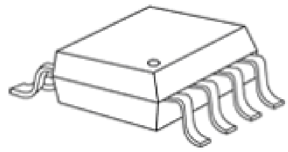
High Power Factor AC/DC LED Driver

Features

- Constant current LED driver
- Macroblock patent-pending primary side regulation (PSR)
- Built-in active power factor correction
- Support 85V_{AC} - 265V_{AC} universal input voltage range
- Support up to 28W output
- Full protection: thermal/UVLO/soft-start/LED open-/short- circuit
- Available in SOP-8 package

Small Outline Package



GD: SOP8-150-1.27

Product Description

MBI6802 is a universal input AC-DC converter designed to deliver constant current to high power LED with primary side regulation (PSR) control (US/TW patent pending). With the built-in active power factor correction circuit, MBI6802 adjusts its input current according to the main waveform to maintain high power factor. MBI6802 is optimized for applications based on flyback converter with output power up to 28 Watt. It is designed to operate in boundary conduction mode (BCM) or discontinuous conduction mode (DCM). In addition, the embedded soft-start function eliminates the inrush current during the power-on period. MBI6802 also features under voltage lock-out (UVLO), over-temperature protection, LED open-circuit protection and LED short-circuit protection to protect IC from being damaged accidentally.

Applications

- T8 light tube LED alternative solutions
- E26/E27 light bulb LED alternative solutions
- PAR light LED alternative solutions

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Typical Application Circuit

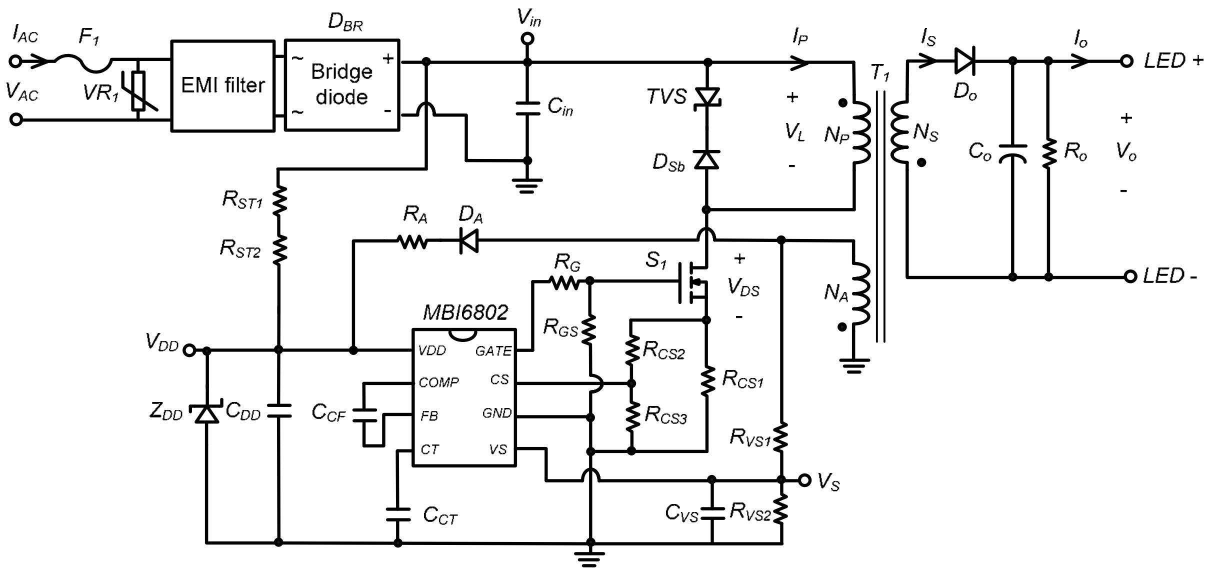


Fig.1 typical application circuit of MBI6802

Functional Diagram

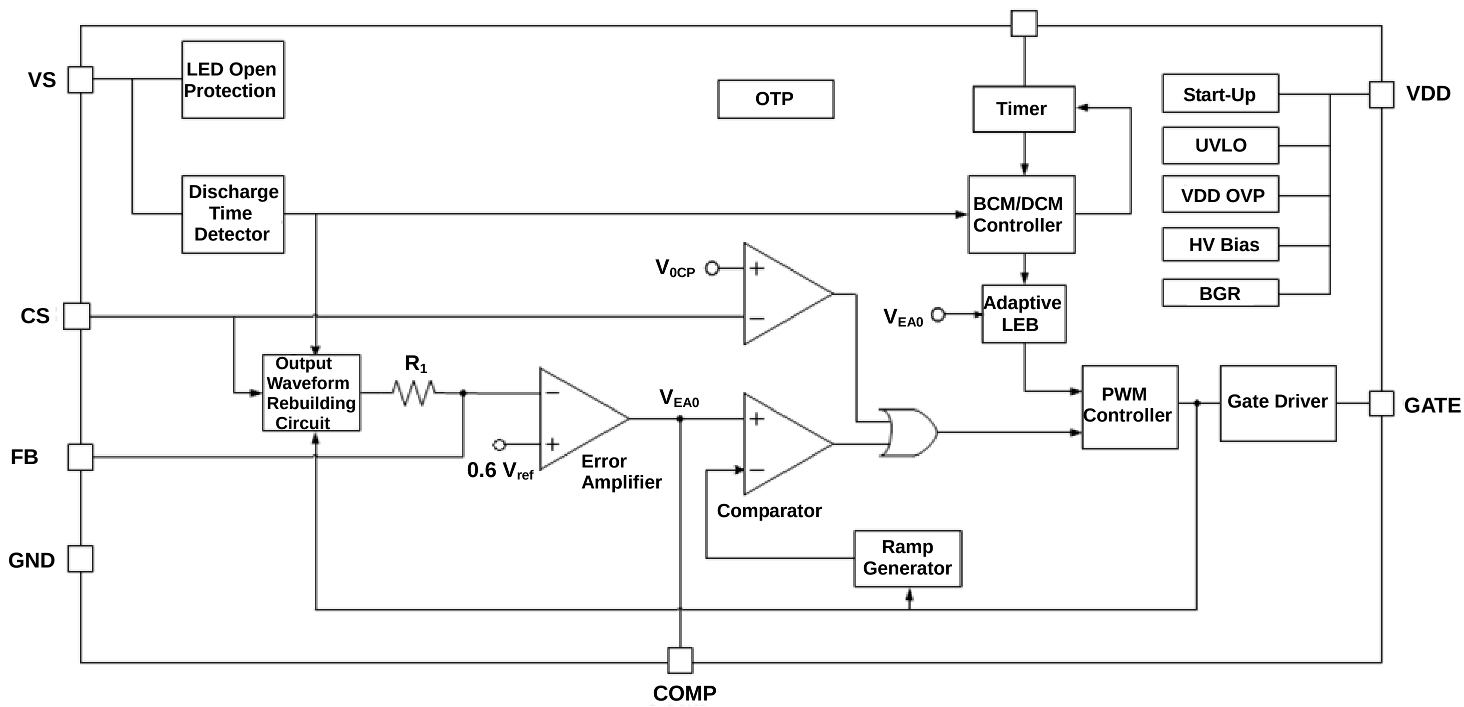


Fig.2 functional diagram of MBI6802

Pin Configuration

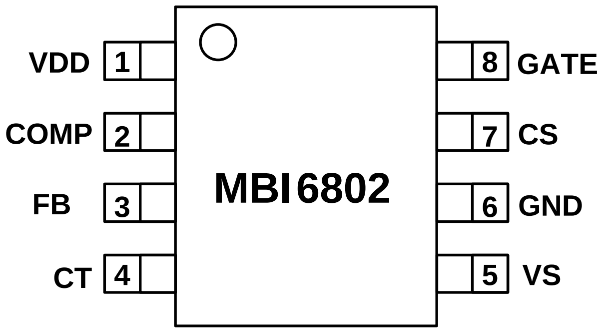


Fig. 3 pin configuration of MBI6802

Pin Description

Pin	Number	Description
VDD	1	Supply Voltage
COMP	2	Terminal to connect a compensator
FB	3	Output Current Feedback
CT	4	Terminal to connect a frequency-adjustment capacitor
VS	5	Auxiliary winding voltage sensing
GND	6	Ground
CS	7	MOSFET current sensing
GATE	8	Gate driver output to the external MOSFET

Absolute Maximum Ratings

NOTE: Operations above the maximum ratings may cause device failure or reduce device reliability.

Characteristics		Symbol	Min	Max	Unit
Supply voltage		V_{DD}	-0.3	40	V
CS pin input voltage		V_{CS}	-0.3	7	V
VS pin input voltage		V_{VS}	-0.3	7	V
FB pin input voltage		V_{FB}	-0.3	7	V
COMP pin input voltage		V_{COM}	-0.3	7	V
CT pin input voltage		V_{CT}	-0.3	7	V
Junction temperature		$T_{J,MAX}$	-	150**	°C
Operating ambient temperature		T_{OPR}	-40	85	°C
Storage temperature		T_{STG}	-55	150	°C
ESD protection	Human body mode	HBM(MIL-STD_833H METHOD 3015.8)	-	Class 3A 4000V~7999V	-
	Machine mode	MM(JESD22-A115C)	-	Class M4 >=400V	-
Power dissipation (On 4 layer PCB, Ta=25°C)		P_D	-	3.13	W
Thermal resistance (By simulation, on 4 layer PCB)*		$R_{th(j-a)}$	-	72.1	°C/W

*The PCB size is 76.2mm x 114.3mm in simulation. Please refer to JEDEC JESD51.

** Operation at the maximum rating for extended periods may reduce the device reliability; therefore, the suggested junction temperature of the device is under 125°C.

Note: The performance of thermal dissipation is strongly related to the size of thermal pad, thickness and layer numbers of the PCB. The empirical thermal resistance may be different from simulative value. Users should plan for expected thermal dissipation performance by selecting package and arranging layout of the PCB to maximize the capability.

Electrical Characteristics

Test condition: V_{DD}=20V, C_{IN}=10μF, and T_A=25°C unless otherwise specified.

Characteristics	Symbol	Conditions	Min	Typ	Max	Unit
Supply Voltage						
Continuous operating voltage	V_{OP}		8	20	28	V
Start-up voltage	V_{START_UP}	start-up	14	16	18	V
Under-voltage lockout	V_{UVLO}	UVLO	6.5	8	9.5	V
V_{DD} over-voltage protection	V_{DD-OVP}		26	28	30	V
Operating current	I_{DD-OP}		-	-	5	mA
Stand-by current	I_{DD-ST}	I_{DD} before start-up	-	25	40	uA
CT (Oscillator Frequency Adjustment)						
Charging current	F_{OSC}		-	6	-	uA
Threshold voltage	V_{CTTH}		-	1.2	-	V
Maximum oscillator frequency	$F_{OSC,MAX}$		-	150	-	kHz
Minimum oscillator frequency	$F_{OSC,min}$		-	30	-	kHz
Frequency variation over V_{DD}	f_{DV}	V_{DD}=8V-28V	-	-	5	%
Frequency variation over temperature	f_{DT}	Temp.=-40-85℃	-	-	25	%
Current Sense						
Propagation delay to GATE output	T_{PD}		-	100	200	ns
Leading edge blanking time	T_{LEB}		100	200	400	ns
Threshold voltage for current limit	V_{CSTH}		2.4	2.5	2.6	V
Over-Voltage Protection (OVP)						
Open protection threshold	V_{S-open}		1.4	1.5	1.6	V
Open protection hysteresis	$V_{S-open-Hys}$		-	0.1	0.2	V
Gate Driver						
Maximum duty ratio	D_{MAX}		-	50	-	%
Output high voltage	V_{OH}		14	15	16	V
Output low voltage	V_{OL}		-	-	0.5	V
Rising time	T_R	20%-80% of full swing	-	125	250	ns
Falling time	T_F	20%-80% of full swing	-	40	100	ns
Thermal Shutdown						
Thermal shutdown threshold	T_{SD}	Hysteresis=30°C	-	155	-	°C
Soft Start						
V_{OCP} ramp period	-		-	-	10	ms

Application Information

MBI6802 is a primary side regulator (PSR) optimized for flyback converters. With the primary side detection technique (patent pending), the output LED current can be precisely sensed and regulated without the area-consuming photocoupler. The built-in power factor correction (PFC) circuit senses the main voltage and adjusts the input current accordingly to maintain high power factor while suppresses the harmonic current to conform to EN61000-3-2 regulations. MBI6802 is also equipped with full protections, inclusive of over-temperature protection, LED open-circuit protection, and LED short-circuit protection. The built-in soft-start circuit prevents the converter from undergoing in-rush current.

Operation Principle

A simplified equivalent circuit of MBI6802-based flyback converter during power-on period is illustrated in Fig.4. When the input voltage V_{in} rises, V_{DD} slowly rises in accordance with a time constant set by R_{ST} and C_{DD}. Once V_{DD} exceeds $V_{DD\text{-}ON}$, MBI6802 starts working and the whole PSR functions properly. The current consumption also rises from I_{DD_ST} to the steady-state value of I_{DD_NORMAL}. Before the output voltage is fully established, the steady state current consumption I_{DD_NORMAL} is supplied by C_{DD}. In Figure 4, t_{hold} is the time period for V_{DD} to drop from V_{DD_ON} to the under-voltage lockout threshold V_{UVLO}. If V_O fails to reach $[(V_{DD\_ON}\text{-}V_{drop})\times N_S/N_A]$ within t_{hold}, the system will restart again. For a typical one-stage converter with active power factor correction, the output capacitor is usually very large to suppress the output current ripple. Therefore the system may restart a few times before the output voltage can be properly established.

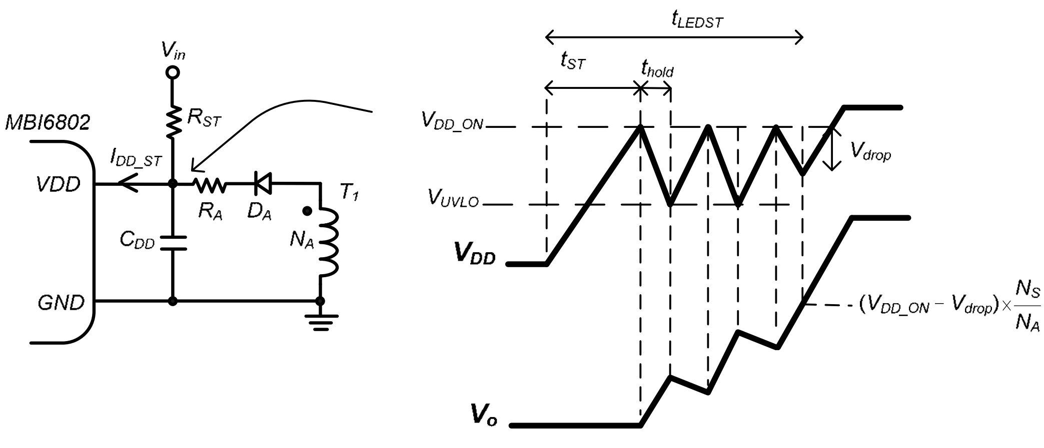


Fig.4 equivalent circuit for start-up period and corresponding waveforms

Fig.5 is a simplified diagram of a flyback converter controlled by MBI6802. When S_1 is on, input V_{IN} charges the magnetizing inductor L_M; the secondary side is reversely-blocked by D_O and the load current is supplied by C_O. when S_1 is off, energy stored on the magnetizing inductor is discharged to the secondary side and therefore supplies the load current and recharges C_O.

When S_1 is off and D_O conducts, the output voltage is approximately equal to the voltage across the secondary winding, which can be detected indirectly by measuring the voltage waveform across the auxiliary winding N_{AUX}.

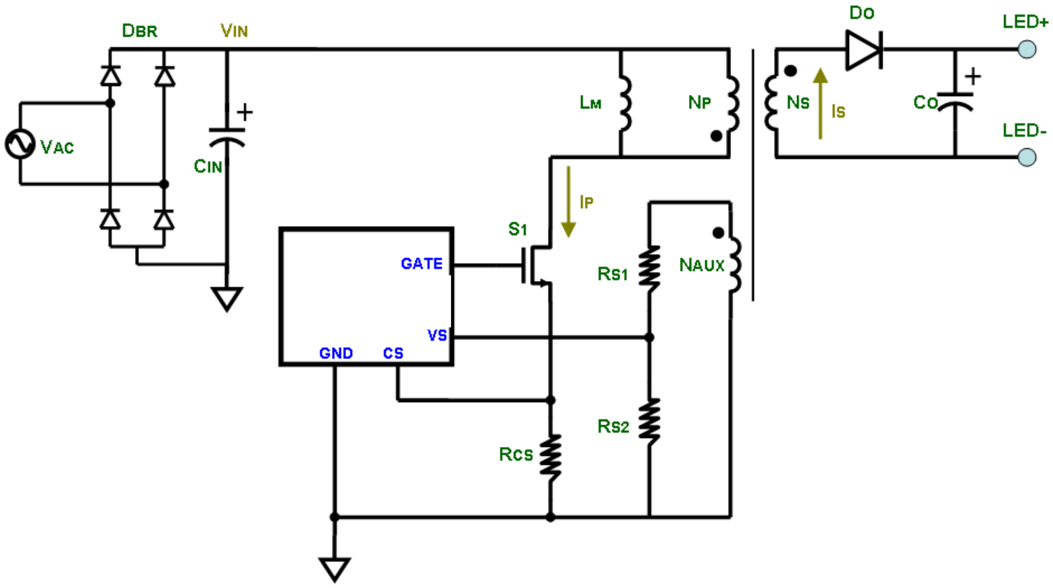


Fig. 5 simplified flyback converter controlled by MBI6802

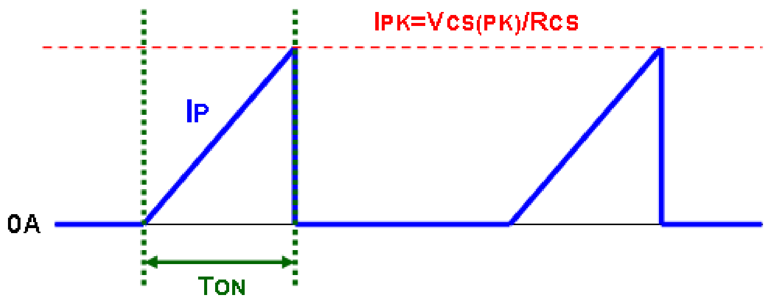


Fig.6 typical primary-side current waveform

Fig.6 illustrates a typical primary-side current waveform. The energy stored in LM per cycle is therefore,

$$Eg = \frac{1}{2} \cdot L_M \cdot I_{PK}^2 \text{ ....(1)}$$

Since the converter is operated in DCM, the energy stored in LM is completed discharged to the load in each cycle. Consequently, the average output power is,

$$P = \frac{1}{2} \cdot L_M \cdot I_{PK}^2 \cdot fsw \text{ ....(2)}$$

where f_{SW} is the switching frequency of S_1.

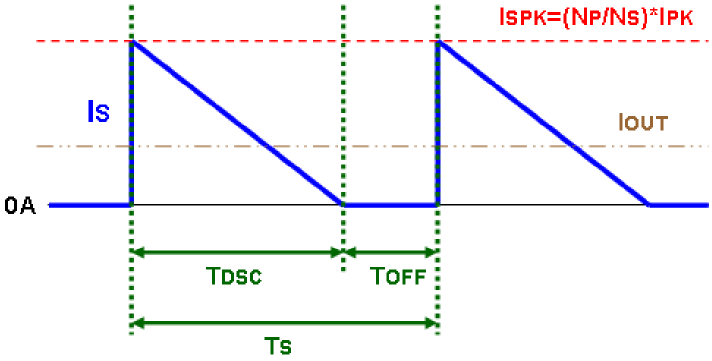


Fig. 7 typical secondary-side current waveform

As illustrated in Fig.7, T_{DSC} is the conducting time of D_O, and T_S is a single switching period. The average output current is therefore,

$$I_{OUT} = \frac{1}{2} \cdot \frac{T_{DSC}}{T_S} \cdot I_{SPK} = \frac{1}{2} \cdot \frac{T_{DSC}}{T_S} \cdot I_{PK} \cdot \frac{N_P}{N_S} = \frac{1}{2} \cdot \frac{N_P}{N_S} \cdot \frac{T_{DSC}}{T_S} \cdot \frac{V_{CS(PK)}}{R_{CS}} \quad \text{.................} \ (3)$$

It should be emphasized that all of the equations above are derived under DCM operations. In order to prevent any operation in the continuous conduction mode (CCM), the maximum duty ratio of S_1 is limited to less than 0.45.

Operation Modes

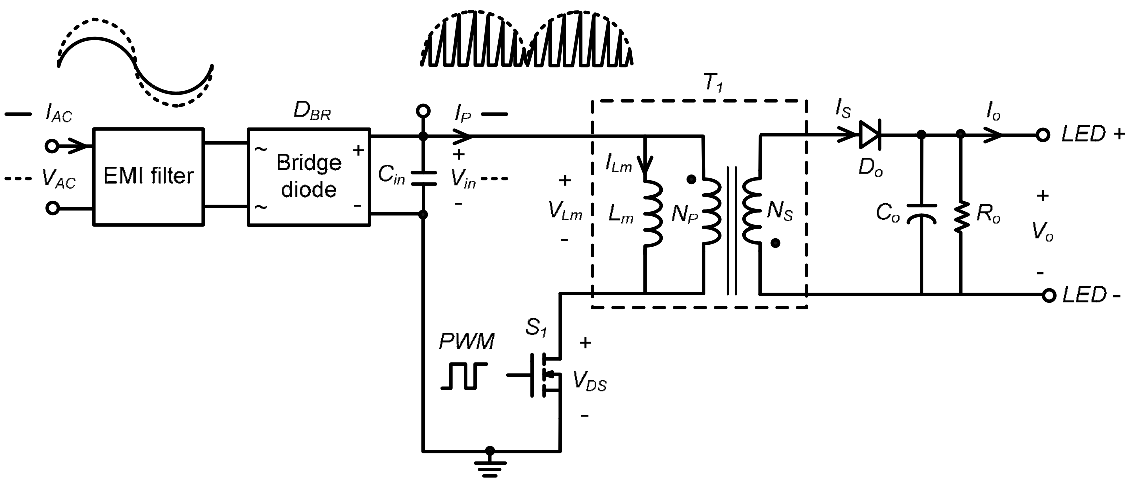


Fig.8 flyback PFC converter and corresponding waveforms

Fig.8 illustrates a typical flyback converter along with nodal voltage waveforms. By adjusting the magnetizing inductance and the switching frequency, the operation mode of MBI6802 can be set in either Discontinuous Conduction Mode (DCM) or Boundary Conduction Mode (BCM). DCM operation is illustrated in Fig.9, in which the switching frequency is fixed. BCM operation is illustrated in Fig.10, in which the switching frequency varies with the input line voltage. It is also viable to design a converter to operate under alternating DCM and BCM, as exemplified in Fig.11. Typically, converters operated in DCM yield higher power factor, while the switch components inevitably suffer higher current stress and the output current ripple is larger. Converters operated in BCM may suffer lower current stress and output current ripple compared to DCM, while the power factor would be slightly lower. Meanwhile, BCM operation inherently offers better EMI characteristics due to its variable-frequency nature.

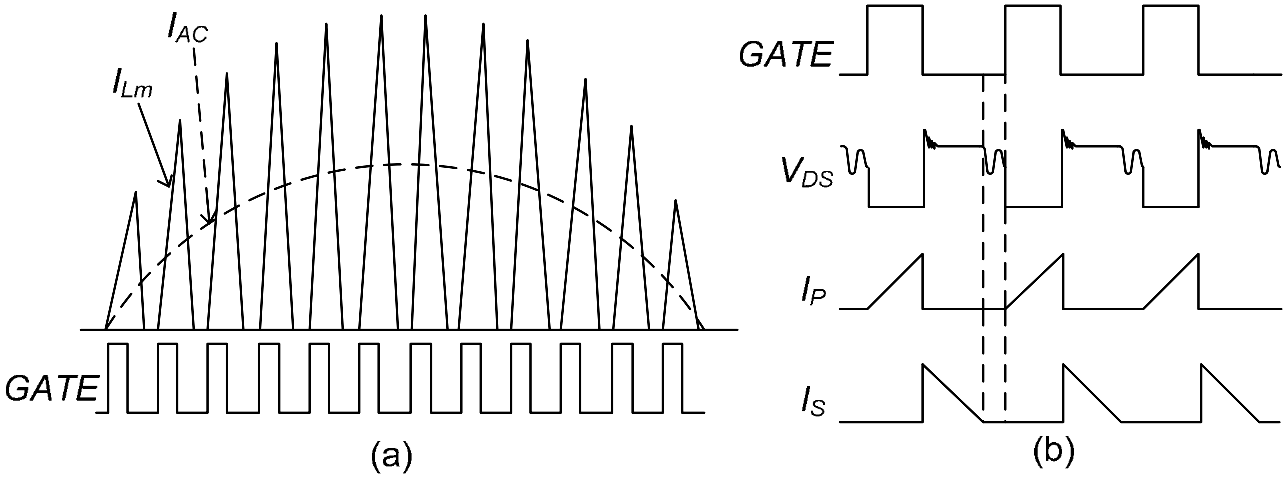


Fig.9 DCM operation and waveforms of (a) input and magnetizing inductance current, (b)main components

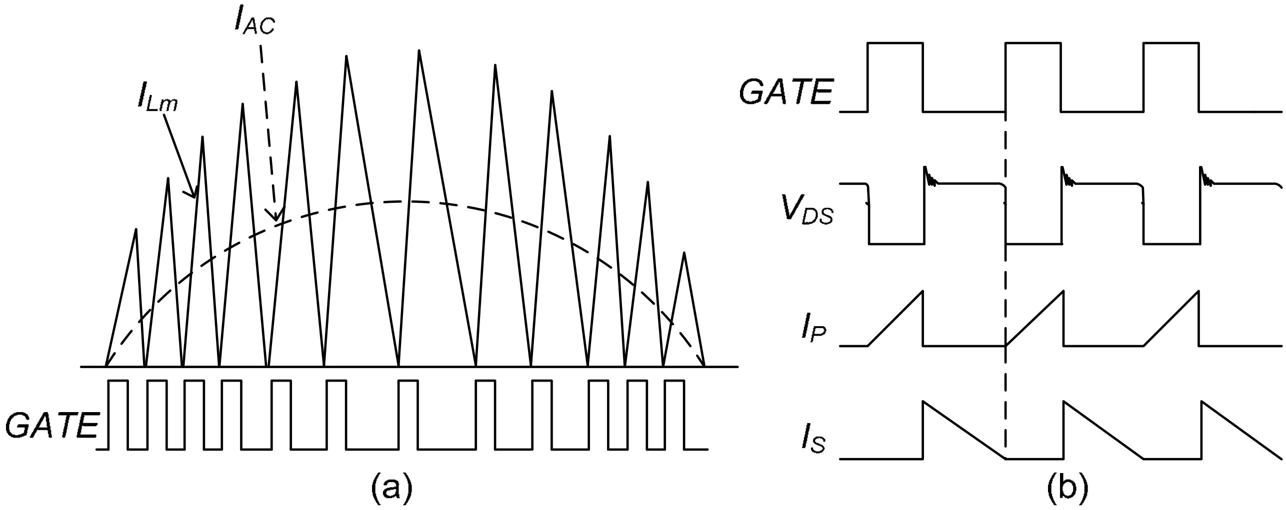


Fig.10 BCM operation and waveforms of (a) input and magnetizing inductance current, (b)main components

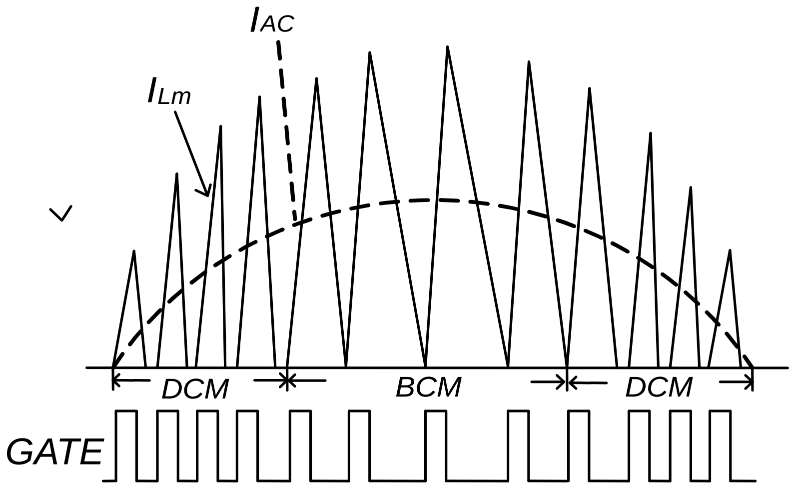


Fig.11 alternating DCM/BCM operation

Active Mode Power Factor Correction

Theoretically, when the input main voltage and input current are in phase and proportional to each other, the power factor will be unity. In a flyback converter, this is equivalent to the proportionality between the voltage across the magnetizing inductor V_{LM} and the average current of the primary side $I_{P(avg)}$. This statement can be implicitly interpreted by equations of both V_{LM} and $I_{P(avg)}$ being proportional to the peak value of the magnetizing inductor current $I_{LM(peak)}$, which is stated as (4)(5).

$$\begin{cases} V_{Lm} \propto I_{Lm(peak)} \quad \text{(4)} \\ I_{Lm(peak)} \propto I_{P(avg)} \quad \text{(5)} \end{cases}$$

For a flyback converter, if the conduction period t_{on} and the magnetizing inductance L_M are fixed, equation (4) will stand for reason according to equation (6) regardless of operations in either DCM or BCM. Meanwhile, based on equation (7), D_{on} has to be kept constant, which in turns indicates the period of the switching cycle T_S must also be kept constant. Therefore, variations of L_M, t_{on}, D_{on}, and T_S must be small in order to obtain a high PF design.

$$V_{Lm} = L_m \frac{I_{Lm(peak)}}{t_{on}} \quad \text{(6)}$$

$$I_{P(avg)} = \frac{1}{2}\frac{I_{Lm(peak)}t_{on}}{T_s} = \frac{1}{2}\frac{I_{Lm(peak)}D_{on}T_s}{T_s} = \frac{1}{2}I_{Lm(peak)}D_{on} \quad \text{(7)}$$

If the transformer is properly designed, the magnetizing inductance L_M should be constant without core saturation. By adjusting the system response to be slower than the input line frequency, t_{ON} can be guaranteed relatively constant for several successive line cycles. Besides, an operation in DCM indicates a fixed-frequency operation, which means T_S and D_{ON} will be constant and therefore a high power factor can be achieved. On the other hand, BCM is an inherent variable-frequency operation in nature; therefore T_S and D_{ON} will not be constant and achievable power factor is relatively low. Users should be fully aware of the trade-off between operations in DCM and BCM.

Internal Soft-Start Protection

The embedded soft-start function of MBI6802 prevents damage caused by inrush current during the power-on period. It is realized by the cycle-by-cycle over-current protection of the external power MOSFET, which is achieved by detecting the voltage at pin CS. When the voltage at pin CS exceeds the preset value V_{OCP}, the converter will terminate the GATE signal. In MBI6802, V_{OCP} rises from 1.25V to 2.5V within 1ms upon start-up, as shown in Fig.12. After the soft-start completes, V_{OCP} is kept at 2.5V to limit the maximum current in the MOSFET during normal operations.

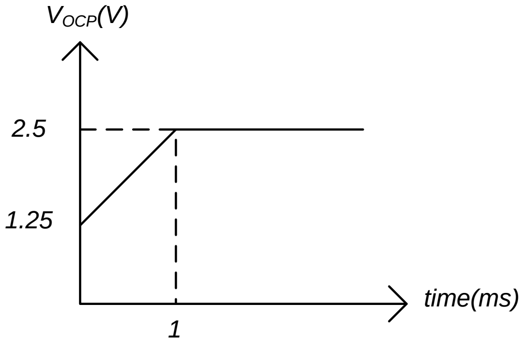


Fig. 12 soft-start operation of MBI6802

LED Open-Circuit Protection

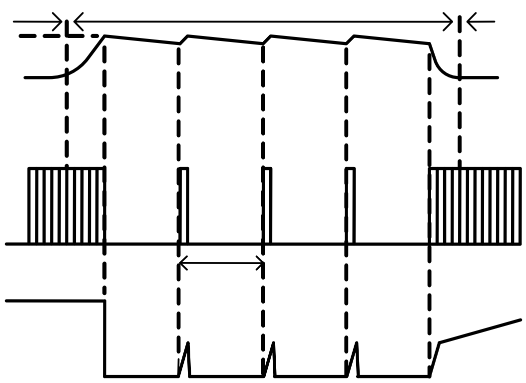


Fig.13 LED open-circuit protection

The operation of LED open-circuit protection is illustrated in Fig.13. When the LED is open-circuited, the output voltage rises, causing the voltage at the auxiliary winding and pin VS to rise accordingly. Once the voltage at pin VS exceeds the preset threshold V_{O_OPEN}, the switching frequency is immediately demoted to 1kHz while V_{OCP} is reset to zero and the system restarts from the soft-start mode again. Only when the open-circuit condition is removed will the system resume normal operations without re-powering on the entire system.

LED Short-Circuit Protection

The operation of LED short-circuit protection is illustrated in Fig.14. By judging whether the voltage at pin VS drops to zero while the voltage at pin CS exceeds 1.6V, MBI6802 can detect the occurrence of LED short-circuit failure. Once LED short-circuit failure occurs, MBI6802 forces the external power MOSFET to stop switching and V_{DD} gradually decreases till UVLO is activated. The converter will restart from soft-start mode again. Only when the short-circuit condition is removed will the system resume normal operations without re-powering on the entire system.

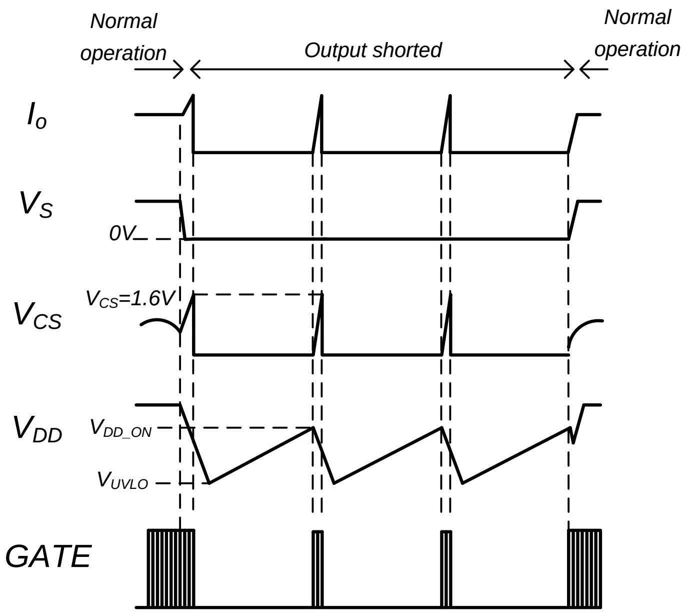


Fig.14 LED short-circuit protection

Under Voltage Lock-Out Protection

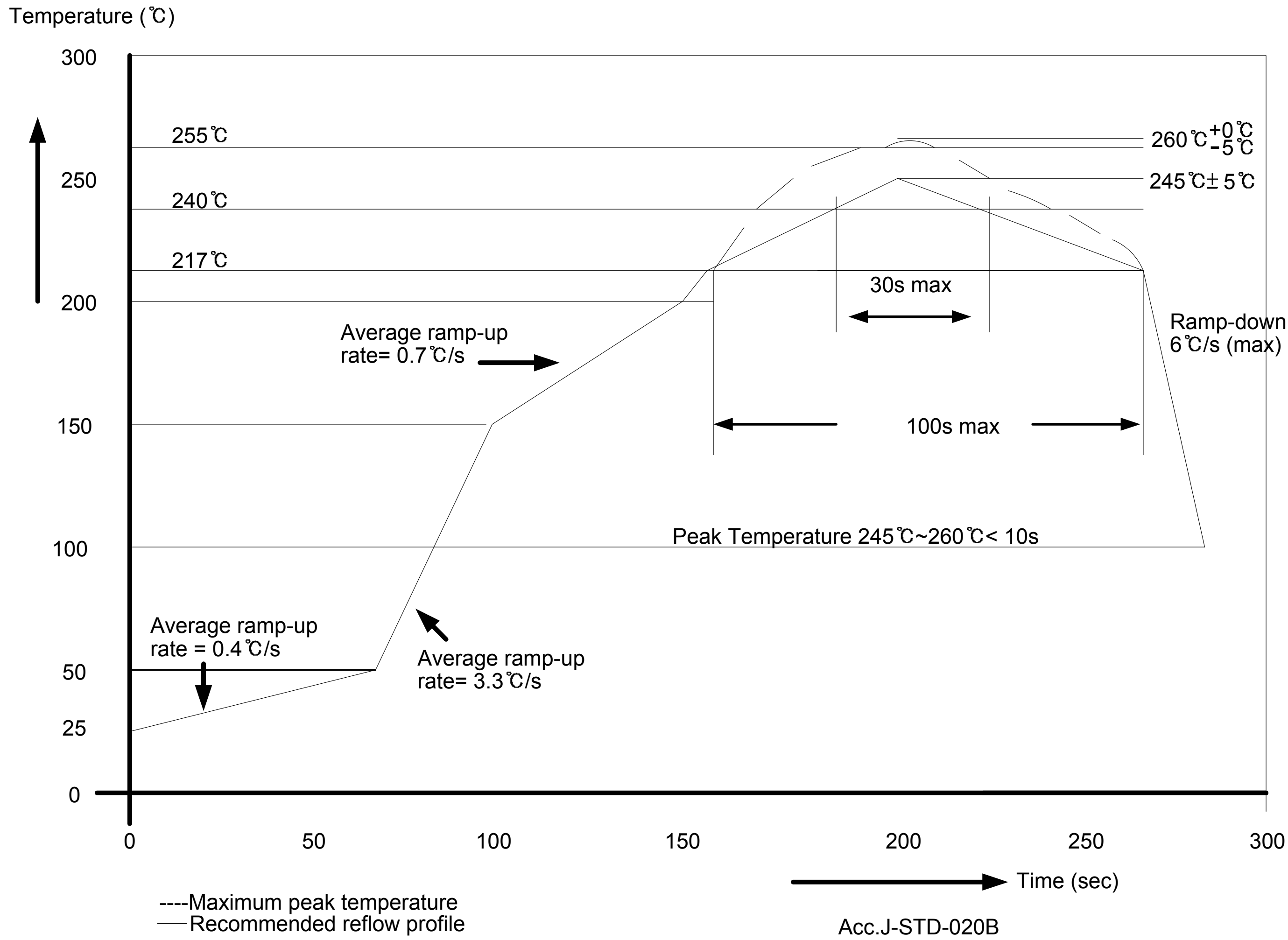
When V_{IN} drops below 8.0V, the GATE output will be forced low to turn off the external power MOSFET. When V_{IN} rises above 16.0V, the GATE output resumes normal operation and the external power MOSFET starts switching.

Over-Temperature Protection

When the junction temperature exceeds 155°C, the built-in over-temperature protection (OTP) is activated to force off the external power MOSFET. Once the junction temperature drops below 125°C, OTP is deactivated and MBI6802 resumes normal operation.

Soldering Process of "Pb-free & Green" Package Plating*

Macroblock has defined "Pb-Free & Green" to mean semiconductor products that are compatible with the current RoHS requirements and selected 100% pure tin (Sn) to provide forward and backward compatibility with both the current industry-standard SnPb-based soldering processes and higher-temperature Pb-free processes. Pure tin is widely accepted by customers and suppliers of electronic devices in Europe, Asia and the US as the lead-free surface finish of choice to replace tin-lead. Also, it adopts tin/lead (SnPb) solder paste, and please refer to the JEDEC J-STD-020C for the temperature of solder bath. However, in the whole Pb-free soldering processes and materials, 100% pure tin (Sn) will all require from 245 °C to 260°C for proper soldering on boards, referring to JEDEC J-STD-020C as shown below.

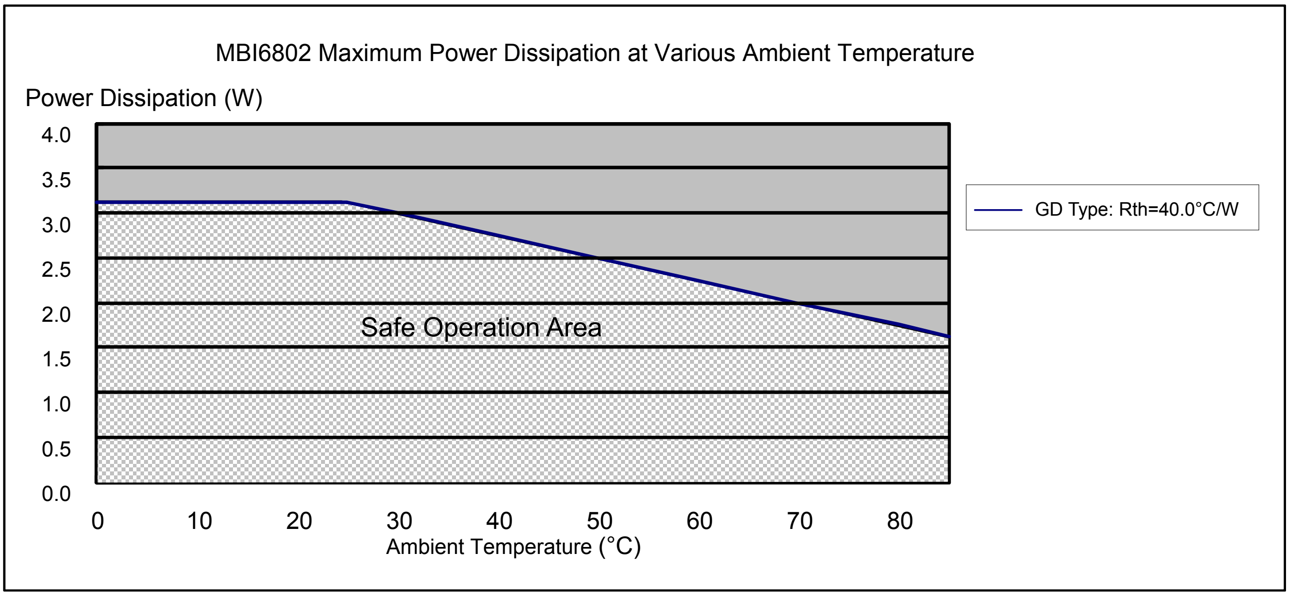


Package Thickness	Volume mm³ <350	Volume mm³ 350-2000	Volume mm³ ≧2000
<1.6mm	260 +0 °C	260 +0 °C	260 +0 °C
1.6mm – 2.5mm	260 +0 °C	250 +0 °C	245 +0 °C
≧2.5mm	250 +0 °C	245 +0 °C	245 +0 °C

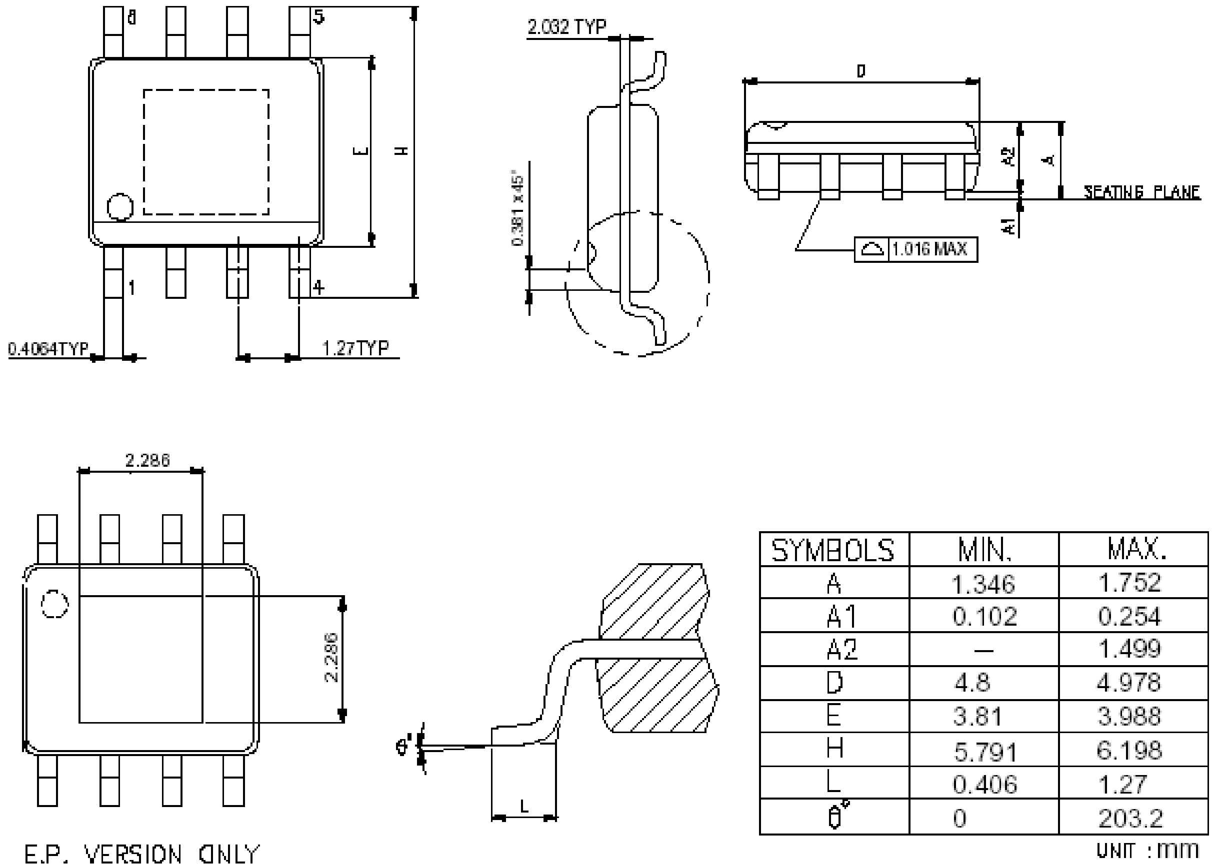
*Note: For details, please refer to Macroblock's "Policy on Pb-free & Green Package".

Package Power Dissipation (PD)

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



Outline Drawings



SYMBOLS	MIN.	MAX.
A	1.346	1.752
A1	0.102	0.254
A2	—	1.499
D	4.8	4.978
E	3.81	3.988
H	5.791	6.198
L	0.406	1.27
θ°	0	203.2

UNIT : mm

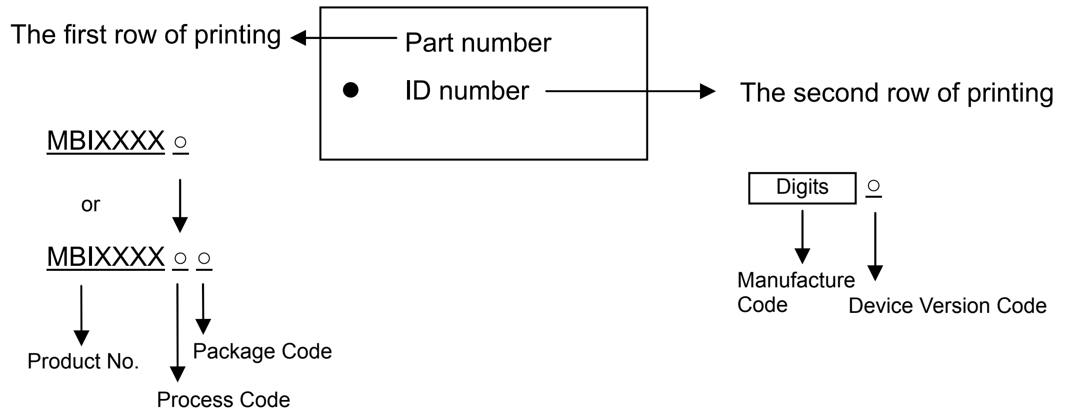
MBI6802 GD outline drawing

Note1: The unit for the outline drawing is mm.

Note2: 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

GD(SOP-8)



Product Revision History

Datasheet version	Device Version Code
V1.00	A
V1.01	A
V1.02	A

Product Ordering Information

Part Number	**“RoHS Compliant” Package Type**	**Weight (g)**
MBI6802GD-A	SOP8L-150-1.27	0.079g

Disclaimer