



Navitas

Let's go **GaNFast**[™]

Systematic Approach to GaN Power IC Reliability

APEC 2019 PSMA Industry Session IS11: "Current reliability and product qualification topics for SiC and GaN wide band gap devices", March 20th, 2019

Dr. Darshan Gandhi, Sr. Director Reliability Engineering

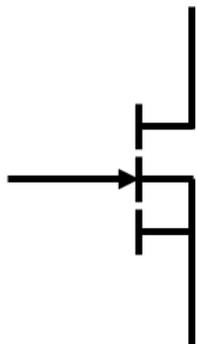
darshan.gandhi@navitassemi.com



World's First GaNFast™ Power ICs



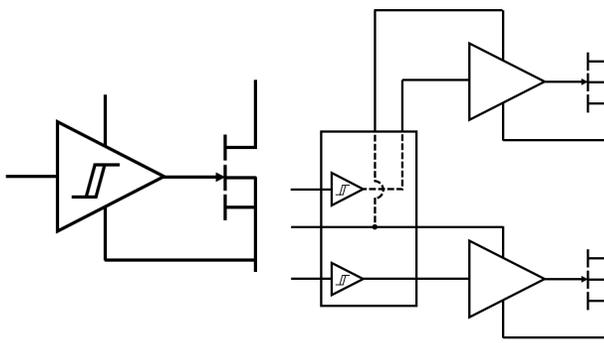
Fastest, most efficient
GaN Power FETs



- >20x faster than silicon
- >5x faster than cascoded GaN
- Proprietary design
- Gate is fragile and sensitive to noise



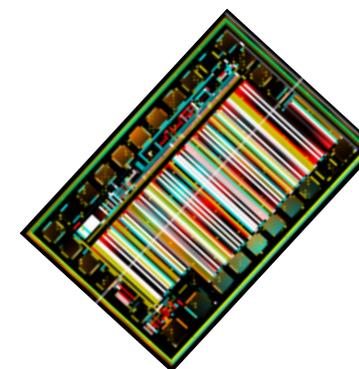
First & Fastest Integrated
GaN Gate Drivers



- >3x faster than any other gate driver
- Proprietary design
- 30+ patents granted
- Fast, protected gate, no need for negative drive



World's First
GaNFast™
Power ICs

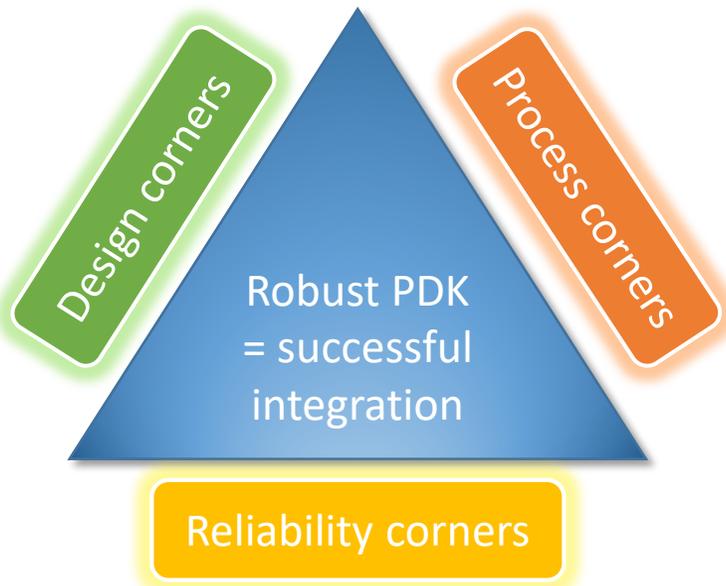
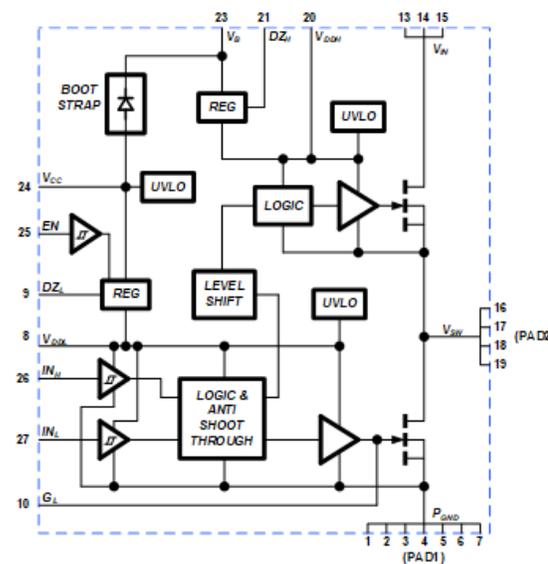
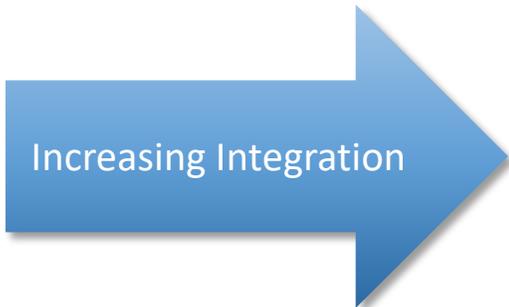
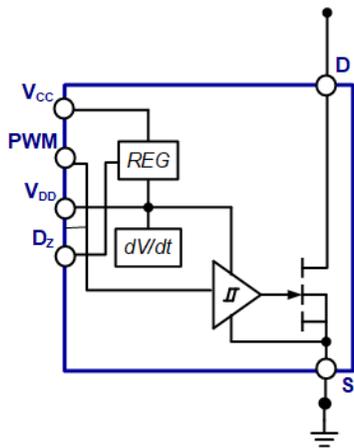


- Simple, fast and reliable
- Easy to use and package

Up to 40MHz switching, 5x higher density & 20% lower system cost



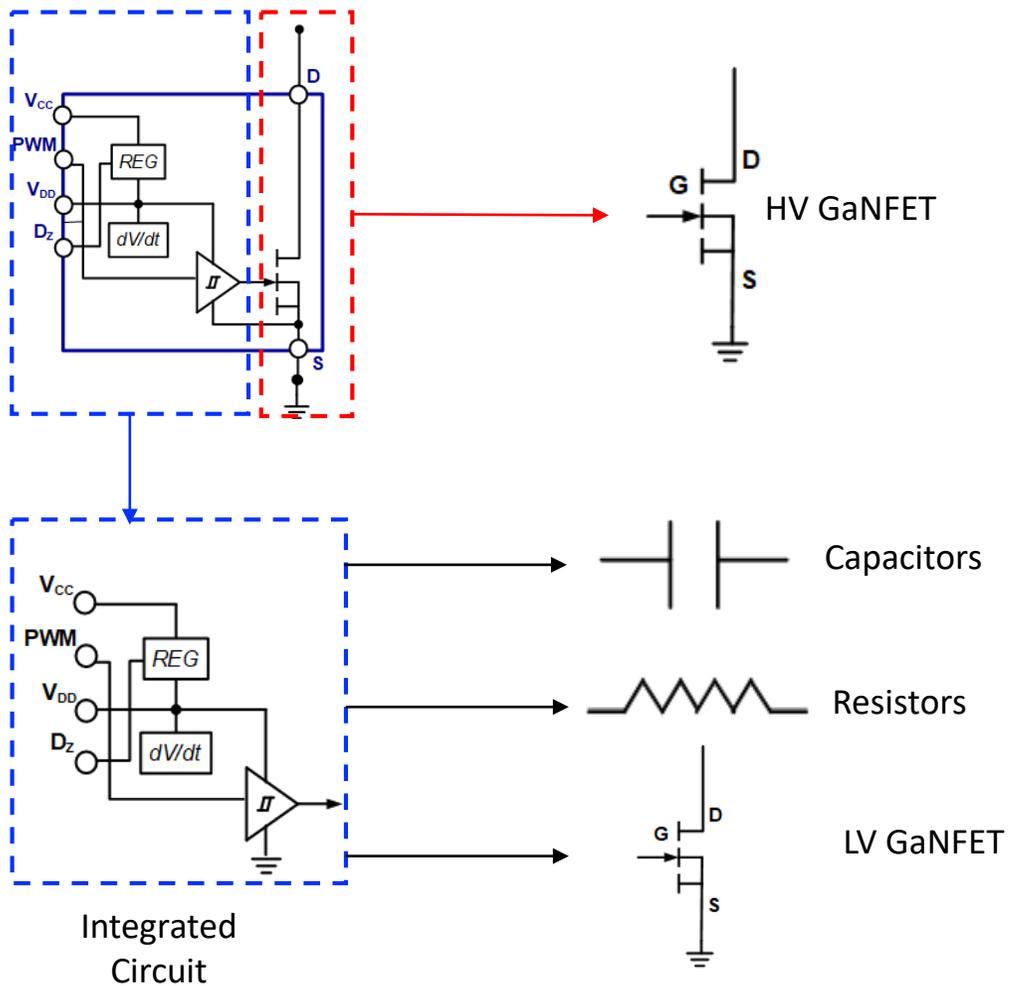
Enabling Advanced Technologies



Reliability corners defined using reliability physics based lifetime models



PDK Analysis



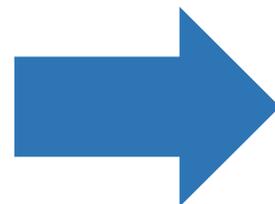
Device element	Reliability model requirement
Capacitor	Guaranteed by proprietary design, verified by characterization – reliability models not required
Resistor	
Electro-migration	Mature process and Foundry qualified
LV GaNFET	Reliability models required
HV GaNFET	

Reliability models need to replicate stresses seen in real application



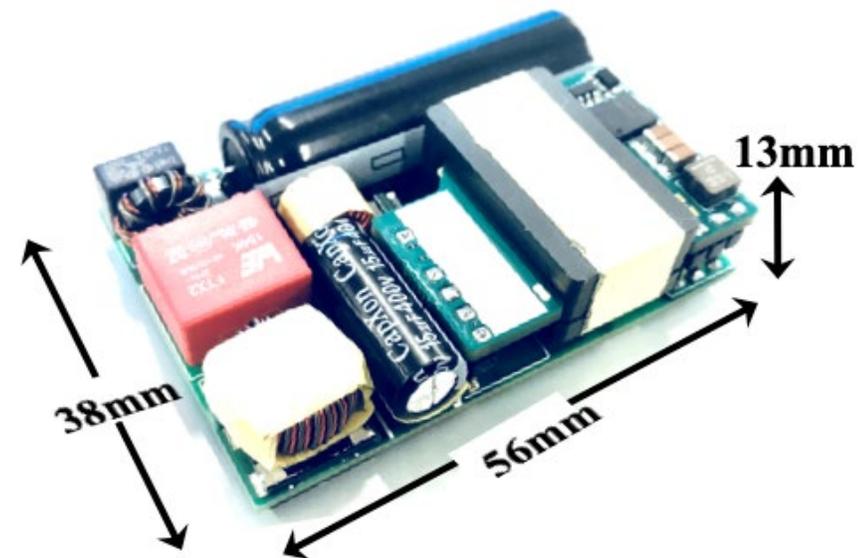
Typical Application: Mobile Chargers

MacBook <100 kHz
<6.5 W/in³, 92%



- ACF (ZVS) Topology
- 300kHz – 1 MHz
- 120 V – 240 V AC

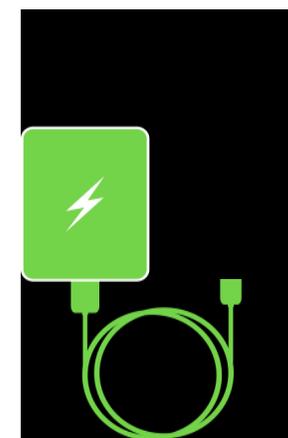
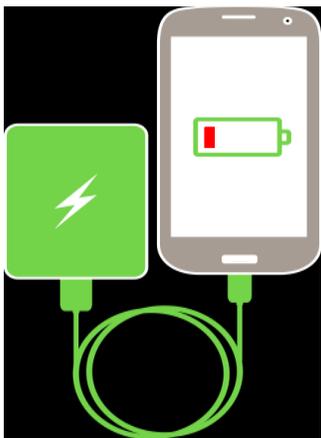
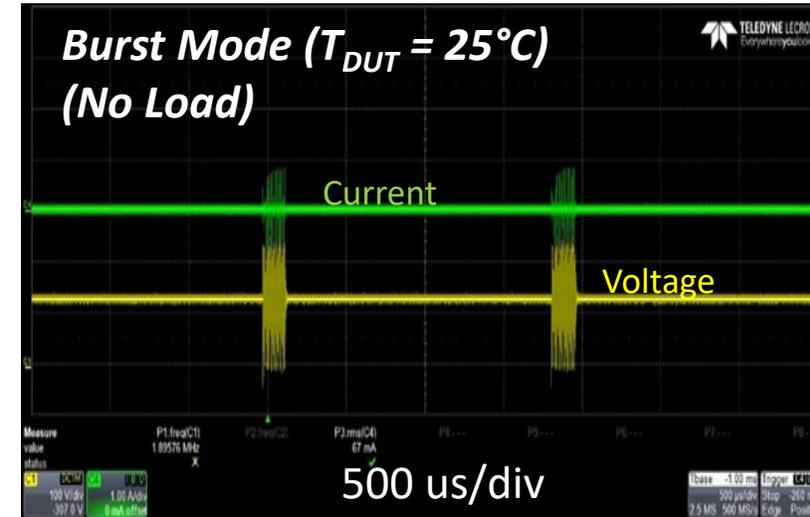
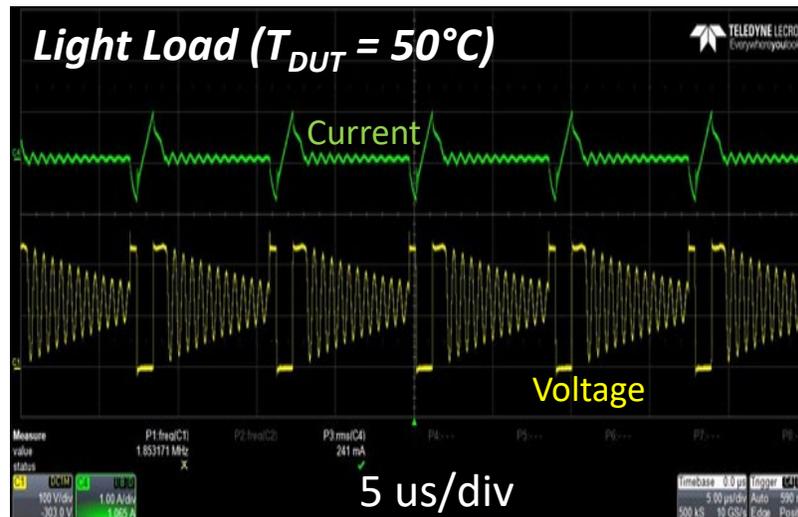
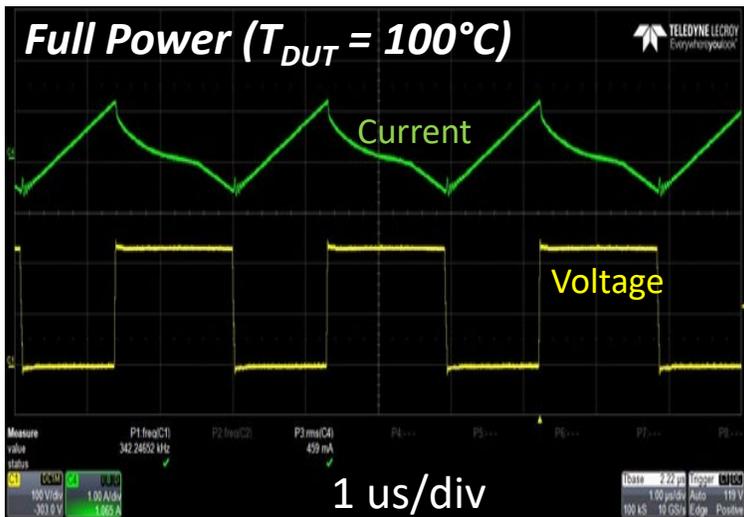
Navitas ~300 kHz
Power density = 39 W/in³



65W USB-PD

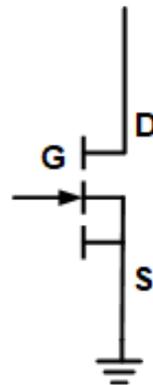
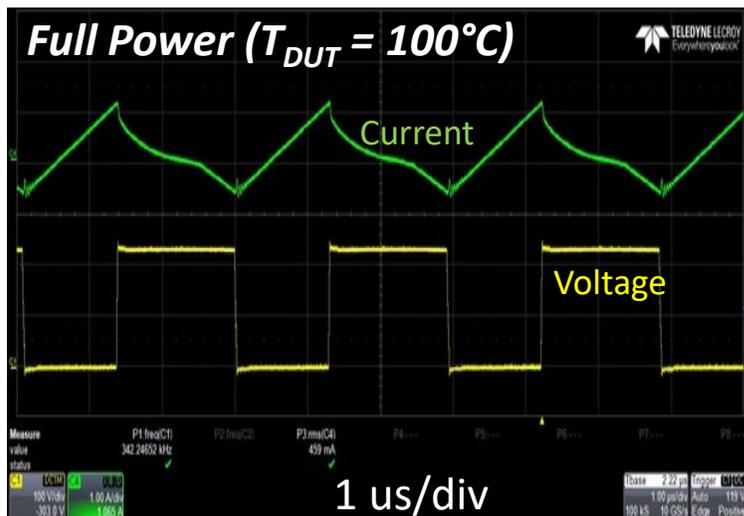


Application Profile for ACF Charger



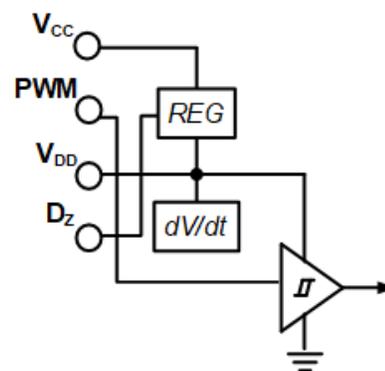
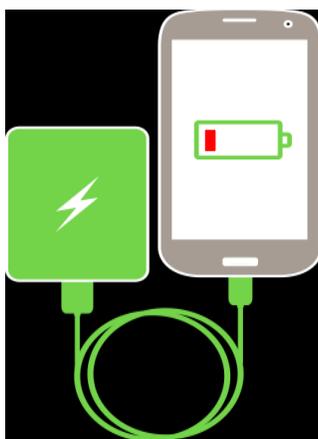


Full Power Stress Breakdown



Stress seen by HV GaNFET:

- High Temperature
- High Frequency
- High Voltage (Switching)
- High Current

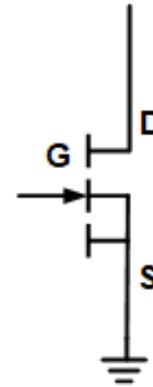
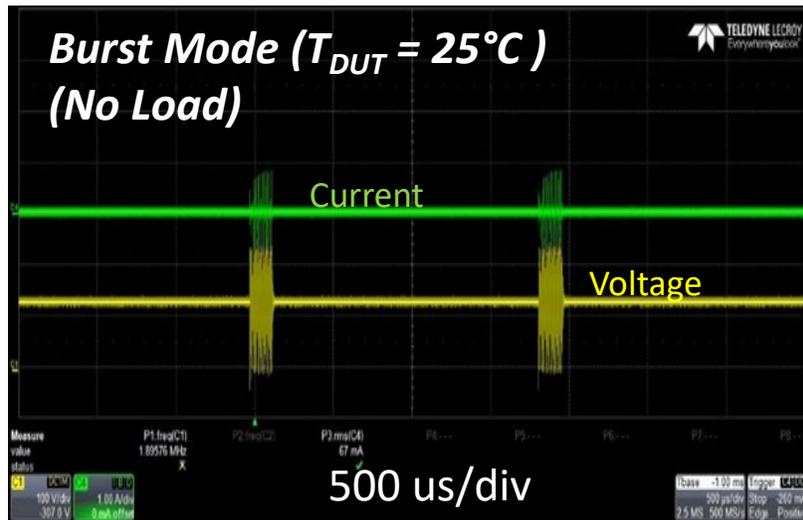


Stress seen on LV GaNFET:

- High Temperature
- High Frequency

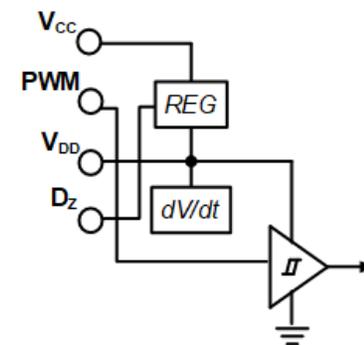
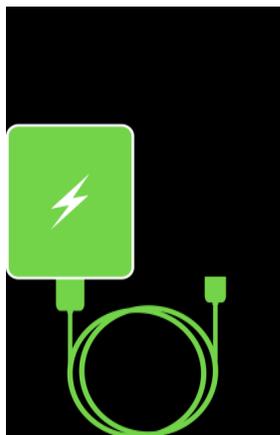


Burst Mode Stress Breakdown



Stress seen on HV GaNFET:

- Low Temperature
- Low Frequency (~static)
- High Voltage (Blocking)
- Low/No Current



Stress seen on LV GaNFET:

- Low Temperature
- Low Frequency (~static)



Reliability Stresses to Model

Relevant stress to model	Test method used to characterize
Static stress on HV GaNFET Drain	High Temperature Reverse Bias
Static stress on Gate	High Temperature Gate Bias
Switching stress on Gate	Gate Switching Reliability
Switching stress on HV GaNFET Drain	High Temperature Operating Life



Reliability Stresses to Model

Relevant stress to model	Test method used to characterize
Static stress on HV GaNFET Drain	High Temperature Reverse Bias
Static stress on Gate	High Temperature Gate Bias
Switching stress on Gate	Gate Switching Reliability
Switching stress on HV GaNFET Drain	High Temperature Operating Life

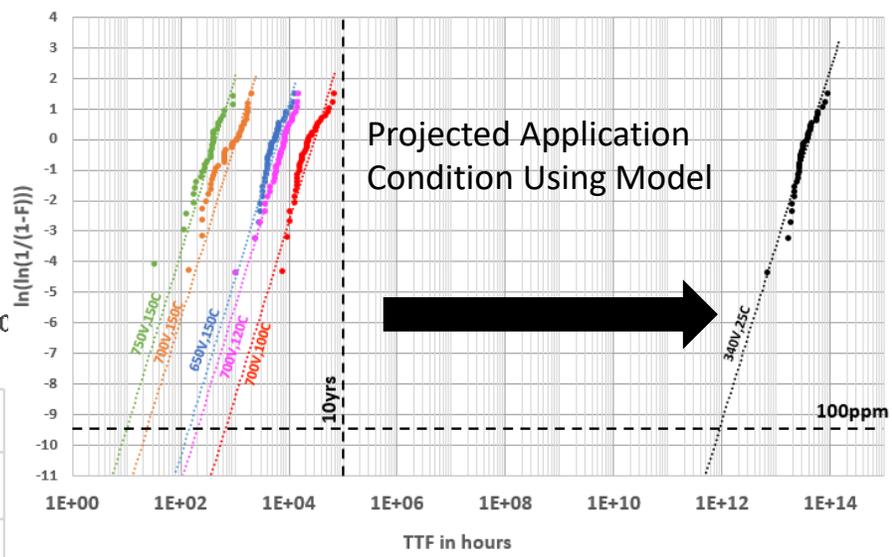
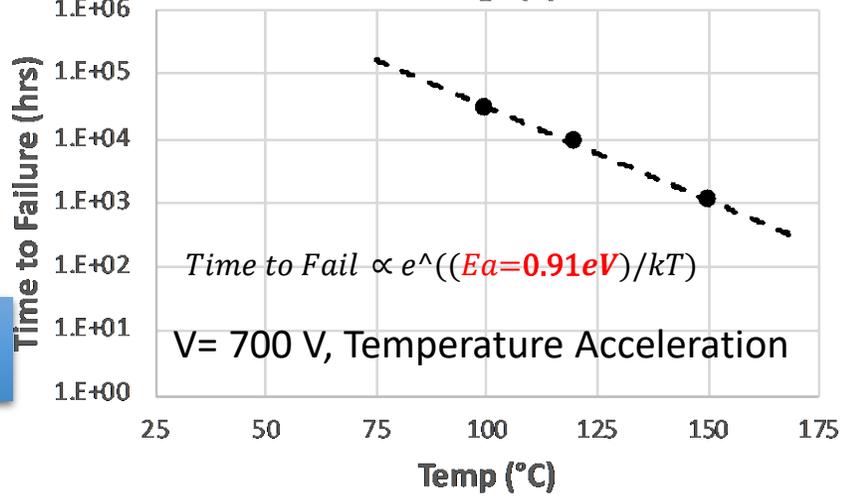
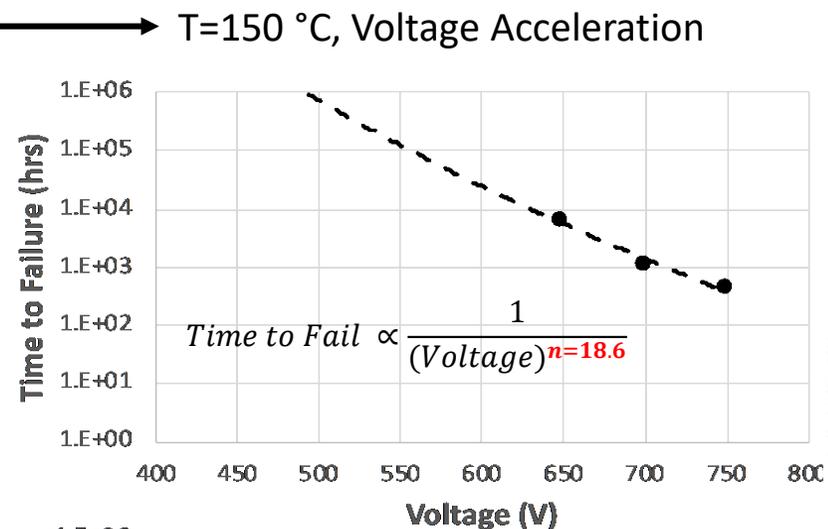


HTRB Acceleration & Lifetime Models



Voltage/ Temperature	100°C	125°C	150°C
650V			✓
700V	✓	✓	✓
750V			✓

$$Lifetime = A \times (V^{-n}) \times (e^{\frac{E_A}{kT}})$$



Lifetime in no load condition is >1E8 years, significant built-in margin



Reliability Stresses to Model



Relevant stress to model	Test method used to characterize
Static stress on HV GaNFET Drain	High Temperature Reverse Bias
Static stress on Gate	High Temperature Gate Bias
Switching stress on Gate	Gate Switching Reliability
Switching stress on HV GaNFET Drain	High Temperature Operating Life

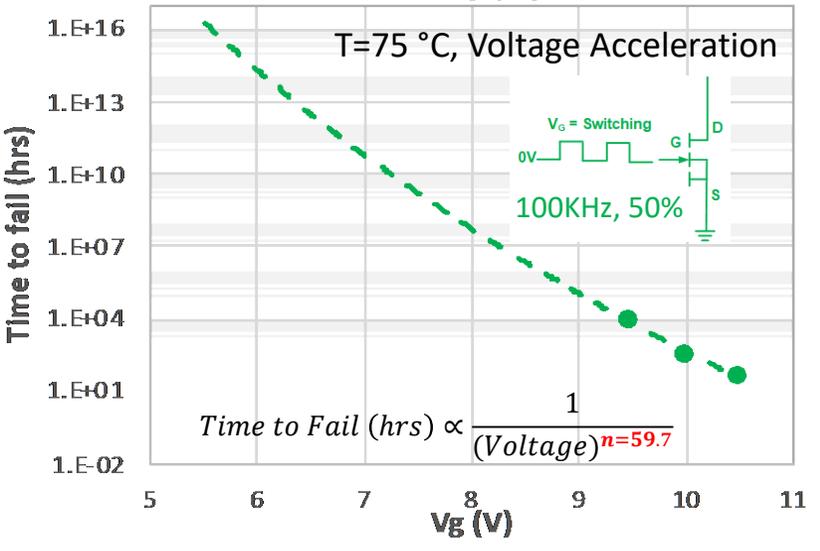
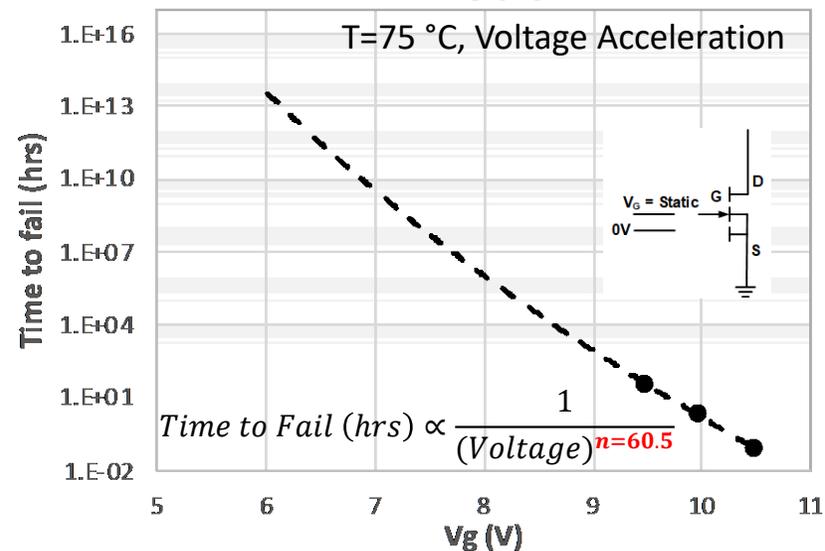
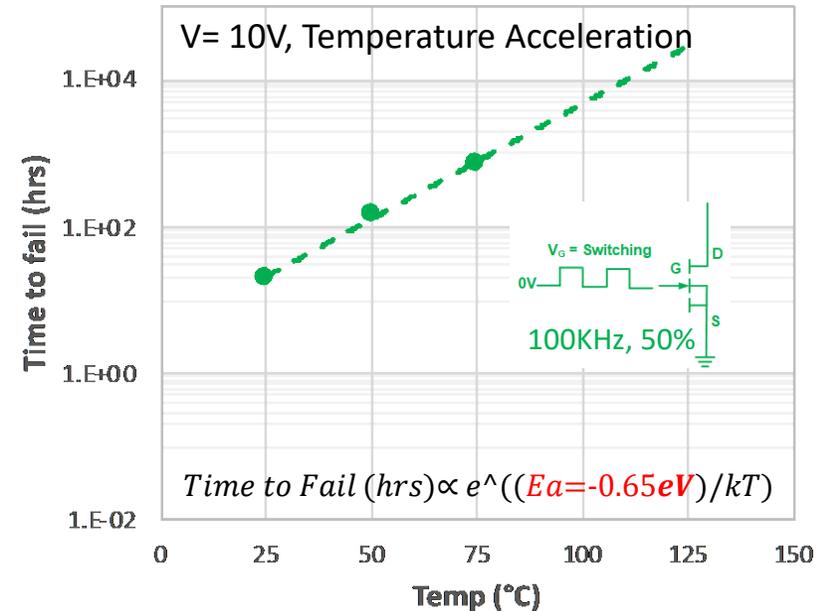
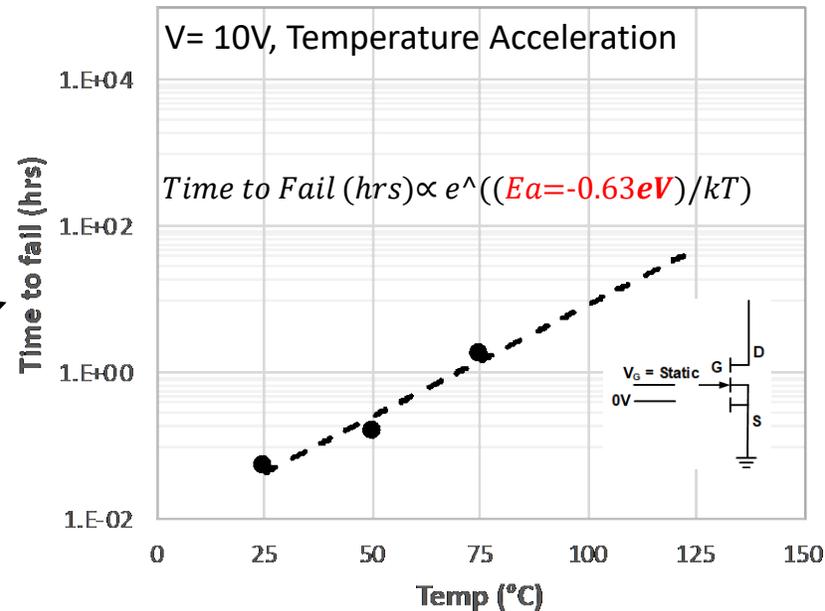


Gate Reliability Acceleration Models



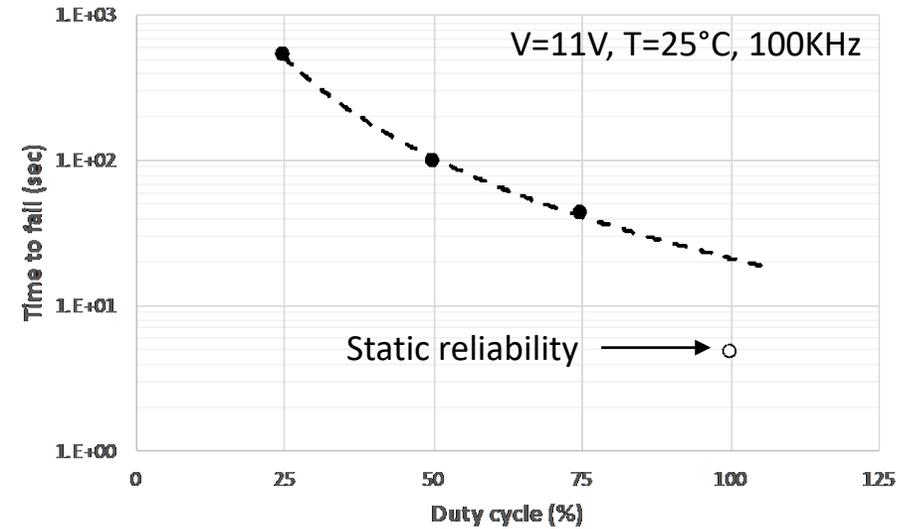
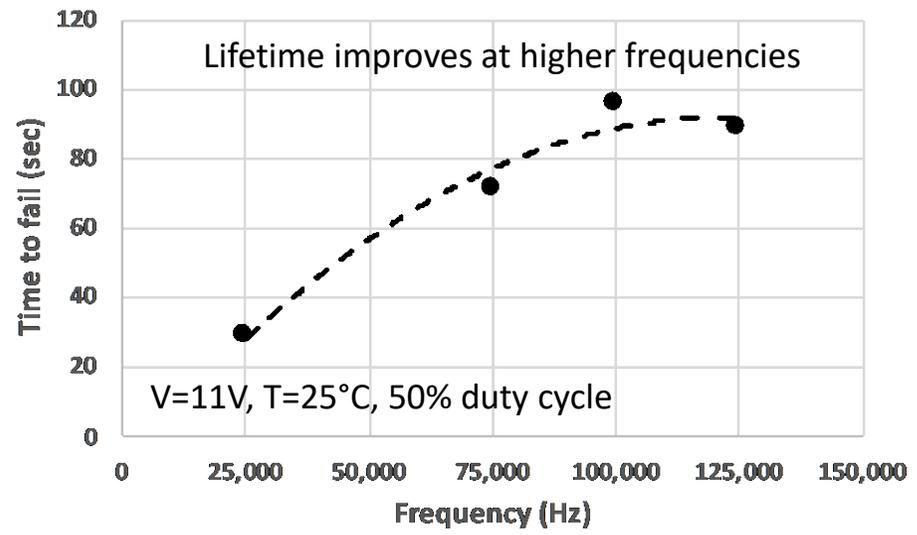
Voltage/ Temperature	25°C	50°C	75°C
9.5V			✓
10.0V	✓	✓	✓
10.5V			✓

Static and switching stresses have same acceleration factors



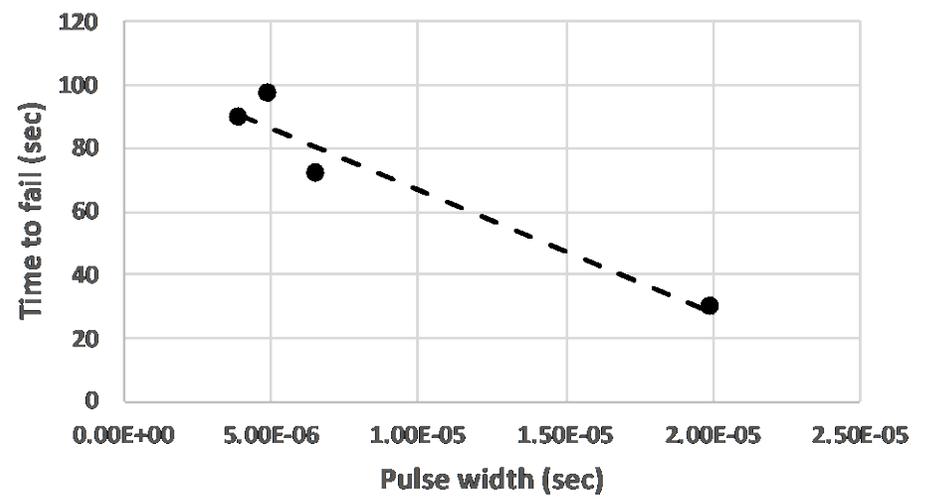


Frequency Acceleration



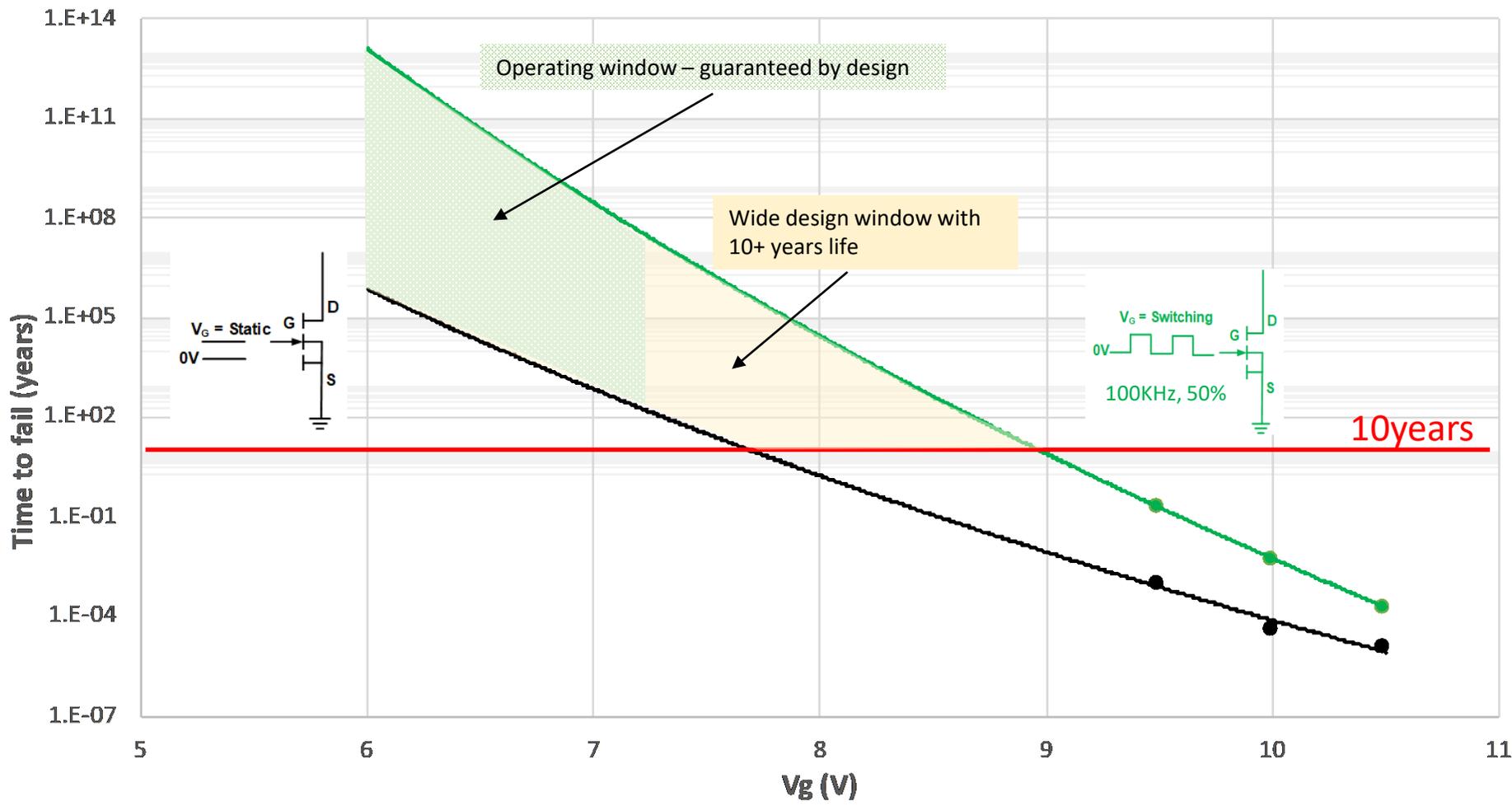
Frequency ↓ / Duty cycle ↑ / Pulse width ↑ ⇔ Closer to static stress

Typical applications for GaN devices operate at >100KHz





Gate Reliability Lifetime Estimation



Integrated regulator guarantees operation with 10+ years of estimate life



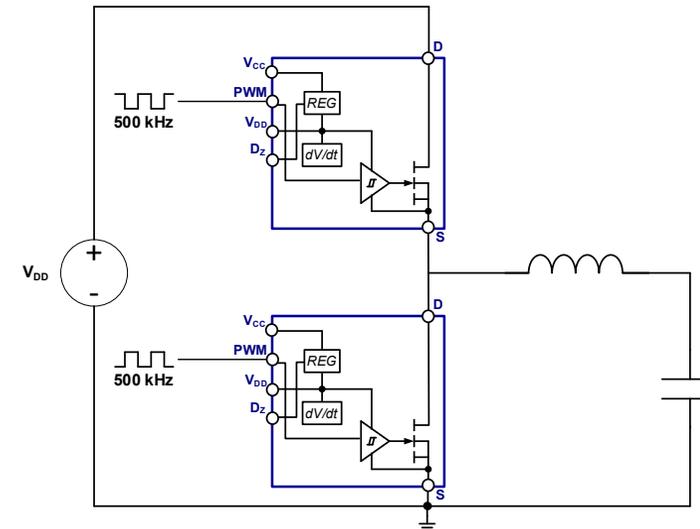
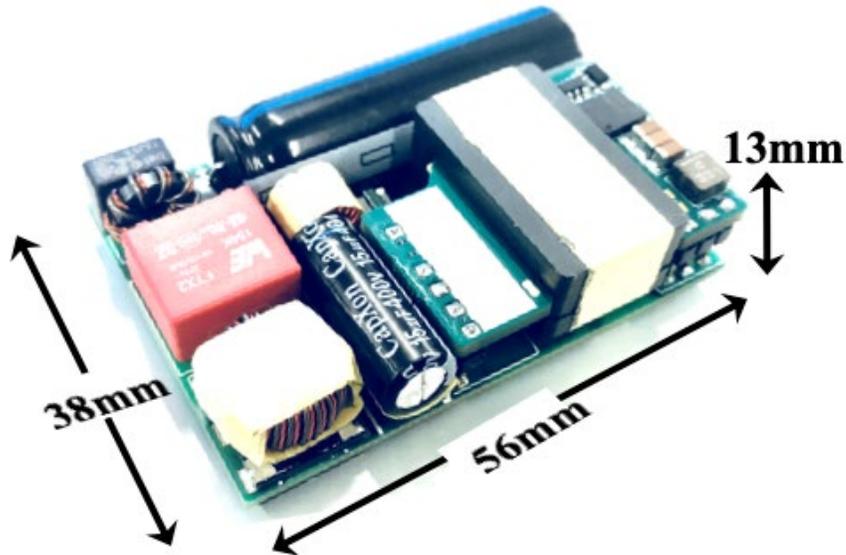
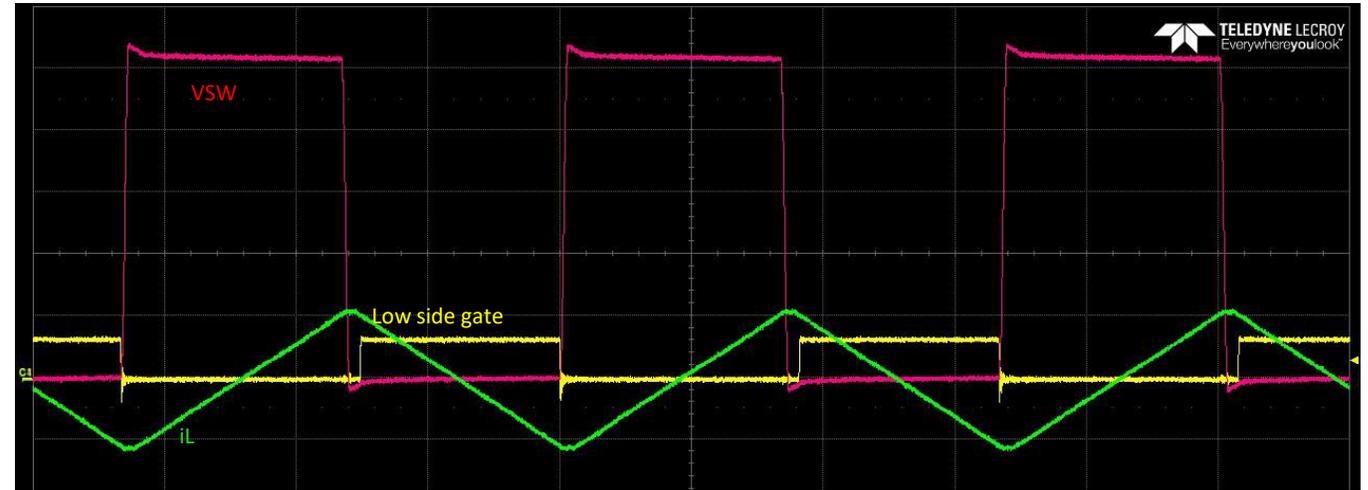
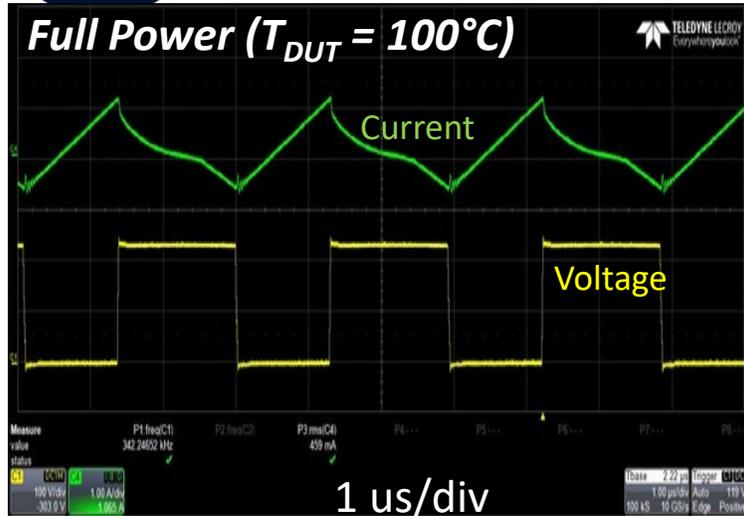
Reliability Stresses to Model



Relevant stress to model	Test method used to characterize
Static stress on HV GaNFET Drain	High Temperature Reverse Bias
Static stress on Gate	High Temperature Gate Bias
Switching stress on Gate	Gate Switching Reliability
Switching stress on HV GaNFET Drain	High Temperature Operating Life



Mission Profile Driven HTOL (ZVS)

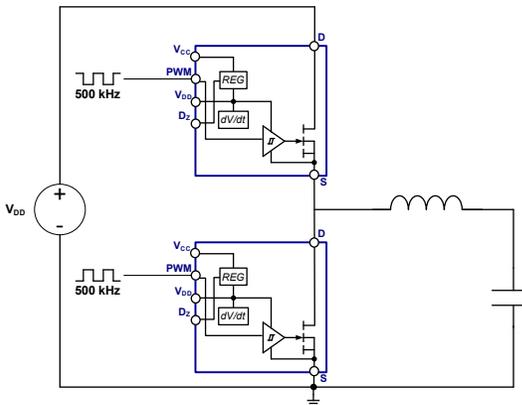


ZVS test bench replicates stresses seen in ACF application



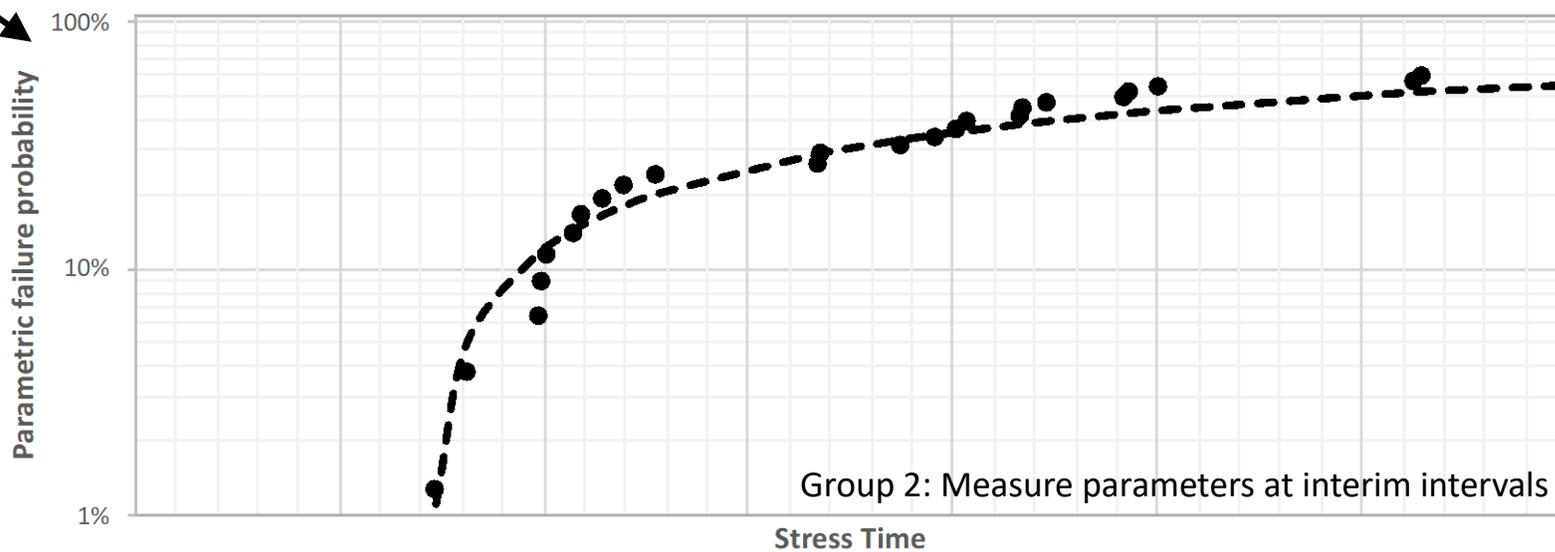
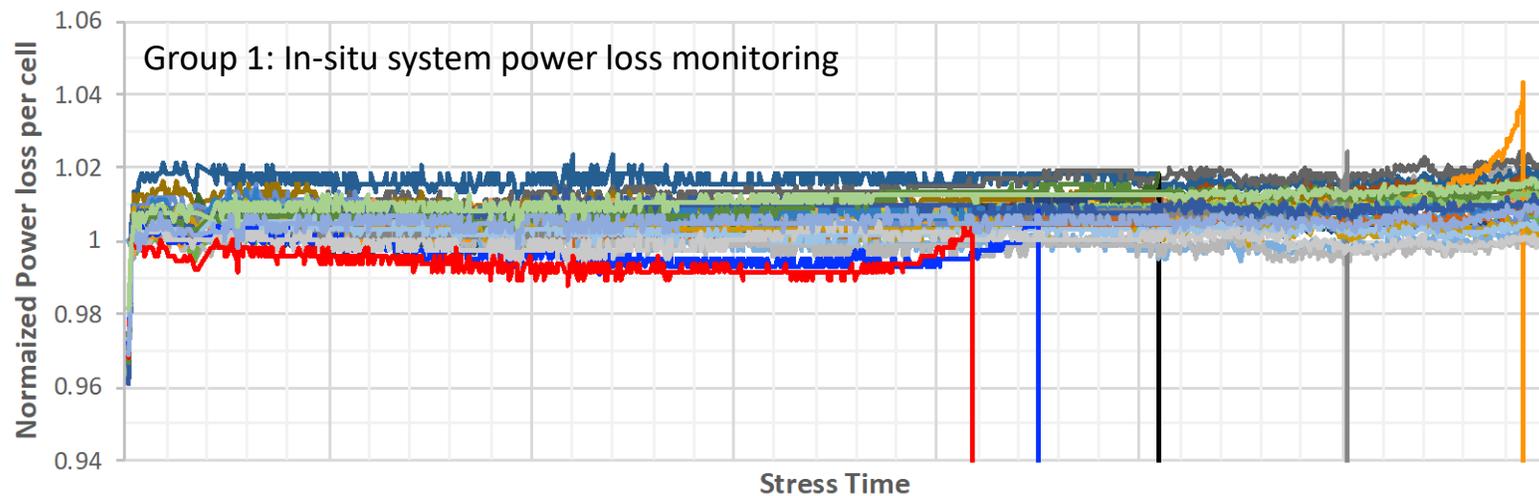
Failure Mode Matters

650V, 150°C HTOL



System degradation

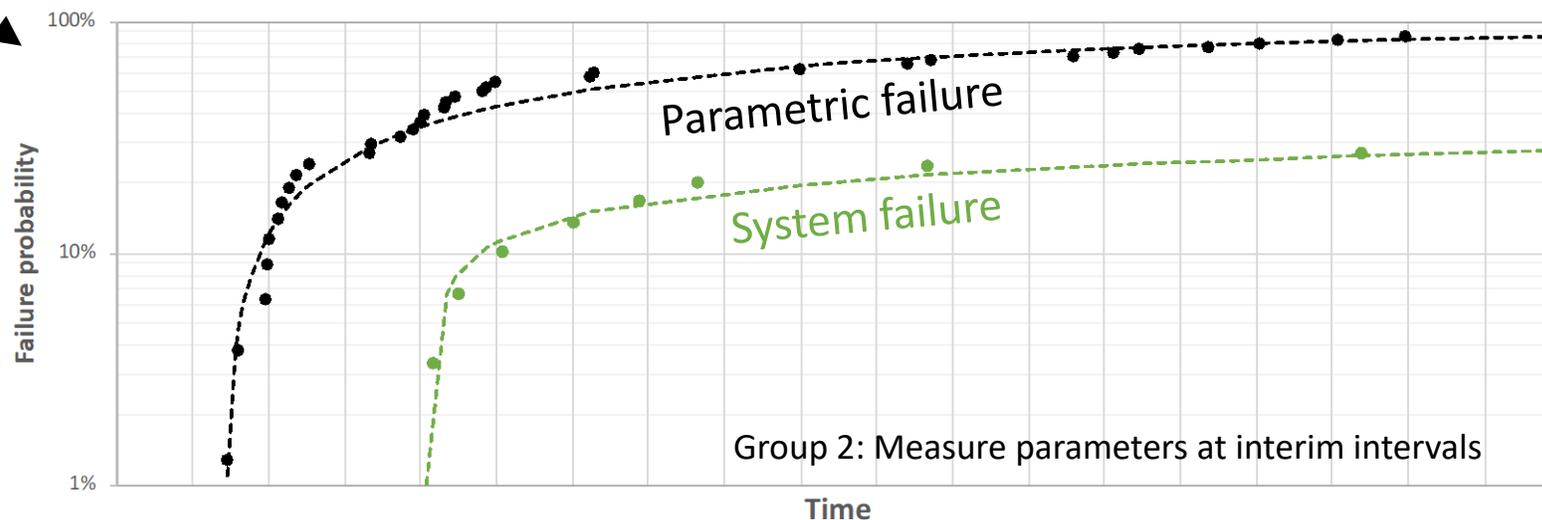
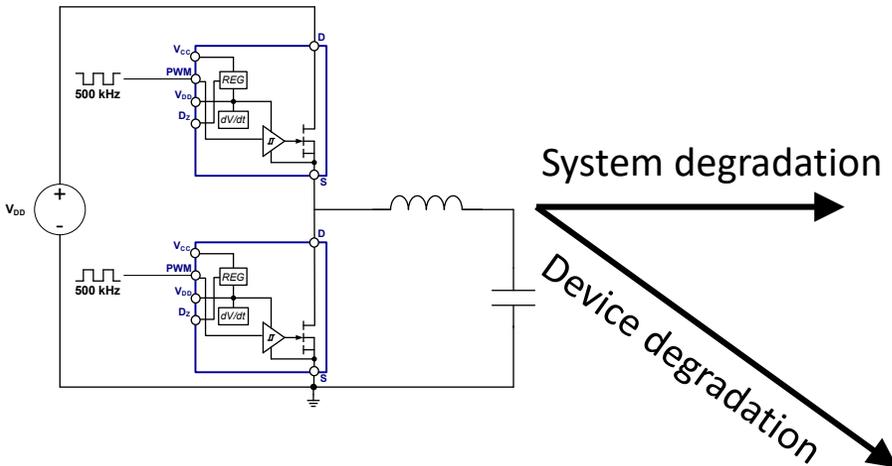
Device degradation





Failure Mode Matters

650V, 150°C HTOL



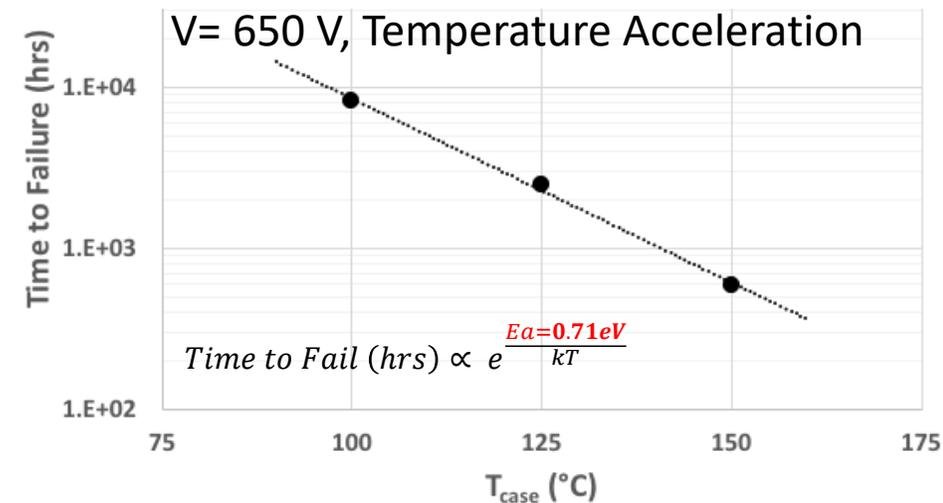
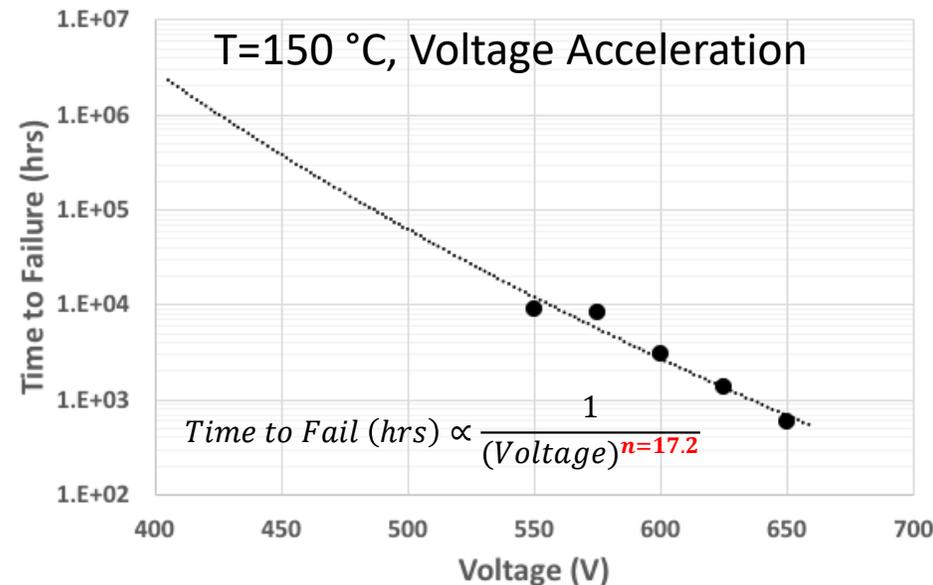
Parametric failure = minor efficiency degradation

Lifetime estimation using parametric failure → conservative approach



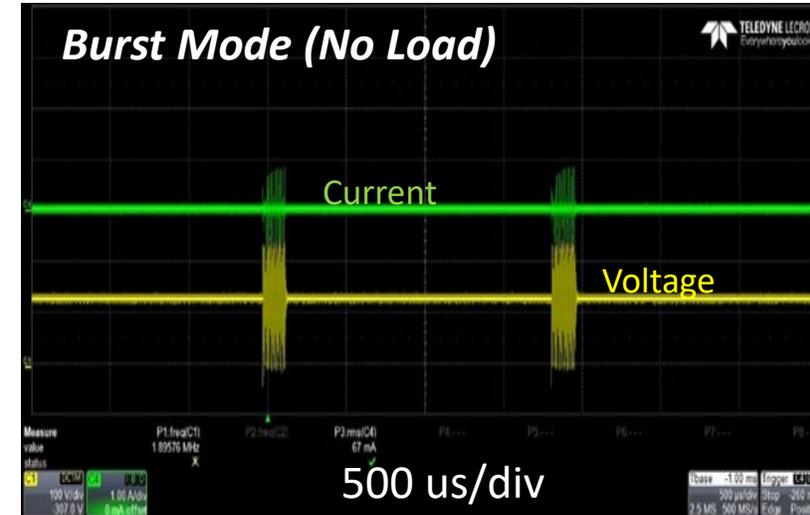
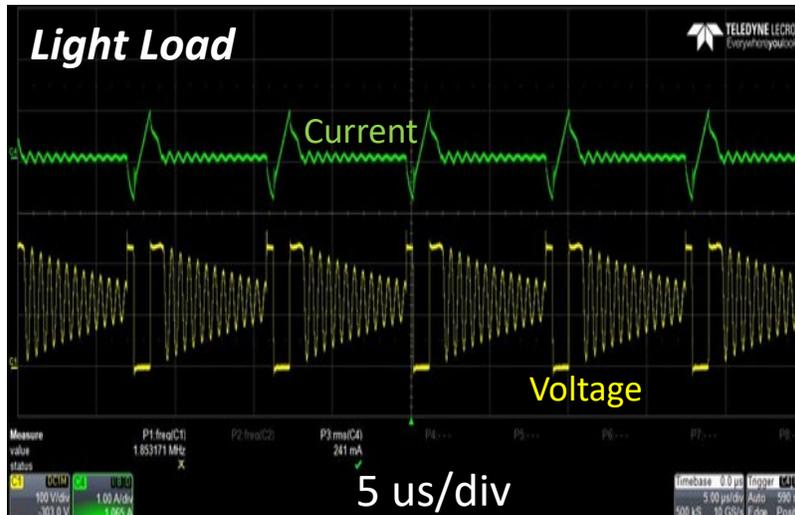
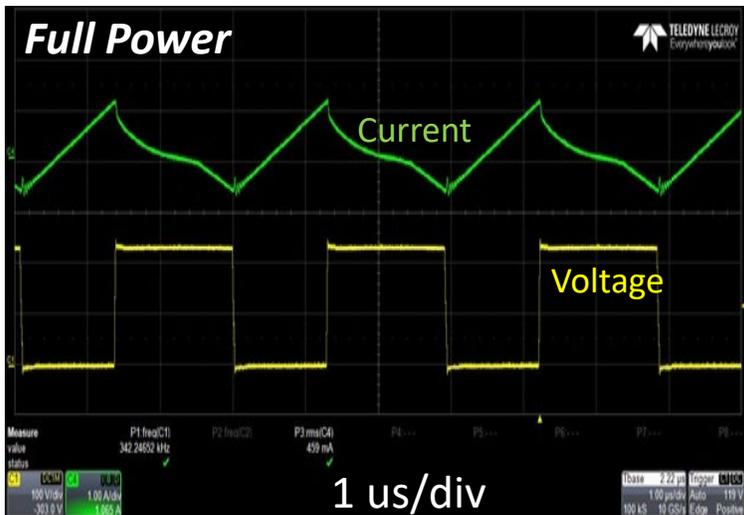
HTOL-based Lifetime Model

Voltage/ Temperature	100°C	125°C	150°C
550V			✓
575V			✓
600V			✓
625V			✓
650V	✓	✓	✓





Stress Profile in ACF



Mode	Voltage	DUT T_{case}	Typical time spent (1 charge/day)	Relevant reliability stress
Full Power	460V	100°C	8 hours (33%)	HTOL
Light Load	460V	50°C	4 hours (17%)	HTOL
No Load (burst)	340V	25°C	12 hours (50%)	HTRB HTOL

Assuming worst case scenario at 240VAC

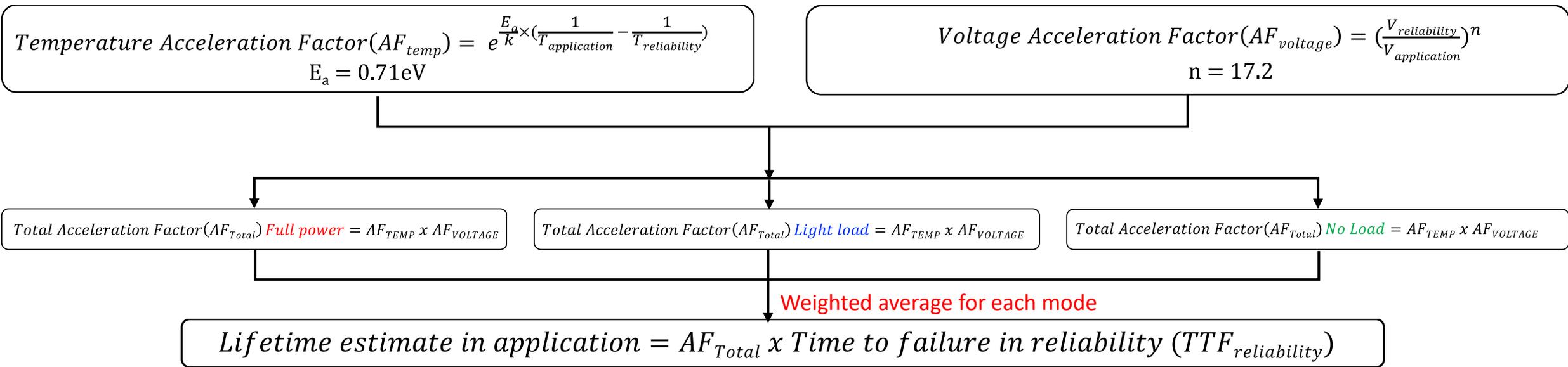
HTOL is more aggressive than HTRB



Lifetime Estimation Methodology

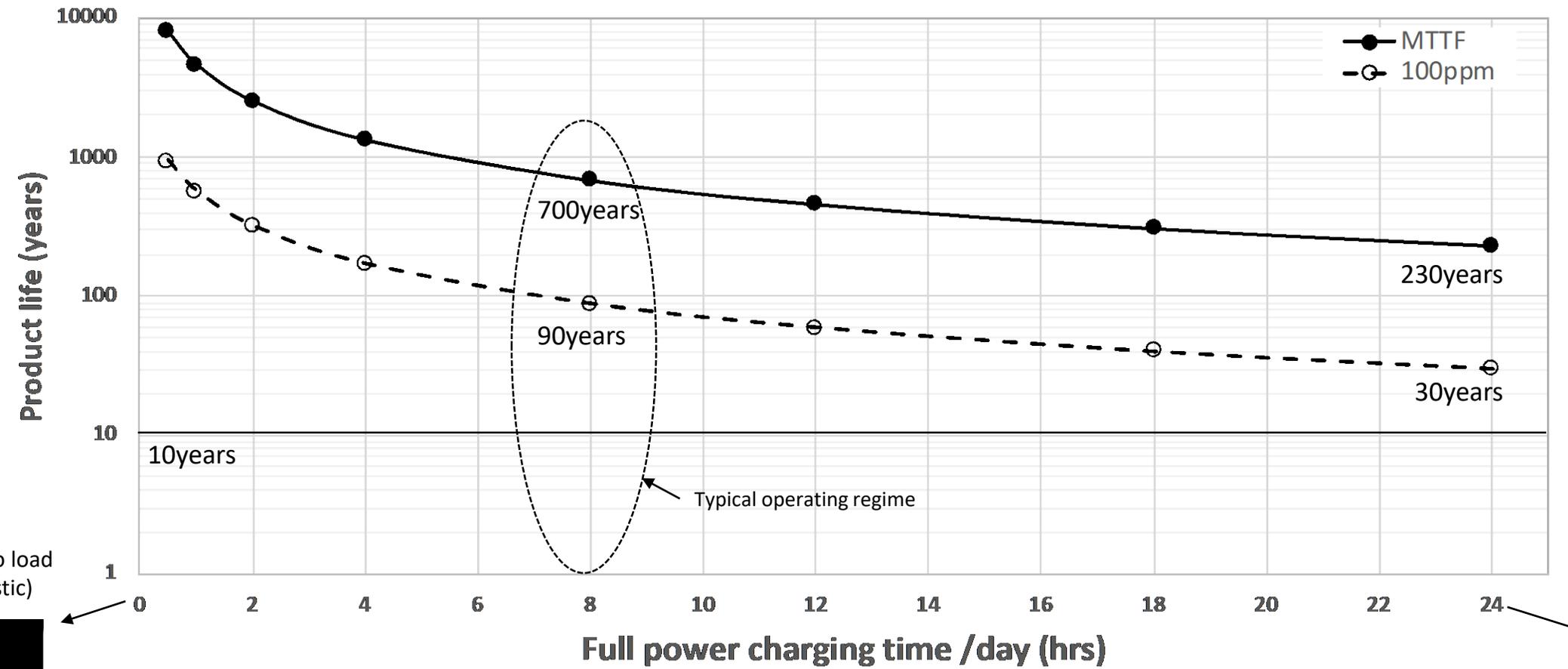


Mode	Voltage	DUT T _{case}	Typical time spent (1 charge/day)	Relevant reliability stress
Full Power	460V	100°C	8 hours (33%)	HTOL
Light Load	460V	50°C	4 hours (17%)	HTOL
No Load (burst)	340V	25°C	12 hours (50%)	HTOL



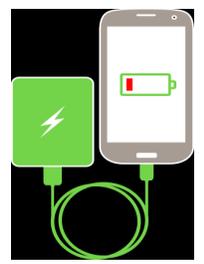
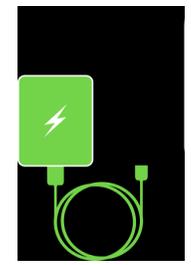


Lifetime Estimation in Charger Application



100% No load (unrealistic)

100% full power (unrealistic)



Significant built-in reliability margin → even at worst case conditions (exceeds 10+ year lifetime requirement)



Reliability → Qualification → Release



Reliability models on IC building blocks = Robust design

Mission profile driven reliability = Protected Customer

Comprehensive reliability monitoring

Reference	Test Conditions	Duration	Lots	S.S.	
JESD22-A 113 J-STD-020	Preconditioning (MSL1): Moisture Preconditioning + 3x reflow: HAST, UHAST, TC & PC	N/A	3	308	PASS (0/308)
JESD22-A 104	Temperature Cycle: -55°C / 150°C	1,000cy	3	77	PASS (0/231)
JESD22-A 122	Power Cycle: Delta Tj = 100°C	10,000cy	3	77	PASS (0/231)
JESD22-A 110	Highly Accelerated Stress Test: 130°C / 85%RH / 100V V _{DS}	96hrs	3	77	PASS (0/231)
JESD22-A 108	High Temperature Reverse Bias: 150°C / 520V V _{DS}	1,000hrs	3	77	PASS (0/231)
JESD22-A 108	High Temperature Gate Bias: 150°C / 6V V _{GS}	1,000hrs	3	77	PASS (0/231)
JESD22-A 108	High Temperature Operating Life	1,000hrs	3	77	PASS (0/231)
JESD22-A 108	Early Life Failure Rate	24 hrs	3	1,000	PASS (0/3,000)
JS-001-2014	Human Body Model ESD	N/A	1	3	PASS 0/3
JS-002-2014	Charged Device Model ESD	N/A	1	3	PASS 0/3

Metric	Results
Equivalent device hours tested*	1.5 billion hours
FIT*	0.6

*Statistics calculated from HTOL tests

GaNFast™
POWER ICs

Quality

Speed

Efficiency

Now in high volume production!

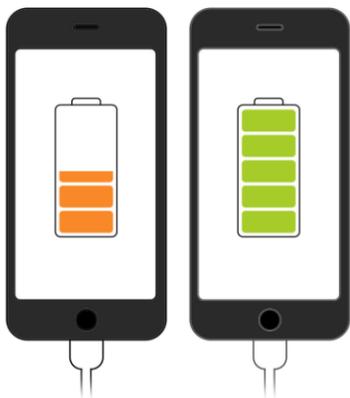


GaNFast Chargers now in production



Fast

Up to 3x more power
Up to 3x faster charging



Mobile

Half the size & weight
of traditional chargers



Universal

One charger for **ALL** your devices
One and Done!!



Macbook 12"
Dell XPS 15/13

iPhone XS
Google Pixel 2

Nintendo Switch
And more...

AUKEY



27W



24W



30W

MADE IN MIND



45W

RAVPOWER®

45W





GaNFast™



Let's go **GaNFast™**