

# ZXLD1360

## 1A LED driver with internal switch

### Description

The ZXLD1360 is a continuous mode inductive step-down converter, designed for driving single or multiple series connected LEDs efficiently from a voltage source higher than the LED voltage. The device operates from an input supply between 7V and 30V and provides an externally adjustable output current of up to 1A. Depending upon supply voltage and external components, this can provide up to 24 watts of output power.

The ZXLD1360 includes the output switch and a high-side output current sensing circuit, which uses an external resistor to set the nominal average output current.

Output current can be adjusted above, or below the set value, by applying an external control signal to the 'ADJ' pin.

The ADJ pin will accept either a DC voltage or a PWM waveform. Depending upon the control frequency, this will provide either a continuous or a gated output current. The PWM filter components are contained within the chip.

The PWM filter provides a soft-start feature by controlling the rise of input/output current. The soft-start time can be increased using an external capacitor from the ADJ pin to ground.

Applying a voltage of 0.2V or lower to the ADJ pin turns the output off and switches the device into a low current standby state.

An internal thermal protection circuit reduces output current to 50% of the set value if the die temperature exceeds 155 °C; total shutdown will occur if the die temperature exceeds 175 °C

The device is assembled in a TSOT23-5 pin package.

### Features

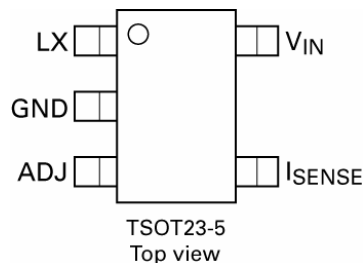
- Simple low parts count
- Internal 30V NDMOS switch
- 1A output current
- Single pin on/off and brightness control using DC voltage or PWM
- Internal PWM filter
- Soft-start
- High efficiency (up to 95%<sup>(\*)</sup>)
- Wide input voltage range: 7V to 30V
- 40V transient capability
- Output shutdown
- Up to 1MHz switching frequency
- Inherent open-circuit LED protection
- Typical 4% output current accuracy
- Thermal protection

### Applications

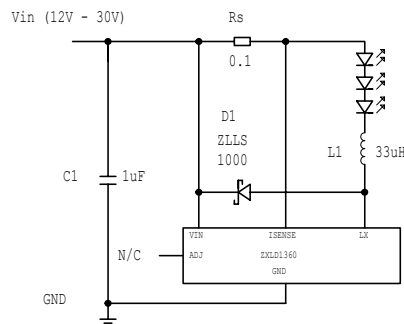
- Low voltage halogen replacement LEDs
- Automotive lighting
- Low voltage industrial lighting
- LED back-up lighting
- Illuminated signs

(\*) Using standard external components as specified under electrical characteristics. Efficiency is dependent upon the number of LEDs driven and on external component types and values.

### Pin connections



### Typical application circuit



**Absolute maximum ratings (voltages to GND unless otherwise stated)**

Input voltage ( $V_{IN}$ )	-0.3V to +30V (40V for 0.5 sec)
$I_{SENSE}$ voltage ( $V_{SENSE}$ )	+0.3V to -5V (measured with respect to $V_{IN}$ )
LX output voltage ( $V_{LX}$ )	-0.3V to +30V (40V for 0.5 sec)
Adjust pin input voltage ( $V_{ADJ}$ )	-0.3V to +6V
Switch output current ( $I_{LX}$ )	1A
Power dissipation ( $P_{tot}$ ) (Refer to package thermal de-rating curve on page 18)	1W
Operating temperature ( $T_{OP}$ )	-40 to 105°C
Storage temperature ( $T_{ST}$ )	-55 to 150°C
Junction temperature ( $T_{J\ MAX}$ )	150°C

These are stress ratings only. Operation outside the absolute maximum ratings may cause device failure. Operation at the absolute maximum ratings, for extended periods, may reduce device reliability.

**Thermal resistance**

Junction to ambient ( $R_{\theta JA}$ )	125°C/W
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**Electrical characteristics (test conditions:  $V_{IN}=12V$ ,  $T_{amb}=25^{\circ}C$  unless otherwise stated)<sup>1</sup>**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{IN}$	Input voltage		7		30	V
$V_{SU}$	Internal regulator start-up threshold	$V_{IN}$ rising		5.65		V
$V_{SD}$	Internal regulator shutdown threshold	$V_{IN}$ falling		5.55		V
$I_{INQoff}$	Quiescent supply current with output off	ADJ pin grounded		20	40	$\mu A$
$I_{INQon}$	Quiescent supply current with output switching	ADJ pin floating $f=250kHz$		1.8	TBD	mA
$V_{SENSE}$	Mean current sense threshold voltage (Defines LED current setting accuracy)	Measured on $I_{SENSE}$ pin with respect to $V_{IN}$ $V_{ADJ}=1.25V$	95	100	105	mV
$V_{SENSEHYS}$	Sense threshold hysteresis			$\pm 15$		%
$I_{SENSE}$	$I_{SENSE}$ pin input current	$V_{SENSE}=V_{IN}-0.1$		1.25	10	$\mu A$
$V_{REF}$	Internal reference voltage	Measured on ADJ pin with pin floating	1.21	1.25	1.29	V
$\Delta V_{REF}/\Delta T$	Temperature coefficient of $V_{REF}$			50		ppm/°C
$V_{ADJ}$	External control voltage range on ADJ pin for dc brightness control <sup>2</sup>		0.3		2.5	V
$V_{ADJoff}$	DC voltage on ADJ pin to switch device from active (on) state to quiescent (off) state	$V_{ADJ}$ falling	0.15	0.2	0.25	V
$V_{ADJon}$	DC voltage on ADJ pin to switch device from quiescent (off) state to active (on) state	$V_{ADJ}$ rising	0.2	0.25	0.3	V

<sup>1</sup>Production testing of the device is performed at 25°C. Functional operation of the device and parameters specified over a -40°C to +105°C temperature range, are guaranteed by design, characterization and process control.

<sup>2</sup>100% brightness corresponds to  $V_{ADJ} = V_{ADJ(nom)} = V_{REF}$ . Driving the ADJ pin above  $V_{REF}$  will increase the  $V_{SENSE}$  threshold and output current proportionally.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$R_{ADJ}$	Resistance between ADJ pin and $V_{REF}$	$0 < V_{ADJ} < V_{REF}$ $V_{ADJ} > V_{REF} + 100mV$	135 13.5		250 25	$k\Omega$
$I_{LXmean}$	Continuous LX switch current				1	A
$R_{LX}$	LX Switch 'On' resistance			0.3	0.6	$\Omega$
$I_{LX(leak)}$	LX switch leakage current				5	$\mu A$
$D_{PWM(LF)}$	Duty cycle range of PWM signal applied to ADJ pin during low frequency PWM dimming mode	PWM frequency < 500Hz PWM amplitude = $V_{REF}$ Measured on ADJ pin	0.01		1	
	Brightness control range				100:1	
$D_{PWM(HF)}$	Duty cycle range of PWM signal applied to ADJ pin during high frequency PWM dimming mode	PWM frequency > 10kHz PWM amplitude = $V_{REF}$ Measured on ADJ pin	0.16		1	
	Brightness control range				5:1	
$T_{SS}$	Soft start time	Time taken for output current to reach 90% of final value after voltage on ADJ pin has risen above 0.3V		500		$\mu s$
$f_{LX}$	Operating frequency (See graphs for more detail)	ADJ pin floating $L=33\mu H$ (0.093 $\Omega$ ) $I_{OUT}=1A$ @ $V_{LED}=3.6V$ Driving 1 LED		280		KHz
$T_{ONmin}$	Minimum switch 'ON' time	LX switch 'ON'	200			ns
$T_{OFFmin}$	Minimum switch 'OFF' time	LX switch 'OFF'	200			ns
$f_{LXmax}$	Recommended maximum operating frequency				1	MHz
$D_{LX}$	Recommended duty cycle range of output switch at $f_{LXmax}$		0.3		0.7	
$T_{PD}$	Internal comparator propagation delay			50		ns
$T_{50\%}$	50% shutdown temperature		145	155		$^{\circ}C$
$T_{0\%}$	Total shutdown temperature		165	175		$^{\circ}C$

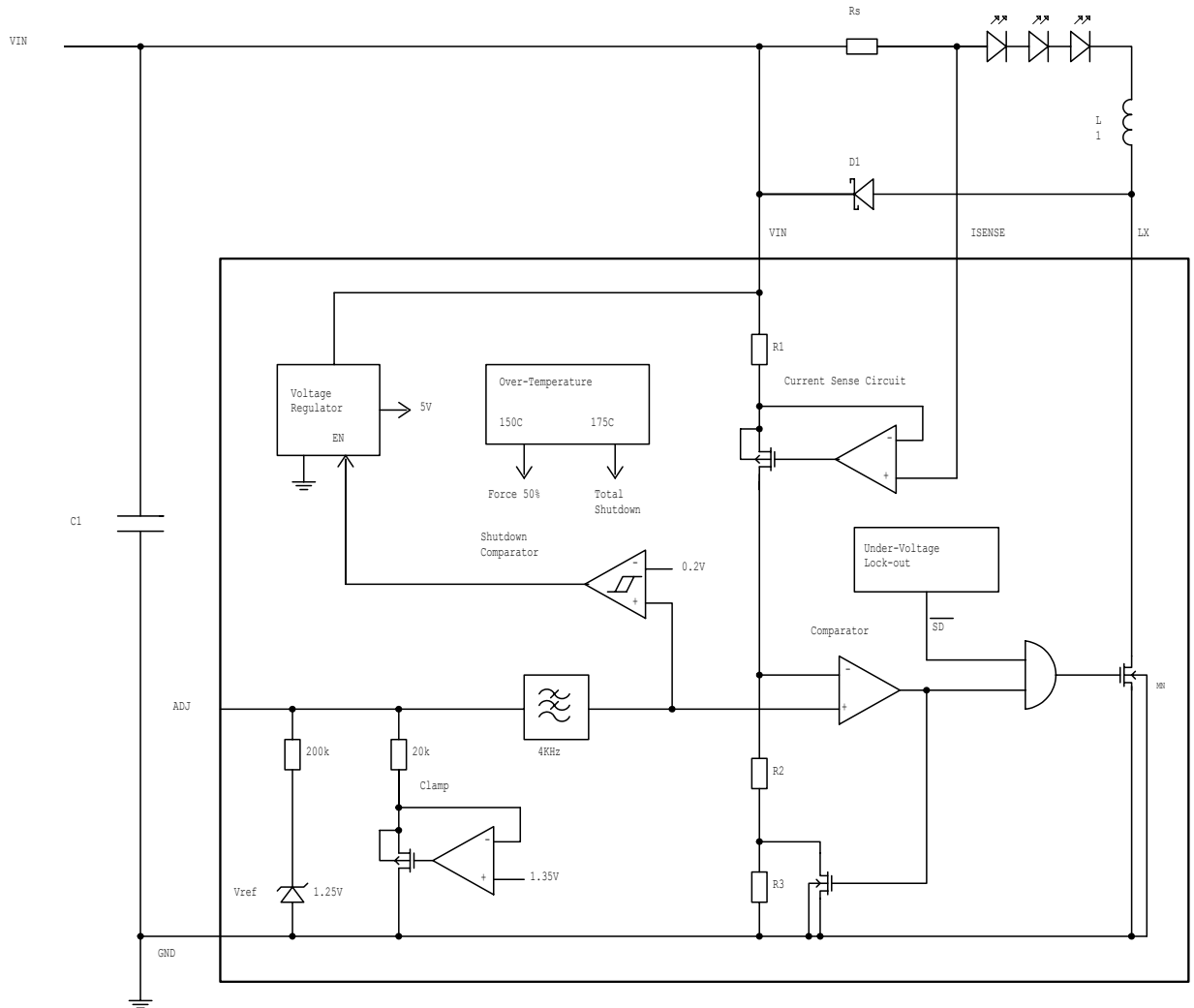
**Pin description**

Name	Pin No.	Description
LX	1	Drain of NDMOS switch
GND	2	Ground (0V)
ADJ	3	Multi-function On/Off and brightness control pin: <ul style="list-style-type: none"> <li>• Leave floating for normal operation. (<math>V_{ADJ} = V_{REF} = 1.25V</math> giving nominal average output current <math>I_{OUTnom} = 0.1/R_S</math>)</li> <li>• Drive to voltage below 0.2V to turn off output current</li> <li>• Drive with DC voltage (<math>0.3V &lt; V_{ADJ} &lt; 2.5V</math>) to adjust output current from 25% to 200% of <math>I_{OUTnom}</math></li> <li>• Drive with PWM signal from open-collector or open-drain transistor, to adjust output current. Adjustment range 25% to 100% of <math>I_{OUTnom}</math> for <math>f &gt; 10kHz</math> and 1% to 100% of <math>I_{OUTnom}</math> for <math>f &lt; 500Hz</math></li> <li>• Connect a capacitor from this pin to ground to increase soft-start time. (Default soft-start time = 0.5ms. Additional soft-start time is approx. <math>0.5ms/nF</math>)</li> </ul>
$I_{SENSE}$	4	Connect resistor $R_S$ from this pin to $V_{IN}$ to define nominal average output current $I_{OUTnom} = 0.1/R_S$ (Note: $R_{SMIN} = 0.1\Omega$ with ADJ pin open-circuit)
$V_{IN}$	5	Input voltage (7V to 30V). Decouple to ground with $1\mu F$ or higher X7R ceramic capacitor close to device

**Ordering information**

Device	Reel size (mm)	Reel width (mm)	Quantity per reel	Device mark
ZXLD1360ET5TA	180	8	3,000	1360

**Block diagram**



## Device description

The device, in conjunction with the coil (L1) and current sense resistor ( $R_S$ ), forms a self-oscillating continuous-mode buck converter.

## Device operation (Refer to block diagram and Figure 1 - Operating waveforms)

Operation can be best understood by assuming that the ADJ pin of the device is unconnected and the voltage on this pin ( $V_{ADJ}$ ) appears directly at the (+) input of the comparator.

When input voltage  $V_{IN}$  is first applied, the initial current in L1 and  $R_S$  is zero and there is no output from the current sense circuit. Under this condition, the (-) input to the comparator is at ground and its output is high. This turns MN on and switches the LX pin low, causing current to flow from  $V_{IN}$  to ground, via  $R_S$ , L1 and the LED(s). The current rises at a rate determined by  $V_{IN}$  and L1 to produce a voltage ramp ( $V_{SENSE}$ ) across  $R_S$ . The supply referred voltage  $V_{SENSE}$  is forced across internal resistor R1 by the current sense circuit and produces a proportional current in internal resistors R2 and R3. This produces a ground referred rising voltage at the (-) input of the comparator. When this reaches the threshold voltage ( $V_{ADJ}$ ), the comparator output switches low and MN turns off. The comparator output also drives another NMOS switch, which bypasses internal resistor R3 to provide a controlled amount of hysteresis. The hysteresis is set by R3 to be nominally 15% of  $V_{ADJ}$ .

When MN is off, the current in L1 continues to flow via D1 and the LED(s) back to  $V_{IN}$ . The current decays at a rate determined by the LED and diode forward voltages to produce a falling voltage at the input of the comparator. When this voltage returns to  $V_{ADJ}$ , the comparator output switches high again. This cycle of events repeats, with the comparator input ramping between limits of  $V_{ADJ} \pm 15\%$ .

## Switching thresholds

With  $V_{ADJ} = V_{REF}$ , the ratios of R1, R2 and R3, define an average  $V_{SENSE}$  switching threshold of 100mV (measured on the  $I_{SENSE}$  pin with respect to  $V_{IN}$ ). The average output current  $I_{OUTnom}$  is then defined by this voltage and  $R_S$  according to:

$$I_{OUTnom} = 100mV/R_S$$

Nominal ripple current is  $\pm 15mV/R_S$

## Adjusting output current

The device contains a low pass filter between the ADJ pin and the threshold comparator and an internal current limiting resistor (200k $\Omega$  nom) between ADJ and the internal reference voltage. This allows the ADJ pin to be overdriven with either DC or pulse signals to change the  $V_{SENSE}$  switching threshold and adjust the output current. The filter is third order, comprising three sections, each with a cut-off frequency of nominally 4kHz.

Details of the different modes of adjusting output current are given in the applications section.

## Output shutdown

The output of the low pass filter drives the shutdown circuit. When the input voltage to this circuit falls below the threshold (0.2V nom), the internal regulator and the output switch are turned off. The voltage reference remains powered during shutdown to provide the bias current for the shutdown circuit. Quiescent supply current during shutdown is nominally TBD  $\mu$ A and switch leakage is below 5 $\mu$ A.

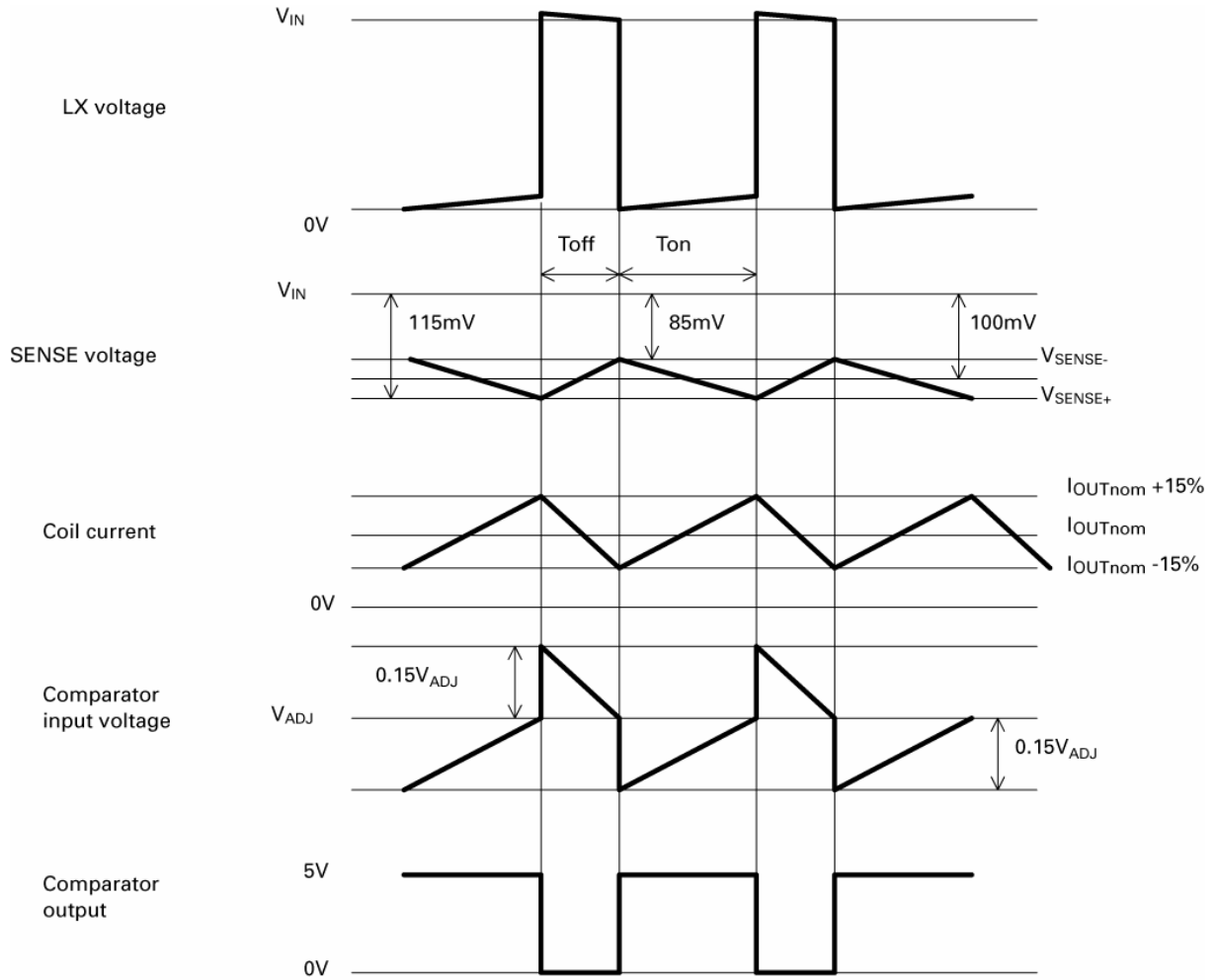


Figure 1 Operating waveforms

Typical operating waveforms [ $V_{IN}=12V$ ,  $R_S=0.1\Omega$ ,  $L=33\mu H$ ]

Normal operation. Output current (Ch3) and LX voltage (Ch1)

Start-up waveforms. Output current (Ch3), LX voltage (Ch1) and VADJ (Ch2)



### **Typical operating conditions**

For typical application circuit driving 3W Luxeon<sup>®</sup> white LED(s) at  $V_{IN} = 12V$  and  $T_{amb} = 25^{\circ}C$  unless otherwise stated.

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**Application notes**

**Setting nominal average output current with external resistor  $R_S$**

The nominal average output current in the LED(s) is determined by the value of the external current sense resistor ( $R_S$ ) connected between  $V_{IN}$  and  $I_{SENSE}$  and is given by:

**$I_{OUTnom} = 0.1/R_S$  [for  $R_S > 0.1\Omega$ ]**

The table below gives values of nominal average output current for several preferred values of current setting resistor ( $R_S$ ) in the typical application circuit shown on page 1:

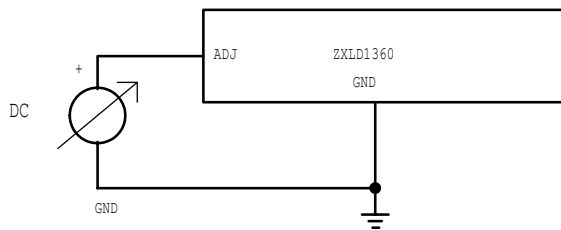
$R_S$ ( $\Omega$ )	Nominal average output current (mA)
0.1	1000
0.13	760
0.15	667

The above values assume that the ADJ pin is floating and at a nominal voltage of  $V_{REF}$  (=1.25V). Note that  $R_S=0.1\Omega$  is the minimum allowed value of sense resistor under these conditions to maintain switch current below the specified maximum value.

It is possible to use different values of  $R_S$  if the ADJ pin is driven from an external voltage. (See next section).

**Output current adjustment by external DC control voltage**

The ADJ pin can be driven by an external dc voltage ( $V_{ADJ}$ ), as shown, to adjust the output current to a value above or below the nominal average value defined by  $R_S$ .



The nominal average output current in this case is given by:

**$I_{OUTdc} = 0.08 \cdot V_{ADJ} / R_S$  [for  $0.3 < V_{ADJ} < 2.5V$ ]**

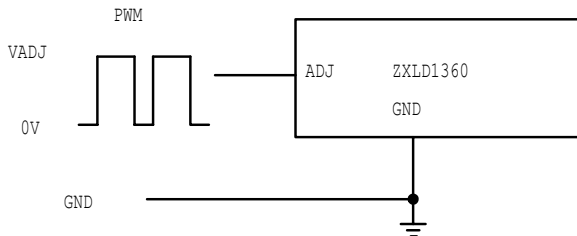
Note that 100% brightness setting corresponds to  $V_{ADJ} = V_{REF}$ . When driving the ADJ pin above 1.25V,  $R_S$  must be increased in proportion to prevent  $I_{OUTdc}$  exceeding 1A maximum.

The input impedance of the ADJ pin is  $200k\Omega \pm 25\%$  for voltages below  $V_{REF}$  and  $20 k\Omega \pm 25\%$  for voltages above  $V_{REF} + 100mV$

## Output current adjustment by PWM control

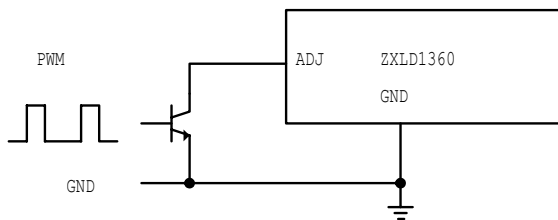
### Directly driving ADJ input

A Pulse Width Modulated (PWM) signal with duty cycle  $D_{PWM}$  can be applied to the ADJ pin, as shown below, to adjust the output current to a value above or below the nominal average value set by resistor  $R_S$ :



### Driving the ADJ input via open collector transistor

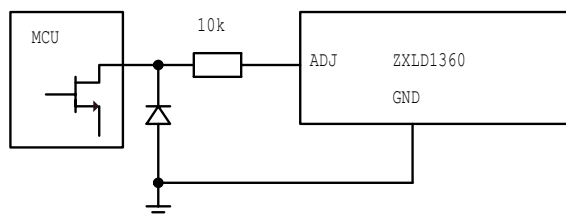
The recommended method of driving the ADJ pin and controlling the amplitude of the PWM waveform is to use a small NPN switching transistor as shown below:



This scheme uses the 200k resistor between the ADJ pin and the internal voltage reference as a pull-up resistor for the external transistor.

### Driving the ADJ input from a microcontroller

Another possibility is to drive the device from the open drain output of a microcontroller. The diagram below shows one method of doing this:



The diode and resistor suppress possible high amplitude negative spikes on the ADJ input resulting from the drain-source capacitance of the FET. Negative spikes at the input to the device should be avoided as they may cause errors in output current, or erratic device operation.

See the section on PWM dimming for more details of the various modes of control using high frequency and low frequency PWM signals.

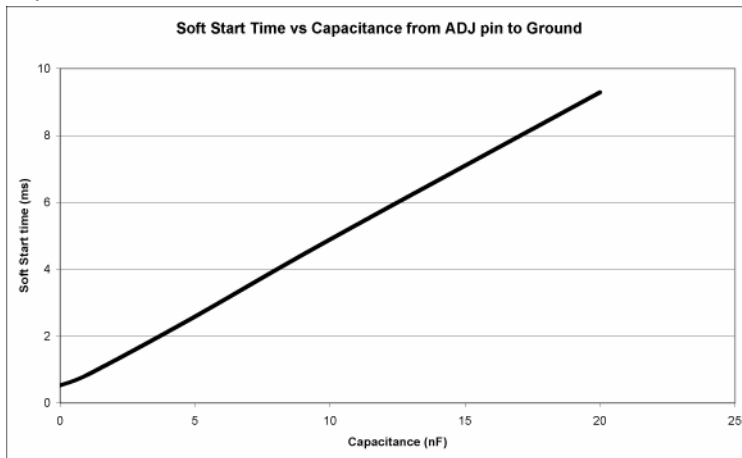
**Shutdown mode**

Taking the ADJ pin to a voltage below 0.2V for more than approximately 100µs, will turn off the output and supply current will fall to a low standby level of TBDµA nominal.

Note that the ADJ pin is not a logic input. Taking the ADJ pin to a voltage above V<sub>REF</sub> will increase output current above the 100% nominal average value. (See graphs for details).

**Soft-start**

The device has inbuilt soft-start action due to the delay through the PWM filter. An external capacitor from the ADJ pin to ground will provide additional soft-start delay, by increasing the time taken for the voltage on this pin to rise to the turn-on threshold and by slowing down the rate of rise of the control voltage at the input of the comparator. With no external capacitor, the time taken for the output to reach 90% of its final value is approximately 500µs. Adding capacitance increases this delay by approximately 0.5ms/nF. The graph below shows the variation of soft-start time for different values of capacitor.



**Inherent open-circuit LED protection**

If the connection to the LED(s) is open-circuited, the coil is isolated from the LX pin of the chip, so the device will not be damaged, unlike in many boost converters, where the back EMF may damage the internal switch by forcing the drain above its breakdown voltage.

**Capacitor selection**

A low ESR capacitor should be used for input decoupling, as the ESR of this capacitor appears in series with the supply source impedance and lowers overall efficiency. This capacitor has to supply the relatively high peak current to the coil and smooth the current ripple on the input supply. A minimum value of 1µF is acceptable if the input source is close to the device, but higher values will improve performance at lower input voltages, especially when the source impedance is high. The input capacitor should be placed as close as possible to the IC.

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

A table of recommended manufacturers is provided below:

Manufacturer	Website
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com
Kemet	www.kemet.com
AVX	www.avxcorp.com



**Inductor selection**

Recommended inductor values for the ZXLD1360 are in the range 33µH to 100µH.

Higher values of inductance are recommended at higher supply voltages in order to minimize errors due to switching delays, which result in increased ripple and lower efficiency. Higher values of inductance also result in a smaller change in output current over the supply voltage range. (See graphs). The inductor should be mounted as close to the device as possible with low resistance connections to the LX and V<sub>IN</sub> pins.

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

Suitable coils for use with the ZXLD1360 are listed in the table below:

Part No.	L (µH)	DCR (Ω)	I <sub>SAT</sub> (A)	Manufacturer
MSS1038-333	33	0.093	2.3	CoilCraft
MSS1038-683	68	0.213	1.5	
				Sumida
				Taiyo Yuden

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

The following equations can be used as a guide, with reference to Figure 1 - Operating waveforms.

**LX Switch 'On' time**

$$T_{ON} = \frac{L I}{V_{IN} - V_{LED} - I_{avg} R_S + rL + R_{LX}}$$

**Note:** T<sub>ONmin</sub>>200ns

**LX Switch 'Off' time**

$$T_{OFF} = \frac{L I}{V_{LED} + VD + I_{avg} R_S + rL}$$

**Note:** T<sub>OFFmin</sub>>200ns

**Where:**

L is the coil inductance (H)

rL is the coil resistance (Ω)

R<sub>s</sub> is the current sense resistance

I<sub>avg</sub> is the required LED current (A)

ΔI is the coil peak-peak ripple current (A) {Internally set to 0.3 x I<sub>avg</sub>}

V<sub>IN</sub> is the supply voltage (V)

V<sub>LED</sub> is the total LED forward voltage (V)

R<sub>LX</sub> is the switch resistance (Ω) {=0.3Ω nominal}

V<sub>D</sub> is the diode forward voltage at the required load current (V)

**Example:**

For  $V_{IN} = 12V$ ,  $L = 33\mu H$ ,  $rL = 0.093\Omega$ ,  $R_s = 0.1\Omega$ ,  $R_{LX} = 0.3\Omega$ ,  $V_{LED} = 3.6V$ ,  $I_{avg} = 1A$  and  $V_D = 0.49V$

$$T_{ON} = (33e-6 \times 0.3) / (12 - 3.6 - 0.493) = 1.25\mu s$$

$$T_{OFF} = (33e-6 \times 0.3) / (3.6 + 0.49 + 0.193) = 2.31\mu s$$

This gives an operating frequency of 280kHz and a duty cycle of 0.35.

These and other equations are available as a spreadsheet calculator from the Zetex website. Go to [www.zetex.com/zxld1360](http://www.zetex.com/zxld1360)

Note that in practice, the duty cycle and operating frequency will deviate from the calculated values due to dynamic switching delays, switch rise/fall times and losses in the external components.

Optimum performance will be achieved by setting the duty cycle close to 0.5 at the nominal supply voltage. This helps to equalize the undershoot and overshoot and improves temperature stability of the output current.

**Diode selection**

For maximum efficiency and performance, the rectifier (D1) should be a fast low capacitance Schottky diode with low reverse leakage at the maximum operating voltage and temperature. Recommended diodes for use with this part are the ZLLS1000 and ZLLS2000. These have approximately ten times lower leakage than standard Schottky diodes, which are unsuitable for use above 85°C. They also provide better efficiency than silicon diodes, due to a combination of lower forward voltage and reduced recovery time.

The table below gives the typical characteristics for the ZLLS1000 and ZLLS2000:

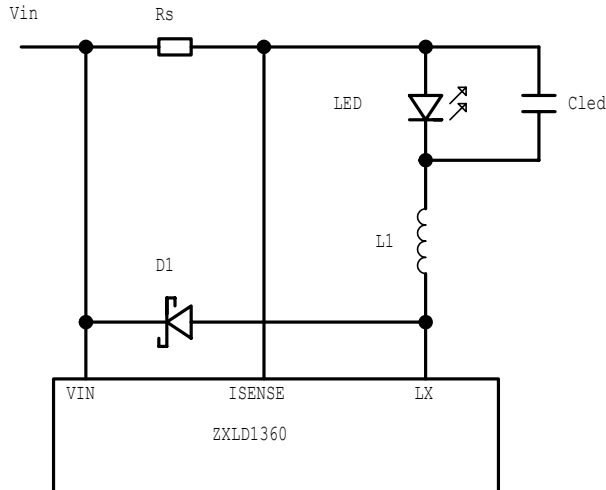
Diode	Forward voltage at 1A (mV)	Continuous current (max) (mA)	Reverse Leakage At 30V 85°C (µA)	Package	Manufacturer
ZLLS1000	490	1160	800	SOT233	Zetex
ZLLS2000	395	2200	1500	SOT236	Zetex

If alternative diodes are used, it is important to select parts with a peak current rating above the peak coil current and a continuous current rating higher than the maximum output load current. It is very important to consider the reverse leakage of the diode when operating above 85°C. Excess leakage will increase the power dissipation in the device.

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

## Reducing output ripple

Peak to peak ripple current in the LED can be reduced, if required, by shunting a capacitor  $C_{led}$  across the LED(s) as shown below:



A value of  $1\mu F$  will reduce nominal ripple current by a factor three (approx.). Proportionally lower ripple can be achieved with higher capacitor values. Note that the capacitor will not affect operating frequency or efficiency, but it will increase start-up delay, by reducing the rate of rise of LED voltage.

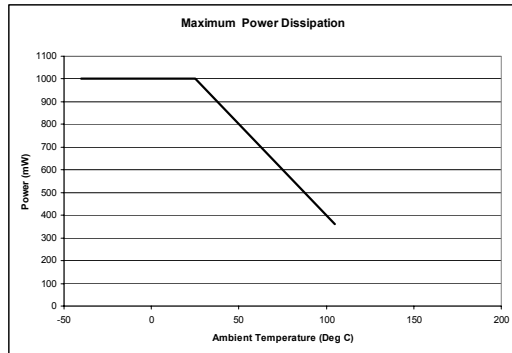
### Operation at low supply voltage

The internal regulator disables the drive to the switch until the supply has risen above the start-up threshold ( $V_{SU}$ ). Above this threshold, the device will start to operate. However, with the supply voltage below the specified minimum value, the switch duty cycle will be high and the device power dissipation will be at a maximum. Care should be taken to avoid operating the device under such conditions in the application, in order to minimize the risk of exceeding the maximum allowed die temperature. (See next section on thermal considerations). The drive to the switch is turned off when the supply voltage falls below the under-voltage threshold ( $V_{SD}$ ). This prevents the switch working with excessive 'on' resistance under conditions where the duty cycle is high.

Note that when driving loads of two or more LEDs, the forward drop will normally be sufficient to prevent the device from switching below approximately 6V. This will minimize the risk of damage to the device.

### Thermal considerations

When operating the device at high ambient temperatures, or when driving maximum load current, care must be taken to avoid exceeding the package power dissipation limits. The graph below gives details for power derating. This assumes the device to be mounted on a  $25\text{mm}^2$  PCB with 1oz copper standing in still air.



Note that the device power dissipation will most often be a maximum at **minimum** supply voltage. It will also increase if the efficiency of the circuit is low. This may result from the use of unsuitable coils, or excessive parasitic output capacitance on the switch output.

The device incorporates a thermal protection circuit to reduce LED current to approximately 50% of the set value if die temperature exceeds 150°C. This feature reduces the probability of LED or device failure due to excessive power dissipation under fault conditions. Total shutdown of the output switch will occur if the chip temperature exceeds 175°C.

### Thermal compensation of output current

High luminance LEDs often need to be supplied with a temperature compensated current in order to maintain stable and reliable operation at all drive levels. The LEDs are usually mounted remotely from the device, so for this reason, the temperature coefficients of the internal circuits for the ZXLD1360 have been optimized to minimize the change in output current when no compensation is employed. If output current compensation is required, it is possible to use an external temperature sensing network - normally using Negative Temperature Coefficient (NTC) thermistors and/or diodes, mounted very close to the LED(s). The output of the sensing network can be used to drive the ADJ pin in order to reduce output current with increasing temperature.

## Layout considerations

### LX pin

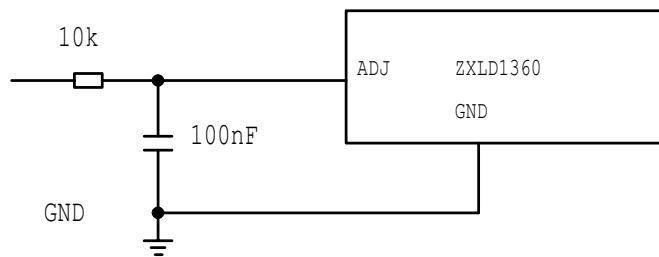
The LX pin of the device is a fast switching node, so PCB tracks should be kept as short as possible. To minimize ground 'bounce', the ground pin of the device should be soldered directly to the ground plane.

### Coil and decoupling capacitors

It is particularly important to mount the coil and the input decoupling capacitor close to the device to minimize parasitic resistance and inductance, which will degrade efficiency. It is also important to take account of any track resistance in series with current sense resistor  $R_S$ .

### ADJ pin

The ADJ pin is a high impedance input for voltages up to 1.35V, so when left floating, PCB tracks to this pin should be as short as possible to reduce noise pickup. A 100nF capacitor from the ADJ pin to ground will reduce frequency modulation of the output under these conditions. An additional series 10kΩ resistor can also be used when driving the ADJ pin from an external circuit (see below). This resistor will provide filtering for low frequency noise and provide protection against high voltage transients.



### High voltage tracks

Avoid running any high voltage tracks close to the ADJ pin, to reduce the risk of leakage currents due to board contamination. The ADJ pin is soft-clamped for voltages above 1.35V to desensitize it to leakage that might raise the ADJ pin voltage and cause excessive output current. However, a ground ring placed around the ADJ pin is recommended to minimize changes in output current under these conditions.

**Evaluation PCB**

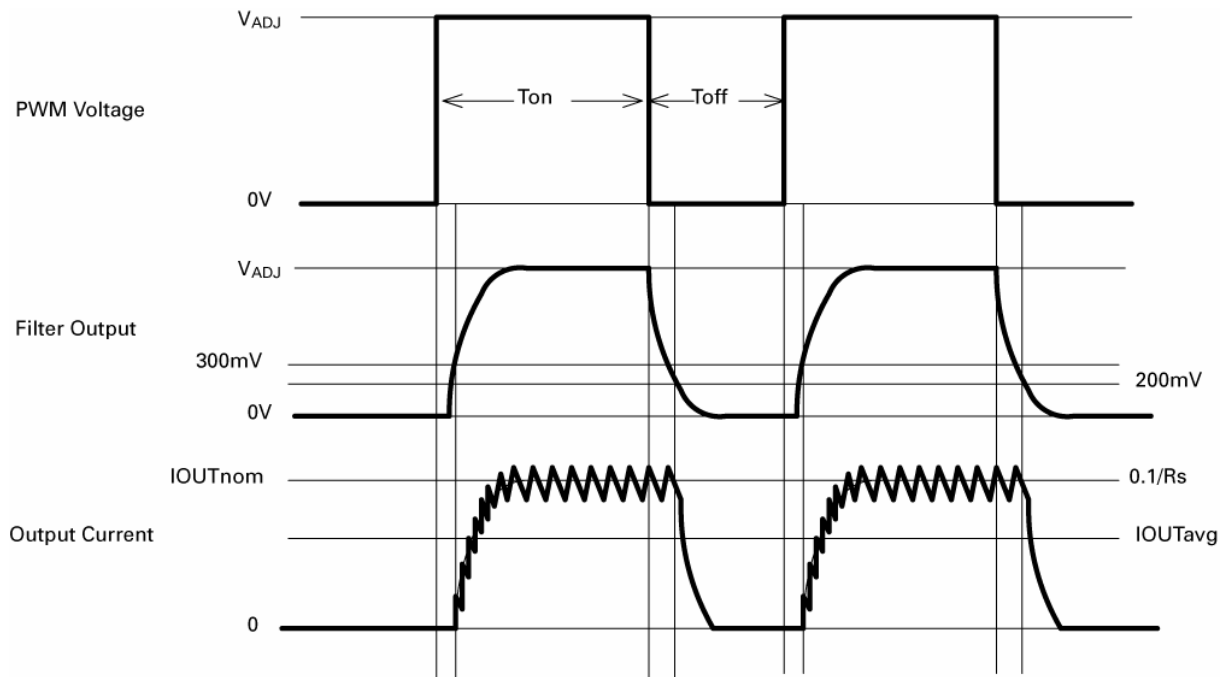
The picture below shows the top copper layout of the 3 LED ZXLD1360EV2 evaluation board. This board and other evaluation boards for the ZXLD1360 are available upon request.

<<Picture TBD>>

## Dimming output current using PWM

### Low frequency PWM mode

When the ADJ pin is driven with a low frequency PWM signal (eg 100Hz), with a high level voltage  $V_{ADJ}$  and a low level of zero, the output of the internal low pass filter will swing between 0V and  $V_{ADJ}$ , causing the input to the shutdown circuit to fall below its turn-off threshold (200mV nom) when the ADJ pin is low. This will cause the output current to be switched on and off at the PWM frequency, resulting in an average output current  $I_{OUTavg}$  proportional to the PWM duty cycle. (See Figure 2 - Low frequency PWM operating waveforms).



**Figure 2 Low frequency PWM operating waveforms**

The average value of output current in this mode is given by:

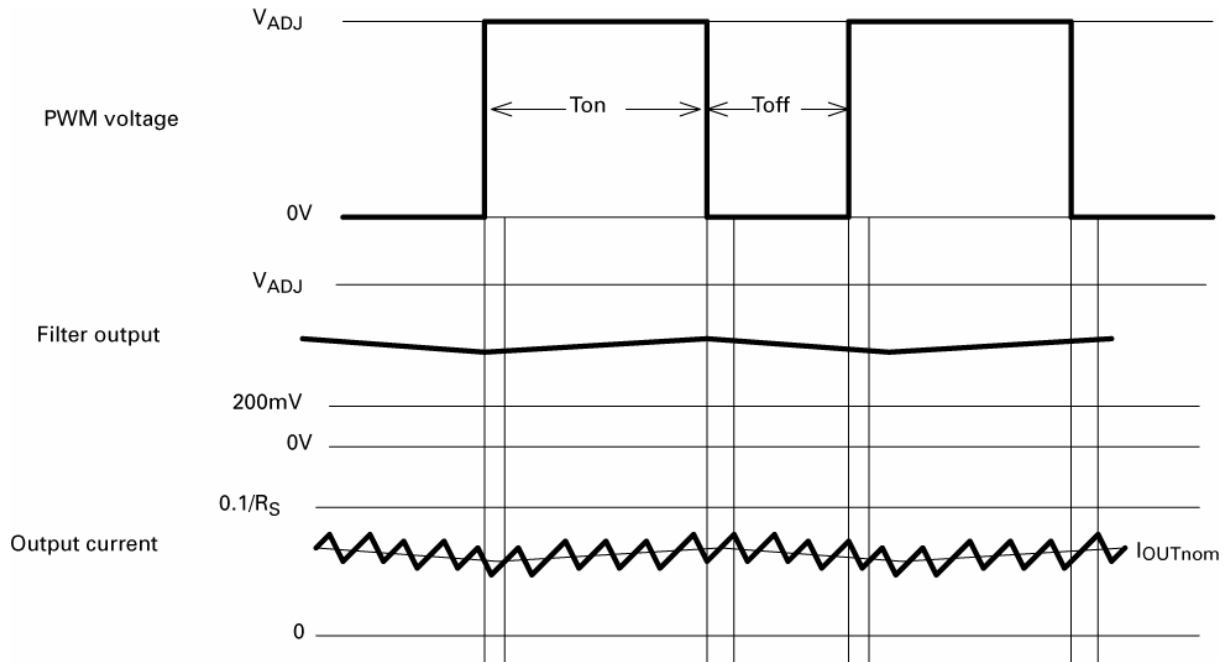
$$I_{OUTavg} = 0.1D_{PWM}/R_s \text{ [for } D_{PWM} > 0.01]$$

This mode is preferable if optimum LED 'whiteness' is required. It will also provide the widest possible dimming range (approx. 100:1) and higher efficiency at the expense of greater output ripple.

Note that the low pass filter introduces a small error in the output duty cycle due to the difference between the start-up and shut-down times. This time difference is a result of the 200mV shutdown threshold and the rise and fall times at the output of the filter. To minimize this error, the PWM frequency should be as low as possible consistent with avoiding flicker in the LED.

**High frequency PWM mode**

At PWM frequencies above 10kHz and for duty cycles above 0.16, the output of the internal low pass filter will contain a DC component that is always above the shutdown threshold. This will maintain continuous device operation and the nominal average output current will be proportional to the average voltage at the output of the filter, which is directly proportional to the duty cycle. (See Figure 3 - High frequency PWM operating waveforms). For best results, the PWM frequency should be maintained above the minimum specified value of 10kHz, in order to minimize ripple at the output of the filter. The shutdown comparator has approximately 50mV of hysteresis, to minimize erratic switching due to this ripple. An upper PWM frequency limit of approximately one tenth of the operating frequency is recommended, to avoid excessive output modulation and to avoid injecting excessive noise into the internal reference.



**Figure 3 High frequency PWM operating waveforms**

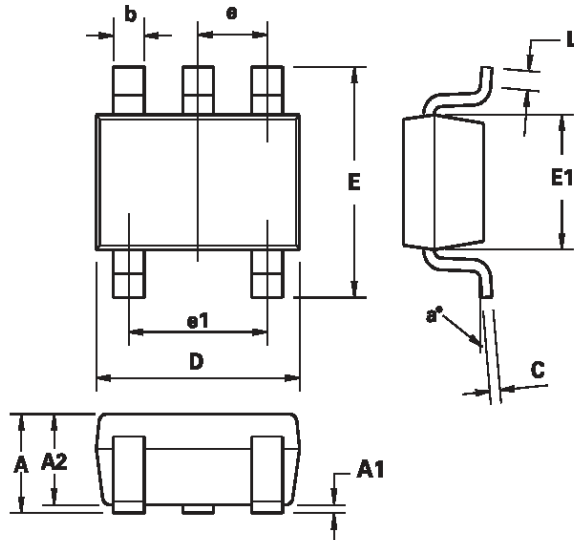
The nominal average value of output current in this mode is given by:

$$I_{OUTnom} \approx 0.1 D_{PWM} / R_S \text{ [for } D_{PWM} > 0.16]$$

This mode will give minimum output ripple and reduced radiated emission, but with a reduced dimming range (approx.5:1). The restricted dimming range is a result of the device being turned off when the dc component on the filter output falls below 200mV.



**Package outline**



DIM	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	0.90	1.45	0.0354	0.0570
A1	0.00	0.15	0.00	0.0059
A2	0.90	1.30	0.0354	0.0511
b	0.20	0.50	0.0078	0.0196
C	0.09	0.26	0.0035	0.0102
D	2.70	3.10	0.1062	0.1220
E	2.20	3.20	0.0866	0.1181
E1	1.30	1.80	0.0511	0.0708
e	0.95 REF		0.0374 REF	
e1	1.90 REF		0.0748 REF	
L	0.10	0.60	0.0039	0.0236
a°	0°	30°	0°	30°

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

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