White Paper

"Recent History and Current Trends in Gallium-Nitride (GaN) Reliability Testing"

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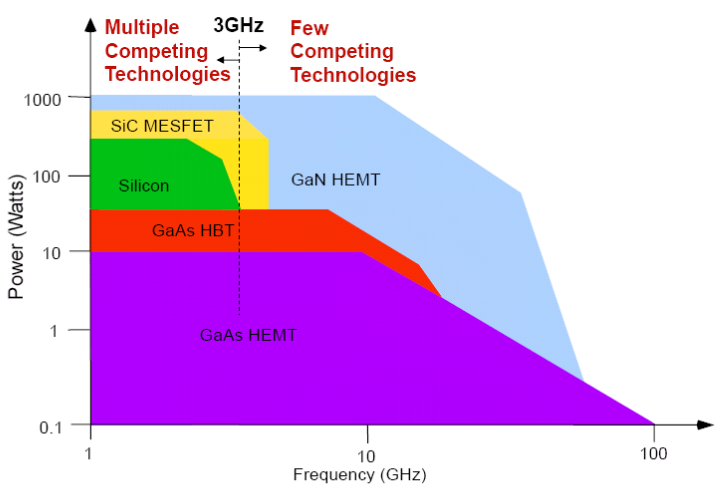
Introduction

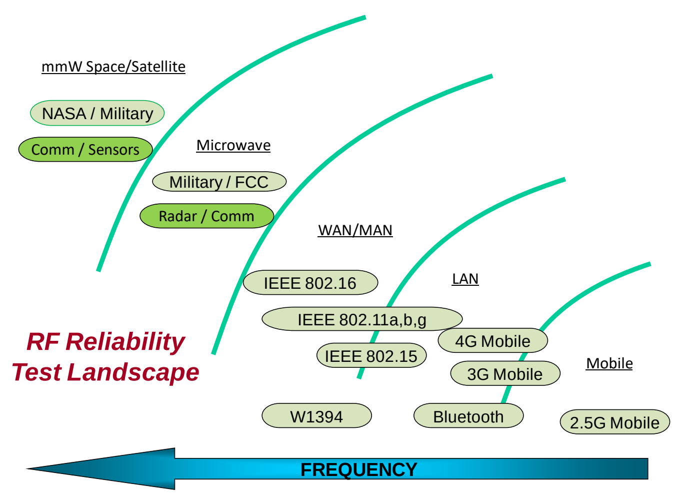
Gallium Nitride (GaN) compound-semiconductors are taking front and center stage in almost every electronic and electrical circuit and system being developed today. Applications for GaN are rapidly expanding to every electronic market-segment known today and “enabling” new market-segments just being imagined. Tomorrow’s light-bulb, wireless LAN, AC-motor electronic starter, and numerous electronic-sensors will be implemented with GaN semiconductor devices. Light emitting diodes (LEDs), Cellular base-station transistors, DC and AC power-conversion diodes, and industrial-control integrated-circuit chips will all be framed around GaN. From space and military systems to consumer electronics, GaN is going to be the essential technology of choice. The GaN semiconductor market-segment is forecasted to grow at a CAGR of 68% to 1.75 billion dollars over the next decade.

If GaN could out-run a speeding bullet, out-power a locomotive, and leap a tall building in a single bound it was demonstrated using an Accel-RF Instruments platform product. As the industry standard in reliability testing of GaN transistors and monolithic microwave integrated-circuits (MMIC), as well as all other compound-semiconductor devices, Accel-RF is the benchmark of test equipment for RF High Temperature Operating Life (HTOL) performance measurement. Accel-RF’s platform solution is the only available integrated instrument that can demonstrate a compliance with aerospace, government, and commercial RF semiconductor life-test standards. Accel-RF’s customers receive maximum return-on-investment (ROI) through reduced development time, demonstrated reliability assessment, and increased “permission-to-play” market opportunities.

Measured Reliability Performance – Why Should We Care?

Today’s wireless systems are enabled by innovative compound semiconductor devices i.e. Gallium-Arsenide (GaAs), Silicon-Germanium (SiGe), Gallium-Nitride (GaN), Silicon-Carbide (SiC), Indium-Phosphide (InP), and RF integrated circuits (RFICs), capable of transmitting and receiving RF signals in an increasingly hostile physical and electronic environment. As RF systems continually push for higher frequency, higher efficiency, and wider frequency-bandwidth applications, the capability to perform RF reliability testing on devices and integrated circuits (MMICs) will dramatically impact technology insertion time-lines, industry test-standards, and product manufacturing quality and reliability assurance (QRA) programs. System reliability concerns will drive execution strategies for future military sensor, electronic warfare, cellular mobility, HVAC power systems, and wireless communication systems.





Gallium-Nitride – The Super Transistor

The technology that drives the key performance metrics of any wireless system is the semiconductor device technology used as the RF signal amplification transistors. There appear to be several factors associated with semiconductor technology that may limit its implementation:

1. insufficient performance-level of the device or technology (specifically in terms of power-density per area and RF power-added efficiency),
2. inconsistent performance levels due to immature semiconductor device manufacturing processes,
3. lack of qualified/numerous sources of supply,
4. lack of demonstrated long-term device reliability, and
5. high total cost of procurement.

At frequencies above 10 GHz, the Gallium-Arsenide (GaAs) Field Effect Transistor (FET) has been the mainstay semiconductor device technology for solid-state power amplifiers (SSPAs) over the last twenty years. The development of Gallium-Arsenide semiconductor device manufacturing technology and wide-spread implementation of GaAs-based products into today's communication systems has given impetus to the development of other compound-semiconductor device technologies. The primary alternative device technologies that offer various advantages over GaAs technology are: silicon-germanium (SiGe), indium-phosphide (InP), silicon-carbide (SiC), and gallium-nitride (GaN). Each of these technologies has advantages in one or more of the 5 key factors listed above particular to the material properties associated with the semiconductors used in the compound. However, for SSPA applications high power-density material is preferred. The compound semiconductors that offer a significant increase in power density over GaAs devices are SiC and GaN.

Table 1: Comparison of GaN to other Semiconductor Materials

Parameter of Merit	Si	GaAS	GaN	SiC
Bandgap (eV) @ 300^{O}C	1.1	1.4	3.4	2.9
Electron Mobility (cm^2/V-sec) @ RT	1400	8500	1000	600
Hole Mobility (cm^2/V-sec) @ RT	600	400	30	40
Saturation Velocity (cm/sec), 10^7	1	2	2.5	2
Breakdown Field (V/cm), 10^6	0.3	0.4	>5	4
Thermal Conductivity (W/cm)	1.5	0.5	1.5	5
Relative Dielectric constant	11.8	12.8	9.0	10.0
Melting Point (^{O}K)	1690	1510	>1700	>2100

GaN technology has higher carrier-mobility, higher electron peak velocity, and the ability to incorporate complex (heterojunction) geometries. The primary advantage it has over SiC is its ability to operate at higher frequencies with optimized performance from employing heterostructure geometries.

Heterostructure GaN devices can therefore achieve the attributes of power-density and power-added efficiency at much higher frequencies (>>10GHz) than corresponding SiC devices. Table 1 shows a list of the benefits of GaN material over other semiconductor materials [7].

Many issues have been investigated during the development of GaAs device technology that allow for leveraging knowledge to the implementation of SiC and GaN. GaAs development has created breakthroughs in areas of processing equipment, material characterization techniques and equipment, and computer-aided design and modeling software [1]. Therefore, GaN and SiC maturation will be significantly accelerated because of prior GaAs technology successes. However, because the base material is different, most of the processes that have been painstakingly developed over the last thirty years for GaAs semiconductors must be modified in order to be effective with SiC and GaN.

As can be seen in table 1, GaN transistors will have a unique combination of high bandgap energy (high current density), high breakdown electric-field, and good thermal conductivity. This combination of characteristics offers an enormous opportunity for application to high-frequency, high-power semiconductor devices.

Figure 1 shows an indication of the significant impact GaN material will have on microwave power performance for solid state transistors.

Figure 1: Comparison of GaN to Other Semiconductors for Microwave FOMs (Series 1 & 2)

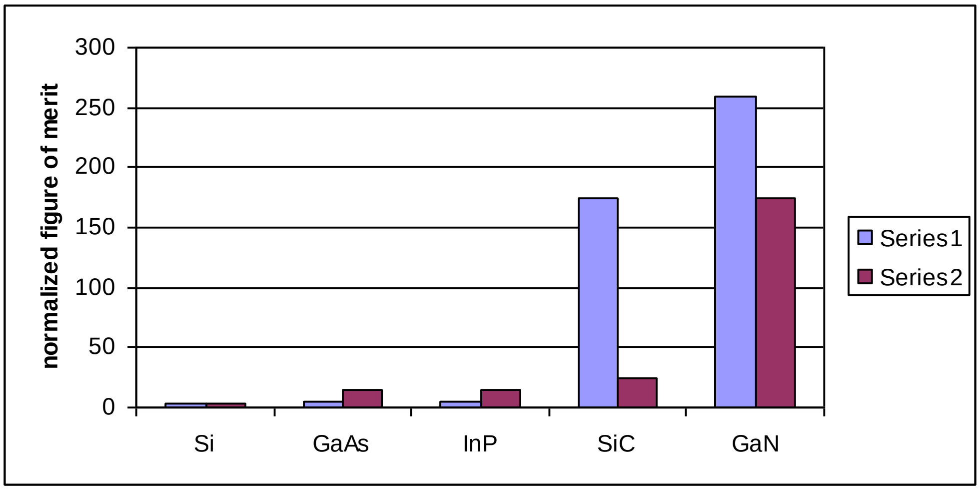


Figure 1 is the comparison of GaN material to the other semiconductor materials of table 2 for two major microwave transistor figures of merit (FOM). The Series1 FOM is the square of the product of the electron saturation velocity and the critical breakdown field $(VsatEc)^2$, the Series2 FOM is the square of the product of the low field electron velocity and the critical breakdown field $(uEc)^2$.

GaN RF power devices offer the opportunity for significant performance improvements over GaAs RF power devices. Some of the more important parameters of interest are:

- GaN devices are capable of sustaining high power densities. GaN devices have demonstrated levels above 10 W/mm power densities at 10 GHz. Typical GaAs power density is limited to approximately 1.5 W/mm at 10 GHz.
- GaN devices have 2.5 times the bandgap energy and 3 times higher electron saturation velocity than GaAs. This allows GaN devices to sustain two orders of magnitude higher voltage levels than GaAs. This is ideal for very high power, low-noise, high dynamic range analog and mixed-signal applications.
- GaN has a relative dielectric strength of 50 times higher than Si and GaAs. This makes it more suited to high power amplifiers with high stand-off voltage requirements.

- GaN devices should operate at extremely high temperatures (>250^{O}C). This should lead to increased reliability and new applications for RF semiconductor power devices. GaAs devices stop working around 150^{O}C.
- GaN devices have higher RF output impedances allowing them to have a greater power-bandwidth product. This makes GaN-based power amplifiers inherently wider bandwidth than GaAs amplifiers.
- GaN devices have high operating voltage levels offering a potential efficiency advantage over GaAs devices at the circuit level and subsystem level.
- GaN devices have potential benefits to allow high dynamic range receivers due to their large power capability and relatively low corresponding noise figure.

RF Reliability Test Paradigm: In-House Customization (Old-School)

Since historically no turnkey, commercially available RF life-test instrument existed to demonstrate technology and product reliability, the semiconductor manufacturer/user had to create a kluge of independently controlled RF, DC, and thermal instruments. Figure 2 shows a collage of non-integrated test benches required to carry out reliability tests. In addition, the entity had to develop their own test integration methodology and independent means of acquiring accelerated life-test measurement results.

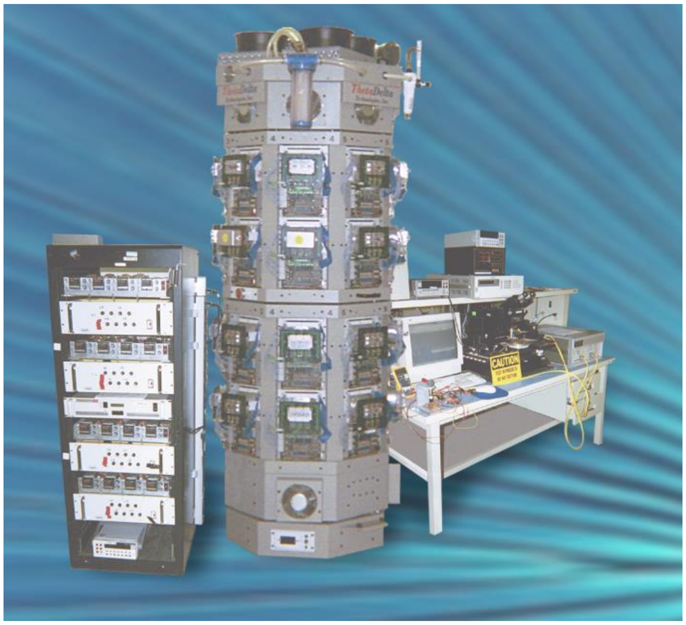


Figure 2: In-House Paradigm of Non-Integrated Test Environments

This approach requires a high level of sophistication and customization in the equipment and test data acquisition process.

To develop and maintain an in-house custom test capability, a company has to develop expertise in several key disciplines (i.e., RF, DC, thermal, test and measurement software development). They should expect continuous capital outlays to modify the equipment as new device technology is attempted. To house the various test systems required, they must set aside large areas of lab space.

Additionally, since developing special test equipment is not generally the focus of the company, reliability assurance from in-house test systems comes with long-lead times associated with developing custom test methodologies, systems, and software.

From a practical implication, companies with in-house non-integrated test environments experience cumbersome inefficiencies prone to inaccuracies in data acquisition and are more likely to expose the device to environments that will damage the sample.

Also, most in-house developed systems are performance-limited by either relatively low-frequency analog functionality or narrow frequency bandwidth and do not include in-situ RF performance measurement capability. However, as new compound semiconductor technologies are being developed for RF use, RF biased life test (RFBL) performance parameters are becoming more critical to eventual application insertion. Left with no option, most in-house test equipment users address the RF issue by extrapolating DC failure models to RF parameter degradation.

RF Reliability Test Paradigm: Commercial Turn-Key Integrated Systems (The World We Live in)

Measurement of RF "wear-out" and performance degradation in semiconductor devices requires elevated-temperature testing and parameter monitoring under signal conditions similar to actual system operation. This testing includes device stimulation with continuous wave (CW) RF, modulated RF, and/or pulsed-tone RF signals.

NASA began to address the difficulties of RF life testing in the early 1990s due to RF sub-system reliability concerns experienced on several space and development programs. Under an SBIR contract, a multiple-channel test system was developed that was compact, modular, easily configurable and reconfigurable, and software controlled and monitored – Automated Accelerated Reliability Test System or AARTS. In 1996, this turn-key test system won support from other commercial semiconductor laboratories for performing automated RF accelerated life testing.

Features of the commercial version included semi-automated recording and storing of data, calibration sequencing, and device-under-test automated graceful shutdown. By 1999, the test system had found an application in commercial fabrication lines. Its capabilities included full automation for bias, temperature, and RF-level stimulus and control, and the integration of an off-the-shelf semiconductor parametric analyzer to allow dynamic performance measurement capability. It was also network-compatible to allow remote monitoring, data presentation, reconfiguration, and special test sequencing. Figure 3 depicts the integration and size benefits realized from the turn-key commercially available system.

Figure 3: Turn-Key Paradigm - Commercial System of Integrated Test Environments

RF Reliability Test Paradigm: High Capacity RF Biased Life (RFBL) Test System (A Brave New World)

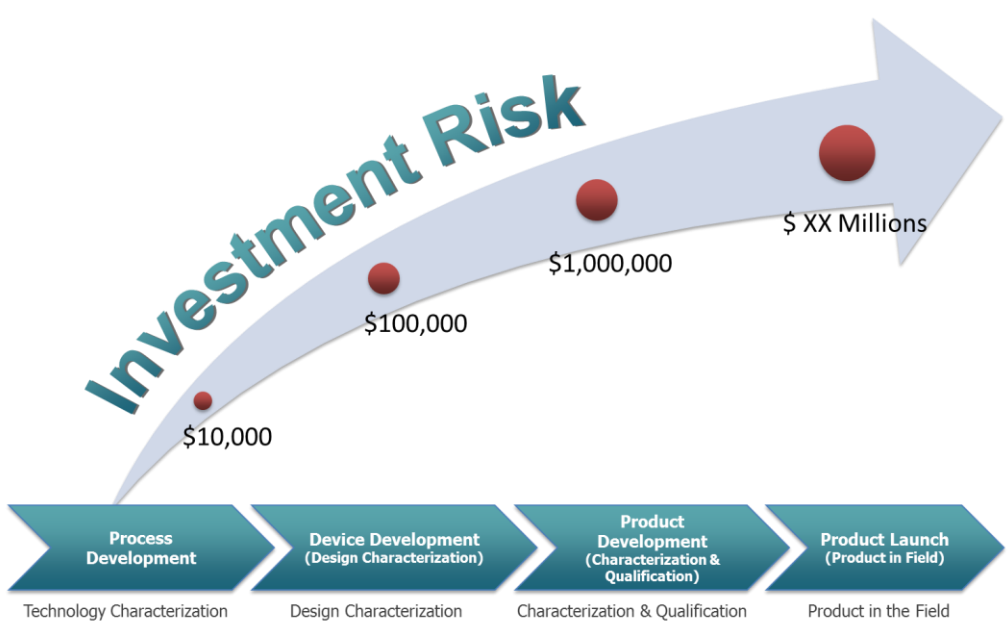
Many years ago, device-level manufacturers only provided system-level engineers with testing information detailing the rate-of-failure due to device catastrophic event failure or wear-out. Traditionally the rate was specified in failures-in-one-thousand hours or FIT-rate, sometimes expressed in kilo-fits (kfits). However, as the end-user community realized, catastrophic wear-out of a device usually does not determine system-level reliability. Instead system failure is determined by device degradation, which hinders the ability of the system to perform a required function under stated conditions for a stated period of time, and thus results in an effective, if not actual, system failure.

Two fundamental problems plague companies developing new products and technologies for competitive markets;

1) unexpected costs and schedule slip in product time-to-market, and
2) failure of the product to reliably perform its intended purpose in the customer's (end-user's) application.

The cost in dollars and in company reputation is much less when potential performance reliability issues are found and mitigated early in the production-cycle, see Figure 4. The critical performance monitors for potential product failure must be identified and mitigated so that the end product is able to achieve the advertised expected useful-life in the user's intended application. In order to measure the critical indicators for product failures, test instruments must precisely control the stimulus and measurement of the thermal and electrical environments to the device being tested. Further, the test instrument must remove the stress such that the failed or degraded device is able to be analyzed for accurate failure mechanism causes. Excessive test damage makes forensic analysis much more difficult if not impossible.

Figure 4: New Technology Investment Risk Levels



How to spend less time and dollars in the development and quality assurance phases and consequently reduce time to the sales phase of the new technology is the best path for maximizing ROI, i.e., getting to market first and being able to leverage the best price point.

A turn-key test solution, providing accurate test results that can be correlated through the entire development life-cycle saves a tremendous amount of time within and across organizations. Figure 5 gives an indication of the typical investment ROI cycle for product/technology development.

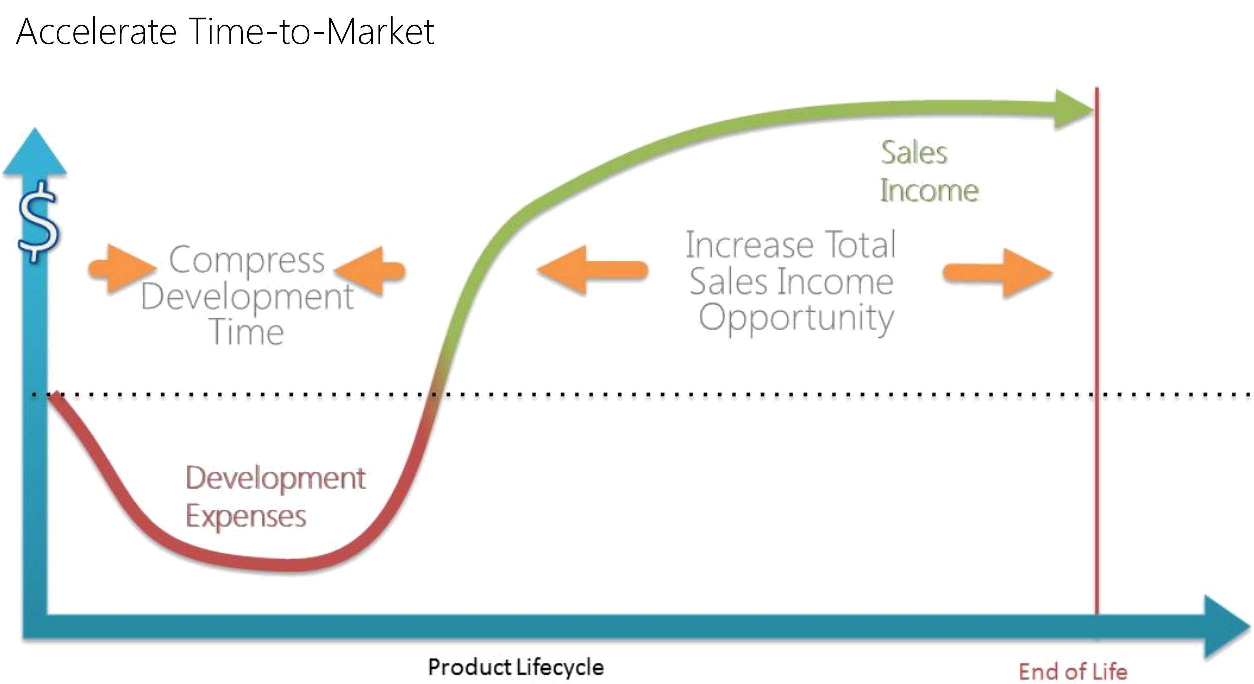


Figure 5: New Technology Time-to-Market Acceleration Impact on ROI

Because device manufacturers provided only catastrophic-event test data, truly accurate system reliability based on device performance-degradation rates was ignored. As a result, a gap existed between device degradation performance and its effect on system reliability assurance. To bridge the gap between device life testing and system reliability assurance, device performance limits have been suggested that more accurately reflect expected system functionality.

At the start, DC parametric changes with age were used for system reliability prediction based on device performance degradation. This was probably due to the fact that DC stimuli are easy to generate, are already required to operate the device, and off-the-shelf DC measurement instruments existed that were affordable and reusable from device type to device type.

In most commercial wireless market segments, RF Biased Life (RFBL) test programs will be implemented to supersede DC High Temperature Operating Life (DC-HTOL). RFBL is desired because it is seen as providing a “superset” of aging conditions. RFBL and DC-HTOL are considered exclusive test methods in the commercial QRA regime. For example, if RFBL is performed, then no other DC- HTOL test will be required. If we define traditional HTOL as a DC test and RFBL as the RF counterpart, then it really becomes a choice for which test best represents field stresses. For some parts with simple architectures, DC stress may adequately represent field conditions. In other cases, RF power may be necessary to truly exercise the product.

Reliability and Quality Assurance Trends

Wide band-gap semiconductors, such as silicon-carbide (SiC) and gallium-nitride (GaN), offer many device, component, and system-level benefits over traditional silicon (Si) and gallium-arsenide (GaAs) semiconductors for use in RF and microwave systems and specifically solid-state power amplifiers (SSPAs). GaN devices can achieve 10 times the power density of GaAs devices at microwave and millimeter-wave frequencies. GaN transistors will have a unique combination of high-current density, high breakdown electric-field, and good thermal conductivity. This combination of characteristics offers an enormous opportunity for applications to high-frequency, high-power semiconductor devices.

As stated in this paper, GaN device technology is maturing and long-term reliability issues are being addressed. As progress continues in these areas significant industry guidelines for consistent and meaningful qualification and reliability-assurance test methodologies need to be developed and accepted. Without development and adoption of these guidelines, procurement of hi-rel or space qualified GaN devices will require extended delivery schedules with prohibitive financial impact [1].

Reliability assessment and assurance of each step in the development of GaN RF power semiconductors will lag behind performance drivers for higher levels of performance.

Since GaN is still evolving and many planed applications are yet to be entered, the existing trend in product reliability assurance is to perform RF Biased Burn-In (RFBI) test programs on all or a large "acceptable quality level (AQL)" for field-deliverables.

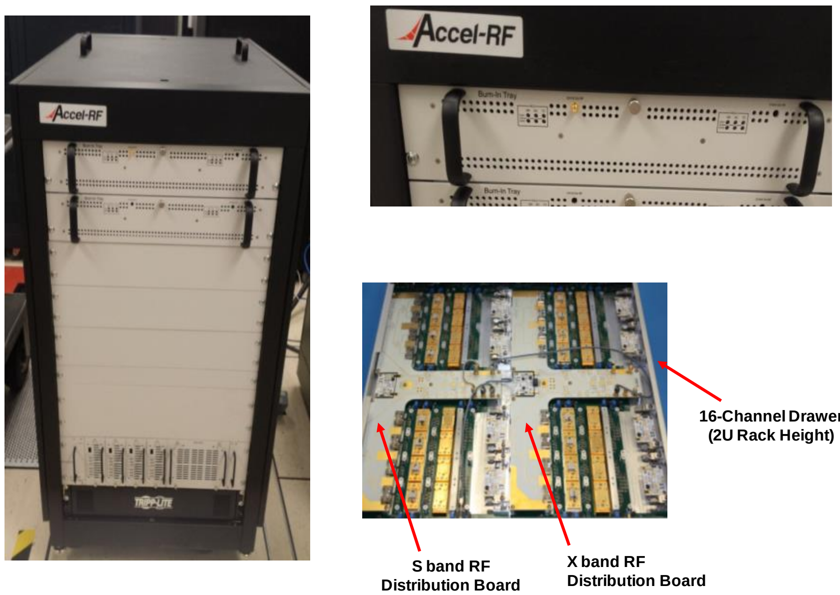
RFBI practices will be used for the foreseeable future of several years as WBG technology matures. This will have a practical implication to remove outliers and manufacturing-defect parts before failing in the field. Table 6 below gives a demarcation breakout for the device performance levels that will drive the requirements of reliability and burn-in test instruments to be used in these test campaigns. At device power levels exceeding 50 watts of dissipation most multi-device burn-in systems will need liquid or closed-loop refrigeration capability in order to maintain desired baseplate temperatures on the device-under-test and also in the system.

Table 6: Summary of RF Biased Burn-In Market Segmented Device Requirements

RF Performance Metric	DC Pdiss (W)	Application
<2W RF Output Power (CW)	3-6	Cell Phone / Wireless
5W to 10W RF Output Power (CW)	12-30	Phased Arrays / Sensors / Instrumentation
25W – 60W RF Output Power (CW)	60-130	Telecom Base Station
75W – 125W RF Output Power (CW)	160-260	Radar and Communication transmitters
>200W RF-Pulsed Output Power	200-400	Radar transmitters / Industrial

Instruments that are capable of RFBL measurement must have multiple channel capacity to handle the large aggregate number of devices to be tested. Typically, the number of devices in a single burn-in test scenario is 77 or more, including up to several hundred. Accel-RF Corporation offers an 80-Channel RF Bias Burn-In (RFBI) System. The system architecture is derived from the highly developed and fieldproven measurement platform product, AARTS. Accel-RF has supplied AARTS reliability systems to top-tier semiconductor manufactures for over 12 years, and more recently, has supplied equipment to most of the contractors participating in the DARPA wide-band-gap (WBG) semiconductor initiative and the follow-on Title III Program.

Figure 7: Accel-RF's 80-Channel RFBI System Modular Concept

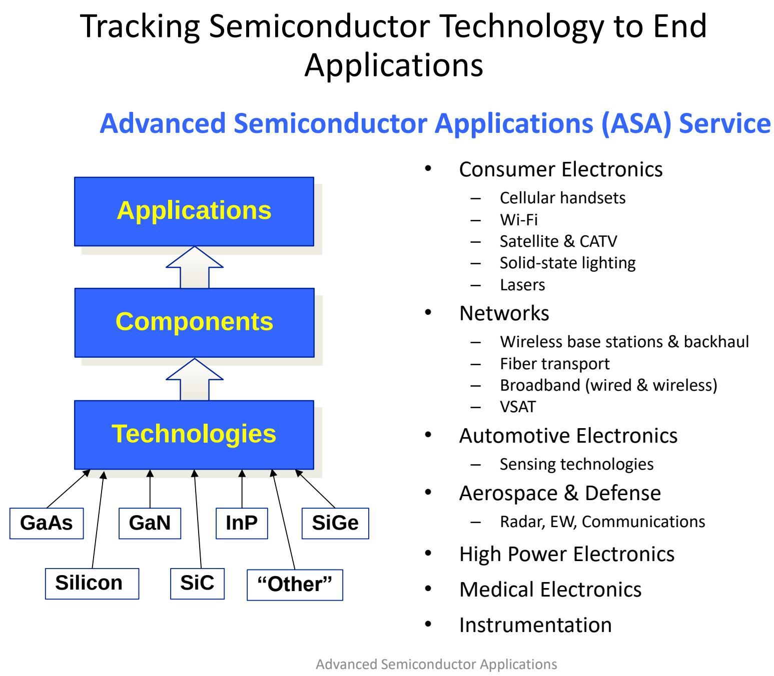


RFBL systems must deliver an unbeatable combination of advantages over a wide range of RF frequencies and power levels. Accel-RF's **Automated Multi-Channel RF-Biased Burn-In Test System** is a turnkey system that incorporates all of the capability needed for accelerated-aging and parametric testing of RF semiconductor devices. The system includes a powerful software operating system that supports data acquisition, storage, and presentation. For GaN implementation and quality assurance the use of RFBL testing will accelerate product time-to-market, saving many months of product development.

Figure 8: Multi-Channel Burn-In Drawer

Application-Specific Performance Characterization

Characterization of performance specifically required for advanced semiconductor applications (ASA) allows measurement of critical parametrics needed for that service. These performance characteristics may then be used for RF-HTOL burn-in/reliability studies, performance-degradation studies, environmental parameter-variation analysis, or for automated functional-test measurement.



For ASA measurement characterization a standalone integral software and hardware platform capable of functioning as an independent single-channel or virtual multi-channel characterization test subsystem would be ideal. In addition, if the platform was able to be USB controlled to provide temperature stimulus and control, RF-signal stimulus and control, and bias stimulus and control to a device-under-test (DUT) then the instrument would be a self-contained virtual instrument. Adding capability to stimulate and measure pulsed DC and RF signals would be necessary for many of the ASA services being considered.

A standalone integral platform will allow bench-top functional characterization of technology standard evaluation circuits (SECs) and application-specific devices to be carried out efficiently and effectively. A typical RF characterization platform instrument is shown in the figure to the right.

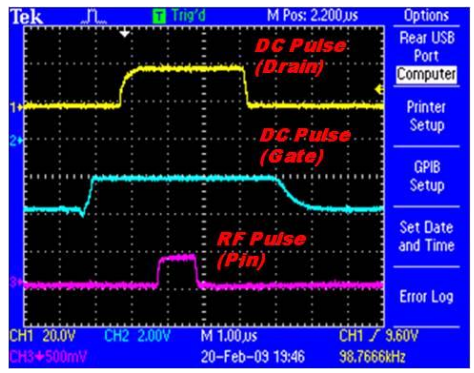
The RF Characterization Platform is designed to support easy implementation of very generic step-stress stimuli, including DC and RF bias stress variations as well as temperature stress variations. The fact that any number of test sequences and stimulus definitions may be arbitrarily defined opens a world of test methodologies previously unavailable in a single test system platform. The following examples give only a small sampling of the myriad of test scenarios that can be accomplished quickly and consistently with the Accel RF Characterization Platform.

1. Step-Stress Testing

Step-Stress stimulus is useful for a variety of purposes. Specifically, the JEDEC JEP118 standard suggests a methodology for determining the upper temperature in a 3-temperature life test. Further, step-stress testing may be used to develop accelerated-life testing algorithms and RFBL paradigms.

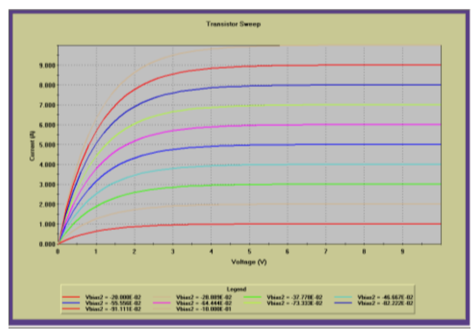
2. Infra-Red (IR) Thermal Characterization while under RF Drive

Determining an accurate Channel-Temperature for a semiconductor device is an important step in characterizing product reliability. Typically, the measurement setup, data acquisition, and device test fixture are a challenge to implement. The RF Characterization Platform, when used in conjunction with an infrared or micro-Raman thermal imaging system, provides an elegant method for thermally characterizing a device to determine thermal-resistance and channel-temperature under DC and RF conditions.



3. DC and RF synchronized pulsing

The RF Characterization Platform's hardware and software provide an easy interface to DC power-supply bias and RF signal-source stimulus circuitry for applying synchronized pulsed signals to the DUT. This enables application-specific testing to be carried out on a bench-top or custom location without the need for external cables or modulation equipment.

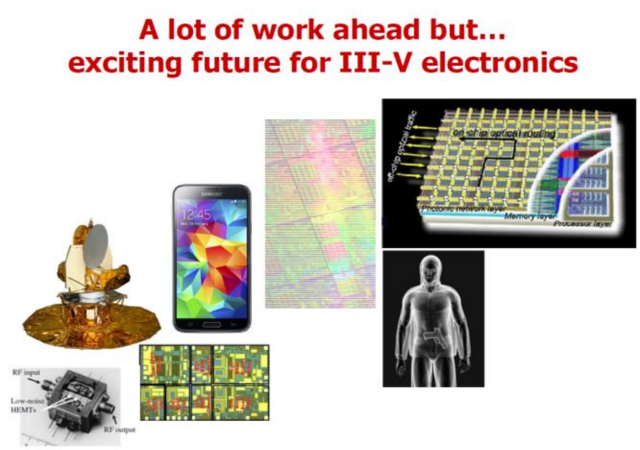


4. Semiconductor Parameter Analyzer (SPA) support

A Semiconductor Parameter Analyzer (SPA) is useful for observing performance degradation in the DC parameters of a device. The RF Characterization Platform allows one of a number of commercially available SPA models to be integrated with the test subsystem.

GaN Semiconductor Mainstream Deployment – Are We There Yet?

The next age of semiconductor evolution is poised to become a reality. Most electronic systems in use today and many more on development roadmaps will make use of advanced compound semiconductor devices. To the most part, these enabling devices will be GaN based hetero-structures. Given the various applications and environments envisioned, the capability of GaN based systems to meet high levels of reliability and long-term durability is critical.



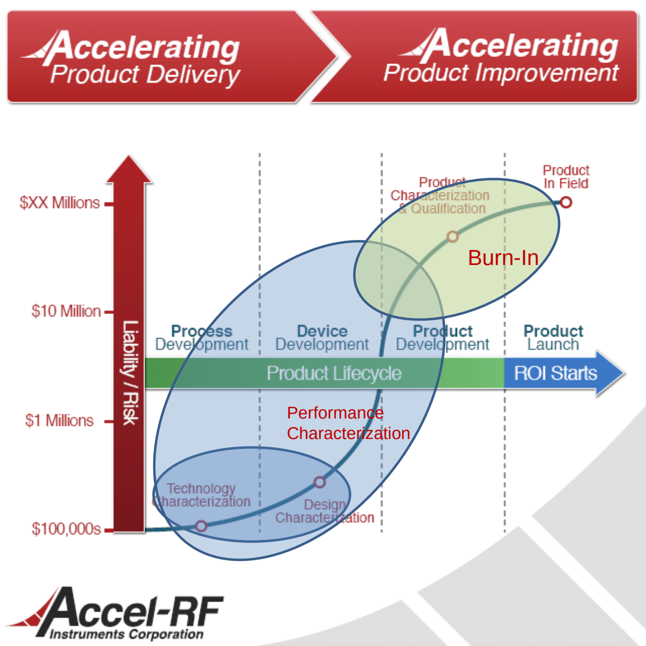
The primary industry constituents that drive specifications and test standards in the market (mobile/cellular, advanced defense, high-voltage power electronics, and digital logic) have begun the conversion of test requirements to validate this technology. Figure 9 shows a table of validation testing methodologies to be used for GaN technology insertion.

Figure 9: Summary of Current Trends in GaN Validation Testing

Item	Test Durations	Application
"In-Use" Test Validation	4000-10000 hrs	**Reliability Validation**
Burn-In Screening & Qualification	96-240 hrs	**Deliverable Part Screen**
RF-Biased HTOL	24-68 hrs	**Process Validation / Part Screen**
Advanced Semiconductor Application (ASA) Functional Validation	1-12 hrs	**"Functional" Validation (Digital Control & mulit I/O signals)**

Mapping test requirements from figure 9 on to the standard product development life-cycle chart we can see a segmented but complete coverage of all aspects of the quality and reliability continuum.

Figure 10: Product Development Test Map



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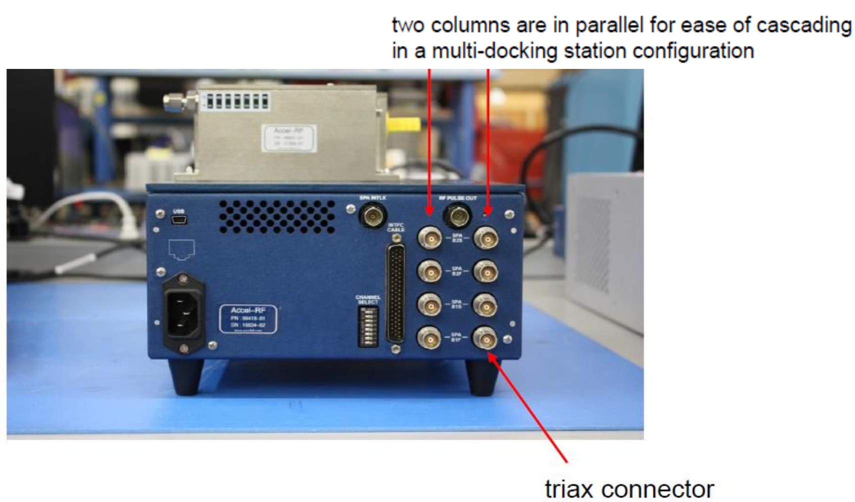
Options for Raytheon to Upgrade Existing Capabilities

Option 1: Pulsed RF and DC testing capability.

Item No.	*P/N and Description*	*Features*	*Unit Price*
1.A	*P/N: 99418-01* *RF Test Platform with virtual system cascadable network and USB controller.*	*RF Test Characterization Platform (Used with SMART Fixture P/N:97385-01 or 97390-01)* • *Includes embedded control board for interfacing to external power supplies, thermal controller, and RF source.* • *Semiconductor Parametric Analyzer (SPA) interface with 2-Bias Supply connection and Kelvin sensing at DUT.* • *Includes individually settable address and USB control interface.* • *Software definable test paradigm and parameter monitoring.*	*$3,495.00*
1.B	*AARTS LIFETEST Software with USB Controller*	• *LIFETEST Software Code Version 6.1 for use with P/N 99418-01 Test Platform and P/N 97390-01 SMART Test Fixture.* *Includes documentation*	*$1,995.00* *($1,995.00)*
2.	*P/N: 97390-01* *Independent SMART-Fixture for device DC/RF/Thermal Characterization*	*Integral Device Under Test (DUT) Fixture for thermal/RF/DC performance characterization and evaluation.* • *Includes embedded control board for interfacing to external power supplies, thermal controller, and RF source.* • *Includes Programmable DC and RF pulse control circuit.* • *Internal heater for elevated temperature measurement capability. Baseplate temperature range to 250ºC.* • *Thermo-couple monitor under DUT location used for on-board measurement and control.* • *Secondary thermocouple monitor on DUT heater-block surface with external meter connectivity.* • *Safety-interlock circuit for over-temperature setting and fail-safe.* • *DUT package "easy-mount" system for quick and easy device insertion and removal.* • *DUT package adapter-plate mounting system for quick change of DUT package type.* • *Embedded RF input and output networks for routing of RF and DC signals to DUT package leads.* • *Frequency range to 16GHz with higher frequency coverage available (consult Accel-RF)*	*$6,495.00*

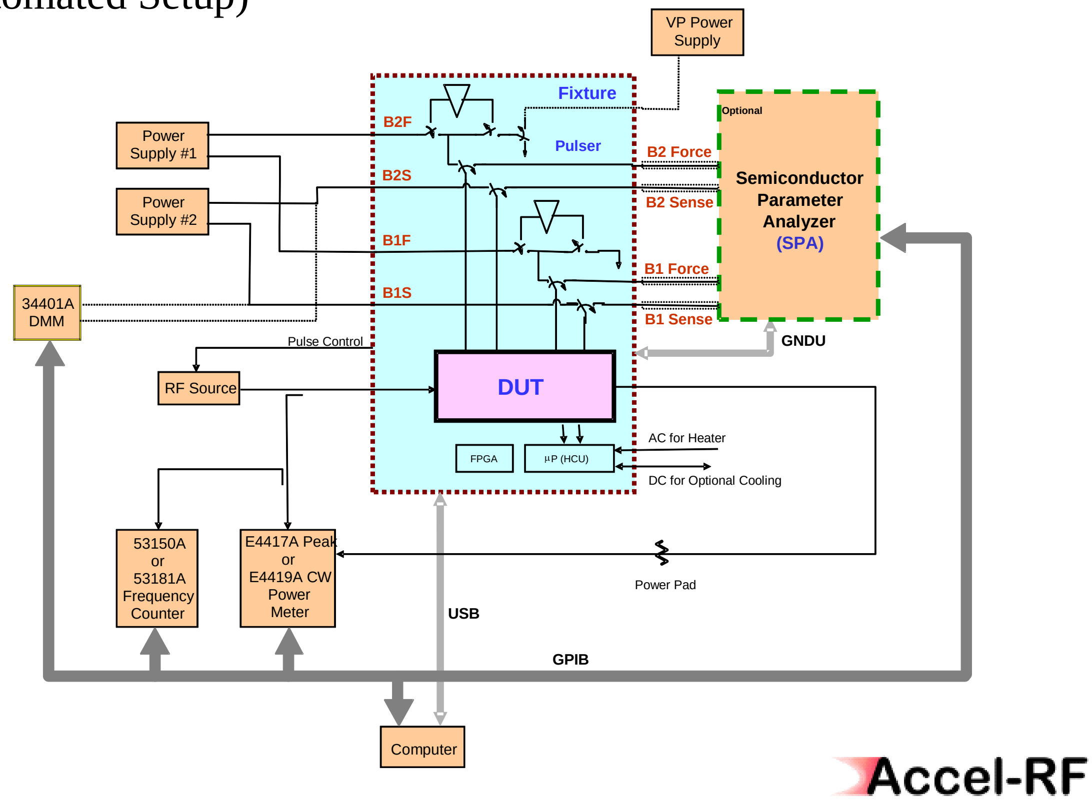


Option 1A: Add Software Controlled DC Power Supply for automated bias control (CW and Pulsed)

3	P/N 99103-03 2-Channel DC Power Supply	AARTS Power Control Unit (PCUHCU) • Power Control Unit for 2-channels of dual power supplies for independent automated bias control. Bias1 (Drain/Collector) to 60W per channel. Bias2 (Gate/Base) to 4W per channel. See detailed specifications in appendix. • Chassis capable of rack-mount of benchtop environment equipped with front-loading modules. • Includes external cable for interfacing to Characterization Docking Stations Alternate power ratings and number of channels available upon request.	*$15,995.00*

Typical Application Block Diagram

Accel-RF Smart Fixture Test Characterization (Automated Setup)



Note Option 1A, automated power supply, replaces DMM and power supplies. Accel-RF will be able to supply all RF equipment if desired.

Option 2: Upgrade Existing Raytheon AARTS for new SMART Fixture capability. Include new DUT Chambers with upgraded cooling capability.

Option 2 Pricing Table

Item No.	Description	Features	Price
1.	Upgrade to: Model AARTS RF10000-16	Upgrade Includes:	
		• Dual-Bay Rack, with global forced-air cooling SMART Fixture DUT Chamber for 16 DUT capacity. ➢ Includes SPA integration option with use of SMART Fixture DUT. ➢ Heater control functionality localized to SMART Fixture DUT. ➢ DC Pulsing functionality localized to SMART Fixture DUT.	$18,000
		• New PC and Monitor with Microsoft Excel Software, ➢ 2U Rack Mount computer with GPIB card, OS software, ➢ AARTS software upgrade, and dual hard drives ➢ Network Capability.	$4,995
		• (16) SMART Fixtures configured for two-bias supplies. DUT fixtures are capable of multiple package-type mounting configurations. DUT Fixture.	$57,500
		• Shipment of system to Accel-RF and back to Raytheon. ➢ Includes crate and transportation for air-ride transit.	$3,600
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		• LifeTest Software Version 5.1 with Automated Test Sequencing Capability and Aggregate Analysis Feature,	Included
		• Verify and repair but not replacement of (2) Power Control Units for 16-channels of dual power supplies for independent automated bias control. Power supply is 60W per device Drain bias (see specification table).	Included
		• Verify and repair but not replacement of (1) sixteen channel RF Distribution Unit with 0.9 GHz to 10 GHz bandwidth. Automated RF level and frequency control, and automatic RF calibration software. Delivers up to +15 dBm RF input drive to each DUT without the solid state power amplifier option.	Included
		• Verify and repair but not replacement of (1) Power Distribution Unit for mains input power distribution and individual circuit breaker switching (mains power is assumed 208VAC, 60Hz, 3-Phase, 5-wire, Wye-configuration, 40A).	Included
		• Verify and Repair all interconnection-harnesses and cables	Included
		• Update Software and Hardware Documentation.	Included
		Total	**$84,095**