

Description

The AL1783Q is an automotive grade three-channel PWM linear LED driver with independent PWM dimming and current setting controls for each channel. The device is designed to target automotive LED lighting applications.

The key merits of the AL1783Q are attributed to a compact solution, eBOM cost effectiveness, excellent PWM dimming performance, low standby power, ease of system implementation, and up to 55V input and LED pin operating voltage.

The AL1783Q is available in the TSSOP-16EP package to minimize PCB space and external component count.

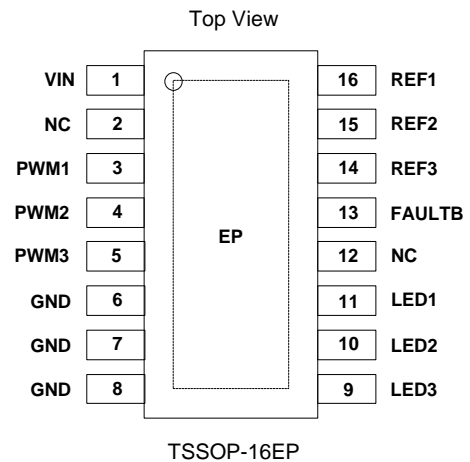
Features

- AEC-Q100 (Grade 1) Qualified
- Wide Input-Voltage Range from 6.5V to 55V
- -40°C to +125°C Ambient Temperature Operation Range
- ±4% LED Current Tolerance @125mA
- Independent PWM Dimming Control for Each Channel
- Three External Ref Pins to Set LED Current for Each Channel
- Enter and Exit Standby Power-Saving Mode Automatically
- Support Fast 40kHz PWM Dimming
- Robust Protections: Undervoltage Lockout (UVLO), Overvoltage Protection (OVP), LED String Open Protection (LED Open)
- Overtemperature Protection (OTP): Thermal Foldback, Thermal Shutdown, and Automatic Thermal Recovery
- Fault Reporting: UVLO, OTP, LED Open and Short
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **The AL1783Q 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/>

- 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

- Daytime running lights
- Position lights
- Fog lights
- Rear lights
- Stop or taillights
- Interior lighting

Typical Application Circuit

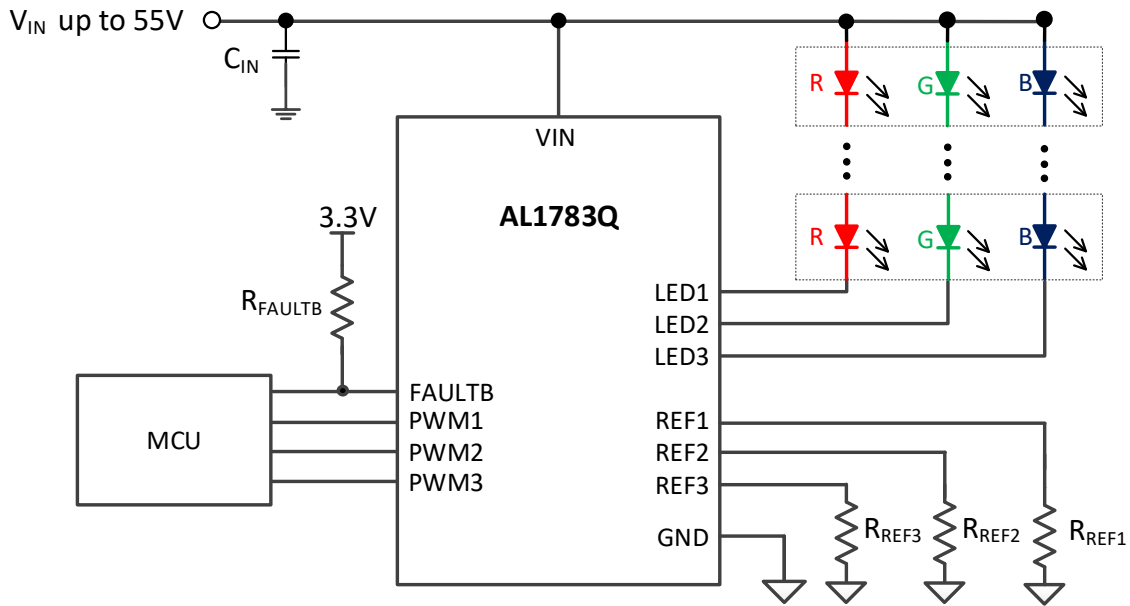


Figure 1. Typical Application

Pin Descriptions

Pin Number	Pin Name	Function
VIN	1	Power Supply for Chip
NC	2	No Connection
PWM1	3	PWM Dimming Signal and Enable Input for 1 st Channel of LED1, Internally Pulled Down 200kΩ Typical.
PWM2	4	PWM Dimming Signal and Enable Input for 2 nd Channel of LED2, Internally Pulled Down 200kΩ Typical.
PWM3	5	PWM Dimming Signal and Enable Input for 3 rd Channel of LED3, Internally Pulled Down 200kΩ Typical.
GND	6	Ground
GND	7	Ground
GND	8	Ground
LED3	9	3 rd Channel for LED String Cathode
LED2	10	2 nd Channel for LED String Cathode
LED1	11	1 st Channel for LED String Cathode
NC	12	No Connection
FAULTB	13	Fault Report. Open Drain Asserted Low to Report Faulty Conditions. Needs an External Pullup Resistor.
REF3	14	Reference Current Setting Through External Resistor (R_{ref3}) for 3 rd Channel
REF2	15	Reference Current Setting Through External Resistor (R_{ref2}) for 2 nd Channel
REF1	16	Reference Current Setting Through External Resistor (R_{ref1}) for 1 st Channel
—	Exposed PAD	Exposed pad must connect to GND. It should be externally connected to GND to reduce thermal impedance. It should not be used as an electrical conduction path.

Functional Block Diagram

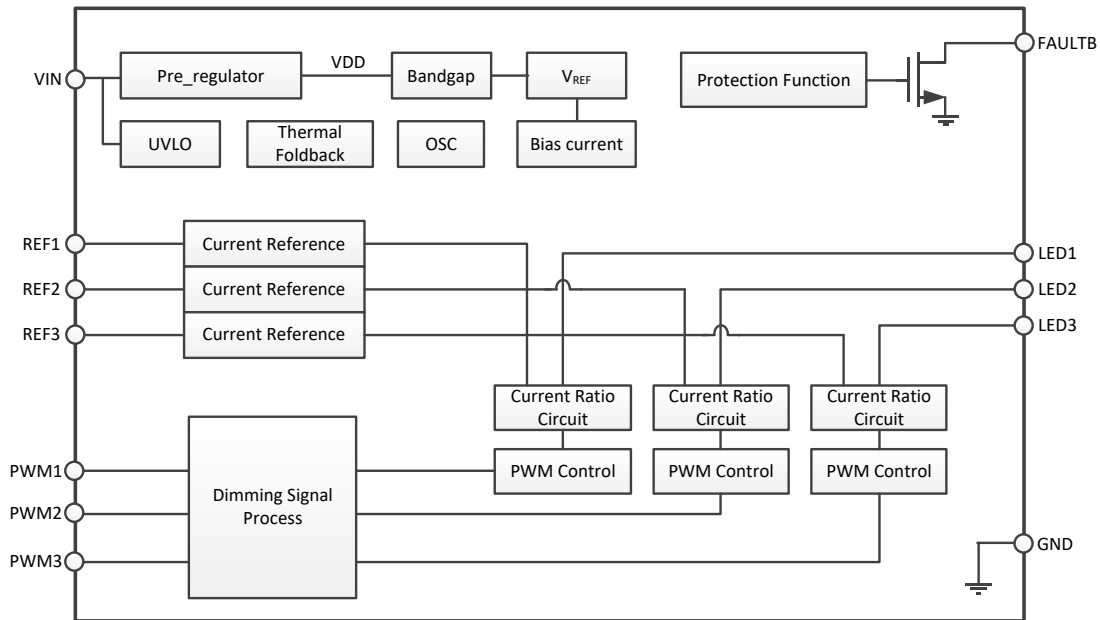


Figure 2. Functional Block Diagram

Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Ratings	Units
V _{VIN}	Input Voltage Relative to GND	-0.3 to 62	V
V _{LED1,2,3}	LED1,2,3 Voltage Relative to GND	-0.3 to 62	V
I _{LED1,2,3}	LED1,2,3 Output Current	300	mA
V _{PWM1,2,3} , V _{REF1,2,3} , V _{FAULTB}	PWM1,2,3, REF1,2,3, and FAULT Voltage Relative to GND	-0.3 to 7	V
T _J	Operating Junction Temperature	-40 to +150	°C
T _{ST}	Storage Temperature	-55 to +160	°C

Note: 4. Stresses greater than *Absolute Maximum Ratings* specified above can 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 can be affected by exposure to absolute maximum rating conditions for extended periods of time. Semiconductor devices are ESD sensitive and can be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices.

ESD Ratings

Symbol	Parameter	Rating	Unit
V _{ESD}	Human Body Model (HBM)	+/-4000	V
	Charged Device Model (CDM)	+/-1000	

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{VIN}	Input Voltage Relative to GND	6.5	55	V
V_{IH}	High-Level Input Voltage on PWM1,2,3	1.4	5.5	V
V_{IL}	Low-Level Input Voltage on PWM1,2,3	0	0.4	V
T_J	Operating Junction Temperature Range	-40	+150	°C
T_A	Operating Ambient Temperature	-40	+125	°C

Thermal Information (Note 5)

Symbol	Parameter	Rating	Unit
θ_{JA}	Junction-To-Ambient Thermal Resistance	45	°C/W
θ_{JC}	Junction-To-Case (Top) Thermal Resistance	10	°C/W

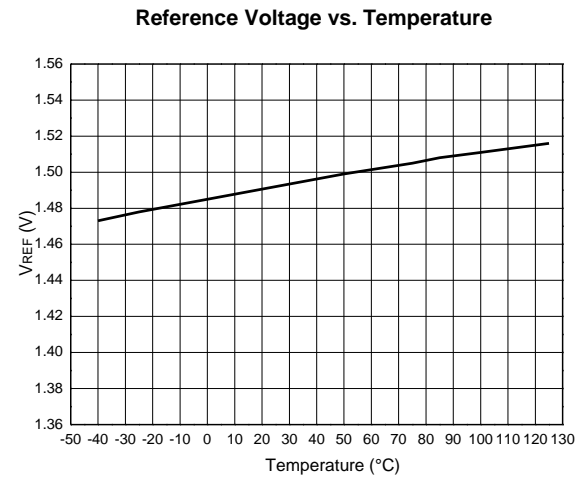
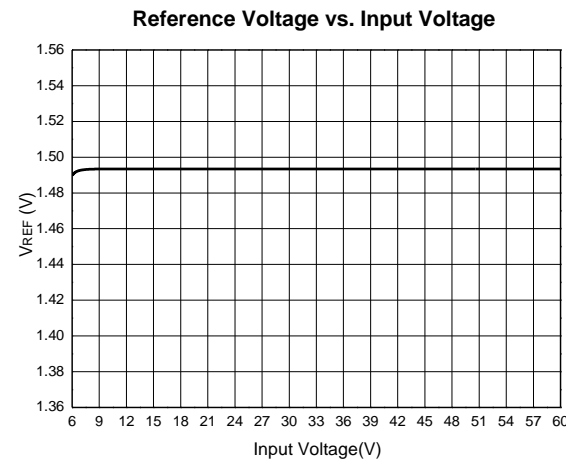
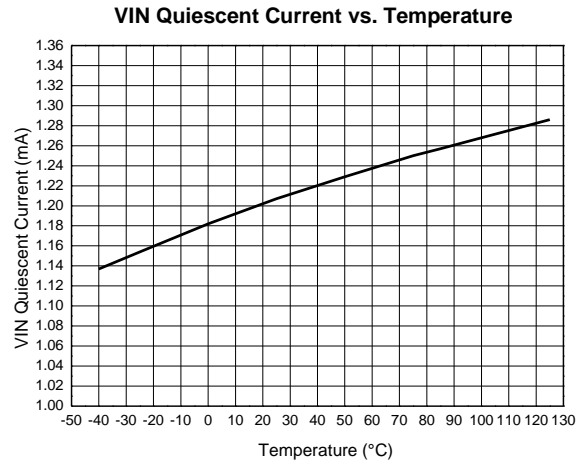
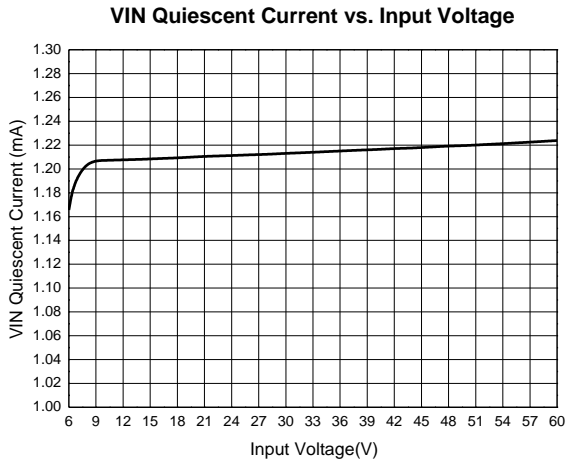
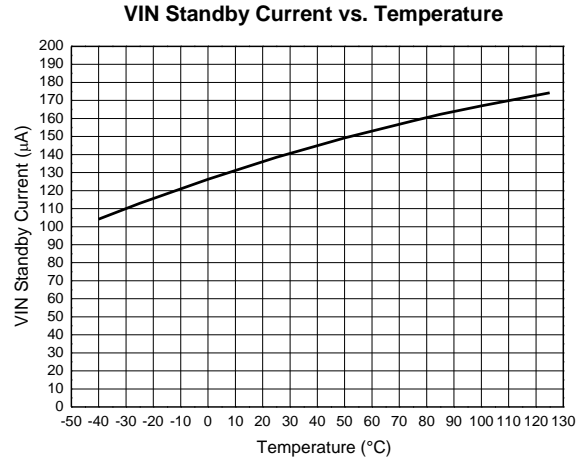
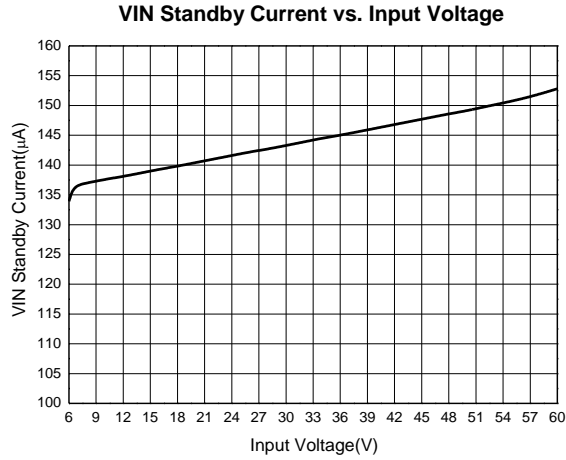
Note: 5. Device mounted on 2" × 2" FR-4 substrate PCB, 2oz copper, with minimum recommended pad on top layer and thermal vias to bottom layer ground plane.

Electrical Characteristics (@ $T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$, $V_{IN} = 12\text{V}$, unless otherwise specified. Typical values are at $T_A = +25^{\circ}\text{C}$)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{VIN_UVLO}	VIN UVLO Voltage	$V_{PWM1,2,3} = 0$, V_{VIN} Rising	5.6	6.0	6.6	V
$V_{VIN_UVLO_HYS}$	VIN UVLO Hysteresis	$V_{PWM1,2,3} = 0$, V_{VIN} Falling	—	300	—	mV
$I_{VIN_Standby}$	Input Current in Standby Mode	Standby Mode, all PWM1,2,3 are "L" for 4ms	80	130	180	μA
I_{DVCC_Q}	Input Current in Normal Mode	Enabled, LED1,2,3 Floating, any PWM1,2,3 is "H", $R_{REF1,2,3}$ is 48k Ω	—	1.5	2.5	mA
$V_{IL_PWM1,2,3}$	PWM Low Voltage	—	—	—	0.4	V
$V_{IH_PWM1,2,3}$	PWM High Voltage	—	1.4	—	—	V
$f_{PWM1,2,3}$	PWM Frequency	—	0.5	—	40	kHz
$I_{PWM1,2,3_PD}$	PWM Internal Pulldown	$V_{PWM1,2,3} = 5\text{V}$	0.35	—	3.5	μA
$t_{PWM1,2,3_MIN_ON}$	Minimum PWM1,2,3 On Time	—	10	—	—	μs
$t_{PWM1,2,3_SHDN}$	Entrance Time for Standby Mode When All PWM1,2,3 are "L"	—	1	4	6	ms
$V_{REF1,2,3}$	Reference Voltage	$T_A = +25^{\circ}\text{C}$	1.470	1.5	1.530	V
		$T_A = -40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$	1.455	1.5	1.545	V
$I_{REF1,2,3}$	Reference Current	$R_{REF1,2,3} = 48\text{k}\Omega$	—	31.25	—	μA
$I_{LED1,2,3_NOM}$	Nominal Regulation Current for Channel 1,2,3	$R_{REF1,2,3} = 48\text{k}\Omega$, $T_A = +25^{\circ}\text{C}$	120	125	130	mA
		$R_{REF1,2,3} = 48\text{k}\Omega$, $T_A = +125^{\circ}\text{C}$	118.5	125	131.5	mA
$I_{LED1,2,3_Max}$	Max Regulation Current for Channel 1,2,3	$R_{REF1,2,3} = 24\text{k}\Omega$ (Note 6)	—	250	—	mA
$I_{LED1,2,3_Min}$	Min Regulation Current for Channel 1,2,3	$R_{REF1,2,3} = 200\text{k}\Omega$ (Note 6)	—	30	—	mA
$V_{LED1,2,3_REG}$	Minimum LED Regulation Voltage	$I_{LED1,2,3} = 125\text{mA}$	—	0.7	—	V
$I_{LED1,2,3_LEAK}$	LED1,2,3 Leakage Current	$V_{PWM1,2,3} = 0$, $V_{LED1,2,3} = 12\text{V}$	—	0.1	1.5	μA
$V_{LED1,2,3SHP}$	LED Short Protection Threshold	(Note 7)	13	15	17	V
$t_{LED1,2,3SHDG}$	Short-Detection Deglitch	100% Duty-Cycle	—	3	—	ms
$N_{LED1,2,3SHDG}$		PWM Dimming (Count the Number of Continuous Cycles when LED Short is Detected)	—	7	—	Cycles
$t_{LED1,2,3SH_HICCUP}$	LED Short Protection Hiccup Time	—	—	128	—	ms
$t_{LED1,2,3OPDG}$	Open-Detection Deglitch	100% Duty-Cycle	—	3	—	ms
$N_{LED1,2,3OPDG}$		PWM Dimming (Count the Number of Continuous Cycles when LED Open is Detected)	—	7	—	Cycles
$t_{LED1,2,3OP_HICCUP}$	LED Open Protection Hiccup Time	—	—	128	—	ms
t_{SS}	Soft-Start Time	$V_{PWM1,2,3} = 5\text{V}$, 90% of $I_{LED1,2,3_NOM}$	—	200	—	μs
V_{FOL}	FAULTB Output Low Voltage	$I_{FAULTB} = 1\text{mA}$	—	—	180	mV
I_{FOH}	FAULTB Leakage Current	$V_{FAULTB} = 5\text{V}$	—	—	1	μA
T_{SHDN}	Junction Temperature for Thermal Shutdown Threshold	(Note 6)	—	+160	—	$^{\circ}\text{C}$
T_{REC}	Junction Temperature for Thermal Recovery Threshold	(Note 6)	—	+140	—	$^{\circ}\text{C}$

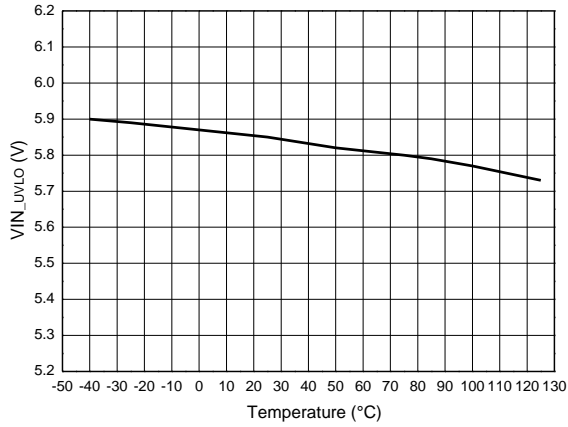
Notes: 6. These parameters, although guaranteed by design, are not 100% tested in production.
7. LED short is detected when $V_{LED1,2,3} > 15\text{V}$.

Typical Performance Characteristics (@ $T_A = +25^\circ\text{C}$, $V_{IN} = 12\text{V}$, $R_{REF} = 48\text{k}\Omega$, $I_{LED} = 125\text{mA}$, unless otherwise specified.)

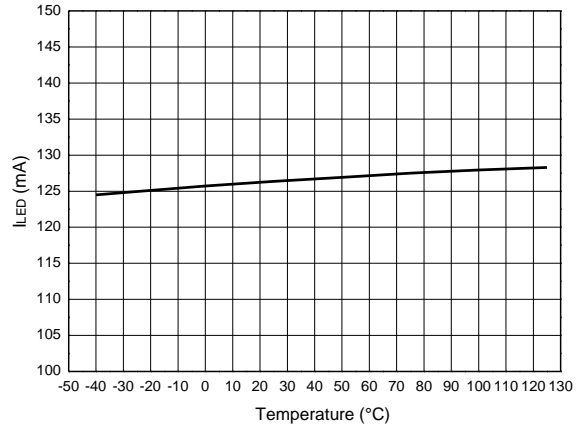


Typical Performance Characteristics (@ $T_A = +25^\circ\text{C}$, $V_{IN} = 12\text{V}$, $R_{REF} = 48\text{k}\Omega$, $I_{LED} = 125\text{mA}$, unless otherwise specified.)
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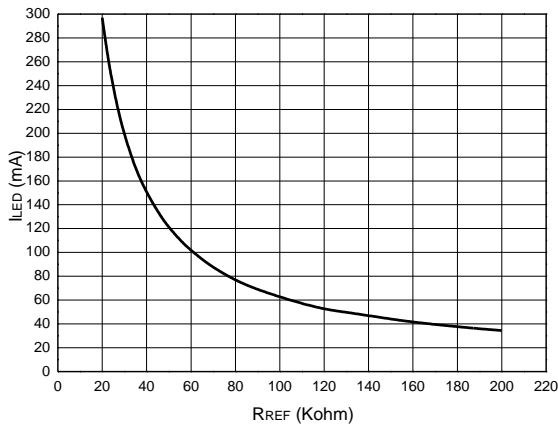
VIN UVLO Voltage vs. Temperature



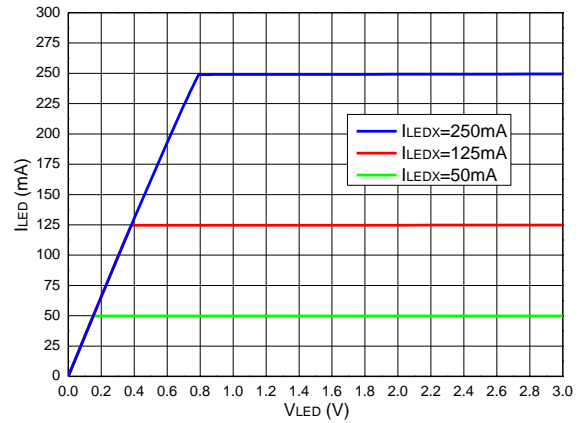
LED Current vs. Temperature



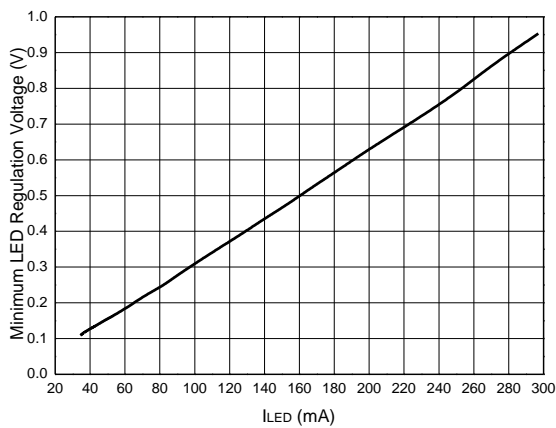
LED Current vs. RREF



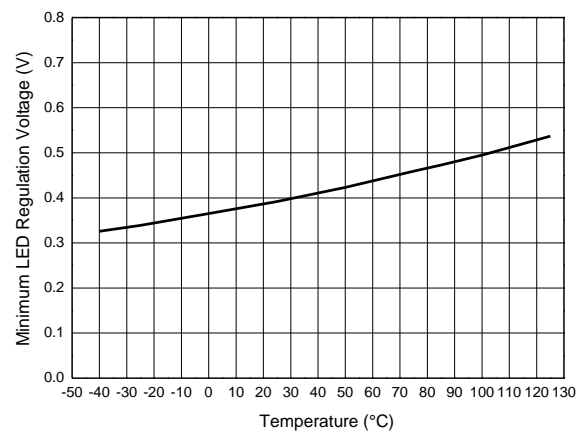
LED Current vs. VLED Voltage



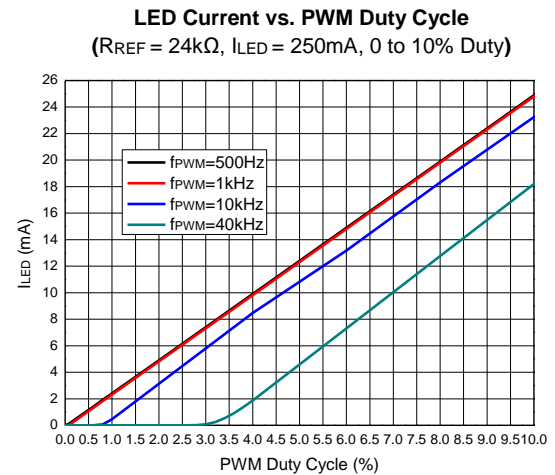
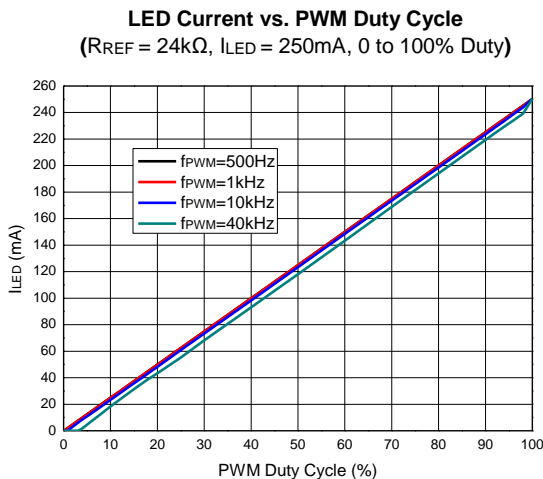
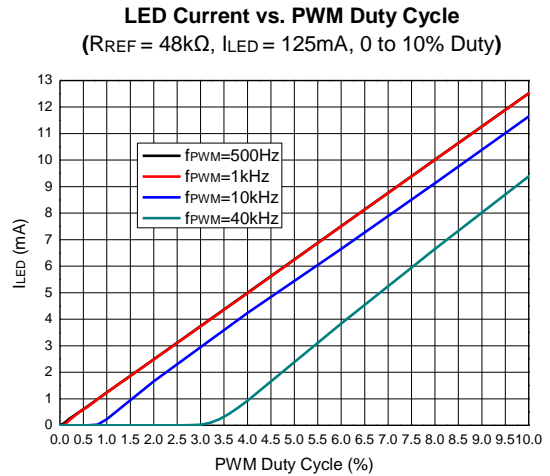
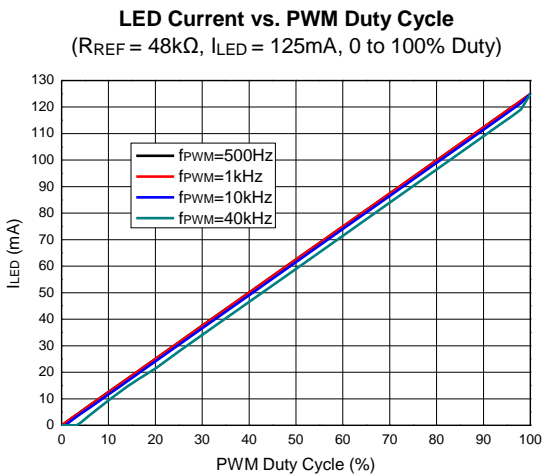
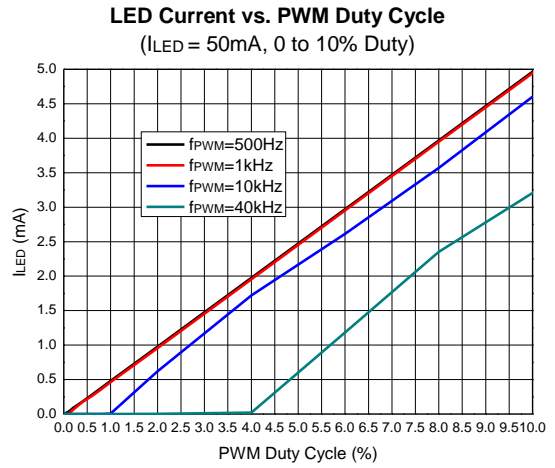
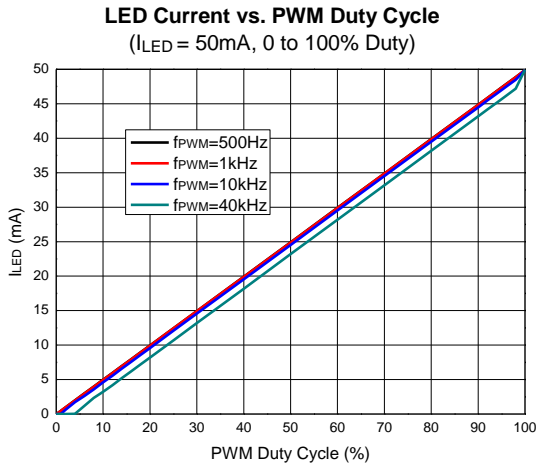
Minimum LED Voltage vs. LED Regulation Current



Minimum LED Voltage vs. Temperature
($R_{REF} = 48\text{k}\Omega$, $I_{LED} = 125\text{mA}$)



Typical Performance Characteristics (@ $T_A = +25^\circ\text{C}$, $V_{IN} = 12\text{V}$, $R_{REF} = 48\text{k}\Omega$, $I_{LED} = 125\text{mA}$, unless otherwise specified.)
(continued)



Application Information

Linear LED Driver Design Topology and Implementation

The AL1783Q adopts a multichannel linear LED driver topology with independent PWM dimming, and current setting control implementation for each channel. The parallel linear LED driver channel structure associated with the power conversion stage covers mainstream applications for many LED lighting dimming and color tuning applications. Given the maximum operating input voltage at 55V, it is possible to drive more than 16 RGB emitters by splitting LED emitter string voltage and VIN, as long as it is below 55V.

The AL1783Q is a three PWM current sink regulator. In order to meet channel current accuracy and short protection requirements, the recommended maximum current of each channel is 250mA and the recommended minimum channel current is 30mA. Each channel can be individually and digitally controlled by the PWM dimming the signal down to less than 1% @ 1kHz.

As in the case of three-channel tunable color LED lighting, the AL1783Q drives three emitter strings. Using RREF1, RREF2, and RREF3 of 24kΩ, the maximum output current for Channel 1, Channel 2, and Channel 3 will be 250mA when each PWM signal is turned on. The associated microcontroller unit (MCU) shall program and generate the suitable PWM duty cycle to meet the required and targeted tuning color output. RREF1, RREF2, and RREF3 can also be set dynamically for different peak values to achieve the desired channel peak current if another dimension adjustment is needed.

The LED driving element detects fault conditions and reports its status on the FAULTB pin. It features LED open detection, LED short detection, overtemperature protection (OTP), and undervoltage lockout (UVLO). The AL1783Q provides supreme current matching between channels and devices. Along with bus-mode fault reporting, multiple devices can be employed together to increase current driving capabilities or channel count versatility.

Interface with Emitter Strings

The power conversion stage provides necessary constant output voltages (CVs) to power the microcontroller unit, LED strings, and LED drivers. A typical application requires 3.3V for the MCU and 12V/24V/48V anodes of LED emitter strings. The cathodes of the bottom LED emitter strings are connected to the LED1,2,3 pins of the AL1783Q.

Interface with MCU

The physical layer interfaces between the microcontroller unit and the AL1783Q are the PWM1,2,3 pins and FAULTB. The MCU activates the PWM1,2,3 (asserted high) to turn on the AL1783Q during normal LED lighting operation applications. When the PWM1,2,3 pins are asserted low and greater than 4ms, the device enters into standby mode with minimum power consumption. For typical light dimming or mixing operations, the MCU generates proper dimming control output signals to the PWM1,2,3 pins. If any general fault occurs in the AL1783Q, the FAULTB pin is asserted LOW to interrupt and request the MCU to take proper actions.

Current Setting

The AL1783Q is designed to have individual LED channel currents set by its corresponding current setting from the RSET1,2,3 resistor. The LED channel current level is expressed as below:

$$I_{LED1,2,3} = 4000 * \frac{V_{REF}}{R_{SET1,2,3}}$$

where $V_{REF} = 1.5V$ nominally for all channels

For example, when an RREF of 24kΩ is used, each channel of the AL1783Q provides the same output current of 250mA.

The maximum LED current for each channel can be adjusted up to 250mA via the RREF resistor for the AL1783Q. Any two or more channels can be tied together to drive one LED string with aggregated current. So when the current needed for any channel is greater than the maximum value the device can provide, two or more channels or devices can be connected and paralleled together to provide the higher drive current necessary.

Application Information (continued)

Support Higher Current

While the recommended maximum operating current is at 250mA for each channel, and total 750mA for the AL1783Q, by setting R_{REF1} , R_{REF2} , and R_{REF3} at 24k Ω ; the system design can drive an LED string with higher current by connecting the cathodes of the LED emitter string to two or more LED channel outputs (LED1,2,3) and tie the associated PWM pins (PWM1,2,3) to the same PWM signal from the MCU. The total current through the LED emitter string is the sum of the current through each individual channel.

Similarly, it is also possible to further increase the current for a specific LED string by connecting two or more AL1783Q IC chips in parallel and drive all associated PWM pins with a common PWM signal.

PWM Dimming Control

A PWM frequency greater than 500Hz is recommended. A high level of PWM signals will turn the current sink on to flow through the LED pin, and a low level will turn it off. Consequently, each LED channel and LED brightness of the corresponding channel can be adjusted cycle-by-cycle accordingly.

The pulse width of the PWM signal should be no less than 10 μ s, supporting down to 1% @ 1kHz deep dimming capability. PWM signals can be driven static high/low to turn on/off the corresponding channels.

Enable and Soft-Start LED Drivers (EN Pin)

The PWM of the AL1783Q is enabled when the voltage at any PWM1,2,3 pin is greater than the typical voltage of 2.5V, and disabled when all PWM1,2,3 are lower than 0.4V. When PWM1,2,3 pin is asserted and the VIN pin is ramped up beyond minimum operation voltage, a soft-start will be performed with a slew-rate controlled current ramp over 200 μ s at the LED1,2,3 output pins. For optimal system reliability, this minimizes the current overshooting through the LED strings. When all PWM1,2,3 are asserted low for > 4ms, the LED driver will enter into standby mode with ultra-low standby power, the standby current is less than 200 μ A typical.

Standby Mode

When in this standby mode, the power consumption saved is $I_{VIN_Standby}$ (standby power supply current) * V_{IN} (V_{IN} for LED driver circuit). Refer to the case of the R_{REF} at 24k Ω (for 250mA channel current in the AL1783Q, $I_{standby}$ is typical at 0.2mA) and V_{IN} is 50V, or 10mW for the LED driver portion.

When any PWM signal driving AL1783Q is detected, the AL1783Q will automatically exit the standby mode and perform the designated functions properly.

Fault Reporting (FAULTB Pin)

The AL1783Q detects and reports the FAULTB status upon the occurrence of thermal shutdown in OTP, LED short, LED open, 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 pullup resistor.

Undervoltage Lockout (Hysteresis Mode)

Undervoltage lockout function (UVLO) guarantees that the device is initially off during startup. The AL1783Q is not turned on until the power supply has reached 6V. Whenever the input voltage falls below approximately 5.7V, the device is turned off and the FAULTB status will be reported. The UVLO detection-trigger circuitry has a hysteresis of 300mV.

LED Open Protection (Hiccup Mode)

The AL1783Q detects the LED status by monitoring the current of the LED pin. When LED opens and lasts for a period of time period, the AL1783Q enters protection mode and shuts down all channels. The time period is 7 cycles of the input PWM signal or 3ms timer when the PWM duty is 100%. The abnormal channel will be retested afterward to check if the abnormal condition is cleared. The AL1783Q periodically checks every 128ms if the abnormal condition is removed. The LED driver will re-activate once the abnormal condition is cleared. The LED open protection is effective when the input PWM1,2,3 signal on time is higher than 10 μ s, or 1% @ 1kHz. The FAULTB pin will be asserted low when the LED pin detects that the LED string is open, and will resume high once the LED open condition is removed.

Application Information (continued)

LED Short Protection (Hiccup Mode)

The AL1783Q detects the LED status by monitoring voltage at the LED1,2,3 pins. When the LED string anode is short to cathode, $V_{LED1,2,3}$ will be pulled up. When $V_{LED1,2,3}$ voltage exceeds 15V and lasts for a short time period, the AL1783Q enters protection mode and shuts down all channels. The time period is 7 cycles of the input PWM signal or 3ms timer when the PWM duty is 100%. The abnormal channel will be periodically rechecked every 128ms afterward to detect if the abnormal condition is cleared. The LED driver will re-activate once the abnormal condition is cleared. The LED short protection is effective when the input voltage is higher than 15V and the input PWM1,2,3 signal on time is higher than 10 μ s, or 1% @ 1kHz. The FAULTB pin will be asserted low when the LED shorts, and will resume high once the LED short condition is removed.

Thermal Foldback and Overtemperature Protection (Hysteresis Mode)

Temperature is a concern when driving the LEDs at high currents. Take care at high temperatures so as not to exceed the LED operating temperature requirements. In order to cool down the LEDs before they are damaged, the current going through the LEDs must be decreased when the LED temperature begins to increase.

When the chip temperature is higher than the threshold temperature (+130°C), the AL1783Q starts to reduce the V_{REFX} voltage and the LED current starts to fall from the nominal current. As illustrated in Figure 3, the LED current decreases as the temperature increases.

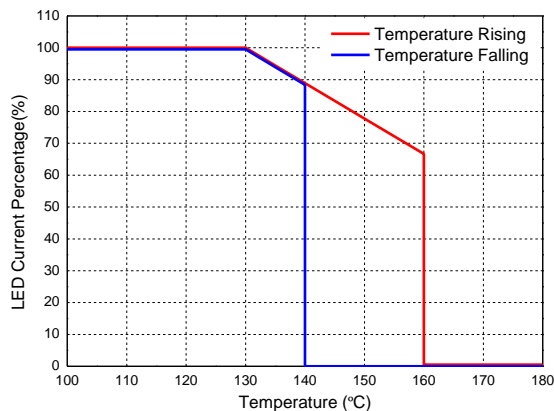


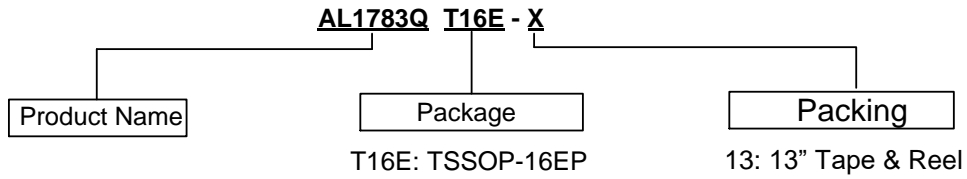
Figure 3. Thermal Foldback Diagram

Thermal protection prevents the IC from being damaged when the temperature exceeds safe margins. When the junction temperature reaches +160°C, the device will enter thermal shutdown, and all currents will sink and while no current flows to the LED strings. The normal current level can be automatically restored to its set current from OTP by triggering a soft-start once the temperature cools down below +140°C. The LED driver's thermal shut mode will also be reported at the FAULTB pin.

Design Tools (<https://www.diodes.com/design/tools/>)

- Evaluation Board User Guides
- Spice Models (PSPICE Digital Simulation)
- Design Calculators

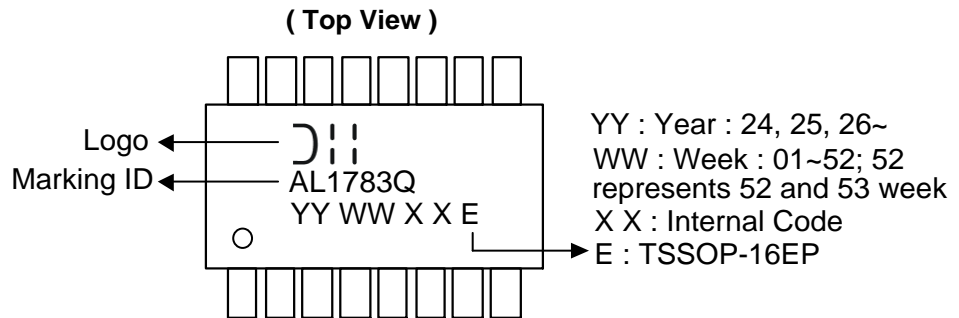
Ordering Information (Note 8)



Part Number	Package Code	Package	Packing	
			Qty.	Carrier
AL1783QT16E-13	T16E	TSSOP-16EP	2500	13" Tape and Reel

Note: 8. For packaging details, go to our website at <http://www.diodes.com/products/packages.html>.

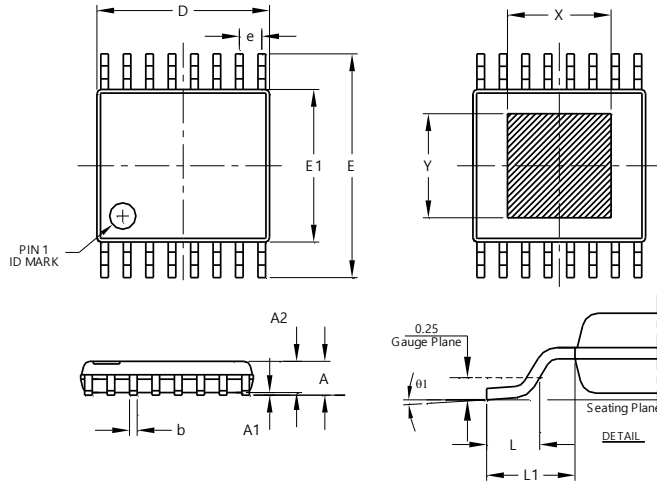
Marking Information



Package Outline Dimensions

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

TSSOP-16EP

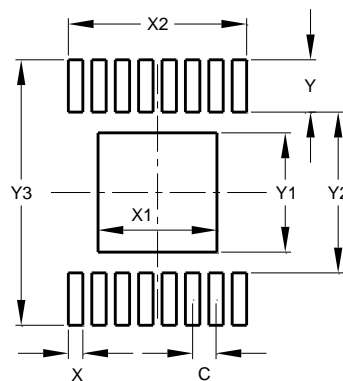


TSSOP-16EP			
Dim	Min	Max	Typ
A	-	1.20	-
A1	0.025	0.100	-
A2	0.80	1.05	0.90
b	0.19	0.30	-
c	0.09	0.20	-
D	4.90	5.10	5.00
E	6.20	6.60	6.40
E1	4.30	4.50	4.40
e	0.65 BSC		
L	0.45	0.75	0.60
L1	1.0 REF		
L2	0.65 BSC		
X	-	-	2.997
Y	-	-	2.997
θ1	0°	8°	-
All Dimensions in mm			

Suggested Pad Layout

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

TSSOP-16EP



Dimensions	Value (in mm)
C	0.650
X	0.450
X1	3.290
X2	5.000
Y	1.450
Y1	3.290
Y2	4.450
Y3	7.350

Mechanical Data

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish - Matte Tin Plated Leads, Solderable per JESD22-B102 ③
- Weight: 0.056 grams (Approximate)

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