# Two Step Dimmable Isolated 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 protections: 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

- 2 steps dimmable by input voltage toggling

- High 2nd step output current accuracy

- Package MSL Level : 3

Small Outline Package

GD: SOP8-150-1.27
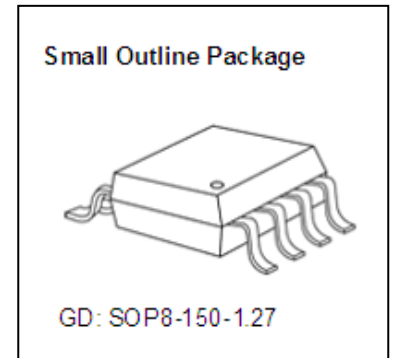
Product Description

MBI6804 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. MBI6804 is optimized for applications of output power up to 50 Watt, and the efficiency is enhanced with quasi-resonant switching technique. MBI6804 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. MBI6804 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

July 2015, V3.00
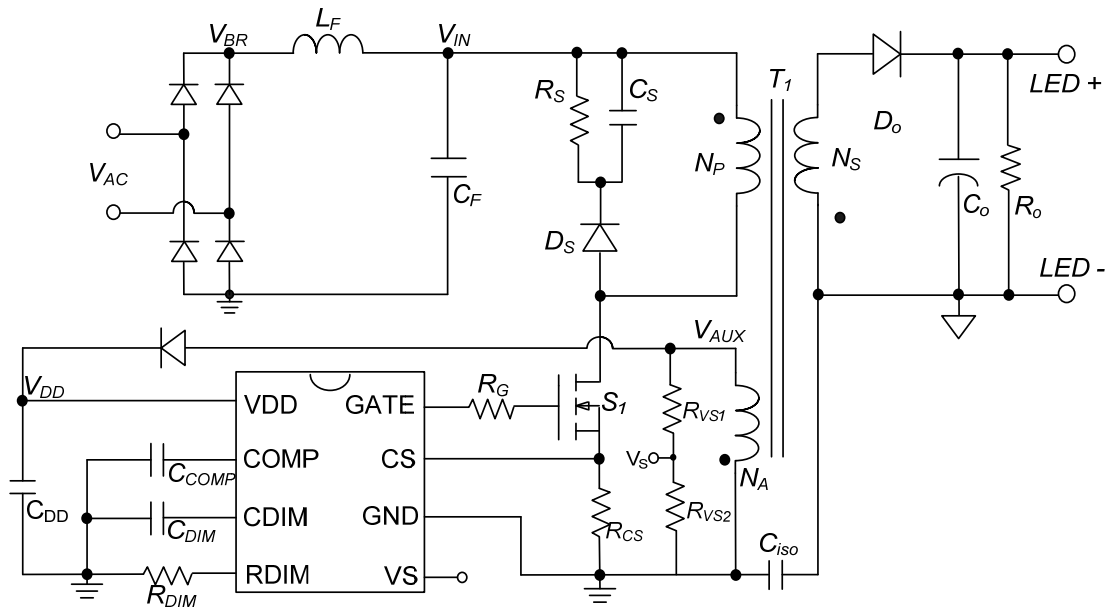
Typical Application Circuit

Fig.1 Typical application circuit of MBI6804

Functional Diagram

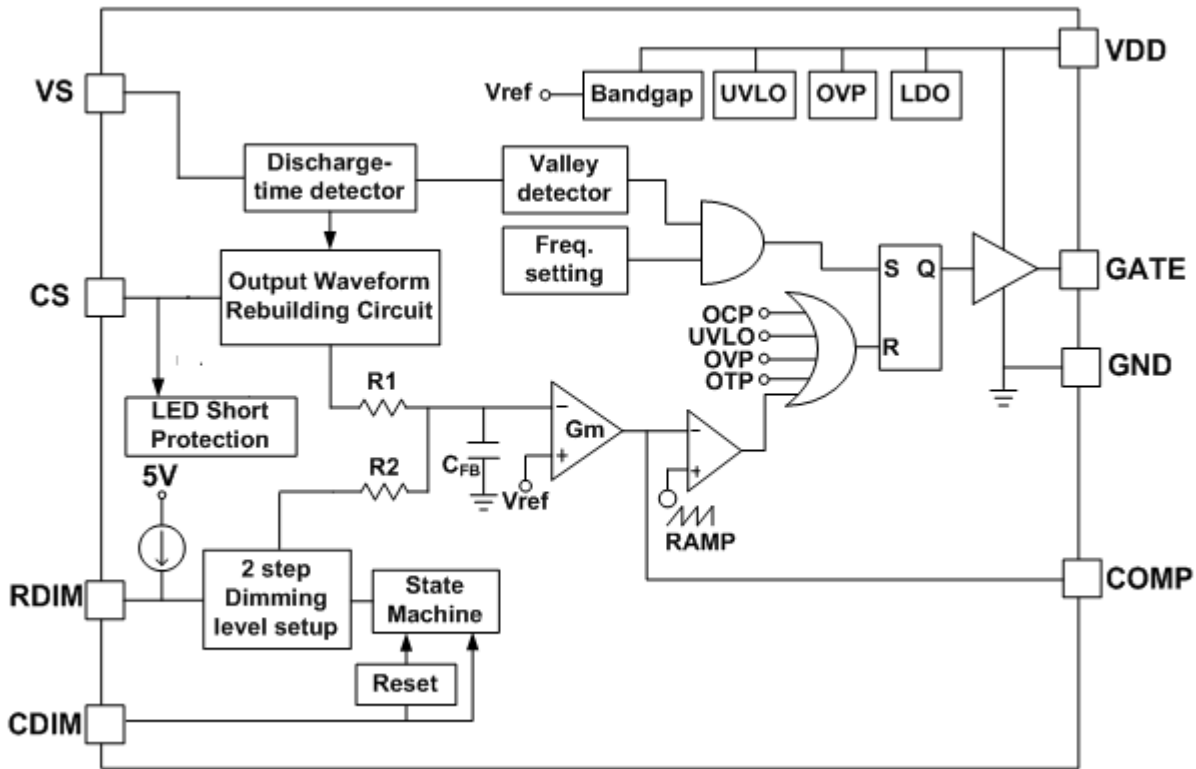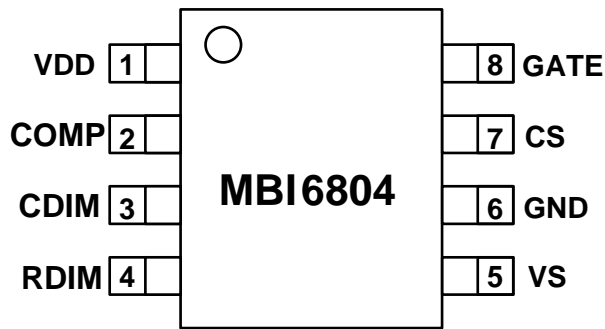

Fig.2 Functional diagram of MBI6804

Pin Configuration

Fig. 3 Pin configuration of MBI6804

Pin Description

Pin	Number	Description
VDD	1	Supply voltage terminal
COMP	2	Terminal to connect the compensator
CDIM	3	Terminal to connect the Cdim capacitor
RDIM	4	Terminal to connect the Rdim resistor
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	22	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
CDIM pin input voltage		V_{CDIM}	-0.3	7	V
RDIM pin input voltage		V_{RDIM}	-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 (5KV)	-
	Machine mode	MM(ANSI/ESD S5.2-2009)	-	Class M4 (450V)	-
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}=18V, 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}	-	-	14	-	V
Start-up voltage	V_{START_UP}	Start-up	-	17	-	V
Under-voltage lockout	V_{UVLO}	UVLO	-	7	-	V
V_{DD} over-voltage protection	V_{DD-OVP}	-	18	20	22	V
Operating current	I_{DD-OP}	VDD=18V,C_L=1nF, F_{SW}=20kHz	-	1.2	2	mA
		VDD=18V,C_L=1nF, F_{SW}=120kHz	-	2.5	5	mA
Stand-by current	I_{DD-ST}	IDD before start-up	-	20	30	uA
Error Amplifier						
Reference Voltage	V_{REF}	-	1.176	1.2	1.224	V
COMP Pre-charge Voltage	ΔV_{PC}	At first start up	-	1.25	-	V
COMP Clamping Voltage	V_{CLAMP}	-	-	4	-	V
Maximum COMP Charging Current	I_{COMP}	-	-	65	-	uA
Current Sense						
Current Limit Threshold Voltage	V_{CL}	-	0.9	1	1.1	V
Voltage Sense						
VS Pin Sourcing Current	I_{Source_VS}	VS=-0.3V	--	0.8	-	mA
Gate Driver						
Output high voltage	V_{OH}	V_{DD}=20V at operating	-	12	-	V
Output low voltage	V_{OL}	V_{DD}=20V at operating	-	-	0.5	V
Rising time	T_R	V_{DD}=20V, 20%-80% of swing	-	35	70	ns
Falling time	T_F	V_{DD}=20V, 20%-80% of swing	-	25	60	ns
Maximum On-time	T_{ON_Max}	COMP=3.8V	-	14	-	us
Minimum On-time	T_{ON_min}	CS=1.5V	-	200	-	ns
Maximum Off-time	T_{OFF_Max}	-	-	50	-	us
Maximum Switching Frequency	F_{Switch_Max}	-	105	120	135	kHz
Thermal Shutdown						
Thermal shutdown threshold	T_{SD}	Hysteresis=30℃	140	155	170	°C
Dimming						
Dimming Step Number	-	-	-	2	-	time
Dimming Block Current	-	-	-	6	10	uA
Dimming Block Hold Time	-	C_{DIM}≦10uF	1	-	-	S
Dimming Block Operating Voltage	-	-	-	4.5	-	V
Dimming Reset Voltage	-	-	-	2.2	-	V
Rdim Output Current	-	-	-	105	-	uA

Application Information

MBI6804 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. MBI6804 is also equipped with full protections, inclusive of over-temperature protection, LED open-circuit protection, and LED short-circuit protection. 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 MBI6804. 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}.
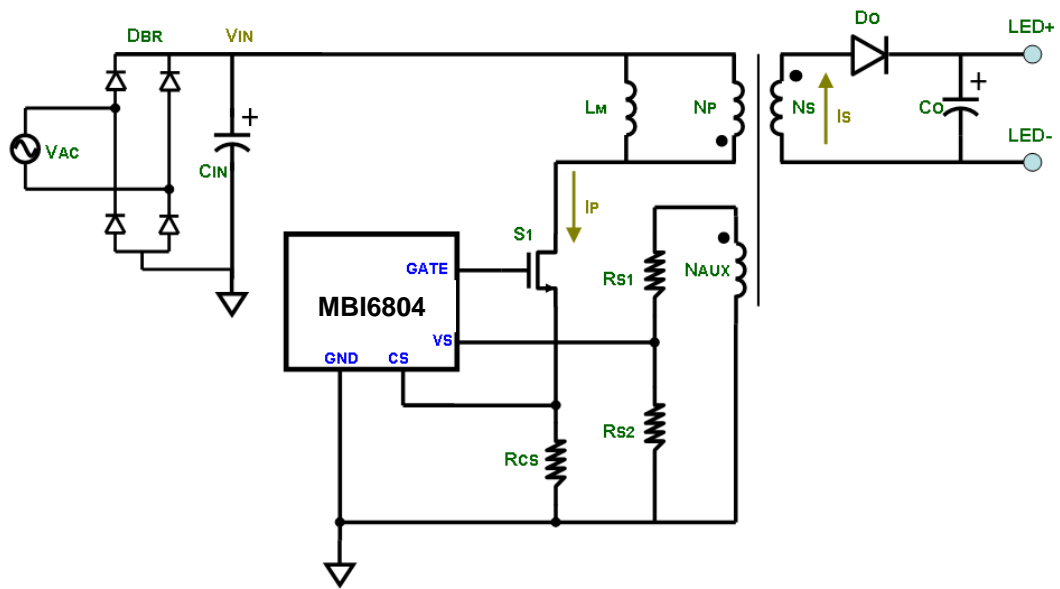

Fig. 4 Simplified flyback converter controlled by MBI6804
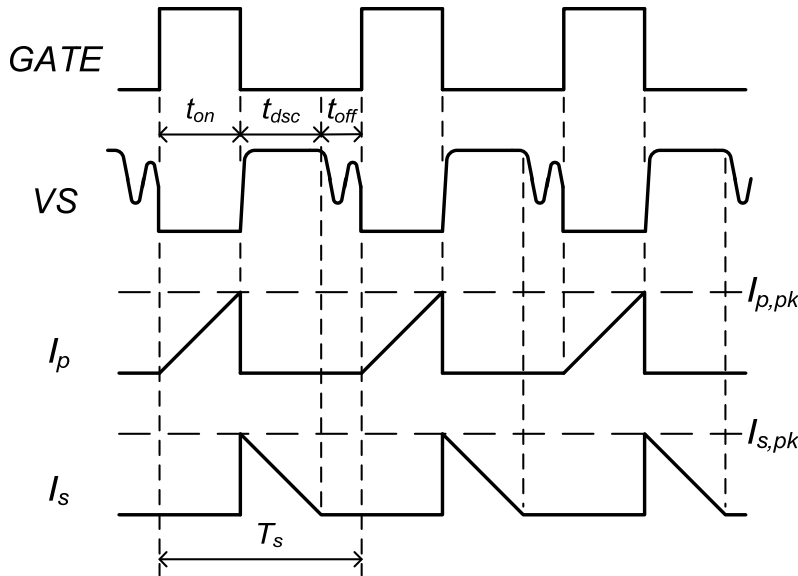
Primary Side Regulation

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

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

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

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

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).

$$V_{LM} \propto I_{P(avg)} \begin{cases} V_{LM} \propto I_{LM(peak)} & \text{.. (4)} \\ \\ I_{LM(peak)} \propto I_{P(avg)} & \text{.. (5)} \end{cases}$$

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 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*, MBI6804 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.
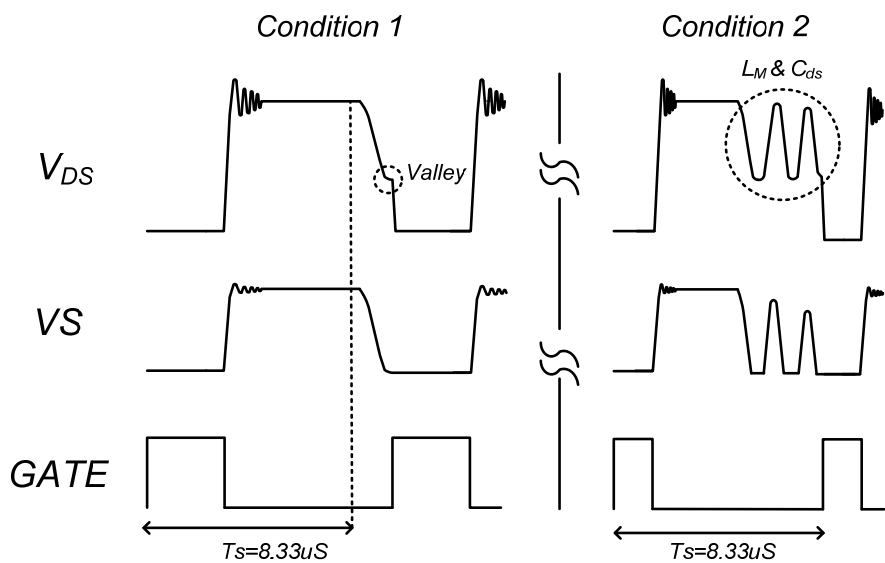

Fig.6 Typical quasi-resonant switching waveforms of MBI6804

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}, MBI6804 starts normal operation with quiescent current I_{DD_NORMAL}. Before the output voltage V_o is fully established, the chip power consumption of MBI6804 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}.
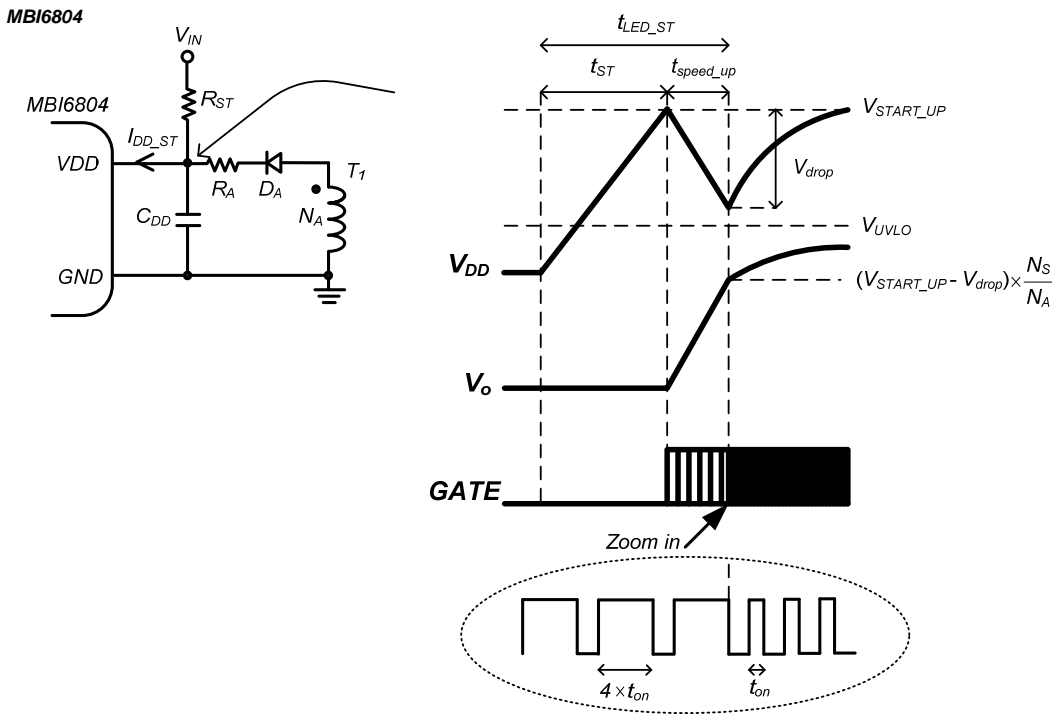

Fig. 7 Typical start-up waveforms of MBI6804

Dimming Methodology

The dimming method can be described simply as the combination of the following actions.
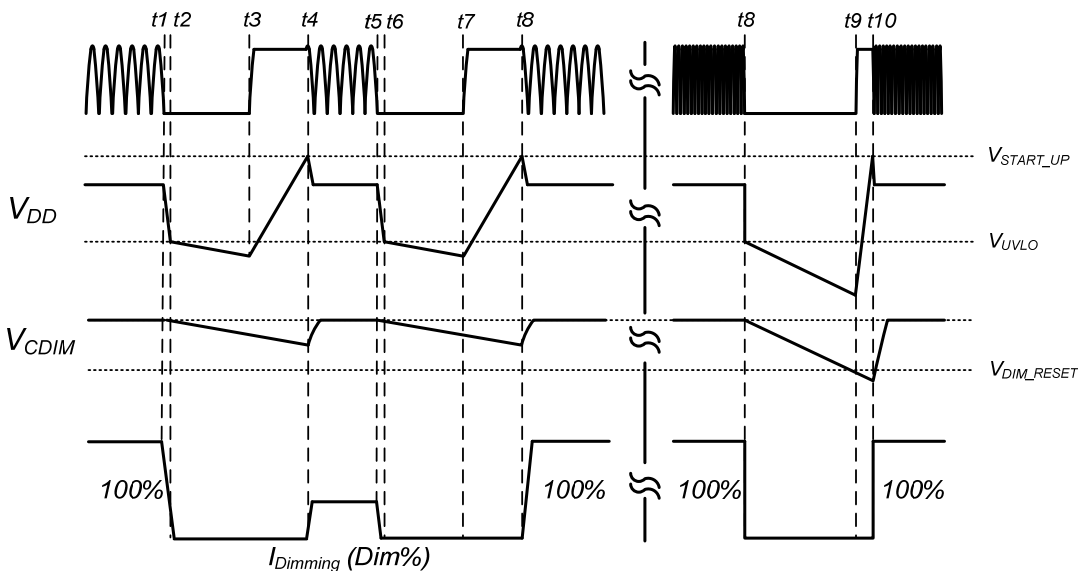

Fig.8 Dimming method of MBI6804

- • 1. t1= power-off started

- • 2. t2= V_{DD} drops below UVLO 6.7V, V_{CDIM} starts to drop. Power-on before it reaches 1.7V, the dimming function can be triggered.

- • 3. After power-off, if power-on before VDD reaches UVLO, the output state will not change.

- • 4. Power-on after V_{CDIM} drops below 1.7V.   The output will reset to 100%.

I_{RDIM}=100uA: V_{RDIM} = I_{RDIM} x R_{DIM}

V_{RDIM}(V)	Dimming %
>4	100
3~4	50
2.5~3	45
2~2.5	40
1.5~2	35
1~1.5	30
0.5~1	25
<0.5	20

Protection

V_{DD} Over Voltage Protection (OVP)

The build-in over voltage protection is implemented by VDD pin. When the voltage on VDD exceeds V_{DD_OVP} due to the abnormal voltage on auxiliary winding, the GATE signal will stop switching immediately and shut off MBI6804 until the V_{DD} voltage drops to 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 MBI6804 resumes normal operation.

LED Open-Circuit Protection

The operation of LED open-circuit protection is illustrated in Fig.9. When LED is opened, the voltage on VDD pin rises with the output voltage; once the V_{DD} voltage achieves the threshold voltage of open circuit protection (V_{DD_OVP}), the GATE signal will stop switching until the V_{DD} voltage drops to UVLO. When the V_{DD} drops to UVLO, and then the converter will restart from soft start mode again. The cycle will be repeated until the fault is removed. In general, to prevent IC being damaged by spike voltage, a clamp circuit is paralleled with *VDD* pin. To ensure IC works normal, the clamp voltage should be designed between the maximum rating of *VDD* and V_{DD_OVP}. The

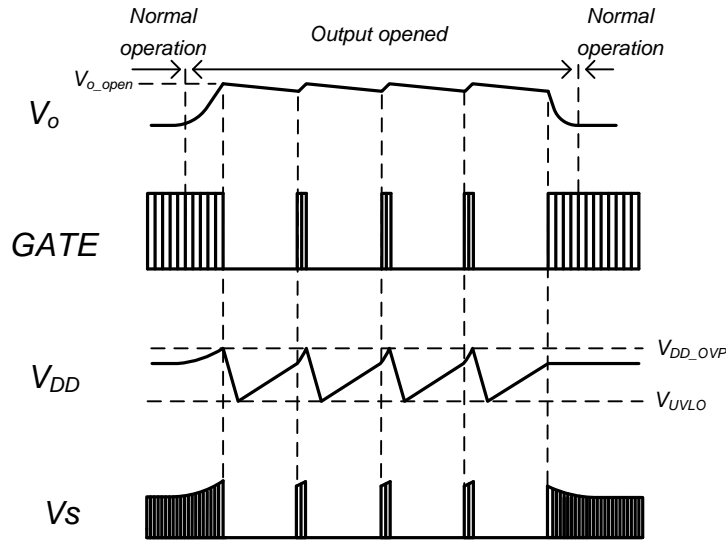specification of zener diode, 1SMA4749, from Panjit could be the reference of clamp circuit.

Fig.9 Conceptual waveform of V_O, GATE, V_{DD} and V_S when output is opened and recovered

LED Short-Circuit Protection

The operation of LED short-circuit protection is illustrated in Fig.10 By detecting whether the voltage at pin *VS* drops to zero while the voltage at pin CS exceeds 1.0V, MBI6804 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, MBI6804 will shut down the converter again if the short-circuit condition still exists or resume normal operation once the short-circuit condition is removed
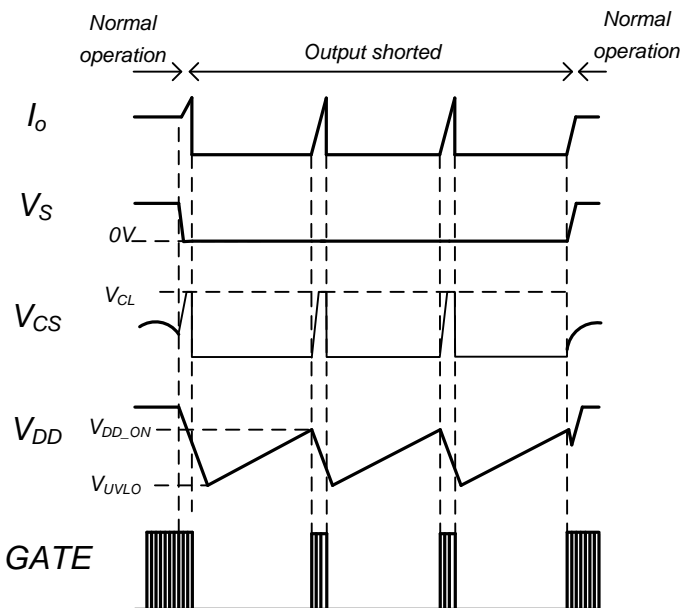

Fig. 10 LED short-circuit protection

Current Sensing Resistor Open/Short Protection

MBI6804 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. MBI6804 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 ^{o}C to 260°C for proper soldering on boards, referring to JEDEC J-STD-020C as shown below.

For managing MSL3 Package, it should refer to JEDEC J-STD-020C about floor life management & refer to JEDEC J-STD-033C about re-bake condition while IC's floor life exceeds MSL3 limitation.
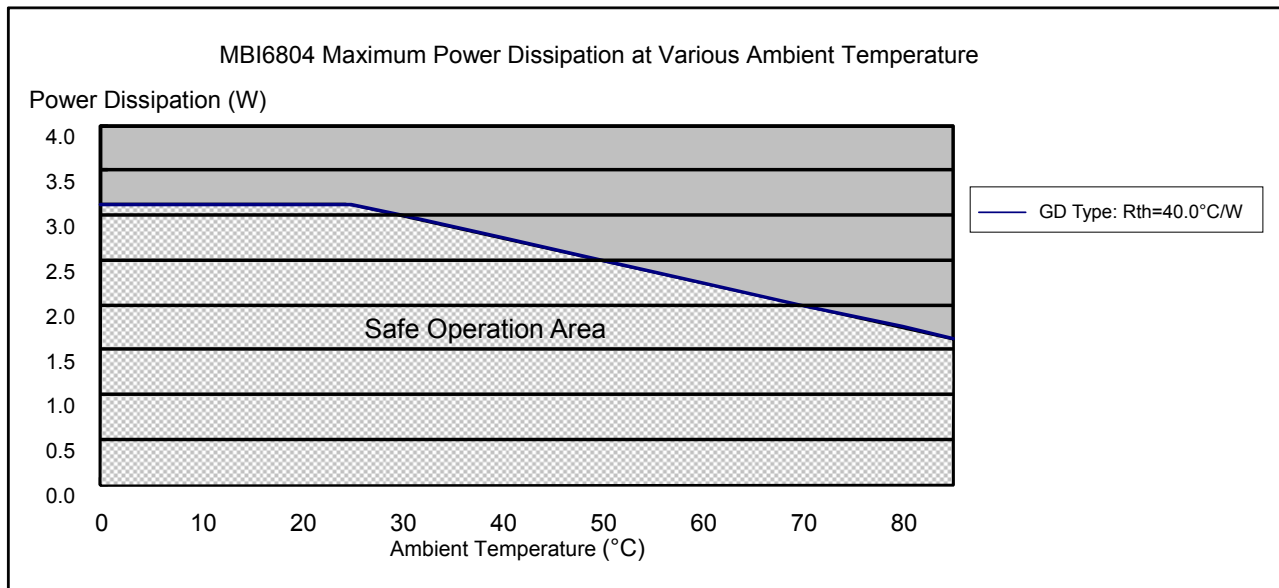
Temperature (℃)

----Maximum peak temperature
——Recommended reflow profile
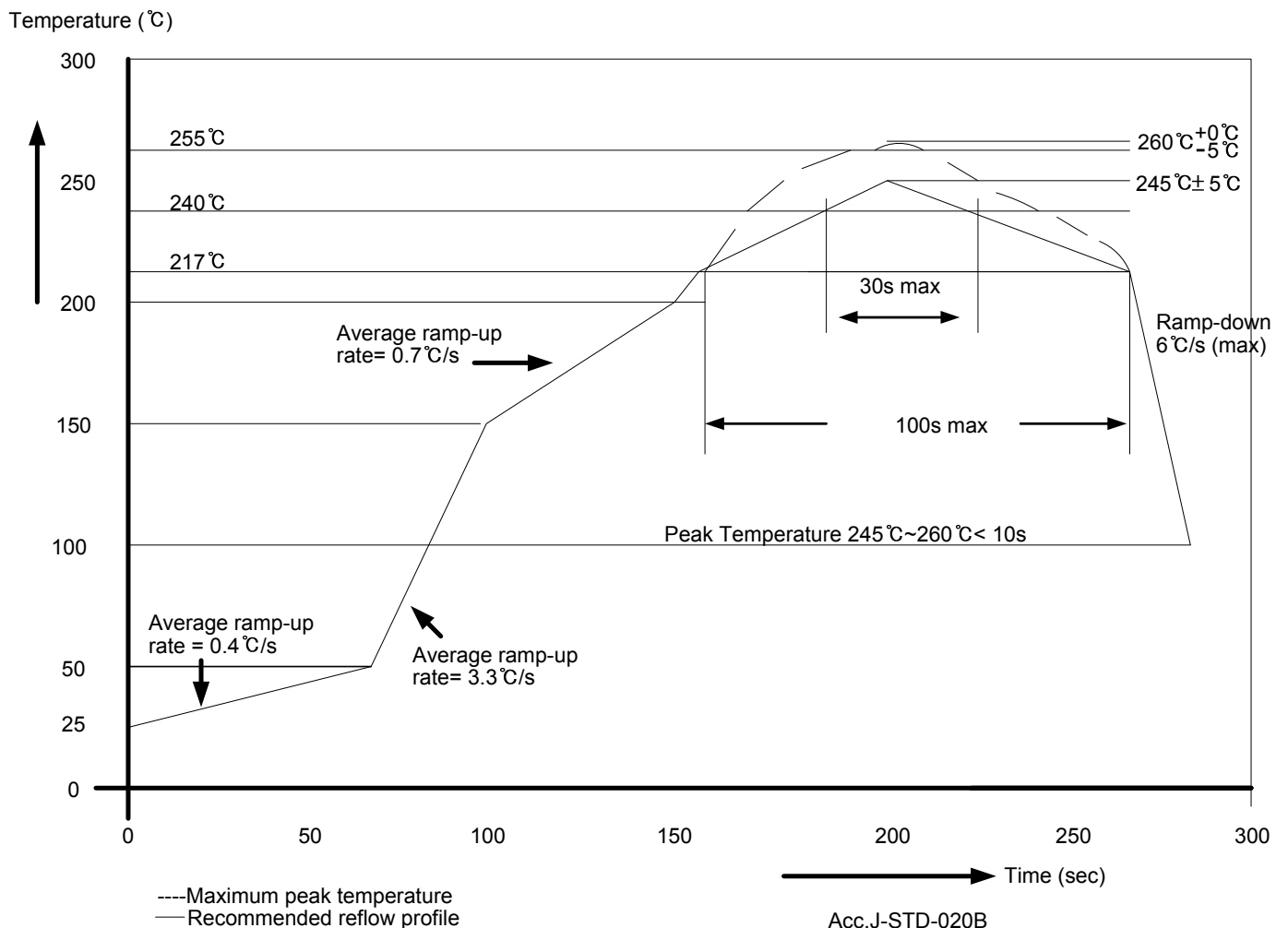
Acc.J-STD-020B

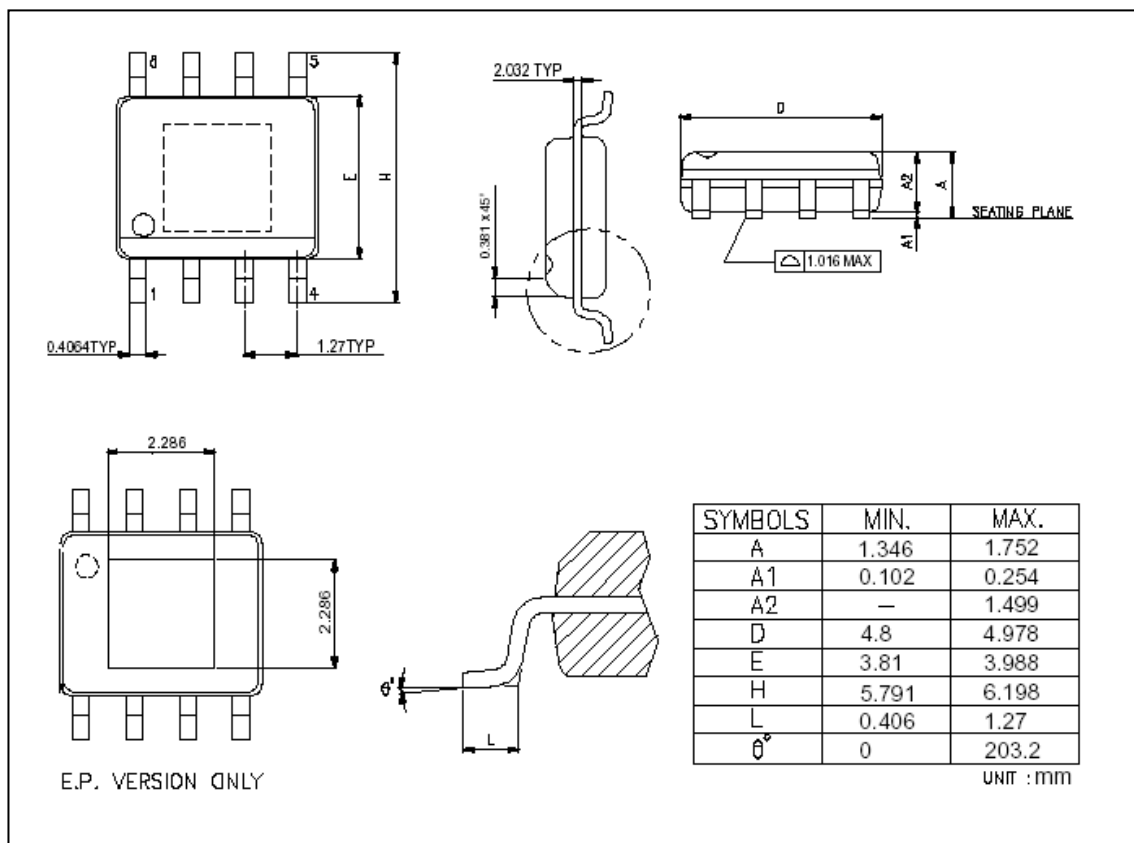| Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 ≧2000
<1.6mm	260 +0 ^{o}C	260 +0 ^{o}C	260 +0 ^{o}C
1.6mm – 2.5mm	260 +0 ^{o}C	250 +0 ^{o}C	245 +0 ^{o}C
≧2.5mm	250 +0 ^{o}C	245 +0 ^{o}C	245 +0 ^{o}C

*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.
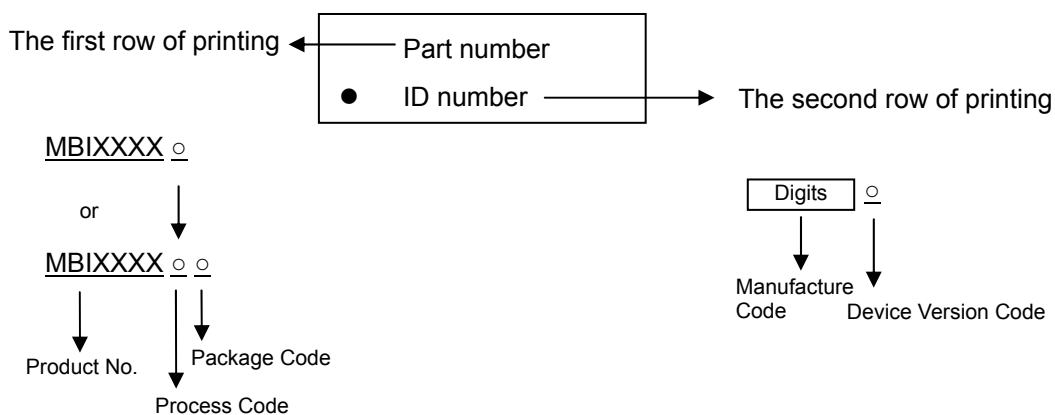

MBI6804 Maximum Power Dissipation at Various Ambient Temperature

GD Type: Rth=40.0°C/W

Safe Operation Area

Power Dissipation (W)

Ambient Temperature (°C)

Outline Drawings

MBI6804 GD outline drawing

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

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)

The first row of printing ◄────── Part number

●   ID number ──────► The second row of printing

MBIXXXX ○

or

MBIXXXX ○ ○

Product No.　　Process Code　　Package Code

| Digits | ○ |

Manufacture Code　　Device Version Code

Product Revision History

Datasheet version	Device Version Code
V1.00	A
V2.00	B
V3.00	C

Product Ordering Information

Part Number	"RoHS Compliant" Package Type	Weight (g)
MBI6804GD-C	SOP8-150-1.27	0.079g

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

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