

# GR716A / GR716B

GR716 Rad-Hard Microcontroller  
For Space Applications

AMICSA 2021

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Cobham Gaisler AB

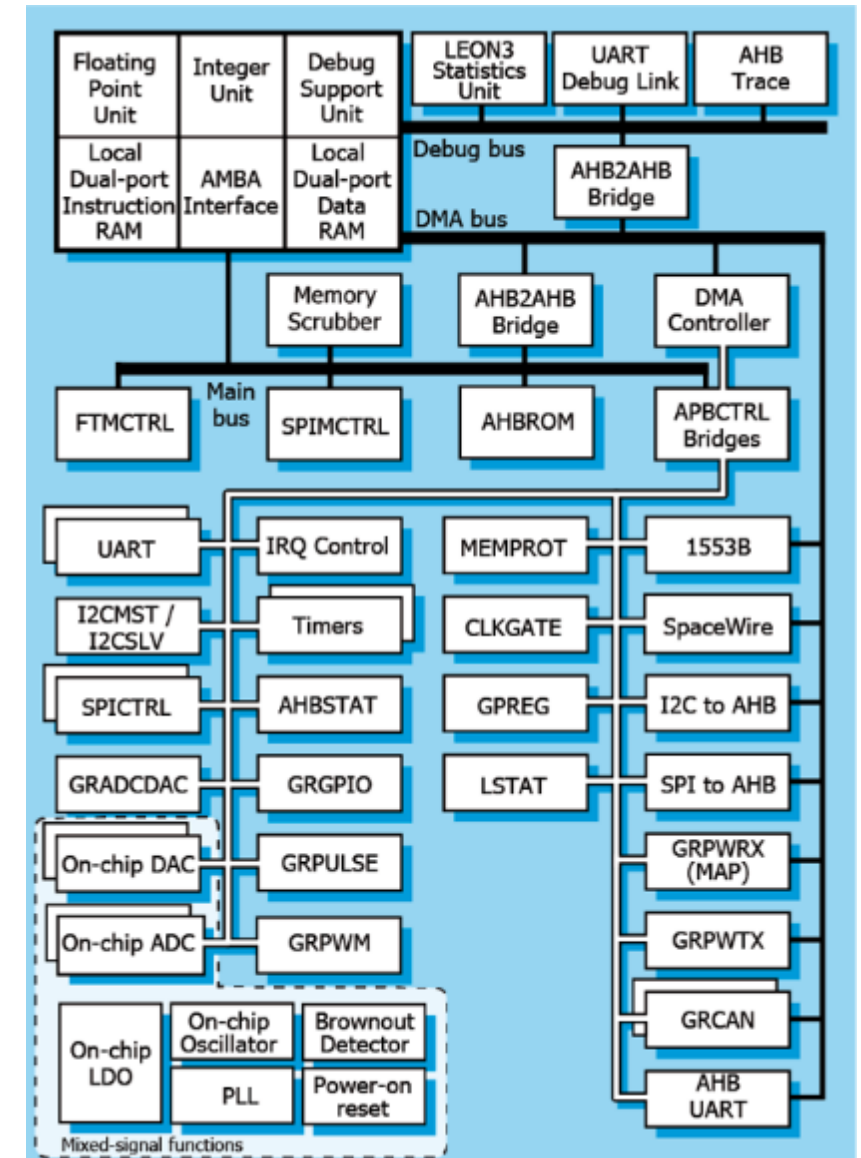
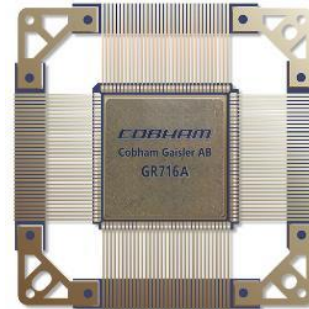
# GR716

Single-Core LEON3FT Microcontroller

# GR716A - LEON3FT Microcontroller

## Features

- LEON3FT - Fault-tolerant SPARC V8 32-bit processor, 50 MHz
  - LEON-REX – extension with 16-bit instructions: improved code density
  - Floating Point Unit
  - Memory protection units
  - Non-intrusive advanced on-chip debug support unit
  - Determinism: Multi-bus, fixed interrupt latency, cache-less architecture...
- 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
- Interrupt controller, Status registers, JTAG debug, etc.
- UARTs, I2C, GPIO, Timers with Watchdog
- 2x ADC 11bits resolution @ 200ksps, 4 diff or 8 single channels
- 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



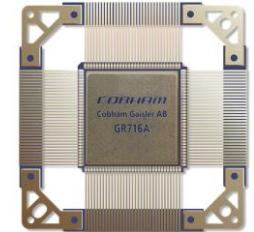
# GR716A - LEON3FT Microcontroller



- **On-chip SRAM w/ Dual Port, EDAC 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**
  - Dhrystone: 1.24 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

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
	Embedded trace buffer	yes
	Processor MHz	50
Performance	Dhrystone / MHz	0.93 / 1.24 / 1.46
	Whetstone / MHz	0.43
	CoreMark / MHz	2.21

# GR716A - LEON3FT Microcontroller



- **Standby**
  - Current consumption direct after boot has finished (Waiting remote boot)
- **CoreMark**
  - Highest measured current consumption while running CoreMark (All code is executed from internal memory protected by EDAC)
- **WhetStone**
  - Highest measured current consumption while running WhetStone (All code is executed from internal memory protected by EDAC)
- **MIL-1553 / SRAM / RTEMS**
  - Highest measured current consumption while receiving and transmitting MIL-1553 traffic.
  - RTEMS operating systems and drivers are executed from external SRAM
- **Miscellaneous**
  - LVDS adds 4mA per LVDS
  - ADC adds 2mA per ADC
  - DAC adds 4mA per DAC
  - PLL adds 2mA
  - External voltage reference 2-4mA

Mode	Supply Mode	Frequency	1.8V Supply	3.3V Supply
Standby	Dual Supply	10MHz	18mA	10mA
	Single Supply	10MHz	-	34mA
	Dual Supply	25MHz	58mA	11mA
	Single Supply	25MHz	-	75mA
CoreMark	Dual Supply	10MHz	36mA	10mA
	Single Supply	10MHz	-	52mA
	Dual Supply	25MHz	104mA	11mA
	Single Supply	25MHz	-	121mA
WhetStone	Dual Supply	10MHz	34mA	10mA
	Single Supply	10MHz	-	48mA
	Dual Supply	25MHz	97mA	11mA
	Single Supply	25MHz	-	117mA
RTEMS/1553	Dual Supply	10MHz	35mA	15mA
	Single Supply	10MHz	-	56mA
	Dual Supply	25MHz	78mA	20mA
	Single Supply	25MHz	-	104mA

\* Values represents maximum measured current consumption in mode or test  
 \*\* Values are an average of 128 sample averaging with 532us between samples

# GR716A - LEON3FT Microcontroller

- **BCC2.2.0 Development Environment**

- GCC-10.2 or LLVM-8.0
- GR716 BSP and Drivers Support build in
- Free download from [www.gaisler.com](http://www.gaisler.com)

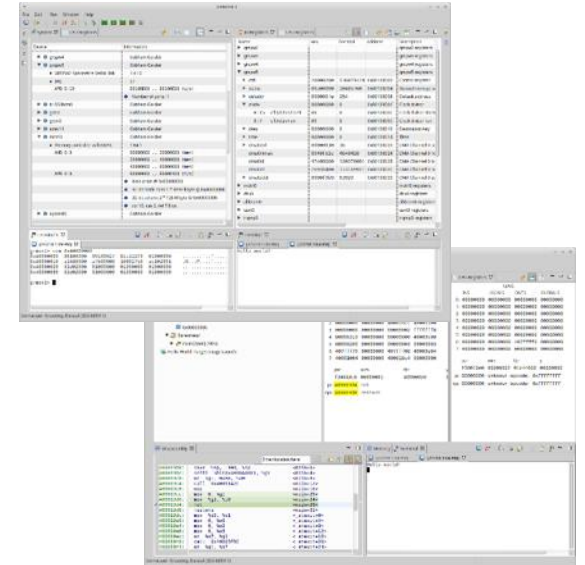
- **GRMON3 Debugger**

- 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

- **TSIM3 Software Simulator**

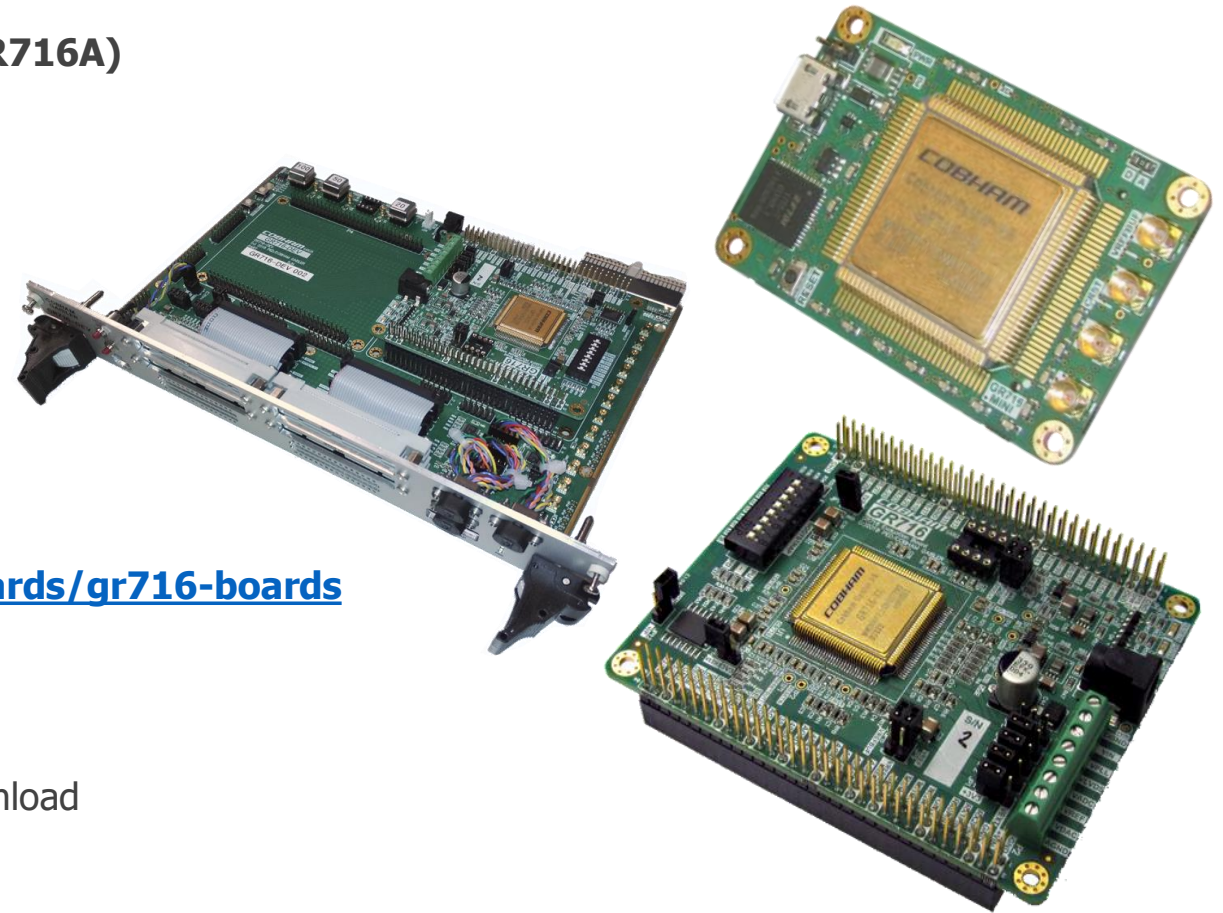
- **Zephyr RTOS support**

- *To be released in 2021*



# GR716A - LEON3FT Microcontroller

- **GR716 Evaluation and Development Boards**  
(All development boards are available today for GR716A)
  - GR716 Software Evaluation Board
  - GR716 Hardware Engineering board
  - GR716 Interface Development Board
- **Board Information and support**
  - Boards supported by current BSP
  - Quick start guides and examples
- **For more information about boards see**  
<https://www.gaisler.com/index.php/products/boards/gr716-boards>
- **Evaluation boards can be shipped immediatly**
  - Loaner agreement for 3 months
  - Compiler, debugger and software available for download
  - Current version is shipped with GR716A



- **Build your application via available interface boards**
- **Compatible boards possible to direct connect and use from Cobham Gaisler:**

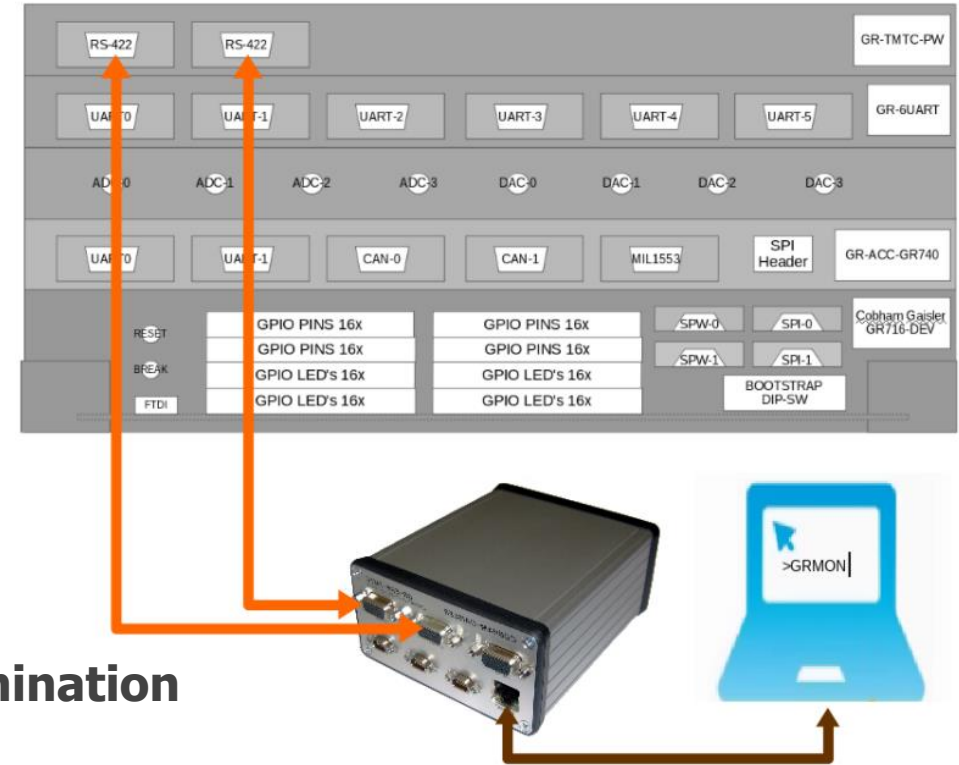
- GR-ACC-6U-6UART
  - Extend number of UARTs in the system
- GR-ACC-GR740
  - Dual CAN 2.0 transceiver, Dual MIL-1553B interface and SPI interface
- GR-CPCI-CAN
  - Dual CAN 2.0 transceiver
- GR-TMTC-PW (6U)
  - RX/TX PacketWire interface
- SPI4S Test Board
  - Reference board for SPI for Space demonstration
- 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

- **For further information and inquiries**

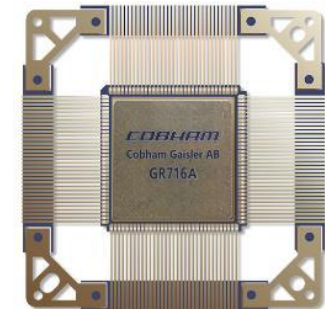
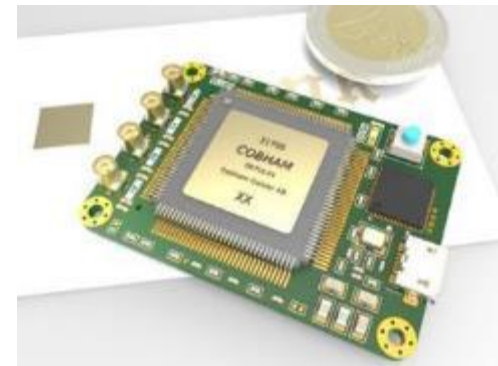
- [www.caes.com/gaisler](http://www.caes.com/gaisler)
- [sales@gaisler.com](mailto:sales@gaisler.com)





# GR716A - LEON3FT Microcontroller

<u>GR716A</u>	<u>Status</u>	<u>Milestone</u>	<u>Comments</u>
Prototype level functional test	done	Q4 2018	completed in December
Prototype level performance test	done	Q2 2019	Completed in April
Prototype level part delivery	done	Q2 2019	Completed in April
Evaluation board delivery	done	Q2 2019	Completed in April
Datasheet and User's manual released on website	done	Q2 2019	Completed in May
Prototype Radiation test	done	Q3 2019	Completed in September
Prototype with improved analogue performance	done	Q3 2019	Available for order
Qualification lot production		Q2 2021	On-going
Flight qualification complete GR716A		Q3 2021	On-going



# GR716B

Enhanced Single-Core LEON3FT Microcontroller

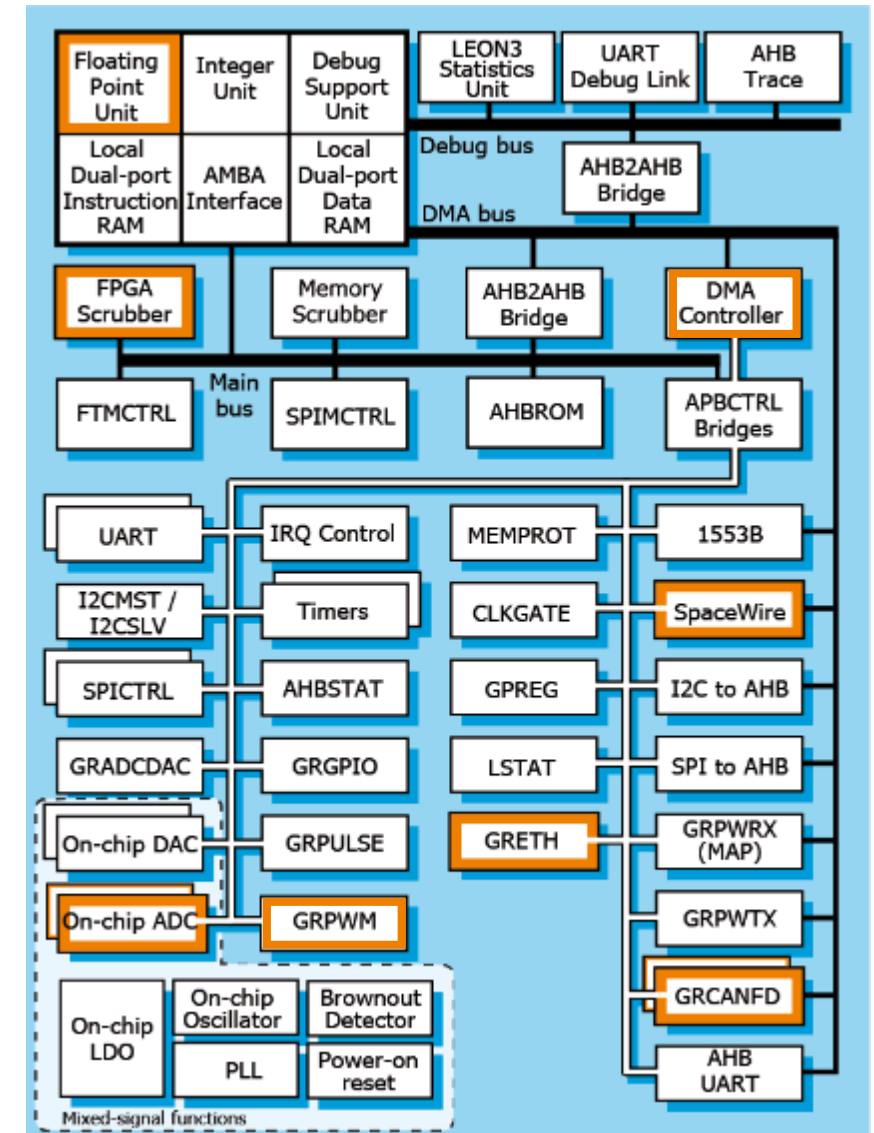
# GR716B - LEON3FT Processor

## Features

- LEON3FT - Fault-tolerant SPARC V8 32-bit processor, **100 MHz**
  - LEON-REX – extension with 16-bit instructions: improved code density
  - **Pipelined** Floating Point Unit
  - Memory protection units
  - Non-intrusive advanced on-chip debug support unit
  - Determinism: Multi-bus, fixed interrupt latency, cache-less architecture...
- External EDAC memory: 8-bit PROM/**SRAM, SPI (4 Byte address)**, I2C
- **Hardware FPGA programming : Xilinx Virtex5, UltraScale, ...**
- **2-Port SpaceWire Router** with time distribution support, **200 Mbps**
- **Robust** MIL-STD-1553B interface
- **2x CAN-FD** controller interface with **CANopen support for remote boot**
- PacketWire with CRC acceleration support
- Programmable **Enhanced PWM** interface with **Digital voltage control loop support**
- SPI with SPI-for-Space protocols
- **Ethernet**, UARTs, I2C, GPIO, Timers with Watchdog
- **Programmable Enhanced DMA** with **AES-256 Encryption support**
- Interrupt controller, Status registers, JTAG debug, etc.
- **4x ADC 13bits resolution @ 500Ksps**, 8 differential or 16 single ended channels
- DAC 12bits @ 3Msps, 4 channels
- **LVDS with ColdSpare and Fail-Safe support**, Mixed General-purpose inputs and outputs
- Power-on-Reset and Brown-out-detection
- **20xAnalogoue comparator**
- Temperature sensor, Integrated PLL
- On-chip regulator for 3.3V single supply



**LEON**



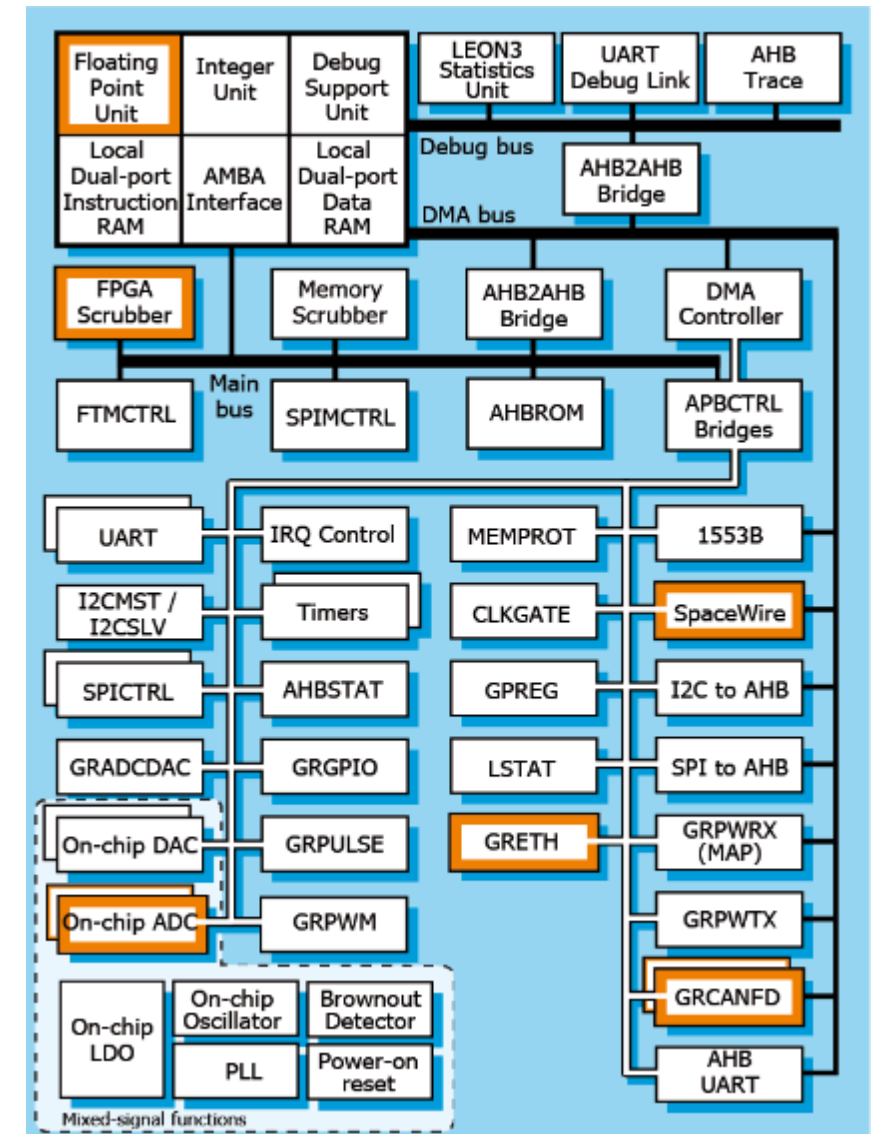
# GR716B - LEON3FT Processor

## Application areas required to be supported by the controller

- Up to 4 switching power controllers for Buck, Boost, Full-bridge topologies, etc.
- Overcurrent and overvoltage power-converter protections
- Power system monitoring
- Latch-up detection, to support e.g. space usage of commercial FPGAs and other COTS
- Motor control

## Application areas desired to be supported by GR716B

- Magnetorquer control
- High voltage and high current generators
- General application areas for GR716B:
  - Propulsion Unit control
  - Sun-sensor control
  - Reaction-wheel control
  - Mass Memory control
  - Program and scrubber support of COTS FPGA
  - Instrument Control Unit
  - Remote Terminal Unit control
  - Solar panel control
  - Antenna control and tuning
  - Nanosatellite Controller

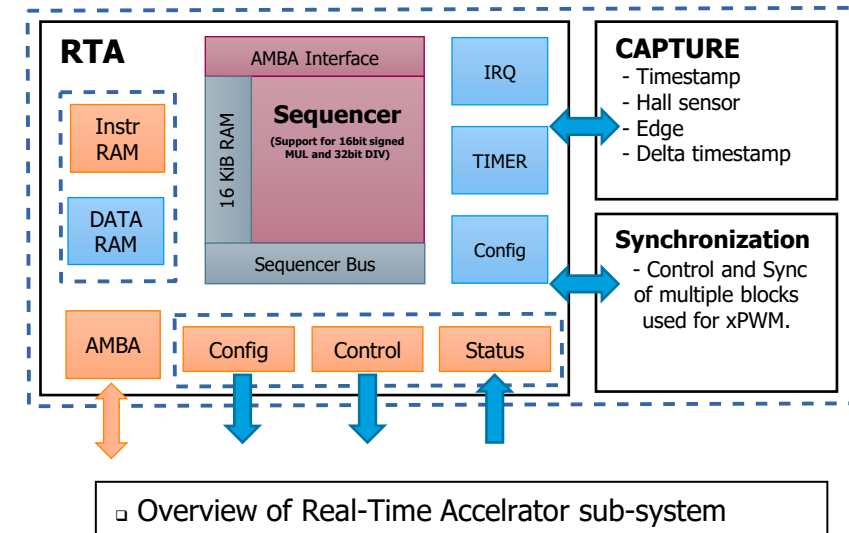


## 2x Real-Time Accelerator (RTA)

- Two independent LEON3 subsystems:
  - Speed up response time for time critical applications
  - Fast access to peripheral and interface
  - Upto 16KiB of instructions and data ram
  - 3x Processing power

## 13b ADC with Fast Analogue Comparator

- 20 Fast Analogue Comparators
  - External or internal reference
  - FIR filter and timestamp support
- 4 ADC with increased resolution up to 13 bits
  - Simultaneously sample up to 4 channels at the same time
  - Interleave 3 channels to reach higher sampling speed
  - Up to 16 single ended sources



# GR716B - LEON3FT Microcontroller

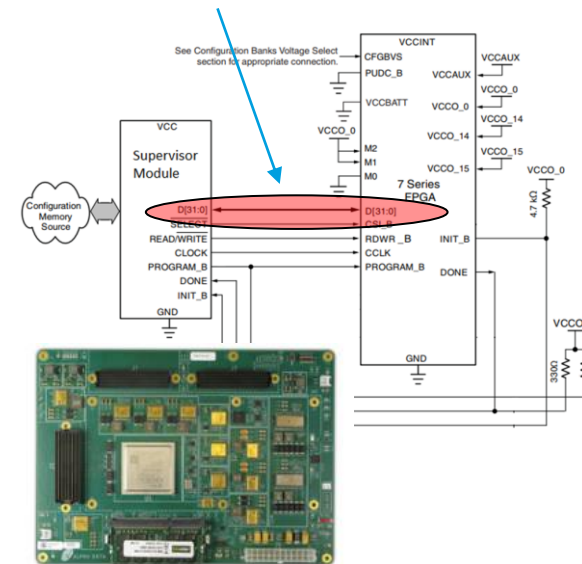
- **FPGA supervisor core (GRSCRUB)**

- Compatible with Xilinx FPGAs
- SelectMap interface
- Programming
- Scrubbing
- Blind or readback
- Full or partial
- CRC, ECC, or Full Frame Check (FFC)

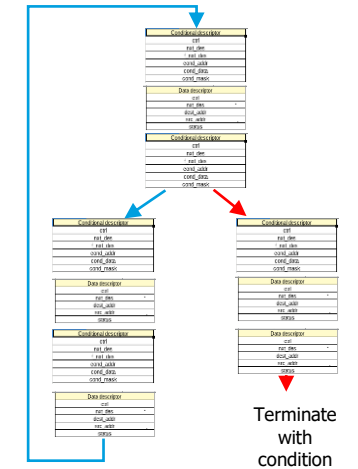
- **GRDMA core (GRDMAC2)**

- **Simplified** programming model
- Single descriptor queue
- **Easier** to manage descriptor table
- Pause, resume and restart from SW
- Support for **if-else** statements
- Support **AES-256** Encryption/Decryption
- Termination condition based upon combination of register value and interrupt
- More debug and diagnostic features

□ Support for 8b interface for reducing number of pins used will be supported by GR716B



The ADA-SDEV-KIT2 is a Development Kit for the Xilinx Kintex Ultrascale XQRKU060 Space-Grade FPGA

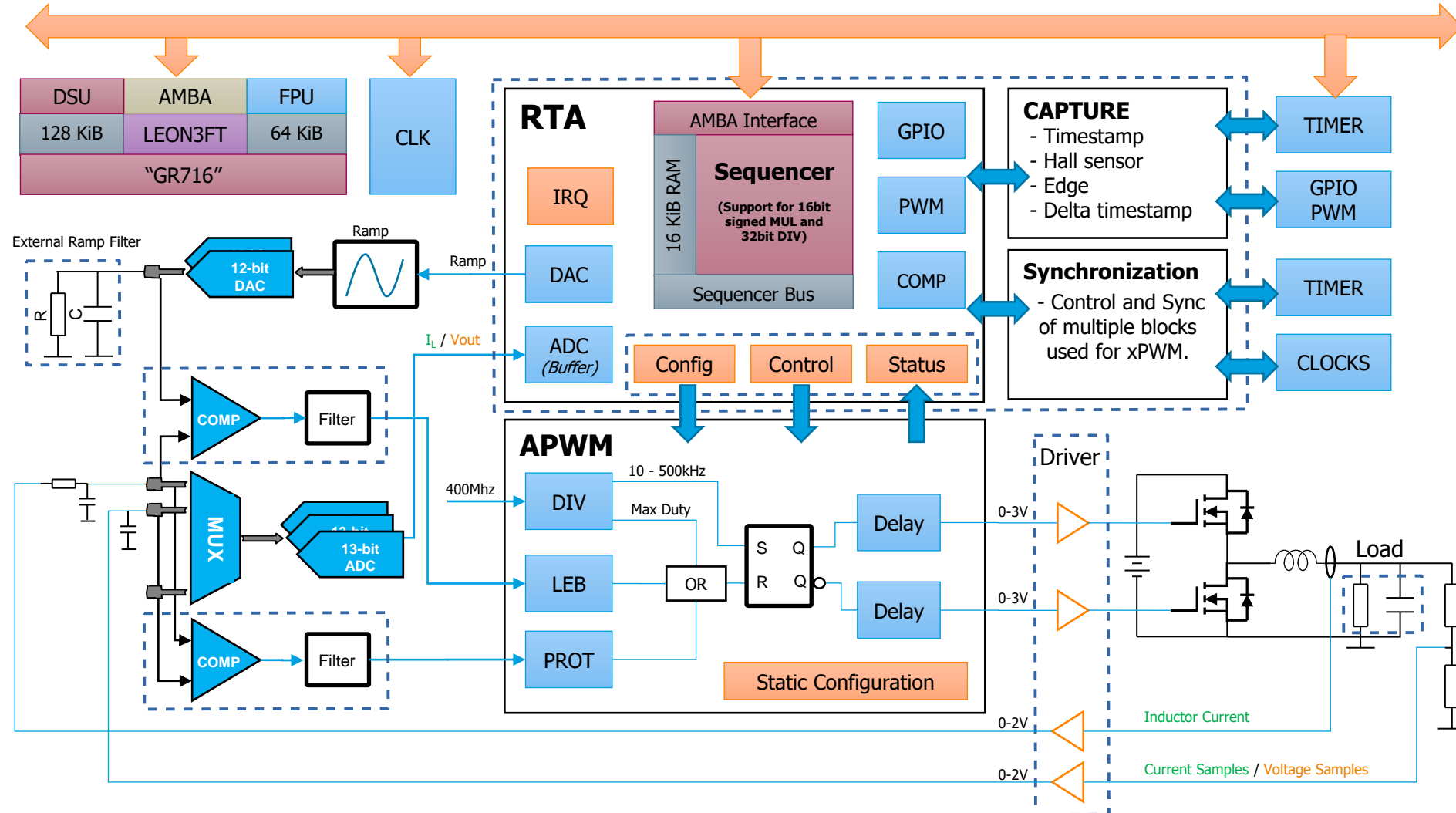


□ Support for if-else statement makes it possible to support more complex DMA sequence

# GR716B - LEON3FT Microcontroller

## On-Chip DC/DC Controller:

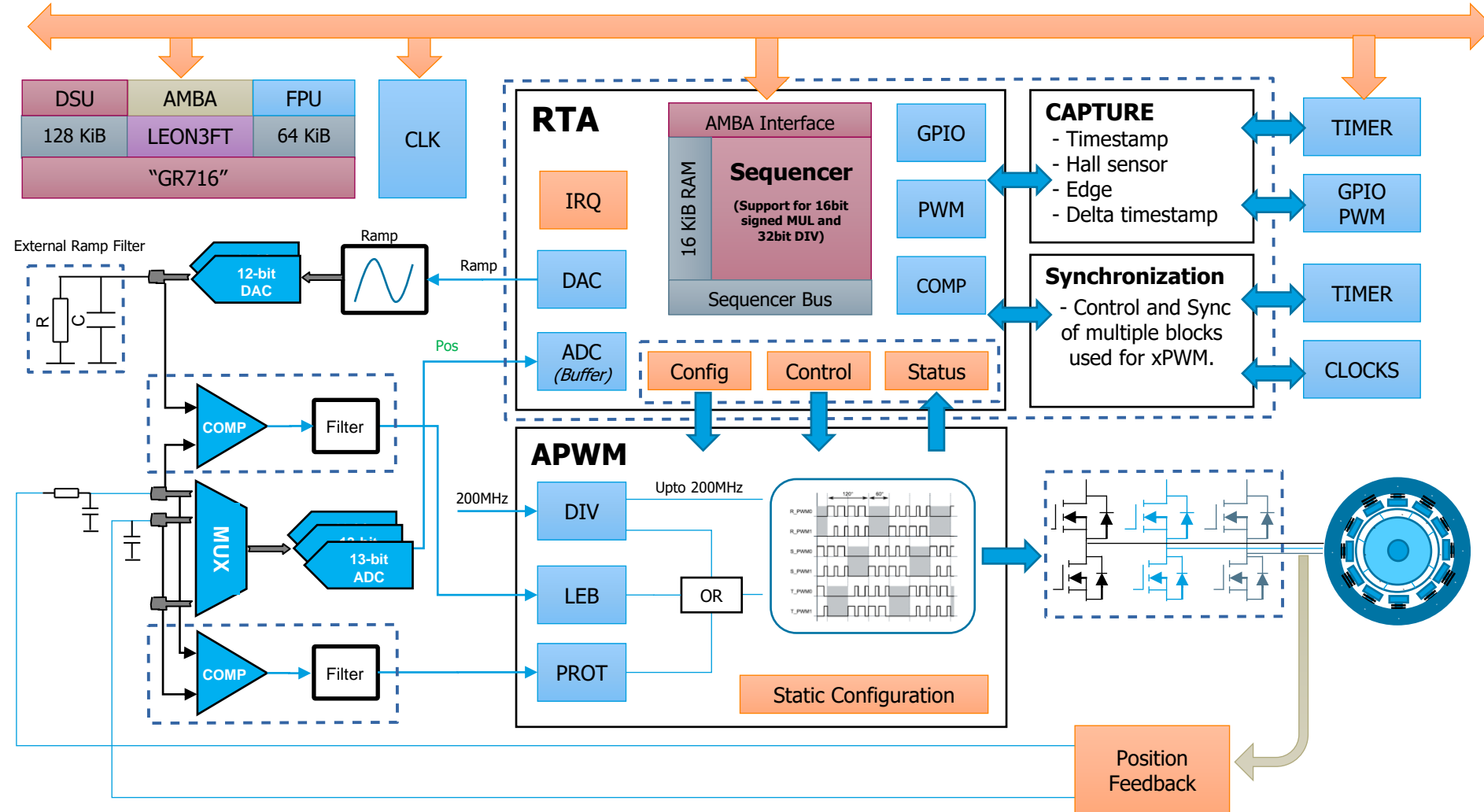
- Switching power converters such as the Buck and Boost topology
- Overcurrent and overvoltage power-converter protections
- Programmable control loop



# GR716B - LEON3FT Microcontroller

## Motor Control:

- Up to 4 BLDC motors can be controlled.
- Support for PWM-control mode, block-commutation mode, etc.
- Over-current detection.

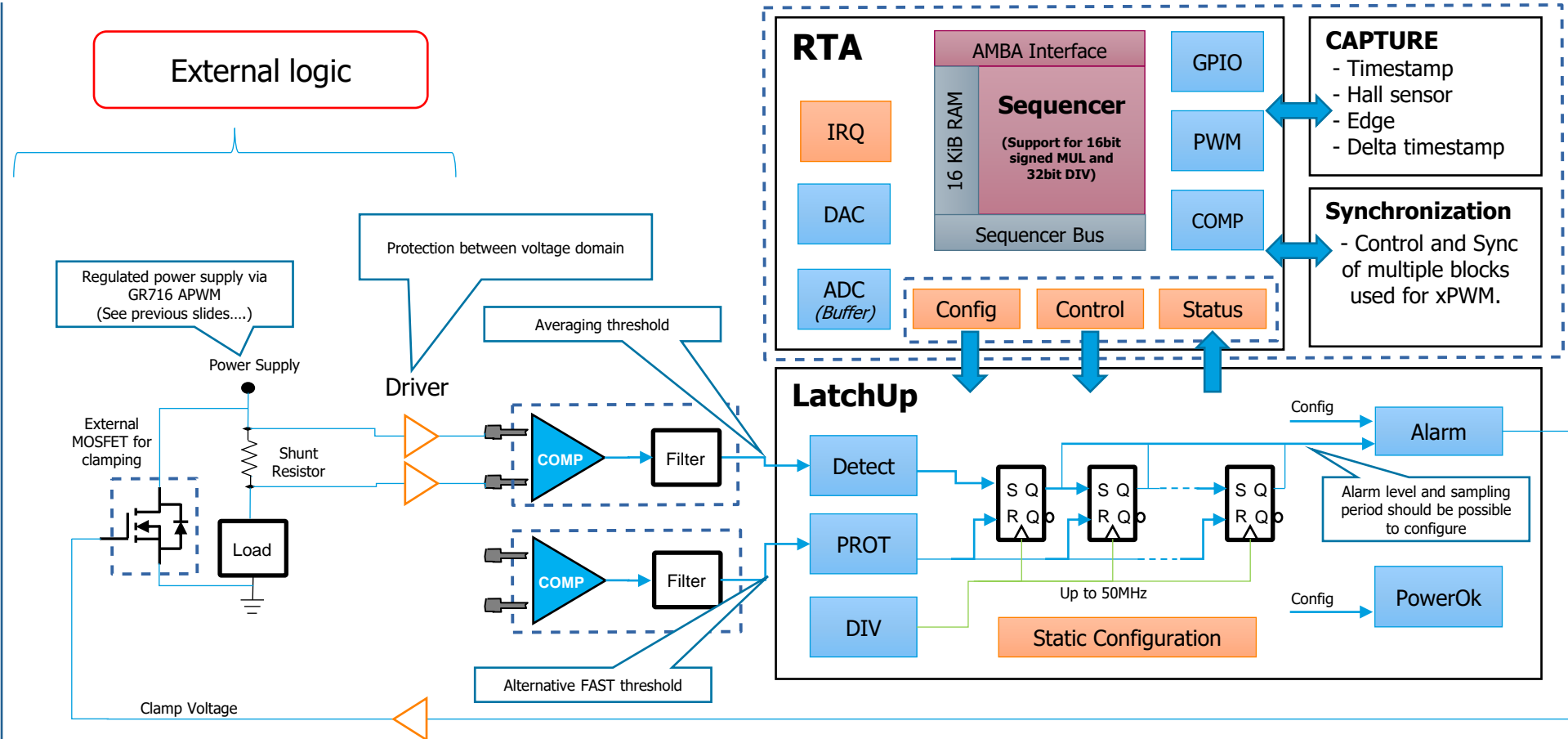




# GR716B - LEON3FT Microcontroller

## Power system monitoring / Latch-Up Detector:

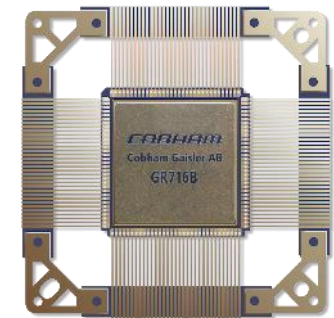
- Overall system requirement is to detect and shut-down within 12us
- Latch Up detector should have 2 programmable thresholds ("Averaging" and "Fast")Current
- Current TID-Test Setup : Clamp when 9 Detection over last 16 samples (16 Samples = Detection period)



# GR716B - LEON3FT Microcontroller

<u>GR716B</u>	<u>Status</u>	<u>Milestone</u>	<u>Comments</u>
Scrubber interoperability test w Xilinx UltraScale FPGAs	done	Q1 2020	FPGA prototype
Tape-out of improved LVDS test chip w Cold Spare	done	Q2 2020	Samples back in Q3
GR716B ESA ARTES* System Requirements Review	done	2 <sup>nd</sup> July 2020	
GR716B ESA ARTES* Preliminary Design Review	done	Dec 2020	
Early GR716B prototype samples		Q3 2022	
GR716B prototypes tested in full temperature range		Q3 2022	
Evaluation board delivery		Q3 2022	
Datasheet and User's manual release online		Q3 2022	Draft version Q3 2020
Flight part qualification complete		TBC	To be determined after funding secured

\* GR716B ARTES Competitiveness & Growth Full activity aims to develop and test a new generation microcontroller GR716B based on the GR716A microcontroller. GR716B shall enable use of commercial off the shelf (COTS) FPGAs in critical space applications (beneficial not the least for satcom constellations), support switching power applications, enhance analogue functions, increase processing performance and support more advanced interfaces. The proposed activity shall also enrich the software ecosystem by industrialization of state-of-the art operating systems, development and simulation tools

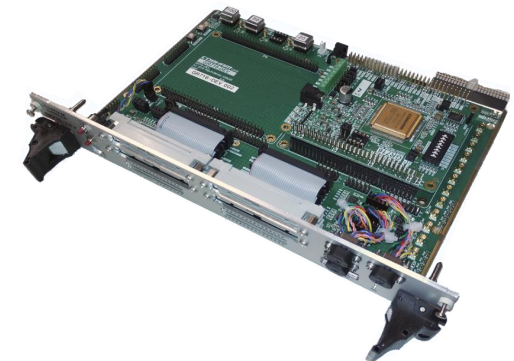
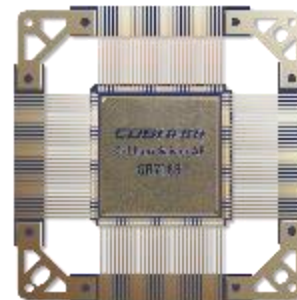
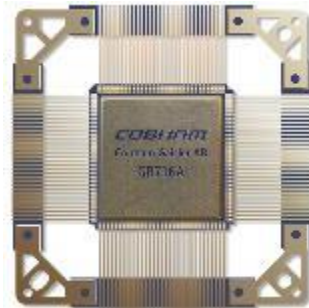


# GR716A and GR716B - LEON3FT Microcontroller

## Specification

Part nr.	Processor core	Clock frequency	Performance	TID krad (Si)	SEL LET (MeV-cm <sup>2</sup> /mg)	Power cons.	Package	Qualification status	Availability	Development board
GR716A	Single-Core LEON3FT	50 MHz	>98 DMIPS	100	118	< 200mW at 40 deg C	132-Pin Ceramic Quad Flat Pack	<ul style="list-style-type: none"> <li>Screening and qualification tests planned for Q2 2021</li> <li>Life testing extended into Q3 2021</li> <li>Qualification tests as per PCA defined by ESCC Basic Specification No. 2567000</li> <li>Screening tests as per ESCC 9000</li> </ul>	<ul style="list-style-type: none"> <li>Flight parts in Q3 2021</li> </ul>	<ul style="list-style-type: none"> <li>GR716 Software Evaluation Board</li> <li>GR716 Hardware engineering board</li> </ul>
GR716B	Single-Core LEON3FT	100 MHz*	>196 DMIPS*	100*	118*	< 200mW at 40 deg C*	132-Pin Ceramic Quad Flat Pack			<ul style="list-style-type: none"> <li>GR716 interface development board</li> </ul>

Complete software toolchain and debuggers are available



\* Products under development, Values can be changed without notice

**For further information and inquiries**

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[sales@gaisler.com](mailto:sales@gaisler.com)

Thank you for listening!

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