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Description

The AL8853 is a highly integrated and cost effective Light Emitting Diode (LED) controller. It provides a high performance LED backlight solution with low BOM cost.

The AL8853 contains a PWM boost driver which uses current mode control and fixed frequency operation to regulate the LED current. The LED current is sensed through an external current sense resistor. The voltage across the sensing resistor is compared with reference level of 200mV, the error is amplified to control the pulse width of the power switch thus to regulate the current flowing the LED.

The AL8853 offers PWM to analog dimming mode for a wide range of dimming control.

The AL8853 has comprehensive protection features such as power MOSFET Over Current Protection (OCP), Output Over Voltage Protection (OVP), Diode & Inductor short protection, LED cathode short to GND protection, IC power supply Under Voltage Lockout (UVLO), LED open protection, V_{OUT} short protection and Over Temperature Protection (OTP).

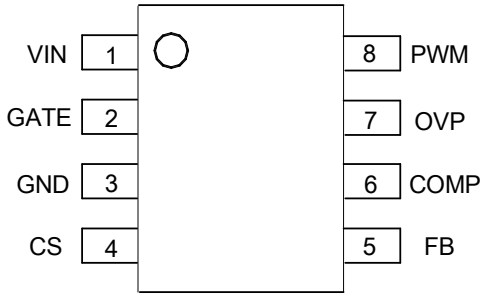
The AL8853 is available in the SO-8 (Type TH2) package.

Features

- Wide Input Voltage Range: 6.0V to 40V
- High Precision Feedback Reference Voltage: 200mV/±3%
- Current Mode PWM Controller with Good Dynamic Response
- PWM to Analog Dimming Mode
- Built-In Comprehensive Protections
  - Under Voltage Lock Out (UVLO)
  - Output Over Voltage Protection (OVP)
  - Power MOSFET Over Current Protection (OCP)
  - Diode and Inductor Short Protection
  - LED Cathode Short to GND Protection
  - LED Open Protection
  - V_{OUT} Short Protection
  - Over Temperature Protection (OTP)
- Available in Pb-Free SO-8 (Type TH2) Package
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

Pin Assignments

(Top View)



SO-8 (Type TH2)

Applications

- LCD TV
- LCD Monitor
- Flat Panel Display
- Constant Output Voltage Driver

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.

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Typical Applications Circuit

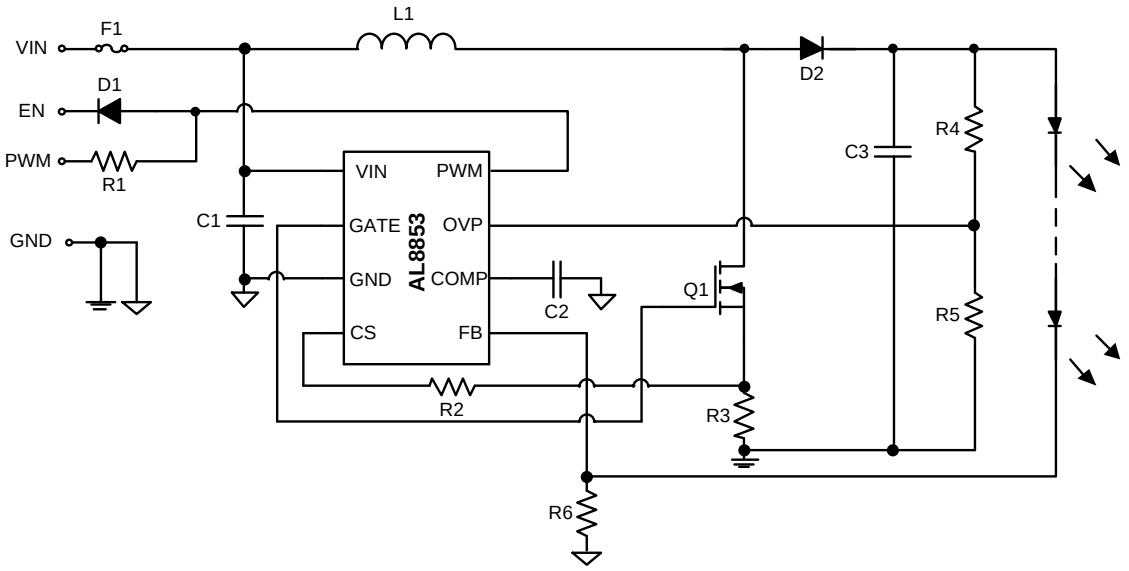


Figure 1. Typical Applications Circuit

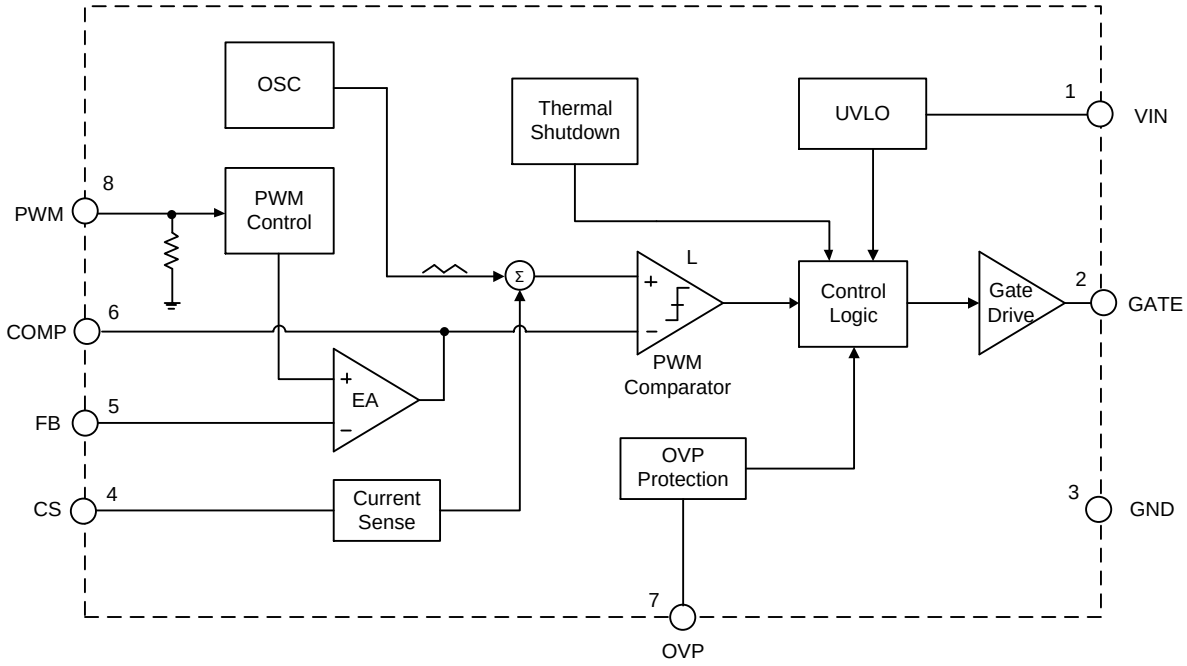
Pin Descriptions

Pin Number	Pin Name	Function
1	VIN	Power Supply Input
2	GATE	Gate Drive Output
3	GND	Ground
4	CS	Current Sense Input
5	FB	LED Current Feedback
6	COMP	Boost Converter Loop Compensation
7	OVP	Over Voltage Protection Sense
8	PWM	PWM Signal Input for Analog Dimming Control

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Functional Block Diagram



Absolute Maximum Ratings (@T_A = +25°C, unless otherwise specified. Note 4)

Symbol	Parameter	Rating	Unit
V_{IN}, V_{GATE}, V_{OVP}	VIN, GATE, OVP Pin Voltage	-0.3 to 43	V
V_{CS}, V_{FB}, V_{COMP}, V_{PWM}	CS, FB, COMP, PWM Pin Voltage	-0.3 to 7	V
T_J	Operating Junction Temperature	+150	°C
T_{STG}	Storage Temperature Range	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10s)	+260	°C
θ_{JA}	Thermal Resistance (Junction to Ambient) (Note 5)	+105	°C/W
θ_{JC}	Thermal Resistance (Junction to Case) (Note 5)	6.6	°C/W
—	ESD (Charge Device Model)	750	V
—	ESD (Human Body Model)	2000	V

Notes: 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.

5. Device mounted on 1"x1" FR-4 substrate PCB, 2oz copper, with minimum recommended pad layout.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{IN}	VIN Pin Voltage	6	40	V
f_{PWM}	PWM Frequency for Analog Dimming	5	50	kHz
T_A	Ambient Temperature	-40	+125	°C

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Electrical Characteristics (V_{IN} = 12V, V_{PWM} = 5V, @T_A = +25°C, unless otherwise specified.) (Note 6)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Supply Voltage						
V_{IN}	Input Voltage	—	6.0	—	40	V
I_{OP}	Operating Supply Current	V_{IN} = 12V, V_{PWM} = 5V, No Load	—	2	3	mA
I_{SHDN}	Shutdown Supply Current	PWM Low > 50ms, Sleep Mode	—	130	180	μA
Under Voltage Lockout						
V_{UVLO}	Input UVLO Threshold	V_{IN} Rising	4.9	5.3	5.7	V
V_{HYS}	Input UVLO Hysteresis	—	—	400	—	mV
Soft Start						
I_{SS_SLOP}	Soft Start Slope	—	—	22	—	mV/ms
Error Amplifier						
V_{FB}	Feedback Reference Voltage	Reference Voltage at Non-Inverting Input	194	200	206	mV
A_m	Open Loop Voltage Gain	—	—	70	—	dB
G_m	Transconductance of EA	—	—	100	—	μA/V
I_{SOURCE}	Output Source Current	—	—	30	—	μA
I_{SINK}	Output Sink Current	—	—	60	—	μA
PWM to Analog Dimming Control						
—	PWM Duty	—	0	—	100	%
V_{PWM_H}	PWM Logic Input for Analog Dimming	—	2.5	—	—	V
V_{PWM_L}		—	—	—	1.2	V
Protection Threshold						
V_{OVP_OV}	Output Over Voltage Threshold Voltage	—	1.9	2.0	2.1	V
V_{OVP_HYS}	Output Over Voltage Hysteresis Voltage	—	—	100	—	mV
V_{OVP_UVLO}	OVP UVLO Threshold Voltage	Normal Operation	—	200	—	mV
		System Startup	—	100	—	mV
V_{CS_OCP}	Over Current Threshold Voltage	Duty = 90%	255	300	345	mV
V_{CS_HIGH}	CS High Protection Threshold	Diode or Inductor Short	1.1	1.2	1.3	V
V_{COMP_HIGH}	COMP High Protection Threshold	FB Pin Short to GND	2.9	3.2	3.5	V
T_{OTP}	Over Temperature Threshold	—	—	+160	—	°C
T_{OTP_HYS}	Over Temperature Hysteresis	—	—	+30	—	°C
Gate Driver						
f_{OSC}	Oscillator Frequency	—	110	120	130	kHz
D_{MAX}	Maximum Duty Cycle	—	93	95	97	%
V_{GATE}	Gate Pin Output Voltage	V_{IN} = 24V	—	13	—	V
t_{RISE}	Rising Time	1nF load	—	40	—	ns
t_{FALL}	Falling Time		—	20	—	ns

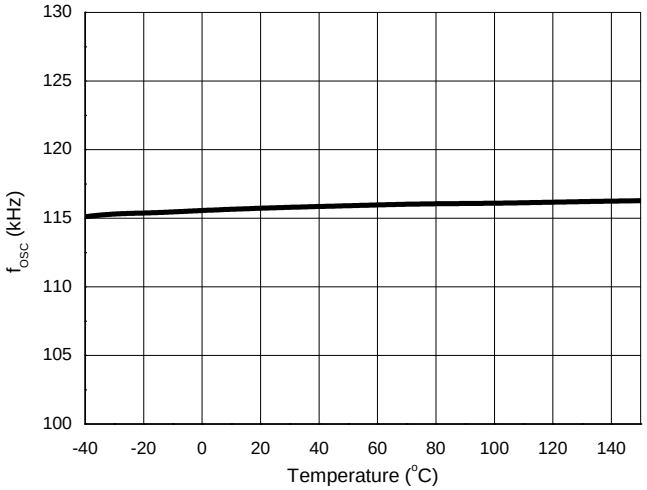
Note: 6. These parameters, although guaranteed by design, are not 100% tested in production.

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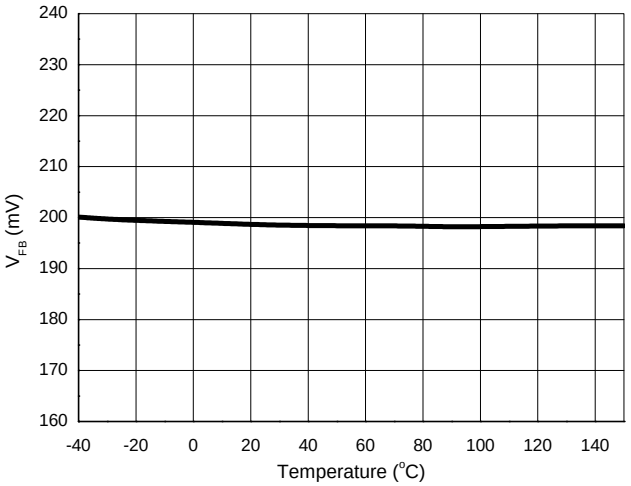
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Performance Characteristics

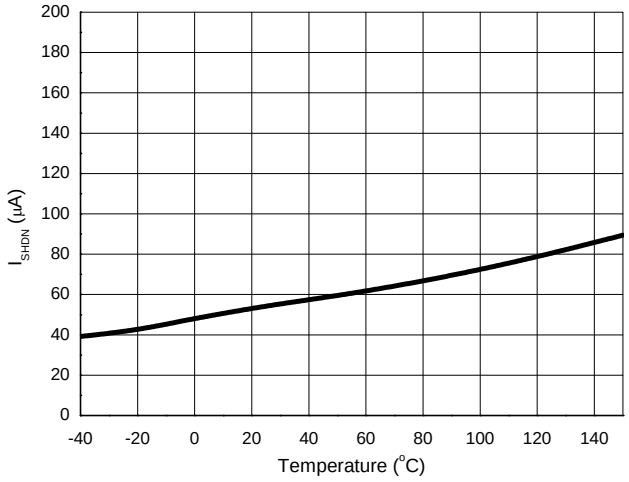
Operating Frequency vs. Ambient Temperature



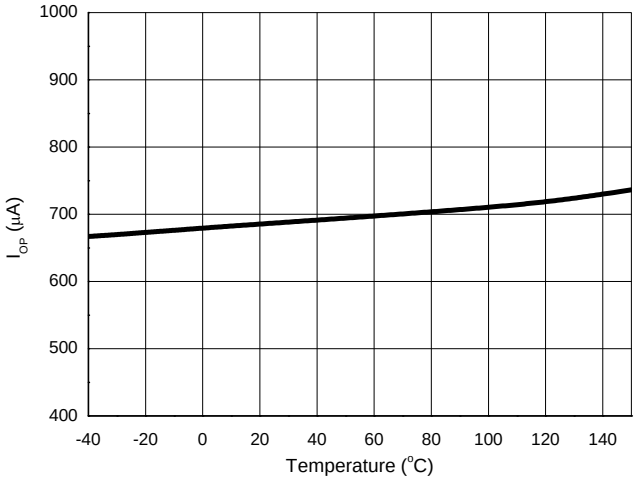
Reference Voltage vs. Ambient Temperature



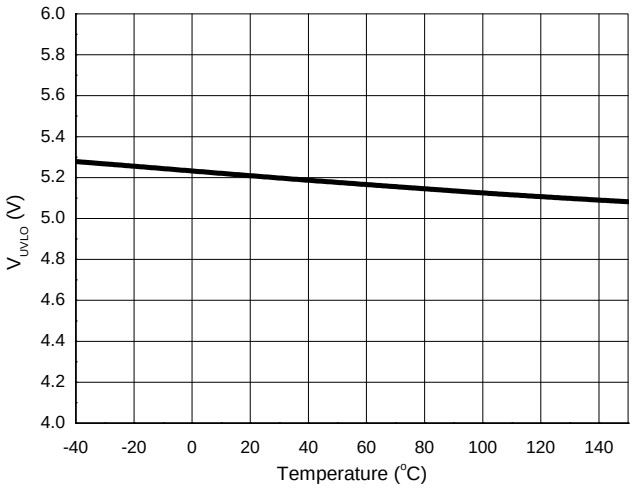
Shutdown Supply Current vs. Ambient Temperature



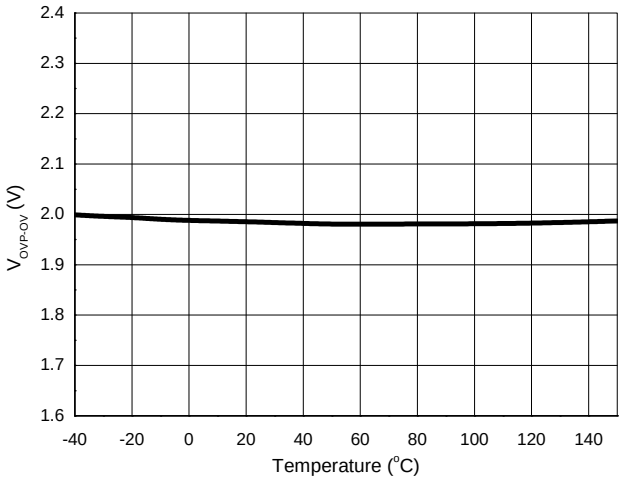
Operating Supply Current vs. Ambient Temperature



Input UVLO Threshold (V_{IN} Rising) vs. Ambient Temperature



Over Voltage Threshold Voltage vs. Ambient Temperature

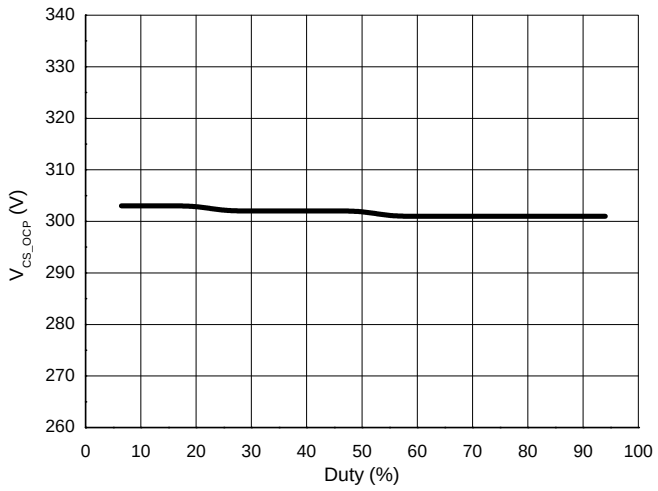


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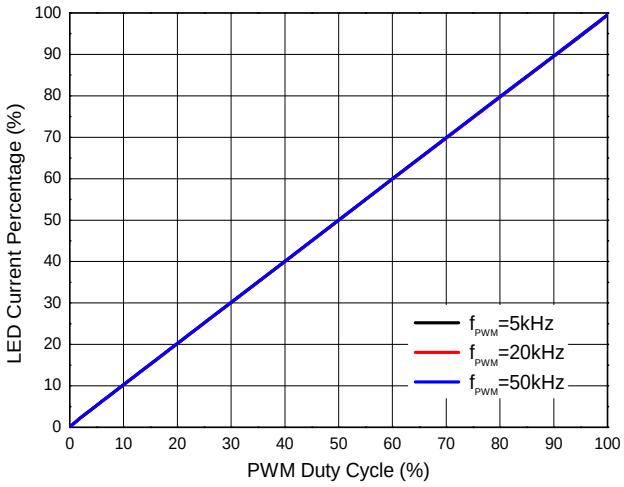
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Performance Characteristics

Over Current Threshold Voltage vs. Duty



PWM to Analog Dimming Curve



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Function Description

The AL8853 is a LED driver controller designed for boost converters in a constant frequency mode. It implements a peak current mode control scheme and an internal trans-conductance amplifier to accurately control the output current over a wide input and load conditions.

The AL8853 has comprehensive protection features such as power MOSFET Over Current Protection (OCP), Output Over Voltage Protection (OVP), Diode & Inductor short protection, LED cathode short to GND protection, IC power supply Under Voltage Lock Out (UVLO), LED open protection, V_{OUT} short protection and Over Temperature Protection (OTP).

Startup

The AL8853 is enabled by applying a voltage of greater than 2.5V to the PWM pin. The PWM pin is pulled down to GND with an on-chip 220kΩ resistor. When the first rising edge is applied to the PWM pin, the AL8853 will power up immediately, and remains powered up until the PWM input is lower than 1.3V for at least 20ms (typical), at this time the IC will enter standby mode. At standby mode, the current consumption of the AL8853 will be lower than 130μA (typical). Once the AL8853 is enabled, the internal 5V regulator will be activated and consumes less than 4mA.

When PWM is active high, the AL8853 checks the topology connection first. The IC monitors the OVP pin to see if the Schottky diode is connected or the boost output is short to GND. If the voltage at OVP pin is lower than 100mV, the output will be disabled. The AL8853 will also check other faults (UVLO, CS high, CMP high, FB high, OCP and OTP), and the boost converter will boost up the output with the internal soft start if no fault conditions.

UVLO

The AL8853 contains an Under Voltage Lock Out (UVLO) protection. The AL8853 is not turned ON until the power supply V_{IN} has reached 5.3V (typical). Whenever the input voltage falls below approximately 4.9V (typical), the device is turned off. The UVLO circuit has a hysteresis of 400mV.

LED Current Regulation

The AL8853 senses the FB pin voltage to control the LED current. The error between the sensed voltage and the internal FB reference voltage is amplified and compared to the CS pin sensing current signal plus the slope compensation to determine the power MOSFET on-time. The error amplifier sources or sinks current to the COMP pin to adjust the required inductor current responding to the load changes. The slope compensation signal is added to the current-sense signal to guarantee system stability at high duty cycle.

The error amplifier reference is set by internal reference voltage and the PWM duty cycle at PWM pin. And the average LED current is approximated by Equation 1:

$$I_{LED}[\mathrm{mA}] = \frac{200mV \cdot DUTY}{R_{FB}[\Omega]} \quad \text{..... (1)}$$

The AL8853 enters the pulse skip mode at light load, to improve efficiency and prevent over charging the output capacitor. The AL8853 turns the GATE signal high for a minimum on-time (typical 600ns), and remains low until another pulse is needed to maintain the boost converter output voltage.

Dimming Control

The LED current is controlled by the external PWM signal with different duty cycles. The AL8853 can support PWM signals with frequency ranging from 5kHz to 50kHz, and the PWM signal shall be higher than 2.5V for high logic and be lower than 1.2V for low logic. An internal square wave with duty cycle same as the external PWM signal is filtered to provide reference voltage of EA input, which determines the FB reference.

Slope Compensation

The AL8853 adopts a peak current mode control scheme. The main advantages of current mode are inherent cycle-by-cycle current limit of the power MOSFET and simple control loop characteristics. However, current mode control could cause the sub-harmonic oscillation for duty cycles greater than 50%, leading to system instability. The AL8853 has a built-in slope compensation to avoid the sub-harmonic oscillation.

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Function Description (continued)

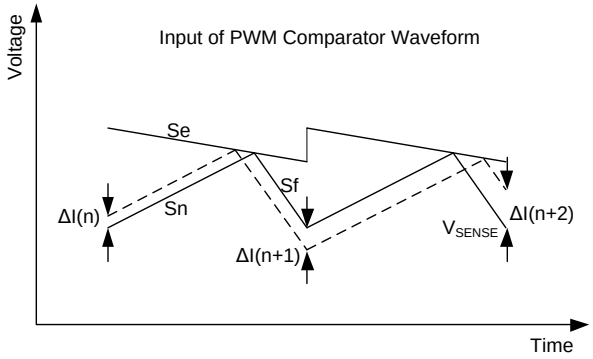


Figure 2 Sub-Harmonic Oscillation at Duty>50% and Compensation Slope to Avoid Sub-Harmonic Oscillation

In Figure 2, ΔI(n), ΔI(n+1) and ΔI(n+2) represent the inductor current increments when there is disturbance in the inductor current. And the relationship of the inductor current increment can be calculated with Equation 2.

$$\Delta I_{(n+1)} = \frac{S_f - S_e}{S_n + S_e} \cdot \Delta I_{(n)} \quad \text{..... (2)}$$

Where S_n is the slope of the inductor current when rising, S_f is the slope of the inductor current when falling and S_e is the slope of control signal.

If the control signal has no compensation, the inductor current will ramp up till slope reaches the control signal, and then ramps down. If the PWM duty is higher than 50%, the distribution will not be converged from duty to duty, and system runs into sub-harmonic oscillation. To avoid sub-harmonic oscillation, a control compensation is needed and (S_f - S_e) / (S_n + S_e) should always be smaller than 1. For boost applications, the slopes S_e, S_f and S_n can be calculated with the equations below.

$$S_e = V_{SL} \cdot f_s \quad \text{..... (3)}$$

$$S_f = R_{SEN} \cdot (V_{OUT} - V_{IN})/L \quad \text{..... (4)}$$

$$S_n = R_{SEN} \cdot V_{IN}/L \quad \text{..... (5)}$$

Where R_{SEN} is the current sense resistance and typical value of V_{SL} is 100mV.

From the equations, the factor (S_f - S_e) / (S_n + S_e) will decrease if Se increases. When the duty cycle is greater than 50%, lower inductance can also result in the factor increase. And for more flexibility, slope compensation amplitude can be increased by adding one external resistor, R_{SL}, in the CS path. Figure 3 shows the circuit setup. The external generated slope compensation is then added to the internal slope compensation of the AL8853. When using external slope compensation, the equation for Se becomes:

$$S_e = (V_{SL} + I_S \cdot R_{SL}) \cdot f_s \quad \text{..... (6)}$$

Where typical value of I_S is 50μA.

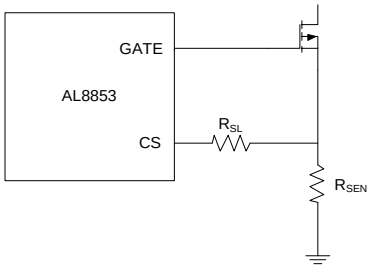


Figure 3. Adding External Slope Compensation

It is a good design practice to only add as much slope compensation as needed to avoid sub-harmonic oscillation. Additional slope compensation minimizes the influence of the sensed current in the control loop. With very large slope compensation, the control loop characteristics are similar to a voltage mode regulator which compares the error voltage to a saw tooth waveform rather than the inductor current.

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Function Description (continued)

LED Open Protection

The AL8853 will shut down the output if the output voltage is higher than the preset threshold level. When LED failure happens, the LED current and the resulted voltage drop on sensing resistor is nearly zero; the converter will run at maximum duty cycle that boosts the output voltage to a very high level. To prevent this from happening, the output voltage is monitored through the OVP pin, and the converter is shut down and the COMP capacitor is discharged if the output voltage exceeds the preset level. A soft-start sequence is initiated once the voltage on OVP pin drops below the hysteresis threshold (100mV).

LED Cathode Short to GND Protection

When the LED cathode is shorted to GND, the output voltage will increase to the OVP voltage and IC will turn off the GATE signal. However, in some conditions, if the output power is limited by the OCP protection before the output voltage reaches the OVP voltage, the GATE will never be turned off. In this case, large current goes through both the power MOSFET and Schottky diode, and leads to damage. To enhance safety, the AL8853 monitors the voltage on the COMP pin and latches the GATE signal if the COMP voltage is continuously greater than 3.2V for 37ms.

Diode and Inductor Short Protection

When the Schottky diode or the inductor is shorted, the current of the power MOSFET will increase significantly, which would cause the MOSFET damage if the IC continues working. The AL8853 monitors the voltage on the CS pin cycle by cycle. If the CS pin voltage is greater than 1.2V (typical) for continuous 17 cycles, the IC will latch and shut down the GATE output to prevent the MOSFET from permanent damage.

V_{OUT} Short Protection

V_{OUT} short condition is monitored by the voltage at OVP pin. In normal operation, when the OVP voltage drops below a threshold of approximately 0.2V (typical), V_{OUT} short protection is triggered and the GATE turns off. This state is latched and can be reset from VIN or PWM.

Thermal Shut Down

The AL8853 includes a thermal protection circuit to ensure that the system will not run into condition of thermal runaway and blow up. When the junction temperature exceeds +160°C, the AL8853 will shut down. And if the junction temperature falls below +130°C, the AL8853 will automatically restart.

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Application Information

The AL8853 is a highly integrated and cost effective LED controller optimized for LCD monitor and LCD TV backlighting application. It provides a high performance LED backlight solution with low BOM cost.

To build a boost converter with AL8853, several configurations are in need. The LED current, OCP and OVP should be set with corresponding resistors, and proper inductor, power MOSFET and Schottky diode should be selected.

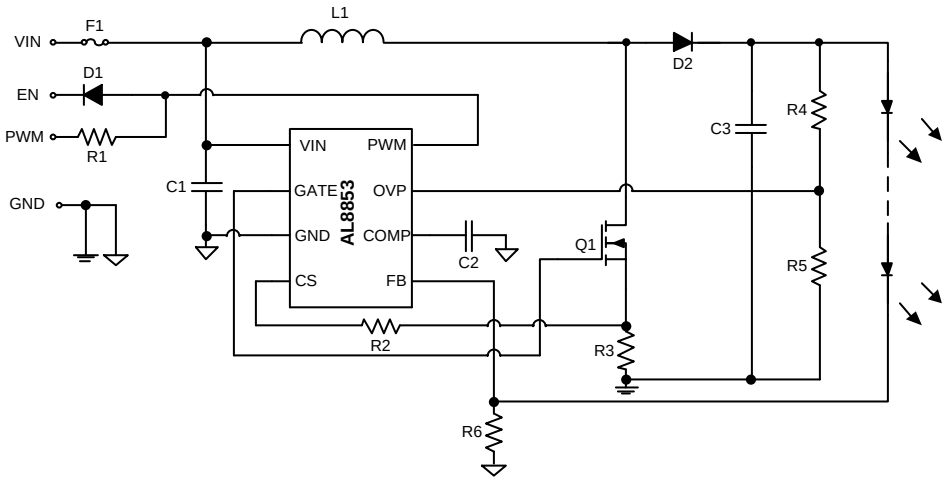


Figure 4. Typical Circuit Schematic of AL8853 LED Driver Application

LED Current Setting

The LED current is controlled by the feedback resistor (R6 in Figure 4). LED current accuracy is determined by the regulator's feedback threshold accuracy and is independent of the LED's forward voltage variation. So, precision resistors are preferred.

$$I_{LED} = \frac{200mV}{R_{FB}} (\text{mA}) \quad \text{..... (7)}$$

Inductor Design

An inductor is the energy storage component in a converter. Designing an inductor means specifying its size, structure, material, inductance, saturation level, DC-Resistance (DCR), and core loss. In a boost converter, inductance has a direct impact on the inductor ripple current. The peak-to-peak inductor ripple current can be calculated as:

$$I_{P-P} = \frac{V_{IN} \cdot (V_{OUT} - V_{IN})}{V_{OUT} \cdot L \cdot f} \quad \text{..... (8)}$$

where V_{IN} is the input voltage, V_{OUT} is the output voltage, f is the switching frequency, and L is the inductance. The boost converter average inductor current can be calculated with Equation 9, in which η is the converter efficiency. And the inductor current ripple rate is defined with Equation 10.

$$I_L = \frac{I_{LED} \cdot V_{OUT}}{V_{IN} \cdot \eta} \quad \text{..... (9)}$$

$$\gamma = \frac{I_{P-P}}{I_L} \quad \text{..... (10)}$$

Higher inductance means lower ripple current, lower RMS (Root Mean Square) current, lower voltage ripple on both input and output, and higher efficiency unless the resistive loss of the inductor dominates the overall loss. However, higher inductance also means a bigger inductor size and a slower response to transients. For optimal practical design, the inductor current ripple rate γ is set 0.3 to 0.5. The saturation level is another important parameter in designing inductor. The peak inductor current can be calculated with Equation 11:

$$I_{PK} = \frac{I_{LED} \cdot V_{OUT}}{V_{IN} \cdot \eta} + \frac{I_{P-P}}{2} \quad \text{..... (11)}$$

The inductor saturation current should be higher than the inductor peak current with a reasonable margin.

Considering the system efficiency, cost requirements and the peak inductor current limitations, an inductor is then designed accordingly.

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Application Information (continued)

OCP Setting

To protect the power MOSFET from over current and other anomalies, the AL8853 integrates an Over Current Protection (OCP) function. The AL8853 senses the CS pin voltage and enters the OCP protection when the threshold voltage is touched. The OCP current should be set 30% higher than the maximum peak inductor current at the lowest input voltage and full load output. The OCP resistor (R3 in Figure 4) sets the desired OCP current with the Equation 12.

$$R_{OCP} = \frac{300mV}{I_{OCP}} \quad \text{..... (12)}$$

OVP Setting

The AL8853 will shut down the output if the output voltage is higher than the preset output threshold voltage. The threshold voltage must be set higher than the nominal output voltage with at least 20% margin to avoid mis-trigger. The threshold voltage is set by a resistor divider (R4 and R5 in Figure 4) with Equation 13.

$$V_{OUT_OVP} = \frac{R_4+R_5}{R_5} \cdot 2V \quad \text{..... (13)}$$

The output threshold voltage cannot be set to a much too high voltage, since the AL8853 monitors the OVP pin voltage during start up and shuts the system if OVP pin voltage is lower than 100mV.

MOSFET Selection

To select a proper power MOSFET, a few key parameters are considered, such as the drain source breakdown voltage (BV_{DSS}), on-resistance ($R_{DS(ON)}$) and package type (i.e. TO220, TO252, etc.). The MOSFET BV_{DSS} should be higher than the OVP voltage with 20% margin, since the MOSFET stress voltage when OVP is exactly the output voltage. The package of a power MOSFET greatly affects its thermal performance, a TO252 (DPAK) package is recommended for typical applications. A low $R_{DS(ON)}$ MOSFET is beneficial for both system efficiency and the MOSFET thermal performance, but lower $R_{DS(ON)}$ usually means higher cost. Taking the peak inductor current and RMS current into account, a trade-off system efficiency, thermal performance and cost is needed for selection.

Diode Selection

To maximize converter efficiency, the use of a Schottky diode is strongly recommended. In a boost converter, the average forward current of the rectifier diode I_F is equal to the output current I_{OUT}.

$$I_F = I_{OUT} \quad \text{..... (14)}$$

In practical application diode selection, the forward current rating should be at least 3 times of the LED current.

The peak repetitive reverse voltage (V_{RRM}) of the diode should be higher than the OVP voltage with at least 20% margin, since when OVP happens, the stress voltage is exactly the output voltage. A low forward drop diode is preferable for its efficient advantages and low power dissipation of the diode.

Constant Voltage Application

Besides boost converter for LED driver applications, the AL8853 can also be applied in constant output voltage boost applications. Figure 5 shows the typical circuit schematic for constant voltage applications.

To make the output voltage constant, resistor dividers (R6 and R7) are added and the FB pin is connected to sense the divided output voltage. The output voltage V_{OUT} is set with Equation 15.

$$V_{OUT} = \frac{R_6+R_7}{R_7} \cdot 0.2V \quad \text{..... (15)}$$

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Application Information (continued)

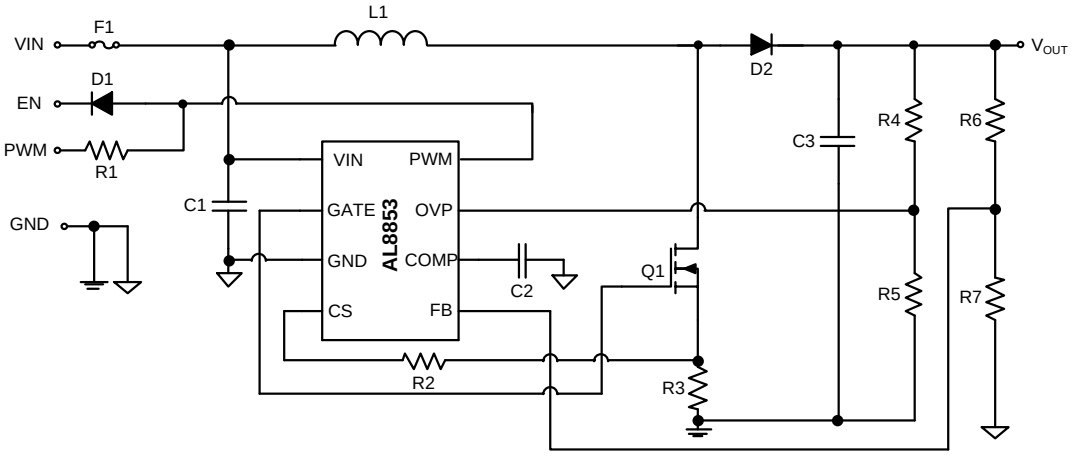


Figure 5. Typical Circuit Schematic of AL8853 Constant Output Voltage Application

For the OCP setting, OVP setting, inductor design, power MOSFET selection and Schottky diode selection, the above configuration guides for LED driver are also applicable.

Layout Guide

The PCB layout is critical for the optimal performance of the boost converter design. A good PCB layout is fundamental to correct operation and high performance of the converter. And the EMI performance is especially dependent on the PCB layout. So, the following important guidelines should be followed:

1. The traces of the power loops should be wide and short, and the power components should be placed close together to make the loop area as small as possible. There are two high-current power loops in the converter. One is the high-current input loop, and the other is the high-current output loop. The high-current input loop goes from the positive terminal of the C_{IN} to the inductor, to the MOSFET, then to the current-sense resistor, and to the negative terminal of C_{IN}. The high-current output loop goes from the positive terminal of the C_{IN} to the inductor, to the diode, to the positive terminal of the C_{OUT}, reconnecting between the C_{OUT} and the C_{IN} ground terminals.

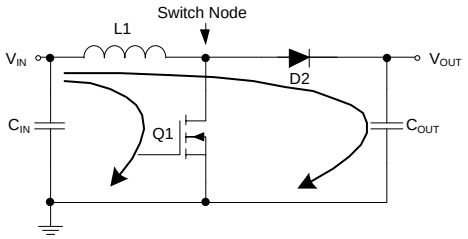


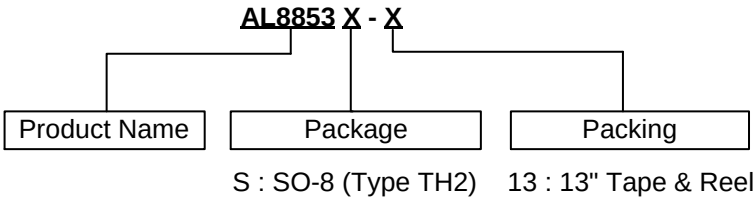
Figure 6. The Power Loops of a Boost Converter

2. A decoupling capacitor of the VIN pin is recommended and it should be placed as close as possible to the pin, to reduce the noise on the power source for the internal logic circuit.
3. To keep the gate signal clean, the gate driving trace should be placed away from the inductor, since the alternating magnetic field is the primary noise source in a switching converter.
4. For the OVP resistor divider, the both resistors should be placed close to the IC, and the divider should be grounded close to the IC ground.
5. For the compensation capacitor, it should be placed as close as possible to the COMP pin.
6. Copper area of the power loop, especially around the switching node, should be as big as possible for good thermal performance.

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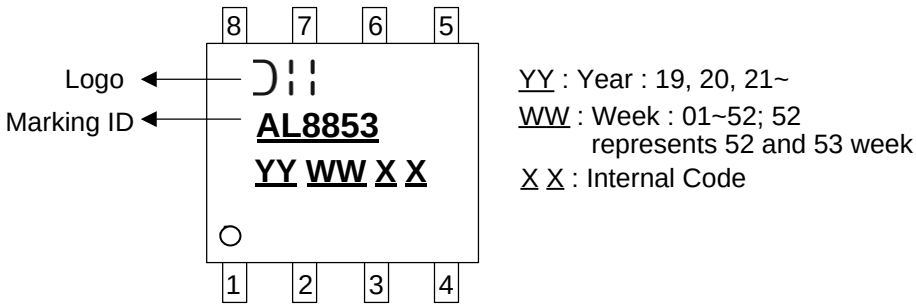
Ordering Information



Part Number	Package Code	Package	13" Tape and Reel	
			Quantity	Part Number Suffix
AL8853S-13	S	SO-8 (Type TH2)	4000/Tape & Reel	-13

Marking Information

(Top View)



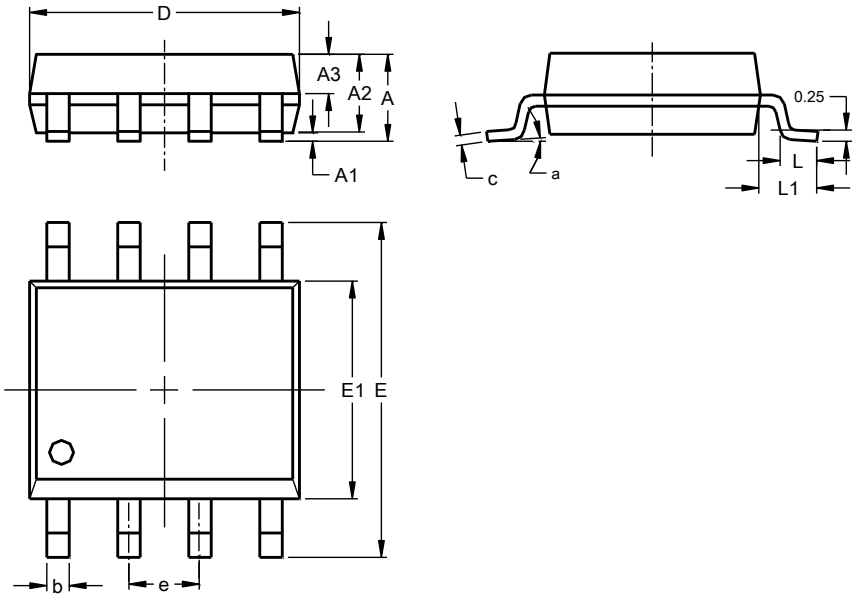
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Package Outline Dimensions

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

SO-8 (Type TH2)

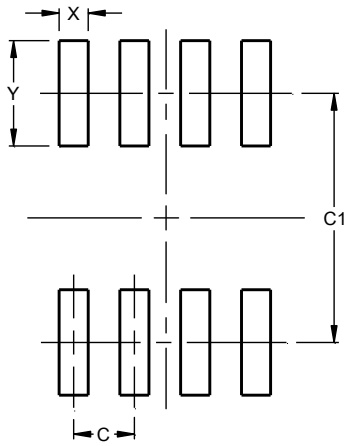


SO-8 (Type TH2)			
Dim	**Min**	**Max**	**Typ**
A	—	1.75	—
A1	0.10	0.225	—
A2	1.30	1.50	1.40
A3	0.60	0.70	0.65
b	0.39	0.47	—
c	0.20	0.24	—
D	4.80	5.00	4.90
E	5.80	6.20	6.00
E1	3.80	4.00	3.90
e	1.27BSC		
h	0.25	0.50	—
L	0.50	0.80	—
L1	1.05REF		
Ø	0°	8°	—
All Dimensions in mm			

Suggested Pad Layout

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

SO-8 (Type TH2)



Dimensions	Value (in mm)
C	1.27
C1	5.20
X	0.60
Y	2.20

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