



Technical Guideline

Number

F-TG-C-03e

Controls
Department

Equipment Interlock and Status Signal Interface

Status

Version 3.0
06. Aug. 2012

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1 General

All accelerator equipment (e.g. power converters, RF systems, beam diagnostic systems, vacuum valves and pumps, etc.) is connected to the GSI/FAIR control system to be controlled or at least monitored. The control system will account for reliable operation of equipment under control as well as for the facility as a whole.

However, the control system cannot take sole responsibility for excluding harm to the connected equipment and even less for safety of personnel. Therefore, dedicated safety systems will be implemented to take care of such requirements. This technical guideline covers the interfaces for the Interlock System only. Further safety systems and its interfaces will be described in other documents.

The **Interlock System** concentrates various interlock signals and triggers machinery safety critical actions. It protects the accelerator from damage by mislead beams and e.g. minimizes radioactive contamination by unforeseen beam deposition. In case of relevant equipment failures (interlocks) or other inappropriate equipment states, the Interlock System triggers appropriate protection actions. These could range from reduction of beam intensities (e.g. shorter beam pulses) up to disabling further beam production and – if necessary – dump the beam in an upstream accelerator to get rid of beam already produced.

1.1 Standards and Compliance Regulations

No other than the interface standards here will be featured or supported by FAIR to connect to the Interlock System. Consequently, it is absolutely mandatory for all equipment suppliers and project partners that the equipment developed for and supplied to FAIR fully complies with the interlock and status signal interface definitions stated here.

The Technical Guidelines [4] and [1], [2], [3] fully apply.

If the interface definitions for any equipment are considered incomplete, insufficient, or not appropriate by the equipment supplier, it is the responsibility of the equipment supplier to immediately contact the accelerator control system coordinator to ask for refinement of the specification or to explore and discuss options.

The definition of equipment interlock and status signal interfaces remains the full authority of FAIR, represented by the designated control system coordinator.

1.2 Definitions and Terminology

In the context of this guideline, accelerator **equipment** is the umbrella term for all physical systems to be controlled and/or monitored by the control system which are needed to facilitate the production and delivery of beam to the designated destinations.

Any equipment must be designed to be intrinsically safe (self-protection). Potential dangerous conditions to the equipment must be detected by the equipment itself and must lead to a safe state of the equipment.

An **equipment interlock** is an asynchronous condition usually resulting from an equipment internal fault (abnormal behaviour). There are usually several **interlock conditions** leading to an equipment interlock. An interlock forces the equipment to stop normal operation and adopt a safe state (usually "power off") to prevent potential damage to the equipment. An interlock sets all dependent units/actuators to their fail safe condition/position. In addition to internal fault



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conditions, external signals fed from other systems might also lead to equipment interlocks (e.g. safety shutdown signals).

The interlock condition(s) that triggered an actual equipment interlock can be read-out from the control system. An equipment interlock requires manual acknowledgement before restarting the equipment again (e.g. remotely via command by the control system).

Equipment publishes their status to the Interlock System and the control system. The electrical signal of an equipment interlock is referred as equipment **summary interlock** (German: "Summen-Interlock"); the detailed interlock conditions are often shortly referred as **interlock**.

2 Equipment Interlock and Status Signals

The Interlock System requires monitoring and interfacing different types of equipment:

- General Beam Control Equipment
- Beam-Intercepting Mechanical Actuators

For both types of equipment electrical signal interfaces are defined in the following sections which have to be provided by the respective equipment supplier.

Despite the specification of electrical interface, the developer and supplier of the Interlock System reserves the right to decide whether the electrical interface will actually be used for every single component or if other existing control system interfaces are also adequate and can be used.

In general, all interlock signals and reactions have to be designed as broken wire interlock circuit (closed-circuit connection).

2.1 General Beam Control Equipment

The Interlock System requires monitoring all relevant active accelerator equipment that is required or even able to manipulate and guide the beam or which causes beam loss or deterioration of beam quality in case of malfunction.

Examples for such equipment are:

- power converters
- RF systems
- beam kickers
- relevant feedback systems

Any such accelerator equipment must signal an equipment **summary interlock** condition to the Interlock System. Any internal equipment fault as well as external shutdown conditions triggers a summary interlock condition.

2.1.1 Interface

The equipment must provide a dry contact (see Figure 3, case A) which opens on an equipment interlock condition. The dry contact must open immediately, latest within 50 ms (switch-off delay) after fault occurrence.

Electrical specifications

Voltage level	24 V
Rated insulation voltage	50 V
Maximum switch-off delay	50 ms
Rated operational current, DC-12 (resistive load) to 24 V DC	1 A
Continuous thermal current	1 A
Minimum switching voltage	10 V
Minimum switched current	20 mA

Connector

IEC 61076-2-101 circular connector	
Size	M12
Gender	female
Coding	A
Poles	5



Figure 1: M12 circular connector,
example

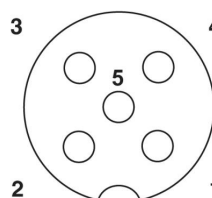


Figure 2: Pin assignment M12 socket, 5-
poles, A-coded, socket side view

Table 1: Connector Pinout (see Figure 3)

Signal	Pin	Description
X11	1	Dry contact
X12	3	Dry contact

Table 2: Contact state in dependence of equipment state

Equipment state	Dry contact O3 open	Dry contact O3 closed
Off	X	
Switch on		X
Ready		X
Operation		X
Disable		X
Interlock / Error	X	

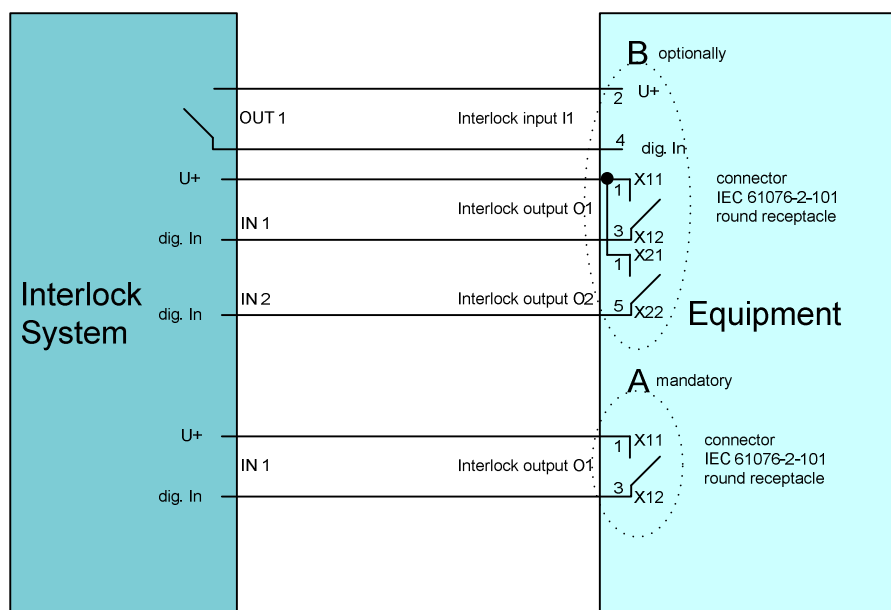


Figure 3: Signal exchange principle

2.2 Beam-Intercepting Mechanical Actuators

The Interlock System requires information about the motion position of any mechanical actuator which can intercept the beam. In general, two different types of mechanical actuators have to be distinguished.

2.2.1 Non-positionable Actuators

Actuators of this category have stable motion positions only in the state "in" (inner limit) and "out" (outer limit) in respect of the beam path. There is no defined stable position in-between these end positions (transition only).

Examples of such equipment are:

- vacuum valves
- beam diagnostic actuators for inserts (e.g. pressurized air driven profile grids, scintillation screens, Faraday cups, beam blockers, etc.)

Since the Interlock System needs to monitor both inner and outer limit positions, any such mechanical actuator system must provide dry contacts for both end positions (2 separate contacts).

The supplier of such mechanical actuator systems is required to specify the maximum transition time between both end positions for supervision by the control system and/or the Interlock System.

2.2.2 Freely-positionable Actuators

Actuators of this category can be freely positioned in respect to the beam, e.g. by a stepping motor drive. Such actuators have a defined outer limit position to ensure that the actuator is definitively out of the beam path and can engage a variable position in respect to the beam. Such systems are usually (but not necessarily) being controlled by the control system).

Examples of such equipment are:

- beam collimator
- stochastic cooling pick-ups and kickers
- detector inserts for in-beam experiments

The Interlock System needs to monitor the outer limit position. Therefore, any such mechanical actuator system must provide a dry contact for the outer end position.

2.2.3 Interface

The dry contacts provided by the equipment are closed in the respective end position(s) and open upon leaving the respective end position. The dry contacts must open within 150 ms after leaving the mechanical end position.

Contacts can be either directly derived from limit switches or provided by the controller of the equipment (e.g. PLC, taking into account the control loop period). In case a controller handles several actuators, independent dry contacts for every single actuator must be provided.



Electrical specifications

Voltage level	24 V
Rated insulation voltage	50 V
Maximum switch-off delay	150 ms
Rated operational current, DC-12 (resistive load) to 24 V DC	1 A
Continuous thermal current	1 A
Minimum switching voltage	10 V
Minimum switched current	20 mA

Connector

IEC 61076-2-101 circular connector	
Size	M12
Gender	female
Coding	A
Poles	5

Table 3: Connector Pinout (see Figure 3)

Pin	Description		
2	n.c.		
4	n.c.		
1		Dry contact	outer limit
3		Dry contact	
1		Dry contact	inner limit (if applicable)
5		Dry contact	



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3 Equipment Shutdown Signals

If requested by the control system coordinator, an optional safety interlock signal must be foreseen by the equipment supplier.

Such accelerator equipment must provide an input channel (I1) to switch off, power down and de-energize the respective system. Such a signal is usually treated as an external interlock condition of the equipment (safety shutdown).

For acknowledgement of these requests, two signals are defined: As a fast response, the equipment provides a summary interlock signal (O1), indicating that the safety shutdown signal was detected and the shutdown process was initiated. Following with delay (equipment specific), a second acknowledgement signal (O2) indicates that the shutdown process has finished and the equipment has actually achieved the safe state.

Signal specification (see Figure 3)

Safety Interlock Request, safety shutdown signal (I1)

Summary Interlock Indicator (O1): dry contact; make contact, opens if equipment is in interlock state.

Safe State Indicator (O2): dry contact; make contact, opens if equipment is in safe state

Electrical specifications:

Voltage level	24 V
Power supply output U+	+24 V \pm 10 %
Digital input, "dig. In":	
Signal "1", High	+15 VDC ... U+ -1 V, \geq 0,01 ... \leq 1 A
Signal "0", Low	0 ... \leq 6 VDC
Interlock outputs, O1, O2:	
Rated insulation voltage	50 V
Rated operational current,	
DC-12 (resistive load) to 24 V DC	1 A
Continuous thermal current	1 A
Minimum switching voltage	10 V
Minimum switched current	20 mA
Maximum command duration, T1	50 ms

The maximum shutdown duration, T2 must be specified by the equipment supplier.

Connector

IEC 61076-2-101 circular connector	
Size	M12
Gender	female
Coding	A
Poles	5

Table 4: Connector Pinout (see Figure 3)

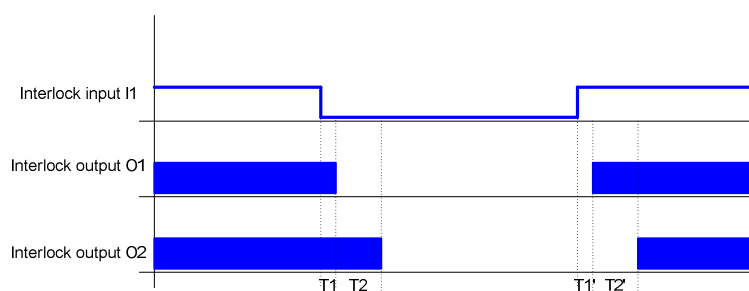
Signal	Pin	Description	
U+	2	Supply voltage output	
dig. In	4	Digital input, safety shutdown signal input	
X11	1	Dry contact	Summary Interlock Indicator
X12	3	Dry contact	
X21	1	Dry contact	Safe State Indicator
X22	5	Dry contact	

Table 5: Contact states in dependence of safety shutdown signal I1 (see also Figure 4)

Equipment state	I1	O1	O2
Off	1	1	0
Switch on	1	1	0 → 1
Ready	1	1	1
Operation	1	1	1
Disable	1	1	1
Fault condition / Error	1	1 → 0	1 → 0
Off	0	0	0
Switch on	0	0	0
Ready	0	1 → 0	1 → 0
Operation	0	1 → 0	1 → 0
Disable	0	1 → 0	1 → 0
Fault condition / Error	0	0	0

“1” Dry contact is closed, safety shutdown signal is high

“0” Dry contact is open, safety shutdown signal is low


Figure 4: Switching sequence during safety shutdown



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4 Attached Documents

List of abbreviations for controls (Abbreviations_Controls.pdf).

5 Related Documentation

- [1] F-TG-C-01e, Technical Guideline "Ethernet Network Connectivity"
- [2] F-TG-C-02e, Technical Guideline "Control System Equipment Control Interfaces"
- [3] F-TG-C-04e, Technical Guideline "Control System Equipment Functional Requirements"
- [4] F-TG-ET-01e, Technical Guideline "Electrical Design Rules and Regulations"