

## Description

The AL8806Q is a step-down DC/DC converter designed to drive LEDs with a constant current. The device can drive up to 8 LEDs, depending on the forward voltage of the LEDs, in series from a voltage source of 6V to 30V. The AL8806Q switches at frequencies up to 1MHz. This allows the use of small size external components, hence minimizing the PCB area needed.

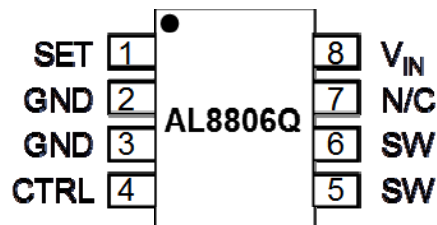
Maximum output current of AL8806Q is set via an external resistor connected between the  $V_{IN}$  and SET input pins. Dimming is achieved by applying either a DC voltage or a PWM signal at the CTRL input pin. An input voltage of 0.4V or lower at CTRL switches off the output MOSFET simplifying PWM dimming.

The AL8806Q has been qualified to AEC-Q100 Grade 1 and is Automotive Grade supporting PPAPs

## Features

- LED driving current up to 1.5A
- Better than 5% accuracy
- High efficiency up to 98%
- Optimally controlled switching speeds
- Operating input voltage from 6V to 30V
- PWM/DC input for dimming control
- Built-in output open-circuit protection
- Automotive Grade with AEC-Q100 Qualification
- MSOP-8EP: Available in "Green" Molding Compound (No Br, Sb)
  - **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
  - **Halogen and Antimony Free. "Green" Device (Note 3)**
- Automotive Grade
  - **Qualified to AEC-Q100 Standards for High Reliability**
  - **PPAP Capable (Note 4)**

## Pin Assignments

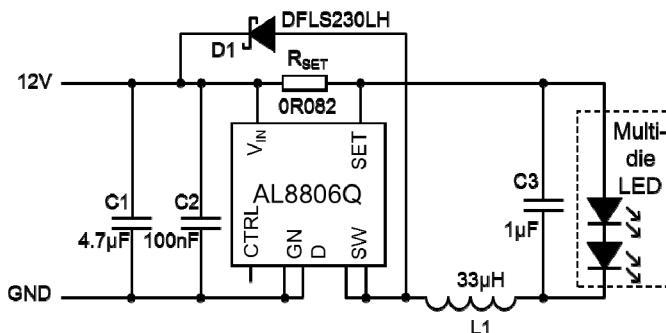


## Applications

- Automotive LED Lamps
- Multi-Die LED Driver

- Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
  2. See [http://www.diodes.com/quality/lead\\_free.html](http://www.diodes.com/quality/lead_free.html) for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
  3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
  4. Automotive products are AEC-Q100 qualified and are PPAP capable. Automotive, AEC-Q100 and standard products are electrically and thermally the same, except where specified. For more information, please refer to [http://www.diodes.com/quality/product\\_compliance\\_definitions/](http://www.diodes.com/quality/product_compliance_definitions/).

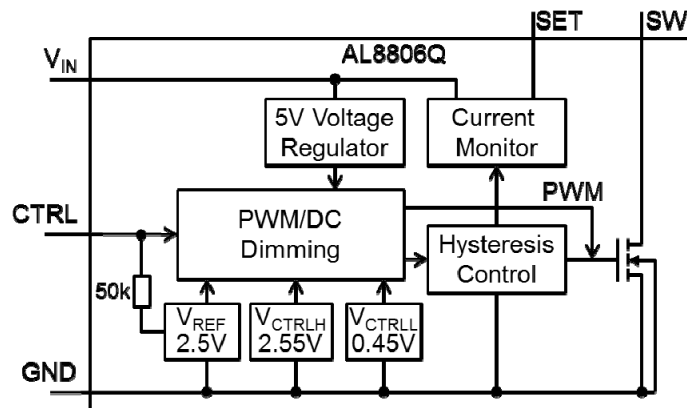
## Typical Applications Circuit



## Pin Descriptions

Pin Name	Pin Number	Functions
SET	1	Set Nominal Output Current Pin. Configure the output current of the device.
GND	2, 3	GND Pin
CTRL	4	Dimming and On/Off Control Input. <ul style="list-style-type: none"> <li>Leave floating for normal operation.</li> <li>(<math>V_{CTRL} = V_{REF} = 2.5V</math> giving nominal average output current <math>I_{OUTnom} = 0.1/R_s</math>)</li> <li>Drive to voltage below 0.4V to turn off output current</li> <li>Drive with DC voltage (<math>0.5V &lt; V_{CTRL} &lt; 2.5V</math>) to adjust output current from 20% to 100% of <math>I_{OUTnom}</math></li> <li>A PWM signal (low level <math>\leq 0.4V</math> and high level <math>&gt; 2.6V</math>; transition times less than 1us) allows the output current to be adjusted below the level set by the resistor connected to SET input pin.</li> </ul>
SW	5, 6	Switch Pin. Connect inductor/freewheeling diode here, minimizing track length at this pin to reduce EMI.
N/C	7	No Connection
V <sub>IN</sub>	8	Input Supply Pin. Must be locally decoupled to GND with $\geq 2.2\mu F$ X7R ceramic capacitor – see applications section for more information.
EP	EP	Exposed pad: Connect to GND and thermal mass for enhanced thermal impedance. It should not be used as electrical ground conduction path.

## Functional Block Diagram



## Absolute Maximum Ratings (@T<sub>A</sub> = +25°C, unless otherwise specified.)

Symbol	Parameter	Ratings	Unit
ESD HBM	Human Body Model ESD Protection	2.5	kV
ESD MM	Machine Model ESD Protection	200	V
ESD CDM	Charged Device Model ESD Protection	—	V
V <sub>IN</sub>	Continuous V <sub>IN</sub> pin voltage relative to GND	-0.3 to +36	V
	Transient V <sub>IN</sub> pin voltage relative to GND	-0.3 to +40	
V <sub>SW</sub>	SW voltage relative to GND	-0.3 to +36	V
V <sub>CTRL</sub>	CTRL pin input voltage	-0.3 to +6	V
I <sub>SW-RMS</sub>	DC or RMS Switch current	1.65	A
I <sub>SW-PK</sub>	Peak Switch current (<10%)	3	A
T <sub>J</sub>	Junction Temperature	150	°C
T <sub>LEAD</sub>	Lead Temperature Soldering	300	°C
T <sub>ST</sub>	Storage Temperature Range	-65 to +150	°C

Caution: Stresses greater than the 'Absolute Maximum Ratings' specified above, may cause permanent damage to the device. These are stress ratings only; functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time. Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices.

**Recommended Operating Conditions** (@ $T_A = +25^{\circ}\text{C}$ , unless otherwise specified.)

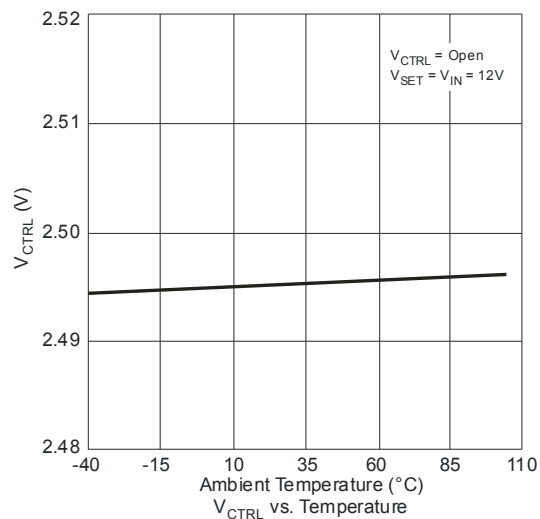
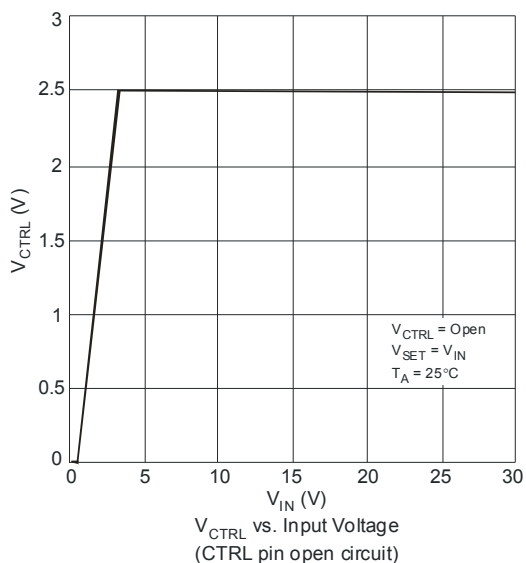
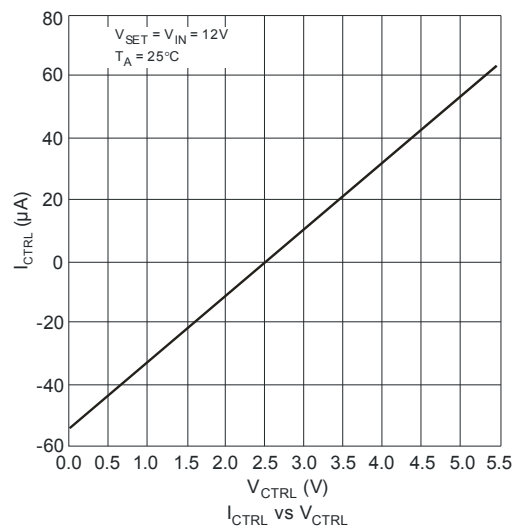
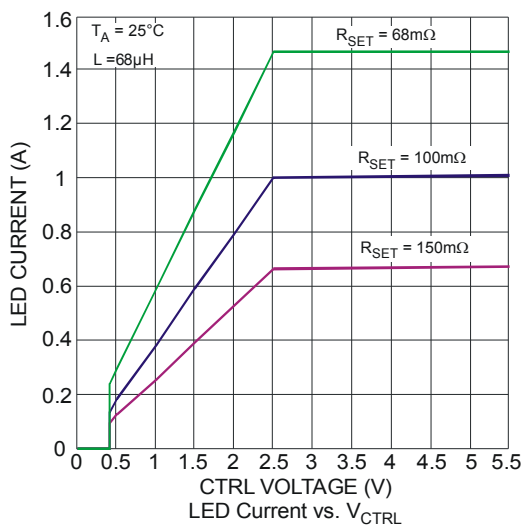
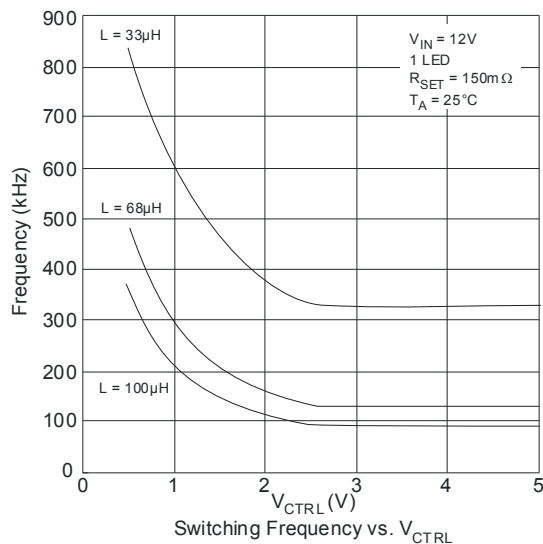
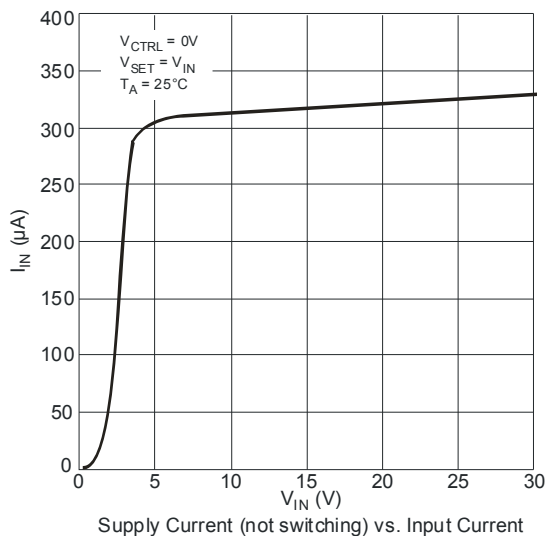
Symbol	Parameter	Min	Max	Unit
$V_{IN}$	Operating Input Voltage relative to GND	6.0	30	V
$V_{CTRLH}$	Voltage High for PWM Dimming Relative to GND	2.6	5.5	V
$V_{CTRLDC}$	Voltage range for 20% to 100% DC Dimming Relative to GND	0.5	2.5	V
$V_{CTRLLL}$	Voltage Low for PWM Dimming Relative to GND	0	0.4	V
$f_{SW}$	Maximum Switching Frequency	—	1	MHz
$I_{SW}$	Continuous Switch Current	—	1.5	A
$T_J$	Junction Temperature Range	-40	+125	$^{\circ}\text{C}$

**Electrical Characteristics** (@  $V_{IN} = 12\text{V}$ ,  $T_A = +25^{\circ}\text{C}$ , unless otherwise specified.)

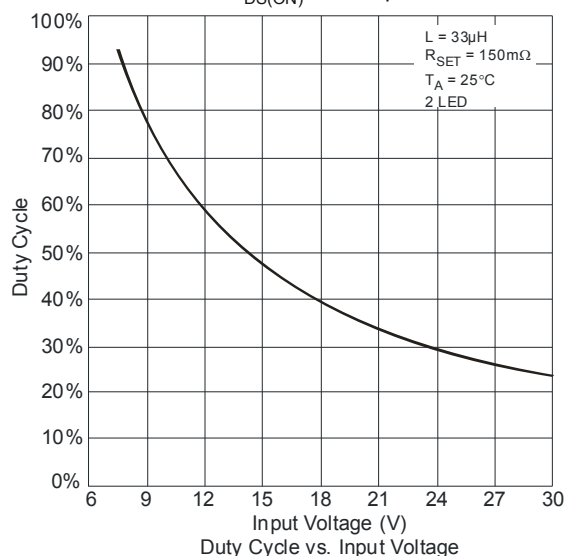
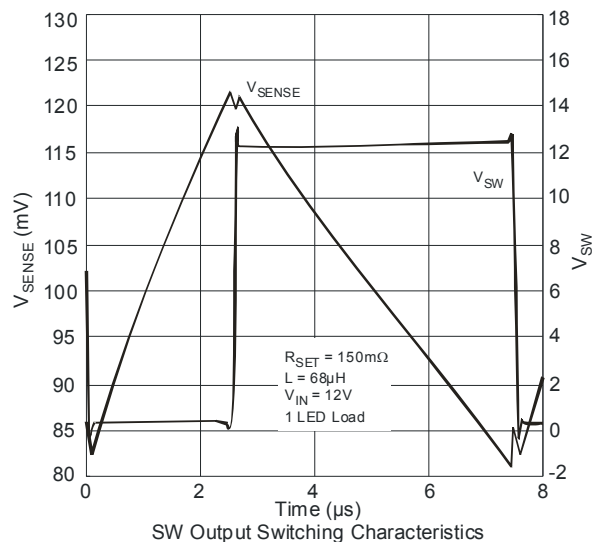
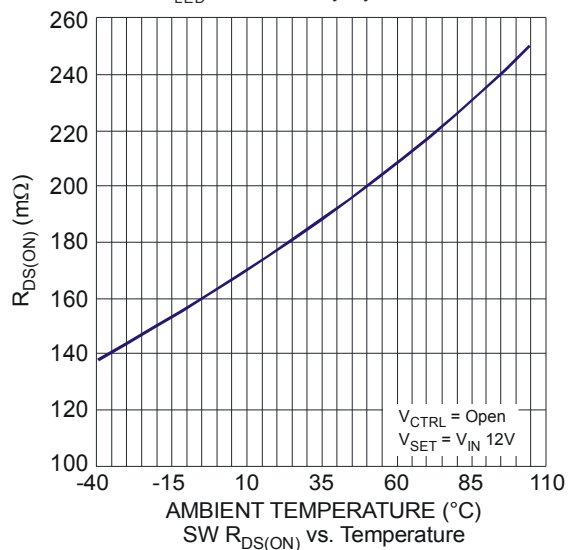
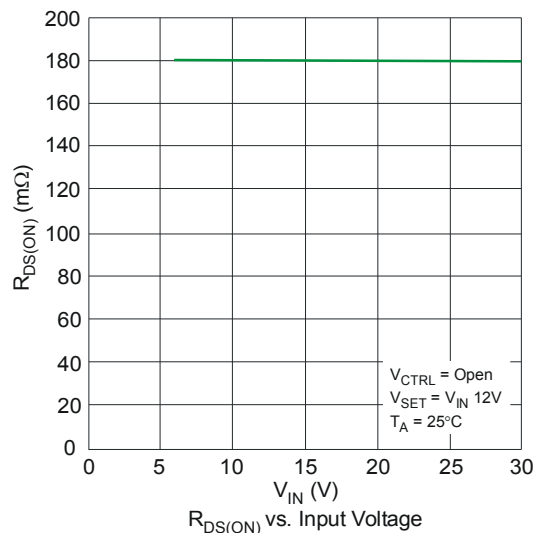
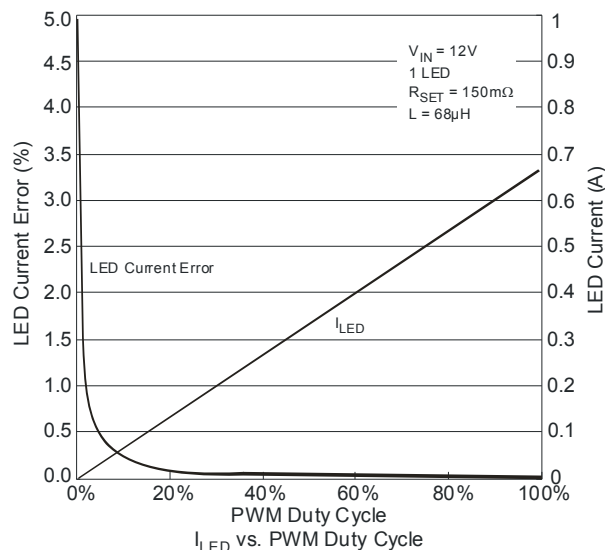
Symbol	Parameter	Conditions	Min	Typ.	Max	Unit
$V_{INSU}$	Internal regulator start up threshold	$V_{IN}$ rising	—	—	5.9	V
$V_{INSH}$	Internal regulator hysteresis threshold	$V_{IN}$ falling	100	—	300	mV
$I_Q$	Quiescent current	Output not switching (Note 5)	—	—	350	$\mu\text{A}$
$I_S$	Input supply Current	CTRL pin floating $f = 250\text{kHz}$	—	1.8	5	mA
$V_{TH}$	Set current Threshold Voltage	$V_{CTRL} \geq 2.6\text{V}$ or floating.	95	100	105	mV
$V_{TH-H}$	Set threshold hysteresis	—	—	$\pm 20$	—	mV
$I_{SET}$	SET pin input current	$V_{SET} = V_{IN} - 0.1$	—	16	22	$\mu\text{A}$
$R_{CTRL}$	CTRL pin input resistance	Referred to internal reference	—	50	—	k $\Omega$
$V_{REF}$	Internal Reference Voltage	—	—	2.5	—	V
$R_{DS(on)}$	On Resistance of SW MOSFET	$I_{SW} = 1\text{A}$	—	0.18	0.35	$\Omega$
$I_{SW\_Leakage}$	Switch leakage current	$V_{IN} = 30\text{V}$	—	—	0.5	$\mu\text{A}$
$\theta_{JA}$	Thermal Resistance Junction-to-Ambient (Note 6)	(Note 7)	—	69	—	$^{\circ}\text{C/W}$
$\theta_{JC}$	Thermal Resistance Junction-to-Case (Note 6)	(Note 7)	—	4.3	—	

- Notes: 5. AL8806Q does not have a low power standby mode but current consumption is reduced when output switch is inhibited:  $V_{SENSE} = 0\text{V}$ . Parameter is tested with  $V_{CTRL} \leq 2.5\text{V}$
6. Refer to figure 5 for the device derating curve.
7. Measured on an FR4 51x51mm PCB with 2oz copper standing in still air with minimum recommended pad layout on top layer and thermal vias to bottom layer maximum area ground plane. For better thermal performance, larger copper pad for heat-sink is needed.
8. Dominant conduction path via exposed pad. Refer to figure 5 for the device derating curve.

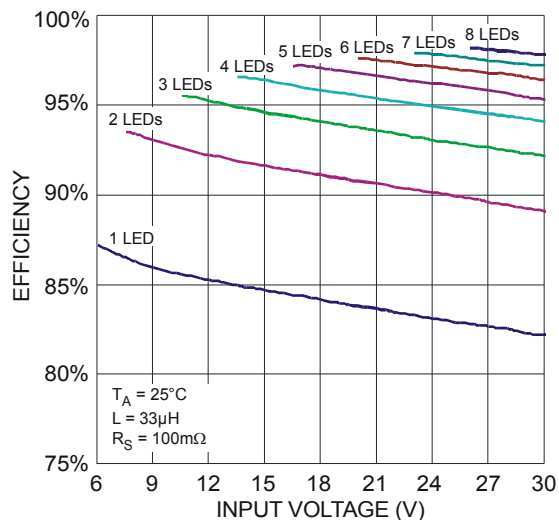
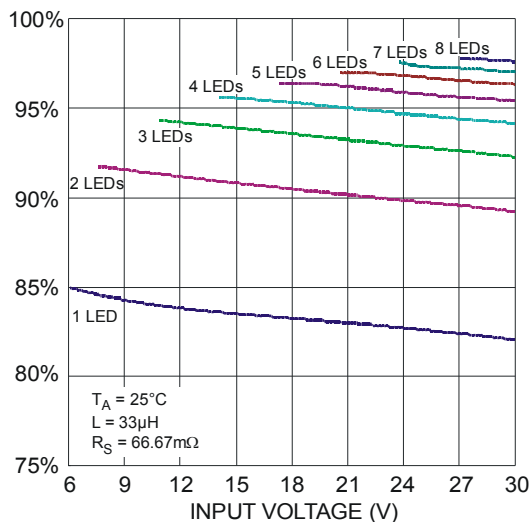
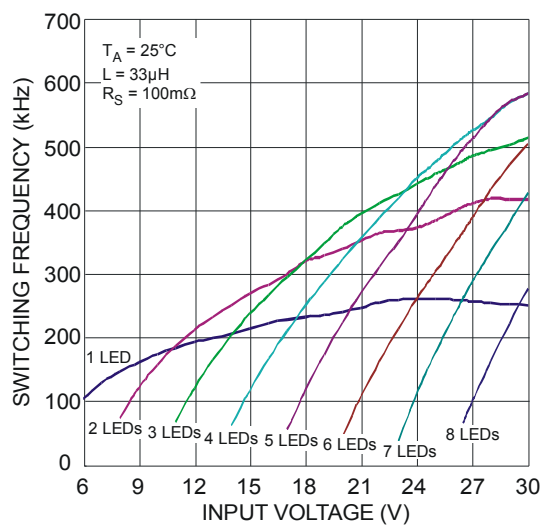
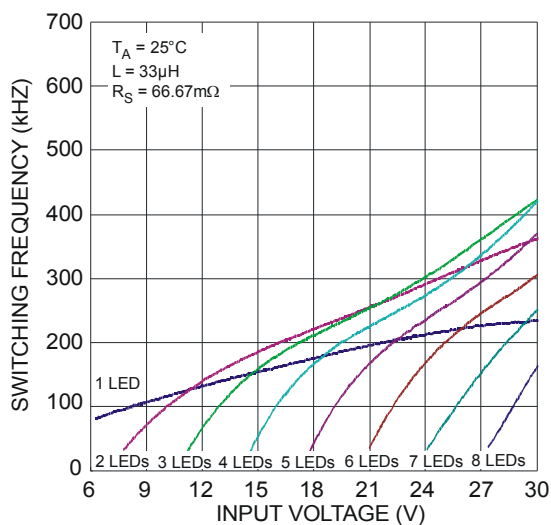
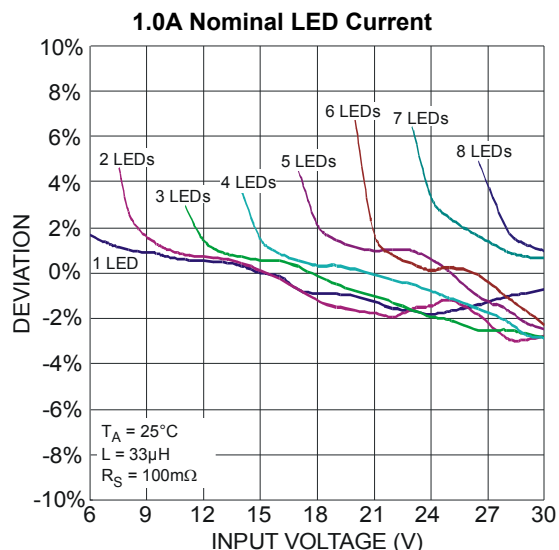
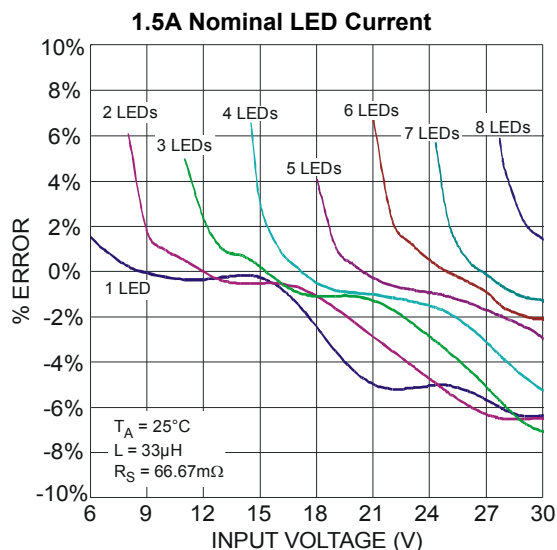
**Typical Performance Characteristics** (@ $T_A = +25^\circ\text{C}$ , unless otherwise specified.)



**Typical Performance Characteristics** (cont.) (@ $T_A = +25^\circ\text{C}$ , unless otherwise specified.)



**Typical Performance Characteristics** (cont.) (@ $T_A = +25^\circ\text{C}$ , unless otherwise specified.)



## Application Information

### AL8806Q Operation

In normal operation, when voltage is applied at  $V_{IN}$ , the AL8806Q internal switch is turned on. Current starts to flow through sense resistor  $R_{SET}$ , inductor  $L1$ , and the LEDs. The current ramps up linearly, and the ramp rate is determined by the input voltage  $V_{IN}$  and the inductor  $L1$ .

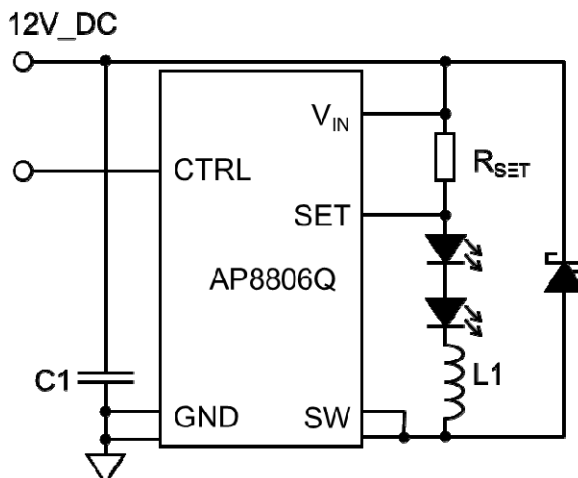


Figure 1 Typical Application Circuit

This rising current produces a voltage ramp across  $R_{SET}$ . The internal circuit of the AL8806Q senses the voltage across  $R_{SET}$  and applies a proportional voltage to the input of the internal comparator.

When this voltage reaches an internally set upper threshold, the internal switch is turned off. The inductor current continues to flow through  $R_{SET}$ ,  $L1$ , the LEDs and the schottky diode  $D1$ , and back to the supply rail, but it decays, with the rate of decay determined by the forward voltage drop of the LEDs and the schottky diode.

This decaying current produces a falling voltage at  $R1$ , which is sensed by the AL8806Q. A voltage proportional to the sense voltage across  $R_{SET}$  is applied at the input of the internal comparator. When this voltage falls to the internally set lower threshold, the internal switch is turned on again.

This switch-on-and-off cycle continues to provide the average LED current set by the sense resistor  $R_{SET}$ .

### LED Current Control

The LED current is controlled by the resistor  $R_{SET}$  in Figure 1.

Connected between  $V_{IN}$  and SET the nominal average output current in the LED(s) is defined as:

$$I_{LED} = \frac{V_{THD}}{R_{SET}}$$

If the CTRL pin is driven by an external voltage (higher than 0.4V and lower than 2.5V), the average LED current is:

$$I_{LED} = \frac{V_{CTRL}}{V_{REF}} \frac{V_{THD}}{R_{SET}}$$

For example for a desired LED current of 1.33A and a default voltage  $V_{CTRL}=2.5V$  the resulting resistor is:

$$R_{SET} = \frac{V_{THD}}{I_{LED}} \frac{V_{CTRL}}{V_{REF}} = \frac{0.1}{1.33} \frac{2.5}{2.5} \approx 75m\Omega$$

### Analog Dimming

The CTRL pin can be driven by an external DC voltage ( $V_{CTRL}$ ), to adjust the output current to a value below the nominal average value defined by  $R_{SET}$ . The LED current decreases linearly with the CTRL voltage when  $0.5V \leq V_{CTRL} \leq 2.5V$ , as shown on page 4 for 4 different current levels.

## Application Information (cont.)

### Analog Dimming (cont.)

Note that 100% brightness setting corresponds to  $V_{CTRL} = V_{REF}$ , nominally 2.5V. For any voltage applied on the CTRL pin that is higher than  $V_{REF}$ , the device will not overdrive the LED current and will still set the current according to the equation  $V_{CTRL} = V_{REF}$ .

When the CTRL voltage falls below the threshold, 0.4V, the output switch is turned off which allows PWM dimming.

### PWM Dimming

LED current can be adjusted digitally, by applying a low frequency Pulse Width Modulated (PWM) logic signal to the CTRL pin to turn the device on and off. This will produce an average output current proportional to the duty cycle of the control signal. In particular, a PWM signal with a max resolution of 10bit can be applied to the CTRL pin to change the output current to a value below the nominal average value set by resistor  $R_{SET}$ . To achieve this resolution the PWM frequency has to be lower than 500Hz, however higher dimming frequencies can be used - at the expense of dimming dynamic range and accuracy.

Typically, for a PWM frequency of 500Hz the accuracy is better than 1% for PWM ranging from 1% to 100%.

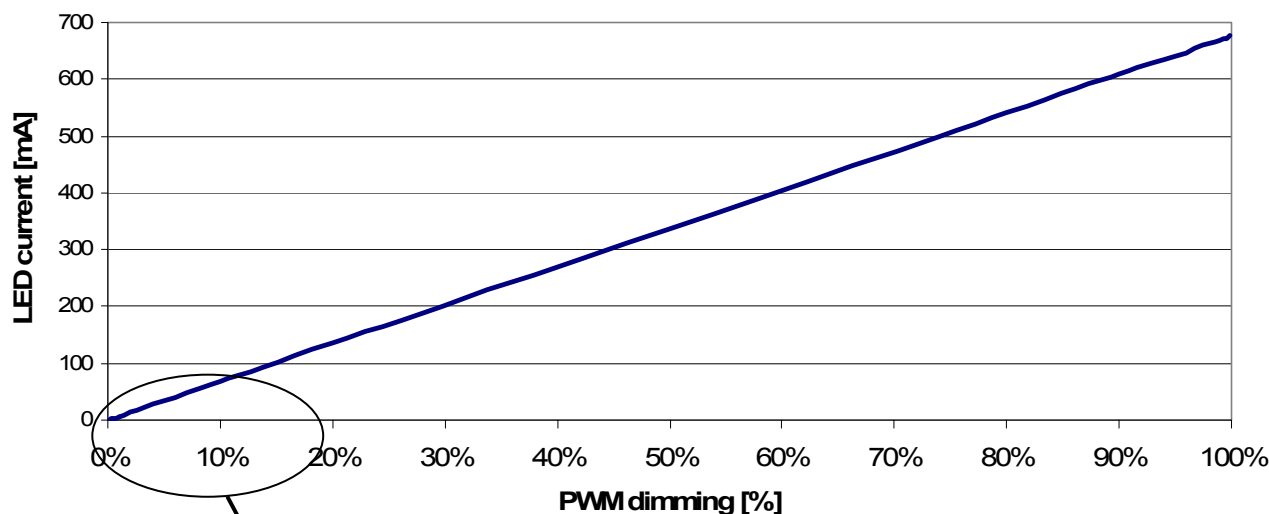


Figure 2 PWM Dimming at 500Hz

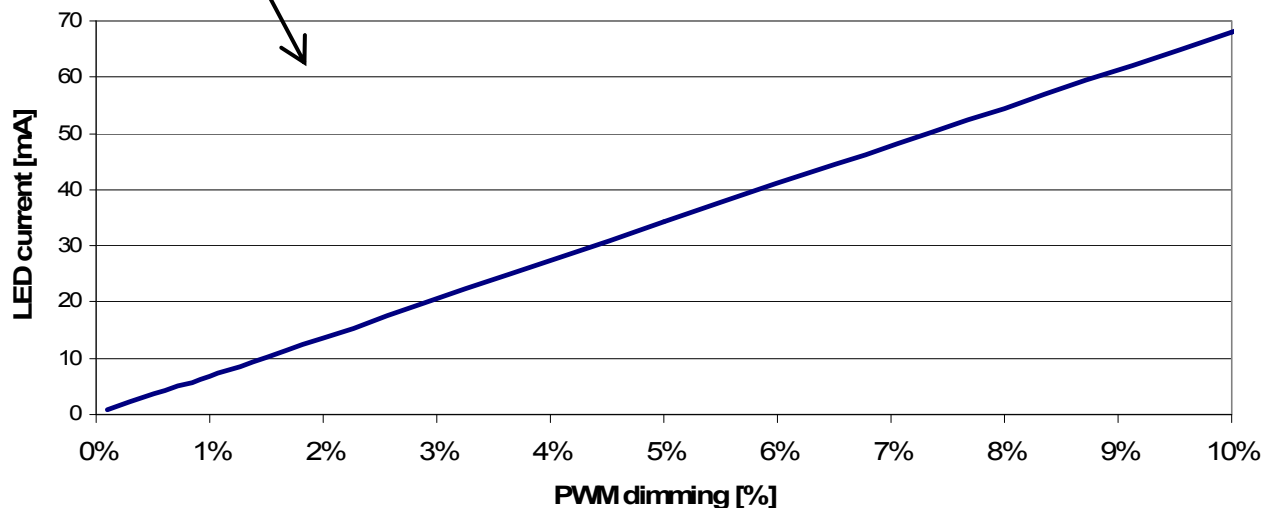


Figure 3 Low duty cycle PWM Dimming at 500Hz

The PWM pin is designed to be driven by both 3.3V and 5V logic levels directly from a logic output with either an open drain output or push-pull output stage.



## Application Information (cont.)

### Soft Start

The AL8806Q does not have in-built soft-start action – this provides very fast turn off of the output the stage improving PWM dimming accuracy; nonetheless, adding an external capacitor from the CTRL pin to ground will provide a soft-start delay. This is achieved by increasing the time taken for the CTRL voltage to rise to the turn-on threshold and by slowing down the rate of rise of the control voltage at the input of the comparator.

Adding a capacitor increases the time taken for the output to reach 90% of its final value, this delay is 0.1ms/nF, but will impact on the PWM dimming accuracy depending on the delay introduced.

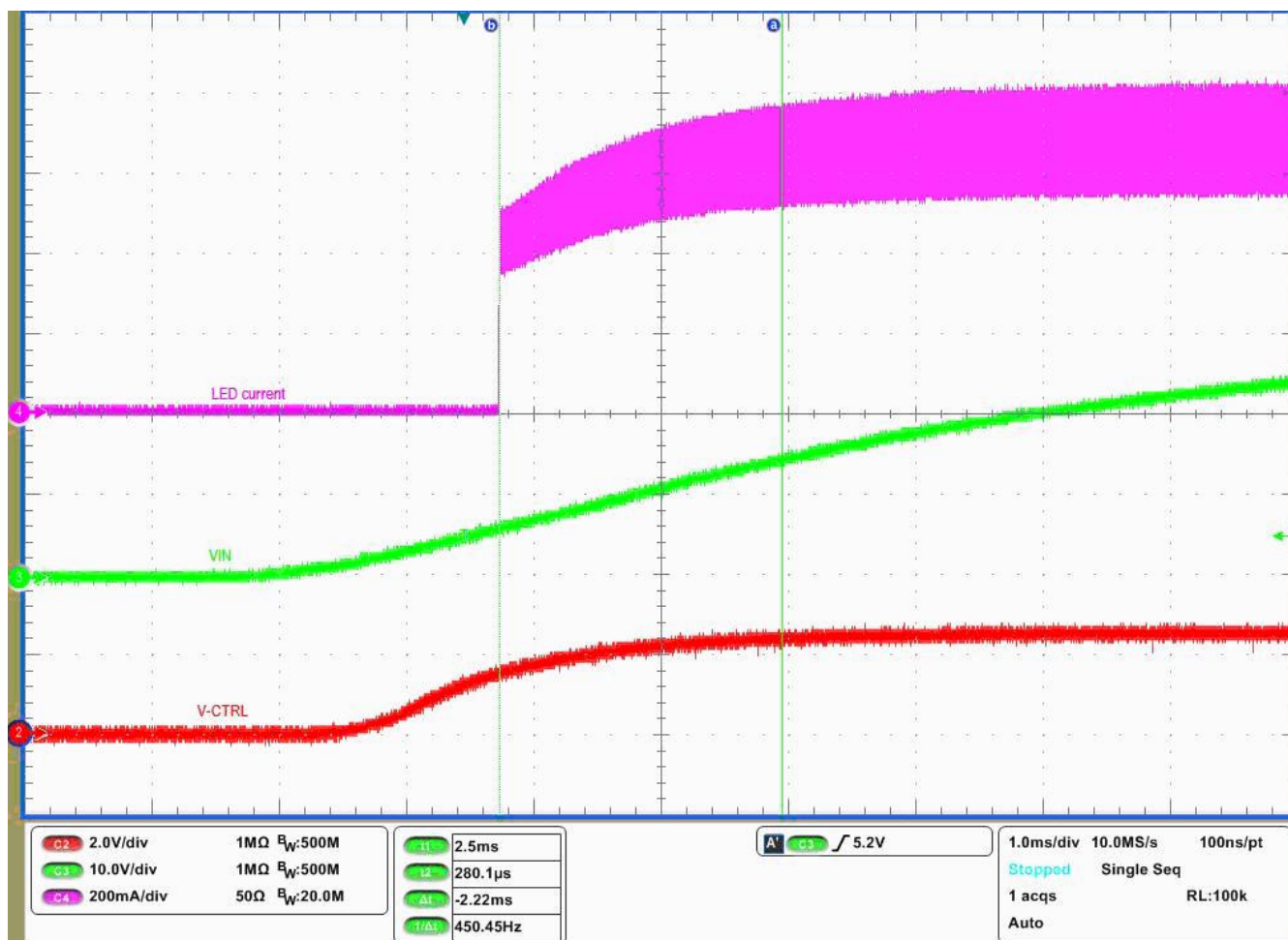


Figure 4 Soft Start with 22nF Capacitor on CTRL pin ( $V_{IN} = 30V$ ,  $I_{LED} = 667mA$ , 1 LED)

## Application Information (cont.)

### Reducing Output Ripple

Peak to peak ripple current in the LED(s) can be reduced, if required, by shunting a capacitor C2 across the LED(s) as shown already in the circuit schematic.

A value of 1µF will reduce the supply ripple current by a factor three (approx.). Proportionally lower ripple can be achieved with higher capacitor values. Note that the capacitor will not affect operating frequency or efficiency, but it will increase start-up delay, by reducing the rate of rise of LED voltage. By adding this capacitor the current waveform through the LED(s) changes from a triangular ramp to a more sinusoidal version without altering the mean current value.

### Capacitor Selection

The small size of ceramic capacitors makes them ideal for AL8806Q applications. X5R and X7R types are recommended because they retain their capacitance over wider voltage and temperature ranges than other types such as Z5U.

A 2.2µF input capacitor is sufficient for most intended applications of AL8806Q; however a 4.7µF input capacitor is suggested for input voltages approaching 30V.

### Diode Selection

For maximum efficiency and performance, the rectifier (D1) should be a fast low capacitance Schottky diode with low reverse leakage at the maximum operating voltage and temperature. The Schottky diode also provides better efficiency than silicon PN diodes, due to a combination of lower forward voltage and reduced recovery time.

It is important to select parts with a peak current rating above the peak coil current and a continuous current rating higher than the maximum output load current. In particular, it is recommended to have a diode voltage rating at least 15% higher than the operating voltage to ensure safe operation during the switching and a current rating at least 10% higher than the average diode current. The power rating is verified by calculating the power loss through the diode.

Schottky diodes, e.g. B240 or B140, with their low forward voltage drop and fast reverse recovery, are the ideal choice for AL8806Q applications.

### Thermal and Layout Considerations

For continuous conduction mode of operation, the absolute maximum junction temperature must not be exceeded. The maximum power dissipation depends on several factors: the thermal resistance of the IC package  $\theta_{JA}$ , PCB layout, airflow surrounding the IC, and difference between junction and ambient temperature.

The maximum power dissipation can be calculated using the following formula:

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

where

$T_{J(MAX)}$  is the maximum operating junction temperature,

$T_A$  is the ambient temperature, and

$\theta_{JA}$  is the junction to ambient thermal resistance.

The recommended maximum operating junction temperature,  $T_J$ , is 125°C and so maximum ambient temperature is determined by the AL8806Q's junction to ambient thermal resistance,  $\theta_{JA}$ . To support high LED drive at higher ambient temperatures the AL8806Q has been packaged in thermally enhanced MSOP-8EP package.

$\theta_{JA}$ , is layout dependent and the AL8806Q's  $\theta_{JA}$  in MSOP-8EP on a 51 x 51mm double layer PCB with 2oz copper standing in still air is approximately 69°C/W.

Therefore the maximum power dissipation at  $T_A = 25^\circ\text{C}$  is:

$$P_{D(MAX)} = \frac{(125^\circ\text{C} - 25^\circ\text{C})}{69^\circ\text{C/W}} = 1.45\text{W}$$

Figure 5, shows the power derating of the AL8806Q on an FR4 51x51mm PCB with 2oz copper standing in still air.

As the ambient temperature increases and/or the PCB area reduces the maximum allowable power dissipated by the AL8806Q will decrease.

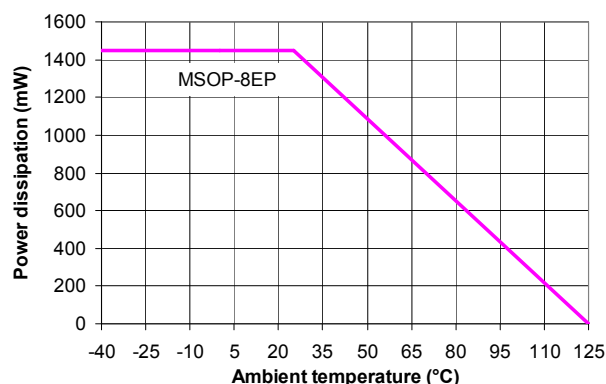


Figure 5 Derating Curve

## Application Information (cont.)

### EMI and PCB Layout Considerations

The AL8806Q is a switching regulator with fast edges and measures small differential voltages; as a result of this care has to be taken with decoupling and layout of the PCB. To help with these effects the AL8807Q has been developed to minimise radiated emissions by controlling the switching speeds of the internal power MOSFET. The rise and fall times are controlled to get the right compromise between power dissipation due to switching losses and radiated EMI. The turn-on edge (falling edge) dominates the radiated EMI which is due to an interaction between the Schottky diode (D1), Switching MOSFET and PCB tracks. After the Schottky diode reverse recovery time of around 5ns has occurred; the falling edge of the SW pin sees a resonant loop between the Schottky diode capacitance and the track inductance,  $L_{\text{TRACK}}$ , See figure 6.

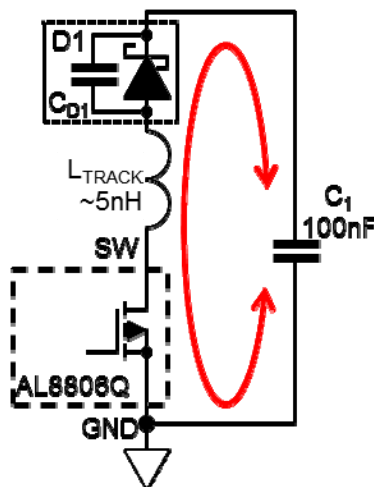


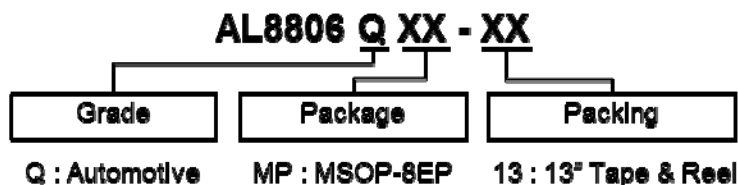
Figure 6 PCB Loop Resonance

The tracks from the SW pin to the Anode of the Schottky diode, D1, and then from D1's cathode to the decoupling capacitors C1 should be as short as possible. There is an inductance internally in the AL8807Q this can be assumed to be around 1nH. For PCB tracks a figure of 0.5nH per mm can be used to estimate the primary resonant frequency. If the track is capable of handling 1A increasing the thickness will have a minor effect on the inductance and length will dominate the size of the inductance. The resonant frequency of any oscillation is determined by the combined inductance in the track and the effective capacitance of the Schottky diode.

Recommendations for minimising radiated EMI and other transients and thermal considerations are:

1. The decoupling capacitor (C1) has to be placed as close as possible to the  $V_{\text{IN}}$  pin and D1 Cathode
2. The freewheeling diode's (D1) anode, the SW pin and the inductor have to be placed as close as possible to each other to avoid ringing.
3. The Ground return path from C1 must be a low impedance path with the ground plane as large as possible
4. The LED current sense resistor (R1) has to be placed as close as possible to the  $V_{\text{IN}}$  and SET pins.
5. The majority of the conducted heat from the AL8807Q is through the GND pin 2. A maximum earth plane with thermal vias into a second earth plane will minimise self-heating
6. To reduce emissions via long leads on the supply input and LEDs low RF impedance capacitors (C2 and C5) should be used at the point the wires are joined to the PCB

## Ordering Information



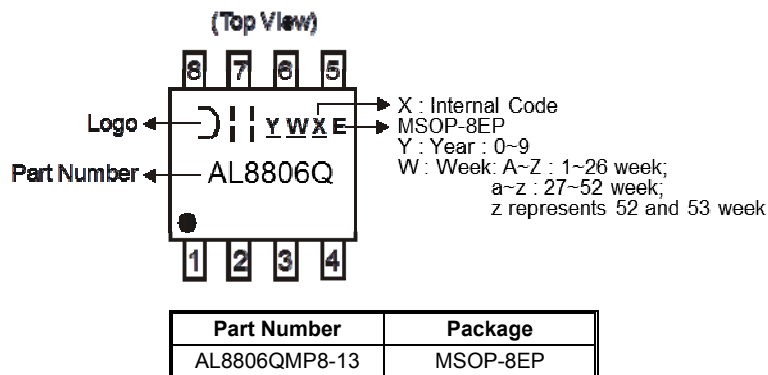
Part Number	Package Code	Packaging (Note 9)	Packing: 13" Tape and Reel			Qualification Grade (Note 10)
			Quantity	Tape Width	Part Number Suffix	
AL8806QMP-13	MP	MSOP-8EP	2500	12mm	-13	Automotive Grade

Note: 9. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at <http://www.diodes.com/datasheets/ap02001.pdf>

10. AL8806Q have been qualified to AEC-Q100 grade 1 and is classified as "Automotive Grade" which supports PPAP documentation. See AL8806 datasheet for commercial qualified versions.

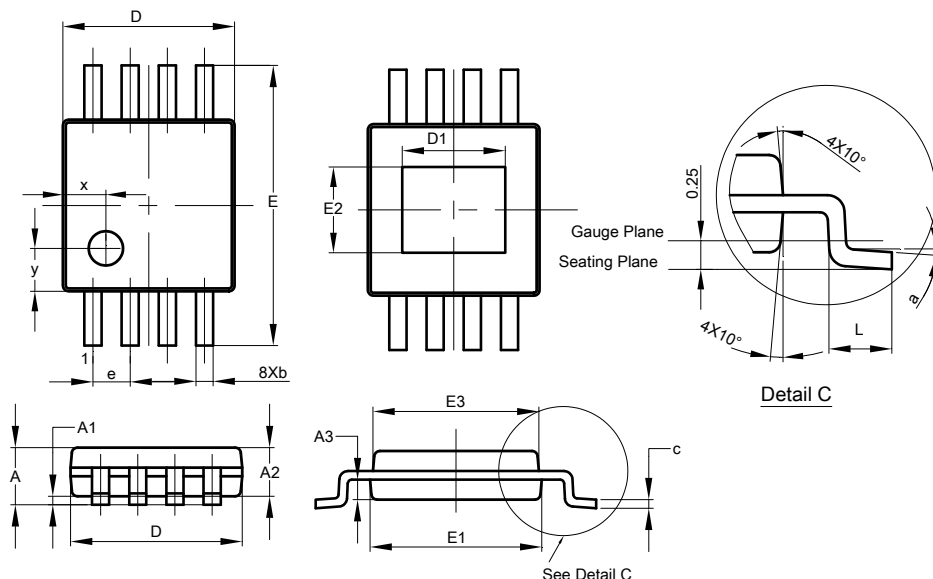
## Marking Information

### (1) MSOP-8EP



## Package Outline Dimensions (All dimensions in mm.)

Please see AP02002 at <http://www.diodes.com/datasheets/ap02002.pdf> for latest version.

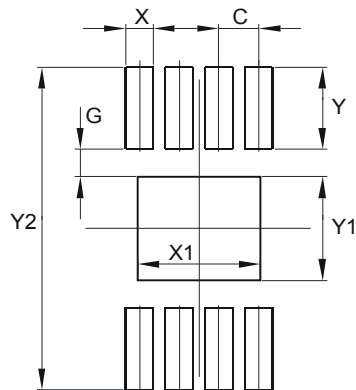


MSOP-8EP			
Dim	Min	Max	Typ
A	-	1.10	-
A1	0.05	0.15	0.10
A2	0.75	0.95	0.86
A3	0.29	0.49	0.39
b	0.22	0.38	0.30
c	0.08	0.23	0.15
D	2.90	3.10	3.00
D1	1.60	2.00	1.80
E	4.70	5.10	4.90
E1	2.90	3.10	3.00
E2	1.30	1.70	1.50
E3	2.85	3.05	2.95
e	-	-	0.65
L	0.40	0.80	0.60
a	0°	8°	4°
x	-	-	0.750
y	-	-	0.750

All Dimensions in mm

## Suggested Pad Layout

Please see AP02001 at <http://www.diodes.com/datasheets/ap02001.pdf> for the latest version.



Dimensions	Value (in mm)
C	0.650
G	0.450
X	0.450
X1	2.000
Y	1.350
Y1	1.700
Y2	5.300

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