Radiation-hardened ARM® Cortex®-M0 Microcontroller for CubeSats / SmallSats

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VORAGO Technologies

- Privately held fabless semiconductor company headquartered in Austin, TX
- Patented HARDSIL® foundation technology
- Focused on space technology since 2004. Commercializing technology since 2015

HARDSIL® – Technology

- Patented semiconductor technology (13 patents to date)
- Licensed to LSI, TI and Global Foundries
- Embedded into standard CMOS manufacturing process
  - Standard manufacturing equipment
  - Fully design agnostic
  - Enhances EOS/ESD performance
  - Eliminates latch-up
  - Improves noise floor immunity
  - Enables high temperature performance beyond 200°C
- Hardens silicon against radiation, temperature and electrical stress

HARDSIL® – Products

- Radiation hardened portfolio up to 300k RAD
  - 8M & 16M SRAMs
  - ARM® Cortex®-M0 MCU
- High temperature portfolio 200°C
  - ARM® Cortex®-M0 MCU
Component Options for CubeSats

- Lots of choices
- State-of-the-art
- Inexpensive
- Risky

Up-screening is paying to reduce risk

- Limited choices
- Legacy art
- Expensive
- Not so risky
Component Options for CubeSats

VORAGO products are rad-hard
Component Options for CubeSats

VORAGO CMOS-based HARDSIL® technology enables rad-hard solutions at a price lower than up-screening COTS.
What is radiation-induced latch-up?
What is radiation-induced latch-up?

Short circuit VDD-VSS

Substrate (p-well)
How does HARDSIL® prevent latch-up?

HARDSIL® creates a highly conductive layer underneath the CMOS devices and wells combined with a high conductivity connection to well contacts.
How does Total Ionizing Dose (TID) cause my device to fail?

Positive charge build-up in oxide regions
How does Total Ionizing Dose (TID) cause my device to fail?

Positive charge build-up in oxide creates low resistance pathways that allow n+ to n-well leakage.
How does the VA10820 deal with Single Event Upsets?

**SEU – Memory**

- EDAC (detect 2 correct 1 bit, per byte)
- Scrub Engine – programmable rate, prevents accumulated uncorrectable errors
- Layout designed to space logically adjacent bits apart
- SER – EDAC enabled – 1e-15 errors / bit-day*
- HARDSIL reduces SEEs

**SEU – Logic**

- DICE latches
- TMR DICE latches
- All internal registers
- Clock glitch filters
- HARDSIL reduces SEEs

* At geosynchronous solar min. with 100 mils of aluminum shielding
VA10820
Radiation-hardened ARM® Cortex®-M0 Microcontroller

Key Features and Advantages
- Latch up Immune with HARDSIL® Hardened by Process Technology
- Power Gating and Hardware Debugger
- 32KB Data and 128KB Program Memory
- 1Kb One Time Programmable Configuration Memory (OTP)
- 24 Counter/Timers with Extensive Hardware/Software Triggering
- 3 SPI (one SPI is master only), 2 I²C, and 2 UART External Interfaces
- 56 Multiplexed General Purpose 3.3V I/O (GPIO)

Specifications
- Total Ionizing Dose (TID) – 300K rad(Si)
- Soft Error Rate (SER) with EDAC disabled – 1.3e-7 errors/bit-day
- Soft Error Rate (SER) with EDAC enabled – 1e-15 errors/bit-day
- Linear Energy Transfer (LET) – 110 MeV-cm²/mg (at T=125°C)

<table>
<thead>
<tr>
<th>Description</th>
<th>Part number</th>
<th>Environment</th>
<th>Temperature Range</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation-hardened microcontroller</td>
<td>VA10820-D0000F0PCA</td>
<td>Rad-hard 300K rad (Si)</td>
<td>-55 to 125°C</td>
<td>Die</td>
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<tr>
<td>Radiation-hardened microcontroller</td>
<td>VA10820-CQ128F0ECA</td>
<td>Rad-hard 300K rad (Si)</td>
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<td>Ceramic 128 LQFP</td>
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Radiation Testing on VA10820

- Terrestrial Neutron

TRIUMF

- TID

UMASS Lowell

- Heavy Ion

BERKELEY LAB

Radiation Performance Specifications

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- Soft Error Rate (SER) with EDAC disabled – 1.3e-7 errors/bit-day
- Soft Error Rate (SER) with EDAC enabled – 1e-15 errors/bit-day
- Linear Energy Transfer (LET) – 110 MeV-cm²/mg (at T=125C)
Two Common Use-Cases for VORAGO MCUs in CubeSats Today

Standalone OBC

- Main system controller
- Tech Brief available (Pumpkin compatible board)

System Monitor / Watchdog

- Monitor FPGA and other subsystems
- Configuration of FPGA
**ARM® Cortex®-M0 is optimized for low power consumption**

- Clock gating implemented on all peripherals
- WFI (Wait For Interrupt) instruction idles CPU
- CPU frequency can be adjusted to reduce power
- Power management Application Note available

**VA10820 MCU IDD Breakdown**

**VA10820 MCU Core IDD with Operating Frequency**

![Graph showing power consumption at different frequencies](image)
**REB1-VA10820 Development Board**

- Huge ecosystem of development tools
- All popular ARM compilers support VORAGO
- Board Support Package available
- Application notes available

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<th>Supplier</th>
<th>Software Development Kit</th>
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<tr>
<td>ARM Keil</td>
<td>MDK Microcontroller Development Kit</td>
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<td>IAR Systems</td>
<td>IAR Embedded Workbench</td>
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<td>iSYSTEM</td>
<td>winIDEA</td>
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<tr>
<td>FreeRTOS</td>
<td>Real-time Operating System</td>
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VORAGO TECHNOLOGIES

Opening up new possibilities

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