

A configurable Interlock System for RF-Stations at XFEL

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- *XFEL* → *European X-ray free-electron laser project*
- opens many possibilities for research with short wave length x-rays (below 1 nm)
- start of construction 2007
- initial operation 2012
- requires 33 ... 40 RF-Stations for the accelerator sections based on super-conducting cavities



HELMHOLTZ GEMEINSCHAFT  **Content** 

- **Interlock Concept**
- Interlock Hardware
- Software for the Interlock

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HELMHOLTZ GEMEINSCHAFT  **Main Task of the RF-Interlock-System** 

- Prevent any damage from the cost expensive components of the RF-Station
- Prevent also any damage from other equipment
- Support secure operation of the RF-System

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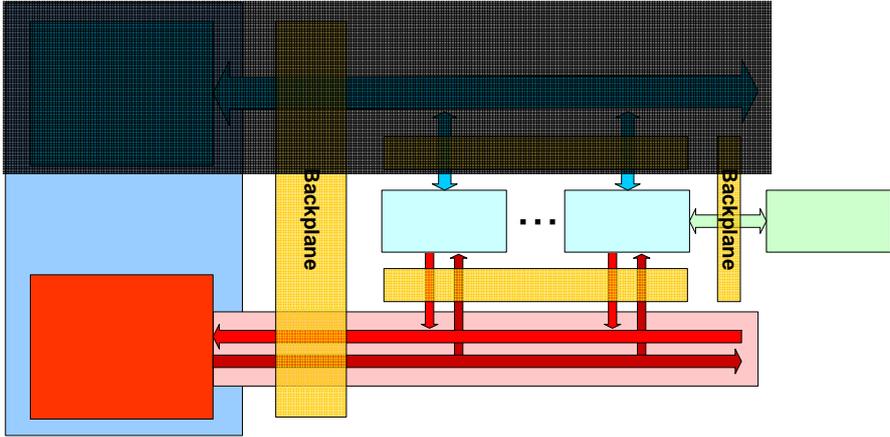


- Hardware failures (non-reversible malfunctions)
 - broken cable or damaged contact, dead sensor,...
- Soft errors (reversible error conditions)
 - sparks in the klystron or wave guide system
 - temperature outside a valid range, ...
- Error conditions caused by transient noise from the RF-Station itself

- Configurable and scaleable System
- Modular structured
- Interlock functionality independent from software
- Support of different signal types
 - digital, LWL, analog inputs and outputs
- Selftest and reliability check on power up

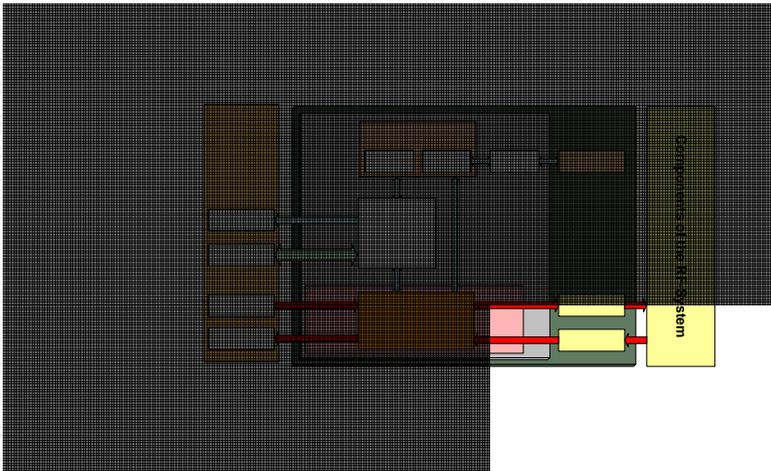
HELMHOLTZ GEMEINSCHAFT  **Interlock3 architecture overview**

- interlock function completely implemented in hardware
- **Strict** separation of interlock logic and processor bus



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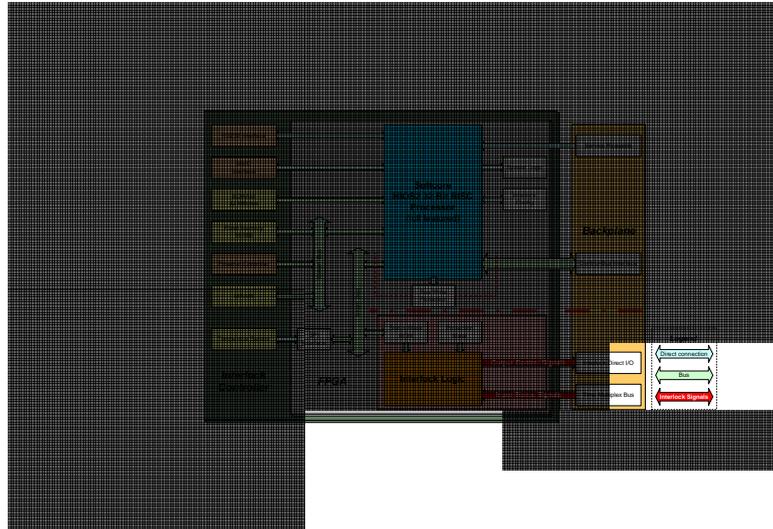
HELMHOLTZ GEMEINSCHAFT  **Interlock3 Module Architecture**



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Software
C Processor
NIOS-II

**Interlock
Controller**

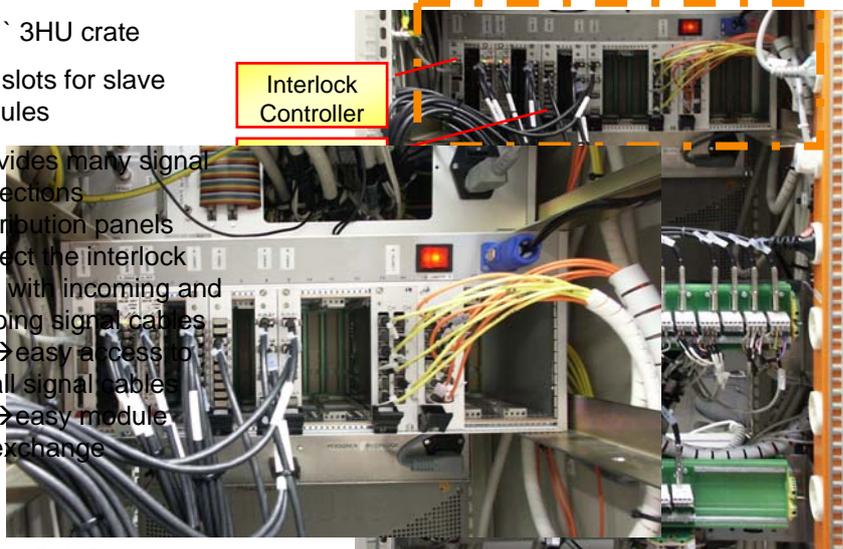


- Interlock Concept
- **Interlock Hardware**
- Software for the Interlock

Interlock Crate

- 19" 3HU crate
- 20 slots for slave modules

- provides many signal connections
- distribution panels connect the interlock crate with incoming and outgoing signal cables
 - easy access to all signal cables
 - easy module exchange



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Components of the Interlock System



- **Controller Module**
 - NIOS II Processor, 64MB RAM, 16MB Flash
 - Ethernet Interface
- **Slave Modules**
 - Digital I/O, 32 input, 8 output channels
 - Analog window comparator, 36 input channels
 - Light I/O, 6 input, 6 output channels,
 - Analog I/O, 8 input, output channels
- **Backplane, power supply**

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Interlock Modules



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NIOS/II Experiences



- 😊 easy scaleable by *Altera SOPC-Builder*
- 😊 good IDE integration and development flow
- 😊 close to hardware development
- 😞 no Memory Management Unit (*MMU*)
 - not suitable for our software project
 - software errors hard to find
- 😞 strange behavior with LWIP-Stack and μ C/OS on our board
- 😞 fixing errors is very time consuming

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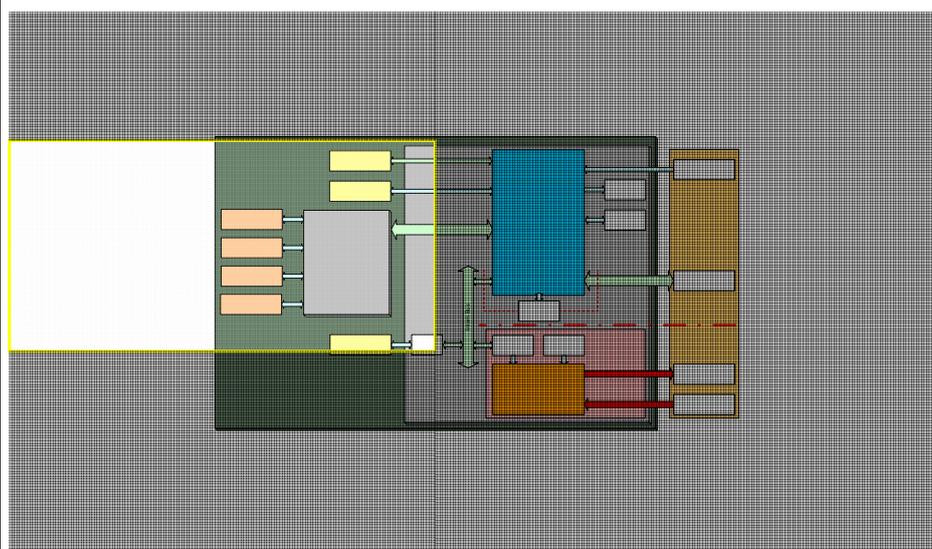
Planned future development

- move on-board applications from NIOS/II to another platform
- shrink on-board applications on NIOS/II side
- put computer-on-board module on intlk.-controller (f.ex. x86-architecture, X-Board)
- use Linux as operating system



- AMD Geode SC1200 CPU 266 MHz
- Up to 128MB RAM / 128MB Flash on board
- Integrated video controller with up to 4MB DRAM
- Power consumption 3-4Watts
- On board 10/100MBit Ethernet
- IDE interface with UDMA-33 support
- PCI and LPC expansion busses
- 3 USB 1.1 ports OHCI
- 2 serial interfaces (TTL signals)

Interlock Controller Architecture with X-Board



HELMHOLTZ GEMEINSCHAFT  **Content** 

- Interlock Concept
- Interlock Hardware
- **Software for the Interlock**

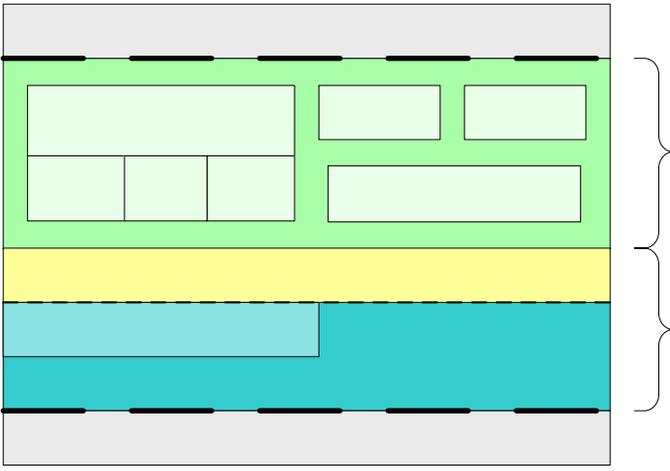
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HELMHOLTZ GEMEINSCHAFT  **Software capabilities**

- Perform system-selftest at power-up
- Offer access over intranet via browser
- Access secured by authentication
- Display signal status and change signal mask
- Special mode for updating firmware and FPGA design

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HELMHOLTZ GEMEINSCHAFT  **Klystron Interlock Server - Architecture**



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HELMHOLTZ GEMEINSCHAFT  **System-Test**

- runs on power-up
- System-selftest checks:
 1. controller
 2. backplane
 3. TM-bus, control-bus
 4. modules
 5. FPGA design compatibility
 6. module configuration
- **System-selftest must not fail, to put interlock system into operation mode**

Saved Systest output at startup(1238 Bytes)

```

ID-Signature of station #0:
INTLK3_CTRL_M Rev.: C142 Powerups:0 Serial: 0000:0000:0000:0000
-----
[ Board-Test-#0] : passed
[ ICS-Test-#0] : passed
ID-Signature of station #2:
INTLK3_WIMC_V Rev.: B456 Powerups:88 Serial: 0000:0000:FFFF:FFFF
-----
[CtrlrBus-Test-#2] : passed
[ SRQ-Test-#2] : passed
[ TM-Bus-Test-#2] : passed
[ ICS-Test-#2] ERROR: station is a untested virgin module!
ID-Signature of station #3:
INTLK3_WIMC_V Rev.: B456 Powerups:88 Serial: 0000:0000:FFFF:FFFF
-----
[CtrlrBus-Test-#3] : passed
[ SRQ-Test-#3] : passed
[ TM-Bus-Test-#3] : passed
[ ICS-Test-#3] ERROR: station is a untested virgin module!
ID-Signature of station #5:
INTLK3_DIGIIO Rev.: C123 Powerups:0 Serial: 0000:0000:0000:0000
-----
[CtrlrBus-Test-#5] : passed
[ SRQ-Test-#5] : passed
[ TM-Bus-Test-#5] : passed
[ ICS-Test-#5] ERROR: station is a untested virgin module!

System Test finished.
Error = 1
Systest FAILED !

```

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HTT

Manage
Interlock
Configuration

Interlock



Interlock HTTP Interface

- display actual signal states
- edit signal-masks
- edit interlock configuration

Sig.	Used (<input type="checkbox"/>)	Name	Threshold	Off Action	Type
1	<input checked="" type="checkbox"/>	Flow Transformer Tank	F < Fmin	Blockade of B by F off	beck_Condict got free
2	<input type="checkbox"/>	Flow Klystron Collector	F < Fmin	Blockade off	beck_Condict got free
3	<input checked="" type="checkbox"/>	Flow Klystron Body	F < Fmin	Blockade off	beck_Condict got free
4	<input checked="" type="checkbox"/>	Flow Solenoid 1..3	F < Fmin		
5	<input type="checkbox"/>	Flow Modulator	F < Fmin		
6	<input checked="" type="checkbox"/>	Flow PreAmp	F < Fmin		
9	<input checked="" type="checkbox"/>	Flow Circulator 1	F < Fmin		

INTLK3 Status

Views: [Standard View](#) [Alternate View](#) [View All](#) [Overview \(matrix\)](#) [Refresh](#)

STATMASK Config was **changed** - store config or - reload config

FlowBox

Sig.	Used (<input type="checkbox"/>)	Name	Threshold
1	<input checked="" type="checkbox"/>	Flow Transformer Tank	F < Fmin
2	<input type="checkbox"/>	Flow Klystron Collector	F < Fmin
3	<input checked="" type="checkbox"/>	Flow Klystron Body	F < Fmin
4	<input checked="" type="checkbox"/>	Flow Solenoid 1..3	F < Fmin
5	<input type="checkbox"/>	Flow Modulator	F < Fmin
6	<input checked="" type="checkbox"/>	Flow PreAmp	F < Fmin
9	<input checked="" type="checkbox"/>	Flow Circulator 1	F < Fmin

1	2	3	4	5	6	7
11	12	13	14	15	16	17
21	22	23	24	25	26	27
31	32	33	34	35	36	37
41	42	43	44	45	46	47
51	52	53	54	55	56	57
61	62	63	64	65	66	67
71	72	73	74	75	76	77
81	82	83	84	85	86	87
91	92	93	94	95	96	97
101	102	103	104	105	106	107
111	112	113	114	115	116	117
121	122	123	124	125	126	127
131	132	133	134	135	136	137
141	142	143	144	145	146	147
151	152	153	154	155	156	157

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Klystron Interlock Server

- server runs on the controller, NIOS/II processor
- web-interface, access via browser

XFEL Interlock

[Login](#)

Display

[System Info](#)

[Interlock Status](#)

[Window Comp.](#)

[Slow Control](#)

[DOOCS Statistic](#)

[Logbook](#)

[Measurements](#)

Debug

[Dump Flashcontent](#)

[Dump Flashcontent as File](#)

[Memory Dump](#)

[Debug Info](#)

Welcome to

Klystron Interlock Control Server

system is 0h 12m 53s online

no user online

Interlock is **NOT** active working. Check systest-result!

Interlock Protocoll

Num.	Typ	Message
0	[WARNING]	Module configuration has been changed!
1	[ERROR]	Systest not passed!

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Access Privileges

- User authentication
- Different User Roles (chief engineer, engineer, technician)
- IP-Address check , 2 addresses possible

User Configuration

Note: There exists three levels of privileges:

- **'technician'** allows only viewing information and uncritical modifications
- **'engineer'** allows critical modifications
- **'chief engineer'** allows critical modification and user administration. Only the first user in table has this privilege.

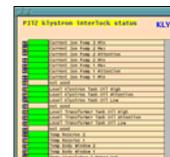
	Enabled?	Username	Password	Role	Check IP?	Allowed IPs (2)	Logincount	Last IP
<input type="button" value="Set"/>	always	admin	*****	Chief Engineer	<input type="checkbox"/>	0.0.0.0 0.0.0.0	3	141.34.3.226
<input type="button" value="Set"/>	<input checked="" type="checkbox"/>	inueler	*****	Engineer	<input checked="" type="checkbox"/>	141.34.30.118 0.0.0.0	0	0.0.0.0
<input type="button" value="Set"/>	<input checked="" type="checkbox"/>	klauz	*****	Technician	<input checked="" type="checkbox"/>	141.34.30.220 0.0.0.0	0	0.0.0.0
<input type="button" value="Set"/>	<input type="checkbox"/>			Technician	<input checked="" type="checkbox"/>	0.0.0.0 0.0.0.0	0	0.0.0.0

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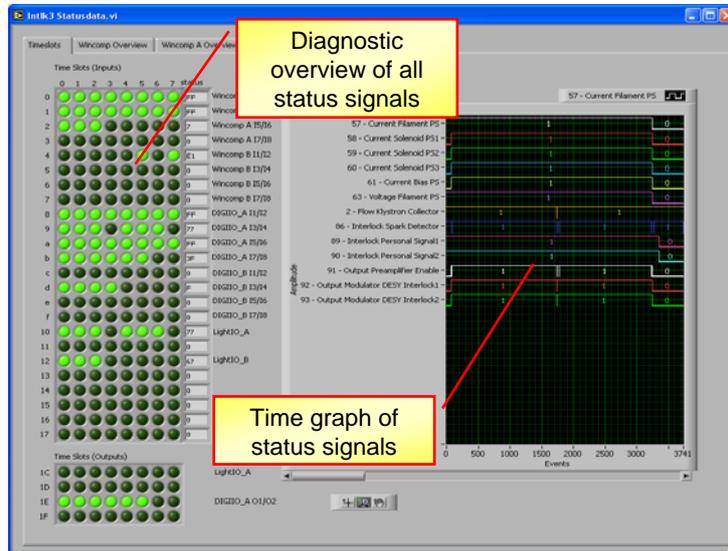
Client Applications - Overview

- DOOCS Interface for viewing state
 - Integration into the control-system
- Tools under  **LabVIEW**™
 - Detailed error diagnostics



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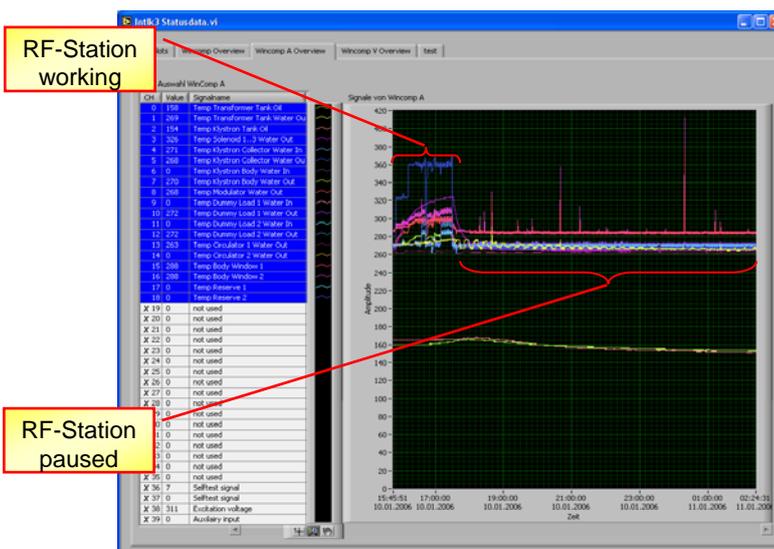
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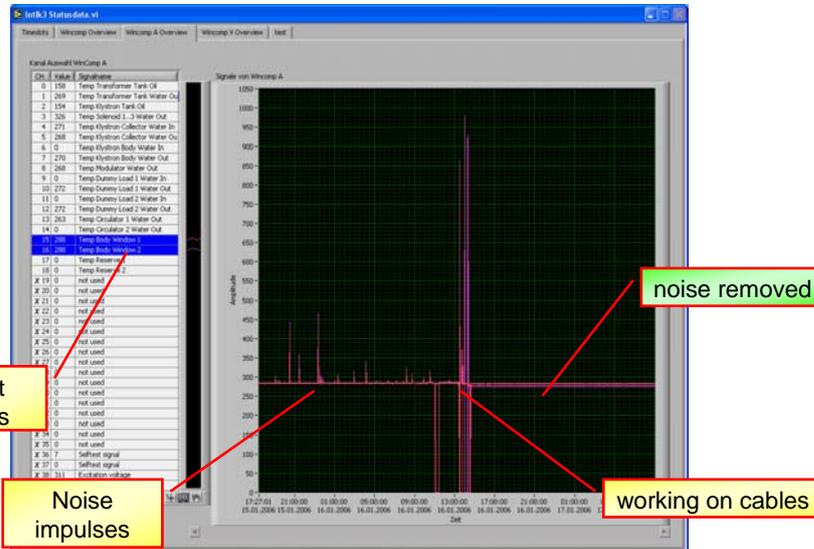
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- Highly flexible Interlock System for XFEL
- Interlock-function implemented in hardware
- Process many signals with different types
- Signals can be masked
- Updateable firmware over intranet
- High connectivity to other applications
 - DOOCS, LabVIEW, HTML-Browser

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Thank you for your attention!

