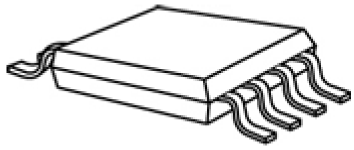
AC/DC LED Controller

Features

- Universal AC input from $80V_{AC}$ to $265V_{AC}$
- Efficiency=90% @ V_{AC} =110V, 350mA, 6-LEDs
- Setting current accuracy within ±5%
- To drive external MOSFET current up to few Amperes
- Hysteretic PFM improves efficiency at light loading
- Full protection: Thermal/UVLO/OVP/LED Open-/Short- Circuit
- Available in package: MSOP-8L

Mini Small Outline Package



GMS: MSOP-8L-118mil

Product Description

The MBI6901 is a high efficiency and step-down AC/DC controller which is designed to deliver constant current. The MBI6901 accepts universal input from $80V_{AC}$ to $265V_{AC}$. It is specifically designed with hysteretic PFM control scheme to enhance the efficiency at light loading. The MBI6901 regulates the output current within ±5% preset current by well controlling the external MOSFET. In addition, LED current dimming can be controlled via output of photo coupler through DIM pin. The MBI6901 also has multiple features to protect the controller from fault conditions, including under voltage lockout (UVLO) and over voltage protection (OVP). Additionally, to ensure the system reliability, the MBI6901 is built with the thermal protection (TP) function. The function protects IC from over temperature (155°C) by turning off the external MOSFET. As soon as the temperature is below 125°C, the external MOSFET will resume to work again. The MBI6901 is available in MSOP-8L package.

Applications

- T-8 CFL Replacement LED Solution
- General Illumination
- Power Supply for Light Panel

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Typical Application Circuit

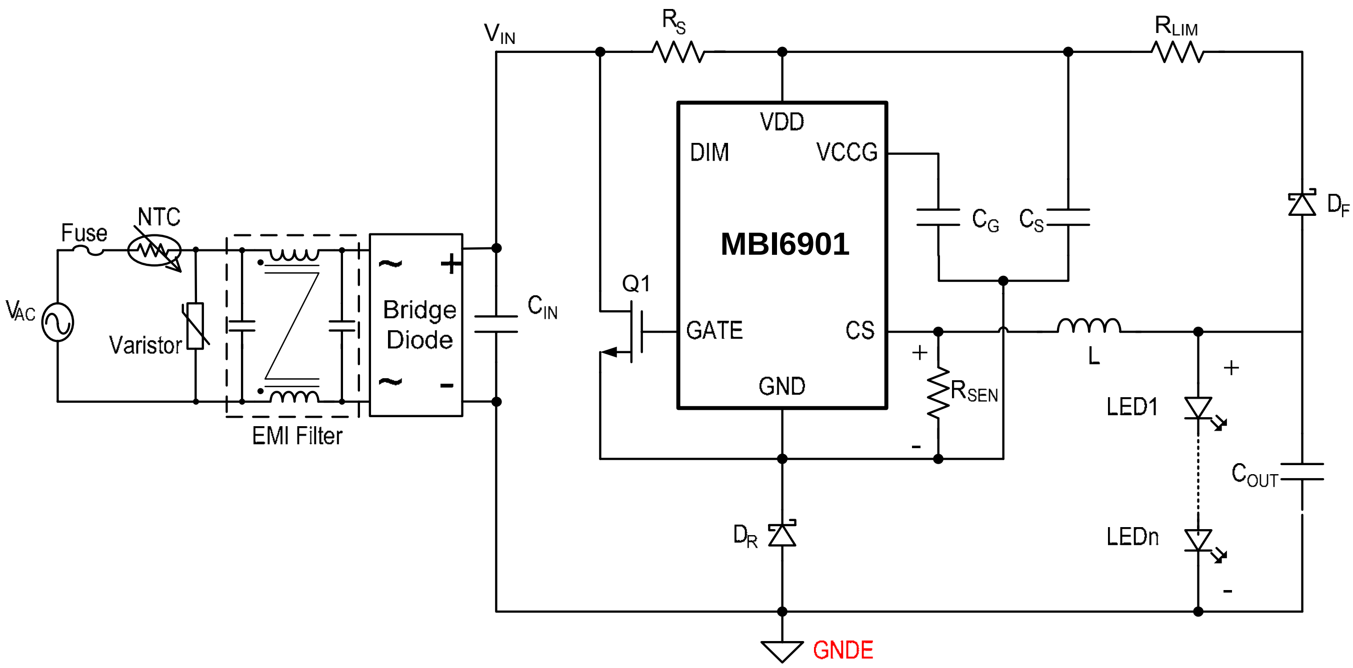


Figure 1

C_{IN}: 10µF/400V, 105℃ 5000hrs electrolytic capacitor
C_{OUT}: 10µF/400V, 105℃ 5000hrs electrolytic capacitor
D_R: 600V/1A, ultrafast diode
D_F: 600V/1A, ultrafast diode
L: 2.2mH, 14*15 power inductor
R_S: 1MegΩ, resistor (sustaining voltage at least 400V)
R_{LIM}: 12Ω, SMD resistor
C_S: 1µF/50V, ceramic capacitor
C_G: 0.2µF/25V, ceramic capacitor
Q1: 600V/3.3A, N-channel MOSFET

Note: GND and GNDE **CAN NOT** directly connect together to avoid IC damage and system malfunction.

Functional Diagram

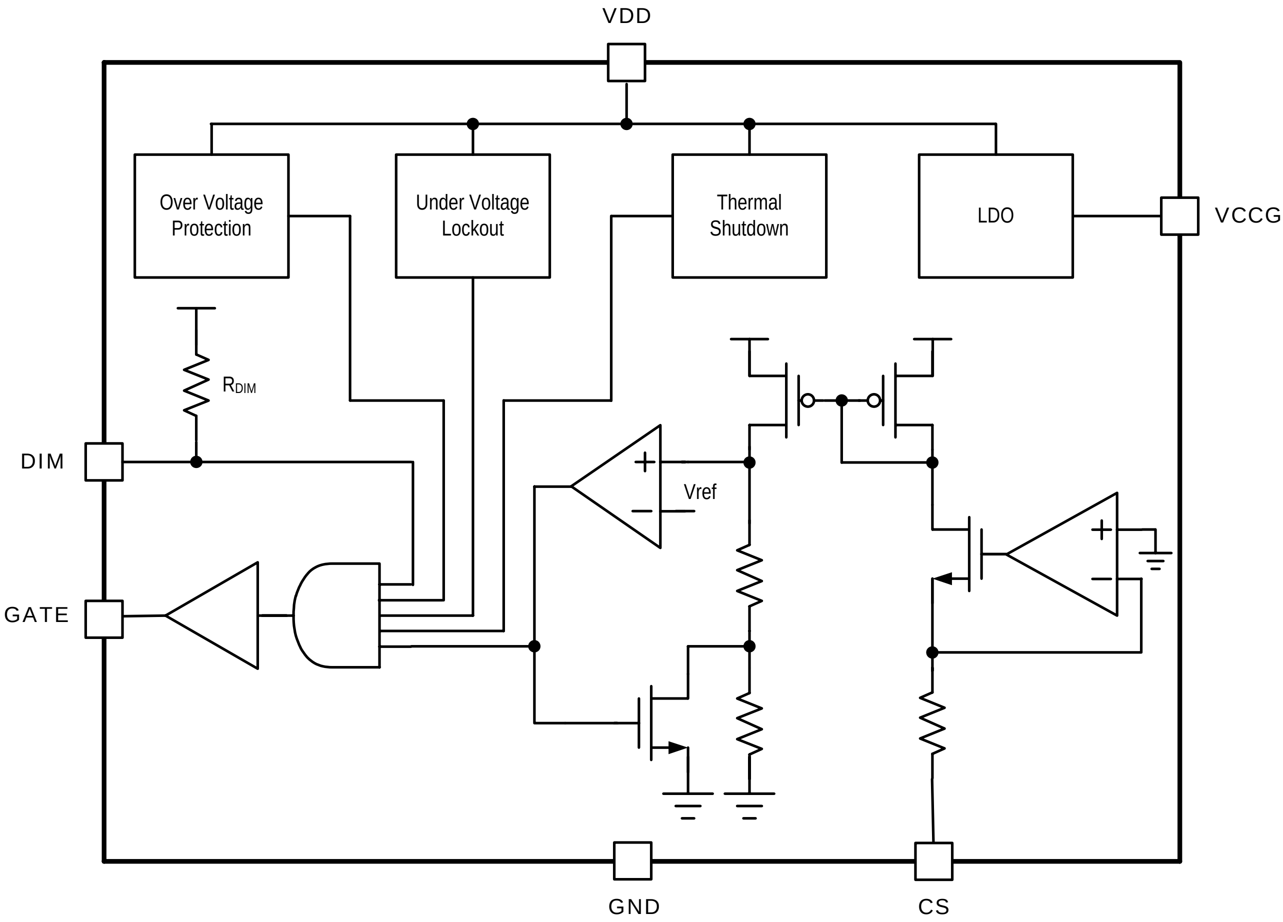
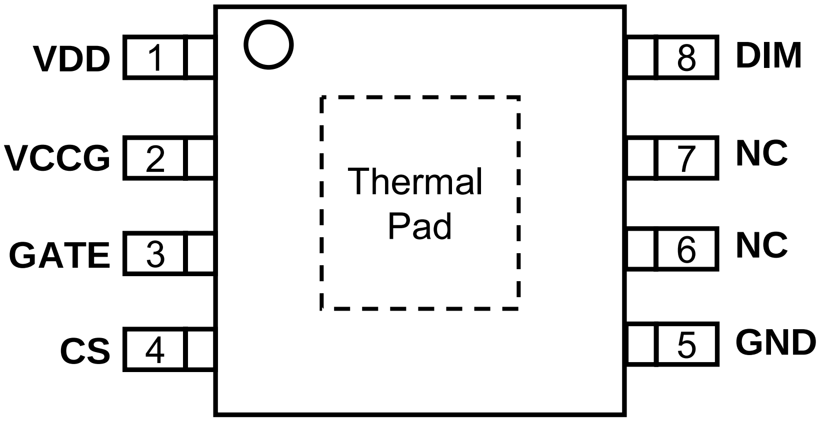


Figure 2

Pin Configuration



MSOP-8L (Top View)

Pin Description

Pin Name	Pin No.	Function
VDD	1	Supply voltage terminal and overvoltage protection
VCCG	2	Terminal to connect a capacitor to enhance the stability of VCCG
GATE	3	Terminal to drive the gate of the external MOSFET
CS	4	Terminal to sense LED string current
GND	5	Ground terminal for control logic and current sink
NC	6, 7	No connection
DIM	8	Terminal for dimming control. If the dimming function is unused, this pin can be kept floating.
Thermal Pad	-	Power dissipation terminal connected to GND*

*To eliminate the noise influence, the thermal pad should connect to GND(Pin No. 5) on PCB. In addition, a heat-conducting copper foil on PCB soldered with thermal pad will improve the desired thermal conductivity.

Maximum Ratings

Operation above the maximum rating may cause device failure and affect the device reliability.

Characteristic		Symbol	Rating	Unit
Supply Voltage		V_{DD}	-0.4~44	V
Thermal Resistance (By simulation, on 4 Layer PCB)*	GMS Type	$R_{th(j-a)}$	38.93	°C/W
Operating Junction Temperature		$T_{j,max}$	125	°C
Operating Temperature		T_{opr}	-40~+85	°C
Storage Temperature		T_{stg}	-55~+150	°C

* The PCB size is 76.2mm*114.3mm in simulation.

Electrical Characteristics

Test condition: V_{DD}=12V, C_{IN}=1μF, C_{OUT}=0.5nF, T_A=25°C; unless otherwise specified.

Characteristics		Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage		V_{DD}	-	9	-	40	V
Quiescent Current		I_{DD1}	The current before start-up voltage	-	20	30	uA
		I_{DD2}	Switching frequency = 100KHz, driving 0.5nF load at gate terminal	-	2.5	4.0	mA
HYSTERESIS CONTROL							
Sense Regulation Threshold Voltage		V_{CSH}	Change V_{CS} until V_{GATE}=High, please refer to Figure 3	-	-170	-	mV
Sense Over Current Threshold Voltage		V_{CSL}	Change V_{CS} until V_{GATE}=Low, please refer to Figure 3	-	-230	-	mV
Threshold Hysteresis of V_{CS}		-	-	-	15	-	%
Input Current of V_{CS}		I_{SEN}	V_{CS}= - 0.2V	20	40	60	uA
Internal Propagation Delay Time		T_{PDHL}	V_{CS} to GATE loop delay from high to low, V_{DD}=12V, V_{CS} = -0.15V to -0.25V, C_{OUT}=0.5nF	-	150	300	ns
		T_{PDLH}	V_{CS} to GATE loop delay from low to high, V_{DD}=12V, V_{CS}= -0.15V to -0.25V, C_{OUT}=0.5nF	-	150	300	ns
GATE DRIVER							
Output Voltage of Gate		V_{GATE}	-	7.0	7.5	7.8	V
Gate Driver Rising Time		t_{RISE}	C_{OUT} =0.5nF	-	30	60	ns
Gate Driver Falling Time		t_{FALL}	C_{OUT} =0.5nF	-	30	60	ns
THERMAL OVERLOAD							
Thermal Shutdown Threshold		T_{SD}	-	145	155	175	°C
Thermal Shutdown Hysteresis		T_{SD-HYS}	-	-	30	-	°C
START-UP & UNDER VOLTAGE LOCKOUT							
Start-up Voltage		$V_{Start-up}$	-	15	16	17	V
UVLO Voltage		V_{UVLO}	-	7.5	8.0	8.5	V
OVER VOLTAGE PROTECTION							
Over Voltage Protection		V_{OVP}	-	41	44	48	V
PWM DIMMING							
Digital Dimming Logic	"H" level	V_{DIMIH}	-	3.5	-	-	V
	"L" level	V_{DIMIL}	-	-	-	0.5	V
Internal Pull-up Resistor		R_{DIM}	-	-	100	-	KΩ

Test Circuit for Electrical Characteristics

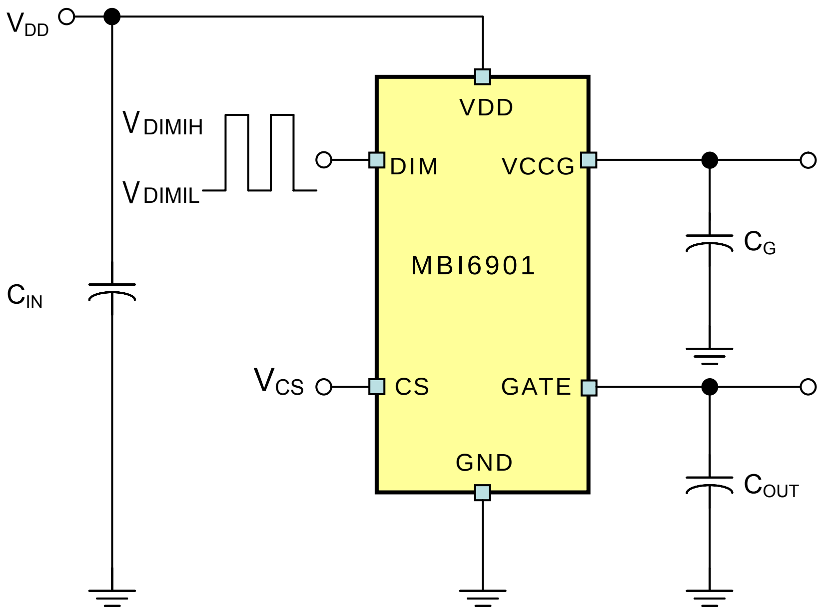


Figure 3

Application Information

The MBI6901 is a universal AC/DC constant current LED driver designed for high power LED applications. In the application, there are GND and GNDE in the circuit. The GND is the reference ground for internal circuit of MBI6901 while GNDE is the earth. Users should be aware that GND and GNDE **CAN NOT** directly connect together to avoid IC damage and system malfunction.

Start-Up and UVLO (Under Voltage Lockout)

When power is on, the voltage of C_{IN} will charge Cs which is parallel to MBI6901 through Rs. The time for charging up to $V_{Start\text{-}up}$ is start-up time. The $V_{Start\text{-}up}$ is designed at 16V. The MBI6901 also includes UVLO protection. When V_{DD} is below the UVLO threshold 8V (typ.), the UVLO starts to work and MBI6901 will be disabled as shown in Figure 4. The hysteresis of UVLO is 8V. Once reaching the $V_{Start\text{-}up}$ again, the output of GATE will turn on external MOSFET and start to regulate the desired constant current.

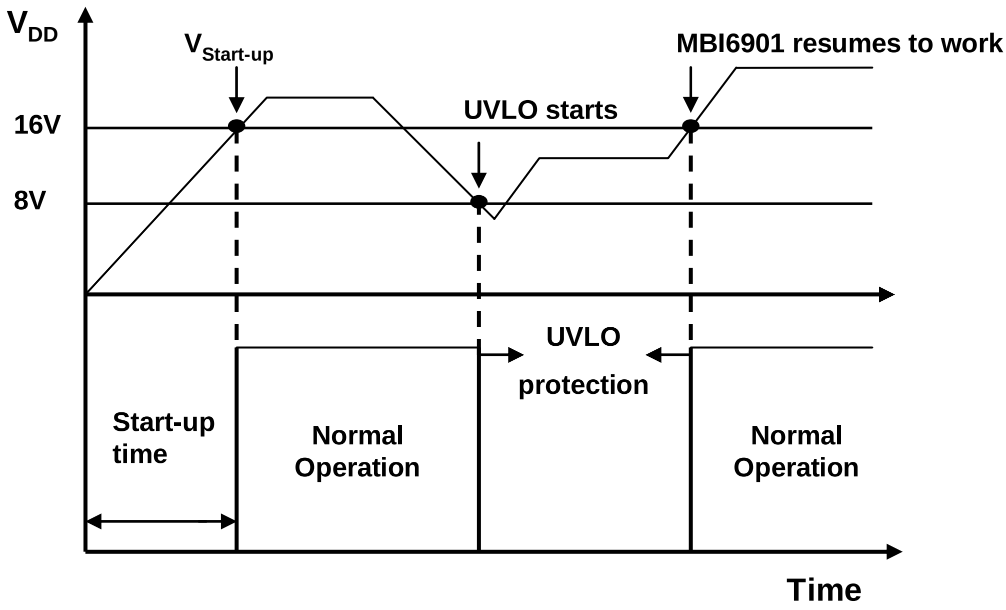


Figure 4

Setting Output Current

The output current (I_{OUT}) is set by an external resistor, R_{SEN}. The relationship between I_{OUT} and R_{SEN} is as below:

V_{CS}= - 0.2V;

R_{SEN}= | V_{CS} | /I_{OUT}= 0.2V/I_{OUT};

I_{OUT}= | V_{CS} | /R_{SEN}= 0.2V/R_{SEN}

where R_{SEN} is the resistance of the external resistor connecting to CS and GND pin. V_{CS} is the voltage with respect to GND which is across on R_{SEN} resistor. The magnitude of current (as a function of R_{SEN}) is around 350mA at 0.57 Ω.

Hysteresis Operation

In the MBI6901, there is ±15% threshold hysteresis design in V_{CS}. The parameter implies magnitude of LED ripple current as well. The operation of the MBI6901 is based on a hysteretic PFM control scheme resulting in the operating frequency remaining relatively constant with load and input voltage variations. The hysteretic PFM control requires no loop compensation resulting in very fast load transient response and achieving excellent efficiency performance at light loading.

Dimming Control

Due to system configuration, it is a must to use photo coupler to dim the LED current when applying PWM signal as a dimming source as shown in Figure 5. It is suggested to add ceramic capacitor (C_{DIM}) to filter out noise when coupling to DIM. Also, a $R_{Pull\text{-}up}$ to speed up IC dimming is recommended. Users can refer to the Application Note of the MBI6901 for detailed information.

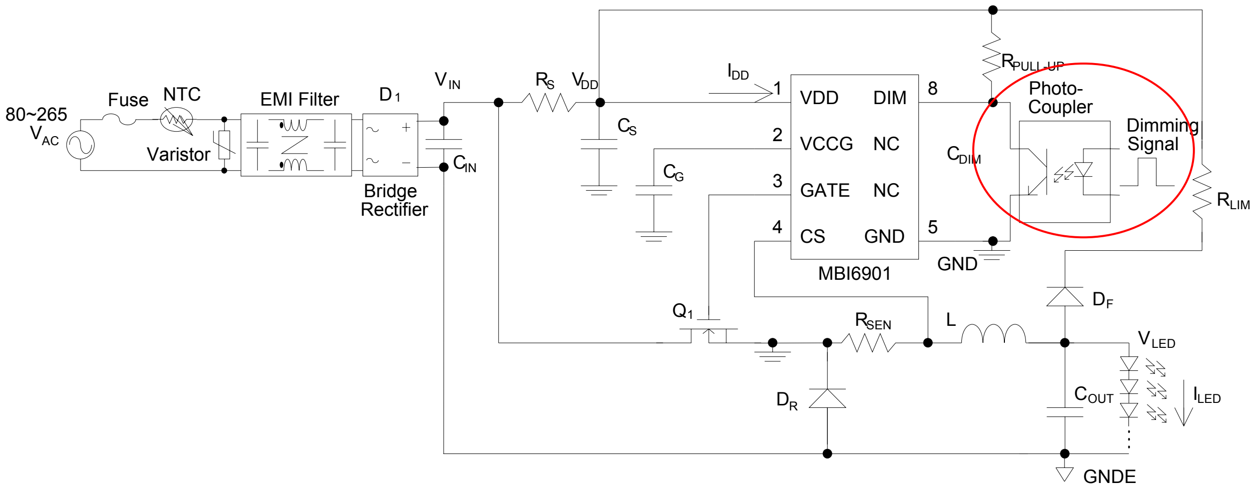


Figure 5

OVP (Over voltage Protection)

When V_{DD} reaches the OVP threshold 44V, the GATE is forced to go low. The GATE will start to pull high until the voltage falls down to the hysteresis level of 23V. This function prevents the driver from high voltage damage and protects LEDs. The threshold also limits the V_{LED} and LED numbers that can be light up.

LED Open-Circuit Protection

When any LED connecting to the MBI6901 is open-circuited, it will trigger OVP and turn off the output current of the MBI6901.

LED Short-Circuit Protection

When any LED connecting to the MBI6901 is short-circuited, the MBI6901 will adapt and regulate the new loading.

TP Function (Thermal Protection)

When the junction temperature exceeds the threshold, T_{SD} (155°C), the MBI6901 turns off the external MOSFET. Thus, the junction temperature starts to decrease. As soon as the junction temperature is below 125°C, the external MOSFET will be turned on again.

Design Example

There is a design example for application reference. The design example is based on:

The Input voltage of the target specification is from $80V_{AC}$ to $265V_{AC.}$

The expected LED current is 350mA.

The LED numbers are 6pcs. V_F=3.72V.

Select LED Current

The LED current(I_{LED}) is set by R_{SEN}

Where R_{SEN} = 0.2V/0.35A = 0.57Ω.

Choose R_{SEN} =0.56Ω.

Therefore the power dissipation of P_{RSEN} =$(0.2V)^2$ / 0.56Ω = 0.0224W. It is suggested to use the R_{SEN} resistance to equal 0.56Ω/0.25W within 1% deviation. The result of LED current will be modified as I_{LED} = 0.2V/ 0.56Ω = 357mA.

Select the Inductor (L) and Switching Frequency (fsw)

The inductance is determined by two factors: the switching frequency and the inductor ripple current. The calculation of the inductance, L, can be described as below:

$$L = \frac{(V_{IN} - V_{LED}) \times D}{f_{SW} \times \Delta I_{LED}}$$

where

D is the duty cycle of the MBI6901, D=V_{LED}/V_{IN}.

f_{SW} is the switching frequency of the MBI6901.

ΔI_{LED} is the ripple current of inductor, ΔI_{LED} =(1.15xI_{LED}) – (0.85x I_{LED})=0.3xI_{LED}.

To avoid audio noise and overheating of power MOSFET (Q_1), it is recommended to set f_{SW} range within 40kHz ~ 100kHz. Based on the requirement, the selection of L and switching frequency f_{SW} will both be satisfied within a range as well and can be calculated by equation below:

Where

$L_{, REC-MAX}$ = {[(80V x $\sqrt{2}$) – (3.72 x 6)] x [(3.72 x 6) / (80V x $\sqrt{2}$)]} / [0.3 x (40 x 1000) x 0.357] = 4.18 mH

$L_{, REC-MIN}$ = {[(265V x $\sqrt{2}$) – (3.72 x 6)] x [(3.72 x 6) / (265V x $\sqrt{2}$)]} / [0.3 x (100 x 1000) x 0.357] = 1.96 mH

Choose the inductor L = 2.2 mH,

Choose the saturation current 1A and DCR=1.48Ω.

$f_{SW, MIN}$ = {[(80V x $\sqrt{2}$) – (3.72 x 6)] x [(3.72 x 6) / (80V x $\sqrt{2}$)]} / [0.3 x (2.2 / 1000) x 0.357] = 76.04kHz

$f_{SW, MAX}$ = {[(265x $\sqrt{2}$) – (3.72 x 6)] x [(3.72 x 6) / (265 x $\sqrt{2}$)]} / [0.3 x (2.2 / 1000) x 0.357] = 89.05kHz

Select Bridge diode and Power MOSFET (Q1)

The voltage rating of the bridge diode depends on the maximum value of the input voltage. It is reasonable to choose 1.2 times of $V_{IN. MAX.}$ as safety margin. Therefore, a 600V/1A bridge diode is enough.

$$V_{BRIDGE} = 1.2 \times \sqrt{2} \times V_{IN.MAX} = 1.2 \times \sqrt{2} \times 265 = 450V$$

In this example, we adapt the bridge with the rating as 1000V/1.5A and forward voltage as 1.1V. Similar to the bridge diode, the voltage rating of power MOSFET can follow the calculation above.

In typical application of the MBI6901, the output current usually ranges from 350mA to 1000mA. The 600V/2A

MOSFET or higher ratings are suitable. It is a recommended to minimize conduction loss by choosing the devices with low turn-on resistance. In the example, the rating of power MOSFET is 600V/3.3A.

Select Freewheeling Diode (D_R and D_F)

In this example, the adopted device has the specification of reverse breakdown as 600V, forward current as 1A and forward voltage as 1.7V. The voltage rating of the freewheeling diode depends on the maximum value of the input voltage. It is reasonable to choose 1.2 times of $V_{IN.\,MAX.}$ as safety margin. The formula to select D_R and D_F is :

$$1.2\times\sqrt{2}\times V_{IN.MAX}=1.2\times\sqrt{2}\times 265=450V$$

Therefore, a 600V/1A ultrafast diode is enough.

Select Current Limit Resistor (R_{LIM}) (Optional)

The purpose of the R_{LIM} is to protect D_F. The small R_{LIM} is enough. In this design example, R_{LIM} =12Ω is suggested.

Select Input Capacitor (C_{IN})

The rated voltage of input capacitor should be at least 1.2 times of input voltage. An electrolytic capacitor can be used as an input capacitor. It is recommended to use 10μF/400V for 350mA and 22μF for above 700mA LED current application.

Select Output Capacitor (C_{OUT}) (Optional)

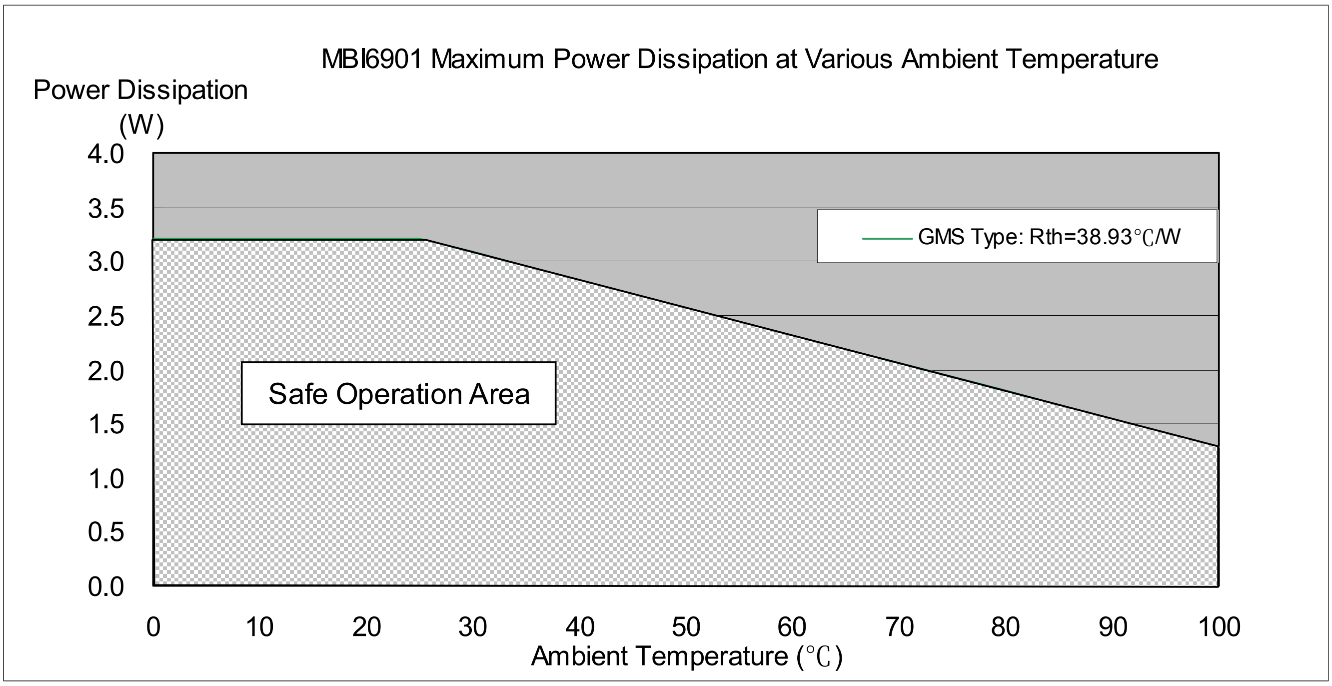
A capacitor paralleled with cascaded LEDs can reduce the LED ripple current. An electrolytic capacitor can be used as an input capacitor. It is recommended to use 10μF/400V.

Select Fuse, NTC, Varistor and EMI Filter

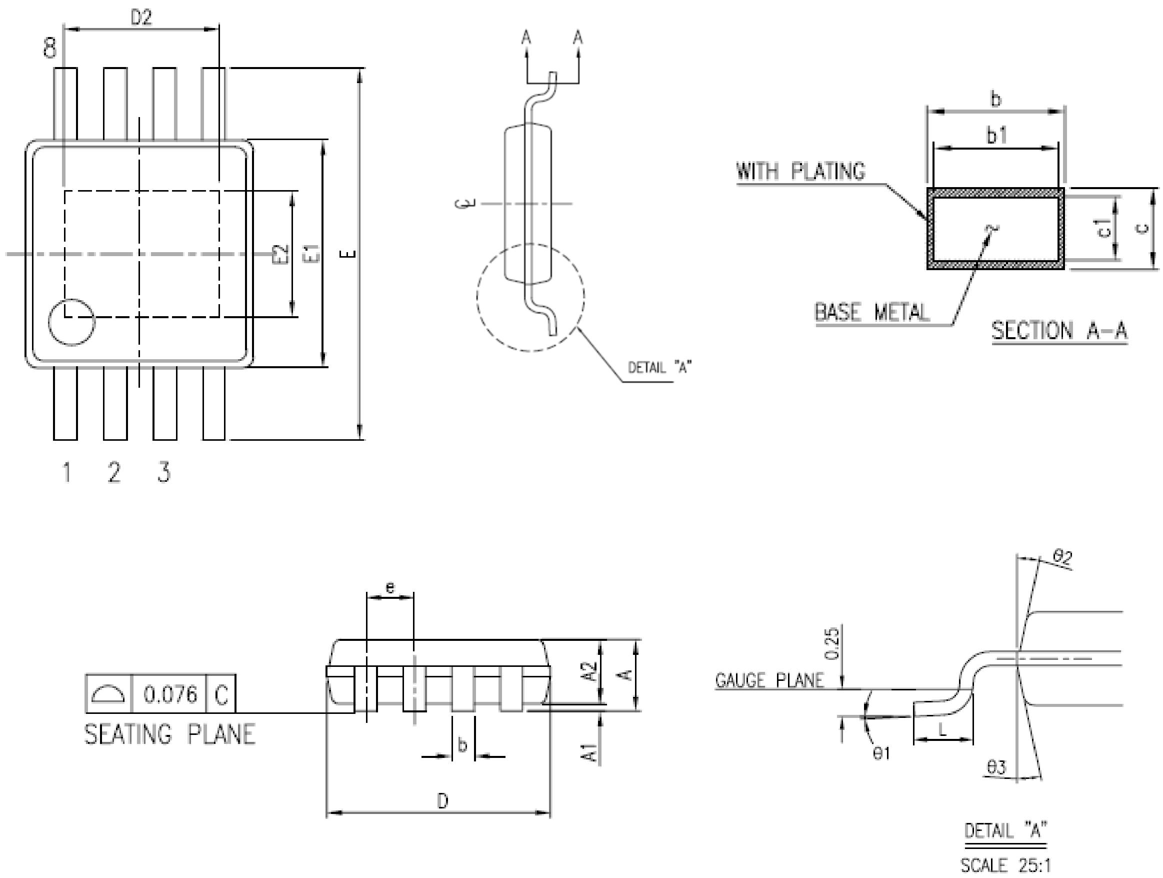
Please refer to MBI6901 Application Note and Design Tool for the selection of fuse, NTC and varistor. The EMI filter is optional. Therefore, users should choose the one based on their applications.

Package Power Dissipation (PD)

The maximum power dissipation, $P_D(max)=(Tj–Ta)/R_{th(j-a)}$, decreases as the ambient temperature increases.



Outline Drawing



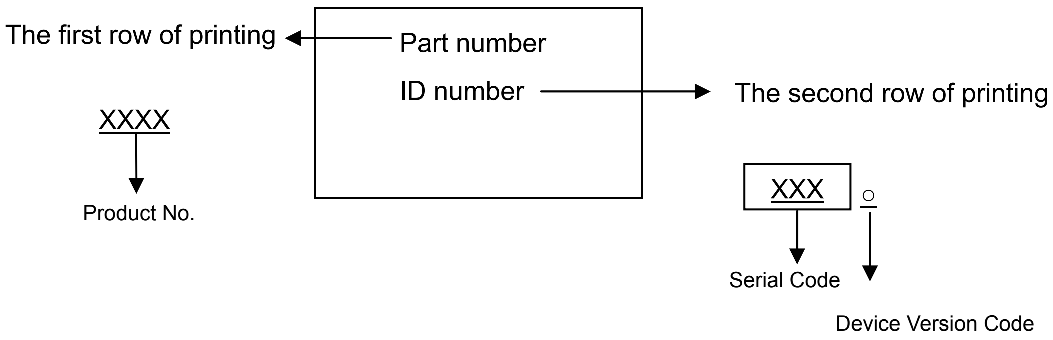
SYMBOL	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	---	---	1.10	---	---	0.043
A1	0.05	---	0.10	0.002	---	0.006
A2	0.81	0.86	0.91	0.032	0.034	0.036
c	0.13	---	0.23	0.005	---	0.009
c1	0.13	0.15	0.18	0.005	0.006	0.007
D	2.90	3.00	3.10	0.114	0.118	0.122
E	4.90 BSC			0.193 BSC		
E1	2.90	3.00	3.10	0.114	0.118	0.122
L	0.445	0.55	0.648	0.0175	0.0217	0.0255
θ1	0°		6°	0°		6°

SYMBOL	8L		
	MIN.	NOM.	MAX.
b	0.25	---	0.40
b1	0.25	0.30	0.35
D2	2.00	2.05	2.10
E2	1.60	1.65	1.70
e	0.65 BSC		
JEDEC	MO-187AA		

MBI6901 GMS Outline Drawing

Note: The unit for the outline drawing is mm. Please use the maximum dimensions for the thermal pad layout. To avoid the short circuit risk, the vias or circuit traces shall not pass through the maximum area of thermal pad.

Product Top Mark Information



Product Revision History

Datasheet version	Device Version Code
V1.00	A
V1.01	A

Product Ordering Information

Part Number	"Pb-free" Package Type	Weight (g)
MBI6901	GMS: MSOP-8L-118mil	0.023 g

Disclaimer