

## 700V 42mΩ SolidGaN with Short Circuit Protection

### 1. Features

- 42mΩ E-Mode GaN with Integrated Gate Clamp
- 700V Continuous, 800V Transient Voltage Rating
- Wide 10V to 24V Gate Input Voltage Range
- Adjustable Turn-On and Turn-Off Slew Rate
- Integrated Miller Clamp
- dv/dt Immunity up to 100V/ns
- Paralleling Capability
- Zero Reverse Recovery Charge
- High Frequency Operation up to 2MHz
- Short Circuit Protection with Built-In DESAT
- Input UVLO and OTP Protection
- Available in TO-247-4L Package

### 2. Applications

- High-Power Switch-Mode Power Supplies
- AC-DC, DC-DC, DC-AC Converters
- Half-Bridge and Full-Bridge Converters
- Data Center / AI Server PSU
- Air Conditioner, Solar Inverter, Motor Drive
- Automotive OBC & DC-DC Converter

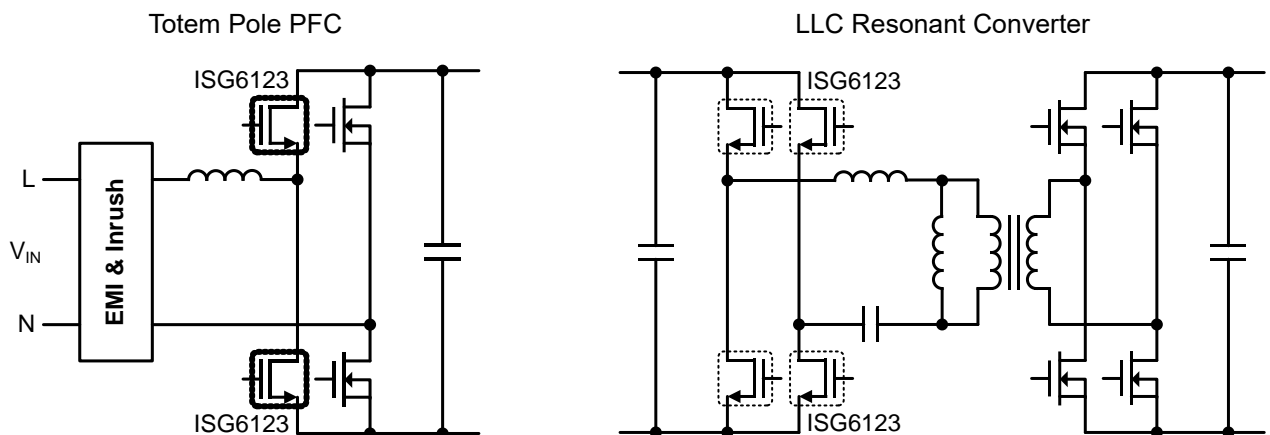
### 3. Description

The ISG6123 SolidGaN IC seamlessly integrates a 700V E-Mode GaN FET with advanced features, setting a new standard for performance, easy-of-use, and reliability in power electronics. The integrated gate clamp, driven by an accurate LDO-based circuitry, maintains a tightly regulated driving voltage for the GaN FET within a flexible gate-input voltage range of 10V to 24V, ensuring full protection of the GaN power transistor against excessive voltage stress while maximizing GaN performance.

The ISG6123 offers users the ability to adjust the turn-on and turn-off slew rate of the GaN FET with external gate resistors, optimizing both EMI and power efficiency. Equipped with built-in protections including DESAT protection, Input UVLO, and OTP, the ISG6123 further ensures device robustness and system safety. The integrated miller clamp prevents false turn-on caused by the high dv/dt slope of the drain voltage.

The ISG6123's high integration level with a GaN FET and robust protection, makes it suitable for a range of applications, from simple setups with low component count to high-frequency and high-power applications.

### 4. Typical Application



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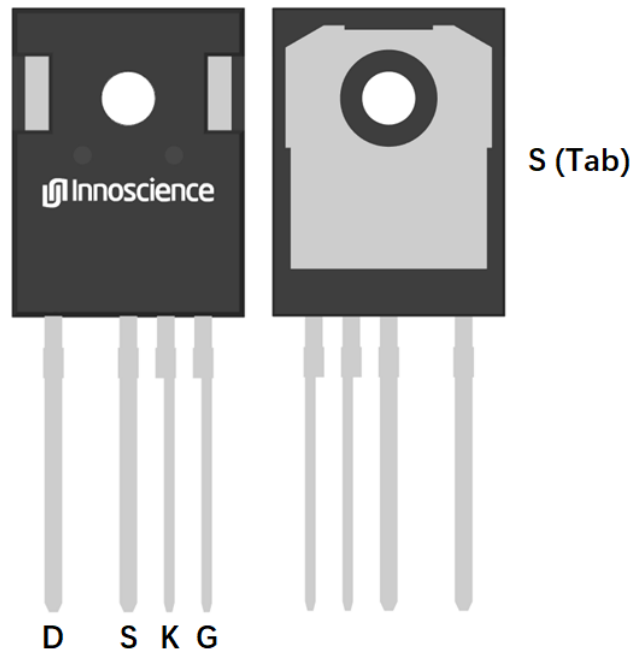
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## 5. Revision History

Major changes since the last revision

| Revision | Date       | Description of changes                         |
|----------|------------|--|
| 1.0      | 2024-12-16 | Final datasheet release                        |
| 1.1      | 2024-12-30 | Update package outline dimensions (Section 16) |

## 6. Pin Configuration and Functions



4-Lead TO247 Package – Top and Bottom View

| Pin Number | Pin Name | Description  |
|------------|----------|--|
| 1          | D        | Drain of Power GaN FET.  |
| 2, Tab     | S        | Source of Power GaN FET.   |
| 3          | K        | Kelvin Source.   |
| 4          | G        | Gate Input. Connect to the driver output of controller or gate driver. |

## 7. Absolute Maximum Ratings

All pins are referred to S pins, unless otherwise specified. Stress beyond the absolute maximum ratings can cause permanent damage or deteriorate device lifetime.

| Parameter   | Value      | Unit             |
|---|------------|------------------|
| Drain Voltage, Continuous   | 700        | V                |
| Drain Voltage, Transient <sup>(1)</sup>   | 800        | V                |
| Drain Voltage, Pulsed <sup>(2)</sup>  | 750        | V                |
| Drain Current, Continuous ( $T_C = 25^\circ\text{C}$ , $T_J = 150^\circ\text{C}$ )  | 46         | A                |
| Drain Current, Continuous ( $T_C = 100^\circ\text{C}$ , $T_J = 150^\circ\text{C}$ ) | 29         | A                |
| Drain Current, Pulsed (10us @ $T_J = 25^\circ\text{C}$ )                            | 90         | A                |
| Drain Current, Pulsed (10us @ $T_J = 150^\circ\text{C}$ )                           | 45         | A                |
| Gate Input Voltage, Continuous  | -0.6 to 27 | V                |
| Gate Input Voltage, Pulsed <sup>(2)</sup>   | -10 to 27  | V                |
| Drain-to-Source Slew Rate – dV/dt   | 100        | V/ns             |
| Power Dissipation ( $T_C = 25^\circ\text{C}$ )                                      | 255        | W                |
| Operating Junction Temperature $T_J$  | -55 to 150 | $^\circ\text{C}$ |
| Storage Temperature   | -55 to 150 | $^\circ\text{C}$ |

(1) Intended for non-repetitive events,  $t_{\text{PULSE}} < 200\mu\text{s}$ .

(2) Intended for repetitive events,  $t_{\text{PULSE}} < 100\text{ns}$ .

## 8. ESD Ratings

$T_J = 25^\circ\text{C}$  unless otherwise specified.

| Parameter  | Value      | Unit |
|--|------------|------|
| Human Body Model (HBM), per ANSI/ESDA/JEDEC JS-001     | $\pm 2000$ | V    |
| Charged Device Model (CDM), per ANSI/ESDA/JEDEC JS-002 | $\pm 1000$ | V    |

## 9. Recommended Operating Conditions

| Parameter               | Min  | Max | Unit |
|-------------------------|------|-----|------|
| Gate Input High Voltage | 10   | 24  | V    |
| Gate Input Low Voltage  | -0.3 | 0.3 | V    |

## 10. Thermal Information

| Symbol          | Parameter                               | ISG6123TD | Unit                      |
|-----------------|---|-----------|---------------------------|
| $R_{\theta JA}$ | Thermal Resistance, Junction to Ambient | 35.65     | $^\circ\text{C}/\text{W}$ |
| $R_{\theta JC}$ | Thermal Resistance, Junction to Case    | 0.49      | $^\circ\text{C}/\text{W}$ |

According to standards defined in JESD51 and JESD51-1, thermal characteristics of the package are simulated.  $R_{\theta JA}$  is determined with the device mounted on one square inch of copper pad, single layer 2 oz copper on FR4 board.

## 11. Electrical Characteristics

$T_J = 25^\circ\text{C}$ ,  $V_{GS} = 15\text{V}$ ,  $V_{DS} = 400\text{V}$ , unless otherwise noted.

| Parameter   | Symbol           | Min | Typ | Max | Unit             | Test Condition   |
|---|------------------|-----|-----|-----|------------------|--|
| <b>Gate Characteristics</b>                                 |                  |     |     |     |                  |  |
| Gate input high threshold <sup>(3)</sup>                    | $V_{G\_HI}$      |     | 4   |     | V                | Gate Rising  |
| Gate input low threshold <sup>(3)</sup>                     | $V_{G\_LO}$      |     | 3.3 |     | V                | Gate Falling   |
| Gate quiescent current                                      | $I_{G\_Q}$       |     | 1.9 | 5.2 | mA               | $V_{GS} = 15\text{V}$ , $V_{DS} = 0\text{V}$                             |
| <b>Protection</b>   |                  |     |     |     |                  |  |
| DESAT protection threshold <sup>(3)</sup>                   | $V_{D\_DESAT}$   |     | 7.3 |     | V                |  |
| DESAT blanking time <sup>(3)</sup>                          | $t_{BLK\_DESAT}$ |     | 300 |     | ns               |  |
| Gate UVLO threshold   | $V_{G\_UVLO}$    | 8.2 | 8.7 | 9.3 | V                |  |
| Over temperature threshold <sup>(3)</sup>                   | $T_{OTP}$        |     | 160 |     | $^\circ\text{C}$ |  |
| Over temperature hysteresis <sup>(3)</sup>                  | $T_{HYS}$        |     | 20  |     | $^\circ\text{C}$ |  |
| <b>Power GaN FET</b>  |                  |     |     |     |                  |  |
| Drain-source leakage current                                | $I_{DSS}$        |     | 8   | 100 | $\mu\text{A}$    | $V_{DS} = 700\text{V}$ , $V_{GS} = 0\text{V}$                            |
| Drain-source resistance                                     | $R_{DS(ON)}$     |     | 42  | 55  | $\text{m}\Omega$ | $V_{GS} = 15\text{V}$ , $I_{DS} = 8\text{A}$                             |
| Drain-source resistance <sup>(3)</sup>                      | $R_{DS(ON)}$     |     | 92  |     | $\text{m}\Omega$ | $V_{GS} = 15\text{V}$ , $I_{DS} = 8\text{A}$ , $T_J = 150^\circ\text{C}$ |
| Source-drain reverse voltage                                | $V_{SD}$         |     | 2.7 |     | V                | $V_{GS} = 0\text{V}$ , $I_{SD} = 4\text{A}$                              |
| Total gate charge <sup>(3)</sup>                            | $Q_G$            |     | 9.7 |     | nC               |  |
| Output charge <sup>(3)</sup>                                | $Q_{OSS}$        |     | 104 |     | nC               | $V_{DS} = 400\text{V}$ , $V_{GS} = 0\text{V}$                            |
| Reverse recovery charge <sup>(3)</sup>                      | $Q_{RR}$         |     | 0   |     | nC               |  |
| Input capacitance <sup>(3)</sup>                            | $C_{ISS}$        |     | 353 |     | pF               |  |
| Output capacitance <sup>(3)</sup>                           | $C_{OSS}$        |     | 128 |     | pF               | $V_{DS} = 400\text{V}$ , $V_{GS} = 0\text{V}$                            |
| Effective output capacitance, energy related <sup>(3)</sup> | $C_{O(er)}$      |     | 190 |     | pF               | $V_{DS} = 400\text{V}$ , $V_{GS} = 0\text{V}$                            |
| Effective output capacitance, time related <sup>(3)</sup>   | $C_{O(tr)}$      |     | 260 |     | pF               | $V_{DS} = 400\text{V}$ , $V_{GS} = 0\text{V}$                            |

## 12. Switching Characteristics

$T_J = 25^\circ\text{C}$ ,  $V_{GS} = 15\text{V}$ ,  $V_{DS} = 400\text{V}$ , unless otherwise noted.

| Parameter  | Symbol        | Min | Typ | Max | Unit | Test Condition |
|--|---------------|-----|-----|-----|------|----------------|
| Minimum input pulse width that changes the output <sup>(3)</sup> | $t_{GH\_PW}$  |     | 20  |     | ns   |                |
| Turn-on propagation delay <sup>(3)</sup>                         | $t_{ON\_PD}$  |     | 35  |     | ns   |                |
| Turn-off propagation delay <sup>(3)</sup>                        | $t_{OFF\_PD}$ |     | 20  |     | ns   |                |
| Minimum on time <sup>(3)</sup>                                   |               |     | 30  |     | ns   |                |
| Rise time <sup>(3)</sup>   | $t_r$         |     | 10  |     | ns   |                |
| Fall time <sup>(3)</sup>   | $t_f$         |     | 10  |     | ns   |                |

(3) Not 100% tested and guaranteed by design.

## 13. Typical Characteristics

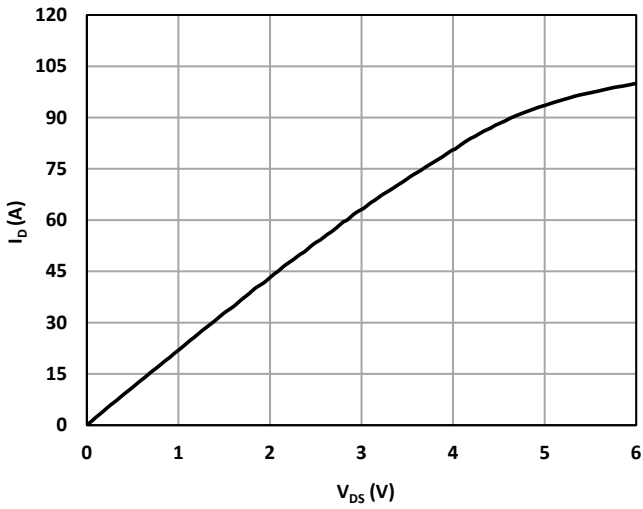


Figure 1. Drain Current vs. Drain-to-Source Voltage,  $T_J=25^\circ\text{C}$

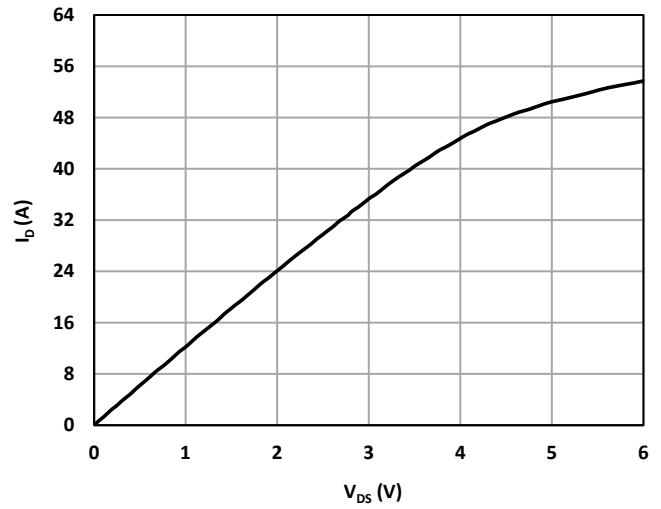


Figure 2. Drain Current vs. Drain-to-Source Voltage,  $T_J=150^\circ\text{C}$

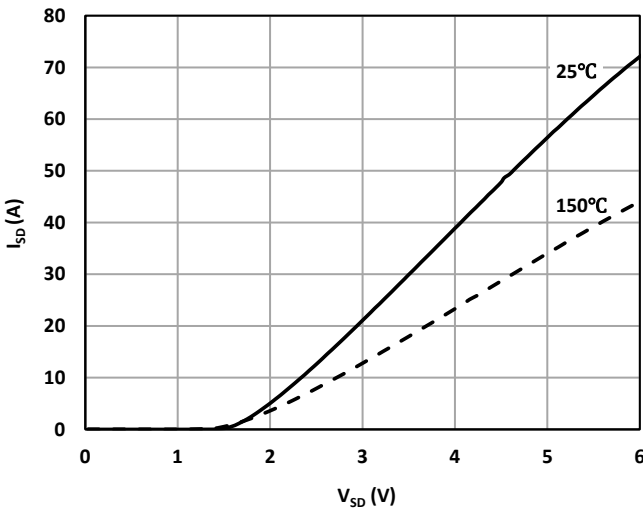


Figure 3. Source-Drain Reverse Conduction Voltage,  $T_J=25^\circ\text{C}$

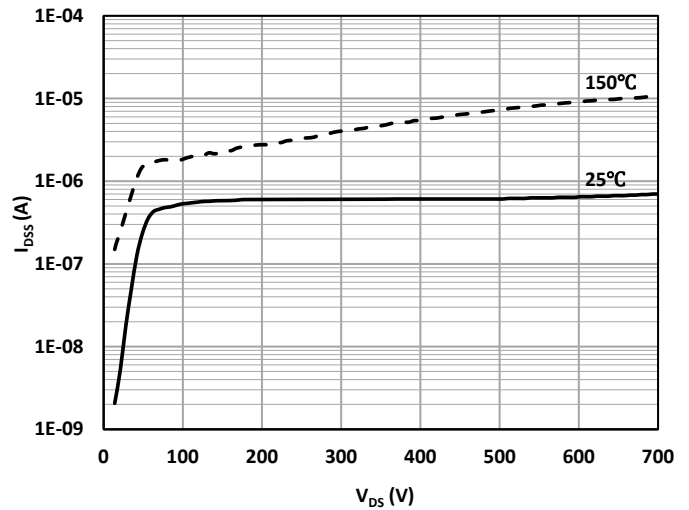


Figure 4. Drain Leakage Current vs Drain Voltage

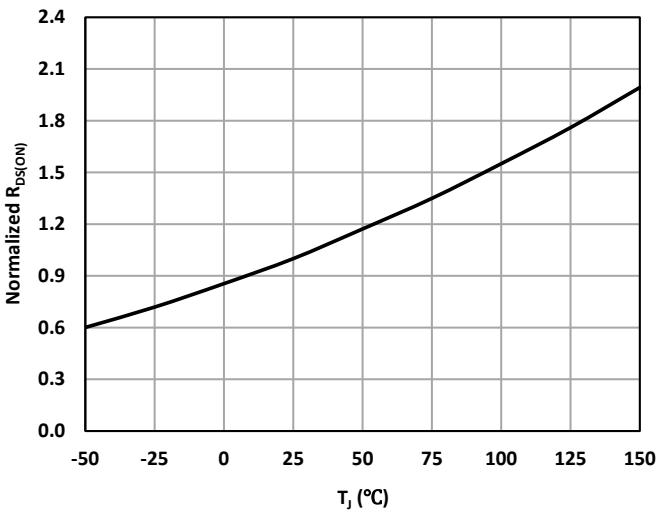


Figure 5. Normalized  $R_{DS(ON)}$  vs Temperature

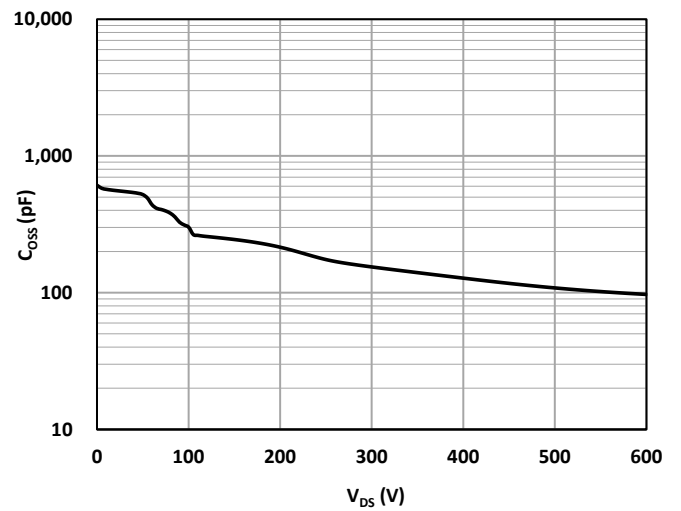


Figure 6. Output Capacitance vs Drain Voltage

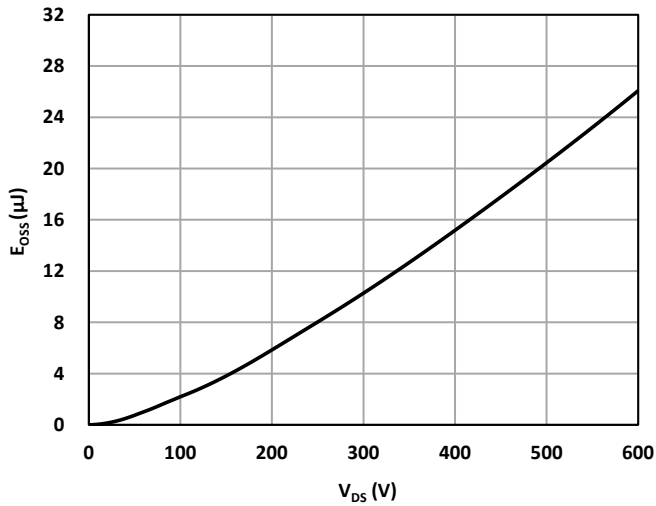


Figure 7. Output Capacitance Stored Energy vs Drain Voltage

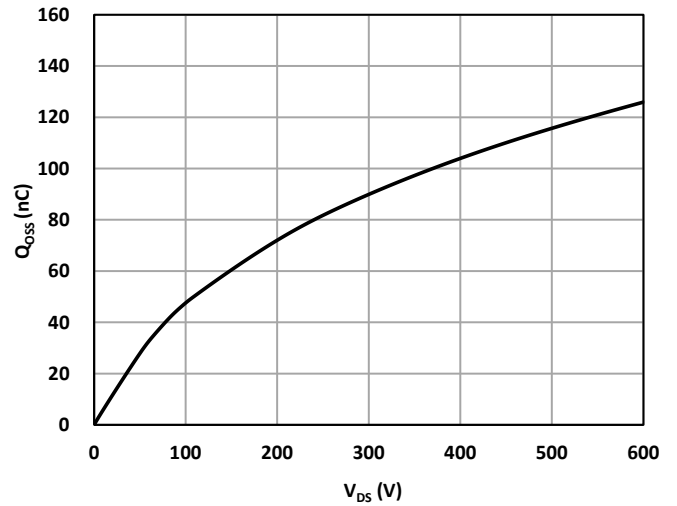


Figure 8. Output Charges vs Drain Voltage

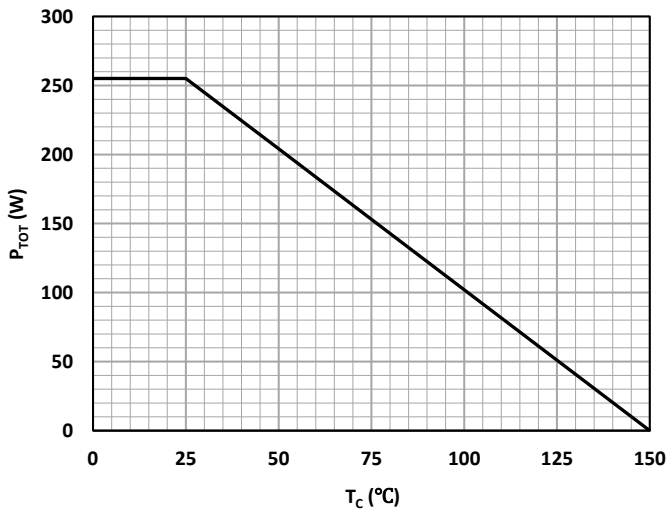


Figure 9. Power Dissipation

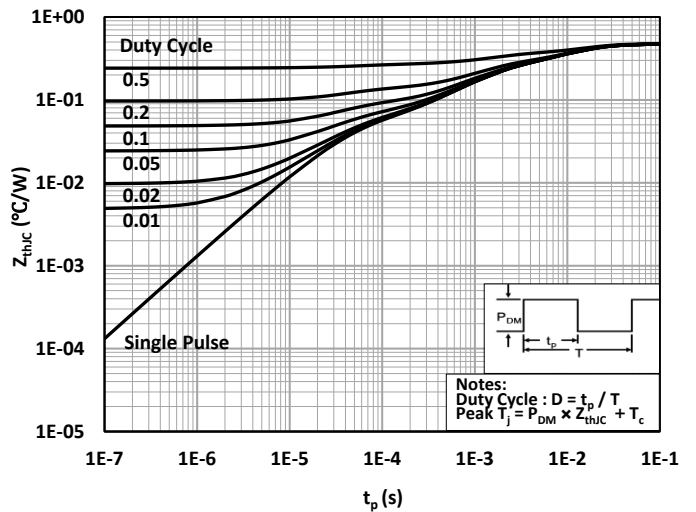


Figure 10. Max. Transient Thermal Impedance

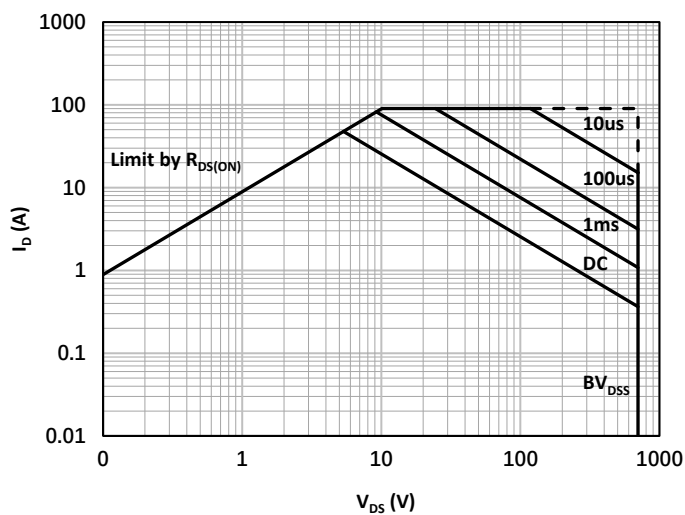


Figure 11. Safe Operating Area,  $T_J=25^\circ\text{C}$

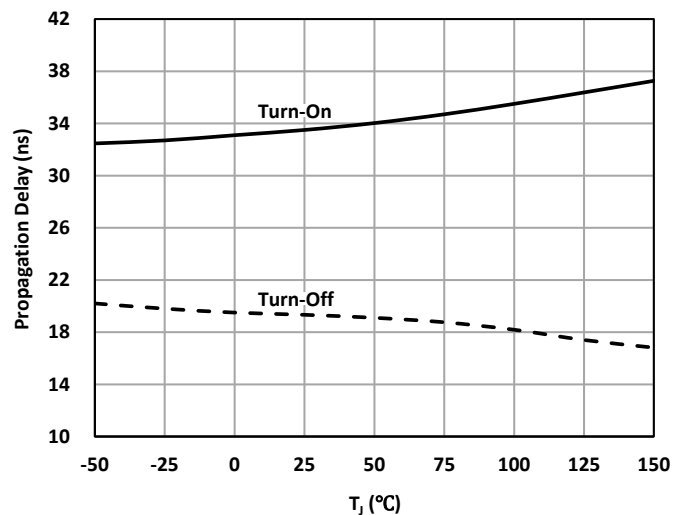


Figure 12. Turn-On/Off Propagation Delay vs Temperature

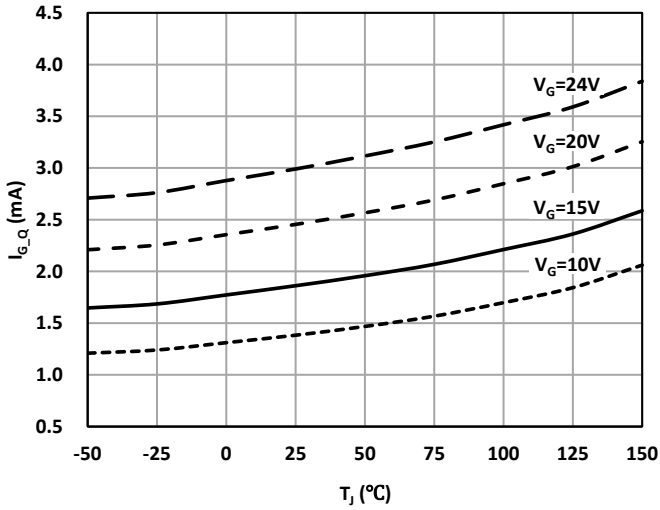


Figure 13. Gate Quiescent Current vs Temperature

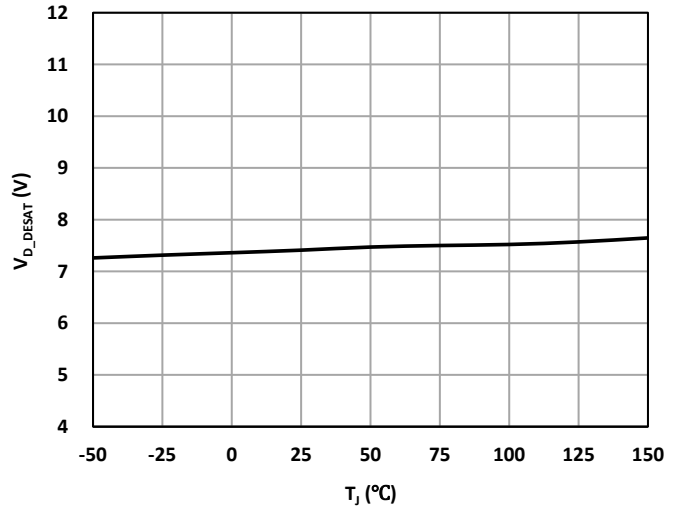


Figure 14. DESAT Threshold Voltage vs Temperature

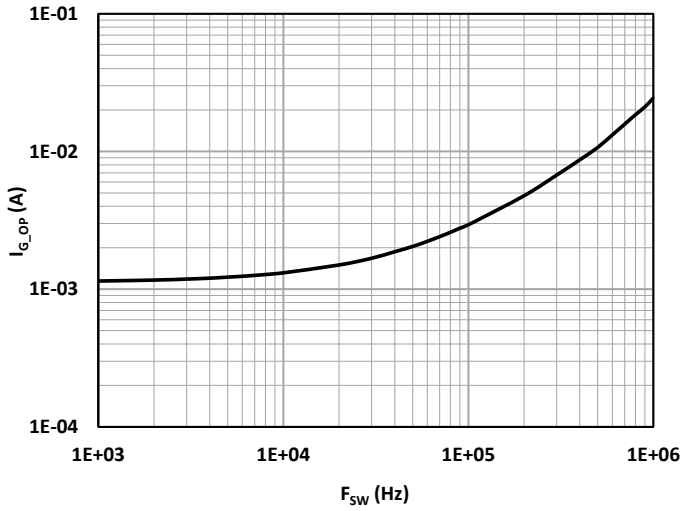


Figure 15. Gate Operating Current vs Switching Frequency



## 14. Block Diagram

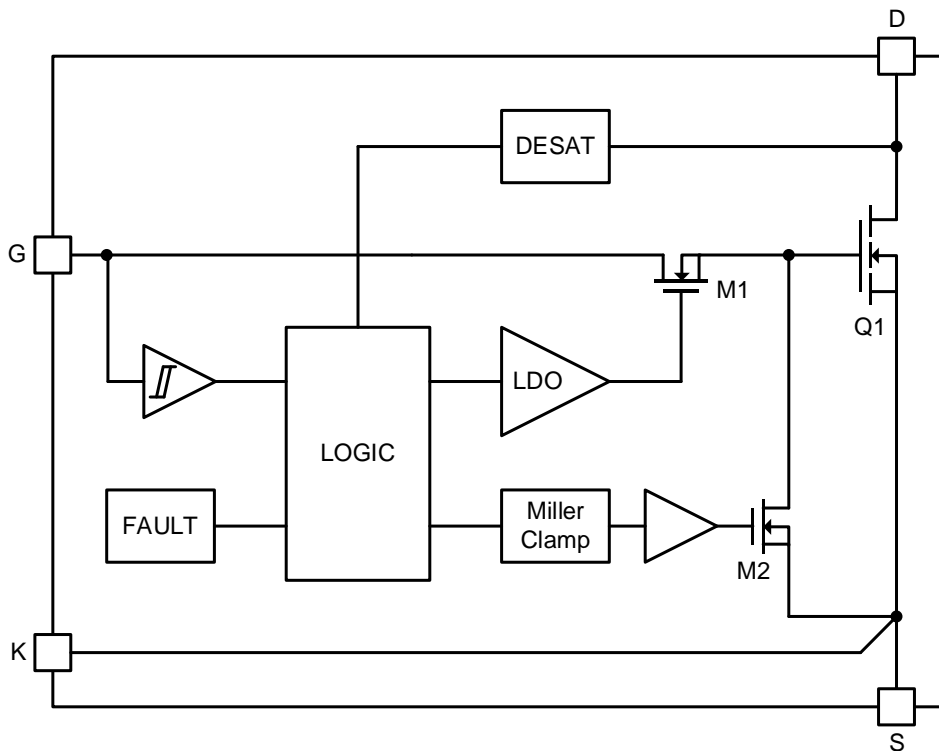


Figure 16. Functional Block Diagram

## 15. Function Description

The ISG6123 is a 700V SolidGaN IC integrating a high-performance enhancement-mode GaN FET with advanced features, offering the most reliable, efficient, and easy-to-use GaN power device.

The ISG6123 features a gate clamp to provide a wide G input voltage range of 10V to 24V. With an accurate LDO-based circuitry, the gate voltage is tightly regulated to protect the GaN FET from excessive voltage stress while maximizing the performance. The ISG6123 allows adjusting both turn-on and turn-off slew rate of the GaN FET by adding external gate resistors, optimizing both EMI and efficiency.

Rich fault protection is provided including de-saturation (DESAT) protection, input undervoltage lockout (UVLO), and over temperature protection (OTP). The ISG6123 integrates a miller clamp with a strong pull-down strength at the gate, preventing high dv/dt induced false turn-on of the GaN FET. All the features are provided without requiring a sustainable supply voltage for internal supply.

Highly integrated with a GaN FET and robust protection in a conventional TO-247-4L package, the ISG6123 offers simple setups with low component counts and drives next-generation high-frequency and high-power applications.

### Input and Output

The ISG6123 has an input pin, G, to control the integrated GaN FET. When the input G voltage exceeds the input high threshold (4.0V typical), the ISG6123 propagates the input signal to the gate of GaN FET, turning the GaN FET on and shorting the drain, D, to the source, S, with a resistance of 42mΩ (typical). When the input G voltage falls below the input low threshold (3.3V typical), the ISG6123 blocks the input-signal propagation and pulls down the gate of GaN FET

to S, turning the GaN FET off and opening the output of D. Figure 17 illustrates the timing diagram of the input and output with the gate-to-source voltage of the GaN FET,  $V_{GS}$ . The ISG6123 features a 10ns (typical) input deglitch filter for turn-on to remove unwanted pulses from the G input. A narrow input pulse exceeding this deglitch delay time will be extended to a minimum output pulse of 40ns (typical).

The ISG6123 provides a wide G input voltage range of 10V to 24V for the maximum flexibility. This is achieved by integrating internal gate clamp driven by an accurate LDO-based circuitry, ensuring a tightly regulated gate voltage to protect the GaN FET from excessive voltage stress while maximizing the performance.

The internal circuitry of the ISG6123 is powered from the G input, eliminating the need for a sustainable supply voltage from an external power source.

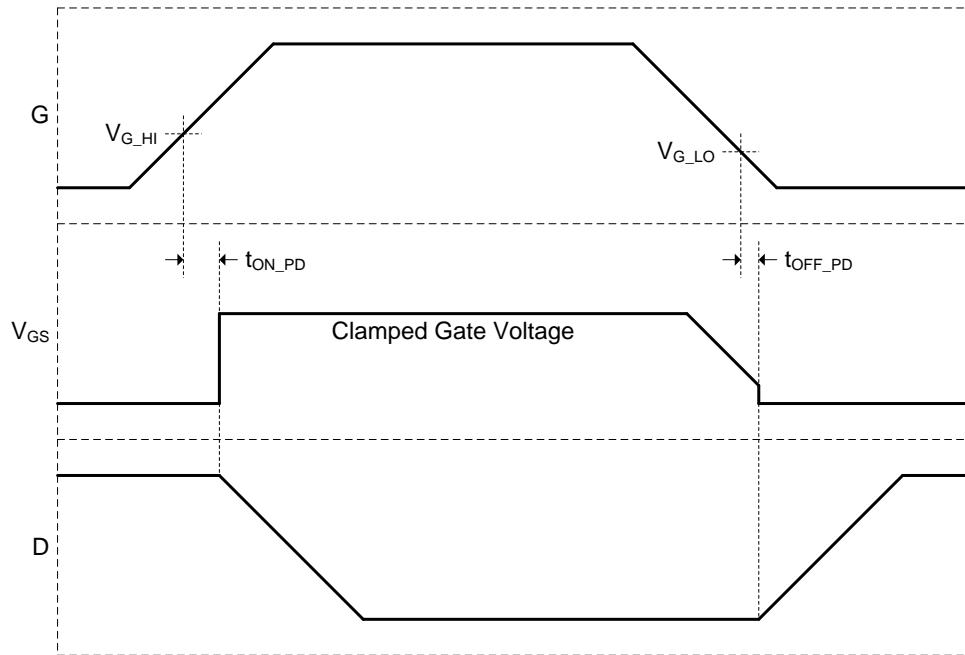


Figure 17. Timing Diagram of Input and Output

### Adjustable Turn-On and Turn-Off Slew Rate

The ISG6123 supports users the ability to adjust both turn-on and turn-off slew rate of the GaN FET independently. This is achieved by adding external gate resistors and diode between the driver output and G pin of ISG6123 as shown in Figure 18, targeting optimization of efficiency, reliability, and EMI performance.

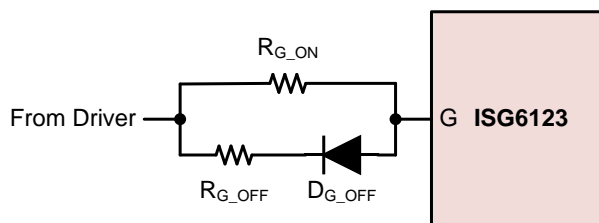


Figure 18. Configuration of Adjustable Turn-On and Turn-Off Slew Rate

### Integrated Miller Clamp

GaN FETs can switch much faster than traditional silicon based MOSFETs, resulting in higher  $dv/dt$  slope of the drain voltage. The ISG6123 integrates a miller clamp with a strong pull-down strength of 0.5Ω (typical) at gate to provide a

robust low impedance path necessary for eliminating high  $dv/dt$  induced gate turn-on. This feature allows to remove negative power supply for gate drivers in a conventional design.

## DESAT Protection

The ISG6123 provides cycle-by-cycle DESAT protection by monitoring the drain-source voltage,  $V_{DS}$ , to protect the GaN FET from potential damage in the desaturation region. As illustrated in the timing diagram of Figure 19, when the  $V_{DS}$  exceeds the DESAT protection threshold ( $7.3V$  typical), the GaN FET is turned off. The GaN FET will be turned on again at the next rising edge of G signal. The blanking time of  $300ns$  (typical) is added to prevent false triggering during the GaN FET turn-on.

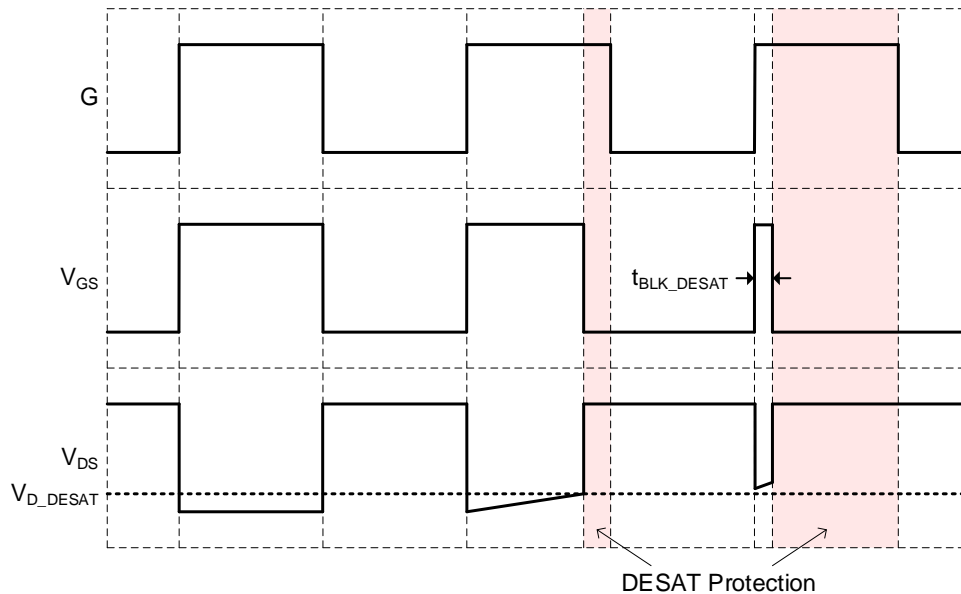


Figure 19. Timing Diagram of DESAT Protection

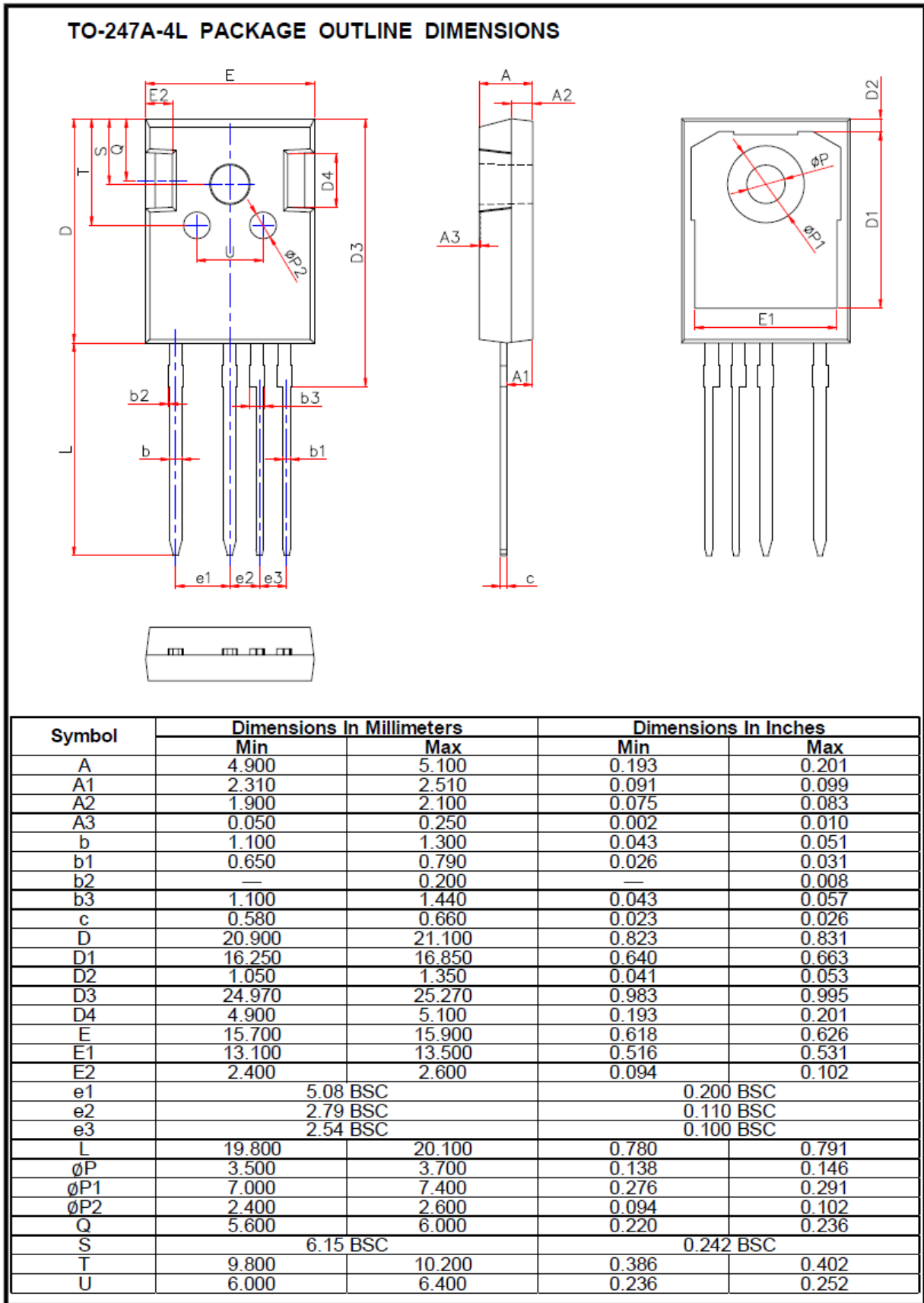
## Input UVLO Protection

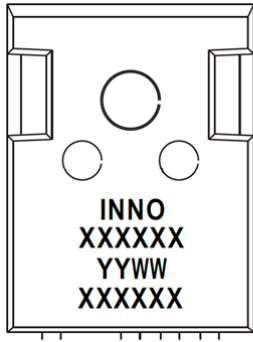
The ISG6123 features a cycle-by-cycle UVLO protection for G input, ensuring the operation under the robust conditions of devices. When the G voltage is below its UVLO threshold ( $8.7V$  typical), the ISG6123 enters UVLO mode and turns off the GaN FET. The GaN FET will be turned on again at the next rising edge of G signal.

## Over Temperature Protection (OTP)

The ISG6123 features OTP protection. If the internal junction temperature,  $T_j$ , exceeds  $160^{\circ}C$  (typical), the G input is ignored and the GaN FET is turned off. When the temperature recovers to below  $140^{\circ}C$  (typical), the ISG6123 will resume normal operation.

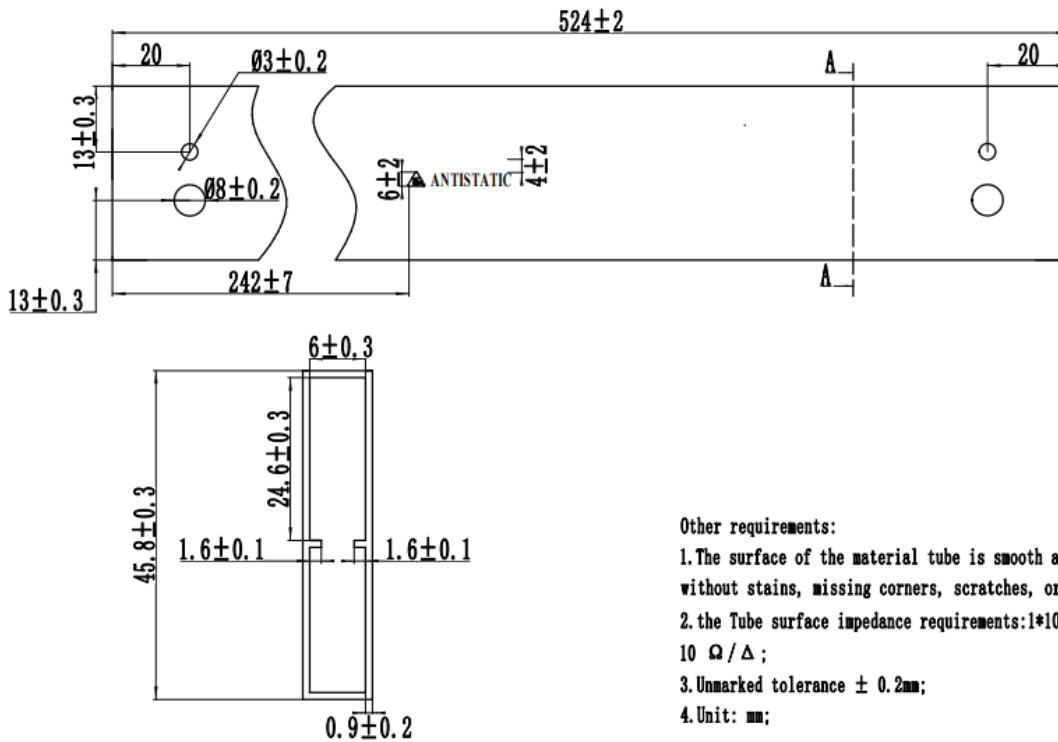
## 16. Package Information





| Row  | Description             | Example |
|------|-------------------------|---------|
| Row1 | Company Name            | INNO    |
| Row2 | Product Code (In short) | XXXXXX  |
| Row3 | Date Code               | YYWW    |
| Row4 | ASSY Lot No.            | XXXXXX  |

## 17. Tube Information



### Other requirements:

1. The surface of the material tube is smooth and transparent, without stains, missing corners, scratches, or obvious burrs;
2. the Tube surface impedance requirements:  $1 \times 10^6 \Omega / \Delta \sim 1 \times 10^8 \Omega / \Delta$ ;
3. Unmarked tolerance  $\pm 0.2\text{mm}$ ;
4. Unit: mm;

## 18. Order Information

| Ordering Code | Package    | Product Code | Packing (Tube) |
|---------------|------------|--------------|----------------|
| ISG6123TD     | TO-247A-4L | 6123TD       | 30pcs/Tube     |

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## Important Notice

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