Need for Efficient and Reliable Power

GaNFET design solution for resiliency in the age of faster and cheaper

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PacketDigital

Who is Packet Digital?

Growing footprint
25,000-square-foot manufacturing
80,000-square-foot battery cell plant

Capabilities & Services
Power management, mechanical design, printed circuit boards, software design, solar integration, battery design

Rapidly growing company

Resiliency Areas of Focus

- Redundancy and Fault Tolerance
- System Monitoring and Recovery
- Mission Sustainability
- Thermal Management
- Radiation Effects Mitigation

How do we design the next generation of Power Management?

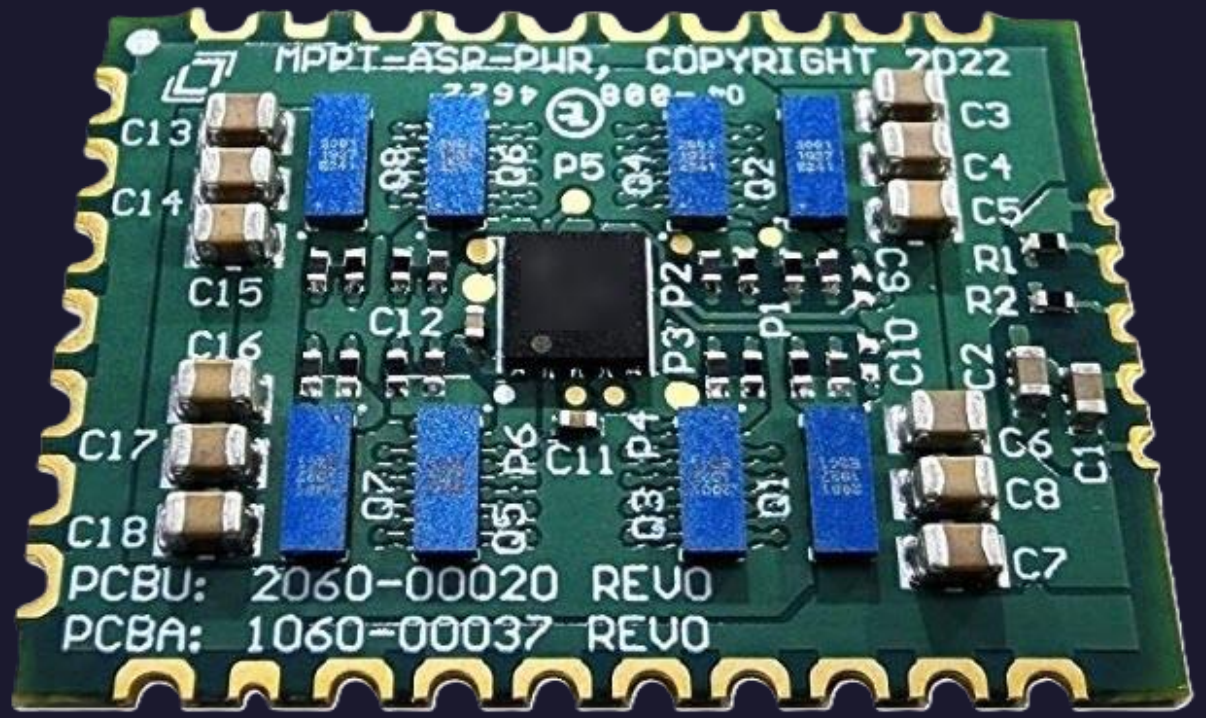
Gallium Nitride (GaN) FET

Benefits:

- Enables faster switching transitions which allow higher frequency operation and reduces volume/mass of magnetics
- Minimizes parasitic effects to improve performance
- Achieves compact circuit design, freeing up SWaP budget for redundancy and scalability

Challenges:

- Implement an optimized thermal design to ensure reliable performance
- Calibrate gate drive timing to handle fast switching speeds



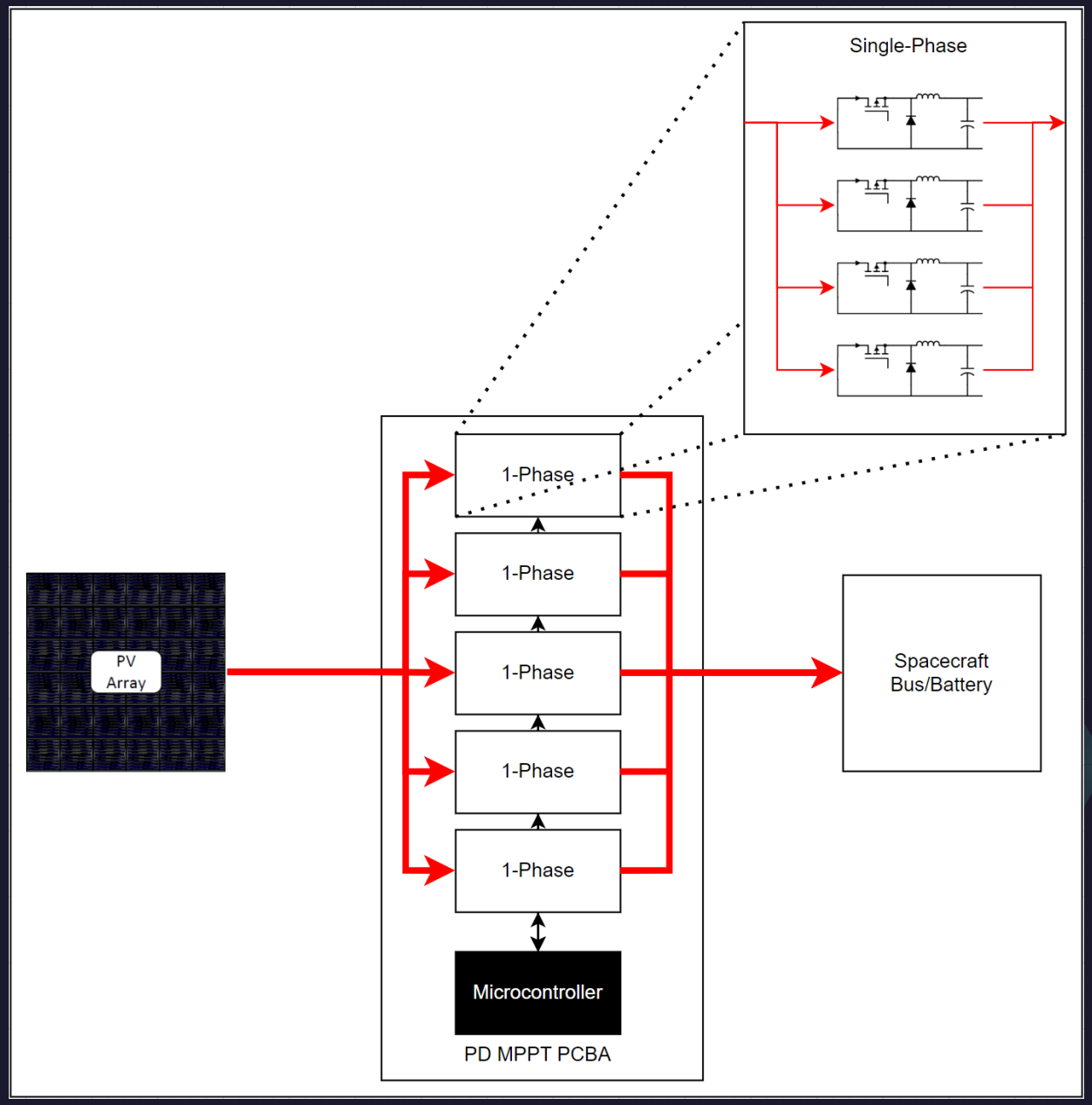
GaN Based MPPT High-Power System Architecture

Single Phase

- 4x GaN Buck-Converters
- 800W Max

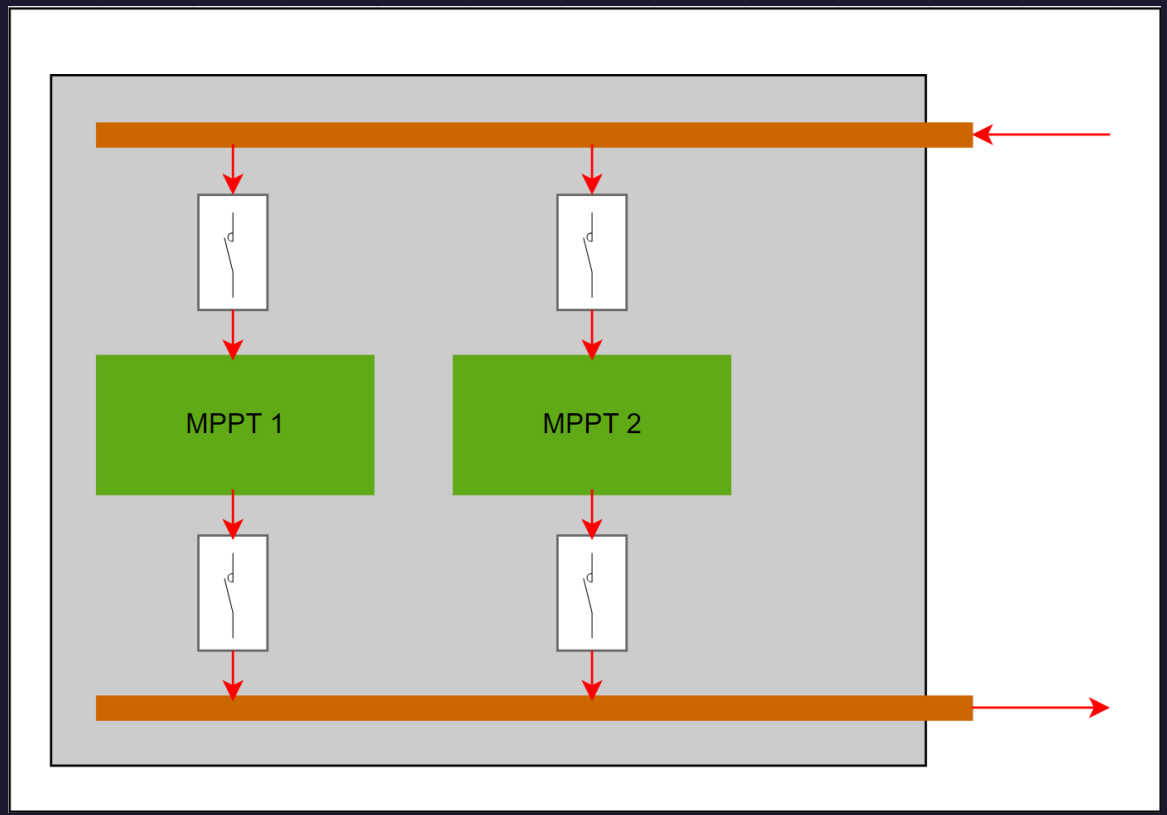
MPPT System

- N Phases (5 validated so far)
- Digitally controlled
- Helps spread thermal load



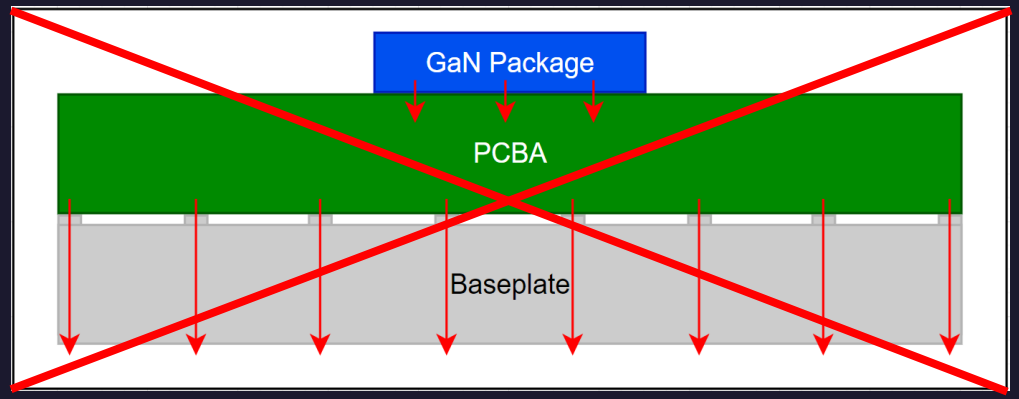
Redundancy, Fault Tolerance and Recovery

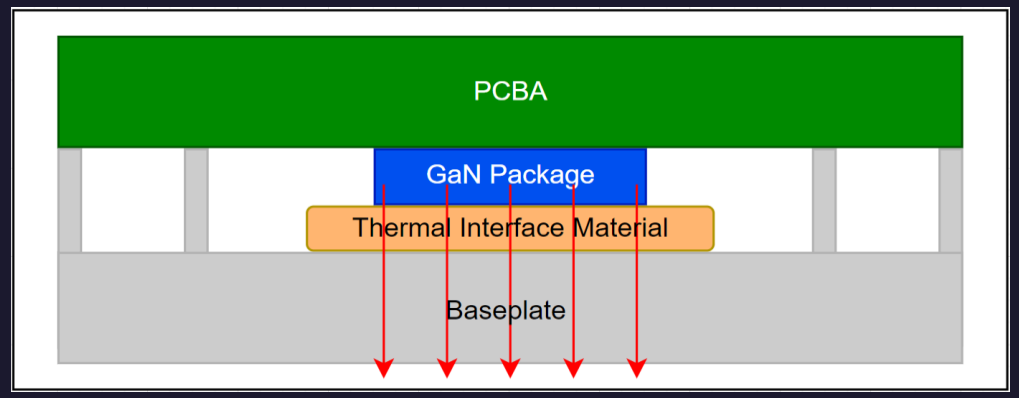
- Incorporate input/output high-power contactors to ensure complete converter isolation from spacecraft systems when needed
- Implement robust hardware safety trips to protect against voltage, current and thermal faults.
- Incorporate independent watchdogs to enable hard resets of microcontrollers, ensuring continuous and reliable operation.
- Design with N+1 redundancy to maintain mission-critical functionality.



Thermal Management

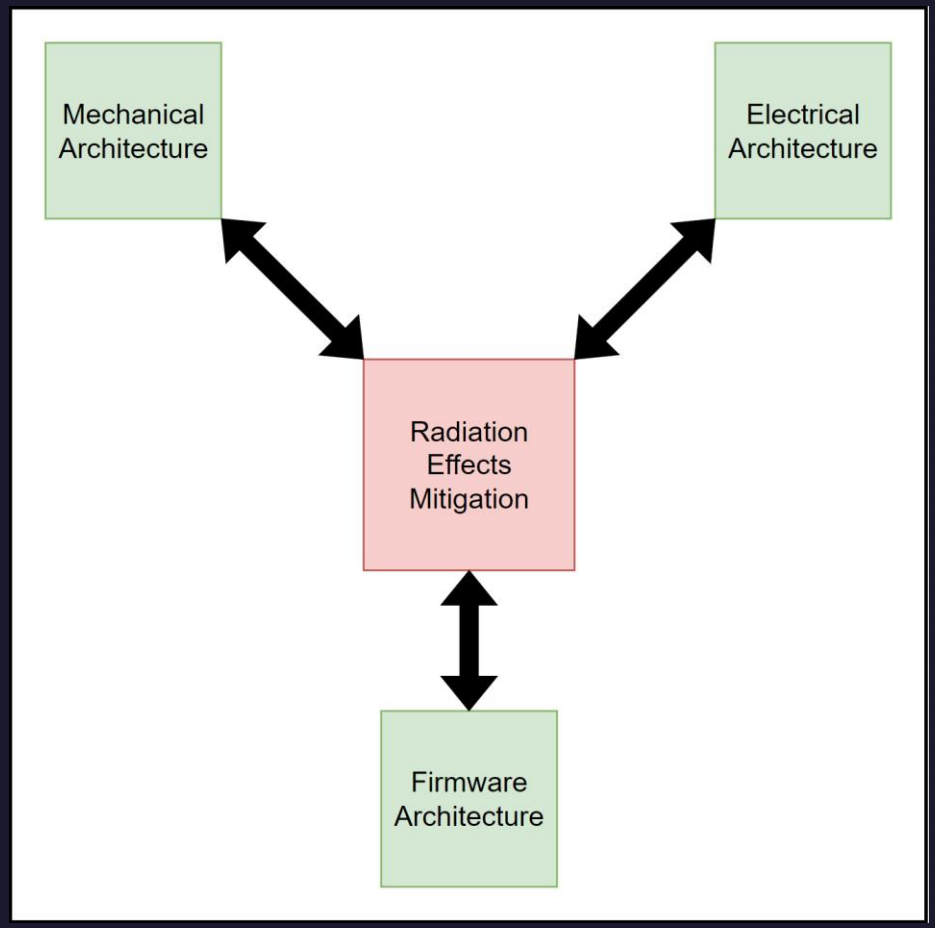
- Problem: Small GaN package size does not allow for good thermal conduction to PCBA to manage thermal relief.
- Solution: Create a lower resistance thermal path from top of GaN device directly to power supply baseplate.
- Largest expected thermal load has an improved thermal path to spacecraft chassis.





Radiation Effects Mitigation

- Mechanical Architecture
  - Material: Aluminum
  - Panel thickness per NASA STD
  - EMI gaskets between panels
- Electrical Architecture
  - Independent hardware watchdog
  - Full power on reset (POR)
  - Hardware driven clocking source
- Firmware Architecture
  - External watchdog heartbeat
  - Fast timing loops with real time telemetry

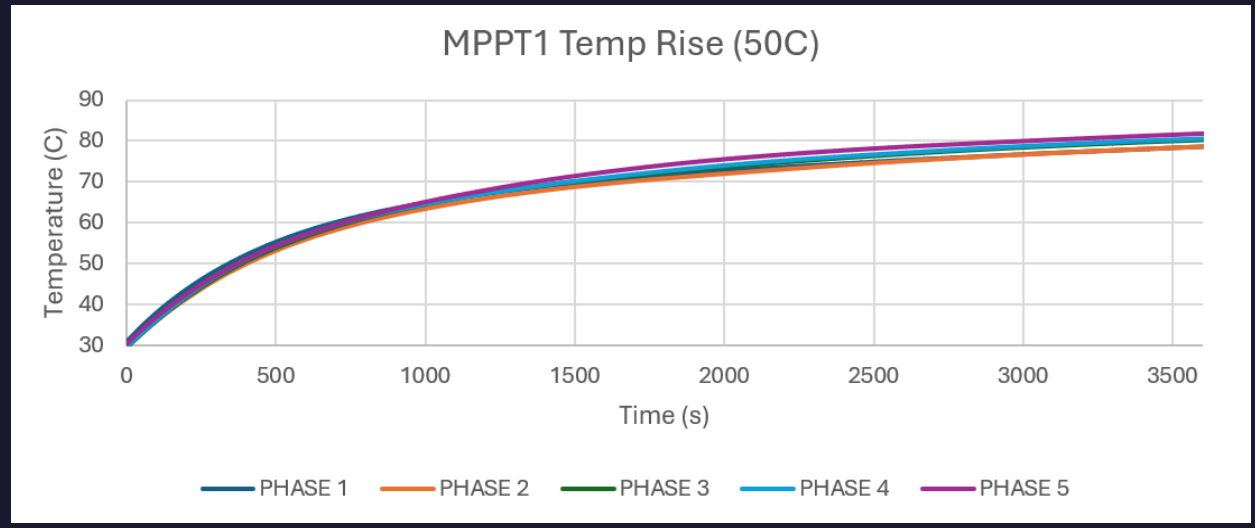


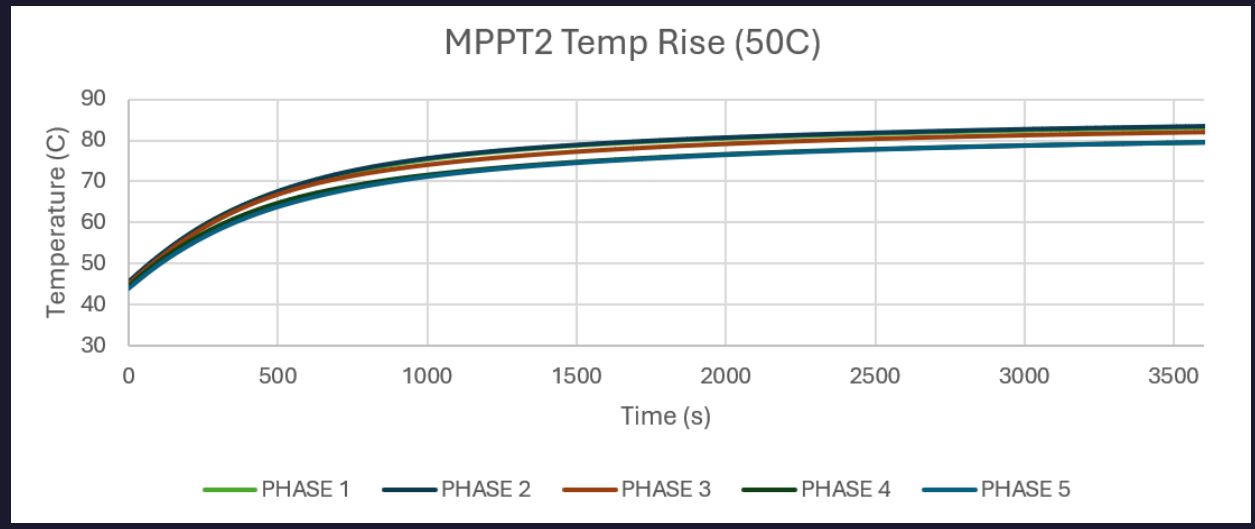
System Thermal Performance

Test Parameters

- 5-Phase Configuration
- Output Power: 3000W
- Input/Output Voltage: 41Vin / 28Vout
- Time: 60 minutes
- Baseplate Temp: 50 ℃

Assembly	Average Eff.	Temp Max
MPPT 1	95.6%	86.9 ℃
MPPT 2	95.9%	84.1 ℃



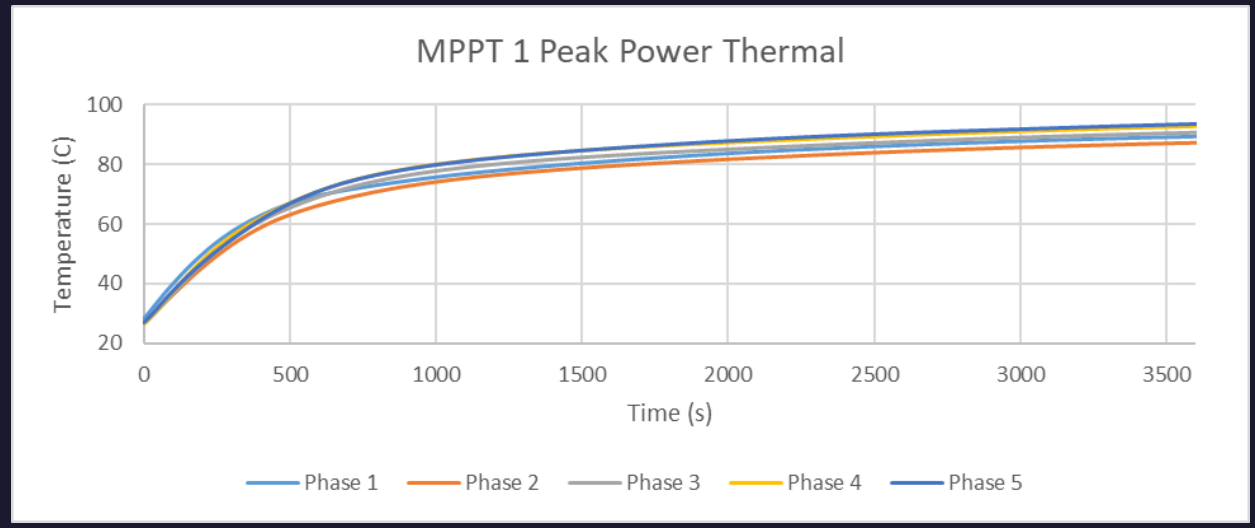


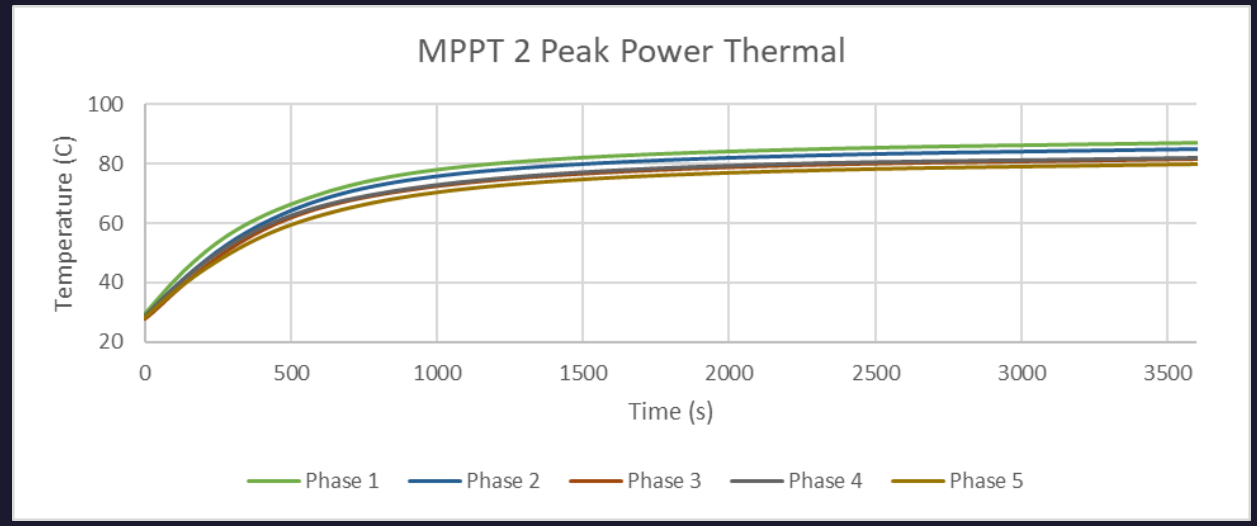
System Peak Power Thermal Performance

Test Parameters

- 5-Phase Configuration
- Output Power: 4000W
- Input/Output Voltage: 41Vin / 28Vout
- Time: 60 minutes

Assembly	Average Eff.	Temp Max
MPPT 1	95.1%	94.2 ℃
MPPT 2	95.5%	87.8 ℃



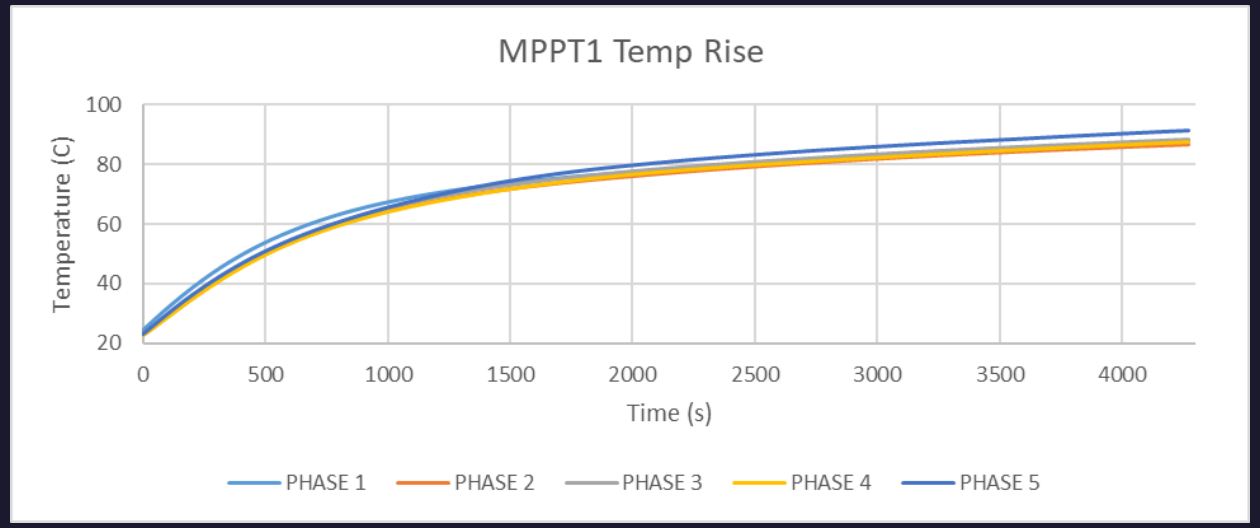


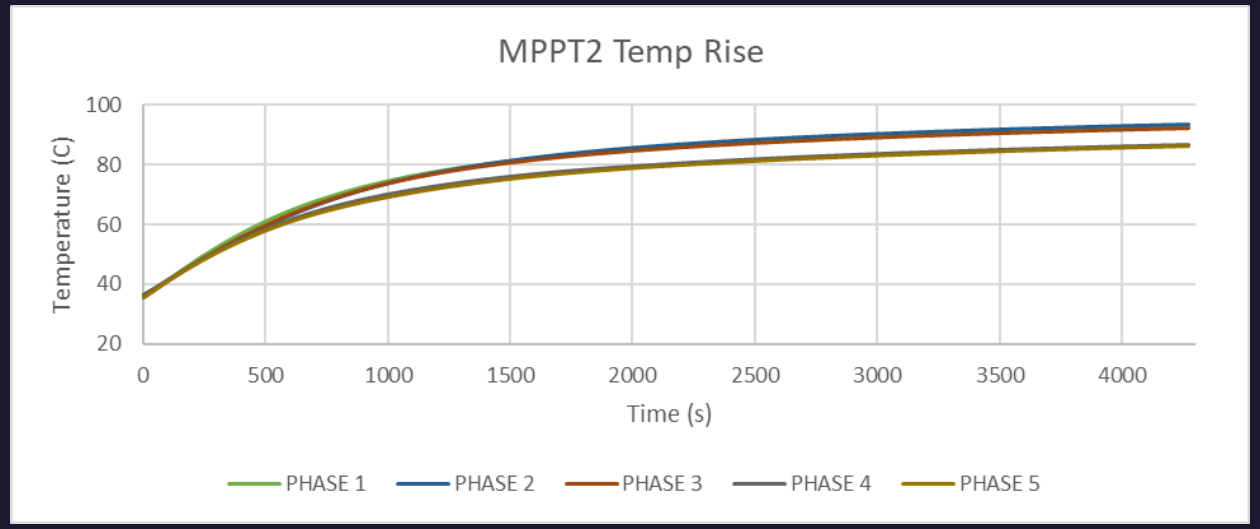
System Vacuum Thermal Performance

Test Parameters

- 5-Phase Configuration
- Power: 3000W
- Input/Output Voltage: 41Vin / 28Vout
- Time: 70 minutes

Assembly	Average Eff.	Temp Max
MPPT 1	95.6%	94.2 ℃
MPPT 2	95.9%	93.7 ℃





Critical Component Radiation Testing

Test Setup

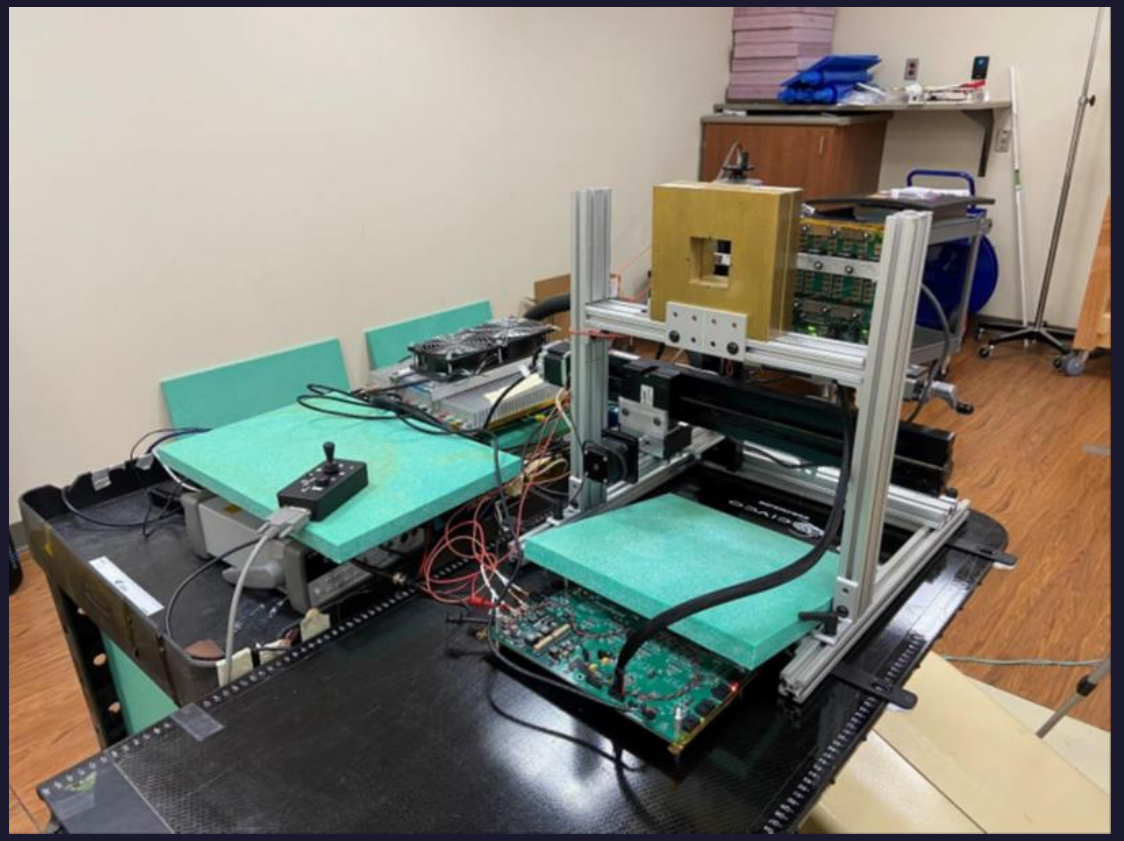
- PCBAs installed on adjustable fixture
- All areas of bare PCBA exposed to beam while operating

Radiation Profile

- Species: Protons
- Energy: 100-200 MeV/n

Single Event Effect (SEE) Test High Level Results

- 57 beam runs
- 1 Destructive Event



MPPT Assembly Positioned for Exposure

Radiation Performance

Part Performance

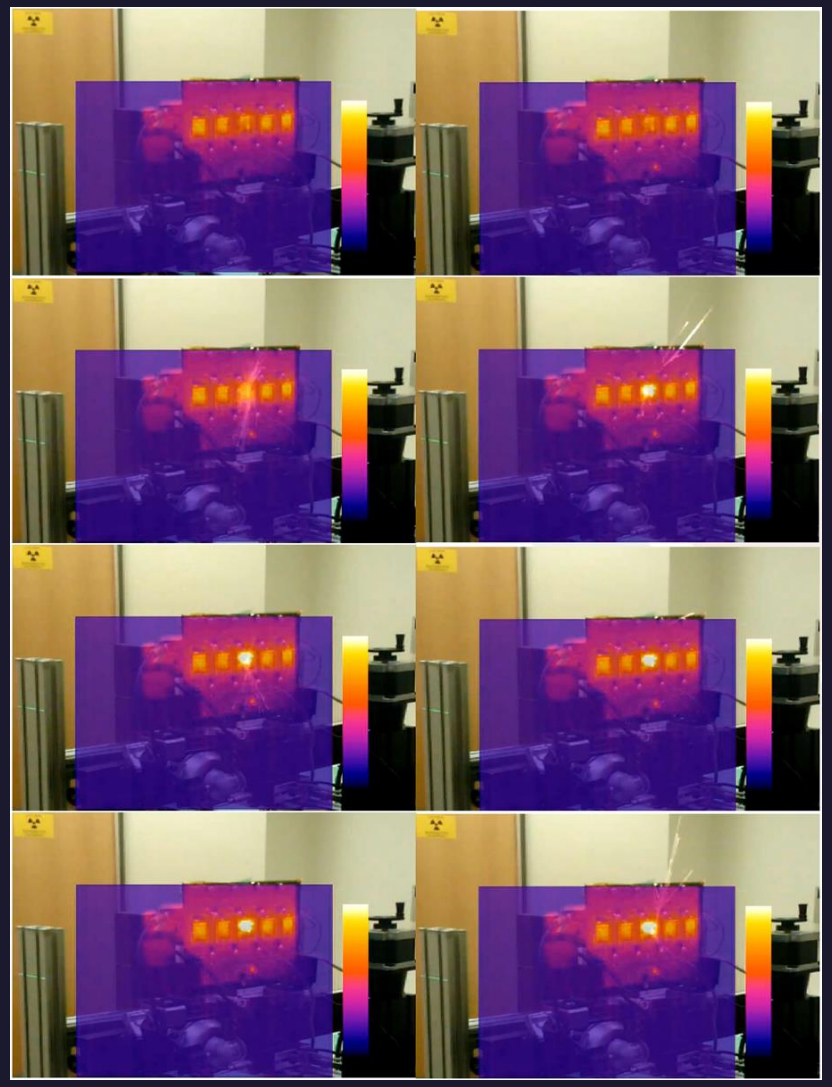
- eGaN modules had no events occur while exposed
- Microcontroller exposure caused 3 events
  - 2 recovered via POR
  - 1 destructive event

Destructive Event

- An SEL event occurred, affecting the control loop phase timing
- A shoot thru event caused part destruction which did not allow the system to recover

Lesson Learned

- Secondary PWM signal on-time detection required to prevent destruction



3kW eGaN Based MPPT SmallSat PSU Prototype

- Power: 3kW Nominal, 4kW Peak
- 98% Peak Converter Efficiency
- Mass: 11kg
- Volume: 11,027 cm^3
- N+1 Redundancy
- System Safety Features
  - Overvoltage
  - Overcurrent
  - Thermal
- Radiation Environment Protections
  - Single-Event Upset (SEU)
  - Single-Event Latch-Up (SEL)

Looking to the Future

- Deliver a scalable MPPT design architecture to meet evolving power needs:
    - Provide a software-driven, parallel, and phased design for seamless support across multiple power levels.
- Integrating PD MPPT technology into a fully optimized system with comprehensive power management.
- Proactively pursuing spaceflight heritage experiments to ensure proven reliability.

Power Module	Power Targets	Efficiency Targets
Cubesat EPS	80W - 400W	93% - 95%
Smallsat PMAD	600W - 3000W	97%

Conclusion

- Packet Digital, leveraging over two decades of expertise in power system innovation to deliver reliable, efficient, and scalable power solutions tailored to current and future spacecraft mission needs.

- Developed a high-efficiency GaNFET based MPPT solution designed for Smallsats.
  - Provides up to 4kW of power with a maximum converter efficiency of 98%, ensuring the most out of satellite power systems.
  - Incorporates N+1 redundancy to enhance reliability and mission success.

- Developing a scalable solution to support future space mission needs, ensuring adaptability as power needs grow.

PacketDigital

Innovative Power Solutions

Thank you!

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