

Description

The DIODES™ AL5871Q is an automotive-grade single channel linear LED driver with PWM and analog dimming control. The AL5871Q can drive up to 750mA and the LED current can be set by the low power reference resistor connected to the REF pin.

The AL5871Q regulates LED current accurate to $\pm 4\%$, with excellent PWM and analog dimming performance. The AL5871Q enters standby mode to save power if no PWM signal is detected.

The AL5871Q monitors the temperature and reduces the LED current if the chip temperature exceeds the threshold temperature. And the input under voltage lock-out (UVLO), LED string open / short protection, and over temperature protection (OTP) are designed for automotive applications to improve system robustness. The FAULTB pin is pulled low if any protection is triggered.

The AL5871Q is a simple solution to deliver constant current for a single LED string with one fail all fail function, and can work with DIODES™ AL5873Q to address different requirements. The AL5871Q is available in TSSOP-16EP (Type DX) package.

Features

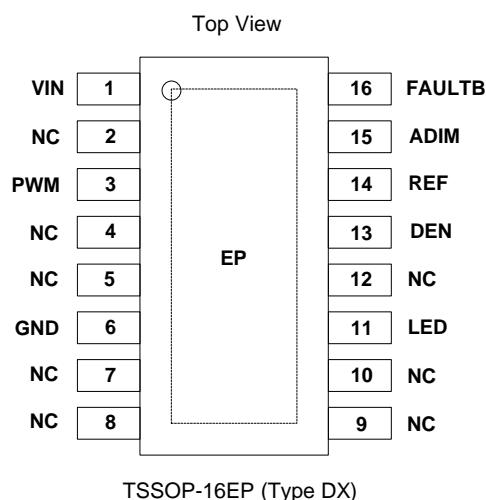
- Wide Input Voltage Range from 5V to 55V
- Up to 750mA Output Current Capacity
- Low Drop-out Voltage on LED Pin
- Output Current Adjustable by a Low Power External Reference Resistor
- PWM and Analog Dimming with Excellent Linearity
- Automatically Enter and Exit Standby Mode Without Enable Pin
- Internal Protections:
 - Input Under Voltage Lock-out (UVLO)
 - Enable LED String Open Protection
 - LED String Short Protection
 - Over Temperature Protection (OTP)
 - Diagnostic Enable with Adjustable Threshold for Low-Dropout Operation
- Thermal Fold-Back if Chip Temperature Exceeds the Threshold
- Fault Reporting: UVLO, OTP, LED Open, and LED Short
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **The AL5871Q is suitable for automotive applications requiring specific change control; this part is AEC-Q100 qualified, PPAP capable, and manufactured in IATF16949 certified facilities.**

<https://www.diodes.com/quality/product-definitions/>

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.

Pin Assignments



Applications

- Automotive interior lighting: dome light, reading lamps
- Automotive exterior lighting:
 - Small light: blind-spot detection indicators, charging inlets, door handles
 - Rear light: rear lamps, center high mounted stop lamps, side markers

Typical Application Circuit

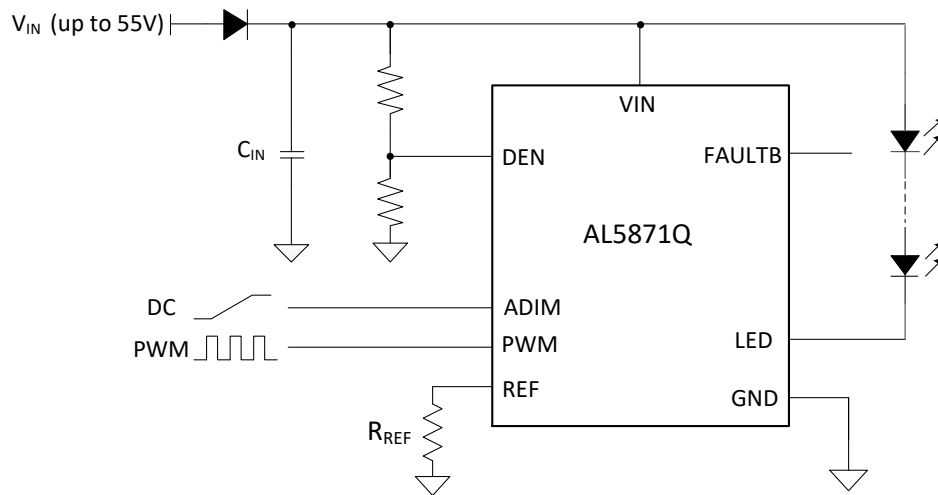


Figure 1. Typical Application

Pin Descriptions

Pin Name	Pin Number	Function
VIN	1	Power Supply for LED Driver
PWM	3	PWM Signal Input, Internally Pulled Down.
GND	6	Ground for LED Driver
LED	11	Connect to LED Cathode
DEN	13	Enable pin for LED open-circuit detection and thermal fold back function. <ul style="list-style-type: none"> $V_{DEN} > 1.2V$, Open LED detection is enable. $V_{DEN} < 1.1V$, Open LED detection is disable to avoid false open diagnostics during low dropout operation. $V_{DEN} > 0.3V$, Thermal fold back function is enable. $V_{DEN} < 0.2V$, Thermal fold back function is disable.
REF	14	Reference Current Setting
ADIM	15	Analog Dimming Input. Drive with DC voltage ($0.3V < V_{ADIM} < 1.5V$)
FAULTB	16	Fault Report. Asserted Low to report faulty conditions.
NC	2, 4, 5, 7, 8, 9, 10, 12	No Connection
Exposed Pad	Exposed Pad	Exposed Pad. Internally connected to GND. It should be externally connected to GND and thermal mass for enhanced thermal impedance. It should not be used as electrical conduction path.

Functional Block Diagram

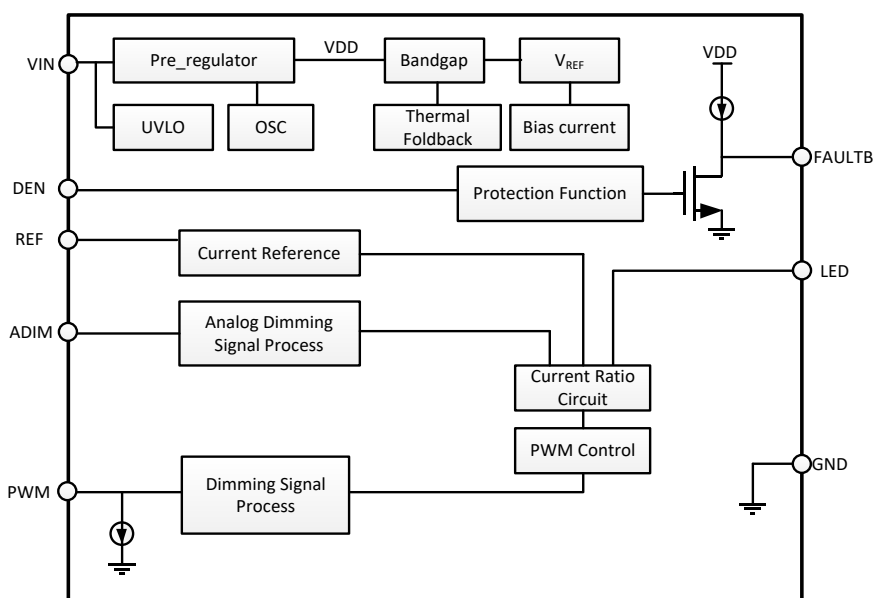


Figure 2. Functional Block Diagram

Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Ratings	Units
V_{VIN}	Input Voltage Relative to GND	-0.3 to 65	V
$V_{LED}, V_{DEN}, V_{PWM}, V_{FAULTB}$	LED, DEN, PWM and FAULTB Voltage Relative to GND	-0.3 to 65	V
V_{REF}, V_{ADIM}	REF and ADIM Voltage Relative to GND	-0.3 to 6	V
T_J	Operating Junction Temperature	-40 to +150	°C
T_{ST}	Storage Temperature	-55 to +150	°C
θ_{JA}	Junction-to-Ambient Thermal Resistance (Note 5)	42.7	°C/W
θ_{JC}	Junction-to-Case (Top) Thermal Resistance (Note 5)	3.4	°C/W
—	Human-Body Model (HBM)	2000	V
—	Charged-Device Model (CDM)	1000	V

- Notes:
- 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. 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.
 - Device mounted on 2" x 2" FR-4 substrate PCB, 2oz copper, with minimum recommended pad on top layer and thermal vias to bottom layer ground plane.

Recommended Operating Conditions

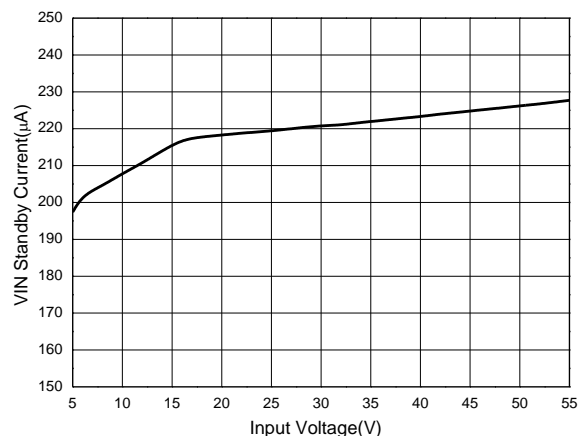
Symbol	Parameter	Min	Max	Unit
V_{VIN}	Input Voltage Relative to GND	5	55	V
f_{PWM}	PWM Frequency	0.2	1	kHz
I_{LED}	LED Output Current	0	750	mA
V_{IH}	High-Level Input Voltage on PWM	1.4	5.5	V
V_{IL}	Low-Level Input Voltage on PWM	0	0.4	V
T_J	Operating Junction Temperature	-40	+150	°C
T_A	Operating Ambient Temperature	-40	+125	°C

Electrical Characteristics (@T_A = +25°C to +125°C, V_{IN} = +12V, unless otherwise specified.)

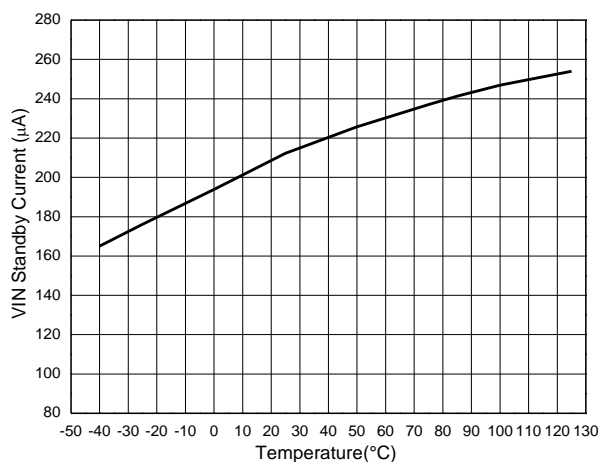
Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V _{VIN_UVLO}	VIN UVLO Voltage	V _{VIN} Rising	4.75	5.0	5.25	V
V _{VIN_UVLO_HYS}	VIN UVLO Hysteresis	V _{VIN} Falling	—	300	—	mV
I _{VIN_Standby}	Input Current in Standby Mode	Standby Mode, PWM is "L" for 7ms	—	300	—	μA
I _{DVCC_Q}	Input Current in Normal Mode	Enabled, LED Pin Floating, PWM is "H", R _{SET} is 48kΩ	—	0.7	—	mA
V _{IL_DEN}	DEN Logic Low Voltage for Open LED Detection	—	—	1.1	—	V
V _{IH_DEN}	DEN Logic High Voltage for Open LED Detection	—	—	1.2	—	V
V _{TH_DEN}	DEN Logic Low Voltage for Thermal Fold Back	—	—	0.2	—	V
V _{TH_DEN}	DEN Logic High Voltage for Thermal Fold Back	—	—	0.3	—	V
V _{IL_PWM}	PWM Logic Low Voltage	—	—	—	0.4	V
V _{IH_PWM}	PWM Logic High Voltage	—	1.4	—	—	V
I _{PWM_PD}	PWM Internal Pulldown	V _{PWM} = 5V	0.35	—	3.5	μA
t _{PWM_SHDN}	Entrance Time for Standby Mode When PWM is Low	—	—	15	25	ms
V _{ADIM}	Voltage Range on ADIM Pin	For Analog Dimming	0.3	—	1.5	V
V _{ADIM_ON}	DC Voltage on ADIM Pin for Analog Dimming On	V _{ADIM} Rising	—	—	0.35	V
V _{ADIM_OFF}	DC Voltage on ADIM Pin for Analog Dimming Off	V _{ADIM} Falling	0.15	—	—	V
I _{ADIM}	ADIM Sourcing Current	—	19	20	22	μA
V _{REF}	Base Reference Voltage	—	1.47	1.5	1.53	V
I _{LED_NOM}	Regulation Current	R _{REF} = 48kΩ	—	375	—	mA
V _{LED_REG}	Minimum LED Regulation Voltage	I _{LED} = 125mA	—	0.2	—	V
I _{LED_LEAK}	LED Pin Leakage Current	V _{PWM} = 0V, V _{LED} = 12V	—	0.1	5	μA
I _{LED_ACCURACY}	LED Current Accuracy	R _{REF} = 48kΩ	-4	—	4	%
t _{LED_SHDG}	Short-Detection Deglitch	100% Duty-Cycle	—	5	—	ms
N _{LED_SHDG}		PWM Dimming (count the number of continuous cycles when LED short is detected)	—	7	—	Cycles
t _{LED_SH_HICUP}	LED Short Protection Hiccup Time	—	—	128	—	ms
t _{LED_OPDG}	Open-Detection Deglitch	100% Duty-Cycle	—	5	—	ms
N _{LED_OPDG}		PWM Dimming (count the number of continuous cycles when LED open is detected)	—	7	—	Cycles
t _{LED_OPDG_CYCLE}	Open-Detection Deglitch Time per Cycle	(Internal Only)	—	20	—	μs
t _{LED_OP_HICUP}	LED Open Protection Hiccup Time	—	—	128	—	ms
I _{F_PULLUP}	FAULTB Pullup Current	V _{FAULTB} = 1.6V	—	500	—	μA
V _{F_PULLUP}	FAULTB Pullup Voltage	Fault Pin Floating	—	3	—	V
V _{FOL}	FAULTB Output Low Voltage	I _{FAULTB} = 1mA	—	—	600	mV
V _{FIN_TH}	FAULTB Input Detect Threshold Voltage	—	—	1.33	—	V
I _{F_LKG}	FAULTB Leakage Current	V _{FAULTB} = 5V	—	—	5	μA
T _{SHDN}	Thermal Shutdown Threshold	—	—	+160	—	°C
T _{REC}	Thermal Recovery Threshold	—	—	+130	—	°C

Typical Performance Characteristics ($T_A = +25^\circ\text{C}$, $V_{IN} = 12\text{V}$, $R_{REF} = 48\text{k}\Omega$, $I_{LED} = 375\text{mA}$, unless otherwise specified.)

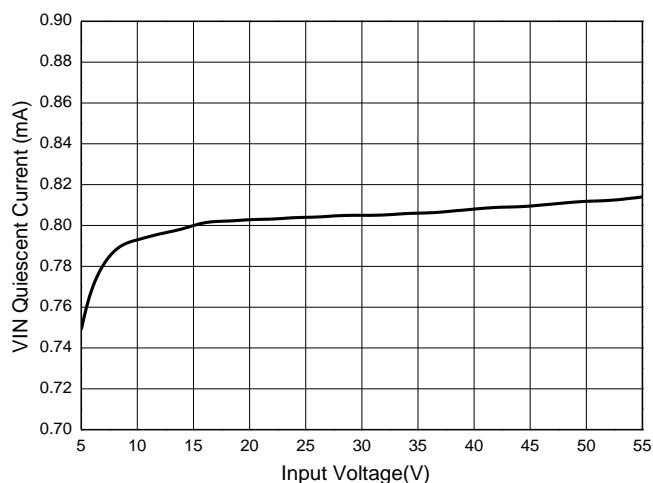
VIN Standby Current vs. Input Voltage



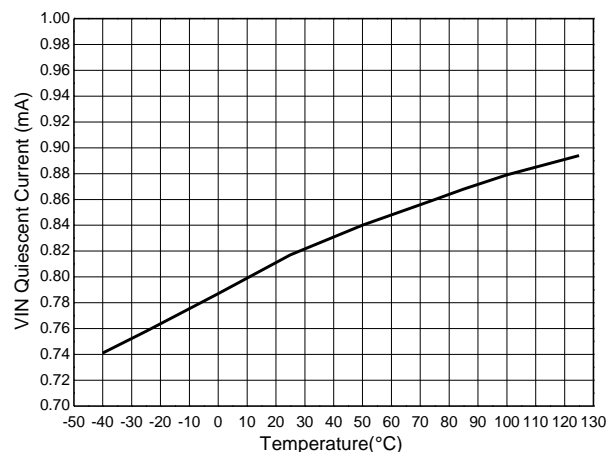
VIN Standby Current vs. Temperature



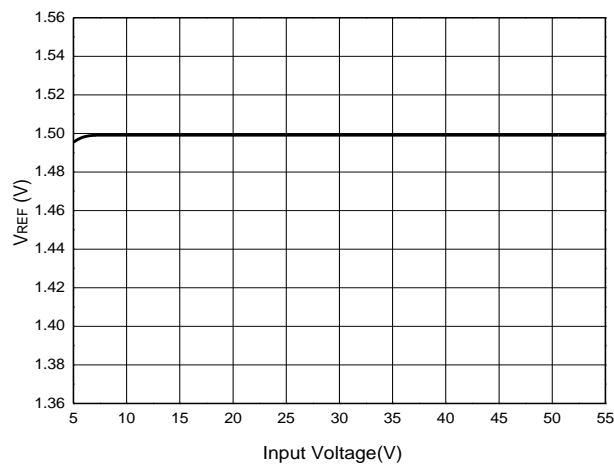
VIN Quiescent Current vs. Input Voltage



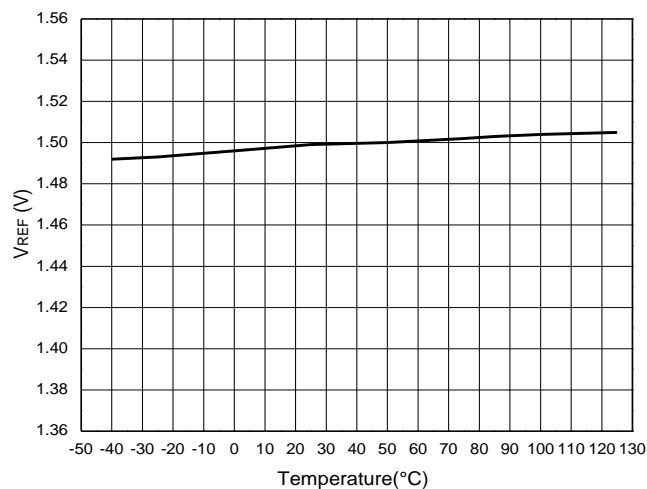
VIN Quiescent Current vs. Temperature



Reference Voltage vs. Input Voltage

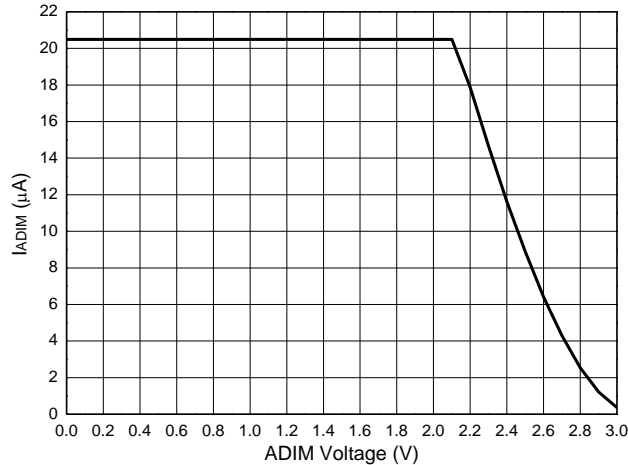


Reference Voltage vs. Temperature

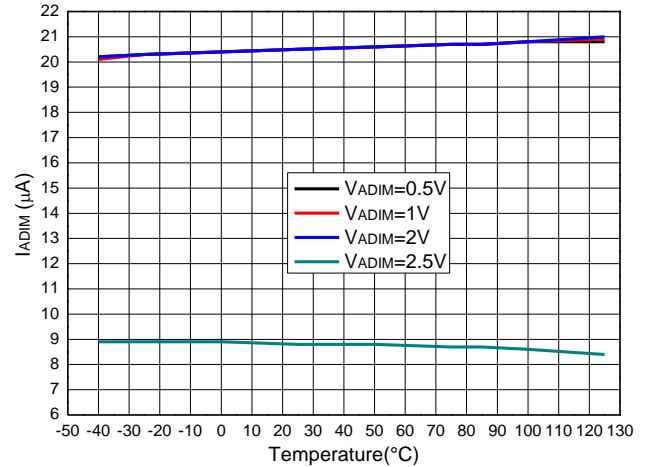


Typical Performance Characteristics (continued) ($T_A = +25^\circ\text{C}$, $V_{IN} = 12\text{V}$, $R_{REF} = 48\text{k}\Omega$, $I_{LED} = 375\text{mA}$, unless otherwise specified.)

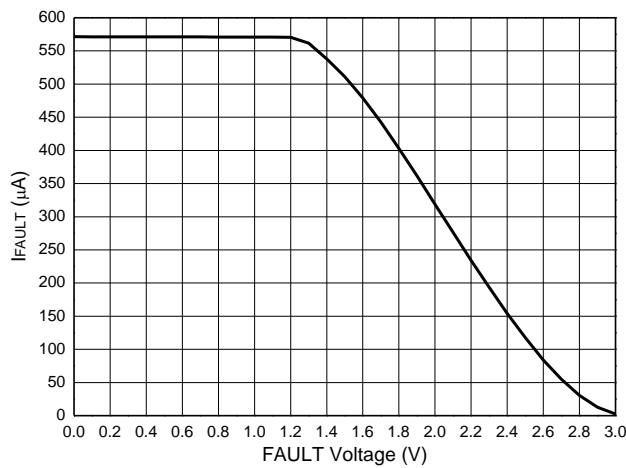
ADIM Sourcing Current vs. ADIM Voltage



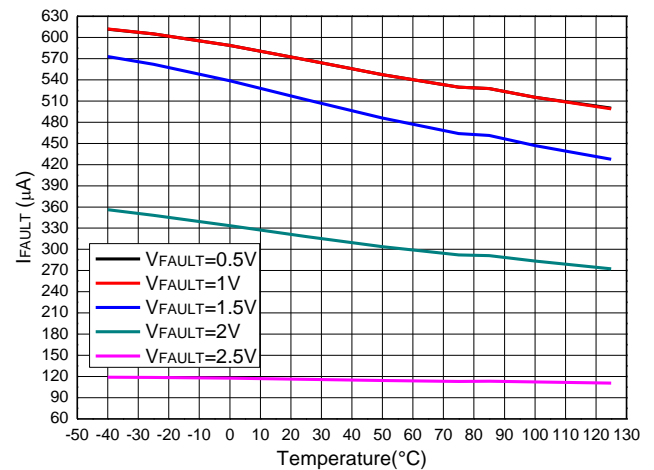
ADIM Sourcing Current vs. Temperature



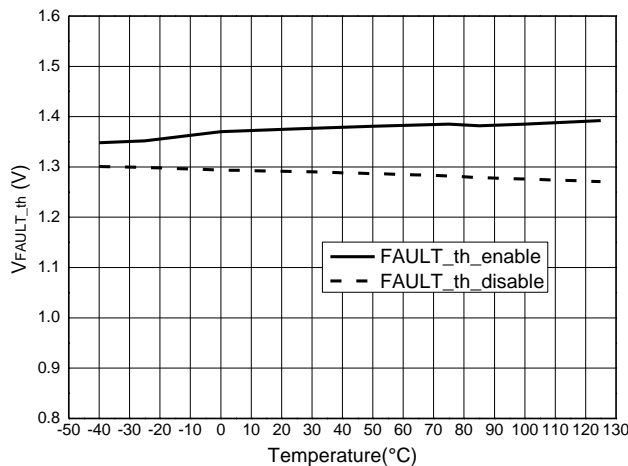
FAULT Sourcing Current vs. FAULT Voltage



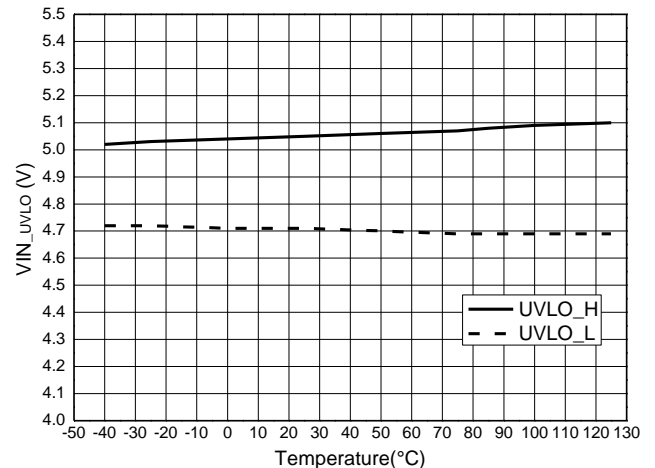
FAULT Sourcing Current vs. Temperature



FAULT Input Detection Threshold vs. Temperature

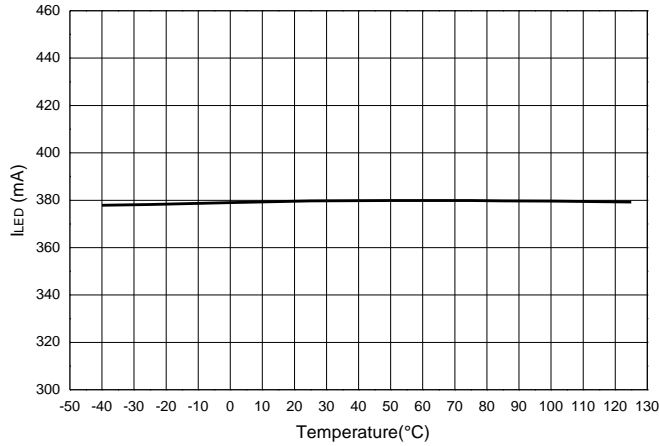


VIN UVLO Voltage vs. Temperature

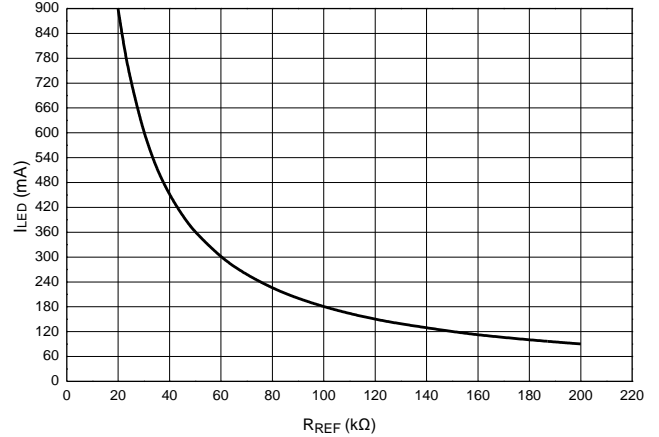


Typical Performance Characteristics (continued) ($T_A = +25^\circ\text{C}$, $V_{IN} = 12\text{V}$, $R_{REF} = 48\text{k}\Omega$, $I_{LED} = 375\text{mA}$, unless otherwise specified.)

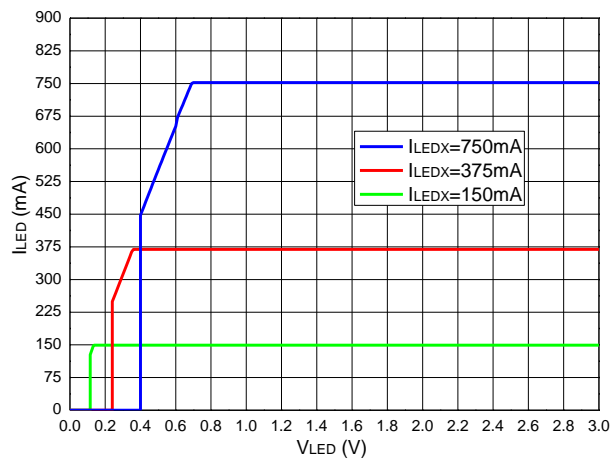
LED Current vs. Temperature



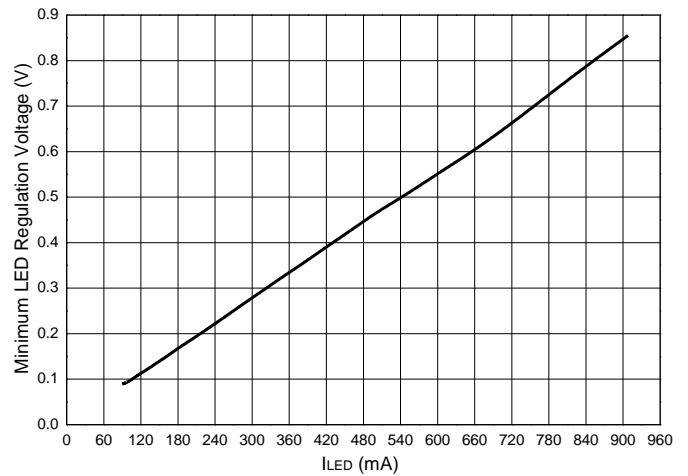
LED Current vs. R_{REF}



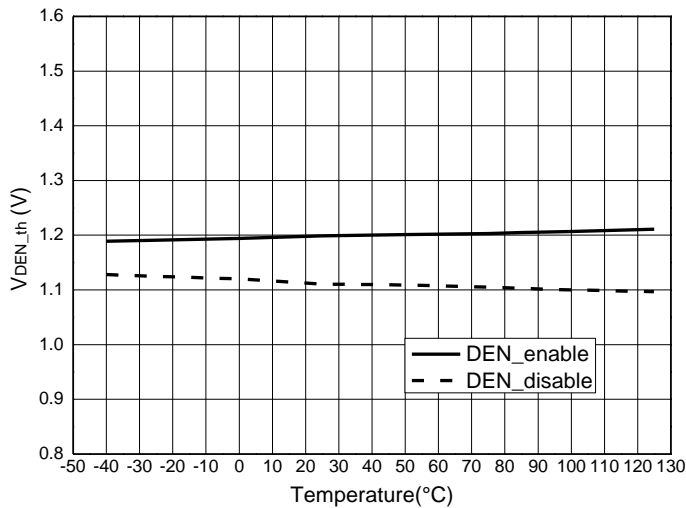
LED Current vs. V_{LED} Voltage



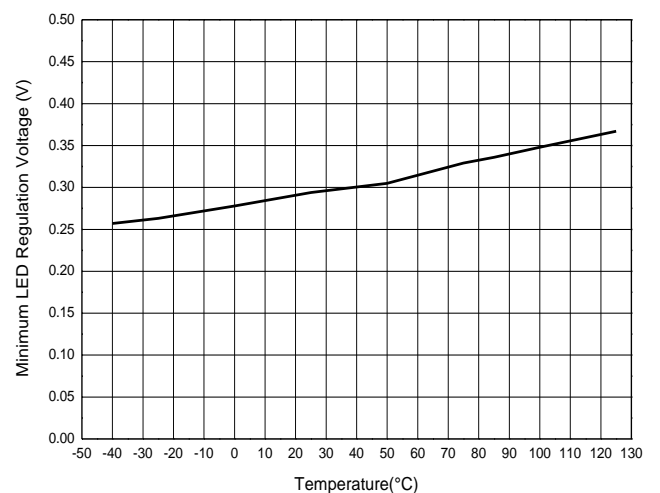
Minimum LED Voltage vs. LED Regulation Current



DEN Open LED Detection vs. Temperature

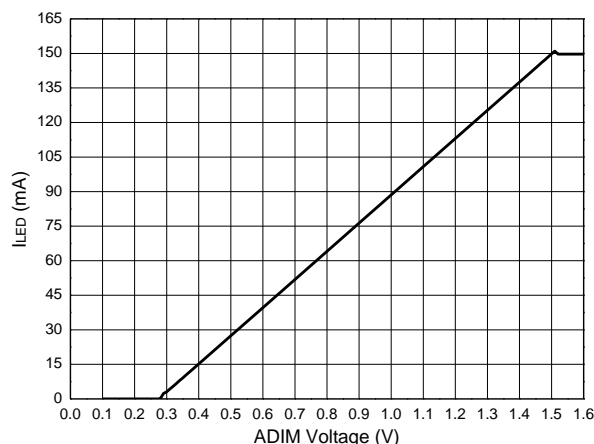


Minimum LED Voltage vs. Temperature

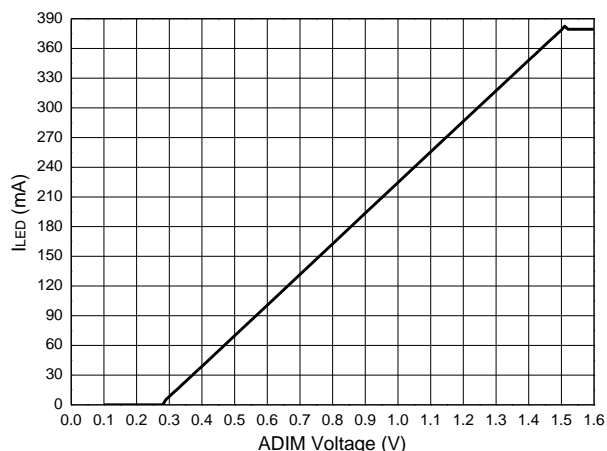


Typical Performance Characteristics (continued) ($T_A = +25^\circ\text{C}$, $V_{IN} = 12\text{V}$, $R_{REF} = 48\text{k}\Omega$, $I_{LED} = 375\text{mA}$, unless otherwise specified.)

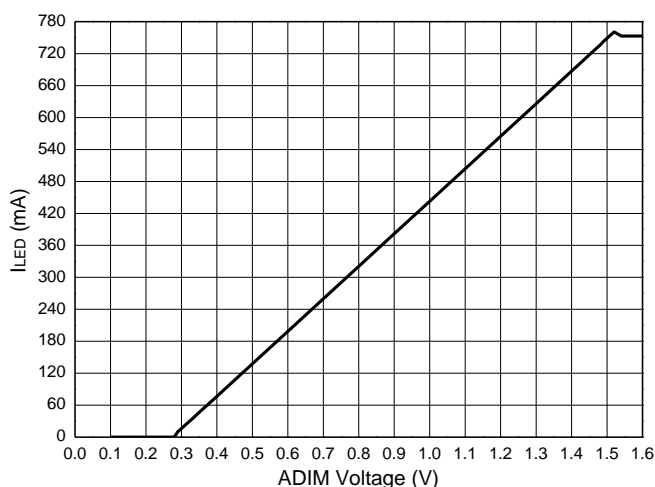
LED Current vs. ADIM Voltage
 ($R_{REF} = 120\text{k}\Omega$, $I_{LED} = 150\text{mA}$)



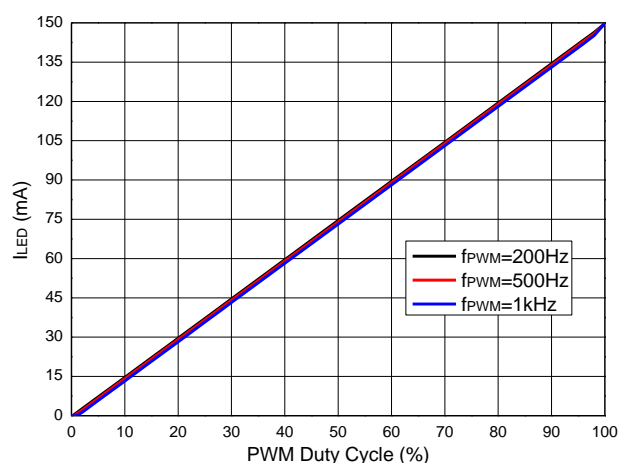
LED Current vs. ADIM Voltage
 ($R_{REF} = 48\text{k}\Omega$, $I_{LED} = 375\text{mA}$)



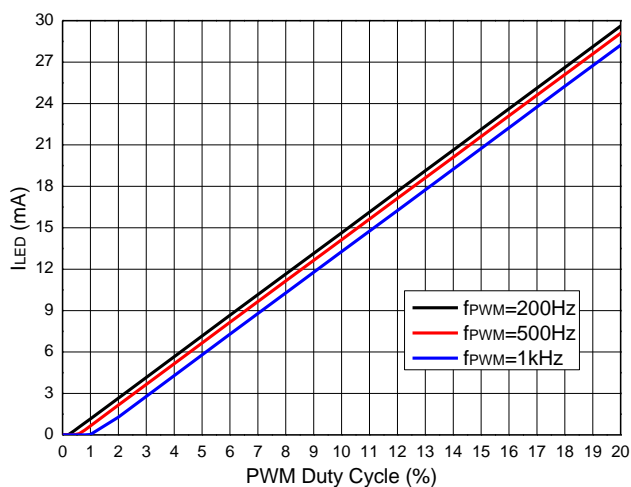
LED Current vs. ADIM Voltage
 ($R_{REF} = 24\text{k}\Omega$, $I_{LED} = 750\text{mA}$)



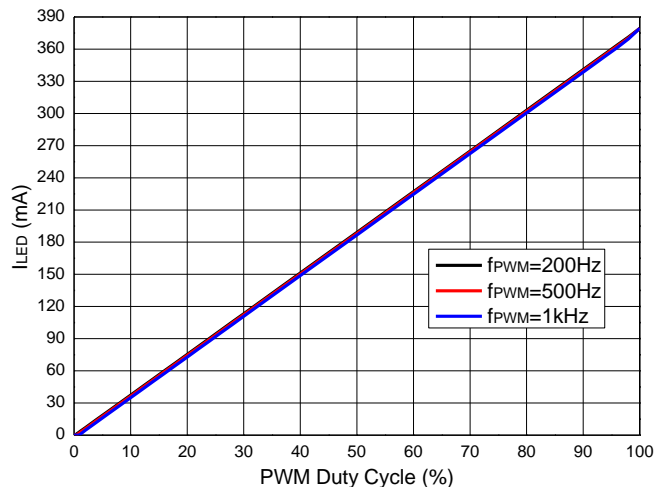
LED Current vs. PWM Duty Cycle
 ($R_{REF} = 120\text{k}\Omega$, $I_{LED} = 150\text{mA}$, 0 to 100% Duty)



LED Current vs. PWM Duty Cycle
 ($R_{REF} = 120\text{k}\Omega$, $I_{LED} = 150\text{mA}$, 0 to 20% Duty)

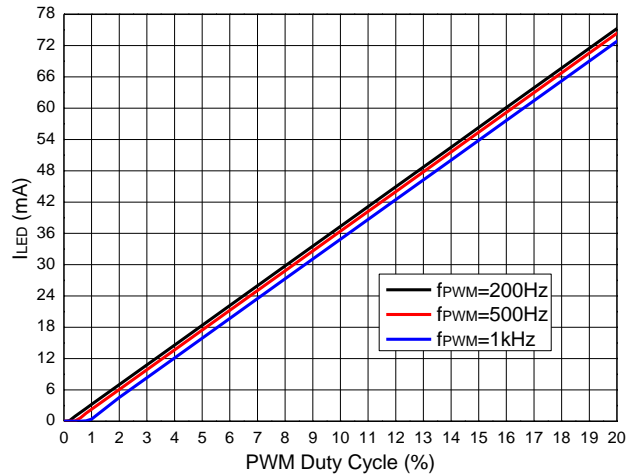


LED Current vs. PWM Duty Cycle
 ($R_{REF} = 48\text{k}\Omega$, $I_{LED} = 375\text{mA}$, 0 to 100% Duty)

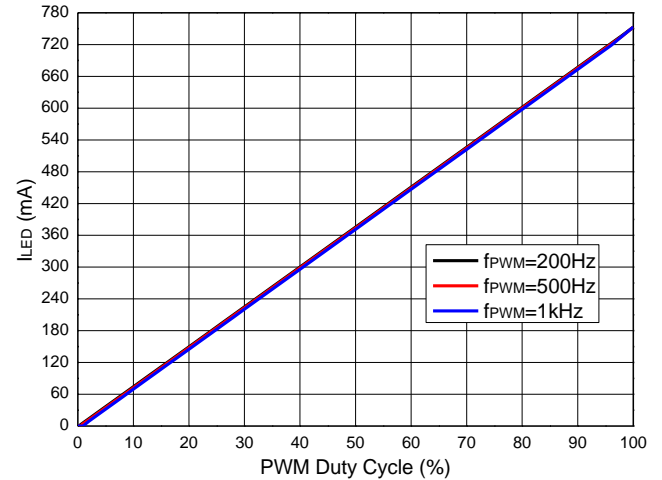


Typical Performance Characteristics (continued) ($T_A = +25^\circ\text{C}$, $V_{IN} = 12\text{V}$, $R_{REF} = 48\text{k}\Omega$, $I_{LED} = 375\text{mA}$, unless otherwise specified.)

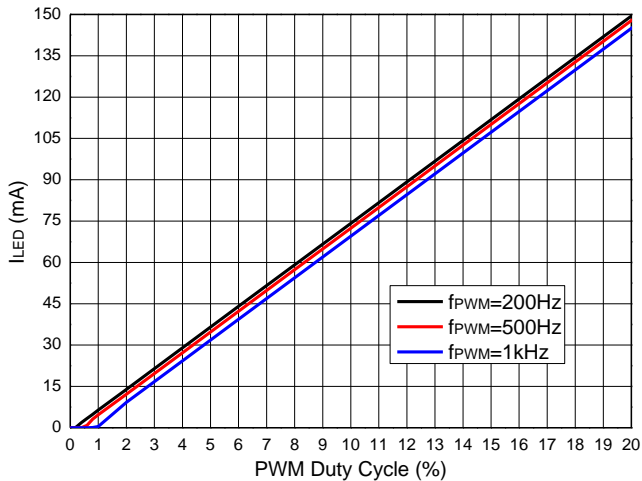
LED Current vs. PWM Duty Cycle
($R_{REF} = 48\text{k}\Omega$, $I_{LED} = 375\text{mA}$, 0 to 20% Duty)



LED Current vs. PWM Duty Cycle
($R_{REF} = 24\text{k}\Omega$, $I_{LED} = 750\text{mA}$, 0 to 100% Duty)



LED Current vs. PWM Duty Cycle
($R_{REF} = 24\text{k}\Omega$, $I_{LED} = 750\text{mA}$, 0 to 20% Duty)



Function Description

The AL5871Q is a cost-effective constant-current linear driver optimized for automotive LED applications. The AL5871Q can drive up to 750mA output LED current. The LED current can be controlled by digital PWM signal or analog dimming signal.

AL5871Q detects fault conditions and reports its status on the FAULTB pin. It features LED open detection, LED short detection, Over Temperature Protection (OTP), and Under Voltage Lockout (UVLO).

Integrated thermal fold-back function reduces the regulated current level at high junction temperatures to limit power dissipation.

LED Current Setting

The AL5871Q current is set by the current setting resistor R_{REF} . The LED current level is expressed as below:

$$I_{LEDX} = 12000 \times \frac{V_{REF}}{R_{REF}}$$

where V_{REF} nominally 1.5V, I_{LED} is in mA, and R_{REF} in k Ω . For example, if R_{REF} is 24k Ω , the AL5871Q provides 750mA output current.

Under Voltage Lockout

Under-voltage lockout function (UVLO) guarantees that the device is initially off during start-up. AL5871Q is not turned ON until the power supply has reached 5.0V. Whenever the input voltage falls below approximately 4.7V, the device is turned off. The UVLO circuit has a hysteresis of 300mV. During UVLO, a FAULTB status will be reported.

Enable and Start-up LED Drivers

The AL5871Q is enabled when the voltage at PWM pin is greater than typical voltage of 1.4V, and disabled when PWM is lower than 0.4V. Upon PWM pin is asserted and VIN pin is ramped up beyond minimum operation voltage, a start-up process will be performed.

Standby Mode

When PWM pin is pulled down to voltage lower than 0.4V for 25ms or longer, the AL5871Q will automatically enter the standby mode for power saving purpose. When in the standby mode, most of blocks in the AL5871Q are turned off to reduce the quiescent supply current. When the PWM pin is pulled up to voltage higher than 1.4V, the AL5871Q will automatically exit the standby mode and perform its designated functions properly.

PWM Dimming Control

The AL5871Q features PWM dimming control for three output channels. High level of PWM signal will turn on the current sink to flow current through the LED and low level will turn it off. Consequently, the LED current and LED brightness of each channel can be adjusted in according to the duty cycle of PWM signal. The PWM frequency is recommended to be greater than 200Hz and less than 1kHz for better dimming linearity.

Analog Dimming Control

In addition to PWM dimming, the AL5871Q also provides an analog dimming feature on the ADIM pin. The LED current can be linearly adjusted from 0 to 100% by varying the voltage at ADIM pin from 0.3V to 1.5V. AL5871Q shuts the LED current when the voltage on ADIM pin is lower than 0.15V. The LED current is constant, rather than switching when PWM dimming.

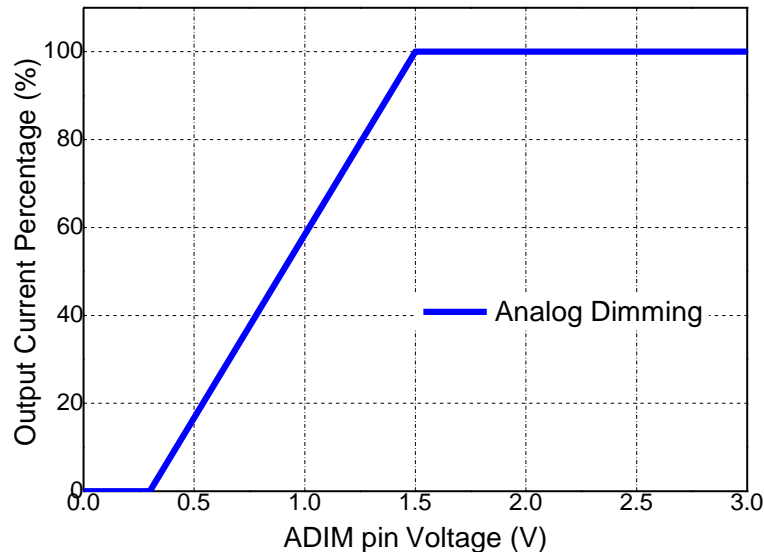


Figure 3. Analog Dimming Diagram

Function Description (continued)

Thermal Foldback and Over Temperature Protection

The AL5871Q integrates over temperature protection to prevent the device from overheating. When the junction temperature of IC is higher than +160°C, the device will enter OTP in which all current sinks are shut down and no current flows to LED strings. When the chip is cooled down and temperature is lower than +130°C, the AL5871Q will trigger a start-up process and the LED current will be automatically restored to its set current value. OTP protection is reported on the FAULTB pin.

In addition, to prevent LEDs from flickering because of rapid thermal changes, the AL5871Q features thermal fold back function to reduce power dissipation at high junction temperatures. As shown in Figure 4, the AL5871Q reduces the LED current as the silicon junction temperature of device increases above the threshold temperature (+135°C). As the temperature rising, the LED current drops down to 50% of nominal value and keeps constant. If the junction temperature of IC is continually rising above +160°C, the OTP will be triggered and shut down the LED current. By mounting the AL5871Q on the same thermal substrate with LEDs, this feature can also limit the dissipation of the LEDs, protecting the IC and LEDs

AL5871Q supports enable/disable thermal foldback function via DEN pin. The thermal foldback function is enabled when the voltage on DEN is higher than 0.3V, and disabled when the voltage on DEN pin is less than 0.2V.

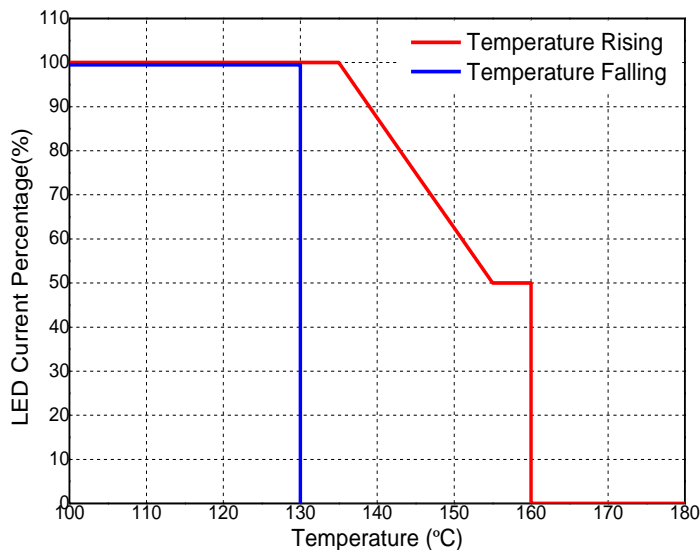


Figure 4. Thermal Fold-Back Diagram

LED Open Protection

The AL5871Q detects the LED open status by monitoring the current and voltage status of the LED strings. The voltage at LED pin is compared with a reference voltage proportional to LED current. The comparator will output high if the voltage at LED pin is lower than reference voltage. When LED opens and lasts for a short time period, the AL5871Q enters protection and shuts down output. The time period is 7 cycles of the input PWM signal or 5ms timer when the PWM duty is 100%. The abnormal channel will be periodically rechecked every 128ms afterward to see if the abnormal condition is cleared. The LED driver will be re-activated if the abnormal condition is cleared. FAULTB pin will be pulled low if LED open condition happens, and will resume high if LED open condition is removed. The comparator in LED open protection has a typical deglitch time of 20μs to avoid wrong trigger, therefore the LED open protection is invalid when the PWM on time is shorter than 20μs during PWM dimming.

AL5871Q supports the DEN pin with an accurate threshold to disable the LED open-circuit diagnostic functions. The DEN pin can be used to enable or disable LED open-circuit protection based on input voltage sensed by an external resistor divider. When the voltage on the DEN pin is high than 1.2V, the device enables LED open-circuits protection. When the voltage on the DEN pin is lower than 1.1V, the device disables LED open-circuit protection. With this feature, the device is able to avoid false error reports due to low dropout voltage and to drive maximum current when the input voltage is not high enough for current regulation.

Function Description (continued)

LED Short Protection

The AL5871Q detects the LED short status by monitoring voltage at the LED pin. When the LED string anode is short to cathode, V_{LED} will be pulled up to nearly V_{IN} . And if the voltage gap ($V_{IN} - V_{LED}$) is less than 1V and lasts for a short time period, the AL5871Q enters protection and shuts down output. The time period is 7 cycles of the input PWM signal or 5ms timer when the PWM duty is 100%. The abnormal channel will be periodically rechecked every 128ms afterward to check if the abnormal condition is cleared. The LED driver will be re-activated if the abnormal condition is cleared. FAULTB pin will be pulled low if LED short condition happens, and will resume high if LED short condition is removed. The comparator in LED short protection has a typical deglitch time of 20 μ s to avoid wrong trigger, therefore the LED short protection is invalid when the PWM on time is shorter than 20 μ s during PWM dimming.

Fault Reporting

When the PWM is active, AL5871Q detects and reports the FAULTB status upon the occurrence of OTP, LED short protection, LED open protection, and UVLO. The FAULTB pin is an open-drain output design. Multiple devices can share a single FAULTB signal by connecting all FAULTB pins together with an external pull-up resistor. Any FAULTB assertion from any device pulls the signal down and informs MCU of the faulty condition.

In case there is no MCU, up to 15 FAULTB pins can be connected together. When one or more devices have errors, the respective FAULTB pin goes low, pulling the connected FAULTB bus down and shutting down all devices outputs. Figure 5 shows the fault-line bus connection. The device releases the FAULTB bus when external circuitry pulls the FAULTB pin high, on toggling of the EN pin, or on a power cycle of the device. In case there is no MCU, only a power cycle clears the fault.

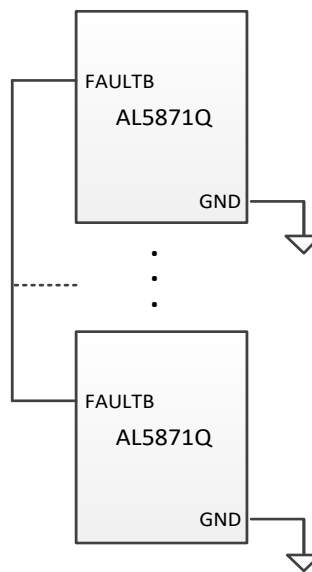
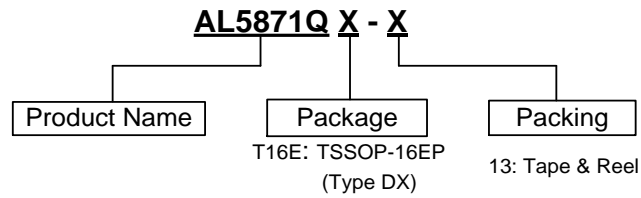


Figure 5. Fault-Line Bus Connection

AL5871Q pulls the FAULTB low upon the occurrence of thermal shutdown, LED short protection, LED open protection. For thermal shutdown and LED open, the FAULTB pin is released when the fault condition is removed. For LED short protection, the FAULTB pin stays low even if the fault condition does not exist. Clearing the faults requires a power cycle of the device.

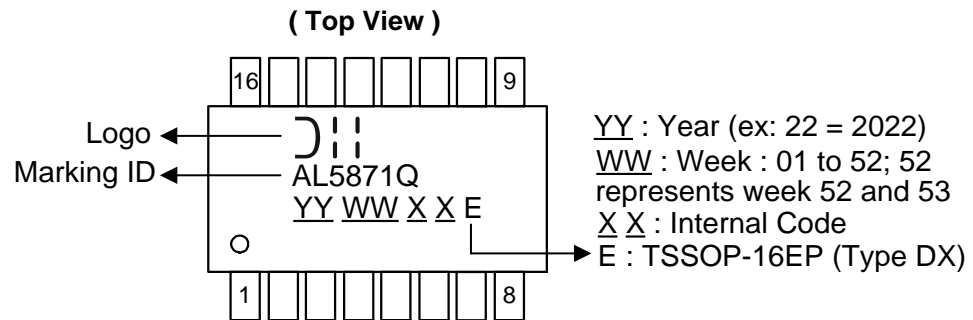
Ordering Information



Part Number	Part Number Suffix	Package Code	Package	Packing	
				Qty.	Carrier
AL5871QT16E-13	-13	T16E	TSSOP-16EP (Type DX)	2500	Tape & Reel

Marking Information

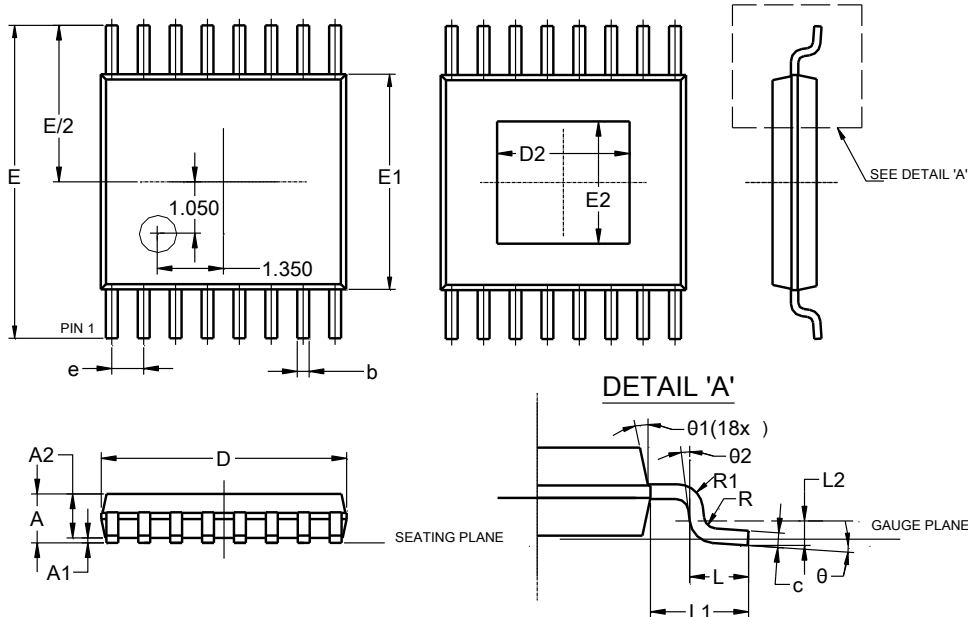
Package Type: TSSOP-16EP (Type DX)



Package Outline Dimensions

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

TSSOP-16EP (Type DX)

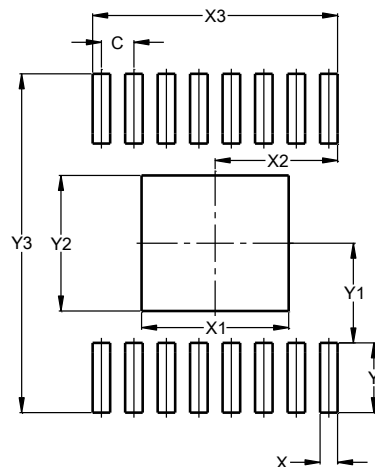


TSSOP-16EP (Type DX)			
Dim	Min	Max	Typ
A	--	1.08	--
A1	0.05	0.15	--
A2	0.80	0.93	--
b	0.19	0.30	--
c	0.09	0.20	--
D	4.90	5.10	--
D2	2.70	--	--
E	6.40 BSC		
E1	4.30	4.50	--
E2	2.50	--	--
e	0.65 BSC		
L	0.45	0.75	--
L1	1.00 REF		
L2	0.25 BSC		
R	0.09	--	--
R1	0.09	--	--
θ	0°	8°	--
θ1	5°	15°	--
θ2	0°	--	--
All Dimensions in mm			

Suggested Pad Layout

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

TSSOP-16EP (Type DX)



Dimensions	Value (in mm)
C	0.65
X	0.35
X1	2.94
X2	2.45
X3	4.90
Y	1.40
Y1	2.00
Y2	2.72
Y3	6.80

Mechanical Data

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads, Solderable per JESD22-B102 (e3)
- Weight: 0.055 grams (Approximate)

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