GaN Systems

GN002 Application Note

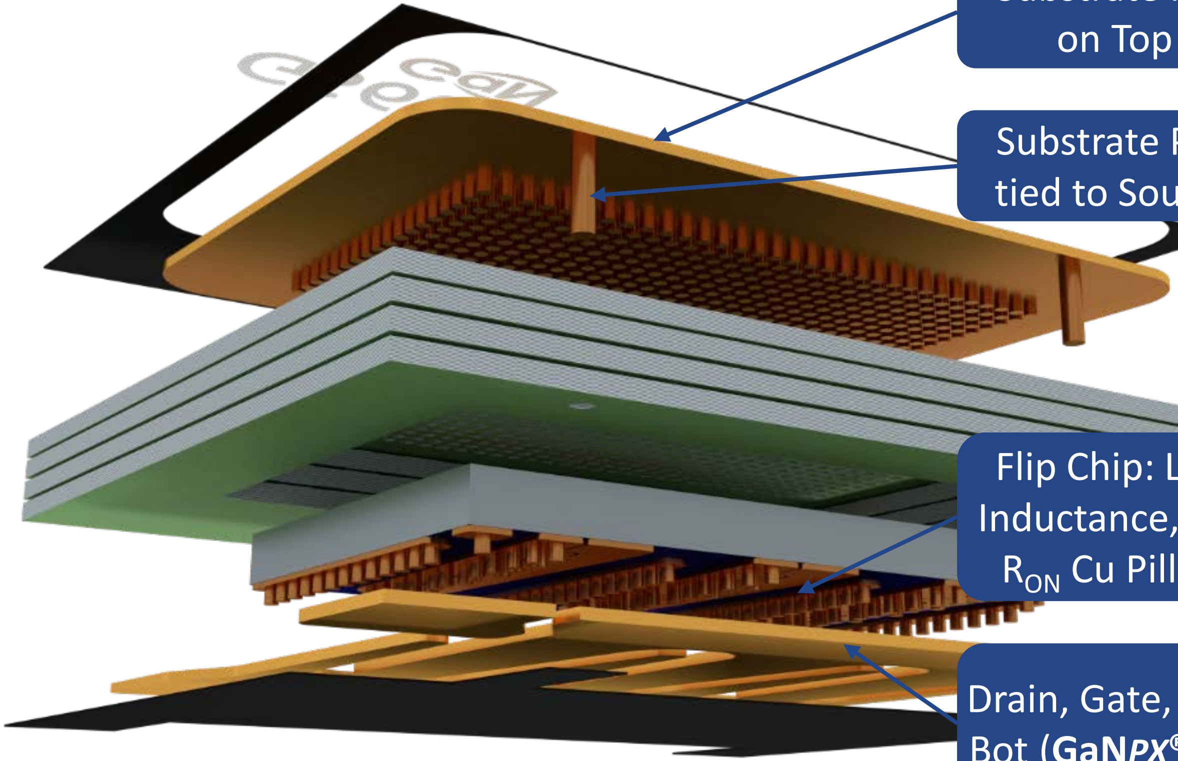
Thermal Design for GaN Systems' Top-side cooled GaN*PX*®-T packaged devices

Updated on April 3, 2018

Application Note Outline

- The Basics - Our top side cooled GaN*PX*®-T package
- Thermal Design for high-power with GaN*PX*®-T package
- Heatsink Mounting Design Considerations
- Bending Pressure and Deformation Limits

GaN*PX*®-T - Embedded Package for Top Side Cooling

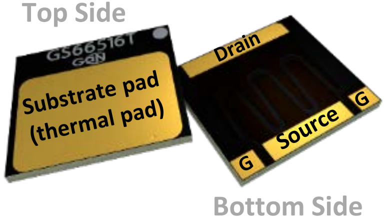


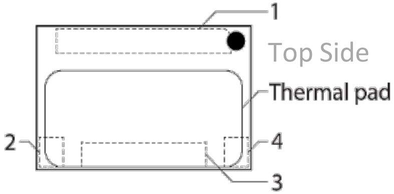
Substrate Pad on Top

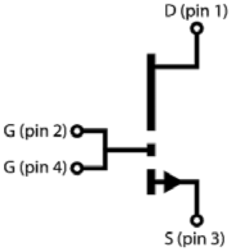
Substrate Pad tied to Source

Flip Chip: Low Inductance, low R_{ON} Cu Pillars

Drain, Gate, Source on Bot (**GaN*PX*®** package)







GaN*PX*®-T package, optimized for high power applications with Top-Side Heat Sinking

Advantage of GaN*PX*®-T Package with top-Side Cooling

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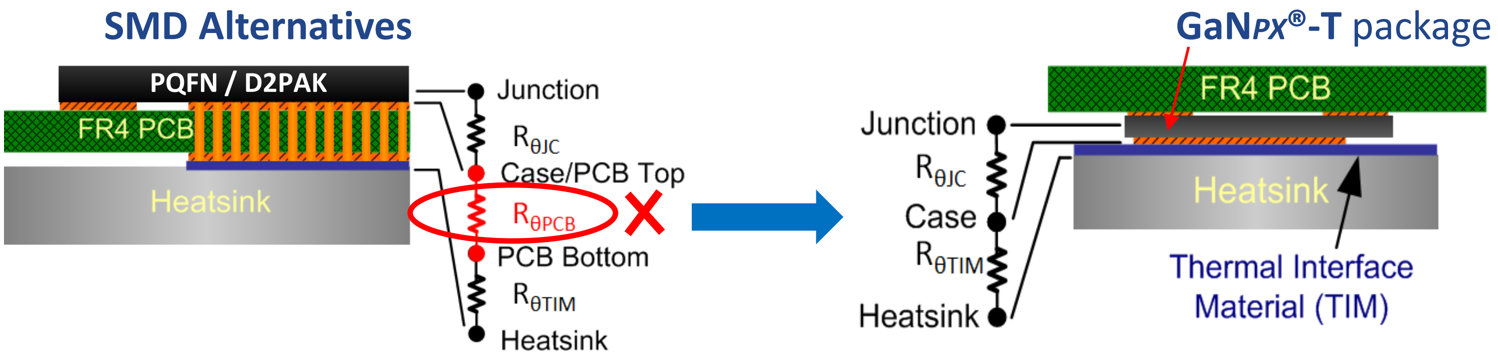
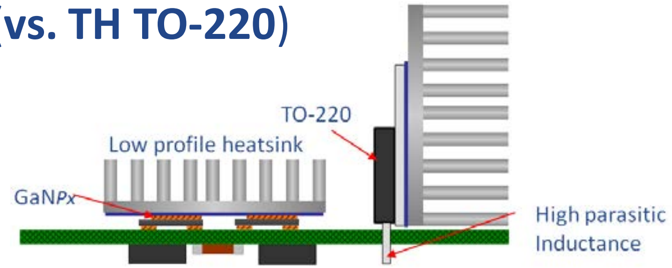
Eliminates PCB from thermal path (vs. SMD alternatives)

- Simpler PCB layout
- Free up PCB space for improved parasitics
- Better thermal performance



Enables a more compact, low profile design (vs. TH TO-220)

- High power density, low profile design
- Improved power loop inductance
- Reduced EMI
- Smallest footprint for ultra-high density design



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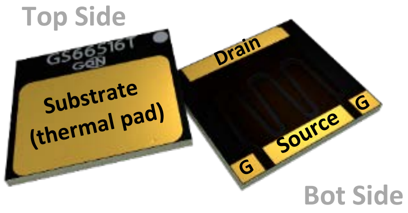
Heat Transfer Fundamentals

Heat transfer occurs in three different ways

- **Conduction** – through direct contact
- Convection – through fluid movement (air is a fluid)
- Radiation – through electromagnetic waves



Our top-side cooled GaN*PX*®-T packages rely primarily on conduction cooling to transfer heat from the internal die surface (junction) to the exterior top and bottom surfaces of the GaN*PX*®-T package. At a system level convection cooling dominates.

$R_{\theta JC}$

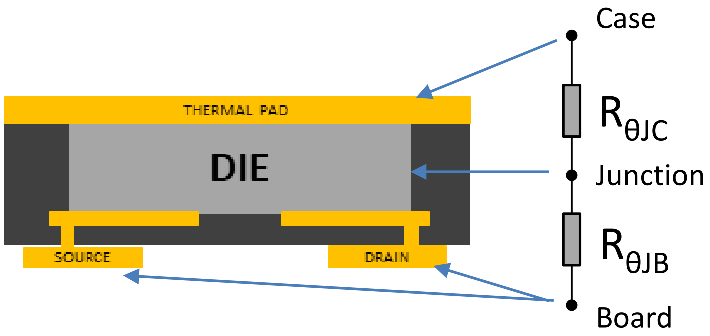
Junction-to-Case Thermal Resistance

Thermal Resistance from the Die (junction) to the Substrate pad (case) on the top of the device

$R_{\theta JB}$

Junction-to-Board Thermal Resistance

Thermal Resistance from the Die (junction) to the Drain and Source on the bottom of the device (board)



$$R_{\theta JC} = \frac{T_J - T_{Case}}{P}$$

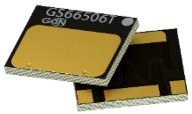
$$R_{\theta JB} = \frac{T_J - T_{Board}}{P}$$

GaN*PX*® -T Package, Thermal Characteristics

650 V Devices

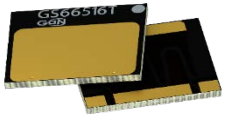
GaN*PX*® package	$R_{\theta JC}$ (°C/W)	$R_{\theta JB}$ (°C/W)
GS66506T	0.7	7.0
GS66508T	0.5	5.0
GS66516T	0.3	3.0

GS66506T



GS66508T

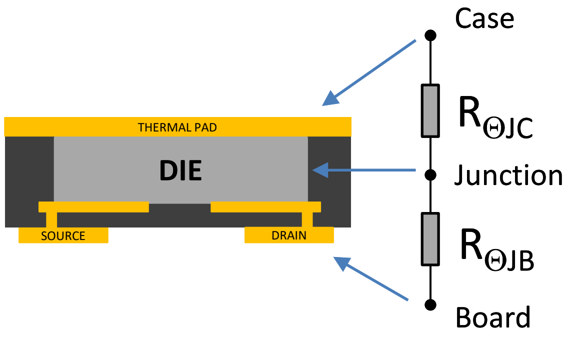
GS66516T



100 V Devices

GaN*PX*® package	$R_{\theta JC}$ (°C/W)	$R_{\theta JB}$ (°C/W)
GS61008T	0.55	5.5

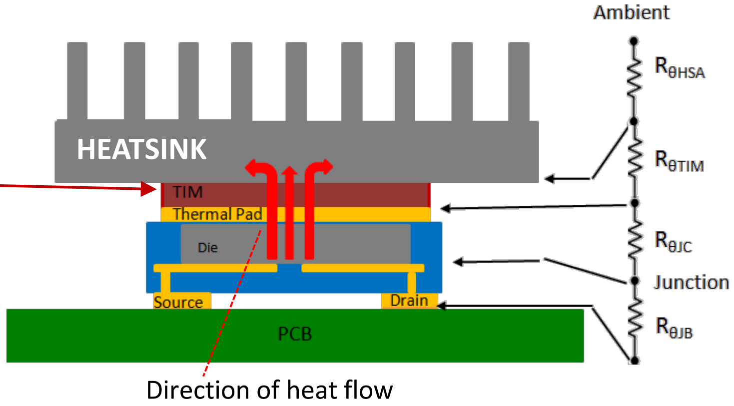
GS61008T



Using Heatsinks and TIM

The top-side thermal pad provides a path of low thermal resistance for attaching a heatsink.

For improved heat transfer, a **Thermal Interface Material** (TIM) should be placed between the device's thermal pad and the external heatsink. The TIM fills air gaps and voids to improve heat transfer between the device and the heatsink. TIM are available with different thermal resistances.



$$R_{\theta JA} = R_{\theta JC} + R_{\theta TIM} + R_{\theta HSA}$$

$R_{\theta TIM}$

TIM Thermal Resistance

TIM considerations:
- Thermal Conductivity
- Contact Resistance
- Thickness / Phase
- Electrical Isolation

$R_{\theta HSA}$

Heatsink-to-Ambient Thermal Resistance

Heat Sink considerations
- Thermal Conductivity
- Heatsink size / weight
- Heat Convection path:
  Fin geometry / Air-flow to achieve max efficiency under Zero LFM Air-flow

GS66516T Thermal Simulation (Typical Design)

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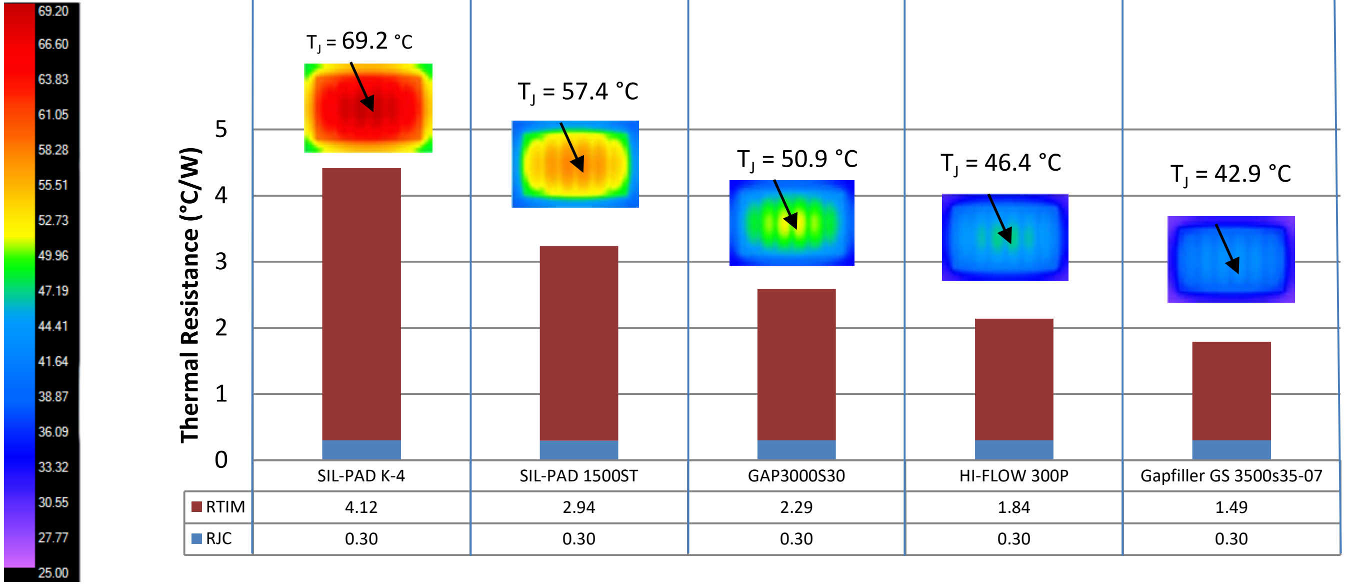
Operating Conditions

- Power = 10 W
- T_{HS} = 25 °C

THE BERGQUIST COMPANY http://www.bergquistcompany.com/thermal_materials/

	SIL-PAD K-4	SIL-PAD 1500ST	GAP3000S30	HI-FLOW 300P	GAPFILLER GS 3500S35-07
TIM Thickness (mm)	0.152	0.203	0.25	0.102	0.178
Thermal conductivity (W/m·K)	0.9	1.8	3.0	1.6	3.6



	SIL-PAD K-4	SIL-PAD 1500ST	GAP3000S30	HI-FLOW 300P	Gapfiller GS 3500s35-07
RTIM	4.12	2.94	2.29	1.84	1.49
RJC	0.30	0.30	0.30	0.30	0.30

For high-power Electrical Design with GS66516**T** and **PCB** (Schematic and Layout), refer to **GN004**

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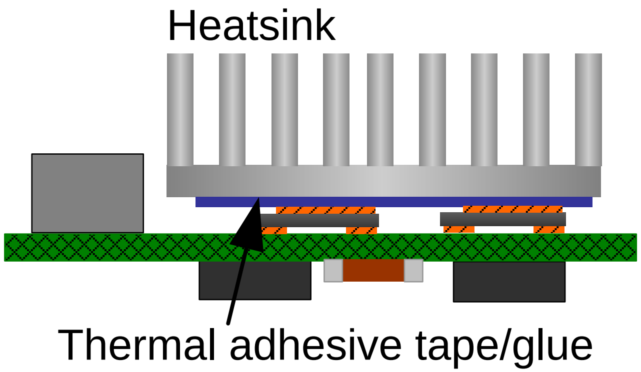
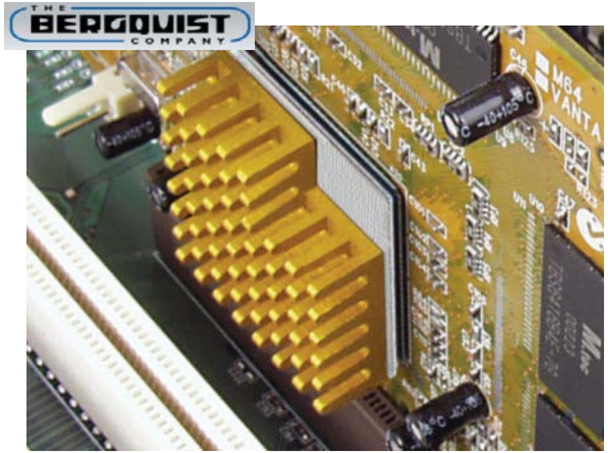
Mounting Techniques

Thermal adhesive tape/glue:

For low power design with small lightweight heatsink

- Low cost
- Simple mechanical design
- No required mounting holes
- Pre-applied pressure during assembly
- Heatsink floating or grounded via clip for EMI



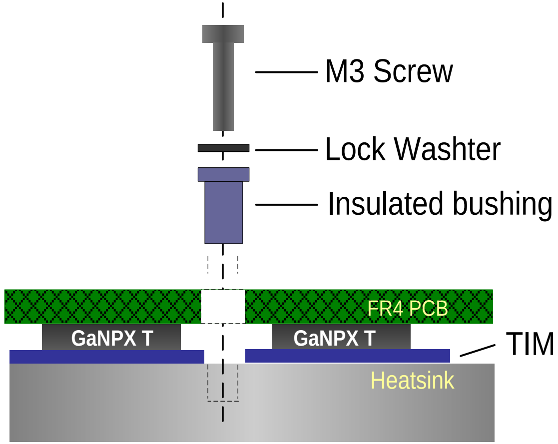


Example: Bergquist® BondPly series 100

Mounting Techniques

Center mounting hole

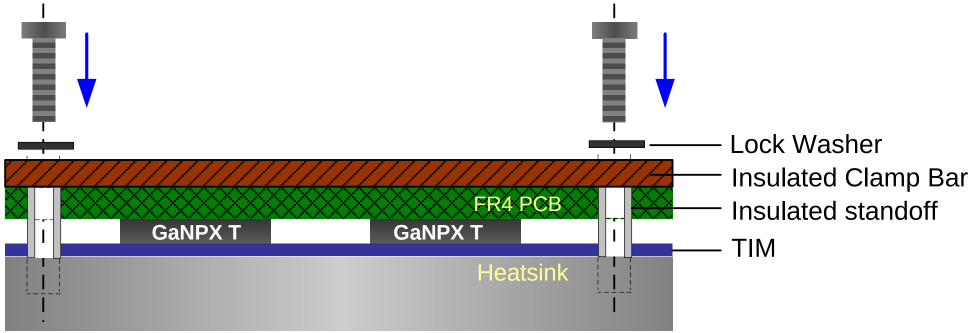
- Balanced pressure across 2 devices
- Typical recommended maximum pressure ~50psi: For M3 screw with 2 devices: ~2in-lb for GS66508T and 4in-lb for GS66516T
- Tested up to 100psi without failure
- Suitable for small heatsink attachment



2 or more mounting holes for large heatsink

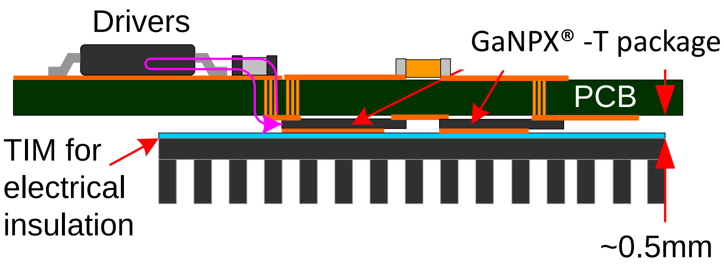
More susceptible to PCB bending stress:

- Excess PCB bending causes stress to GaN*PX*®-T package and other SMD parts which should be avoided
- Locate mounting holes close to GaN*PX*®-T package
- Recommended to use a supporting clamp bar on top of PCB for additional mechanical support



Thermal design solutions with T package

GaN*PX*®-T package on opposite side to other components



Heatsink/chassis mechanically attached to GaN*PX*®-T package

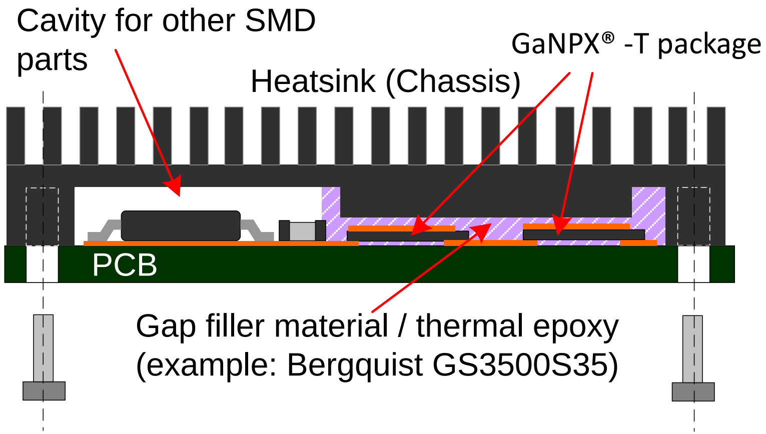
Pros

- Good thermal performance
- Simple heatsink design

Cons

- Mechanical stress
- Creepage distances
- Longer gate drive loop

GaN*PX*®-T package on same side as other components



Heatsink mechanically attached to PCB
Bottom of heatsink contoured to define the gap and accommodate other parts
Gap filled with gap filler or thermal epoxy.

Pros

- No direct mechanical stress to GaNPX®-T package
- Single side placement
- Tight gate drive layout

Cons

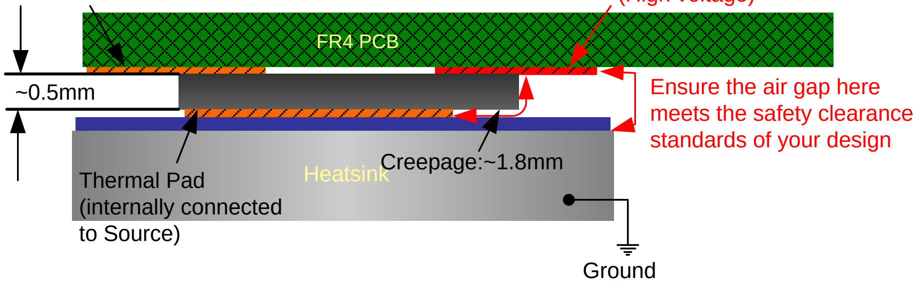
- Higher thermal resistance
- Complicated heatsink design

Pedestal Heatsink Design and Voltage Isolation Clearance

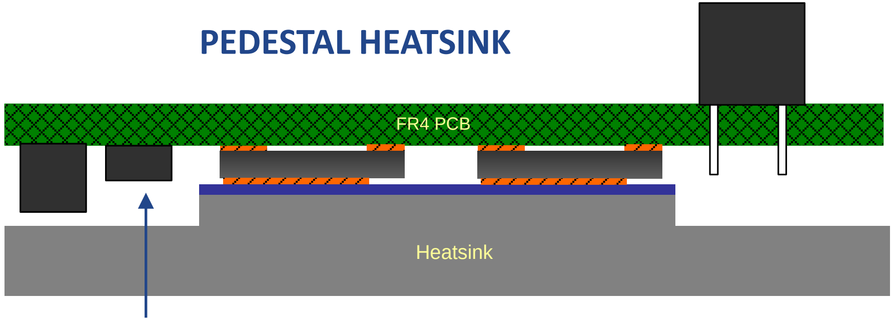
When using a heatsink, design to meet the Regulatory creepage and clearance requirements

- Use TIM to cover Heatsink edge in areas where clearances must meet Standards
- Avoid placing Through Hole Components near GaN*PX*® -T package
- Use **Pedestal Heatsink** design to increase clearances and allow for placement of SMT components under the heatsink

STANDARD HEATSINK



PEDESTAL HEATSINK



A pedestal heatsink provides clearance beneath the heatsink for the placement of SMT devices

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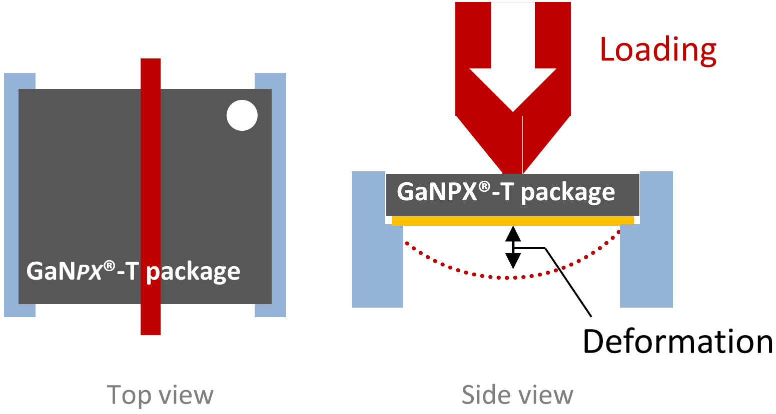
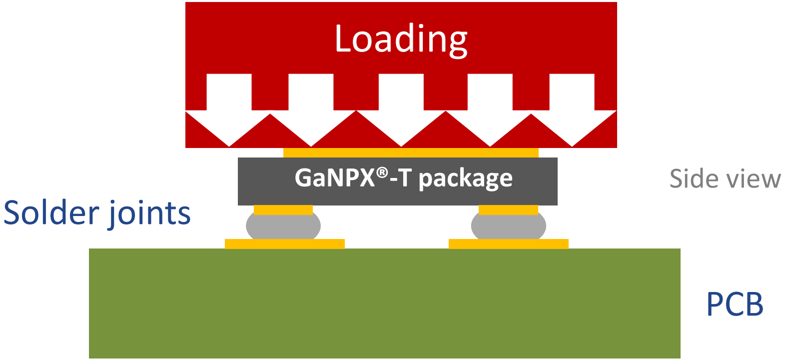
GaN*PX*®-T Package Bending Pressure and Deformation

Part Number	Deformation Safe Limit (μm)	Pressure Safe Limit (PSI)
GS66508T	50	100
GS66516T	120	100

Deformation Test

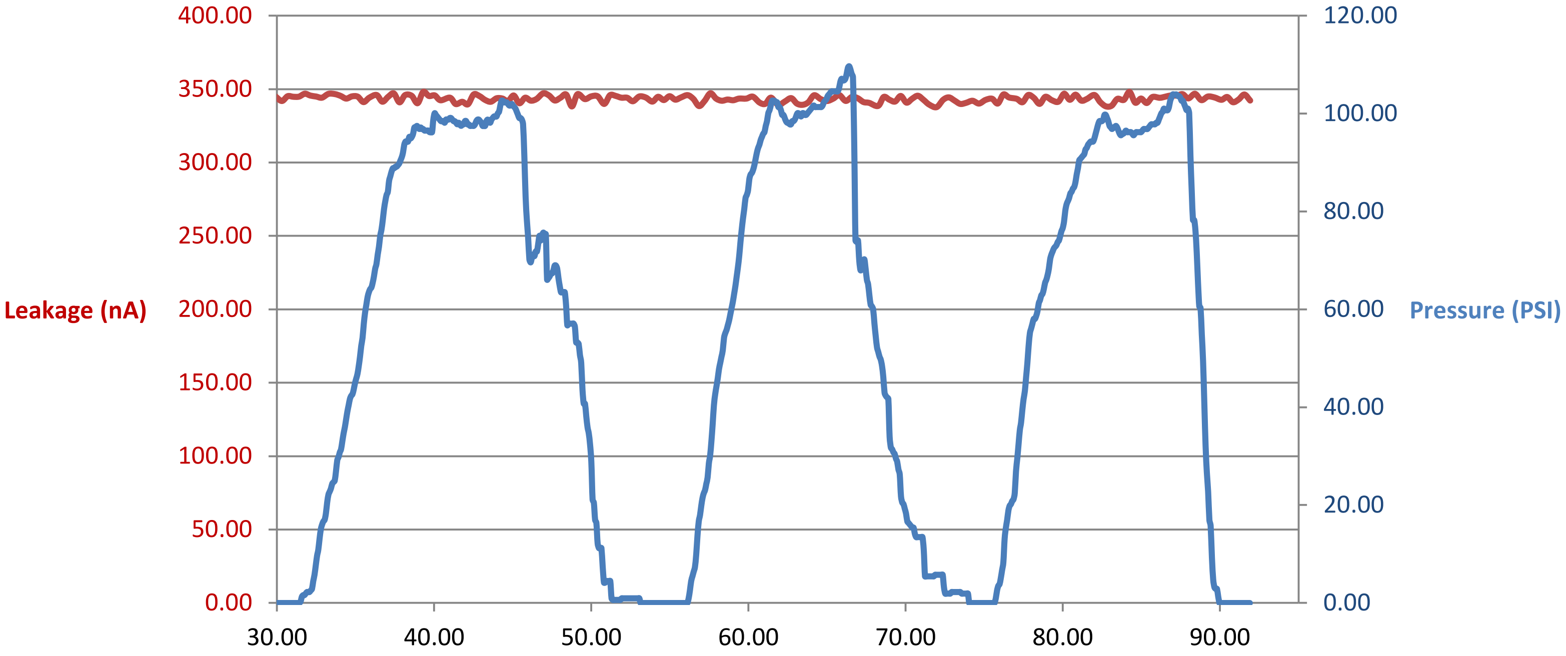


Pressure Test



Bending Pressure Test Methodology

Example: GS66508T



DUT subject to 100 PSI over 3 pulses, with no shift in Leakage Currents

400 volts V_{DS} applied to each DUT (@ 25˚C)

Leakage Current = $I_{DSS} + I_{GS} + I_{BULK}$* (*Substrate)

Mounting screw torque calculation

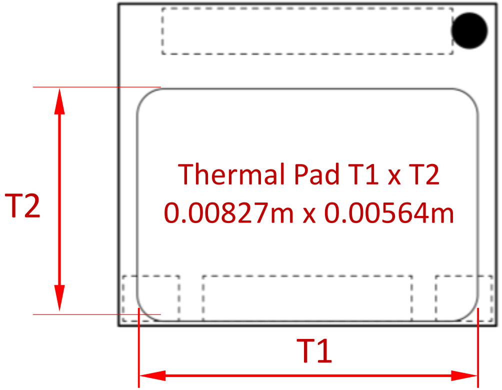
The contact area of the thermal pads must be calculated. In this example the total contact area value of both devices is 0.0000933 m^2.

Also required are the properties of the fastener itself. In this case a M3 x 0.5 steel screw

- Thread diameter = 0.003 m
- 75% of proof loading = 847.5 N

Values for other fasteners can be found by referencing the following ISO standards

- **ISO 898-1:2013**
- **ISO 898-7:1992**



Torque vs. Pressure relationship

With these values we can now use the following formulas to plot the relationship between fastener torque and the pressure exerted on the devices in this example

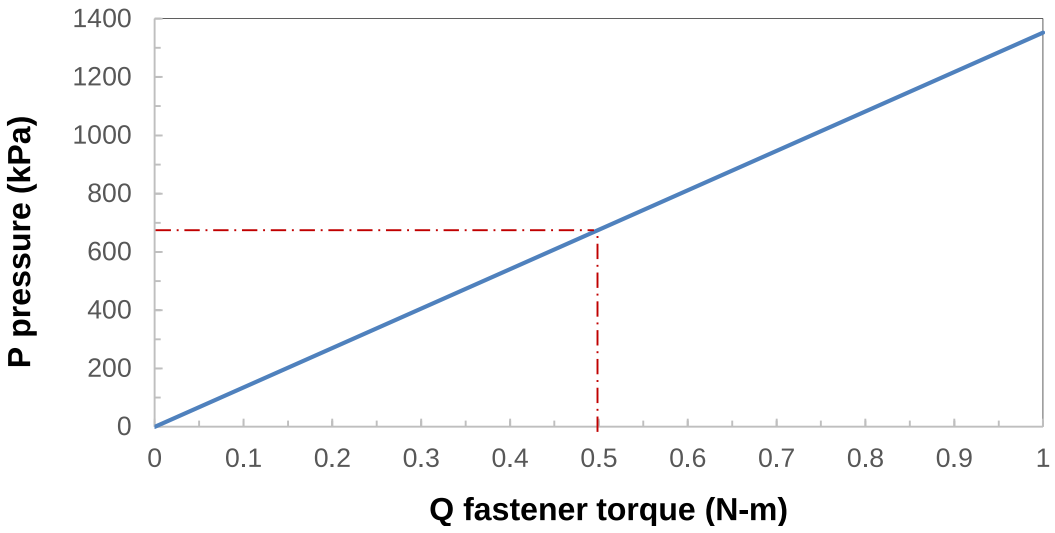
$$P_{i(i=0,1;0.1)} = \frac{F_{i(i=0,1;0.1)}}{A}$$

$$F_{i(i=0,1;0.1)} = \frac{Q_{i(i=0,1;0.1)}}{\beta \times \gamma \times d}$$

Q = fastener torque (N-m)
P = pressure on device (kPa)

A = contact area of thermal pad(s) (m^2)
d = screw diameter (m)
F = 75% ISO proof loading (N)

β = 0.2 (threads factor)
γ = 0.115 (PCB assembly factor)



A torque of **0.5 N-m** generates a pressure of ~680 kPa (98.6 PSI) on the thermal pads of the GS66516T devices, the published maximum.

Tomorrow's power today™

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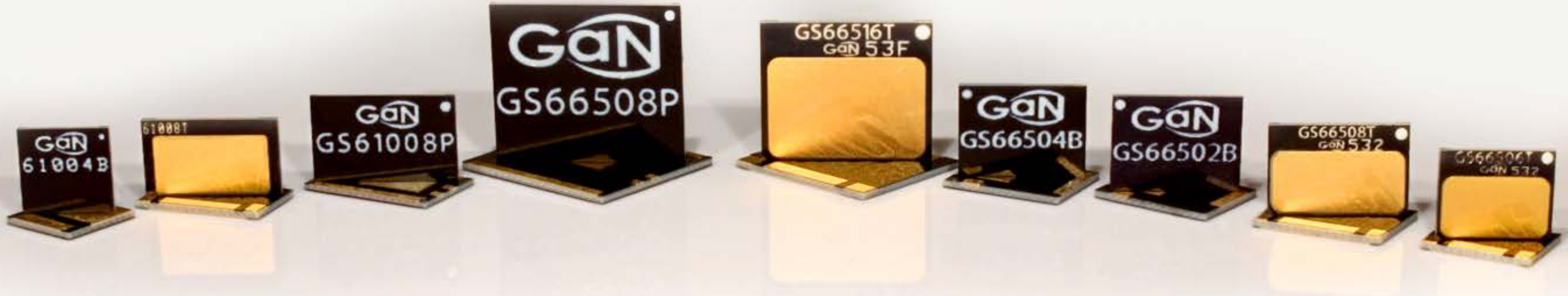

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