DESCRIPTION

The MT7910 is a hysteresis current mode control LED driver IC. The MT7910 operates in constant off-time mode. It allows efficient operation of High Brightness (HB) LEDs from voltage sources ranging from 14V_{DC} up to 450V_{DC} or 85V_{AC} ~ 265V_{AC}. The MT7910 includes a PWM dimming input that can accept an external control signal with a duty ratio of 0 - 100% and a frequency of up to a few kilohertz. It also includes a 0 - 245mV linear dimming input which can be used both for linear dimming and temperature compensation of the LED current.

The MT7910 is ideally suited for buck LED drivers. Since the MT7910 operates in hysteresis current mode control, the controller achieves good output current regulation without the need for any loop compensation. Further, with Maxic proprietary control technology (patent pending), MT7910 achieves precision output current accuracy from 85VAC ~ 265VAC. PWM dimming response is limited only by the rate of rise and fall of the inductor current, enabling very fast rise and fall times.

Frequency jittering is used to reduce the EMI.

FEATURES

- Proprietary constant-current control. Great LED current accuracy.
- Wide input range from 14VDC to 450VDC or 85VAC to 265VAC
- Application from a few mA to more than 1A output
- Up to 92% efficiency
- Up to hundreds of LEDs
- Linear and PWM dimming capability
- Requires few external components for operation
- Temperature compensation to regulate LED current
- Embedded Over-temperature, LED open circuit, LED short-circuit protection
- SOP-8 package

APPLICATION

- DC/DC or AC/DC LED driver applications
- RGB backlighting LED driver
- General purpose constant current source
- Signal and decorative LED lighting
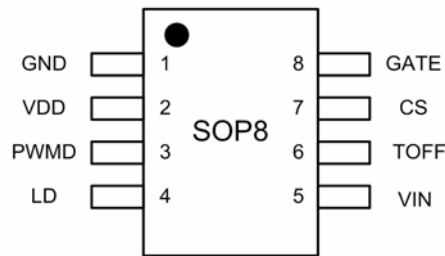- E14/E27/PAR30/PAR38/GU10 LED lamp

TYPICAL APPLICATION CIRCUIT
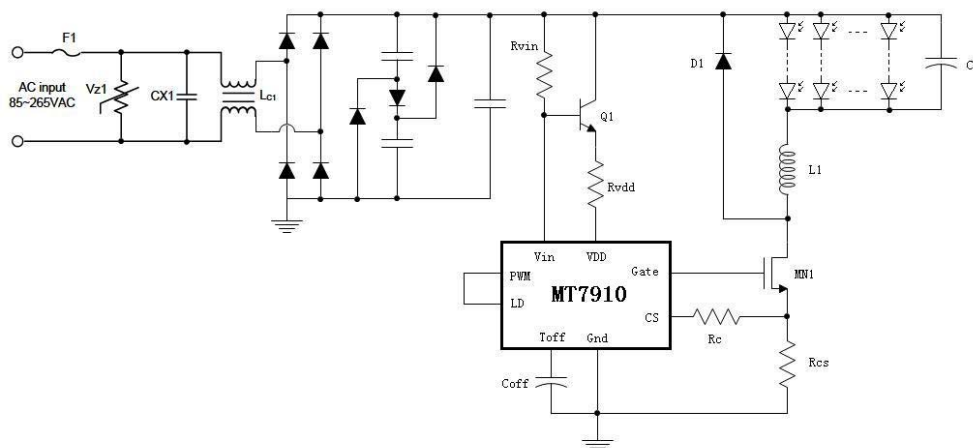
ORDERING INFORMATION

Part Number	Temp Range	Quantity per reel	Package	Vcs
MT7910_BIN1	-40℃ ~ 105℃	2500	SOP8	217mV (208mV~226mV)
MT7910_BIN2	-40℃ ~ 105℃	2500	SOP8	245mV (235mV~255mV)
MT7910_BIN3	-40℃ ~ 105℃	2500	SOP8	269mV (258mV~280mV)

PIN CONFIGURATIONS

PIN DESCRIPTION

Name	Pin No.	Description
GND	1	Ground return for all internal circuitry.
VDD	2	Internal circuits power supply. Internally clamped at 10V. It must bypass to GND with a capacitor as close as possible.
PWMD	3	This is the PWM dimming input of the IC. When this pin is pulled to GND, the gate driver is turned off. When the pin is pulled high, the gate driver operates normally. Internal 300kohm pull-up to 4V. During PWM dimming, LD pin can short with PWMD pin.
LD	4	Linear dimming input and sets the current sense threshold as long as the voltage is less than 245mV (typ). When the voltage at this pin large than 245mV, the current sense threshold clamped at 245mV internally. This pin can also used as temperature compensation threshold voltage. *Special Note: LD Pin can't leave floating.* When no analog dimming is required, this pin can short with PWMD pin (PWMD pin already pull-up by internal resistor).
VIN	5	This pin is the input of an 14V – 450V voltage supply through a resistor, internally clamped at 12V. It also used to sense the line voltage for output current compensation.
TOFF	6	This pin sets the off time of the power MOSFET. It can be floating with the internal set off time 500ns. When a capacitor is connected between TOFF and GND, the off time is increased.
CS	7	This pin is the current sense pin used to sense the FET current by means of an external sense resistor. When this pin exceeds the lower of either the internal 245mV or the voltage at the LD pin, the gate output goes low.
GATE	8	This pin is the output gate driver for an external N-channel power MOSFET.

ABSOLUTE MAXIMUM RATINGS

VIN / VDD / GATE Pin	-0.3V to +16V
All other pins	-0.3V to +6V
ESD (HBM)	$\pm$4000V
Storage Temperature	-55°C to 150°C
Thermal Resistance	
Junction to ambient (RθJA)	128°C/W

ELECTRICAL CHARACTERISTICS

(Test conditions: TA=25°C unless otherwise stated.)

Symbol	Description	Conditions	Min	Typ	Max	Unit
VDC	Input DC supply voltage range	Connect an appropriate resistor from DC supply voltage to VIN pin and VDD pin	14		450	
VDD	Internal regulated voltage	Get power from DC power rail through a resistor or transistor		10		V
VIN	Internal regulated voltage for line compensation	Connect to DC power rail through a resistor		12		V
Iin	Operating current	Gate floating		0.5		mA
Under Voltage lockout						
UVLO	Under voltage lockout	VDD rising.		8		V
ΔUVLO	UVLO hysteresis	VDD falling		2		V
Enable						
$V_{EN(lo)}$	PWMD input low voltage				1.2	V
$V_{EN(hi)}$	PWMD input high voltage		2			V
R_{EN}	PWMD pull up resistance			300		KΩ
Linear Dimming						
V_{LD}	Linear dimming low voltage			50		mV
	Linear dimming high voltage			245		mV
Current sense stage						
Vcs	Current sense pull-in threshold voltage	BIN1	208	217	226	mV
		BIN2	235	245	255	mV
		BIN3	258	269	280	mV
Tblank	Current sense blank time			430		ns
Toff	Off time	TOFF Pin floating		200		ns
Ioff	Off time current			20		uA

Driver stage						
trise	Gate output rise time	Cgate=500pF		42		ns
tfall	Gate output fall time	Cgate=500pF		30		ns
Over Temperature Protection						
OTP	Thermal protection threshold			160		°C
	OTP hysteresis			30		°C

APPLICATION INFORMATION

MT7910 is a low-cost off-line buck, boost or buck-boost converter control IC specifically designed for driving multi-LED strings or arrays. It can be operated from either universal AC line or any DC voltage between 14-450V. Optionally, a passive power factor correction circuit can be used in order to pass the AC harmonic limits set by EN 61000-3-2 Class C for lighting equipment having input power less than 25W. The MT7910 can drive up to hundreds of High-Brightness (HB) LEDs or multiple strings of HB LEDs. The LED arrays can be configured as a series or series/parallel connection.

The MT7910 regulates constant current by using hysteresis current mode that ensures controlled brightness and spectrum of the LEDs, and extends their lifetime. This control method provides fairly accurate LED current control without the need for a high side current sensing or the design of any additional loop compensation. The IC uses very few external components and provides for either Linear or PWM control of the LED current.

A capacitor connected to the TOFF (Pin6) pin programs the off-time of the oscillator inside. The oscillator produces pulses at regular intervals. These pulses set the SR flip-flop in the MT7910 which causes the GATE driver to turn on. When the MOSFET turns on, the current through the inductor starts ramping up. This current flows through the external sense resistor R_{CS} and produces a ramp voltage at the CS pin. The comparators are constantly comparing the CS pin voltage to both the voltage at the LD pin and the internal 245mV (for BIN2; for BIN1 is 217mV; for BIN3 is 269mV). Once the blanking time is complete, the output of these comparators is allowed to reset the flip-flop. When the output of either one of the two comparators goes high, the flip-flop is reset and the GATE output goes low to shut off the external MOSFET.

Assuming a 70% ripple in the inductor, the current sense resistor R_{CS} can be set using (for BIN2):

$$R_{CS} = \frac{245mV(or V_{LD})}{(1 + 70\%/2) \bullet I_{LED}(A)} = \frac{245mV(or V_{LD})}{1.35 \bullet I_{LED}(A)}$$

Note: For BIN1, use 217mV to calculate. For BIN3 use 269mV to calculate.

Input Voltage Regulator

When a voltage is applied through a suitable input resistor or transistor to the VDD pin (Pin2), the MT7910 maintains a constant 10V (typ.) at the VDD pin. This voltage is used to power the IC. The VDD pin must be bypassed by a low ESR capacitor to provide a low impedance path for the high frequency current of the output GATE driver. The input current drawn from VDD pin is a sum of the 0.5mA(typ.) current drawn by the internal circuit and the dynamic current drawn by the GATE driver (which in turn depends on th switching frequency and the GATE charge of the

external MOSFET).

$$I_{VDD} \approx 0.5mA + Q_G \bullet f_S$$

Where f_S is the switching frequency and Q_G is the GATE charge of the external MOSFET (which can be obtained from the datasheet of the MOSFET).

Input voltage further applied through a suitable resistor to VIN pin (Pin5), MT7910 clamped VIN pin at 12V. This regulated voltage can be used to bias the base or gate of the NPN or NMOS transistor, which provides power to the VDD pin. Further more, MT7910 detects the line voltage VDC through VIN pin and compensates the line voltage variation. Combined with the peak current at CS pin control scheme, the accuracy of the LED current is greatly improved and almost insensitive to input voltage variation.

Current Sense

The current sense input of the MT7910 goes to the noninverting inputs of two comparators. The inverting terminal of one comparator is tied to an internal 245mV (for BIN2, BIN1 is 217mV, BIN3 is 269mV) reference, whereas the inverting terminal of the other comparator is connected to the LD pin. The outputs of both comparator are fed into an OR gate and the output of the OR gate is fed into the reset pin of the flip-flop. Thus, the comparator which has the lowest voltage at the inverting terminal determines when the GATE output is turned off.

The outputs of the comparator also includes a typical 430ns blanking tie which prevents spurious turn-offs of the external MOSFET due to the turn-on spike normally present in peak current mode control. In rare cases, this internal blanking time might not be enough to filter out the turn-on spike. In these case, an external RC filter needs to be added between the external sense resistor (R_{CS}) and the CS pin.

Please note that the comparators are relatively fast with a typical 80ns response time. A proper layout minimizing external inductances will prevent false triggering of these comparators.

Oscillator

Reference to Fig.1, the oscillator in the MT7910 is controlled by the capacitor connected at TOFF pin and series resistor connected to CS pin.
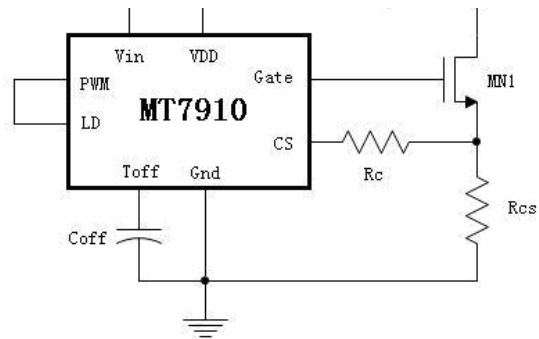

Fig.1 Setup Toff time

First the charge current is determined by R_C and R_{CS}, calculated as:

$$I_{off} = \frac{185mV}{(R_C + R_{CS})} \approx \frac{185mV}{R_C}$$

Where, normally R_{CS} << R_C. Typically, R_C=10KΩ, Ioff = 18.5uA.
Then, Toff time of the oscillator is given by:

$$T_{off} = \frac{C_{off} \bullet 2V}{I_{off}} \approx \frac{C_{off} \bullet R_C \bullet 2V}{185mV} = 10.8 \bullet C_{off}$$

where Coff is in pF and Toff is in us.
As equation shows, the Toff time is determined by external RC value. So the constant-off time is accurately controlled and consistency.

Linear Dimming

The Linear Dimming pin (LD pin) is used to control the LED current. An external voltage between 50mV to 245mV can be applied to the LD pin to adjust the LED current during operation. There are two cases when it may be necessary to use the Linear Dimming pin.

> In some cases, it may not be possible to find the exact R$_{CS}$ value required to obtain the LED current when the internal 245mV is used. In these cases, an external voltage divider from the VDD pin (Pin 2) can be connected to the LD pin to obtain a voltage (less than 245mV) corresponding to the desired voltage across R$_{CS}$.

> Linear dimming may be desired to adjust the current level to reduce the brightness of the LEDs. Connecting a resistor between VDD pin (Pin 2) and the LD pin (Pin 4), and also connecting an NTC thermistor between LD pin and ground (refer to Fig.3). The MT7910 is able to realize the temperature compensation function. (See more detail in **Temperature Compensation** section)

The use the internal 245mV, the LD pin must be connected to PWMD pin.

LD pin also works as enable pin. Pull LD pin to low (less than 50mV), MT7910 enters into shutdown mode. GATE goes low to turn off the external MOSFET. Applying a control voltage higher than 245mV will not change the output current setting. When higher current is desired, select a smaller sense resistor.

LD pin can't leave floating. When no analog dimming is required, even during PWM dimming, LD pin can short with PWMD pin to get the input level.

PWM Dimming

PWM Dimming can be achieved by driving the PWMD pin (Pin 3) with a low frequency square wave signal. When the PWM signal is low, the GATE driver is disabled; and when the PWMD signal is high, the GATE driver is enabled. The PWM signal can be generated by a microcontroller or a pulse generator with a duty cycle proportional to the amount of desired light output. This signal enables and disables the converter modulating the LED current in the PWM fashion. In this mode, LED current can be

in one of the two states: zero or the normal current set by the current sense resistor. Since the PWMD signal does not turn off the other parts of the IC, the response of the MT7910 to the PWMD signal is almost instantaneous. The rate of rise and fall of the LED current is thus determined solely by the rise and fall times of the inductor current.

To disable PWM dimming function, leave the PWMD pin floating.

Temperature Compensation

MT7910 provides thermal protection for LEDs. Refer to Fig.3, applying a NTC thermistor close to the LEDs string will realize the temperature compensation of LEDs current. If the temperature of the LEDs rises, the resistance of the NTC thermistor decreases until the voltage of the LD pin falls below 245mV. Then the average current is controlled by the LD pin and the temperature compensation function starts. The formula is as below:

$$\frac{R_{NTC} \bullet V_{DD}}{R_1 + R_{NTC}} = 245mV$$

Here VDD=10V. Assuming a 70% ripple in the inductor, the temperature compensated continues current may be computed as:

$$I_{out} = \frac{R_{NTC} \bullet V_{DD}}{(R_1 + R_{NTC}) \bullet R_{CS} \bullet 1.35}$$

Make sure the value of R1 is more than 5K.

When the LD pin voltage reduces to less than 50mV, the chip is shutdown.

After the ambient temperature returns to a safe temperature, the current will return to the set value.

Power Factor Correction

When the input power to the LED driver does not exceed 25W, a simple passive power factor correction circuit consisting of 3 diodes and 2

capacitors can be added across the rectified AC line input to improve the line current harmonic distortion and a achieve a power factor greater than 0.85. Reference to MT7910 typical application circuit (Fig.2, Fig.3).

LEDs Open Circuit Protection

When the buck topology is used, the LEDs is connected in series with the inductor, there is no need for any protection against an open circuit condition in the LED string. Open LED connection means no switching and the output current will ceased automatically.

Special note should be mentioned here, in LED open condition, V_O will reach V_{INDC_max}, so the capacitor C_O parallel with LED will tolerance V_{INDC_max} voltage instead of V_O.

LEDs Short-Circuit Protection

In buck topology, the LED string is short circuited, the output current will become bigger and bigger. When the output current reach MT7910 internal Over-current/Short-circuit protection threshold, MT7910 will stop switching, output current will drop to zero.

Short-circuit protection can only be cleared by power down.

DESIGN EXAMPLE

AC input voltage range: 85VAC ~ 265VAC
Output LED String: V_O = 48V (15 LEDs in series, 3.2V each)
I_O = 360mA (18 parallel LEDs, 20mA each branch)

Input Circuits

AC voltage through the full-bridge rectifier and capacitor, becomes approximately DC voltage,

$$V_{DC\_MAX} = \sqrt{2} \bullet V_{AC} = 120V \sim 375V \ ,$$ further

through the passive PFC circuit (3 diodes, 2 capacitors), the voltage valley is about half. So,

the final DC voltage to the MT7910 system is:

$$V_{INDC} = 60V \sim 375V$$

As current draw from VDD pin is about

$$I_{VDD} \approx 0.5mA + Q_G \bullet f_S \ , \text{ assume 1mA}$$

Refer to Fig.2 application circuit,

$$R_{vdd} = \frac{V_{INDC\_min} - VDD}{I_{VDD}}$$

$$= \frac{60V - 10V}{1mA} = 50k\Omega$$

When VINDC becomes maximum,

$$I_{VDD\_max} = \frac{V_{INDC\_max} - VDD}{R_{vdd}}$$

$$= \frac{375V - 10V}{50k} = 7.3mA$$

Even MT7910 only need 1mA, but the 6.3mA extra current is wasted. The power burn on R_{vdd} resistor is

$$(V_{INDC\_max} - VDD) \times I_{VDD\_max}$$
$$= (375V - 10V) \times 7.3mA = 2.66W$$

This is a huge power being wasted and will lower the system efficiency. So, application circuit shown in Fig.2 only suits for relatively low input voltage and low cost application, such as 110VAC input application.

In order to support full input voltage range, 85VAC~265VAC, application circuit in Fig. 3 will be considered.

MT7910 VDD power is supplied by an NPN transistor.

As VIN = 12V, VDD = 10V,

$$R_{vdd} = \frac{VIN - VDD - V_{be\_Q1}}{I_{VDD}}$$

$$= \frac{12V - 10V - 0.6V}{1mA} = 1.4k\Omega$$

Rin is around 500K to 800K, fine tune for line compensation to improve the output LED current

accuracy.

C_{vin} and C_{vdd} can chose 2.2uF/40V ~ 10uF/40V capacitor.

Toff Time Regulation Capacitor

For higher output voltage, lower output current application, we need to shorter Toff Time to obtain the application inductor smaller. For high output current application, it is suggested that the frequency is set no more than 50KHz (typical 25~30KHz). In MT7910, set Rc=10K, Ioff = 18.5uA,

$$T_{off} = \frac{C_{off} \bullet 2V}{I_{off}} \approx \frac{C_{off} \bullet R_C \bullet 2V}{185mV} = 10.8 \bullet C_{off}$$

where Coff is in pF, Toff is in us. For this application, chose Coff = 120pF, Toff = 12.96us.

The inductor (L1)

The inductor value depends on the ripple current in the LEDs. Normally, ripple current is about 30%~100% of the average current. Set ripple current as 60% of the output average current,

$$I_{ripple} = 60\% \times I_O = 60\% \times 360mA = 216mA$$

$$L = \frac{V_O \times T_{off}}{I_{ripple}} = \frac{48 \times 12.96us}{216mA} = 2.88mH$$

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

The DC resistance (DCR) of the inductor is also essential when choosing an inductor. Bigger DCR will leader to more heat. The value of the inductor will reduce as its temperature rises, leading to higher current ripple, which, in turn, reduces the average output current.

Current Sense Resistor (R$_{cs}$)

Designing for low current ripple will improve current accuracy, but it also requires a large value of inductor. High current ripple allows a lower cost inductor. So we need to consider these two factors when selecting an inductor. A capacitor C_O placed in parallel with the array of LEDs can be used to reduce the LED current ripple while keeping the same average current. A typical value is 1uF.

Since the output average current I_O = 360mA, Iripple = 216mA as above section calculated, then

$$I_{O\_Peak} = 0.5 \times I_{ripple} + I_O$$
$$= 0.5 \times 216 + 360 = 468mA$$

For BIN1: $R_{CS} = \dfrac{217mV}{I_{O\_Peak}} = \dfrac{217mV}{468mA} = 0.464\Omega$

For BIN2: $R_{CS} = \dfrac{245mV}{I_{O\_Peak}} = \dfrac{245mV}{468mA} = 0.524\Omega$

For BIN3: $R_{CS} = \dfrac{269mV}{I_{O\_Peak}} = \dfrac{269mV}{468mA} = 0.575\Omega$

MOSFET (MN1) and Diode (D1)

The peak voltage seen by the MOSFET is equal to the maximum input voltage. Using a 50% safety margin,

$$V_{FET} = 1.5 \times V_{INDC\_max} = 1.5 \times 375 = 563V$$

The maximum RMS current through the MOSFET depends on the maximum current. Hence, the current rating of the MOSFET is:

$$I_{FET} = 1.5 \times I_{O\_Peak} = 1.5 \times 468mA = 702mA$$

For the application, choose a MOSFET 600V, 1A to 2A. 2N60 is a good choice.

The peak voltage rating of the diode is the same as the MOSFET.

$$I_{diode} = 1.5 \times I_{O\_Peak} = 1.5 \times 468mA = 702mA$$

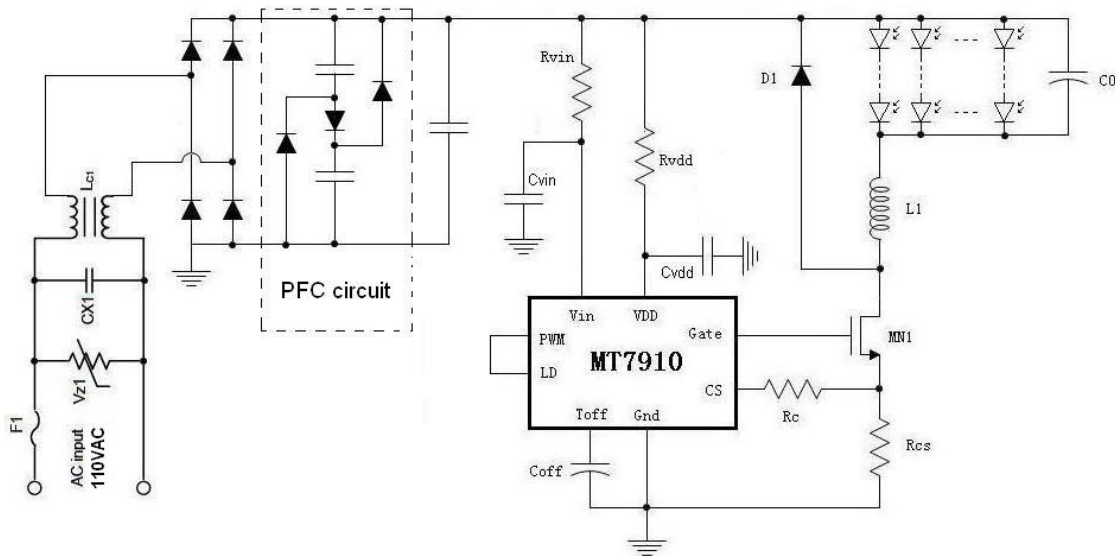For this application, 600V/1A fast recovery diode is recommended.

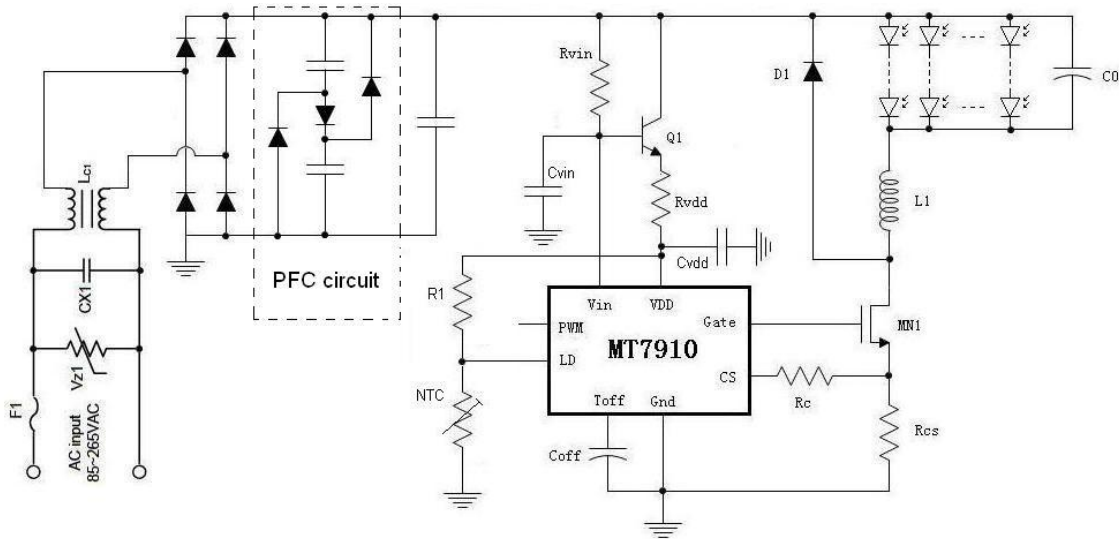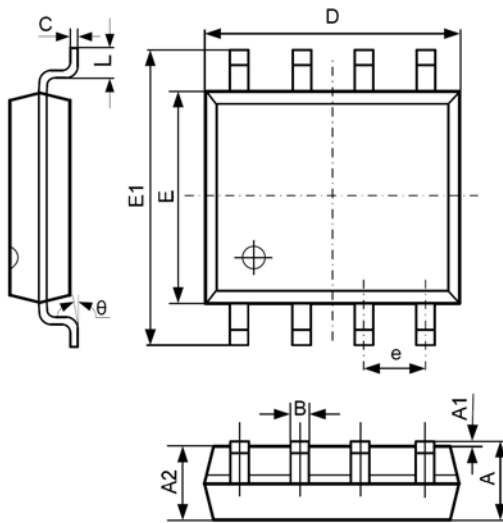Fig.2   MT7910 Application Circuit (Low Cost)

Fig.3   MT7910 Application Circuit with Temperature Compensation

PACKAGE INFORMATION

SOP-8 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°

For detail products information and sample requests, please contact:

Maxic Technology Corporation (Beijing Office)

Room 911, Building 3, Zi Jin Digital Garden, Hai Dian District, Beijing, China, 100190

Tel: 86-10-62662828

Fax: 86-10-62662951

Maxic Technology Coporation (Shenzhen office)

7K, Block B, Fortune Plaza, Futian District, Shenzhen   518040

Tel: 86-0755-83021778

Fax: 86-0755-83021336

Maxic Technology Corporation(Hong Kong office)

Rm D1, 7th floor, JianAn Commercial Building,

No. 49-51, Suhong Str., Sheung Wan, Hong Kong

Web: www.maxictech.com

E-mail: sales@maxictech.com, info@maxictech.com