

Next Generation Power Discretes

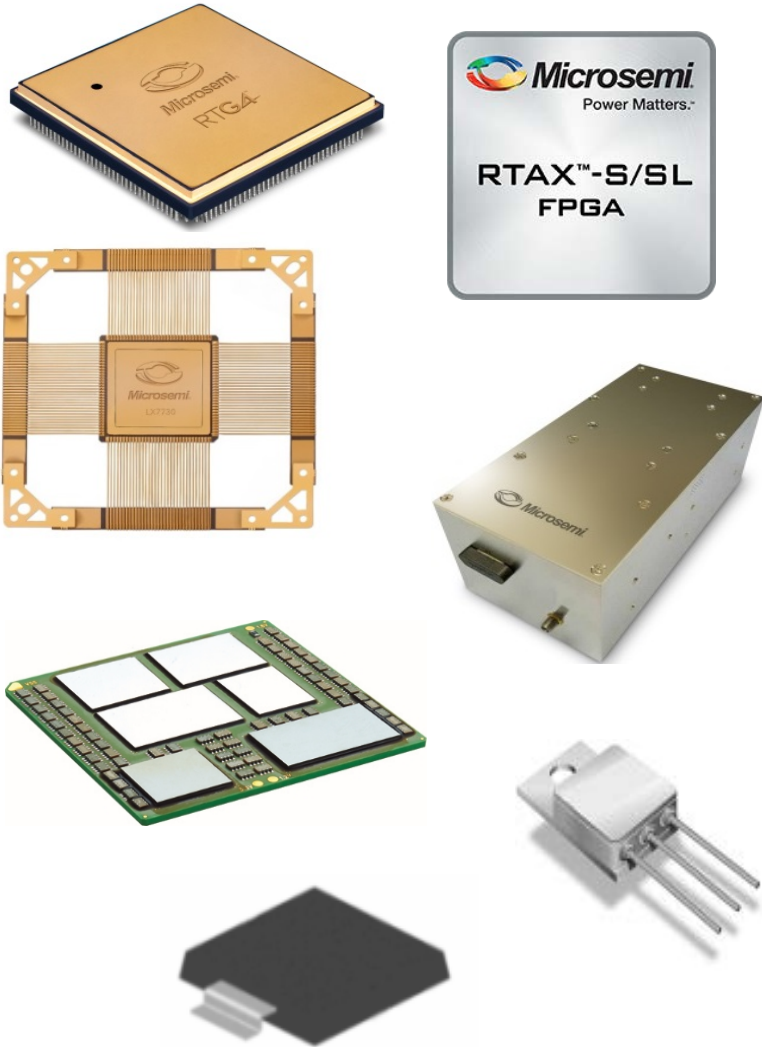
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Company Overview



- Leading-Edge Semiconductor Solutions Differentiated by:
 - Performance
 - Reliability
 - Security
 - Power
- Solid Financial Foundation
 - FY2016 Revenue: \$1.6B
 - 4800 employees today
- Major Focus Products
 - FPGA and ASIC
 - Timing and OTN
 - Mixed-Signal and RF
 - Switches and PHYS
 - Storage Controllers
 - Discretes and integrated power solutions

Microsemi Space Pedigree



Extensive Space Heritage

- Developing space solutions for six decades
- Proven track record of innovation, quality, and reliability

Broad Solutions Portfolio



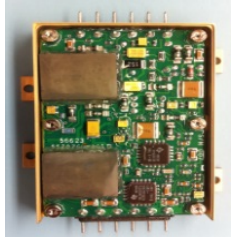
- Power, mixed-signal, and digital, for bus and payload applications

Expanding our Product Portfolio through Continuous Innovation

Partner for the Long Run

- 60 Year space heritage

Delivering Comprehensive Space Portfolio

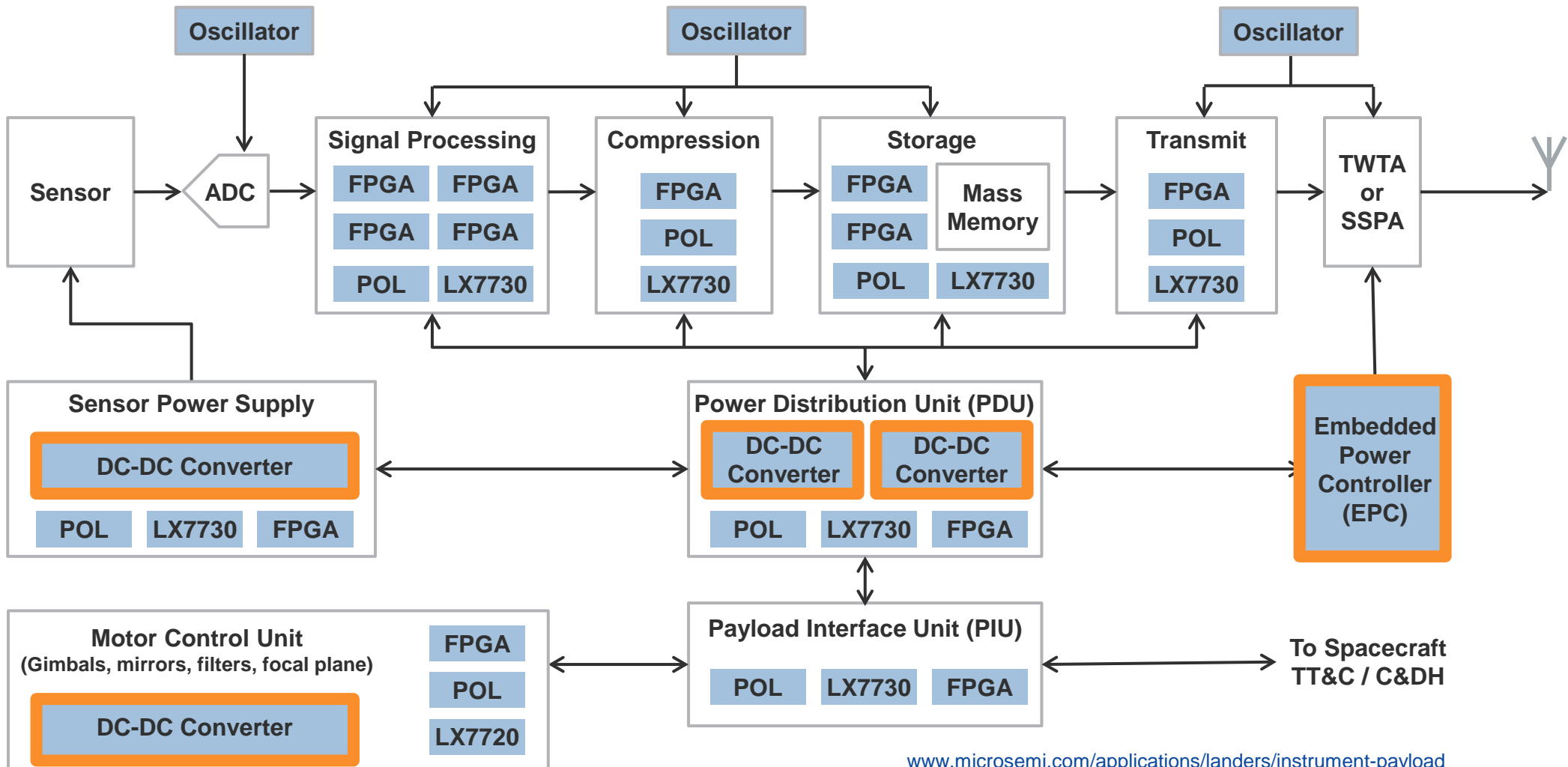
Radiation-Tolerant FPGAs	<p>High Performance, High Density, Low Power TID up to 300 Krad, SEL Immune RTG4 FPGAs up to 300 MHz and 150K LE RTProASIC3, RTAX and RTSX-SU QML Qualified</p>   
Rad-Hard Mixed Signal Integrated Circuits	<p>Telemetry and Motor Control Space System Managers High Side Drivers Regulators and PWMs Extensive Custom IC Capability</p> 
Space Qualified Oscillators	<p>Ovenized Quartz Oscillators Hybrid Voltage Controlled and Temperature Compensated Crystal Oscillators Cesium Clocks</p>  
Rad-Hard Power Solutions	<p>Rad-hard JANS Diodes, Bi-Polar Small Signal Transistors, and MOSFETs Rad-hard Isolated DC-DC Converter Modules Custom Power Supplies 2 W to > 5 KW Linear and POL Hybrids Electromechanical Relays</p>    

Agenda

- Discrete Power Product Overview
- Quality and Manufacturing Excellence
- Discrete Highlights
- New space
- What's next for power discretes?

Portfolio Breadth: Example Signal Processing Payload

- Integrated Power Solutions and Discretes



www.microsemi.com/applications/landers/instrument-payload

Space Executive Overview

- **60 years of flight heritage** on hundreds of space programs
- **Widest discrete product portfolio** of any space component manufacturer
 - **Dominate role** in Defense Logistics Agency (DLA) Qualified Manufacturers List: **>75% of total slash sheets**
 - **First company to have diodes qualified to space level** (JANS qualification) by DLA (formerly DSCC)
 - **Over 95%** of the product portfolio is **EAR99**
- **Over 30 years of space power supply** design expertise with zero in-flight failures
- Internal **packaging and radiation-hardened by design expertise** for discretes and hybrids
- **Comprehensive** High-Reliability Plastic / Non-hermetic Product Portfolio
- **Superior manufacturing and quality** system ideal for **high-reliability** applications
 - AS9100/ISO9001, MIL-PRF-38534, MIL-PRF-19500, LEAN processing
- Continue to be a **market leader in space and radiation-hardened applications**
 - Intense focus on system level solutions to meet our customers' needs today and tomorrow
 - Leverage our breadth of technology and core strengths around packaging, radiation effects and design, quality, and reliability

Investment in Customer Experience

"Increase our value to our customers to enable them to develop highly reliable systems using our products"

- **Developing strategic relationships with our customers**
 - Understand our customers and their requirements
 - Determine and improve customer relationships through feedback
- **Making information you need easier to get**
 - Improved online web experience
 - Information, structure, search, contact information, and customer portals
- **Streamlined customer communication channels**
 - Dedicated product point of contacts for specific markets (ie...Aerospace, Defense, Industrial)
- **Facilitating customer education**
 - Space Forum (North America, Europe, and India)
 - Space Brief News Letter



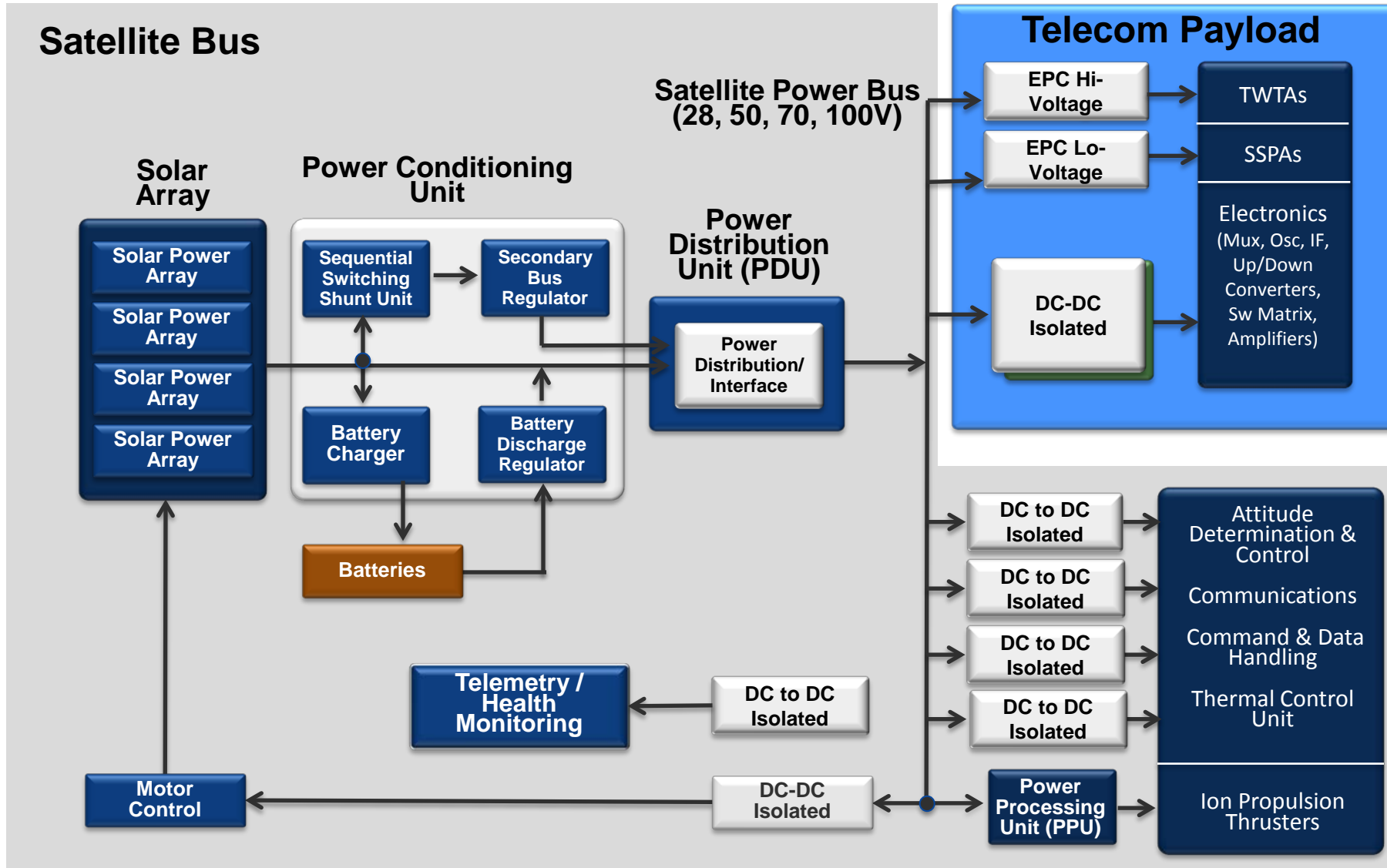
Investment in Operational Excellence

“Ship highly reliable products on time with excellent quality at optimal cost”

- **Optimizing global operations capability and developing centers of excellence**
 - Massachusetts, Ireland, and Philippines
- **Operations: Metric driven organisation based on responsibility and communication**
 - 5S, LEAN, Continuous Improvement, Value stream, TWI standardised training, Supply Chain partners
- **Engineering: Data-driven connected workplace for process understanding, control and improvement**
 - Cross-site engineering competency and capability enabling best practice process development
 - Industry leading data harvesting and analysis with full genealogy from fab through to conformance inspection
 - Extensive use connected test equipment for statistical process control
 - Enhancing University Relationships – Materials science studies, intern programs aiding in best practice development
- **Quality: Building a Quality Culture based on metrics for continuous improvement**
 - Driving compliance through culture and metrics
- **Leverage expertise, knowledge, and resources across Microsemi to develop best in class processes**
 - Knowledge sharing across product lines and markets



Satellite Power System (Telecom Payload)



System Architecture Drivers

- Isolated power topologies provide **fault isolation**
- **High voltage** power bus provides significant cost savings through weight reduction
- Long inductance paths between supply and load drive **distributed power topologies**
- Distributed power topologies are often **non-efficient** due to multiple stages
- Point of load solutions take up valuable **real estate** for digital designer
- **Radiation performance** in power supply is critical to avoid single point of failure

Space Power Products

Product Family	Target Application/ Sub-System	Key Differentiation	Key Products
Radiation-Hardened Isolated DC-DC Converters	<ul style="list-style-type: none"> Power conditioning unit (PCU) Electronic Power Convertor (EPC) Power distribution unit (PDU) System power bus convertor (DC-DC) Power Processing Unit (PPU) Ion propulsion thrusters 	<ul style="list-style-type: none"> Highest output power and efficiency Robust SMT construction Hundreds of successful space missions Greatest customization flexibility without added schedule risk Shortest lead times 	<ul style="list-style-type: none"> SA50 Family - Catalog and semi-custom power solutions w/ EMI filtering 25+years of flight hours with 0 failures Worst-case analysis on hundreds of space programs
Radiation-Hardened Power Discretes: JANS Diodes, Bi-Polar Transistors, MOSFETs	<ul style="list-style-type: none"> Power conditioning unit (PCU) Electronic Power Convertor (EPC) Power distribution unit (PDU) System power bus convertor (DC-DC) Power Processing Unit (PPU) Ion propulsion thrusters 	<ul style="list-style-type: none"> Broadest JANS QPL portfolio Low Dose Rate guaranteed bipolar transistors Largest glass diode and transistor family in the market Devices on over 75% of the available slash sheets 	<ul style="list-style-type: none"> Small Signal Glass Diodes, Rectifiers, Schottky Diodes Voltage and Current Regulators Protection Devices Bipolar Transistors
Radiation-Hardened Hybrids: Linear and Switching	<ul style="list-style-type: none"> Point of Load (POL) Distributed power supplies in payloads 	<ul style="list-style-type: none"> DLA MIL-PRF-38534-certified facility Highest level of integration to allow for optimal power footprint near digital circuits Optimized for distributed power architectures 	<ul style="list-style-type: none"> MHP8565A (smallest radiation-hardened, QML-certified 4 A solution on the market—ideal for LEO orbits)
High-Voltage Electromechanical Relays	<ul style="list-style-type: none"> Power conditioning unit (PCU) Power distribution unit (PDU) System batteries Latching relays High Voltage switching for thrusters 	<ul style="list-style-type: none"> Vacuum-sealed, ultra-low leakage rates Broad range of High Voltage 4 kV–10 kV Highest reliability Extensive heritage in space 	<ul style="list-style-type: none"> Several hundred relays are used per satellite in various applications New investments being made in new high voltage

Quality and Screening Flows

- **MIL-PRF-19500 (radiation hardness assured (RHA) supported on many bipolar transistors)**
 - JAN (Joint Army/Navy)
 - JANTX (Extra testing)
 - JANTXV (Extra testing + visual)
 - JANS (Full Space Screening)
 - Eight radiation hardness assurance (RHA) levels (M, D, P, L, **R**, **F**, **G**, and H)
 - JANHC—TX Level LAT/testing for die sales (bare die)
 - JANKC—Space Level (JANS) LAT/testing for die sales
 - Others—M, MA, MX, MXL (non-JAN “equivalent” screening)
- **MIL-PRF-38534 (radiation hardness assured (RHA) on several hybrids)**
 - QML Classes H and K
- **MIL-PRF-35835 (supported by other divisions within Microsemi)**
 - QML Classes Q and V

MIL-PRF-19500—Performance requirements for discretes

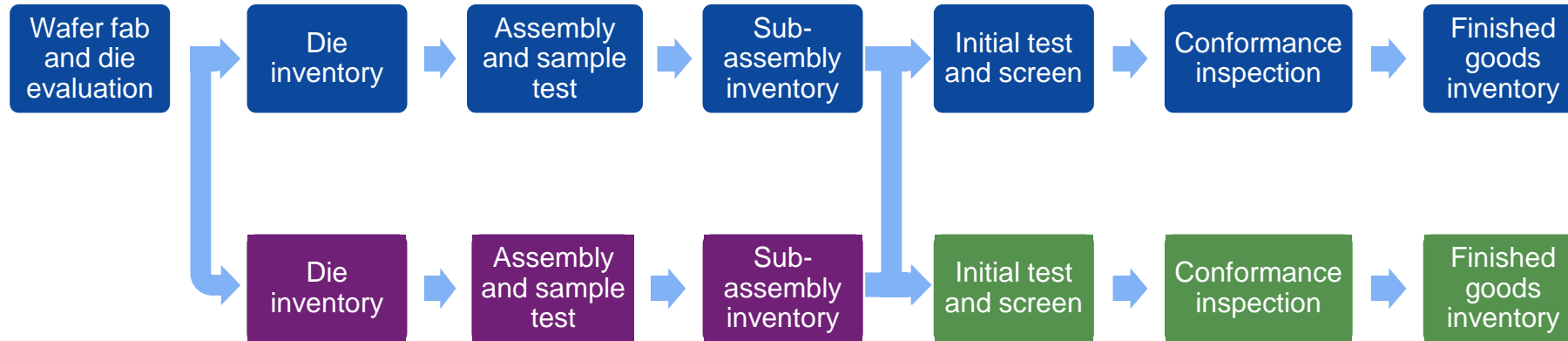


MIL-STD-750
Test Methods



Slash Sheet—Specifications for individual device (e.g., MIL-PRF-19500/123)

Discrete Manufacturing Flow



Microsemi Lawrence (160 sq ft facility)

Wafer fab, JANS and SCD assembly/screening (export-controlled handling capabilities for assembly, test, screening on custom products), package development



Microsemi Ireland (90 sq ft facility)

Screening, test, verification of JANTX and JANTXV (over 600K test sockets and over 100 test methods qualified to MIL-STD-750)—No major audit findings by DLA, Aviation Center of Excellence



Microsemi Philippines :

Assembly of hermetic glass and metal can product up to JANTXV level

Microsemi Discrete Heritage Product Offering

- **Widest discrete product portfolio** of any space component manufacturer
 - **Dominate role** in Defense Logistics Agency (DLA) Qualified Manufacturers List: **>75% of total slash sheets**
 - **First company to have diodes qualified to space level** (JANS qualification) by DLA (formerly DSCC)
 - **Over 95%** of the product portfolio is **EAR99**
- **Today, Microsemi's Discrete Products leads the way in...**
 - Product Breadth
 - Diodes, Rectifiers, Schottkys, Zeners, Transient Voltage Suppressor (TVS) Diodes, Bipolar Junction Transistors
 - Standard Generation and Improvements with DLA
 - JANS, Low Dose Rate tested Bipolars, Specification Standardization, and Screening
 - Power system expertise
 - Application support for discrete designs as well as internal design capabilities
 - Manufacturing capacity
 - Over 600,000 burn-in sockets in Ireland alone
- No one has the **product breadth, expertise, and capacity Microsemi** does...



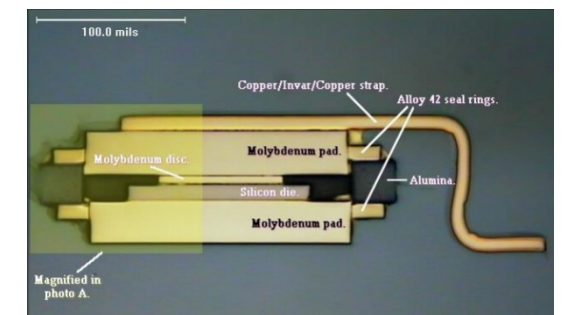


Discrete Products and Packages

Unique Microsemi Power Solution for High Power Schottky Diodes – ThinKey™
Glass Package and Metal Can Packages and Products – Small Signal and Power
Surface Mount Packages - Power

ThinKey™—Maximize Power Supply Performance

- JANTXV1N6872-6905 and 6910-6942, (MIL-PRF-19500/719-726)
 - (25 A–150 A, 15 V–100 V, Schottky)
- Double plug construction, no wire bonds
- Surface mount with top strap available on anode or cathode
- Double-side cooling to maximize heat dissipation
- High surge capability, no internal strap or wire bonds
- Low inductance due to no internal strap or wire bonds
- Weight: 0.9 g–1.8 g (9x lighter than TO-254)
- Low thermal resistance: typical 0.2 °C/W–0.85 °C/W
- No soft solder used in construction
 - Eliminates solder creep and re-crystallization during power cycling and high-temperature storage
 - Prevents solder seal from mixing with mounting solders to ensure no compromise of the hermetic seal
- Pre-cap inspection easily performed prior to seal (JANTXV and JANS equivalent)
- Rugged ceramic and metal construction, no glass seals
- All dies (Schottky, TVS, and rectifier) made on MSC QPL line.



Hermetic Packages (Glass and Metal Can)

Hermetic Glass Devices

- Schottky, signal diode, rectifier, TVS Zener



MELF
(surface mount)
Size: A/B/C/D



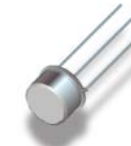
AXIAL (through-hole)
Size: A/B/C/D

Metal Can Through-Hole Packages

- Bipolar transistors, MOSFET, Schottky, diode



TO-46



TO-18



T-39 / TO-5



TO-78



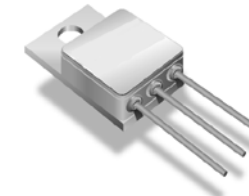
TO-3



DO-13



TO-254



TO-257 AA



DO-4 / 5

Various power
and current
ratings
depending on die
size

Microsemi Discrete Heritage Glass Product Offering

- Devices offered in hermetic glass packages
 - **Small Signal Diodes**
 - **Rectifiers**
 - **Schottkys**
- Glass Packages and Ratings
 - Surface Mount and Axial Lead

MELF (surface mount) Size: A/B/C/D



AXIAL (through-hole) Size: A/B/C/D



Package	Current Rating (A) Rectifier	Power Rating (W) Zener
A	1	1
B	3	5
C	12–20	1500 (TVS)
D	0.5	0.5

Sample Set of Hermetic Glass Small Signal Diodes

Part Number	Slash Sheet	Package	Rated Voltage	Device Speed	Rated Current	Max Tj
1N4148-1	/116	DO-35 (Axial)	75V	5ns	0.2A	175°C
1N4148UR-1	/116	DO-35UR (DO213AA)	75V	5ns	0.2A	175°C
1N4150-1	/231	DO-35 (Axial)	50V	4ns	0.2A	175°C
1N4150UR-1	/231	DO-35UR (DO213AA)	50V	4ns	0.2A	175°C
1N6638	/578	DO-35 (Axial)	150V	4.5ns	0.3A	175°C
1N6638U	/578	D-Pkg US (SM)	150V	4.5ns	0.3A	175°C
1N6638US	/578	D-Pkg US (SM)	150V	4.5ns	0.3A	175°C
1N6640	/609	DO-35 (Axial)	50V	4ns	0.3A	175°C
1N6640US	/609	D-Pkg US (SM)	50V	4ns	0.3A	175°C
1N6642	/578	DO-35 (Axial)	100V	5ns	0.3A	175°C
1N6642U	/578	D-Pkg US (SM)	100V	5ns	0.3A	175°C
1N6642US	/578	D-Pkg US (SM)	100V	5ns	0.3A	175°C
1N4148 should be replaced with 1N6642 for all new designs						
1N4150 should be replaced with 1N6640 for all new designs						

Sample Set of Hermetic Glass Rectifiers

	Part Number	Slash Sheet	Package	Rated Voltage	Device Speed	Rated Current	Max Tj
from	1N5550	/420	B-Pkg	200V	2000ns	5A	175°C
to	1N5554US		B-Pkg US	1000V	2000ns	5A	175°C
from	1N5614	/427	A-Pkg	200V	2000ns	1A	175°C
to	1N5622US		A-Pkg US	1000V	2000ns	1A	175°C
from	1N5615	/429	A-Pkg	200V	150ns	1A	175°C
to	1N5623US		A-Pkg US	1000V	500ns	1A	175°C
from	1N6620	/585	A-Pkg	200V	30ns	1.5A	175°C
to	1N6625US		A-Pkg US	1000V	60ns	2A	175°C
from	1N5802	/477	A-Pkg	50V	25ns	2.5A	175°C
to	1N5811US		B-Pkg US	150V	30ns	6A	175°C

Microsemi Discrete Heritage Glass Product Offering

- Devices offered in hermetic glass packages
 - Small Signal Diodes
 - Rectifiers
 - **Schottkys**

- **Power Ratings for Glass Package Sizes**

Package	Current Rating (A)	Power Rating (W)
	Rectifier	Zener
A	1	1
B	3	5
C	12–20	1500 (TVS)
D	0.5	0.5

Sample Set of Schottky Diodes

Part Number	Slash Sheet	Package	Rated Voltage	Rated Current	Max Tj
1N5819-1	/586	DO-41	45V	1A	125°C
1N5819UR-1	/586	DO-41UR (DO213AB)	45V	1A	125°C
1N5822	/620	B-Pkg	40V	3A	125°C
1N5822US	/620	B-Pkg US	40V	3A	125°C
1N6864	/620	B-Pkg	80V	3A	125°C
1N6864US	/620	B-Pkg US	80V	3A	125°C

Microsemi Discrete Heritage Metal Can Product Offering

- Devices offered in metal can packages
 - Bipolar Transistors, Schottkys, Diodes, MOSFETs

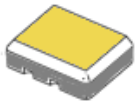
Various power and current ratings depending on die size



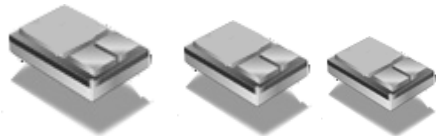
TO-18



T-39 / TO-5



3 / 4 / 6 PIN LCC(UA / UB / U)



SMD 2 / 1 / 0.5 / 0.22

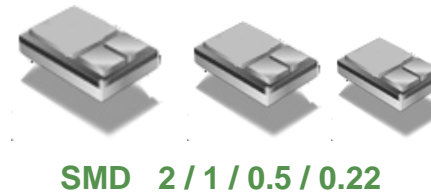
Sample Set of Bipolar Junction Transistors

Part Number	Slash Sheet	Package	Polarity	Rated Voltage	Device Speed	Rated Power	Max Tj	MSC RHA Level	Qual Level	DLA Qual Level
2N2222A	/255	TO-18	NPN	50V	300ns	0.5W	200°C	D, R, F, H	JXVSH, HKC	JXVS
2N2222AL	/255	TO-18	NPN	50V	300ns	0.5W	200°C	D, R, F, H	JXVSH, HKC	JXVS
2N2222AUA	/255	LCC4 UA	NPN	50V	300ns	1W	200°C	D, R, F, H	JXVSH, HKC	JXVS
2N2222AUB	/255	LCC3 UB	NPN	50V	300ns	1W	200°C	D, R, F, H	JXVSH, HKC	JXVS
2N2222AUBC	/255	LCC3 UBC	NPN	50V	300ns	1W	200°C	D, R, F, H	JXVSH, HKC	JXVS
2N2484	/376	TO-18	NPN	60V	60MHz	0.36W	200°C	D, R	JXVSR	JXVS
2N2484UA	/376	LCC4 UA	NPN	60V	60MHz	0.36W	200°C	D, R	JXVSR	JXVS
2N2484UB	/376	LCC3 UB	NPN	60V	60MHz	0.36W	200°C	D, R	JXVSR	JXVS
2N3019	/391	TO-39KM	NPN	80V	100MHz	0.8/5W	200°C	F	JXVSR	JXVS
2N3019S	/391	TO-39KM	NPN	80V	100MHz	0.8/5W	200°C	F	JXVSR	JXVS
2N3501U4	/366	SMD.22 (U4)	NPN	150V	1150ns	5W	200°C	M, R	JXV	JXV
2N3501UB	/366	LCC3 UB	NPN	150V	1150ns	0.5W	200°C	M, R	JXVS, R, KC	JXVS
2N2907A	/291	TO-18	PNP	60V	300ns	0.5W	200°C	R	JXVS, R	JXVS
2N2907AL	/291	TO-18	PNP	60V	300ns	0.5W	200°C	R	JXVS, R	JXVS
2N2907AUA	/291	LCC4 UA	PNP	60V	300ns	1W	200°C	R	JXVS, R	JXVS
2N2907AUB	/291	LCC3 UB	PNP	60V	300ns	1W	200°C	R	JXVS, R	JXVS
2N2907AUBC	/291	LCC3 UBC	PNP	60V	300ns	1W	200°C	R	JXVS, R	JXVS

Hermetic Surface Mount Packages

- MOSFET, Rectifiers, Schottky, Transistors, TVS

Package	Current Rating (A)
SMD-2.0	75
SMD-1.0	35
SMD-0.5	15
SMD-0.22	3
THINKEY1	100
THINKEY2	25
THINKEY3	150
THINKEY 4	75
SLUGGER	50
3/4/6 PIN LLC	--
18 PIN LLC	--



In-House Testing Capabilities to Support the Mission

■ Total Ionizing Dose (TID)

- First company to supply TID-rated rad-hard BJTs to MIL-PRF-19500 slash sheets (JANSR)
 - Working with DLA on adding ELDRS to MIL-PRF-19500 and MIL-STD-750
- Testing performed per MIL-STD-883, Method 1019

■ Failure Analysis Lab

- Scanning electron microscope (SEM)
- High-magnification optical microscopes
- Real-time X-ray
- Digital curve-tracer
- Micro-sectioning capabilities
- Chemical and mechanical decap capabilities



- DLA-certified test facility at Microsemi
 - Lawrence, MA
- Cobalt-60 LDR TID gamma source
 - JL Shepherd 484 irradiator with a Dual-Hemisphere
 - 10 and 100 mRad (Si)/sec simultaneously

Total Ionizing Dose Expertise Fix Potential Mission Issues

■ JANS2N2907AUB—LDR Sensitivity

- JANS2N2907AUB—surface mount
- JANSR2N2907A—through hole

■ Initial Testing

- ELDRS testing on die from the same wafer lot
- Unbiased for this PNP transistor is worst-case (biased for HDR and unbiased for LDR)—**Pass**

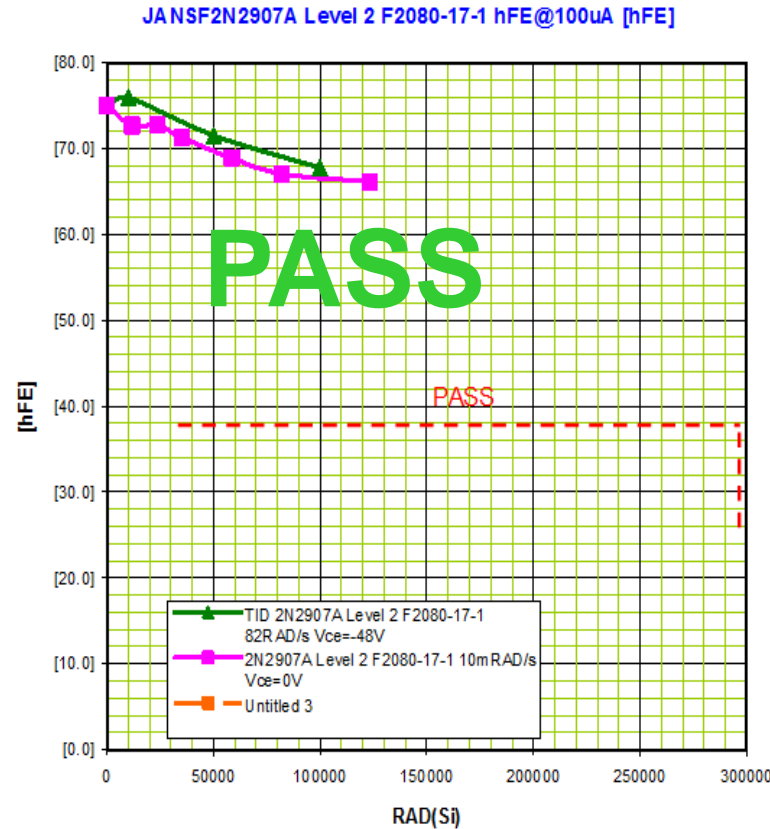
■ Further Investigation

- RGA analysis found traces of H₂ in the surface mount package (lid seal)

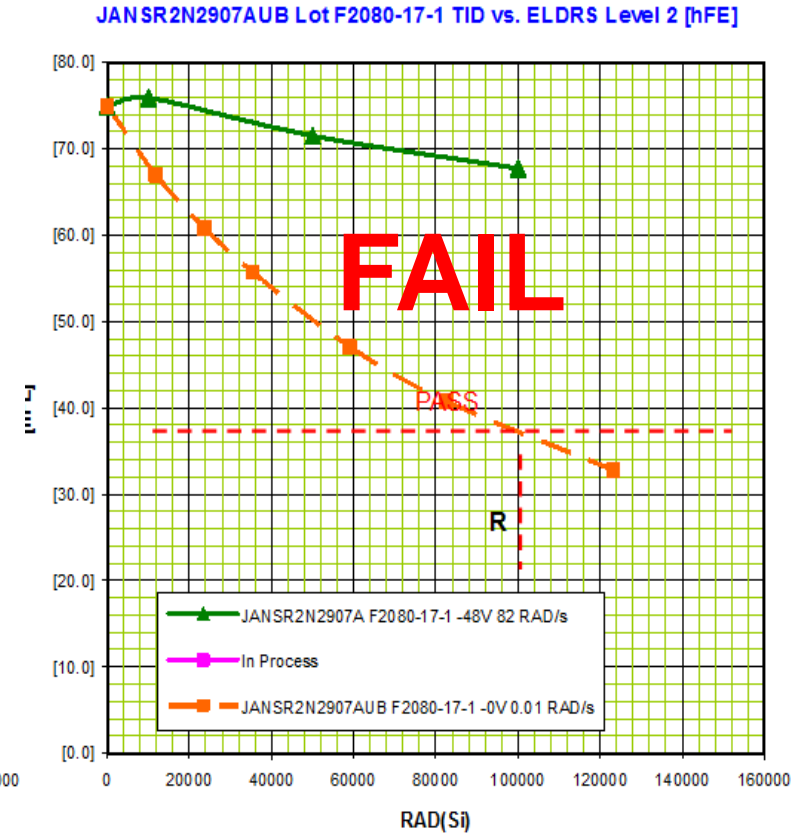
■ Root Cause

- ELDRs testing with surface mount—**Fail**
- H₂ during package assembly process causes Hfe shift during LDR testing

- Microsemi fixed the issue through die change and elimination of H₂



JANS2N2907A
(biased HDR, unbiased LDR)



JANS2N2907A—biased
JANS2N2907AUB—unbiased

Packaging can affect LDR performance

New Space

New Space Overview

- Reliability is created through redundancy at the satellite, board, and system level
 - Traditional space high-reliability screening is too costly, but a certain level of screening must be maintained due to the **large number of satellites** and the radiation **environment**
 - Small manufacturing differences can have huge impacts on the constellation
 - Due to the inclination of the orbit in LEO, SEE effects are still a major concern (60 MeV is desired)
 - TID levels are often around 30 krad due to the short life (1–5 years) of the mission
- Microsemi can support this market need with our New Space Quality Flow
 - Hermetic and non-hermetic package options
 - Multiple device families available
 - Si and SiC diodes, rectifiers, Schottkys, transistors
 - MOSFETs, IGBTs, Zeners, and TVSs

“New Space”—Reliability with Lower Cost

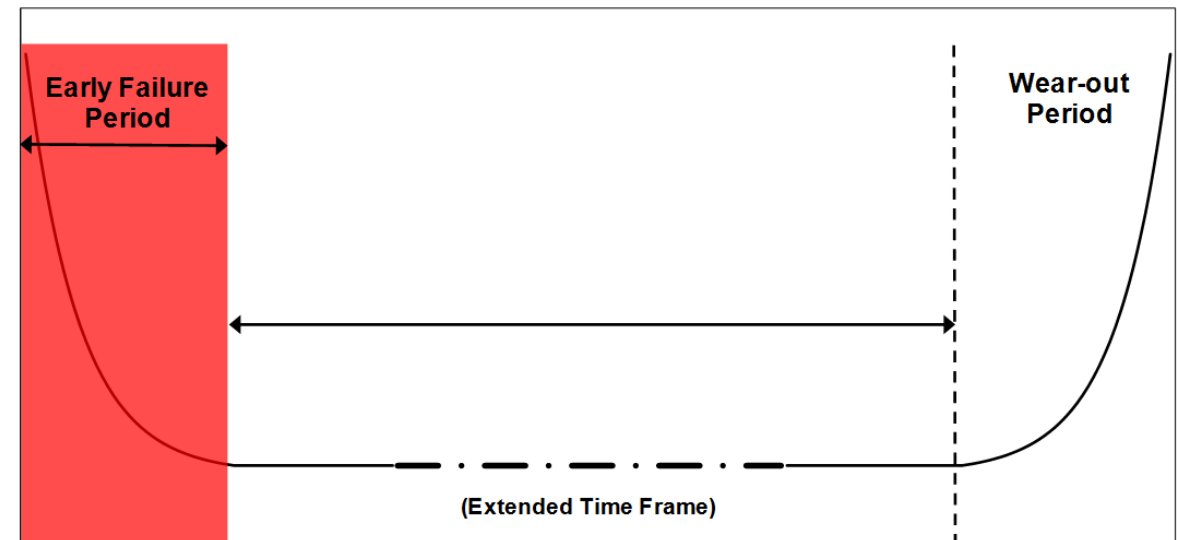
- Leveraging extensive, high-reliability capability and heritage
 - Microsemi applications support can help with reliability calculations and reliability testing
 - Based on a combination of the following:
 - MIL-PRF-19500, AEC-Q101, NASA PEM-INST-001
- Microsemi New Space Flow (MNS) highlights
 - Broad portfolio of package options and devices
 - Low-dose rate radiation test provides RLAT
 - 100% hot and cold electrical testing
 - Controlled baseline to minimize manufacturing difference and provide enhanced traceability
 - Date-code traceability, wafer-lot traceability, C of C
 - Enhanced obsolescence policy
 - 12 months’ notice prior to LTB with 6 months to take delivery
 - High-reliability process monitoring at the wafer level
 - High-reliability facility certifications
 - ISO 9001-2008, AS9100-2009C, DLA certification (19500 and 38534) on certain product families*)

Typical Process Step		Quality Level				
Per MIL-PRF-19500, Appendix E	MIL-STD-750, TM	COTS	M - Non Hermetic	M - Hermetic	MNS (Hermetic or Non-Hermetic)	JANS or MS
Wafer Fabrication			Controlled Source	Approved Facility	Controlled or Approved Facility	Approved Facility
Controlled Baseline (Assembly / Test)		No	Yes	Yes	Yes	Yes
Die Visual	2073					100%
Assembly			Controlled Source	Approved Facility	Controlled or Approved Facility	Approved Facility
Eng Lot Release					Sample	Sample
Stabilization Bake	1032				Optional	100%
Temp Cycle	1051				100%	100%
Thermal Impedance/First Test	3101/Various	No	No	100%	100%	100%
Internal Visual (Pre Encapsulation for Cavity Packages)	2074					100%
Constant Acceleration (Cavity Package)	2006					100%
PIND (Cavity Package)	2052				Cavity Hermetic Package Only	100%
Serialisation						100%
Read and Record	Various					100%
HTRB	1038A/1039A etc					100%
Read and Record	Various					100%
Burn-in (Not for TVS)	1038B/1039B etc					100% (240 hours)
Read and Record	Various					100%
Hot and Cold Test	Various				100% per applicable parameters	100%
Plating (where applicable)		Tin or Tin/Lead	Tin or Tin/Lead	Tin or Tin/Lead	Tin/Lead	Tin/Lead
Marking		Ink/Laser	Ink/Laser	Ink/Laser	Ink/Laser	Ink/Laser
Hot Solder Dip (where applicable)		Optional	Optional	Optional	Optional	
Scope Display (where applicable)	4023			100%		100%
Go No Go Test						100%
Radiography	2076					100%
External Visual	2071					100%
Pack		Various	Various	Various	Various	Various
FQA						
Conformance - Group A	Various				Sample	Sample
Conformance - Group B - JAN	Various					
Conformance - Group B - JANS	Various					Sample
Conformance - Group C	Various					Sample
Conformance - Group D					Yes	Yes
MNS - Microsemi New Space						

High-Reliability Non-Hermetic M Flow

- Non-hermetic, plastic high reliability devices undergo screening procedures similar to JAN military screening
 - Cracked die and ionic contamination may go undetected by standard commercial testing
 - Large die devices are particularly vulnerable
 - Stress tests that constitute Microsemi's M-flow program uncover these flaws

Screening removes early-period failures while ensuring performance over desired temperature range using production test vectors



Hi-Rel Non-Hermetic Products—M Flow Options

Commercial Standard:

SMBJ36CA

HiRel Standard:

MSMBJ36CA

HiRel “MA” Up-screened:

MASMBJ36CA

HiRel “MXL” Up-screened:

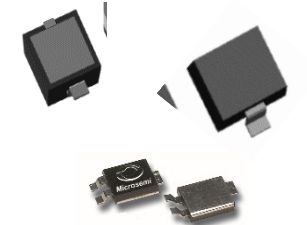
MXLSMBJ36CA

HiRel “MX” Up-screened:

MXSMBJ36CA0

Process, Screen, or Test Description	Product Assurance Level Requirement			
Part Number Prefix:	M	MA	MXL	MX
100% DC electrical test, go/no-go	R	R	R	R
3 Sigma lot norm of key parameters	R	R	R	R
Initial surge test (TVS diodes)	1x	1x	1x	1x
Post-surge electrical	R	R	R	R
Temperature cycling	10x (PLAD only)	10 cycles	20 cycles	20 cycles
Post temperature cycling surge	1x (PLAD only)	3x	10x	10x
Pre-HTRB electrical test, read and record			R	R
HTRB		24 hours ¹	96 hours ²	96 hours ²
Interim electrical test, read and record			R	R
Final electrical test, read and record	go/no-go (PLAD)	go/no-go	R	R
Delta calculations			R	R
PDA evaluation			R	R
Group A conformance inspection			R	R
Group B conformance inspection				R
Group C conformance inspection				R
Certificate of conformance	R	R	R	R
R: Required and performed based on MIL-PRF-19500 conditions and limits				
1: 24 hours for unidirectional; 24 hours each side for bidirectional				
2: 96 hours for unidirectional; 48 hours each side for bidirectional				

Non-Hermetic Products

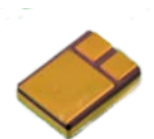
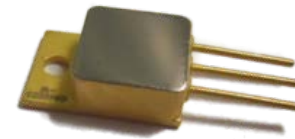


Space Roadmap

*Roadmaps are subject to change and will evolve throughout the course of development.
Please stay engaged with your local sales or marketing contact.*

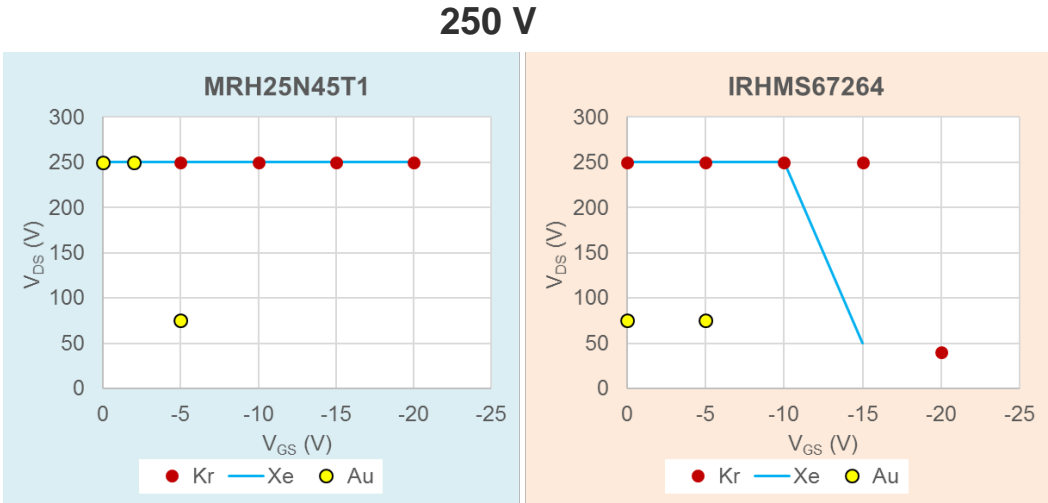
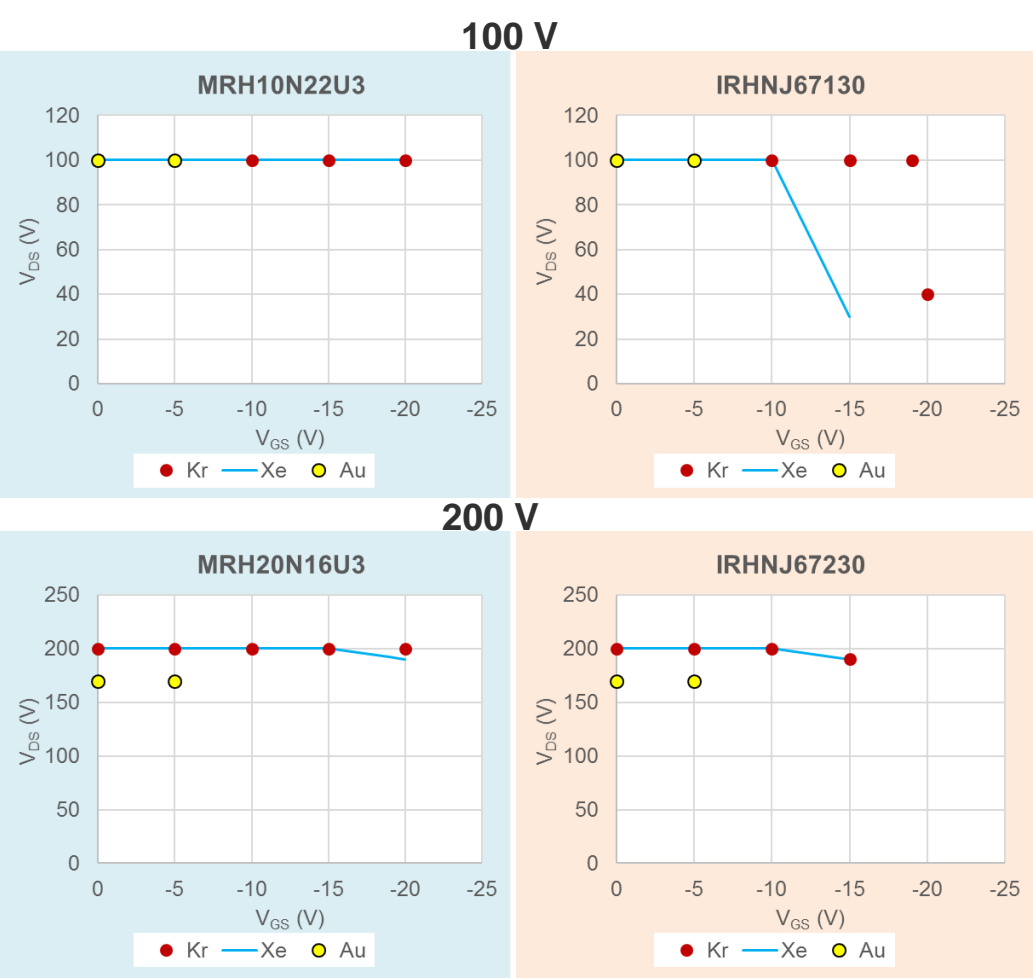
Rad-Hard MOSFET (M6)—Performance Benefits

- Device family—technical feasibility complete!
 - V_{dss} —100 V, 150 V, 200 V, and 250 V
- Improved efficiency through lower switching conduction losses by lowering $R_{ds(on)}$ and Q_{gd}
 - Figure of merit ($R_{ds(on)} \times Q_g$) improvement over competition
 - 100 V—47% (SMD0.5)
 - 150 V—90% (SMD0.5)
 - 200 V—2x (TO-254), 4x (SMD0.5)
 - 250 V—2x (SMD2), 3x (TO-254)
- Improved $R_{ds(on)}$ will translate to a 10%–20% higher current rating
- Commerce ECCN: EAR99 and 9A515.e
- Higher confidence level when performing worse case analysis and less de-rating
 - SEE SOA improved over competition and functional at full-rated bias under worst case conditions (see next slide)
 - +60 MeV at full-rated BV_{ss}
 - Avalanche rating is better by design by 5x over the competition



Rad-Hard MOSFET (M6)—SEE Performance

- Full-voltage entitlement up to 61 MeV (LEO) for SEE SOA curve
 - Preliminary testing at 90 MeV shows full performance, but more data needs to be taken to confirm



SEE SOA FOM		In process		
Manufacturer	Part Number	Kr 39MeV/(mg/cm ²)	Xe 61MeV/(mg/cm ²)	Au 90MeV/(mg/cm ²)
Microsemi	MRH10N22U3	78,000	122,000	45,000
IR	IRHNJ67130	76,830	80,825	45,000
Microsemi	MRH20N16U3	156,000	242,475	76,500
IR	IRHNJ67230	124,950	181,475	76,500
Microsemi	MRH25N45T1	195,000	305,000	88,875
IR	IRHMS67264	196,900	198,250	33,750

[Note] $FOM_{SEE} = V_{ds} * V_{gs} * LET$. Unit = $V^2 * MeV / (mg/cm^2)$. The higher value indicates the better SEE capability.

**50% improvement
at 60 MeV!!**

Next Steps for M6 Si MOSFET – Manufacturing Plan

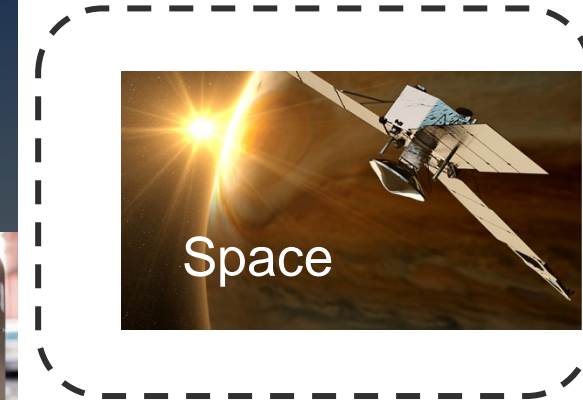
- For longevity of supply and qualification the N-channel 100-250V family will be ported to our foundry partner for qualification and release to market
- Devices from MSCC Bend fab are qualified (Microsemi 19500 equivalent) and available to support targeted programs while fab transfer is in process
- Customer Requests
 - Feedback on current datasheet performance
 - Confirmation of targeted devices or request for other devices
 - Strategic partnerships on targeted programs with qualified MOSFETs from Bend

Wide Band Gap Technologies for Space?

Reliability Concerns with GaN Power Devices

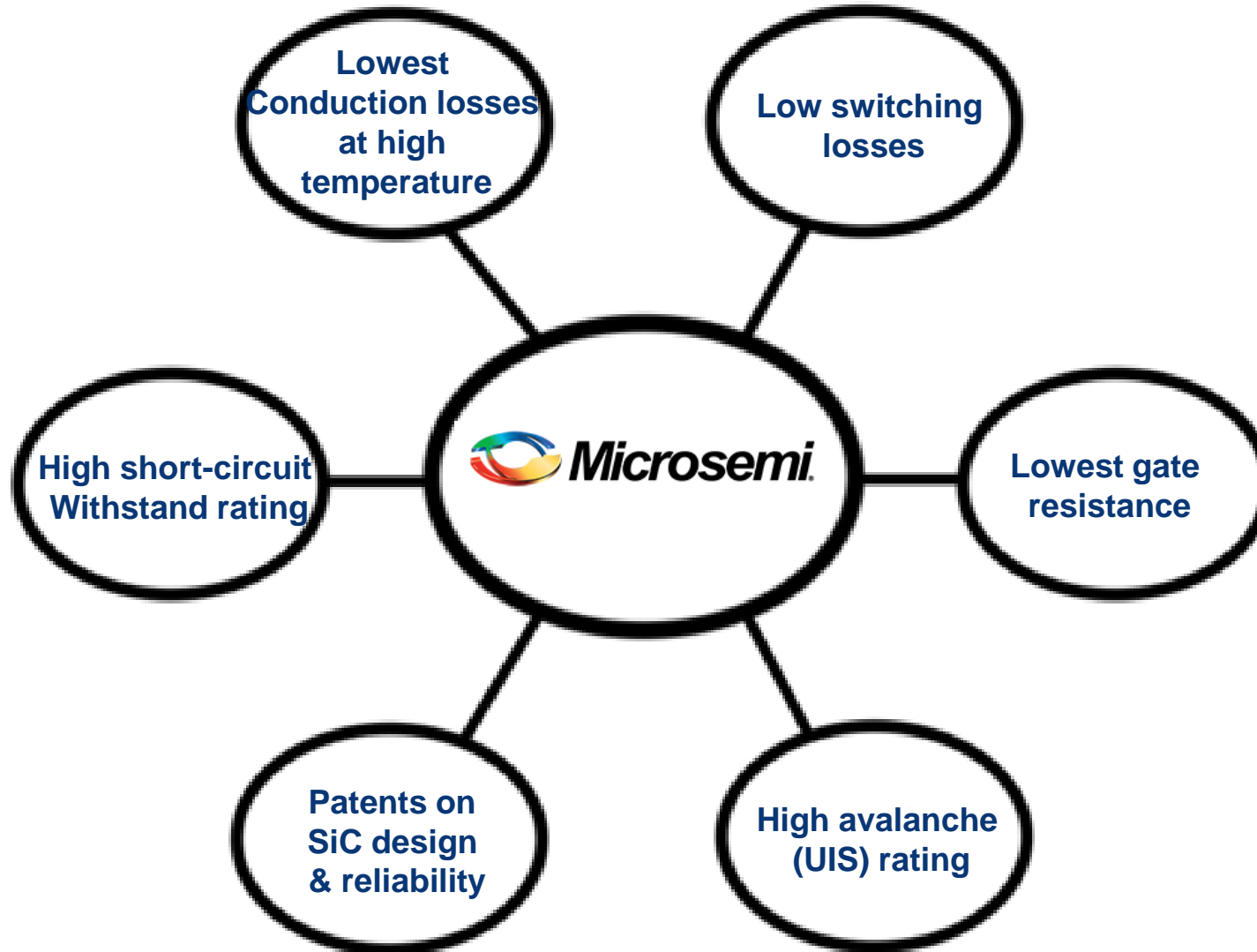
- Off-State Condition:
 - Dynamic R_{on} increase
 - V_{th} (threshold voltage) shift
 - Time-dependent degradation
- On-State Condition:
 - V_{th} shift (NBTI and PBTI)
 - Time-dependent gate breakdown
- Semi-On State:
 - V_{th} shift/ R_{on} increase
- Avalanche State:
 - Device permanently destroyed in avalanche mode – no avalanche/UIS (unclamped inductive switching) ratings

Current SiC Solutions Target Markets for Microsemi



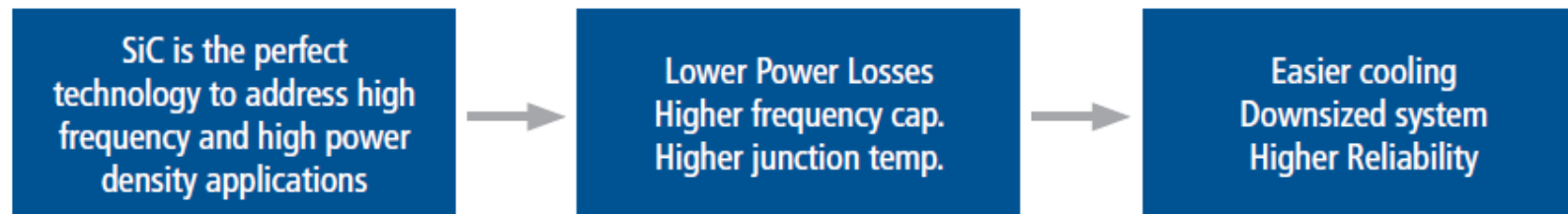
It's only of mater
of when😊

Microsemi SiC Technology Advantages



SiC Advantages Vs. Silicon

Characteristics	SiC vs. Si	Results	Benefits
Breakdown field (MV/cm)	10x Higher	Lower On-Resistance	Higher efficiency
Electron sat. velocity (cm/s)	2x Higher	Faster switching	Size reduction
Bandgap energy (ev)	3x Higher	Higher Junction temperature	Improved cooling
Thermal conductivity (W/m.K)	3x Higher	Higher power density	Higher current capabilities
Positive Temperature coefficient	-	Self regulation	Easy paralleling



Microsemi SiC Schottky Diodes (Gen1)

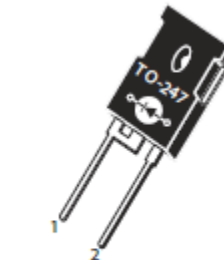
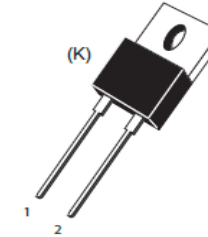
Not recommended for new designs – See next-generation SiC SBDs

650V SiC Schottky Diodes (Gen1*)				
Volts	$I_{F(avg)}$ Amps	V_F Volts	Part Number	Package
650	10	1.5	APT10SCD65K	TO-220
	20	1.5	APT20SCD65K	TO-220
	30	1.5	APT30SCD65B	TO-247
	2 x 10	1.5	APT10SCD65KCT	TO-220

1200V SiC Schottky Diodes				
1200	10	1.5	APT10SCD120B	TO-247
		1.5	APT10SCD120K	TO-220
	20	1.5	APT20SCD120B	TO-247
		1.5	APT20SCD120S	D ³
	30	1.5	APT30SCD120B	TO-247
		1.5	APT30SCD120S	D ³
	2 x 10	1.5	APT10SCD120BCT	TO-247
		1.5	APT10SCD120BCT	TO-247

1700V SiC Schottky Diodes				
1700	10	1.5	APT10SCE170B	TO-247
	---	---	---	TO-247
	---	---	---	TO-247

* Gen2 SiC SBD will offer 700V, 1200V, and 1700 devices rated at 10A, 30A, and 50A

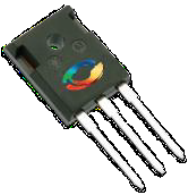


Microsemi SiC MOSFETs

Voltage	Current	R _{DS(ON)} (typical)	Part Number	Package
700V	35A	125mΩ*	APT35SM70B APT35SM70S	TO-247 D ³ PAK
700V	58A	75mΩ*	APT70SM70B APT70SM70S APT70SM70J	TO-247 D ³ PAK SOT-227
700V	78A	35mΩ*	APT130SM70B APT130SM70J	TO-247 SOT-227
1200V	25A	140mΩ	APT25SM120B APT25SM120S	TO-247 D ³ PAK
1200V	40A	80mΩ	APT40SM120B APT40SM120S APT40SM120J	TO-247 D ³ PAK SOT-227
1200V	80A	40mΩ	APT80SM120B APT80SM120S APT80SM120J	TO-247 D ³ PAK SOT-227
1700V	5A	800mΩ*	APT5SM170B APT5SM170S	TO-247 D ³ PAK

Not recommended for new designs – See next-generation SiC MOSFETs

TO-247
3-lead



TO-268
D³PAK



*Preliminary Current & typical R_{ds(on)} values. Consult the datasheet for device ratings by package.

Next Steps for Gen 2 SiC – Evaluate SEE Performance

- Gen1 SiC MOSFETs and Diodes are available
 - Gen2 will be at the end of 2018
- Customer Requests under NDA
 - Feedback on datasheet performance of Gen2 for space applications
 - Confirmation of targeted devices or requests for modifications
 - Strategic partnerships to evaluate devices under radiation testing

Summary

- Reviewed our discrete offerings in detail (packages and devices)
- Covered our expertise for supporting space missions and the new space market
- Next steps for M6 Si MOSFETs and technology development for SiC Gen 2

Your Partner for Space Technology



- Leadership in space
- Leveraging our product breadth
- Innovative new products
- Focused on system solutions

Thank You



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