GR716
Single-Core LEON3FT Microcontroller

Cobham Gaisler

AMICSA 2018

GR716 – LEON3FT Microcontroller

Introduction

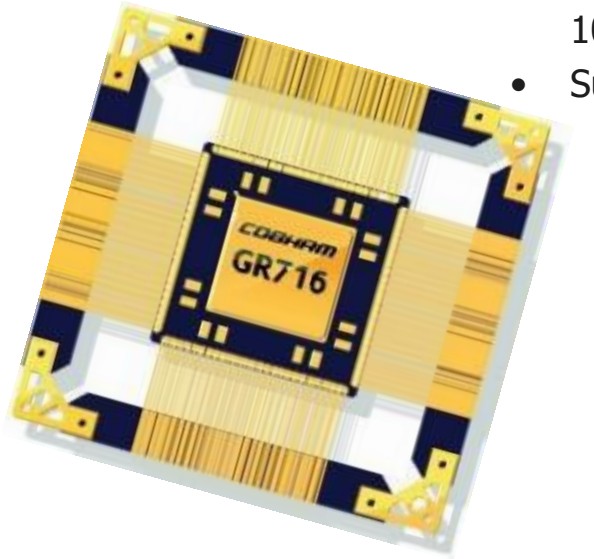
Description

The GR716 features a fault-tolerant LEON3 SPARC V8 processor, communication interfaces and on-chip ADC, DAC, Power-on-Reset, Oscillator, Brown-out detection, LVDS transceivers, regulators to support for single 3.3V supply, ideally suited for space and other high-rel applications

Applications

Support for many different standard interfaces makes the GR716 microcontroller is ideally fit for handling supervision and control in a satellite, such as

- propulsion system control
- sensor bus control
- robotics applications control
- simple motor control
- mechanism control
- power control
- particle detector instrumentation
- radiation environment monitoring
- thermal control
- antenna pointing control
- remote terminal unit control
- simple instrument control



Specifications

- System frequency up-to 50 MHz
- SpaceWire links up-to 100 Mbps
- CQFP132 hermetically sealed ceramic package
- Total Ionizing Dose (TID) up to 100 krad (Si, functional)
- Single-Event Latch-Up (SEL) to LET_{TH} > 118 MeV-cm^{2}mg
- Single-Event Upset (SEU) below 10^{-12} bit error rate
- Support for single 3.3V supply

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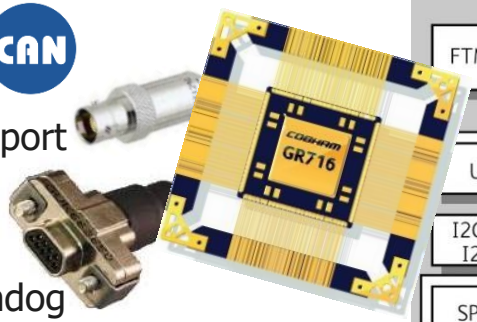
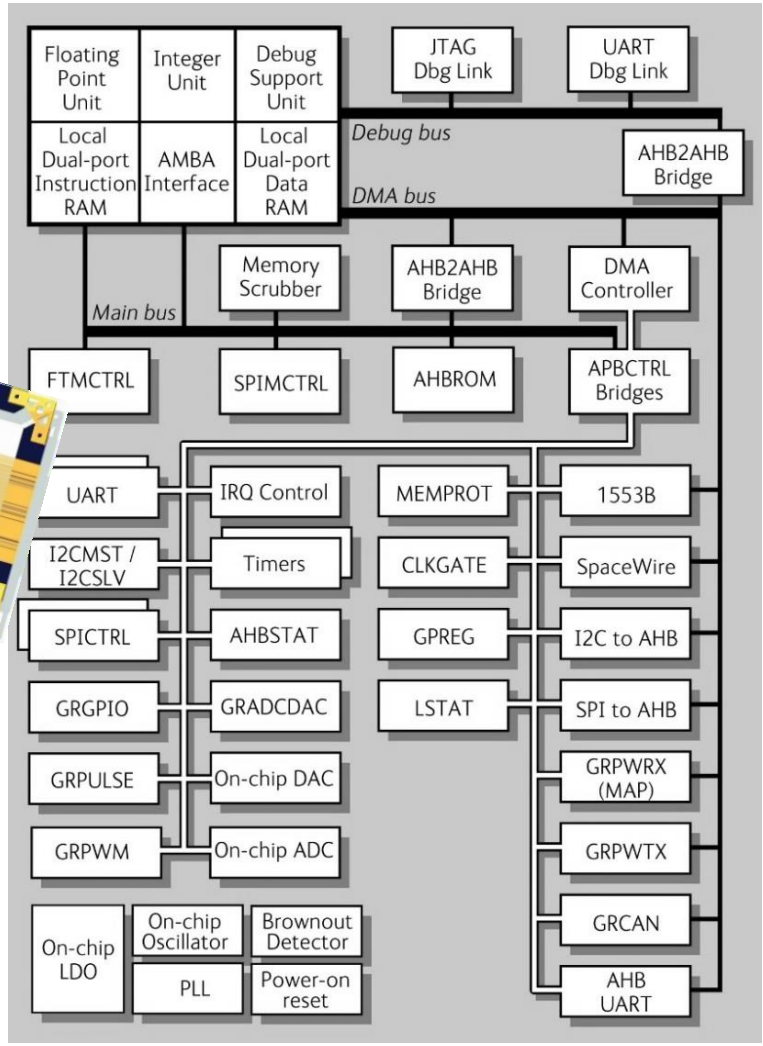
Features

- LEON3FT - Fault-tolerant SPARC V8 32-bit processor, 50 MHz
  - 16-bit instruction set: LEON-REX - improved code density
  - Floating Point Unit
  - Memory protection units
  - Non-intrusive advanced on-chip debug support unit
- External EDAC memory: 8-bit PROM/SRAM, SPI, I2C
- SpaceWire interface with time distribution support, 100 Mbps
- MIL-STD-1553B interface
- 2x CAN 2.0B controller interface
- PacketWire with CRC acceleration support
- Programmable PWM interface
- SPI with SPI-for-Space protocols
- UARTs, I2C, GPIO, Timers with Watchdog
- Interrupt controller, Status registers, JTAG debug, etc.
- Dual ADC 11bits @ 300Ksps, 4 differential or 8 single ended
- DAC 12bits @ 3Msps, 4 channels
- Mixed General purpose inputs and outputs
- Power-on-Reset and Brown-out-detection
- Temperature sensor, Integrated PLL
- On-chip regulator for 3.3V single supply
- 132 pin QFP, 24 mm x 24 mm





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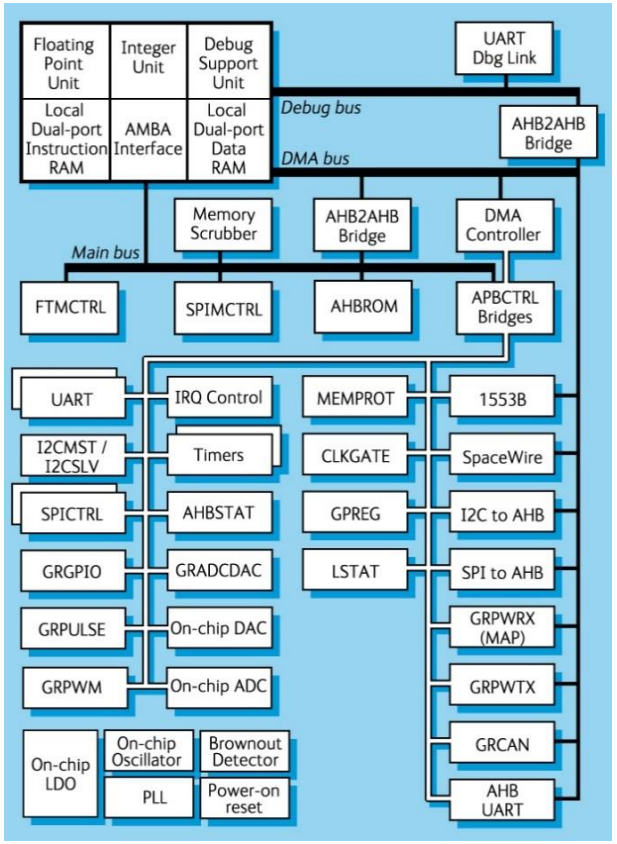
Key features – system support

- On-chip voltage regulators for single supply support. Capability to sense core voltage for trimming of the embedded voltage regulator for low power applications.
- Power-on-reset, Brownout detection and Dual Watchdog for safe operation. External reset signal generation for companion chips.
- Crystal oscillator support and external clock reference
- One PLL for System and SpaceWire clock generation. In-application programming of system clock and peripheral clocks. System and SpaceWire clocks switches glitch free.
- Low power mode and individual clock gating of functions
- Temperature and core voltage sensor
- External voltage reference for precision measurement
- Statistics unit for profiling of the system



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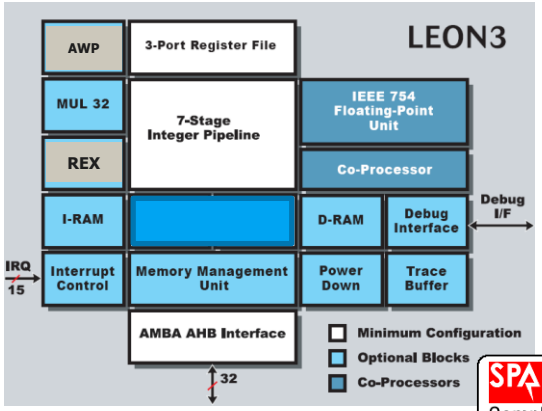
Key features – processor and memory

Processor core

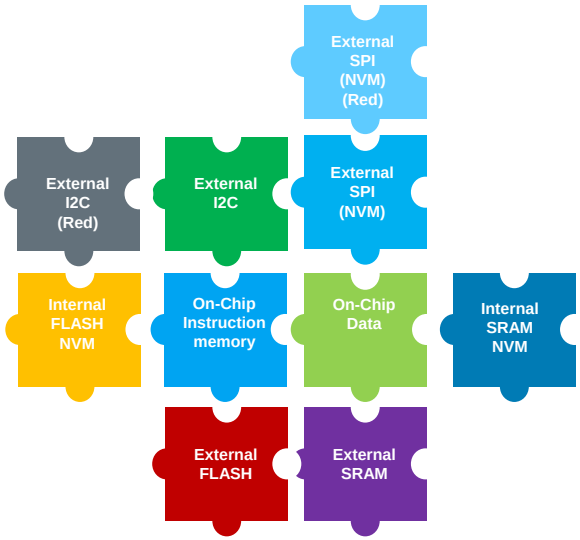
- Fault-tolerant SPARC V8 processor with 31 register windows and support 16-bit instruction operation (REX)
- Double precision IEEE-754 floating point unit
- Memory protection units with 8 zones and individual access control of peripherals
- Advanced on-chip debug support unit with trace buffers and statistics
- Deterministic software execution and non-intrusive debugging
- Fast context switching (PWRPSR, AWP, register partitioning, SVT, MVT)
- Interrupt zero jitter delay



Fault-tolerant SPARC V8 processor

Memory support

- 192KiB EDAC protected tightly coupled memory with single cycle access from processor and ATOMIC bit operations
- Dedicated SPI Memory interface with boot ROM capability and EDAC
- I2C memory interface with boot ROM capability
- 8-bit SRAM/ROM I/F with support up to 16MiB ROM and 256MiB SRAM
- Scrubber with programmable scrub rate for all embedded memories and external PROM/SRAM and SPI memories
- Redundant boot memory (PROM/SRAM/SPI/I2C/NVRAM)
- Application software container for checking software integrity using CRC
- Boot from internal SRAM, external PROM/FLASH/SRAM/SPI/I2C memory



Support of many variety of memory types

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Key features – Processor Performance

- On-chip SRAM w/ Dual Port, EADC and Scrubbing, Radiation Tolerant
  - 192 KiB Instruction and Data – User defined mix of instruction vs data
- Integrated Floating Point Unit
  - IEEE-754 compliant floating-point unit, supporting both single and double precision operands
- Memory Protection Unit
  - 8 zones and individual access control of peripherals
- System Clock frequency: 50MHz
  - Dynamic reconfiguration of system clock for low power
  - 100 MHz system clock for high performance system under restricted environment conditions
- System Benchmark
  - Dryshtone: 1.83 Dhrystone / MHz
  - Whetstone: 0.43 Whetstone / MHz
  - CoreMark: 2.21 CoreMark / MHz
  - EDAC, Scrubbing, DMA transfers and debug are non-intrusive and do not affect performance

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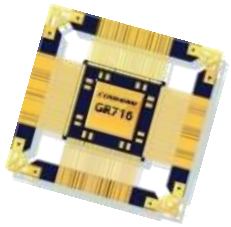

Processor	**Processor core**	LEON3FT
	Architecture	SPARC V8 w. V8e subset
	RISC type	32bit
	Instruction set	SPARC V8(e), LEON REX
	Pipeline stages	7
	Tightly coupled memory	192 KiB
	FPU	IEEE-754
	MPU	yes
	Mul/Div	Mul/Div
	Peripheral DMA	multi-channel
	Interrupt handling	deterministic
	Performance counters	yes
	Debug unit	yes
	Embeded trace buffer	yes
	Processor MHz	50
Performance	**Dhrystone / MHz**	1.83
	Whetstone / MHz	0.43
	CoreMark / MHz	2.21

Real Time features and enhancements

- Fast context switching (PWRPSR, AWP, Register partitioning, SVT, MVT)
  - Very low interrupt response time can be achieved by switching register window
  - A unique trap handler can executed in its own register window (Register partitioning)
  - Benefits from register partitioning:
    - Extremely low interrupt latency
    - All local and input registers are preserved
    - Nested interrupt are supported by hardware
- Interrupt zero jitter delay
- Deterministic software execution and non-intrusive debugging
  - Advanced on-chip debug support unit with trace buffers and statistic unit

- Custom flat register window model
- Typical flat register window model (MVT) using BCC 2.0.2
- Typical flat register window model (SVT) using BCC 2.0.2

	Typical		Worst	
	IRQ to ISR	ISR EXIT	IRQ to ISR	ISR EXIT
BCC 2.0 Custom ISR	11	6	11	6
BCC 2.0 flat ISR	22	15	37	15

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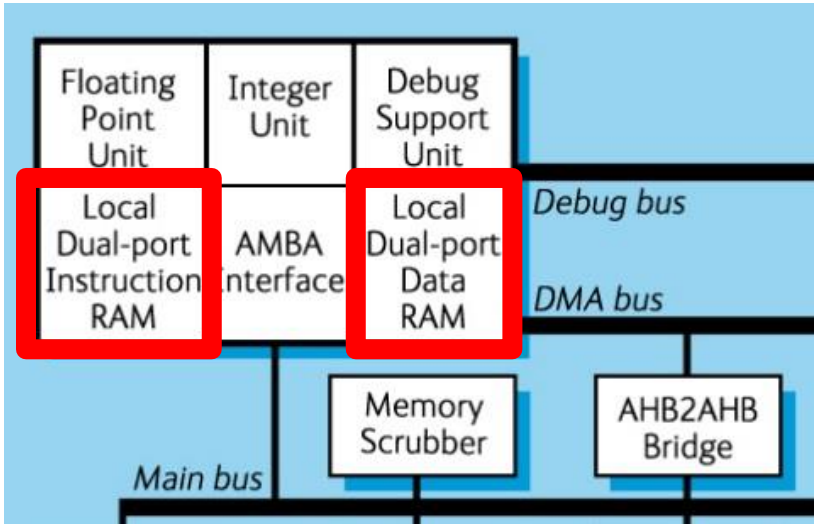
Key features – tightly coupled local memory

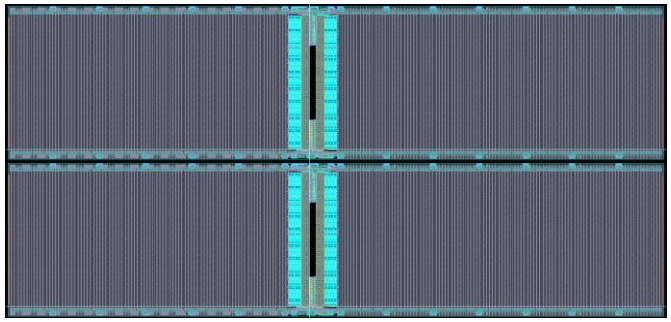
The microcontroller has **local instruction** and **data** on-chip RAM connected to the LEON3FT processor

Local RAM features:

- 128KiB Instruction memory
  - single cycle access
- 64KiB Data memory protected by EDAC
  - single cycle access
- Scrubber support
- Dual port access enables
  - seamless uploading of new program
  - DMA traffic direct into data memory without affecting program execution or data fetch
  - scrubber access and EDAC correction without affecting program execution or data fetch
- Support atomic bit-filed operations
  - OR, AND, XOR, Set & Clear
- Instructions can be executed from data memory and data can be stored in instruction memory



Local instruction and data memory is located close to LEON3FT processor for single cycle access



Rad Hardened High density SRAM Integration - Integrated error detection and correction. One error can be corrected and two errors can be detected, which is performed by using a (32, 7) BCH code

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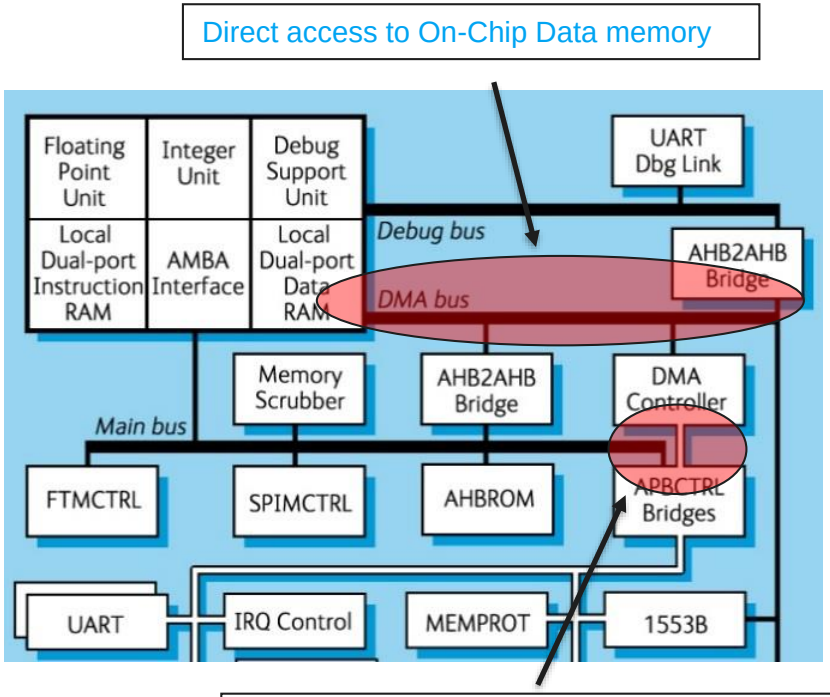
Key features - Direct Memory Access Controller

- System DMA overview
  - 4 individual DMA cores (each core has multiple channels)
  - Multiple AHB interface and direct access to APB Peripheral
- Programmable DMA transfers through stand-alone DMA controller
  - Responds to Interrupts, Polling register, Loop support
  - Responds to combination of interrupt and register polling
- Programmable DMA user scenarios
  - Offload processor
  - Autonomous transfers from/to ADC/DAC without CPU intervention
  - Autonomous transfers between: UART to UART, SPI to SPI or I2C to I2C
  - Transfer data, update register synchronous to event e.g. PWM output levels



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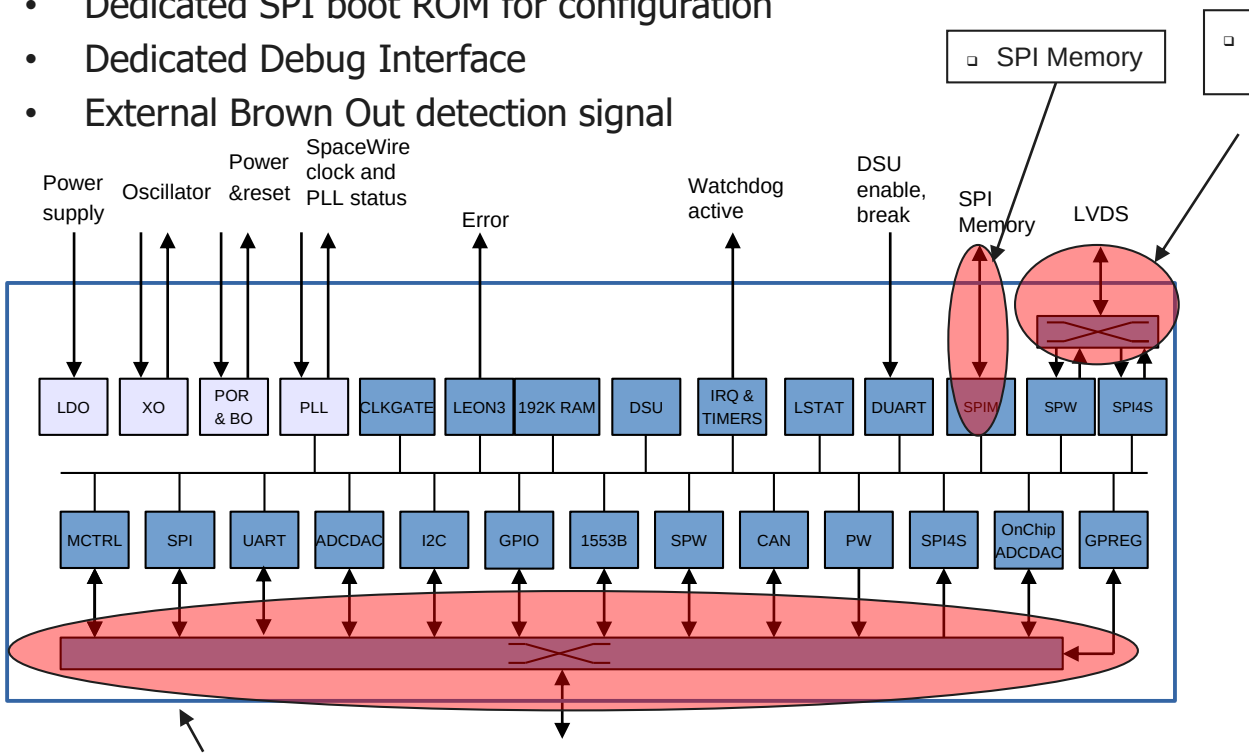
Key features – inputs/outputs

I/O

- Configurable I/O selection matrix with mixed signals, internal pull-up/pull-down resistors
- LVDS transceivers for SpaceWire or SPI4Space
- Clock and reset for companion chips e.g. GPIO-expander, external RAM etc.
- Dedicated SPI boot ROM for configuration
- Dedicated Debug Interface
- External Brown Out detection signal



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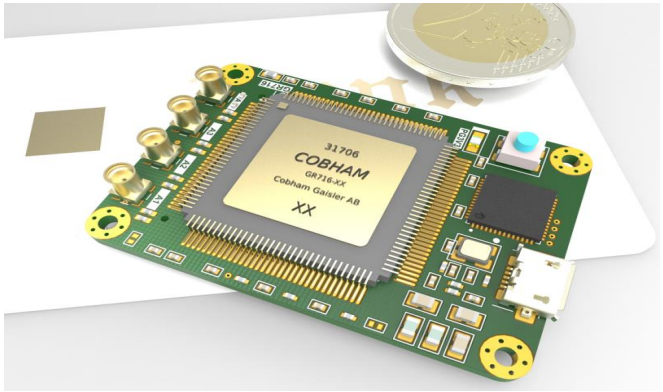
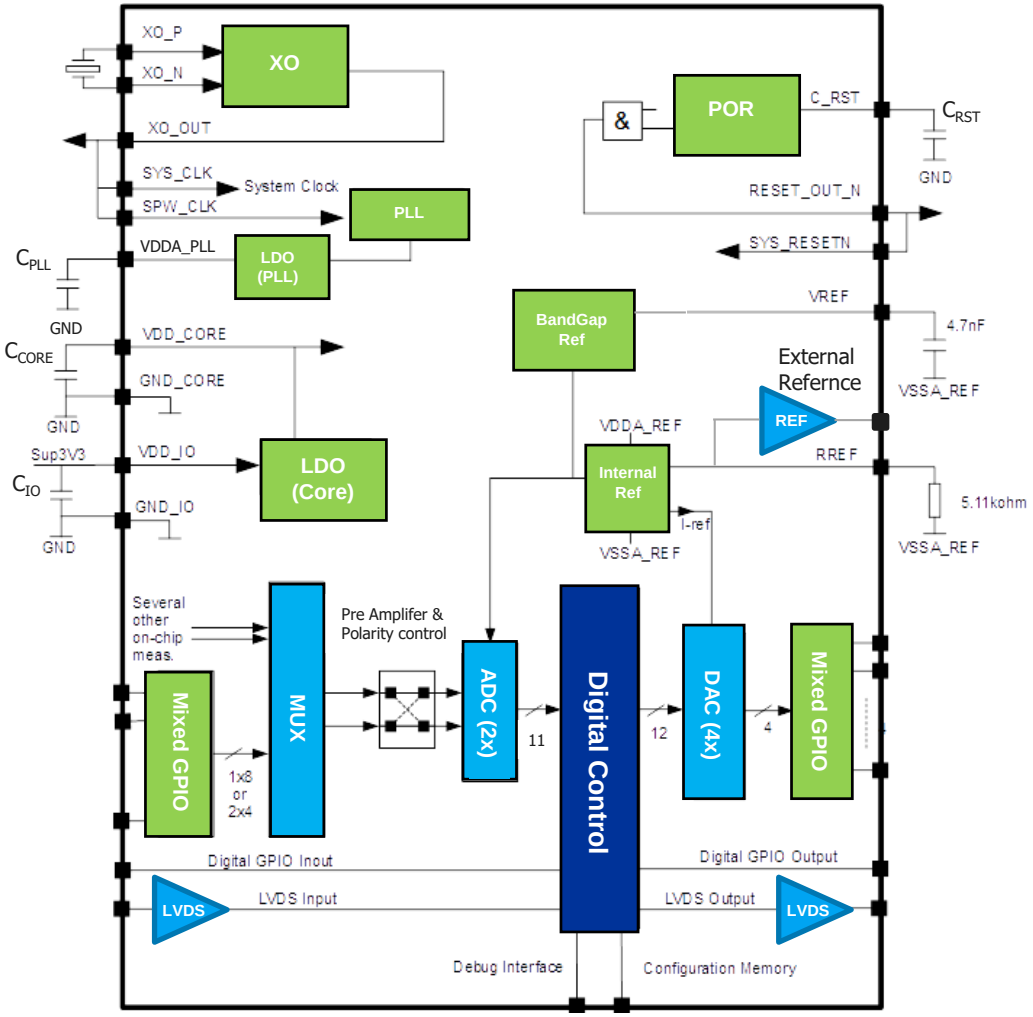
Key features – a minimum of external parts

- Minimum application requirements:
  - 3.3V supply
  - frequency resonator in the range of 5MHz to 25MHz
  - de-coupling capacitor
  - reference resistor
- Minimum application enables
  - system clock and reset
  - remote access to GR716 via SpaceWire, SPI, UART and I2C
  - access to all functions





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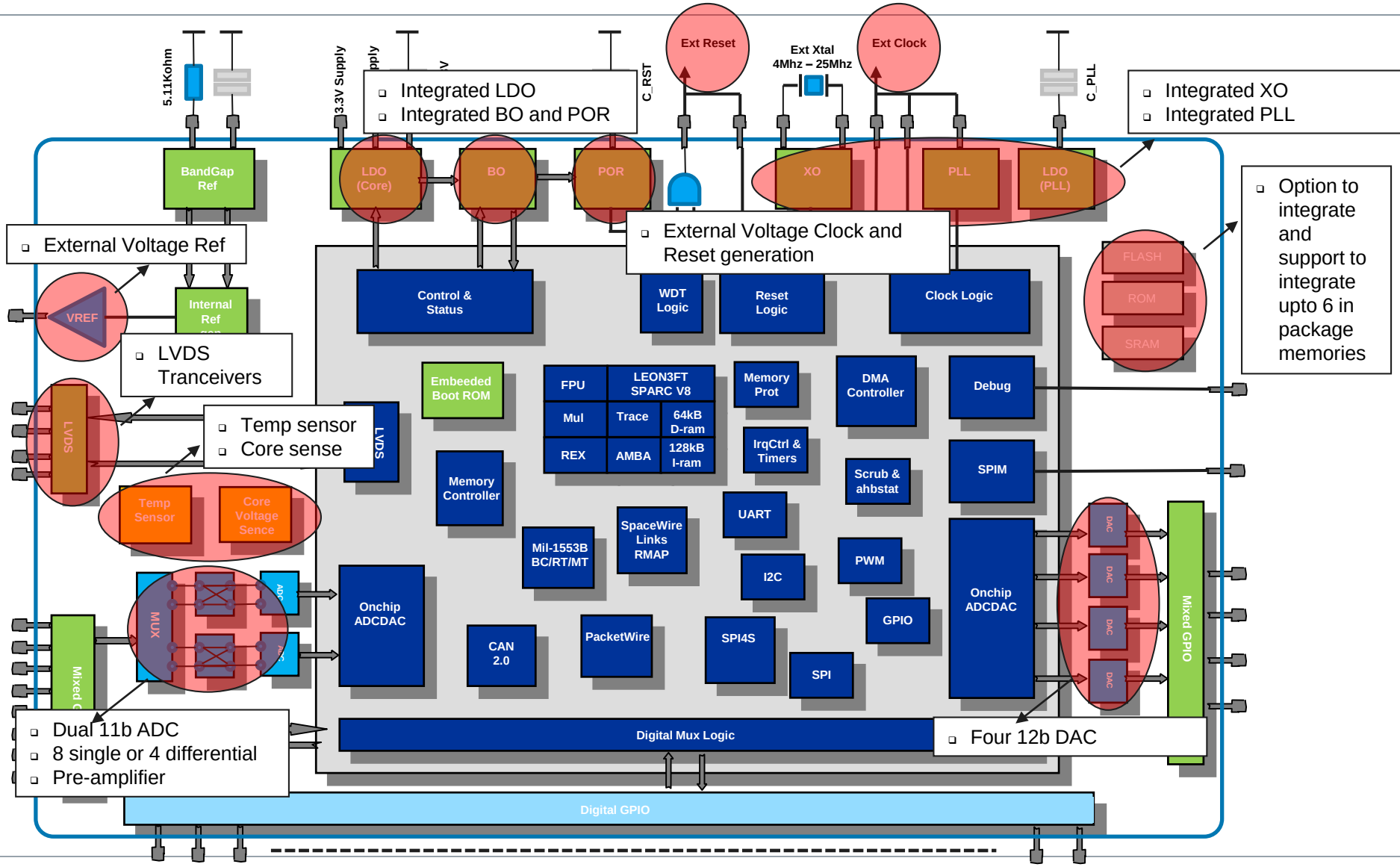
Analogue architecture – Schematic Overview



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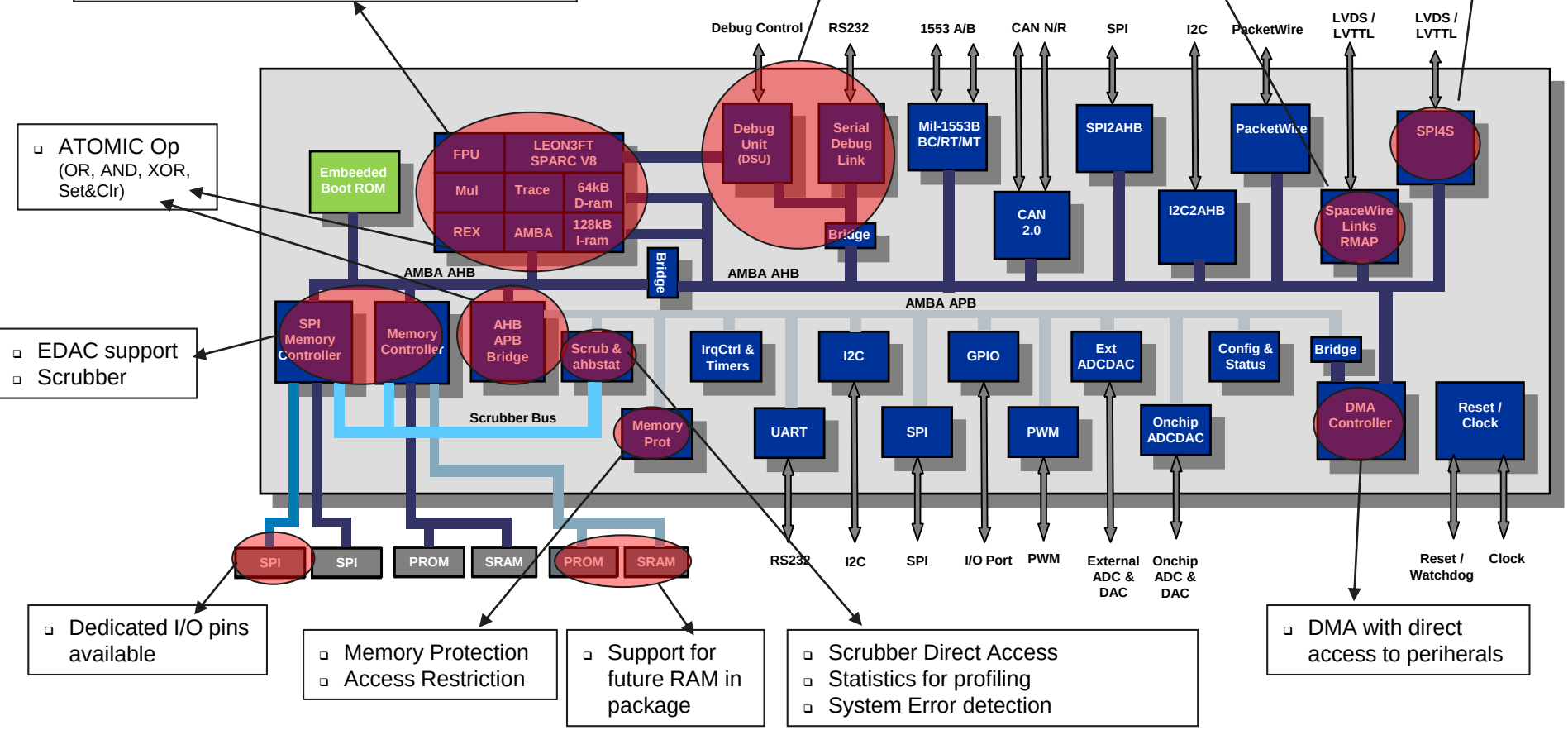
Digital architecture – plenty is not enough

- Support for AWP and fast context switch
- FPU and 32bit MUL
- 192KiB EDAC Protected Memory
- Single cycle instruction execution
- Determenistic execution and interrupt latency

- Debug Link
- Instruction/AHB trace
- Non-Intrusive

- RMAP Support
- TDP Support

- HW support for Protocol level 0,1 and 2



- ATOMIC Op (OR, AND, XOR, Set&Clr)

- EDAC support
- Scrubber

- Dedicated I/O pins available

- Memory Protection
- Access Restriction

- Support for future RAM in package

- Scrubber Direct Access
- Statistics for profiling
- System Error detection

- DMA with direct access to periherals

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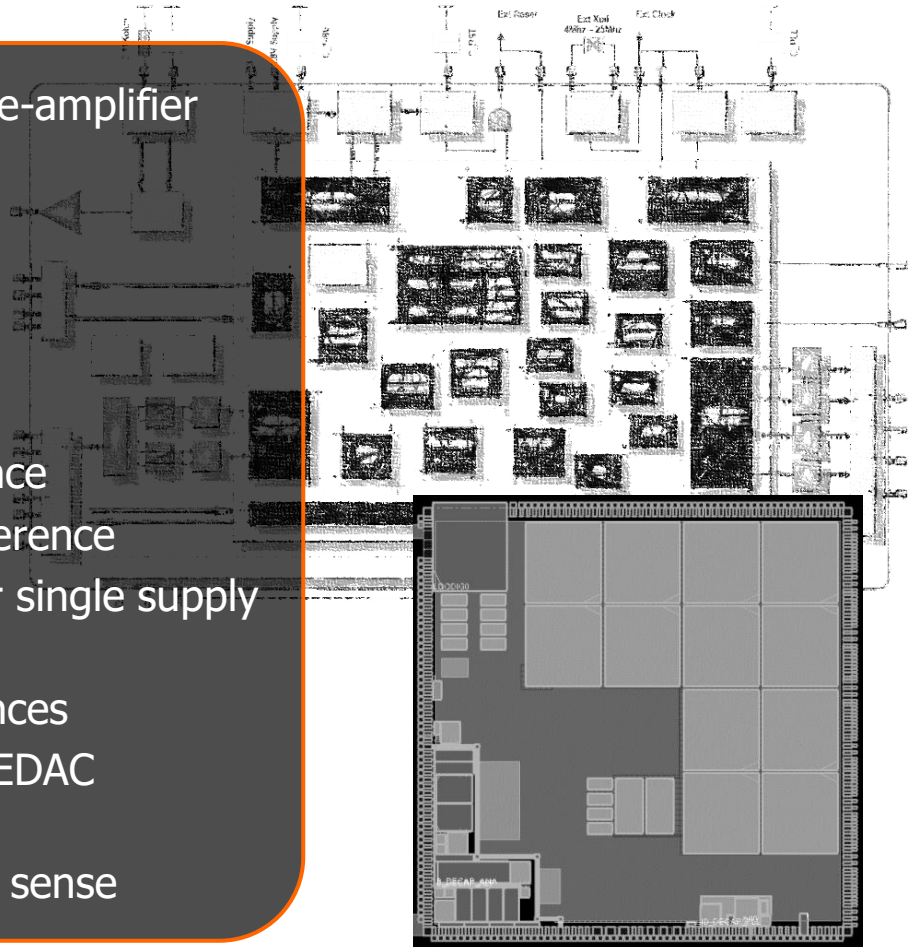
Key features – Integrated Analogue features

- Dual 11 bits 300KS/s SAR ADC with Pre-amplifier
- 12 bit 3.75MS/s Rad Hardened DAC
- Crystal Oscillator
- Power On Reset
- 1.8V and 3.3V voltage monitors
- GPIO with local Power on Control
- LVDS transceivers with build-in reference
- Rad Hardened voltage and current reference
- Rad Hardened Low-drop regulators for single supply support
- Rad Hardened external voltage references
- Rad Hardened high density RAM with EDAC protection
- Temperature sensors and core voltage sense



- Radiation Hardened
  - TID 100krad(Si), SEL 118 MeV-cm^{2}mg, SEU 10^{-12}

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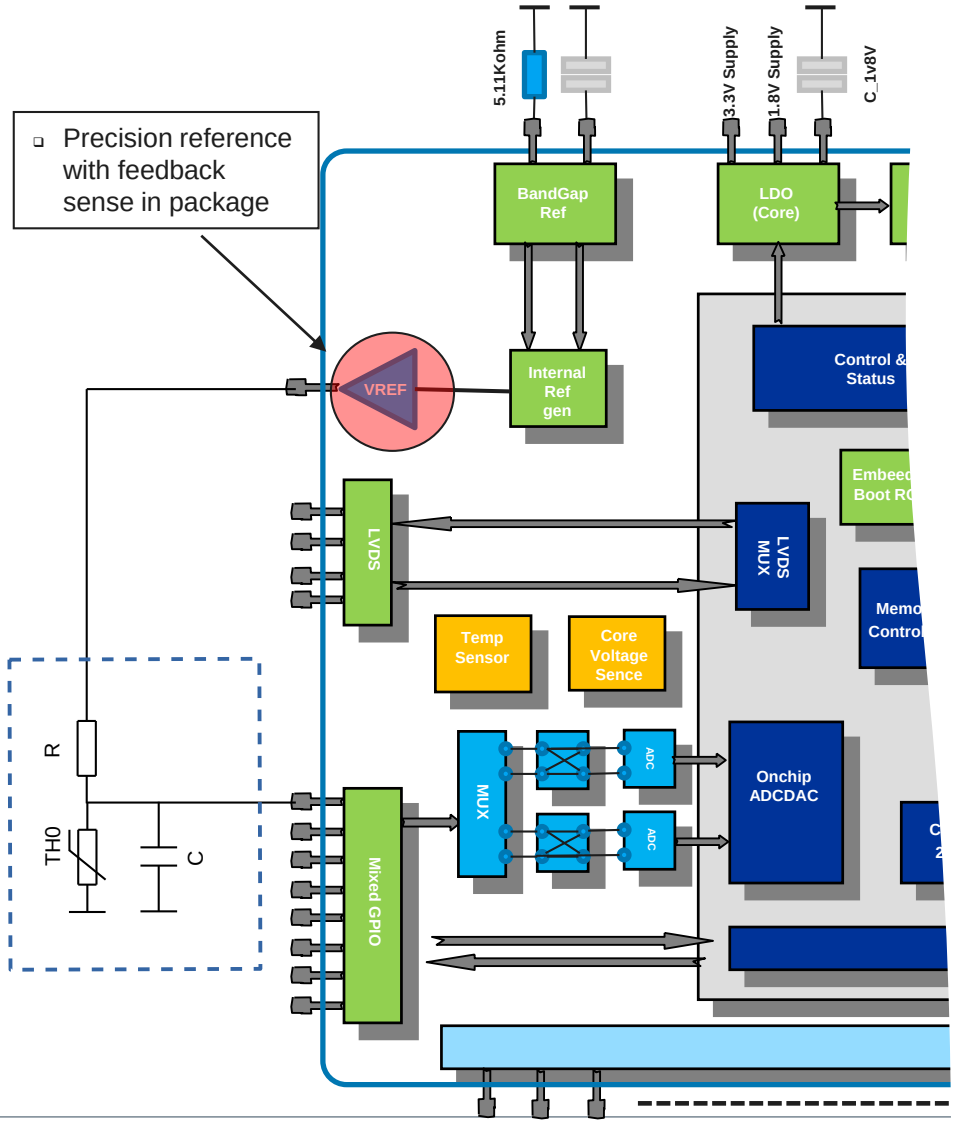
Analog feature Overview – External precision reference

- Thermistor Measurements Application
- Internal ADC and External Thermistor use the same precision voltage reference
- Internal precision voltage reference can be used as external voltage reference on PCB. (Max 2mA load. Higher load application requires external buffer)
- Sense in package for precision reference



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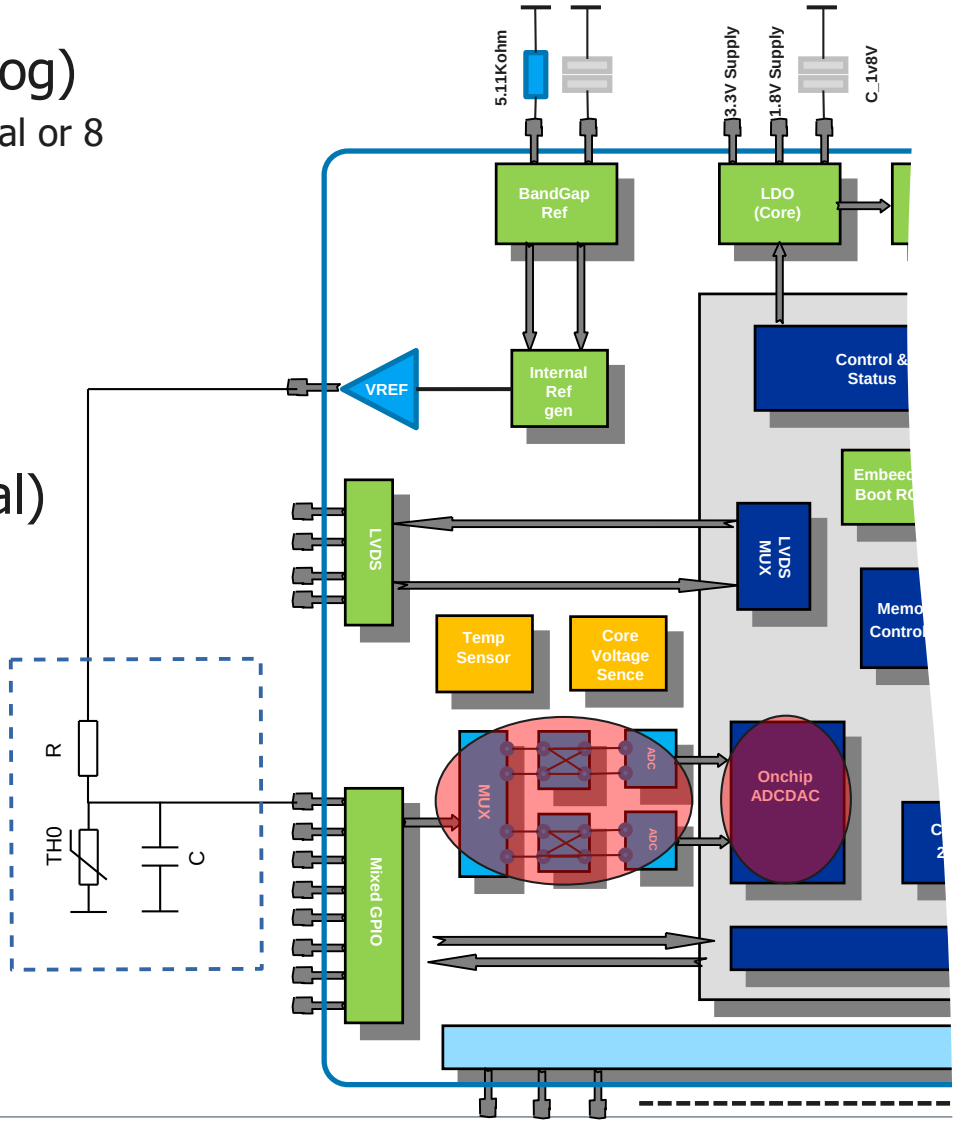
Analog feature Overview – On-chip Analog to Digital – Digital Functions

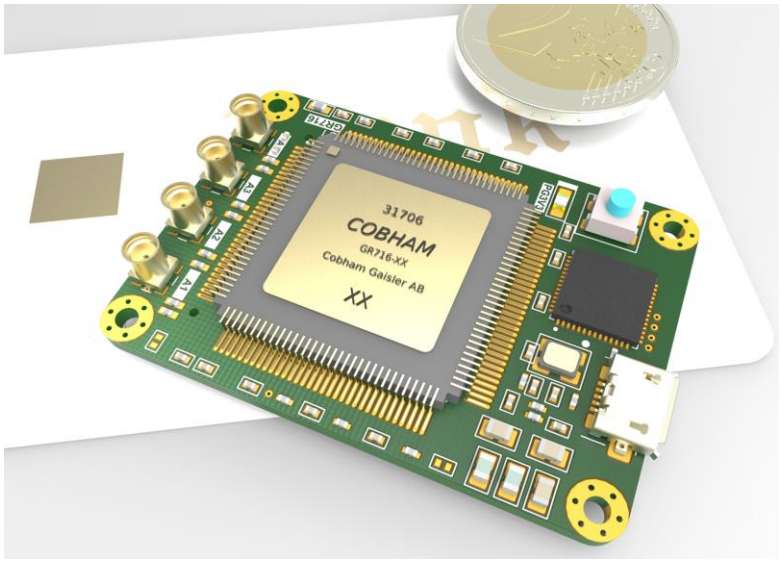
- Analog to Digital Converter (Analog)
  - 11bits @ 300Ksps, 4 channel differential or 8 channel single ended (possible to mix)
  - Pre-amplifier (0dB, 6dB or 12dB)
  - Dual Sample and hold circuits
  - Temperature sensor
  - Monitor core voltage
- Analog to Digital Converter(Digital)
  - Oversampling support
  - Sequence programming
  - Automatic level supervision
  - Automatic pre-amplifier control
  - Programmable sample triggers. Possible to trigger on internal and external events
  - Automatic channel arbitration
  - DMA support, automatic transfer of data to local or external RAM
  - Low noise sampling support

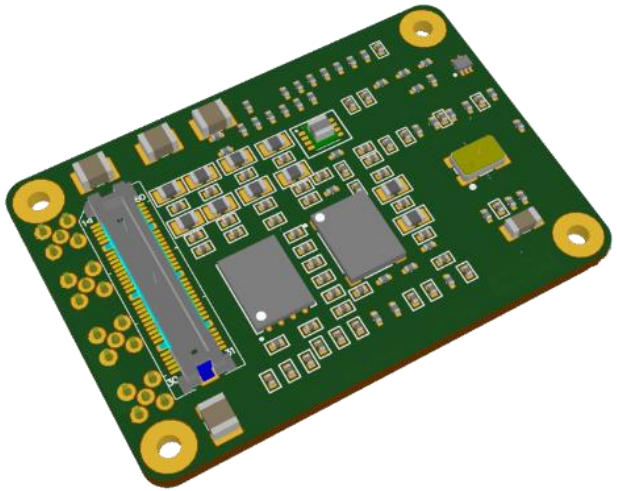


GR716 evaluation board

GR716-MINI – GR716 Sowftare evaluation board

- Baseline design for evaluation board:
  - GR716 microcontroller
  - SPI Flash PROM (32 MiB)
  - SRAM (2 MiB)
  - FTDI USB interface
    - GRMON3 debug I/F via Debug UART
    - 2x UART interfaces, 1x I2C interface
    - control of reset, configuration pins etc.
    - power supply
  - 4x MMCX (micro-miniature coaxial):
    - 2x ADC, 2x DAC
  - miniature 80 pin mezzanine connector:
    - addition ADC, DAC, LVDS, GPIO, etc.
  - Oscillator
  - LED for power indication etc.
  - 50mm x 35mm (37.5% of a credit card)
- Shipped with:
  - free GRMON3 GUI (limited) download
  - free compilers, OS, tools downloads
  - USB cable (debug and power)

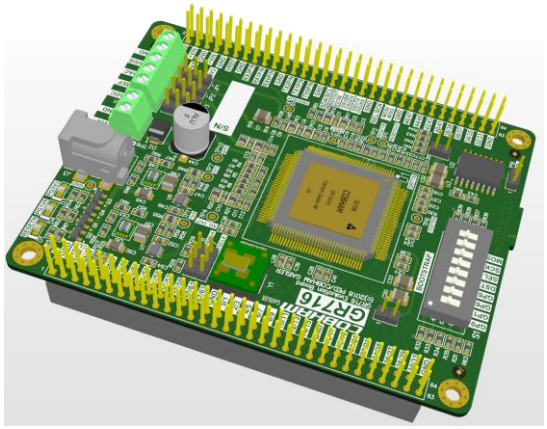




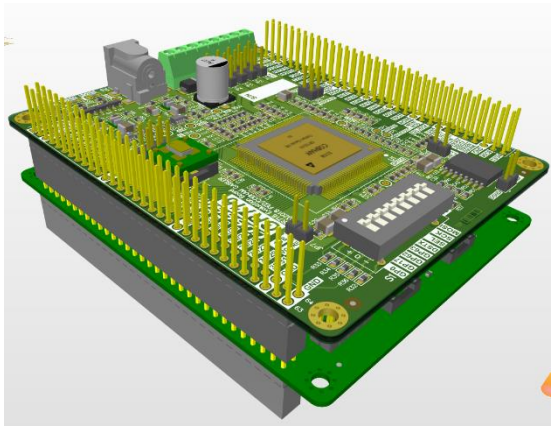
GR716 development board

GR716-BOARD – GR716 Hardware engineering board

- Baseline design for development board:
  - GR716 microcontroller
  - SPI Flash PROM (32 MiB)
  - PCI104 style stackable headers (2 x 64 pin) for interfaces
    - measurement points on all GPIO/interface signals for monitoring/debug
    - interface to user defined modules (memory, digital I/F, analog I/F)
    - interface to cPCI mother board in 6U rack or box format
  - Debug UART /IF
  - LVDS in/out (3+3 pairs) for 1x SpW or x SPI for Space
  - GPIO (64 pins)
    - digital I/O
    - external memory I/F
    - 6x UART
    - Mil-Std-1553B, PacketWire, CAN, I2C, 3x SPI, 16x PWM out
    - 8x analog in, 4x analog out, external ADC/ADC interface
    - 1x SpaceWire, 1x TDP
  - Socketed oscillator (5–25MHz)
  - DIP-switch for bootstrap options
  - Powered from external supply (range 5V to 12V)
  - Single supply operation or individual supplies
  - 80mm x 100mm format



GR716 Standalone Board

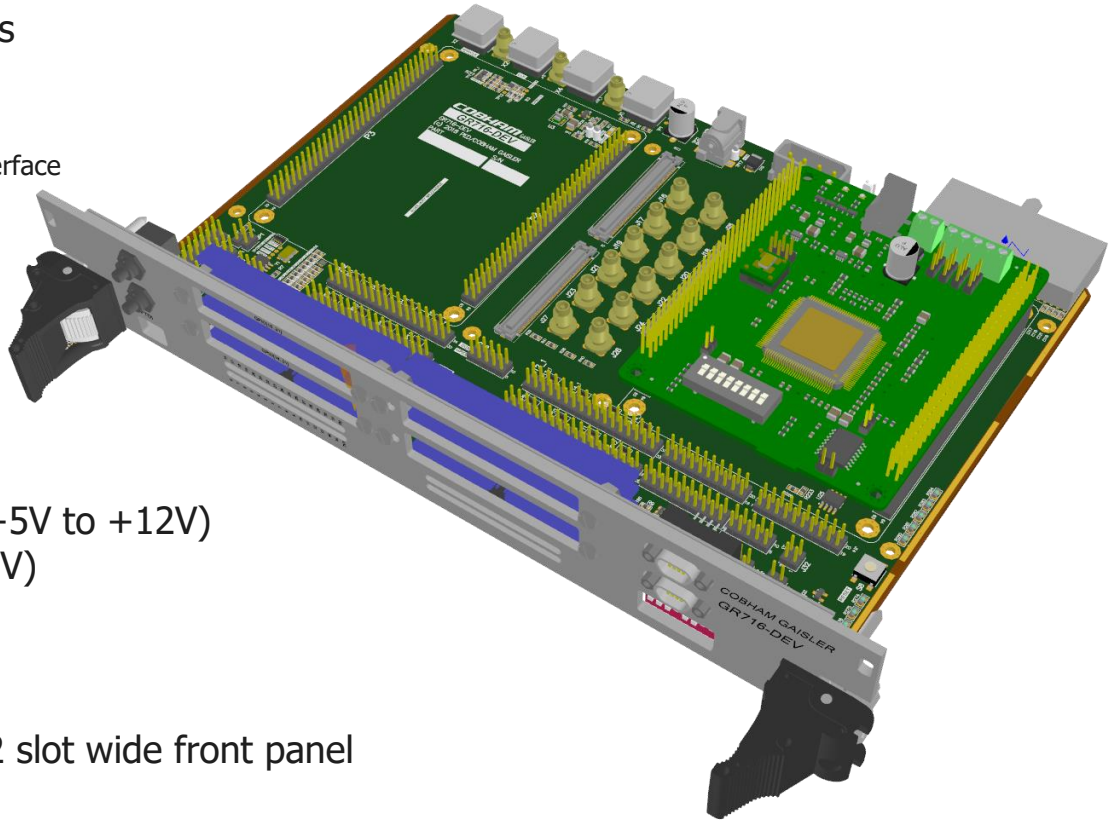


Stack multiple boards via PC104 connector

GR716 development board

GR-CPCI-GR716-DEV – GR716 interface development board

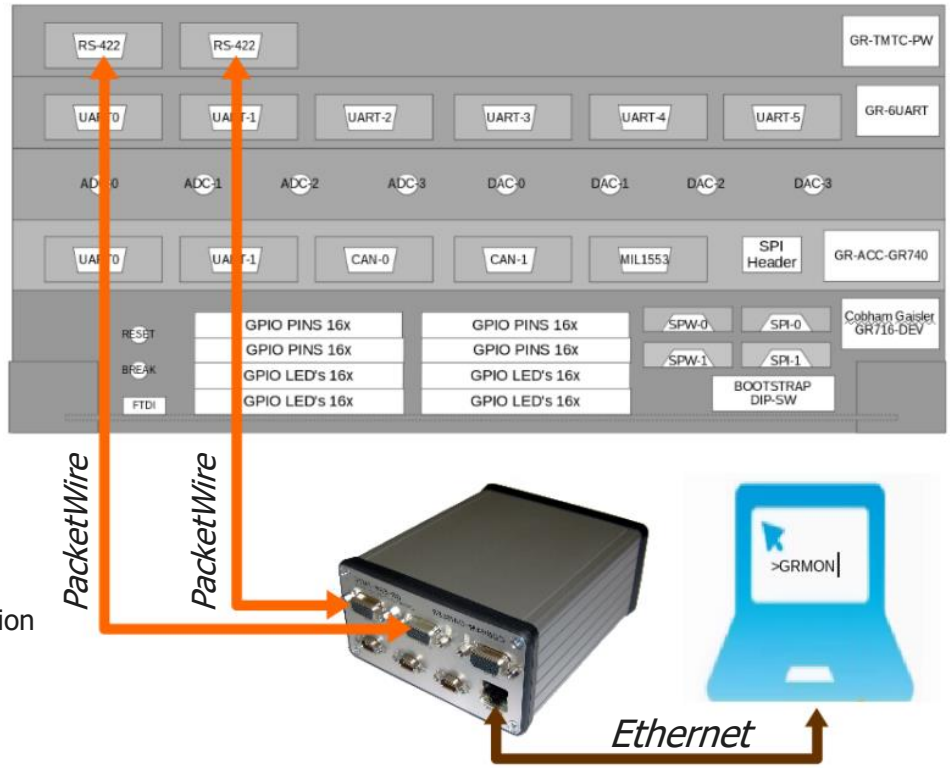
- Baseline design for interface application board:
  - GR716-BOARD engineering board in dedicated slot
    - Multiple slots for possibility to attach multiple GR716 engineering boards
  - Expansion slot for memory or user defined functions (e.g. SRAM, ADC/DAC)
  - Socketed oscillators for system, SpaceWire, Mil-Std-1553B and PWM clocks
  - Configuration of front panel functions
  - Front panel interfaces
    - MDM9S for fixed SpW (LVDS) interface
    - MDM9S for configurable SpW/SPI4S (LVDS) interface
    - GPIO (64 pins on standard 0.1" connectors)
    - LED indicators (64) for GPIO pins
    - DIP switch for bootstrap options
    - Reset and DSU Break push-button switches
    - LEDs for power and reset status
    - FTDI USB interface
      - GRMON3 debug I/F via Debug UART
      - 2x UART interfaces, 1x I2C interface
  - Power from external supply (range +5V to +12V) or via cPCI backplane connector (+5V)
  - Expansion through accessory boards
    - 6x UARTs using GR-CPCI-6U-UART
    - CAN, Mil-Std-1553B, SPI using GR-CPCI-GR740
  - 233mm x 160mm, 6U cPCI format, 2 slot wide front panel



GR716 development board

Build your application

- Build your application via available interface boards
- Compatible boards possible to direct connect and use from Cobham Gaisler:
  - GR-ACC-6U-6UART
    - Extend number of UARTs in the system
  - GR-ACC-GR740
    - Dual CAN 2.0 transceiver, Dual MIL-1553B interface and SPI interface
  - GR-CPCI-CAN
    - Dual CAN 2.0 transceiver
  - GR-TMTC-PW (6U)
    - RX/TX PacketWire interface
  - SPI4S Test Board
    - Reference board for SPI for Space demonstration
  - Analog Front end
    - Easy connection of external ADC and DAC

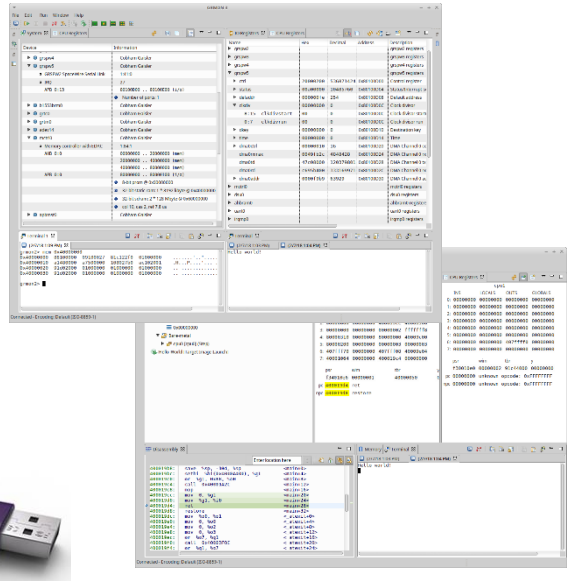


- Use Configuration Board to avoid driver contamination
  - Possible to fit mezzanine board on the development board to avoid erroneous configuration of the IOs

GR716 Development Platform

BCC2 and GMRON3 software development environment

- BCC2 Development Environment
  - GCC 7.3.0 or CLANG 7.0.0
    - Performance increase with '*link time optimization*'
    - CLANG 7.0.0 to be released in 2018
  - GR716 BSP Support build in
    - Fast interrupt support
- GRMON3 Debugger
  - Graphical User Interface (GUI) based on Eclipse TCF (Target Communication Framework) platform (used by Wind River and Xilinx)
  - GRMON displays HW/SW state in GUI without GDB in-between
  - ***Low cost limited GR716 versions***
- Future features in GRMON3 PRO
  - New TCL API and inline C-debug

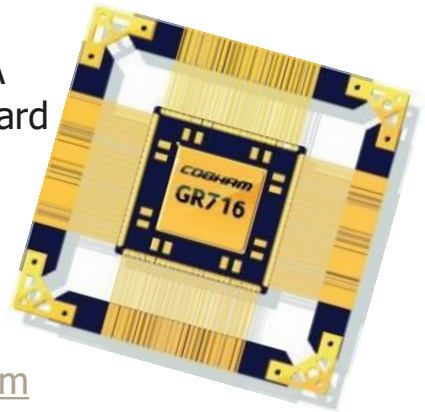


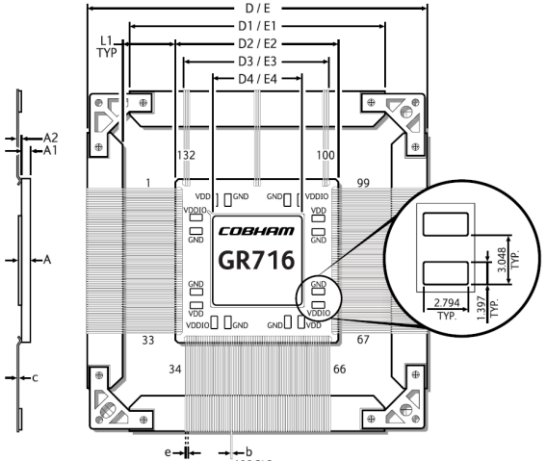
GR716 Status and Schedule

Tape-out and schedule

GR716	Status	Milestone	Comments
Advanced Data Sheet & User's Manual	*done*	*Q2 2017*	*available*
PDR	*done*	*Q2 2017*	*review passed in June*
CDR - tapeout	*done*	*Q2 2018*	*review passed in May*
Prototype level assembly		Q3 2018	2018 Sep
Prototype level test		Q3 2018	2018 Oct
Prototype level part delivery		Q3 2018	2018 Nov
Evaluation board delivery		Q3 2018	2018 Nov

- GR716 microcontroller is funded by ESA up to prototype design and validation, output from ESA activity will be prototype parts and evaluation board
- Currently there is partial funding from ESA/SNSB and Cobham (IR&D) for GR716 ESCC 9000 Lot Validation in 2019
- For more information about the GR716 device and evaluation board contact support@gaisler.com





THANK YOU FOR LISTENING!

Contact support@gaisler.com for more information