D^{3}GaN for E.Drive

Ran Soffer, SVP of Sales and Marketing
VisIC Technologies

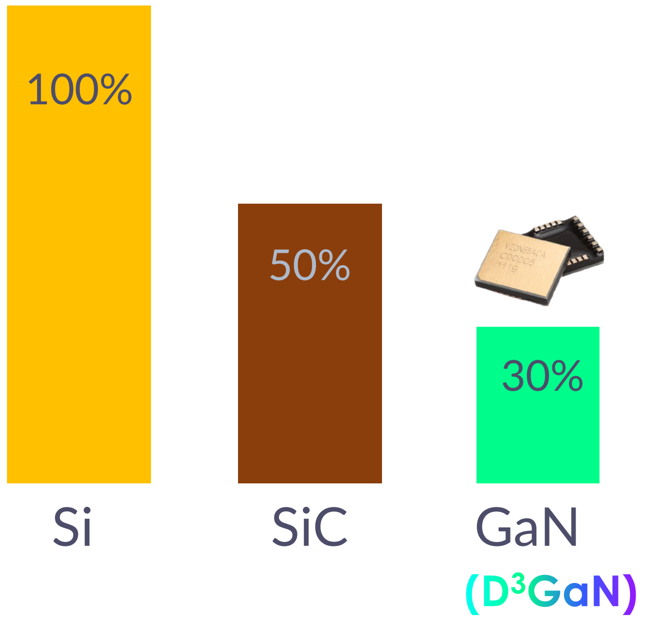
GaN power switches reduce inverter losses

VisIC TECHNOLOGIES

3 X lower losses than Si
2 X lower losses than SiC

- **Operation:**
  $1000 car cost reduction
- **Financials:**
  5% net income improvement
- **Performance:**
  Increase driving distance by 50km

Actual test data



Power losses over WLTP (done by Tier-1)

Market drivers in numbers

Electrical cars cost is ~ **25%** more expensive to produce from ICE cars

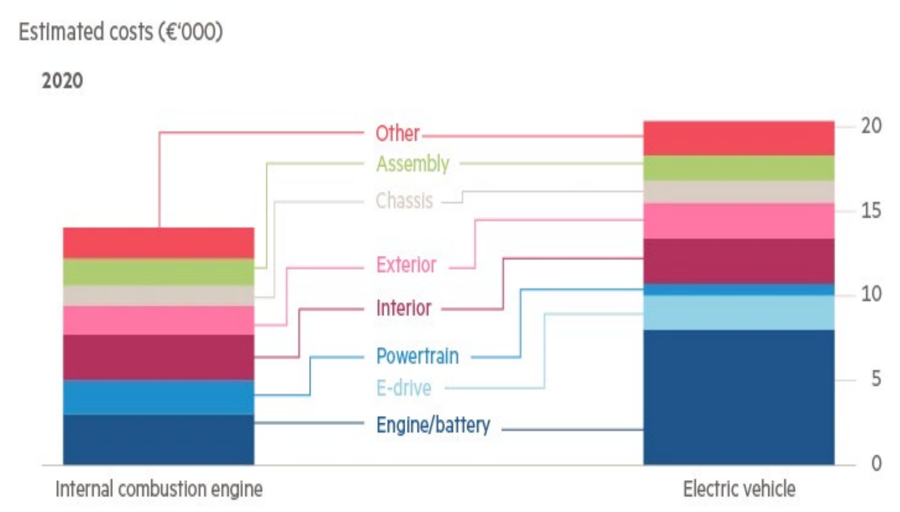
It mean **$400,000,000,000** additional cost for OEMs

Main cost contributor is the battery pack, **33%** in average of car cost

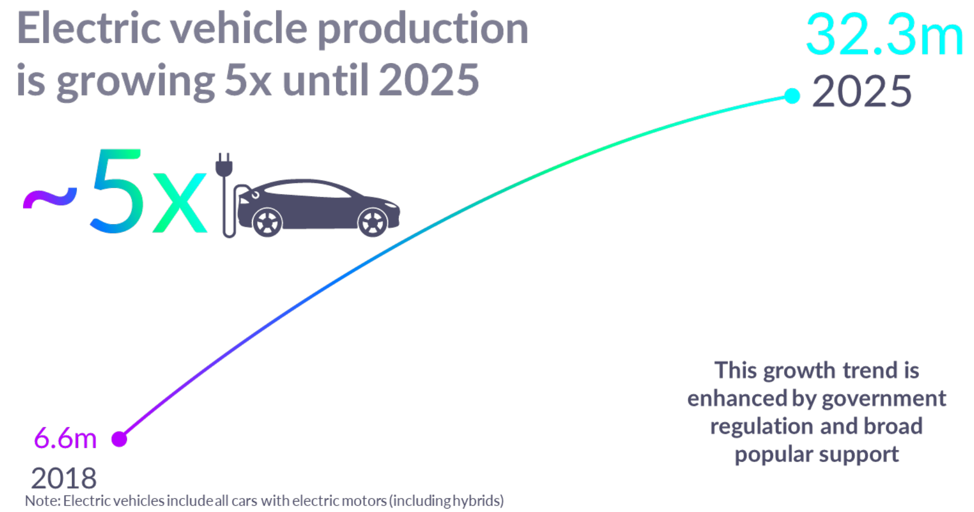
Expected to be below $100 per kW/h in 2030

Electrical cars market is booming

Regulations and saving our planet



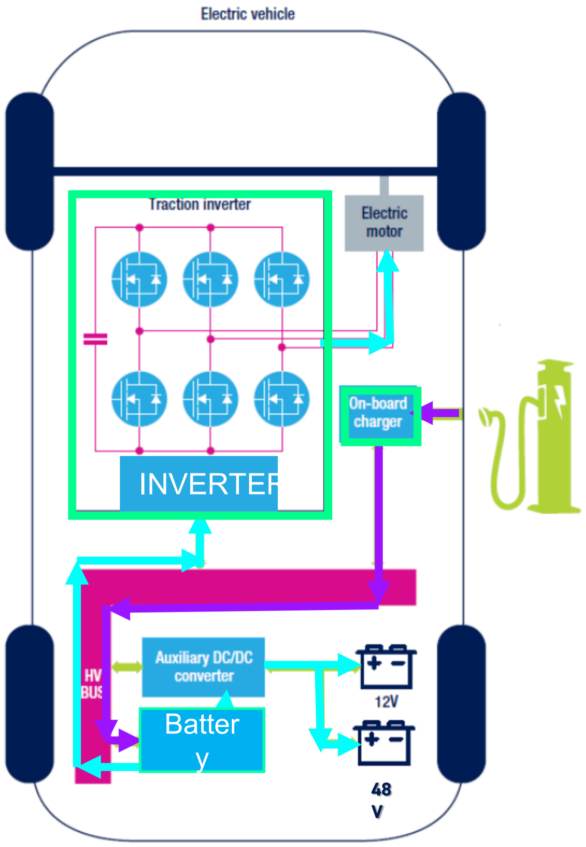
The cost of a 50kWh battery will fall from the current average of €8,000 to approximately €4,300 by the end of the decade,



Financial times Joe Miller in Frankfurt, AUGUST 31, 2020

Power switches for EV

Power conversion in electrical cars

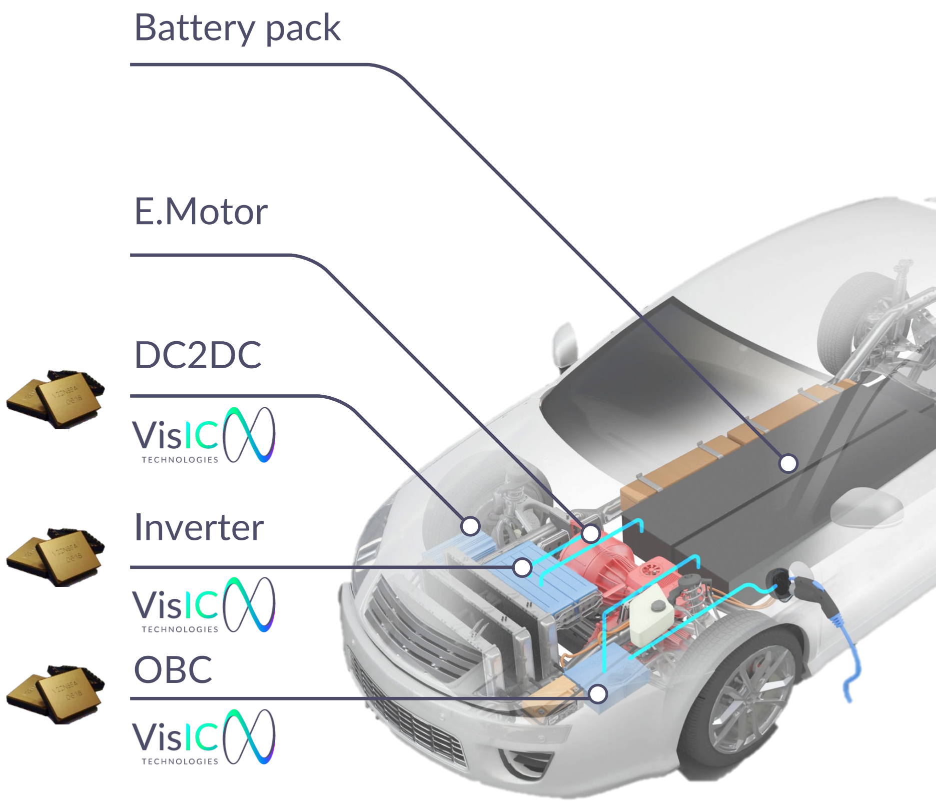


Power switches are used in three main places in EV

1 Inverter (~80%) to deliver electrical energy from battery to motor

2 OBC -(10%) - to deliver electrical energy from grid to battery

3 DC2DC -(10%) - to deliver electrical energy from battery to infotainment, ADAS etc



Low efficient inverter

Waist battery energy

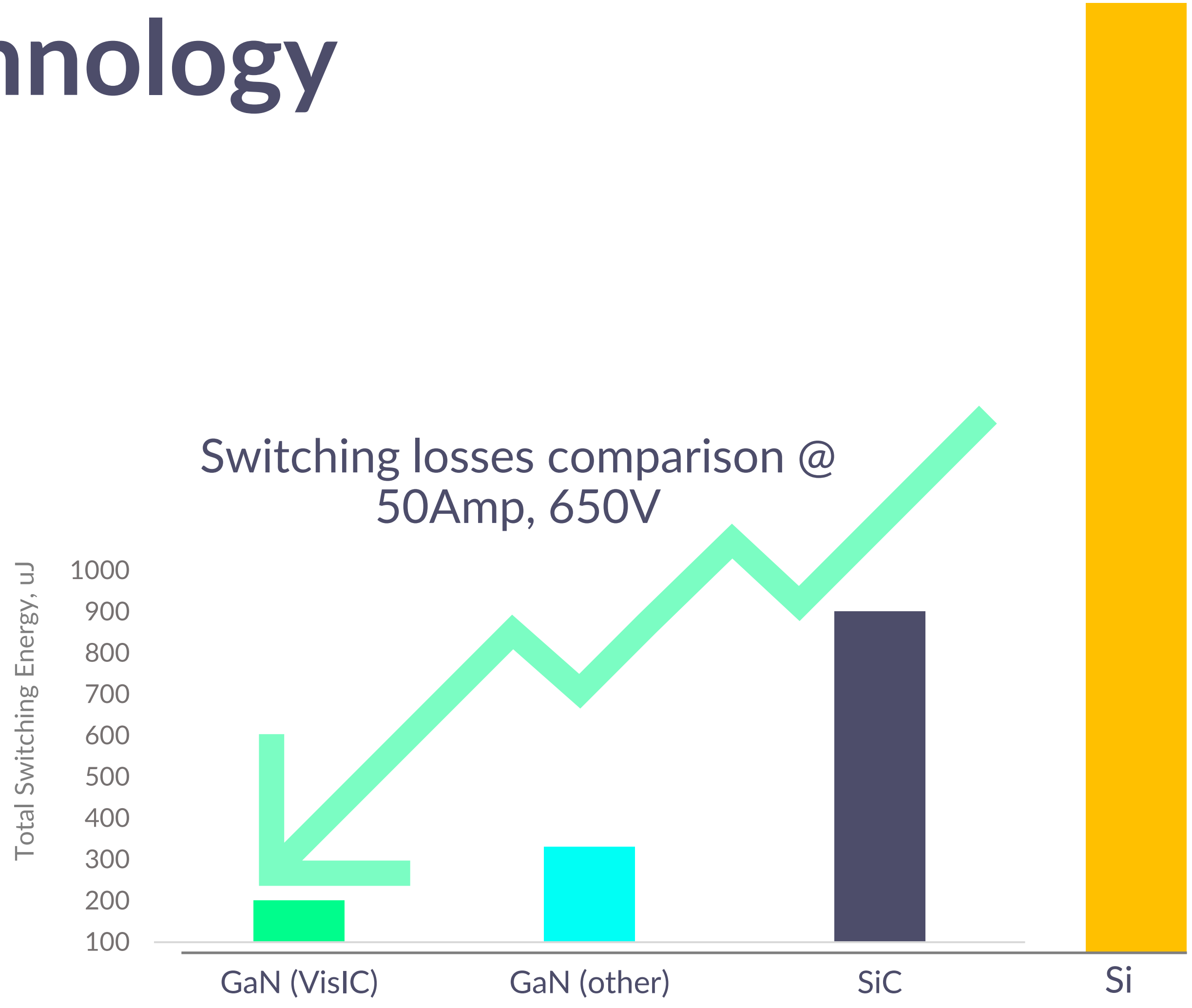
Enlarge & complicate the E.drive system

Generate more heat

Power losses must be reduced

Improving Inverter efficiency reduce battery size and increase driving distance

Moving to a more efficient technology

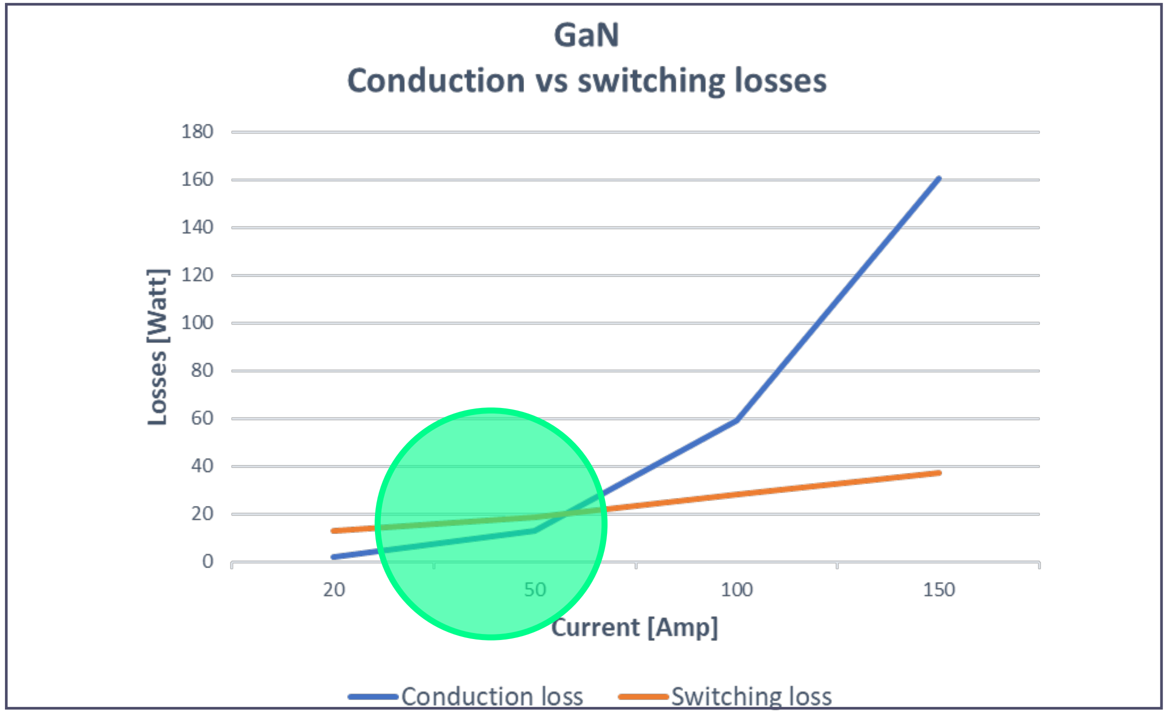


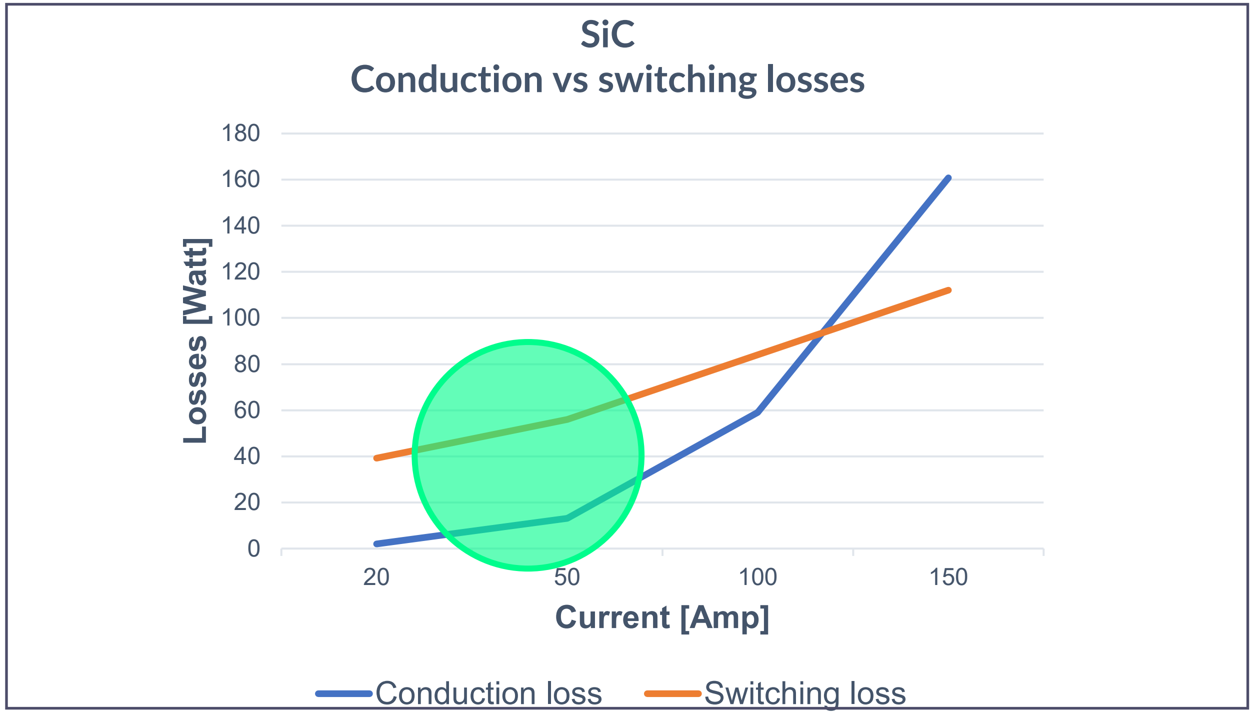
GaN is
X5 better
than SiC

SiC is
X10 better
than Si

A more detailed analysis

The WLTP average is around 25% of the peak power. So, lets analyze this point.

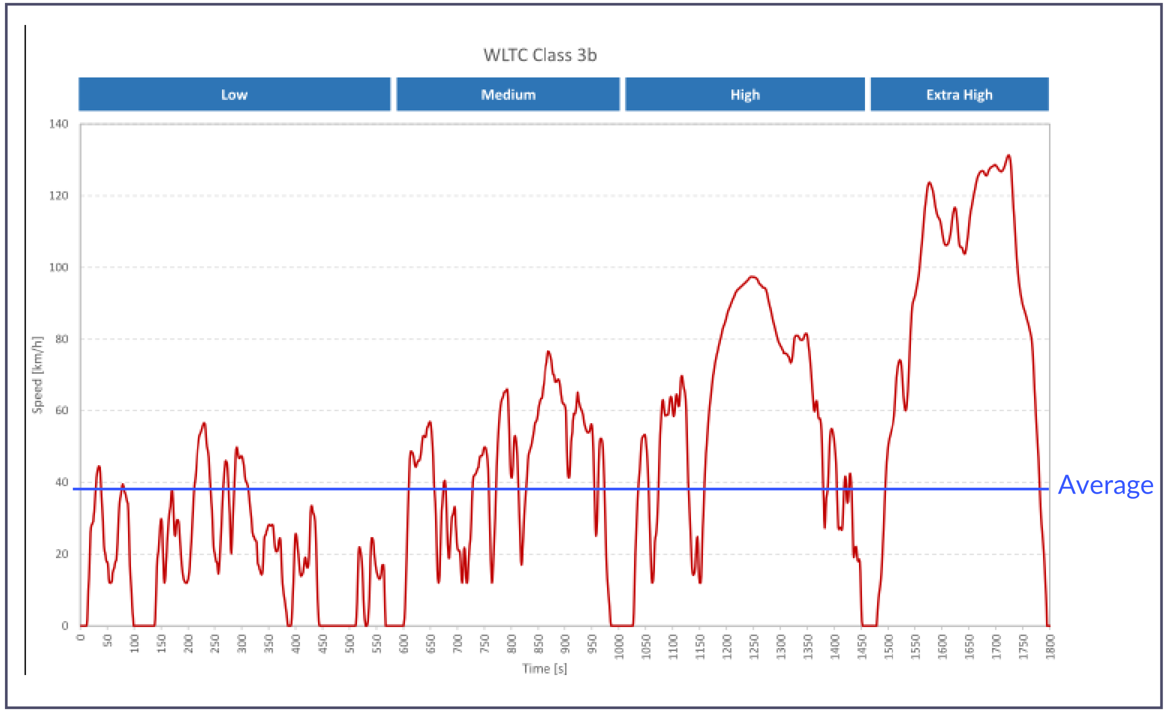




Switching losses have a major contribution to the E.Drive Inverter losses

Impact of the driving cycle

Losses over the driving cycle



3 X lower losses than Si

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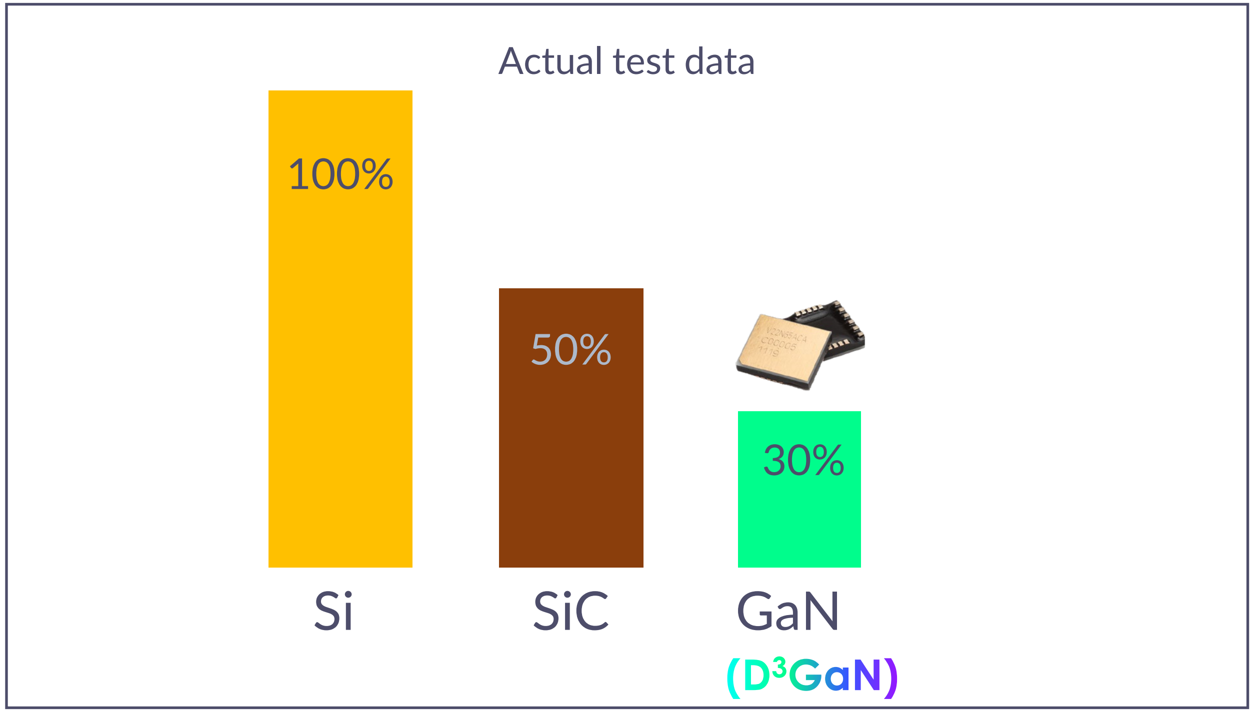
Power losses over WLTP



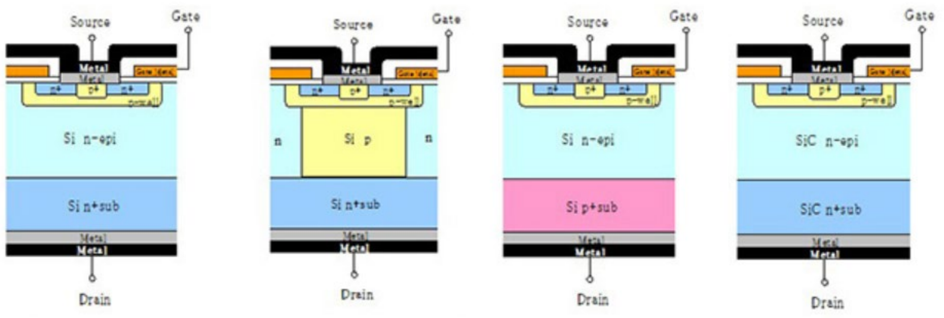
Conditions:

150 kW peak/ 100kW nom

Load current: 500A peak, 300A nom

Semiconductor values are based on actual test data

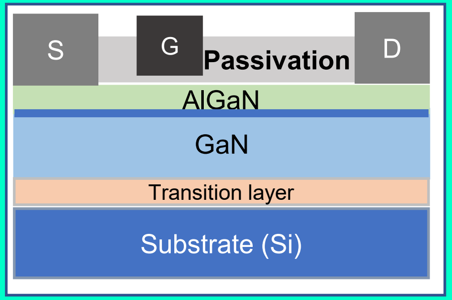
GaN difference from other technologies



Si-DMOS Si Super Junction MOS Si-IGBT SiC-DMOS

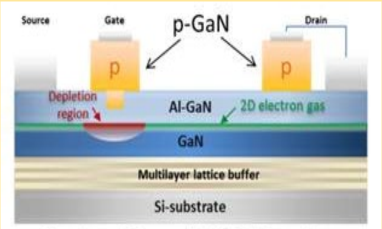
https://micro.rohm.com/en/techweb/knowledge/sic/s-sic/04-s-sic/5664

D-MODE
Direct Drive - GaN



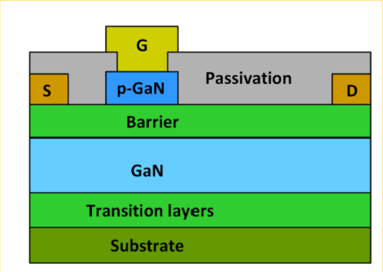
VisIC schematic view of transistor

E-MODE



Structure of Panasonic's HD-GiT transistor

1.https://na.industrial.panasonic.com /products/semiconductors/x-gan-power/power-devices



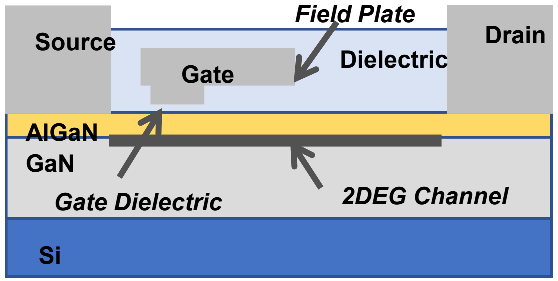
1.J.Wei et al, ISDPS 2019, pp 291

- Similar structure and similar processing leads to similar reliability questions for Si- and SiC MOSFETs
- Unique physics of GaN changes some of the reliability concerns
- Gate is critical to understand device's reliability

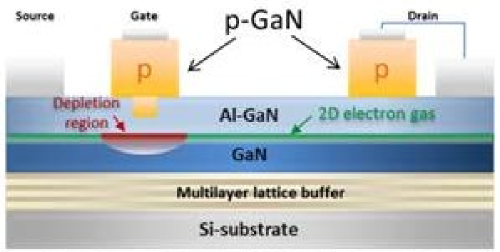
VisIC D^{3}GaN Solution

D^{3}GaN

Basic D-mode Structure



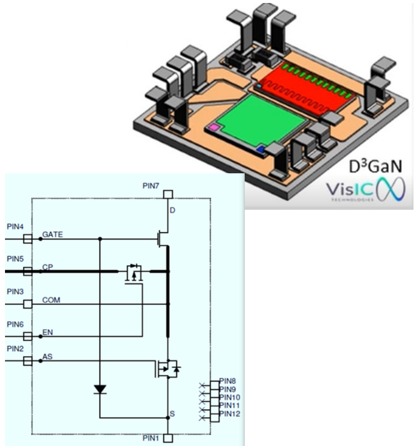
E-mode p-GaN Structure



Structure of Panasonic's HD-GiT transistor

Depletion mode (d-mode)

- Normally on die
- Advantages
  - Standard GaN processing
  - Standard gate drivers can be used
  - Large negative threshold voltage
  - Gate reliability not a concern
- Disadvantages
  - Must have circuitry to be normally off
    - Uses cheap and reliable Si solutions



Enhancement Mode (e-mode)

- Normally off die
- Advantages
  - Single chip solution
- Disadvantages
  - Special processing needed
  - Gate junction is critical
    - P-GaN gate is a p-n junction
    - Dielectrics are very sensitive to trapped charge
    - High leakage levels compromise reliability
  - Small margin to positive gate overstress
  - Specialized gate drivers needed
  - Sensitive to threshold voltage shift

D-mode provides highest reliability for power components

More robust and more reliable

VisIC TECHNOLOGIES

Transient BV; x3.5 surge energy;

CPES

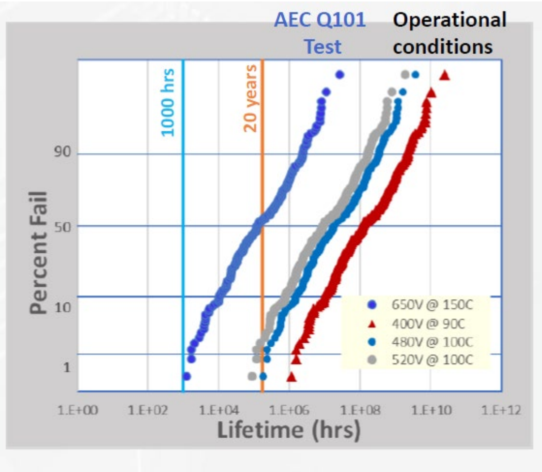
Practical consideration: surge energy withstand capability

- **Assuming negligible loop parasitics:** $E_{surge}^{max} = \frac{1}{2} C_{OSS} BV^2$
- C_{oss} is the energy-related output capacitance, BV is the transient breakdown voltage

Device Manufacturer	Device Type	Voltage Rating	Current Rating	C_{OSS} (pF)	Transient BV	Max surge energy (µJ)	Method
VisIC	D^3GaN (D-mode)	650 V	100 A	480*	2040 V	1175	Experiment
Company A	GIT	650 V	31 A	110*	1150 V	73	Experiment
Company B	P-GaN HEMT	650 V	30 A	130*	1450 V	137	Experiment
Company B	P-GaN HEMT	650 V	~100 A	302**	1450 V	320	Projection

Qihao Song, Ruizhe Zhang, Joseph P. Kozak, Yuhao Zhang

2020/06/17

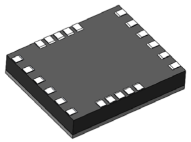


D^3GAN shows that the Q101 conditions provide a wearout lifetime of > 20yrs at nominal operating conditions

VisIC GaN Products

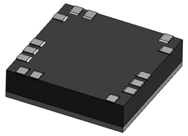
VisIC provides discrete transistors, dies and modules

DISCRETE DEVICES



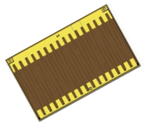
22mOhm 650V 100A

concept

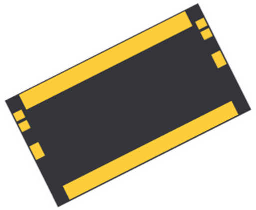


60mOhm 650V 40A

DIES

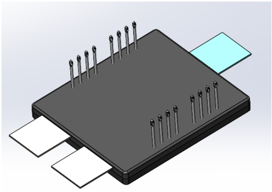


18mOhm 650V 100A

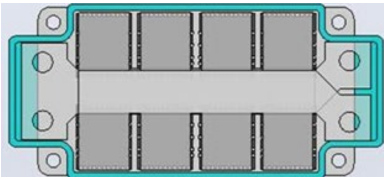


7mOhm 650V 200A

MODULES



In development



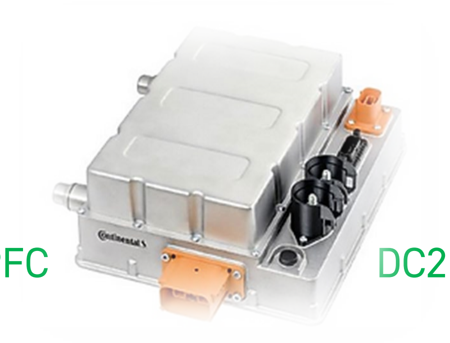
600A / 650V HB

300A / 650V HB

and 3 phase module

Product Fit

OBC



V22 is optimized for **PFC** up to 7.2kW:
- Single die per switch supports PFC half-bridge
- High switching frequencies are supported

V60 optimized for 7.2kW **DC2DC**
- Single die per switch supports DC2DC full-bridge
- Smaller package size allows system size reduction

Combination of V22 in PFC and V60 in DC2DC allows best system performance and cost solution

Inverter

V22 for inverters up to **50-80kW**:
- Flexible solution with discrete devices
  - Optimization per power (fine granularity)
- Highest efficiency and cost optimization

V8 for inverters **> 100kW**
- Reduced number of components paralleled
- Available as modules and bare dice
- Modules with V8 (e.g. half-bridge module) for motor integration

Summary

How to improve EV cost/performance

Developed for EV

Adopted by Teir-1s & OEMs

✓Reliable technology for Automotive

- Goes beyond Q101 qualification

✓Reduce losses over the driving cycle

- Reduce car cost: e.g., battery size and cooling system

VisIC's D³GaN supports it

THANK YOU FOR ATTENTION