Navitas Let's go GåNFast™

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

Navitas Proprietary & Confidential

World's First GaNFast[™] Power ICs

Fastest, most efficient GaN Power FETs First & Fastest Integrated GaN Gate Drivers







World's First GaNFast™ Power ICs

GàNFast[™]



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

>3x faster than any other gate driver

- Proprietary design
- 30+ patents granted
- Fast, protected gate, no need for negative drive
- Simple, fast and reliable
- Easy to use and package

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

Enabling Advanced Technologies



GàNFast™

PDK Analysis





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

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

GaNFast[™]



65W USB-PD

Application Profile for ACF Charger GaNFast













Navitas Proprietary & Confidential

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





IS

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 | | | | |
| Switching stress on HV GaNFET Drain | High Temperature Operating Life | | | |

HTRB Acceleration & Lifetime Models



GaNFast™

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



GàNFast™

Frequency Acceleration





GàNFast™



Frequency \downarrow / Duty cycle \uparrow / Pulse width $\uparrow \Leftrightarrow$ 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

GaNFast™

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

GàNFast™

Failure Mode Matters





Failure Mode Matters





HTOL-based Lifetime Model





Navitas Proprietary & Confidential

Stress Profile in ACF









HTOL is more aggressive than HTRB

| 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

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



GaNFast™

Reliability → **Qualification** → **Release**

Reliability models on IC building blocks = Robust design

Mission profile driven reliability = Protected Customer

| Reference | Test Conditions | Duration | Lots | S.S. | | |
|--------------------------|--|----------|------|-------|-------------------|--|
| JESD22-A113 J-STD-020 | Preconditioning (MSL1): Moisture Preconditioning + 3x reflow: HAST, UHAST, TC & PC | N/A | 3 | 308 | PASS (0/308) | |
| JESD22-A104 | Temperature Cycle: -55°C / 150°C | 1,000cy | 3 | 77 | PASS (0/231) | |
| JESD22-A122 | Power Cycle: Delta Tj = 100°C | 10,000cy | 3 | 77 | PASS (0/231) | |
| JESD22-A110 | Highly Accelerated Stress Test: 130°C / 85%RH / 100V V _{DS} | 96hrs | 3 | 77 | PASS (0/231) | |
| JESD22-A108 | High Temperature Reverse Bias: 150°C / 520V V _{DS} | 1,000hrs | 3 | 77 | PASS (0/231) | |
| JESD22-A108 | High Temperature Gate Bias: 150°C / 6V V _{GS} | 1,000hrs | 3 | 77 | PASS (0/231) | |
| JESD22-A108 | High Temperature Operating Life | 1,000hrs | 3 | 77 | PASS (0/231) | |
| JESD22-A108 | 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 | |

Comprehensive reliability monitoring

| | Metric | Results |
|----|---------------------------------|-------------------|
| -> | Equivalent device hours tested* | 1.5 billion hours |
| | FIT* | 0.6 |

*Statistics calculated from HTOL tests



GaNFast[™]

GaNFast Chargers now in production



Fast

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





Mobile

Half the size & weight

Universal

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



AUKEY



27W



24W





RAVPUWER



Navitas Proprietary & Confidential





Let's go GaNFast™