1A High-Brightness LED Driver with Integrated NMOS Switch

REV：00

General Description

The LD7860 is a controller for step-down converters, operating in continuous conduction mode and ideally for driving high brightness of power LEDs. The device operates with inputs from 6V to 30V and utilizes an external high-side current sense resistor to set the normal average output current of up to 1A. Depending on the selection of input voltage and external components, it can drive up to 7pcs of WLEDs (VF=3.5V). Output current can be adjusted below the set value, by applying an external analog or PWM control signal to DIM pin. The device can operate with the switching frequency of up to 1MHz, making it ideal for the applications requiring small footprint and low value external inductors. Some additional features include under-voltage lockout, over current protection and thermal shutdown.

Features

- Wide input voltage range: 6V to 30V
- Integrated with 30V NMOS switch
- Up to 1A output current
- Hysteretic Control
- Output current accuracy for ±5% (typ.)
- Up to 1MHz switching frequency
- Brightness control using analog or PWM signal
- High efficiency
- Over current protection
- Over temperature protection
- Inherent open-circuit LED protection
- Output shutdown

Applications

- MR16 or LED bulbs
- Architectural, Ambient and Low-voltage industrial lightings
- LED replacement for Low-voltage halogen
- General lighting applications
- Indicators or emergency lighting
- LED back-up lighting

Typical Application

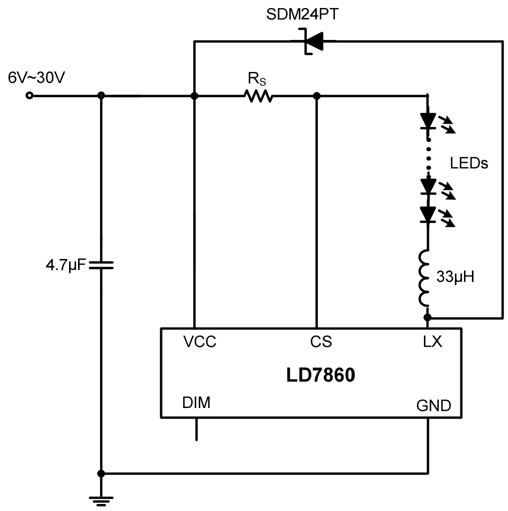
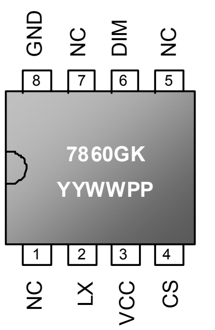


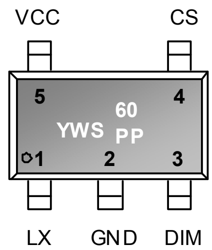
Fig. 1 Typical application circuit

Pin Configuration

MSOP-8 (TOP VIEW)

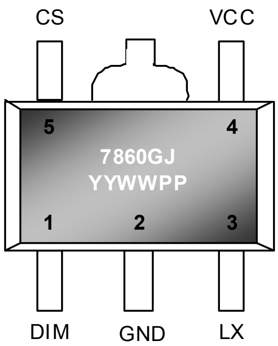


TSOT23-5 (TOP VIEW)



S 60:	LD7860
Y, YY:	Year code
W, WW:	Week code
P, PP:	Production code

SOT89-5 (TOP VIEW)



Ordering Information

Part number	Package	TOP MARK	Shipping
LD7860 GL	TSOT23-5	YWS/60	3000 /tape & reel
LD7860 GK	MSOP-8	7860GK	2500 /tape & reel
LD7860 GJ	SOT89-5	7860GJ	1000 /tape & reel

The LD7860 is Green Packaged.

Pin Descriptions:

MSOP-8

PIN	NAME	FUNCTION
1	NC	No connection.
2	LX	Drain of NMOS switch
3	VCC	Input voltage (from 6V to 30V). Bypass this pin with a 4.7μF of ceramic capacitor or larger one to GND.
4	CS	Connect a current sense resistor, R_S between this pin and VCC pin to set average LED current $I_{LEDAVG}(A)=0.1(V)/R_S(\Omega)$ with DIM pin floating.
5	NC	No connection.
6	DIM	● Remain floating during normal operation. (V_{DIM}=5V) ● Dimming can be accomplished by analog or by PWM control, depending on the desired applications. ● If V_{DIM} is below 0.35V, IC will be disabled. ● Connect a capacitor from it to GND to set the soft-start time.
7	NC	Connect a current sense resistor between it and VCC pin to set average LED current $I_{LEDAVG}(A)=0.1(V)/R_S(\Omega)$ with DIM pin floating.
8	GND	IC GND.

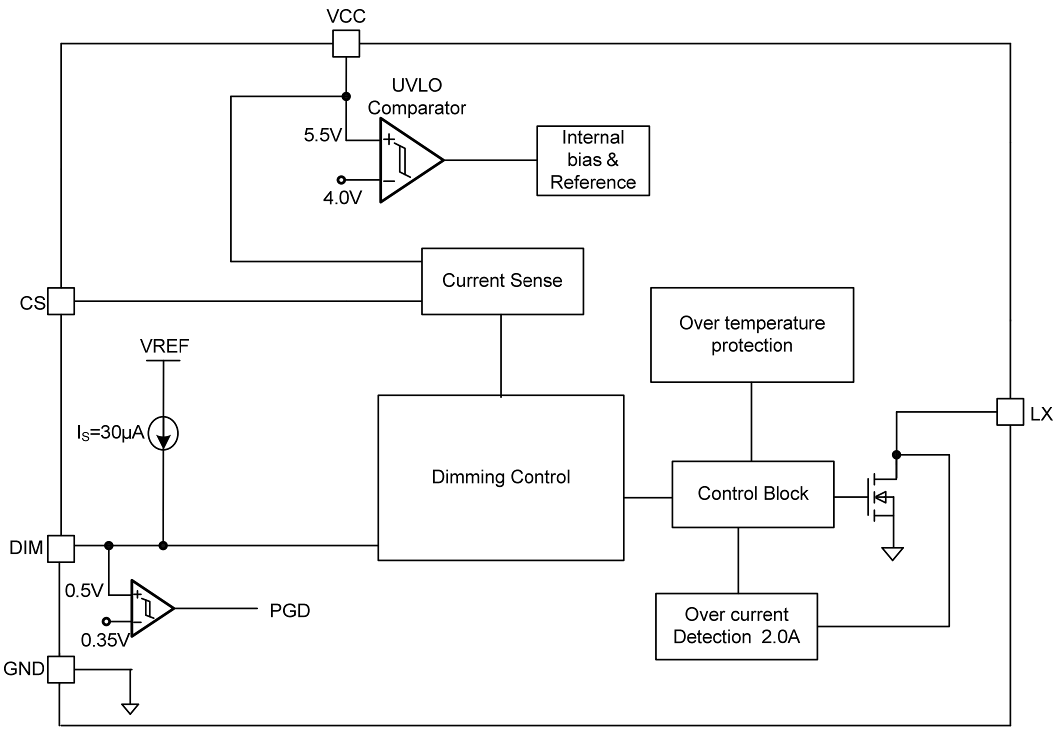
TSOT23-5

PIN	NAME	FUNCTION
1	LX	Drain of NMOS switch
2	GND	IC GND.
3	DIM	● Remain floating during normal operation. (V_{DIM}=5V) ● Dimming can be accomplished by analog or by PWM control, depending on the desired applications. ● If V_{DIM} is below 0.35V, IC will be disabled. ● Connect a capacitor from it to GND to set the soft-start time.
4	CS	Connect a current sense resistor between it and VCC pin to set average LED current $I_{LEDAVG}(A)=0.1(V)/R_S(\Omega)$ with DIM pin floating.
5	VCC	Input voltage (from 6V to 30V). Bypass this pin with a 4.7μF of ceramic capacitor or larger one to GND.

SOT89-5

PIN	NAME	FUNCTION
1	DIM	● Remain floating during normal operation. (V_{DIM}=5V) ● Dimming can be accomplished by analog or by PWM control, depending on the desired applications. ● If V_{DIM} is below 0.35V, IC will be disabled. ● Connect a capacitor from it to GND to set the soft-start time.
2	GND	IC GND.
3	LX	Drain of NMOS switch
4	VCC	Input voltage (from 6V to 30V). Bypass this pin with a 4.7μF of ceramic capacitor or larger one to GND.
5	CS	Connect a current sense resistor between it and VCC pin to set average LED current $I_{LEDAVG}(A)=0.1(V)/R_S(\Omega)$ with DIM pin floating.

Block Diagram



Absolute Maximum Ratings

VCC and CS Pin to GND	-0.3V~32V (33V for 0.5s)
LX Pin to GND	-0.3V~33V (34V for 0.5s)
LX Current	3.5A
DIM Pin to GND	-0.3V~6V
Power dissipation TSOT-25@Ta=25°C	454mW
Package Thermal Resistance TSOT-25	220°C/W
Power dissipation SOT89-5@Ta=25°C	571mW
Package Thermal Resistance SOT89-5	175°C/W
Power dissipation MSOP-8@Ta=25°C	625mW
Package Thermal Resistance MSOP-8	160°C/W
Operating Ambient Temperature Range	-30°C to 85°C
Storage Temperature Range	-55°C to 125°C
Maximum Operating Junction Temperature	125°C
Lead Temperature (Soldering, 10sec)	260 °C
ESD Level (Human Body Model)	2kV
ESD Level (Machine Model)	200V

Caution:

Stresses beyond the ratings specified in “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied

Electrical Characteristics

(T_A = +25°C, VCC=12V unless otherwise stated)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Power					
Operating Voltage VCC		6		30	V
UVLO(ON)		5.25	5.5	5.75	V
UVLO(OFF)		3.75	4.0	4.25	V
VCC de-bounce time			5		μs
Nominal Quiescent Current, I_Q	DIM= floating		0.8	1.5	mA
Shutdown Current, I_{SD}	DIM= GND		60	100	μA
Sense Comparator					
V_{SENSE}	Mean Value of Sense Voltage DIM= floating	95	100	105	mV
V_{SNHYS}	Hysteresis voltage of VSENSE		±15		mV
Comparator from H to L Propagation Delay Time, T_{DH}.	Rising edge of V_{SENSE} delay to LX low.		80		ns
Comparator from L to H Propagation Delay Time, T_{DL}.	Falling edge of V_{SENSE} delay to LX high.		80		ns
Current Sense Input Current, I_{SENSE}	V_{SENSE}= (VCC-V_{CS})=100mV			10	μA
DIM					
Internal Current Source, I_S	Measurement on DIM pin R_{ADJ}=20kΩ~83.3kΩ		30		μA
V_{DIM}	V_{DIM} voltage range for analog dimming control	0.5		2.5	V
V_{DIM} de-bounce time			2		μs
V_{DIM} On/Off Threshold	Enabled	0.5			V
	Disabled			0.35	V
Duration Low Status of Off-Time to Shutdown	V_{DIM} =Low	10			ms

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
LX					
LX Leakage Current, $I_{LX(leakage)}$	V_{LX}=30V			5	μA
$R_{DS(ON)}$	Switch on resistance, I_{LX}=1A		0.4	0.6	Ω
Over Current Protection			2.0		A
Others					
TSD	Thermal shutdown threshold		150		°C
THYS	Thermal shutdown threshold hysteresis		30		°C
Recommended switching frequency range, fS		20		1000	kHz

Typical Performance Characteristics

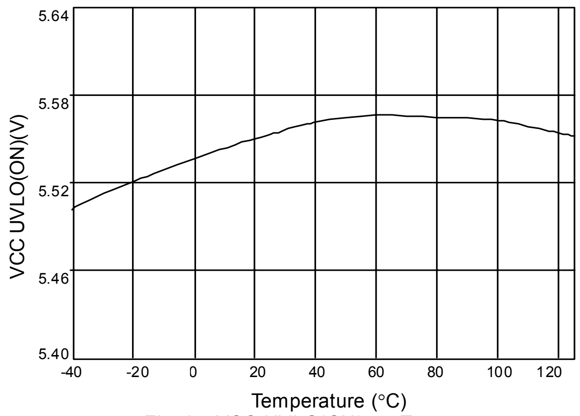


Fig. 2 VCC UVLO(ON) vs. Temperature

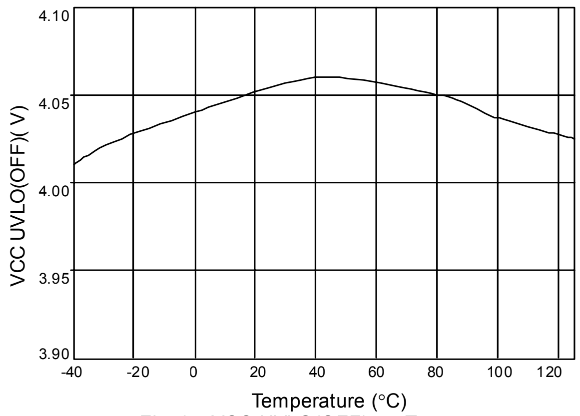


Fig. 3 VCC UVLO(OFF) vs. Temperature

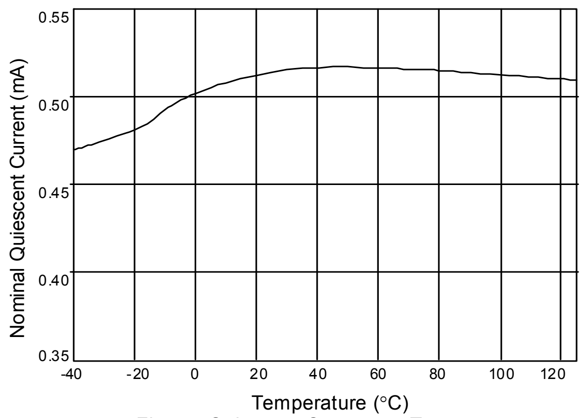


Fig. 4 Quiescent Current vs. Temperature

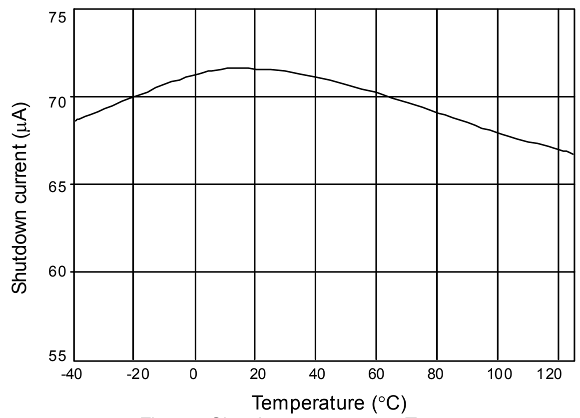


Fig. 5 Shutdown current vs. Temperature

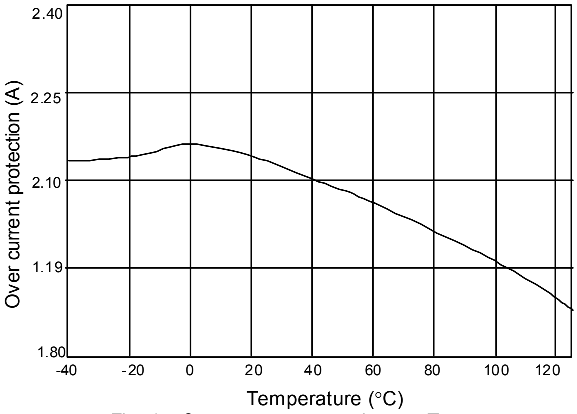


Fig. 6 Over current protection vs. Temperature

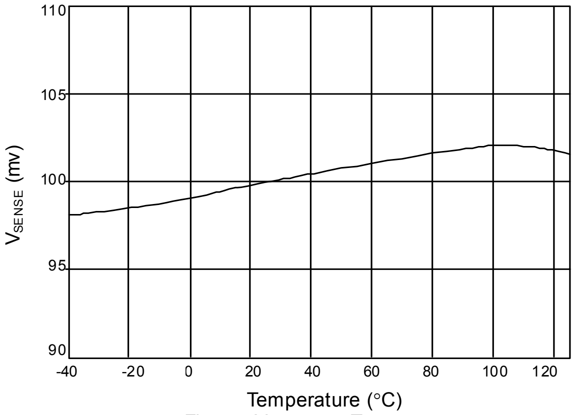


Fig. 7 V_{SENSE} vs. Temperature

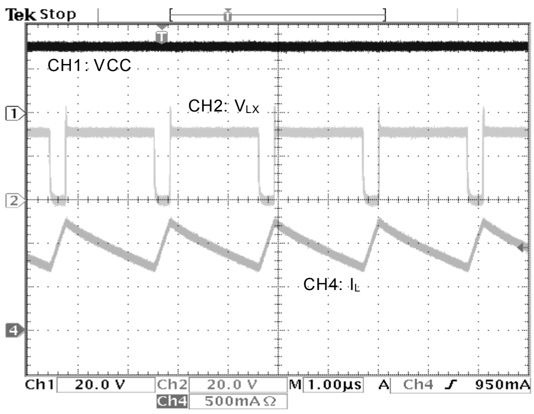


Fig. 8 Normal switching waveform

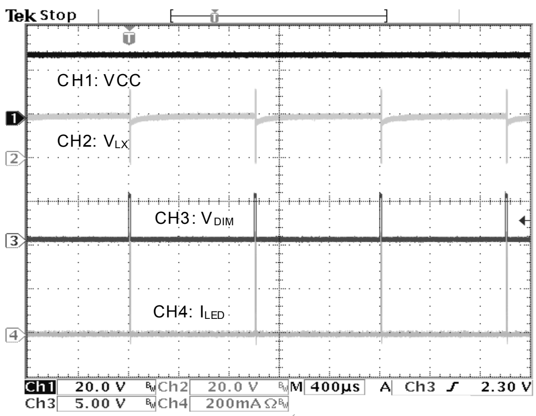


Fig. 9 1% PWM dimming control

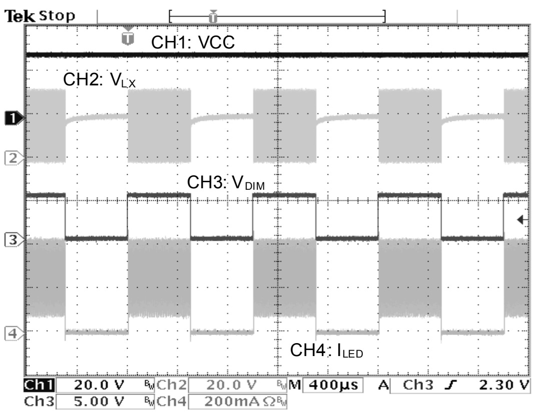


Fig. 10 50% PWM dimming control

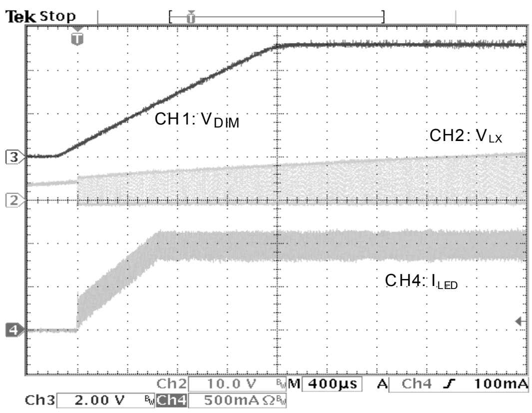


Fig. 11 Soft-start (C_{DIM}=10nF)

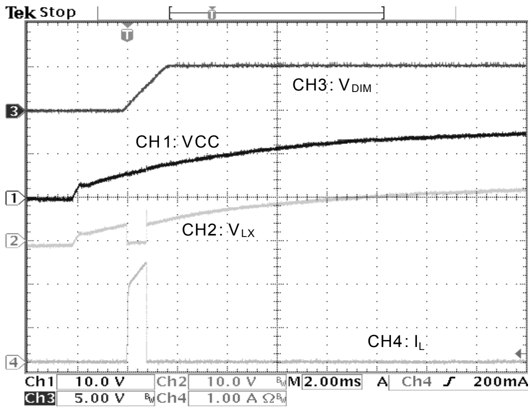


Fig. 12 Over Current Protection

Function Description

LED Current Program

The normal average LED current can be set through an external high-side current sense resistor, R_S, which is connected between VCC pin and CS pin. The following equation can be used to calculate the current sense resistor, R_S

$$R_S\,(\Omega) = 0.5\frac{(V_{SENSE(H)} + V_{SENSE(L)})(V)}{I_{LEDave}(A)}$$

The table below lists various average LED current and the associated current sense resistor, R_S.

Average LED current (A)	R_S (Ω)
1.0	0.1
0.7	0.143
0.35	0.286
0.3	0.333

In order to obtain accurate LED average current, high precision of current sense resistors are preferred (1% is strongly recommended).

Analog Dimming Control

The analog dimming can be achieved by putting an adjustable R_{ADJ} between DIM pin and GND to adjust the averaged LED current. Floating or pulling DIM pin high above 2.5V will achieve the maximum brightness.

The average output current in this case is given by:

$$I_{LEDave} = \frac{V_{DIM}}{2.5V}\cdot\frac{0.1V}{R_S}\,(A)$$

$$V_{DIM} = 30\mu A \cdot R_{ADJ}(V) \quad (20k\Omega \le R_{ADJ} \le 83.3k\Omega)$$

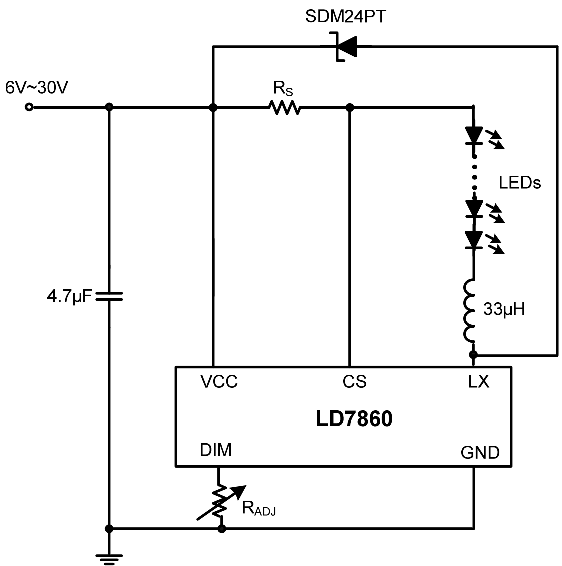


Fig.13

PWM Dimming Control

The PWM dimming control can be achieved by applying DIM pin external PWM signal with a logic high level of above 2.5V and a minimum pulse width of 5μs to adjust the averaged LED current by the duty cycle, which is proportional to the brightness of LED. The PWM signal can be generated by a microcontroller or a pulse generator for the duty cycle. The frequency of the PWM signal should be high enough to avoid from visibly-flashing of LED. The frequency of the PWM signal for DIM pin is recommended to be in the range from 200Hz to 1kHz.

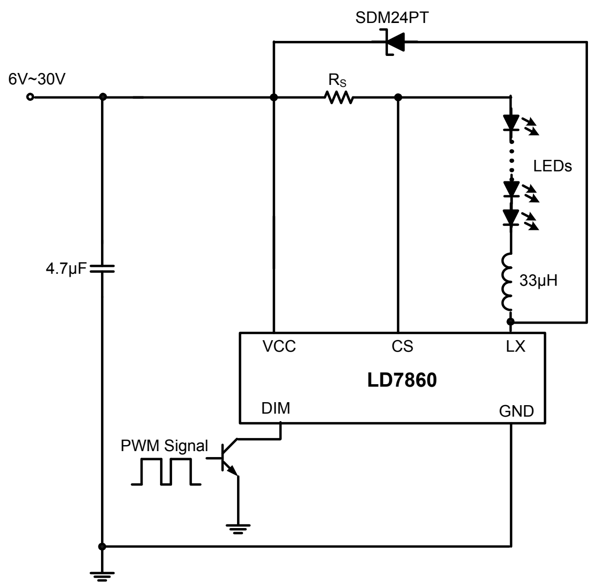


Fig.14

Shutdown Mode

The LD7860 will enter shutdown mode soon as DIM pin provides voltage of logic low signal for over 10ms. During shutdown, the suspend current for the device will be less than 100μA (max).

Soft Start

The soft start can be activated through an external soft start capacitor C_{DIM} between DIM and GND (refer to Fig. 15). The soft start time can be estimated by following formula.

$$T_{SS} \cong \frac{2.05 \times C_{DIM}}{I_S} (mS)$$

Where,

T_{SS}: soft start time (ms)

C_{DIM}: external soft start capacitor (nF)

I_S: internal current source (μA) = 30μA (typ.)

Example:

Assume C_{DIM}=4.7nF

The soft start time, $T_{SS} \approx 2.05 \times 4.7 \div 30 = 0.321$ (ms)

If the soft start function is not required, open this capacitor to achieve quick start-up.

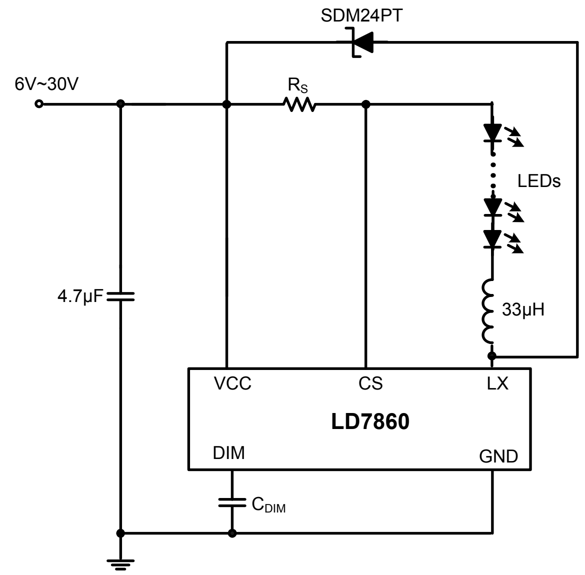


Fig.15

Over Current protection (OCP)

OCP will be triggered if the current through LX exceeds 2.0A. Once the over-current condition is detected, the IC will be latched off and stop switching.

Inherent LED Open Circuit Protection

The LD7860 employs buck converter topology to protect the IC when there's open-circuit occurring among the LED strings. In addition, the device is free from damage since the inductor is isolated from the LX pin.

Inductor Selection

The minimum current rating of inductor must be equal to or over 1.5 times of the programmed average LED current. It's recommended to select inductors in the range from 12µH to 150µH. Larger inductor possesses less current ripple and minimizes the error due to propagations delays due to higher input voltage, lower V_{LED} and light load situation. Those inductors with lower equivalent series resistance can improve the efficiency further.

When selecting the inductor, make sure it is capable to handle the peak current without saturation even at maximum operating temperature.

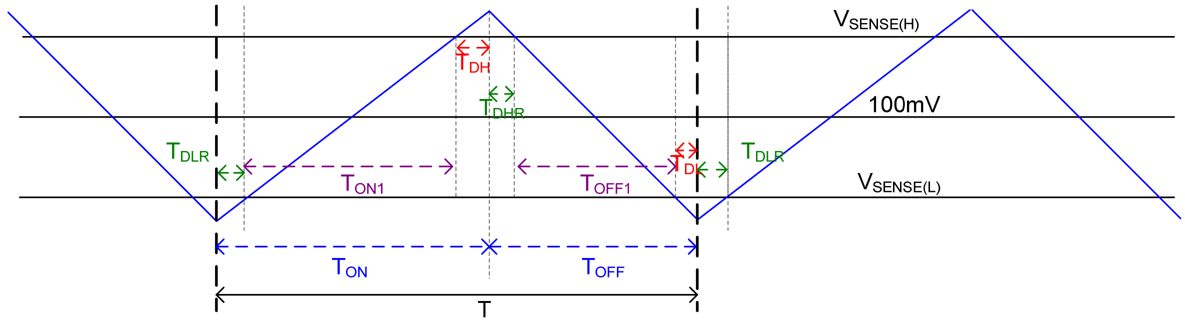


Fig.16

Fig. 16 illustrates the actual operating frequency of LD7860. Following it is an approximate formula.

$$f_{SW} = \frac{1}{T_{ON} + T_{OFF}} (Hz)$$

Where:

$T_{ON} = T_{ON1} + T_{DH} + T_{DLR}$ →NMOS switch 'on time'(s).

$T_{OFF} = T_{OFF1} + T_{DL} + T_{DHR}$ →NMOS switch 'off time'(s).

T_{ON} is NMOS switch on time (Neglect T_{DH} and T_{DLR}).

$$T_{ON1} = \frac{L \cdot \Delta I}{V_{L1}}$$

T_{OFF1} is NMOS switch off time (Neglect T_{DL} and T_{DHR}).

$$T_{OFF1} = \frac{L \cdot \Delta I}{V_{L2}}$$

V_{L1} is the across voltage of inductor when NMOS is switched on.

$$V_{L1} = VCC - V_{SENSE} - N \cdot V_{LED} - I_{LEDave}(r_L + R_{DS(ON)})$$

V_{L2} is the across voltage of inductor when NMOS is switched off.

$$V_{L2} = N \cdot V_{LED} + V_{FD} + V_{SENSE} + I_{LEDave} \cdot r_L$$

T_{DHR} is the recovery time caused by T_{DH}.

$$T_{DHR} = \frac{V_{L1}}{V_{L2}} \cdot T_{DH}$$

T_{DLR} is the recovery time caused by T_{DL}.

$$T_{DLR} = \frac{V_{L2}}{V_{L1}} \cdot T_{DL}$$

VCC is the supply voltage (V).

L is the inductance of inductor (H).

ΔI is the inductor peak to peak current ripple of hysteresis (A).

{Internally set for 30% of $I_{LED(AVE)}$}

V_{LED} is the total forward conduction voltage of LED (V).

N is the number of LEDs.

$I_{LED(AVE)}$ is the average LED current (A).

r_L is the equivalent series resistance of inductor (Ω).

$R_{DS(ON)}$ is the internal switch resistance (Ω).

V_{FD} is the forward conduction voltage of schottky diode (V).

T_{DH} is comparator for propagation delay time from H to L (ns).

T_{DL} is comparator for propagation delay time from L to H (ns).

Example:

VCC=12V, V_{SENSE}=100mV, R_S=0.286Ω, L=33μH, r_L=0.124Ω, V_{LED}=3.5V, V_{FD}=0.36V, number of LED =1, $I_{LED(AVE)}$=350mA.

Actual operating frequency:

$$f_S = \frac{1}{T_{ON} + T_{OFF}} = 605.46\,kHz$$

The operating frequency between 20 kHz and 1MHz will effectively suppress the audible noise.

Diode Selection

With lower forward voltage and quick reverse recovery, the fast schottky diode offers improved efficiency and performance. To prevent any breakdown or leakage, its peak current rating of the diode is required for higher than the current through the inductor, the continuous current rating higher than the RMS value of LED current, and also, the voltage rating higher than the peak input voltage transient.

Recommended T_{ON} and T_{OFF}

Set T_{ONMIN} and T_{OFFMIN} for more than 300ns and 350ns respectively in order to enhance output current precision against propagation delay time.

Input Capacitor Selection

Since ceramic capacitors features high ripple rating, low ESR, low cost, and tiny size, it's an ideal companion part for LD7860. Place a capacitor of at least 4.7μF between VCC and GND to ensure steady input voltage and filter out the pulsing input current. The minimum distance between the IC and capacitor is, the maximum efficiency will achieve. To obtain constant capacitance over temperature and voltage, capacitors with X5R, X7R or better dielectric are recommended.

Output Capacitor

In most cases, the LED current ripple is equal to the inductor current ripple. If it's required to minimize LED's current ripple, just place an output capacitor across the LED's terminals. An output capacitor C_O connected in parallel with the LEDs can reduce the LED's current ripple while there's same average current flowing through both the inductor and the LEDs. See below for the application. (Fig.16)

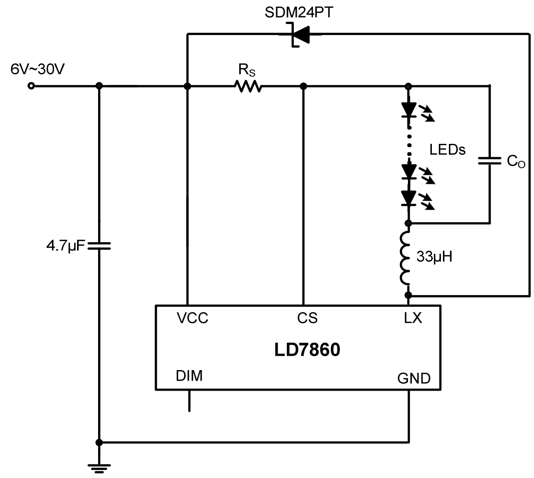


Fig.16

Just a 1μF output capacitor is required to reduce the LED current ripple remarkably. Its capacitance will not affect the switching frequency, overall efficiency and the average LED current value.

The following approximate equation will give calculation for LED's current ripple, Δi_R.

$$\Delta i_R = \Delta i_L \cdot \frac{Z_c}{Z_c + r_d}$$

Where

Δi_L is the inductor current ripple

Z_C is the equivalent impedance of output capacitor

r_D is the LED dynamic resistance

The calculation for Z_C assumes the shape of the inductor current is approximately sinusoidal.

Thermal consideration

Most LED drivers usually operate in high ambient temperature, so IC junction is a crucial issue in the applications. It's recommended to control the junction temperature under 125°C.

$$P_{D(MAX)} = \frac{(125°C - T_A)}{\theta_{JA}}$$

$P_{D(MAX)}$= the power consumption for the IC

θ_{JA}: Package Thermal Resistance

Layout Consideration

- Place the VCC bypass capacitor, 4.7µF at least, much near VCC pin and GND pin.
- Place the flywheel diode and inductor near the LX pin.
- Locate the current sense resistor near their associated pins as possible. And route away from switching nodes, such as LX pin.
- The high current path should be wide and short as possible.
- CS sense path should be thin as possible and be isolated with the other pins by ground to minimize the noise and interference.
- For the sake of noise depression, a 33pF ceramic capacitor is recommended to place between CS and GND.

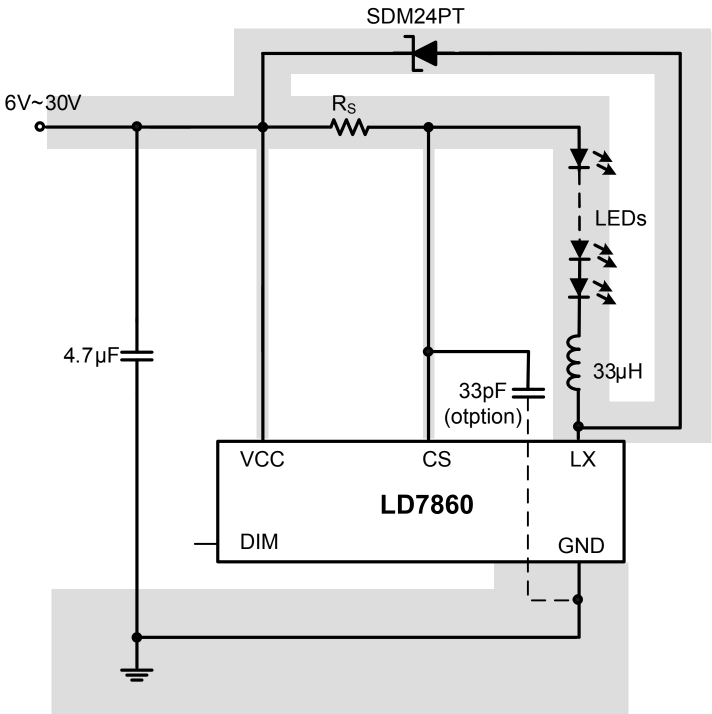
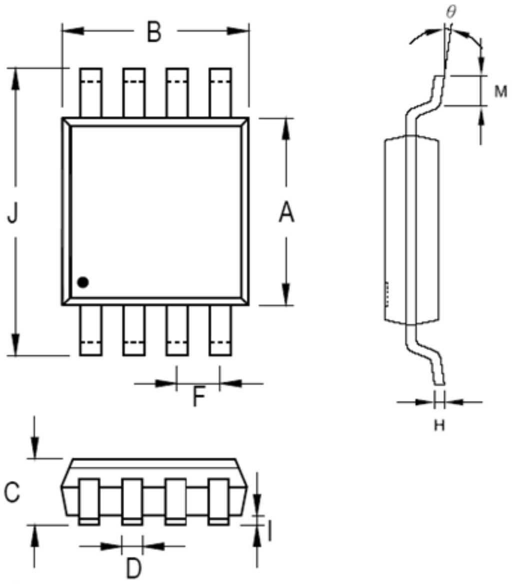


Fig. 17 the recommended PCB layout

Package Information

MSOP-8



Symbol	Dimension in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	2.896	3.099	0.114	0.122
B	2.896	3.099	0.114	0.122
C	0.813	1.219	0.032	0.048
D	0.220	0.380	0.009	0.015
F	0.65 TYP.		0.026 TYP.	
H	0.127	0.229	0.005	0.009
I	0.050	0.150	0.002	0.006
J	4.699	5.105	0.185	0.201
M	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

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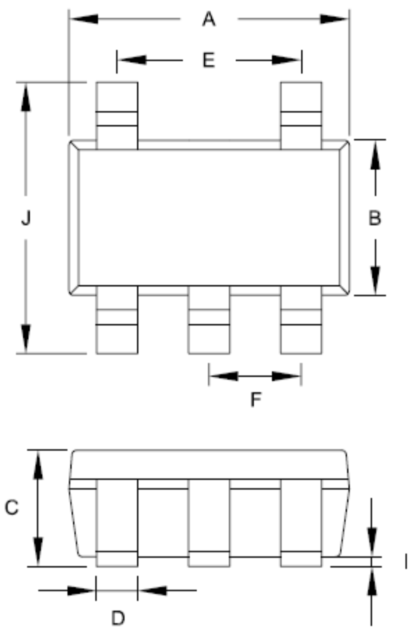
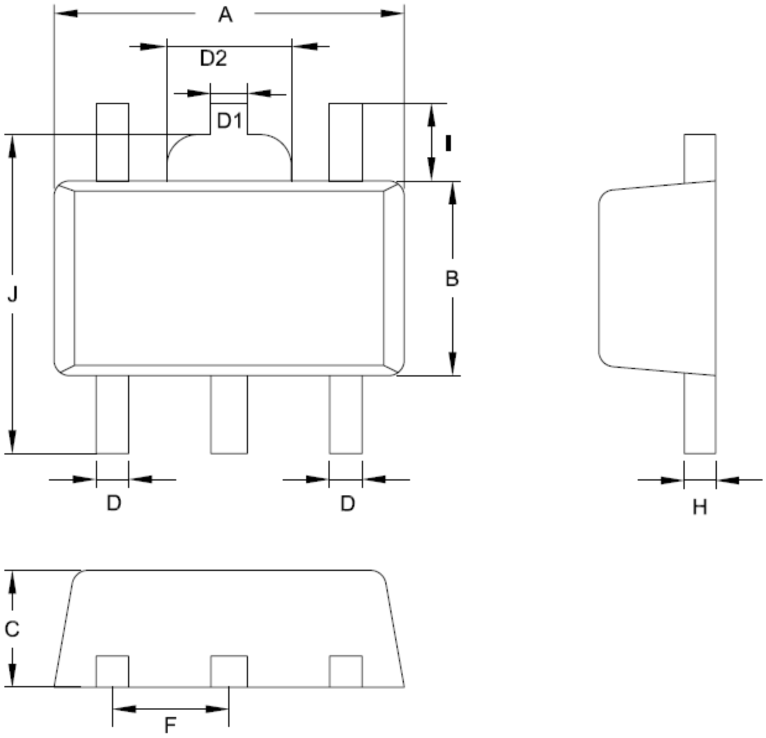


Symbol	Dimension in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	2.692	3.099	0.106	0.122
B	1.397	1.803	0.055	0.071
C	0.750	0.900	0.030	0.035
D	0.300	0.500	0.012	0.020
E	1.90 TYP		0.074 TYP	
F	0.95 TYP		0.037 TYP	
H	0.080	0.254	0.003	0.010
I	0.000	0.150	0.000	0.006
J	2.600	3.000	0.102	0.118
M	0.300	0.600	0.012	0.024
θ	0°	10°	0°	10°

SOT89-5



Symbol	Dimension in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	4.394	4.597	0.173	0.181
B	2.290	2.600	0.090	0.102
C	1.397	1.600	0.055	0.063
D	0.360	0.480	0.014	0.019
D1	0.440	0.560	0.017	0.022
D2	1.397	1.753	0.055	0.069
F	1.50 typ.		0.059 typ.	
H	0.355	0.432	0.014	0.017
I	0.787	1.200	0.031	0.047
J	3.940	4.250	0.155	0.167

Important Notice

Leadtrend Technology Corp. reserves the right to make changes or corrections to its products at any time without notice. Customers should verify the datasheets are current and complete before placing order.

Revision History

Rev.	Date	Change Notice
00	12/30/2009	Original Specification