

## General Description

The AOZ1948 is a high-efficiency Buck controller for general purpose high voltage and low voltage LED backlight applications. It does not require a separate dimming MOSFET. It utilizes fixed off time control and operates using average current control feedback, features internal compensated reference and no external compensation is required

Low feedback voltage (0.6V) helps reduce power loss. The AOZ1948 features selectable Off Time control to allow for wide range of applications, and auto-restart OCP/short-circuit protection.

The AOZ1948 is available in a standard SO-8 package and operates over the temperature range of -40°C to +85°C.

## Features

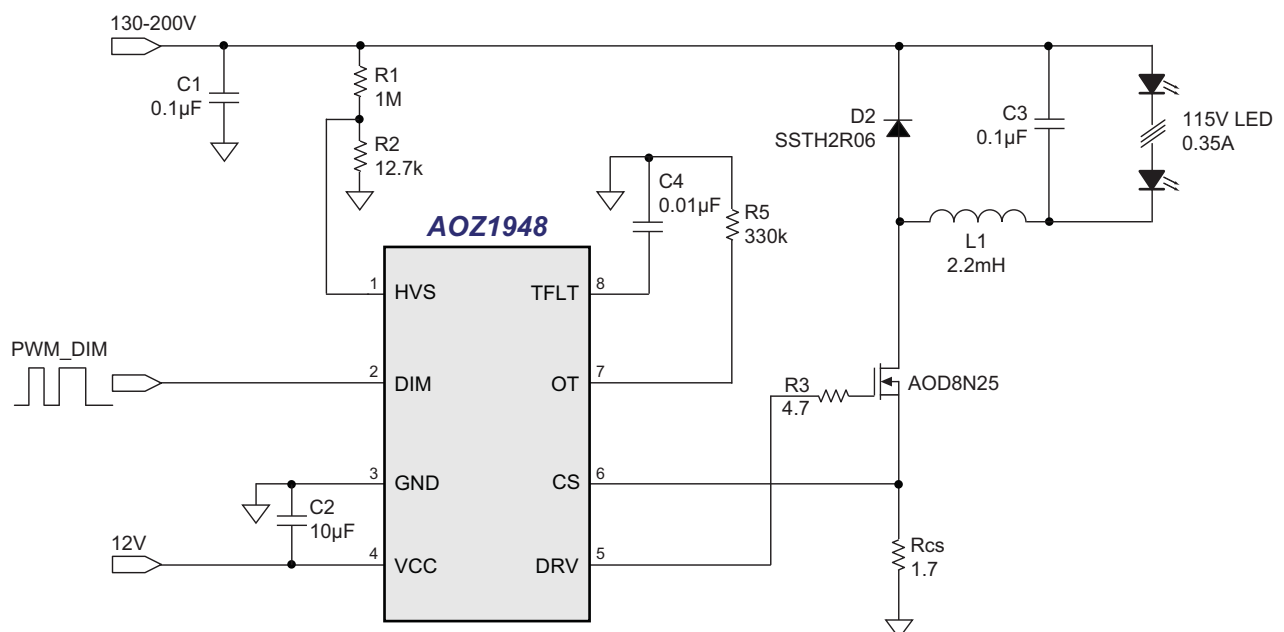
- 8V to 16V input voltage range
- Up to 16V driving capability at GATE pin
- Short circuit protection
- High voltage input sensing
- Stable operation up to 89% duty cycle
- 0.6V ( $\pm 2\%$ ) average current feedback regulation
- PWM dimming resolution as low as 1%
- Auto-restart OCP for output short protection
- Thermal overload protection
- SO-8 package
- Adjacent pin short reliability
- High humidity operation

## Applications

- LCD TV LED backlight
- DC/DC or AC/DC LED driver applications
- General purpose LED lighting



## Typical Application



## Ordering Information

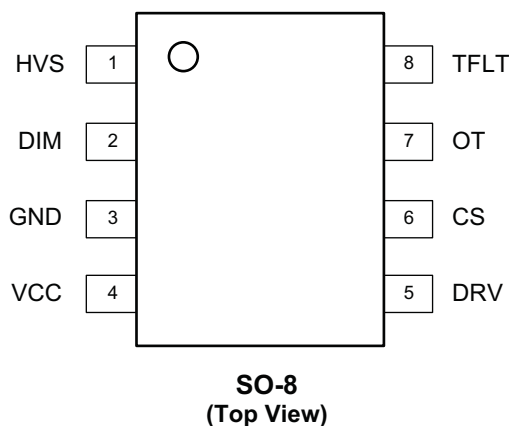
Part Number	Ambient Temperature Range	Package	Environmental
AOZ1948AI	-40°C to +85°C	SO-8	Green Product



AOS Green Products use reduced levels of Halogens, and are also RoHS compliant.

Please visit [www.aosmd.com/media/AOSGreenPolicy.pdf](http://www.aosmd.com/media/AOSGreenPolicy.pdf) for additional information.

## Pin Configuration



## Pin Description

Number	Name	Description
1	HVS	High Voltage Sense, UVP Under Voltage Protection.
2	DIM	Logic Level Input for PWM Dimming.
3	GND	IC Ground Pin. Connect directly to current sense resistor GND.
4	VCC	IC Bias Voltage.
5	DRV	Gate Drive for N-Fet.
6	CS	0.6V Average Current Sense Input.
7	OT	Connect appropriate resistor value to set OFF Time.
8	TFLT	Fault Auto Restart Timing. Connect appropriate Cap to set auto restart period.

## Absolute Maximum Rating

Exceeding the Absolute Maximum Ratings may damage the device

Parameter	Rating
DRV, VCC to GND	-0.3V to +20V
DIM, TFLT, OT, CS, HVS to GND	-0.3V to +6V
Storage Temperature (T <sub>S</sub> )	-65°C to +150°C
Junction Temperature (T <sub>J</sub> ) <sup>(2)</sup>	-40°C to +150°C
ESD Rating <sup>(1)</sup>	2kV

### Note:

1. Devices are inherently ESD sensitive, handling precautions are required. Human body model rating: 1.5kΩ in series with 100pF.
2. Thermal shutdown at T<sub>J</sub> 140°C.

## Maximum Operating Ratings

The device is not guaranteed to operate beyond the Maximum Operating Ratings.

Parameter	Rating
Supply Voltage (V <sub>CC</sub> )	8V to 16V
Ambient Temperature (T <sub>A</sub> )	-40°C to +85°C
Package Thermal Resistance SO-8 (θ <sub>JC</sub> )	63°C/W

## Electrical Characteristics

T<sub>A</sub> = 25°C, V<sub>CC</sub> = 12V, unless otherwise specified.<sup>(2)</sup>

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
V <sub>CC</sub>	VCC Supply Voltage		8		16	V
I <sub>VCC_ON</sub>	VCC Quiescent Current	Non Switching VCC = 12V			2	mA
V <sub>UVLO_RISE</sub>	VCC UVLO Threshold	VCC Rising		7.3	7.8	V
V <sub>UVLO_FALL</sub>		VCC Falling	6.4	7		V
V <sub>VIN_HYS</sub>	VCC UVLO Hysteresis			300		mV
V <sub>UVP_RISE</sub>	HVS High Voltage Sense (UVP under-voltage protection)	UVP Rising	-3%	1.5	+3%	V
V <sub>UVP_FALL</sub>		UVP Falling	-3%	1.3	+3%	V
OSCILLATOR						
OT	Off Time	R <sub>OT</sub> = 100kΩ	0.8	1	1.2	μs
		R <sub>OT</sub> = 500kΩ	3.3	4.4	5.5	μs
T <sub>ON_MIN</sub>	Minimum ON Time				0.75	μs
D <sub>MAX</sub>	Maximum Duty Cycle	100KHz Switching	88.9		90.9	%
GATE DRIVE						
I <sub>DRV_SOURCE</sub>	Source Current	GATE = 0V, VCC = 12V	300			mA
I <sub>DRV_SINK</sub>	Sink Current	GATE = 12V, VCC = 12V	450			mA
T <sub>DRV_RISE</sub>	Rise Time	C <sub>GATE</sub> = 1.5nF, VCC = 12V, 10% to 90% of VDD		70	85	ns
T <sub>DRV_FALL</sub>	Fall Time	C <sub>GATE</sub> = 1.5nF, VCC = 12V, 10% to 90% of VDD		35	45	ns
INPUTS						
CS <sub>BLANK</sub>	Leading Edge Blanking Time		150		350	ns
V <sub>CS_REG</sub>	CS Regulation	0.6V average <sup>(3)</sup>	-2		+2	%
I <sub>CS</sub>	CS Input Current	CS = 1.2V, Gate Drive = 12V			5	μA
I <sub>HVS</sub>	HVS Input Current	HVS = 1.2V			5	μA
I <sub>DIM</sub>	DIM Input Current	DIM = 5V			5	μA
F <sub>DIM</sub>	DIM Dimming Frequency				1000	Hz

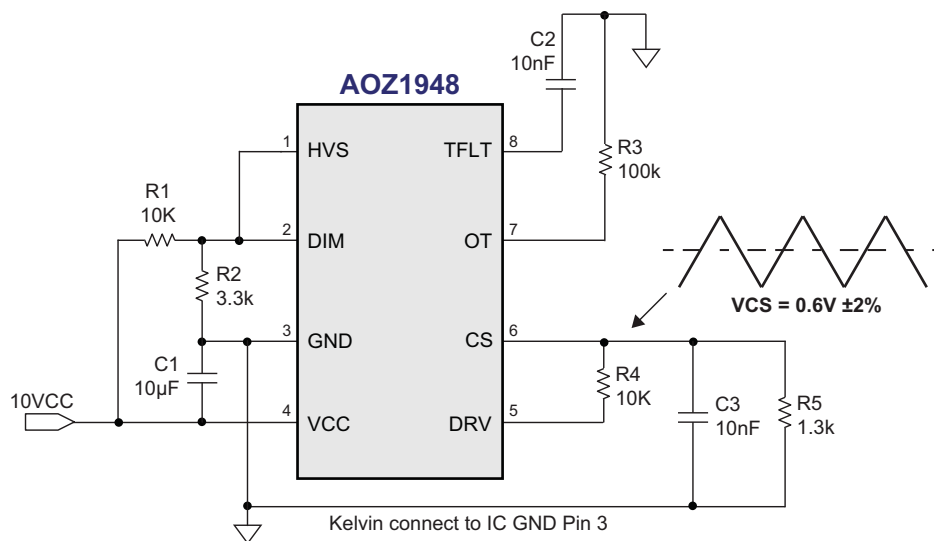
## Electrical Characteristics (continued)

$T_A = 25^\circ\text{C}$ ,  $V_{CC} = 12\text{V}$  unless otherwise specified.<sup>(2)</sup>

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>OVER CURRENT PROTECTION</b>						
OCP1	Over Current Protection 1	$V_{CS\_avg} = 4 \text{ Cycles}$		130 ( $V_{CS\_avg}$ )		%
OCP2	Over Current Protection 2	$V_{CS\_pk} = 1 \text{ Cycle}$			1.6	V
$T_{FLT}$	Fault Timer Period	$C_{TFLT} = 0.01\mu\text{F}$ , output shorted	-25%	1.5	+25%	ms
$T_{THERMAL\_SD}$	Thermal Shutdown Threshold			140		$^\circ\text{C}$
$T_{THERMAL\_HYS}$	Thermal Shutdown Hysteresis			40		$^\circ\text{C}$
<b>LOGIC INPUT</b>						
$V_{DIM\_HI}$	DIM Logic High Threshold		2			V
$V_{DIM\_LO}$	DBRT Logic Low Threshold				0.8	V

**Note:**

- Specifications in BOLD indicate an ambient temperature range of  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ .
- See test circuit below to measure VCS.



## Pin Descriptions

### Pin 1: HVS

The high voltage sense pin needs to be connected to a resistor divider from the VIN pin to monitor the input voltage. This monitoring will disable and shutdown the controller when input voltage drops below a set limit. The HVS pin can be also used to enable or disable the part if monitoring input voltage is not desired.

### Pin 2: DIM

This is the logic level PWM input which adjusts LED brightness. Only at power up the first rising edge at this input is considered a start-up pulse, the initial 8 switching cycles will be peak current limited, which will allow the output cap to charge up without exceeding the steady state inductor peak current. This pin should not be left floating. If driven using an open drain output, a pull-up resistor will be required.

### PIN 3: GND

To achieve good current regulation and performance it's important to Kelvin connect the GND of the current sense resistor to this pin. This also applies to the OT resistor, it should Kelvin connect IC GND as well.

### Pin 4: VCC

The VCC is the bias supply of the IC as well as the supply for the FET driver, the drive voltage and the VCC voltage are the same. It's strongly recommended to use a low ESR 10µF ceramic capacitor connected at this pin.

The rising edge of the VCC resets the controller and sets it to initial start-up mode. This means that the first 8 switching cycles of the first dimming cycle will only be peak current limited at 0.6V CS voltage, all consecutive switching cycles will be average current control.

### Pin 5: DRV

DRV is the gate drive output for the NMOS, the drive voltage from this pin is the same as VCC applied. The max ON time for this gate is limited to 10 times the selected OFF time is set by the OT resistor at pin 7. Depending on the NMOS used and system noise susceptibility, it is recommended to use a low value resistor 1-10Ω when connecting the DRV pin to the NMOS gate.

### Pin 6: CS

The current sense pin is the feedback input of the controller, the output current is regulated by this pin. CS senses the voltage produced by the current ramping through the R<sub>SENSE</sub> resistor, it measures the average voltage during the ON time only and maintains it at 0.6V.

This pin also senses and protects against over current events with two protection levels. The first level is for soft shorts and requires four cycles above 0.78V of average voltage, the second level is a single cycle above 1.5V peak. In both cases the TFLT is triggered and auto restart is initiated.

### Pin 7: OT

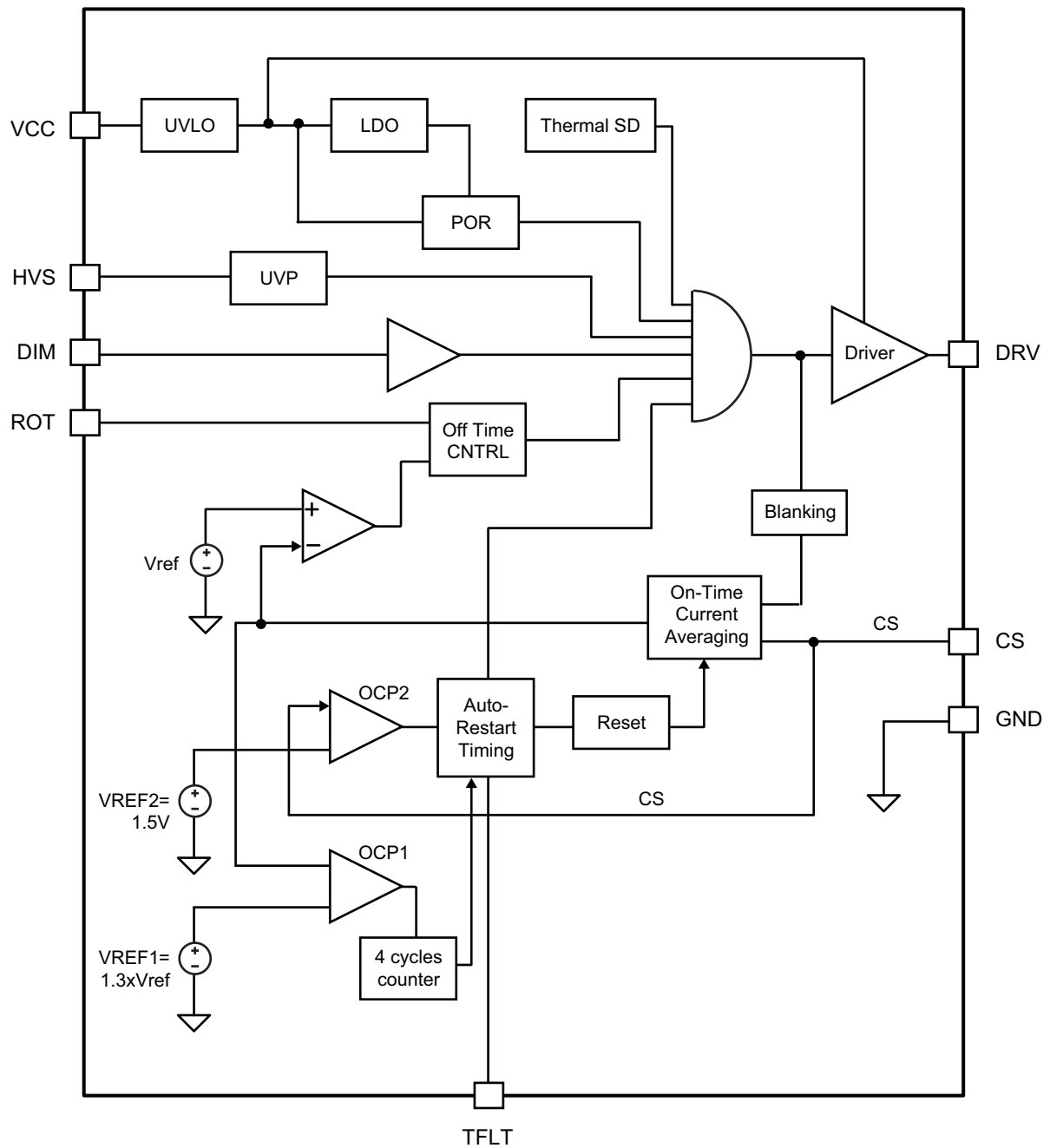
Off time is set by connecting the appropriate resistor to this pin. Off time also sets Maximum On time to be 10 times the duration of OT. Minimum On time is always fixed to 0.5µs regardless of the resistor value selected.

### Pin 8: TFLT

Connecting a small cap to this pin (Fault Timer) will determine the auto restart rate for fault conditions. The rate can be set using the following equation:

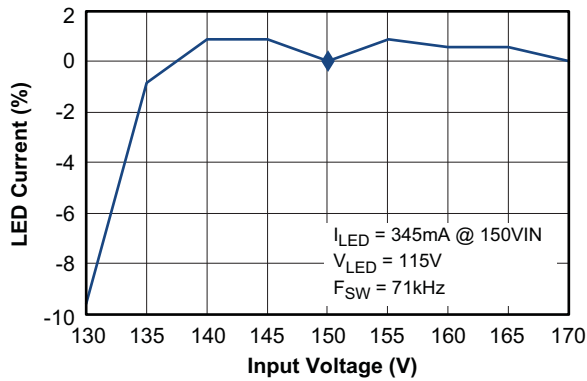
$$C_{TFLT} = 5\mu A \times \frac{TFLT}{0.76V} < 47nF$$

## Functional Block Diagram

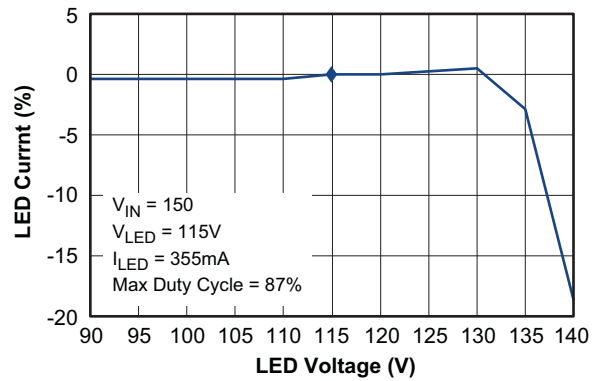


## Typical Performance Characteristics

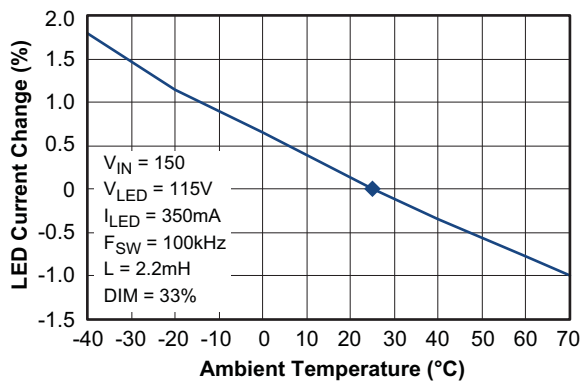
**LED Current Line Regulation**



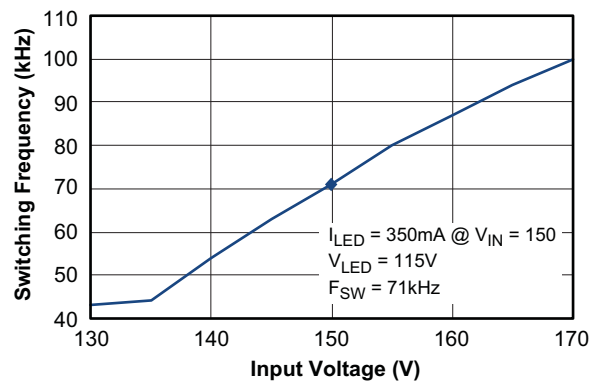
**LED Current vs. LED Voltage**



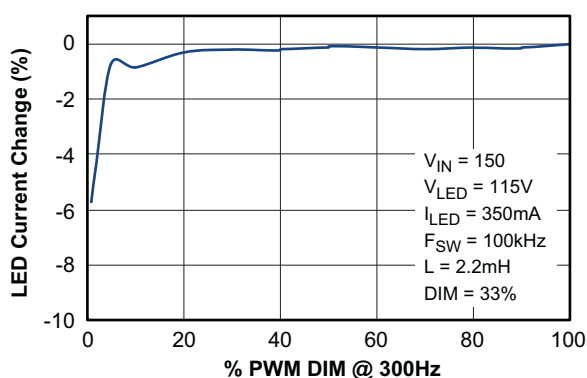
**LED Current Change vs. Ambient Temperature**



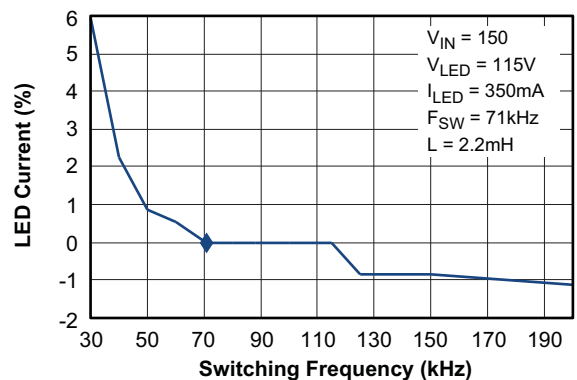
**Switching Frequency vs. Input Voltage**



**LED PWM Linearity**

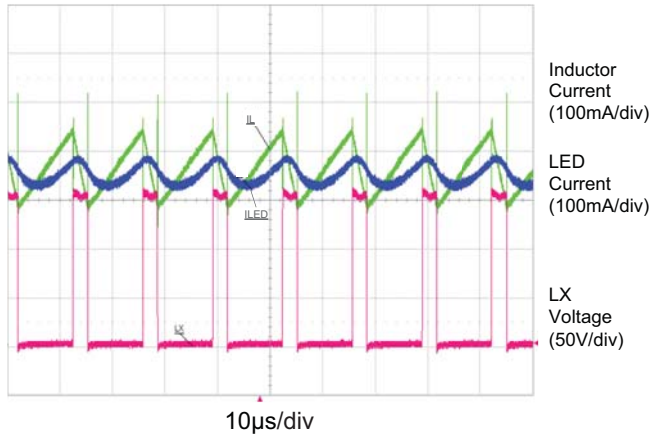


**LED Current vs. Switching Frequency**

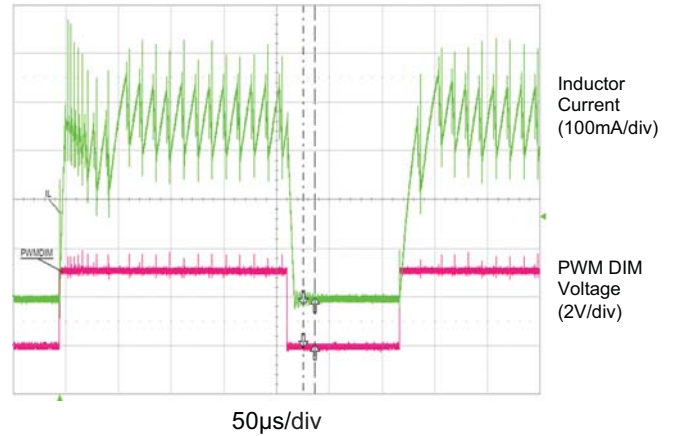


## Functional Characteristics

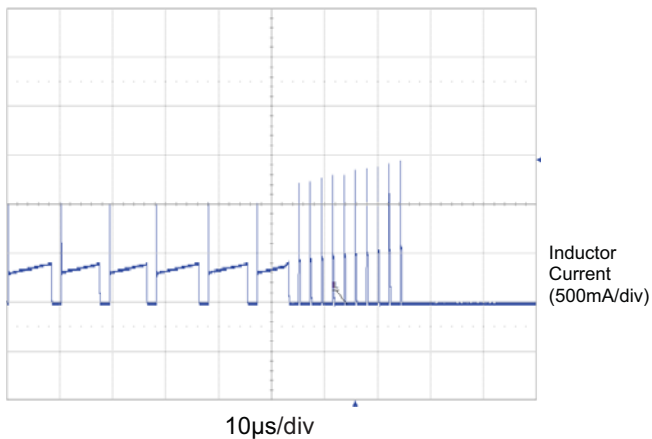
**Typical Operating Waveforms**  
VIN=150V, VOUT=115V, ILED=350mA



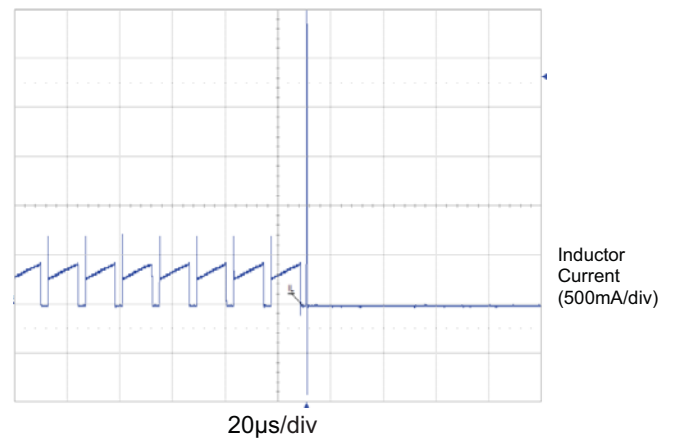
**Inductor Current @ Initial Start-Up**  
8 cycles of peak current limit successive cycles are average current



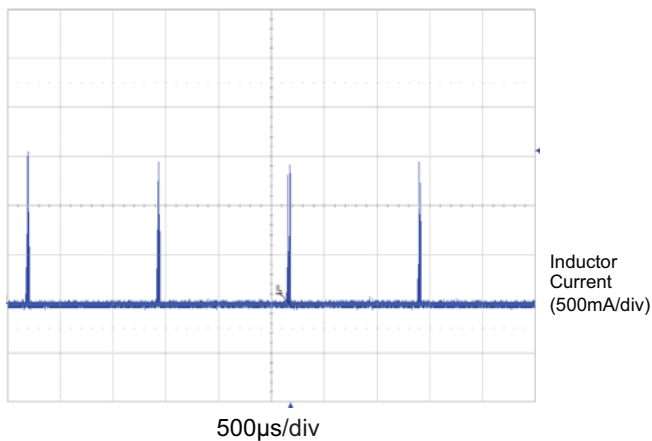
**N-FET Drain Current**  
(During OCP1 Event due to a Soft Short)



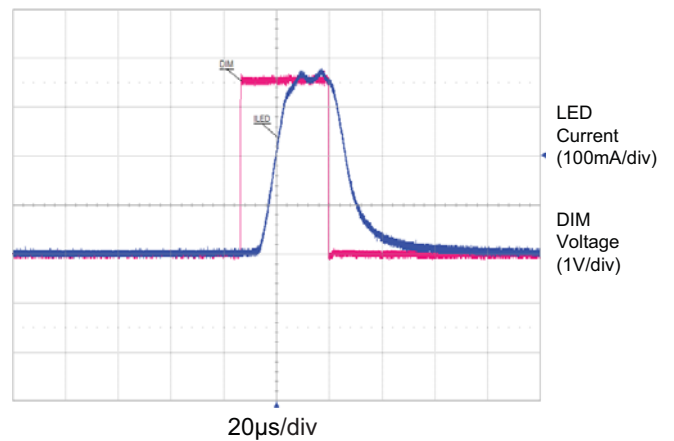
**N-FET Drain Current**  
(During OCP2 Event due to a Hard Short)



**Auto-Restart N-FET Drain Current**  
(During OCP Event)



**300Hz LED Dimming @ 1%**



## Application Information

The AOZ1948 is a low-side, single switch, off time buck controller, optimized to drive backlight LEDs. It incorporates a unique average current control method which provides a better than 2% LED current regulation and supports duty cycles as high as 90%. AOZ1948 operates in CCM continuous current conduction mode to provide higher efficiency and lower output ripple, thus requiring less output capacitance. It is suitable for a wide range of applications as low as 9V and as high as 500V input. The switching frequency is independent of inductor value and is only a function of VIN variation, it can operate at switching frequencies as high 500kHz and as low as 50kHz. AOZ1948 provides several protection features such as over current protection, high voltage sensing and adjustable fault timer.

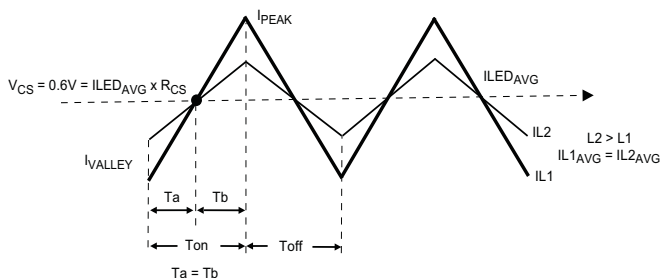
The Dimming capability is fully linear with the applied PWM signal and accommodates dimming as low as 1% at 500Hz.

### Average Current control

In a buck topology, when operating in continuous conduction mode (CCM) the average load current is equal to the average inductor valley current and Peak current or:

$$I_{LED} = \frac{I_{Lvaly} + I_{Lpk}}{2}$$

To achieve good current regulation, the AOZ1948 is able to regulate by simply averaging the load current only during the On cycle or the portion of the current that is flowing in the switch.



Determining the value of the desired LED current is done by simply selecting the appropriate current sense resistor at the CS pin:

$$R_{sense} = \frac{V_{cs\_avg}}{I_{LED}}$$

This equation above does not include the 250ns blanking at turn on, this causes the average LED current to be slightly higher than the design requirement. This additional current can be calculated as:

$$I_{LED\_Correction} = \frac{250ns \times (V_{IN} - V_{LED}) / L}{2}$$

or

$$R_{sense} = \frac{V_{cs\_avg}}{I_{LED} - I_{LED\_Correction}}$$

### Over Current Protection

The AOZ1948 provides two over current protection levels, OCP1 and OCP2.

OCP1 is average over current protection for soft shorts that occur when inductor current rises gradually due to inductor saturation or a drop in the LED string voltage. In either case, the controller will look for four consecutive cycles where the inductor current has exceeded the average set current by 30%, this will initiate a fault condition and will cause it to auto restart.

OCP2 is peak current protection, designed for hard instantaneous shorts such as catch diode or NMOS shorts. If the controller detects a sudden rise or a single cycle in the CS pin voltage greater than 1.5V, it will auto restart.

### Inductor Current Ripple Ratio

Ripple ratio is defined as:

$$\frac{I_{Lpk} - I_{Lvaly}}{I_{LED}}$$

The more continuous the design is the lower the ripple ratio will be.

In order to maintain good regulation, it is important to select an inductor that will operate within current ripple ratio recommended limits between 0.3 and 0.7. In a typical design, the chosen inductor should produce 0.5 ripple ratio under typical operating conditions, this will maintain the ratio within the recommended limits regardless to variations in VIN, VLED or inductor manufacturer tolerances.

### Off Time

The AOZ1948 is an Off Time controller, the cycle-by-cycle switching is not clocked but is determined by the

duty cycle of the design and OT off time selection. The switching frequency can be calculated as:

$$F_{SW} = \frac{1-D}{OT}$$

A change in either VIN or VLED will cause a change in the switching frequency. A change in inductance has no effect on the switching frequency, a Kelvin connection from R<sub>OT</sub> resistor GND to IC GND is recommended. The following equation can be used to select the appropriate resistor to set Off Time:

$$OT = (0.01 \times R_{OT}) + 0.1$$

where,

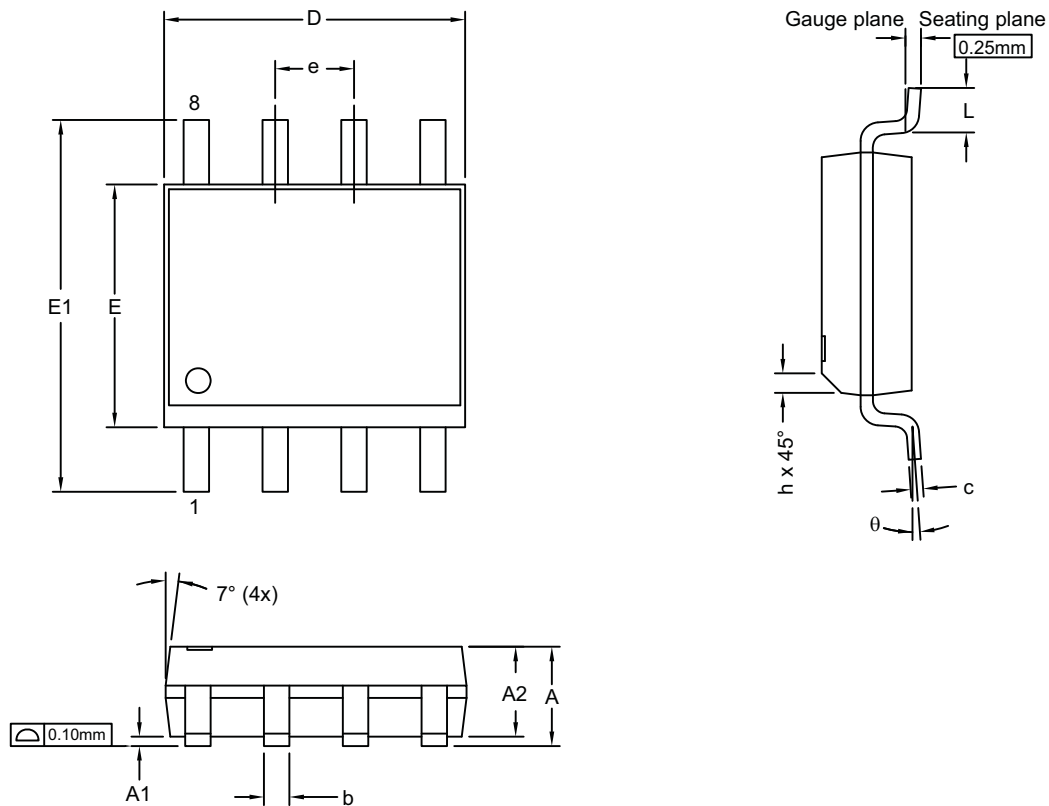
OT =  $\mu$ s and R<sub>OT</sub> = k $\Omega$

The maximum On Time is limited to 10 times the Off Time and the minimum On Time is 0.75 $\mu$ s.

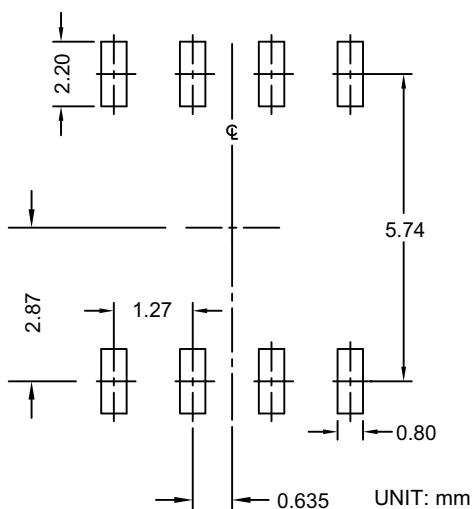
### Start Up

Startup is defined as the initial first rising edge of the PWM DIM signal applied after VCC has crossed the UVLO threshold. By design, the first 8 switching cycles at initial startup are not average current control but instead peak current control. This means that V<sub>cs\_reg</sub> will not average the voltage at CS pin, instead it will terminate the switching cycle-by-cycle for 8 consecutive times when the peak voltage reaches 0.6V at CS pin. This startup method allows the output capacitor to charge up without allowing inductor peak current from exceeding steady-state operation. If a too large output cap is used making 8 cycles insufficient to charge up, then 4 more cycles of OCP1 are counted before TFLT auto restart is triggered. The AOZ1948 does not require a large cap at the output because it operates in CCM and ripple current is much lower than a DCM design.

## Package Dimensions, SO-8L



### RECOMMENDED LAND PATTERN



### Dimensions in millimeters

Symbols	Min.	Nom.	Max.
A	1.35	1.65	1.75
A1	0.10	—	0.25
A2	1.25	1.50	1.65
b	0.31	—	0.51
c	0.17	—	0.25
D	4.80	4.90	5.00
E	3.80	3.90	4.00
e	1.27 BSC		
E1	5.80	6.00	6.20
h	0.25	—	0.50
L	0.40	—	1.27
θ	0°	—	8°

### Dimensions in inches

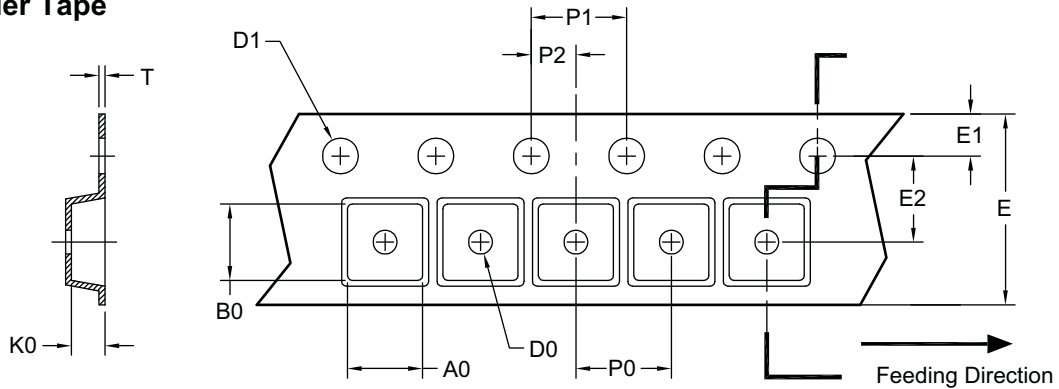
Symbols	Min.	Nom.	Max.
A	0.053	0.065	0.069
A1	0.004	—	0.010
A2	0.049	0.059	0.065
b	0.012	—	0.020
c	0.007	—	0.010
D	0.189	0.193	0.197
E	0.150	0.154	0.157
e	0.050 BSC		
E1	0.228	0.236	0.244
h	0.010	—	0.020
L	0.016	—	0.050
θ	0°	—	8°

### Notes:

1. All dimensions are in millimeters.
2. Dimensions are inclusive of plating.
3. Package body size exclude mold flash and gate burrs. Mold flash at the non-lead sides should be less than 6 mils each.
4. Dimension L is measured in gauge plane.
5. Controlling dimension is millimeter, converted inch dimensions are not necessarily exact.

## Tape and Reel Dimensions, SO-8L

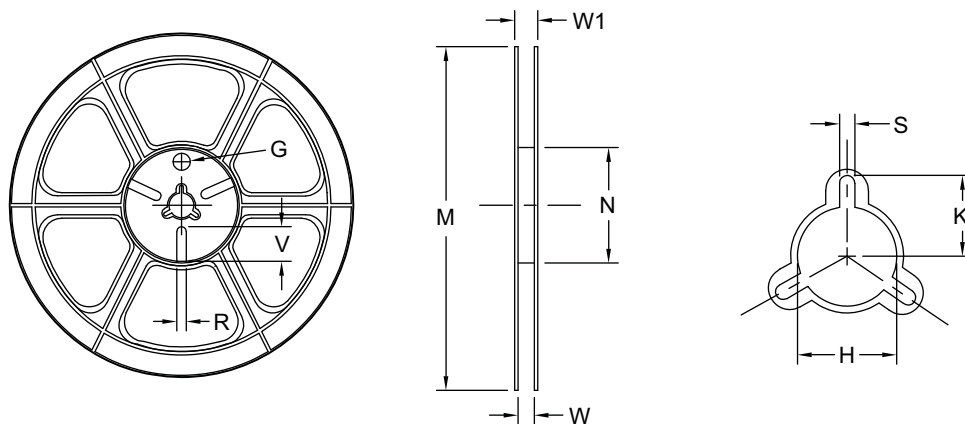
### Carrier Tape



UNIT: mm

Package	A0	B0	K0	D0	D1	E	E1	E2	P0	P1	P2	T
SO-8 (12mm)	6.40 ±0.10	5.20 ±0.10	2.10 ±0.10	1.60 ±0.10	1.50 ±0.10	12.00 ±0.10	1.75 ±0.10	5.50 ±0.10	8.00 ±0.10	4.00 ±0.10	2.00 ±0.10	0.25 ±0.10

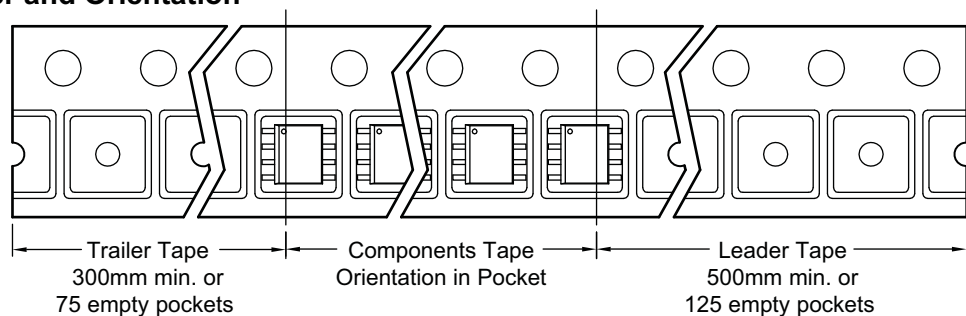
### Reel



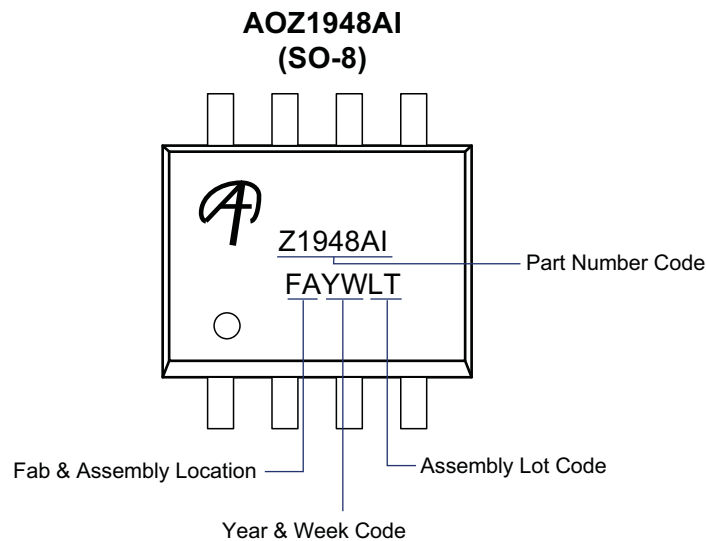
UNIT: mm

Tape Size	Reel Size	M	N	W	W1	H	K	S	G	R	V
12mm	ø330	ø330.00 ±0.50	ø97.00 ±0.10	13.00 ±0.30	17.40 ±1.00	ø13.00 +0.50/-0.20	10.60	2.00 ±0.50	—	—	—

### Leader/Trailer and Orientation



## Package Marking



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2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.