

# Fault Tolerant Local and Monitoring Control Board Status



*J.A. Lucio Martínez  
Infrastructure and  
Computer Systems in  
Data Processing (IRI)  
Goethe University  
Frankfurt*

# Outline

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1. Requirements in a particle accelerator experiment
2. The Cortex R5F - TMS570
3. SRAM Scrubbing
4. Beam Time Results
5. ALICE Rand 1 Experience
6. Board Concept Status
7. Interfacing
8. EPICS
9. Interfaces
10. On Demand

# Requirements

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- Autonomous and alarm capable
- Able to operate in environments:
  - Radiation: correct most errors, report uncorrectable errors
  - Strong magnetic field: Interfacing immunity to coil saturation
- Boot Capability and reachable through LAN TCP/SPI/I<sup>2</sup>C/CANBus
- Real Time capabilities

# MCU TMS570 features CORTEX R5F

- 1 Up to 512 kB ECC on internal SRAM
- 2 4MB ECC Internal Flash
- 3 Lockstep redundancy
- 4 128MB external module (EMIF)
- 5 DMA and CRC
- 6 EPICS on RTEMS running
- 7 Low cost

- 1 ECC allows internal memory scrubbing
- 2 Scrubbing verified with manually induced errors
- 3 Scrubbing verified in beam-time

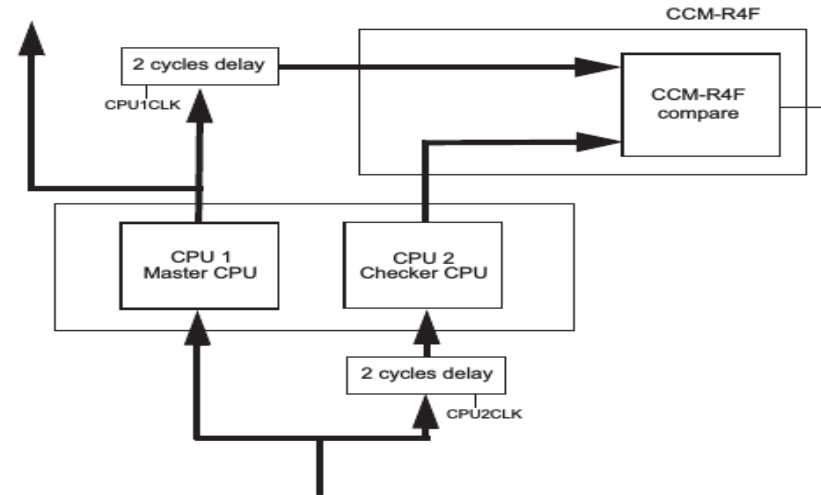


Figure from Texas Instruments:  
Fig 9-1 SPNU499B August 2013

# Internal SRAM Scrubbing

- 1Scrubbing corrects single event upsets (SEU)
- 2ECC allows to implement a scrubbing mechanism
- 3If a single bit error is found, register contains details
- 4Multiple bit errors are detected as well
- 5Memory content is refreshed periodically

```

lucio@iri15: ~/repos
root@fepdev1:~/antonio  x  lucio@iri15: ~/repos
/* Error injection
 * Disabling Error Detection/Correction
 */
tcram1REG->RAMCTRL=0x00050105U;
tcram2REG->RAMCTRL=0x00050105U;
/* Bit flip*/
(*(volatile epicsUInt32 *) (0x084000C0U)) ^= 0x1U;
/*Enabling Error Detection/Correction back*/
tcram1REG->RAMCTRL=0x0005000AU;
tcram2REG->RAMCTRL=0x0005000AU;

lucio@iri15: ~/repos/tools/rtems-openocd/openocd
lucio@iri15: ~/repos/tools/...  x  antonio@iri81: ~
fepdev1 linux-x86_64 #
fepdev1 linux-x86_64 # ./caget CHKECC:TEST.TWVL
Successfully locked memory using mlockAll
CHKECC:TEST.TWVL          0
fepdev1 linux-x86_64 # ./caget CHKECC:TEST.TWVL
Successfully locked memory using mlockAll
CHKECC:TEST.TWVL          1
fepdev1 linux-x86_64 #
[0] <- 1:ssh* "root@fepdev1:~/antoni" 11:57 10-Mar-16

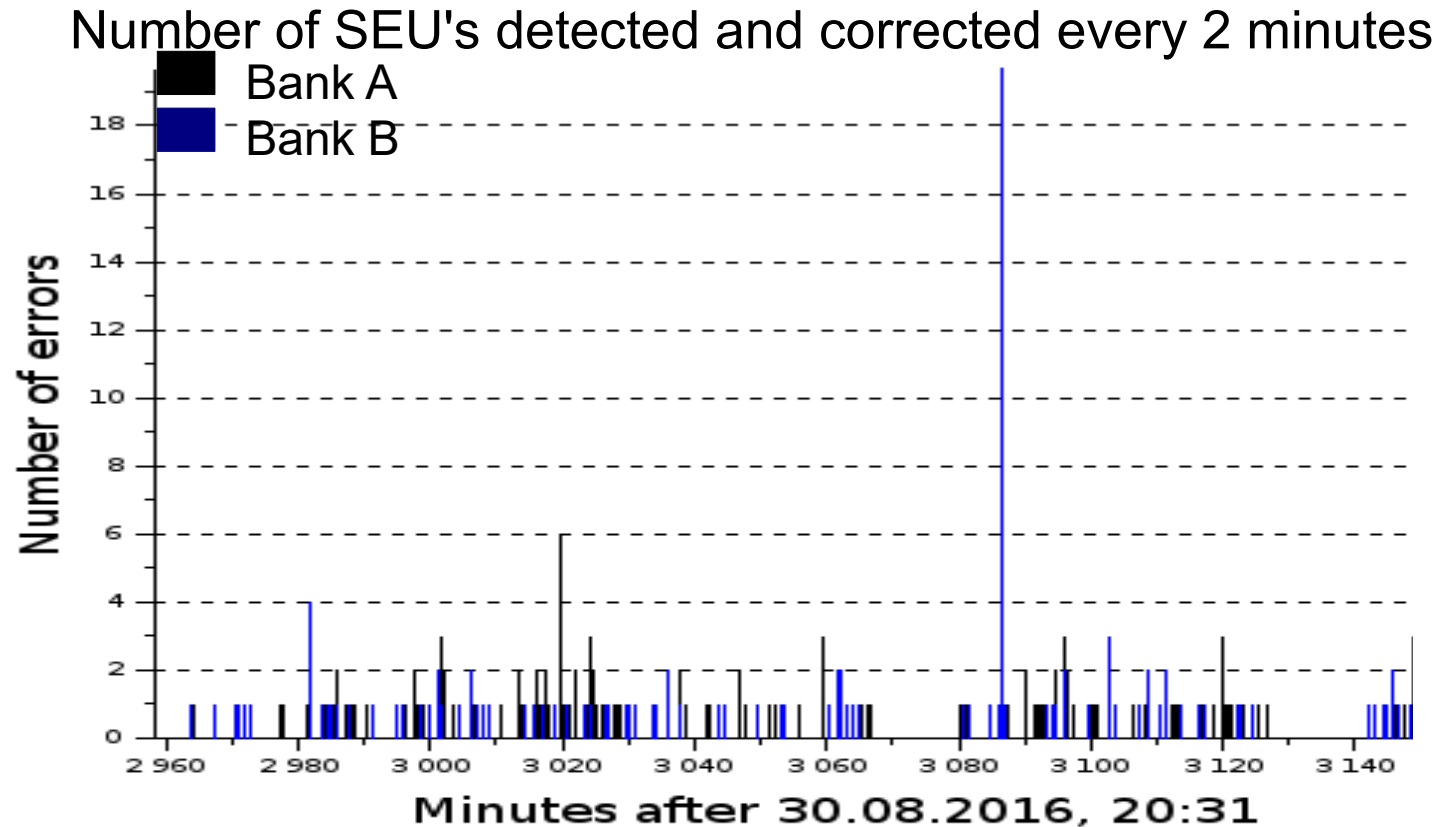
```

# Test Conditions

- 1 Total Beam time : 13 hours
- 2 1 GeV,  $10^9$  beam spill
- 3 Total detected and corrected SEUs:
  - 1 in Bank A: 718
  - 2 In Bank B: 686
- 4 No multiple bit errors
- 5 EPICS used to monitor failure registers
- 6 Database with error time-stamp
- 7 No errors during beam off times detected



# Beamtime results internal SRAM



# Existing solutions comparison

	Cortex R5F based	AVR RISK based	FPGA Solution
RealTime capability	●		●
Lockstep run / SRAM ECC / CRC	●		
Low Cost Commercial Off The Shelf	●	●	
Full SCADA functionality	●	●	●

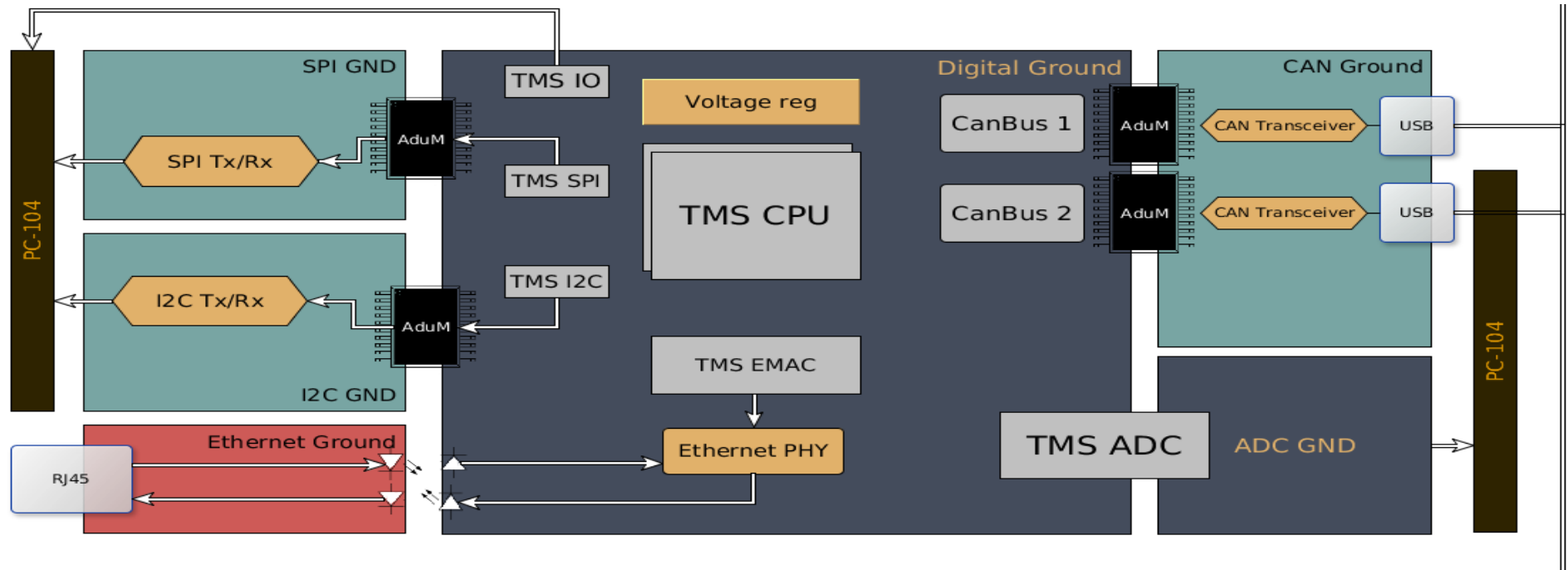


# ALICE Rand 1 Experience

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- Please Refer to Alice Technical Board talk by André Augustinus, 9.03.2017
  - *“devices have stringent constrains on the length of Ethernet cable”*
  - *“Special Ethernet receivers, compatible with magnetic field”*
  - *“DCS Baords inside L3 magnet”*
  - *“Cable lengths too short to reach the IT startpoints”*
  - *“Decided to install intermediate switches in the cavern racks”*
  - *“Original switches started to fail”*
  - *“Redundancy switches installed”*

# Concept Status



# Interfacing

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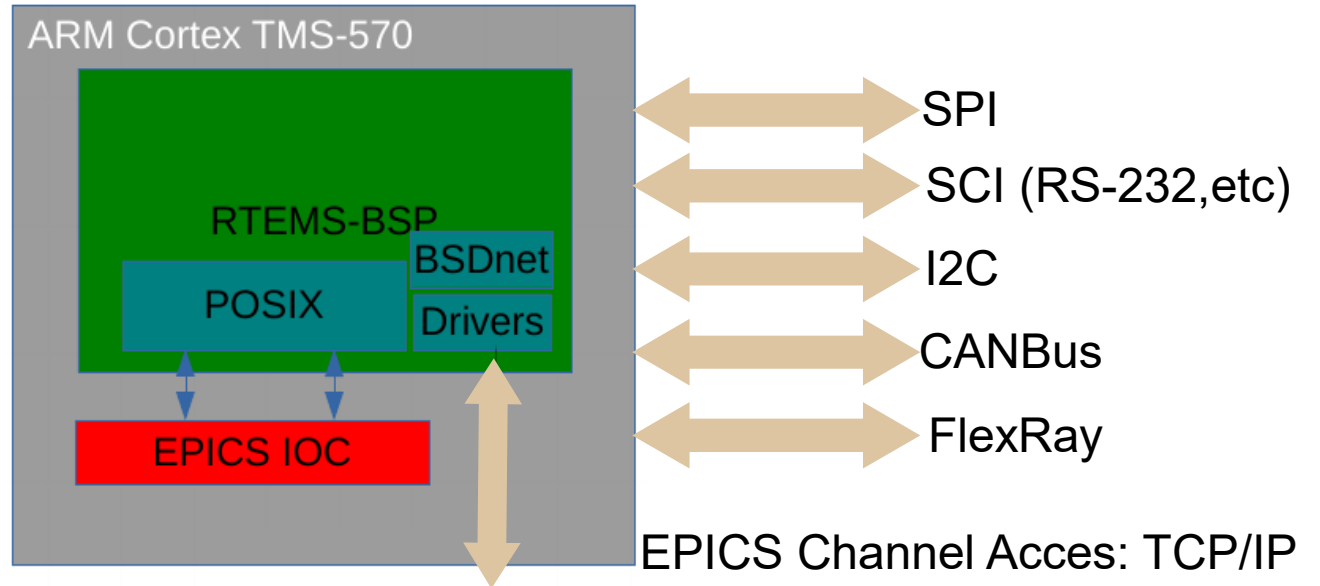
- SPI or CANBus, alternative for booting for SCA GBTx interfacing
- TCP booting and interfacing successful
- Ethernet inside the Cave to control the power supplies in the racks.
- Ethernet isolation solution being tested

# EPICS

- EPICS (Experimental Physics and Industrial Control System)
  - EPICS IOC (Input Output Controller): recommended on RTEMS or VxWorks
  - EPICS Base: recommended on Windows or Linux

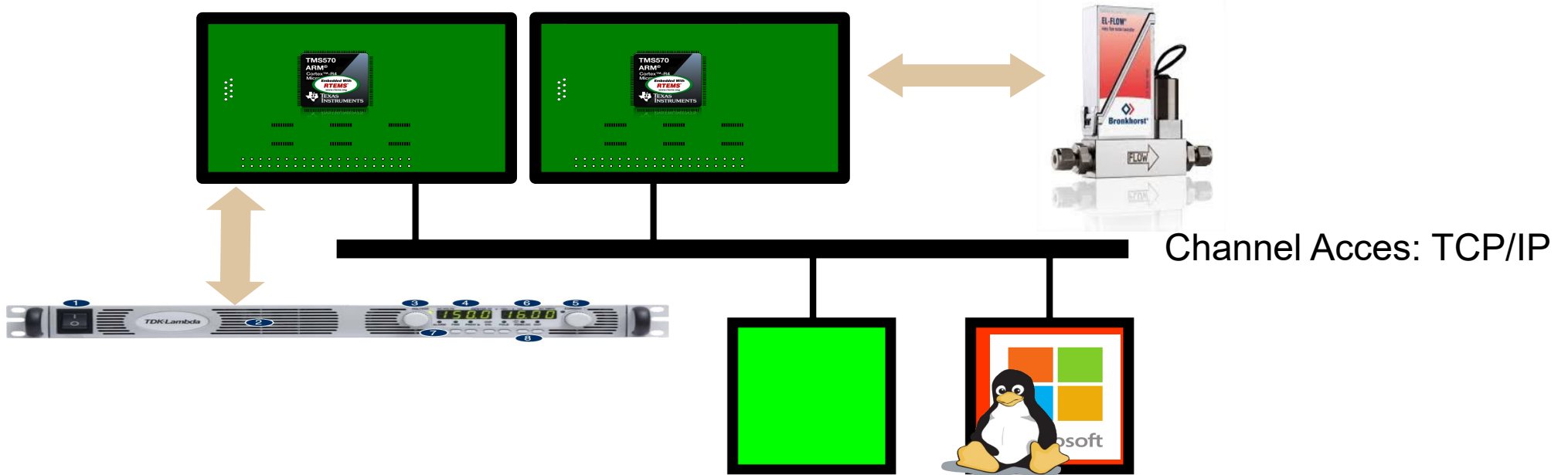


RTEMS: Real Time Executive Multiprocessor System currently running in Curiosity Mars rover



# EPICS

- EPICS (Experimental Physics and Industrial Control System)
  - EPICS Channel Access (CA): TCP Based Protocol for Variables Monitoring Access
  - Any node is able to access any variable (Example Bronkhorst Gas valve Flow value)



# EPICS

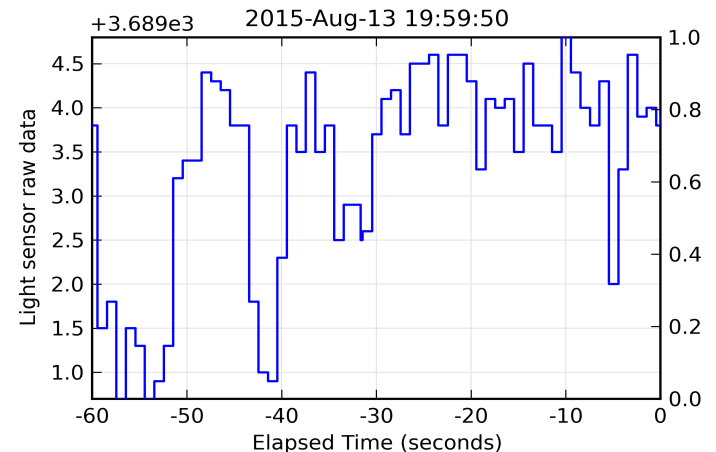
- EPICS (Experimental Physics and Industrial Control System)
  - Works with databases that describe variables named Process Variables
  - Process Variables (PV) can be digital, analog, boolean or array information
  - PV's of all devices can be called from any device (IOC or Base) and issue alarms

```
Open Save Undo
PVStripChart_LIGHT_SENS_VAL.dat x
# Epics PV Strip Chart Data for PV: LIGHT:SENS.VAL
# Current Time = Thu Sep 10 13:30:32 2015
# Earliest Time = Thu Sep 10 13:28:21 2015
#-----
# Timestamp      Value      Time-Current_Time(s)
1441884501.077   373230    -131.061
1441884500.261   373230    -131.878
1441884501.261   373140    -130.878
1441884502.261   373200    -129.878
1441884503.261   373240    -128.878
1441884504.261   373230    -127.878
1441884505.261   373220    -126.878
1441884506.261   373230    -125.878
1441884508.261   373050    -123.878
1441884509.261   372640    -122.878
1441884512.261   372660    -119.878
1441884513.261   372680    -118.878
1441884514.261   372630    -117.878
1441884516.261   372650    -115.878
1441884517.261   373300    -114.878
1441884518.261   373310    -113.878
1441884519.261   373300    -112.878
1441884520.261   373290    -111.878
1441884522.261   373310    -109.878
1441884524.261   373300    -107.878
```

ai record example: analog input

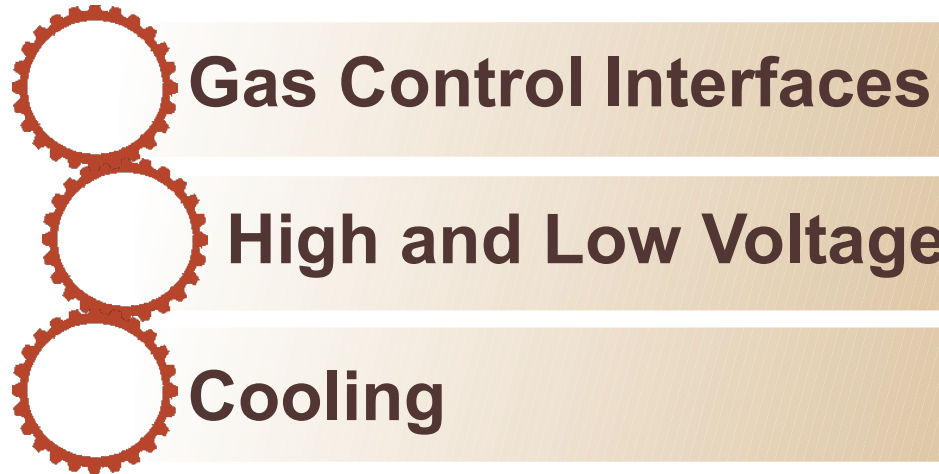
**LIGHT:SENS**

Desc: Light sensor raw data  
DTYP: Light  
SCAN 1 second  
EGUF: 1  
EGUL: 0  
EGU: Light\*2  
LINR: LINEAR  
ASLO: 10  
AOFF: 0  
MDEL: 1



# Tested Interfaces

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# Tested Interfaces








## Gas Control Interfaces

### Voegtlin

Analog IF	Digital IF	FTLMC support	Per Board
0(4)-20mA	RS-485	 	128
0(1)-5V	Modbus	 	32   1
0(2)-10V	Profibus	 	

### Bronkhorst

0(4)-20mA	RS-232	 	2
0-5(10)V	Modbus	 	32   1
	Profibus		









# Tested Interfaces



## High and Low Voltage

### Low Voltage: TDK-Lambda

Analog IF	Digital IF	FTLMC support	Per Board
0(4)-20mA	RS-485	 	128
0-5V	RS-232	 	32   2
0-10V	LAN	 	1

### High Voltage: ISEG EDS






CAN Bus		256 EDS
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# Tested Interfaces

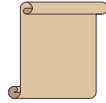


## Cooling

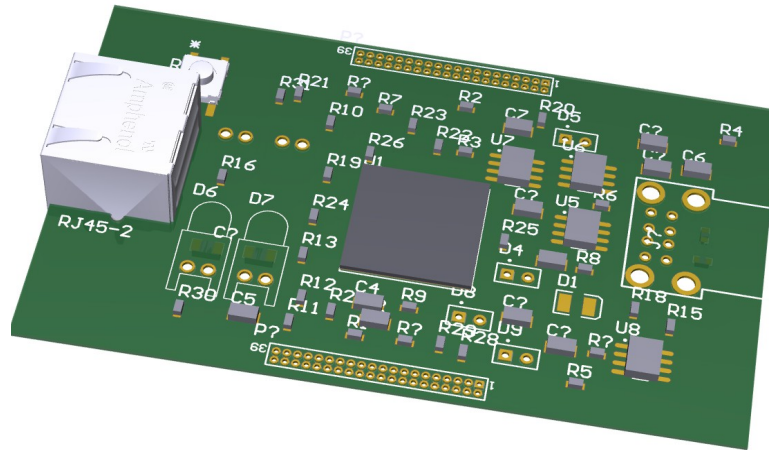
### Bronkhorst Liquid Flow Valve

Analog	Digital	FTLMC	Availability
0(4)-20mA	RS-232	 	2
0-5(10)V	Modbus	 	32   1
	Profibus		

# On Demand



- 4-20mA Still not considered to be included in FTLMC, probably will
- Stackable boards can fulfill additional needs (further 4-20mA, other protocols etc)



Thank you!