CSP: High Performance Reliable Computing for SmallSats

Katherine Conway, Bert Vermeire, Jordan Healea, David Strobel
Space Micro Inc.

CubeSat Developers’ Workshop 2017
Cal Poly San Luis Obispo
April 26-28, 2017
Hybrid Product Design Philosophy

- Combines industrial and space grade parts
- Superior performance and reliability are achieved while staying within typical CubeSat program cost constraints
- Radiation tolerant devices monitor and manage COTS devices
- Fault tolerant computing (Hardware, software, information, networking, and time redundancy)
- Customized parts selection is applied to achieve configurations for different reliability requirements and radiation environments (up to 100 krad)

CSP Radiation Testing
CubeSat Space Processor (CSP) single board computer

- Hybrid Product Design Strategy
- Designed to meet space environments
  - Vibe, Shock, Conduction cooled
  - Parts selected for TID resilience
  - Embedded soft error mitigation
- Powered by Xilinx Zynq-7020
  - Dual ARM cores
  - 7-series FPGA fabric
- DDR3 SDRAM
- Flash Memory

Extensive Software Options

Modularity

Heritage
- Currently flying on ISS
- Selected for five Space Missions
| **Processor** | Xilinx Zynq-7020  
2.5 DMIPS/MHz per CPU  
CPU frequency: Up to 667 MHz (-1)  
Up to 866 MHz (-3) |
| **FPGA Programmable Logic** | 33 MHz or 100 MHz Clock  
24 differential pairs, 12 single ended  
140 - 36Kb Block RAM (4.9 Mb)  
Programmable I/O Blocks Supports LVCMOS, LVDS, and SSTL, with 1.2~3.3 V I/O  
12 bit ADCs up to One Million Samples per Second |
| **Total IO** | 24 LVDS and 38 Single-ended |
| **Operating Systems** | Wumbo GNU/Linux, RTEMS, VxWorks, ThreadX |
| **Supported Interfaces** | 8 Channels DMA  
SpaceWire  
10/100 Ethernet  
USB 2.0 OTG  
CAN 2.0B (1 Mb/s)  
SPI (3 chip selects)  
JTAG  
I2C (external 3.3 V pull-ups required)  
UART (Max baudrate of 921600 bps)  
Hardware & Software Watchdog timer  
Camera Link |
| **Memory** | 8 Gbit NAND Flash (EM)  
RadTolerant 32 Gbit NAND Flash (FM)  
Two 1 Gbit DDR3 SDRAM |
| **Connector** | Samtec SEAF-RA-RA 4 x40  
Designed to be Connected to a Samtec SEAM 4 x 40 Backplane |
| **Power Consumption** | 1.6 – 2.85 Watts |
| **Temperature Rating** | CSP-EM: 70 °C  
CSP-FM: -40 °C to +85 °C |
| **Thermal** | Conduction cooled |
| **Mechanical Size** | Designed in a 1U CubeSat form factor (8.8 cm x 8.9 cm)  
Thickness: 1.65 cm (tallest component) |
| **Mass** | 60 grams |
CSP Development Kit

Solution for Interface and Software Testing

Development Kit Contents:
- CSP Engineering Model
- CSP Evaluation Board
  - JTAG programming support
  - 10/100 Ethernet
  - MIO and EMIO breakout
  - 3 SpaceWire breakouts
  - Cameralink breakout
- USB to UART Board
  - USB to UART Converter (1.8, 2.5, 3.3V logic supported)
- Software
  - Access to CSP software and firmware repository
CSP Software

- **Operating Systems**
  - Wumbo GNU/Linux, RTEMS, VxWorks, ThreadX

- **Interfaces**
  - 8 Channels DMA
  - SpaceWire
  - 10/100 Ethernet
  - USB 2.0 OTG
  - CAN 2.0B (1 Mb/s)
  - SPI (3 chip selects)
  - JTAG
  - I2C (external 3.3V pull-ups required)
  - UART (Max baudrate of 921600 bps)
  - Hardware & Software Watchdog timer
  - Camera Link

- **Applications**
  - Multiple open source and third party IP
  - Core Flight Executive/Core Flight System
Modularity and Expansion

- **Backplane**
  - Dense, high-speed 160-pin backplane connector
  - 24 LVDS and 38 Single-ended IO

- **Examples**
  - Multiple CSPs (e.g. Super-CSP)
  - Modem Board
- Radiation tolerant Software Defined Modem in 1U form factor
- Supports IF frequencies up to 150 MHz
- Occupied bandwidth up to 25 MHz
- Typical configuration is 5-10 MHz occupied bandwidth at 70 MHz IF

Transmit data, Receive data, control & status (to SBC)

Digital control, analog status, analog control (to RF module)

Reconfigurable Microsemi FPGA

Receive IF
Transmit IF
Synthesizer Reference
Configuration Management

Design Analyses

- Structural, Mechanical & Thermal analysis
- Reliability, Part Stress & Worst Case analysis
- Radiation (destructive events, TID, SEE, SEU, SEFI)
  - Standard space products typically targeted to 30 or 100 krad(Si)
  - Use many parts databases
  - Routinely conduct radiation testing
  - Shielding can be provided for extra TID margin

Parts, Materials and Processes

- Traceability with MRP and travelers
- Counterfeit (CF) parts avoidance
- No pure tin
- Capable of working to NASA Level 1/Class “S” or TOR (Level 2 & Commercial Space are most common)
- In-house parts screening capability
- Regular participation in various industry groups (SPWG)
Industry Standard Manufacturing Practices

- **Parts Procurement**
  - Strong relationship with manufacturers and distributors of parts
  - Purchase from authorized distributors or OEM’s
  - Quality clauses
  - Ability to purchase larger quantities of long lead parts

- **Manufacturing and Test**
  - Sub-tier Management
  - Acceptance Testing

- **Documentation**
  - End Item Data Package (EIDP)
  - Certificate of Conformance
We are an ISO 9001 registered house since 2008
- Undergone two re-certification audits
- Last was October 2014

Quality Policy
- Space Micro Inc. is committed to customer satisfaction by producing defect-free products that conform to customer requirements and expectations, through systematic and controlled operations, on-time deliveries, and a culture of continuous process improvement.

Quality Manual

Standard Operating Procedures address Space Micro processes

Workmanship Standards
Purchased Parts and Materials
- MAM reviews Purchase Requests & Inserts Appropriate Quality Clauses
  - Quality clauses also adapted from customer flow downs
  - Applicable command media (SCDs, MI’s, Drawings) accompanies Purchase Order
  - Purchased Items are verified at Source and/or Receiving Inspection

Contracted Supplier Processes
- MAM reviews Purchase Requests & Inserts Appropriate Quality Clauses
  - Applicable command media (SCDs, MI’s, Drawings) accompanies Purchase Order
  - Source Inspection:
    - PCB Assembly House: Placement, orientation, workmanship
    - Conformal Coat/Staking House: Workmanship

Internal Processes
- Applicable command media (Travelers, BOM’s, MI’s, Drawings) accompany kitted/built up assemblies
- In-Process inspection verifies command media and workmanship
- Space Micro Standard Operating Procedures (SOPs) apply
- Non-Conformance Management
Quality Assurance Participation

- Perform Inspections to Ensure Compliance to Workmanship Requirements
  - IPC-A-610 Acceptability of Electronic Assemblies
  - J-STD-001 Requirements of Soldered Electrical and Electronic Assemblies
  - J-STD-001 Space Addendum
  - NASA-STD-8739 workmanship standards

- Ensure Facilities Compliance
  - Equipment Calibration
  - Facilities Cleanliness
  - ESD Safeguards

- Audit Manufacturing Documentation
  - Proper Revisions, Approvals, Sign-offs, Stamps
  - Operations Completed Correctly and Signed-Off
  - Oversight/Review Contract Manufacturing Workmanship and Documentation
  - End-Item Data Package (e.g. Test Data, Travelers, Photos/X-Rays, etc.)
  - Provide Certificate of Conformance