

DESCRIPTION

The PT6988 is a high precision buck LED Driver IC intended for dimming products with ordinary switch by on/off state in dimming time. The IC has a wide range input range which is 85V~265V and the default dimming state is three Level.

The PT6988 integrates high precision current detection and constant current circuit which can realize high precision LED constant current and excellent line voltage regulation. The PT6988 works in CRM mode, the LED current is constant with inductance and LED output voltage change, good load regulation.

The PT6988 integrates a 500V power MOSFET, uses the source driver architecture, with a low operating current, so the PT6988 doesn't need the auxiliary winding for sensing and supplying the chip. It has a few external components, saves the cost of volume system.

The multi-protection features of PT6988 greatly enhance the system reliability and safety. The PT6988 provides CS resistance short-circuit protection, short LED protection, open LED protection, VIN under voltage protection, temperature intelligent control, etc.

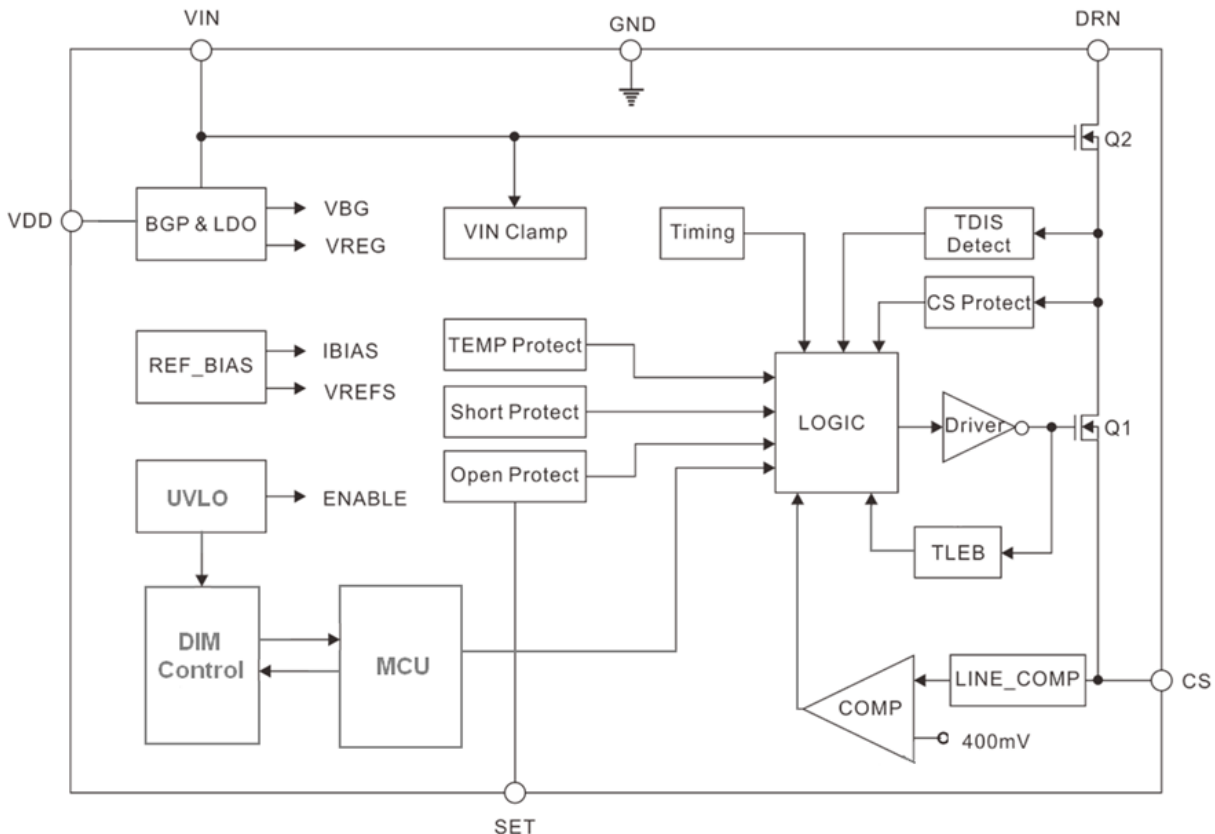
FEATURES

- Integrates 500V Power MOSFET
- 3-Level ON/OFF Dimming Function
- CRM Mode(rated light)
- No Auxiliary Winding for Sensing and Supplying
- Low Operating Current
- $\pm 5\%$ Output Current Accuracy
- LED Open/Short Circuit Protection
- CS Resistor Short Circuit Protection
- VIN Under Voltage Protection
- Temperature Intelligent Control
- System Auto-Restart Function
- SOP-8 Package

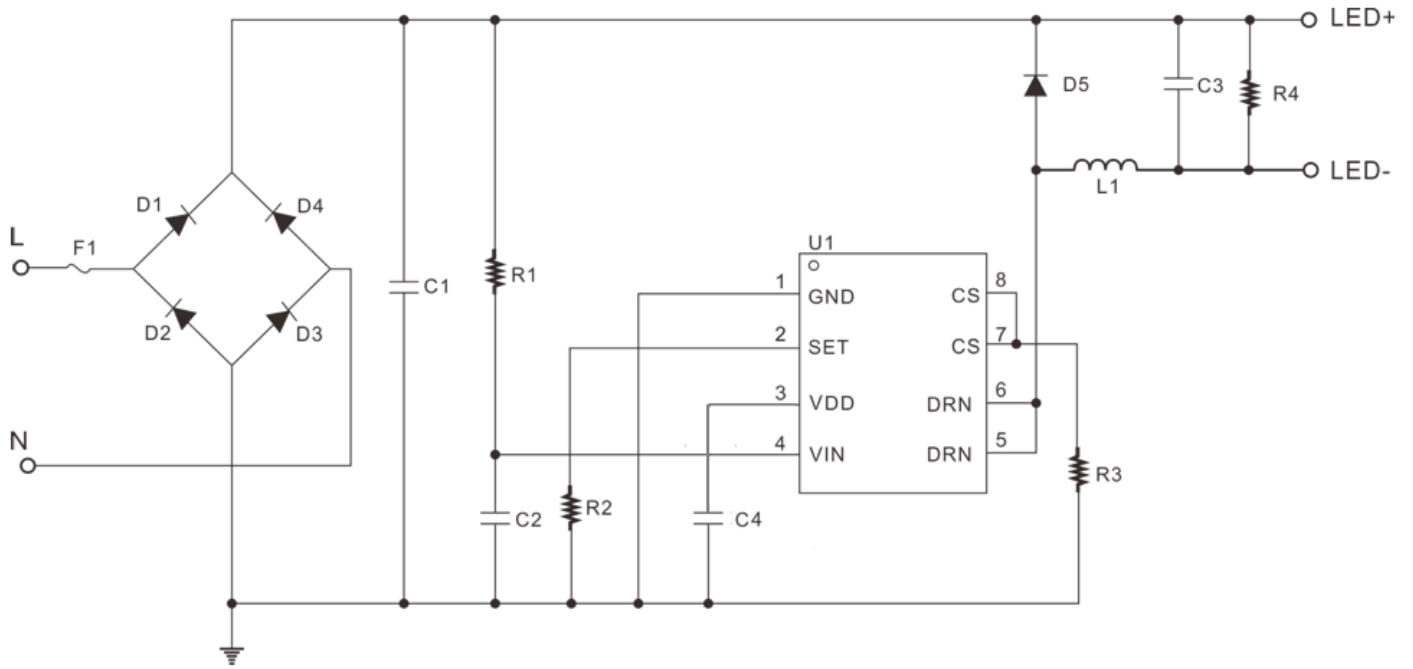
APPLICATIONS

- LED Bulb lamp, LED PAR lamp
- LED Tube lamp
- Other LED lighting

BLOCK DIAGRAM



TYPICAL APPLICATION

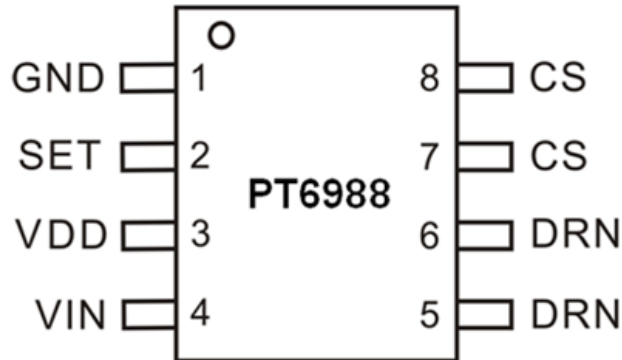


ORDER INFORMATION

| Valid Part Number | Package Type | Top Code |
|-------------------|--------------|-----------|
| PT6988-S | SOP8 | PT6988-S |
| PT6988B-S | SOP8 | PT6988B-S |

Note: PT6988 Integrates 500V/3A Power MOSFET
PT6988B Integrates 500V/1A Power MOSFET

PIN CONFIGURATION



PIN DESCRIPTION

| Pin Name | Description | Pin No. |
|----------|--|---------|
| GND | Ground | 1 |
| SET | LED open-circuit voltage protection Settings, by connecting the resistance to the ground | 2 |
| VDD | The holding supply pin | 3 |
| VIN | Power supply pin | 4 |
| DRN | Power MOSFET Drain | 5, 6 |
| CS | Current sense pin, sense the inductor current while the switch is on-stage. | 7, 8 |

FUNCTION DESCRIPTION

OPERATION

Under the rated situation of current output (100% light), PT6988 is designed to work in CRM mode and is especially suitable for non-isolated buck LED lighting applications. It is designed to work in CRM mode, can achieve high precision LED constant current without any closed loop control. PT6988 integrates a 500V power MOSFET, and doesn't need the auxiliary winding for sensing the output current and supplying the chip. System only needs a few peripheral devices can achieve excellent line regulation and load regulation.

When the VIN pin voltage is higher than chip's starting-threshold, PT6988 begins to work, when the switch of PT6988 is turned on, the inductor current sensed by the CS resistor rises up linearly at a rate. When the CS pin voltage rises up to the internal reference voltage, the switch will be turned off. During the switch is off-level, the inductor current falls down linearly at a rate. When the inductor current drop to zero, the switch will be turned on again. This switching process will be repeated to realize the constant current control.

START-UP

The PT6988 provides VIN under voltage protection. Under the UVLO mode, closed switch of MOSFET, so the PT6988 has a low start-up current (180μA Typical). When VIN voltage is greater than 16V, PT6988 begins to work. The PT6988 has a low operating current (125μA Typical) which means the current could be provided by the resistor R1 connected between DC-BUS and VIN pin. So, the PT6988 doesn't need the auxiliary winding for supplying the chip. The PT6988 integrates a power-supply clamped circuit to realize the over voltage protection, the clamped voltage is 16.8V typically.

CONSTANT CURRENT CONTROL

The PT6988 output current is controlled by the inductance peak current. The inductance peak current sensed by the resistor R_{CS}. When the CS voltage rises up to the internal reference voltage, the switch is turned off. The inductor peak current is given by the following equation:

$$I_{PEAK} = \frac{V_{CS}}{R_{CS}} \quad (1)$$

Where, R_{CS} is the current sense resistor which connects CS pin and GND. V_{CS} is reference voltage sense peak current, dimming first level and second level is 400mV, the third level is 150mV.

Under the rated situation of current output (100% light), PT6988 works in CRM mode, the LED output current is half the peak inductor current. The output current is given by the following equation:

$$I_{LED} = \frac{I_{PEAK}}{2} = \frac{1}{2} * \frac{0.4V}{2} \quad (2)$$

INDUCTANCE CALCULATION

The PT6988 is a buck controller for LED lighting, and it works in CRM mode. The switch on-time is given by the following equation:

$$T_{ON} = \frac{L \times I_{PEAK}}{V_{BUS} - V_{LED}} \quad (3)$$

The switch off-time is given by the following equation:

$$T_{OFF} = \frac{L \times I_{PEAK}}{V_{LED}} \quad (4)$$

The L is the value of the inductance. The I_{PEAK} is the inductor peak current. The V_{BUS} is the DC-BUS voltage after rectification. The V_{LED} is the LED output voltage.

The value of the inductances given by the following equation:

$$L = \frac{V_{LED} \times (V_{BUS} - V_{LED})}{f_{osc} \times I_{PEAK} \times V_{BUS}} \quad (5)$$

Where, f_{osc} is the operating frequency. When the inductance L is selected, the system operating frequency rises with the DC-BUS voltage rising. To define the inductance L, the parameters should be set with the minimum input voltage (V_{BUSMIN}), the minimum LED output voltage (V_{LEDMIN}) and the minimum operating frequency (f_{oscmin})

3-LEVELS ON/OFF DIMMING FUNCTION

PT6988 provides 3-level ON/OFF dimming function. The ON/OFF dimming function uses traditional ON/OFF switch which needn't other dimmer. As the application circuit simple and reliable, PT6988 can furtherly save cost and reduce volume.

PT6988 senses ON/OFF state through VIN Pin. VDD is the holding supply power of internal latch circuit. When the first system's power on (ON), VIN Pin is charged by supply resistant, and VDD voltage rises with VIN voltage; when VIN voltage rises larger than 16V, PT6988 begins to work, and the LED outputs rated current (rated light). When the first system's power off (OFF), VIN power falls less than 9V, PT6988 locks output state and introduces sensed VIN's on/off state to internal dimming latch circuit of the IC; VDD supplies power to internal latch circuit by the external capacitor connected to VDD Pin. When the second system's power on, PT6988 enlarges the MOSFET's off time to make system work on DCM state; PT6988 works at the second level of LED whose current is 50% of the rated current (first level). When the second system's power off and the third power on, PT6988 regulates off time of MOSFET and internal reference voltage that makes the system work in the third level whose LED current is 10% of the rated current. When the system switches on/off state again, the dimming level will go back to the first level. And then the system will go on and go on in cycle.

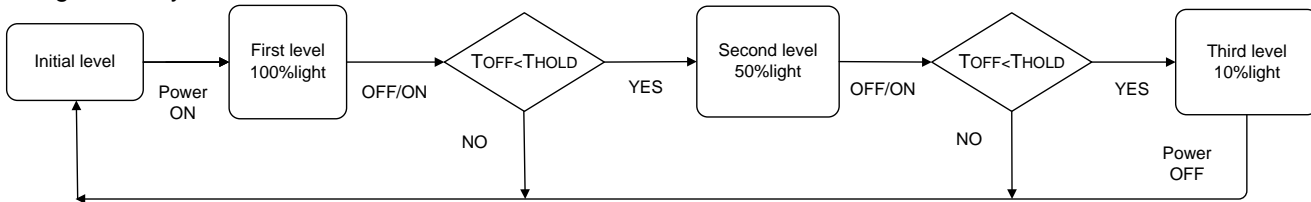


figure1: the flow chart of on/off states

VDD is the holding power of internal latch circuit. When system is power off, the capacitor connected to VDD Pin supplies power to the internal latch circuit and the value of capacitor decides the holding time (T_{HOLD}). The capacitance is 1uF and the holding time is 0.6s typically. When system's power off time (T_{OFF}) is more than the holding time, the internal dimming latch will be reset; at this time, the system is powered on again, PT6988 will go back to the first level.

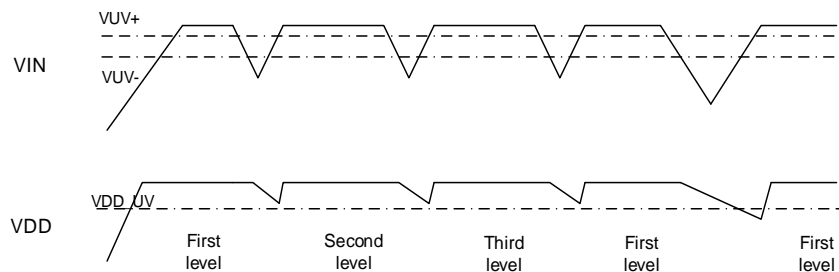


figure2: VIN and VDD sequence chart of dimming

PT6988 uses unique patented ON/OFF dimming technology which can save the system dimming cost and realize a good group controlling function.

PROTECTION FEATURES

To greatly enhance the system reliability and safety, the PT6988 provides multi-protection functions such as VIN under voltage protection, LED open circuit protection, LED short circuit protection, CS resistor short circuit protection, temperature intelligent control, etc.

When the LED short circuit happens, the system works at a low frequency, which is 4kHz typically, and the internal reference voltage V_{REF} will be changed to 150mV.

When the LED open circuit happens, protection logic is active. PT6988 enters a stage of HIPCUP mode. So VIN voltage began to decline, the system restart when VIN drops to the UVLO threshold. When the LED open circuit happens, the output capacitance has been charging, output voltage is slowly rising. So to set the maximum output voltage, prevent to damage output capacitance when the LED open circuit happens. PT6988 provides LED open-circuit voltage protection which set by connecting the resistance to the ground to set the maximum output voltage. The SET resistance formula is equation (6), Where V_{CS} is the internal reference voltage (400mV), V_{OVP} the maximum output voltage, When the LED open circuit happens, the system will goes into the auto-restart mode, therefore need a resistor paralleled in the output capacitance to discharge energy produced during the restart system.

$$R_{SET} \approx 15 \times \frac{V_{CS} \times L}{R_{CS} \times V_{OVP}} \times 10^6 (k\Omega) \quad (6)$$

When the CS resistance short circuit protection happens, protection logic is active. PT6988 enters a stage of HIPCUP.

The temperature intelligent control function is built in the PT6988 to protect the chip and system. when the temperature of PT6988 rises up to 145°C typically, the output current is reduced gradually with the temperature rises; when the temperature of PT6988 rises up to 165°C typically, the output current decreases to zero. To control the output power and temperature, The PT6988 temperature changes smoothly. This can not only protect the chip, and can avoid the traditional way of chip over heat shut off as a result of the LED flashing phenomenon, in order to improve the reliability of the system.

ABSOLUTE MAXIMUM RATINGS

| Parameter | Symbol | Rating | Unit |
|--------------------------------|-------------|-----------|------|
| Input Voltage | V_{IN} | 18 | V |
| Maximum V_{IN} Input Current | I_{VIN} | 5 | mA |
| DRN to GND | V_{DRN} | -0.3~500V | V |
| SET to GND | V_{SET} | -0.3~6 | V |
| CS to GND | V_{CS} | -0.3~6 | V |
| Power Loss | P_{Total} | 0.45 | W |
| Operating Temperature | T_{OP} | -40~150 | °C |
| Storage Temperature | T_{ST} | -40~150 | °C |
| ESD | ESD | 2 | KV |

RECOMMENDED OPERATING CONDITIONS

| Parameter | Conditions | Rating | Unit | |
|--------------|--|-----------|------|----|
| I_{LED} | Input AC Voltage: 176V~265V, Output Voltage 140V | PT6988-S | 200 | mA |
| | | PT6988B-S | 130 | |
| | Input AC Voltage: 176V~265V, Output Voltage 80V | PT6988-S | 300 | |
| | | PT6988B-S | 180 | |
| | Input AC Voltage: 90V~265V, Output Voltage 40V | PT6988-S | 300 | |
| | | PT6988B-S | 180 | |
| V_{LEDMIN} | Minimum LED Output Voltage | PT6988-S | >12 | V |
| | | PT6988B-S | >15 | |

ELECTRICAL CHARACTERISTICS

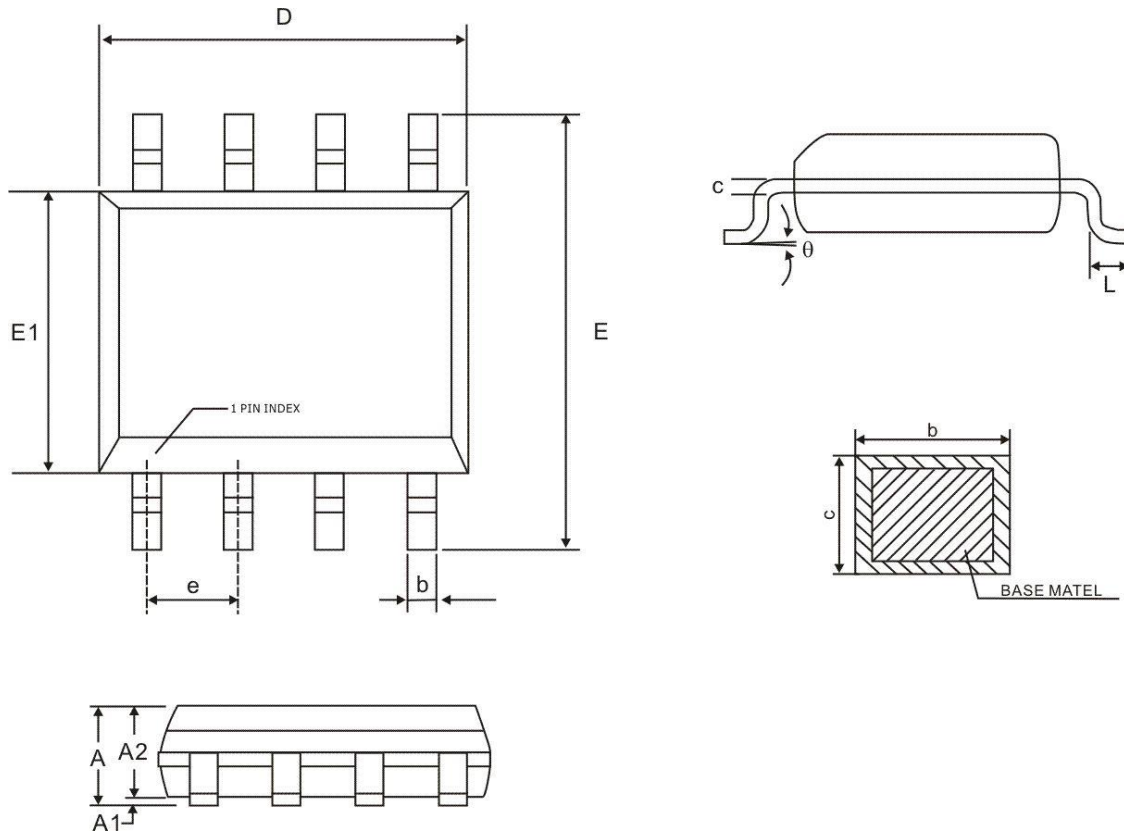
 (Unless otherwise specified, $T_a=25^{\circ}\text{C}$, $V_{IN}=15\text{V}$)

| Parameter | Symbol | Condition | Min. | Typ. | Max. | Unit |
|--|-----------------|--|------|------|------|--------------------|
| Supply Characteristics | | | | | | |
| VIN Start-up Voltage | V_{ST} | V_{VIN} rising | | 16 | | V |
| VIN Shutdown Voltage | V_{SD} | V_{VIN} falling | | 9 | | V |
| VIN Clamp Voltage | V_{CLAMP} | $I_{VIN}=1\text{mA}$ | | 16.8 | | V |
| IC Start-up Current | I_{ST} | $V_{VIN}=V_{ST}-1\text{V}$ | | 180 | | μA |
| IC Operating Current | I_{OP} | $F_{OSC}=70\text{KHZ}$ | | 125 | | μA |
| VDD Open Voltage | V_{VDD_ON} | | | 3.3 | | V |
| VDD Close Voltage | V_{VDD_OFF} | | | 2.7 | | V |
| VDD Current | I_{DD} | | | 5.0 | | μA |
| Current Sense Section | | | | | | |
| Internal Reference Voltage | V_{CS} | | 388 | 400 | 412 | mV |
| peak current sense reference voltage 1 | V_{CS1} | | | 400 | | mV |
| peak current sense reference voltage 2 | V_{CS2} | The third level | | 150 | | mV |
| Internal Reference Voltage at LED Short Status | V_{CS_SHORT} | LED short | | 150 | | mV |
| Leading Edge Blanking Time | T_{LEB} | | | 350 | | ns |
| Switch-off Delay Time | T_{DELAY} | | | 200 | | ns |
| Switching Section | | | | | | |
| Max OFF Time | T_{DIS_MAX} | | | 280 | | μs |
| Min OFF Time | T_{DIS_BLK} | | | 5 | | μs |
| Max ON Time | T_{ON_MAX} | | | 55 | | μs |
| Power MOSFET Section | | | | | | |
| Drain-Source On-Resistance (PT6988) | R_{ON} | $V_{GS}=15\text{V}/I_{DS}=1.0\text{A}$ | | 3 | | Ω |
| Drain-Source On-Resistance (PT6988B) | R_{ON} | $V_{GS}=15\text{V}/I_{DS}=0.5\text{A}$ | | 10 | | Ω |
| Drain-Source Leakage Current | I_{LEAK} | $V_{GS}=0\text{V}/V_{DS}=500\text{V}$ | | | 1 | μA |
| Drain-Source Breakdown Voltage | BV_{DSS} | $V_{GS}=0\text{V}/I_{DS}=0.5\text{A}$ | 500 | | | V |
| Protection Features | | | | | | |
| SET Reference Voltage | V_{SET} | | | 1.5 | | V |
| Thermal Shutdown Starting Temperature | T_{STR} | | | 145 | | $^{\circ}\text{C}$ |
| Thermal Shutdown Cutoff Temperature | T_Z | | | 165 | | $^{\circ}\text{C}$ |

Note: The VIN voltage first rise up over the V_{ST} voltage, and then fall down to 15V.

PACKAGE INFORMATION

SOP8, 150MIL



| Symbol | Dimensions(mm) | | |
|----------|----------------|------|------|
| | Min. | Nom. | Min. |
| A | 1.35 | 1.60 | 1.77 |
| A1 | 0.08 | 0.15 | 0.28 |
| A2 | 1.20 | 1.40 | 1.65 |
| b | 0.33 | - | 0.51 |
| c | 0.17 | - | 0.26 |
| D | 4.70 | 4.90 | 5.10 |
| E | 5.80 | 6.00 | 6.20 |
| E1 | 3.70 | 3.90 | 4.10 |
| e | 1.27BSC. | | |
| L | 0.38 | 0.60 | 1.27 |
| θ | 0° | - | 8° |

Notes:

1. Refer to JEDEC MS-012AA
2. All dimensions are in millimeter

IMPORTANT NOTICE

Princeton Technology Corporation (PTC) reserves the right to make corrections, modifications, enhancements, improvements, and other changes to its products and to discontinue any product without notice at any time.

PTC cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a PTC product. No circuit patent licenses are implied.

Princeton Technology Corp.
2F, 233-1, Baociao Road,
Sindian Dist., New Taipei City 23145, Taiwan
Tel: 886-2-66296288
Fax: 886-2-29174598
<http://www.princeton.com.tw>