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SECOND TARGET STATION (STS) PROJECT

Interface Sheet for Instrument Motion Systems and Integrated Control Systems Process Controls

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1st March 2023

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Interface Sheet for Instrument Motion Systems and IProcess Controls

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1. PURPOSE

This document defines the interface between Instrument Systems motion systems and Integrated Control Systems (ICS) process controls. The interface will provide inputs to the design of the motion systems and the process control systems. Requirements that may be derived from this document will be included in the requirements documents for Instrument Systems and ICS. This interface will be applicable to all motion systems across the STS Instruments and Bunker.

2. SCOPE

The scope of this document is the complete interface definition between Instrument Systems motion systems and the process controls that will be part of the ICS. The interface points are summarized in the parent Interface Control Document [1] between Work Breakdown Structure (WBS) S.04 Instrument Systems and WBS S.06 Integrated Control Systems. The interface points are expected to include:

- Electrical interfaces for general purpose motion systems
- Cabinet or rack space needs
- Equipment protection & interlock logic
- Communication interfaces for specialized motion systems

As the motion systems and process controls preliminary design progresses, additional interface points may become apparent and will be captured in this document. Cable tray needs, power panel and grounding interfaces will be handled in separate interface sheets between ICS and Conventional Facilities (CF) and between Instrument Systems and CF.

The Instrument Systems motion systems include all motorized assemblies, such as:

- Shutters (maintenance and operation)
- Steerable optics systems
- Chopper translation stages (but not chopper rotations)
- Slits, apertures, and attenuators
- Guide translations and mirror translations
- Detector motions
- Sample motions

A motorized assembly means a combination of a translation or rotation stage, gear reduction, electric motor, switches, and position encoding devices.

2.1 INTERFACING PARTS OR COMPONENTS

No.	Instrument Systems	Integrated Control Systems
1	Conventional stepper motors, encoders, and limit switches	Motor controller, cables, and connectors
2	Specialized motorized systems (purchased with controllers)	Network communication and network protocol
3	Equipment protection needs and interlocks	Process control system and interlock implementation
4	Floor space, wall space	Racks, cabinets, and cables

3. ACRONYMS AND DEFINITIONS

CF Conventional Facilities
FTS First Target Station
ICD Interface Control Document
ICS Integrated Control Systems
IS Interface Sheet
NEMA National Electrical Manufactures Association
PI Physik Instrumente (motion systems vendor)
PLC Programmable Logic Controller
SSC Structure, System or Component
WBS Work Breakdown Structure

4. REFERENCES

4.1 DOCUMENTS APPLICABLE TO THE INTERFACING SSCS

Ref	Document Titles	Document Control System Location
[1]	Interface Control Document for S.04 Instrument Systems and S.06 Integrated Control Systems	S01020500-ICD10004
[2]	Standard Device & Software Interfaces for STS Integrated Control Systems	S06000000-DC0003
[3]	Programmable Logic Controller (PLC) Hardware Design Description Document	S06000000-DCD10000

5. INTERFACE DEFINITION

5.1 TECHNICAL DESCRIPTION OF THE INTERFACE

The interface for each of the points listed in section 2.1 is described below. Where the word 'responsible' is used, this will indicate that either Instrument Systems or Integrated Control Systems are responsible for designing, specifying, purchasing (or fabrication), installation, and testing the equipment or sub-system.

5.1.1 Interface 1. Conventional stepper motors, encoders, and limit switches - Motor controller, cables, and connectors

This interface deals with what is expected to be most of the motorized equipment at the STS instruments, which includes stepper motors, encoders, limit switches and any other sensors that are part of the motorized system (such as proximity sensors).

Instrument Systems:

- Responsible for the motorized equipment physically located on each instrument and in the bunker. This includes the motorized stages, gearboxes, motors, encoders, limit switches, home switches and any other sensors that are part of the same motion system.
- Responsible for providing equipment that is electrically compatible with the motion control standards jointly developed by Instrument Systems and ICS (which will be developed during preliminary and final design). This includes the electrical characteristics of each piece of equipment and the cabling, fly leads or connectors that are provided with the equipment.

Integrated Control Systems:

- Responsible for the motion controller and encloser cabinet.
- Responsible for the associated cabling from the cabinet to the motorized equipment, including terminating the cables and adding connectors onto the motorized equipment if needed.
- Responsible for electrical power cables between the electrical power panels and the motion control racks or cabinets. Note: the electrical power panels themselves are the responsibility of the Conventional Facilities (CF) and not the ICS.
- Responsible for installing ethernet network communication cables between the motion cabinet and the ICS network switch.
- Responsible for the motion control software.
- Responsible for conducting the motion equipment commissioning and integrated testing. This typically will be done in collaboration with Instrument Systems. This includes setting up the motion control hardware, testing basic motion, limit switch operation and establishing homing sequences and any other motion sequences or coordinated motion.

The technical scope and financial scope are illustrated below in Figure 1.

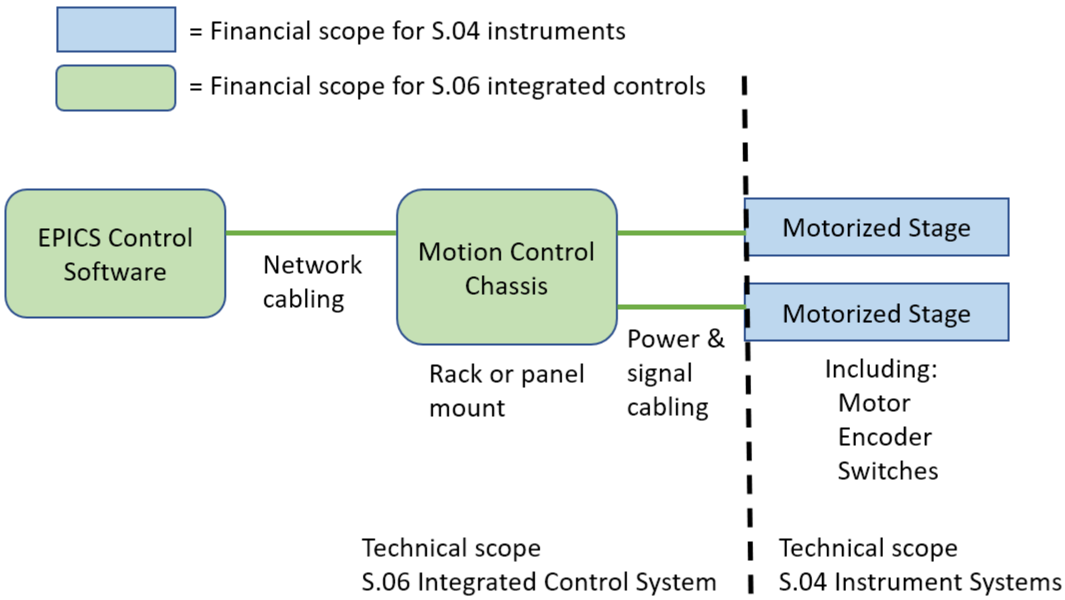


Figure 1: Technical and financial scope for conventional motorized systems

5.1.2 Interface 2. Specialized motorized systems (purchased with controllers) - Network communication and network protocol

If any specialized equipment is needed, that cannot (or cannot easily) be controlled using the standard motion control electronics, such as piezo motors, hexapod systems, etc, then Instrument Systems will be responsible for purchasing this specialized equipment and electronics with ICS acting as consultant to ensure compatibility.

Instrument Systems:

- Responsible for the specialized equipment which typically would include the motorized equipment, cables, and a controller.
- Responsible for providing power to the controller (unless the controller can be added to an ICS process controls rack or cabinet, in which case ICS will provide the power).
- Responsible for selecting a controller that can be integrated into the ICS. This typically would be done in collaboration with ICS. ICS device interface guidelines are documented in [2] and [3].
- Where appropriate, responsible for setting up the equipment in advance so that ICS can develop the necessary software in advance of the equipment being installed on an instrument.

Integrated Control Systems:

- Responsible for the software necessary to communicate to and control the specialized equipment controller. This may include using vendor software to configure the specialized equipment controller.

- Responsible for installing ethernet network communication cables between the specialized equipment and the ICS network switch.

The technical and financial scope for specialized systems such as piezo stages or hexapod systems are illustrated below in Figure 2.

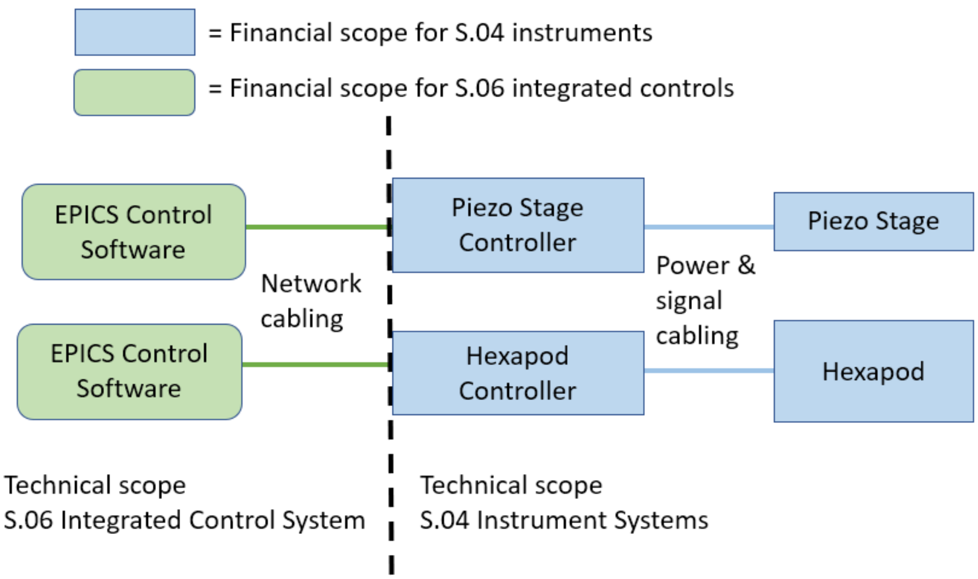


Figure 2: Technical and financial scope for specialized motorized systems (for example hexapods)

An example of a specialized controller for a PI hexapod system is shown below in Figure 3. This controller is typically purchased with the hexapod and implements the kinematic calculations to provide an easy way to move the hexapod in cartesian coordinates.

Figure 3: Specialized controller for a PI hexapod system

5.1.3 Interface 3. Equipment protection needs and interlocks - Process control system and interlock implementation

It is common for motorized equipment to need equipment protection systems and interlocks, above what can usually be provided by a standard motion control system, either to protect itself or to protect other equipment. Typically, a Programmable Logic Controller (PLC) is used for equipment protection and interlocks.

Instrument Systems:

- Responsible for identifying the need for equipment protection and developing a list of interlocks that must be implemented by the ICS.
- Responsible for the equipment protection hardware (switches and sensors) and, in collaboration with ICS, ensuring they are electrically compatible with the ICS controllers.

Integrated Control Systems:

- Responsible for the cabling and connectors to the equipment protection hardware (switches or sensors).
- Responsible for integration of the equipment protection hardware into the ICS PLC system and the implementation and testing of the associated interlocks.
- Responsible for the PLC and enclosing cabinet.
- Responsible for electrical power cables between the electrical power panels and the PLC cabinets.
- Responsible for installing ethernet network communication cables between the PLC cabinet and the ICS network switch.
- Responsible for the control software interface to the PLC.

5.1.4 Interface 4. Floor space, wall space - ICS racks, cabinets, and cables

The ICS motion control and ICS equipment protection controls will be housed in either rack mount chassis or wall mounted cabinets. The cables will typically be routed between ICS racks/cabinets to the equipment in cable trays or conduit. The cable trays and conduit will be handled by the CF group and so this is dealt with in separate interface sheets between Instrument Systems and CF, and between ICS and CF.

Instrument Systems:

- Responsible for providing wall and floor space for the ICS racks and cabinets.
- Responsible for providing a list of motorized equipment and equipment protection equipment to enable ICS to estimate the size and design the racks layout or cabinets layout.

Integrated Control Systems:

- Responsible for providing information to Instrument Systems on the size of the required cabinets or rack space.
- As mentioned in interfaces 1-3, responsible for installation of the cabinets and racks.

5.2 INTERFACE DATA

It is possible to define some interface details based on what is likely the type of equipment involved based on experience at the existing SNS and some early preliminary design work. This section can be updated as the preliminary design for Instrument Systems and ICS is more fully developed.

Most of the motorized systems are expected to use standard 2-phase stepper motors, limit switches, incremental encoders, and absolute encoders. These are each discussed below and data that is relevant to the interface will be presented.

It is currently not possible to define the interface details for any specialized non-standard equipment as this is likely to remain unknown for several years. These interfaces will be agreed upon between Instrument Systems and ICS as soon as possible, and the details are likely to vary on a case-by-case basis. However, the interfaces for specialized equipment should be guided by the electrical and communication guidelines developed by ICS in [2].

5.2.1 Motors

The standard 2-phase stepper motor will generally have frame size NEMA11-34 and rated for up to 6.0A (usually less than 3A, but large motors can have a rating >3A). These motors will generally be purchased with fly leads (without connectors) so that the STS standard motor cable connectors can be installed by ICS.

Stepper motors can be wired to a stepper motor amplifier in different ways, which can change the torque/speed characteristics of a motor, but the standard SNS method is wiring in bipolar series. The motor torque specification should be chosen assuming that it will be wired in bipolar series (as opposed to unipolar or bipolar parallel). An example wiring scheme for an 8-lead Nanotech stepper motor (model ST5918S3008-B) is shown below in Figure 4, which shows that the motor is capable of being wired according to bipolar series (called bipolar serial in the figure).

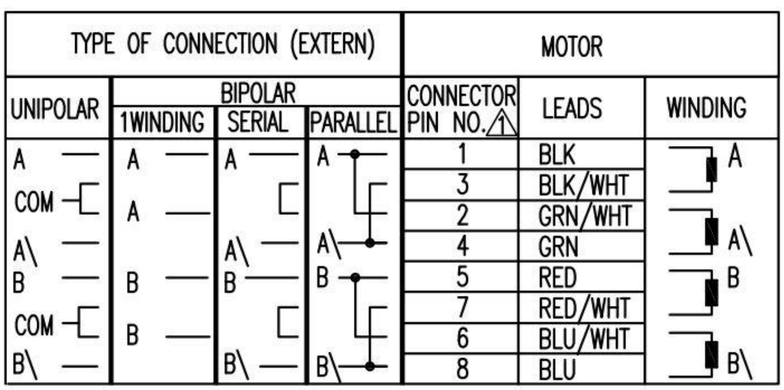


Figure 4: Bipolar series wiring scheme for Nanotech 8-lead stepper motor

The wiring scheme in Figure 4 is sometimes presented in a graphical form, which is otherwise equivalent, and an example of this is shown below in Figure 5. As can be seen in Figure 4 and Figure 5 the color assignment on the motor leads can vary between motor manufacturers.

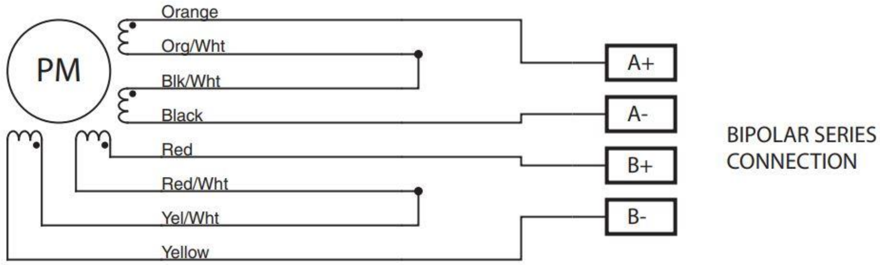


Figure 5: Bipolar series wiring diagram for Applied Motion Products 8-lead stepper motor

The current SNS standard motor connector wiring diagram is shown below in Figure 6. This shows the 4 wires for the two motor phases (A+/A- and B+/B-) and the circular connector type ITT Cannon KPT01A10-6P. The KPT01A10-6P is a cable connecting plug with pins that would be soldered to the motor wires. SNS standard connectors are usually chosen such that they meet standard MIL-DTL-26482.

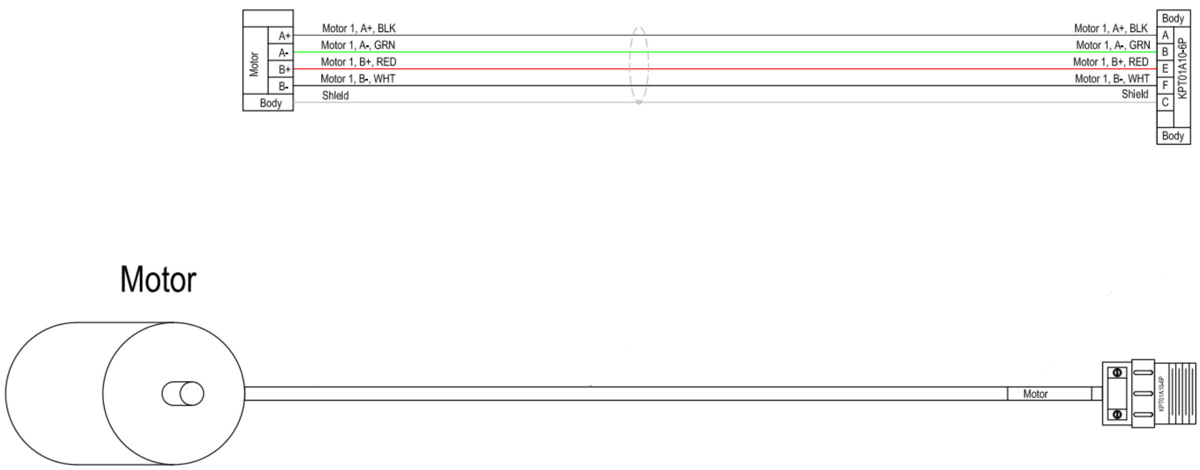


Figure 6: Standard SNS motor cable and connector

In general, it is preferred to purchase motors with fly leads so that the standard SNS connector can be installed by ICS. If a motor is purchased with a cable with a non-standard connector, then it may be necessary to cut off the connector and replace it with the SNS standard.

Sometimes it is preferable to use panel mount connectors and an example of this is shown below in Figure 7. In this case the connector type is ITT Cannon KPT02A12-10P and it handles the motor signals, a negative limit switch, a positive limit switch and a home switch. In the case of panel mount connectors, it will be necessary for coordination between Instrument Systems and ICS for the location and mounting of a panel. In general, a mounting panel would be provided by Instrument Systems as part of a mechanical assembly for a set of motors. ICS would be responsible for the panel mount connector, mounting the connector to the panel and wiring the motor and switches to the connector.

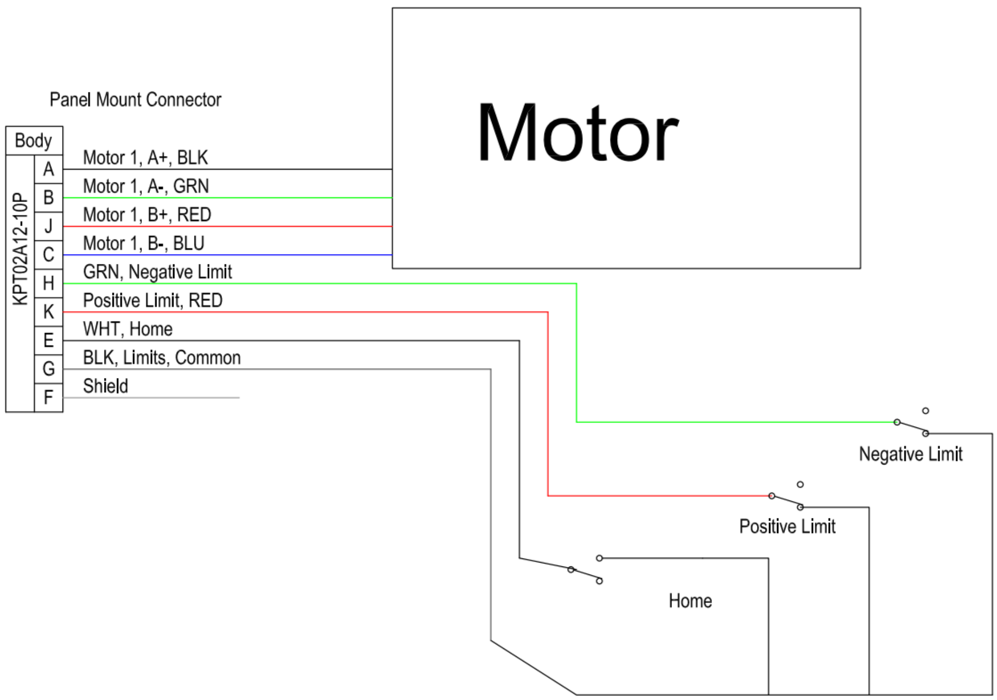


Figure 7: Standard SNS panel mount connector for a motor and set of switches

The electrical properties for the Nanotech ST5918S3008-B motor that was mentioned above are shown below in Figure 8. The motor will be rated to operate with up to a maximum current (Amps), will have a particular resistance (Ohms) and inductance (mH). The information in Figure 8 is merely an example to demonstrate the type of information that is relevant to the interface, and which needs to be checked when purchasing a particular motor. In practice there will be a permissible range of each of the electrical parameters, that will depend on the standard STS motion control system which will be developed during preliminary and final design.

SPECIFICATION \ CONNECTION	UNIPOLAR OR BIPOLAR-1 WINDING	BIPOLAR	
		SERIAL	PARALLEL
VOLTAGE (VDC)	2.16		
AMPS/PHASE	3.0	2.12	4.24
RESISTANCE/PHASE (Ohms)@25°C	0.72±10%	1.44±10%	0.36±10%
INDUCTANCE/PHASE (mH) @1KHz	0.9±20% ⚠	3.6±20% ⚠	0.9±20% ⚠

Figure 8: Nanotech ST5918S3008-B stepper motor electrical properties

It will be possible to cater for non-standard motors, either stepper motors that may have electrical requirements outside the standard STS range or other kinds of motors such as servo motors, piezo motors, etc. However, any non-standard solution should be carefully considered and discussed with ICS in case a specialized controller, drive amplifier or other non-standard electronics are needed.

5.2.2 Encoders

There are many options for encoder readhead technology, but the interface should be incremental quadrature signals (usually called AB quadrature), with index signal (called a Z-channel), or absolute BiSS serial format. Other types of encoder interface may be able to be accommodated but this would need to be reviewed by ICS on a case-by-case basis.

An example of an electrical interface to a Renishaw incremental encoder (model HLxIC) is shown below in Figure 9. As can be seen the encoder information is sent using RS-422 (which is common for incremental encoders), and it requires a 4.75-12V power supply (which is typical). The information in Figure 9 is shown only to be representative of the type of information that would need to be reviewed by ICS to ensure compatibility with the motion controls.

Digital output signals, RS422

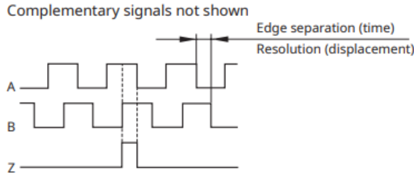
HLxIC

Specifications

Power supply	4.75 V to 12 V – voltage on readhead Reverse polarity and overvoltage protection (up to 15 V)
Current consumption	<450 mA (with termination) <250 mA (without termination)
Voltage drop over cable	1.3 V (worst case; lowest supply voltage, maximum load, maximum cable length)
Power supply rise time	0.1 ms - 100 ms
Response time	30 µs
Output signals	3 square-wave signals A, B, Z and their inverted signals A–, B–, Z–
Reference signal	1 or more square-wave pulse Z and its inverted pulse Z–
Signal level	Differential line driver compatible with EIA standard RS422
Permissible load	$Z_0 \geq 100\ \Omega$ between associated outputs Outputs are protected against short circuit Only one output shorted at a time
Alarm / Error signalisation	High impedance on output lines A, B, A–, B–, Z, Z–
Switching time (10 to 90 %)	145 ns
Cable length	Max. 10 m

Timing diagram

Complementary signals not shown



Recommended signal termination

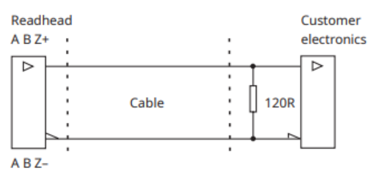


Figure 9: Example Renishaw incremental encoder electrical specification

The same Renishaw encoder can be purchased with either fly leads, an 8-pin M8 connector or a 9-pin D-type connector. This shown in Figure 10, which also shows the pin or lead color assignment for each signal that needs to be wired into a motion controller. The choice of flying leads or connector may be application specific, and the choice will vary between encoder manufactures and encoder form factors, but in general fly leads are preferred so that the standard SNS connectors can be used by ICS.

Function	Signal	Readhead connector pinout	Flying leads (option F)	9 pin D type plug (option A)
Power*	Vcc	2	Brown	5
	GND	8	White	9
Incremental / analogue signals	A	5	Green	4
	A–	6	Yellow	8
	B	7	Blue	3
	B–	1	Red	7
Reference signals	Z	3	Pink	2
	Z–	4	Grey	6
Cable shield	Chassis	Case	–	Case

Figure 10: Connector options for example Renishaw incremental encoder

Figure 11 shows an example of wiring a standard incremental encoder to a an SNS standard connector (ITT Cannon KPT01A12-8P).

Figure 11: Standard SNS incremental encoder wiring and connector

5.2.3 Switches

Switches means either limit switches, home switches, proximity switches or similar. Normally closed switches must be used as limit switches. Home switches can be normally closed or normally open (but the choice must be consistent across a system). The electrical rating should normally be compatible with 5-24V DC signals. Active 'non-contact' switches can also be used if necessary. An example wiring diagram for a set of limit and home switches was shown in section 5.2.1 in Figure 7.

5.2.4 Motion control cabling

A few examples of cabling and connectors have been shown in the previous sections for motors, limits, and encoders. They show the pin and wire assignments for each signal to standard SNS connectors. These connectors are local to the equipment and may not connect directly to a motion control panel. In general, additional longer cable sets are needed to route the signals back to a motion control panel that may be several meters away or in a different room. These longer cables are generally routed in cable trays or conduit and will connect directly to a rack or panel mounted motion control cabinet.