transphorm
Highest Performance, Highest Reliability GaN

Head-to-Head Comparison

72 mΩ SuperGaN FET Outperforms 50 mΩ e-mode

We took a 280 W GaN gaming laptop charger and dropped in pin-to-pin compatible SuperGaN® devices, replacing the paralleled TSMC e-mode GaN devices shipped in the adapter.

Notable SuperGaN performance and long-term reliability advantages prove that power systems deploying Transphorm GaN can deliver higher power with longer end product lifecycles.

Test Profile

Product:	280 W power adapter
Topology:	PFC (DCM/CrM), LLC
Original GaN:	TSMC e-mode HEMTs (x2)
On-Resistance:	50 mΩ
GaN Package:	PQFN 8x8
Drop-in GaN:	SuperGaN FETs (x2)
On-Resistance:	72 mΩ
GaN Package:	PQFN 8x8 with reduced drive circuit passive count

The Big Picture: Transphorm GaN Outperforms and Is More Reliable than TSMC e-mode GaN

A primary factor driving GaN adoption is its inherent promise of higher power efficiency.

Analysis of the competitive devices in the same in-production laptop charger demonstrates that SuperGaN FETs deliver higher efficiency than the alternative TSMC e-mode GaN HEMTs.* [Figure 1]

Further analysis will also show SuperGaN FETs proving more reliable than e-mode devices. [Figure 2]

However, let's first identify where the performance differs.

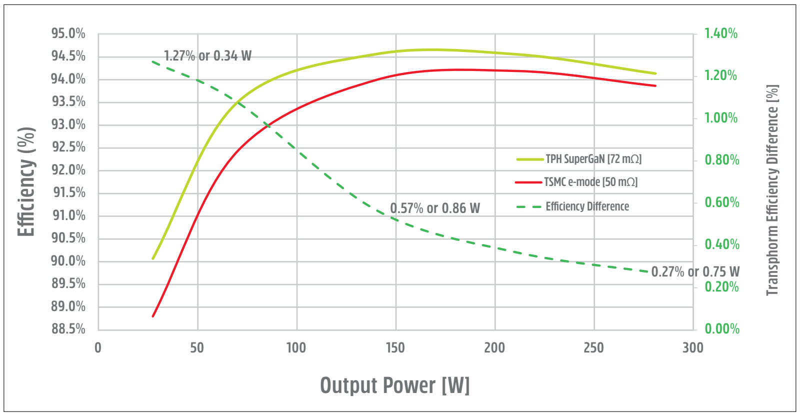

Figure 1: 280 W Razer power adapter performance results using 90 V_{AC}

What Drives the SuperGaN Platform's Higher Efficiency?

Analysis shows a major discrepancy between the competing GaN solutions' operating temperatures. SuperGaN clearly demonstrates an advantage. [Figure 2]

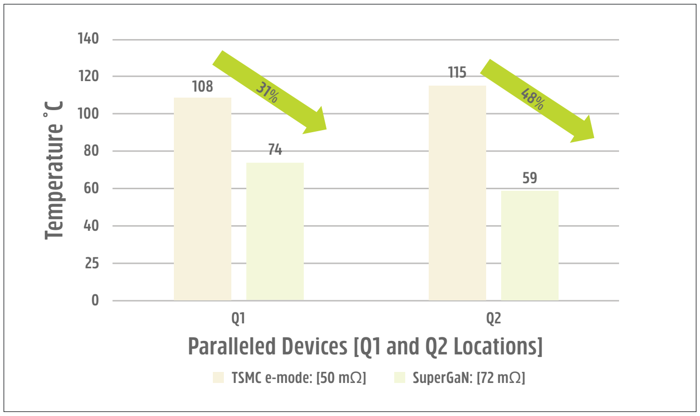

Figure 2: Paralleled devices Q1 and Q2 with an input voltage of 115 V_{AC} @ 280 W

Case Temperatures at One Continuous Hour of Operation

Input Voltage	90 V_{AC}		115 V_{AC}	
Location	Q1	Q2	Q1	Q2
SuperGaN	88°C	72°C	74°C	59°C
e-mode	Unkown, unable to reach steady-state thermal case condition		108°C	115°C

*Reference hereafter to "e-mode", "e-mode GaN", "e-mode device", etc. in document refers to tested 50 mΩ TSMC e-mode HEMT.

What Causes the Temperature Difference?

Datasheet and die size investigations indicate that the SuperGaN and e-mode devices offer similar die size and C_{OSS} output energy losses (E_{OSS}).

With the similar die sizes, the coefficient of junction-to-case thermal resistance (RthJC) will also be similar—resulting in similar heat spreading.

The devices' E_{OSS} shown in Figure 3 indicate that output losses are also similar. Switching waveforms observed also verify this.

With gate drive losses also being negligible, logic then suggests the temperature difference is caused by conduction losses (on-resistance).

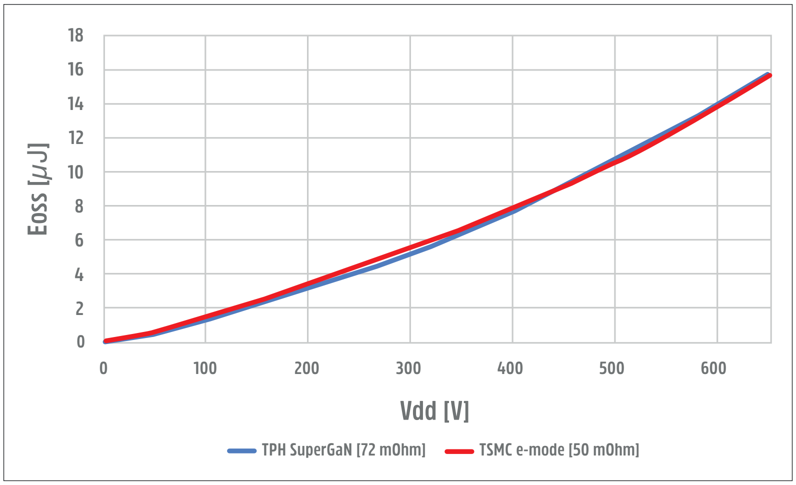

Figure 3: Typical COSS Stored Energy (E_{OSS}) according to datasheet specs.

SuperGaN Advantage: On-Resistance Performance Over Temperature and Voltage

The adapter system operates with a standard gate drive output voltage of 0 to 13 V.

The e-mode devices are level shifted to -0.07 to 5.1 V. However, Figure 4 shows that they are still not fully optimized at 5.1 V. This is likely an intentional design feature used to provide headroom between the 5.1 V V_G and the $V_{G(max)}$ of 7 V to avoid causing device failure. While the reasoning is an assumption, the design feature suggests acknowledgement of and accommodation for the higher temperature threats identified in Figure 2.

The existence of these higher TSMC e-mode thermals are independently verified in IEEE-published research.[1] That report states that TSMC e-mode can result in a 3.72x increase over typical on-resistance values based on temperature and voltage operation. Taking this into account, the e-mode device's on-resistance can be as high as 186 mΩ [Figure 4], which is 58 mΩ higher than the published datasheet metric.

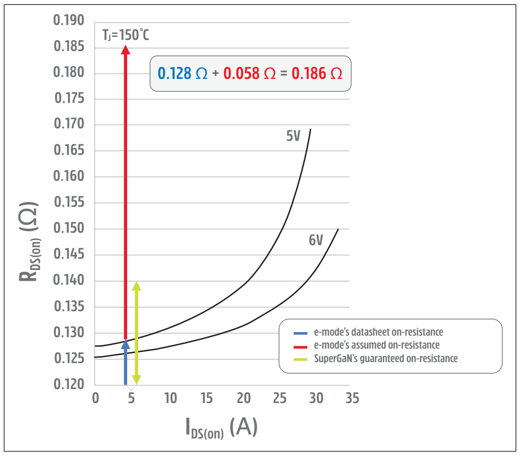

Figure 4: At 5 V, e-mode's assumed dynamic on-resistance far exceeds what's expected per datasheet.

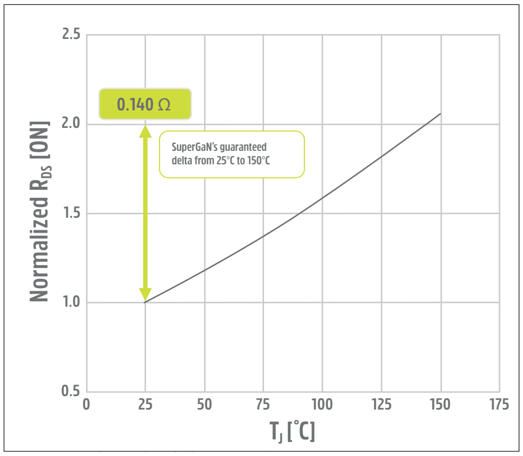

Figure 5: SuperGaN's guaranteed dynamic on-resistance is similar to Si MOSFET at 150°C.

SuperGan Results

Alternatively, SuperGaN devices operate at the standard gate drive voltage of 0 to 13 V without issue. [Figure 5] Considering, they deliver superior performance over temperature and voltage which, in turn, equates to higher power output potential with higher device reliability.

[1] *R. Hou, Y. Shen, H. Zhao, H. Hu, J. Lu and T. Long, "Power Loss Characterization and Modeling for GaN-Based Hard-Switching Half-Bridges Considering Dynamic on-State Resistance," in IEEE Transactions on Transportation Electrification, vol. 6, no. 2, pp. 540-553, June 2020, doi: 10.1109/TTE.2020.2989036.*