

FPGA Cheatsheet for Spacecraft and Missions

This cheat sheet provides an overview of the essential characteristics, types, and considerations for space-grade FPGAs used in spacecraft, rockets, satellites, and other space missions.

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1. Key FPGA Characteristics for Space

Radiation Tolerance

- Must withstand **Total Ionizing Dose (TID)**, **Single Event Upsets (SEUs)**, and **Single Event Latch-ups (SELs)**.
- Mitigation techniques:
 - **Antifuse technology** (non-volatile, robust).
 - **Triple Modular Redundancy (TMR)** to handle SEUs.
 - **Error Correction Codes (ECC)**.

Thermal Resistance

- Operating temperature: **-55 °C to +125 °C**.
- **Ceramic packaging** enhances thermal performance.

Power Efficiency

- Low power consumption is crucial for space missions.
- **Static and dynamic power optimization** techniques are employed.

Robust Packaging

- **Hermetically sealed ceramic or metal packages** are used for extreme environments.
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2. Common FPGA Types for Space

FPGA Type	Examples	Features	Applications
Antifuse	Microsemi RTAX/RTSX	Radiation-hardened, non-volatile, one-time programmable.	Flight control systems, low-power subsystems.
SRAM-Based	Xilinx Virtex Q Pro (Rad-Hard)	High-performance, reconfigurable, requires mitigation.	Image processing, communications.
Flash-Based	Microsemi RTG4, NanoXplore NG	Reconfigurable, radiation-resistant, low power.	General-purpose space applications.

3. Space-Grade FPGA Examples

Microsemi RTG4

- **TID tolerance:** 100 krad.
- Integrated **SEU** mitigation.
- Suitable for **control** and **processing** systems.

Xilinx Kintex UltraScale Space-Grade

- High **DSP count** and **memory bandwidth**.
- Used in advanced **payload** and **communication systems**.

NanoXplore NG-Large

- European-manufactured, **ESA-compliant**.
- Optimized for radiation resistance and reconfigurability.

BAE Systems RAD750 FPGA

- Proven reliability in numerous **NASA missions**.

4. Selection Criteria for FPGAs in Space

Factor	Considerations
Radiation Level	Mission orbit (LEO, GEO, or interplanetary) affects radiation requirements.
Thermal Range	Wider temperature tolerances are needed for deep space missions.
Application Type	Compute-intensive tasks require high DSP and memory capacity .
Budget	SRAM and Flash-based FPGAs can be more cost-effective than antifuse types.

5. Common Space Applications for FPGAs

Application	FPGA Role
Attitude and Orbit Control	Control signal processing and redundancy management.
Image Processing	On-board data compression and analysis for Earth imaging.
Communication Systems	Encoding/decoding, signal filtering, and custom protocols.
Payload Processing	High-performance tasks such as radar or hyperspectral imaging.

6. FPGA Design Tips for Space

Implement Redundancy

- Use **TMR** for critical logic paths to mitigate **SEUs**.

Radiation Testing

- Simulate radiation effects and validate mitigation strategies during the design phase.

Use Proven IP Cores

- Opt for **radiation-hardened IP cores** certified for space use.

Optimize Power Consumption

- Leverage **clock gating** and **voltage scaling** to minimize power consumption.

Verification Tools

- Use simulators like **Synopsys** or **Mentor Graphics** for detailed validation.
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7. Resources and Standards

Standard/Resource	Description
MIL-STD-883	Testing procedures for electronics in aerospace applications.
NASA EEE-INST-002	Guidelines for selecting EEE parts for space applications.
ESA Space Standards (ECSS)	Framework for European space missions.
Microsemi Space-Grade FPGA Guide	Comprehensive guide for Microsemi FPGAs in space.

For more in-depth design details and guidance, consult the official documentation from manufacturers and aerospace standards.

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