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MT7896

TRIAC Dimmable Constant Current LED Driver

DESCRIPTION

MT7896 is a high precision LED constant current controller. It operates in critical conduction mode (CRM) with zero current switched-on and peak current switched-off. It's mainly targeted for BUCK-BOOST LED power systems. MT7896 supports high power factor application. The Power Factor (PF) can reach 0.8 or higher.

CRM ensures that the MT7896 turns on the internal power MOSFET when the inductor current reaches zero, reducing the power MOSFET switching loss. With critical conduction mode, and line compensation, MT7896 outputs high accuracy LED current, and further achieves excellent line regulation and load regulation.

MT7896 embedded with 600V power MOSFET, it can achieve simplified peripheral circuits and low BOM cost.

MT7896 provides various protection features to improve the system reliability, including over current protection (OCP), short circuit protection (SCP), adjustable over voltage protection (OVP) and over temperature LED current foldback, etc. With a wide dimmer compatibility, the dimming curve meets the NEMA SSL6 standard.

FEATURES

- Supports high PF application (PF>0.8)
- Wide range of dimmer compatibility
- Deep dimming level (<1%)
- Internal 600V power MOSFET
- Highly accurate constant LED current
- Cycle-by-cycle current limiting
- LED short circuit protection
- Adjustable LED over voltage protection
- Under-voltage lockout (UVLO) protection
- Over temperature LED current foldback
- Available in SOP7 package

APPLICATIONS

- LED bulb, panel light
- Filament bulb
- General purpose constant current source

Typical Application Circuit
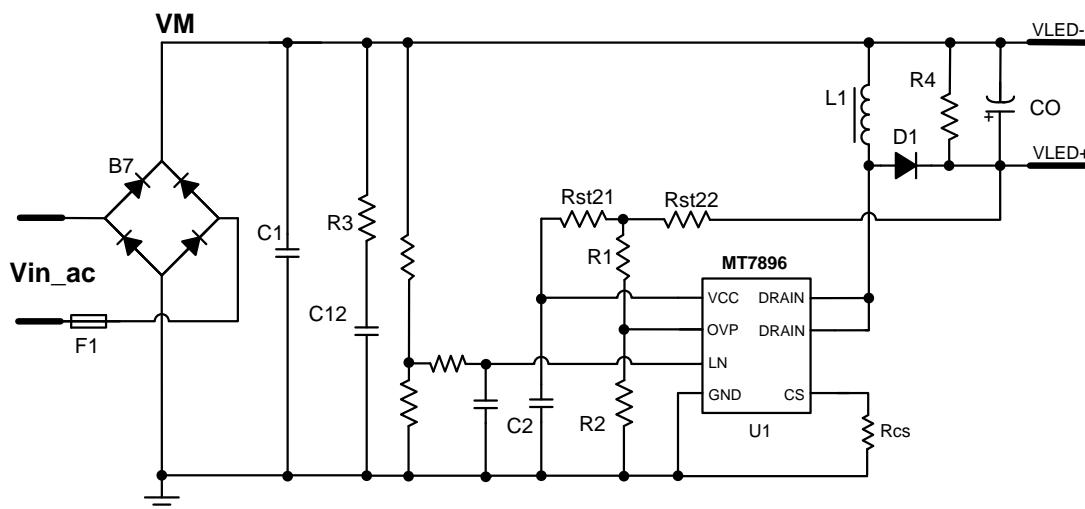
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ABSOLUTE MAXIMUM RATINGS

VCC maximum sink current	5mA
OVP (over voltage protection pin voltage)	-0.3 ~ 6V
LN (line compensation pin voltage)	-0.3 ~ 6V
DRAIN (internal HV power MOSFET drain voltage)	-0.3V ~ 600V
CS (current sense pin input voltage)	-0.3V ~ 6V
P_{DMAX} (maximum power consumption)	0.8W
Storage Temperature	-55°C ~ 150°C
Junction Temperature (Tj)	150°C

RECOMMENDEDE OPERATING CONDITIONS

Operating Temperature range	-40°C ~ 105°C
Output Power	<8W @ V_{OUT}=72V

Thermal resistance

Junction to ambient ($R_{\theta JA}$)	128°C/W
Junction to Case ($R_{\theta JC}$)	90°C/W

PIN CONFIGURATIONS
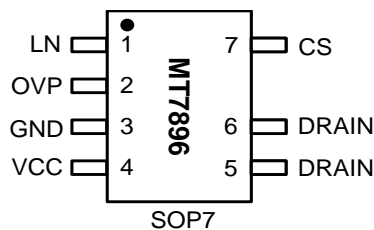
Chip Mark

MT7896
YY WW xx

— Manufacture code
— Week code
— Year code

PIN DESCRIPTION

Name	Pin No.	Description
LN	1	Line compensation pin. Tie to GND to disable line compensation function
OVP	2	Adjustable over voltage protection pin
GND	3	Chip ground
VCC	4	Power supply, internal clamped at 19V
DRAIN	5/6	Drain of internal high-voltage power MOSFET
CS	7	Current sense pin, connect a sense resistor to ground

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ELECTRICAL CHARACTERISTICS

(Test condition: VCC=12V, TA=25°C unless otherwise stated.)

Symbol	Parameter		Min	Typ	Max	Unit
Start-up and supply voltage (VCC Pin)						
I_{START}	Start up current	$V_{CC} < V_{CC\_UV}$		160	200	µA
V_{CC_UV}	Lower threshold voltage of V_{CC} (UVLO)	V_{CC} Pin ramp down		7		V
V_{START}	Start-up voltage	V_{CC} Pin ramp up		14		V
$V_{CC-CLAMP}$	V_{CC} Clamping voltage	$I_{DD} < 5mA$		19		V
I_{op}	Operating current			0.3		mA
Current sense (CS Pin)						
V_{CS-TH}	Threshold voltage for peak current limit		390	400	410	mV
LEB	Leading edge blanking time for current sense			500		ns
V_{LN}	Threshold voltage for line compensation			2.7		V
Over voltage protection						
V_{TH_OVP}	Threshold voltage for OVP			1		V
Thermal Protection						
T_{ADJ}	Temperature threshold for LED current foldback			150		℃
Driver Circuit						
T_{OFF_MIN}	Minimum OFF time			2		us
T_{OFF_MAX}	Maximum OFF time			200		us
T_{ON_MAX}	Maximum ON time			10		us
POWER MOSFET (DRAIN)						
R_{DSON}	Static drain-source on-resistance	VGS=10V/I_{DS}=1A		7.8		Ω
BV_{DSS}	Drain-source breakdown voltage	VGS=0V/I_{DS}=250uA	600			V

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BLOCK DIAGRAM
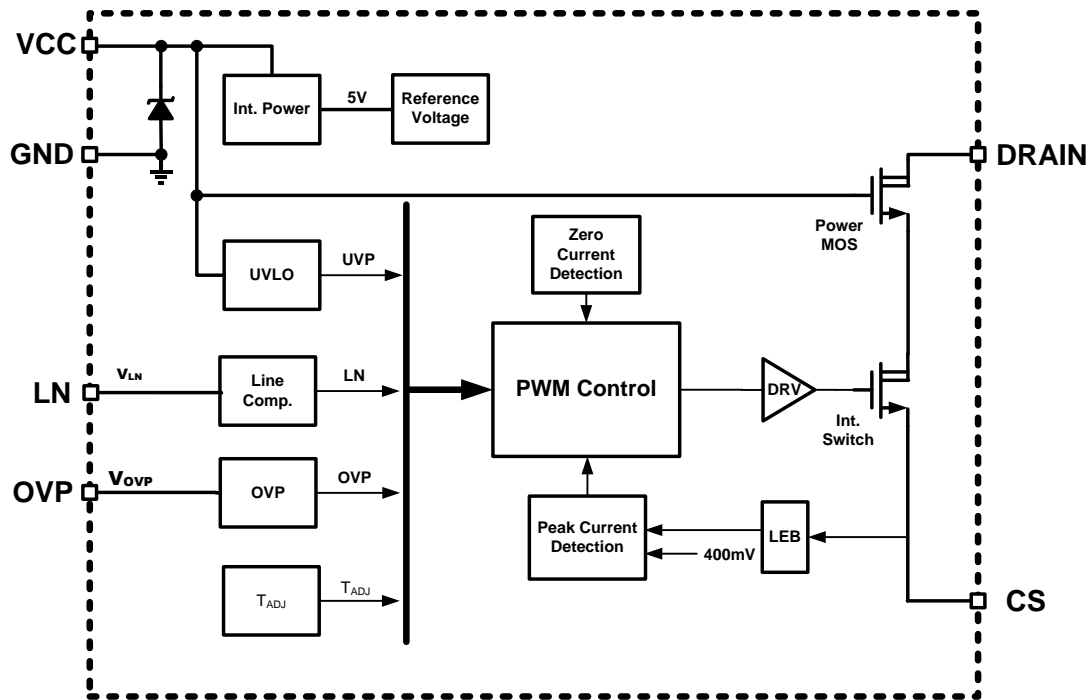
APPLICATION INFORMATION

MT7896 is a constant current driver with build-in 300V power MOSFET and is suitable for TRIAC dimmable LED system. The critical conduction mode and line compensation ensures that MT7896 outputs high accuracy LED current, and further achieves excellent line regulation and load regulation. With very few peripheral components, the system cost and size are greatly reduced.

Start up

VCC is charged by the startup resistor (or other startup circuit) once the system is powered on. As the VCC reaches 14V, the control logic starts to work, and internal switch starts toggling. When the VCC rises up to 19V, it will be clamped. MT7896 shuts down as VCC falls below 7V.

CRM and Output Current Setup

The peak current of the internal power MOSFET is cycle-by–cycle detected by monitoring the voltage on the CS pin. When the voltage reaches 400mV (internal reference voltage without line compensation function), the internal power MOSFET is turned off, when the inductor current drops to zero, it will be turned on again.

The peak inductor current without line compensation function is given by:

$$I_{LPK} = \frac{400}{R_{CS}}(mA) \qquad (1)$$

Where, R_{CS} is the current sense resistor in ohm. The CS comparator also includes a 500ns leading edge blanking time to block the transient noise as the power switch just turned on.
The current at LED can be calculated as:

$$I_{LED} = k \times \frac{I_{LPK}}{2} = k \times \frac{400\,mV}{2 \times Rcs}(mA) \qquad (2)$$

Where, I_{LPK} is the peak current of the inductor;
k is the compensation factor, and is less than 1. Shown in the equation (2), the output current is

determined by the R_{CS} and the 400mV reference voltage, insensitive to the inductance. Please utilize the design tool that Maxic provided to calculate the initial value of R_{CS}.
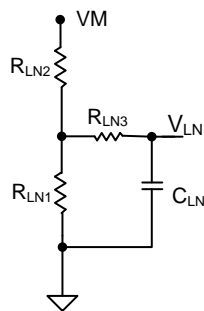
Line Compensation

MT7896 integrates the line compensation function. Once the voltage on LN pin (V_{LN}) exceeds 2.7V, the threshold for peak current limit decreases, thus, the input voltage compensation is achieved.

The relationship between V_{CS_PEAK} and V_{LN} as shown below:
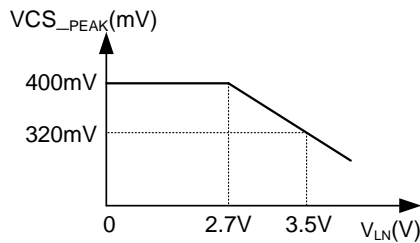
Where, V_{LN} is proportional to the average value of the rectified input voltage, which is obtained by sampling and filtering the input voltage as shown below:

Where, R_{LN1} is about 10kohm; R_{LN3} is about 200kohm; C_{LN} is about 1uF.

The passive filter R_{LN3} and C_{LN} converts the input line voltage VM to the DC-like line compensation voltage V_{LN}. Adjusting the ratio of R_{LN2} and R_{LN1} achieves optimized line compensation effect.

If the line compensation function is not needed, tie LN pin to ground.

Maxic provides design tool of MT7896 to help customer to design appropriate R_{LN1} and R_{LN2} ratio.

Switching Frequency

MT7896 operates in critical conduction mode. When the inductor current is zero, the system turns on the internal power MOSFET, the inductor current rises up from the ground. The on time of the power MOSFET is calculated by the equation:

$$T_{ON} = \frac{L \times I_{LPK}}{V_{IN}} \qquad (3)$$

Where, L is the inductance of the inductor;
I_{LPK} is the peak current through the inductor;
V_{IN} is the DC voltage of the rectified input voltage.

The internal power MOSFET is turned off, while the voltage on the CS pin increases to 400mV. The inductor current will discharge the LED through the free-wheeling diode. The internal power MOSFET won't be turned on until the current in the inductor drops to zero. The off time of the power MOSFET is calculated by the equation:

$$T_{OFF} = \frac{L \times I_{LPK}}{V_{LED}} \qquad (4)$$

Operating frequency of the system is:

$$F = \frac{1}{T_{ON} + T_{OFF}} = \frac{V_{IN} \times V_{LED}}{L \times I_{LPK} \times (V_{IN} + V_{LED})} \qquad (5)$$

From the equation, it's showing that MT7896 operating frequency is determined by the input voltage V_{IN}, the LED forward voltage drop V_{LED} and the inductance L. The higher input voltage V_{IN} makes the operating frequency to be higher. For both EMI and efficiency consideration, it's recommended to set the operating frequency between 30kHz ~ 120kHz. The appropriate inductance should be determined at minimum input voltage condition to meet the requirement. MT7896 sets the minimum off time T_{OFF_MIN}=2us. Shown in T_{OFF} equation, if the inductance is too small, the T_{OFF} may be shorter than T_{OFF_MIN}, the

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system will operate in discontinuous conduction mode. The actual LED current will be smaller than the target value.

MT7896 determines the line valley automatically. The valley detection circuit is integrated in the MT7896. It senses when the input voltage reaches its lowest level (valley) automatically. MT7896 sets the maximum off time $T_{OFF\_MAX}=2.5us$ when the valley is detected in order to limit the operating efficiency. In application, the inductance should not be too big, it may cause the real current may not exactly match the design value by longer demagnetization time during valley.

Maxic provides design tool of this chip, it helps customer to come out proper solution and to choose the right inductance.

Over-current Protection

MT7896 immediately turns off the internal power MOSFET once the voltage on CS pin exceeds 400mV. This cycle-by-cycle current limitation scheme prevents the relevant components, such as power MOSFET, transformer, etc. suffers from damage.

LED Over voltage protection

The OVP threshold of MT7896 is adjustable by tuning the ratio of R1 and R2, which is connected to OVP pin (pin2).

The OVP threshold can be calculated as:

$$V_{OVP} = 0.9V \times \frac{R1}{R2} \qquad (6)$$

Resistor R2 is between 2.2kohm ~ 10kohm. Under the LED open circuit condition, MT7896 stops switching once the output voltage exceeds the OVP threshold, until the VCC is discharged to below UVLO threshold, the system restarts.

The OVP setting is as following circuit:
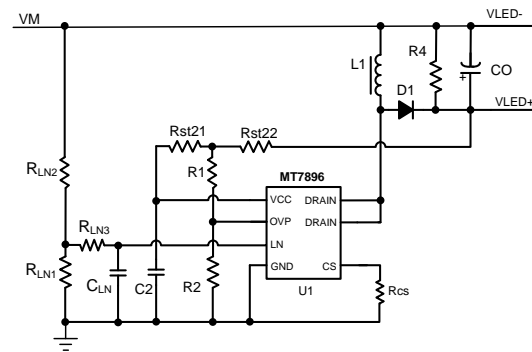
Consideration for OVP Setup：

1) For simplify design, sets Rst21= Rst22 to equally share the output voltage and to keep the equation (6) to be true. Rst21 and Rst22 are between 150k ~ 400k ohms. If it needs to support lower input voltage, these two resistors should be smaller. On the contrary, these resistors can be larger to improve efficiency.

2) Considering the accuracy of resistors R1, R2 and internal reference voltage, the calculated value of OVP threshold by Equation (6) may not exactly match the real value. The accurate OVP threshold can be achieved by adjusting the resistor R2. If the real OVP threshold is lower than expected, then the R2 should be decreased. On the contrary, R2 should be increased. It's recommended to set the initial value of R2 to around 4.7k ohms, R1 can be determined by the equation (6), finally, fine tuning R2 to get the accurate OVP threshold.

3) It is highly recommended to set the OVP threshold to be 1.5 times of the maximum LED voltage, not less than 1.3 times. For example, the maximum LED voltage is 60V, the OVP threshold is better configured as 1.5×60 = 90V. It is not recommended to set the OVP threshold too close to the normal operating LED voltage. It may false trigger the OVP protection during normal operation, resulting in flickering.

4) The OVP threshold can't be set too high

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once the inductor L is determined. Replacing the OVP threshold (V_{LED}) into the Equation (4), if the calculated value of the off time T_{OFF} is less than the T_{OFF_MIN} (2us), the system will work under discontinues conduction mode under open-circuit condition. In this case, the real OVP threshold will be much higher than the calculated value by Equation (6). In this case, it is recommended that the customers either lowering the OVP threshold or redesign the inductance to ensure that the off time T_{OFF} is longer than the T_{OFF_MIN} (2us) under open-circuit condition.

PCB Layout Consideration

1) The VCC de-couple capacitor (typically 1uF ~ 4.7uF ceramic capacitor) should be kept as close to the VCC pin as possible (no more than 5mm). This can greatly improve the system noise immunity.

2) The pin5, pin6 are the drain of the power MOSFET. They are the major noise disturbance source. Should put GND plane under the chip to shield the drain terminal with other pins. Recommended to put copper plane at DRAIN pins for better thermal dissipation.

3) The OVP (pin2) connection wire should be as short as possible. The connection wire and the related resistor terminals must be placed far away from the high voltage components (>3mm), such as the MOSFET drain (pin5, pin6), VCC pad, etc.

4) The RC filter of LN pin (pin1) should be kept as close to the LN pin as possible, and the divider terminals must be placed far away from the high voltage components and other noise sources

5) The area of main current loop should be as small as possible to reduce EMI radiation, such as the related pathways area of the inductor current.
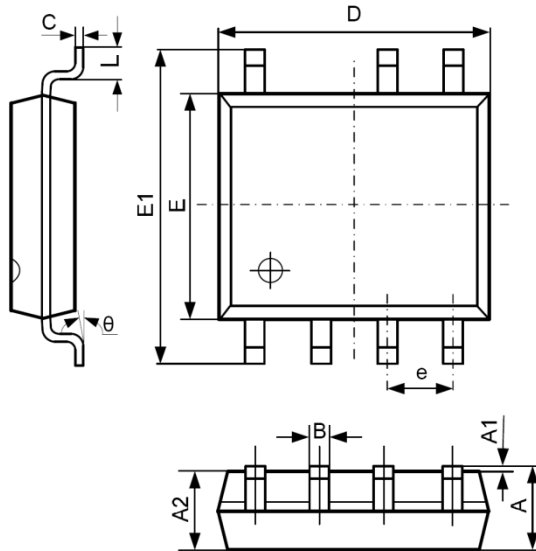
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PACKAGE INFORMATION

SOP-7 PACKAGE OUTLINE AND DIMENSIONS

SYMBOL	DIMENSION IN MILLIMETERS		DIMENSION IN INCHES	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
B	0.330	0.510	0.013	0.020
C	0.190	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	3.800	4.000	0.150	0.157
E1	5.800	6.300	0.228	0.248
e	1.270 TYP		0.050 TYP	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

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