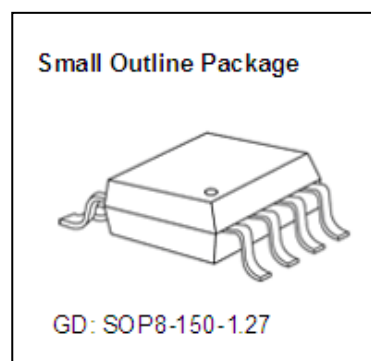


**High Power Factor AC/DC LED Driver**

Features

- Constant current LED driver
- Primary side regulation without photocoupler
- Built-in active power factor correction
- Quasi-resonant switching
- Universal input voltage range
- Support up to 50W output
- Full protection: Thermal shutdown
 - V_{DD} over voltage (OVP)
 - Under voltage lock-out (UVLO)
 - LED open-/short- circuit
 - Current sensing resistor open/short-circuit
 - Compensating capacitor open/short-circuit
- Available in SOP-8 package



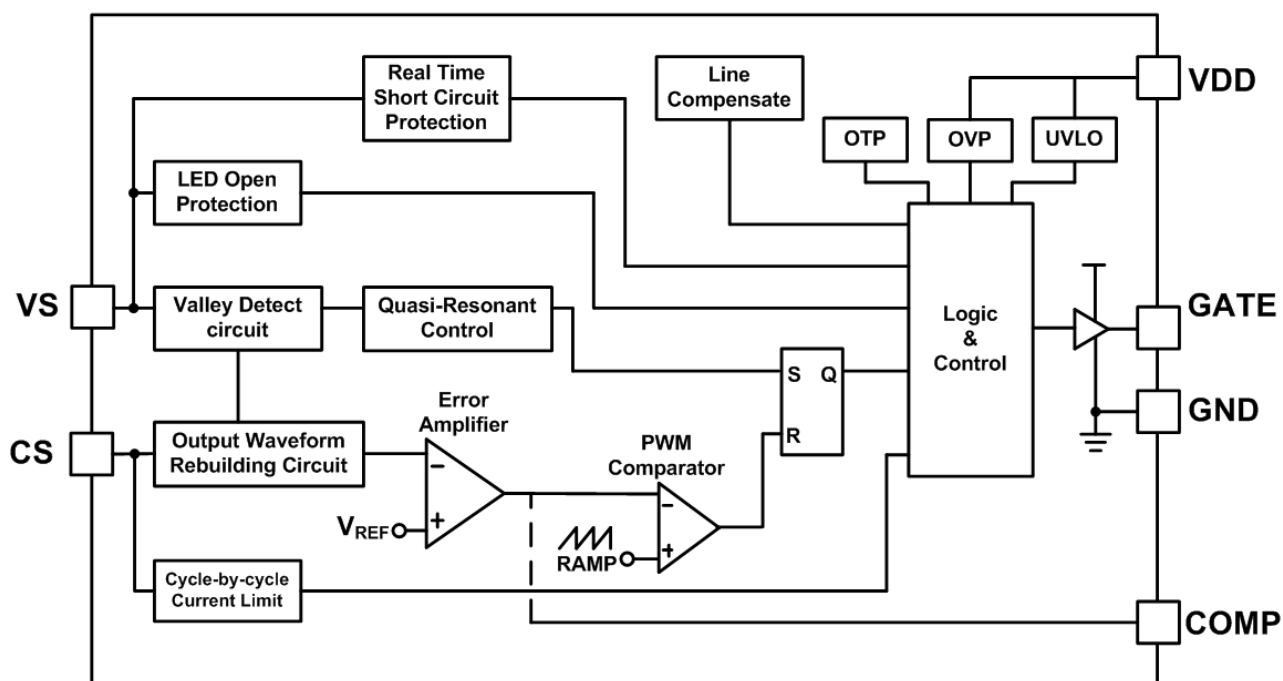
Product Description

MBI6812 is a universal input AC-DC converter designed to deliver constant current with primary side regulation (PSR) control. The built-in active power factor correction circuit maintains high power factor over a wide input voltage range. MBI6812 is optimized for applications of output power up to 50 Watt, and the efficiency is enhanced with quasi-resonant switching technique. MBI6812 is also featured with under voltage lock-out (UVLO), over temperature protection (OTP), LED open-circuit protection and LED short-circuit protection to protect the converter from being damaged accidentally. MBI6812 is specifically designed with current sensing resistor short protection to prevent MOSFET over-current and transformer saturation caused by manufacturing defect such as solder splash or abnormal operation such as accidental short-circuit by earthquake.

Applications

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

Functional Diagram



March 2014, V1.00

Pin Configuration

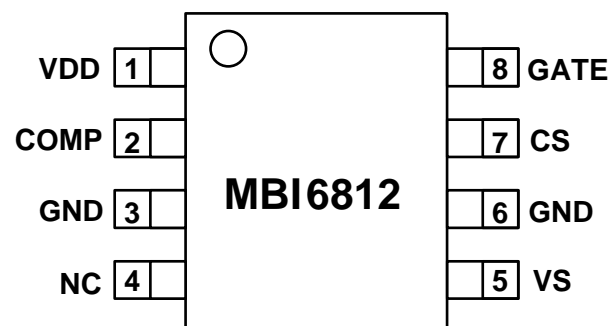


Fig. 3 Pin configuration of MBI6812

Pin Description

| Pin | Number | Description |
|------|--------|--|
| VDD | 1 | Supply voltage terminal |
| COMP | 2 | Terminal to connect the compensator |
| GND | 3 | Ground terminal |
| NC | 4 | No connection |
| VS | 5 | Terminal to connect the sensing circuit of the auxiliary winding voltage |
| GND | 6 | Ground terminal |
| CS | 7 | Terminal to connect the MOSFET current sensing resistor |
| GATE | 8 | Terminal to connect the gate of 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 |
| COMP pin input voltage | | V_{COM} | -0.3 | 7 | V |
| Gate pin output voltage | | V_{GATE} | -0.3 | 16 | 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_883H METHOD 3015.8) | - | Class 3A 4000V~7999V | - |
| | Machine mode | MM(JESD22-A115C) | - | Class M4 ≥400V | - |
| Power dissipation (On 4 layer PCB, $T_a=25^{\circ}\text{C}$) | | 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: $V_{DD}=20V$, $C_{IN}=10\mu F$, and $T_A=25^{\circ}C$ unless otherwise specified.

| Characteristics | Symbol | Conditions | Min | Typ | Max | Unit |
|-------------------------------------|-------------------|----------------------------|-------|------|-------|------|
| Supply Voltage | | | | | | |
| Continuous operating voltage | V_{OP} | | | 14 | | V |
| Start-up voltage | V_{START_UP} | start-up | 14.6 | 16 | 17.6 | V |
| Under-voltage lockout | V_{UVLO} | UVLO | 5.8 | 6.5 | 7.2 | V |
| V_{DD} over-voltage protection | V_{DD-OVP} | | 19.5 | 21.5 | 23.5 | V |
| Operating current | I_{DD-OP} | $C_L=1nF$, $F_{SW}=25kHz$ | - | 2.8 | 5 | mA |
| Stand-by current | I_{DD-ST} | I_{DD} before start-up | - | 30 | 50 | uA |
| Error Amplifier | | | | | | |
| Reference Voltage | V_{REF} | | 0.588 | 0.6 | 0.612 | V |
| COMP Pre-charge Voltage | V_{PC} | | - | 1.4 | - | V |
| COMP Clamping Voltage | V_{CLAMP} | | - | 3.2 | - | V |
| Maximum COMP Charging Current | I_{COMP} | | - | 60 | - | uA |
| Current Sense | | | | | | |
| Propagation delay to GATE output | T_{PD} | | - | 100 | 200 | ns |
| Leading edge blanking time | T_{LEB_CS} | | - | 170 | - | ns |
| Threshold voltage for current limit | V_{CSTH} | | 0.5 | 0.6 | 0.7 | V |
| Voltage Sense | | | | | | |
| Open protection threshold | V_{S-open} | | 1.4 | 1.5 | 1.6 | V |
| VS Leading Edge Blanking | T_{LEB_VS} | | | 1.0 | | us |
| VS Pin Sourcing Current | I_{Source_VS} | | - | 1.2 | | mA |
| Gate Driver | | | | | | |
| Maximum duty ratio | D_{MAX} | | - | 50 | - | % |
| Output high voltage | V_{OH} | | | 12 | | V |
| Output low voltage | V_{OL} | | - | - | 0.5 | V |
| Rising time | T_R | 20%-80% of swing | - | 50 | 100 | ns |
| Falling time | T_F | 20%-80% of swing | - | 40 | 80 | ns |
| Maximum On-time | T_{ON_Max} | | | 11.5 | | us |
| Minimum On-time | T_{ON_min} | | | 200 | | ns |
| Maximum Off-time | T_{OFF_Max} | | | 36 | | us |
| Minimum Off-time | T_{OFF_min} | | | 1.5 | | us |
| Maximum Switching Frequency | F_{Switch_Max} | | | 120 | | kHz |
| Thermal Shutdown | | | | | | |
| Thermal shutdown threshold | T_{SD} | Hysteresis=30°C | 140 | 155 | 170 | °C |

Application Information

MBI6812 is a primary side regulator (PSR) optimized for flyback converters. With the primary side regulation technique, the output LED current can be precisely sensed and regulated without any photocoupler. The built-in power factor correction (PFC) circuit maintains high power factor over a wide input voltage range while suppresses the harmonic current to conform to EN61000-3-2 regulations. The embedded quasi-resonant switching technique enables each cycle to start at the relative valley of the drain-source voltage (V_{DS}) of the MOSFET, which greatly enhances the conversion efficiency and alleviates radiation EMI. MBI6812 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 eliminates the in-rush current, while the current sensing resistor short protection prevents the damage caused by manufacturing defect or abnormal operation which leads to short-circuit of the current sensing resistor.

Operation Principle

Flyback Converter

Fig.4 is a simplified diagram of a flyback converter controlled by MBI6812. 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 LED current is supplied by C_O . When S_1 is off, the energy stored on the magnetizing inductor is discharged to the secondary side and therefore supplies the LED 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} .

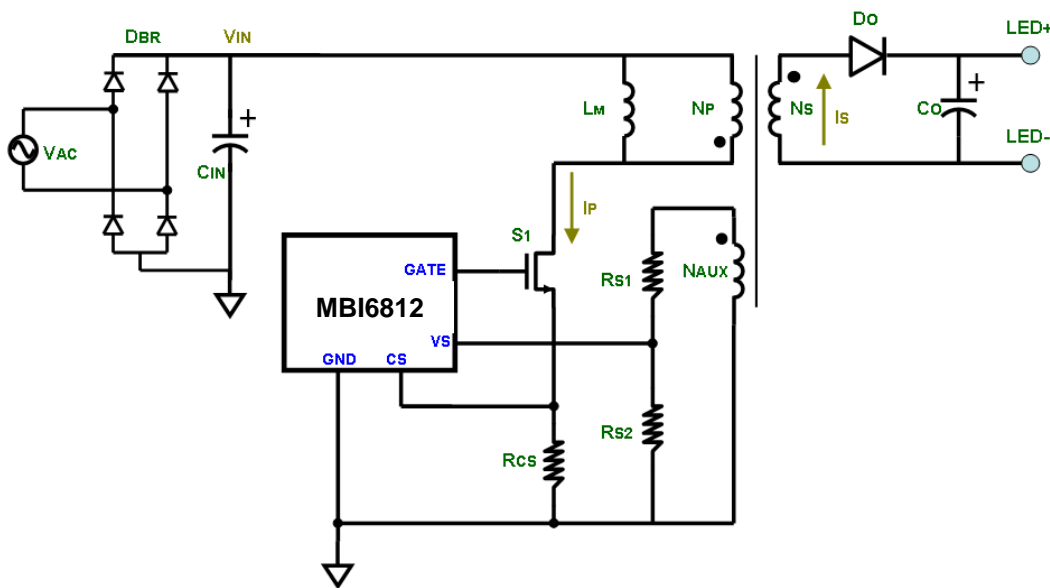


Fig. 4 Simplified flyback converter controlled by MBI6812

Primary Side Regulation

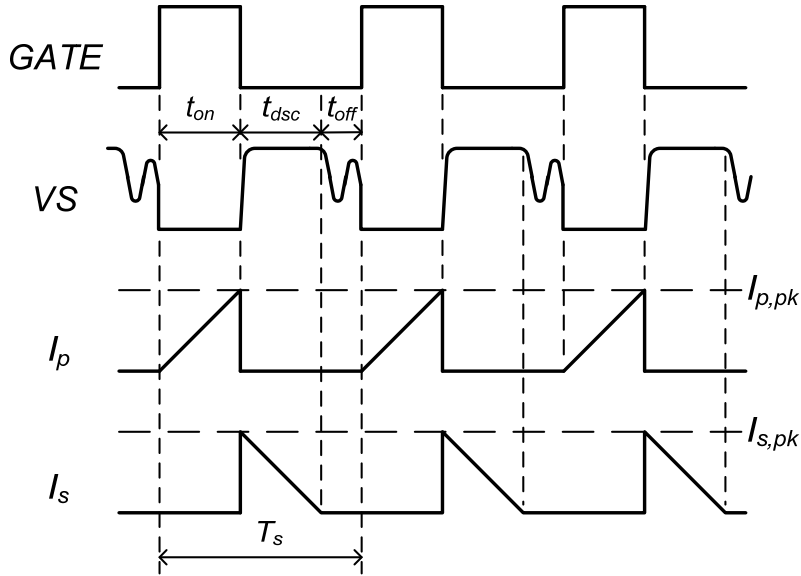


Fig.5 Typical switching waveforms of primary components of a flyback converter

Fig.5 illustrates a typical waveforms of a flyback converter operated in discontinuous conduction mode (DCM), in which t_{on} is the conduction period of the MOSFET, t_{dsc} is the conduction period of output diode, t_{off} is the period in which both MOSFET and the output diode are cut off, and T_s represents the entire switching period. The signal GATE is the control signal of the gate terminal of the MOSFET, and the signal VS is the voltage-dividing replica of the auxiliary winding voltage. When the magnetizing inductor is fully discharged, the secondary side current I_s decreases to zero and VS abruptly drops accordingly. By detecting the onset of this voltage drop, the secondary side discharge time t_{dsc} can be calculated. The average output current I_o can be mathematically deduced as

$$I_o = \frac{1}{2} \cdot \frac{t_{dsc}}{T_s} \cdot I_{s, pk} \dots\dots\dots (1)$$

$$= \frac{1}{2} \cdot \frac{t_{dsc}}{T_s} \cdot \frac{N_P}{N_S} \cdot I_{p, pk} \dots\dots\dots (2)$$

$$= \frac{1}{2} \cdot \frac{t_{dsc}}{T_s} \cdot \frac{N_P}{N_S} \cdot \frac{V_{cs, pk}}{R_{CS}} \dots\dots\dots (3)$$

The primary side peak current $I_{p, pk}$ can be directly sensed at pin CS.

Active Power Factor Correction (APFC)

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 $I_{P(avg)}$, both of which are also proportional to the peak value of the magnetizing inductor current $I_{LM(peak)}$, as stated in equations (4) and (5).

$$V_{LM} \propto I_{P(avg)} \left\{ \begin{array}{l} V_{LM} \propto I_{LM(peak)} \dots\dots\dots (4) \\ I_{LM(peak)} \propto I_{P(avg)} \dots\dots\dots (5) \end{array} \right.$$

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.

$$V_{LM} = L_M \frac{I_{LM(peak)}}{t_{on}} \dots\dots\dots (6)$$

$$I_{P(avg)} = \frac{1}{2} \frac{I_{LM(peak)} t_{on}}{T_s} = \frac{1}{2} \frac{I_{LM(peak)} D_{on} T_s}{T_s} = \frac{1}{2} I_{LM(peak)} D_{on} \dots\dots\dots (7)$$

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 kept relatively constant for several 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.

Quasi-Resonant (QR) Switching

Fig. 6 illustrates typical switching waveforms of a quasi-resonant flyback converter. When the magnetizing inductor is fully discharged, the residue charge on the MOSFET parasitic capacitance C_{ds} induces a resonant between the magnetizing inductor L_M and C_{ds} . As illustrated in *Condition 1*, MBI6812 detects the first valley of the resonant response and turns on the MOSFET to initiate the very next switching cycle. In some applications, as depicted in *Condition 2*, the MOSFET is turned on at another relative valley of the resonant due to minimum switching period limitation (8.33μs, or equivalently 120kHz maximum switching frequency). In both cases, the switching loss is minimized and the radiation EMI is alleviated because to the onset of each switching cycle is at the voltage valley.

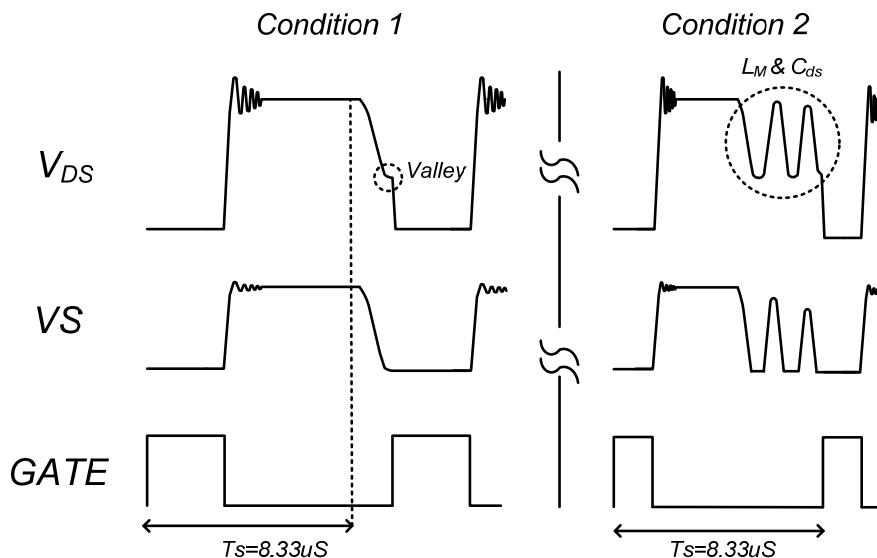


Fig.6 Typical quasi-resonant switching waveforms of MBI6812

Start-Up

Upon system power-on, the input voltage V_{IN} charges capacitor C_{DD} through resistor R_{ST} with start-up current I_{DD_ST} . Once V_{DD} reaches start-up threshold V_{DD_ON} , MBI6812 starts normal operation with quiescent current I_{DD_NORMAL} . Before the output voltage V_o is fully established, the chip power consumption of MBI6812 is solely supplied by the capacitor C_{DD} . As depicted in Fig. 7, the built-in speedup circuit shortens the start-up time by quadrupling the conduction period of the MOSFET within the pre-defined t_{speed_up} .

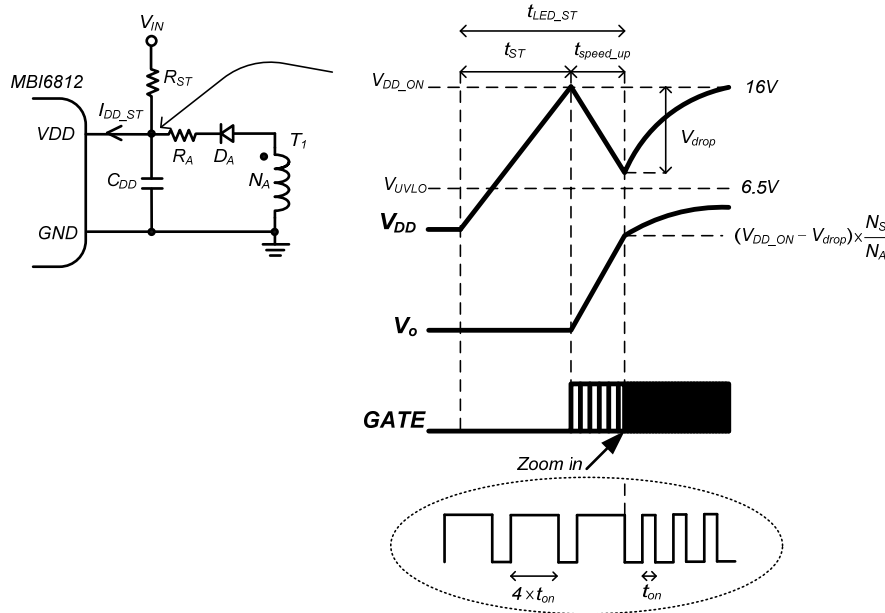


Fig. 7 Typical start-up waveforms of MBI6812

Protection

V_{DD} Over Voltage Protection (OVP)

MBI6812 realizes input over voltage protection by sensing the input voltage at pin V_{DD} . Once any abnormal spike occurs and exceeds the V_{DD} OVP threshold V_{DD_OVP} , numerically 21V, $GATE$ signal ceases switching and V_{DD} drops accordingly. The converter is fully turned off when V_{DD} drop below V_{UVLO} .

Under Voltage Lock-Out (UVLO)

When V_{IN} drops below 6.5V, 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 (OTP)

When the junction temperature exceeds 155°C, the built-in over-temperature protection (OTP) is activated to force off the MOSFET. Once the junction temperature drops below 125°C, OTP is deactivated and MBI6812 resumes normal operation.

LED Open-Circuit Protection

By detecting the auxiliary winding voltage during the conduction period of the output diode D_o , MBI6812 can equivalently calculate the output voltage to achieve output open-circuit protection. Once V_S exceeds the preset voltage V_{O_OPEN} of 1.5V, $GATE$ signal ceases switching and V_{DD} drops accordingly. The converter is fully turned off when V_{DD} drop below V_{UVLO} and the converter automatically restarts. After the system restarts, MBI6812 will shut down the converter again if the open-circuit condition still exists or resume normal operation once the open-circuit condition is removed, as shown in Fig. 8.

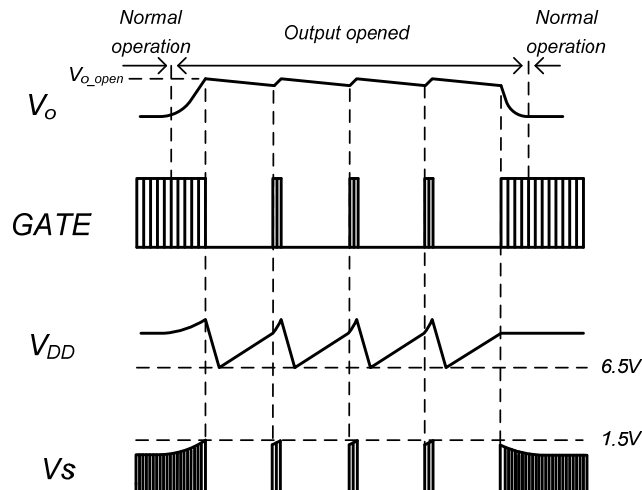


Fig. 8 LED open-circuit protection

LED Short-Circuit Protection

The operation of LED short-circuit protection is illustrated in Fig. 9. By detecting whether the voltage at pin VS drops to zero while the voltage at pin CS exceeds 0.6V, MBI6812 can judge the occurrence of LED short-circuit failure. Once LED short-circuit failure occurs, $GATE$ signal ceases switching and V_{DD} drops with the output voltage. The converter is fully turned off when V_{DD} drop below V_{UVLO} and the converter automatically restarts. After the system restarts, MBI6812 will shut down the converter again if the short-circuit condition still exists or resume normal operation once the short-circuit condition is removed.

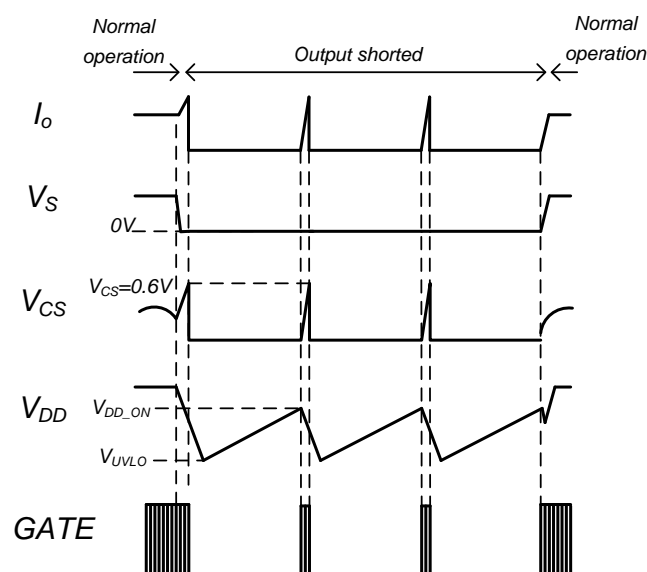


Fig. 9 LED short-circuit protection

Current Sensing Resistor Open/Short Protection

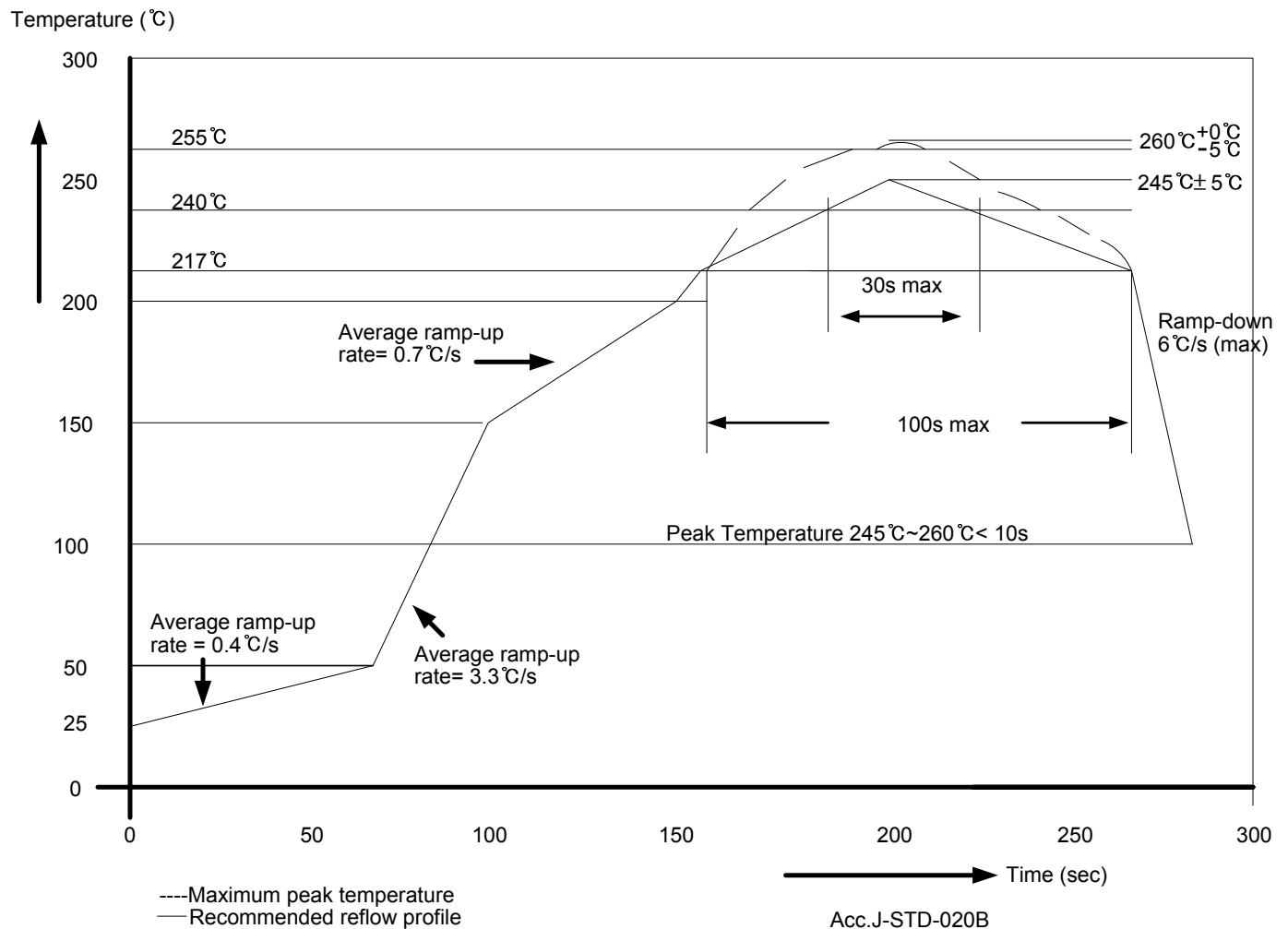
MBI6812 is designed with current sensing resistor open/short protection to prevent extreme fault conditions from irrecoverably damaging the converter, such as cold welding or solder splash during manufacturing process, and accidental short circuit caused by earthquake or abnormal vibration during normal operations.

Compensating Capacitor Open/Short Protection

In normal operation without additional protection, floating or short-circuit of the compensating capacitor would lead to unexpected behavior of the internal error amplifier, which primarily guarantee the close-loop stability. MBI6812 specially provides compensating capacitor open/short protection against these fault conditions from destabilizing the converter.

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.

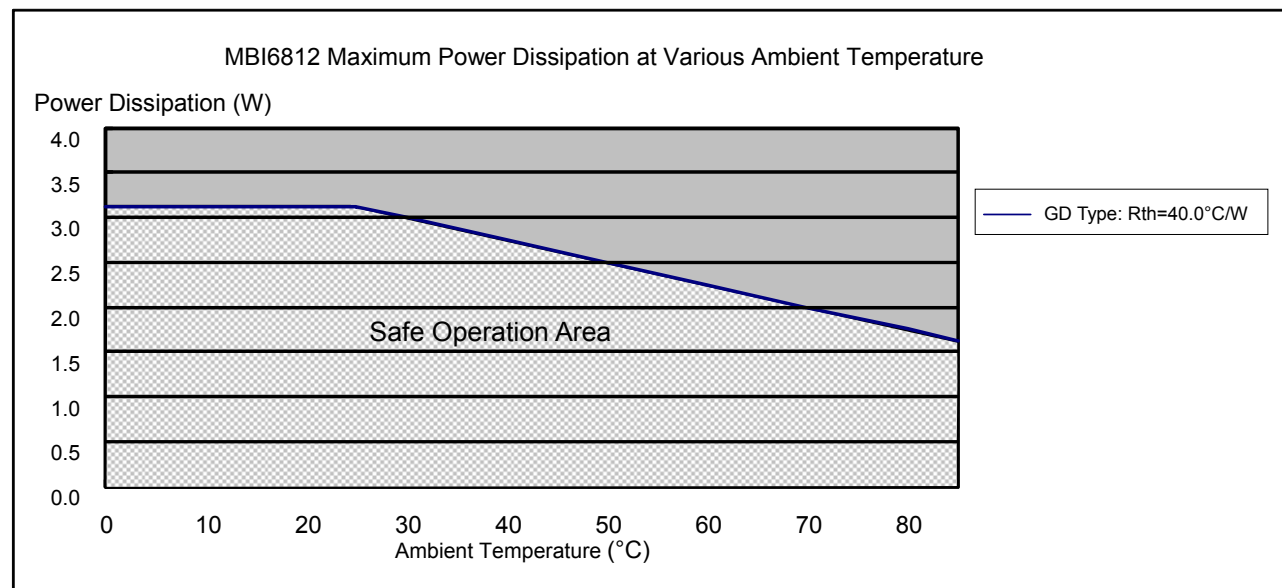


| Package Thickness | Volume mm ³ <350 | Volume mm ³ 350-2000 | Volume mm ³ ≥ 2000 |
|-------------------|--------------------------------|------------------------------------|----------------------------------|
| <1.6mm | 260 +0 °C | 260 +0 °C | 260 +0 °C |
| 1.6mm – 2.5mm | 260 +0 °C | 250 +0 °C | 245 +0 °C |
| ≥ 2.5mm | 250 +0 °C | 245 +0 °C | 245 +0 °C |

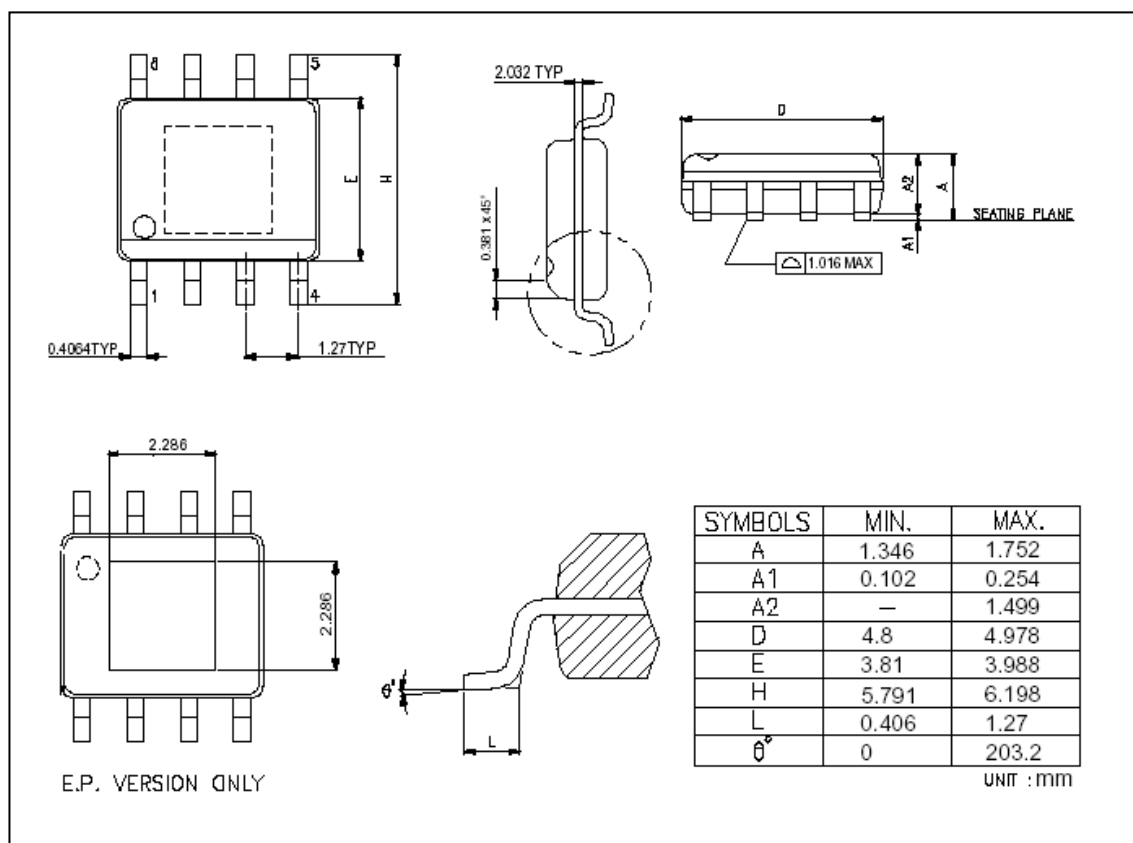
*Note: For details, please refer to Macroblock's "Policy on Pb-free & Green Package".

Package Power Dissipation (PD)

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



Outline Drawings



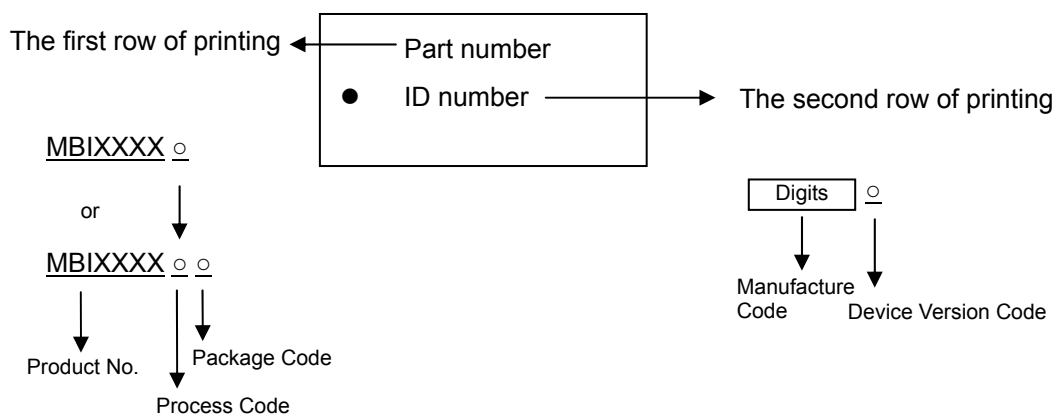
MBI6812 GD outline drawing

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 |

Product Ordering Information

| Part Number | "RoHS Compliant" Package Type | Weight (g) |
|-------------|-------------------------------|------------|
| MBI6812GD-A | SOP8-150-1.27 | 0.079g |

*Please place your order with the "**product ordering number**" information on your purchase order (PO).

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