Science & Technology Facilities Council
Rutherford Appleton Laboratory

STFC ISIS

Project:
PR16176 – ISIS Motion Control Units.

This document details the requirements for the tender of the Next Generation Motion Control Project. The document has sections written by ISIS Design, Experimental Operations, Instrumentation and Science divisions

Revision History

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Approvals

This document has the following approvals:

Name	Title
Stephen Cox	ISIS Next Generation Motion Control System – Project Manager
Matt Fletcher	Project Sponsor

1 Introduction and Scope

1.1 Definitions and abbreviations within this document

Shall - Used to indicate a requirement that is contractually binding and shall be implemented.
Will - Statement of fact and not subject to verification.
Should - Requirements that shall be addressed but are not formally verified.

STFC – Science and Technology Facilities Council
RAL – Rutherford Appleton Laboratory, Chilton, UK
ISIS – Facilities department within STFC concerned with procuring this equipment
UK SBS – UK Shared Business Services Ltd - Agents acting for and on behalf of STFC

Bidder – Company who offers a tender return
Supplier – Company who is awarded the contract
Tender – The response from the company to this specification
Commencement of contract – The date when the contract is signed.

Motion Control Unit (MCU) – The main processing and control unit providing motion control functionality.
MCU Accessories – Components, supplied by the bidder, to be used in conjunction with the MCU. For example, motor drive amplifiers, encoder interface electronics and general I/O
Beamline System –High Performance applications (such as the example described in *3.3 - High Performance Application Use Case B – 6 Axis synchronised scan).* Beamline systems will often require the control of large numbers of axes. For the purpose of this tender, 32 axes is the nominal number to be controlled in a Beamline System application.
Portable System – Low Performance applications, nominally less than 4 axes of motion, such as the example described in *3.2 - Low Performance – Application Use Case A – Sample Alignment and Rotation.* Requirements for this system type are detailed in *2.3.12 -19" Portable Rack from factor.*

Hard Real-time – A critical real time system element that is operating with a cycle time of under 100 microseconds
IDE – Integrated Development Environment
SDR – System Design Review
MCU – Motion control Unit – This contains the main system processor and can have integrated or separate motor drive amplifiers
Drive amplifiers – The module that takes a control signal from the MCU and applies current to the motor.
SIL – Safety Integrity Level
Beamline Instrument – One of the 34 experimental stations on the ISIS facility. Each of these areas currently has up to 32 axes of controlled motion.
STFC PC – A PC maintained by STFC that sits external to the MCU system and from which requests to the MCU to perform various action will be made. Here control of the MCU will be

integrated with STFC’s beamline software to allow sequences of motion to be initiated as part of a higher level control loop.

Remote Access of MCU – A method of connecting to a STFC MCU from an off-site location for the purpose of providing support. Security arrangements should be considered when referring to remote access.

1.2 Introduction.

This document provides detailed information on the Requirements and Applications for the ISIS Standard Motion Control Unit. STFC ISIS is currently running 34 experimental beamline instruments. An instrument is often in excess of 20m in length and each may have 32 or more axes of controlled motion, distributed along the length of the beamline. The axes of motion are used to drive equipment located in different sections of the beamline to obtain optimal conditions for the experiments. There is a central STFC control PC per instrument beamline, that communicates with the individual motion controllers, specifying the sequence of movements (often from a script) and recording all the positons to correlate with the resulting experiment data.

STFC require MCU’s that can be used for a wide range of applications. The facility also has equipment that is transferred between multiple beamlines. The same MCU type will be used on beamline instruments, which have large numbers of motion axes and for portable setups, which will often require single, two or four axes of motion. We would like for both types of application to use the same brand of MCU due to improved system familiarity, programming and ongoing support. The majority of this tender refers to requirements for the more complex ‘Beamline System’ type. Section 2.3.12 refers to the more baseline MCU requirements for the ‘Portable System’ type and lists the items from the Essential technical requirements that this system shall meet.

The current generation of standard motion control system is used to control over 600 axes of motion across the facility and has been purchased for the last 14 years.

The scope of this contract is a system for use within the STFC ISIS Neutron Facility. Other STFC departments may also choose to use this contract, although they are not automatically included in it as of the 2017 tender. STFC would like to setup a contract with the selected bidder and aim for this to be in place for a period of 4 years.

Throughout the contract, STFC may purchase MCUs for ‘Beamline System’ and ‘Portable System’ applications, as well as standard MCU accessories from the MCU product range to support these systems, depending on the particular application at the time, and the level of customisation required for any bespoke solution. Please see section 4 of the PR16176 RFP Request for Proposal for further details about how the Contract will operate.

1.3 Support Requirements.

1.3.1 Training.

STFC will need to arrange training on the new MCU system for around 15 members of staff. It is preferential for training to be provided within the UK at the STFC site RAL. Bid response should show willingness and approach to training, and ideally flexibility to tailoring courses to specific needs.

1.3.2 Support.

Support to STFC should be available as part of the Contract. This support may be in the form of telephone, email and/or remote MCU access.

1.3.3 Warranty.

Warranty should be provided for the systems supplied to STFC, and the Bidder shall confirm the duration offered for such warranty as part of this Contract.

1.3.4 Spare Parts.

STFC ISIS runs as a 24 hours/7 days per week facility and operational support is therefore very important. As part of your response, please provide details of lead times for complete 'Beamline Systems' MCU to be ordered and delivered.

1.3.5 Product Range.

STFC ISIS require the MCU solution to be able to actuate a large range of motor types and/or applicable drivers and also various expansion modules as required – such as safety, I/O, and communication modules. It is an advantage to STFC ISIS to be able to purchase the components that are commonly used under the same contract.

Please advise of your ability to supply each of the 20 items listed below as part of the solution range.

If the particular item is already –built in – to one of the items listed, this will also count towards the total in the table below.

Item	Description of component part / module
1.	Motion Controller (CPU/Central Processing Unit, PLC or Embedded PC)
2.	Digital Input / Output modules
3.	Analogue I/O modules
4.	Feedback Interface (Incremental, Resolver and BiSS-C) modules
5.	Infrastructure/Fieldbus Extension modules

6. Stepper Motor Drive Amplifier modules
7. Servo Motor Drive Amplifier modules
8. Piezo Ceramic Motor Drive Amplifiers
9. Safety Rated modules (Controllers and Input / Output modules)
10. Timing Master Clock Synchronisation modules
11. Stepper Motors
12. Servo Motors
13. Piezo Ceramic Motors
14. Systems Training
15. HMI Panels
16. Any necessary IDE Software Licence
17. Motor connection cables
18. Feedback connection cables
19. Technical Support
20. Jog Box units

2. Technical Specification.

2.1 Introduction.

STFC require the bidder to confirm that 'Beamline System' applications are capable of meeting, as a minimum, all of the essential technical requirements defined in Section 2.2 of this specification and that 'Portable System' applications are capable of meeting, as a minimum, the subset of essential technical requirements as defined in Section 2.3.12.

In association with the essential requirements a number of desirable requirements that will be of particular interest to STFC are also defined.

2.1.1 Block Diagram of a 32 Axis MCU system.

To give STFC ISIS an idea of how the HP MCU offered solution may look, please provide a simple block diagram of the component parts required to control motion on a 32 axis beamline instrument. This is important because it gives confidence about how well the system will scale and how many different control units will be required on each beamline.

2.1.2. Functional Test

Bidders are required to supply an MCU system that enables STFC ISIS to perform a functional test. The test will take place at STFC ISIS premises and will be conducted by STFC ISIS motion control staff without technical support from the bidder. The bidder must provide STFC ISIS with an MCU system, software, user guides and any other information expected to be of use to enable STFC ISIS staff to

complete the test. The test will consist of STFC ISIS motion control staff connecting the bidder supplied MCU system to a rotation stage, configuring the system to perform closed-loop control and testing rotation stage functionality.
The equipment provided by STFC ISIS to complete the test is listed below:

- Rotation stage complete with motor and encoder.
- Interface cables between stage and MCU system.
- Local PC running Windows OS.

Rotation stage interface details:

- 1.8° Stepper Motor, 4.7A/Ph, Bipolar operation.
- Renishaw RGH20 Incremental Encoder, RS422 Electrical Interface.

2.2 Essential technical requirements.

2.2.1 Single MCU Manufacturer

For design and operational consistency across the facility MCUs supplied for 'Beamline System' and 'Portable System' applications must be produced by the same manufacturer, ideally as part of a product family.

2.2.2. Open Source Real-Time Network Drive Interface.

Communication between the Motion Control Unit CPU module and the drives shall be realised using a hard real-time field bus. For the purpose of this tender, hard real-time is defined as a cycle time of under 100 microseconds. STFC ISIS already uses and works with partners who use open source, EtherCAT based devices. It is therefore required that this fieldbus is used within the MCU. This requirement will benefit some of the other MCU requirements such as Synchronisation of axes and Position Timestamping. Open source protocols are preferred by STFC because this will allow for extra flexibility when selecting drives for one off, specific motion applications.

EtherCAT Technology Group - https://www.ethercat.org/default.htm

2.2.3 Closed-Loop, Dynamic control of stepper motor with encoder.

It shall be possible to dynamically control the position, and velocity, of a stepper motor through the feedback provided by an encoder. This encoder is either integrated within the motor housing or is mounted as an external, load encoder. The minimum sampling frequency should be 1kHz, although our current MCU system provides up to 32 kHz.
The system shall be capable of 'closed-loop stepper with step-loss compensation', and 'closed loop stepper with load position control' with continuous compensation during the full move.

The position servo closed-loop mode for the stepper motor shall run at 1KHz or higher.

2.2.4 Synchronised move of 9 Stepper Motors from a master axis.

There is a science requirement on multiple ISIS instruments to control a group of motion axes as one geared component. To achieve this requirement, the MCU shall provide functionality to specify axis relationships such as Master and Slave. The axes would be linked as a group with geared electronic camming. Each axis will have its own encoder for dynamic closed loop control.

2.2.5 Incremental Encoder Feedback Interface.

Incremental encoders are used to provide positional feedback in some applications. Optical quadrature encoders are used to provide shaft angle feedback, as well as tape style encoders for load position feedback.
The system shall be capable of interfacing with incremental quadrature + index RS422 encoders (with differential inputs), through appropriate line receiver circuitry. Typical incremental encoders used are Renishaw RGH24, RGH25F, US Digital E5 series, Kubler KIS40.1362.2048.

2.2.6 Streaming of Virtual axis position every 20ms.

Some instruments require functionality to allow for live tuning of an axis stage. The MCU shall be able to provide the STFC host PC with the single axis position value either every 20ms or as buffered set of values at no less frequently than once a second.

2.2.7 Absolute Encoder Feedback Interface.

The MCU shall be compatible with Absolute encoder profiles. Biss-C and SSI are two of the preferred absolute encoder profiles for STFC ISIS. If extra components or 3rd party fieldbus modules are required details of these should be provided in the bid.

2.2.8 Resolver Feedback Interface.

The system shall be capable of interfacing to single and multi-turn resolvers for angular feedback, for example AMCI R11X-J10/7N. The system should provide a suitable excitation waveform and contain ADC circuitry designed for calculating the shaft angle from the two output coils. If extra components or 3rd party fieldbus modules are required details of these should be provided in the bid.

2.2.9 External hardware signals when motion reaches certain positions.

The MCU shall be able to trigger an external output when a given axis reaches a pre-programmed set of positions. There shall be flexibility for the user to set positions at any point along the axis travel and for greater than 5 positions to be programmed.

2.2.10 STFC Host PC Hardware Connection - Interface with a long life span.

We require a STFC PC to MCU connection interface with a long life span i.e. likely future developments in off the shelf PC hardware will not render us unable to communicate with the motion hardware in a widely distributed system. The connection shall be via a standard RJ45 Ethernet connector to a network switch (which in turn is connected via a an Ethernet network to the host PC), it is possible but should not be assumed that the connection will be made directly to a PC network port.

2.2.11 STFC Host PC Hardware Connection - No control cards needed in host PC.

The hardware connection shall not require additional control cards (e.g. PCI) to be installed inside the STFC PC to communicate/control motion.

2.2.12 Drive IEC/EN 60204-1 Stop Category 0.

The MCU shall be capable of performing the Safe Torque Off (STO) function of Stop Category. The MCU will often take outputs from the instrument Personnel Protection System and the status of other equipment.

The STO function corresponds to Stop Category 0 to IEC/EN 60204-1 and is the basic foundation for drive-based functional safety. It is typically used for the prevention of an unexpected start-up (EN 1037) and to prevent unexpected motor rotation in the event of an emergency, while the drive remains connected to the power supply. When STO is activated, the torque power cannot reach the drive, thus stopping and preventing any further driven motor shaft rotation. In this case the motor will be "free running" and will slow down until it stops under its own inertia and frictional forces or an external measure is implemented. This state is monitored internally in the drive.

2.2.13 Control of MCU from programs running on STFC PC.

As part of beamline experiments, STFC will need to be able to direct motion operations from its own software so as to allow users to coordinate motion with control of other equipment present. Our software is written in C/C++, so it shall be a feature of the MCU that it supports control by external 3rd party applications written in C/C++. This could be achieved by approaches such as:

- providing a complete description of the wire protocol and command set understood by the MCU so STFC could develop its own control driver software

- providing a library (DLL) of functions that can be linked into STFC programs on the STFC PC and used by the software there to perform motion operations

- If the MCU has embedded processing power, providing details of how STFC could develop its own “server” program to run on the MCU and so provide a mechanism to control motion from its own PC and software over the network link.

STFC uses virtual PCs running 64bit Windows 7 and Windows 10, the solution shall be applicable to this situation. If a library is provided which it is not in source code form, then details of future support (up to 10 years) through changes in the Windows operating system and Microsoft Visual Studio versions shall be provided. It should also be specified what would happen on discontinuation of product support or closure of the supplier e.g. source code escrow.

2.3 Desirable technical requirements

2.3.1 Synchronisation of the MCU Clock with an external controller clock (Example: IEEE1588 Precision Time Protocol).

STFC require the MCU to be used with other data collection systems on our Instrument Beamlines. The MCU requires a method for its internal time to be synchronised between different nodes on an Ethernet network. The different systems shall be synchronised to 2mS or better. The time synchronisation should ideally be done using an RJ45 Ethernet network connection.

Bidders shall provide STFC with video evidence of the MCU internal clock being automatically adjusted from an 'External Master' reference clock. Bidders shall also provide details of the mechanism to prove it could be used to synchronise time on nearby Windows and Linux PCs, for example. Bidders should provide Photographs, test data and references from customers who use this technology.

2.3.2 Timestamping of an axis RS422 differential input incremental encoder value.

Some experiments would benefit from the MCU having the ability to add a timestamp to encoder position data of a master axis. The STFC ISIS neutron beam is pulsed at a rate of 50Hz and therefore the timestamp would need to performed in a real-time element of the MCU and at least every 20ms. Providing a higher resolution of timestamping is an advantage for specific applications. Please provide details of the method for allowing the timestamp feature if this is available with the MCU.

2.3.3 User Mode Driver.

It is preferred that any motion control driver software required to be installed on an STFC host PC be user mode[1] rather than kernel mode, this makes it less dependent on future changes to operating system driver models. In any case it should be possible to install the driver/software on a virtual machine[2] as this is the preferred way for STFC ISIS to manage its control PCs. Future software support details as discussed in section 2.3.11 should be provided for future driver support. Any driver should be available on both Windows 7 and 10, 64bit. Making use of existing operating system drivers would be preferred.

2.3.4 Profile moves.

STFC require a method to specify a table of data points for an axis to execute and follow. The minimum number of points required with this function is 5, although a greater number of data points would be an advantage and provide for more complex trajectories. It shall also be possible to construct a profile separately to any IDE and execute it on the controller using the interface specified in section 2.3.11. The MCU would need to interpolate the position and axis speed between each of the points. This function shall be independent of motor type and shall therefore work for both stepper and servo motors. Position and either velocity or time variables shall be available.

2.3.5 Download an Array or Table of points to control a master axis.

STFC ISIS require a method to allow for a group of geared axes to be controlled from an array or table of points that is downloaded to a master axis. This will allow for non-linear trajectories to be executed easily from the STFC host PC. It is also useful for STFC ISIS to be able to top up a buffer of data points, allowing for a continuously varied profile. Please provide details of how this function would operate with the MCU and STFC host PC.

2.3.6 Step / Direction Drive Interface.

The 1st generation of standard ISIS MCU have been used at the ISIS facility for over 10 years and is therefore deployed on many of the beamline instruments. It is essential that it can be shown that the proposed solution can be interfaced to the existing hardware. Some instruments will be upgraded by replacing the MCU only, using the existing SmartDrive DM series stepper drives to reduce cost.
http://www.smartdrive.co.uk/motion-products/stepper-drives/eurocard-stepper-drives/

The interface to the drives is provided through ISIS Stepper Diagnostic cards (custom component), which require step/clock, direction and enable logic signals at 24V 10mA, suitable for driving optically-isolated inputs.
The enable signal causes the drive to energise the motor windings, the step/clock signal causes the drive to advance one step, and the direction signal selects the direction of the step; forward or backward. The maximum stepping frequency acceptable to the DM drives is 30 kHz.

Appendix C contains the user handbook for the existing 1st generation motion control hardware

Please provide details of how the offered MCU solutions will be able to interface with ISIS Stepper Diagnostic cards.

2.3.7 Analogue +/- 10v Drive Interface.

STFC ISIS have some components that contain Ultrasonic Piezo Ceramic motors. To interface to Nanomotion HR series Piezo Ceramic motor drives we will require a system that is able to operate analogue drive interfaces with minimal reconfiguration effort, such as a standard software option or module change for example. Bespoke firmware changes and 3rd party modules are less desirable for enabling this interface. The interface shall support velocity mode for dynamic positioning, along with a minimum 10-bit resolution digital to analogue conversion of the +/-10V analogue output signal.

2.3.8 Absolute Encoder Feedback Interface types supported.

STFC ISIS would like to be able to easily use absolute encoders with the standard MCU. There are numerous encoder interfaces available on the market.

The open source BiSS Interface (bidirectional/serial/synchronous) is based on a protocol which implements a real time interface. This is the preferred absolute encoder interface of STFC ISIS. It enables a digital, serial and secure communication between controller, sensor and actuator. The BiSS protocol is designed in B mode and C mode (continuous mode).

BiSS Interface – Protocol Description (C-Mode) http://biss-interface.com/files/Bissinterface_c5es.pdf
SSI and EnDat 2.2 are also useful absolute encoder interfaces for STFC ISIS applications. Please state which absolute encoder interfaces are available and how these can be selected with the MCU solutions offered.

2.3.9 Drive IEC/EN 60204-1 Stop Category functions.

Please provide details of any other IEC/EN 60204-1 Stop Category functions and types of stop that are also available with the MCU. The flexibility to use different stop types is useful in the varied applications found at the STFC ISIS facility.

2.3.10 Diagnostics Hand held jog control for technicians.

STFC often requires a hand held interface 'jog box' which, when connected to a motion system, provides control and diagnostic indication for each axis in place of the MCU. Higher scoring will be given to bidders who can demonstrate exactly how the control and diagnostic features detailed below can be provided to a hand held interface.

2 Modes of Operation:

- Control Mode – Hold to Run Axis Control & Diagnostics Enabled.
- Diagnostic Mode – Axis Control Disabled, Diagnostic Indicators Enabled.

Standard control mode functionality shall include:

- Axis selection
- Axis Speed selection
- Axis Direction selection
- Override limit/home (allow movement on limits)

In addition, comprehensive control mode functionality shall include:

- Jog to predetermined position (position set by computer interface)

Standard diagnostic mode functionality shall include:

- Indication of selected axis
- Indication of limits/home state

In addition, comprehensive diagnostic mode functionality shall include:

- Indication of encoder operation

2.3.11 Disconnection of Power to individual drives.

It is desirable to 'Hot Swap' (disconnect/reconnect power) to individual drives, without powering down the entire MCU. This allows for faulty drives to be replaced with minimal disruption to the motion control system. Please describe how this is done with the offered MCU solutions and how such a hot swap is perceived by software on/connected to the MCU.

2.3.12 19" Portable Rack form factor.

It shall be possible to package a minimum of 4 axis of control into a 19" portable rack, ideally in a 3U but no bigger than 4U size chassis. The portable unit shall weigh less than 20kg for manual handling purposes. The contents of the rack shall include the MCU (controller), closed-loop stepper motor drive electronics, connections for communication, encoder and limit/home interfaces for 4 motion axes.

The portable system will be powered by a 13A single phase supply.

The portable system must meet the following Essential Requirements and therefore does not require the full functionality of a 32 axis system.

Essential Requirements

- 2.2.3 Closed-Loop, Dynamic control of stepper motor with encoder
- 2.2.5 Incremental Encoder Feedback Interface
- 2.2.10 STFC Host PC Hardware Connection - Interface with a long life span
- 2.2.11 STFC Host PC Hardware Connection - No control cards needed in host PC
- 2.2.13 Control of MCU from programs running on STFC PC

2.3.13 Maximum beamline rack volume for 32 axes.

The current MCU implementation at STFC ISIS is physically large compared to many modern systems. It can provide 32 axes of motion, for stepper and low current servo motors, from a control rack of the dimensions 800mm Wide X 400mm Deep x 1200mm High. The new system is expected to be smaller than this therefore please indicate the total control system volume for 32 axes.

2.3.14 Block area of axis.

In some applications it may be necessary to impose restrictions on the available range of motion, to prevent collision with external systems. The MCU should allow for the range of motion of linked axes to be restricted in software. This is useful for avoiding damage to motion equipment during an experiment and will not either directly or indirectly form part of any personal safety system. This function cannot be implemented by setting soft limits on a single axis and shall allow for the dynamic nature of moving groups of axes in a confined area.

2.3.15 Existing EPICS support.

ISIS is currently in the process of moving its beamline control software to EPICS, and EPICS is being used on all new beamlines. EPICS is a set of Open Source software tools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems for scientific instruments such as a particle accelerators, telescopes and other large scientific experiments. It is an advantage if the MCU solutions offered already have existing users. Please specify if EPICS drivers and support are already available or if an EPICS driver would be produced as part of this contract.

More information on EPICS is available at this website: www.aps.anl.gov/epics/

2.3.16 Motion started by external trigger.

In some applications it is useful to start a pre-programmed move, across a number of axes, on receiving an external event trigger at an MCU input. Please give details of how this could be done using the offered MCU.

2.3.17 Digital I / O – Electrical Interface availability.

Due to the varied applications at this facility, STFC require a flexible motion control system. It should be possible for each type of input to be used as variables within a control loop program and this shall be confirmed within the reply to this section. Please provide details of component parts that are included within the MCU, available from your standard range or available through the fieldbus from a 3rd party to cover the following:

- At least 8 electrically isolated input terminals. These should be volt free contacts (potential free). The inputs shall not be specific to an individual axis and separate to limit signals for example.
- At least 8 sourcing outputs. This is preferred because a short on a cable to ground is less likely to activate an input in a fault state.
- Hardware input options should be available for signals that are likely to bounce, such as signals from mechanical relays. These inputs should contain electronics to latch a single change of state.

2.3.18 Analogue I / O – Electrical Interface availability.

Due to the varied applications at this facility, STFC require a flexible motion control system. It should be possible for each type of input to be used as variables within a control loop program and this shall be confirmed within the reply to this section. Please provide details of component parts that are included within the MCU, available from your standard range or available through the fieldbus from a 3rd party to cover the following:

Standard functionality shall include

- 4-20mA inputs and outputs with a minimum of 16 bit resolution.
- 0 to 10v inputs and outputs with a minimum of 16 bit resolution.
- Thermocouple inputs

In addition, comprehensive I/O functionality shall include:

- 4-20mA inputs and outputs with a minimum of 24 bit resolution.
- 0 to 10v inputs and outputs with a minimum of 24 bit resolution.

The number of analogue I/O meeting these specifications should be included in the response.

3 Appendix A

3.1 Example MCU Applications

This Appendix describes some of the applications associated with both ‘Beamline System’ and ‘Portable System’ applications at the STFC ISIS facility. It is intended as a reference to provide context for the essential and desirable technical requirements.

3.2 Low Performance – Application Use Case A – Sample Alignment and Rotation

3.2.1 Background

A common motion configuration across the ISIS beamlines for sample environment control is a dual axis configuration for the control of 1 linear stage and 1 rotation stage. This system provides control of a sample’s alignment perpendicular to a neutron beam by positioning an angle of rotation and an in or out of beam option on a vertical linear stage.
The linear stage is driven between two pre-determined locations on the travel and has over-travel limit switches. The rotation stage is set to a nominal zero position then rotated to predetermined points. The sample held in position for some time, in the order of hours, whilst sample measurements are taken.

3.2.2 System Description

Sample environment stages are mounted to sample environment equipment (cryo coolers, furnace heaters etc.) which is transported between beamline instruments. At each beamline there is a control PC, motion controller and in some cases, a patch panel providing the electrical infrastructure to connect between the location of the rotation stage at the beamline and the motion controller at the beamline cabin.

3.2.3 Equipment Form Factor

There is a frequent need for controllers to be portable allowing ad-hoc delivery and substitution between beamlines where applicable. A 3U 19” chassis is the standard size for the MCU crates use for this purpose, delivering up to 2 axis of control.

3.2.4 Control Methodology

The instrument control PC provides a software interface that includes GUI’s and drivers for Interfacing to the motion controller. Communication is a master/slave configuration where the slave controller is polled at a rate set by the master control PC. This is currently done using the RS232communication standard.

A hardware interface, separate to the control PC, is provided for set up and fault diagnosis in the form of a 'jogbox'. This unit provides independent control over the axis selection, direction and speed of a stage.

3.2.5 Motion Control

The MCU controls stepper motors in closed loop mode using a Renishaw incremental tape encoder mounted on to each stage. The motors are micro-stepped at either 1/4 or 1/8 micro-stepping, depending on the type of stage.

Both stages are driven by a 48V stepper motor at 4.7A/phase, with phases wired in series.

3.2.6 Fault Diagnostics

The MCU control card provides diagnostic codes via the front panel. Dependent on the information communicated between the control PC and the motion controller, there may be some diagnostics information recorded for later analysis.

3.3 High Performance Application Use Case B – 6 Axis synchronised scan

3.3.1 Background

Some STFC instrument beamlines use multiple motorised stages to fine tune (scan) the neutron beam angle.

3.3.2 System Description

To do this STFC will need the MCU to control multiple axes simultaneously and to record or report the 6 axis positions against an absolute timestamp. Crucially, the encoder information and the neutron data collection should have a common time stamp, which is synchronised to 2ms or better.

A less desirable technical solution would be to have the controller take care of axis synchronisation and to only 'flag up' when multiple motor positons are not within tolerance. In this case the position of one single (master) encoder could be reported to the data acquisition system. Crucially, the encoder information and the neutron data collection should have a common time stamp, which is synchronised to 2ms or better.

3.3.3 Motion Control

The scanning of a detector height and rotation is required together with beam aperture slit collimation and analyser position to accurately align a reflecting sample.

Motorised stages to be controlled:

- Detector height - DC servo motor with Biss-C closed loop feedback
- Detector rotation - DC servo motor with Biss-C closed loop feedback
- Analyser height - DC servo motor with Biss-C closed loop feedback
- Analyser rotation - Stepper motor with incremental quadrature closed loop feedback

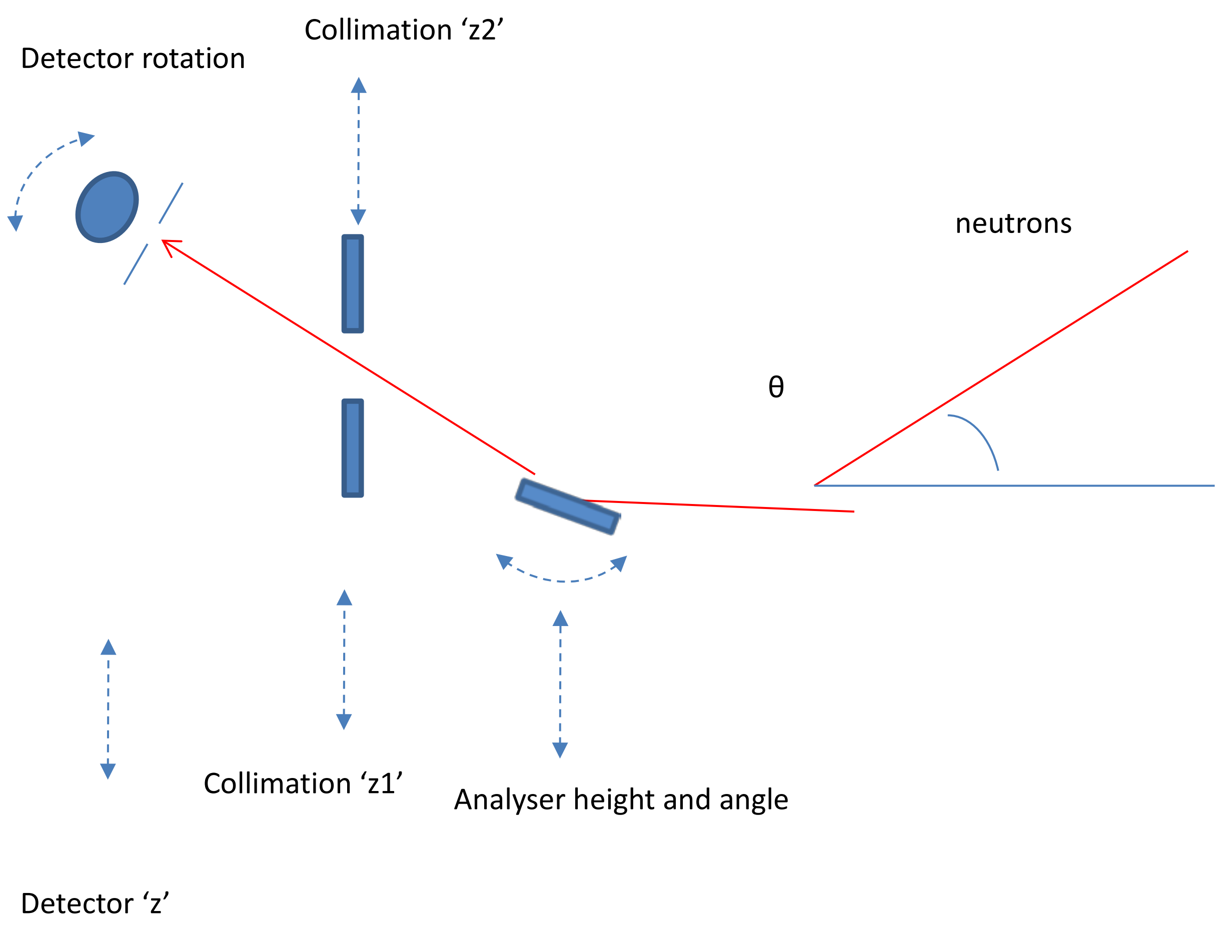
- Slit north jaw - Stepper motor with incremental quadrature closed loop feedback
- Slit south jaw - Stepper motor with incremental quadrature closed loop feedback

The MCU will need to move a total of 6 motors, of different types, in a synchronised manner.

In this case motor position accuracy is ~10 microns or 0.001 degrees. The velocities required are in the region of 0.15 meters per second. All motors should be controlled in a closed-loop mode that can react to a deviation from the set point value in under 5 mS.

The 6 encoder values / single axis encoder value (master) are streamed to a separate data acquisition system. The timestamp information can be added at the MCU or DAE, but both systems should have synchronised clocks to under 2mS. The data rate required for encoder sampling is 50Hz, therefore one sample every 20mS.

3.3.4 Scan scenario with 6 motors



3.4 Low Performance – Application Use Case C – Beam Aperture Slit Set

3.4.1 Background

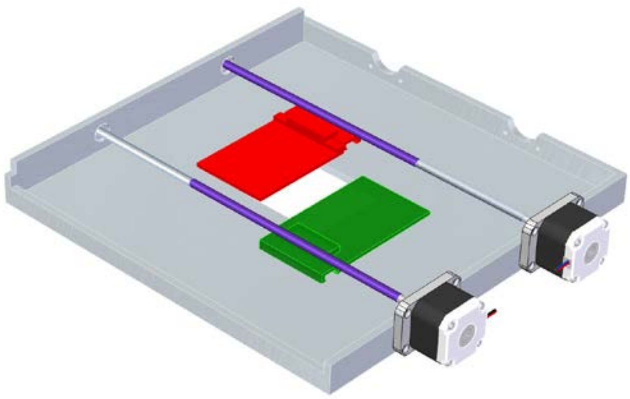
A Slit Set is one of the most common motion components in operation on the ISIS beamline instruments. This component is used for defining the beam aperture. The jaws will consist of four independently controlled axes of motion (consisting of two Y and two Z axes) mounted upon a structure. Each axis will drive a neutron absorbing 'blade' in order to define a neutron beam to the required rectangular aperture.

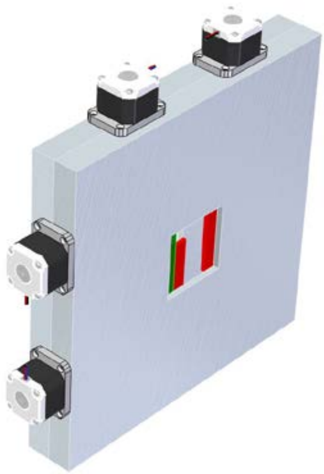
3.4.2 Motion Control

Type of Drive	Stepper or DC Servo Motors
Speed	5mm/s (minimum)
Positional Accuracy	± 10µm Locally (over full range)
Positional Repeatability	± 10µm Locally (home position from a high precision limit switch)
Travel Restriction	Limit switch at both ends of all axes
Type of Encoder	Linear Incremental Encoder or Mechanical Resolver (High Radiation Area)
Power Off Condition	Self-supporting mechanism capable of holding blade mass without a brake. Resolvers live at all times.

3.4.3 Basic Slit Set Model

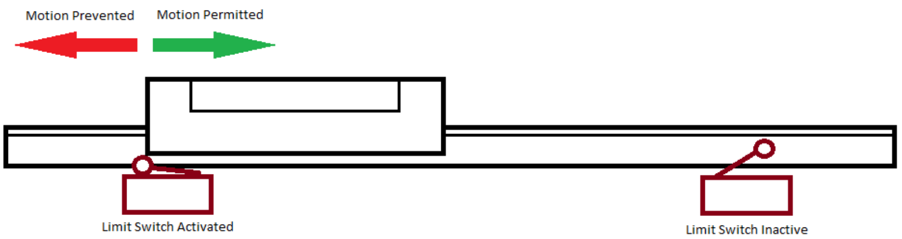
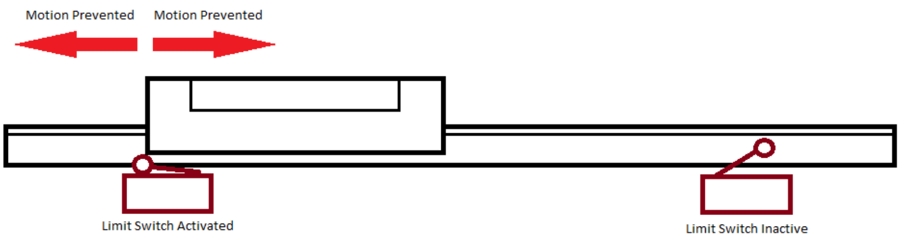
The slit set is made up of a 'horizontal' and a 'vertical' assembly that are bolted together to form one component.





4 Appendix B

4.1 Glossary of technical terms

1 -Virtual Machine	ISIS Instrument control systems run as software emulated "virtual PC" systems on hardware "host" servers of differing physical architectures. The virtual machines will only have access to network connections (up to 1Gb/s or 10Gb/s) and network based serial communication servers (RS232/485/422).
2 -User Mode Driver	Generally, access to network or serial "COM port" based solutions from a virtual machine do not require software drivers to have "system" or "kernel" driver privileges on the virtual PC. Software bugs in driver systems in Kernel or privileged mode may crash the communicating ISIS PC performing other critical operations and will be avoided where possible. Please note that this does not necessarily apply to system privileges needed to install the software (which may be just a security requirement).
3 - DAE	The STFC developed Data Acquisition Electronics that processes the information collected from experiment neutron detector elements.
4 - Limit Switches	On many axes, limit switches are used to both inhibit motion and act as a reference point during homing routines. To be compatible with these axes, the MCU should employ limit switches in such a way that motion is exclusively prevented in the direction of travel when they become engaged, whilst allowing motion back away from the switch." Good:  Bad: 

5 Appendix C

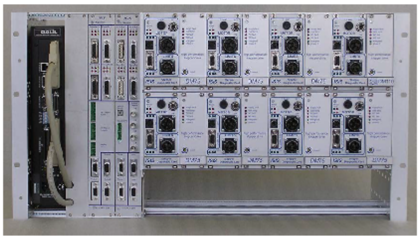
5.1 ISIS Standard 1st Generation MCU – System Handbook

Double click on the front page below to open the 35 page .pdf document

Technical Specification
of the ISIS
Standard Motion Controller.

Version 7.8 Sept 2012

Piezo data added
Low current servo added
Optional 5V supply from limit switch connector on diagnostic card added
Added piezo link back pin
Optional +24v for limit switches
Revised ABCD card front panel legend for digital inputs
Correct Appendix H 15 pin D pin 15 – Analog I/P
7.5 Interlock pin on servo diagnostics added
7.8 Notes on digital input power conflicts added



V7.8 DLC

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