LT-C-XFD-SPC-CO-IIS-001

Beamline Systems Instrumentation Interfacing Standard

Revision 2

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Assistance from many of our colleagues at NSLS-II plus staff from Diamond Light Source, Australian Synchrotron, and Soleil is gratefully acknowledged.

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Version History

Version	Date	Description	Comment
1	May 13, 2011	First version ready for release	
2	April 4 2012	Updates include: Servo phase wiring definition and limit switch pin labelling clarification. Motion direction standard clarification.	

Concurrence and Approval Signatures

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Contents

Acronyms

ADC	Analog to Digital Converter
AWG	American Wire Gauge
EMC	Electromagnetic Compatibility
EPICS	Experimental Physics and Industrial Control System
EPS	Equipment Protection System
FDR	Final Design Review
LSZH	Low Smoke Zero Halogen
LVDT	Linear Variable Displacement Transducer
PLC	Programmable Logic Controller
PDR	Preliminary Design Review
PPS	Personnel Protection System
PSD	Position Sensing Device
RFQ	Request for Quote
RTD	Resistive Thermal Device
SIP	Sputter-Ion Pump

1 Introduction

1.1 Scope definition

This document defines the electrical connectivity and interfacing for motion control, vacuum control and diagnostic equipment within a photon beamline and endstation at NSLS-II.

This document provides a set of guidelines which will ensure that all of the electrical components in a beamline can be integrated into the control system, allowing all aspects to be controlled and monitored from one terminal. It is also the intention to promote commonality of components wherever possible.

Appendices A and B bring a summarized list of standard connectors (Souriau UT0 and Type "D" connectors) adopted by NSLS-II for reference.

1.2 Scope exclusions

Data acquisition in the endstations is excluded from the scope of this document.

This document does not cover the mains electrical power supply and interfaces.

1.3 Statutory requirements of the supplier

This document is not exhaustive, and does not remove the obligation on suppliers to comply with any and all applicable statutory instruments. It is the supplier's responsibility to ensure conformance of each technical detail at the commencement of any supply contract.

1.4 Other general requirements

1.4.1 Protection of electronic equipment from radiation

Radiation shielding shall be provided where required for devices exposed to radiation, or, if electrically acceptable, the solid state device should be located outside the hutch.

1.4.2 Cable construction and materials

All cables supplied for installation at NSLS-II shall be Low Smoke, Zero Halogen (LSZH).

All cables to be installed in a cable tray shall be rated for Cable Tray use. The cable shall have the TC (Tray Cable) and NRTL markings. Where a cable is not marked for Tray Cable use then cable shall meet the IEEE 1202 Vertical-Wire Flame Test.

1.5 Applicable Documents

Document Number	Document Title
LT-C-XFD-STD-BL-COORD-001	Beamline Coordinate Systems Standard

2 Vacuum

Most parts of the beamline must be maintained under vacuum. All vessels, devices etc. will require adequate vacuum pumping, gauging, control and isolation. Overall control of the valves will be provided by a standard Equipment Protection System (PLC), which will also provide interfacing with the EPICS control system. It is envisaged that the various pumps will be run continuously except during essential maintenance.

2.1 Vacuum instrumentation

There will be a number of different vacuum instruments employed on the NSLS-II machine and beamlines. They are as follows:

2.1.1 Gauge controller

The gauge controller shall power and control a number of gauges heads and provide the analog, relay, or TTL signals for interlocking. The NSLS-II standard vacuum gauge controller is the MKS 937B. The preferred communication interface for gauge controllers will be RS-232/422/485. All other wiring (e.g., to the gauge heads) will be using the manufacturer's standard cable schematics and connectors.

2.1.2 Thermal conductivity/convection Pirani gauges

The thermal conductivity/convection Pirani gauges have a range of Atmosphere to 1×10^{-3} mbar and connect to the vacuum vessel via a DN 40 CF or DN 16 CF flange. They feed signals back to a gauge controller directly. The connection is to be made in accordance with the manufacturer's instructions.

2.1.3 Cold cathode gauge

The cold cathode gauge has a pressure measuring range of 1×10^{-2} mbar to 1×10^{-11} mbar and connects to the vacuum vessel via a DN 40 CF flange. The connecting cable will be LSZH, tray rated, and UL listed unless otherwise approved by BSA in writing. The connection is to be made in accordance with the manufacturer's instructions.

2.1.4 Partial pressure gauge (Residual Gas Analyzer, RGA)

The system includes an analyzer probe, controller and interface unit. Its analyzer head shall be mounted on a DN 40 CF flange. The device will have a mass range of 200 AMU. The connecting cable will be LSZH, tray rated, and UL listed unless otherwise approved by BSA in writing. The connection is to be made in accordance with the manufacturer's instructions.

2.2 Vacuum interlocks

Equipment supplied to NSLS-II requiring interlocks (e.g., to prevent the operation of piezo elements at vacuum levels where electrical arcing could occur) shall have the interlock functionality documented at the appropriate design review and in the operating manual.

2.3 Vacuum valves

The vacuum isolating valves shall be UHV compatible and all metal. They are available in flange sizes from DN 40 up to DN 200. The vacuum valves are pneumatic, although DN 40 and DN 63 manual valves may also be used.

The pneumatic valve actuator shall be double acting , and include open/close limit switches (plus spares for redundancy), 24 V DC solenoid.

The limit switches will be utilized as feedback for both the valve controller and EPS. The connection is to be made in accordance with manufacturer's instructions.

2.4 Sputter-Ion Pumps (SIPs) and controllers

The ion pump requirements will be met using a range of pumps including 100 l/s, 150 l/s, 300 l/s, and 500 l/s. The pump element assemblies shall be of a diode configuration. The controller-to-EPICS interface is realized using RS232/422/485. The SIP operates typically at 5 kVDC.

The ion pumps will connect to the vacuum vessel via DN 100 CF or DN 160 CF flanges. They will require connection to their controller using customized cable. The connecting cable will be LSZH, tray rated, and UL listed unless otherwise approved by BSA in writing. The connectivity is as follows.

- The HV connection is made using a 10 kV coaxial cable. It connects to the controller via a special Kings SHV coaxial connector. There is also an integral safety connection which only allows the HV supply to operate when both ends are properly connected.
- The SIP controller shall be located in the beamline electronics rack, outside of any hutch.

The bakeout heaters shall be supplied and mounted to the pump body, operate at 110 VAC, and capable of maintaining the temperature >200 °C. Temperatures of 250 °C are to be avoided unless the magnet is removed.

2.5 Oil-free roughing pumps

There will be a requirement for oil-free roughing pumps either on carts or permanently installed. Any requirements for roughing pumps require concurrence from the electrical and vacuum groups. Details of the standard NSLS-II roughing pumps will be provided upon request.

2.6 Turbo molecular pumps

There may be a requirement for turbo pumps either on carts or permanently installed. Any electrical requirement for a turbo pump must be established with the electrical and vacuum groups. Details of the NSLS-II standard turbo molecular pumps will be provided upon request.

2.7 Bakeout

Bakeout procedures and equipment must be approved by the NSLS-II Vacuum Group. Any bakeout jackets or tapes must be 110 VAC and incorporate thermocouple over-temperature measurement to prevent excessive heat damaging the equipment.

3 Motion control

Many of the devices required to complete a beamline require accurate motion control. Stepper motors are the standard, and preferred, NSLS-II solution for conventional motion axes. All motorized motions shall have limit switches, and should also be fitted with encoders where appropriate. Wherever possible, the number of variations shall be kept as small as practicable to reduce the spares requirement. Piezo actuators are acceptable where there are special motion requirements (e.g., high precision / small step) for the axis that cannot be met with a conventional stepper motor.

For applications that require solutions other than stepper motors, the supplier shall agree on motor and drive card combinations with BSA.

The interface to the NSLS-II standard motion controller is defined in LT-C-XFD-RSI-CO-001. For motors requiring up to 5A at 50V or less, this controller can directly drive 2/4 phase stepper motors and DC servo motors. For higher or lower-power motors, the controller will provide differential step (pulse) and direction signals.

Any motion axis using an AC motor will require a variable frequency drive unit. This must be capable of interfacing with EPICS via the digital interface board or compatible communications medium.

Where appropriate, in-vacuum devices should be kept to a minimum. Any in-vacuum devices on a component that will be baked must also be bakeable.

3.1 Motion direction

The definition of positive motion for the motion controller is in the "Motion Controller" subsection of the "Control System" section of LT-C-XFD-STD-BL-COORD-001, Beamline Coordinate System Standards.

3.2 The motor shall be wired according to the pinouts defined in 3.3.3.6. or 3.3.5.1. If this results in the opposite axis motion direction to that required, the motion direction should be inverted in the motion controller configuration.Stepper motors and DC servos

NSLS-II has preference for 2-phase, bipolar stepper motors. The connection of any extra wires (i.e., from six- or eight-wire motors) must be made between the motor and the motor connector so the interface to the at the component patch panel is effectively a four-wire bipolar configuration. All six or eight lead stepper motors shall be wired in “parallel” configuration, unless otherwise specified.

Units should be capable of direct mounting to an assembly via frame-mounted fixing holes rather than a clamp arrangement. Wherever possible, frame sizes shall be standard NEMA sizes (example: NEMA-23).

Any motor situated within a vacuum vessel shall be vacuum rated (e.g., AML or Phytron types or equivalent) and should include provision for temperature monitoring/protection. The resolution of an in-vacuum axis must be achieved in full-step mode in order to keep the holding current at the minimum possible level or to allow the motor amplifier to be disabled without losing its position. In-vacuum motors require electrical screening of the connection leads. Since the lead assembly for an in-vacuum motor is usually individual Kapton insulated wires, the connection wiring will require an overall metal screen connected at both the motor and the vacuum feedthrough connector.

5-phase motors may be used on beamline equipment where two phase stepper motors are not available or cannot meet the specifications, but details should be provided to BSA for review and approval prior to use on the Equipment. Wiring connections will be approved on a case by case basis.

3.3 General motor connections

The motor cable and connector specification is detailed below. This is split into two sections. Low-power motors are defined in section 3.3.3, while high-power motors (such as those used on insertion devices) are defined in section 3.3.4.

The motor cable and connector specification is illustrated in appendix C.

3.3.1 Limit switches

Limit switches are used to define the limit of the travel. They are used to provide protection against mechanical damage. Limit switches can also be used as a reference/home switch. The resolution and hysteresis of the limit switch should be appropriate to its function (i.e. limit only or limit and reference combined).

All motorized axes shall be fitted with a single limit switch at each end of travel.

Limit switches shall be mechanical switches, with normally closed, dry, volt-free contacts rated at 24 VDC. Any variation from this specification must be approved in writing by BSA.

The use of alternative solutions such as normally open mechanical switches, open-collector, or TTL limit signals is strongly discouraged.

Limit switches shall be interfaced with the controller in such a way as to be consistent with the definitions of “positive motion”, referenced in 3.1 (i.e., the limit switch associated with maximum travel in the positive direction shall be interfaced with the motor controller’s positive limit input for that axis). The same logic shall apply to other switches associated with a given physical axis (e.g. “kill switches”).

3.3.2 Homing switches

Switches that are to be used as homing or reference indicators shall have a low switching hysteresis and a highly repeatable switching position. The precision required will be determined by the requirements of the specific motion axis.

Homing switches shall have dry, volt-free contacts rated at 24 VDC.

3.3.3 Low-power stepper motors

This section covers low-power motors, typically operating below 50 V and 5 A.

3.3.3.1 Motor cable

The following specifies suitable motor cable for stepper motor systems. Limit and home switches and motor power may be combined in the same main cable core. They shall be separately shielded to prevent interference between the motor drive signals and the home/limit signals.

Motor cores: 3 x 2 x 0.75 mm^2 (min) with overall shield (alt AWG 18)

Limit / home cores: 3 x 2 x 0.25 mm^2 (min) (alt AWG 22)

3.3.3.2 Motor connectors

Connectors are all-metal UTO (Trim Trio) series by Souriau, or equivalent. Shell size is 14, with an insert arrangement of 12 contacts:

http://www.souriau.com/index.php?id=511

The connection strategy is to avoid live exposed pins. All motors shall be terminated close to the motor at termination panels or directly on the motor using flying leads.

Figure 1: Motor connectors. Note that the connectors used at NSLS-II will have 12 contacts.

3.3.3.3 Motor controller (or motor controller termination panel)

Item	Comment	Part Number
Motor controller (or motor controller termination panel)	Wall mounting receptacle, socket contacts	UTO 01412 SH

3.3.3.4 Motor connection

In the case of the connector being mounted to a mounting panel, the following connector shall be utilized:

Item	Comment	Part Number
Panel-mounted motor connector	Wall mounting receptacle, pin contacts	UTO 01412 PH

In the case of the connector being mounted to motor flying leads the following connector shall be utilized, with appropriate strain relief. Plastic cable clamp with strain relief is acceptable.

Item	Comment	Part number
Cable mounted motor connector	Cable mounting receptacle, pin contacts	UTO 11412 PH
Strain relief	Plastic cable clamp with strain relief. Cable diameter range: 4–13.8 mm	UTG 14AC

3.3.3.5 Cable connector convention

The connection strategy avoids exposed live pins, hence the connectors on each end of the cable are not the same. The following table shows the cable connectors, with strain relief at both ends.

Item	Comment	Part Number
Motor cable connector (motor controller end)	Cable mounting receptacle, Pin contacts	UTO 61412 PH
Motor cable connector (motor end)	Cable mounting receptacle, Socket contacts	UTO 61412 SH
Strain relief (both ends)	Plastic cable clamp with strain relief. Cable diameter range: 4 – 13.8 mm	UTG 14 AC
Strain relief (for radiation areas)	Metal cable clamp with strain relief	UTO 14AC

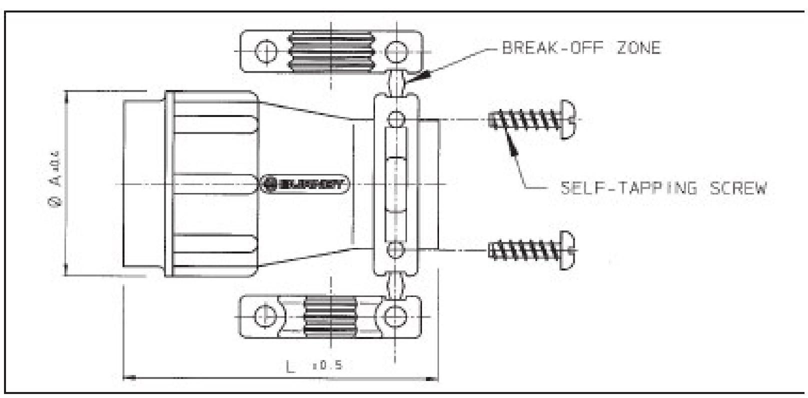


Figure 2: Photo and diagram of the plastic cable clamp.

3.3.3.6 Motor Cable Pin Assignments

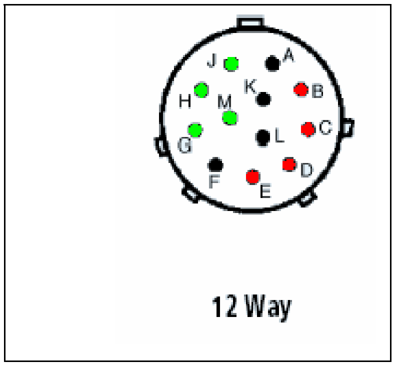


Figure 3: Red shows motor connections, green shows limits.
Connector viewed from plug mounting face, contact side.

The following table shows pin assignments for 2-phase stepper motor and limit cables.

Pin	Pin No.	Min Conductor	Color (provisional)	General description
A	1	0.75 mm^2	Black	Motor GND
B	2	0.75 mm^2	Brown/Green	Motor A+
C	3	0.75 mm^2	White/Green	Motor A-
D	4	0.75 mm^2	Grey/Pink	Motor B+
E	5	0.75 mm^2	Red/Blue	Motor B-
F	6	0.75 mm^2	Cable Shield	Cable Shield GND
G	7	0.25 mm^2	White	Positive Limit Switch
H	8	0.25 mm^2	Yellow	Negative Limit Switch
J	9	0.25 mm^2	Grey	Home Switch
K	10	0.25 mm^2	Orange	5 V limit supply
L	11	0.25 mm^2	Pink	24 V limit supply
M	12	0.25 mm^2	Green	0 V

Note: Limit and home switches operate with shared voltage supply (Pin K or L).

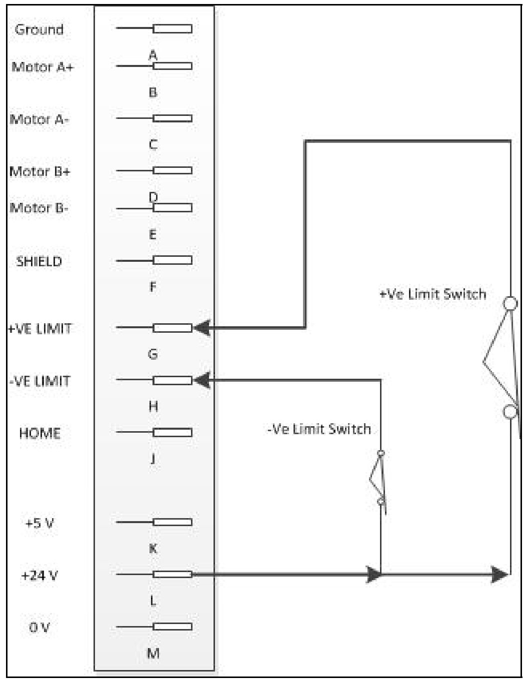


Figure 4: Example limit switch connection schematic using common 24 VDC supply.

3.3.3.7 Motor cable contact specification

Machined contacts shall be used in all connectors. The contact size shall be Souriau #16.

The contact wire connection size shall be appropriate for the wire size. Part numbers for the contacts currently in use are in the following table. Crimp connectors shall be used wherever possible.

Cable size (AWG/mm^2)	**Pin contact**	**Socket contact**
18/0.75 (motor cores)	RM16M23K	RC16M23K
22/0.25 (limit switch cores)	RM20M12K	RC20M12K

3.3.4 High-power motors

High-power motors are defined as those requiring greater than 5 A of continuous current at more than 50 V. In this case, the proposed NSLS-II standard motion controller’s integrated drives are insufficient to power such motors, so external amplifiers must be supplied. The controller-amplifier control interface for external stepper and servo drives (so-called stepper replacement drives) shall be differential step and direction signals, such that the amplifier is compatible with the NSLS-II standard motion controller interface.

3.3.5 DC servo motors

DC servo motors are treated the same as stepper motors as described in 3.3.3, except for the connector pin assignment.

3.3.5.1 Motor cable pin assignments

The following table shows pin assignments for DC Servo motor and limit cables.

Pin	Pin No.	Min Conductor	Color (provisional)	General description
A	1	0.75 mm^2	Black	Motor GND
B	2	0.75 mm^2	Brown/Green	U Phase
C	3	0.75 mm^2	White/Green	W Phase
D	4	0.75 mm^2	Grey/Pink	V Phase
E	5	0.75 mm^2	Red/Blue	NC
F	6	0.75 mm^2	Cable Shield	Cable Shield GND
G	7	0.25 mm^2	White	Positive Limit Switch
H	8	0.25 mm^2	Yellow	Negative Limit Switch
J	9	0.25 mm^2	Grey	Home Switch
K	10	0.25 mm^2	Orange	5 VDC limit supply
L	11	0.25 mm^2	Pink	24 VDC limit supply
M	12	0.25 mm^2	Green	0 V

Note: Limit and home switches operate with shared voltage supply (Pin K or L).

3.3.6 AC motors

The use of AC motors is relatively unusual on beamlines and agreement must be received from the responsible technical person prior to their inclusion in any equipment. In any event they shall be wired in accordance with the manufacturer's written instructions.

3.3.7 Other motor types

Any motor type not explicitly covered in this document shall only be used with BSA approval.

3.4 Motion control local E-stop

Any motion that could potentially cause injury to personnel, or that could cause damage in the event of a collision, must have a local E-Stop connected to allow emergency isolation in the event of a failure. The design of this E-Stop system shall meet all applicable standards and regulations.

3.4.1 Motion controller abort/watchdog connector

The standard NSLS-II motion controller has an interface to allow an external abort signal to be sent to the motion controller. When it receives this abort signal, the motion controller will perform a controlled deceleration.

The motion controller provides an output indicating the watchdog status.

The pinout for this connector is in the following table.

Pin	General description
A	0 V
B	Controller enable/abort
C	Watchdog NC
D	Watchdog Common
E	Watchdog NO
F	Signal to reset external relay
G	Signal to reset external relay
H	24 V

To enable the motion controller operation, Pin H must be connected to Pin B. Disconnecting 24 V from Pin B causes the motion controller to execute the abort process.

The watchdog signals are relay contacts, and can be used as a signal the motion controller status to an external system.

Pins F and G are an output from the motion controller that can be used to reset a safety relay or similar device, if that is required. It is not expected that these pins will be used at NSLS-II.

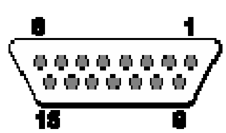
3.5 Encoders

Encoder resolution shall be appropriate to the motion axis for which the encoder is providing feedback. The preferred solution is an optical encoder. X-ray shielding of these encoders shall be considered at the equipment design stage.

Absolute encoders shall be used wherever there is a requirement for position recovery without initialization after a power failure.

Motion axes that do not require an absolute encoder may be fitted with an incremental encoder. These axes shall have a reference mark in the form of an encoder precision reference signal, precision datum switch or precision limit switch.

The connection in the control rack will be made via a 15-way high-density D-type panel-mounted socket, EMC-shielded connector, for which pin-out is as follows:



Pin	Encoder feedback
Pin 1	Ch A+
Pin 2	Ch A-
Pin 3	Ch B+
Pin 4	Ch B-
Pin 5	Ch C+

Pin 6	Ch C-
Pin 7	Encoder power (5 V)
Pin 8	Encoder power (0 V)
Pin 9	Commutation Input U/Stepper Direction +
Pin 10	Commutation Input V/Stepper Direction -
Pin 11	Commutation Input W/Stepper Pulse +
Pin 12	Commutation Input T/Stepper Pulse -
Pin 13	Resolver Excitation +
Pin 14	Encoder Power (5 V)
Pin 15	Resolver Excitation - / Encode power (0 V)

The field connection to the encoder should be made via a 15-way D-type bulkhead connector or directly to encoder electronics (e.g. interpolator).

Encoders to be used in-vacuum must be bakeable and rated at the required vacuum level.

3.6 LVDTs and potentiometer-type position sensing devices

LVDTs and potentiometer-type position sensing devices (PSDs) may be required in specific applications. They may be supplied with a matched controller. A suitable interface with EPICS would be Ethernet (preferred), RS232/422, digital, or analog. Analog inputs can be translated directly by an ADC.

3.7 Strain gauges

Strain gauges may be used for measuring small but highly precise movements. They are 4-wire devices that require a voltage source connection for excitation and then provide a sense output. This will be supplied with a matched strain gauge amplifier. Suitable interface to EPICS will be Ethernet, RS232/422, or analog via a 16-bit analog input module.

3.8 Piezo actuators

Piezo devices can be used where precise nanometer positioning is required and there are very low torque requirements. They are typically 2-wire devices that require voltage input over several hundred volts, depending on the movement required. They are not screened, but the connections could be screened before being terminated at the controller. Typical interfacing will be either Ethernet, RS232, or analog to a dedicated piece of control equipment installed close to the Piezo actuators themselves. A step-and-direction interface to the piezo device is also acceptable. The supplier and BSA must agree on the type of controller to be used.

High-voltage piezos will require interlocking with the vacuum to inhibit movement when only under partial vacuum.

Feedback for piezos can be from an inbuilt capacitive feedback system, a strain gauge, a digital length gauge device, an interferometer or other suitable measurement device.

3.9 Digital length gauge devices.

Gauge systems are used for precise length measurement. They also serve as position encoders. Solutions come in various measuring ranges, (from 12 to 101 mm) and are available in accuracies of ±1µm, ±0.5µm, and ±0.2µm. These devices can interface through RS232/422/485, TTL outputs, or analog signals.

3.10 High precision motion actuators

Specialised actuators (e.g. Picomotors) shall be supplied with a matched drive or controller.

The matched controller shall provide an Ethernet or RS232/422/485 interface.

Where the actuator is supplied with a drive only, the required interfaces are defined in the External Motor Drives section in LT-C-XFD-RSI-CO-001.

4 Beamline protection and interlocks

The various cooling systems associated with the beamline are designed to keep the beamline components at a suitable operating temperature by removing heat absorbed from the photon beam. In the event of a system failing to do this, the beam must be stopped from entering the affected area. This will be achieved by shutting an upstream beam shutter in the beamline or front end.

The wiring of sensors and actuators for the Personnel Protection System (PPS) is a specialist activity and outside the scope of this document.

4.1 Flow protection

Flow protection will be provided wherever required. This will be achieved using flow switches. They provide positive confirmation of flow in the form of normally closed volt-free contacts. They are available with either DN-style flanges or short swage lock-style pipe suitable for compression fittings. Electrical connection is made using an elbow terminator connected to the body, which provides individual terminals for one (1) twisted pair 0.5 mm cable.

If a large number of flow switches are required, it is acceptable to group them into a larger connector and run them in a larger multicore, terminated in a 25-way D-type EMC shielded connector.

Flow switches must be placed downstream of the component being cooled.

4.2 Flow monitoring

If flow monitoring is required, the flow meter shall produce a 4-20 mA analog signal. The flow meter should operate using a 24 VDC supply. Flow monitors must be placed downstream of the component being cooled.

4.3 Overtravel limits

Where overtravel limits are provided, they will use DB9 panel mounted female connector on the equipment panel. Up to 2 axes may be wired to single DB9 overtravel limit connector.

Overtravel limit switches shall be mechanical switches, with normally closed, dry, volt-free contacts rated at 24 VDC. Any variation from this specification must be approved in writing by BSA.

Pin	Overtravel Limits
Pin 1	Motor 1 Negative Overtravel Limit Supply
Pin 2	Motor 1 Negative Overtravel Limit Return
Pin 3	Motor 1 Positive Overtravel Limit Supply
Pin 4	Motor 1 Positive Overtravel Limit Return
Pin 5	Motor 2 Negative Overtravel Limit Supply
Pin 6	Motor 2 Negative Overtravel Limit Return
Pin 7	Motor 2 Positive Overtravel Limit Supply
Pin 8	Motor 2 Positive Overtravel Limit Return

Pin 9	N/C

4.4 Temperature monitoring

4.4.1 Resistive Thermal Devices (RTDs)

The NSLS-II standard temperature sensor is the PT100 4-wire RTD. This shall be a 4-wire sensor to allow lead length compensation. It should be capable of reading from -50°C up to +250°C. PT100 sensors can be sheathed in stainless steel with an outside diameter of 3 mm.

Where direct temperature monitoring in vacuum is required, it is preferable to use a PT100 in conjunction with a feedthrough electrical connector.

The cable standard for PT100 is a 2-pair twisted LSZH cable. The connections should be terminated in a 4-pole fixed socket shell EMC UT0 with pins. Pinout is as follows:

Pin	Description
A	Excitation +
B	Sense +
C	Excitation -
D	Sense -

The interface to the control rack is made via 25-way D-type EMC-shielded connector in the PLC crate. Each connector will provide interface up to six PT100. The pinout is as follows:

25-way D-type Connector

Pin	Description
1 to 4	Channel 1 (Exc+, Sense+, Sense-, Exc-)
5 to 8	Channel 2
9 to 12	Channel 3
13 to 16	Channel 4
17 to 20	Channel 5
21 to 24	Channel 6

When a particular equipment assembly requires a significant number of PT100 sensors (six or more), they can be wired to a single 25-way, D-type EMC connector, in groups of six sensors, in order to simplify cable management between the equipment in the beamline and the PLC crate. Pinout to be the same as above.

4.4.2 Thermocouples

The use of thermocouples is acceptable. Where thermocouples are used, any necessary compensating cable, plugs, and sockets shall be provided.

Type K thermocouples should be used for liquid nitrogen cryogenic applications.

A thermocouple feedthrough should be a dedicated 15-way, D-type connector, which can serve up to six thermocouples and shall NOT be shared with other devices. Pinout should be as follows:

15-way D-type Connector

Pin	Description
1, 9	Channel 1 (chromel/green/+, alumel/white/-)
2, 10	Channel 2
3, 11	Channel 3
4, 12	Channel 4
5, 13	Channel 5
6, 14	Channel 6

Contacts shall be in the appropriate materials (chromel, alumel) – in both the feedthrough and cable connector, as well as in the cables. BSA can advise, if necessary.

The preference for the cable connection to the NSLS-II control rack is a 6-pair twisted thermocouple cable, screened, with LSZH insulation. BSA can advise, if necessary.

4.4.3 Other temperature sensors

For liquid helium cryogenic applications, a suitable temperature sensor (e.g., silicon diode, chromel-gold/iron thermocouple) shall be selected and approved by BSA.

4.5 Beam Diagnostics

There will be many devices required to verify the position and quality of both the monochromatic and white beam, whose results will be displayed on a screen. As all screen devices are essentially pneumatically operated devices, the interface to the controls equipment rack can be achieved in the same way as with a normal pneumatic valve, as described in section 2.3.

Camera connections and connections to other detectors shall be made per the manufacturer's recommendations, but shall be approved by BSA.

Standard camera specifications are defined in LT-C-XFD-RSI-CO-001.

4.6 Pressure interlocking

If a beamline contains a pressure rig, then pressure transducers will be required. Solutions such as a strain gauge-style unit can be used to provide safety interlocking. These devices can give an mV output and require excitation voltage. This makes them compatible with a standard ADC card.

The interfacing shall be made by a 4-pole, bracket-mounted, fixed-socket shell UT0 connector with pins. Pinout as follows:

Pin	Description

A	Excitation +
B	Sense +
C	Excitation -
D	Sense -
	Screen to EMC connector shell

4.7 Shutters

Shutters are used to protect vacuum valves and other downstream components from damage by the beam. They are essentially the same as any other pneumatically operated device and therefore interface as described in section 2.3. The shutter controlled by the EPS and reports its position to the PPS.

Shutters are normally water cooled devices and are capable of dissipating heat loads of hundreds of watts.

The shutter must operate at the same time as the valve(s) it is protecting. If the cooling fails it may be necessary to dump the beam.

4.8 Position-indicating switches

Position sensing and limit switches that are used in non-motorized stages (e.g., hydraulic or pneumatic actuators) are normally required, and will often be connected to a controlling PLC. Connectivity at the field end must be via a UT0 EMC connector (refer to appendix A), as follows:

Pin	Description
A	+12 VDC
B	+VE Travel
C	-VE Travel
D	Home/Datum

5 General Purpose IO

5.1 Digital IO

The signalling levels for digital IO are defined in the Digital IO section of LT-C-XFD-RSI-CO-001.

5.2 Analog IO

Interface details for analog IO are defined in the Analog IO section of LT-C-XFD-RSI-CO-001.

5.3 Actuated devices

Any components that are actuated and have two states shall have limit switches at each end of the travel range to indicate the position of the component.

An actuated component shall interface to the control system as defined in the Digital IO section of LT-C-XFD-RSI-CO-001.

The pneumatic actuator for a component may be single or double acting. Where a position is preferred in the event of power or compressed air failure, a single acting actuator should be chosen with the spring direction moving the component to the preferred failure position.

6 General NSLS-II standards and service provisions

Within each beamline area there will be common electrical and mechanical services provided. All NSLS-II policies and standards as detailed in this section must be strictly followed.

6.1 Electrical wiring diagrams

This section should be read in conjunction with the relevant Specification and SOW for beamline components, particularly the SOW section "Documentation and Data Management."

BSA requires copies of all drawings, cable schedules, and specialist pin-outs, etc. Full documentation to allow interfacing into the NSLS-II controls will also be required (e.g., protocol commands and instruction set, etc.).

The NSLS-II standard drawing package consists of at least the following:

- An overall system block diagram showing the integration of the system and subsystems and connectivity of the scheme
- Hook-up drawings to show electrical connections in detail required for wiring, commissioning, etc.
- General assembly drawing for the system showing detailed mechanical assembly

All drawings must be submitted on the official NSLS-II drawing template.

NSLS-II title blocks will have Drawing No, Revision, and Drawing Status entered correctly.

Electrical drawings shall comply with the document "NSLS-II Design Room Standards."

NSLS-II drawing numbers will be issued on request.

6.2 Cabling and labyrinths

Beamline lengths can be well in excess of 50 meters. Care must be exercised when supplying cable harnesses to ensure adequate allowance for cable specification to allow for voltage drops, etc. Voltage drops of 10 to 15% are expected, but larger losses are to be avoided.

Where cabling passes from inside the hutch to the outside, it is routed through a system of labyrinths. There are multiple labyrinths per hutch, and cable types are segregated according to discipline to ensure that there is no interference. Cable bunches must be flexible enough to be fed through the system of Z-shaped ducts. Care must be taken to ensure that all cables required are run through at the same time, because retro-fitting cables will be very difficult in highly populated labyrinths.

Finished beamlines shall not contain a large proliferation of cables festooned from pieces of equipment with multiple in-line connectors, etc. The final solution shall be neat and tidy.

Where devices need to be mobile, consideration for some kind of drag chain cable tray assembly should be given. The other alternative to this would be Tensator for a large, multi-core cable running all signals wherever possible.

6.3 Interconnections

Localized plugs and sockets for interconnections to cable runs, etc. will be EMC-shielded metal connectors. UT0 multi-pole circular connectors are the preferred style (refer to appendix A for details).

Other connectors may be used with approval from BSA. They must conform to basic standards:

- Connectors must provide 360^{o} connection to cable screen and equipment housing.
- Connectors must provide mechanical locking in the connected state.
- Connectors must provide adequate strain relief for the cable to be sufficiently robust to withstand everyday handling and impacts.
- Connectors must provide gold-plated plug and mating receptacle pins. The shell must be plated with a non-corroding conductive layer to ensure screen continuity.
- Connectors must provide adequate ratings for current, voltage, and frequency. Some spare pins are recommended.

Some cabling will be required within UHV. This will need to be UHV compatible and any harnessing must not contain trapped air voids, etc. Care must be taken to continue the screen path from transducer or actuator out through the feedthrough.

6.4 Trigger connections

All trigger signal connections, either inputs or outputs, shall be Lemo Series 00 unipole sockets.

6.5 Cable routes and tray

NSLS-II will not be using open-style basket tray systems. All runs will be installed on galvanized tray. Cable tray routes will be provided by BSA for manufacturer cable runs. Cables cannot be bundled together any higher than the lip of the tray. Cables gathered into bunches should contain a parallel earth conductor at their center. Cable exit from the tray will need to be organized to be as tidy and rational as possible.

Wherever possible, equipment shall be rationalized into cabinet-style rack enclosures—but the number of enclosures should be kept to a practical minimum. The goal is to discourage the proliferation of freestanding pieces of electrical control equipment. Therefore, all standalone electronics provided must be capable of being mounted in a 19-in. wide, 42 U high rack enclosure.

Strict segregation of signal types is required; therefore, the NSLS-II cable schedule standard shall be adhered to. Signals are segregated by types and tolerance to noise, so information on these characteristics will be required during installation planning.

Access to the cable database will be provided for any manufacturer tendering for a complete beamline solution. It would then be the responsibility of the manufacturer to populate the data base, employing the NSLS-II naming standard.

Specialist equipment required for the duration of a specific experiment will be treated as a temporary installation and will be cabled accordingly. Care should be exercised to ensure that this is carried out neatly and safely. Temporary power and networking will be provided.

All cabling must strictly adhere to NSLS-II EMC policy. Care must be taken to ensure that all cabling is neat and complies with all relevant regulations.

6.6 Connections to EPICS

The preferred IOC hardware platform is defined in LT-C-XFD-RSI-CO-001.

The preferred terminal server hardware is defined in LT-C-XFD-RSI-CO-001. The pinouts for the preferred terminal servers are defined in the following table.

Pin	RS-232	RS-422
1	DSR (in)	-
2	RTS (out)	TxD+
3	GND	GND
4	TxD (out)	TxD-
5	RxD (in)	RxD+
6	DcD (in)	RxD-
7	CTS (in)	-
8	DTR (out)	-

6.7 Electrical wiring requirements

Any circuits with micro switches must be wired fail safe. This ensures that interruptions in the cabling or open connections are promptly noticed by the controller, minimizing “silent” failure events. If the device is in vacuum, both sides of the switch should be wired out to the feed-through to allow fault diagnosis.

Cables carrying greater than 50 V must be color coded in accordance with US NEC standards.

Low voltage multi-core cables must be color coded or labelled to allow unique identification of each cable conductor.

All interlock outputs will take the form of fail-safe connections. The preferred choice is volt-free contacts.

6.8 Shielding

All motor cable shields shall be grounded at the motor controller end and shall remain ungrounded at the motor end.

Appendix A: UTO connectors – Quick Reference

(For full details see Souriau catalog).

Step 1: Refer to Souriau connector catalog and visit www.souriau.com for full details of connectors including assembly guide and tooling. This is only a summary.

Step 2: Choose connector body for cable or chassis mounting, for number of poles required (4, 8, 12, etc.) and whether for male or female contacts.

UTO6 = cable mounting, UTO0 = chassis mounting
Size 1412 = 12-pole, Size 128 = 8-pole, Size 104 = 4-pole
PH is for male contacts, SH is for female contacts
Example: **UTO0128PH** is a chassis-mounting 8-pole male connector body

Step 3: Choose backshell to fit insert, and according to overall diameter of cable entry. Ensure UTOS chosen for EMC shielding.

Size 14 = 12-pole, Size 12 = 8-pole, Size 10 = 4-pole
For 4-pole, JCL = cable diameter from 5mm to 8.5mm, JC = cable diameter from 4mm to 6.5mm
For 8-pole and 12-pole, JCL = cable diameter from 8mm to 12.5mm, JC = cable diameter from 7mm to 10.5mm
Example: **UTOS12JCL** is an EMC-shielded backshell to suit 8-pole connector body and cable diameter from 8 to 12.5mm

Step 4: Choose male or female contacts to suit wire size.

RC = female, RM = male
Size 28M1K = wire size from 0.05 sq mm to 0.08 sq mm (30 to 28 AWG)
Size 24M9K = wire size from 0.13 sq mm to 0.25 sq mm (26 to 24 AWG)
Size 20M12K = wire size from 0.32 sq mm to 0.52 sq mm (22 to 20 AWG)
Size 16M23K = wire size from 0.52 sq mm to 1.5 sq mm (20 to 16 AWG)
Size 14M30K = wire size 2.5 sq mm (14 AWG)
Example: **RM16M23K** is a male contact to suit wire from 20 to 16 AWG

Appendix B: Subminiature D-Type connectors – Quick Reference

Standard density crimp D connectors with tinned and dimpled shells are preferred, and should be used in conjunction with machined gold-plated contacts. The connectors must be rated to withstand at least 200 mating cycles.

Jackscrews (UNC 4-40) are the preferred method of ensuring secure retention of mated connectors. Suitable connectors from the "Conec" range include:

Description	Conec Part No.
9 Way D plug	163X10019X
9 Way D socket	164X11769X
15 Way D plug	163X10029X
15 Way D socket	164X11779X
25 Way D plug	163X10039X
25 Way D socket	164X11789X
37 Way D plug	163X10049X
37 Way D socket	164X11799X
Crimp Pin (24-20 AWG, 0.25-0.56mm^2)	161B18299X
Crimp Pin (28-24 AWG, 0.09-0.25mm^2)	161B18309X
Crimp Socket (24-20 AWG, 0.25-0.56mm^2)	162B18709X
Crimp Socket (28-24 AWG, 0.09-0.25mm^2)	162B18719X

Suitable D connector hoods shall be of die-cast metal construction. Additionally, screw-together construction with captive jackscrews and 360-degree EMC shielding is required.

Suitable top-entry connector hoods from the "FCI" range include:

Description	FCI Part No
9-way hood	8655MH0911LF
15-way hood	8655MH1511LF
25-way hood	8655MH2511LF
37-way hood	8655MH3711LF