IS31LT3380

40V/1.2A LED DRIVER WITH SWITCH DIMMING

OCTOBER 2011

GENERAL DESCRIPTION

The IS31LT3380 is a continuous mode inductive step-down converter, designed for driving a single LED or multiple series connected LEDs efficiently from a voltage source higher than the LED voltage. The chip operates from an input voltage between 8.5V and 40V and provides an output current up to 1.2A.

The IS31LT3380 includes a high-side output current sensing circuit, which uses an external resistor to set the nominal average output current. The IS31LT3380 includes an integrated output switch which has a very low conducting impedance to ensure high system efficiency.

The IS31LT3380 has switch dimming function. The chip detects external switch action to adjust output current, allowing for dimming functionality to be achieved without changing the original lighting system circuitry.

The switch dimming is implemented in either two-level mode or three-level mode. The output current of every level and the total number of levels are customer selected by setting the corresponding input conditions of DIM1 and DIM2 pin.

The output current is set at the initial value the first time that power is supplied to the chip. After the initial power up sequence, the chip adjusts the output current according to the external switch action. After the lowest current level, the current cycles back to the initial value if more switch action is detected. If the power is switched off for longer than 2 seconds, the device will return to it's initial state, and the output current will be set to the initial value at the next time that power is applied.

FEATURES

- Multi-modes switch dimming
- Up to 1.2A output current
- High efficiency (up to 98%)
- Wide input voltage range: 8.5V to 40V
- Internal 40V power switch
- Simple low parts count
- Typical 5% output current accuracy
- Up to 1MHz switching frequency
- Inherent LED open-circuit/short-circuit protection
- Thermal shutdown protection circuitry
- SOP8 package

APPLICATIONS

- MR16, MR11 LED spotlight
- LED street lighting
- PAR LED bulb
- Other LED lighting

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b.) the user assume all such risks; and
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APPLICATION CIRCUIT

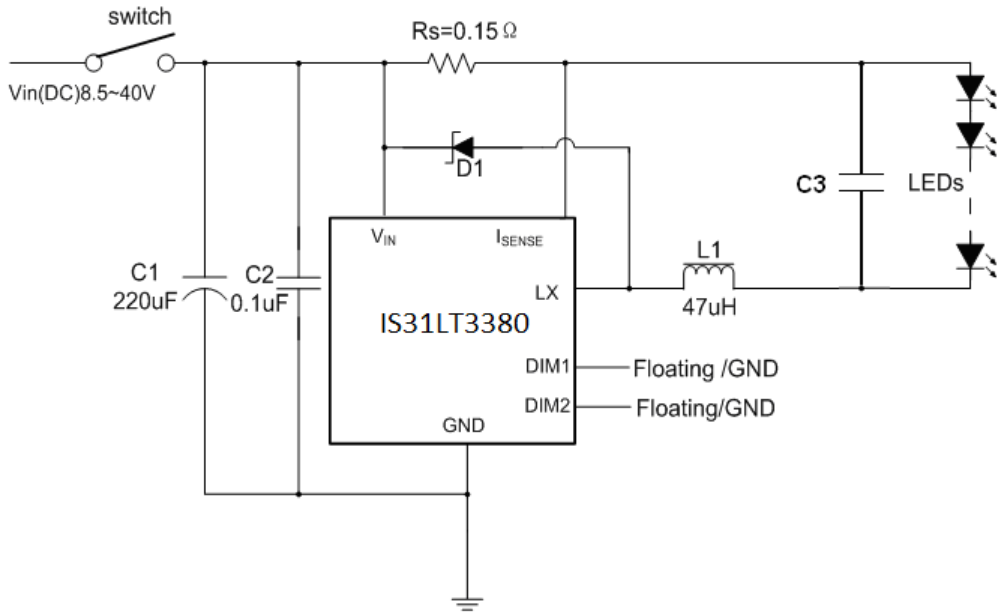


Figure 1-A

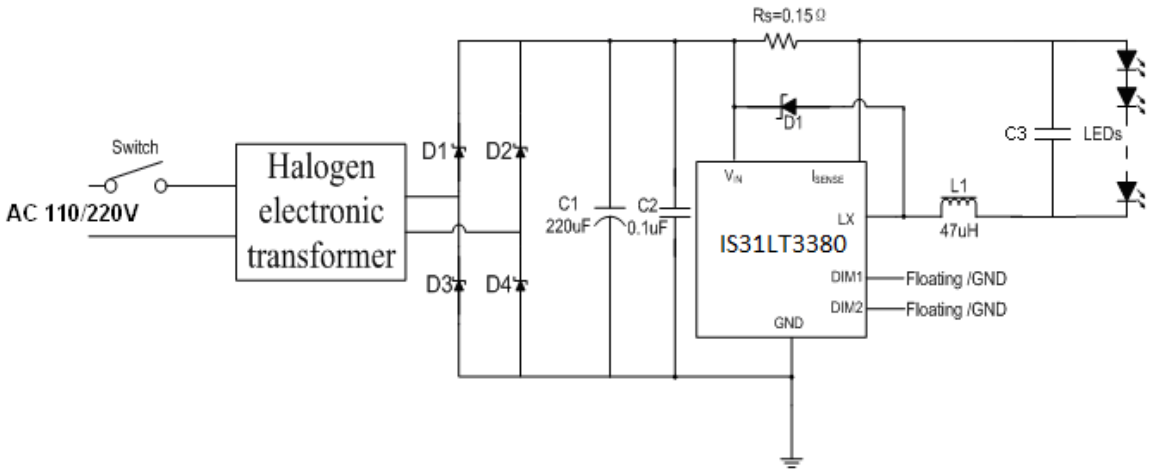
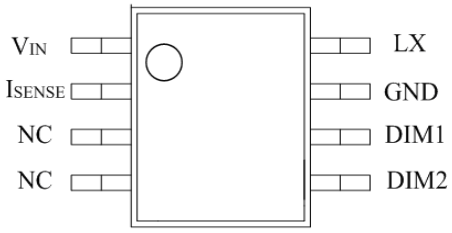


Figure 1-B

PIN CONFIGURATIONS

Package	Pin Configurations
SOP-8	

PIN DESCRIPTION

Pin Name	NO.	Description
V_{IN}	1	Input voltage (8.5V to 40V). Decouple to ground with 0.1μF X7R ceramic capacitor close to device. While using the switch dimming function, connect a 220Uf or higher capacitor close the device.
I_{SENSE}	2	Connect resistor R_S from this pin to V_{IN} to define nominal average output current I_{OUTnom} =0.1/R_S
DIM1	6	Set the current-levels number of and current ratio of each level of switch dimming function as below: DIM1="floating" DIM2="floating"，not dimming； DIM1="floating" DIM2="GND"，three-levels，100%---50%---20%； DIM1="GND" DIM2="floating"，three-levels，100%---60%---30%； DIM1="GND" DIM2="GND"，two-levels，100%---30%。
DIM2	5	
GND	7	Ground (0V)
LX	8	Drain of power switch
NC	3,4	Not connect. Float required

ORDERING INFORMATION

Industrial Range: -40°C to 105°C

Order Number	Package	QTY/Reel
IS31LT3380-GRLS3-TR	SOP-8, Lead-free	2500

ABSOLUTE MAXIMUM RATINGS (NOTE1)

Symbol	Parameter	Rating
V_{IN}	Input voltage	-0.3V to +50V
V_{ISENSE}	I_{SENSE} voltage	Vin+0.3V to Vin-5V ,Vin>5V
		Vin+0.3V to -0.3V,Vin<5v
V_{LX}	LX output voltage	-0.3V to +50V
V_{DIM}	DIM1 ,DIM2 pin input voltage	-0.3V to +6V
I_{LX}	Switch output current	1.5A
P_{tot}	Power dissipation	0.5W
T_{OP}	Operating temperature	-40 °C to 105°C
T_{ST}	Storage temperature	-55 to 150°C
$T_{j\,MAX}$	Junction temperature	150°C
$R_{\theta JA}$	Junction to ambient	100°C/W
	ESD Rating (HBM)	3kV

ELECTRICAL CHARACTERISTICS

(V_{IN}=12V, T_A=25°C unless otherwise stated) (NOTE 2)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Input voltage		8.5		40	V
I_{INQoff}	Quiescent supply current with output off		70	120	140	μA
I_{INQon}	Quiescent supply current with output switching			450	600	μA
V_{ISENSE}	Mean current sense threshold voltage		95	100	105	mV
UVLO	Undervoltage lockout threshold	V_{IN} falling	5.05	5.85	6.65	V
ΔUVLO	Undervoltage lockout hysteresis			1.65		V
$V_{SENSEHYS}$	Sense threshold hysteresis			±15		%
I_{SENSE}	I_{SENSE} pin input current	V_{SENSE} =V_{IN} -0.1		8		μA
Ts	the interval time between the external switch action			2		S
Kmode1	In dimming mode 1,the ratio of different output current level to the initial current (DIM1="floating" DIM2="GND")	Level 1		100%		
		Level 2		50%		
		Level 3	17%	20%	23%	

ELECTRICAL CHARACTERISTICS

(V_{IN}=12V, TA=25°C unless otherwise stated) (NOTE 2) (continued)

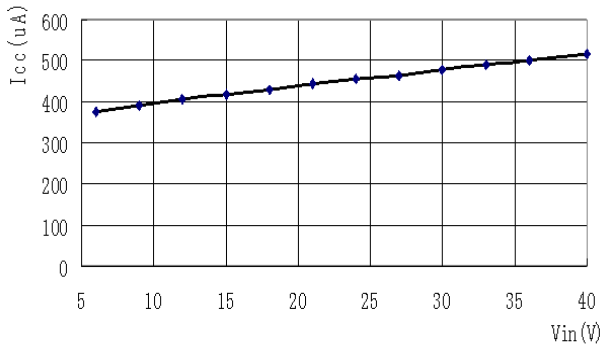
Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Kmode2	In dimming mode 2,the ratio of different output current level to the initial current (DIM1="GND" DIM2="floating")	Level 1		100%		
		Level 2		60%		
		Level 3	28%	30%	32%	
Kmode3	In dimming mode 3,the ratio of different output current level to the initial current (DIM1="GND" DIM2="GND")	Level 1		100%		
		Level 2	28%	30%	32%	
I_{LXmean}	Continuous LX switch current			1.2		A
$I_{LX(leak)}$	LX switch leakage current				1	μA
R_{LX}	LX Switch 'On' resistance			0.3	0.4	Ω
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
T_{PD}	Internal comparator propagation delay			25		ns
T_{SD}	Thermal shutdown temperature			150		°C
T_{SD-HYS}	Thermal shutdown hysteresis			20		°C

NOTES:

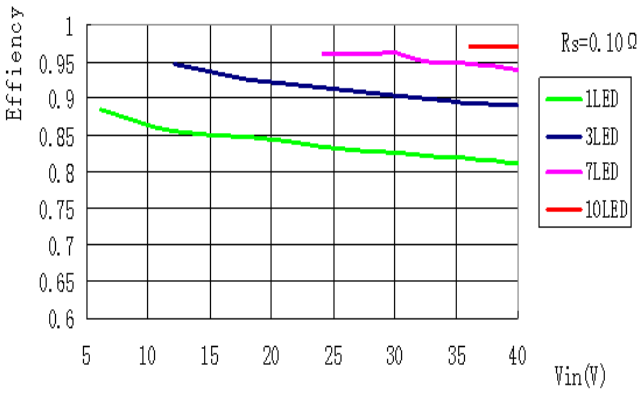
1. Work beyond maximum absolute voltage and current will cause permanent damage to the device. Long time working under absolute conditions will lower the reliability of the dice.
2. Production testing of the chip is performed at 25°C. Functional operation of the chip and parameters specified are guaranteed by design, characterization and process control in other temperature.

TYPICAL OPERATING CONDITIONS

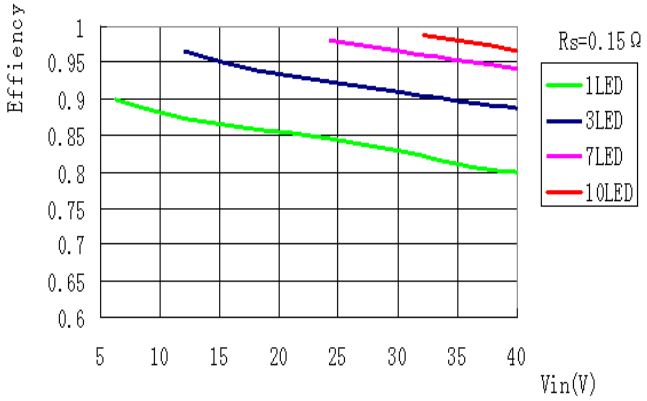
For typical application circuit and T_A=25°C unless otherwise stated.



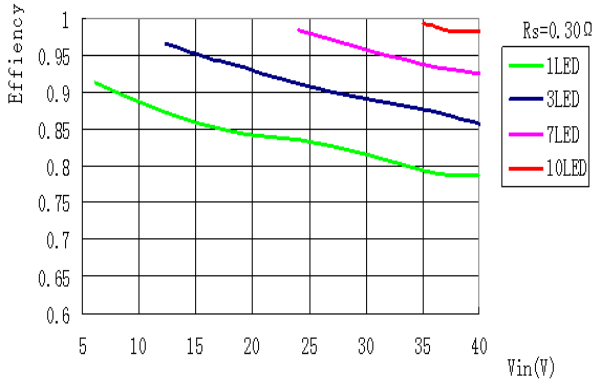
Supply Current vs. Vin (Operating)



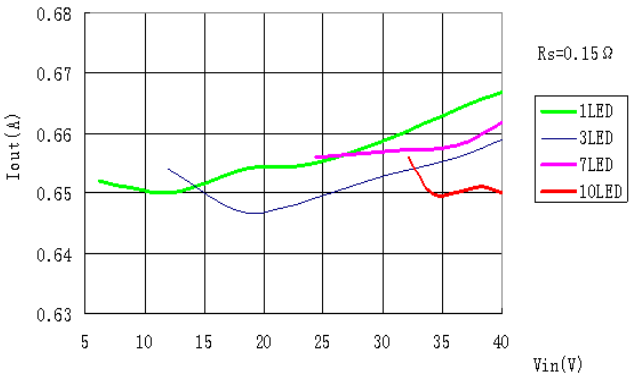
Efficiency vs. No. of LEDs
L=47uH, Rs=0.10Ohm



Efficiency vs. No. of LEDs
L=47uH, Rs=0.15Ohm

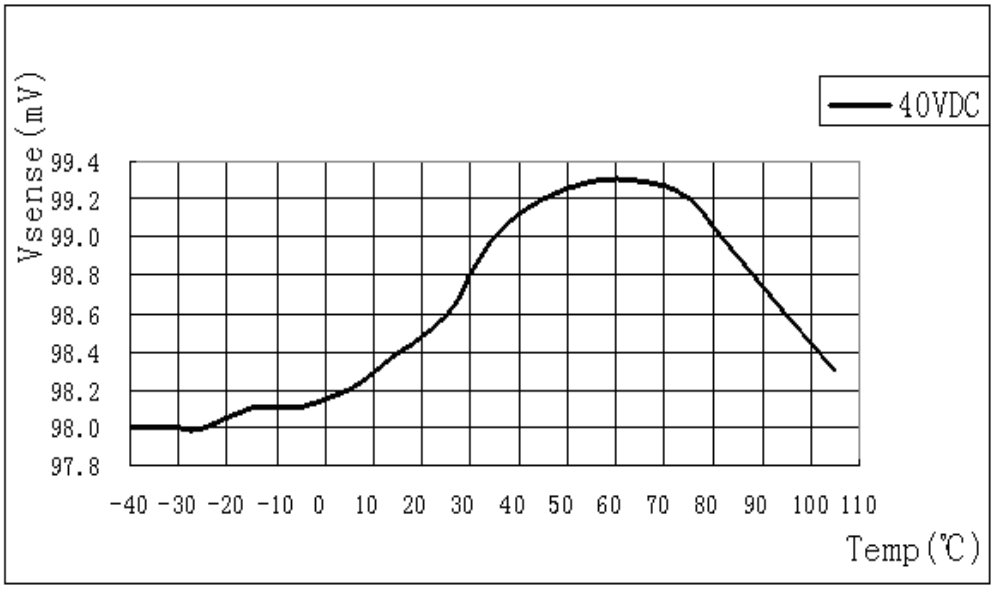


Efficiency vs. No. of LEDs
L=47uH, Rs=0.30Ohm



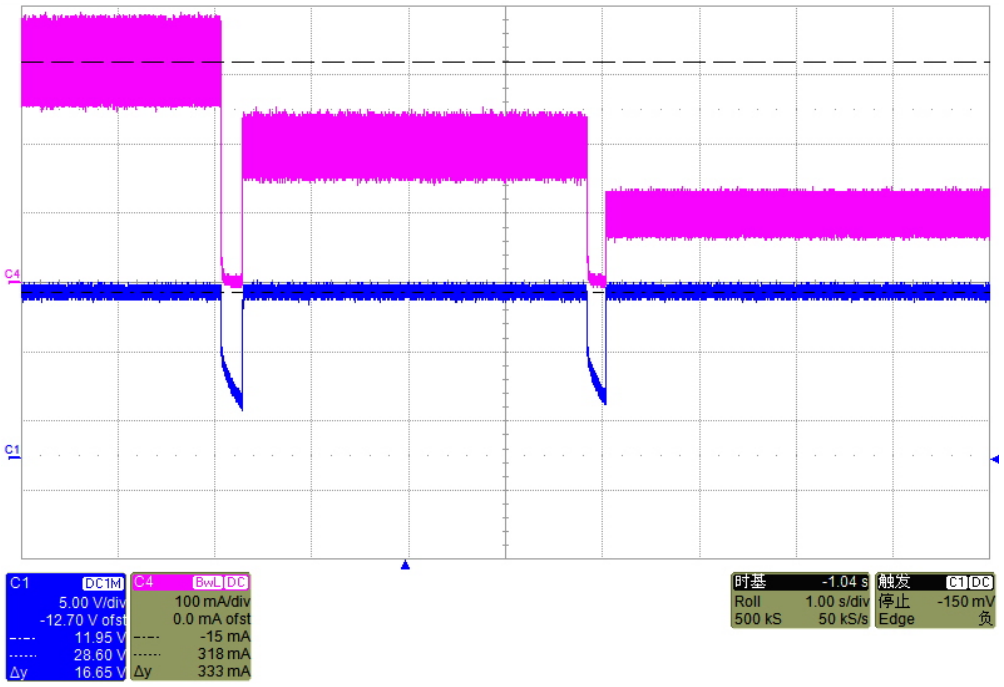
Output current variation with output Voltage
L=47uH, Rs=0.15Ohm

TYPICAL OPERATING CONDITIONS

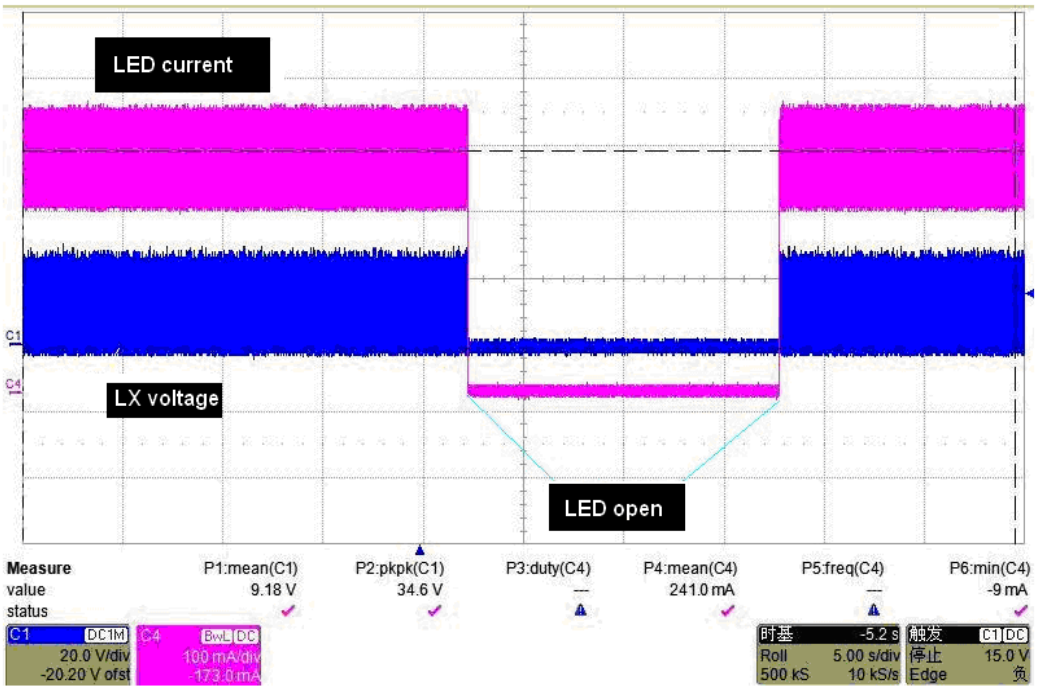


Temperature VS Vsense voltage

L=47uH, Rs=0.10Ohm

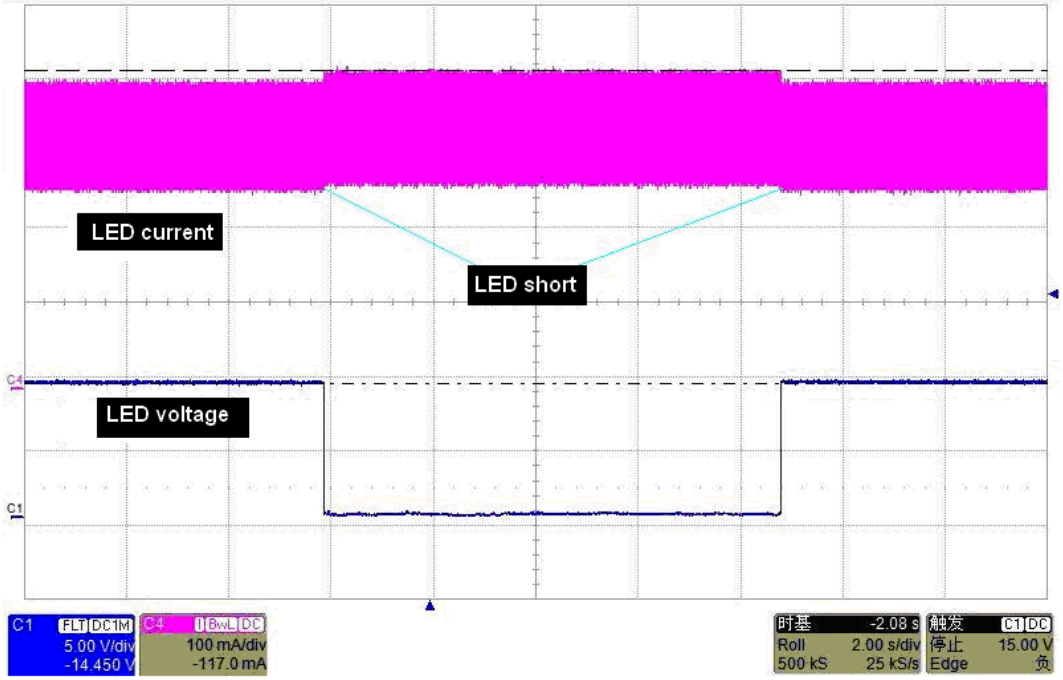


SWITCH DIMMING WAVEFORM



LED open waveform

Vin=24VDC，L=47uH, Rs=0.30Ohm



LED short waveform

Vin=24VDC，L=47uH, Rs=0.30Ohm

APPLICATION INFORMATION

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:

$I_{OUT\ nom}$ = 0.1/Rs

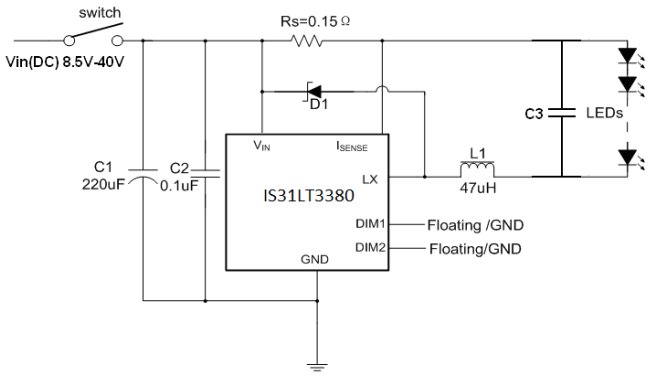
The table below gives values of nominal average output current for several preferred values of current setting resistor (RS) in the typical application circuit shown on page 2:

R_S (Ω)	Nominal average output current (mA)
0.082	1200
0.15	667
0.3	333

The resistance tolerance of Rs should be 1%, and the power rating must be high enough to continuously handle the average output current. Good over-temperature performance of the resistor is also recommended.

Multi-modes Switch dimming

The IS31LT3380 detects external switch action to adjust output current.



There are two types of switch action: a normal switch, which means the off-time between each subsequent switching is longer than 2s; and a dimming-switching, which means the off-time between each subsequent switch actions is less than 2s.

The nominal average output current is given by:

I_{OUT} = K*0.1/R_S [K is the current ratio to initial current]

The input condition of the DIM1 and DIM2 pins set the number of current-levels and current ratio for the switch dimming function as shown below:

DIM1	DIM2	Dim-ratio
floating	floating	Not dimming
floating	GND	100%---50%---20%---100%
GND	floating	100%---60%---30%---100%
GND	GND	100%---30%---100%

For instance, suppose the DIM1 pin is floating and the DIM2 pin is connected to GND. The first time the switch is turned on, the initial current is $I_{OUTnom.}$

After the 1st dimming-switch, $I_{OUT(1)}$ = 50% * I_{OUTnom} ;

After the 2nd dimming-switch, $I_{OUT(2)}$ = 20% * I_{OUTnom} ;

After the 3rd dimming-switch, $I_{OUT(3)}$ = 100%* I_{OUTnom} ;

This process recycles.

If a normal-switch is detected or DIM1 and DIM2 are both floating, the output current goes back to the initial state of 100%.

Since the chip needs to count the time for more than 2 seconds after the switch is OFF, during the OFF time one capacitor bigger than 220uF is required to keep the chip work in low quiescent current mode.

Inherent open-circuit LED protection

If the connection to the LED(s) is open-circuited, the circuit is open, so the chip 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.

If the source is a DC supply, the capacitor is decided by ripple of the source, the value is given by:

$$C_{\min} = \frac{I_F * T_{on}}{\Delta U_{MAX}}$$

I_F is the value of output current, ΔU_{MAX} is the ripple of power supply. Ton is the "ON" time of the MOSFET, normally set at about twice the "OFF" time.

If the source is an AC supply, the output voltage ripple from a nominal 12V AC transformer can be ±10%. If the input capacitor value is lower than 200μF, the AC input waveform will be distorted, and sometimes the lowest input voltage can be lower than the forward voltage of the LED strings. This lowers the average current of the

LEDs. Therefore, it is recommended to select the value of the capacitor bigger than 200uF.
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.

Inductor selection
Recommended inductor values for the IS31LT3380 are in the range of 47µH to 220µH.
Higher values of inductance are recommended at higher supply voltages and low output current 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. The inductor should be mounted as close to the chip as possible with low resistance connections to the LX and V_{IN} 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. It is recommended to use inductor with saturation current bigger than 1.2A for 700mA output current and inductor with saturation current bigger than 500mA for 350mA output current,etc.
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.

LX Switch 'On' time

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

Note: T_{ONmin}>200ns

LX Switch 'Off' time

$$T_{OFF} = \frac{L\Delta I}{V_{LED} + V_D + I_{AVG}(rL + R_S)}$$

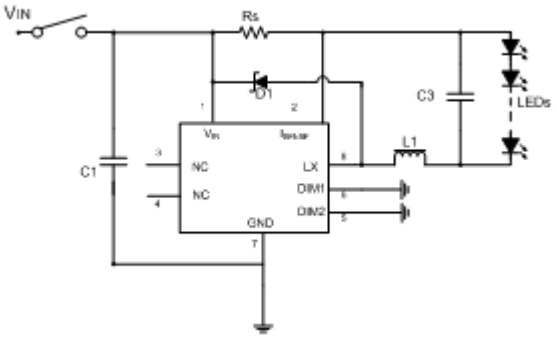
Note: T_{OFFmin}>200ns

Where:
L is the coil inductance (H)
r_L is the coil resistance (Ω)
I_{avg} is the required LED current (A)
ΔI is the coil peak-peak ripple current (A) {Internally set to 0.3 × Iavg}
V_{IN} is the supply voltage (V)
V_{LED} is the total LED forward voltage (V)
R_{LX} is the switch resistance (Ω)
V_D is the diode forward voltage at the required load current (V)

Example:
For V_{IN}=12V, L=47µH, r_L=0.26Ω, V_{LED}=3.4V, Iavg =333mA and V_D =0.36V, R_{LX}=0.27Ω
T_{ON} = (47e-6 × 0.105)/(12 - 3.4 - 0.274) = 0.59µs
T_{OFF} = (47e-6 × 0.105)/(3.4 + 0.36 + 0.188)= 1.25µs
This gives an operating frequency of 543kHz and a duty cycle of 0.32
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.
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 C3 across the LED(s) as shown below:



A C3 value of 1µF will reduce nominal ripple current by a factor of approximately three. 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.

Thermal considerations

When operating the chip at high ambient temperatures, or when driving maximum load current, care must be taken to avoid exceeding the package power dissipation limits. Note that the chip power dissipation will be a maximum at the 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.

Layout considerations

VIN/GND pin

The GND of the power supply usually has some distance between it and the chip GND pin, causing parasitic resistance and inductance, resulting in ground voltage bounce when the MOSFET switches. To minimize ground bounce, the ground pin of the chip should be soldered directly to the ground plane. Connecting a 0.1uF capacitor between the VIN and GND pins as close to the chip as possible minimizes the effects of ground bounce.

LX pin

The LX pin of the chip is a fast switching node, so PCB traces should be kept as short as possible.

Coil and decoupling capacitors

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

DIM pin

The DIM pin is a high impedance input, when it is left floating; this pin is pull up to 3.3V by internal circuit. Avoid running any high voltage traces close to the DIM pins.

PACKAGE INFORMATION

SOP-8

