

# A configurable Interlock System for RF-Stations at XFEL

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- Introduction
- Interlock requirements
- Interlock Hardware
- Interlock Software
- Summary

**XFEL – X-Ray Free Electron Laser** 

- The XFEL Project has become one of the most important future project for DESY
- The experience and knowledge of more than 10 years of research in the field of superconducting acceleration technology is now applied to the XFEL
- DESY, Zeuthen site contributes to this activities with the Photo Injector Teststand (PITZ) and the Modulator Test Facility (MTF)











### **XFEL - Overview**







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### **RF-System setup**



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- Interlocks required for up to 27 RF-Stations (powering the cavities in the accelerator tunnel)
- Requirements:
  - Protection of the cost expensive components of the RF-Station
  - Prevent any damage from other equipment
  - Send status information to the control system
  - Allow remote diagnostic
  - Guarantee reliable and safe operation



Dealing with different types of errors:

- 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 limits, ...
- Error conditions caused by transient noise from the RF-Station itself



- Configurable and scaleable system
- Module-based repair strategy
- Interlock functionality independent from software failures
- Different signal types supported

   digital, optic, analog inputs and outputs
- Min./Max. thresholds
- Individual channel masking
- Hardware and Software self test



- interlock function completely implemented in hardware structures
- **<u>Strict</u>** separation of interlock logic and processor bus



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### •Strict separation hardware / software

•1 controller / n slave modules architechture





### **Interlock Modules Overview**



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- Complete system self-test at power-up
- Access over intranet via http-server
  - View actual signal status
  - View/Change channel masks
  - View/Change signal thresholds
  - Perform slow control functions
  - View/Change Configuration
- Access to the system secured by authentication
   Optional user ip address check
- Software & Firmware update



### **Interlock Remote Interface**

| System Info                                   |   |  |  |  |  |  |
|---|---|--|--|--|--|--|
| Firmware and Software Information             |   |  |  |  |  |  |
| System name                                   | MTF-RF3 Klystron Interlock (Thomson Modulator)        |  |  |  |  |  |
| Software                                      | NIOS2 Server Ver. 1.19r                               |  |  |  |  |  |
| Software compile date                         | Sep 12 2008 13:10:29                                  |  |  |  |  |  |
| Software with Firmware compatible?            | Yes, perfect match.                                   |  |  |  |  |  |
| Network                                       |   |  |  |  |  |  |
| MAC   | 00:50:c2:66:c0:04                                     |  |  |  |  |  |
| IP Addr                                       | 141.34.38.108   |  |  |  |  |  |
| IP Mask                                       | 255.255.255.0   |  |  |  |  |  |
| Gateway                                       | 141.34.38.1   |  |  |  |  |  |
| Miscellaneous                                 |   |  |  |  |  |  |
| Preamp Lock Func.                             | active  |  |  |  |  |  |
| Temperature                                   | 28 celsius degree                                     |  |  |  |  |  |
| CPU usage                                     | 13%   |  |  |  |  |  |
| Memory used                                   | 7156 KB   |  |  |  |  |  |
| Memory free                                   | 25612 KB  |  |  |  |  |  |
| Self integrity check                          | 71327 checks, 0 errors, 34 active probes, 51808 bytes |  |  |  |  |  |
| Users logged in                               |   |  |  |  |  |  |
| User 'admin'                                  | IP: 141.34.30.147                                     |  |  |  |  |  |
| System description                            |   |  |  |  |  |  |
| Modulator Test Facility Zeuthen, RF-3 Thomson |   |  |  |  |  |  |

### Interlock Signal Status

Standard View | Alternate View | View All | Overview (matrix) | Refresh

### Mask configuration has changes

| FlowBox |                   |                            |                      |  |       |  |  |  |
|---------|-------------------|----------------------------|----------------------|--|-------|--|--|--|
| Sig.    | Sig. Used (☑ Name |                            | OK Cond.<br>(elect.) | Off Action   |       |  |  |  |
| 1       | V                 | Flow Transformer<br>Tank   | contact closed       | "Modulator off, Bias PS off"   | 30 ms |  |  |  |
| 2       | V                 | Flow Klystron<br>Collector | contact closed       | Modulator off  | 30 ms |  |  |  |
| 3       | V                 | Flow Klystron Body         | contact closed       | Modulator off  | 30 ms |  |  |  |
| 4       | V                 | Flow Solenoid 13           | contact closed       | "Modulator off, Solenoid PS1 off, Solenoid PS2 off,<br>Solenoid PS3 off" | 30 ms |  |  |  |
| 5       | V                 | Flow Modulator             | contact closed       | Modulator off  | 30 ms |  |  |  |
| 6       |                   | Flow PreAmp                | contact closed       | Preamp off   | 30 ms |  |  |  |
| 9       | V                 | Flow Circulator 1          | contact closed       | Preamp off   | 30 ms |  |  |  |
| 10      |                   | Flow Circulator 2          | contact closed       | Preamp off   | 30 ms |  |  |  |
| 11      | V                 | Flow Dummy Load 1          | contact closed       | Preamp off   | 30 ms |  |  |  |
| 12      |                   | Flow Dummy Load 2          | contact closed       | Preamp off   | 30 ms |  |  |  |

Refresh Page

### **TempBox** Sig. Used (⊠) Name OK Cond. (elect.) Min def.Min Max def.Max Value 17 Temp Transformer Tank Oil 19.9 °C 19.9 °C 35.1 °C 35.1 °C 26.2 °C inside Window 18 19.9 °C | 19.9 °C | 40.0 °C | 40.0 °C | 31.5 °C Temp Transformer Tank Water Out inside Window 19 Temp Klystron Tank Oil inside Window 19.9 °C 19.9 °C 40.0 °C 40.0 °C 26.6 °C 20 Temp Solenoid 1..3 Water Out 19.9 °C 19.9 °C 40.0 °C 40.0 °C 32.2 °C inside Window 21 22.1 °C 22.1 °C 35.1 °C 35.1 °C 26.7 °C inside Window Temp Klystron Collector Water In 22 22.1 °C 55.1 °C 55.1 °C 24.5 °C Temp Klystron Collector Water Out inside Window 22.1 °C 23 inside Window 22.1 °C 22.1 °C 30.1 °C 30.1 °C 26.0 °C Temp Klystron Body Water In 24 Temp Klystron Body Water Out inside Window 22.1 °C 22.1 °C 45.0 °C 45.0 °C 28.0 °C 25 19.9 °C 55.1 °C 55.1 °C 27.7 °C Temp Modulator Water Out inside Window 19.9 °C 26 Temp Dummy Load 1 Water In inside Window 19.9 °C 19.9 °C 30.1 °C 30.1 °C 26.5 °C

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### **Interlock Software - Architecture**

| Client applications                                     |     |                  |                |                    |                          |                            |                              |         |
|---|-----|------------------|----------------|--------------------|--------------------------|----------------------------|------------------------------|---------|
| ÷   | OSe | Control<br>Inter | System<br>face | Diagnose Interface |                          | HTTP Server                |                              | Laver   |
| Sel   | agn |                  |                |                    |                          |                            |                              | tion    |
| i<br>I  | Di  | Logging Se       |                | ervice             | Interlock<br>System Test | Interlock<br>Configuration | Interlock Data<br>Aquisition | oplicat |
| μC/OS II with <b>NichelP</b> Interlock Hardware Drivers |     |                  |                |                    |                          |                            | nd Al                        |         |
|   |     |                  |                |                    |                          |                            |                              | Backe   |
| Altera HAL  |     |                  |                |                    |                          |                            |                              |         |
| Interlock controller and slave modules                  |     |                  |                |                    |                          |                            |                              |         |



- runs on power-up
- System-selftest checks:
  - 1. controller
  - 2. Backplane, signal busses
  - 3. Slave modules and Firmware Compatibility
  - 4. Slave module configuration
- To put interlock system into operation mode, system self-test must not fail

### Saved Systest output at startup(1741 Bytes)

```
----- Svstest ---
Sysbustest Step 1, Mode 0]
  +Test 'srq line readback' ...
  -Found module at slot 5
  +Test 'srq line readback' passed
Sysbustest Step 1, Mode 1+2]
 -Test module at slot 5:
 +Test 'tmdata <= ctrladdr' ...
 +Test 'tmdata <= ctrladdr' passed
 +Test 'ctrldata <= ctrladdr'
  +Test 'ctrldata <= ctrladdr' passed
 +Test 'tmdata <= directio' ...
  +Test 'tmdata <= directio' passed
 +Test 'ctrldata <= directio' ...
  +Test 'ctrldata <= directio' passed
Sysbustest Step 2]
 -ERROR: Old slave-module with ICS V2 at slot 2
 -ERROR: Old slave-module with ICS V2 at slot 3
-Test module at slot 5:
 +Test 'cntrlbusinf <= tmaddr' ...
 +Test 'cntrlbusinf <= tmaddr' passed
 -ERROR: Sysbustest failed
     --- Sysbustest Step 1+2 Result -----
Modules found
Modules O.K.
Cntrlbus Interface : fine
Address Conficts
                   : no
 Sysbustest
                    : FAILED
```



- Self-Test task with low priority
- If it fails, hardware watchdog gets active
- Periodically tests each second:
  - If any task has a stack under-/overflow
  - If read-only marked memory areas are corrupted
  - If any tasks are dead or hanging
  - If any tasks reports an unusual amount of errors
- On error, sends report and reboots the system



## **Self-Test Technics in Detail**





## **Interlock Signal List**

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- Signal-list in form of a Excel 729 sheet is used to configure:
  - Interlock Software
  - Interlock Firmware Logic
  - Interlock Control System GUI
- Automated Generation of subsequent files
  - VHDL sourcefiles  $\rightarrow$
  - configuration files and scripts

```
-- (190) Prog Current Solenoid PS1
                                     (Mod:9 TA:0x24 Bit:4)
out 190 prog curr solenoid psl <=
     -- (4) Flow Solenoid 1..3 (Mod:5 TA:0x14 Bit:3)
    intlk input(163)
     -- (20) Temp Solenoid 1..3 Water Out
                                             (Mod:2 TA:0x8 Bit:3)
 AND intlk input(67)
     -- (173) Interlock Soft PS Enable
                                        (Mod:0 TA:0x0 Bit:0)
 AND intlk input(0);
-- (191) Prog Voltage Solenoid PS1 (Mod:9 TA:0x24 Bit:5)
out 191 prog voltage solenoid psl <=
     -- (4) Flow Solenoid 1..3 (Mod:5 TA:0x14 Bit:3)
    intlk input(163)
     -- (20) Temp Solenoid 1..3 Water Out
                                             (Mod:2 TA:0x8 Bit:3)
 AND intlk input(67)
     -- (173) Interlock Soft PS Enable
                                        (Mod:0 TA:0x0 Bit:0)
 AND intlk input(0);
-- (194) Prog Current Solenoid PS2
                                     (Mod:9 TA:0x24 Bit:6)
out 194 prog curr solenoid ps2 <=
     -- (4) Flow Solenoid 1..3 (Mod:5 TA:0x14 Bit:3)
    intlk input(163)
     -- (20) Temp Solenoid 1..3 Water Out
                                             (Mod:2 TA:0x8 Bit:3)
 AND intlk input(67)
     -- (173) Interlock Soft PS Enable
                                        (Mod:0 TA:0x0 Bit:0)
 AND intlk input(0);
-- (195) Prog Voltage Solenoid PS2
                                    (Mod:9 TA:0x24 Bit:7)
out 195 prog voltage solenoid ps2 <=
     -- (4) Flow Solenoid 1..3 (Mod:5 TA:0x14 Bit:3)
    intlk input(163)
     -- (20) Temp Solenoid 1..3 Water Out
                                             (Mod:2 TA:0x8 Bit:3)
 AND intlk input(67)
     -- (173) Interlock Soft PS Enable (Mod:0 TA:0x0 Bit:0)
 AND intlk input(0);
```



- Interlock managed by a signal-list (up to 300 Signals)
- Automation eases adapting to new setups

|        | Basic Information                 |                             |   |                           |                                 |                                |  |
|--------|-----------------------------------|-----------------------------|---|---------------------------|---------------------------------|--------------------------------|--|
|        | Interlock Zeuthen for MTF         |                             |   |                           |                                 | Date: 2008-08-22               |  |
| List # | Signal name                       | Distrib<br>Panel<br>Address | Intlk Crate<br>Destination<br>Slot:Board:Conn:Pin | Signal type               | Signal OK<br>Physical Condition | Signal OK<br>Logical Condition | Action (if errornous state)  |
| 1      | Flow Transformer Tank             | DI.1A/1                     | S5:DIGIIO:In:0                                    | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | Modulator off, Bias PS off   |
| 2      | Flow Klystron Collector           | DI.1A/2                     | S5:DIGIIO:In:1                                    | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | Modulator off  |
| 3      | Flow Klystron Body                | DI.1A/3                     | S5:DIGIIO:In:2                                    | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | Modulator off  |
| 4      | Flow Solenoid 13                  | DI.1A/4                     | S5:DIGIIO:In:3                                    | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | Modulator off, Solenoid<br>PS1 off,<br>Solenoid PS2 off,<br>Solenoid PS3 off |
| 5      | Flow Modulator                    | DI.1A/5                     | S5:DIGIIO:In:4                                    | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | Modulator off  |
| 6      | Flow PreAmp                       | DI.1A/6                     | S5:DIGIIO:In:5                                    | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | Preamp off   |
| 7      | Flow Collector In (HH)            | DI.1A/7                     | S5:DIGIIO:In:6                                    | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | Modulator off  |
| 8      | Flow Reserve 1                    | DI.1A/8                     | S5:DIGIIO:In:7                                    | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | -  |
| 9      | Flow Circulator 1                 | DI.1B/1                     | S5:DIGIIO:In:8                                    | mech. Contact (pot. free) | contact closed                  | F ≻ Fmin                       | Preamp off   |
| 10     | Flow Circulator 2                 | DI.1B/2                     | S5:DIGIIO:In:9                                    | mech. Contact (pot. free) | contact closed                  | F ≻ Fmin                       | Preamp off   |
| 11     | Flow Dummy Load 1                 | DI.1B/3                     | S5:DIGIIO:In:10                                   | mech. Contact (pot. free) | contact closed                  | F ≻ Fmin                       | Preamp off   |
| 12     | Flow Dummy Load 2                 | DI.1B/4                     | S5:DIGIIO:In:11                                   | mech. Contact (pot. free) | contact closed                  | F ≻ Fmin                       | Preamp off   |
| 13     | Flow Reserve 2                    | DI.1B/5                     | S5:DIGIIO:In:12                                   | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | -  |
| 14     | Flow Reserve 3                    | DI.1B/6                     | S5:DIGIIO:In:13                                   | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | -  |
| 15     | Flow Reserve 4                    | DI.1B/7                     | S5:DIGIIO:In:14                                   | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | -  |
| 16     | Flow Reserve 5                    | DI.1B/8                     | S5:DIGIIO:In:15                                   | mech. Contact (pot. free) | contact closed                  | F > Fmin                       | -  |
| 17     | Temp Transformer Tank Oil         | TI.1A/1                     | S2:ANAIN:In:0                                     | PT100 > analog (420mA)    | inside Window                   | T < Tmax                       | Modulator off  |
| 18     | Temp Transformer Tank Water Out   | TI.1A/2                     | S2:ANAIN:In:1                                     | PT100 > analog (420mA)    | inside Window                   | T < Tmax                       | Modulator off  |
| 19     | Temp Klystron Tank Oil            | TI.1A/3                     | S2:ANAIN:In:2                                     | PT100 > analog (420mA)    | inside Window                   | T < Tmax                       | Modulator off  |
| 20     | Temp Solenoid 13 Water Out        | TI.1A/4                     | S2:ANAIN:In:3                                     | PT100 > analog (420mA)    | inside Window                   | T < Tmax                       | Modulator off, Solenoid<br>PS1 off,<br>Solenoid PS2 off,<br>Solenoid PS3 off |
| 21     | Temp Klystron Collector Water In  | TI.1B/1                     | S2:ANAIN:In:4                                     | PT100 > analog (420mA)    | inside Window                   | T ≺ Tmax                       | Modulator off  |
| 22     | Temp Klystron Collector Water Out | TI.1B/2                     | S2:ANAIN:In:5                                     | PT100 > analog (420mA)    | inside Window                   | T ≺ Tmax                       | Modulator off  |







- **Reliable**, **robust** Interlock-function independent from software failure
- Supports many signals of different type
- In field software / firmware update
- Configurable and adaptable to new applicatons
- Very flexible Interlock System for XFEL



# Thank you for your attention!