JEDEC JC-70 Datasheet, Qualification, and Test Standards for Wide Bandgap: Progress and Impact

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WBG MarketS: >$0.5B, Growing to >$2B by 2024

SiC power projected
~**$1.9B** **by** **2024**
with CAGR of **29%***

GaN power projected
~ **$350M** **by** **2024**,
with CAGR of **85%****

* 2018-24 CAGR: https://www.i-micronews.com/products/power-sic-2019-materials-devices-and-applications/
**2018-24 CAGR: https://www.i-micronews.com/products/power-gan-2019-epitaxy-devices-applications-technology-trends/
Figure Courtesy of Texas Instruments

Outline

- JC-70 History & Structure
- GaN Results & Status
- SiC Results & Status
- Future Directions, including Automotive
- Collaborations and Other Standards Bodies
- How to Become Involved with JEDEC

JEDEC JC-70 Journey

- APEC 2016: Gauge Interest Meeting held which resulted in launching GaNSPEC DWG (JEDEC participated)
  - See “Standardization for Wide Bandgap Devices: GaNSPEC DWG,” Stephanie Watts Butler, APEC 2017
- At WiPDA 2016: With assistance from GaNSPEC, SiCSPEC DWG launched
  - See “Status of Wide Bandgap Device Qualification Standards Effort by New JEDEC Committee JC70,” Stephanie Watts Butler and Tim McDonald, APEC 2018
- At WiPDA 2017: First JEDEC JC-70 Meeting Held
  - See “Status of Wide Bandgap Device Qualification Standards Effort by New JEDEC Committee JC70,” Stephanie Watts Butler and Tim McDonald, APEC 2018
- At WiPDA 2018: First Document Approved by Committee to send to JEDEC BOD for approval
  - January 2019: JEP173: Dynamic On-Resistance Test Method Guidelines for GaN HEMT Based Power Conversion Devices https://www.jedec.org/standards-documents/docs/jep173
- At APEC 2019: First Presentation of Results
  - See “Update on GaN and SiC Activities Within JEDEC JC-70 Committee,” Jeffrey Casady, Stephanie Watts Butler, Tim McDonald, Peter Friedrichs, Kurt Smith, APEC 2019
  - GaN Subcommittee announced the inclusion of transient voltage guidelines in recognition of the valuable role these effects have on power device operation
  - First Public Update of Silicon Carbide (JC-70.2) status
- Progress since APEC 2019: Focus of today’s talk

Purpose of Standards

- Enabling Market Growth
- Ramp Maturity of the Industry
- Accelerate industry-wide adoption by creating consistency across the supplier base
- Consistency that is important to the user
- *Addressing Specific Market Needs*

JC-70 created October 2017
(Committee for Wide Bandgap Power Electronic Conversion Semiconductors)

JEDEC Global Standards for the Microelectronics Industry

- Products
  - discrete devices and integrated circuits; wide bandgap and ultra wide bandgap
  - power conversion circuits regardless of device type, polarity, mode of operation, packaging, electrical ratings, and end applications.
- RF/microwave amplification and signal conditioning applications generally not covered
- Industry standards concerned with
  - reliability verification and qualification procedures,
  - test methods and measurement techniques,
  - data sheet elements and device specifications,
  - unique packaging considerations
  - cataloging and consideration of mission profiles
  - formulation of terms, definitions, and symbols

JC-70 Membership Stats

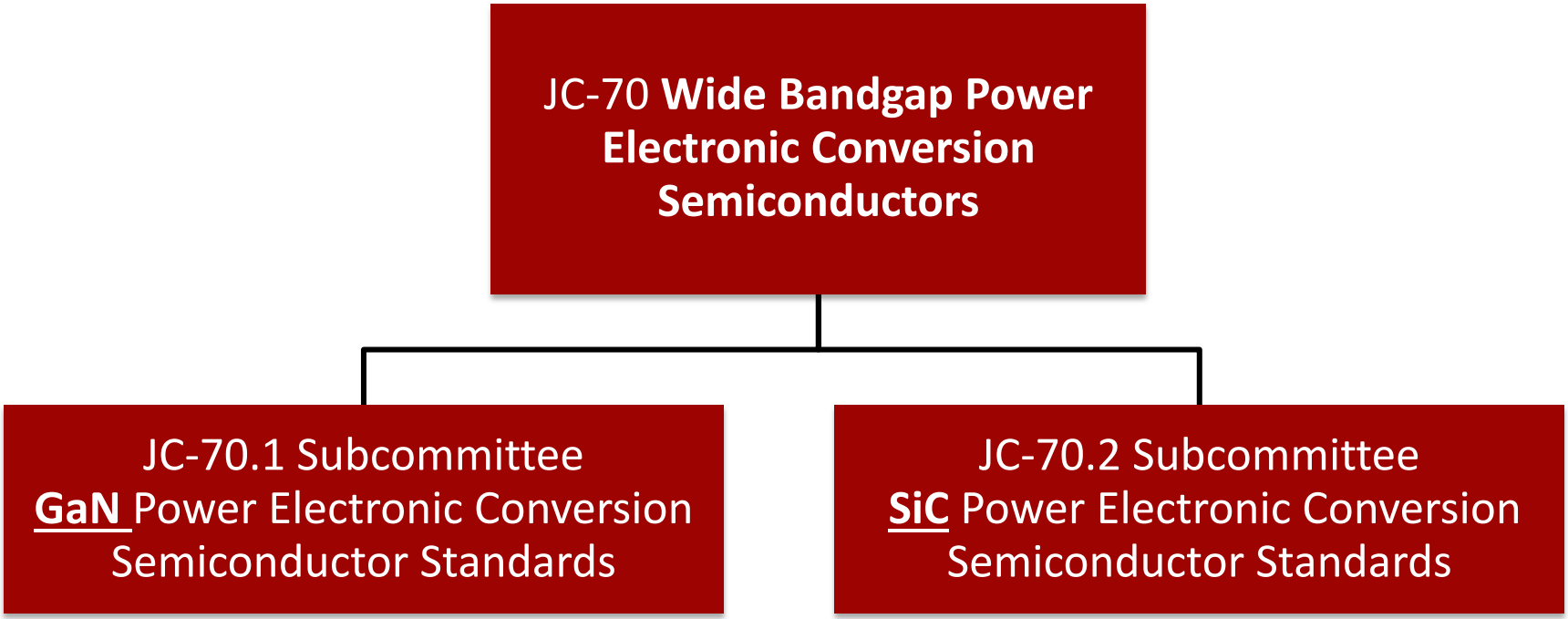
- JEDEC's 3rd Largest Committee and the Fastest Growing
- Began with 23 member companies, now over 60 Companies
  - US, Europe, Middle East, and Asia
  - Global multinational corporations & technology startups
  - Power GaN and SiC semiconductor manufacturers, users of wide bandgap power devices, test and measurement equipment suppliers.
- 2 subcommittees:
  - JC-70.1 covers GaN
  - JC-70.2 covers SiC
- Each subcommittee has task groups
  - Comprised of industry experts
  - Technical experts from universities and national labs also contribute

JC-70 Members List (March 2020)

- ABB
- Accel RF Instruments Corporation
- Alibaba (China) Co., Ltd.
- Alpha and Omega Semiconductor, Inc.
- Alter Technology France
- Analog Devices Inc.
- CEA Tech
- ChangXin Memory Technologies Inc.
- CSA Catapult
- Cyntec Co., Ltd
- Dell Inc.
- Efficient Power Conversion Corp
- Evans Analytical Group (EAG)
- ExaGan
- Freebird Semiconductor Corporation
- GaN Systems
- GaN Ventures Semiconductor
- GaNPower International Inc.
- GigaDevice Semiconductor (Beijing)
- GLOBAL FOUNDRIES U.S. Inc.
- Group NIRE
- Hewlett Packard Enterprise Co
- HP Inc.
- Infineon
- Innoscience Technology Co., Ltd
- Intel Corporation
- John Deere Electronic Solutions
- Keysight Technologies Inc.
- Lenovo
- M/A-COM Technology Solutions
- Mentor, a Siemens Company
- Microchip Technology Inc.
- Navitas Semiconductor
- Nexgen Power Systems
- Nexperia Germany GmbH
- Northrop Grumman Corporation
- NSWC Crane
- NXP Semiconductors
- ON Semiconductor
- Panasonic Corporation
- PN Junction Semiconductor Co., Ltd.
- Power Integrations
- Renesas
- Rohde & Schwarz GmbH & Co KG
- Rohm Semiconductor
- Samsung Semiconductor
- Silicon Works
- STAr-Edge Technologies, Inc.
- STMicroelectronics
- Sumitomo Electric Industries
- SZ DJI Technology Co., Ltd.
- Taiwan Semiconductor Mfg. Company
- Tektronix
- Texas Instruments Inc.
- The Boeing Company
- Transphorm
- U.S. Army AMRDEC
- Vishay Corporation
- VisIC Technologies
- Wolfspeed, a Cree Company
- Xi'an Semipower Electronic Technology
- Xiamen Sanan Integrated Circuit Co
- Yangtze Memory Technologies Co., Ltd

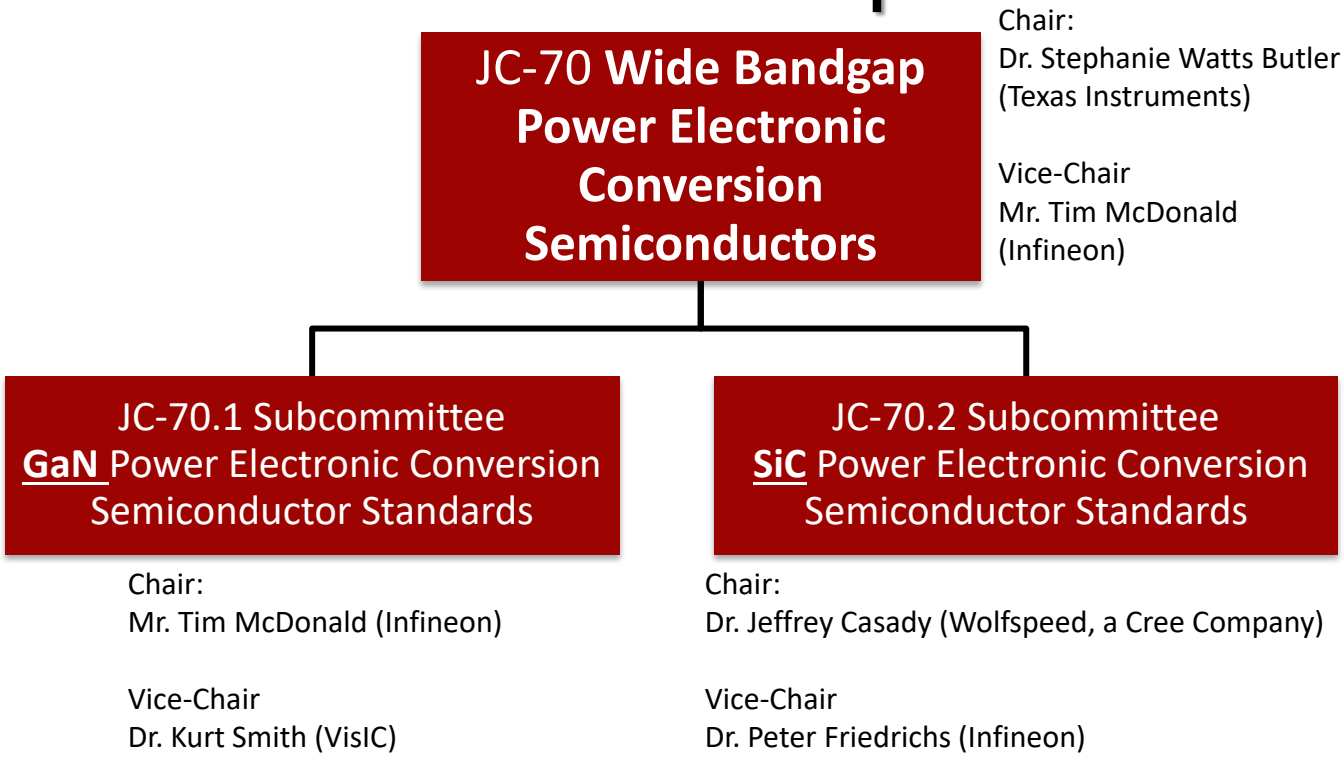
63…and still growing!

JC-70 Structure:
Wide Bandgap (GaN & SiC)



JC-70 Structure:

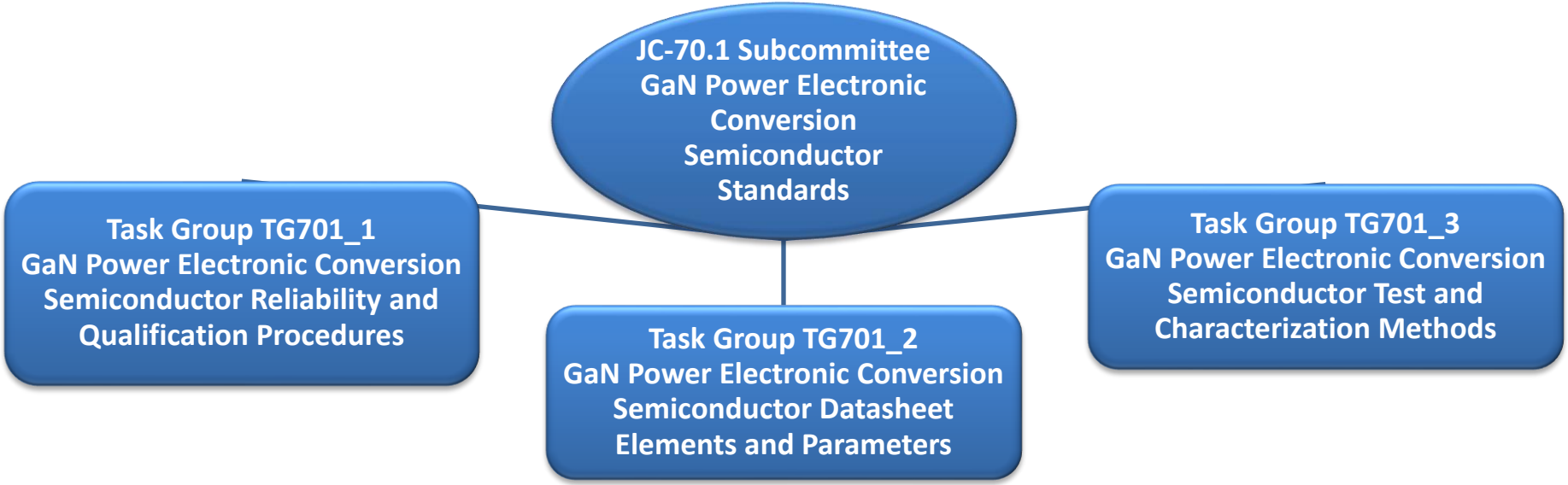
Leadership



JEDEC Committee JC-70.1 (GaN) Task Group Structure

JEDEC

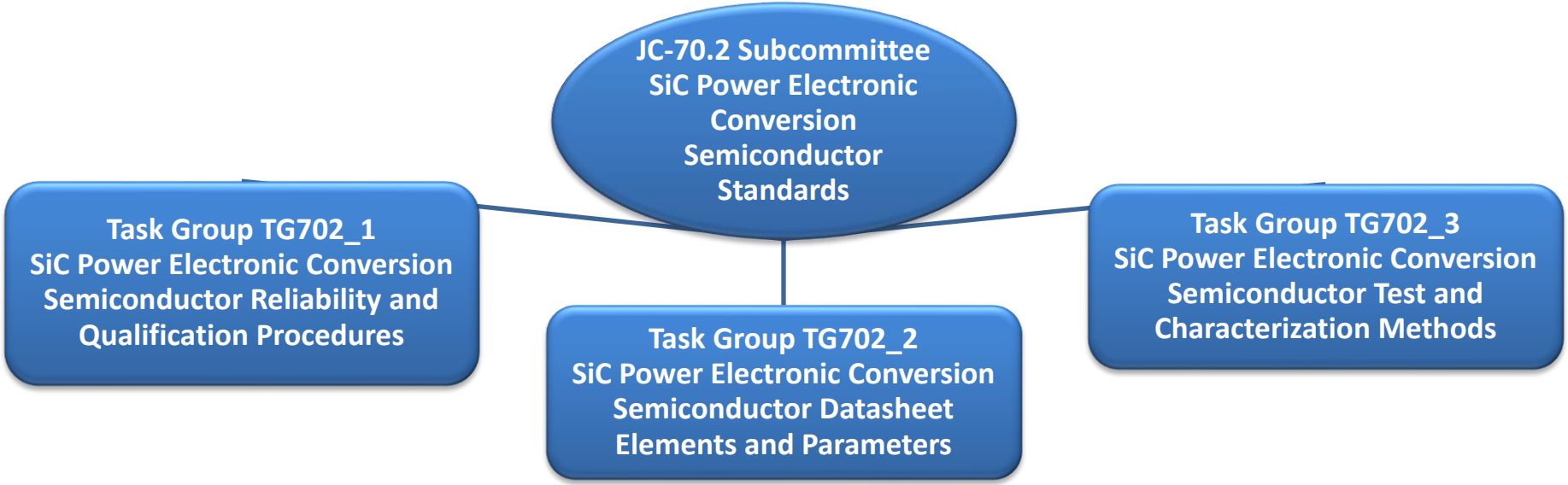
Global Standards for the Microelectronics Industry



JEDEC Committee JC-70.2 (SiC) Task Group Structure

JEDEC

Global Standards for the Microelectronics Industry



Results & Status for GaN JC-70.1

First Guideline Published January 16, 2019

- **JEP173: Dynamic On-Resistance Test Method Guidelines for GaN HEMT Based Power Conversion Devices**
  - https://www.jedec.org/standards-documents/docs/jep173

- **Address key need of user community:**
  - Method for measurement of Drain-to-Source Resistance in the ON-state ($RDS_{(ON)}$) encompassing dynamic effects
- **Dynamic effects are characteristic of GaN power FETs**
  - The value of the resulting measured $RDS_{(ON)}$ is method dependent
- **Help accelerate industry-wide adoption of GaN by ensuring consistency across the supplier base**

JEDEC Wide Bandgap Power Semiconductor Committee Publishes Guideline for Switching Reliability Evaluation Procedures for GaN Devices

February 27, 2020

ARLINGTON, Va.--(BUSINESS WIRE)--JEDEC Solid State Technology Association, the global leader in standards development for the microelectronics industry, announces the publication of JEP180: Guideline for Switching Reliability Evaluation Procedures for Gallium Nitride Power Conversion Devices. Developed by JEDEC's JC-70 Committee for Wide Bandgap Power Electronic Conversion Semiconductors, JEP180 is available for free download from the JEDEC website.

"This new guideline provides engineers a robust evaluation of switching behavior, which will further accelerate industry-wide adoption of GaN, especially in automotive and industrial markets where efficiency, power density and reliability matter the most"

Tweet this

To enable the successful adoption of GaN power transistors, both reliable operation in power conversion applications and switching lifetime need to be demonstrated. Existing tests for silicon power transistors do not necessarily validate operation under actual-use conditions of power conversion equipment and may not be applicable for GaN power transistors.

To address this need, JEP180 is intended for use by manufacturers of GaN power transistors and power conversion equipment. For the first time since the introduction of GaN power transistors, JEP180 will enable manufacturers to evaluate switching reliability of GaN power transistors and to assure their robustness at the technology level and in power conversion applications. The document provides guidelines for Switching Accelerated Life and Dynamic High-Temperature Operating-Life tests that are applicable to GaN planar enhancement-mode, depletion-mode, cascode power transistors, and integrated power solutions.

JEP180 was developed over a period of more than two years by a team of respected industry experts from leading GaN power device manufacturers.

"This new guideline provides engineers a robust evaluation of switching behavior, which will further accelerate industry-wide adoption of GaN, especially in automotive and industrial markets where efficiency, power density and reliability matter the most," said Dr. Stephanie Watts Butler, GaN technology innovation architect at Texas Instruments and the chair of JC-70.

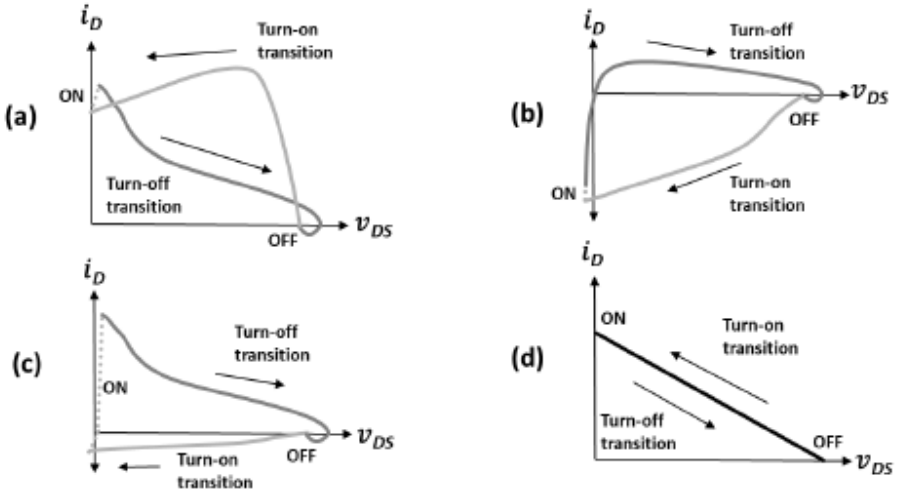
"This latest guideline covers switching reliability and helps assure successful usage of GaN devices in a wide range of applications by addressing one of the key topics identified by our committee members. We continue in our work to build a full coverage of guidelines and standards for use of both GaN and SiC devices." Tim McDonald, Senior Advisor to Infineon's CoolGaN™ program and the chair of the JC-70.1 subcommittee.

2nd Guideline Published February 2020

- **JEP180:** Guideline For Switching Reliability Evaluation Procedures For Gallium Nitride Power Conversion Devices
  - –https://www.jedec.org/standards-documents/docs/JEP180
- Guidelines for both
  - –Switching Accelerated Life
  - –Dynamic High-Temperature Operating-Life
- Procedures for capturing stresses

5.1 Switching Locus Curve

The switching locus is the trajectory of the i_D-v_{DS} waveform during a switching cycle. It is plotted by capturing both i_D and v_{DS} waveforms during a switching period, and plotting i_D vs. v_{DS} at each sampling instant [4]-[7]. There are three common types of switching experienced during switching transitions, as shown in Figure 2: hard, soft and resistive.



a) hard-switched turn-on and turn-off, e.g., high-side DUT in a buck converter with inductive storage element,

b) soft-switched ZVS-turn-on and turn-off transitions e.g., low-side DUT in a buck converter with inductive storage element,

c) switching in a resonant topology with soft-switched (ZVS) turn-on and hard-switched turn-off transitions,

d) resistive-load switching.

Proposed Items for GaN Guidelines/Standards

Presented at APEC 2019

REL
- List of Failure Mechanisms & Resulting Failure Mode (summarizing Literature)
- Offstate voltage/ temperature Reliability
- Switching Reliability
- Stress Procedures & Acceleration
- List of Failure Mechanisms & Resulting Failure Mode

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 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

Results & Status for SiC JC-70.2

Proposed Items focus for SiC Guidelines/Standards

Presented at APEC 2019

REL
- BTI
- ALT-HTRB
  - ➢GaN collaboration?
- Body Diode
- neutron radiation
- TDDB
- Corresponding Acceleration & Stress Procedure
- dV/dt
  - ➢Perhaps most difficult to address
- List of Failure Mechanisms & Resulting Failure Mode

Test
- Vth measurement
- Qg Measurement
- Short-circuit measurement

Datasheet
- TBD

Caution: Work in Progress

Proposed Items focus for SiC Guidelines/Standards

Status Update 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

Silicon Carbide threshold voltage

Presented initially at APEC 2019; updated to advanced document status at APEC 2020 by multiple task groups

Test methods influence results

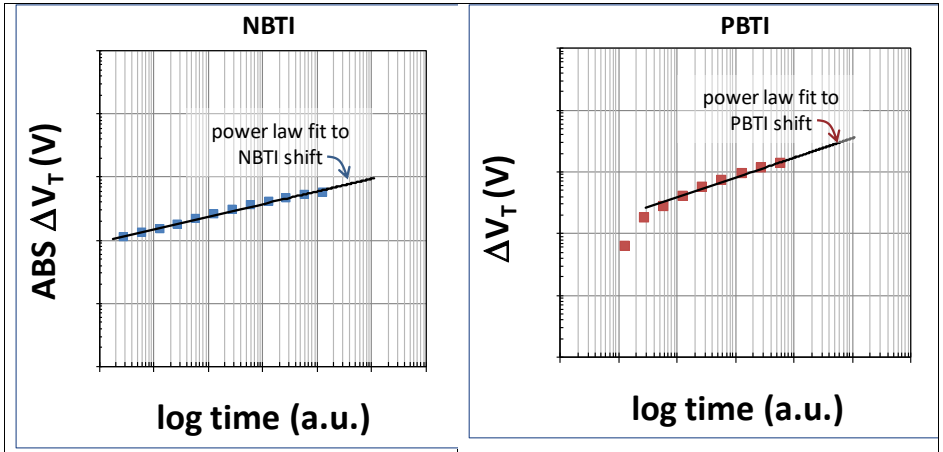


Figure 5.4. Graph showing the absolute value of the NBTI $V_{(th)}$ shift (the shift is expected to be negative) as a function of time, fit to a power law.

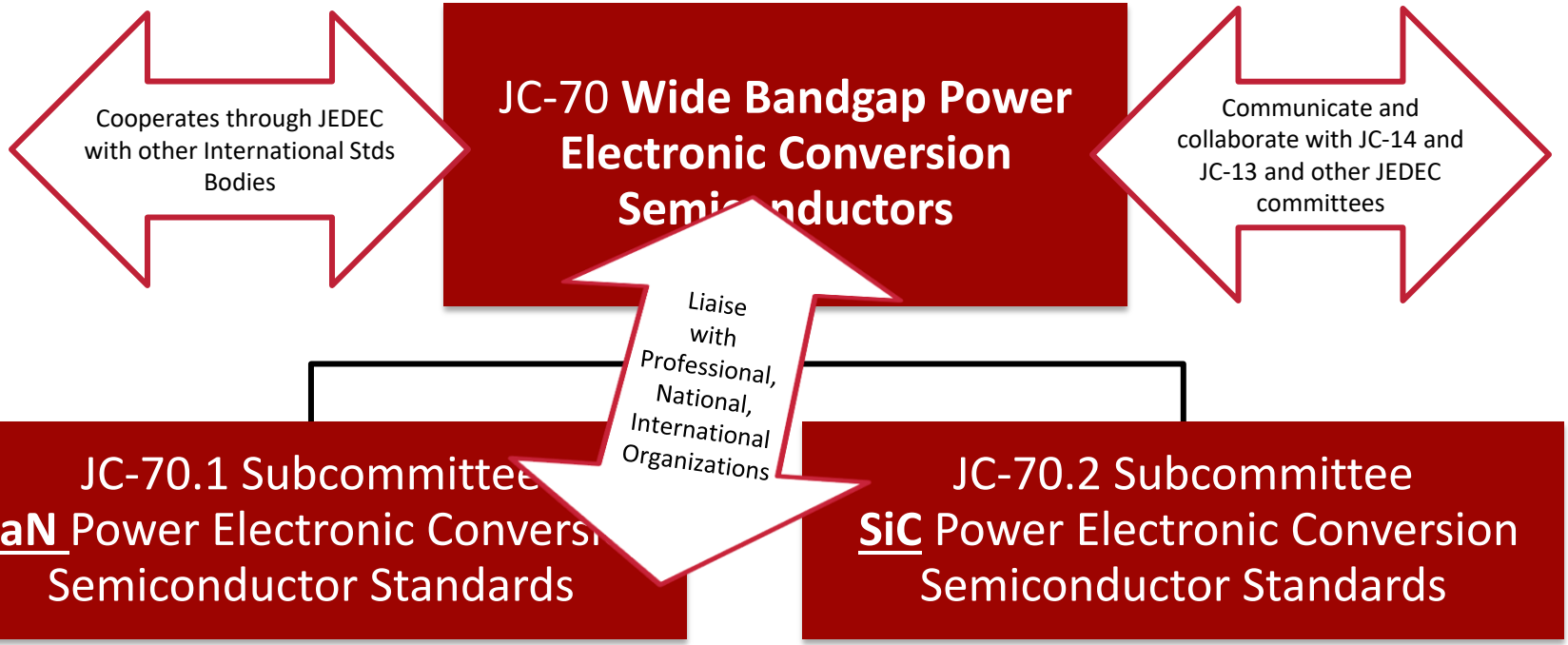
Figure 5.5. Graph showing the absolute value of the PBTI $V_{(th)}$ shift as a function of time, fit to a power law. The early time portions of $V_{(th)}$ shift do not always follow power law behavior.

S. Sabri, et al, "SiC Power Device Reliability Studies," 13th Annual SiC MOS Workshop, Aug. 2018, University of Maryland, USA.

JC-70.2 Task Group (TG) evaluations

- Example SiC topic is threshold shift, or sometimes referred to as Bias Temperature Instability (BTI)
  - Shifts with voltage, temperature and time
  - It can affect reliability if shift is too severe causing circuit failure
  - It can be reported differently in datasheets without common agreement on test procedures

JC-70 Structure:
interaction and relationships



Working with Other Organizations

- JEDEC has history of working with IEC and JEITA
- IEC: International Electrotechnical Commission
  - https://www.iec.ch/
  - MOU to enable work based upon JEP173 (Dynamic RDSon)
  - Approved to proceed to new work package

Addressing Specific Market Needs

- Wide Bandgap Ramp is occurring in Automotive
- JEDEC recognizes need for automotive standards
  - Automotive Forums held 2015/17/18/19
  - Hosted by JEITA in 2020 - *delayed*
- JC-70 actively assessing unique needs of Auto
- JC-70 in discussions with automotive related organizations

Acknowledgments

- **JEDEC Staff**
- **Mikhail Guz, JEDEC Secretary to JC-70, Consultant, IP and Technology Experts**
- **JC-70.1 Task Group Leaders**

TG701_1 (REL) Co-Chairs:
- Sameh Khalil (Infineon)
- Mark Wasilewski (ON)
- Sandeep Bahl (TI)

TG701_2 (Datasheet) Co-Chairs
- Peter Di Maso (GaNSystems)
- Nick Fichtenbaum (Navitas)

TG701_3 (Test) Co-Chairs:
- Deepak Veereddy (Infineon)
- Jaume Roig (ON)

- **JC-70.2 Task Group Leaders**

TG702_1 (REL) Co-Chairs:
- Don Gajewski (Wolfspeed)
- Thomas Aichinger (Infineon)

TG702_2 (Datasheet) Co-Chairs
- Christian Mueller (Infineon)
- Sauvik Chowdhury (ON Semi)

TG702_3 (Test) Co-Chairs:
- Ryo Takeda (Keysight)
- Thomas Basler (Infineon)

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

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

Key Takeaways

- Document(s) status: both for GaN and SiC
- SiC & GaN Topics can be same AND different
- Exploring new markets, like Automotive
- New engagements with other organizations
- How to participate
  https://www.jedec.org/join-jedec