ACT6330

Rev0, 02-Apr-08

Dual PWM Step-Up DC/DCs in TQFN33

FEATURES

- **Multiple Patents Pending**
- **Two Integrated Regulators**
  - **PWM Step-Up DC/DC with OVP for WLED Bias**
  - **PWM Step-Up DC/DC Converter with OVP**
- **Independent Enable/Disable Control**
- **Minimal External Components**
- **3×3mm, Thin-QFN (TQFN33-16) Package**
  - **Only 0.75mm Height**
  - **RoHS Compliant**

APPLICATIONS

- **Portable Devices and PDAs**
- **MP3/MP4 Players**
- **Wireless Handhelds**
- **GPS Receivers**

GENERAL DESCRIPTION

The patent-pending ACT6330 integrates two step-up DC/DC into a single, thin, space-saving package to provide a cost-effective, highly-efficient *ActivePMU^{TM}* power management solution. This device is ideal for a wide range of portable handheld equipment that can benefit from the advantages of *ActivePMU* technology but does not require a high level of integration.

REG1 and REG2 are fixed-frequency, current mode PWM step-up DC/DC converter. REG1 is optimized for high-efficiency WLED bias applications. REG2 is optimized for voltage regulation applications, while together these output can provide a complete TFT bias and backlighting solution for portable handheld equipment.

The ACT6330 is available in a tiny 3mm x 3mm 16 pin Thin-QFN package that is just 0.75mm thin.

SYSTEM BLOCK DIAGRAM

ActivePMU^{TM} is a trademark of Active-Semi.

FUNCTIONAL BLOCK DIAGRAM
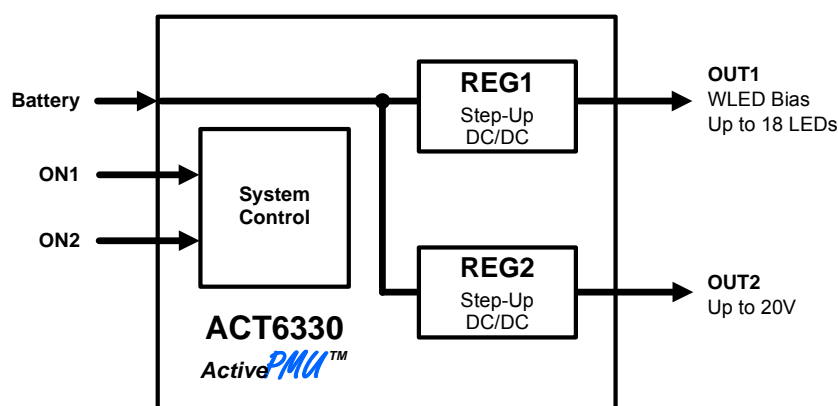
ORDERING INFORMATION

PART NUMBER	PACKAGE	PINS	TEMPERATURE RANGE
ACT6330QK-T	TQFN33-16	16	-40°C to +85°C

All Active-Semi product are offered in lead-free RoHS Compliant packaging. The term "Pb-free" means semiconductor products that are in compliance with current RoHS (Restriction of Hazardous Substances) standards.

PIN CONFIGURATION

TOP VIEW
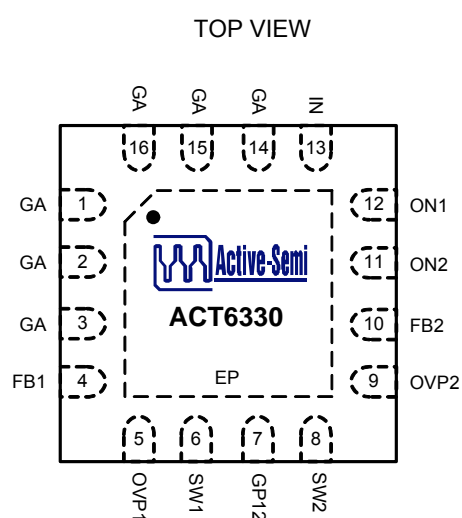
Thin - QFN (TQFN 33-16)

PIN DESCRIPTIONS

PIN	NAME	DESCRIPTION
1, 2, 3, 14, 15, 16	GA	Analog Ground. Connect GAs directly to a quiet ground node. Connect GAs and GP12 together at a single point as close to the IC as possible.
4	FB1	Feedback Sense for REG1. Connect this pin to the LED string current sense resistor to sense the LED current.
5	OVP1	Over-Voltage Protection Input for REG1. Connect this pin directly to the output node to sense and prevent over-voltage conditions.
6	SW1	Switching Node Output for REG1. Connect this pin to the switching end of the inductor.
7	GP12	Power Ground for REG1, REG2. Connect GP12 directly to a power ground plane. Connect GAs and GP12 together at a single point as close to the IC as possible.
8	SW2	Switching Node Output for REG2. Connect this pin to the switching end of the inductor.
9	OVP2	Over-Voltage Protection Input for REG2. Connect this pin directly to the output node to sense and prevent over-voltage conditions.
10	FB2	Feedback Sense for REG2. Connect this pin to the center point of a resistive voltage divider to sense output voltage.
11	ON2	Enable Control Input for REG2. Drive ON2 to IN or to a logic high for normal operation, drive to GA or a logic low to disable REG2.
12	ON1	Enable Control Input for REG1. Drive ON1 to IN or to a logic high for normal operation, drive to GA or a logic low to disable REG1.
13	IN	Power Input for the IC. Bypass IN to GA with a capacitor placed as close as possible to the IC.
EP	EP	Exposed Pad. Must be soldered to ground on the PCB.

ABSOLUTE MAXIMUM RATINGS①

PARAMETER	VALUE	UNIT
IN, ON1, ON2, FB1, FB2 to GA	-0.3 to +6	V
OVP1, OVP2, SW1, SW2 to GP12	-0.3 to +25	V
GP12 to GA	-0.3 to +0.3	V
Junction to Ambient Thermal Resistance (θ_{JA})	33.3	°C/W
Operating Temperature Range	-40 to 85	°C
Junction Temperature	125	°C
Store Temperature	-55 to 150	°C
Lead Temperature (Soldering, 10 sec)	300	°C

①: Do not exceed these limits to prevent damage to the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, T_A = 25°C, unless otherwise specified.)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
IN Operating Voltage Range		3.1		6	V
UVLO Voltage Threshold	IN Voltage Rising	2.9	3	3.1	V
UVLO Hysteresis	IN Voltage Falling		100		mV
Supply Current	ON1 = IN, V_{FB1} = 0.3V		75	150	µA
	ON1 = GA, I_{LOAD} = 0mA		0.1	1	µA
FB1 Feedback Voltage		0.235	0.255	0.275	V
FB1 Input Current			50		nA
Oscillator Frequency		1.35	1.6	1.85	MHz
Minimum On-Time			100		ns
Maximum Duty Cycle		87	92		%
Switch Current Limit	Duty = 83%, L1 = 22uH, C_{OUT1} = 4.7uF	500	750		mA
Switch On-Resistance	I_{SW1} = 100mA		0.67	1.1	Ω
Switch Leakage Current	V_{SW1} = 25V, ON1 = GA			10	µA
Logic High Input Voltage	ON1	1.4			V
Logic Low Input Voltage	ON1			0.4	V
ON1 Leakage Current	V_{ON1} = 0V to 5.5V			1	µA
Over-Voltage Threshold		21	22	23	V
Thermal Shutdown Temperature	Temperature rising		160		°C
Thermal Shutdown Hysteresis	Temperature falling		20		°C

FUNCTIONAL DESCRIPTION

General Description

REG1 is highly efficient step-up DC/DC converter that employs a fixed frequency, current-mode, PWM architecture. This regulator is optimized for white-LED bias applications consisting of up to six white-LEDs.

Over-Voltage Protection

REG1 features internal over-voltage protection (OVP) circuitry which protects the system from LED open-circuit fault conditions. The ACT6330's OVP threshold is set at 22V, and if necessary, regulates the voltage at the top of the LED string to ensure that it never exceeds this voltage. REG1 requires a 10kΩ resistor connected from output capacitor to OVP1 pin.

Thermal Shutdown Protection

The ACT6330 integrates thermal shutdown protection circuitry to prevent damage resulting from excessive thermal stress, as may be encountered under fault conditions. This circuitry disables all regulators if the ACT6330 die temperature exceeds 160°C, and prevents the regulators from being enabled until the IC temperature drops by 20°C (typ).

Enabling and Disabling REG1

REG1 is enabled or disabled using ON1. Drive ON1 to a logic-high to enable REG1. Drive ON1 to a logic-low to disable REG1, reducing supply current to less than 1µA. As with all non-synchronous step-up DC/DC converter, REG1's application circuit procedures a DC current path between the input and the output in shutdown mode. Although the forward drop of the WLEDs makes this leakage current very small in most applications, it is important to consider the effect that this may have in your application particularly when using fewer than three WLEDs.

Compensation and Stability

REG1 utilizes current-mode control and an internal compensation network to optimize transient performance, ease compensation, and improve stability over a wide range of operating conditions. REG1 is a flexible regulator, and with just a simple component, choice can be optimized to achieve minimum total solution size in applications that require the smallest possible footprint, or can be optimized to achieve the highest possible efficiency.

Inductor Selection

REG1 has been designed to provide excellent performance across a wide range of applications, allowing a design to be optimized for both a small footprint as well as for achieving the highest possible efficiency. REG1 was designed for operation with inductor in the 10µH to 22µH range, in order to achieve a small footprint , although larger inductor values of up to 68µH can be used in order to optimize a design to achieve the highest possible efficiency.

Optimizing for Smallest Footprint

REG1 is capable of operating with very low inductor values in order to achieve the smallest possible footprint . When solution size is of primary concern, best results are achieved when an inductance value that ensures discontinuous conduction mode (DCM) operation over the full load current range is used.

Optimizing for Highest Efficiency

REG1 achieves excellent efficiency in applications that demand the longest possible battery life. When efficiency is the primary design consideration, best results are achieved when an inductance value that both results in continuous conduction mode (CCM) operation and achieves a very small inductor ripple current is chosen.

Output Capacitor Selection

REG1 is designed to operate with output capacitors ranging from 1µF to 10µF, providing design flexibility. A 1µF output capacitor is suitable for most applications, although larger output capacitors may be used to minimize output voltage ripple, if needed. Ceramic capacitors are recommended for most applications.

Rectifier Selection

REG1 requires a Shottky diode to rectify the inductor current. Select a low forward voltage drop Shottky diode with a forward current (I_F) rating that is sufficient to support the maximum switch current and a sufficient peak repetitive reverse voltage (V_{RRM}) to support the output voltage.

Setting the LED Bias Current

The LED bias current is set by a resistor connected from FB1 and ground, and regulator is satisfied when the LED current is sufficient to generate 250mV across this resistor. Once the bias current is programmed, the LED current can be adjusted using the ACT6330's Direct-PWM feature. REG1 is also compatible with a variety of well-know LED dimming circuit, such as with a DC control voltage and a filtered PWM signal.
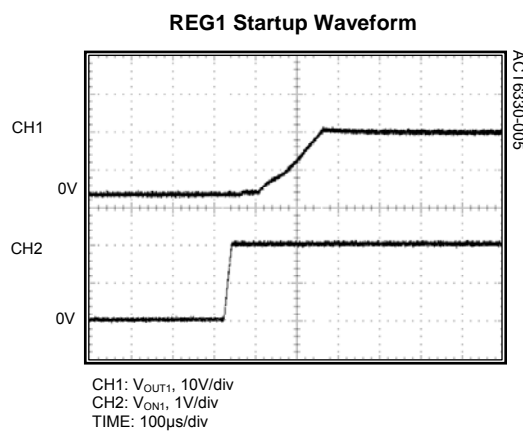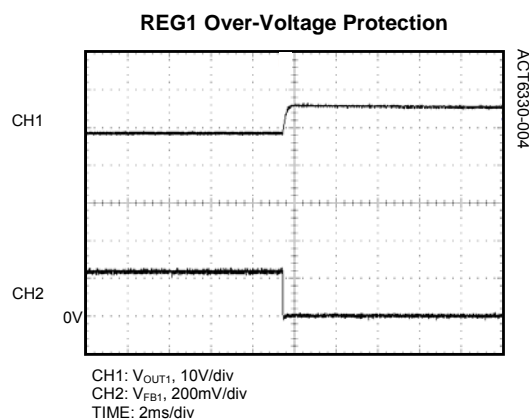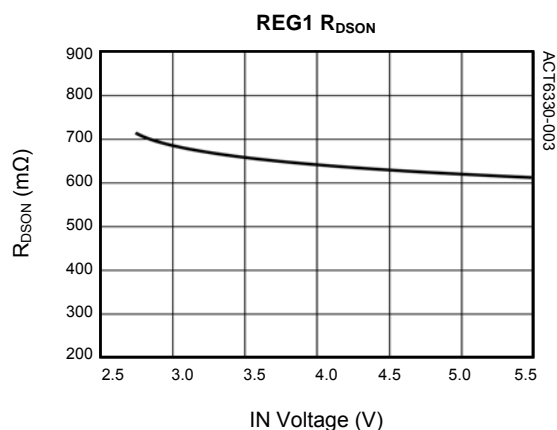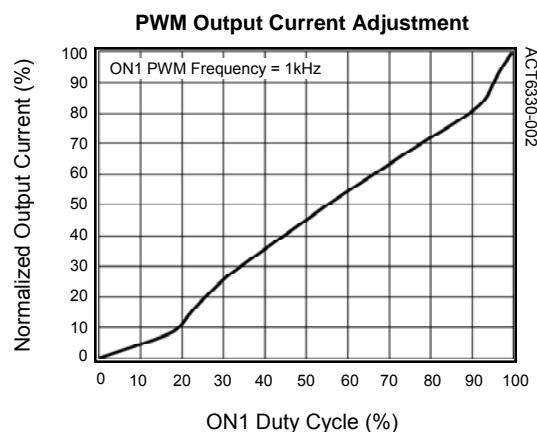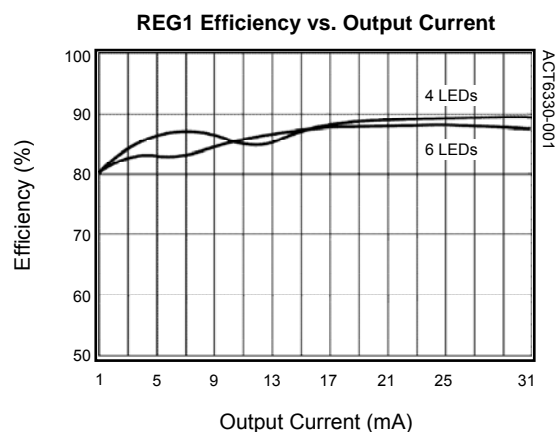
Board Layout

Typical for all switching power supplies, the layout is an important step in design, especially at high peak current and switching frequencies, please refer to *PCB Layout Consideration* for more information.

TYPICAL PERFORMANCE CHARACTERISTICS

(ACT6330QK, V_{IN} = 3.6V, L = 22µH, C_{IN} = 2.2µF, C_{OUT} = 2.2µF, T_A = 25°C, unless otherwise specified.)

REG1 Efficiency vs. Output Current

ACT6330-001

PWM Output Current Adjustment

ON1 PWM Frequency = 1kHz

ACT6330-002

REG1 R_{DSON}

ACT6330-003

REG1 Over-Voltage Protection

ACT6330-004

CH1: V_{OUT1}, 10V/div
CH2: V_{FB1}, 200mV/div
TIME: 2ms/div

REG1 Startup Waveform

ACT6330-005

CH1: V_{OUT1}, 10V/div
CH2: V_{ON1}, 1V/div
TIME: 100µs/div

Active-Semi

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, T_A = 25°C, unless otherwise specified.)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
IN Operating Voltage Range		3.1		6	V
UVLO Voltage Threshold	IN Voltage Rising	2.9	3	3.1	V
UVLO Hysteresis	IN Voltage Falling		100		mV
Supply Current	ON2 = IN, V_{FB2} = 0.3V		75	150	µA
	ON2 = GA, I_{LOAD} = 0mA		0.1	1	µA
FB2 Feedback Voltage		1.23	1.25	1.27	V
FB2 Input Current			50		nA
Oscillator Frequency		1.35	1.6	1.85	MHz
Minimum On-Time			100		ns
Maximum Duty Cycle		87	92		%
Switch Current Limit	Duty = 83%, L2 = 22uH, C_{OUT2} = 4.7uF	500	750		mA
Switch On-Resistance	I_{SW2} = 100mA		0.67	1.1	Ω
Switch Leakage Current	V_{SW2} = 25V, ON2 = GA			10	µA
Logic High Input Voltage	ON2	1.4			V
Logic Low Input Voltage	ON2			0.4	V
ON2 Leakage Current	V_{ON2} = 0V to 5.5V			1	µA
Over-Voltage Threshold		21	22	23	V
Thermal Shutdown Temperature	Temperature rising		160		°C
Thermal Shutdown Hysteresis	Temperature falling		20		°C

FUNCTIONAL DESCRIPTION

General Description

REG2 is a highly efficient step-up DC/DC converter that employs a fixed frequency, current-mode, PWM architecture. This regulator is optimized for use in a wide range of applications including generation constant voltage of up to 20V.

Over-Voltage Protection

REG2 features internal over-voltage protection (OVP) circuitry which protects the system from fault conditions. The ACT6330's OVP threshold is set at 22V, and if necessary, regulates the output voltage to ensure that it never exceeds this voltage. ACT6330 requires a 10kΩ resistor connected from output capacitor to OVP2 pin.

Thermal Protection

The Thermal shutdown protection prevents excessive thermal stress, please refer to *Thermal Shutdown Protection* for more information.

Enabling and Disabling REG2

REG2 is enabled or disabled using ON2. Drive ON2 to a logic-high to enable REG2. Drive ON2 to a logic-low to disable REG2, reducing supply current to less than 1µA. As with all non-synchronous step-up DC/DC converter, REG2's application circuit procedures a DC current path between the input and the output in shutdown mode. It is important to consider the effect that this may have in your application.

Soft-start

REG2 includes soft-start circuitry. When enabled, the output voltage of REG2 tracks an internal 80µs soft-start ramp.

As seen in Figure 1 and Figure 2, the output tracks the internal soft-start ramp and powers up in a monotonic maner that is independent of loading. This circuitry ensures that the output powers up in a controlled maner, greatly simplifying power turn-on design considerations.

Compensation and Stability

REG2 utilizes current-mode control and an internal compensation network to optimize transient performance, ease compensation, and improve stability over a wide range of operating conditions. REG2 is a flexible regulator, and with just a simple compo-

nent, choice can be optimized to achieve minimum total solution size in applications that require the smallest possible footprint, or can be optimized to achieve the highest possible efficiency.
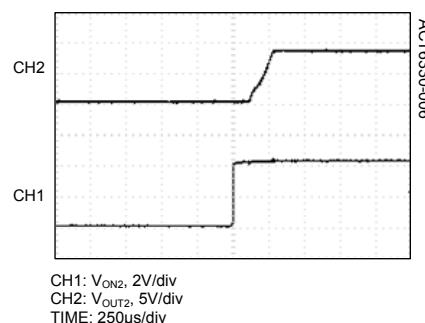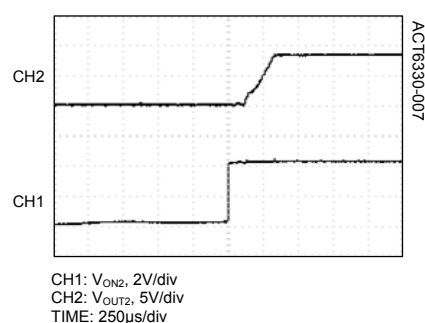
Figure 1:

REG2 Startup Waveform into no load

CH1: V_{ON2}, 2V/div
CH2: V_{OUT2}, 5V/div
TIME: 250µs/div

Figure 2:

REG2 Startup Waveform into full load

CH1: V_{ON2}, 2V/div
CH2: V_{OUT2}, 5V/div
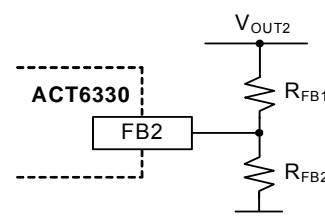TIME: 250µs/div

Output Voltage Selection

Figure 3 shows the feedback network necessary to set the output voltage when using the adjustable voltage option. Select components as follows: Set R_{FB2} = 51kΩ, then caculate R_{FB1} using the following equation:

$$V_{OUT2} = V_{FB2}\left(1 + \frac{R_{FB1}}{R_{FB2}}\right) \qquad (1)$$

Where V_{FB2} is 1.25V.

Figure 3:

Output Voltage Setting

FUNCTIONAL DESCRIPTION CONT'D

Inductor Selection

REG2 has been designed to provide excellent performance across a wide range of applications, allowing a design to be optimized for both a small footprint as well as for achieving the highest possible efficiency.

Optimizing for Smallest Footprint

REG2 is capable of operating with very low inductor values in order to achieve the smallest possible footprint . When solution size is of primary concern, best results are achieved when an inductance value that ensures discontinuous conduction mode (DCM) operation over the full load current range is used.

Optimizing for Highest Efficiency

REG2 achieves excellent efficiency in applications that demand the longest possible battery life. When efficiency is the primary design consideration, best results are achieved when an inductance value that both results in continuous conduction mode (CCM) operation and achieves a very small inductor ripple current is chosen. Table 1 provides recommended inductance values.

Table 1:

Recommended Inductance Values

Output Voltage (V)	L (µH)
9	10
12	15
18	22

Output Capacitor Selection

REG2 is designed to operate with output capacitor ranging from 1µF to 10µF. A 2.2µF output capacitor is suitable for most applications, although lager output capacitor may be used to minimize output ripple, if need. Ceramic capacitors are recommended for most applications.

Rectifier Selection

REG2 requires a Shottky diode to rectify the inductor current. Select a low forward voltage drop Shottky diode with a forward current (I_F) rating that is sufficient to support the maximum switch current and a sufficient peak repetitive reverse voltage (V_{RRM}) to support the output voltage.

PCB Layout Considerations

High switching frequencies and large peak currents make PC board layout a very important part of the design. Good design minimizes excessive EMI on the feedback paths and voltage gradients in the ground plane, both of which can result in instability or regulation errors.

Step-up DC/DCs exhibit continuous input current, so there is some amount of flexibility in placing vias in the input capacitor circuit. The input capacitor should be placed as close as possible to the input pin for good input voltage filtering.
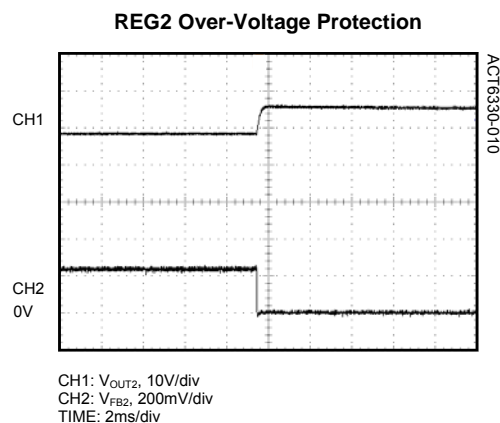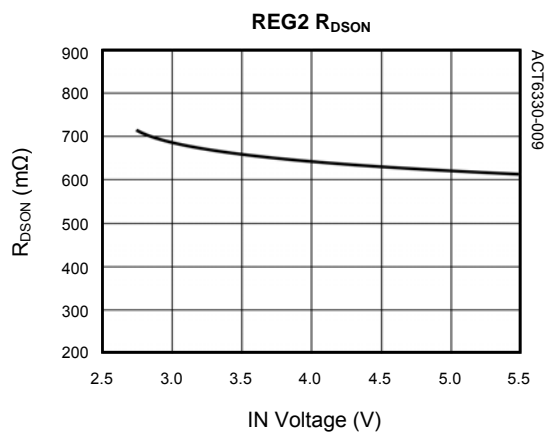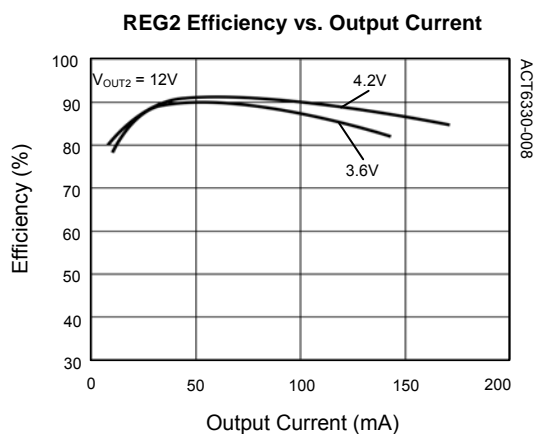
The inductor, input filter capacitor, rectifier, and output filter capacitor should be connected as close together as possible, with short, direct, and wide traces. Avoid using vias in the high-current path. If vias are unavoidable , use many vias in parallel to reduce resistance and inductance.

Place all feedback voltage-divider resistor as close as possible to their respective feedback pins. Connect the ground nodes together in a star configuration, with a direct connection to the exposed pad. Route high-speed switching nodes away from the sensitive analog areas. Finally, the exposed pad should be directly connected to the backside ground plane using multiple vias to achieve low electrical and thermal resistance. Note that since the LED string is a low, DC-current path, it does not generally require special layout consideration.
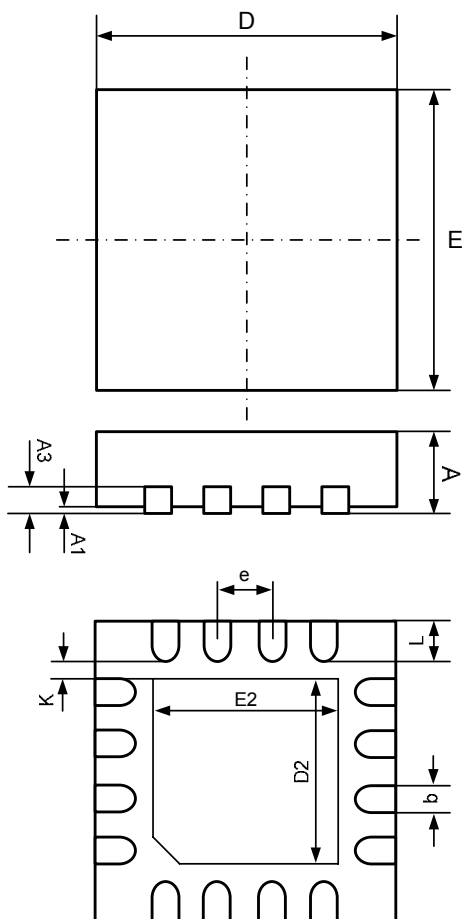
TYPICAL PERFORMANCE CHARACTERISTICS

(ACT6330QK, V_{IN} = 3.6V, L = 22µH, C_{IN} = 2.2µF, C_{OUT} = 2.2µF, T_A = 25°C, unless otherwise specified.)

REG2 Efficiency vs. Output Current

REG2 R_{DSON}

REG2 Over-Voltage Protection

CH1: V_{OUT2}, 10V/div
CH2: V_{FB2}, 200mV/div
TIME: 2ms/div

PACKAGE OUTLINE

TQFN33-16 PACKAGE OUTLINE AND DIMENSIONS

SYMBOL	DIMENSION IN MILLIMETERS		DIMENSION IN INCHES	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.153	0.253	0.006	0.010
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
D2	1.600	1.800	0.063	0.071
E2	1.600	1.800	0.063	0.071
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.300	0.500	0.012	0.020
K	0.200	0.400	0.008	0.016