Universal High Brightness Led Driver

❖ GENERAL DESCRIPTION

The AX9380 is an average current mode control high brightness LED driver IC with active power factor correction function.

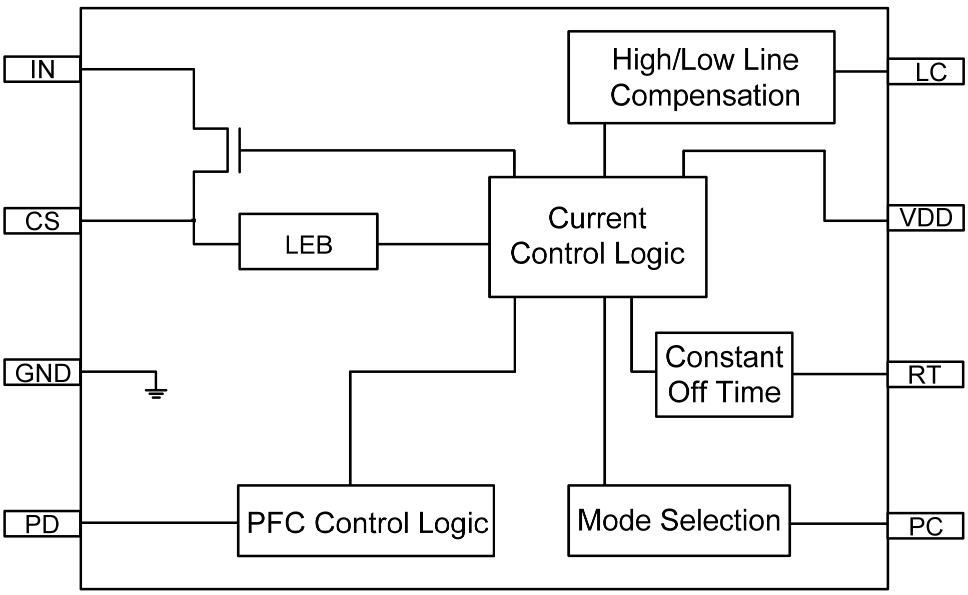
The line and load compensations are applied in the AX9380 to improve the output current regulation. The LED current accuracy is ±5%.

The AX9380 includes a special circuit, is able to reduce AC input current distortion that allows universal operation with an extremely high PF. The AX9380 is ideally suited for buck LED drivers. The IC operates in a constant off-time mode. The AX9380 also provides system output short circuit protection.

❖ FEATURES

- Universal Rectified 90VAC to 264VAC Input Voltage Range
- Built-in Active Power Factor Correction Technique
- Constant Current Control LED Driver
- High Efficiency Application
- Built-in Output Short Circuit Protection
- Constant Off-Time
- No External Loop Compensation Components Required
- Very Tight Line and Load Regulation
- Available in the 8-Pin Pb-Free SOP Package

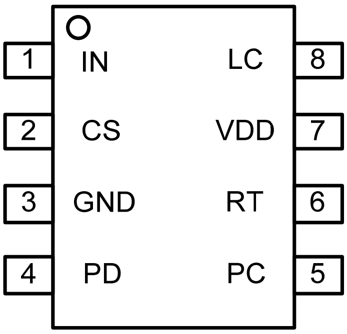
❖ BLOCK DIAGRAM



❖ PIN ASSIGNMENT

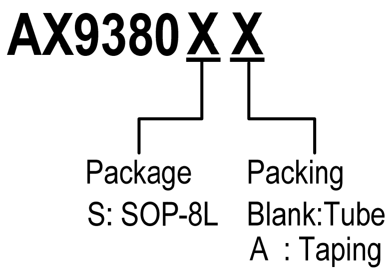
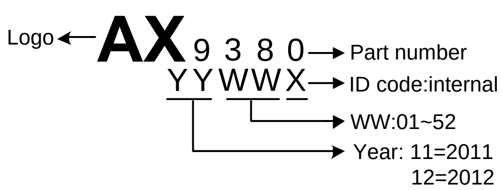
The package of AX9380 is SOP-8L; the pin assignment is given by:

SOP-8L



Name	Description
IN	Input pin of the internal NMOSFET.
CS	Current sense pin.
GND	Ground return for all internal circuitry.
PD	Power line sense pin.
PC	Pull down for average current mode Control. Do not let PC pin floating.
RT	Constant off-time setting.
VDD	Power supply pin for all internal circuit.
LC	Line compensation pin. Provide a potential to set the conduction angle.

❖ ORDER/MARKING INFORMATION

Order Information	Top Marking
	

❖ ABSOLUTE MAXIMUM RATINGS (at T_A=25°C)

Characteristics	Symbol	Rating	Unit
Operating voltage on Internal regulator	V_{DD}	6	V
Internal MOS drain voltage	V_{IN}	40	V
PD voltage to GND	V_{PD}	-0.3 to 40	V
PC voltage to GND	V_{PC}	-0.3 to 5	V
CS voltage to GND	V_{CS}	-0.3 to 5	V
RT voltage to GND	V_{RT}	-0.3 to 5	V
LC voltage to GND	V_{LC}	-0.3 to 5	V
Operating junction temperature rang	T_J	-40 to + 125	°C
Operating ambient temperature rang	T_{OPA}	-40 to +85	°C
Storage temperature rang	T_{ST}	-65 to +150	°C
Lead temperature (Soldering 5 sec)	T_{LEAD}	260	°C
Power dissipation	P_D	0.4	W
ESD rating (Human body mode)	V_{ESD}	2	kV
Thermal Resistance from Junction to ambient	θ_{JA}	160	°C/W

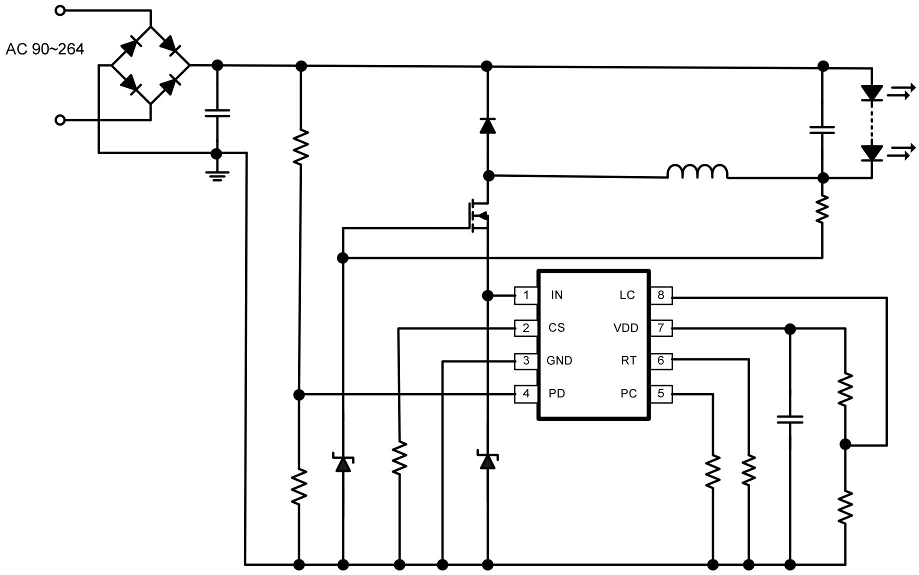
❖ ELECTRICAL CHARACTERISTICS

(T_A=25°C, unless otherwise noted)

Characteristics	Symbol	Conditions	Min	Typ	Max	Units
VDD SECTION						
V_{DD} operation range	V_{DD}	After turn-on	4.8	5.0	5.2	V
V_{DD} turn-on threshold	V_{DD_ON}		-	5	-	V
V_{DD} turn-off threshold	V_{DD_OFF}		-	4	-	V
V_{DD} UVLO hysteresis	V_{UVLO_HY}		-	1.0	-	V
Operation current	I_{OP}	Normal Operation	0.2	0.6	1.0	mA
POWER FACTOR CORRECTION FUNCTION						
Linear operation range	V_{PD}		-	0~20	-	V
LINE COMPENSTION						
Reference voltage	V_{LCREF}		-	0~4	-	V
INTERNAL POWER MOSFET SECTION						
Turned on resistance	$R_{DS(ON)}$		0.1	0.2	0.3	Ω
CURRENT SENSE SECTION						
Current reference voltage	V_{CS}		480	500	520	mV
Leading edge blanking time	T_{LEB}	V_{IN} = 15V to 450V	360	420	500	ns
RT SECTION						
Constant off-time at Low-Line	t_{off}	R_{RT} = 200KΩ at Low-Line	-	18	-	μs
		R_{RT} = 200KΩ at High-Line	-	26.8	-	μs

Note 1: Stresses listed as the above “Absolute Maximum Ratings” may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.
Note 2: Thermal Resistance is specified with the component mounted on a low effective thermal conductivity test board in free air at T_A=25°C.
Note 3: Devices are ESD sensitive. Handing precaution recommended.
Note 4: The device is not guaranteed to function outside its operating conditions

❖ APPLICATION CIRCUIT



❖ APPLICATION INFORMATION

THEORY OF OPERATION

The diode rectifier converts the input sinusoid to unipolar output, which can have pulsating waveform. When V_{DD} is fully charged to a voltage higher than V_{DD_ON}, and then AX9380 will start work. AX9380 is internally compensated inside the digital logic control, and no external components are required for loop compensation. The AX9380 uses an advanced digital control algorithm to simplify design flow and improve reliability.

AX9380 works in on-time modulation control mode and off-time setting is specifically decided by external resistor.

The digital logical control is based on the voltage signal of V-Line and MOSFET current signal to control on-time of each duty cycle. Furthermore, built-in active power factor correction technique enables LED current to shape as sinusoid in phase with the input line voltage cycle by cycle, so an excellent power factor can be implemented.

(1) High and Low Line Input Voltage Compensation

A buck converter operates when the input line voltage (V-Line) is higher than output voltage, and then the converter transfers energy to inductor and load. When V-Line is higher than LED forward voltage, LED can be turned on. As a result, in the condition of high and low line input voltage, due to the difference of LED current conduction angle (θ_t), the input voltage regulation will be influenced.

AX9380 is designed to operate in fixed conduction angle by LC (Line Compensation), enables to get the same conduction angle in high and low line voltage. Hence, AX9380 can achieve excellent input line regulation.

(2) Output Short Circuit Protection

Output short circuit protection is implemented to protect the chip from operating at short circuit conditions. When output load short circuit happens, the inductor current will be over stored; it will be detected by RCS and feed forward to control circuit.

If the voltage at the CS pin reaches higher than 1V within a 2us, the hiccup protection mode will be triggered. If the short circuit condition has not been cleared, the AX9380 will remain hiccup mode until the short is cleared. Thus, it reduces the input power consumption and protects power components.

(3) Off-Time Auto-Extension

The duty cycle of buck converter can be calculated as D=Vo/Vin. As a result, the higher input voltage, the smaller duty cycle. If off-time is fixed, on-time is inversely proportional to the input voltage, and frequency is proportional to the input voltage.

In order to avoid over-high operating frequency at high input voltage, the controller is specially designed to extend the fixed off-time automatically at high input voltage to lower operating frequency.

Off-Time Setting

AX9380 offers an off-time setting function via connect a resistor from RT to GND. A maximum 150 KHz switching frequency is set by the AX9380 to ensure better EMI performance, normally 30~45 KHz are recommended. Furthermore, due to the difference of the off-time at high line and low line voltage conditions. The line input voltage variation needs to be taken into account in design. The relationship between off-time setting and operating frequency is regulated as:

Switching period: $T = \frac{t_{off}}{1-D}$

Duty cycle: $D = \frac{V_{LED}}{V_{IN}}$

$$D_{\min} = \frac{V_{LED}}{V_{IN(PK)}}$$

Operating frequency: $f = \frac{1}{T}$

Minimum switching period: $T_{\min} = \frac{T_{off}}{1-D_{\min}}$

Maximum operating frequency: $f_{\max} = \frac{1}{T_{\min}}$

When input voltage is 115VAC,

$$f_{\max(115Vac)} = \frac{1}{T_{\min(115Vac)}}$$

When input voltage is 230VAC, $f_{\max(230Vac)} = \frac{1}{T_{\min(230Vac)}}$

The relationship between RT value and off-time, please refer to Table 1 and Figure 3.

Table 1

RT	toff (Low-Line)	toff (High-Line)
50KΩ	6.0us	10.8us
60KΩ	7.1us	12.4us
70KΩ	8.1us	13.9us
85KΩ	9.5us	16us
100KΩ	10.8us	17.9us
120KΩ	12.4us	20.1us
150KΩ	14.7us	23us
180KΩ	16.7us	25.4us
200KΩ	18.0us	26.8us
240KΩ	20.2us	29.2us
300 KΩ	23.0 us	32.1 us
360 KΩ	25.4 us	34.4 us
430 KΩ	27.8 us	36.5 us
499 KΩ	29.8 us	38.2 us
600 KΩ	32.2 us	40.1 us
700 KΩ	34.1 us	41.6 us
800 KΩ	35.8 us	42.8 us
900 KΩ	37.1 us	43.7 us
1000 KΩ	38.3 us	44.6 us
RT = V_{DD}	53.5 us	53.5 us

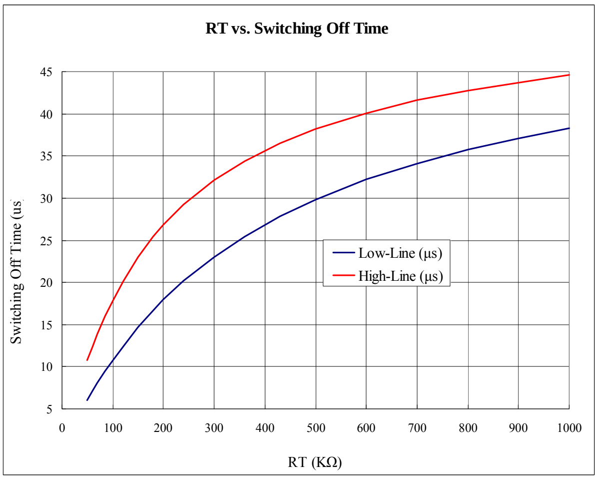


Figure 3

Current Conduction Angle

Due to the limit of structure, if the input voltage is lower than LED forward voltage, the buck converter cannot drive LED load. When the system operates in the range of 90Vac ~ 264Vac, the different conduction angles will result in bad line regulation at high line and low line input voltage conditions.

However, AX9380 has a particular design, enables the threshold angle (θ_{th}) that the current flow through and available conduction angle (θ_t) to be fixed and thus lead to an excellent line regulation. Here, $\theta_t=\pi-2\theta_{th}$ is the available conduction angle (from θ_{th} to $\pi-\theta_{th}$) which can be set by resistor divider, as shown in Table 2 and Figure 4.

Table 2

V_{LED} Range	V_{LED} ≦ 60V	V_{LED} ＞ 60V
RLC1 (Ω)	330KΩ	330KΩ
RLC2 (Ω)	330KΩ	796KΩ
VLC (V)	2.5V	3.535V
θ_{th} (π/180°)	(1/6) π	(1/4) π
θ_t (π/180°)	(2/3) π	(1/2) π
Cos (θth)	0.866	0.707

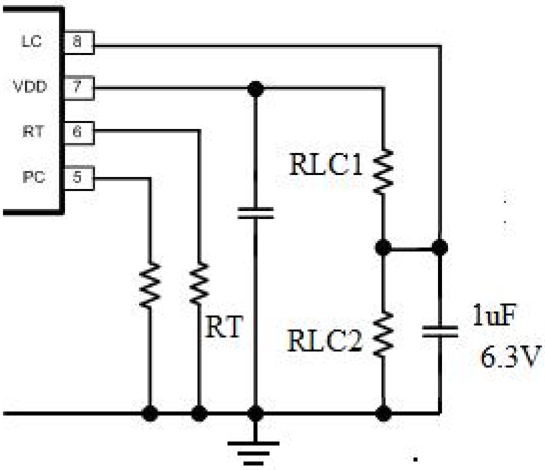


Figure 4

LED Current

The LED average current can be set by the current-sensing resistance from CS pin to GND. R_{CS} is calculated as:

$$R_{CS}=[Cos(\theta_{th})/(\pi\times I_{LED})]\times K$$

$$I_m=\frac{(\pi\times I_{LED})}{2K\times Cos(\theta_{th})}$$

Where K is a constant of AC line voltage, the value is 0.97.

Inductor Selection

For selecting the inductor, the inductance and saturation current have to be considered. Both of these parameters can be obtained from the inductor ripple current, output voltage and off-time.

(1) Peak of Current Command

$$I_m = \frac{(\pi \times I_{LED})}{2K \times Cos(\theta_{th})}$$

Where:

I_m is the mean inductor current at the phase of π/2 line voltage, I_{LED} is the LED average current, θ_{th} is the threshold angle where the LED current starts flowing.

(2) Inductor Ripple Current

To avoid inductor operating in DCM, the current ripple has to meet the following equation:

$$\Delta I_L \leq 2 I_m \sin(\theta_{th})$$

(3) Inductance

The minimum inductance can be calculated by the maximum ripple current, LED voltage and off-time which is at high line input voltage.

$$\Delta I_L = \frac{V_{LED} \times t_{off}}{L}$$

(4) Inductor Saturation Current

In order to avoid an variation of inductor in mass production, the saturation current must be greater 1.5 times of the $I_{L(PK)}$.

$$I_{L(pk)} = \frac{1}{2}\Delta I_L + I_m$$

$$I_{L(set)} \geq 1.5 I_{L(pk)}$$

Where:

$I_{L(PK)}$ = peak inductor current

Power Voltage Phase Detection

As shown in Figure 5, the PD pin is one of the input pin of the internal multiplier. This pin should be connected to the tap of the resistor divider from the rectified instantaneous line voltage. Maximum rating of the resistor must be taken into consideration, here selecting two 1206-280kΩ resistors and a 0805-30kΩ resistor in series. A 10nF~33nF MLCC is added next to the 0805-30kΩ resistor in parallel to bypass noises, and A 1kΩ resistor is also added in series on PD pin to resist the inrush current that may happen from the power line.

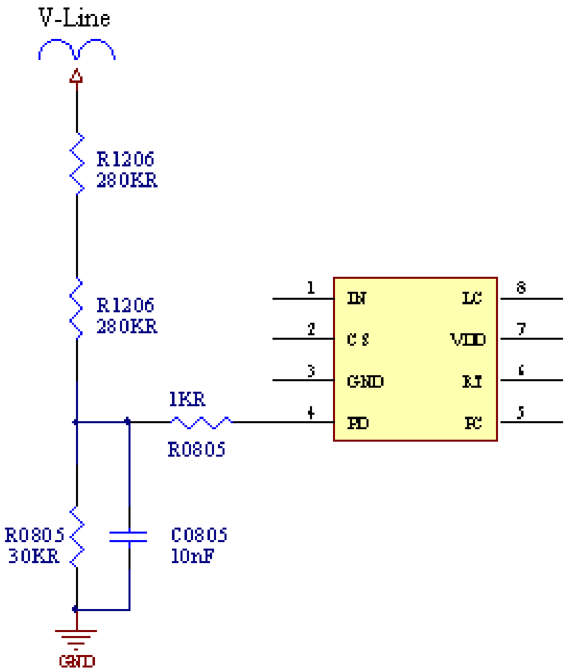
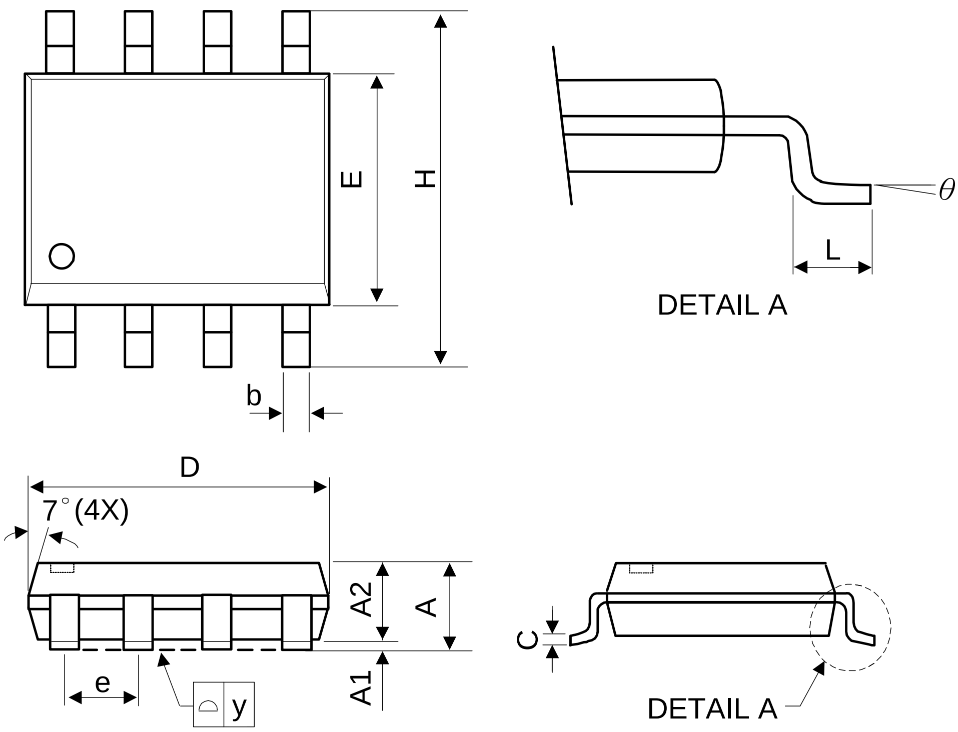


Figure 5

❖ PACKAGE OUTLINES



Symbol	Dimensions in Millimeters			Dimensions in Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	-	-	1.75	-	-	0.069
A1	0.1	-	0.25	0.04	-	0.1
A2	1.25	-	-	0.049	-	-
C	0.1	0.2	0.25	0.0075	0.008	0.01
D	4.7	4.9	5.1	0.185	0.193	0.2
E	3.7	3.9	4.1	0.146	0.154	0.161
H	5.8	6	6.2	0.228	0.236	0.244
L	0.4	-	1.27	0.015	-	0.05
b	0.31	0.41	0.51	0.012	0.016	0.02
e	1.27 BSC			0.050 BSC		
y	-	-	0.1	-	-	0.004
θ	0°	-	8°	0°	-	8°

Mold flash shall not exceed 0.25mm per side
JEDEC outline: MS-012 AA