

Wide Bandgap Quality and Reliability Standards: JEDEC Delivers!

Tim McDonald, JEDEC JC-70 Chair, JC-70.1 Vice Chair

Stephanie Watts Butler, founding past Chair JC-70,
IEC TC47 WG 8 co-convenor

With contributions from:

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Kurt Smith, VisiC, JEDEC JC-70.1 Chair

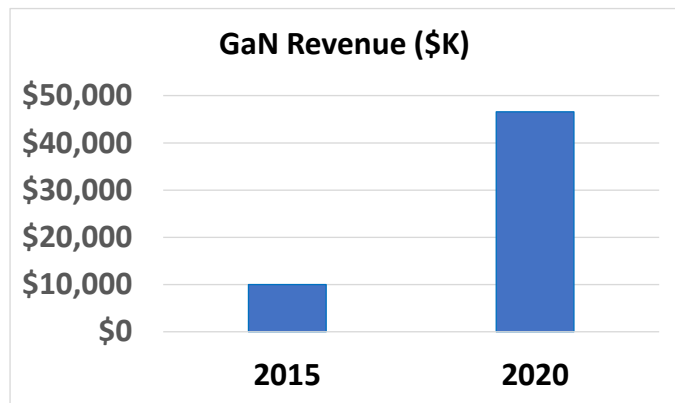
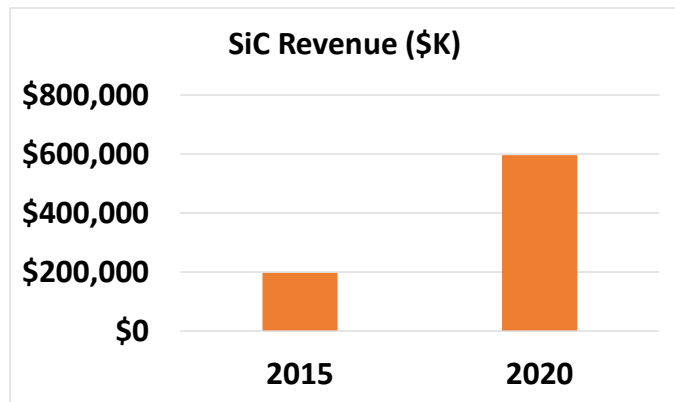
Jeffrey Casady, Wolfspeed, JEDEC JC-70.2 Chair

Outline

- Introduction: what's all this about wide bandgap and JC-70?
- Is JC-70 making an impact?
 - Growing JC-70 membership
 - Quickening the document creation process
 - Influencing Industry and research
 - Collaborating for wider impact
- What's next? Document Roadmaps
- Example topic from current efforts: Dynamic Capacitive losses
- Key Takeaways



Introduction: What's all this about wide bandgap and JC-70?

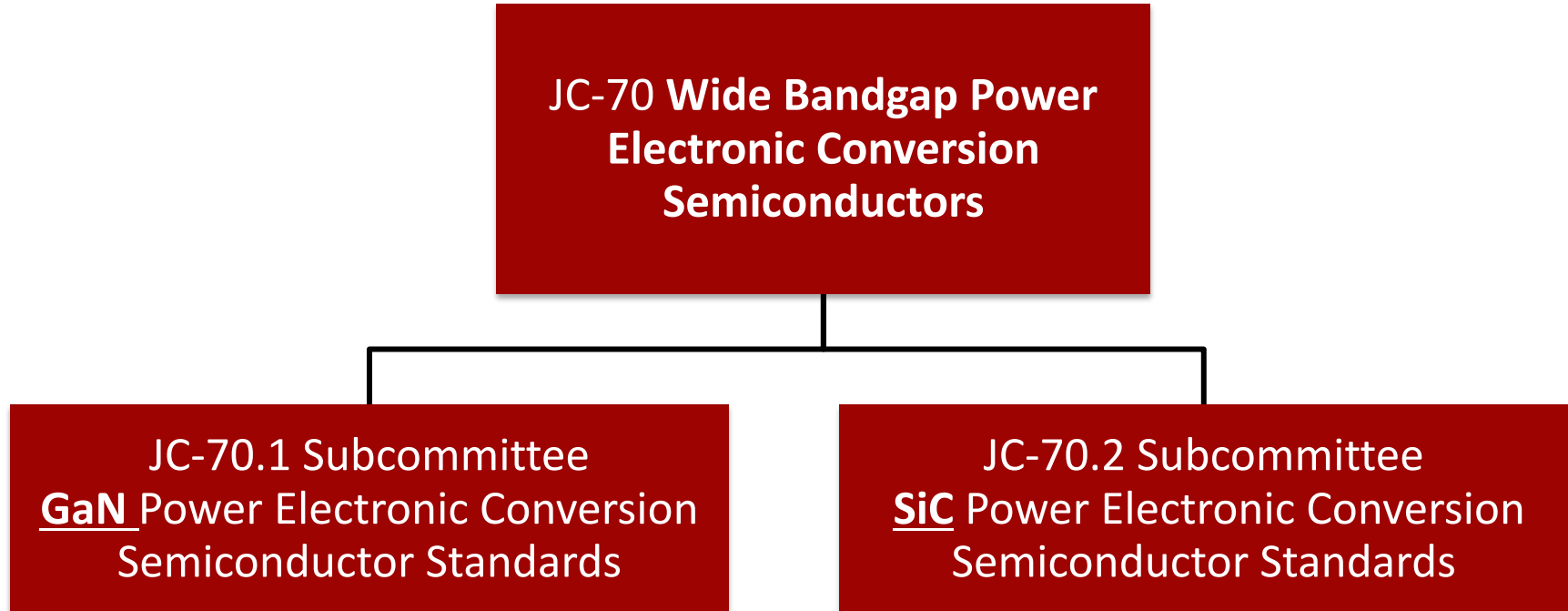


- IN 2015, at the genesis to form JC-70, SiC and GaN were known as fast growth market opportunities
- GaN has grown ~4.5x in revenue and SiC by ~3x based on revenue estimates from Yole's 2015 and 2021 reports.
- JC-70 has helped accelerate adoption into the new applications forming these markets



JC-70 Structure:

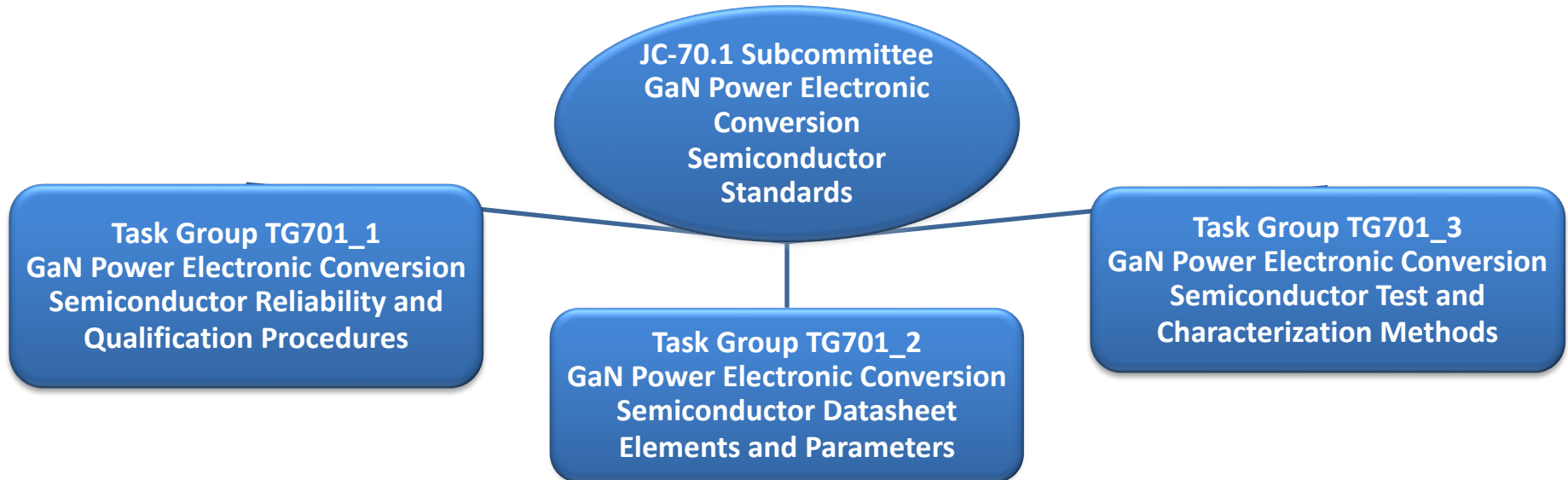
Wide Bandgap (GaN & SiC)



JEDEC Committee JC-70.1 Task Group structure (GaN)



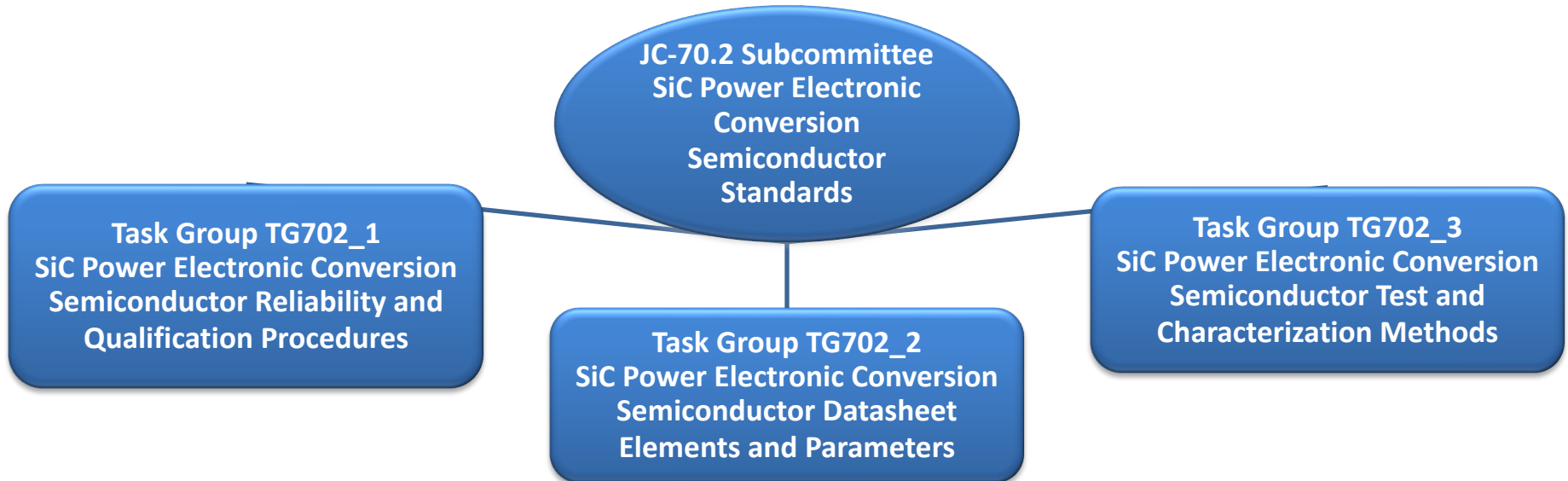
Global Standards for the Microelectronics Industry



JEDEC Committee JC-70.2 (SiC) Task Group Structure

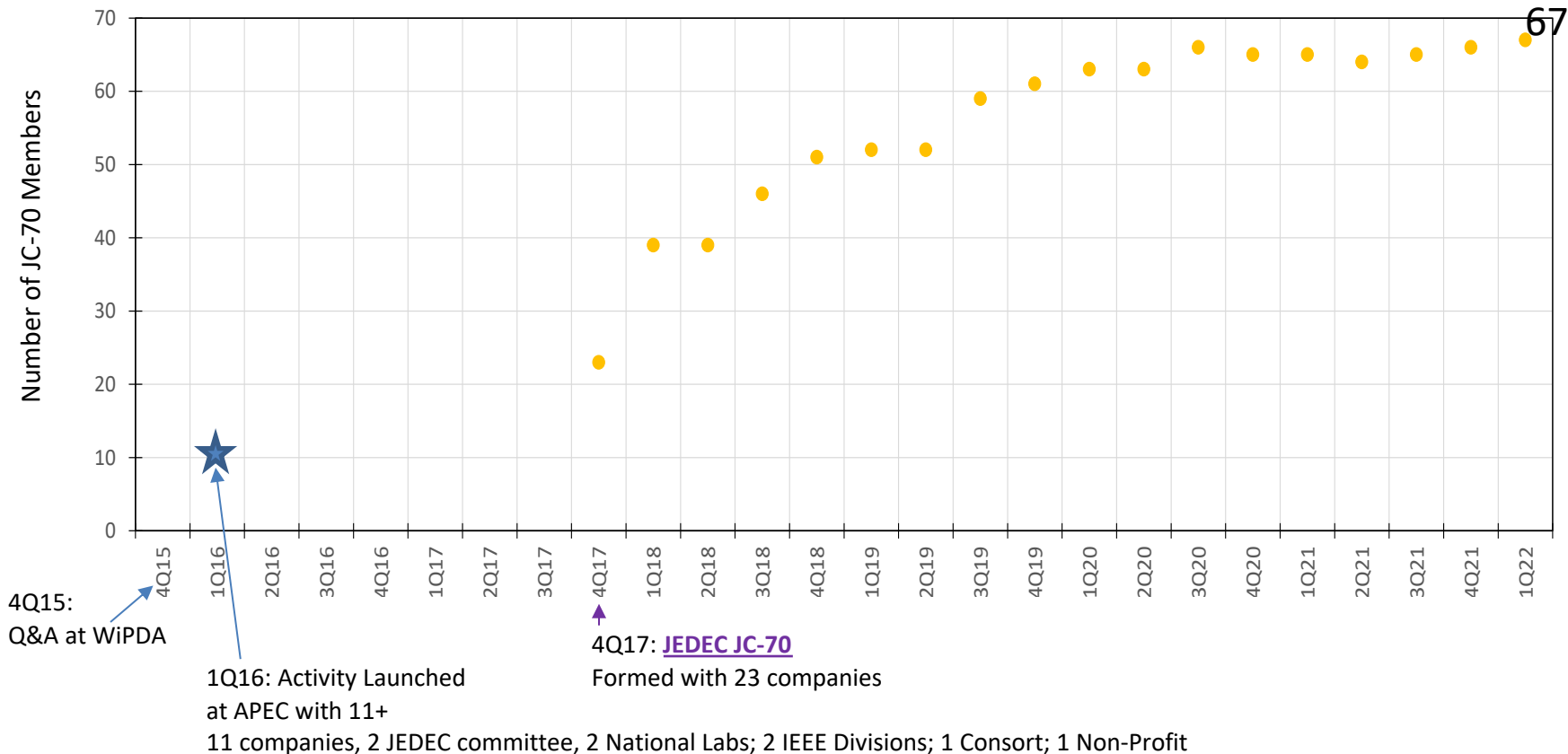


Global Standards for the Microelectronics Industry



JC-70 Membership

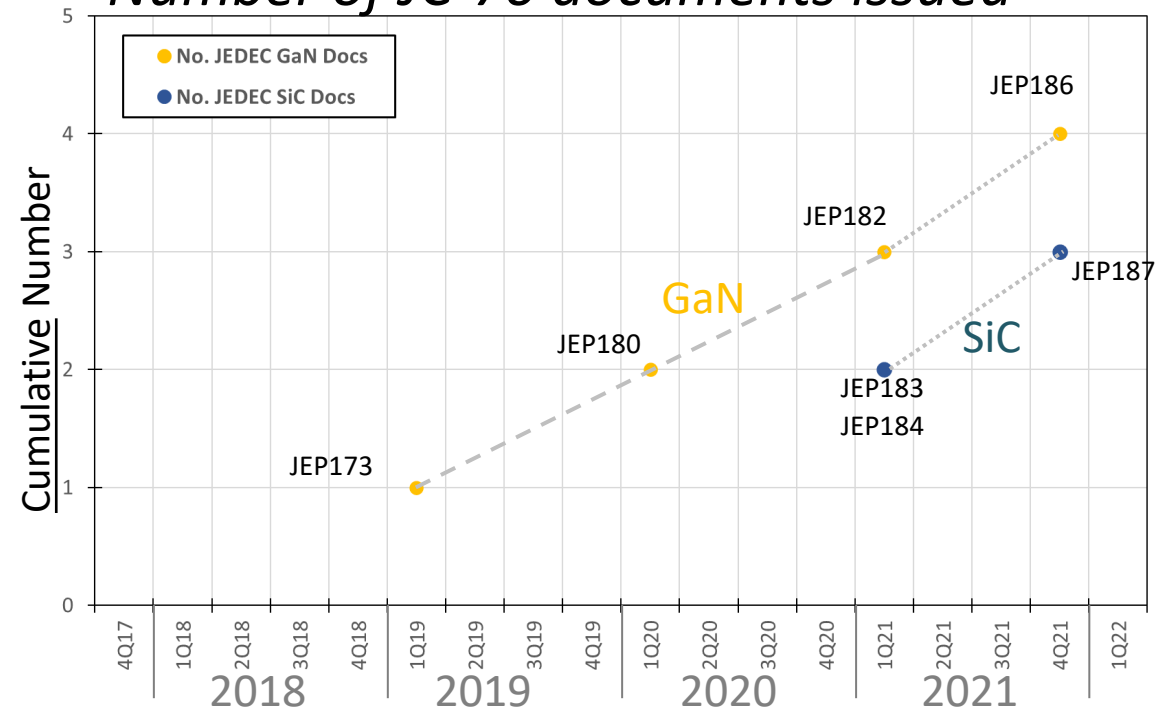
3rd Largest and Fastest Growing JEDEC Committee





Increasing speed of JC-70

Number of JC-70 documents issued



JC-70 | JEDEC

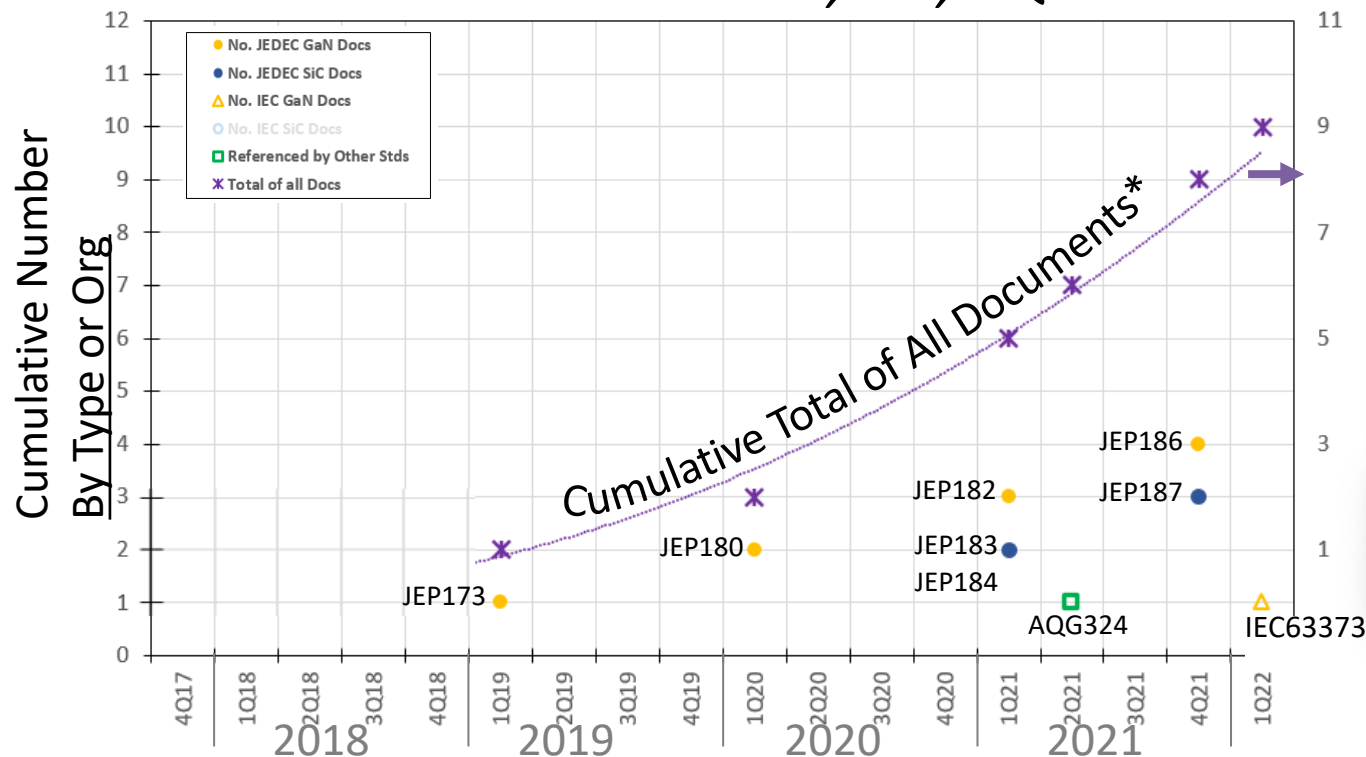
jepec.org/committees/jc-70

Recent Documents

Guideline to Specify a Transient Off-State Withstand Voltage Robustness Indicator in Datasheets for Lateral GaN Power Conversion Devices, Version 1.0	JEP186	Dec 2021
Guidelines for Representing Switching Losses of SiC MOSFETs in Datasheets	JEP187	Dec 2021
GUIDELINE FOR EVALUATING BIAS TEMPERATURE INSTABILITY OF SILICON CARBIDE METAL-OXIDE-SEMICONDUCTOR DEVICES FOR POWER ELECTRONIC CONVERSION	JEP184	Mar 2021
GUIDELINE FOR SWITCHING RELIABILITY EVALUATION PROCEDURES FOR GALLIUM NITRIDE POWER CONVERSION DEVICES	JEP180.01	Jan 2021
Guidelines for measuring the threshold voltage (VT) of SiC MOSFETs	JEP183	Jan 2021
TEST METHOD FOR CONTINUOUS-SWITCHING EVALUATION OF GALLIUM NITRIDE POWER CONVERSION DEVICES	JEP182	Jan 2021
DYNAMIC ON-RESISTANCE TEST METHOD GUIDELINES FOR GaN HEMT BASED POWER CONVERSION DEVICES, VERSION 1.0	JEP173	Jan 2019

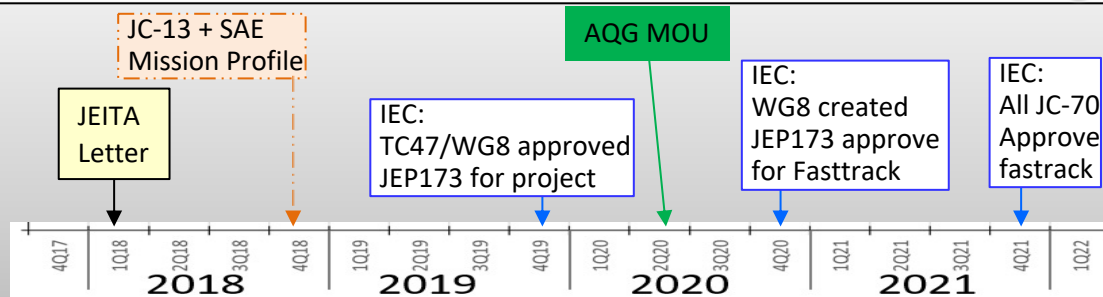
Increasing productivity of JC-70 with organizations across the world

All Documents JEDEC, IEC, AQG



JC-70 JEDEC		
jepec.org/committees/jc-70		
Recent Documents		
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ECPE GUIDELINE AQG 324 (03.1/2021 from 31 May 2021)		
IEC 63373:2022		
Dynamic on-resistance test method guidelines for GaN HEMT based power conversion devices Publication date 2022-02-10		

JC-70 Collaborative Work & Engagement Models



Different organizations

- Different Timings
- Different Purposes
- Different Engagement Models

JEDEC JC-13 committee for “...products used in military, space, and other environments requiring special-use condition capabilities...”

- Team (including SAE) defining Mission Profiles for information to feed into JC-70

AQG 324: ECPE Working Group for Automotive Qualification Guideline: “...power electronic modules for automotive application”

- Leverage JC-70 documents for wide bandgap semiconductor requirements contained in the AQG’s module guideline

IEC: Worldwide standards body with countries as members

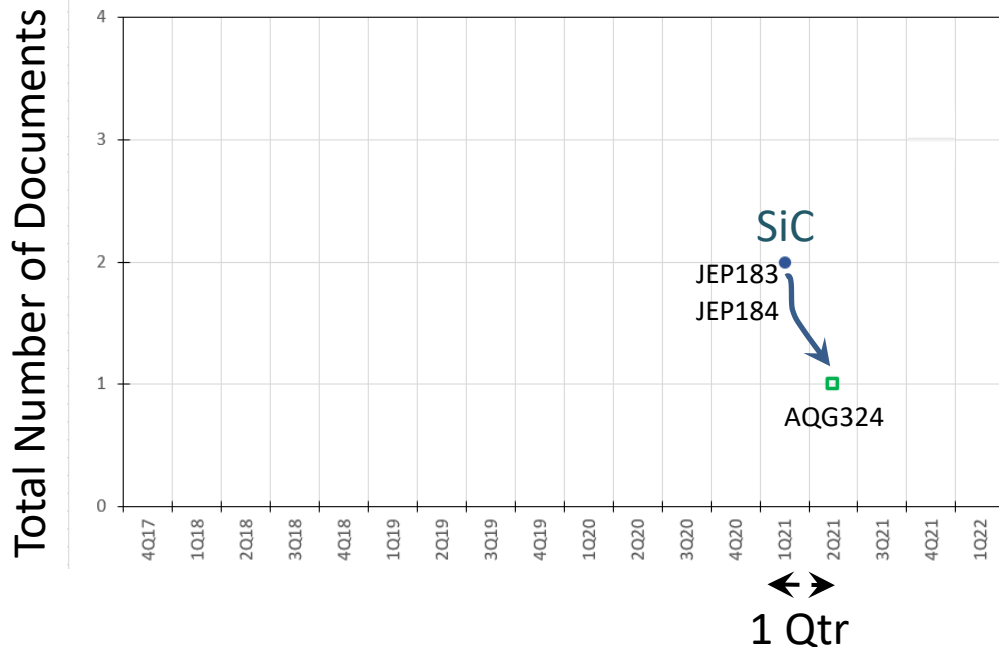
- Utilize JC-70 documents to craft IEC documents to fulfil IEC TC47 WG8 scope “...Harmonize standards internationally”

JEITA (Japan)

- Technical exchanges for JEITA, JC-70, and IEC documents
- Japan has also sponsored 3 additional JC-70 relevant documents in IEC

Collaborating quickly

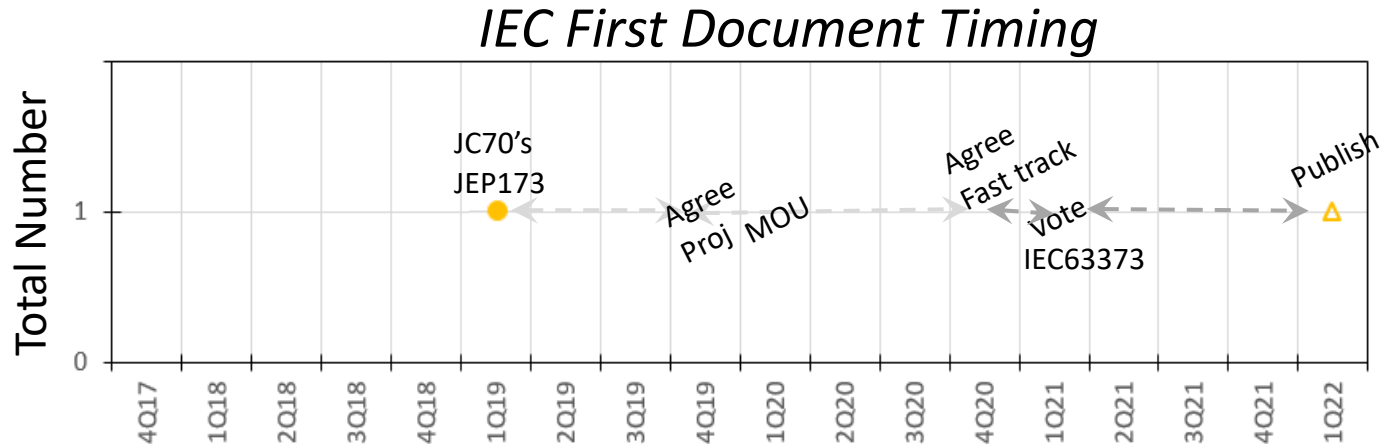
AQG324



- JEP183 and JEP184 are required references in AQG324
- Active exchanges and leverage company membership in both Orgs
- From AQG324 Scope:
“Future releases of the AGQ 324 Guideline will address further wide bandgap power semiconductors (e.g. GaN),”
- AQG324:
<https://www.ecpe.org/research/working-groups/automotive-aqg-324/>

Harmonizing effectively

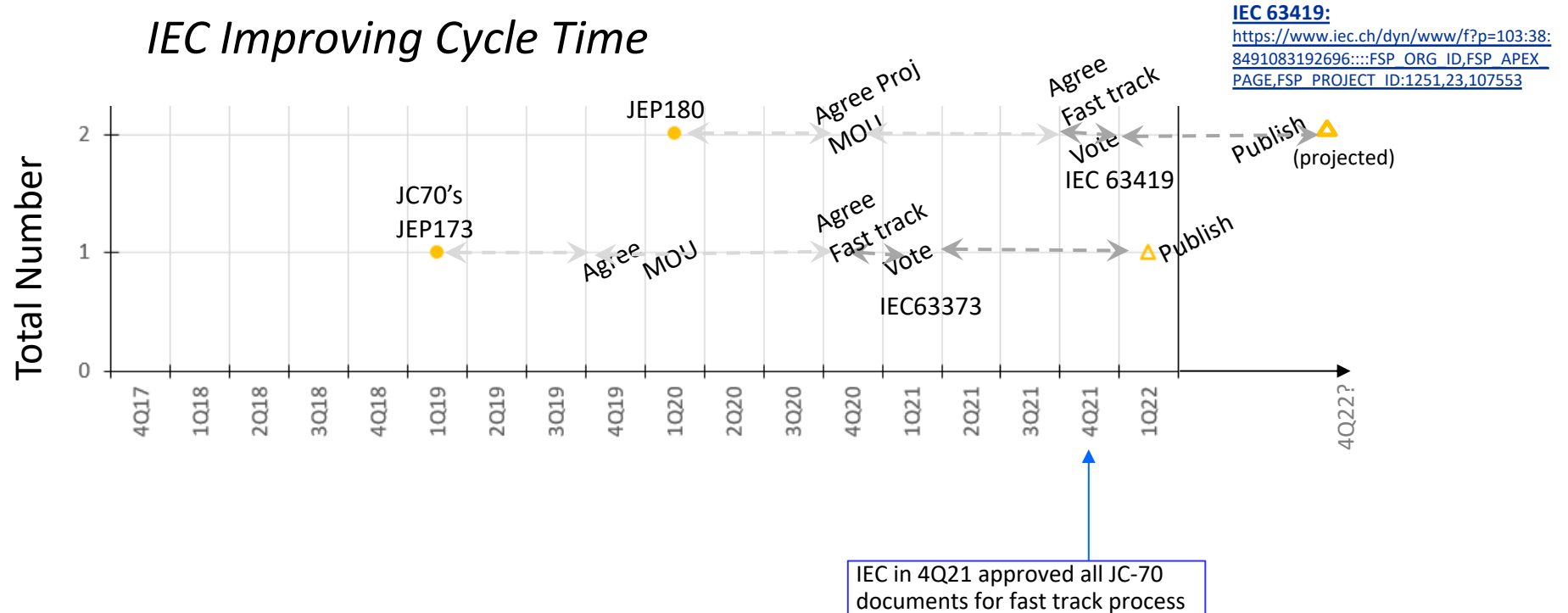
- IEC deploys a formal staged process
- Includes vote to agree for project
- MOU if existing document from another org
- (and several more phases if not fast tracked)
- Vote on document
- (and additional votes if required technical content revisions)



IEC 63373:
<https://webstore.iec.ch/publication/68515>

Harmonizing efficiently

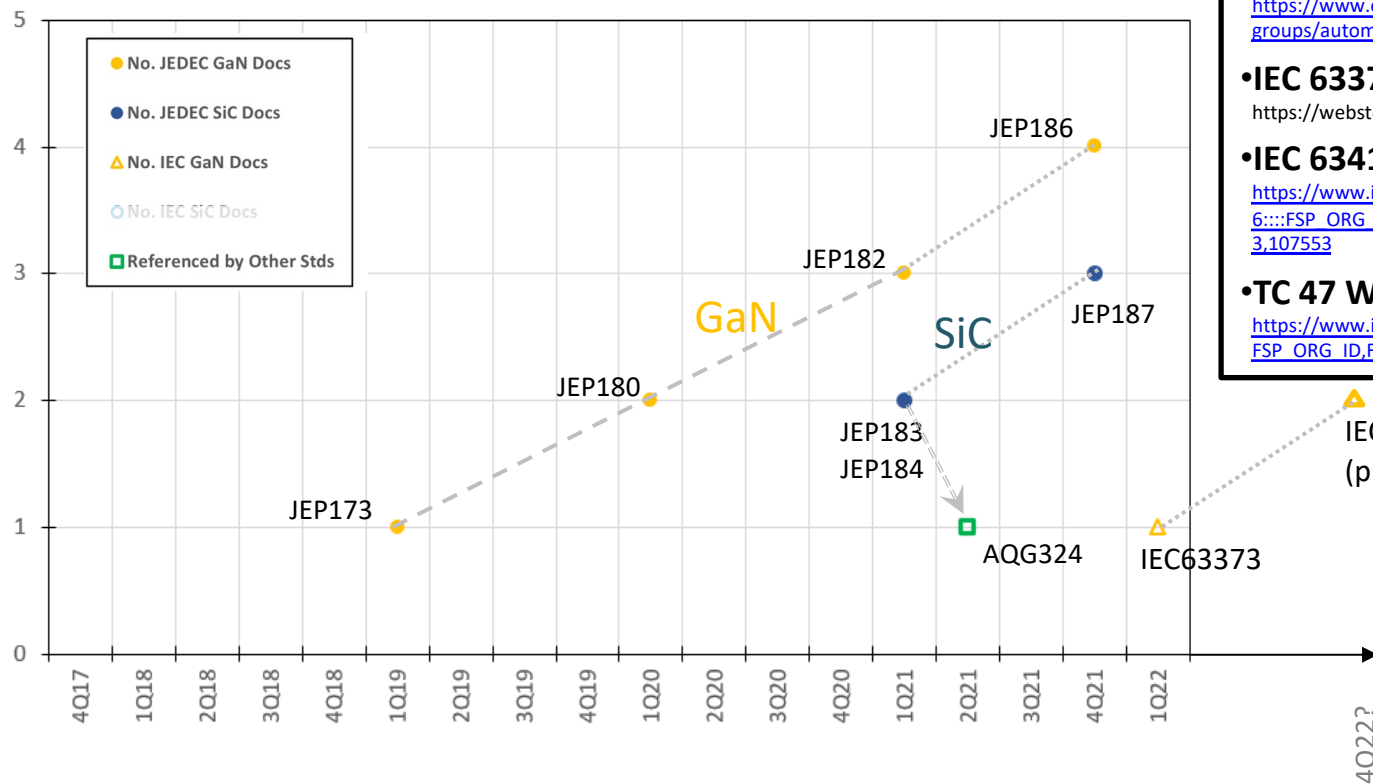
IEC Improving Cycle Time





Demonstrating increasingly efficient and effective engagement with organizations across the world

Cumulative Number By Type or Org



•JC-70 Documents:

<https://www.jedec.org/committees/jc-70>

•AQG324 (JEP183, JEP184):

<https://www.ecpe.org/research/working-groups/automotive-agg-324/>

•IEC 63373 (JEP173):

<https://webstore.iec.ch/publication/68515>

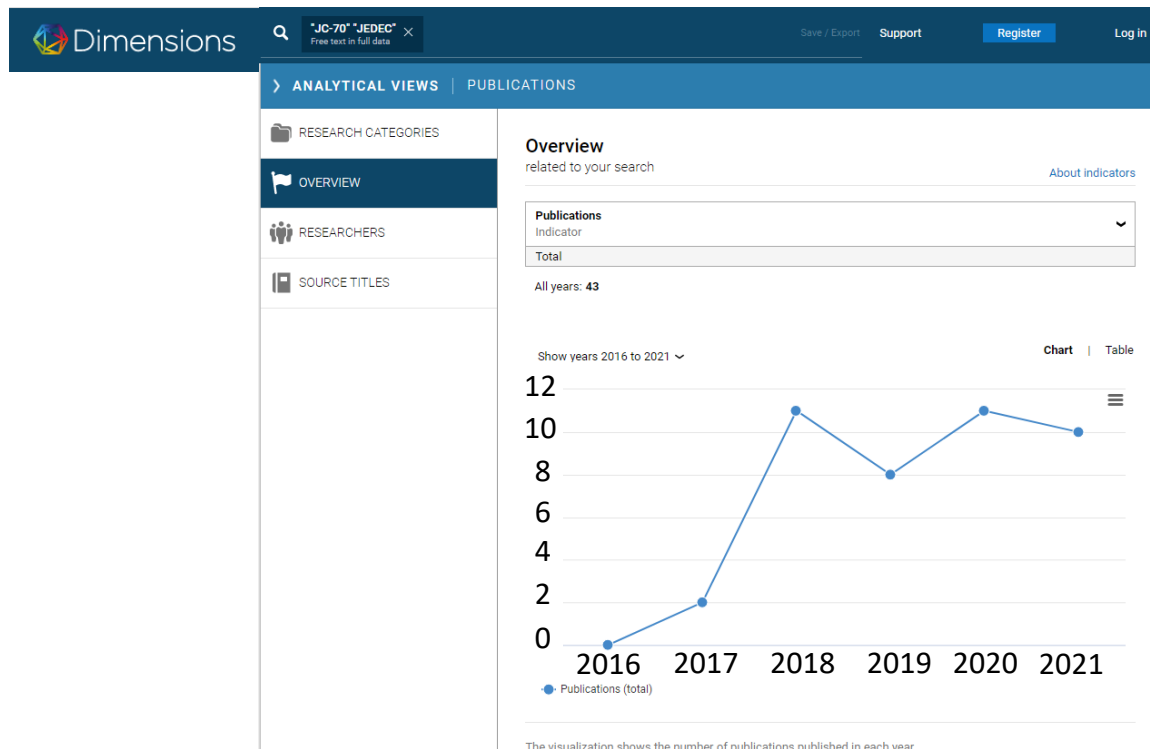
•IEC 63419 (JEP180):

https://www.iec.ch/dyn/www/f?p=103:38:8491083192696:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:1251,23,107553

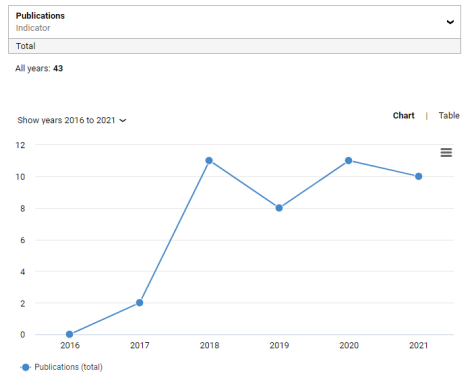
•TC 47 WG 8

https://www.iec.ch/ords/f?p=103:14:500507554697761:::FSP_ORG_ID,FSP_LANG_ID:27401,25

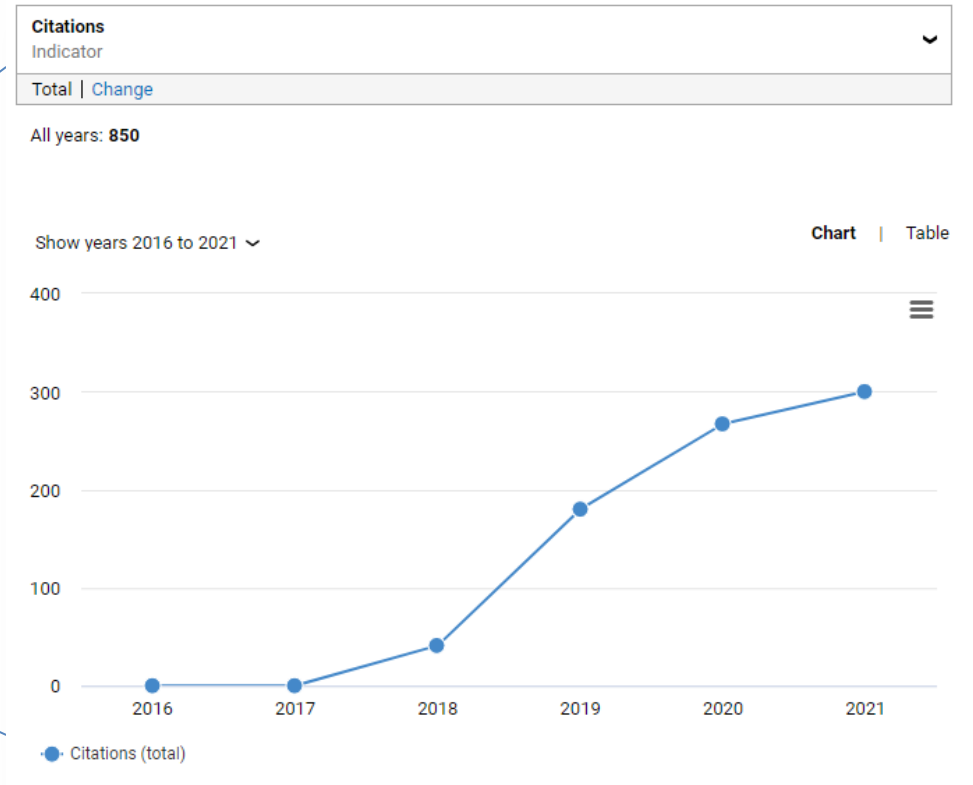
The scholarly literature are recognizing JC-70: 43 publications reference (JC-70 AND JEDEC)



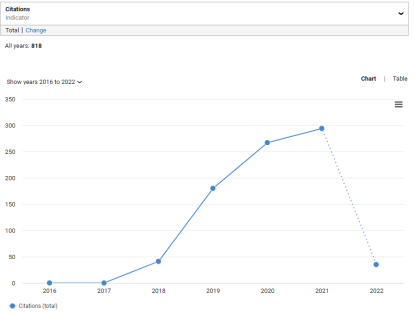
Impact seen in publications: Citations to articles which reference (JC-70 AND JEDEC)



43 articles
Cited
Total
Of 850 times



Referencing (JC-70 AND JEDEC) publications as a group have ABOVE average (citation) impact



850 Citations
Have
Combined
FCR



The Field Citation Ratio (FCR) indicates the relative citation performance of a publication when compared to similarly-aged articles in its subject area. The visualization shows the average FCR per publication published in each year.

Field Citation Ratio (FCR)

The Field Citation Ratio (FCR) indicates the relative citation performance of a publication when compared to similarly-aged articles in its subject area. A value of more than 1.0-1.5 indicates higher than average citation, when defined by FoR subject code, and publication year. The FCR is calculated for all publications in Dimensions which are at least 2 years old...

Proposed Items for GaN Guidelines/Standards

Status from
APEC 2020

REL

- JEP122-like catalog of Failure Mechanisms/Mode (summarizing literature)
- Offstate voltage/Temp Rel (ALT-HTRB)
- ✓ **Switching Reliability**
- Stress Procedures & Acceleration
- Continue to Add to list of Failure Mechanisms

Test

- ✓ **Dynamic $R_{DS}(ON)$**
- Switching reliability test methods

Datasheet

- Include effect of Dynamic $R_{DS}(ON)$
- GaN power transistors specific voltage ratings
- Transistor circuit symbol to reflect distinctive operation GaN HEMTs

• Transient Voltage Aspects

Caution: Work in Progress

Proposed Items for GaN Guidelines/Standards

Status for
APEC 2022

REL

- JEP122-like catalog of Failure Mechanisms/Mode:
 - TDB, Charge trapping, Switching Stress
- ✓ Switching Reliability
- Reverse Bias stress procedure guideline
- Transient Reliability Topic
- Stress Procedures & Acceleration
- Continue to Add to list of Failure Mechanisms

Test

- ✓ Dynamic $R_{DS}(ON)$
- ✓ Switching Reliability test methods
- Dynamic capacitive loss
- Thermal Characterization
- Test for effective $R_{DS}(ON)$ drift
- Test for surge capability
- Test for maximum $V_{DS(tr)}$

Datasheet

- ✓ Transient Voltage Rating

Caution: Work in Progress

Items in Green with check mark: document completed, with no check mark : document in progress, black text: planned for consideration as future work

Proposed Items focus for SiC Guidelines/Standards

Status for
APEC 2020

Liaisons between Task Groups to be fine tuned

REL

• BTI → in advanced status

- ALT-HTRB
 - GaN collab under assessment
- Body Diode
- ~~neutron radiation~~
- TDDB
 - Corresponding Acceleration & Stress Procedure
- dV/dt
 - Work has begun
- List of Failure Mechanisms & Resulting Failure Mode

Test

• Vth → in advanced status

- Qg → first draft
- Short-circuit measurement → t.b.d

Datasheet

• Vth definition

- Datasheet elements to separate re-turn on effects from reverse recovery
- Vth hysteresis
- More to come

Caution: Work in Progress

Proposed Items for SiC Guidelines/Standards

Status for
APEC 2022

REL

- ✓ Evaluating BTI
- ALT-HTRB
- Gate Oxide Reliability and Robustness Evaluation
- SiC stress procedures
- SiC qual procedures
- Power Cycling
- Failure Mechanism and Models:
 - dV/dt Events
 - HV Switching instability
 - Gate Switching Instability
 - Bipolar Instability
 - HTRB
 - Application Level Switching Instability

Test

- ✓ Vth measurement
- Qg Measurement
- Body Diode-reverse recovery test
- Eon/Eoff- double pulse set up
- Avalanche Breakdown
- Short-circuit measurement
- S-parameter measurement
- Dynamic capacitive loss (with 701_3)

Datasheet

- Parasitic Turn on (status?)
- Bipolar and capacitive charges in SiC devices
- ✓ Representing switching losses in SiC MOSFET datasheets

Caution: Work in Progress

Items in Green with check mark: document completed, with no check mark : document in progress, black text: planned for consideration as future work

Current topic: Dynamic Capacitive Losses

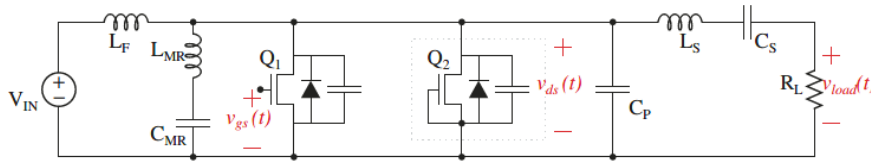
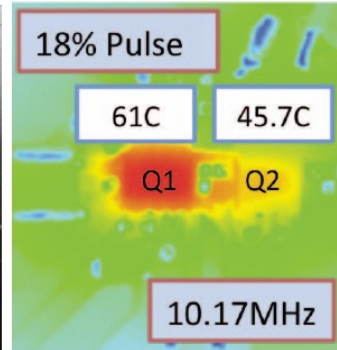
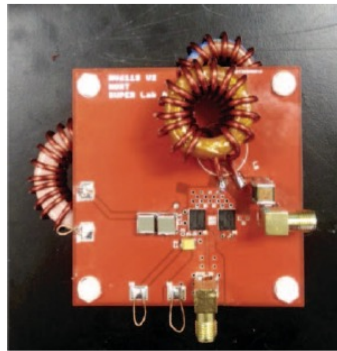
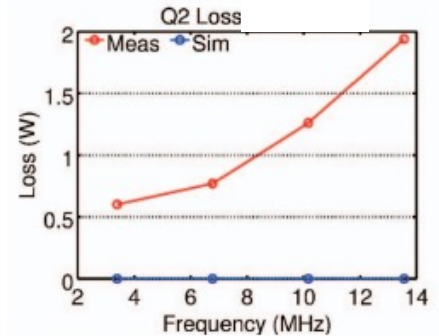
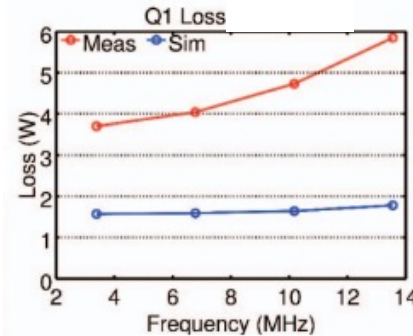


Fig. 3: A Φ_2 inverter with two transistors.

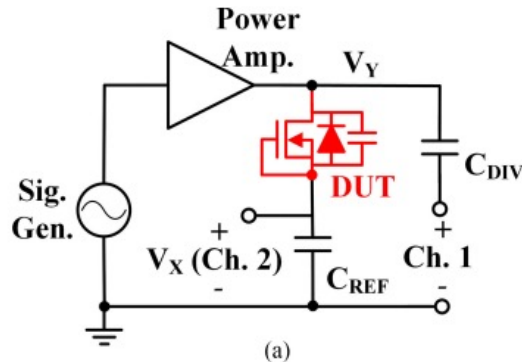
- Efficiency was measured 5-10% lower than expected in GaN based high frequency (Φ_2 topology) converters
 - $f = 3-30$ MHz (beyond range of commercialized applications today)
- Adding a second GaN HEMT (Q_2) in diode mode (G to S shorted) unexpectedly adds to losses



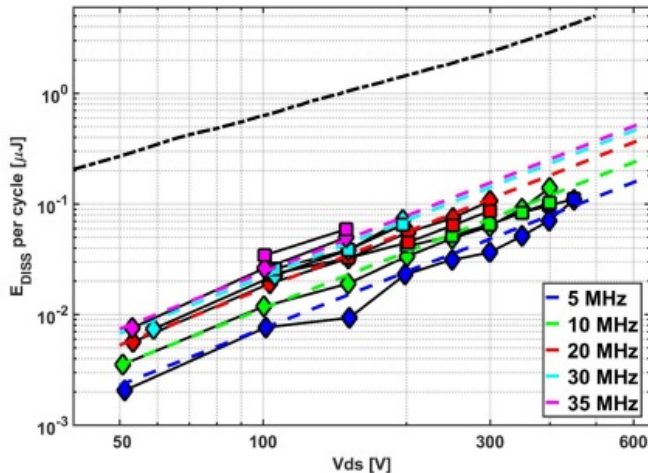
(a) A Φ_2 inverter tuned with (b) Thermal image of this inverter at 18% pulse.



Measuring Dynamic Capacitive Losses



(a)



(b)

- For isolating energy lost due to dynamic hysteresis of device capacitance, several measurement methods have been investigated (shown is Tower-Sawyer circuit)
- Unexpected increase in energy dissipated (E_{DISS} on curve shown) during switching
- Increases with both frequency ($f^{1.6}$) and voltage
- Not just C_{OSS} (recoverable energy)
- Topic is on the roadmap for test method task groups from both 70.1 (GaN) and 70.2 (SiC)

Zulauf, G., et al, "COSS Losses in 600 V GaN Power Semiconductors in Soft-Switched, High- and Very-High-Frequency Power Converters", IEEE Transactions on Power Electronics, Vol. 33, No. 12, December 2018

Key Takeaways

- JC-70 is getting it done:
 - Accelerating document production
 - Influencing the user community
- Collaborating to maximize impact
- Come join us!

How to Join

- Interested companies worldwide are welcome to join JEDEC to participate in this important standardization effort.
- Find more information about membership
 - <https://www.jedec.org/join-jedec>
- or contact [Emily Desjardins](#) to learn more
 - emilyd@jedec.org

Acknowledgments

- JEDEC Staff
- Mikhail Guz, JEDEC Secretary to JC-70, Consultant, IP and Technology Experts
- JC-70.1 chair and vice chair (Kurt Smith and Tim McDonald) and Task Group Leaders:

TG701_1 (REL) Co-Chairs:

- Ron Barr (Transphorm)
- Sandeep Bahl (TI)
- Sameh Khalil (Infineon)

TG701_2 (Datasheet) Co-Chairs

- Peter Di Maso (GaNSystems)
- Nick Fichtenbaum (Navitas)

TG701_3 (Test) Co-Chairs:

- Deepak Veerreddy (Infineon)
- Jaume Roig (ON)

- JC-70.2 chair and vice chair (Jeff Casady and Peter Friedrichs) and Task Group Leaders:

TG702_1 (REL) Co-Chairs:

- Don Gajewski (Wolfspeed)
- Thomas Aichinger (Infineon)

TG702_2 (Datasheet) Co-Chairs

- Christian Mueller (Infineon)
- Alexander Bolotnikov (ON Semi)

TG702_3 (Test) Co-Chairs:

- Ryo Takeda (Keysight)
- Christian Strenger (Infineon)

- Entire Membership of JC-70, JC-70.1, and JC-70.2 and their Task Groups
- The University and National Lab Community

