Description

The AL8862Q is a step-down DC/DC converter designed to drive LEDs with a constant current. The AL8862Q operates with an input supply voltage from 5V to 55V and provides an externally adjustable output current up to 1A. Series connection of the LEDs provides identical LED currents resulting in uniform brightness and eliminating the need for ballast resistors. The AL8862Q switches at frequency up to 1MHz. This allows the use of smaller size external components, hence minimizing the PCB size.

The AL8862Q integrates the power switch and a high-side output current sensing circuit. Maximum output current of AL8862Q is set via an external resistor connected between the VIN and SET input pins. Dimming is achieved by applying either a DC voltage or a PWM signal at the CTRL input pin. The soft-start time can be adjusted using an external capacitor from the CTRL pin to the ground. An input voltage of 0.3V or lower at CTRL pin will shut down the power switch.

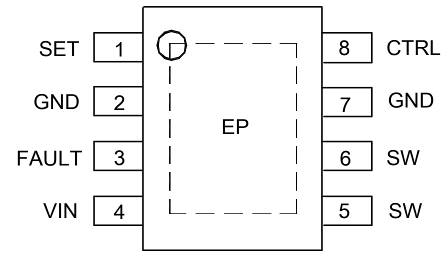
The AL8862Q is qualified to AEC-Q100 Grade 1 and is automotive grade to support PPAPs.

Features

- Wide Input Voltage Range: 5V to 55V
- Output Current up to 1A
- Internal 55V NDMOS Switch
- Typical 4% Output Current Accuracy
- Single Pin for On/Off and Brightness Control by DC Voltage or PWM Signal
- High Efficiency (Up to 97%)
- Fault Status Indication for Abnormal Operation
- LED Short-Circuit Protection
- Inherent Open-Circuit LED Protection
- Current-Sense Resistor Short-Circuit Protection
- Over Temperature Shutdown
- Up to 1MHz Switching Frequency
- SO-8EP Packages 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)**
- **The AL8862Q is suitable for automotive applications requiring specific change control; this part is AEC-Q100 qualified, PPAP capable, and manufactured in IATF 16949 certified facilities.**
  https://www.diodes.com/quality/product-definitions/

Pin Assignments

(Top View)



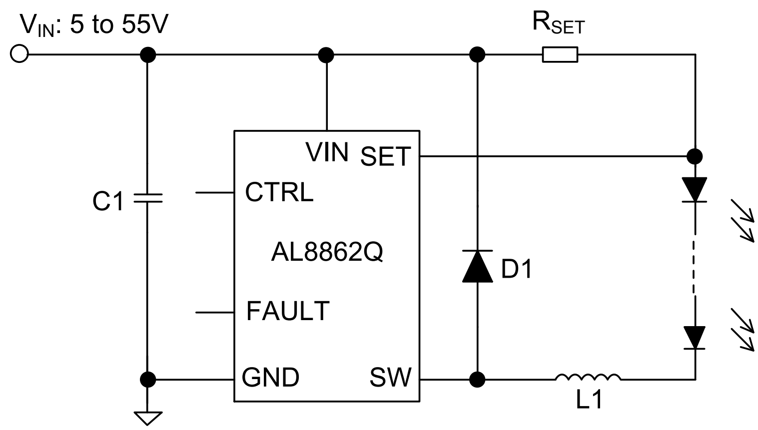
SO-8EP

Applications

- Automotive Interior LED Lamps
- Automotive Exterior LED Lamps

Notes: 1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ 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.

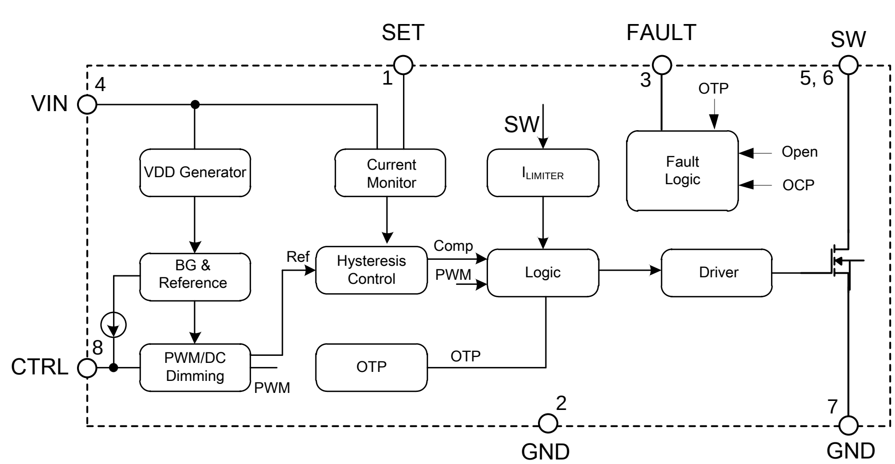
Typical Applications Circuit



Pin Descriptions

Pin Number	Pin Name	Function
1	SET	Set Nominal Output Current Pin. Connect resistor R_{SET} from this pin to VIN to define nominal average output current.
2,7	GND	Ground of IC
3	FAULT	FAULT Indication. Asserted Low to report faulty conditions. Needs an external pull-up resistor.
4	VIN	Input voltage (5V to 55V). Decouple to ground with 10µF or higher X7R ceramic capacitor close to device.
5,6	SW	Switch Pin. Connect inductor/freewheeling diode here, minimizing track length at this pin to reduce EMI.
8	CTRL	Multi-function On/Off and brightness control pin: • Leave floating for normal operation. • Drive to voltage below 0.3V to turn off output current • Drive with DC voltage (0.4V < V_{SET} < 2.5V) to adjust output current from 10% to 100% of I_{OUT_NOM} • Drive with an analog voltage >2.6V output current will be 100% of I_{OUT_NOM} • A PWM signal (Low level <0.3V, High level >2.6V, transition times less than 1µs) allows the output current to be adjusted over a wide range up to 100% • Connect a capacitor from this pin to ground to increase soft-start time. (Default soft-start time = 0.1ms. Additional soft-start time is approximately 1.5ms/1nF)
EP	EP	Exposed pad/TAB connects to GND and thermal mass for enhanced thermal impedance.

Functional Block Diagram



Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{IN}	Input Voltage	-0.3 to +65	V
V_{SW}, V_{SET}	SW, SET Pin Voltage	-0.3 to +65	V
V_{CTRL}	CTRL Pin Input Voltage	-0.3 to +6	V
T_A	Operating Ambient Temperature	-40 to +125	°C
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature Range	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10s)	+300	°C

Note: 4. Stresses greater than those listed under *Absolute Maximum Ratings* can cause permanent damage to the device. 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. Exposure to *Absolute Maximum Ratings* for extended periods can affect device reliability.

ESD Ratings (Note 5)

Symbol	Parameter	Rating	Unit
V_{ESD}	Human-Body Model (HBM), Per AEC-Q100-002	±3000	V
	Charged-Device Model (CDM), Per AEC-Q100-011	±1000	

Note: 5. AEC-Q100-002 indicates that HBM stressing shall be accordance with the ANSI/ESDA/JEDEC JS-001 specification.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{IN}	Input Voltage	5	55	V
f_{SW}	Switching Frequency	—	1	MHz
I_{OUT}	Continuous Output Current	—	1	A
V_{CTRL}	Voltage Range for 10% to 100% DC Dimming Relative to GND	0.4	2.5	V
V_{CTRL_HIGH}	Voltage High for PWM Dimming Relative to GND	2.6	5.5	V
V_{CTRL_LOW}	Voltage Low for PWM Dimming Relative to GND	0	0.3	V
T_A	Operating Ambient Temperature	-40	+125	°C

Thermal Information (Note 6)

Symbol	Parameter	Rating	Unit
θ_{JA}	Junction-to-Ambient Thermal Resistance	58	°C/W
θ_{JC}	Junction-to-Case (Top) Thermal Resistance	6.5	°C/W

Note: 6. Device mounted on 2″×2″ FR-4 substrate PCB, 2oz copper, with minimum recommended pad layout.

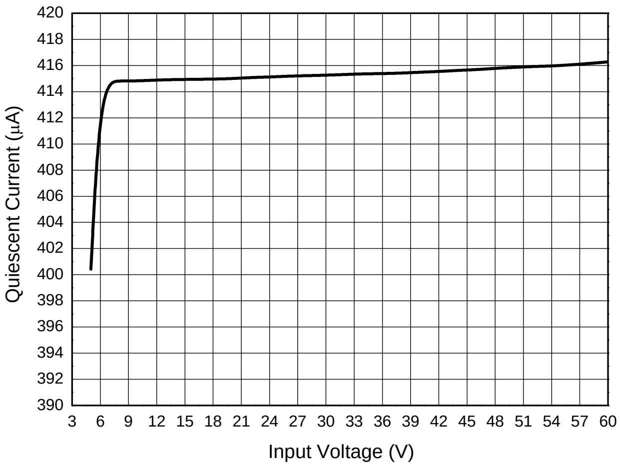
Electrical Characteristics (T_A = -40°C to +125°C, unless otherwise noted).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
SUPPLY VOLTAGE						
V_{IN}	Input Voltage	—	5.0	—	55	V
I_Q	Quiescent Current	CTRL Pin Floating, V_{IN} =16V	—	450	—	µA
V_{UVLO}	Under Voltage Lockout	V_{IN} Rising	—	4.8	—	V
V_{UVLO_HYS}	UVLO Hysteresis	—	—	200	—	mV
HYSTERESTIC CONTROL						
V_{SET}	Mean Current Sense Threshold Voltage	Measured on SET Pin with Respect to VIN	96	100	104	mV
V_{SET_HYS}	Sense Threshold Hysteresis	—	—	±13	—	%
I_{SET}	SET Pin Input Current	V_{SET} = V_{IN} -0.1	—	8	—	µA
R_{SET_INT}	Internal Resistor between VIN Pin and SET Pin	—	—	500	—	Ω
ENABLE AND DIMMING						
V_{CTRL}	Voltage Range on CTRL Pin	For Analog Dimming	0.4	—	2.5	V
—	Analog Dimming Range	—	10	—	100	%
V_{CTRL_ON}	DC Voltage On CTRL Pin For Analog Dimming On	V_{CTRL} Rising	—	0.45	—	V
V_{CTRL_OFF}	DC Voltage On CTRL Pin For Analog Dimming Off	V_{CTRL} Falling	—	0.40	—	V
SWITCHING OPERATION						
R_{ON}	SW Switch On Resistance	@I_{SW} = 100mA	—	0.4	—	Ω
I_{SW_LEAK}	SW Switch Leakage Current	—	—	—	8	µA
t_{SS}	Soft Start Time	V_{IN} = 16V, C_{CTRL} = 1nF	—	1.5	—	ms
f_{SW}	Operating Frequency	V_{IN} = 16V, V_O = 9.6V (3 LEDs) L = 47µH, ΔI = 0.25A (I_{LED} = 1A)	—	250	—	kHz
f_{SW_MAX}	Recommended Maximum Switch Frequency	—	—	—	1	MHz
t_{ON_REC}	Recommended Minimum Switch ON Time	For 4% Accuracy	—	500	—	ns
t_{PD}	Internal Comparator Propagation Delay (Note 7)	—	—	100	—	ns
THERMAL SHUTDOWN						
T_{OTP}	Over Temperature Protection	—	—	+150	—	°C
T_{OTP_HYS}	Temp Protection Hysteresis	—	—	+30	—	°C
I_{SW_MAX}	Current Limit	Peak Inductor Current	—	3	—	A

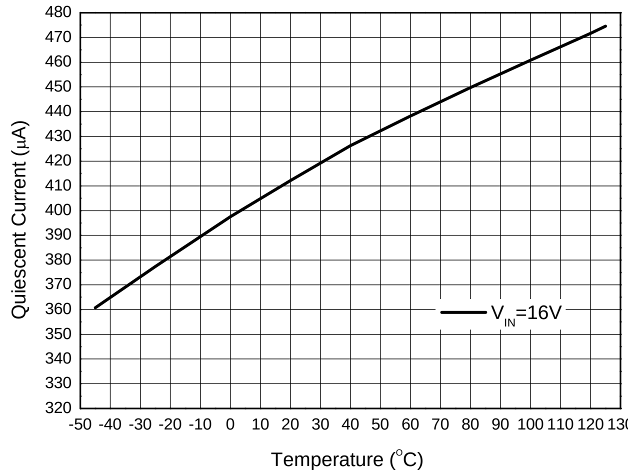
Note: 7. Guaranteed by design.

Typical Performance Characteristics (T_A = +25°C, V_{IN} = 16V, unless otherwise noted).

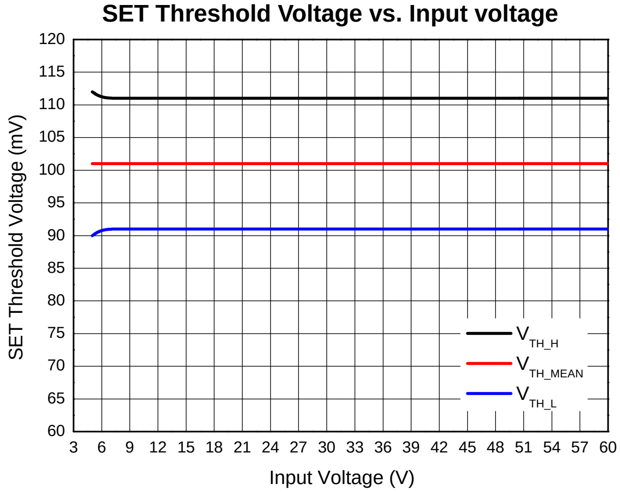
Quiescent Current vs. Input Voltage



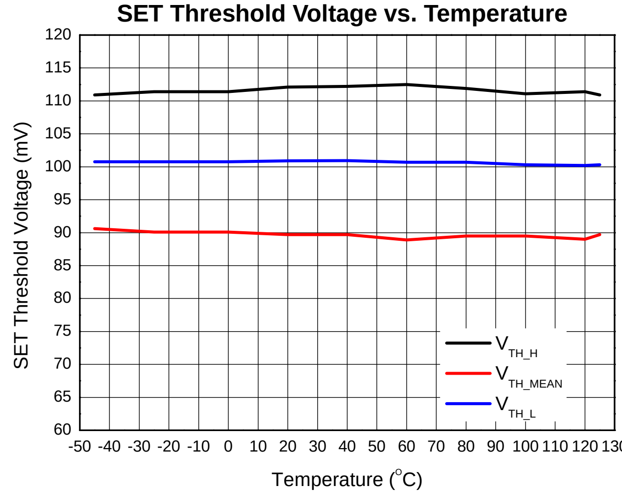
Quiescent Current vs. Temperature



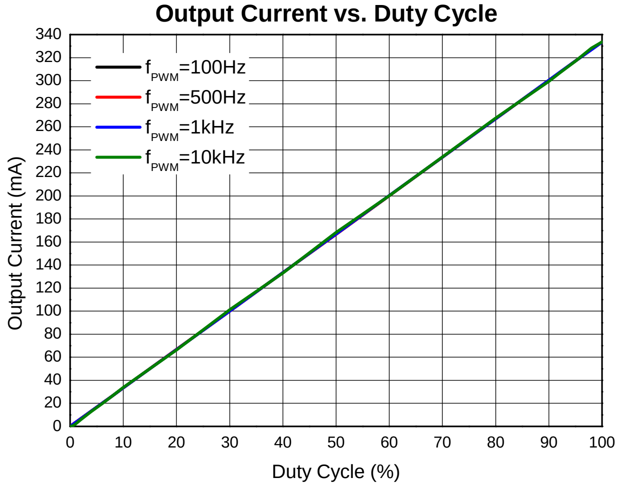
SET Threshold Voltage vs. Input voltage



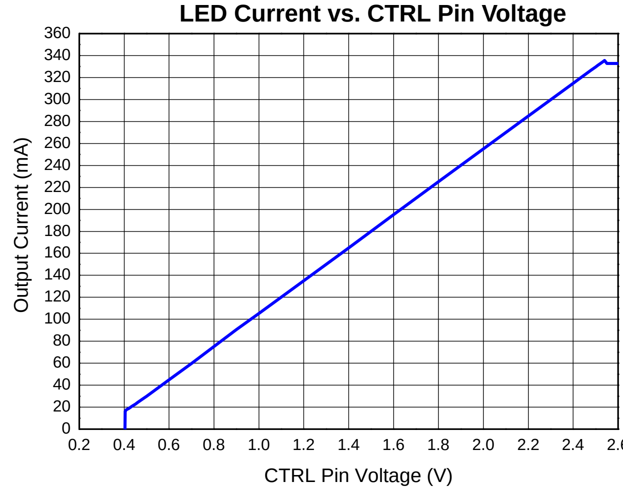
SET Threshold Voltage vs. Temperature



PWM Dimming (V_{IN}=16V, 3LEDs, 68µH, R_S=0.3Ω)
Output Current vs. Duty Cycle

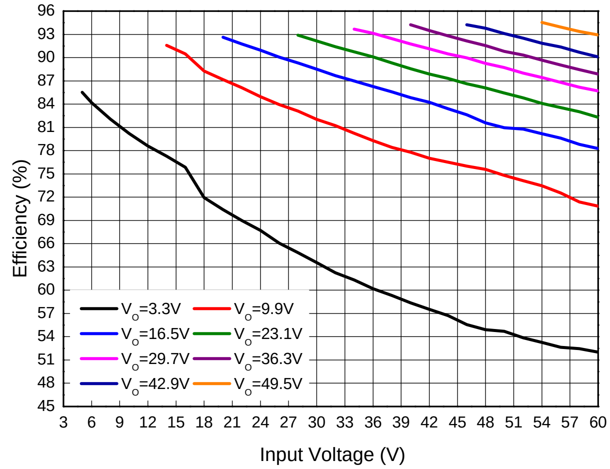


Analog Dimming (V_{IN}=16V, 3LEDs, 47µH, R_S=0.3Ω)
LED Current vs. CTRL Pin Voltage

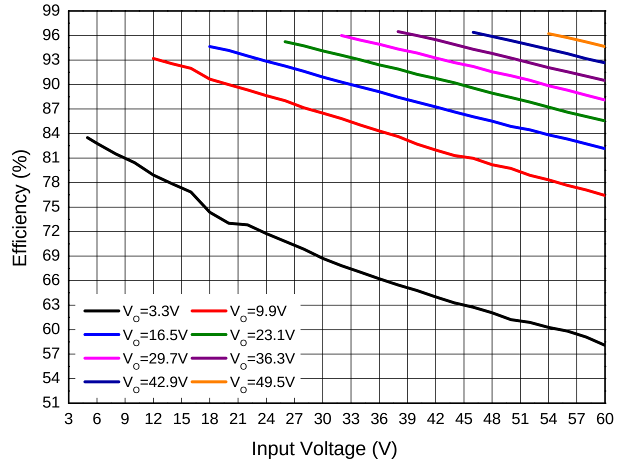


Typical Performance Characteristics (continued) (T_A = +25°C, V_{IN} = 16V, unless otherwise noted.)

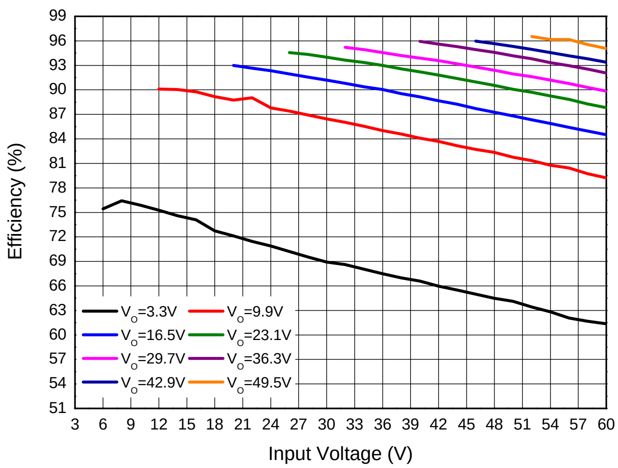
Efficiency vs. Input Voltage
(R_S=0.3Ω, L=100µH)



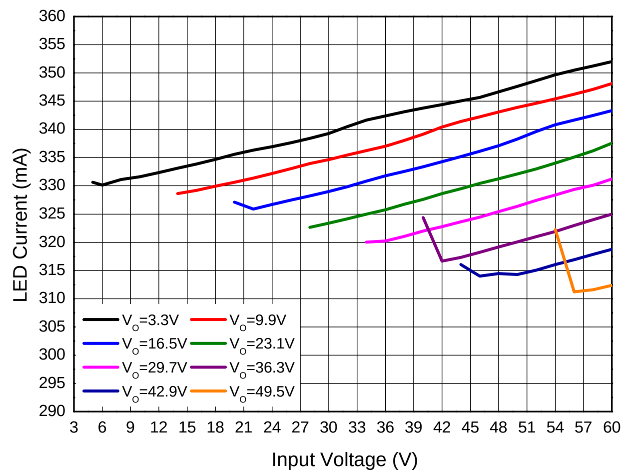
Efficiency vs. Input Voltage
(R_S=0.15Ω, L=68µH)



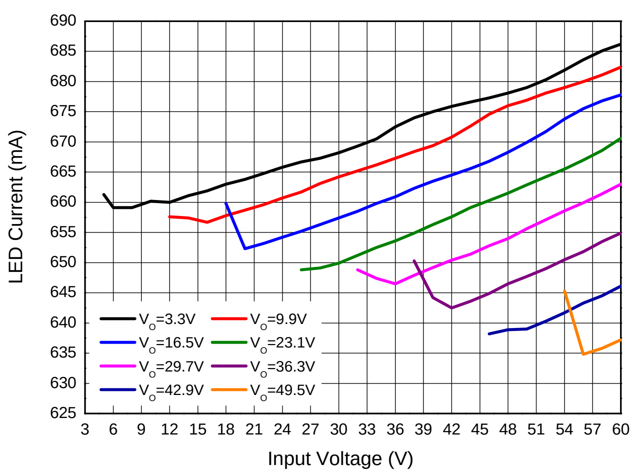
Efficiency vs. Input Voltage
(R_S=0.1Ω, L=100µH)



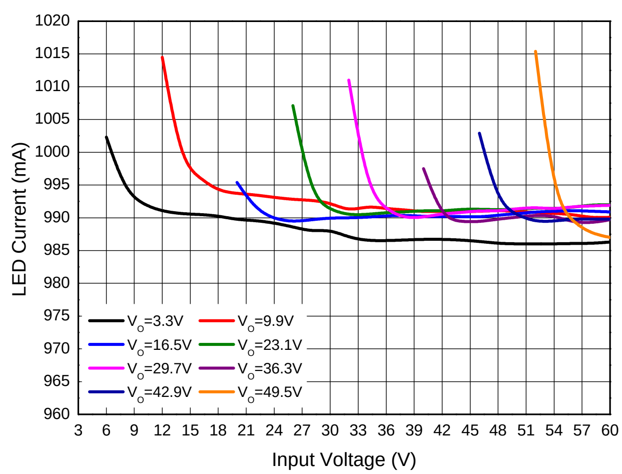
LED Current vs. Input Voltage
(R_S=0.3Ω, L=100µH)



LED Current vs. Input Voltage
(R_S=0.15Ω, L=68µH)

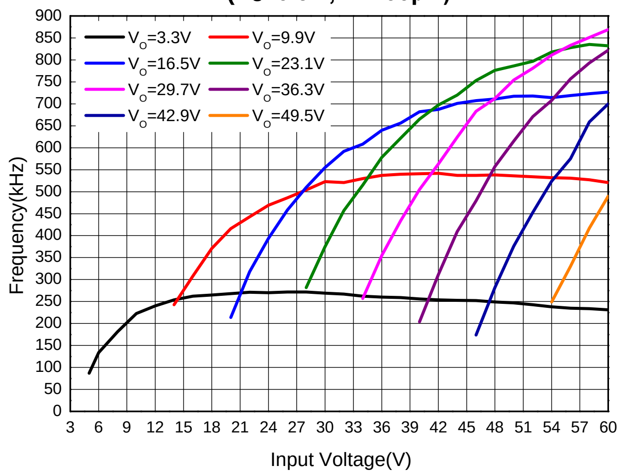


LED Current vs. Input Voltage
(R_S=0.1Ω, L=100µH)

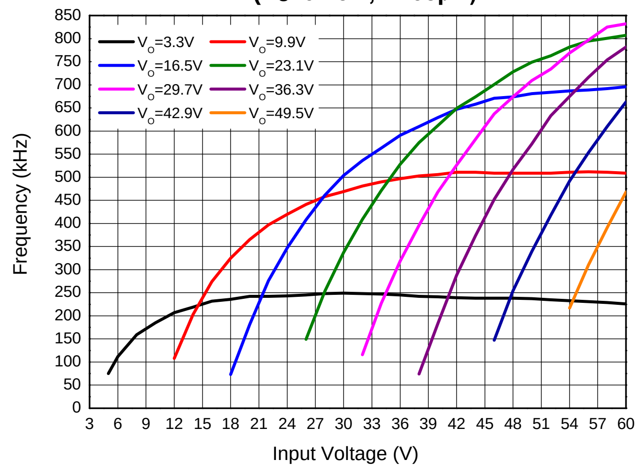


Typical Performance Characteristics (continued) (T_A = +25°C, V_{IN} = 16V, unless otherwise noted.)

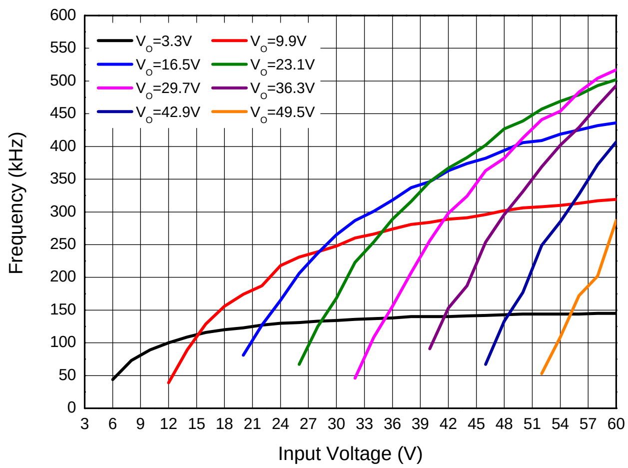
Operating Frequency vs. Input Voltage
(R_S=0.3Ω, L=100µH)



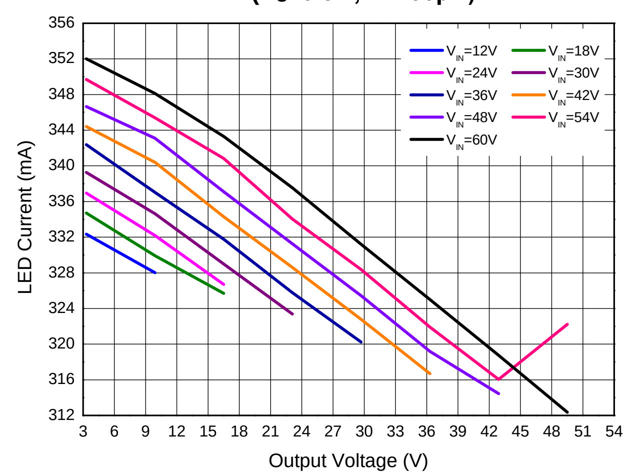
Operating Frequency vs. Input Voltage
(R_S=0.15Ω, L=68µH)



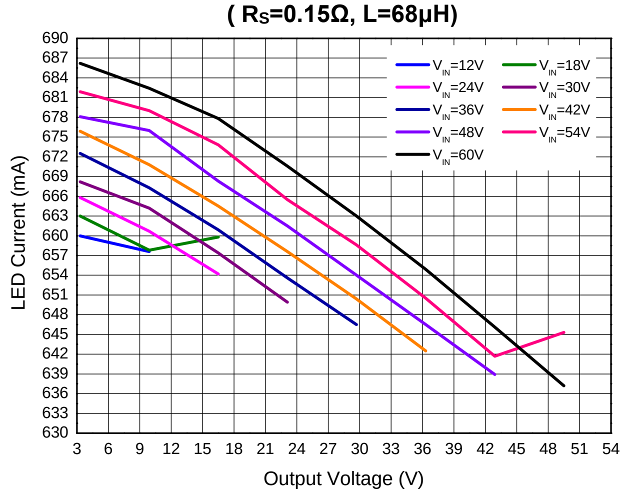
Operating Frequency vs. Input Voltage
(R_S=0.1Ω, L=100µH)



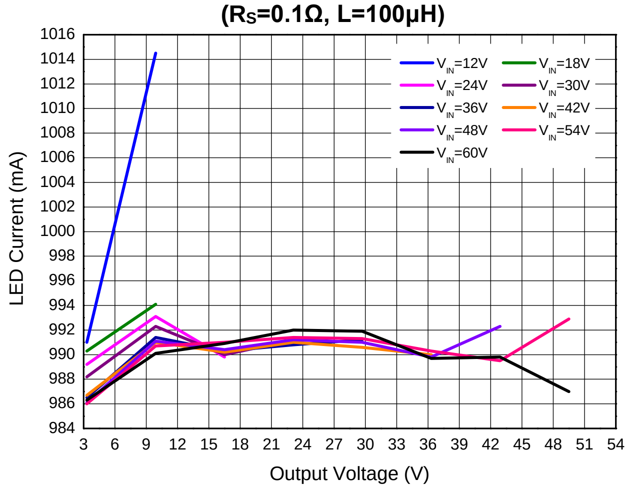
LED Current vs. Output Voltage
(R_S=0.3Ω, L=100µH)



LED Current vs. Output Voltage
(R_S=0.15Ω, L=68µH)



LED Current vs. Output Voltage
(R_S=0.1Ω, L=100µH)



Application Information

AL8862Q Operation

In normal operation, when normal input voltage is applied at VIN pin, the AL8862Q internal switch will turn on. Current starts to flow through the sense resistor R_{SET}, inductor L1, and the LEDs. The current ramps up linearly, and the ramp-up rate is determined by the input voltage V_{IN}, V_{OUT} and the inductor L1.

This rising current produces a voltage ramp across R_{SET}. The internal circuit of the AL8862Q senses the voltage across R_{SET} and applies a proportional voltage to the input of the internal comparator. When this voltage reaches an internal upper-set threshold, the internal switch is turned off. The inductor current continues to flow through R_{SET}, L1, LEDs and diode D1, and back to the supply rail, but it decays with the rate determined by the forward voltage drop of LEDs and the diode D1.

This decaying current produces a falling voltage on R_{SET}, which is sensed by the AL8862Q. A voltage proportional to the sense voltage across R_{SET} will be applied at the input of internal comparator. When this voltage falls to the internal lower-set 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 Configuration

The nominal average output current in the LED(s) is determined by the value of the external current sense resistor (R_{SET}) connected between VIN pin and SET pin, and is given by:

$$I_{OUT(NOM)} = \frac{0.1}{R_{SET} // R_{SET\_INT}} = \frac{0.1}{R_{SET} // 500}$$

If the $R_{SET} < 1\Omega$, the current setting equation is simplified as below:

$$I_{OUT(NOM)} = \frac{0.1}{R_{SET}}$$

The table below gives values of the nominal average output current for setting resistor (R_{SET}) in the *Typical Application Circuit* shown on page 2.

R_{SET} (Ω)	Nominal Average Output Current (mA)
0.1	1000
0.15	667
0.3	333

The above values assume that the CTRL pin is floating and at a nominal reference voltage for internal comparator. It is possible to use different values of R_{SET} if the CTRL pin is driven by an external dimming signal.

Analog Dimming

Applying a DC voltage from 0.4V to 2.5V on CTRL pin can adjust output current from 10% to 100% of I_{OUT_NOM} linearly, as shown in Figure 1. If the CTRL pin is brought higher than 2.5V, the LED current will be clamped to 100% of I_{OUT_NOM}, and the output switch will turn off if the CTRL voltage falls below 0.3V.

PWM Dimming

The 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. To achieve a high resolution, the PWM frequency is recommended to be lower than 500Hz, however high 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%.

The accuracy of the low duty cycle dimming is affected by both the PWM frequency and the switching frequency of the AL8862Q. For best accuracy/resolution, the switching frequency should be increased while the PWM frequency should be reduced.

The CTRL 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 a push-pull output stage.

Application Information (continued)

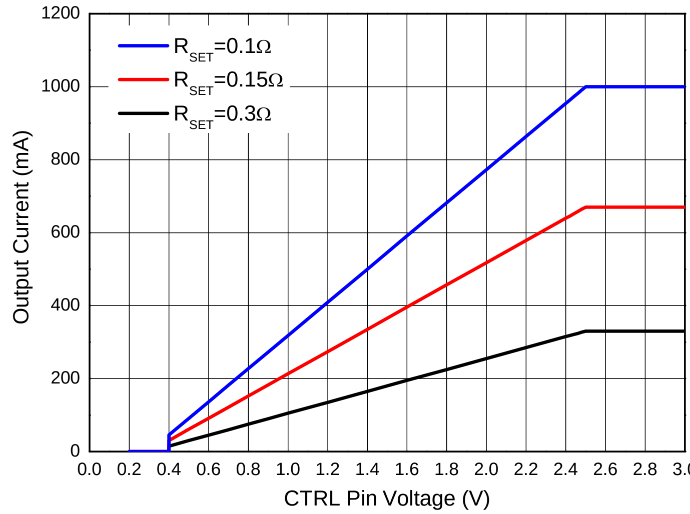


Figure 1. Analog Dimming Curve

Soft Start

The default soft start time for the AL8862Q is 0.1ms – this provides very fast turn-on of the output, improving the PWM dimming accuracy.

Nevertheless, adding an external capacitor from the CTRL pin to ground will provide a longer soft-start delay. This is achieved by increasing the time for the CTRL voltage rising to the turn-on threshold and by slowing down the rising rate of the control voltage at the input of hysteresis comparator. The additional soft start time is related to the capacitance between CTRL pin and GND, the typical value will be 1.5ms/nF.

Capacitor Selection

A low ESR capacitor should be used for input decoupling, as the ESR of this capacitor appears in series with the supply source impedance and will reduce the overall efficiency. This capacitor can supply the relatively high peak current to the coil and smooth the ripple on the input current.

The minimum capacitance needed is determined by input power, cable's length and peak current. 4.7µF to 10µF is a common used value range for most of cases. A higher value will improve performance at lower input voltages, especially when the source impedance is high. The input capacitor should be placed as close as possible to the IC.

For maximum stability over temperature and voltage, capacitors with X7R, X5R, or better dielectric are recommended. Capacitors with Y5V dielectric are not suitable for decoupling in this application and should NOT be used.

Diode Selection

For maximum efficiency and performance, the freewheeling diode (D1) should be a fast low capacitance Schottky diode with low reverse leakage current. It also provides better efficiency than silicon diodes, due to the 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. It is very important to control the reverse leakage current of the diode when operating above +85°C. Excess leakage current will increase power dissipation.

The higher forward voltage and overshoot due to reverse recovery time in silicon diodes will increase the peak output voltage on the SW pins. If a silicon diode is used, more care should be taken to ensure that the total voltage appearing on the SW pins including supply ripple, won't exceed the specified maximum value.

Application Information (continued)

Inductor Selection

Recommended inductor value for the AL8862Q is in the range of 33µH to 100µH. Higher inductance is recommended at higher supply voltages in order to minimize output current tolerance due to switching delays, which will result in increased ripple and lower efficiency. Higher inductance also results in a better line regulation. The inductor should be mounted as close to the device as possible with low resistance connections to SW pins.

The chosen coil should have saturation current higher than the peak output current and a continuous current rating above the required mean output current.

The inductor value should be chosen to maintain operating duty cycle and switch 'on'/'off' times within the specified limits over the supply voltage and load current range. The following equations can be used as a guide.

SW Pins Switch 'On' Time

$$t_{ON} = \frac{L\Delta I}{V_{IN} - V_{LED} - I_{LED}(R_{SET} + R_L + R_{sw})}$$

SW Pins Switch 'Off' Time

$$t_{OFF} = \frac{L\Delta I}{V_{LED} + V_D + I_{LED}(R_{SET} + R_L)}$$

Where: L is the coil inductance; R_L is the coil resistance; R_{SET} is the current sense resistance; I_{LED} is the required LED current; ΔI is the coil peak-peak ripple current (Internally set to 0.26 x I_{LED}); V_{IN} is the supply voltage; V_{LED} is the total LED forward voltage; R_{SW} is the switch resistance (0.55Ω nominal); V_D is the diode forward voltage at the required load current.

Thermal Protection

The AL8862Q includes Over-Temperature Protection (OTP) circuitry that will turn off the device if its junction temperature gets too high. This is to protect the device from excessive heat damage. The OTP circuitry includes thermal hysteresis that will cause the device to restart normal operation once its junction temperature has cooled down by approximately +30°C.

Open-Circuit LED Protection

The AL8862Q has default open LED protection. If the LEDs become open circuit, the AL8862Q will stop oscillating; the voltage at the SET pin will rise to V_{IN} and the voltage at the SW pin will then fall to GND. No excessive voltages will be seen by the AL8862Q.

LED Short-Circuit Protection

If the LED string becomes shorted together (the anode of the top LED becomes shorted to the cathode of the bottom LED), the AL8862Q will continue to switch and the current through the AL8862Q's internal switch will still be at the expected current - so no excessive heat will be generated within the AL8862Q. However, the duty cycle will change dramatically and the switching frequency will most likely decrease. See Figure 2 for an example of this behavior at 24V input voltage driving 3 LEDs.

The on-time of the internal power MOSFET switch is significantly reduced because almost all of the input voltage is now developed across the inductor. The off-time is significantly increased because the reverse voltage across the inductor is now just the Schottky diode voltage (See Figure 2) causing a much slower decay in inductor current.

Application Information (continued)

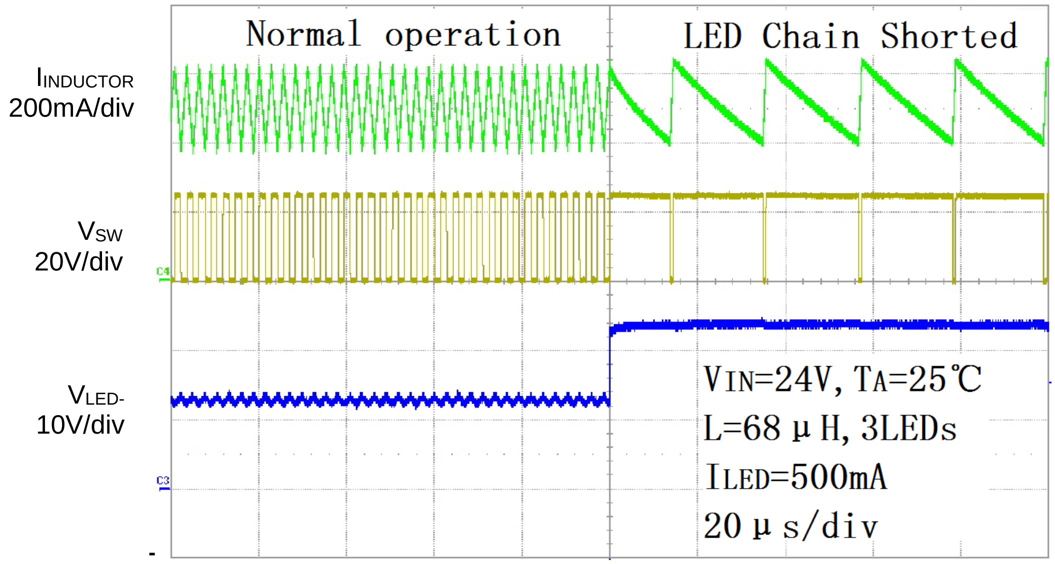


Figure 2. Switching Characteristics (Normal Operation to LED String Shorted)

Current Sense Resistor Short-Circuit Protection

The AL8862Q has an internal current limit at about 3A. If current-sense resistor R_{SET} is shorted, current limit is triggered for accumulated 8 times and the switch will shut down and latch up.

Fault Indicator

The AL8862Q includes an active low, open-drain fault indicator (FAULT). The FAULT pin goes low when one of the following conditions occurs:

1) Open circuit across LED string
2) Short circuit across current sense resistor
3) Over-temperature condition

FAULT	Detection	Action
Open-Circuit across LED String	SW<0.6V lasts for 100µs	When open circuit occurs, the resulted voltage drop on sensing resistor is nearly zero and the SW pin output will be constantly low, leading to output voltage VOUT equals VIN. No excessive voltages will be seen by the AL8862Q and external components. If open circuit condition lasts for accumulated 100µs, FAULT goes low. The AL8862Q resumes normal operation and FAULT resumes high once fault condition is removed.
Short Circuit across Current Sense Resistor	Current limit is triggered for 8 times	When current sense resistor is short circuited, the AL8862Q will continue to switch and the inductor current will continue to go up until reach the internal current limit of 3A. If the current limit is triggered for 8 times, the system is latched and FAULT goes low.
Over-Temperature Condition	T_J > +150°C	When the junction temperature exceeds approximately +150°C, the AL8862Q is forced to shut down and FAULT goes low. A startup sequence is initiated and FAULT resumes high when the junction temperature drops by +30°C.

Application Information (continued)

EMI and Layout Considerations

The AL8862Q 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 AL8862Q has been developed to minimize 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_{TRACK}. See Figure 3.

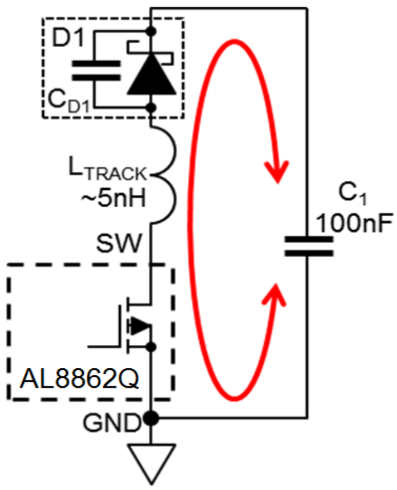


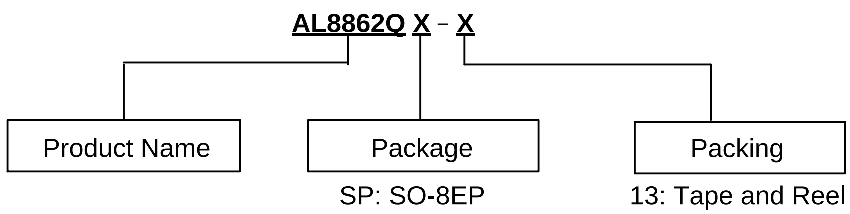
Figure 3. PCB Loop Resonance

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 AL8862Q which 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 minimizing radiated EMI and other transients and thermal considerations are:

1. The decoupling capacitor (C1) has to be placed as close as possible to the VIN 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 (R_{SET}) has to be placed as close as possible to the VIN and SET pins.
5. The majority of the conducted heat from the AL8862Q is through the GND pin 7. 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 should be used at the point where the wires are joined to the PCB.

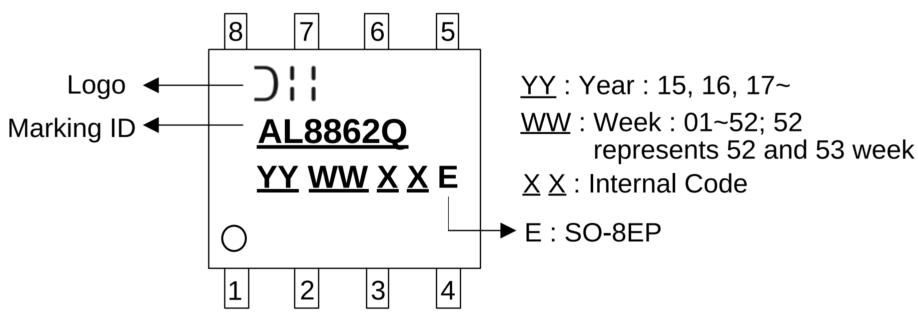
Ordering Information



Part Number	Package Code	Package	13" Tape and Reel	
			Quantity	Part Number Suffix
AL8862QSP-13	SP	SO-8EP	2500/Tape & Reel	-13

Marking Information

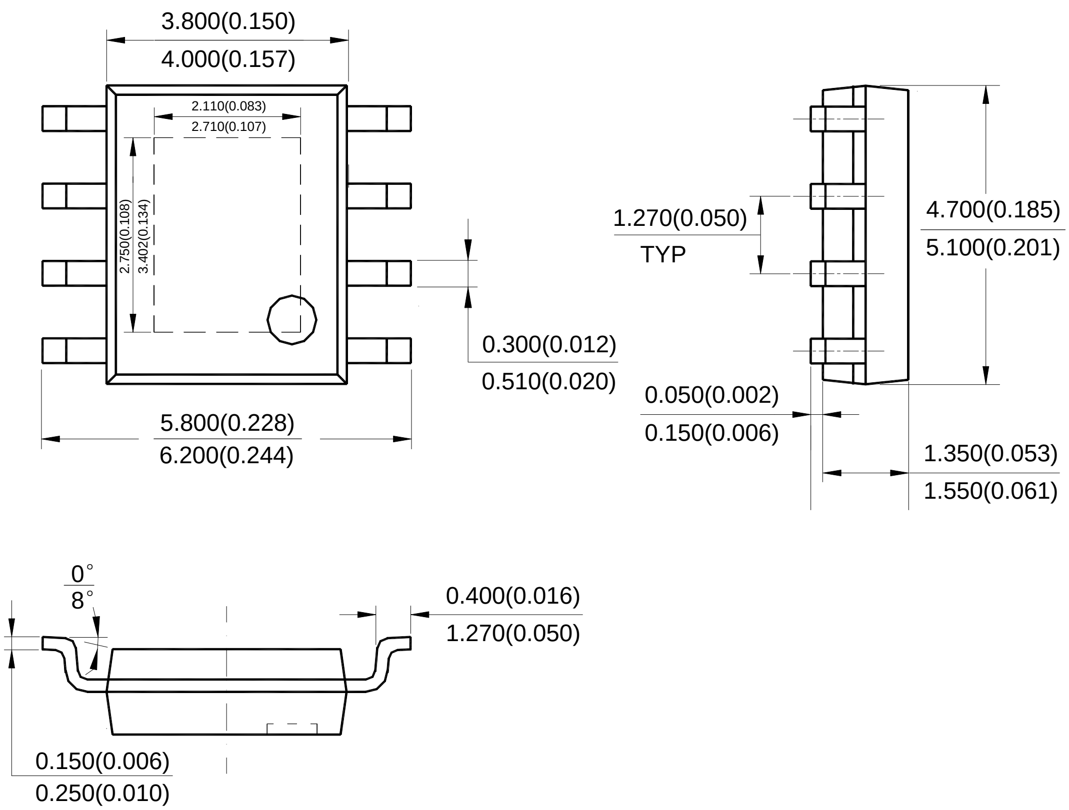
(Top View)



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

Please see http://www.diodes.com/package-outlines.html for the latest version.

Package Type: SO-8EP

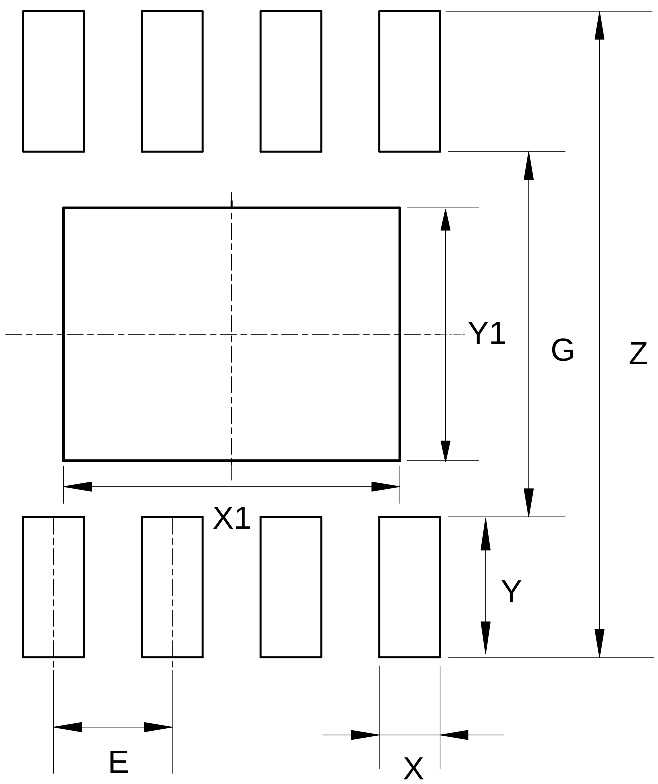


Note: Eject hole, oriented hole and mold mark is optional.

Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.

Package Type: SO-8EP



Dimensions	Z (mm)/(inch)	G (mm)/(inch)	X (mm)/(inch)	Y (mm)/(inch)	X1 (mm)/(inch)	Y1 (mm)/(inch)	E (mm)/(inch)
Value	6.900/0.272	3.900/0.154	0.650/0.026	1.500/0.059	3.600/0.142	2.700/0.106	1.270/0.050

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