COMPUTING DIVISION

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Title
Interfaces to the ALBA Control system

Abstract

This document describes the interfaces to the ALBA control system. It also specifies the connectors that shall be provided by the supplier on the device side, which could be grouped in a patch panel or in a junction box.

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1.1	15.12.06		- Added voltage specs for motor, switches and encoders - Clarified specs for software interfaces - Added reference to CCD-GDCTHW-ES-0001 for connectors and grounding
1.2	19.2.07		- Added 200 steps/rev, full- or half-step operation - Adding Pin-layout of motor connectors - Changing cable connection to crimped
2.0	17.4.07		- Added state interlock signals - Changed motor specs - Added IOC - Added cables as reference
2.1	30.5.07		- Device connector update
2.2	28.6.07		- Text change in Figure 2. Female to MALE.

References

[1] Free Software Foundation, “GNU General Public License”, Version 2, June 1991, http://www.gnu.org/licenses/gpl.html

[2]

[3]

[4]

[5]

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1. Overview of Control system

The overall control of the beamline will be managed by TANGO, a CORBA based open-source control system (www.esrf.fr/tango) written in C++. Device Servers can be written in C++, Java and Python. TANGO runs on various operating systems. It is a distributed object oriented system, organized in client server hierarchy. Many servers exist already for various hardware, and over all, Tango provides specialized tools to help programmers writing and managing servers

2. General

2.1. Definitions

In the following sections the following definitions apply:

“Shall” refers to specifications which are mandatory.

“Should” refers to recommendations. In case of specifications, the supplier/contractor may follow this specifications, but rather is invited to make own suggestions. CELLS is looking forward to discuss those proposed solutions with the supplier/contractor.

“May” refers to permission or a possibility.

In the case of inconsistencies between this and any other document to which this document references, the definitions of this document shall apply.

2.2. Deviation from Standards

The following sections list the standard interfaces used at ALBA. The supplier shall comply with those interfaces. In cases, where those mandatory interfaces and standards do not seem appropriate or not possible to use in order to comply with the specification of the performance of the component, the supplier shall explain the reasons why he sees the necessity to not comply with those standards. The explanation shall be presented to the contact person at CELLS and shall be in written form. CELLS will then carefully evaluate the case and might grant permission to deviate from the standard.

In any case, it is the responsibility of the supplier that the component fulfills the specifications.

3. Control Electronics and Software Interfaces

3.1. Generic Control Electronics

All generic control- and data-acquisition electronics like preamplifiers, motion controller, digital- and analogue I/O, counters, etc, will be supplied by CELLS.

3.2. Particular Controllers

Even though, all generic controllers will be supplied by CELLS, there might be the need that the supplier has to provide CELLS with a particular controller: Either because the ALBA standard controller does not meet the performance requirements or because of a particular piece of hardware to be controlled.

In those cases, the supplier shall make sure that

1. the controller has an interface supported by CELLS (c.f. below),
2. the manufacturer of that controller provides CELLS with sufficient support to enable CELLS to write her own TANGO device server. This includes (but not restricted to):
    a. The interface shall be either
        i. Simple plain ASCII (or equivalent) commands
        ii. Supply of Open Source Libraries
3. Complete documentation of that interface.
4. A sample program (source code, C/C++, user level) which calls the basic functions (e.g. start/stop data acquisition, read data, etc.) of the controller and uses the supplied libraries. The functional range of that sample program will be defined by CELLS well in advance.
5. Nomination of a competent contact person who helps in the development of the TANGO Device Server and provides CELLS with all necessary information.
6. Alternatively, the supplier can provide CELLS with the TANGO Device Server. This Device Server shall be published under the GNU Public License [gpl2].

In any case, the interface of that controller shall be in agreement with CELLS.

3.3. Controller Interface

For connecting any controller to the control system, CELLS prefers the following controller interfaces in the order given below:

1. TCP/IP over Ethernet
2. RS-232 / RS-422 / RS-485
3. GPIB

Other interfaces than the three interfaces listed above shall not be used.

4. Input/Output Controller (IOC)

4.1. CompactPCI

CompactPCI and PXI equipment shall be compatible with the specification PICMG 2.0 R3.0. All equipment shall be 3U, although 6U boards could be used if necessary. CompactPCI crates will be used in favour of PXI crates. The rear I/O shall not be used. The PCI (and PCIe) bus will also be supported. The selection of PCI or cPCI shall be decided for any specific application according to the requirements.

4.2. NIM

All NIM bins will supply ±6 VDC. The delivered power is 150 W.

4.3. VME

VME is not standard at Alba and its use shall be agreed in beforehand.

5. Motion Control

5.1. Motors

As motors, 2-phase (hybrid) stepper motors (also known as 4-phase stepper motors) with a phase current in the range of 1–7 A phase current shall be used. The supply voltage[1] will be 78 VAC_{peak}, connected (typically) through 10–40 m long cables of 0.75 mm^2. The voltage drop due to the cable resistance of about 0.045 Ω/m cable (i.e. 0.5–2 Ω) has to be considered in the selection of the motor, in particular when employing low-resistance (i.e. high-speed) motors.

[1] This is nominal value provided by the ALBA standard motor controller. The maximum power that could be delivered by the ALBA motor controller is 300 W.

The motor shall have 200 steps/revolution and the mechanical specification shall be fulfilled in full- or half-step mode.

As the choice of a particular motor depends highly on the application, the selection of the motors lies in the responsibility of the supplier. This includes in the case of eight-lead motors the declaration whether the motor windings shall be connected in parallel or series. The decision should be made in agreement with CELLS.

Nevertheless, in order to facilitate spares pooling, the CELLS Engineering Division reserves the right to declare a set of standard motors. In this case, the selected motors shall be of those standard motors.

If the supplier wishes to use other motors than the specified 2-phase motors (3- or 5-phase stepper motors, servo motors, etc) or 2-phase motors with a higher or lower current, permission might be granted in written form, if the supplier demonstrates the need to use such a motor.

5.1.1. In-Vacuum Motors

CELLS prefers to have no motors inside vacuum. In the case, where in-vacuum motor need to be deployed nevertheless, the supplier shall define the drive current as well as the stand-by current in order to avoid overheating of the motor. This information shall be submitted as early as possible, ideally at the time of submitting the offer.

5.2. Motion controller and driver

CELLS will provide the standard motion controller and driver. However, if the supplier wishes to use a dedicated controller/driver for a certain axis, CELLS might grant the permission in written form if the supplier demonstrates that the ALBA standard controller/driver will not fulfill the specification of the axis. In that case, the supplier shall provide CELLS with a complete set of instructions to operate the controller together with a low-level sample program for the remote control of the controller, written in C/C++ programming language. Clearly, the sample program shall talk directly to the controller without any additional proprietary third-party libraries. Additionally, the supplier shall nominate a competent contact person to answer all questions which might occur during the development of the TANGO server for that particular controller.

5.3. Limit Switches

Limit switches are used to stop motion beyond a certain position of the axis.

As there is a certain distance required to slow-down the motor properly, the limit switch shall not be placed at the very end of the travel distance. Instead, there shall be sufficiently braking distance available behind the limit switches, depending of the load/mass and typical speed (i.e. momentum) of the manipulator. In contrast, a 'quick-stop', i.e. immediately switching off the generation of pulses, might damage the (high precision) gears.

In order to ensure proper operation of the limit switch, all limit switches shall be dry contacts connected "normally closed", i.e. if the limit switch is not triggered, a current can flow through the switch. Activation of the limit is signaled by opening the limit switch, i.e. the current is interrupted.

At some axes, it might be necessary to use active (e.g. optical) limit switches. In this case, a limit switch with NPN logic shall be deployed. The supply voltage shall be 5 VDC.

Due to the high amount of radiation in the front-end area, radiation hard limit switches shall be used there. It is recommended to use radiation hard limit switches in the optics hutch as well. The actual selection of the limit switches should be done in agreement with CELLS.

Each axis shall be additionally equipped with a hard-stop, which stops the motor mechanically. The hard-stop shall be placed in such a way that the hard-stop is reached before the load is damaged.

5.4. Reference Switches

In order to find the position of a certain axis again, each axis shall be equipped with a separate reference switch (also known as home switch).The precision has to be discussed for every switch.

The order to find the reference switch quickly, the reference switch should be placed close to one of the limit switches.

Various geometries for reference switches are conceivable. Unless otherwise stipulated, the supplier is free to implement the design he wishes to implement. Nevertheless, the supplier should consult CELLS before implementing a certain design.

In any case, the reference switches shall be sry contact connected in the sense normally closed, i.e. reaching the reference position opens the reference switch. When using active (i.e. optical) reference switches, NPN logic shall be deployed. The supply voltage for active reference switches shall be 5 VDC.

Due to the high amount of radiation in the front-end area, radiation hard reference switches shall be used. It is recommended to use radiation hard reference switches in the optics hutch as well. The actual selection of the reference switches should be done in agreement with CELLS.

5.5. Encoders

Encoders and other position sensors are used for a feed-back of the position of a motion. Two types of encoders exist: Incremental and absolute encoders. CELLS prefers incremental encoders.

For incremental encoders, the electrical interface shall be a quadrature signal, using differential RS-422. In the case of high resolution encoders with native analogue sinusoidal output, the supplier/contractor shall provide CELLS with the appropriate interpolator with quadrature differential RS-422 output.

For absolute encoders, the Synchronous Serial Interface (SSI) shall be used. The encoding shall be Gray Code. Synchronized measurements shall be possible. Further details of the protocol (e.g. number of bits) shall be in agreement with CELLS.

For encoders in the front-end area and possibly in the optics hutch, radiation hard position sensors should be used instead of optical encoders and/or an appropriate shielding should be provided. The final selection of the encoder and/or shielding shall be done in agreement with CELLS.

In all cases, the supply voltage of the encoders shall be 5 VDC.

5.6. Piezo

In cases where the manufacturer needs to deploy a piezo actuator, a low-voltage piezo should be used. However, high-voltage piezos will be supported by CELLS, too.

In any case, the piezo shall be compatible with the standard piezo controller to be selected by CELLS. Therefore it is necessary to contact CELLS before selecting any particular piezo.

5.7. Pneumatics

Control valves for pneumatic driven equipment (like gate valves and other two-position translation stages, etc) shall be operated at 24 VDC.

6. Signals

6.1. Frequency Signals/Counters

In case of frequency output of any component, the signal shall be TTL 50 Ohm compatible. The maximum count rate should be limited to 80 MHz. If higher count rates seem to be appropriate and/or necessary, the supplier shall inform CELLS well in advance.

6.2. Analogue Data Interface

In cases where an analog signal is the appropriate interface, CELLS provides an interface for the following signal levels:

- Voltage: 0–10 V
- Current: 4–20 mA

As both signals have their advantages and disadvantages, the final selection shall be done in agreement with CELLS.

6.3. Timing

Regarding optical signals, the HFBR-1528 and HFBR-1414 (high speed) optical link outputs will be supported.

7. Distributed I/O and Fieldbus

The beamlines might need many digital and analog input and output signals, e.g. for handling breaks, pneumatics, temperature- and bending sensors. Those distributed I/O terminals will be provided by CELLS.

7.1. Field-bus

The philosophy at CELLS is to integrate the field components based on TCP/IP over Ethernet and to avoid any particular field-bus. In cases, however, where a field-bus is necessary, the selection of the field-bus shall be done in agreement with CELLS.

8. Equipment Protection System

The Equipment Protection System (EPS) will be provided by CELLS. Nevertheless, the supplier will have to equip the components with parts of the equipment protection system; like switches and temperature sensors:

8.1. Switch logic

Interlocks and controls shall use dry contacts and shall be designed fail-safe.

- A safe state shall be indicated by a closed contact, allowing a current to flow.
- An unsafe state shall be indicated by an open contact that blocks the current flow.
- On power failure, the system shall indicate an unsafe state.

8.2. Temperature Sensor

As temperature sensors either

- K-Type Thermocouples with so-called “Miniature Connector” or
- Pt100 Platinum Resistance Thermometers (PRTs)

shall be used. As the selection of the appropriate temperature sensor depends strongly on the application, the selection should be made by the supplier of the component according to its specific requirements and should be in agreement with CELLS.

8.3. Programmable Logic Controller (PLC)

If for any reason, the supplier sees the need to integrate any own PLC which is accessible from outside (e.g. to control the pump stand of the vacuum vessel of the experimental setup, where communication with the beamline EPS is mandatory), the PLC shall be of the same series/manufacturer as the one which will be selected by CELLS for the Beamline EPS. Therefore, the supplier/contractor shall contact CELLS in advance before selecting a PLC.

The program of that PLC shall well documented and self-explaining. The ownership, including all rights on the program, shall be transferred to CELLS.

The connection of possible field components of that PLC shall be in agreement with CELLS. Moreover the interface of that PLC shall be in agreement with CELLS.

9. Connectors

This section specifies the connectors that shall be provided by the supplier on the device side. These connectors could be grouped in a patch panel or in a junction box. The connectors on the device side will be male when the power is coming from the controller or female, if the power comes from the device.

9.1. Motors and Limit Switches

The motor connection (including the limits switches) shall be with metallic compatible ITT cannon 14-12 pin MALE on the device side. The following picture shows the pinout of this connector, and an example is TNM OU 1400-12P1L. If a four phases motor is used, the phases will be connected in series or in parallel in agreement with the CELLS.

Connector	Pin	Signal			Description
		1-phase	2-phase	3-phase	
 12-pin MALE MIL-C-26482 compatible shell size 14 socket	A	Home			Mechanical reference
	B	PhaseA+	PhaseA+	PhaseA	Motor power
	C	PhaseA-	PhaseA-	PhaseB	
	D	n/c			
	E		PhaseB+	PhaseC	
	F	n/c	PhaseB-	n/c	
	G	Disable			Remote Disable
	H	Limit+			Travel limits
	J	Limit-			
	K	Shield			
	L	5Vpower			Aux power supply
	M	GND			
Examples of mating connectors:		ITT CANNON: TNM6U 1400-12P1L FCI: UTGS6PG1412PN			

Figure 1. Pinout for the phase motor and limit switches

9.2. Encoders

The encoders shall have a 15 pin sub-D MALE connector on the device side, with a pin-out given below:

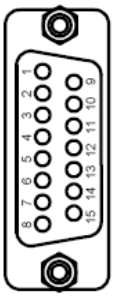
Connector	Pin	Signal		Type/Direction	Description
		Incremental	SSI		
	1	EncIn A+		RS422	Encoder Signal
	9	EncIn A-			
	2	EncIn B+		RS422	Encoder Signal
	10	EncIn B-			
	3	EncAux+	Data+	RS422	Auxiliary Encoder Signal
	11	EncAux-	Data-		
	4		CLK+	RS422	Clock SSI Interface
	12		CLK-		
	5			n/c	
	13			n/c	
	6			n/c	
	14	5V sense+			Sense signals
	7	5V sense-			
	15	+5 VDC power		power supply	Auxiliary Power Supply
	8	GND		power ground	

Figure 2. Encoder pinout

All encoder signals shall be RS422 standard.

If an absolute encoder is used, only SSI protocol is supported. Other protocols have to be agreed with CELLS staff. The SSI protocol has a clock signal provided by the controller in pins 4 (CLK) and 12 (/CLK), and the data signal will be in the pins 3 (DATA) and 11 (/DATA). The signal levels are always RS422 standard.

The preferred option is to receive digital signals from the encoder, but if a digital signal can not be delivered, CELLS could accept analogue signals 1 Vpp differential. The supply voltage for the encoder shall be 5 V. The pinout shall be agreed with CELLS.

9.3. Signals

The signals shall be transmitted through 50 Ohms BNC female connectors (panel or feed-through, with RG58 cables) on the device side. Alternatively, connectors compatible with the Lemo Series 00 female could be used.

If triaxial cables are needed, the triaxial connector shall be Triax BNC 3 lugs.

9.4. High Frequency Signals

High Frequency Signals shall be connected with SMA or N connectors.

9.5. High voltage

For high voltage signals SHV connectors (panel or feed-through) shall be used.

9.6. Video

For video cables 75 Ohm BNC female connectors (panel or feed-through) shall be used.

9.7. Multi-Pin Connector

In cases where multi-pin connectors are required the selection of the connector as well as the pin-out shall be in agreement with CELLS.

9.8. Connection of pins

The connection from the cables to the pins of the connectors shall be crimped.

10. Grounding

All connectors or connection points and internal cabling provided by the supplier shall be EMC compatible and mounted on metallic patch-panels. Those panels shall be electrically and mechanically connected to the equipment according to the EMC recommendations.

The equipment (girders or vacuum components) shall provide, either foot or top side, two holes, one M8 and the other M10, both 15 mm deep. The M8 hole shall contain the appropriated screw to fix a terminal spade, crimped with either a bared copper 25 mm^2 cable or a green/yellow jacket isolated copper 25 mm^2 cable according to the current country safety rules. This cable shall be

connected directly to the ground (or on the cable tray ground) according to the current safety rules. The M10 hole shall contain the appropriated screw to fix a terminal spade, crimped with an EMC ground strap. This EMC ground strap shall be connected to the closest ground (or massif equipment connected to the ground eg Cable trays), to be EMC compatible. The EMC ground strap shall be copper laminated or braided but it shall be completely tinned to provide corrosion resistance. The EMC ground strap shall be 50×5 mm^2 or with a maximum length shorter than 13 times the width.

This electrical connections are required when the device are not electrically connected. If a girder and a magnet are electrically connected through the mechanical connections, they could be considered a single equipment.

11. Summary

The following table summarizes the interface definition above:

Interface Bus	1. TCP/IP, 2. RS-232/RS-422, 3. GPIB
Field-bus	Shall be avoided
Motors	2-Phase Step-Motors, 1–6 A, 78 VAC_{peak}[2]
Limit switches	NC, passive or NPN (5 VDC supply)
Home switch	NC, passive or NPN (5 VDC supply)
Encoders	Quadrature Differential TTL (RS-422), SSI

[2]The actual voltage supplied to the motor depends on the resistance of the motor and the length of the cable, which together act as a voltage divider.

	Power supply: 5V
Piezo	Low-Voltage
Pneumatics	24 VDC
Frequency Signals	TTL, 50 Ω comp., ≤80 MHz
Analogue Signals	0–10 V, 4–20 mA
Temperature Sensor	K-Type TC, Pt100 PRT
PLC	Compatible with ALBA Standard
Connectors	refer to Section 9

12. Cables

The following list of cables applies for the connection of the components to the ALBA facility. They do not belong to the scope of supply. Their use for inside the components itself is recommended, only.

12.1. Motor cables

The motor cable to the control system will be a shielded [2x(2x0.75 mm^2)+ (6x0.34 mm^2)]

12.2. Control lines

For control, 24 VDC shall be used for digital signals (with unshielded twisted pairs [2x0.5 mm^2]).

12.3. High-Voltage

The high voltage cable will be connected with something like the RG213 or the HTC–50–3–2 from Draka Cable (up to 10 A).

12.4. Signal Cables

Signals shall be connected with 50 Ohm BNC female connectors (panel or feed-through) with RG58 cables. Alternatively Lemo Series 00 connectors with RG174 cables can be used.

12.5. High Frequency Signals

High frequency signals shall be connected with SMA or N connectors and RG223 cable.

12.6. Video Cables

Video signals are transmitted through RG59 cables with 75 Ohm BNC female connector.