PE INTERNATIONAL CONFERENCE

ANGELTECH

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Innoscience

What is needed to bring GaN power device into high-volume end-products such as mobile phone?

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PE International Conference

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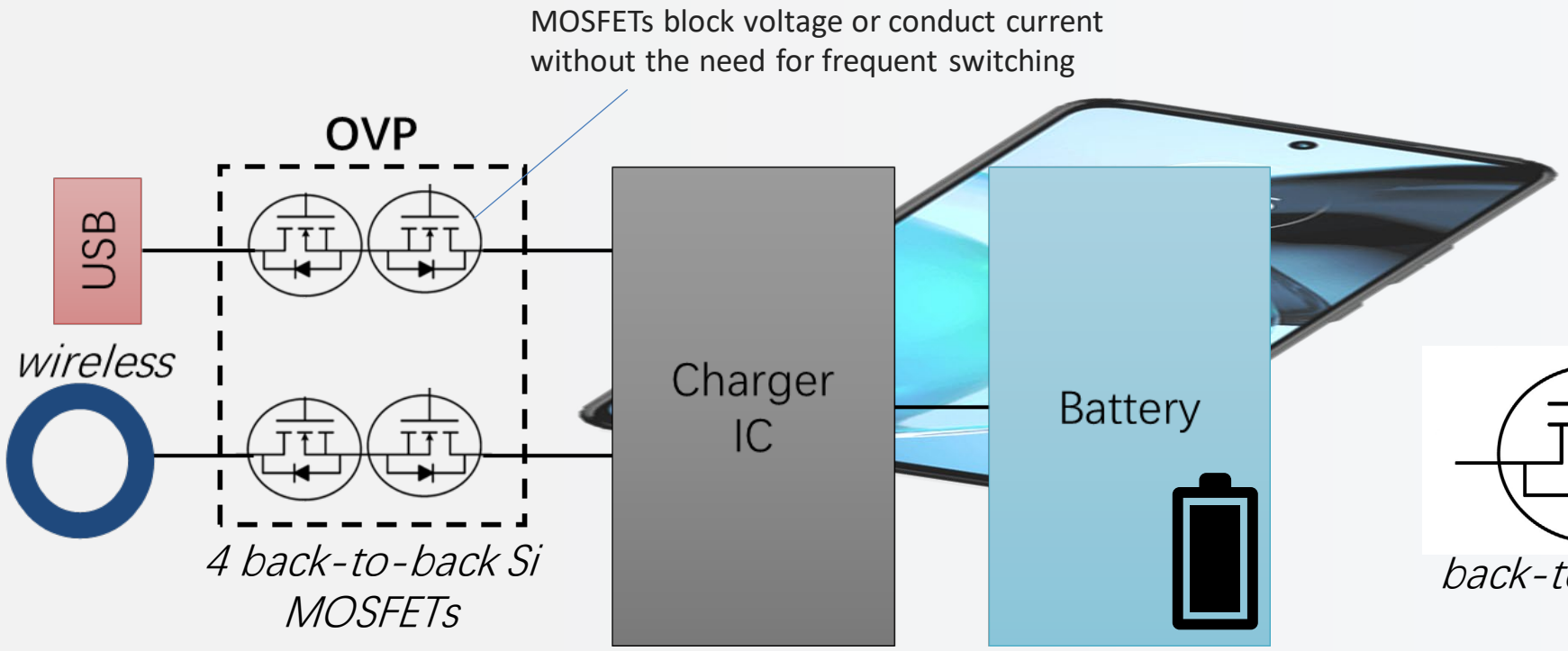
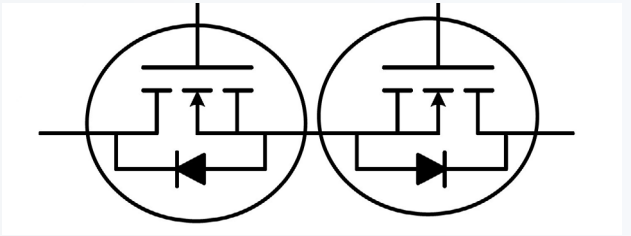
GaN inside the mobile phone

- Mobile phone market
- 1B+ units sold per year
- What is needed to bring GaN to this market:
  - Solid value proposition
  - Stand-by leakage
  - Price competitive with Silicon
  - Huge production volume capacity

Over Voltage protection (OVP)

Shuts down the unit to protect the system when needed





Application requirements

- Lowest conduction loss (on-resistance)
- Smallest foot-print
- Low stand-by leakage
- Low cost

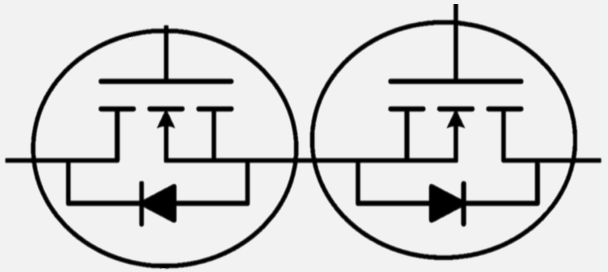
} Specific Rdson

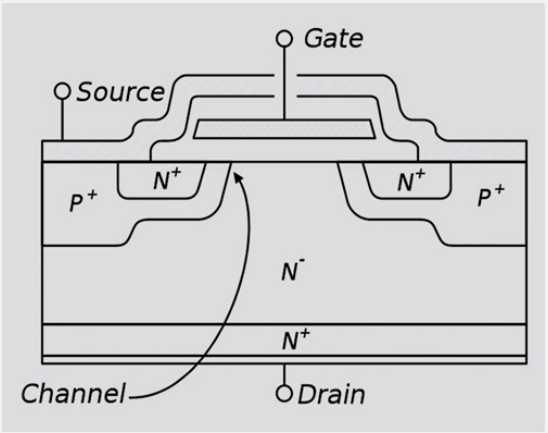
Limitation of Silicon technology

- Large foot print for low Rdson
- Difficult to integrate in one chip
- No bidirectionality due to body diode
- Limited SOA

Bi-directional GaN device

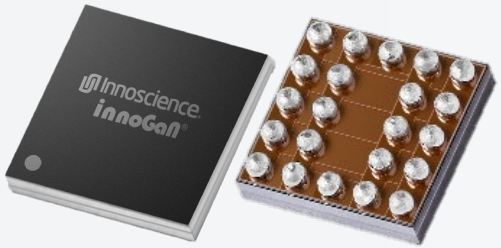
Silicon solution

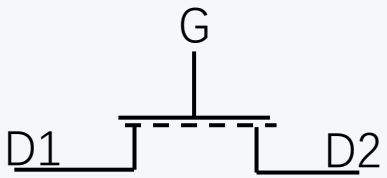


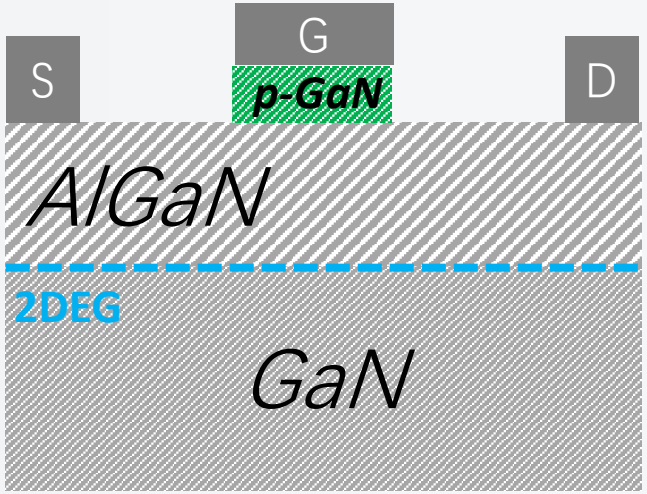


Innoscience Bi-directional GaN

Replacing 2 Si MOSFETs with 1 InnoGaN







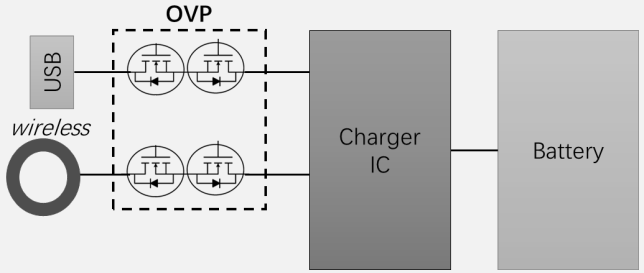
Lateral structure

InnoGaN bi-directional:

- HV Bi-directional functionality on one chip
- Low Rdson/Area
- Low conduction losses
- Wider SOA boundaries

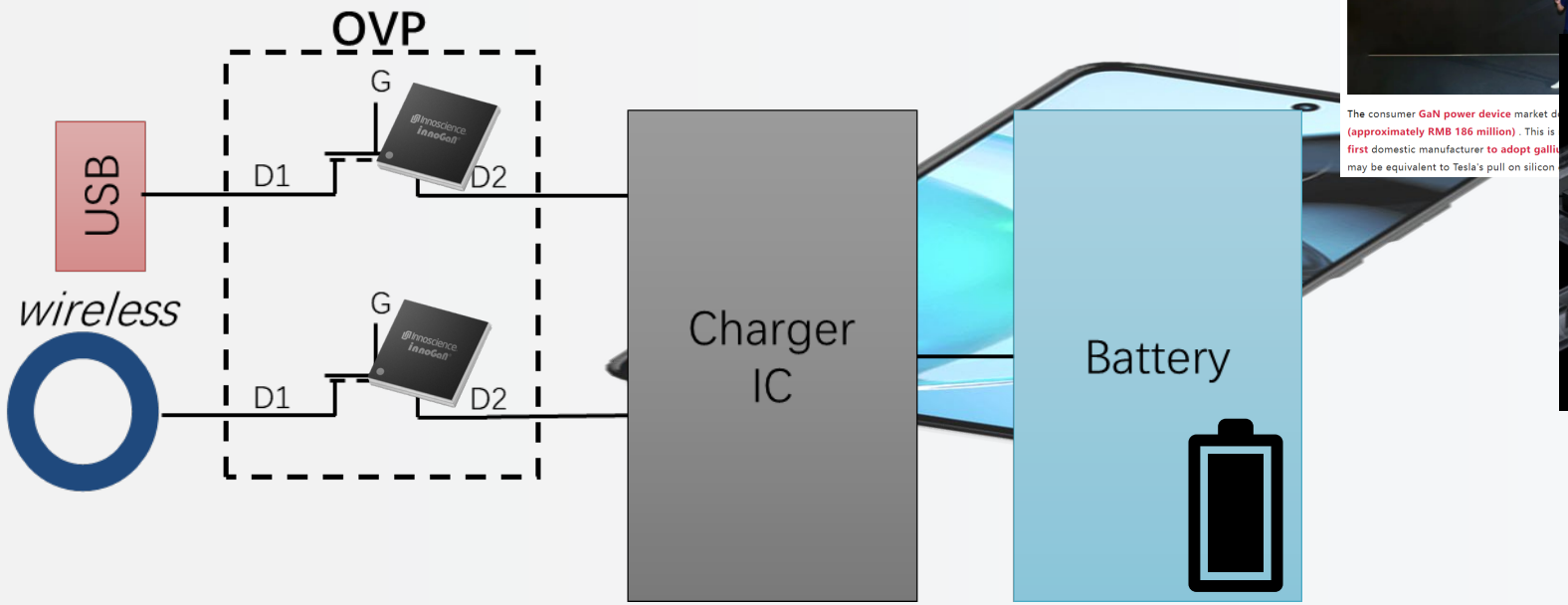
https://www.electronicsforu.com/buyers-guides/guide-to-select-power-mosfets

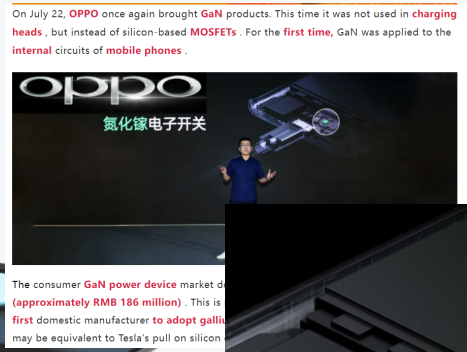
Bi-directional GaN device inside the OVP



InnoGaN makes the Over Voltage Protection (OVP) unit inside the Battery Management System (BMS) at least 50% smaller and more efficient

#2 Si MOSFETs are replaced by #1 Bi-directional InnoGaN

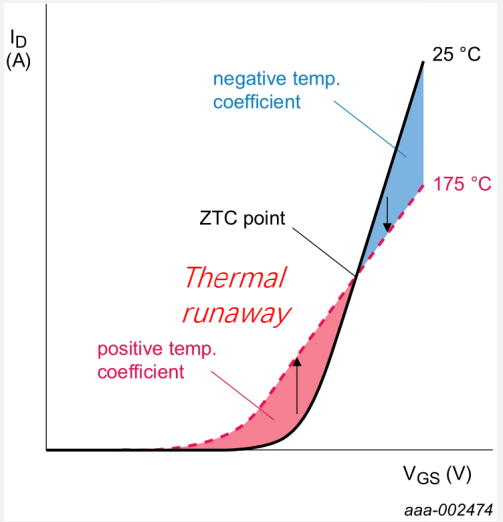


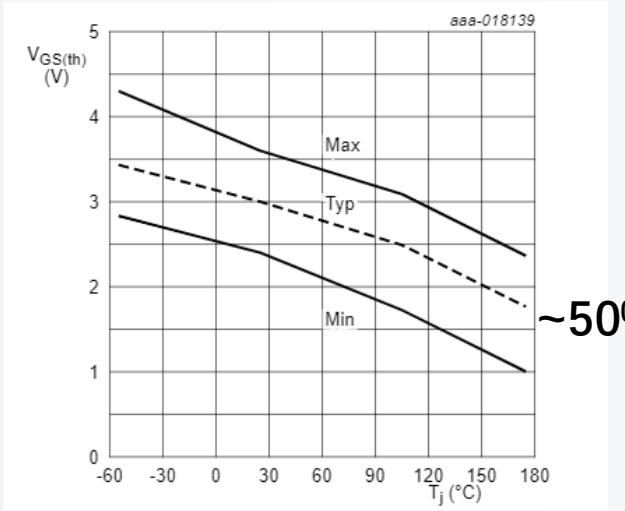


Smaller and… better threshold thermal stability!

ZTC = Zero Temperature Coefficient

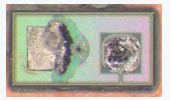
Silicon power MOSFET



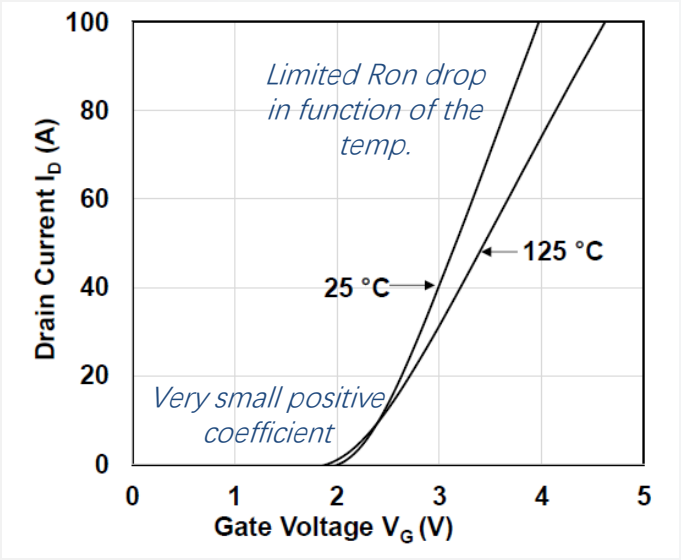


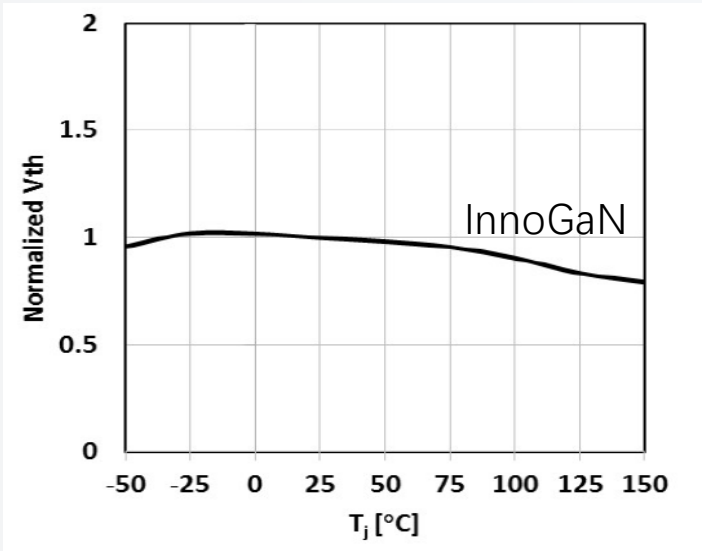
~50%

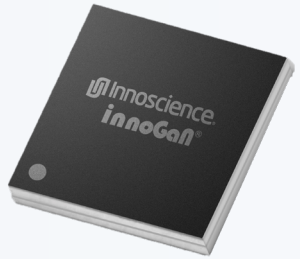
Below the ZTC
Drive more current
Self heating increase
Vth less positive
Thermal runaway



Innoscience Bi-directional GaN



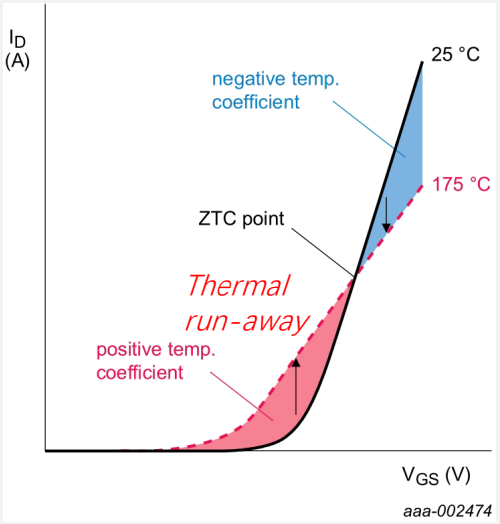


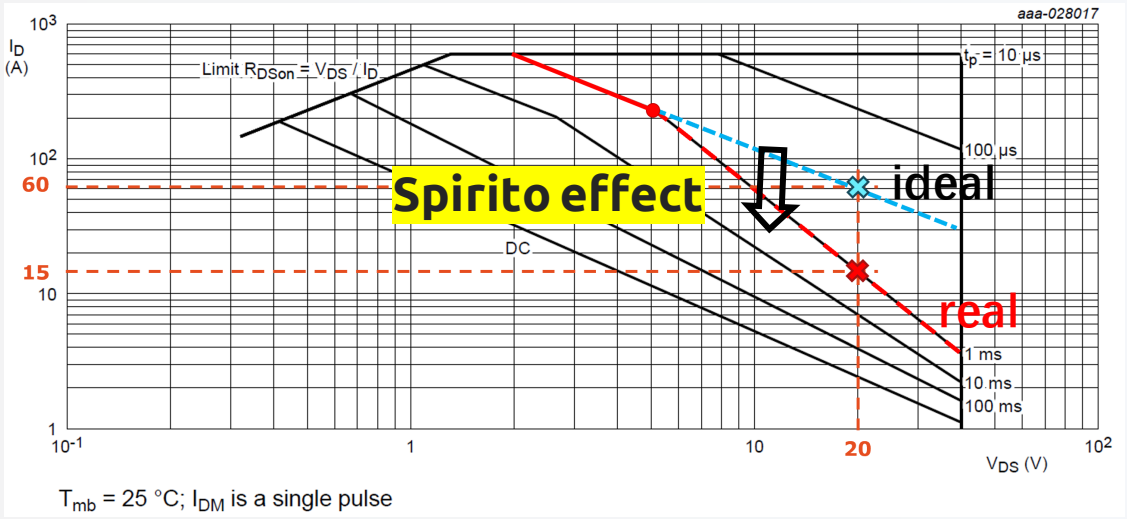


https://www.nexperia.com/applications/interactive-app-notes/IAN50006_Power_MOSFETs_in_linear_mode.html
https://www.innoscience.com/site/product_details/398

Smaller and… better performance/SOA!

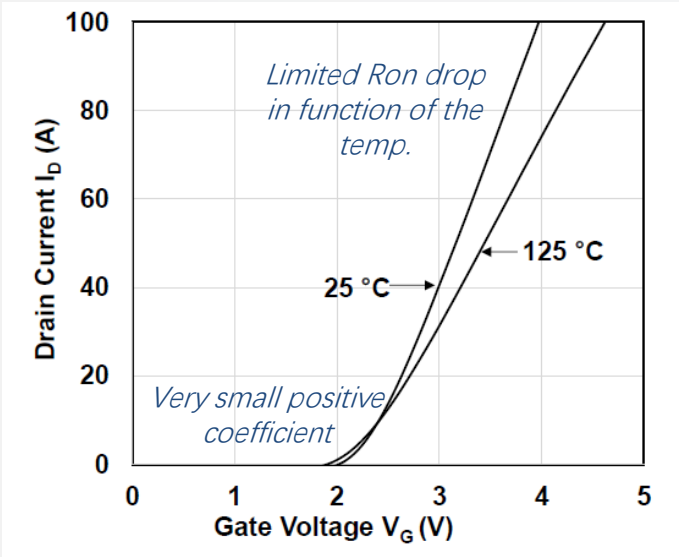
Silicon power MOSFET

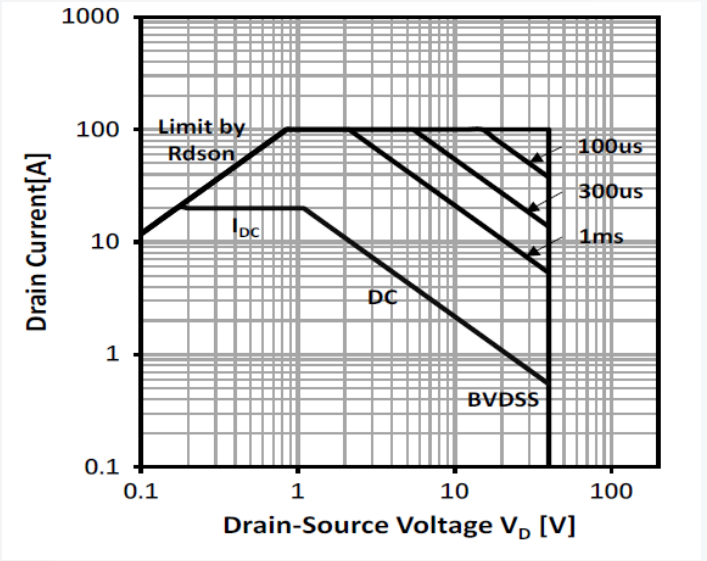


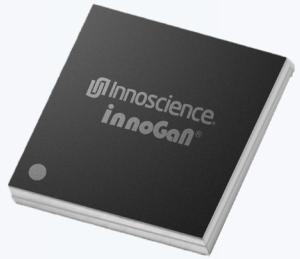


SOA limited by intrinsic Silicon properties

Innoscience Bi-directional GaN







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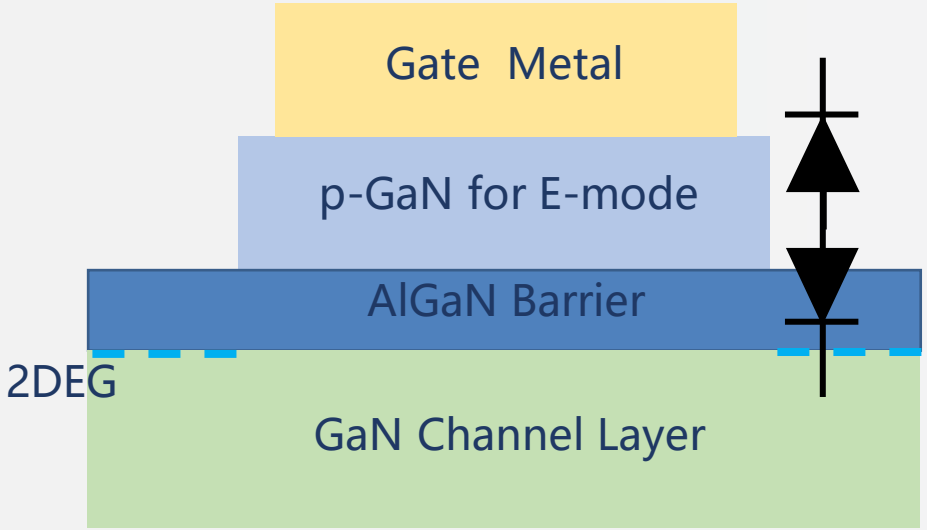
GaN inside the mobile phone

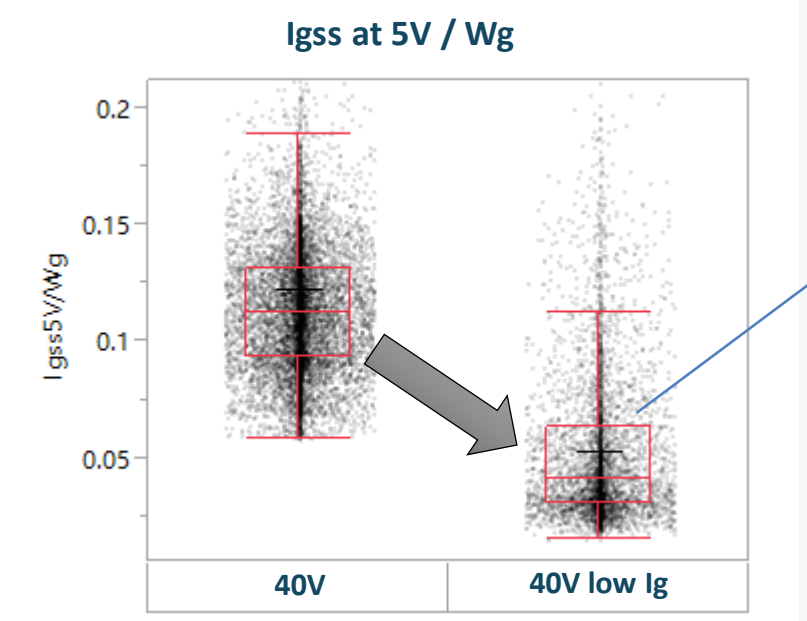
- Mobile phone market
- 1B+ units sold per year
- What is needed to bring GaN to this market:
  - Solid value proposition
  - Stand-by leakage
  - Price competitive with Silicon
  - Huge production volume capacity

Gate leakage breakthrough on E-mode GaN

p-GaN HEMT Gate structure

(Back-to-back diodes in series)





- Epitaxy
- Transistor processing
- Transistor architecture
- Design

- E-mode GaN devices do not have an oxide below the gate
- Need to co-optimize epi, processing, architecture, design etc..
- **~10x reduction of gate leakage**
  - **<3 µA at 85 °C throughout the device lifetime → ok inside smartphone**

GaN inside the mobile phone

Back of the envelope calculation:

- 1B phones sold in 2022
- 10% market penetration: 100M units/year
- Total wafers: ~3,000 8-inch wpm
- Total WW GaN capacity (w/o Innoscience)*: ~9,000 wfm (8-inch equivalent)

30% of WW GaN production capacity (today) required
to serve just 1 application with 10% market share!

- Price competitive with Silicon
- Huge production volume capacity

*Source: Yole report, "GaN Power 2021: Epitaxy, Devices, Applications and Technology Trends"

Status of GaN power device suppliers (today)

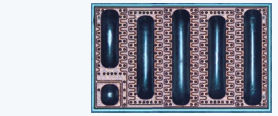
- Limits the ability to differentiate
- How to add value to a discrete device in a foundry process?
- Inherent trend to innovate by adding on-GaN functionality
- **Constraining GaN growth**

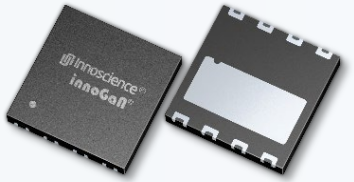
	100% GaN focus	Legacy Si products	Technology development	Product innovation	High volume cost effective GaN production
Fabless startups					
Si power IDMs					
Innoscience: 100% GaN IDM					

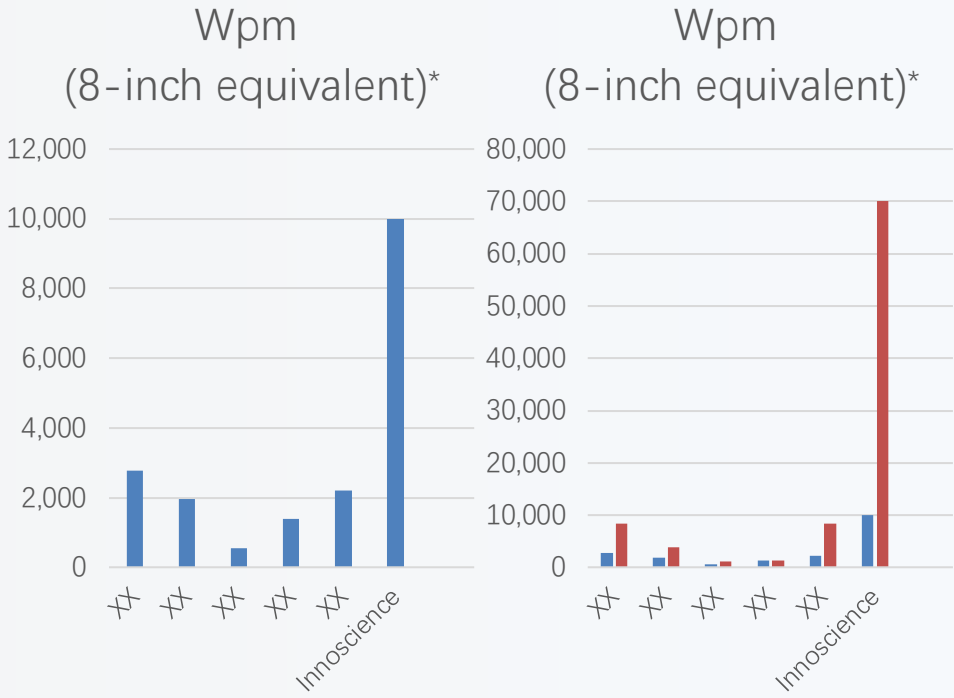
- Internal competition
- Prioritization
- Not enough cost competitive
- Limited production capacity
- **Constraining GaN growth**

Innoscience is the GaN game changer: 100% GaN IDM

- Wide portfolio: **HV (650V), MV (100V-150V) and LV (<100V) GaN** power devices
- **#2** large **8-inch** Silicon-like **high-throughput fabs**: largest GaN capacity worldwide
- **>1500 people** 100% focused on GaN
- **>100Mpcs** shipped so far
- 8-inch + Economy of scale to **slash the cost of GaN** (adoption barrier)







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GaN inside the mobile phone

- Mobile phone market
- 1B+ units sold per year
- What is needed to bring GaN to this market:
  - ✓ Solid value proposition
  - ✓ Stand-by leakage
  - ✓ Price competitive with Silicon
  - ✓ Huge production volume capacity
- Good PPM and reliability

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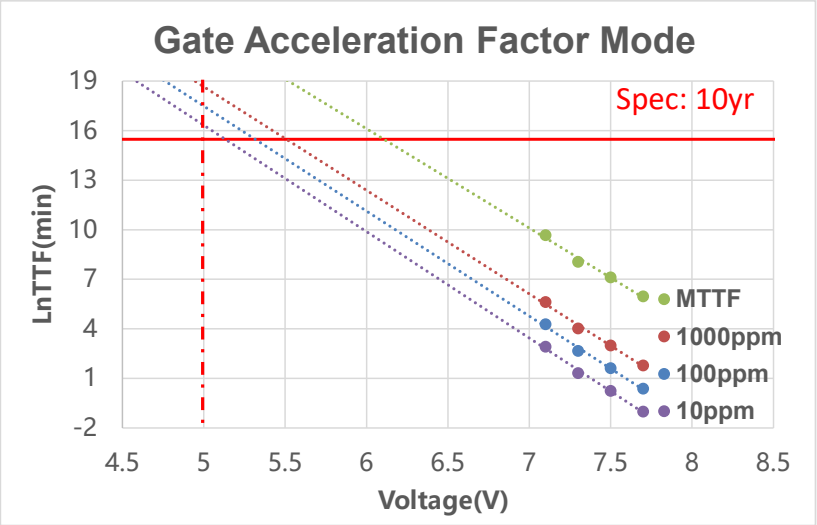
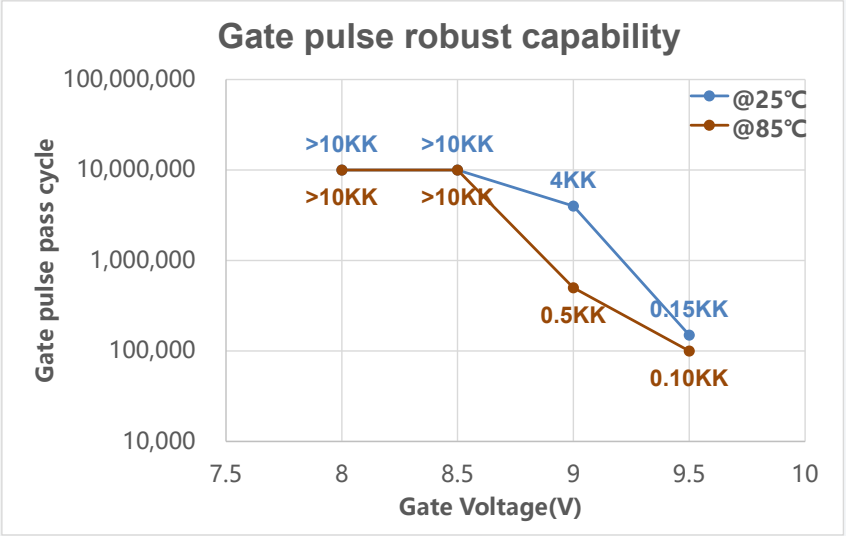
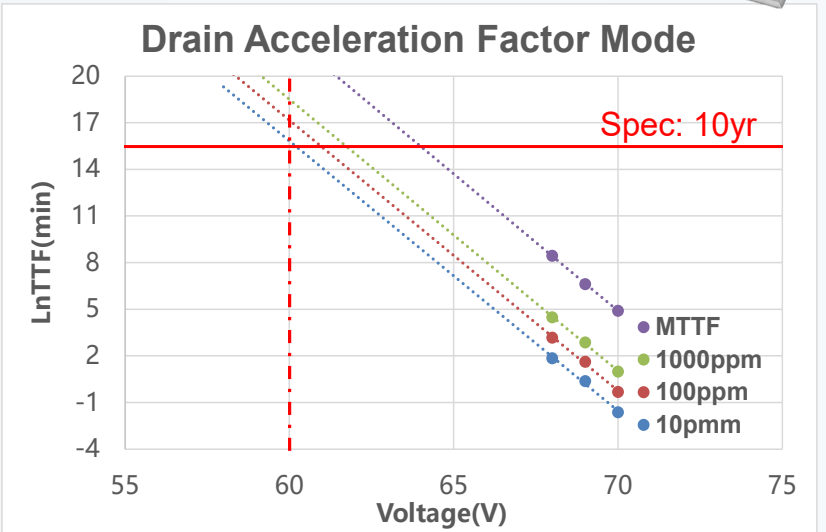
Beyond JEDEC: Accelerated lifetime of 40V BiGaN







Gate reliability

10ppm failure rate exceeds 20years at the forward gate voltage of 5.0 V (V_{GD}) and 125 °C.

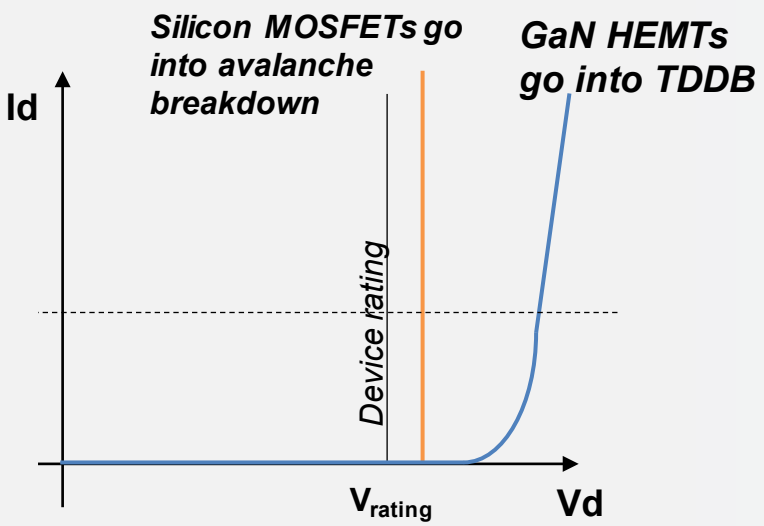
Gate pulse capability

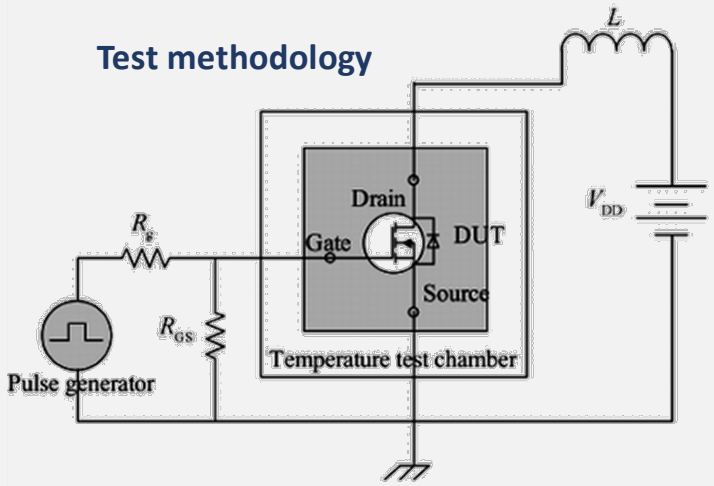
- *10million cycle@≤8.5V with 1μs width (25°C and 85°C)*
- *0.1 million cycle @9.5V, 85°C*

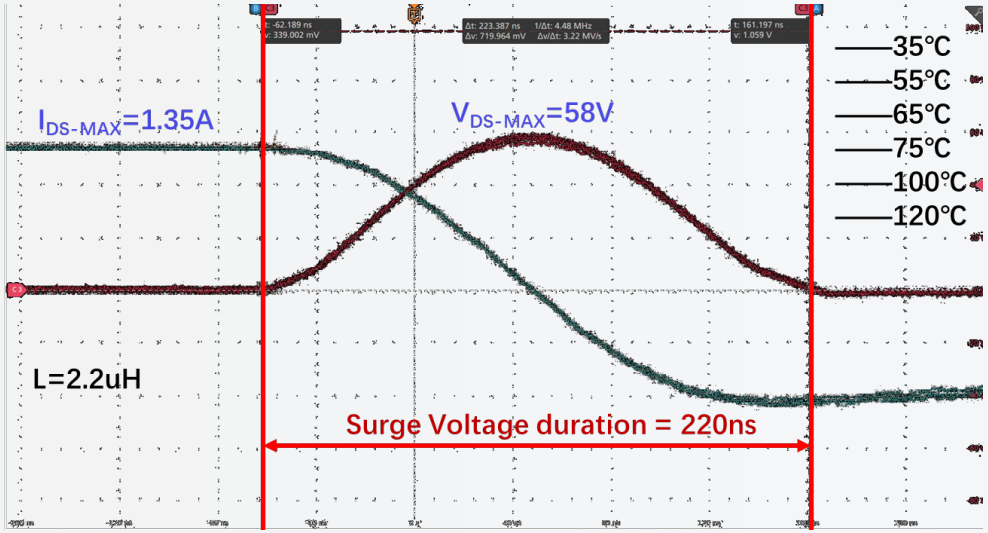
Off-state reliability

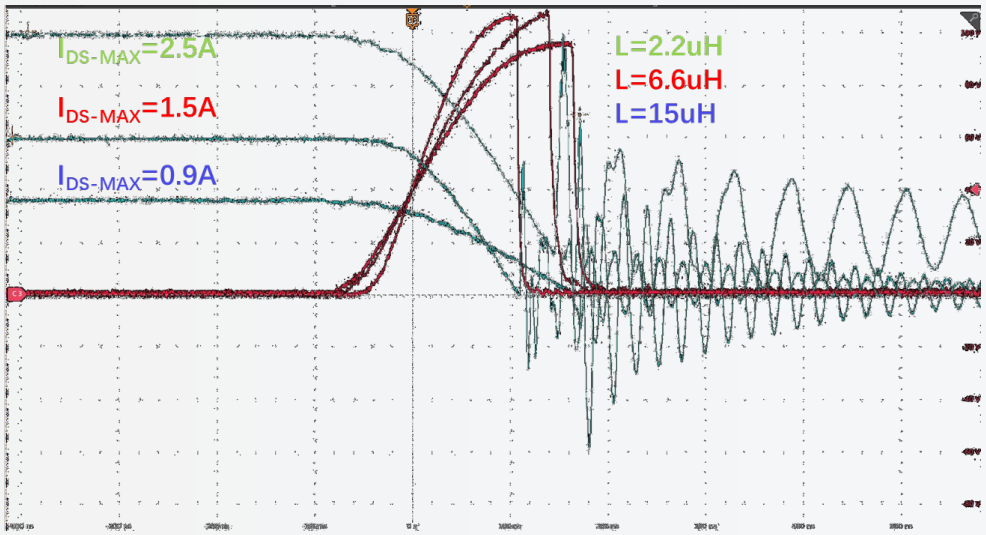
- *10ppm exceeds 10,000 years at 32 V (V_{DD}) and 125 °C*
- *10years at 10ppm at 60V (V_{DD}) and 125°C ~2x operating voltage*

Unclamped inductive switching tests on 40V device



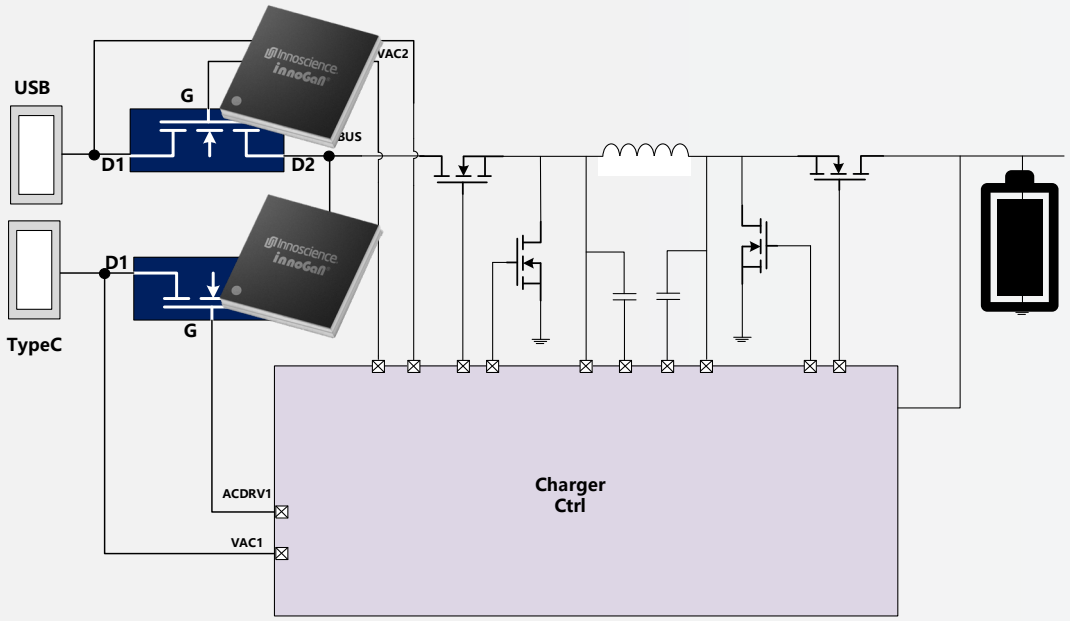






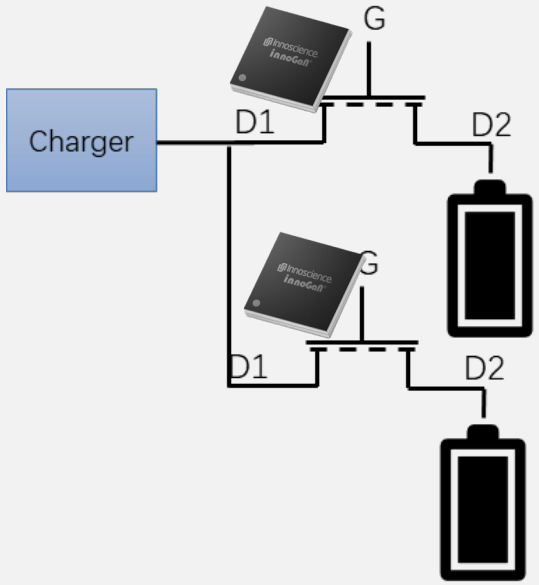
- GaN devices have larger breakdown voltage rating than Silicon
- **40V InnoGaN™ supports repetitive surge voltages up to 58V (full temperature range)**
- **InnoGaN™ max handling: 96V → >2X rated voltage**

Other applications for Bi-directional GaN



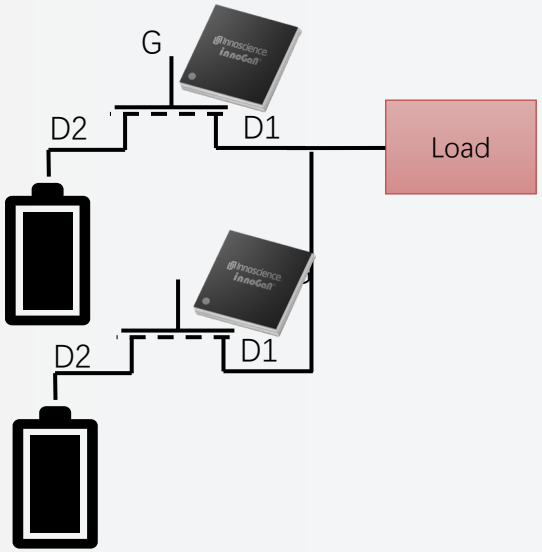
Multiple input switcher of buck-boost converter system in laptop

Or everywhere there is a battery…



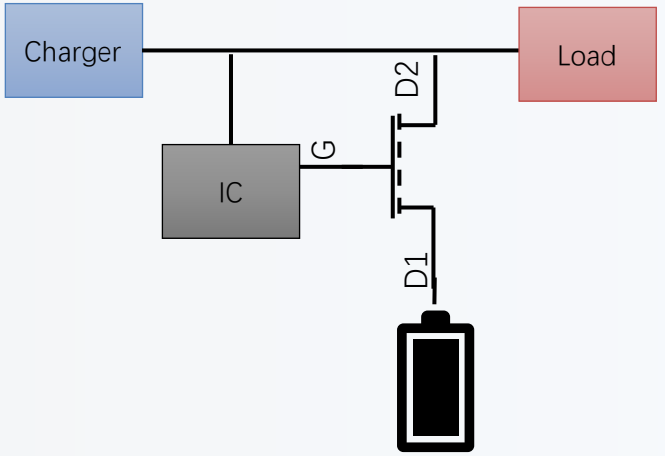
Charger demultiplexing

Single charger to charge multiple battery units. Charging one battery at time and avoid that one battery unit charges another battery unit



High-side battery switching

One of the battery sources is selected to power the load



Stand-by power system

The battery is disconnected from the load when in sleep mode to avoid leaking current from the battery (save battery energy)

https://www.ti.com/lit/ml/slva948/slva948.pdf?ts=1680180731332&ref_url=https%253A%252F%252Fwww.google.com%252F

Or everywhere there is a battery…

Cordless home appliance

Cordless power tools

…

others cordless

...and where there is a battery, there is a charger!

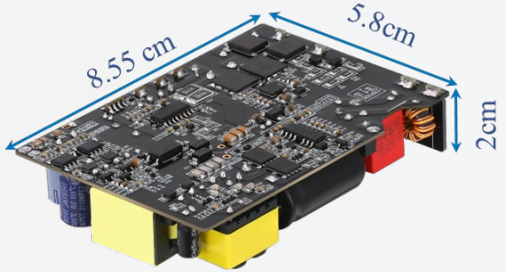
Just few examples..

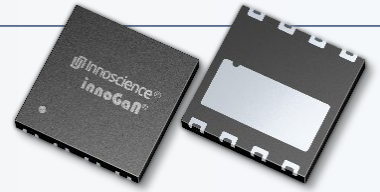
65W PD Chargers

1/3

240W e-bike Chargers

1/4



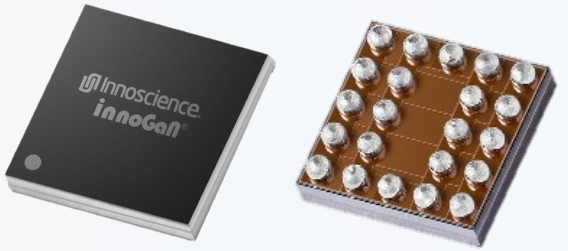


Key features of InnoGaN

- No reverse recovery current → simpler architectures (e.g. totem pole)
- High frequency capabilities → shirking of the passives
- Smaller Ron x Qg → Higher efficiency (at high frequency)

Conclusion

- **#1 Bi-directional InnoGaN substitutes #2 Si MOSFETs**
  - Better performance and SOA
  - OVP with InnoGaN is 50% smaller and more efficient



- **Catch 22: Mobile phone market requires huge capacity** that was not available
- **Innoscience: 100% focused GaN IDM + largest 8-inch wafers capacity**

- **World is going cordless. Everywhere there is a battery there is**
  - A load switch → Bi-directional InnoGaN
  - A charger → smaller and more powerful with InnoGaN

Thank you

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