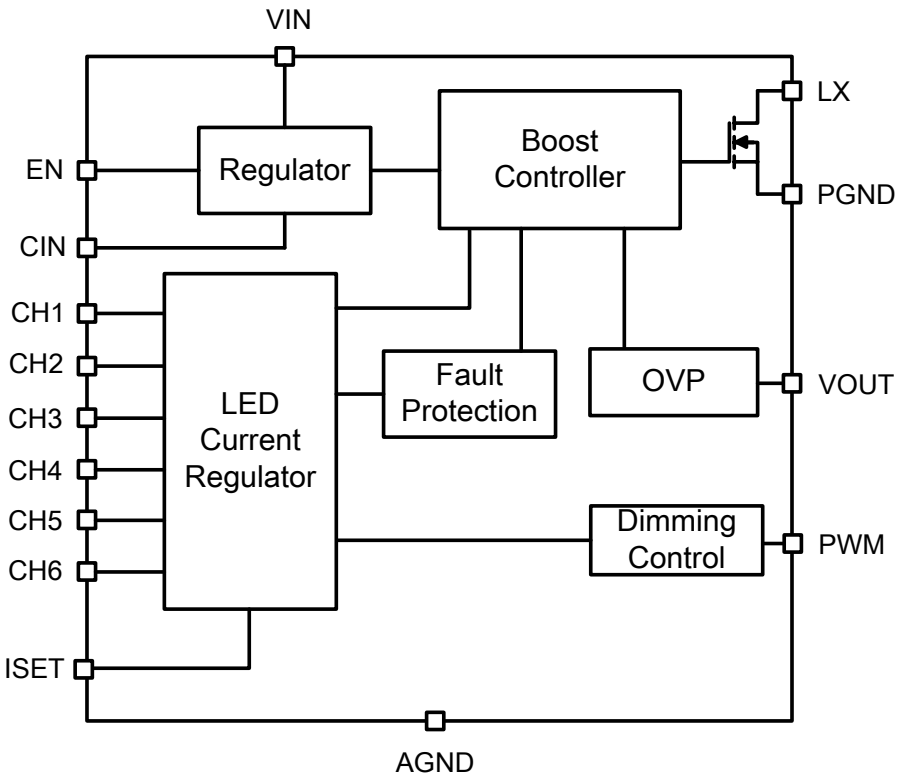
Part Number	Package
ANX6923AAQ	WQFN-16L, 3x3

Preliminary ANX6923_003

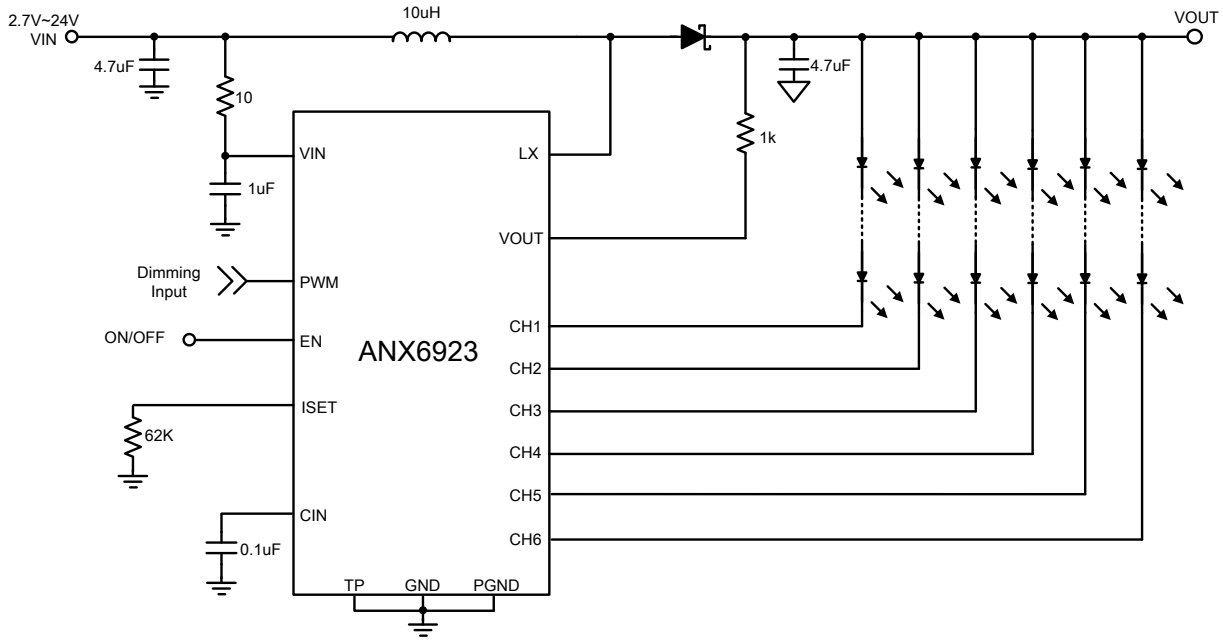
PIN DESCRIPTION

Number	Name	Pin Description
1	PGND	Boost converter power ground. Source of the internal NMOS switch.
2	LX	Boost converter switching node. Drain of the internal NMOS switch.
3	VIN	LED driver input supply voltage.
4	VOUT	Boost converter output voltage sense input for overvoltage protection.
5	ISET	LED current control input. A resistor on this pin sets LED string current.
6	CIN	Connect a 0.1uF ceramic capacitor to ground.
7 – 9	CH1 – CH3	LED string current sinks.
10	AGND	Analog ground.
11	PWM	PWM dimming control input.
12 – 14	CH4 – CH6	LED string current sinks.
15	EN	LED driver enable input.
16	NC	No connection.
-	TP	Exposed thermal pad. Connect to AGND and PGND.

BLOCK DIAGRAM



TYPICAL APPLICATION DIAGRAM



Note1: If the application requires fewer than six LED strings, connecting the unused channels to ground can prevent the boost converter output voltage from temporarily reaching the overvoltage level during power up.

Note2: The 40V rated Schottky diode and 50V rated output capacitor are recommended for the 39V(typically) OVP threshold.

Note3: For most ANX6923 applications, the inductor value ranges from 6.8 µH to 10 µH.

ABSOLUTE MAXIMUM RATINGS

Input Supply Voltage, VIN	-0.3V to 27V
Voltages on CH1 – CH6	-0.3V to 40V
Voltages on LX, VOUT	-0.3V to 45V
Voltages on EN, PWM	-0.3V to 27V
Voltages on ISET, CIN	-0.3V to 6V
Storage temperature range	-65°C to 150°C
Lead temperature (soldering, 10s maximum)	260°C
ESD, Human body mode	4kV
ESD, Machine mode	200V

Note1: All voltages are referenced to ground with AGND and PGND pins grounded.

Note2: “ABSOLUTE MAXIMUM RATINGS” indicate limits beyond which permanent damage to the device may occur. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "Recommended Operating Conditions" is not implied. For guaranteed specifications and test conditions, see the “ELECTRICAL SPECIFICATIONS”.

RECOMMENDED OPERATION CONDITIONS

Input supply voltage	2.7V to 24V
LED current per channel	3mA to 30mA
Junction temperature range	-40°C to 125°C
Ambient temperature range	-40°C to 85°C

POWER DISSIPATION RATINGS

Package	**Thermal Resistance, Θ_{JA}**	**Power Rating (T_A < 25 °C)**	**Power Rating (25 < T_A < 85 °C)**	**Power Rating (T_A = 85°C)**
16-ld QFN	43 °C/W	2325mW	(125 - T_A) / 43 W	930mW

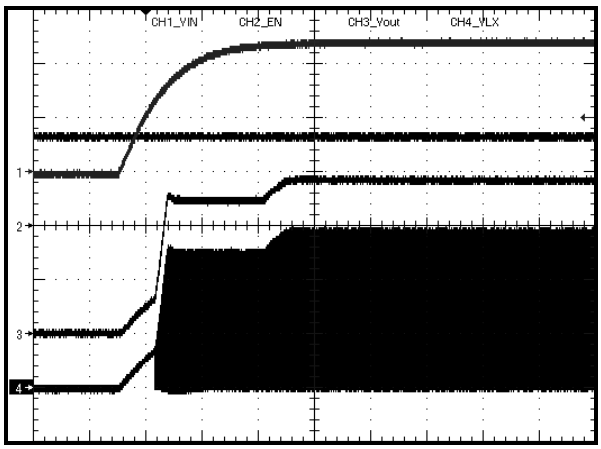
ELECTRICAL SPECIFICATIONS

(V_{IN}=12V, T_A=25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
System Supply						
Input Supply Voltage	V_{IN}		2.7		24	V
VIN Quiescent Current	I_{Q_VIN}	V_{IN}=24V, switching		2	3	mA
VOUT Quiescent Current	$I_{Q\ VOUT}$	VOUT=35V, PWM=0V			60	uA
Undervoltage Lockout Threshold	V_{UVLO}	VIN rising	2.25	2.45	2.65	V
	$V_{UVLO\ HYS}$	VIN rising – VIN falling		200		mV
Shutdown Current	I_{SD}	EN=0V		2	18	uA
Control Inputs						
Logic Low Level (EN, PWM)	V_{IL}	V_{IN}>2.7V			0.7	V
Logic High Level (EN, PWM)	V_{IH}		1.6			
Pull Down Resistor (EN, PWM)	R_{PD}			800		kΩ
PWM Dimming Frequency	f_{DIM}		100		30K	Hz
Boost Converter						
Switching Frequency	F_{OSC}		0.8	1.0	1.2	MHz
Maximum Duty Cycle	D_{MAX}			94		%
Minimum Duty Cycle	D_{MIN}				7	%
LX ON-Resistance	$R_{DS\ ON}$			0.2	0.45	Ω
LX Current Limit	I_{LIM}	V_{IN}>3.3V	2.2	2.7	3.2	A
		V_{IN}=2.6V		0.5 x I_{LIM}		
LED Current Regulation						
CHx Leakage Current	I_{LEAK}	CHx=20V			3	uA
CHx Maximum LED Current	I_{LED_MAX}	V_{IN}>2.7V, CHx>0.7V	30			mA
ISET Pin Voltage	V_{ISET}		1.204	1.229	1.253	V
ISET to CHx Current Ratio	K_{ISET}	ISET current=20uA	970	1000	1030	
LED Current Accuracy	I_{LED}	ISET current=20uA	19.4	20	20.6	mA
LED Current Matching		(I_{MAX}-I_{MIN})/I_{AVG}, LED sink current=20mA		1	2.5	%
Protection						
VOUT Overvoltage Protection Threshold	V_{OVP}	Voltage VOUT > V_{OVP} turns off LX power FET	38	39	40	V
CHx Overvoltage Protection Threshold	V_{OVP_CH}	Voltage CHx >V_{OVP_CH} disables CHx current sink	15	17	20	V
Thermal Shutdown Protection Threshold	T_{TSP}			160		˚C
	T_{TSP_HYST}			15		˚C

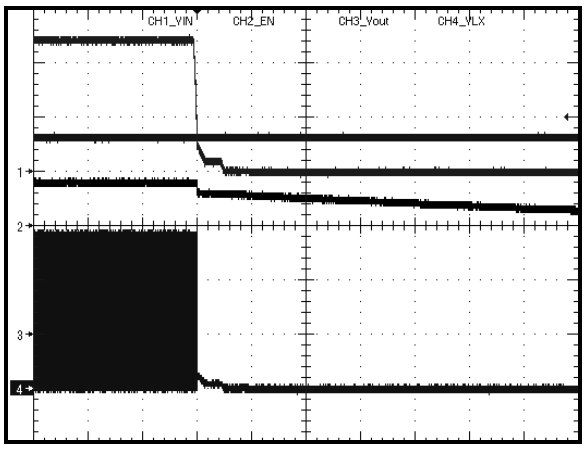
TYPICAL OPERATING CHARACTERISTICS

Power-up Sequence (V_{IN}=12V, 6P9S)



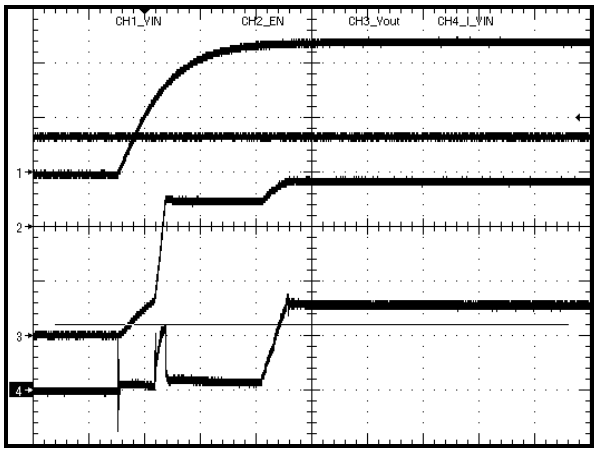
1: V_{IN}, 5V/div
3: V_{OUT} , 10V/div
1: EN, 2V/div
4: V_{LX}, 10V/div

Power-down Sequence (V_{IN}=12V, 6P9S)



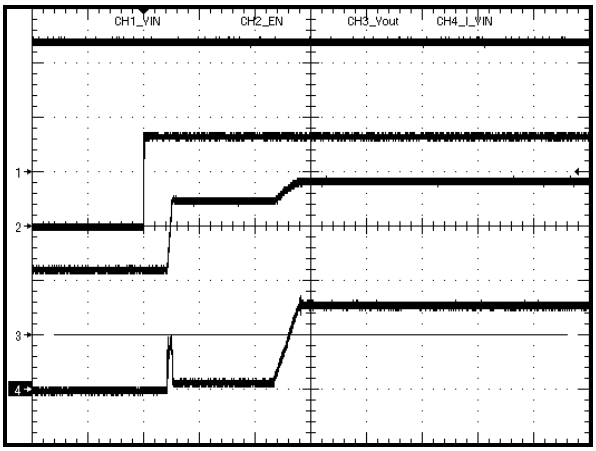
1: V_{IN}, 5V/div
3: V_{OUT} , 10V/div
1: EN, 2V/div
4: V_{LX}, 10V/div

Power-on Inrush Current (V_{IN}=12V, 6P9S)



1: V_{IN}, 5V/div
3: V_{OUT} , 10V/div
1: EN, 2V/div
4: IIN, 200mA/div

EN-on Inrush Current (V_{IN}=12V, 6P9S)



1: V_{IN}, 5V/div
3: V_{OUT} , 10V/div
1: EN, 2V/div
4: V_{LX}, 10V/div

APPLICATION INFORMATION

The ANX6923 can operate with input voltage from 2.7V to 24V. Such a wide input voltage range is beneficial for the tablet and notebook PC backlight applications where the supply can be as low as one lithium-ion cell or as high as 19V from an AC/DC adapter.

The ANX6923 includes all the key functions within a small-size package. The chip contains a boost converter with a built-in 2.7A/40V power FET, six LED string current sink regulators of up to 30mA per channel, LED string open and short detection, overcurrent protection (OCP), overtemperature protection (OTP), and output overvoltage protection (OVP). The ANX6923 also features low output AC ripple during PWM dimming control and a soft start function to avoid inrush current.

BOOST CONVERTER

The ANX6923 has a built-in boost converter to supply the LED strings. The high-efficiency PWM boost converter operates under current mode control with a fixed 1MHz switching frequency.

To minimize the power loss, the boost converter produces the lowest output voltage that allows all LED strings to run at the preset current. If the number of LED's in series is small such that the total voltage drop on the strings is close to VIN or even smaller, the output voltage does not drop below VIN by more than one diode drop. The chip would maintain the preset current in the LED strings as long as the voltage on the CHx pins remains below the protection level.

The boost converter operates as follows. During the on-time period of the 1MHz clock, the power FET connects the LX node to ground. A positive voltage from VIN to ground appears across the inductor and gives rise to a linear increase in inductor current. After the FET turns off, the inductor switching node LX is charged to a positive voltage by the inductor current until the freewheeling Schottky diode turns on and the inductor current continues to flow to the output capacitor. A negative voltage from VIN to VOUT+V_{DIODE} across the inductor results in a linear decrease in inductor current. Under light-load conditions the inductor current decays to zero and the Schottky diode turns off. This condition is known as discontinuous conduction mode (DCM) due to discontinuous nature of the inductor current.

Internal compensation of the control loop ensures stable operation and good transient response for a wide range of application conditions.

LED CURRENT PROGRAMMING

The ANX6923 offers six LED current sink regulators that can each provide current of up to 30mA. The LED current is set by an external resistor connected from ISET pin to ground as follows.

$$I_{LED} = 1000 \times \frac{1.229V}{R_{ISET}} = \frac{1229}{R_{ISET}} mA$$

where the value of R_{ISET} is in kΩ.

The ANX6923 absolute current accuracy is better than 3% and the current matching of the six channels is within 2.5%. Current matching is calculated by dividing the maximum difference of current of any two channels by the average channel current. The absolute accuracy of current is additionally determined by the accuracy of the current-setting resistor therefore a 0.1% tolerance resistor is recommended.

ENABLE AND PWM DIMMING CONTROL

The EN pin serves as the chip enable signal. There is an internal pull-down resistor on the EN pin so applying an external logic high signal is necessary for the chip to turn on. A logic low signal on EN pin makes the device enter the shutdown mode and consume less than 18uA.

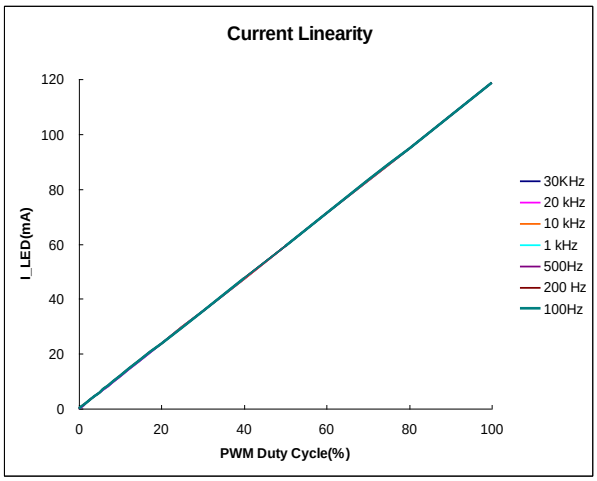
LED brightness is controlled by the duty cycle of a pulse-width-modulated signal applied on the PWM pin. The high duration of the PWM signal

corresponds to the preset current flowing through LED strings. The average LED current can be calculated from PWM dimming duty cycle, D, as follows.

$$I_{LED(average)} = \frac{1229 \times D}{R_{ISET}} mA$$

The ANX6923 supports dimming frequency from 100Hz to 30kHz. In this frequency range screen flickering is avoided while dimming linearity is maintained. With proper output capacitors this device is designed to minimize output AC ripple during PWM dimming.

The relationship of dimming frequency and duty is as below plot. (VIN=12V, EN=3.3V, PWM=3.3V, LEDs=6P9S, ISET=61.9k)



If the PWM pin remains low for longer than 32ms (i.e. the dimming frequency is well below 100Hz) the chip goes into a standby state. As soon as PWM goes H the chip executes soft start and resumes normal operation. This feature protects the system against high inrush current that could occur after a long idle period during which the output capacitor could be depleted of charge.

PROTECTION FUNCTIONS

LED Open Protection

If one of the LED strings is open before the chip powers up, the boost converter output voltage rises to the overvoltage threshold (VOUT>39V) during the start-up period before the chip can automatically detect the open LED string. The controller removes the open CHx pin from the voltage feedback loop and continues to regulate current for the remaining strings. If a LED string connection opens during normal operation, the device detects the open string immediately and does not go to the overvoltage threshold.

LED Short Protection

If one or more LEDs within one string develop a short the total voltage drop on that string becomes smaller than on other LED strings and the voltage on the affected CHx pin will be higher than on the other CHx pins. A current sink driving the CHx pin with higher regulation voltage develops more heat. To prevent current sink damage due to overheating, any CHx pin that exceeds 17V in normal operation is disabled until the chip is power cycled.

Over Voltage Protection (OVP)

When the LED forward voltage is too large or when one of the LED strings is open before the chip powers up, the boost converter ramps up the output voltage to the overvoltage threshold (VOUT>39V). The chip disables boost converter switching for as long as VOUT voltage remains above 39V.

Over Current Protection (OCP)

To protect the boost converter power FET and external components against high current conditions, the LX pin current limit is set at 2.7A for VIN>3.3V. Once current in the power FET exceeds the current limit level the power FET turns off and remains off until the next switching cycle. Under a 100% dimming duty cycle, if the over-current condition persists for more than 8ms, the ANX6923 turns off and requires cycling of the input voltage below the UVLO falling threshold or toggling the EN pin to restart.

VIN Dependency of Current Limit

The 2.7A current limit applies to input voltage VIN of 3.3V or higher. At lower voltages, the boost power FET could reach drain current saturation before the drain current exceeds 2.7A and lead to a simultaneous high LX current and high LX voltage condition and loss of voltage across the inductor. The ANX6923 is protected against this condition by gradually reducing the LX current limit proportionately with VIN until it reaches 50% of the full current limit value (~1.4A) at VIN=2.6V. This feature makes it possible for the chip to operate safely at low input voltage while also providing high current rating at high input voltage. Lower current limit at lower VIN makes it easier for the chip to reach overcurrent condition and possibly turn off.

Over Temperature Protection (OTP)

The ANX6923 provides thermal overload protection to prevent excessive power from overheating and damaging the chip. When the junction temperature exceeds 160°C a thermal sensor triggers fault protection which disables the boost converter and the LED current sinks. The chip automatically resumes operation after the temperature drops by 15°C.

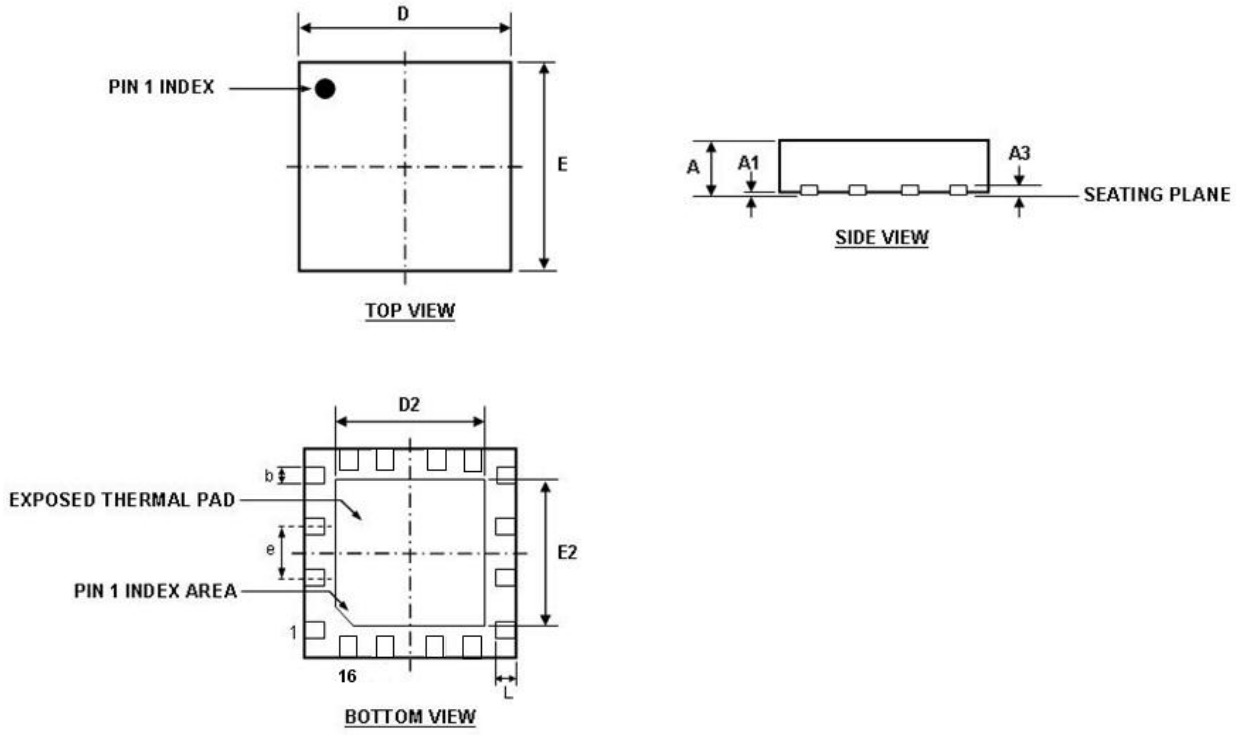
SOFT START

To ensure a predictable VOUT ramp and low input inrush current the chip features a built-in soft-start circuit and inrush controller.

UNUSED LED STRINGS

If the application requires fewer than six LED strings the unused channels can be left open (unconnected) or shorted to ground. Connecting all unused channels to ground prevents the boost converter output voltage from temporarily reaching the overvoltage level during power up.

PACKAGE OUTLINE DRAWING (WQFN-16 3X3 MM)



DIMENSION	MIN (mm)	MAX (mm)
A	0.70	0.80
A1	0.00	0.05
A3	0.20 REF	
b	0.18	0.30
D	3.00 BSC	
D2	1.60	1.80
E	3.00 BSC	
E2	1.60	1.80
e	0.50 BSC	
L	0.30	0.45

Notes:
1) All dimensions are in millimeters.

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