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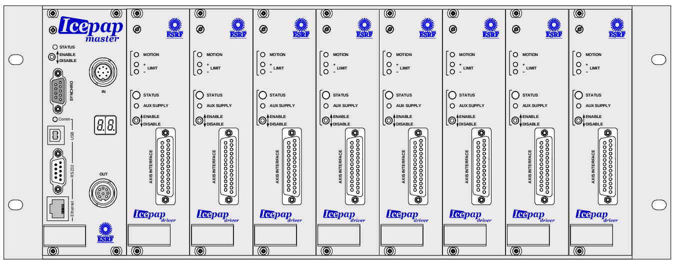
Icepap

Intelligent Controller for Positioning Applications

User Manual



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CONTENTS

MANUAL ORGANIZATION

This manual presents the IcePAP motor control system environment, the different components, their configuration and the command set.

Section 1 gives a brief overview of the different elements of the system and provides with information required for installation of an IcePAP system. The description is made in general terms and specific technical details are minimised.

Section 2 describes the main IcePAP concepts and functionality.

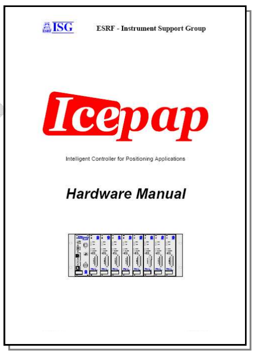
Section 3 details the driver configuration going through all the set of parameters.

Section 4 covers the different aspects of the IcePAP system communication protocol, giving details on types of commands, interfaces, syntax conventions and others.

Section 5 is a reference chapter that contains the full set of IcePAP commands with their description and some usage examples.

Related Documentation

- *IcePAP Hardware Manual*
  Presents in detail the components and functionality of the IcePAP system and provides a complete connector description.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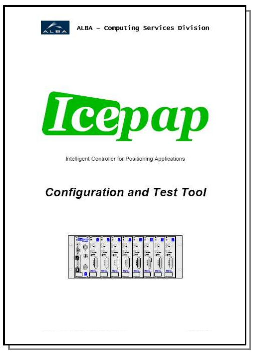
- *IcePAP Configuration and Test Tool*
  Describes the GUI tool used for driver configuration and testing.


ALBA - Computing Services Division
Icepap
Intelligent Controller for Positioning Applications
Configuration and Test Tool

1. INSTALLATION

1.1. System overview and IcePAP components

IcePAP is a motor control system developed at the ESRF and optimised for high resolution position applications. An IcePAP system may drive up to 128 axes and integrates both control features, like trajectory generation, and the motor power management. Although motor control in IcePAP is axis-oriented, it includes system resources that allow the execution of synchronous multi-axis movements. In addition, all the position information signals are driven through internal multiplexers and can be sent to external devices to properly synchronise data acquisition during motion.
Besides high performance, IcePAP is fully software configurable and provides exhaustive diagnostic capabilities. Most of the functionality relies on programmable components what opens the possibility of adding new features by means of firmware upgrade.

The components of an IcePAP system are organised in racks. The mechanical support of each rack is provided by a 19” 3U crate that includes the power supply and an interconnection backplane with nine board slots.
The leftmost slot is wider than the others and must be always equipped with a controller board. The remaining slots may be equipped with up to eight driver boards. Each driver board can operate a motorised axis.
The unused slots must be covered with blank front panel plates to avoid accidental access to internal parts with electrical power.

Figure 1 depicts an IcePAP crate populated with 5 driver boards.

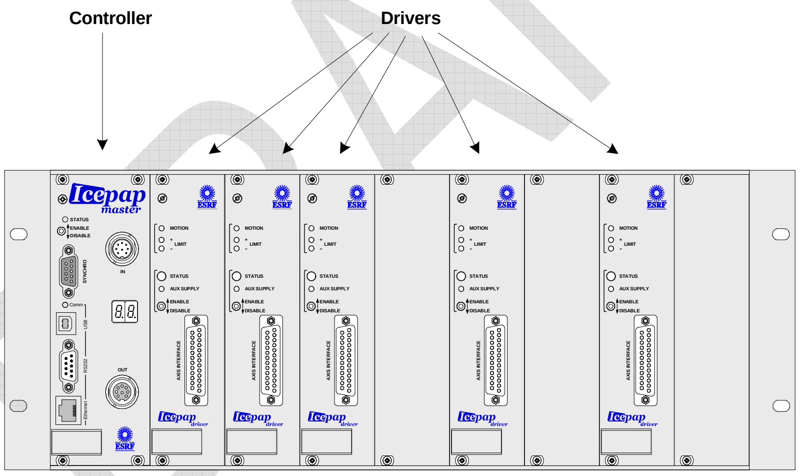


Figure 1: Example of a partially equipped IcePAP rack

Several racks can be connected to form a single multirack IcePAP system. Each rack must be identified with a different number that is visualised in a two-digit display at the front panel of the controller board.
From the point of view of hardware implementation there are two types of controller boards: MASTER and SLAVE. MASTER controllers have additional hardware resources such as a communication processor and certain connectors that are not available in the SLAVE controllers.
An IcePAP system must always include a MASTER board that plays the special role of system master controller and takes care of system management and communication with the host computer.

A more complete description of the IcePAP system and its hardware resources can be found in the *IcePAP Hardware Manual*.

1.2. Hardware connections and configuration

1.2.1. Rack number

Each rack in a multirack system must be identified by a different rack identification number from 0 to 15 that is unique within the same IcePAP system. The rack that contains the system master controller must always be set to number 0. Therefore in the case of single rack systems, the rack number has to be always set to 0.

The identification number of each rack is selected by a rotary switch located at the crate backplane behind the controller board at the leftmost slot. In normal operation the rack number is shown at the from panel display of the controller board as a decimal value. In order to access the rotary switch and change the rack number, the power must be switched off (power switch at the back of the crate) and the controller board extracted. The rack number is selected by the rotary switch in hexadecimal values.

1.2.2. Board installation

Once the rack numbers have been properly selected, the crates can be populated with IcePAP boards. Each rack must include a controller and up to eight driver boards. Controller and driver boards do not required any particular intervention for hardware configuration and, with exception of the Ethernet connection of the system master controller, controller boards do not require any kind of functional set up. Driver configuration is fully described by software parameters as presented in section 3 and can only be modified by mean of software commands, preferably by using the IcePAP configuration tool. (see *IcePAP Configuration and Test Tool* document).

The controller in rack 0 must always be a MASTER board to be used as system master controller. In multirack systems the other rack controllers operate always as slave devices regardless of whether or not they are physically MASTER or SLAVE boards. While a MASTER board can be installed in any rack and operate as slave controller if needed, a SLAVE board can never operate as system master controller and must never be inserted in rack 0.

When a driver board is installed the first time in an IcePAP rack or moved from one slot to a different one, the board becomes not active as a security measurement. This has as a consequence that the motor power cannot be switched on and the associated axis cannot be moved before the driver configuration is validated and the axis reactivated (see 3.1).

1.2.3. Rack interconnection and termination

Multi-racks system needs cable links that extend the internal communication bus following a daisy-chain scheme across all the racks in an IcePAP system. This bus extension is implemented by cables that link the OUT connector of a controller board in one rack with the IN connector of the controller board in the following rack in the chain. This interconnection can chain the racks in any arbitrary order, the rack numbers are not relevant in this context, but the total length of all the link segments must not be more than 30 meters. The internal communication bus of any IcePAP system, even in the case of a single rack, must be equipped with a bus terminator connected at one of the ends of the interconnection chain. This is achieved by plugging the bus terminator either at the IN connector of the first controller in the chain, often the master, or at the OUT connector of the last controller board in the chain. The wiring details and the hardware terminator are described in the *IcePAP Hardware Manual*.

[ADD simple scheme/drawing example with two configurations: 3-racks and single rack, showing terminators, picture of terminator?]

1.2.4. Rack disable

Each rack includes a disable connector at the rear panel that allows disabling remotely the motor power of all the driver boards in that rack. By default, the polarity of the disable circuitry is of type NC (normally closed).
If the rack disable feature is not used in a particular installation, it is good practice to install a dummy plug in the rack disable connector to shortcircuit the disable line.

Each full system has a default polarity value (NORMAL = normally closed, INVERTED = normally open). All the rack controllers receive this polarity at start-up from the master controller. The rack controllers use the default polarity except those that have been assigned explicitely a different polarity.

The default polarity of a system can be changed with the RDISPOL command.
The RDISPOL command allows also to force the use of a default polarity in all the racks of the system, or to change the polarity of a single rack.

For more details on the RDISPOL command, see the command reference (chapter 5).

1.2.5. Communication links

Remote access and control of an IcePAP system can be achieved through one of the communication interfaces of the system master controller plugged in rack 0. Although a multirack system may include more than one MASTER board as rack controllers, only the board operating as system controller in rack 0 can be used for communication and system control. The other MASTER boards operate as slave controllers and do not activate their communication ports.
The interfaces and main functional parameters are summarised in the table.

Interface	***Type***	***Parameters***
Serial Line	**RS232**	9600 bauds, no parity, 1 stop bit
Ethernet	**100baseTFullDuplex**	TCP sockets, port 5000
Universal Serial Bus	**USB 1.0**	Not implemented

The interfaces currently available are RS232 and Ethernet. The connectors are accessible at the front panel of the system master controller and the wiring and connectivity details are compiled in the *IcePAP Hardware Manual*. The functional configuration of the RS232 port is fixed as described in the table while the possible configuration methods of the Ethernet port are discussed in 1.2.6. The communication protocols and syntax conventions are described in section 4.
Note that although the hardware of the USB port is functional, this interface cannot be used with the current firmware and there are no plans to implement this control interface in the future.

1.2.6. Ethernet IP configuration

The IcePAP system controller requires an IP configuration of the Ethernet port that is compatible with the parameters of the local network to which it is connected. Once the controller has a valid IP configuration, it can be accessed from any computer in the network. IcePAP accepts multiple simultaneous connections from different computers. If that can be seen as potential security issue, it is possible to restrict partially the access to a particular IcePAP system by setting the controller to reject commands that come from computers that are not in a certain range of IP addresses (see IPMASK command).

The last IP configuration is always stored in the non volatile RAM of the system controller. At power up, if the configuration values are not changed, the system controller reuses the previous IP configuration. There are various methods to modify the IP configuration but whichever is used, when the IP configuration changes, the system controller writes the new values in its non-volatile memory and reboots to reinitialise the network parameters. This process takes about 30 seconds.

The IP configuration can be modified by using either a DHCP server or the external application “ipassign”:

DHCP Server

The DHCP server must listen the local area network (LAN) where IcePAP is connected and be configured to answer requests from the MAC address of the master controller. This address is unique and is written on a label on the embedded processor module in the system master controller board (ex: 00-0c-c6-69-13-1c). The DHCP server must be set to provide the following information:

• Hostname	(ex: iceid321)
• IP address	(ex: 160.103.52.202)
• Netmask	(ex: 255.255.255.0)
• Gateway	(ex: 160.103.52.99)
• Broadcast	(ex: 160.103.52.55)

“ipassign” Tool

The application “ipassign” is a tool specifically designed for IcePAP at ESRF. It uses the Multicast Protocol to communicate with a master controller. Therefore, even if the previous IP configuration is not valid, “ipassign” will be able to automatically detect any IcePAP master on the network and configure it.

1.2.7. Motor and encoder connection

The motor and encoder connections are described in the *IcePAP Hardware Manual*. As power and control lines are combined in the same cable and connectors, it is particularly important to respect proper grounding techniques during the cabling of the electromechanical components and in particular not to break the continuity of the external and internal cable shieldings from the motor connector down to the motor housing.

By default the disable pin of the motor connector must be connected to the ground pin unless an external axis disable specific circuitry is used. Leaving the disable line unconnected may prevent the driver board to switch on the motor power and inhibit the operation of the axis.

An IcePAP driver has three encoder inputs that accept position encoder signals: two at the rear panel “Encoder” connector and another one at the front panel “Axis Interface” connector. The rear panel encoder inputs are named EncIn and AbsEnc in the IcePAP firmware. The first one accepts incremental encoder signals while the other one implements a SSI absolute encoder interface. The front panel input is also an incremental encoder input and is named InPos.
From the point of view of functionality, all the encoder inputs are interchangeable. See the explanation about functional encoders in 2.1.6. In most of the simple applications that include a single position encoder, it is usually preferable to connect the encoder at the rear of the rack either at AbsEnc or EncIn inputs depending on whether the encoder is absolute or incremental.

1.2.8. Ventilation

IcePAP racks do not include internal fans or other method for forced ventilation. External ventilation may be necessary in case of installation in enclosures with reduced air circulation such as 19’’ cabinets.

1.3. Installation tips

[TO BE COMPLETED]

- Check that the master front panel “COMM” led is green which means that the controller is ready to communicate over the Ethernet and the serial line

2. OPERATION INSTRUCTIONS

2.1. IcePAP concepts

2.1.1. Systems and boards

As explained in 1.1, an IcePAP system may include a variable number of driver boards organised in several racks. Every rack in the system must have a unique identification number that is displayed in the front panel of the rack controller board. The controller board in rack number 0 acts as system master controller and manages communication and system functionality. The communication cable (RS232 or Ethernet) must be plugged into the corresponding connector of the system master controller.

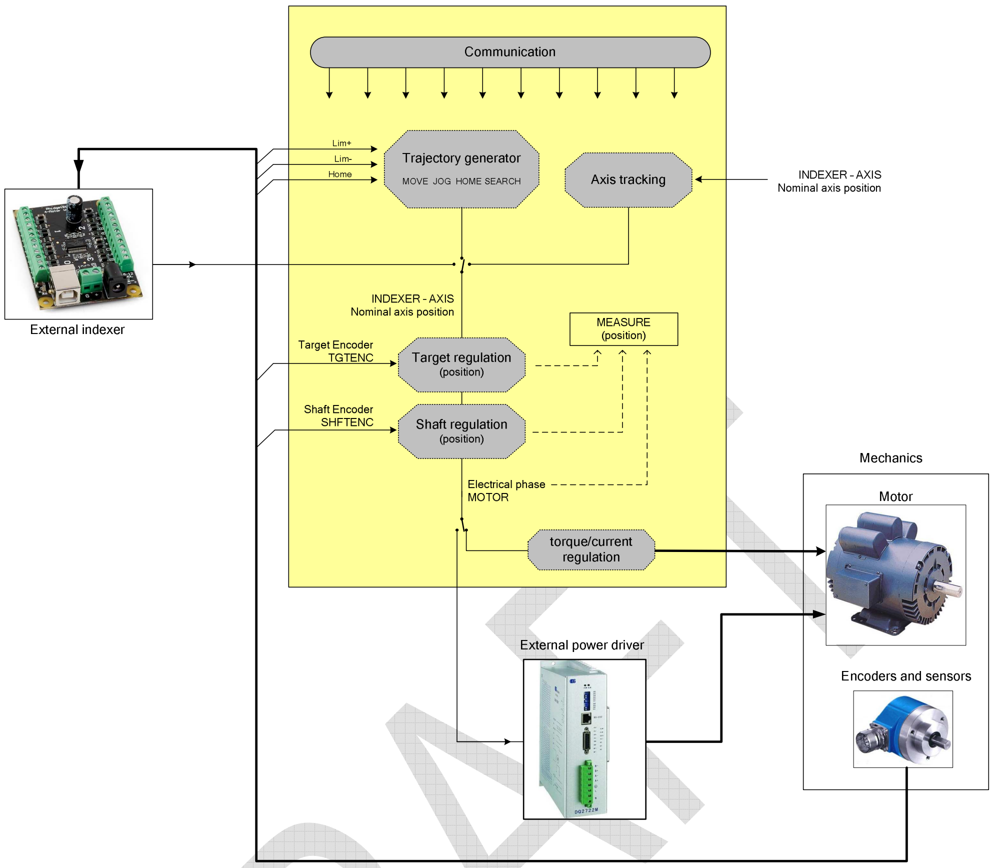
Each board in the system, either driver or controller, has a unique address *A* that is the decimal number formed as $A = 10\times R + S$, where *R* is the rack number and *S* is the slot occupied by the board in the rack. Rack controllers always occupy the slot 0, while driver boards are installed in the slots 1 to 8. With this convention the last decimal digit of the board address easily identifies if the board is a controller or a driver and its slot number. The address 0 is always assigned to the system controller.

The system controller receives and processes ASCII commands from the host computer. If a command includes a prefix starting by a numeric board address, it is considered as a board command and is dispatched to the corresponding board for execution. Board commands can be addressed to both controllers and drivers. If the command does not include an address prefix, it is considered as a system command and is directly processed and executed by the system controller.
Commands that request an answer from an IcePAP module always start by a question mark character ('?') and are often called "queries" in this document.
It is also possible to address board commands to all the boards in the system by using a broadcast mechanism. See chapter 4 for more details on the communication protocol and the command format.

When a system and a board commands have analogous functionality, they usually share the same name. However, as system and board commands are processed in a different way and produce different results, they should not be considered as being the same command. System commands and board commands are grouped in two sets that are presented in chapter 5.
Some board commands are not implemented in rack controllers and can only be executed by driver boards. Note also that the system master controller executes both system commands as well as board commands sent to the address 0.

At any time the host computer may obtain information about the current configuration of an IcePAP system by issuing ?SYSSTAT system queries. This query reports information about the racks connected in the system, the driver boards plugged in each rack and if the plugged boards are responsive or not.

Another useful system query is ?MODE that returns the current functional mode. In normal operation conditions an IcePAP system must be always in OPER mode (see ?MODE system query). Other system modes are useful only for maintenance interventions such as firmware reprogramming or factory testing. Every board can also return its individual mode by the ?MODE board query. The only cases in which the board mode may be reported as different from the system mode are either when a driver is being configured (CONFIG mode), or when there is an unrecoverable hardware failure that switches a driver board into FAIL mode.



2.1.2. Motor types and built-in power stages

Although an IcePAP driver can be configured to drive a motor by using an external power module, in most of the cases the driver boards operate by using their built-in internal PWM amplifiers and motor power regulation schemes.
With the current firmware release, the IcePAP power drivers support current regulation of two motor phases what is sufficient to drive most stepper motors. Support of three-phase motors and torque regulation is foreseen in future firmware releases and will open the use of IcePAP to various kinds of DC and brushless motors as well as three-phase steppers without the need of external power drivers.

In addition to allowing current regulation and measurement over a rather wide range of values, one particularity of the IcePAP built-in power stage is the possibility of programming also the operating voltage of the output PWM amplifiers. This extends the capability of driving properly motors of quite different electrical characteristics with the same hardware module.

2.1.3. Driver configuration

IcePAP drivers are highly configurable boards. All the internal functional parameters, such as power and regulation settings, functional modes or I/O and encoder configuration can be set and modified via software commands. The detailed description of the configuration procedure and parameters is presented in chapter 3.
The configuration is stored permanently in the non-volatile memory of the driver boards and can be retrieved at anytime via the ?CFG query. It must be noted that the rack controllers do not require any particular functional configuration.

A convenient way of checking and changing the configuration of IcePAP drivers is by using the graphical tool *IcepapCMS* that eases considerably the configuration procedure and stores the configuration data in an external database for backup purposes. Using *IcepapCMS* is particularly appropriated when it is needed to manage a large number of IcePAP systems and axes. (see *IcePAP Configuration and Test Tool* document for further info on that procedure).

2.1.4. Enabling and disabling axes

Prior to any axis movement, the drivers must be active and the motor power must be switched on. Axis activation is requested by setting a flag in the configuration parameters. The activation state can be checked at any time during operation with the ?ACTIVE query. If an axis is not active, most of the commands addressed to that axis are rejected, the motor power cannot be switched on and the axis is inhibited. The activation flag of an axis can be intentionally cleared by changing the ACTIVE configuration parameter, but the flag is also cleared automatically when the driver board is installed in a new system or if it is moved to a different rack or slot in the same system. This feature prevents switching on the motor power or using a driver board that has never been configured after being plugged in a new slot.

Once the axis has been properly configured and activated, the motor power can be switched on (see POWER command). The advent of any alarm condition (see ?ALARM command in chapter 5 for more information) will switch motor power off again. The alarm condition must be removed in order be able to switch the motor power back on. Examples of alarm conditions are overcurrent conditions, external alarm signals or excessive follow errors when a driver operates in position closed loop mode.

Alarms should not be confused with warnings. Warnings will not prevent the axis from being powered on, but might indicate non ideal conditions that could lead later to an alarm condition or damage the board (i.e. overtemperature).

A driver can be set to restore its previous motor power state after a rack power on/off cycle (see 3.1.1). If any alarm condition is present at power on, the axis will not proceed with the motor power on procedure even if it is configured to do so.

2.1.5. “Axis turn” as a reference mechanical displacement

The configuration of an axis requires as first step the definition of mechanical displacement that is taken as mechanical reference and that is called an “axis turn”. That name is chosen because in the large majority of applications the most convenient and intuitive reference displacement is a turn of the motor. However in certain cases it may be more convenient to use other reference displacement such for instance one revolution of a gear box output shaft or one turn of a transmission screw in the mechanics. In the case of linear motors, the reference displacement necessarily corresponds to a certain linear displacement of the mechanics. However, regardless of whether the motor is rotary or linear and which reference displacement is adopted, that reference displacement is always called “axis turn” in IcePAP terminology and is used to configure the conversion of electrical to mechanical units as well as the resolution of the axis and any encoder that is connected to the board.

The “axis turn” can be chosen freely based on application convenience and the only requirement is that the displacement must correspond to an integer number of full electrical periods of the motor. The conversion of electrical to mechanical units is then simply defined by expressing the number of electrical periods that correspond to one “axis turn”. If the “axis turn” for a rotary motor is chosen to match exactly one motor turn, then the number of electrical periods corresponds to the number of pole pairs in the motor. That is why the number of electrical periods in one “axis turn” is considered to be the number of effective “axis pole pairs” in IcePAP. See 3.1.1 and 3.1.3 for more details on the configuration parameters.

As an example, in a conventional two-phase stepper motor with 200 full-steps per turn, four per electrical period, if the “axis turn” is taken to match one motor turn, the axis must defined as having 50 “axis pole pairs”.

2.1.6. Physical and functional encoders

Each driver board has three encoder inputs named EncIn (rear incremental encoder input), InPos (front axis connector) and AbsEnc (absolute SSI encoder input at the rear encoder connector). The encoders connected to those inputs are referred in the documentation as physical encoders and do not have assigned any predefined function in the control of the axis.

The driver may use the position values of the physical encoders for a variety of purposes but the function of each encoder must be selected first by setting the appropriate configuration parameters. Instead of selecting a particular function for a specific encoder input, the configuration of an IcePAP axis uses the concept of *functional encoders*. A functional encoder is a generic name used to represent a specific internal function. The assignment of specific functions to the physical axis encoders is then achieved by selecting which encoder input is used for each particular functional encoder. The functional encoders in an IcePAP axis are the following:

Target Encoder (TGTENC): This functional encoder is supposed to monitor the final position of the mechanics and may be used for position regulation in closed loop operation.

Shaft Encoder (SHFTENC): This encoder is required to measure the motor shaft position for torque control algorithms. It can be also be used for position regulation.

Control Encoder (CTRLENC): The IcePAP driver uses this encoder as a hardware protection mechanism. The driver monitors the axis operation and trip alarms if the discrepancy between the control encoder and the axis position exceeds a certain safety value.

If any of the functional encoders is not assigned to a physical encoder input, the specific functionality associated to that encoder is usually disabled.

2.1.7. Axis and encoder resolution

The position resolution of an IcePAP axis is determined by defining the size of one *axis step*. The *axis step* unit is used to report axis positions and position errors as well as to define parameters such as velocities. All displacements and position values in movement commands are expressed in such units.

The *axis step* is defined during the configuration of the driver board by selecting arbitrarily the increment of the motor electrical phase that corresponds to such a step. The choice of the step size can be actually independent of the motor and the encoders associated to that axis although in the cases of axis operating in closed loop modes it is convenient to select values that are consistent. By defining a very small *axis step*, the IcePAP resolution can be higher than the actual mechanical resolution of the axis, however the use of excessively high resolution values is discouraged because it is both useless in practice and can be a potential source of problems such as producing position overflows that may be difficult to track and debug.

Comment [j1]: One might wonder here what is 'excessively high'. The way it is explained requires giving a reference for the range of values

Expressing positions in steps allows to present axis positions to the user as 32-bit integer values that are interpreted as number of axis steps as in the large majority of motor controllers. All encoder positions are also represented as signed 32-bit integer values.
However the driver board converts and manages internally all positions as 64-bit fixed point values in electrical units that are completely independent of the actual resolution of the encoders or the arbitrary definition of the axis step. This approach provides calculation resolution that can be considered unlimited in practice, allows combining in the same driver encoders of different step size than the axis and allows for instance certain closed loop operation modes with effective position resolution that is smaller than one axis step.

As it is detailed in 3.1.3, the effective size of an *axis step* in IcePAP is determined by defining the total number of such steps that correspond to a given number of "axis turns". An "axis turn" is not necessarily equal to a motor turn as discussed in 2.1.5. However, whenever it is possible, it is a good practice to set the "axis turn" equal to one motor turn and define the *axis step* by specifying the total number of steps per motor rotation.

The same scheme used to select the axis step must be used to configure the resolution of any physical encoder connected to an IcePAP driver as explained in 3.1.3. The resolution of each encoder is configured independently as the total number of actual encoder steps that corresponds a certain integer number of “axis turns”. It must be taken into account that the “axis turn” may not match the encoder turn.

As the encoders connected to the same driver board can have different resolution that can in addition be different from the nominal resolution of the axis as defined by the *axis step*, there are two different commands, ?ENC and ?POS, to retrieve the current position of the encoders. ?ENC returns the position of an encoder in the particular units of that encoder while ?POS returns the encoder position as its equivalent in axis steps.

2.1.8. Nominal axis, measured and motor positions

The *axis position* of an IcePAP driver is the value used for movement commands and reported by default by the ?POS and ?FPOS queries. The nominal position is expressed by default in axis steps and in normal operation it only changes during axis movements. The axis position does never change when a movement is finished and the axis is idle.
In addition to the nominal position, a driver manages a *measured* axis position. The measured position is obtained from the target or shaft encoders that are assigned to that axis. If both functional encoders are defined, the target encoder is used. If no target or shaft encoders are defined, the driver reports the nominal axis position as the measured position. The measured position can be obtained with the ?POS MEASURE and ?FPOS MEASURE queries for instance. When the measured position is actually retrieved from a physical encoder, its value may change of fluctuate due to mechanical drifts or electronics noise even if the axis is not moving.

The measured position is usually used for reporting purposes. At the end of each movement it may differ from the actual nominal axis position in particular if the axis operates in open loop. If this discrepancy is not desired, it is recommended to set the axis to operate in position closed loop. If in a particular application closed loop operation is not appropriate, the driver can be instructed to replace at the end of each movement the final axis position with the actual measured position (see 3.1.4). This feature is however strongly discouraged and should be only used to cope with limitations of the host computer software.

In closed loop modes, the driver board has to adjust the electrical phase of the motor to compensate for errors in the position of the mechanics measured by the encoder. In these cases the motor electrical phase does not match in general the nominal position of the axis and, in addition to the nominal and measured positions, the driver board must manage the motor electrical phase as a different position value. Although such a motor position is in general an internal value of little practical interest for the normal operation, it can be used for diagnostic and retrieved with the ?POS MOTOR query. In open loop operation, the motor position should always match the nominal axis position.

2.1.9. Closed loop operation

The position closed loop is an integral correction algorithm that forces the target encoder signal to follow the nominal position of the axis. Closed loop operation is activated by selecting the functional encoder to be used as feedback device. Various additional parameters introduced in 3.1.4 allow to fine tune the closed loop mode although not all of them need to be always configured. Only the regulation time constant and the maximum acceptable follow error are critical for setting up closed loop operation. Depending on the setup some times it is also convenient to configure a deadband in which the correction algorithm is disabled.

Two bits are updated in the status of each axis to provide information on the position closed loop behaviour. The *inwindow* bit is active if the position is inside a configured window around the nominal position. The *settling* bit will be active after a movement until the error is smaller than a configured value for a configured amount of time.

2.1.10. Trajectory generation and motion modes
The different motion modes, described in 2.2, are various ways of changing the current axis position:

- Target position (point to point)
- Target velocity (jog)
- Homing
- Tracking (external indexer)
- Variable regulation (external feedback)

2.1.11. Status and diagnostics
Only intro here, detailed description in 2.4
- status register
- diagnostic commands
- data recording facility

2.1.12. I/O signals
- *Info signals*

Each driver has 3 digital outputs (InfoA, InfoB, InfoC) that can be configured to reflect different information inside of the driver board. They can be set to high or low from an external command. See INFOA command for all the available values.

- *OutPos output signal*

Besides the digital outputs, there is also a position output signal (OutPos) that can be used to export any position source to other hardware. The possible signals presented at OutPos are listed in the description of the OUTPOSSRC configuration parameter.

- the driver can output its internally generated trajectory via the OutPos source signal available in the 25pin front connector (check *IcePAP Hardware Manual* document) to an external amplifier, what can be useful in situations where IcePAP drivers might not be able to steer the targeted axis (because the motor type or power is outside of IcePAP specs).

2.1.13. Advanced functionality
Only intro here, motivation and few concepts, detailed description in 2.3

- I/O multiplexer
- Electronic cam
- Position control
- Parametric movements

2.2. Moving motors

2.2.1. Basic movements

In the most usual case, the various IcePAP axes are operated as independent channels via commands like MOVE (absolute), RMOVE (relative), JOG
The current status of the motion is reflected in the status register and can be retrieved with the commands ?FSTATUS and ?STATUS

2.2.2. Homing and search sequences
Each driver has the possibility to latch all of its position sources at a specified event. This capability is used in two built-in commands that start a sequence that will search the position of an external reference signal, thus allowing finding an absolute position of the axis.

Any IcePAP axis can be configured to look for a mechanical reference that can be used as position origin of the axis. The usual source of the home signal (from the motor connector or via the different encoder sources), its electric type (level, pulse, edge,…) and the speed of the axis during the procedure can be stored as parameters. The different positions in the system can be latched upon reference crossing and position can be reseted to a fix value in an automatic way too (see HOMESRC and any HOME* parameters for more details).

2.2.3. Tracking modes (external indexer)

[IN DEVELOPMENT]
In most of the cases a driver will be operated by using its internal indexer to generate the motion trajectory, velocity profile, etc. It is possible however to bypass the internal indexer and drive the motor using pulses coming from an external device such as another IcePAP driver or a multiaxis controller. The actual indexer used by a particular driver can be changed during operation by a user command but the default indexer that is used after power on or after driver reset must be selected by the parameter INDEXER. As mentioned above in most of the cases the default indexer will be set to INTERNAL.

2.2.4. Variable regulation (external feedback)

The position of the axis is regulated in order to cancel the error in an external arbitrary variable with respect to a given setpoint. This mode must be explicitly configured and started during operation by the VCONFIG and VMOVE commands respectively, and not during configuration phase. The current value of the external variable can be transmitted either by mean of an unused encoder input or by a software command (see VVALUE command).

2.2.5. Multiaxis and group movements

Multiaxis motion commands. It is possible to move several axes by using the system motion commands MOVE, UMOVE, RMOVE, JOG and HOME. The multiaxis versions of these commands first check that all the axes in the parameter list can be moved as instructed. If there are invalid parameters or any of the movements cannot be started, the command fails and returns an error. Only once the initial check is successful, all the axes start their movements simultaneously.
The progress of the movement can then be followed by monitoring the status register of the individual axes. It is possible however to read the status of a set of axes by using the ?FSTATUS system query.

Axis groups. Once a multiaxis movement is started, by default every axis is managed as independent from the others. The motion of a given axis finishes either when the motion sequence is completed, when the driver receives a stop command or if a limit switch, an alarm or an error condition is found.
This default behaviour can be changed if the GROUP keyword is used as a flag in the multiaxis command. In that case all the axes included in the same multilink command are not only started simultaneously but are also internally linked as an active group. Whenever any of the axes in an active group is stopped by a STOP command, a limit switch or an alarm condition, all the other axes in the group are forced to stop immediately.

2.2.6. Parametric motion

[IN DEVELOPMENT]

2.3. Advanced features

2.3.1. Motion synchronisation

Use of tracking modes. [TO BE DEVELOPED]

Synchronisation with external signals. [TO BE DEVELOPED]

Linked axes. A special case of multiaxis operation with a single degree of mechanical freedom [TO BE EXPLAINED].

2.3.2. Position control (control encoder)

2.3.3. I/O multiplexer

- *OutPos output signal*

Besides the digital outputs, there is also an position output signal (OutPos) that can be used to export any position source to other hardware. The possible signals presented at OutPos are listed in the description of the OUTPOSSRC configuration parameter.

- the driver can output its internally generated trajectory via the OutPos source signal available in the 25pin front connector (check *IcePAP Hardware Manual* document) to an external amplifier, what can be useful in situations where IcePAP drivers might not be able to steer the targeted axis (because the motor type or power is outside of IcePAP specs).

2.3.4. Electronic cam

[IN DEVELOPMENT]

2.4. Diagnostics

2.4.1. Status registers

The status of each IcePAP board is compiled in a 32 bit register that can be read by the ?FSTATUS, ?STATUS and ?VSTATUS queries.
The ?FSTATUS query returns the board status that is stored in the master controller and therefore present the shortest response latency. It is the recommended query for intensive polling applications.
The ?STATUS query returns the status register read directly from the individual board and therefore guarantees the most updated values.
The ?VSTATUS query reports the board status information in a verbose form that is intended for diagnostics and assistance to application programmers.

The status information consists of a number of status bits and fields that are summarised in Table 1 and described below:

PRESENCE: This field reports if the board is found to be physically present in the system, if it is alive and communicates properly and, in the case of drivers in normal operation, whether or not the board is in configuration mode. Note that the status of not present boards can be obtained from the system by ?FSTATUS query.

MODE: This field represents the current functional mode of the board. See the ?MODE board query for more details.

DISABLE: This field is set to a non zero value if the motor power is disabled. The power can be enabled and disabled by the software POWER command or by the front panel switches. It can also be permanently disabled if the axis is configured as not active, by one of the external disable signals or if an alarm condition happens. In case of alarm conditions, the

STOPCODE field provides more details about the reason of the alarm. See 2.4.3 for more information about alarm sources.

INDEXER: This field indicates if the axis trajectories are generated by the internal indexer, by an in-system indexer signal through the backplane or by and external indexer connected to one of the input position signals InPos or EncIn. It also indicates if the internal indexer is set to operate in linked mode.

READY: This bit is set when the board is ready to accept new motion commands. It must be checked before starting a new movement. If it is not set, the axis is still busy in an operation such as a point to point movement, a settling phase or in a homing sequence.

MOVING: This bit indicates that the axis is in motion. It must be used only for informative purposes and not to decide when the motion is completed and when the axis is able to accept new motion commands. Use the *READY* bit instead.

SETTLING: In closed loop, this bit is set during the settling phase and is cleared once the settling condition is met. See 2.1.9 for more details about closed loop operation.

OUTOFWIN: This bit is set if the axis position is out of the target position window. See 2.1.9 for more details about closed loop operation.

WARNING: This bit is set if a warning condition has been met. See 2.4.2 for more information about possible source of warnings.

STOPCODE: During movements, this field may vary following the deceleration phase or the status of complex movement sequences. However when the movement is finished and the bit READY is set, it indicates the condition that stopped the motion: the field is 0 if the last motion command completed successfully with no interruption. If the movement was interrupted or not even started, a value from 1 to 6 reports the reason. If the power is disabled because the board went into alarm state, a value from 8 to 15 indicates the specific alarm condition. Note in this last case, the *DISABLE* field must also signal that an alarm condition was met.

LIMIT+, LIMIT-: These bits report the actual logic level of the Limit+ and Limit- signals connected at the rear driver connectors.

HSIGNAL: This bit reports the logic level of the homing reference signal. Note that the homing reference signal is selected by the HOMESRC configuration parameter and it may be different from the driver Home signal connected at the rear panel.

VERSERR: This bit is set to if the version of the board firmware is not consistent with the firmware version of the master controller.

INFO: This field provides a progress monitor during the board programming procedures.

		DRIVER Status	***CONTROLLER Status***
Bit #	**name**	**value = description**	**value = description**
0-1	PRESENCE	0 = driver not present 1 = driver not responsive 2 = driver in configuration mode 3 = driver alive	0 = controller not present 1 = controller not responsive 2 = n/a 3 = controller alive
2-3	MODE	0 = OPER 1 = PROG 2 = TEST 3 = FAIL	0 = OPER 1 = PROG 2 = TEST 3 = FAIL
4-6	DISABLE	0 = power enabled 1 = axis configured as not active 2 = alarm condition 3 = remote rack disable input signal 4 = local rack disable switch 5 = remote axis disable input signal 6 = local axis disable switch 7 = software disable	0 = power enabled 1 = n/a 2 = alarm condition 3 = remote rack disable input signal 4 = local rack disable switch 5 = n/a 6 = n/a 7 = software disable
7-8	INDEXER	0 = internal indexer 1 = in-system indexer 2 = external indexer 3 = linked indexer	0 = internal indexer 1 = n/a 2 = n/a (status of multiplexer?) 3 = n/a
9	READY	1 = ready to move	1 = ready to move
10	MOVING	1 = axis moving	1 = virtual axis moving
11	SETTLING	1 = closed loop in settling phase	n/a
12	OUTOFWIN	1 = axis out of settling window	n/a
13	WARNING	1 = warning condition	n/a
14-17	STOPCODE	0 = end of movement 1 = STOP 2 = ABORT 3 = LIMIT+ reached 4 = LIMIT- reached 5 = settling timeout 6 = axis disabled (no alarm condition) 7 = n/a 8 = internal failure 9 = motor failure 10 = power overload 11 = driver overheating 12 = close loop error 13 = control encoder error 14 = n/a 15 = external alarm	0 = end of movement 1 = STOP 2 = ABORT 3 = n/a 4 = n/a 5 = n/a 6 = n/a 7 = n/a 8 = internal failure 9 = n/a 10 = n/a 11 = n/a 12 = n/a 13 = n/a 14 = n/a 15 = external alarm
18	LIMITPOS	current logic value of the Limit+ signal	n/a
19	LIMITNEG	current logic value of the Limit- signal	n/a
20	HSIGNAL	current value of the homing ref. signal	n/a
21	5VPOWER	1 = Aux power supply on	n/a
22	VERSERR	1 = inconsistency in firmware versions	1 = inconsistency in firmware versions
23	POWERON	1 = Motor power on	n/a
24-31	INFO	In PROG mode: programming phase In OPER mode: master indexer	In PROG mode: programming phase

Table 1. Driver and controller board status registers

2.4.2. Warnings

The ?WARNING command reports any warning condition in the system. See documentation of ?WARNING query for the different possible warning sources.

2.4.3. Alarms

The ?ALARM command reports any alarm condition in the system. See documentation of ?ALARM query for the different possible alarm sources.

2.4.4. Data recording

Any driver or master in the system has up to 1Mbyte of onboard memory. Most of this memory can be used for internal data storage (positions, currents) or other diagnostic purposes.[IN DEVELOPMENT]

2.5. Firmware reprogramming

Firmware packages contain binaries for the embedded Linux in the MASTER boards, the DSP and FPGA in controller boards and DSP and FPGA in driver boards.

A built-in command allows to program each of those binaries in each separate board, in all controllers, all drivers or in the whole system. See PROG command for more details.

2.6. Usage tips

Refer to Section 5.1 for all the commands mentioned below.

- It is quite common to have a situation where one wants to change an incremental encoder direction sign. This can be done easily by using the *INV* keyword in the correspondent channel configuration. Moreover, the *INV* keyword can be also used to change the polarity of the input signals.

2.7. Examples of driver configuration

The concept of axis turn is actually associated to a given number of electrical periods (pole pairs) and can be generalised to linear or geared motors as explained in 2.1.2. On a standard motor of 200 full steps (50 pole pairs), a resolution of 200 steps in 1 turn will imply movements with ‘full step’ resolution. For the same case, a resolution of 400 steps in 1 turn will imply movements with ‘half step’ resolution. For further microstepping, for example 16 microsteps per step, the values are 3200 (or 16x200) steps in 1 turn.

Let’s illustrate the different situations that might appear in a system with an example. Attached to the second shaft of a 400 full step per revolution motor moving some mechanics there’s an incremental encoder that generates 1600 encoder steps (sometimes referred in literature as encoder ‘counts’). The motor is connected to the first driver in a single crate IcePAP system. The encoder is connected to the EncIn rear incremental position input.

The first step is to configure the number of pole pairs to 100, since this is the mechanical parameter. The configuration of the resolution of the EncIn encoder source is also clear, 800 steps in 1 turn of the axis.

- If you want to move with ‘full step’ resolution, you will configure the axis resolution (the same as the indexer) as 400 steps in 1 turn. When you move 1 step, you will see your encoder readout changing 2 steps.

- If you want to move with ‘half step’ resolution, axis resolution should be configured as 800 steps in 1 turn. When you move your axis 1 step, you will see your encoder readout changing 1 step.

- If you would want to move with a resolution in positioning of a quarter of step, the axis resolution would be configured as 1600 steps in 1 turn. In order to see a change of 1 step in the encoder readout you would need to move now your axis two steps.

Once explained the resolution at axis and encoder units, how their relationship is established and how to configure it, it is interesting to add that IcePAP can supply the position of any encoder in the axis units. There are two main commands to query position in IcePAP, ?POS and ?ENC. ?ENC will always give the position of an encoder in the units of that encoder. ?POS will give the position of an encoder source as its equivalent in axis units. Back to the previous example, and assuming that before the movement all positions were zero and that you are using the internal indexer as axis position source, after the three movements listed above we would get the following readouts from the ?POS and ?ENC commands:

- 1:?POS would return 1, 1:?ENC ENCIN would return 2, and 1:?POS ENCIN would return 1 (if no steps were lost).
- 1:?POS would return 1, 1:?ENC ENCIN would return 1 and 1:?POS ENCIN would return 1.
- 1:?POS would return 2, 1:?ENC ENCIN would return 1 and 1:?POS ENCIN would return 2.

In the examples above, ?POS and ?POS ENCIN always return the same, and that's the way it should be in an ideal case, since both represent the angle turned by the shaft in the same units. The difference is that ?POS shows the steps that we wanted to make and therefore the steps that have been generated by the internal indexer and ?POS ENCIN shows the steps read by the encoder in the units of the internal indexer (axis units). In a real world case, friction could prevent the mechanical system to arrive to the final encoder mark what would result in a different output value for both commands.

The use of ?POS and ?ENC commands and different resolution for each position source might not result intuitive in the beginning. The need to be able to express the encoder steps in the units of the axis comes from position closed loop operation. In that case, the target position and the read position have to be compared in the same units. Inside IcePAP driver, the comparison is done in axis units.

3. DRIVER CONFIGURATION

The configuration of an IcePAP driver is defined by the values of a set of parameters that are stored in the non-volatile memory of the board. The complete list of configuration parameters as well as their types or possible values is compiled in 3.2.

The configuration parameters can be changed with the CFG command, but only if the driver has been previously switched into a special configuration mode with the CONFIG command. The driver configuration cannot be modified from regular operation mode. Once some of the configuration parameters have been changed, the CONFIG command can be used again to validate the new configuration and switch the driver back to operation. If the new configuration is not properly validated, all changes are lost when driver exits the configuration mode. See the description of the CONFIG command for details.

The ?CFG query can be used at any time to read back the current values of the configuration parameters.?CFGINFO is a utility query that allows to interrogate the driver about the type and possible values of any configuration parameter.

3.1. Configuration parameters

3.1.1. Motor configuration

Motor type
The type of motor must be specified by setting the parameter MOTPHASES to the actual number of electrical phases in the motor. This value must be one for DC motors and either two or three for steppers and brushless devices. Motors with a higher number of electrical phases, such as five-phase steppers, cannot be driven directly with the internal power amplifier in IcePAP drivers. [ONLY 2-PHASE IMPLEMENTED SO FAR]

In the case of two or three phase motors, the parameter MOTPOLES must be set to the number of electrical periods per axis turn. An axis turn, in IcePAP terminology, is the reference mechanical displacement that is used to define the axis and encoder resolution. It usually corresponds to a full rotation of the motor shaft, but for convenience it may be chosen as a different mechanical displacement as it is discussed in 2.1.5. In any case and whatever is the choice for an 'axis turn', it must correspond to the integer number of electrical periods specified in MOTPOLES.

Power control
The MREGMODE parameter is used to select the operation mode of the internal PWM power amplifier or the use of an external power drive. [ONLY CURRENT REGULATION (STEPPERS) IMPLEMENTED SO FAR]
The motor supply voltage of the internal PWM amplifier can be selected with the NVOLT and IVOLT parameters.

The nominal current value must be specified by the NCURR parameter. It is also possible to specify a boost current increment BCURR during acceleration and deceleration periods, as well as a reduced current ICURR when the motor is not moving.

The PID parameters of the current regulator can be set to predefined values with CURRGAIN parameter or individually selected with MREGP, MREGI, MREGD.

At start up or system reset, the motor power is off by default. This behaviour can be changed by setting the POWERON configuration flag to instruct the driver to go into the same power state, on or off, that it had before the system was powered down or reset.

Motion direction and limit switches

The definition of the sense of motion of the axis is fully determined by assignment of the limit switch control lines. When the axis moves in positive direction the mechanics must move towards the Lim+ switch. There is no way of inverting that assignment in the IcePAP configuration, but the actual direction of the motor can be reversed by changing the MOTSENSE value.

3.1.2. I/O configuration

Physical encoders

The two incremental encoder inputs EncIn and InPos can be configured to operate in either 2-phase quadrature or pulse/direction counting mode by setting the EINMODE and INPMODE parameters.

The absolute encoder inputs use a serial synchronous interface (SSI) that can be configured with the parameters SSIDBITS, SSICODE, SSISTATUS, SSICLOCK and SSIDELAY. The absolute values obtained from the encoder are always corrected by adding the fixed 32-bit offset value loaded in ABSOFFSET. This value must be set to zero for no correction.

In most of the practical cases, the sign of the encoders must match the sense of motion of the axis. If needed, the sign of the encoders can be inverted by mean of the parameters EINSENSE, INPSENSE and ABSSENSE.

Position signal output

The signal OutPos can be configured to output any of the internal position signals by setting the OUTPSRC parameter. The signal mode and pulse length if needed can be set with OUTPMODE and OUTPULSE. The signal can be inverted with OUTPSENSE.

The source of the auxiliary line OutPosAux can be selected independently with the parameter OUTPAUXSRC.

General purpose output signals

The signals InfoA, InfoB and InfoC can be used to output logic values related to the internal state of the driver such as READY, MOVING or ALARM, or the level of input control signals such as limit switches, Home signal or the encoder auxiliary inputs. Although this can be changed during operation, the default initial signal sources of those general purpose outputs can be selected with the INFASRC, INFBSRC and INFCSRC configuration parameters.

Polarity of I/O signals

The polarity of all the control and auxiliary input/output lines can be inverted by setting the corresponding parameters. This includes the limit and home switches (LPPOL, LMPOL, HOMEPOL), the encoder auxiliary/index lines (EINAUXPOL, INPAUXPOL, OUTPAUXPOL) as well as the general purpose output signals (INFAPOL, INFBPOL, INFCPOL).

3.1.3. Axis configuration

Axis name lock

The name of the axis is a character string that is stored in the non-volatile memory and is only used for identification purposes (see NAME command). The axis name is not a configuration parameter and by default can be changed at any time during operation. It is however possible to prevent changes of the axis name in operation mode by setting the NAMELOCK configuration flag.

Axis and encoder resolution

The resolution of the axis is arbitrarily defined by specifying the total number of steps ANSTEP that correspond to a given number ANTURN of axis turns. These two parameters

together with the 'axis turn' defined by value of MOTPOLES for a given motor, determine the effective size of each axis step.
In most of the applications with rotary motors, MOTPOLES is set to make the 'axis turn' correspond to one turn of the motor shaft. In those cases it is usually a good practice to set ANTURN to 1 and set ANSTEP to the desired number or steps per motor rotation. See 2.1.5 and 2.1.7 for a more elaborated discussion on position resolution in IcePAP and how to deal with linear motors.

The actual resolution of the encoders connected to the driver must be declared with the similar two parameter scheme: the total number of steps for a given number of axis turns. In this way the pairs of parameters (EINSTEP, EINTURN), (INPNSTEP, INPNTURN) and (ABSSTEP, ABSNTURN) allow to declare the step size of encoders connected to the incremental inputs EncIn, InPos and the absolute encoder SSI interface respectively. It must be noted that the number of turns always refers to the same 'axis turn' defined by MOTPOLES and not to rotations of the encoder itself.

Functional encoders
As explained in 2.1.6, the assignment of physical encoders to specific functionalities is achieved through the definition of functional encoders. The configuration parameters TGTENC, SHFTENC and CTRLENC specify the physical encoders that should be used as target, shaft and control encoders respectively.
The target and shaft encoders may participate to the measure of the position of the axis or motor shaft and be part of the position closed loop. The control encoder, if configured, will trigger an alarm if its difference with respect to the axis position exceeds a maximum value of steps given by the parameter CTRLERROR.

Axis activation and protection level
The ACTIVE parameter can be set to request setting or clearing the internal axis activation flag. This flag must always be set the first time an axis is configured.

The PROTLEVEL parameter is foreseen to implement additional levels of protection. [NOT IMPLEMENTED]

External input functional signals
It is possible to include logic signals coming from external devices in the determination of the logic state of the driver. The EXTBUSY parameter can be used to select an input signal that will be used to prevent the axis to go into ready state. The signals selected by EXTALARM and EXTWARNING contribute to the generation of alarm and warning conditions.
And in the case of using an external power amplifier, the EXTPOWER parameter selects the input that will indicate the power state of the amplifier.

The default use of an external trajectory generator can be selected by the INDEXER parameter.

3.1.4. Position control and motion

Axis position control
Although the velocity and acceleration time of the internal trajectory generator are usually set and changed during operation, the DEFVEL and DEFACCT parameters allow to define default values that are used at power on or after changes the motor configuration.
[Parameter to be deprecated: STRTVEL]

Comment [j2]: Why? Closed loop speed limit?

The POSUPDATE parameter can be used to instruct the driver to replace the axis position with the measured position by the measured position at the end of each movement. See 2.1.8 for details.

The driver can be included in a group of linked axes by setting the LNKNAME parameter to the name of group.

Homing configuration

The input signal used as mechanical reference during homing procedures can be selected among a list of available inputs by the HOMESRC parameter. The logic of the homing signal as well as various flags that specify the homing procedure are defined by HOMETYPE and HOMEFLAGS. The final velocity of the axis during homing can be defined by the HOMEVEL parameter.
The value in the HOMEPOS parameter contains a predefined position that may be used to reset the axis position at the mechanical reference,

Position closed loop

An axis can be instructed to operate by default in closed loop mode by mean of the PCLOOP parameter that also selects the functional encoder to be used for position feedback. The position closed loop mode applies an integral correction algorithm with the time constant set by PCLTAU. The settling and convergence criteria as well as the error conditions are configured by the parameters PCLSETLW, PCLSETLT, PCLERROR and PCLMODE. It is also possible to use the PCLDEADBD parameter to define a dead region around the target position in which the feedback correction is disabled.

3.2. Configuration reference

This section lists all the configuration parameters of a driver board.,

ACTIVE { NO | YES } — **Axis enable/disable flag**

This parameter marks a driver board as active or not. A “non active” driver is disabled, cannot be used to drive motors and rejects most of the power and motion related commands. The ACTIVE parameter does not reflect necessarily the actual state of a driver board that can become “not active” (functionally disabled) if it is moved to a different IcePAP system. See 2.1.4 and the ?ACTIVE query for more information.

PROTLEVEL <integer> — **Protection level**

This value is not actually used by the IcePAP drivers. It is provided as a way to store locally information about the level of protection that must be applied to the corresponding axis. This value is available to be used by the application software.

NAMELOCK { NO | YES } — **Axis name lock**

If this flag is set to NO, the use of the NAME command to change the name of the driver board is not allowed.

POWERON { NO | YES } — **Auto power on**

This flag instructs the driver board to switch on the motor power immediately after board initialisation. The flag has effect only if the driver is active.

MOTPHASES { 1 | 2 | 3 } — **Number of electrical phases**
MOTPOLES <integer> — **Number of pole pairs**

Configure the number of electrical phases and pole pairs of the motor. In case of rotary motors, the number of pole pairs corresponds to the number of electrical periods per motor turn. For instance, this number is 50 for a standard 200 full steps per turn stepper motor.
In case of linear motors, the number of pole pairs corresponds to the number of electrical periods for a certain given displacement distance. Such a distance is somehow arbitrary and can be chosen according to the user convenience, but will be adopted as the effective “*motor revolution*” for all internal calculations. All the configuration parameters that refer to motor turns will actually apply to such a reference linear displacement.

MOTSENSE { NORMAL | INVERTED } — **Sense of motor movement**

This value allows to invert the definition of positive direction for motor movements. Note that the limit switch signal Lim+ always blocks motion in the positive direction while Lim- blocks negative movements.

MREGMODE { EXT | CURR | TORQUE} — **Motor regulation mode**

This value selects the type of power regulation in the motor. In the current firmware version only current regulation (CURR) is implemented. If this parameter is set to EXT, the board disables its internal power driver and assumes that the motor power is applied by an external driver module.

NVOLT <float>	**Nominal operation voltage (volts)**
IVOLT <float>	**Idle operation voltage (volts)**
NCURR <float>	**Nominal current (amps)**
ICURR <integer>	**Idle current (%)**
BCURR <integer>	**Boost current increment (%)**

These parameters set the motor voltage and current values. During movements, the driving voltage and phase current are set to NVOLT (in volts) and NCURR (in amps) respectively. When the motor is stopped the voltage and current are set to IVOLT (in volts) and ICURR. Note that ICURR is not specified in amps, but in a given percentage of the nominal current NCURR.
It is possible to increase the phase current during acceleration and deceleration phases by specifying a boost current increment BCURR greater than zero. BCURR is also specified in percentage of NCURR and adds to the nominal current.

CURRGAIN { CUSTOM | LOW | MEDIUM | HIGH }	**Current regulation gain**
MREGP <float>	**Proportional coefficient**
MREGI <float>	**Integral coefficient**
MREGD <float>	**Derivative coefficient**

MREGP, MREGI and MREGD are the PID coefficients used for motor current regulation. If CURRGAIN is set to CUSTOM, the PID values can be freely set. If CURRGAIN is set to LOW, MEDIUM or HIGH, the PID values are forced to predefined values.

NRES <float>	**Nominal phase resistance**

This parameter sets the value of the nominal electrical resistance of the motor phases in ohms.
If NRES is set to zero, ...

INDEXER { INTERNAL | InPos | EncIn }	**Default indexer source**

Selects if the axis must be operated by using the internal trajectory generator or an external signal applied to one of the encoder InPos or EncIn inputs.
The INDEXER parameter refers to the default value, if the axis is not linked (see LNKNAME), the actual indexer source can be changed during operation (see INDEXER command).

LNKNAME <string>	**Name of the linked axes group**

Selects the group name to be used if the axis is configured to operate in LINKED mode. All the linked axes in the same IcePAP system sharing the same LNKNAME are configured to operate co-ordinately as described in 0. Setting LNKNAME to a non empty string forces the axis to operate in LINKED mode and the INDEXER parameter to INTERNAL. In the same way if the INDEXER parameter is set to a value different from INTERNAL, then LNKNAME is cleared.

SHFTENC { NONE | InPos | EncIn | AbsEnc}	**Shaft encoder**
TGTENC { NONE | InPos | EncIn | AbsEnc}	**Target encoder**
CTRLENC { NONE | InPos | EncIn | AbsEnc}	**Control encoder**

Select which input position signals will be used as shaft encoder, target encoder and control encoder. If any of these parameters is set to NONE the corresponding function is left unassigned.

POSUPDATE { NORMAL | MEASURE }	**....**

Selects whether the axis position is updated to match the measured position during open loop movements. If there is no functional encoder configured as TGTENC or SHFTENC, the measured position matches the nominal axis position and the MEASURE mode has no effect.

ANTURN <integer>	**Axis reference number of turns**
ANSTEP <integer>	**Axis reference number of units/steps**

Defines the resolution of the axis by specifying the number of units/steps (ANSTEP) for a given number of motor turns (ANTURN). This resolution can be selected independently of the actual resolution of the various encoders connected to the driver board and is always the position resolution used by the internal indexer.

DEFVEL <float>	**Default velocity (steps/sec)**
DEFACCT <float>	**Default acceleration time (sec)**

Configures the default values for velocity and acceleration time. The velocity value is specified in axis units (or steps) per second. The acceleration time is specified in seconds.

STRTVEL <float>	**Maximum start velocity (steps/sec)**

Configures the maximum starting velocity. This value, that is specified in axis units (or steps) per second, is the maximum velocity that can be applied to the motor without acceleration ramp. It is only used when the driver has to limit the motor slew rate as it is required in some closed loop modes for instance.

CTRLERROR <integer>	**Maximum control encoder error (steps)**

Configures the ...

PCLOOP { OFF | SHFTENC | TGTENC }	**Default closed loop mode**
PCLTAU <float>	**Position closed loop time constant (sec)**
PCLERROR <integer>	**Maximum closed loop error (steps)**
PCLCHKMD { NORMAL | STRICT }	**Closed loop error checking mode**
PCLDEADBD <integer>	**Minimum closed loop error (steps)**
PCLSETLW <integer>	**Closed loop settling window (steps)**
PCLSETLT <float>	**Closed loop settling time (sec)**

The position closed loop default mode and encoder signal used is selected by the PCLOOP parameter. The position closed loop is an integral correction algorithm that forces the selected encoder value to follow the desired axis value with the regulation time constant set by PCLTAU. The maximum acceptable follow error, defined as the difference between the axis and encoder values, is the number of axis steps in PCLERROR. The difference between the motor electrical phase and the encoder value is also checked to be less than PCLERROR, unless the flag SIMPLECHK in parameter PCLMODE is set. If the follow error is less than PCLDEADBD the correction algorithm does not take any action. If the error is less than PCLSETLW, the driver status bit INWINDOW will be set. At the end of a movement the driver status bit SETTLING will be set until the error remains less than PCLSETLW during the time defined by PCLSETLT.

LPPOL { NORMAL | INVERTED }	**Polarity of the Lim+ signal**
LMPOL { NORMAL | INVERTED }	**Polarity of the Lim- signal**
HOMEPOL { NORMAL | INVERTED }	**Polarity of the Home signal**

These parameters allow to invert the electrical polarity (logic value) of the limit switch signals and the Home input. Note that LPPOL and LMPOL do not change the functional assignment of the limit switches: Lim+ always blocks motion in the positive direction while Lim- blocks always negative movements.

EINTURN <integer>	**EncIn reference number of turns**
EINSTEP <integer>	**EncIn reference number of units/steps**
INPNTURN <integer>	**InPos reference number of turns**
INPNSTEP <integer>	**InPos reference number of units/steps**
ABSNTURN <integer>	**AbsEnc reference number of turns**
ABSNSTEP <integer>	**AbsEnc reference number of units/steps**

Allow to define the resolution of the encoders connected to the physical encoder inputs: EncIn, InPos and AbsEnc. The resolution is defined by specifying the number of encoder units/steps (*encoder*NSTEP) for a given number of motor turns (*encoder*NTURN). These values must match the resolution of the encoders in the actual mechanics.

EINMODE { QUAD | PULSE+ | PULSE- }	**EncIn input counting mode**
INPMODE { QUAD | PULSE+ | PULSE- }	**InPos input counting mode**

Select the input counting mode (quadrature counting or pulse/direction) for the incremental encoder signals connected to the position inputs EncIn and InPos. In the case of pulse/direction counting mode, it is possible to select if the incremental counting takes place at the rise edge (PULSE+) or the falling edge (PULSE-) of the pulse signal.

EINSENSE { NORMAL | INVERTED }	**EncIn sense**
INPSENSE { NORMAL | INVERTED }	**InPos sense**

Allow to change the sign of the incremental encoder signals EncIn and InPos. Inverting the sign of the incremental signal is equivalent to invert the sense of motion of the encoder.

EINAUXPOL { NORMAL | INVERTED }	**Polarity of the EncInAux signal**
INPAUXPOL { NORMAL | INVERTED }	**Polarity of the InPosAux signal**

These parameters allow to invert the electrical polarity (logic value) of the auxiliary signals EncInAux and InPosAux.

ABSSENSE { NORMAL | INVERTED }	**AbsEnc sense**
ABSOFSSET <integer>	**AbsEnc position offset**

Allow to apply a sign inversion and an offset to the absolute encoder value read through the SSI encoder interface.

SSIDBITS <integer>	**SSI data bits**
SSICODE { BINARY | GRAY }	**SSI data coding**
SSISTATUS { S | .S | ES | OS }	**SSI status/control bits**
SSICLOCK { 125KHz | 250KHz | 500KHz | 1.25MHz | 2.5MHz | 5MHz | 12.5MHz | 25MHz | OFF}	**SSI clock frequency**
SSIDELAY { 0 | 5us | 10us | 20us | 30us | 50us | 100us | 500us}	**SSI polling delay**

Configuration parameters for the SSI interface.

HOMESRC { Lim+ | Lim- | Home | EncAux | InpAux}	**Homing signal**
HOMETYPE { LEVEL | PULSE | MPULSE }	**Type of homing signal**

The parameter HOMESRC selects the hardware signal to be used by the homing procedure. The type of signal, i.e. how the homing signal indicates the reference mechanical position, is configured by HOMETYPE. Possible values are LEVEL, if the signal logic level changes at the reference position, PULSE if the signal is a short pulse at the reference position, or MPULSE if the homing device produces multiple pulses with variable distances between them. See for details

HOMEFLAGS [AUTODIR] [REVERSE] [SETPOS] [SLOW] [NEGEDGE] **Homing flags**

Configuration of the behaviour of the homing functionality.

HOMEPOS <integer> **Reference homing position**

Configuration of ...

HOMEVEL <float> **Slow homing velocity (steps/sec)**

Configuration of ...

OUTPSRC { AXIS | MOTOR | MEASURE | SHFTENC | TGTENC | InPos | EncIn | AbsEnc | Sync}	**OutPos source signal**
OUTPMODE { QUAD | PULSE+ | PULSE- }	**OutPos output counting mode**
OUTPPULSE { 50ns | 200ns | 2us | 20us}	**OutPos pulse width**
OUTPSENSE { NORMAL | INVERTED }	**OutPos sense**

Configuration of the OutPos position output signal.

OUTPAUXSRC {LOW | HIGH | Lim+ | Lim- | Home | eCAM | EncAux | InpAux | SyncAux"}	**OutPosAux source signal**
OUTPAUXPOL { NORMAL | INVERTED }	**Polarity of the OutPosAux signal**

Configuration of the OutPosAux auxiliary output signal.

INFASRC { LOW | HIGH | Lim+ | Lim- | Home | EncAux | InpAux | SyncAux | PWRCTRL | ENABLE | ALARM | READY | READY | MOVING | BOOST | STEADY | eCAM}	**InfoA source signal**
INFBSRC { LOW | HIGH | Lim+ | Lim- | Home | EncAux | InpAux | SyncAux | PWRCTRL | ENABLE | ALARM | READY | READY | MOVING | BOOST | STEADY | eCAM }	**InfoB source signal**
INFCSRC { LOW | HIGH | Lim+ | Lim- | Home | EncAux | InpAux | SyncAux | PWRCTRL | ENABLE | ALARM | READY | READY | MOVING | BOOST | STEADY | eCAM }	**InfoC source signal**
INFAPOL { NORMAL | INVERTED }	**InfoA polarity**
INFBPOL { NORMAL | INVERTED }	**InfoB polarity**
INFCPOL { NORMAL | INVERTED }	**InfoC polarity**

Default signal sources and polarities for the InfoA, InfoB and InfoC output signals. This default configuration is effective at initialisation, but can be changed during operation by means of the commands INFOA, INFOB and INFOC respectively. The available signal sources are explained in the documentation of the INFOx commands.

EXTPOWER { NONE | LIMITS | Home | EncAux | InpAux | Disable }	**External power**
EXTDISABLE { NONE | LIMITS | Home | EncAux | InpAux | Disable }	**External disable**
EXTBUSY { NONE | LIMITS | Home | EncAux | InpAux | Disable }	**External busy**
EXTALARM { NONE | LIMITS | Home | EncAux | InpAux | Disable }	**External alarm**
EXTWARNING { NONE | LIMITS | Home | EncAux | InpAux | Disable }	**External warning**
EXTPOWER { NONE | LIMITS | Home | EncAux | InpAux | Disable }	**External power**

Selects of the external functional input signals. If NONE is selected as input signal fro a given function, the external function is disabled. If a signal selection is set to LIMITS, the external function is activated when the two limit switches, Lim+ and Lim-, are active simultaneously. EXTDISABLE can be used to prevent the driver board to switch on the motor power. EXTBUSY blocks the execution of motion commands by preventing the driver to go to READY state. EXTPOWER is only effective when the IcePAP driver is configured to operate with external power drivers, and informs whether or not the motor power is on. EXTWARNING and EXTALARM can be used to generate warning and alarm conditions by external signal sources.

4. COMMUNICATION PROTOCOL

4.1. Communication basics

This section covers the IcePAP communication protocol. The communication interface is implemented at the system master board.

Communication is achieved by bi-directional byte streams. Normal command and response messages are transferred as lines of printable ASCII characters. The only exception is the transfer of binary data blocks, a special feature described in 4.5.
Commands messages sent to IcePAP must be formatted as sequences of printable characters terminated by a "*carriage return*" (ASCII 0x0D). Any additional control character, like "*line feed*" (ASCII 0x0A), is ignored.
Response messages produced by the device consist on lines terminated by a "*carriage return*" + "*line feed*" character sequence (ASCII 0x0D 0x0A).

4.1.1. System commands

Commands that do not include and address prefix are system commands.and are processed by the system master board. Example: ?SYSSTAT

4.1.2. Board commands

Commands addressed to specific boards. Both controller and drivers. They start with the address of the board and executed by the particular board, i.e.: 1:?POS
It is possible to broadcast board commands to all the modules in an IcePAP system.

4.1.3. Local driver interface

Each driver board has an individual communication port for diagnostic purposes. It can also be used for standalone operation.

4.2. Interfaces

The master boards integrate three communication ports: an Ethernet interface, a serial line and an USB port. The characteristics of the different interfaces are the following:

Interface	***Type***	***Parameters***
Serial Line	**RS232**	9600 bauds, no parity, 1 stop bit
Ethernet	**100baseT-FullDuplex**	TCP sockets, port 5000
Universal Serial Bus	**USB 1.0**	Not implemented in the current version

4.2.1. Active control clients

An IP mask can be defined to limitthe execution of commands to the icePAP system.
For every bit in the mask set to 1, the corresponding bit in the icePAP and the client IP addresses must have the same value.
Any incoming command that is not a query queries from a client with an IP address out of the defined mask will be rejected. All the query commands will be answered by the system regardless of the IP mask configured.

By default the IP mask value is set to 0.0.0.0
This means that all commands from any IP address will be executed.

Examples and tips:
To limit the access to clients in the subnet where the icePAP system is, set the IP mask to the value: 255.255.255.0

In order to change the IP mask to a less restrictive value, the corresponding IPMASK command has to be issued from an address that is not masked. Be careful never to set the mask to the value 255.255.255.255.

See IPMASK/?IPMASK in the command reference for information on how to change/read the current IP mask of a system.

[TODO: Develop the IPMask concept here]

4.3. Syntax conventions

In the most usual case remote control is implemented by an application program running in a host computer that sends commands and requests to IcePAP as sequences of ASCII characters. The syntax rules are described below. See X for practical examples.

4.3.1. Commands and requests

- Command lines consist of a command keyword optionally followed by parameters.
  - The number and type of parameters depend on the particular command.
- Command keywords are not case sensitive.
  - The device converts internally all the characters to uppercase before any syntax checking. (TO BE DISCUSSED)
  - Parameters are also converted to uppercase unless they are enclosed between double quotes (″″, ASCII 0x22). (TO BE DISCUSSED)
- Commands may be optionally preceded by the acknowledge character.
  - The acknowledge character is a hash symbol (#, ASCII 0x23) that must appear in the command line immediately before the first character of the command keyword.
- Normal (non query) commands never produce response messages unless the acknowledge character is used.
  - Non query command keywords always start by an alphabetical character (A to Z). Exceptions are binary transfer commands (see XX) that start by an asterisk character (*, ASCII 0x2A).
  - If the acknowledge character is used, the device produces the response string `OK` if the command execution was successful.
  - If the acknowledge character is used and the command does not executes successfully, the device produces either the string `ERROR` or a string containing a human readable error message. The behaviour depends on the current setting of the *echo* mode (see 4.4).
- Requests are query commands that produce response messages from the device.
  - Requests keywords always start by a question mark character (?, ASCII 0x3F).
  - If the request is successful the content of the response message depends on the particular request.
  - If request fails the device produces either the string `ERROR` or a string containing a human readable error message. The behaviour depends on the current setting of the *echo* mode (see 4.4).
  - The acknowledge character has no effect when used with requests.
- Response messages consist of one or more ASCII character lines.

- The way every line in a response message is terminated depends on the type of communication port.
- A response message may contain either the output of a request, an acknowledgement keyword (`OK` or `ERROR`) or a human readable error message.
- When a response message consists of more than one line, the first and last lines contain a single dollar character ($, ASCII 0x3F).

4.3.2. Addressing

- Board commands must be sent to the specific controller or drivers boards by using an addressing prefix. An addressing prefix consists of the board address in decimal format followed by a colon character (`:`, ASCII 0x3A). No spaces are allowed between the last address digit and the colon character.

- An addressing prefix consisting of only the colon character (`:`) with no address string is interpreted as a broadcast command. In that case the command is forwarded to all the boards in the system. Controller boards ignore broadcasts of driver-only commands as well as driver boards ignore controller-only broadcasts. No queries or acknowledge characters are allowed in broadcasts.

4.4. Terminal mode

When an IcePAP system is accessed through a serial port, two possible communication modes are available that can be selected with the commands `ECHO` and `NOECHO`. The differences between these two modes are described below. These commands can be issued through other interfaces (i.e. Ethernet) but they only have effect on the serial port.

Echo mode (terminal mode)

This mode should be used when the IcePAP master board is connected to a dumb terminal. In this case the user types commands on the keyboard and reads the answers and error messages on the terminal screen without computer intervention. This mode is usually not active by default and the user has to send the `ECHO` command every time the device is powered on.

In echo mode all the characters sent to the device are echoed back to the terminal. The device also sends human-readable messages to be printed on the terminal screen whenever an error is detected in commands or requests.
Case conversion takes place before the characters are sent back to the terminal, therefore characters are echoed back as uppercase even if they are typed and sent to the device as lowercase. (TO BE DISCUSSED)
In echo mode the backspace character (ASCII 0x08) has the effect of deleting the last character received by the device. In this way a minimum editing functionality is provided.

Noecho mode (host computer)

This is the default mode. In this case no characters are echoed and no error messages are returned by non-query commands unless they are explicitly requested by the acknowledge character. This mode is intended to be used when a program running in a host computer communicates with the controller, sending commands and analysing the answers.

4.5. Binary transfer

Binary transfer is a special mode that extends the standard protocol allowing faster data transfer. Binary blocks have a maximum size of 65535 data bytes (0xFFFF).

Binary transfer commands or requests are initiated by ASCII command lines that follow the same rules than ordinary commands or requests (see 4.3.1). The only difference is that binary transfer command lines must include an asterisk character (*, ASCII 0x2A) in the command or request keyword. Non-query commands keywords must start by an asterisk character. Request keywords must include the asterisk as the first character after the question mark.

Once IcePAP has received the ASCII command line, the data is transferred as a binary block. In the case of non-query commands, the binary data block is sent from the host computer to the device. In case of binary requests, the device sends the binary block to the host (serial line) or puts it in its output buffer ready to be read by the host (GPIB).

If the device finds an error in a command line containing a binary request, instead of the binary block, it produces the string `ERROR`.
The acknowledge character (#, ASCII 0x23) can be used in the same way that with non-binary commands. If it is included in a non-query command line, the device produces an acknowledgement keyword (`ERROR` or `OK`) to signal if the command line contained errors or not. The acknowledge character has no effect in the case of binary requests.

Although binary transfer is initiated in the same way for both serial line and GPIB communication, the format of the binary data blocks and the management of the end of transfer condition are different in both cases.

4.5.1. Serial port binary blocks

In the case of transfer through a serial port, the binary block contains the binary data and 4 extra bytes. The structure of the block is the following:

byte Number	content
0	0xFF (signature)
1	DataSize (MSB)
2	DataSize (LSB)
3	data byte (first)
…	…
DataSize + 2	data byte (last)
DataSize + 3	Checksum

The first byte contains always the value 0xFF (255) and can be used the signature of the block. The next two bytes contain the number of data bytes to transfer. The last byte contains the check sum value that is used to verify data integrity.

The checksum value is calculated as the lower 8-bits of the sum of all the bytes in the binary block with exception of the signature byte (and the checksum byte itself).

4.5.2. TCP binary blocks

In the case of transfer by Ethernet, the binary block does not contain any additional control or protocol byte. Only the actual data bytes are transferred. The EOI line is asserted during the transfer of the last data byte to signal the end of the transmission.

5. COMMAND SET

BOARD COMMANDS

Command	Description	Controller	Driver	Page
?ACTIVE	Query activation status		❒	42
?MODE	Query board mode	❒	❒	83
?STATUS	Query board status	❒	❒	110
?VSTATUS	Query verbose board status	❒	❒	118
?ALARM	Query board alarm message	❒	❒	45
?WARNING	Query board warnings	❒	❒	120
WTEMP ?WTEMP	Set/query warning temperature	❒	❒	122
CONFIG ?CONFIG	Manage configuration mode		❒	53
CFG ?CFG	Set/query configuration parameters		❒	48
?CFGINFO	Query configuration parameter info		❒	50
CSWITCH ?CSWITCH	Set/query limit switch configuration mode		❒	54
?VER	Query board version information	❒	❒	117
NAME ?NAME	Set/query board name		❒	86
?ID	Query board identification	❒	❒	74
?POST	Query power-on self-test results	❒	❒	93
POWER ?POWER	Set/query motor power state		❒	94
AUXPS ?AUXPS	Set/query auxiliary power supply state		❒	46
?MEAS	Query measured value	❒	❒	81
POS ?POS	Set/query axis position in axis units	❒	❒	91
ENC ?ENC	Set/query axis position in encoder steps	❒	❒	62
?HOMESTAT	Query home search status		❒	73
?HOMEPOS	Query the found home position in axis units		❒	72
?HOMEENC	Query the found home position in encoder steps		❒	71
VELOCITY ?VELOCITY	Set/query programmed axis velocity	❒	❒	115
ACCTIME ?ACCTIME	Set/query acceleration time	❒	❒	43
PCLOOP ?PCLOOP	Set/query current position closed loop mode		❒	88
ESYNC	Synchronise internal position registers		❒	65
CTRLRST	Reset control position encoder		❒	55
MOVE	Start absolute movement	❒	❒	84
UMOVE	Absolute updated movement	❒	❒	114
RMOVE	Start relative movement	❒	❒	102
JOG ?JOG	Set/query jog velocity	❒	❒	79
HOME	Start home signal search sequence		❒	70
MOVEP	Start axis movement to parameter value	❒	❒	85
PMOVE	Start parametric movement	❒	❒	89
VMOVE ?VMOVE	Set/query setpoint for variable regulation motion	❒	❒	118
VCONFIG ?VCONFIG	Set/query variable regulation configuration	❒	❒	115
VVALUE ?VVALUE	Set/query current value of external variable	❒	❒	120
CMOVE	Start relative movement in configuration mode		❒	52
CJOG	Set jog velocity in configuration mode		❒	51
STOP	Stop movement	❒	❒	111
ABORT	Abort movement	❒	❒	41
DISPROT	Request temporary protection disable		❒	57
INDEXER ?INDEXER	Set/query indexer signal source		❒	75
ECAM ?ECAM	Set/query electronic cam mode	❒	❒	58
ECAMDAT ?ECAMDAT *ECAMDAT	Load/query electronic cam data	❒	❒	59
INFOA ?INFOA	Set/query InfoA signal source and polarity		❒	76
INFOB ?INFOB	Set/query InfoB signal source and polarity		❒	76
INFOC ?INFOC	Set/query InfoC signal source and polarity		❒	76

BOARD COMMANDS (cont.)

Command	Description	Controller	Driver	Page
`?HELP`	Query list of available commands	❒	❒	69
`?ERRMSG`	Query last command error message	❒	❒	64
`?FERRMSG`	Query first error message	❒	❒	66
`BLINK ?BLINK`	Set/query remaining blinking time	❒	❒	47
`?TIME`	Query running time	❒	❒	113
`DEBUG ?DEBUG`	Set/query debug level	❒	❒	56
`ECHO`	Select echo mode		❒	61
`NOECHO`	Cancel echo mode		❒	87
`?MEMORY`	Query available memory	❒	❒	82
`?ADDR`	Query board address	❒	❒	44

SYSTEM COMMANDS

Command	Description	Page
`MODE ?MODE`	Set/query system mode	83
`?SYSSTAT`	Query system configuration	112
`?STATUS`	Query multiple board status	110
`?FSTATUS`	Query multiple board fast status	68
`?LINKED`	Query linked axis groups	80
`REPORT ?REPORT`	Set/query asynchronous report settings	98
`?VER`	Query system firmware version information	117
`?RID`	Query rack identification string	100
`?RTEMP`	Query rack temperatures	105
`*PROG` `PROG ?PROG`	Firmware programming	95
`RFPROG`	Factory firmware programming	101
`IPMASK ?IPMASK`	Set/query IP control mask	78
`REBOOT`	System reboot	97
`RESET`	System or rack reset	99
`POWER ?POWER`	Set/querymultiple axis motor power state	94
`POS ?POS`	Set/query multiple axis position in axis units	91
`ENC ?ENC`	Set/query multiple axis position in encoder steps	62
`?FPOS`	Fast query of multiple board positions	67
`?HOMESTAT`	Query multiple axis home search status	73
`?HOMEPOS`	Query the found multiple axis home position in axis units	72
`?HOMEENC`	Query the found multiple axis home position in encoder steps	71
`VELOCITY ?VELOCITY`	Set/query programmed multiple axis velocity	115
`ACCTIME ?ACCTIME`	Set/query acceleration time	43
`MOVE`	Start multiple axis absolute movement	84
`RMOVE`	Start multiple axis relative movement	102
`JOG ?JOG`	Set/query multiple axis jog velocities	79
`HOME`	Start multiple axis home signal search sequence	70
`MOVEP`	Start axis movement to parameter value	85
`PMOVE`	Start parametric movement	89
`STOP`	Stop multiple axis movement	111
`ABORT`	Abort movement	41
`ESYNC`	Synchronise internal position registers for multiple axis	65
`CTRLRST`	Reset control position encoder for multiple axis	55
`DISPROT`	Request multiple axis temporary protection disable	57
`?HELP`	Query list of available commands	69

?ERRMSG	Query last command error message	64
ECHO	Select serial line echo	61
NOECHO	Cancel serial line echo	87

5.1. Command reference

ABORT

Abort movement

Syntax:

<board_addr>:ABORT **(board command)**

or

ABORT [<axis1> [<axis2> … [<axisN>]…]] **(system command)**

Description:

The ABORT command aborts all movement in the specified axis.

When using the system command, if the command cannot be issued for a certain axis, all the movements in the system will be aborted.

If one of the explicitly aborted axis belongs to a predefined group, all the members of that group will be aborted.

Examples:

Command:	`16:ABORT`	
Command:	`ABORT`	// abort all the axes in the system
Command:	`ABORT 30 33 42`	// abort axes 30, 33 and 42
Command:	`#ABORT 30 33 42`	
Answer:	`ABORT ERROR All axes aborted. Axis 33: Board is not present in the system`	
Command:	`#ABORT 30 rrt 42`	
Answer:	`ABORT ERROR All axes aborted. Wrong parameter(s)`	

?ACTIVE

Query activation status

Syntax:

<driver_addr>:?ACTIVE

Answer:

<driver_addr>:?ACTIVE { YES | NO }

Description:

Returns the current activation status of a driver board. A driver will be active if the internal ACTIVE configuration parameter is set to YES and the board is not in PROG or TEST mode. Otherwise the ?ACTIVE query will return NO.

When a driver board is not active, the motor power and the trajectory generation functions are disabled. (to be checked)

The driver's ACTIVE configuration parameter will be reset to the value NO at power on if:

- the address of the driver has changed, for instance if the board has been moved to a different slot within the same system,
- the driver board finds itself plugged in a different IcePAP system, i.e. the master crate AND the master controller are different than the previous ones
- there is a firmware or a command set mismatch between the driver and the master controller board.

A standalone driver (with no master controller) can be activated through the front panel serial line with the command SLACT.

Examples:

Command:	`16:?ACTIVE`
Answer:	`16:?ACTIVE YES`

ACCTIME / ?ACCTIME

Set/query acceleration time

Syntax:

<board_addr>:ACCTIME [<accTime>] **(board command)**

or

ACCTIME [<axis1> <accTime1> … [<axisN> <accTimeN>]…] **(system command)**

Description:

Sets the acceleration time for the corresponding axis to the <accTime> values in seconds. The actual acceleration for each axis is calculated internally based on the current value of the axis velocity (see VELOCITY command).

The acceleration time is internally recalculated every time that the axis velocity changes.

Syntax:

<board_addr>:?ACCTIME **(board command)**

or

?ACCTIME [<axis1> [<axis2> … [<axisN>]…]] **(system command)**

Answer:

<board_addr>:?ACCTIME <accTime> **(board answer)**

or

?ACCTIME <accTime1> <accTime2> … <accTimeN> **(system answer)**

Description:

Returns the current acceleration time of the specified axes in seconds.

Examples:

Command:	`16:?ACCTIME`
Answer:	`16:?ACCTIME 0.25`
Command:	`24:ACCTIME 0.1`
Command:	`?ACCTIME 16 24`
Answer:	`?ACCTIME 0.25 0.1`
Command:	`ACCTIME 16 0.1 17 0.2`

?ADDR

Query board address

Syntax:

<board_addr>:?ADDR

Answer:

<board_addr>:?ADDR <boardAddr>

Description:

The ?ADDR command returns the current board address. This command is only useful when the board is accessed through the local serial line interface.

Examples:

```
Command:    16:?ADDR
Answer:     ?ADDR 16                    // useless information
```

Access through the local serial line interface:

```
Command:    ? ADDR
Answer:     ?ADDR 16
```

?ALARM

Query board alarm message

Syntax:

<board_addr>:?ALARM

Answer:

<board_addr>:?ALARM { NO | <alarm_condition string> }

Description:

If the board is disabled by an alarm condition, this query returns a string describing the such a condition. If not, the query returns the string NO.

Possible alarm conditions are:

Alarm Condition	***Description***
Internal failure	Power-on self test (POST) or motor supply failure
Motor failure	Error detected in motor connection
Power overload	Overcurrent or power overload
Driver overheating	The temperature of the driver board exceeds maximum value
Close loop error	The closed loop follow error exceeds the maximum value (see PCLERROR configuration parameter)
Control encoder error	The control encoder discrepancy exceeds the CTRLERROR configuration parameter
External alarm	The external alarm signal is active (see EXTALARM configuration parameter)

Examples:

```
Command:   115:?ALARM
Answer:    115:?ALARM <alarm condition string>
Command:   115:#POWER ON
Answer:    115:POWER OK
Command:   115:?ALARM
Answer:    115:?ALARM NO
```

AUXPS / ?AUXPS

Set/query axis auxiliary power supply state

Syntax:

<driver_addr>:AUXPS [{ON | OFF}]

Description:

Switches on or off the auxiliary power supply in a driver board. When the auxiliary power supply is switched off, the motor power is also switched off.

Syntax:

<driver_addr>:?AUXPS

Answer:

<driver_addr>:?AUXPS [{ON | OFF}]

Description:

Returns the state of the auxiliary power supply of the driver board.

Examples:

Command:	`83:?AUXPS`
Answer:	`83:?AUXPS ON`
Command:	`83:AUXPS OFF`
Command:	`83:?AUXPS`
Answer:	`83:?AUXPS OFF`

BLINK / ?BLINK

Set/query remaining blinking time

Syntax:

<board_addr>:BLINK <blinkTime>

Description:

If <blinkTime> is greater than zero, sets the board in blinking mode for a period given by <blinkTime> in seconds. If <blinkTime> is zero, this command stops blinking mode.

Syntax:

<board_addr>:?BLINK

Answer:

<board_addr>:?BLINK <remBlinkTime>

Description:

Returns the remaining blinking time.

Examples:

Command:	`83:BLINK 10`
Command:	`83:?BLINK`
Answer:	`83:?BLINK 8.4532`
Command:	`83:?BLINK`
Answer:	`83:?BLINK 6.5439`

CFG / ?CFG

Set/query configuration parameters

Syntax:

<driver_addr>:CFG <configPar> <configVal>

or

<driver_addr>:CFG { DEFAULT | EXPERT }

Description:

The CFG command allows to change the current values of the configuration parameters of a driver board. The driver has to be previously switched into configuration mode (see CONFIG command).

The configuration of driver boards as well as the list of available parameters is detailed in chapter 2.

The command CFG DEFAULT instructs the driver board to revert all its configuration parameters to the default values. The list of default values can be obtain from the driver by means of the ?CFG DEFAULT query.

The command CFG EXPERT sets an internal flag that can be read back with the ?CFG query. This flag has not any specific function in the IcePAP system but it is provided as an facility to external configuration tools to confirm the validity of the current driver configuration when the driver boards are moved among systems. As the expert flag is cleared by any other CFG command, it must be set immediately before the configuration is validated by the CONFIG command.

Syntax:

<driver_addr>:?CFG [<configPar> | DEFAULT | EXPERT]

Answer:

<driver_addr>:?CFG <configPar> <configVal>

or

```
<driver_addr>:?CFG $
              <configPar1>  <configVal1>
              <configPar2>  <configVal2>
                 ...
              <configParN>  <configValN>
              $
```

Description:

The ?CFG query returns the value <configVal> assigned to a particular configuration parameter <configPar>. If no parameter is specified, the query returns a multiline answer with the complete list of configuration parameters and their current values. If the DEFAULT keyword is used, instead of the current values, the ?CFG query returns the complete list of configuration parameters and their default values.

If the EXPERT keyword is used as a parameter name, the ?CFG query returns the value of the internal expert flag set by the CFG EXPERT command and cleared by any other CFG command. The value is returned as a YES/NO boolean value. Note however that EXPERT is not a configuration parameter.

Examples:

Command:	`15:CFG DEFAULT`
Command:	`15:?CFG NCURR`
Answer:	`15:?CFG NCURR 0.1`
Command:	`15:CFG NCURR 2.4`
Command:	`15:?CFG`

Answer:

```
15:?CFG $
ACTIVE NO
PROTLEVEL 0
NAMELOCK NO
POWERON NO
MOTPHASES 2
MOTORSENSE NORMAL
MOTPOLES 50
MREGMODE CURR
...
NCURR 2.4
...
INFCSOURCE Home
INFCPOL NORMAL
$
```

Command:	`23:?CFG EXPERT`
Answer:	`23:?CFG EXPERT NO`

?CFGINFO

Query configuration parameter info

Syntax:

<driver_addr>:?CFGINFO [<configPar>]

Answer:

<driver_addr>:?CFGINFO <configPar> {INTEGER | FLOAT | STRING<n> | *labelList* }

or

<driver_addr>:?CFGINFO $

<configPar1> {INTEGER | FLOAT | STRING<n> | *labelList1* }

<configPar2> {INTEGER | FLOAT | STRING<n> | *labelList2* }

…

<configParN> {INTEGER | FLOAT | STRING<n> | *labelListN* }

$

Where *labelList* is a list of character strings separated by whitespaces and enclosed in curly braces ({}). [FLAG LIST descriptionmissing]

Description:

The ?CFGINFO query returns the type of the configuration parameter <configPar>. Possible types are numeric (*INTEGER* or *FLOAT*) or string. In the case of strings the query may return either *STRING<n>* , where *<n>* is the maximum acceptable length of the string, or the list of acceptable fixed string values.

If no parameter is specified, the query returns a multiline answer with the complete list of type information for all the driver configuration parameters.

Examples:

Command:	`7:?CFGINFO NCURR`
Answer:	`7:?CFGINFO FLOAT`
Command:	`103:?CFGINFO`

Answer:

```
103:?CFGINFO $
ACTIVE {NO YES}
PROTLEVEL INTEGER
NAMELOCK {NO YES}
POWERON {NO YES}
MOTPHASES {1 2 3}
MOTORSENSE {NORMAL INVERTED}
...
INFCPOL {NORMAL INVERTED}
$
```

CJOG

Set jog velocity in configuration mode

Syntax:

<board_addr>:CJOG <signedVelocity>

Description:

Sets the specified axis or axes in jog mode at the given velocity in steps per second. This command can only be executed when the driver is in configuration mode.

The sign of the velocity parameter selects the actual direction of the movement. If a specified axis is already jogging at a certain speed, the speed will be ramped up or down as needed to reach the new velocity value. The acceleration is fixed as the ratio of the current values of axis velocity and acceleration time (see ?VELOCITY and ?ACCTIME queries). A zero velocity value forces an axis to stop.

Examples:

Command:	`5:CJOG 100`
Command:	`5:?JOG`
Answer:	`5:?JOG 100`
Command:	`#5:CJOG 200`
Answer:	`5:CJOG OK`
Command:	`#5:CJOG -200`
Answer:	`3:CJOG ERROR Cannot change jog direction`

Comment [PF3]: This command is undocumented!!!

CMOVE

Start absolute movement in configuration mode

Syntax:

<driver_addr>:CMOVE <absolutePos>

Description:

Performs an absolute movement on the specified driver board. This command can only be executed when the driver is in configuration mode.

Examples:

```
Command:    115:CMOVE -7000
Command:    115:?POS
Answer:     115:?POS -7000
```

CONFIG / ?CONFIG

Manage configuration mode

Syntax:

<driver_addr>:CONFIG [<confID>]

Description:

The CONFIG command allows to switch a driver board into configuration mode. A driver board cannot be switched into configuration mode when the IcePAP system is in *PROG* or *TEST* modes (see MODE command).

When a driver is in configuration mode, the driver configuration parameters can be modified with the CFG command. Once the configuration has been modified, the CONFIG command, issued with a non empty <confID> string as parameter, validates the current configuration and stores it in the internal non volatile memory of the driver board. The <confID> string is also stored in the driver and can be used to identify the particular set of configuration parameters. The board also switches back to *OPER* mode.

If the driver is in configuration mode and the CONFIG command is issued with no parameters, the driver goes back to OPER mode and the last valid configuration before entering CONFIG mode is reloaded. In that case the most recent changes done during configuration mode are lost.

Syntax:

<driver_addr>:?CONFIG

Answer:

<driver_addr>:?CONFIG <confID>

Description:

The ?CONFIG query returns the identifier of the last valid configuration parameter set.

Examples:

```
Command:   32:?CFG ACTIVE
Answer:    32:?CFG ACTIVE NO
Command:   ?MODE
Answer:    ?MODE OPER               // System mode is OPER
Command:   32:CONFIG                // Switch axis 32 into CONFIG mode
Command:   32:?MODE
Answer:    32:?MODE CONFIG
Command:   32:CFG ACTIVE YES        // Change configuration parameter
Command:   32:CONFIG CONF001        // Validate driver configuration
Command:   32:?CFG ACTIVE
Answer:    32:?CFG YES
```

CSWITCH / ?CSWITCH

Set/query limit switch configuration mode

Syntax:

<board_addr>:CSWITCH { NORMAL | SMART | STICKY }

Description:

Sets the behaviour of the limit switches in configuration mode. In addition to the normal mode, the limit switches can be set to operate in either SMART or STICKY mode. This command as well as the special limit switch mode modes is only valid in configuration mode. The STICKY and SMART modes are only intended to assist the user when testing the electrical connection and operation of the physical limit switches and selecting the direction of the motor. When the driver board is in operation mode, the limit switches always operate in normal mode.

The STICKY mode forces any of the limit switches that has been activated once, to remain active until the driver is switched to OPER mode or the CSWITCH command is issued again.

The SMART switch mode forces any movement to stop as soon as any of the two limit switches is activated. If actual switch that was activated is not consistent with the direction of motion, the value of the configuration parameter MOTSENSE is inverted.

Syntax:

<board_addr>:?CSWITCH

Answer:

<board_addr>:?CSWITCH { NORMAL | SMART | STICKY }

Description:

Returns the current value of the limit switch configuration mode.

Examples:

Command:	`15:?CSWITCH`
Answer:	`15:?CSWITCH NORMAL`
Command:	`15:CSWITCH SMART`
Command:	`15:?CSWITCH`
Answer:	`15:?CSWITCH SMART`

CTRLRST

Reset control encoder value

Syntax:

CTRLRST <axis1> <axis2> … <axisN> **(system command)**

or

<driver_addr>:CTRLRST **(board command)**

Description:

This command resets the current value of the control position register to the current value of the axis.

[TODO: needs further explanation]

Examples:

Command:	`#11:CTRLRST`
Answer:	`11:CTRLRST OK`
Command:	`CTRLRST 11 13 14`

DEBUG / ?DEBUG

Set/query debug level

Syntax:

<board_addr>:DEBUG <debugLevel>

Description:

Sets the level of the debug facility to <debugLevel>. If the level is set to 0, the debug facility is switched off.

The debug level is stored in the board non-volatile memory and it is maintained after board reset.

Syntax:

<board_addr>:?DEBUG

Answer:

<board_addr>:?DEBUG <debugLevel>

Description:

Returns the current level of the debug facility.

Examples:

Command:	`15:?DEBUG`
Answer:	`15:?DEBUG 0`
Command:	`15:DEBUG 2`
Command:	`15:?DEBUG`
Answer:	`15:?DEBUG 2`

DISPROT

Request temporary protection disable

Syntax:

<driver_addr>: DISPROT {ALL | {[LINKED] [CONTROL] [HARDCTRL]} }

(driver command)

or

DISPROT {ALL | {[LINKED] [CONTROL] [HARDCTRL]}} <axis1> <axis2> … <axisN>

(system command)

Description:

Request the specified boards to override the selected protections during the execution of the following command. The possible protections to be overriden are selected by the following keywords:

Keyword	***Protection disable***
`ALL`	Disables all the protections, The `ALL` keyword is equivalent to issue `LINKED` and `CONTROL` keywords simultaneously.
`LINKED`	Allows to issue individual commands to linked axes. In normal operation, most movement and related commands can only be sent to linked axes collectively, by addressing the linked group name.
`CONTROL`	Disables the action of the control encoder during the next movement after the DISPROT command. The movement command must follow the DISPROT command.
`HARDCTRL`	Disables the action of the control encoder during the next movement AND limits the maximum movement to a maximum number of steps defined by configuration parameter CTRLERROR. The movement command must follow the DISPROT command.

The `HARDCTRL` flag causes to override the control encoder protection, but adds a new protection. Thus, when the flag `ALL` is used, the `HARDCTRL` flag will not be set internally.

Examples:

Command: `15:DISPROT LINKED`

Command: `DISPROT CONTROL LINKED 23 24 25`

ECAM / ?ECAM

Set/query electronic cam mode

Syntax:

< board_addr>: ECAM [{ OFF | ON | PULSE | LOW | HIGH }]

Description:

The ECAM command ...

ON is the default action.

Syntax:

<board_addr>:?ECAM

Answer:

<board_addr>:?ECAM { OFF | ON } { PULSE | LOW | HIGH } <curr_level>

Description:

Returns the ON/OFF activation state of the electronic cam, the configuration mode as PULSE or level (LOW or HIGH) and the current logic level of the eCAM signal (LOW or HIGH).

Examples:

```
Command:    15:?ECAM
Answer:     15:?ECAM OFF PULSE LOW
Command:    15:ECAMDAT 1000 41000 100
Command:    15:?ECAMDAT
Answer:     15:?ECAMDAT AXIS 1000 41000 100
Command:    15:ECAM ON
Command:    15:?ECAM
Answer:     15:?ECAM ON PULSE LOW
```

ECAMDAT / *ECAMDAT / ?ECAMDAT

Load/query electronic cam data

Syntax:

<board_addr>: ECAMDAT [*ecam_source*] <first> <last> <nIntervals>

<board_addr>: *ECAMDAT [*ecam_source*] {DWORD | FLOAT | DFLOAT}

Description:

The ECAMDAT command ...

The *ECAMDAT binary command ...

ecam_source	***Position value***
`PARAM`	Value of the position parameter
`AXIS`	Current nominal axis position
`MEASURE`	Value of the axis position measurement
`SHFTENC` *	Value of the functional “shaft” encoder
`TGTENC` *	Value of the functional “target” encoder
`CTRLENC` *	Value of the functional “control” encoder
`ENCIN` *	Position of the encoder connected at the rear connector
`INPOS` *	Position of the encoder connected at the front panel connector
`ABSENC` *	Position of the encoder connected at the rear SSI interface
`MOTOR` *	Electrical phase of the motor

* Only valid for driver boards

Syntax:

<board_addr>:?ECAMDAT [<n_values> [<idx_offset>]]

Answer:

<board_addr>:?ECAMDAT *ecam_source* <first> <last> <nIntervals>

or

<driver_addr>:?ECAMDAT $

<< eCAM data dump >>

$

Description:

With no parameters, the ?ECAMDAT query returns the ...

For debugging purposes, the query can be issued with a number of values <n_values> as parameter, and an optional index offset <idx_offset>. In that case ?ECAMDAT returns a list of values.

Examples:

```
Command:    15:?ECAM
Answer:     15:?ECAM OFF PULSE LOW
Command:    15:ECAMDAT 1000 41000 100
Command:    15:?ECAMDAT
Answer:     15:?ECAMDAT AXIS 1000 41000 100
Command:    15:ECAM ON
Command:    15:?ECAM
Answer:     15:?ECAM ON PULSE LOW
```

Comment [PF4]: Review this with reasonable examples

ECHO

Set echo mode

Syntax:

ECHO **(system command)**

or

<board_addr>:ECHO **(board command)**

Description:

Switches the echo mode on. Useful when accessing boards through the serial line.

Example:

Command:	`ECHO`
Command:	`92:ECHO`

ENC / ?ENC

Set/query axis position in encoder steps

Syntax:

<board_addr>:ENC [*pos_sel*] <posVal> **(board command)**

or

ENC [*pos_sel*] <axis1> <posVal1> … <axisN> <posValN> **(system command)**

Description:

Loads the position registers in the specified boards with the <posVal> values. The specific register is selected by the optional parameter *pos_sel*, that must be one of the following values:

pos_sel	***Position register***
`AXIS`	Points to the axis nominal position
`MEASURE`	Points to the register used for position measurement
`SHFTENC` *	Points to the register configured as SHFTENC
`TGTENC` *	Points to the register configured as TGTENC
`CTRLENC` *	Points to the register configured as CTRLENC
`ENCIN` *	ENCIN register
`INPOS` *	INPOS register
`ABSENC` *	ABSENC register
`MOTOR` *	MOTOR register

* Only valid for driver boards

If position is not specified, the value is loaded in the axis position register

Syntax:

<board_addr>:?ENC [*pos_sel*] **(board query)**

or

?ENC [*pos_sel*] <axis1> <axis2> … <axisN> **(system query)**

Answer:

<board_addr>:?ENC <posVal> **(board answer)**

or

?ENC <posVal1> <posVal2> … <posValN> **(system answer)**

Description:

Returns the current signal source used as axis indexer.

Examples:

Command:	`115:ENC AXIS 500`
Command:	`115:ENC MEASURE -3000`
Command:	`115:?ENC`
Answer:	`115:?ENC 500`
Command:	`?ENC MEASURE 5 115`
Answer:	`?ENC 13467895 -3000`

?ERRMSG

Query last command error message

Syntax:

?ERRMSG **(system or local board query)**

Answer:

?ERRMSG [<errorMessage>] **(system or local board answer)**

Description:

If the previous command produced an error, the ?ERRMSG query returns the error message as an ASCII string. If the previous command was successful, the ?ERRMSG query returns and empty string.

This command will retrieve the last error, regardless whether the previous command was a system command or a board command.

The system does not accept it as board command if it is not issued through the serial line.

Example:

```
Command:   ?VER
Answer:    ?VER 1.00
Command:   ?ERRMSG
Answer:    ?ERRMSG
Command:   15:VELOCITY 0
Command:   15:?ERRMSG
Answer:    15:?ERRMSG Out of range value
```

ESYNC

Synchronise internal position registers

Syntax:

ESYNC <axis1> <axis2> … <axisN> **(system command)**

or

<driver_addr>:ESYNC **(board command)**

Description:

This command forces the value in all the position register that are linked to the axis to be synchronised with the measured position.

[TODO: needs further explanation]

Examples:

```
Command:   11:?POS
Answer:    11:?POS 1364
Command:   11:?POS TGTENC
Answer:    11:?POS 1232

Command:   #11:ESYNC
Answer:    11:ESYNC OK

Command:   11:?POS
Answer:    11:?POS 1364
Command:   11:?POS TGTENC
Answer:    11:?POS 1364
```

?FERRMSG

Query first error message

Syntax:

<board_addr>:?FERRMSG

Answer:

<board_addr>:?FERRMSG [command <errorMessage>]

Description:

Returns the message for the first command error that was produced since the last time the ?FERRMSG query was issued. The query returns the command that produced the error and the error message an as ASCII string.

[TODO: Explain difference: system errors, board errors].

Example:

```
Command:   ?VER
Answer:    ?VER 1.00
Command:   ?FERRMSG
Answer:    ?FERRMSG
Command:   15:VELOCITY 0
Command:   15:?FERRMSG
Answer:    15:?FERRMSG Out of range value
```

?FPOS

Fast query of multiple board positions

Syntax:

?FPOS [AXIS | MEASURE] <axis1> <axis2> … <axisN>

Answer:

?FPOS <posVal1> <posVal2> … <posValN>

Description:

Returns the positions for the specified axes. The AXIS keyword is the default value, and it used to return the nominal positions of the specified axes. The MEASURE keyword must be used to return the measured position values.

Examples:

Command:	`?FPOS 25`
Answer:	`?FPOS 5366703`
Command:	`?FPOS MEASURE 17 18 19`
Answer:	`?FPOS 13467895 0 -3000`

?FSTATUS

Fast query of multiple board status

Syntax:

?FSTATUS <axis1> <axis2> … <axisN>

Answer:

?FSTATUS <statusReg1> <statusReg2> … <statusRegN>

Description:

Returns the value of the current status of the selected boards as 32-bit values in C-like hexadecimal notation.

?FSTATUS is a system query that is managed exclusively by the master system controller. ?FSTATUS returns values stored in the system controller that are updated every time that any bit in the status word of a board changes.

The ?FSTATUS query is intended to be used for frequent polling from the control host, as it is faster as it presents less latency than ?STATUS, and it does not load the internal communication bus.

Example:

Command:	`?FSTATUS 80 83 85`
Answer:	`?FSTATUS 0x00000003 0x00000003 0x00000003`

?HELP

Query list of available commands

Syntax:

<board_addr>:?HELP **(board command)**

or

?HELP **(system command)**

Description:

Returns the list of available commands and queries. The list differs between system, controller and driver commands.

Examples:

Command: `16:?HELP`

Answer:
```
$
    RESET
           ?HDWVER
           ?STATE
           ?RETCODE
    CLEAR
           ?LIST
      RUN
$
```

HOME

Start home signal search sequence

Syntax:

<driver_addr>:HOME {+1 | 0 | -1} **(driver command)**

or

HOME [GROUP] <axis1> {+1 | 0 | -1} … <axisN> {+1 | 0 | -1} **(system command)**

Description:

Starts a home search sequence in the direction specified by the direction parameter. Positive and negative directions are selected by the values +1 and -1 respectively.

The HOME command will start a homing sequence only if the source for the homing reference signal has been previously selected by setting the HOMESRC configuration parameter to a value different from NONE. Otherwise the HOME command produces an error.

The direction parameter can be set to 0 for a given axis only if the AUTODIR flag is set in the HOMEFLAGS configuration parameter for that axis. In that case the search direction of the homing sequence is determined from the logic value of the homing reference signal as it is described in 2.2.2. If the direction parameter is set to 0 for a given axis but the AUTODIR flag is not set, the HOME command produces an error.

Examples:

```
Command:   16:?HOMESTAT
Answer:    16:?HOMESTAT NOTFOUND 0
Command:   16:HOME +1
Command:   16:?HOMESTAT
Answer:    16:?HOMESTAT MOVING +1
Command:   16:?HOMESTAT
Answer:    16:?HOMESTAT MOVING -1
Command:   16:?HOMESTAT
Answer:    16:?HOMESTAT FOUND -1
```

?HOMEENC

Query the found home position in encoder steps

Syntax:

<board_addr>:?HOMEENC [*pos_sel*] **(driver command)**

or

?HOMEENC [*pos_sel*] <axis1> … <axisN> **(system command)**

Description:

Query the position registers latched when the configured homing signal event arrived. The answer is a number of encoder steps.

If no homing latch event happened after the last home search, an error is issued

The specific register is selected by the optional parameter *pos_sel*, that must be one of the following values:

pos_sel	***Position register***
AXIS	
MEASURE	
POSERR	
SHFTENC ⁕	
TGTENC ⁕	
ENCIN ⁕	
INPOS ⁕	
ABSENC ⁕	
MOTOR ⁕	

⁕ Only valid for driver boards

If pos_sel is not specified, the value returned is axis position at homing latch event.

Examples:

```
Command:   16:?HOMEPOS
Answer:    16:?HOMEPOS ERROR Last home search was not
successful
Command:   16:HOME +1
Command:   16:?HOMESTAT
Answer:    16:?HOMESTAT FOUND -1
Command:   16:?HOMEENC
Answer:    16:?HOMEENC 12345
Command:   16:?HOMEENC TGTENC
Answer:    16:?HOMEENC 12350
```

?HOMEPOS

Query the found home position in axis units

Syntax:

<board_addr>:?HOMEPOS [*pos_sel*] **(driver command)**

or

?HOMEPOS [*pos_sel*] <axis1> … <axisN> **(system command)**

Description:

Query the position registers latched when the configured homing signal event arrived. The answer is a number of steps in axis units.

If no homing latch event happened after the last home search, an error is issued

The specific register is selected by the optional parameter *pos_sel*, that must be one of the following values:

pos_sel	***Position register***
`AXIS`	
`MEASURE`	
`POSERR`	
`SHFTENC` ⁕	
`TGTENC` ⁕	
`ENCIN` ⁕	
`INPOS` ⁕	
`ABSENC` ⁕	
`MOTOR` ⁕	

⁕ Only valid for driver boards

If pos_sel is not specified, the value returned is axis position at homing latch event.

Examples:

```
Command:   16:?HOMEPOS
Answer:    16:?HOMEPOS ERROR Last home search was not
successful
Command:   16:HOME +1
Command:   16:?HOMESTAT
Answer:    16:?HOMESTAT FOUND -1
Command:   16:?HOMEPOS
Answer:    16:?HOMEPOS 12345
Command:   16:?HOMEPOS TGTENC
Answer:    16:?HOMEPOS 12350
```

?HOMESTAT

Query home search status

Syntax:

<driver_addr>:?HOMESTAT **(driver command)**

or

?HOMESTAT <axis1> … <axisN> **(system command)**

Answer:

<driver _addr>:?HOMESTAT {MOVING | FOUND | NOTFOUND} {+1| 0 |-1} **(driver answer)**

or

?HOMESTAT hStatus1 hDirection1 … hStatusN hDirectionN **(system answer)**

where *home_status* is one of MOVING, FOUND or NOTFOUND

and *home_dir* is one of +1, 0 or -1

Description:

Query information about the ongoing or previous home search sequence. If the homing sequence is in progress, ?HOMESTAT returns MOVING as hStatus keyword. If the sequence is finished, the query returns either FOUND or NOTFOUND depending on whether the home search succeeded or not.

The numeric value hDirection after the hStatus keyword, represents the direction of motion, -1 or +1, either during the search sequence or when the search is successfully completed. If the homing sequence fails, the returned hDirection value is 0.

Examples:

```
Command:    16:?HOMESTAT
Answer:     16:?HOMESTAT NOTFOUND 0
Command:    16:HOME +
Command:    16:?HOMESTAT
Answer:     16:?HOMESTAT MOVING +1
```

?ID

Query board identification

Syntax:

<board_addr>:?ID [{ HW | SN }]

Answer:

<board_addr>:?ID { <hwIDstring> | <serialNumber> }

Description:

The ?ID query returns either the hardware identification string or the serial number as default the HW is return.

Examples:

Command:	`16:?ID`
Answer:	`?ID xxxx.xxxx.xxxx`
Command:	`31:?ID SN`
Answer:	`?ID 0034-44587`

INDEXER / ?INDEXER

Select/query indexer signal source

Syntax:

<driver_addr>:INDEXER [{ INTERNAL | SYNC | INPOS | ENCIN }]

Description:

Selects the signal source used for the axis indexer.

If no value is specified, the indexer source is set to the default value defined by the configuration parameters (see CFG INDEXER).

Available signal sources:

Source	***Indexer signal***
`INTERNAL`	Internally generated indexer is used
`SYNC`	*Sync* signal distributed through the rack backplane
`INPOS`	*InPos* signal at the front panel connector (Axis Interface)
`ENCIN`	*EncIn* signal at the rear panel

Syntax:

<driver_addr>:?INDEXER

Answer:

<driver_addr>:INDEXER { INTERNAL | SYNC | INPOS | ENCIN | LINKED }

Description:

Returns the current signal source used as axis indexer. If the driver is ser to use the internal indexer in linked mode, the query returns the keyword LINKED.

Examples:

Command:	`34:?CFG INDEXER`	
Answer:	`34:?CFG INDEXER INTERNAL`	// the default is INTERNAL
Command:	`34:INDEXER SYNC`	// change the indexer source
Command:	`34:?INDEXER`	
Answer:	`34:?INDEXER SYNC`	
Command:	`34:INDEXER`	// set the default value back
Command:	`34:?INDEXER`	
Answer:	`34:?INDEXER INTERNAL`	

INFOA / ?INFOA
INFOB / ?INFOB
INFOC / ?INFOC

Set/query info signal source and polarity

Syntax:

<driver_addr>:INFOx [*signal_source* [{NORMAL | INVERTED}]]

where INFOx is one of INFOA, INFOB or INFOC.

Description:

Configures the Info lines to output the signal *signal_source* with the selected polarity. If the polarity is not specified it is set to NORMAL.

If *signal_source* is not explicitly specified, the signal is configured to the default value defined in the diver configuration parameters.

The possible values of *signal_source* are summarised in the table:

Source	***Signal, control line or status value***
`LOW`	low logic level
`HIGH`	high logic level
`LIM+`	limit- signal
`LIM-`	limit+ signal
`HOME`	home signal
`ENCAUX`	EncAux signal
`INPAUX`	InPosAux signal
`SYNCAUX`	SyncAux signal
`PWRCTRL`	power control to switch on/off external power drivers
`ENABLE`	current power status
`ALARM`	alarm condition
`READY`	axis ready
`MOVING`	axis moving
`BOOST`	axis in acceleration phase
`STEADY`	axis moving at constant velocity
`ECAM`	electronic cam output. See ECAM command
`.MAIN`	internal signals (only for diagnostic)
`.ISR`	

Syntax:

<driver_addr>:?INFOx

where ?INFOx is one of ?INFOA, ?INFOB or ?INFOC

Answer:

<driver_addr>:INFOx *signal_source* {NORMAL | INVERTED}

where *signal_source* is one of the possible values presented above.

Description:

Returns the configuration of the corresponding Info output signal.

Examples:

Command:	`12:INFOB READY`
Command:	`?12:INFOB`
Answer:	`?12:INFOB READY NORMAL`

IPMASK / ?IPMASK

Set/query IP control mask

Syntax:

IPMASK <IPmask>

Description:

Sets the IP address control mask used to identify active network control clients. If the masked client IP address matches the masked IcePAP IP address, the client is authorised to send both commands and queries to the system. Otherwise only queries are authorised.

The default IP control mask is 0.0.0.0 as described in 4.2.1.

Comment [jmc5]: 255.255.255.0 only at ESRF…

Syntax:

?IPMASK

Answer:

?IPMASK <IPmask>

Description:

Returns the current IP control mask.

Examples:

```
Command:   ?IPMASK
Answer:    ?IPMASK 255.255.255.0
Command:   #IPMASK 255.255.0.0
Answer:    IPMASK OK
```

JOG / ?JOG

Set/query jog velocity

Syntax:

<board_addr>:JOG <signedVelocity> **(board command)**

or

JOG [GROUP] <axis1> <signedVel1> … <axisN> <signedVelN> **(system command)**

Description:

Sets the specified axis or axes in jog mode at the given velocity in steps per second. The sign of the velocity parameter selects the actual direction of the movement. If a specified axis is already jogging at a certain speed, the speed will be ramped up or down as needed to reach the new velocity value. The acceleration is fixed as the ratio of the current values of axis velocity and acceleration time (see ?VELOCITY and ?ACCTIME queries). A zero velocity value forces an axis to stop.

If the GROUP keyword is used with the JOG system command, the set of axes is managed as a group by the system controller as described in 2.2.2.

Syntax:

<board_addr>:?JOG **(board query)**

or

?JOG <axis1> <axis2> … <axisN> **(system query)**

Answer:

<board_addr>:?JOG < signedVelocity > **(board answer)**

or

?JOG < signedVel1> < signedVel2> … < signedVelN> **(system answer)**

Description:

Returns the current jog velocities of the specified axes in steps per second. If an axis is not in jog mod, a zero velocity value is returned.

Examples:

Command:	`#5:JOG 200`
Answer:	`5:JOG OK`
Command:	`#5:JOG -200`
Answer:	`3:JOG ERROR Cannot change jog direction`
Command:	`JOG 5 200 23 100`

?LINKED

Query linked axis groups

Syntax:

?LINKED

Answer:

?LINKED $

<lnkName1> <axis1> <axis2> … <axisN>

…

<lnkNameN> <axisX> <axisY> … <axisZ>

$

Description:

Returns the current list of groups of linked drivers. Each group is returned in a separate line starting by the name of the group and followed by the corresponding list of axes.

See 0 and the configuration parameter LNKNAME for additional information on linked axes.

Examples:

Command:
```
?LINKED
```

Answer:
```
?LINKED $
tripod1 27 28 29
detarm  111 112
$
```

?MEAS

Query measured value

Syntax:

<board_addr>:?MEAS { VCC | VM | I | IA | IB | IC | T | RT}

Answer:

<board_addr>:?MEAS <measuredValue>

Description:

Returns a measured value for the specified axes. The of the possible measured values and their meaning is compiled in the following table:

magnitude	***description***	***units***	***applies to:***
`VCC`	Main power supply voltage	volts	only drivers
`VM`	Motor voltage	volts	only drivers
`I`	Motor current	amps	only drivers
`IA`	Phase A current	amps	only drivers
`IB`	Phase B current	amps	only drivers
`IC`	Phase C current	amps	only drivers
`R`	Motor resistance	ohms	only drivers
`RA`	Phase A resistance	ohms	only drivers
`RB`	Phase B resistance	ohms	only drivers
`RC`	Phase C resistance	ohms	only drivers
`T`	Board temperature	°C	controllers and drivers
`RT`	Power supply temperature	°C	only controllers

Examples:

```
Command:    15:?MEAS VCC
Answer:     15:?MEAS 80.1
Command:    15:?MEAS T
Answer:     15:?MEAS 24
```

?MEMORY

Query available memory

Syntax:

<board_addr>:?MEMORY

Answer:

<board_addr>:?MEMORY <totalMemory> <freeMemory> <maxFreeBlock>

Description:

Returns the amount of total user memory <totalMemory>, unused memory <freeMemory> and the size of biggest available memory block <maxFreeBlock>. All the three quantities are returned in bytes.

Examples:

Command:	`15:?MEMORY`
Answer:	`15:?MEMORY ??? ??? ???`

MODE / ?MODE

Set/query board or system mode

Syntax:

MODE { OPER | PROG | TEST } **(system command)**

Description:

Changes the mode of the IcePAP system to operation (*OPER*), firmware reprogramming (*PROG*) or factory test (*TEST*) modes.

In normal operation, the system must be always set in mode *OPER*.

Syntax:

?MODE **(system query)**

or

<board_addr>:?MODE **(board query)**

Answer:

?MODE { OPER | PROG | TEST } **(system answer)**

or

<board_addr>:?MODE { CONFIG | OPER | PROG | TEST | FAIL } **(board answer)**

Description:

Returns the current mode of the system or the specific mode of one of the boards (controllers or drivers). In normal conditions, all the boards should return the same mode than the system.

If a particular driver is switched into configuration mode (see CONFIG command), the returned mode is CONFIG for that driver (note that CONFIG is not a system mode selectable by the MODE command).

If a non recoverable internal hardware error happens in a particular board, that board switches FAIL mode.

Examples:

Command:	`?MODE`
Answer:	`?MODE OPER`
Command:	`25:?MODE`
Answer:	`25:?MODE OPER`
Command:	`25:CONFIG`
Command:	`25:?MODE`
Answer:	`25:?MODE CONFIG`
Command:	`?MODE`
Answer:	`?MODE OPER`

MOVE

Start absolute movement

Syntax:

<board_addr>:MOVE <absolutePos> **(board command)**

or

MOVE [GROUP] <axis1> <absPos1> … <axisN> <absPosN> **(system command)**

Description:

Moves the specified axis or axes towards the absolute target positions specified as parameters. Axes can only be moved with this command if any previous movement is finished and the axis is in READY state. See the UMOVE command to update the target position of an axis currently in motion.

If the GROUP keyword is used with the MOVE system command, the set of axes is managed as a group by the system controller as described in 2.2.2.

Examples:

```
Command:    115:MOVE 4000
Command:    MOVE 115 4000
Command:    MOVE 31 250000 32 -29888 33 250000
```

MOVEP

Start axis movement to parameter value

Syntax:

<board_addr>:MOVEP <paramVal> **(board command)**

or

MOVEP [GROUP] <paramVal> <axis1> < axis2> … <axisN> **(system command)**

Description:

Moves the specified axis or axes towards the …

.

Examples:

Command:	`115:MOVEP 3.456`
Command:	`MOVEP 3.456 115`

NAME / ?NAME

Set/query board name

Syntax:

<driver_addr>:NAME <driverName>

Description:

Sets the internal axis name to the ASCII string <driverName>. This name is only used for identification purposes and user convenience. The name is stored in the non-volatile memory and is only used for identification purposes. Changing the axis name is not allowed if the NAMELOCK configuration flag is set.

The maximum length is 20 characters. [TODO: CHECK]

If the name is locked (configuration parameter NAMELOCK = YES), this command will not have any effect.

Syntax:

<driver_addr>:?NAME

Answer:

<driver_addr>:?NAME <driverName>

Description:

Returns the board name string.

Examples:

Command:	`#11:NAME phi`
Answer:	`11:NAME OK`
Command:	`12:?NAME`
Answer:	`12:?NAME th`
Command:	`#12:NAME tth`
Answer:	`12:NAME ERROR The name of this board is locked`

NOECHO

Cancel echo mode

Syntax:

NOECHO **(system command)**

or

<board_addr>:NOECHO **(board command)**

Description:

Switches the echo mode off. See the ECHO command for more details. Only applies for serial line communication.

Example:

Command:	`NOECHO`
Command:	`2:NOECHO`

PCLOOP / ?PCLOOP

Set/query current position closed loop mode

Syntax:

<driver_addr>:PCLOOP {ON | OFF}

Description:

Activates/deactivates the position closed loop.

In order to activate the position closed loop, a target encoder must be configured (configuration parameter TGTENC must be different from NONE), and the difference between the position values in tgtenc and indexer must be inside the range +/- PCLERROR(see configuration parameters

---

Syntax:

<driver_addr>:?PCLOOP

Answer:

<driver_addr>:?PCLOOP {ON | OFF}

Description:

Returns the current position closed loop mode.

Examples:

Command:	`15:PCLOOP ON`
Command:	`15:?PCLOOP`
Answer:	`15:?PCLOOP ON`

PMOVE

Start parametric movement

Syntax:

<board_addr>:PMOVE <paramVal> **(board command)**

or

PMOVE [GROUP] <paramVal> <axis1> < axis2> … <axisN> **(system command)**

Description:

Moves the specified axis or axes towards the …

.

Examples:

Command:	`115:PMOVE 3.456`
Command:	`PMOVE 3.456 115`

PMUX / ?PMUX

Position signal multiplexer configuration

Syntax:

PMUX [HARD] [POS] [AUX] <source> [<dest>]

or

PMUX REMOVE [POS] [AUX] [<dest>]

Description:

Defines a rule to manage the …

The specific register is selected by the optional parameter *pos_sel*, that must be one of the following values:

pmux_node	*Node*
xxx or B*xxx*	Board *xxx*
R*nn*	Backplane of rack *nn*
C*nn*	Controller board of rack *nn*
E*nn*	External connector of rack *nn*

If …

Syntax:

?PMUX { POS | AUX } <dest>

or

?PMUX [POS] [AUX]

Answer:

?PMUX …

Description:

Returns the current signal source used as axis indexer.

Examples:

Command:	`PMUX HARD E0`
Command:	`?PMUX`
Answer:	`?PMUX $`

POS / ?POS

Set/query axis position in axis units

Syntax:

<board_addr>:POS [*pos_sel*] <posVal> **(board command)**

or

POS [*pos_sel*] <axis1> <posVal1> … <axisN> <posValN> **(system command)**

Description:

Loads the position registers in the specified boards with the <posVal> values. The specific register is selected by the optional parameter *pos_sel*, that must be one of the following values:

pos_sel	***Position register***
`AXIS`	Points to the axis nominal position
`MEASURE`	Points to the register used for position measurement
`SHFTENC` *	Points to the register configured as SHFTENC
`TGTENC` *	Points to the register configured as TGTENC
`CTRLENC` *	Points to the register configured as CTRLENC
`ENCIN` *	ENCIN register
`INPOS` *	INPOS register
`ABSENC` *	ABSENC register

* Only valid for driver boards

If position is not specified, the value is loaded as axis position

---

Syntax:

<board_addr>:?POS [*pos_sel*] **(board query)**

or

?POS [*pos_sel*] <axis1> <axis2> … <axisN> **(system query)**

Answer:

<board_addr>:?POS <posVal> **(board answer)**

or

?POS <posVal1> <posVal2> … <posValN> **(system answer)**

Description:

Returns the current signal source used as axis indexer.

Examples:

Command: `115:POS AXIS 500`

Command:	`115:POS MEASURE -3000`
Command:	`115:?POS`
Answer:	`115:?POS 500`
Command:	`?POS MEASURE 5 115`
Answer:	`?POS 13467895 -3000`

?POST

Query power-on self-test results

Syntax:

<board_addr>:?POST

Answer:

<board_addr>:?POST <testresultMask>

Description:

Returns the result of the power-on self tests as an binary mask <testresultMask>. A bit set to one in the mask indicates that a particular test has failed. If no tests failed during the power-on sequence, this query returns zero.

The meaning of the individual bits in <testresultMask> is summarised in the following table:

bit	***subsystem under test***	***applies to:***
`0x01`	external RAM	controllers and drivers
`0x02`	non volatile FRAM	controllers and drivers
`0x04`	internal 1-wire bus	controllers and drivers
`0x08`	ADC	only drivers
`0x10`	FPGA	controllers and drivers
`0x20`	external 1-wire bus	only controllers
`0x40`	CANbus	only controllers

Examples:

```
Command:    115:?POST
Answer:     115:?POST 0
```

POWER / ?POWER

Set/query motor power state

Syntax:

<driver_addr>:POWER [{ON | OFF}] **(board command)**

or

POWER [{ON | OFF}] <axis1> … <axisN> **(system command)**

Description:

Switches on or off the motor power in a driver board.

Syntax:

<driver_addr>:?POWER **(board query)**

or

?POWER <axis1> <axis2> … <axisN> **(system query)**

Answer:

<driver_addr>:?POWER {ON | OFF} **(board answer)**

or

?POWER $\{ON \mid OFF\}_1$ $\{ON \mid OFF\}_2$ … $\{ON \mid OFF\}_N$ **(system answer)**

Description:

Returns the power state of the specified driver boards.

Examples:

Command:	`115:POWER OFF`
Answer:	`115:POWER OFF`

*PROG / PROG / ?PROG

Firmware programming

Syntax:

***PROG {NONE | <bAddr> | DRIVERS | CONTROLLERS | ALL} [FORCE] [NOSAVE]**

PROG { <bAddr> | DRIVERS | CONTROLLERS | ALL} [FORCE]

Description:

The *PROG command reprograms the components of the IcePAP system by using firmware code that is transferred as a binary data block (see xxx). By default this firmware code is automatically stored in the non volatile FLASH memory of the system master board. To avoid this storing, the NOSAVE flag must be set.

A mandatory parameter specifies the components to program, that can be either the components in the board with address <bAddr>, in all the driver boards (DRIVERS), in all controller boards (CONTROLLERS) or in both (ALL). If the parameter is set to NONE, no components are programmed, but the *PROG command can be use to store the firmware code in the system except if the NOSAVE flag is used.

If one of the components in the system is already programmed with the same version of firmware, the programming operation for that specific component is skipped. This behaviour changes if the FORCE flag is used. In that case the components in the selected boards are always reprogrammed regardless of their current firmware version.

In the case of reprogramming certain internal components, a REBOOT action may be needed to reload those new components into memory. The REBOOT is not automatically started after the PROG command. Instead, any non query command will produce an explicit error until a REBOOT command is issued by the user or the client program. Only the query commands will not generate such an error and will be properly executed.

The *PROG command initiates the internal programming procedure and completes successfully if it started successfully. The actual progress and the final success of the programming operation can be monitored by means of the ?PROG query.

The PROG command works in the same way than *PROG but uses the firmware code that was previously stored in the internal non volatile FLASH memory of the system master board by a previous *PROG command.

Syntax:

?PROG

Answer:

?PROG [{OFF | ACTIVE <progress> | DONE | ERROR}]

Description:

Returns the state of firmware programming operations.

Examples:

Command:	`?PROG`
Answer:	`?PROG ACTIVE 49.0`
Command:	`?PROG`
Answer:	`?PROG DONE`

REBOOT

System reboot

Syntax:

REBOOT

Description:

Reboots the communication processor in the master controller. Any communication, either through serial line or TCP socket, will be interrupted.

Examples:

REPORT / ?REPORT

Set/query asynchronous report settings

Syntax:

REPORT { ON | OFF } [<firstRack> <lastRack> [ ]]

Description:

The REPORT command allows to activate (ON) or deactivate (OFF) the asynchronous reporting feature on the current communication port. When asynchronous reporting is active in a particular port (RS232 serial line or TCP socket), the IcePAP master controller sends binary data blocks containing status and position information through that port to the listening device, usually the host computer. The binary blocks contain status and position information as the values returned by the ?FSTATUS and ?FPOS queries.

The data blocks contain the status as well as the axis and indexer positions for all the boards in the selected racks. The data block is sent whenever the data in the system master board changes or after a time interval of <maxPeriod> seconds.

The block includes data from all the boards in the racks from <firstRack> to <lastRack> that must be numbers from 0 to 15.

The format of the binary blocks is the following:

[TODO: explain block format and structure]

Syntax:

?REPORT

Answer:

?REPORT { ON | OFF } <firstRack> <lastRack> <maxPeriod>

Description:

Returns the status and range of the asynchronous status reporting feature.

Examples:

RESET

System or rack reset

Syntax:

RESET [<rackNumber>]

Description:

Resets the given rack or the whole system if no parameter is added.

Examples:

Command:	`RESET`
Command:	`RESET 8`

?RID

Query rack hardware identification string

Syntax:

?RID [<rackNumber1> <rackNumber2> ... <rackNumberN>]

Answer:

?RID <hwIDstring1> <hwIDstring2> ... <hwIDstringN>

Description:

The ?RID query returns the hardware identification strings of the racks specified by the list of rack numbers. If the query is issued with no parameters, it returns the identification strings of the rack 0 (the one hosting the system master controller).

Examples:

Command:	`?RID 0`
Answer:	`?RID XXXX.XXXX.XXXX`
Command:	`?RID`
Answer:	`?RID XXXX.XXXX.XXXX     //rack 0 ID string`
Command:	`?RID 5 6`
Answer:	`?RID YYYY.YYYY.YYYY ZZZZ.ZZZZ.ZZZZ`

RFPROG

Factory firmware programming

Syntax:

RFPROG [<rackNumber1> <rackNumber2> ... <rackNumberN>]

Description:

The RFPROG command is intended to reload the firmware in IcePAP driver boards that are not responsive or that have never been programmed (i.e after manufacturing). It cannot be used to reload firmware in controller boards and should not be used in normal operation instead of the PROG command.

RFPROG initiates the programming procedure of all the driver boards in the racks specified in the command line. If the command is issued with no parameters, it initiates the programming of the drivers boards in all the racks present in the system.

The system uses the firmware code that was stored in the non volatile FLASH memory of the system master board by a previous *PROG command.

The progress of the programming procedure can be followed by means of the ?PROG query.

Examples:

```
Command:   MODE PROG
Command:   *PROG NONE
           [firmware as binary data block]
Command:   RFPROG
                       (wait some time)
Command:   ?PROG
Answer:    ?PROG ACTIVE 37%
                       (wait for full reprogramming)
Command:   ?PROG
Answer:    ?PROG DONE
```

RMOVE

Start relative movement

Syntax:

<board_addr>:RMOVE <relativePos> **(board command)**

or

RMOVE <axis1> <relativePos1> … <axisN> <relativePosN> **(system command)**

Description:

Performs a relative movement on the specified axis or axes.

If the GROUP keyword is used with the RMOVE system command, the set of axes is managed as a group by the system controller as described in 2.2.2.

Examples:

```
Command:    115:?POS
Answer:     115:?POS 5000
Command:    115:RMOVE -7000
Command:    115:?POS
Answer:     115:?POS -2000

Command:    RMOVE 115 -7000
Command:    RMOVE 31 250000 32 -29888 33 250000
```

RDISPOL / ?RDISPOL

Set/query Rack Disable Polarity

Syntax:

<board_addr>:RDISPOL {NORMAL | INVERTED | SYSDEFAULT}

(controller board command)

or

RDISPOL {NORMAL | INVERTED | SYSDEFAULT} [FORCE] **(system command)**

Syntax:

<board_addr>:?RDISPOL **(controller board query)**

or

?RDISPOL **(system query)**

Answer:

<board_addr>:?RDISPOL {NORMAL | INVERTED | SYSDEFAULT}

(controller board answer)

or

?RDISPOL {NORMAL | INVERTED} **(system answer)**

Description:

Sets the polarity of the remote disable signal of a rack.

The board command is useful to set a specific polarity for the addressed rack. In that case, the target rack will not use the system default polarity.

If SYSDEFAULT is used, the crate will use whatever polarity is defined as system default polarity.

The system RDISPOL command sets the system default remote rack disable polarity to the value specified by the first parameter.

If the first parameter is SYSDEFAULT, the current system default polarity in the master will be used.

If the flag FORCE is used, all the crates will be forced to use the system default polarity.

Examples:

Command:	`50:RDISPOL SYSDEFAULT`
Command:	`50:?RDISPOL`
Answer:	`50:?RDISPOL SYSDEFAULT`
Command:	`50:RDISPOL INVERTED`
Command:	`50:?RDISPOL`
Answer:	`50:?RDISPOL INVERTED`
Command:	`RDISPOL NORMAL FORCE`
Command:	`?RDISPOL`
Answer:	`RDISPOL NORMAL`
Command:	`50:?RDISPOL`
Answer:	`50:?RDISPOL SYSDEFAULT`

?RTEMP

Query rack temperatures

Syntax:

?RTEMP [<rackNumber1> <rackNumber2> ...   <rackNumberN>]

Answer:

?RTEMP <rackTemp1> <rackTemp2> ...   <rackTempN>

Description:

The ?RTEMP query returns the temperature of the main power supply of the racks specified by the list of rack numbers. If the query is issued with no parameters, it returns the temperatures of the rack with lowest number (the one hosting the system master controller).

Examples:

Command:	`?RTEMP 0`
Answer:	`?RTEMP 35`
Command:	`?RTEMP`
Answer:	`?RTEMP 35`
Command:	`?RTEMP 0 2 5`
Answer:	`?RTEMP 35 32 31`

SRCH

Start signal search sequence

Syntax:

<driver_addr>:SRCH <signal> [<edgetype> <srchdir>] **(driver command)**

With:

<signal> = {Lim- | Lim+ | Home | EncAux | InpAux}

<edgetype> = {POSEDGE | NEGEDGE}

<srchdir> = {+1 | -1}

Description:

Starts a signal search sequence.

The **<signal>** parameter is mandatory.

<edgetype> and **<srchdir>** parameters are ignored if the **<signal>** parameter is either lim- or lim+, otherwhise these parameters have to be specified.

The search is done in the direction specified by **<srchdir>**. Positive and negative directions are selected by the values +1 and -1 respectively.

<edgetype> corresponds to the transition of the signal that defines the reference to search, posedge being a transition from inactive to active.

If the **<signal>** parameter is lim- or lim+, the direction and edge type will be selected automatically in order to start the search towards the specified limit switch position.

Examples:

```
Command:   16:?SRCHSTAT
Answer:    16:?SRCHSTAT NOTFOUND 0
Command:   16:SRCH HOME POSEDGE +1

Command:   16:?SRCHSTAT
Answer:    16:?SRCHSTAT MOVING +1
Command:   16:?SRCHSTAT
Answer:    16:?SRCHSTAT FOUND +1
[. . .]
Command:   16:SRCH LIM-
[. . .]
Command:   16:?SRCHSTAT
Answer:    16:?SRCHSTAT FOUND -1
```

?SRCHENC

Query the found signal search position in encoder steps

Syntax:

<board_addr>:?SRCHENC [*pos_sel*] **(driver command)**

Description:

Query the position registers latched when the signal event arrived during a signal search command. The answer is a number of encoder steps, the resolution being the one configured for the selected encoder.

If no signal search latch event happened after the last search, an error is issued

The specific register is selected by the optional parameter *pos_sel*, that must be one of the following values:

pos_sel	***Position register***
AXIS	
MEASURE	
POSERR	
SHFTENC ⁕	
TGTENC ⁕	
ENCIN ⁕	
INPOS ⁕	
ABSENC ⁕	
MOTOR ⁕	

⁕ Only valid for driver boards

If pos_sel is not specified, the value returned is axis position at signal latch event.

Examples:

```
Command:    16:?SRCHPOS
Answer:     16:?SRCHPOS ERROR Last home search was not
successful
Command:    16:SRCH LIM+
Command:    16:?SRCHSTAT
Answer:     16:?SRCHSTAT FOUND +1
Command:    16:?SRCHENC
Answer:     16:?SRCHENC 12345
Command:    16:?SRCHENC TGTENC
Answer:     16:?SRCHENC 24700
```

?SRCHPOS

Query the found home position in axis units

Syntax:

<board_addr>:?SRCHPOS [*pos_sel*] **(driver command)**

Description:

Query the position registers latched latched when the signal event arrived during a signal search command.

The answer is a number of steps in axis units.

If no signal search latch event happened after the last search, an error is issued

The specific register is selected by the optional parameter *pos_sel*, that must be one of the following values:

pos_sel	***Position register***
AXIS	
MEASURE	
POSERR	
SHFTENC ❋	
TGTENC ❋	
ENCIN ❋	
INPOS ❋	
ABSENC ❋	
MOTOR ❋	

❋ Only valid for driver boards

If pos_sel is not specified, the value returned is axis position at signal latch event.

Examples:

```
Command:  16:?SRCHPOS
Answer:   16:?SRCHPOS ERROR Last home search was not
successful
Command:  16:SRCH LIM1
Command:  16:?SRCHSTAT
Answer:   16:?SRCHSTAT FOUND +1
Command:  16:?SRCHPOS
Answer:   16:?SRCHPOS 12345
Command:  16:?SRCHPOS TGTENC
Answer:   16:?SRCHPOS 12350
```

?SRCHSTAT

Query signal search status

Syntax:

<driver_addr>:?SRCHSTAT **(driver command)**

Answer:

<driver _addr>:?HOMESTAT {MOVING | FOUND | NOTFOUND} {+1| 0 |-1}(driver answer)

Description:

Query information about the ongoing or previous signal search sequence. If the sequence is in progress, ?HOMESTAT returns MOVING as hStatus keyword. If the sequence is finished, the query returns either FOUND or NOTFOUND depending on whether the home search succeeded or not.

The numeric value hDirection after the hStatus keyword, represents the direction of motion, -1 or +1, either during the search sequence or when the search is successfully completed. If the homing sequence fails, the returned hDirection value is 0.

Examples:

```
Command:   16:?SRCHSTAT
Answer:    16:?SRCHSTAT NOTFOUND 0
Command:   16:SRCH LIM+
Command:   16:?SRCHSTAT
Answer:    16:?SRCHSTAT MOVING +1
Command:   16:?SRCHSTAT
Answer:    16:?SRCHSTAT FOUND +1
```

?STATUS

Query board status

Syntax:

<board_addr>:?STATUS **(board query)**

or

?STATUS <axis1> <axis2> … <axisN> **(system query)**

Answer:

<board_addr>:?STATUS <statusReg> **(board answer)**

or

?STATUS <statusReg1> <statusReg2> … <statusRegN> **(system answer)**

Description:

Returns the current status words of the specified boards as 32-bit values in C-like hexadecimal notation.

The system query ?STATUS can be used to return the status of any number of boards in the system. In that case the status value is sampled simultaneously in all the boards.

Note that in the cases of very frequent status polling, the ?FSTATUS query may be preferred to ?STATUS as ?FSTATUS returns values stored in the system controller and therefore suffers from shorter execution latency. ?STATUS on the other hand returns the status information stored in the boards and therefore guarantees more up to date values.

Example:

Command:	`53:?STATUS`
Answer:	`53:?STATUS 0x00000003`
Command:	`?STATUS 80 83 85`
Answer:	`?STATUS 0x002c0403 0x00200403 0x00000403`

STOP

Stop movement

Syntax:

<board_addr>:STOP **(board command)**

or

STOP [<axis1> <axis2> … <axisN>] **(system command)**

Description:

The STOP command finalises the movement in the given axes with a normal deceleration ramp.

If any of the axis is included in one of the currently active axis groups (see 2.2.2), all the other axes of the corresponding group are also stopped.

For security reasons, if the STOP system command fails or any error happens, all the boards in the system are instructed to stop their movements.

Examples:

Command:	`10:STOP`	
Command:	`STOP`	// stop all movements
Command:	`#STOP 30 33 42`	
Answer:	`STOP ERROR All axes stopped, cause in axis 33: Board is not present in the system`	
Command:	`#STOP 30 rrt 42`	
Answer:	`STOP ERROR All axes stopped, cause: Wrong parameter(s)`	

?SYSSTAT

Query system configuration

Syntax:

?SYSSTAT [<rackNumber>]

Answer:

?SYSSTAT <rackPresenceMask>

or

?SYSSTAT <driverPresenceMask> <driverAliveMask>

Description:

By default, with no parameter, the SYSSTAT query returns a 16 bit mask that represents the list of racks present in the system. Every bit in the <rackPresenceMask> mask indicates if the corresponding rack (0 to 15) has been found in the system.

If the SYSSTAT command is issued with a valid rack number (0 to 15) as parameter, it returns two 8 bit values that indicates the drivers found in the rack and which of them are responsive. Every bit of each mask correspond to one of the drivers (1 to 8) within the rack. The bits in <driverPresenceMask> that are set to 1, indicate which driver boards are plugged in the rack. The bits in <driverAliveMask> indicates which drivers are responsive and communicate with the system master board.

In normal conditions <driverPresenceMask> and <driverAliveMask> are identical.

Example:

Command:	`?SYSSTAT`
Answer:	`0x004F`
Command:	`?SYSSTAT 8`
Answer:	`0x13 0x13`

?TIME

Query the board running time

Syntax:

<board_addr>:?TIME

Answer:

<board_addr>:?TIME *time_string*

Description:

Returns the time elapsed since the board processor start execution or was reset. The time is return as an ASCII string.

Examples:

Command:	`115:?TIME`
Answer:	`115:?TIME 1623hrs 31min 14sec`

UMOVE

Absolute updated movement

Syntax:

<board_addr>:UMOVE <absolutePos>

Description:

Performs an absolute movement on the specified axis. This command is similar to MOVE but it can be executed even if the motor has not finished the previous movement command and is still in motion state.

Examples:

VCONFIG / ?VCONFIG

Set/query variable regulation configuration

Syntax: **(board command)**

<board_addr>:VCONFIG SOURCE { SOFT | ABSENC | ENCIN | INPOS }

or

<board_addr>:VCONFIG {GAIN | TAU | DEADBAND } <par_value>

or

<board_addr>:VCONFIG { MINPOS | MAXPOS } { NONE | <soft_limit> }

or

<board_addr>:VCONFIG { AUTOSTOP | DBHYST } { ON | OFF }

Description:

Sets the ….

Syntax: **(board command)**

<board_addr>:?VCONFIG [{ SOURCE | GAIN | TAU | DEADBAND | DBHYST }]

or

<board_addr>:?VCONFIG [{ MINPOS | MAXPOS | AUTOSTOP }]

Answer:

<board_addr>:?VCONFIG <par_value> **(board answer)**

or

<board_addr>:?VCONFIG $ **(board answer)**

```
SOURCE <var_source>
GAIN <gain_factor>
   …
DBHYST { ON | OFF }
$
```

Description:

Returns the...

Examples:

VELOCITY / ?VELOCITY

Set/query programmed axis velocity

Syntax:

<board_addr>:VELOCITY [<velocity>] **(board command)**

or

VELOCITY <axis1> <velocity1> … <axisN> <velocityN> **(system command)**

Description:

Sets the velocity for the corresponding axis to the <velocity> values in steps per second. The actual acceleration for each axis is maintained to the previous value, and the acceleration time is internally recalculated (see ?ACCTIME query).

If no value is specified, the velocity is set to the default value.

Syntax:

<board_addr>:?VELOCITY **(board command)**

or

?VELOCITY <axis1> <axis2> … <axisN> **(system command)**

Answer:

<board_addr>:?VELOCITY <velocity> **(board answer)**

or

?VELOCITY <velocity1> <velocity2> … <velocity1> **(system answer)**

Description:

Returns the current velocity in steps per second.

Examples:

?VER

Query firmware version information

Syntax:

?VER [<verModule>] **(system command)**

or

<board_addr>:?VER [<verModule>] **(board command)**

Answer:

?VER <verModule> <verNumber> **(system answer)**

or

<board_addr>:?VER <verModule> <verNumber> **(board answer)**

Description:

Returns the version number XX.YY of the firmware.

module	**...**	**...**
`SYSTEM`		all cases
`CONTROLLER`		all cases
`DRIVER`		all cases
`DSP`		controllers and drivers
`FPGA`		controllers and drivers
`PCB`		controllers and drivers
`IO`		drivers
`INFO`		all cases

The ?VER INFO query returns a multiline answer with the version numbers of all the modules.

Example:

Command:	?VER
Answer:	`...`

VMOVE / ?VMOVE

Set/query setpoint for variable regulation motion

Syntax:

<board_addr>:VMOVE <setpoint> **(board command)**

Description:

Sets the setpoint and starts variable regulation motion. If the axis is already in that motion mode, only the setpoint value is updated.

Syntax:

<board_addr>:?VMOVE **(board command)**

Answer:

<board_addr>:?VMOVE <setpoint> **(board answer)**

Description:

Returns the current setpoint for variable regulation motion.

Examples:

?VSTATUS

Query verbose board status

Syntax:

<board_addr>:?VSTATUS

Answer:

<board_addr>:?VSTATUS <statusReg>

Description:

Returns the board status as as multiline verbose answer. The status information is the same returned by ?STATUS and ?FSTATUS, but the various status bits and fields are presented and identified separately.

The purpose of ?VSTATUS is to be used to assist application debugging and it is not intended to be used in normal operation.

Example:

Command: `12:?STATUS`

Answer: `12:?STATUS 0x00000003`

Command: `12:?VSTATUS`

Answer:

```
12:?VSTATUS $
0x00000000
  .......1 – 1: Board is present in the system
  .......2 – 1: Board is alive
  .......C – 2: Board mode is OPER
  ......7. – 2: Motor power is ON
  .....18. – 2: Indexer source is INTERNAL
  .....2.. – 1: Board is READY
  .....4.. – 0: Motor is not moving
[...]
  ...4.... – 0: Limit+ signal is not active
  ...8.... – 0: Limit- signal is not active
  ..1..... – 0: Home signal is not LOW
  ..2..... – 1: Aux 5V power supply is ON
  ..4..... – 0: Firmware versions are consistent
  FF...... – 0: Info value is 0
$
```

VVALUE / ?VVALUE

Set/query current value of external variable

Syntax:

<board_addr>:VVALUE [<soft_value>] **(board command)**

Description:

Sets the value of the external variable used for variable regulation motion when the axis is configured to use a software variable (see VCONFIG SOURCE SOFT command).

Syntax:

<board_addr>:?VVALUE **(board command)**

Answer:

<board_addr>:?VVALUE <current_value> **(board answer)**

Description:

Returns the current value of the external variable used for variable regulation motion. This query can be used regardless of whether or not the axis is configured to use a software variable.

Examples:

?WARNING

Query board warnings

Syntax:

<board_addr>:?WARNING

Answer:

<board_addr>:?WARNING NONE

or

<controller_addr>:?WARNING [<temperatureWarning>]

or

<driver_addr>:?WARNING $

[<temperatureWarning>]

[<ssiWarning>]

[<externalWarning>]

$

Description:

Returns a list of strings describing warning conditions that happened since the last ?WARNING query was received by the board. If no warning conditions happened, the query returns no strings.

The warning strings and conditions are cleared immediately after the query is executed.

Examples:

Command:	`115:?WARNING`

Answer:	`115:?WARNING $`
	`blah, blah`
	`$`

Command:	`115:?WARNING`
Answer:	`115:?WARNING NONE`

WTEMP / ?WTEMP

Set/query warning temperature

Syntax:

<board_addr>:WTEMP <warningTemp>

Description:

Sets the temperature threshold used by the board to generate warning conditions to the value <warningTemp> in degrees Celsius.

Syntax:

<board_addr>:?WTEMP

Answer:

<board_addr>:?WTEMP <warningTemp>

Description:

Returns the warning temperature threshold in degrees Celsius.

Examples:

Command:	`11:?WTEMP`
Answer:	`11:?WTEMP 40`
Command:	`12:WTEMP 35.5`

5.2. IcePAP command quick reference

BOARD COMMANDS

BOARD CONFIGURATION and IDENTIFICATION

<board_addr>:?ACTIVE
Query activation status

<board_addr>:?MODE
Query board mode

<board_addr>:?STATUS
Query board status

<board_addr>:?VSTATUS
Query verbose board status

<board_addr>:?ALARM
Query board alarm message

<board_addr>:?WARNING
Query board warnings

<board_addr>:WTEMP <warningTemp>
<board_addr>:?WTEMP
Set/query warning temperature

<driver_addr>:CONFIG [<confID>]
<driver_addr>:?CONFIG
Manage configuration mode

<driver_addr>:CFG <configPar> <configVal>
<driver_addr>:CFG {DEFAULT | EXPERT}
<driver_addr>:?CFG {[<configPar>] | EXPERT}
Set/query configuration parameters

<driver_addr>:?CFGINFO [<configPar>]
Query configuration parameter info

<board_addr>:?VER [<verModule>]
Query board version information

<board_addr>:NAME <boardName>
<board_addr>:?NAME
Set/query board name

<board_addr>:?ID [{HW | SN}]
Query board identification

<board_addr>:?POST
Query power-on self-test results

POWER AND MOTION CONTROL

<driver_addr>:POWER [{ON | OFF}]
<driver_addr>:?POWER
Set/query motor power state

<driver_addr>:AUXPS [{ON | OFF}]
<driver_addr>:?AUXPS
Set/query auxiliary power supply state

<board_addr>:?MEAS {VCC | VM | IM | IA | IB | IC | T | RT}
Query measured value

<board_addr>:POS [*pos_sel*] <posVal>
<board_addr>:?POS [*pos_sel*]
Set/query axis position in axis units

<board_addr>:ENC [*pos_sel*] <posVal>
<board_addr>:?ENC [*pos_sel*]
Set/query axis position in encoder steps

<driver_addr>:?HOMESTAT
Query home search status

<driver_addr>:?HOMEPOS [*pos_sel*]
Query the found home position in axis units

<driver_addr>:?HOMEENC [*pos_sel*]
Query the found home position in encoder steps

<board_addr>:VELOCITY [<velocity>]
<board_addr>:?VELOCITY
Set/query programmed axis velocity

<board_addr>:ACCTIME [<accTime>]
<board_addr>:?ACCTIME
Set/query acceleration time

<driver_addr>:PCLOOP {ON | OFF}
<driver_addr>:?PCLOOP
Set/query current position closed loop mode

`<driver_addr>:ESYNC` Synchronise internal position registers

`<driver_addr>:CTRLRST`
`Reset control encoder value`

`<board_addr>:RMOVE <absolutePos>` Start relative movement

`<board_addr>:JOG <signedVelocity>`
`<board_addr>:?JOG`
Set/query jog velocity

`<driver_addr>:HOME [{+1|0|-1}]` Start home signal search sequence
`<driver_addr>:CMOVE  <absolutePos>` Start relative movement in configuration mode
`<driver_addr>:CJOG  <signedVelocity>` Set jog velocity in configuration mode
`<board_addr>:STOP` Stop movement

`<board_addr>:ABORT`
`Abort movement`

`<driver_addr>:DISPROT {ALL | {[LINKED] [CONTROL] [HARDCTRL]}}` Request temporary protection disable

INPUT/OUTPUT

`<driver_addr>:INDEXER [{INTERNAL | SYNC | INPOS | ENCIN}]`
`<driver_addr>:?INDEXER`
Set/query indexer signal source

`<driver_addr>:INFOA [`*`signal_source`*` [{NORMAL | INVERTED}]]`
`<driver_addr>:INFOB [`*`signal_source`*` [{NORMAL | INVERTED}]]`
`<driver_addr>:INFOC [`*`signal_source`*` [{NORMAL | INVERTED}]]`
`<driver_addr>:?INFOA`
`<driver_addr>:?INFOB`
`<driver_addr>:?INFOC`
Set/query Info signal source and polarity

COMMUNICATION and ERROR MANAGEMENT

`<board_addr>:?HELP` Query list of available board commands
`<board_addr>:?ERRMSG` Local query of last command error message
`<board_addr>:?FERRMSG` Query first error message

`<board_addr>:BLINK <blinkTime>`
`<board_addr>:?BLINK`
`Set/query remaining blinking time`

`<board_addr>:?TIME`
`Query running time`

`<board_addr>:DEBUG <debugLevel>`
`<board_addr>:?DEBUG`
`Set/query debug level`

`<board_addr>:ECHO` Select echo mode
`<board_addr>:NOECHO` Cancel echo mode

`<board_addr>:?MEMORY`
`Query available memory`

`<board_addr>:?ADDR` Query board address

SYSTEM COMMANDS

SYSTEM CONFIGURATION and IDENTIFICATION

MODE {OPER | PROG | TEST} **?MODE**	Set/query system mode
?SYSSTAT [<rackNumber>]	Query system configuration
?STATUS <axis1> <axis2> … <axisN>	Query multiple board status
?FSTATUS [<axis1> <axis2> … <axisN>]	Fast query of multiple board status
?LINKED	Query linked axis groups
REPORT {ON | OFF} [<firstRack> <lastRack> [<maxPeriod>]] **?REPORT**	Set/query asynchronous report settings
?VER [<verModule>]	Query system firmware version information
?RID [<rackNumber1> <rackNumber2> … <rackNumberN>]	Query rack identification string
?RTEMP [<rackNumber1> <rackNumber2> … <rackNumberN>]	Query rack temperatures
***PROG {NONE | <bAddr> | DRIVERS | CONTROLLERS | ALL} [FORCE] [NOSAVE]** **PROG {<bAddr> | DRIVERS | CONTROLLERS | ALL} [FORCE]** **?PROG**	Firmware programming
RFPROG [<rackNumber1> <rackNumber2> … <rackNumberN>]	Factory firmware programming
IPMASK <IPmask> **?IPMASK**	Set/query the IP active control mask
REBOOT	System reboot
RESET [<rackNumber>]	System or rack reset

MOTION CONTROL

POWER [{ON | OFF}] <axis1> <axis2> … <axisN> **?POWER <axis1> <axis2> … <axisN>**	Set/query multiple axis motor power state
POS [*pos_sel*] <axis1> <posVal1> … <axisN> <posValN> **?POS [*pos_sel*] <axis1> <axis2> … <axisN>**	Set/query multiple axis position in axis units
ENC [*pos_sel*] <axis1> <posVal1> … <axisN> <posValN> **?ENC [*pos_sel*] <axis1> <axis2> … <axisN>**	Set/query multiple axis position in encoder steps
?FPOS [AXIS | MEASURE] <axis1> <axis2> … <axisN>	Fast query of multiple board positions
?HOMESTAT <axis1> … <axisN>	Query multiple axis home search status
?HOMEPOS [*pos_sel*] <axis1> … <axisN>	Query the found multiple axis home position in axis units
?HOMEENC [*pos_sel*] <axis1> … <axisN>	Query the found multiple axis home position in encoder steps
?VELOCITY <axis1> <velocityN> … <axisN> <velocityN> **?VELOCITY <axis1> <axis2> … <axisN>**	Set/query programmed multiple axis velocity
ACCTIME <axis1> <accTime1> … <axisN> <accTimeN> **?ACCTIME <axis1> <axis2> … <axisN>**	Set/query acceleration time
MOVE [GROUP] <axis1> <absolutePos1> … <axisN> <absolutePosN>	Start multiple axis absolute movement
RMOVE [GROUP] <axis1> <absolutePos1> … <axisN> <absolutePosN>	Start multiple axis relative movement
JOG [GROUP] <axis1> <signedVel1> … <axisN> <signedVelN> **?JOG <axis1> <axis2> … <axisN>**	Set/query multiple axis jog velocities
HOME [GROUP] <axis1> {+1|0|-1} … <axisN> {+1|0|-1}	Start multiple axis home signal search sequence

STOP [<axis1> <axis2> … <axisN>] Stop multiple axis movement
ABORT [<axis1> <axis2> … <axisN>] Abort movement
ESYNC [<axis1> <axis2> … <axisN>] Synchronise internal position registers
CTRLRST [<axis1> <axis2> … <axisN>] Reset control encoder values
DISPROT {ALL | {[LINKED] [CONTROL] [HARDCTRL]}} <axis1> <axis2> … <axisN> Request multiple axis temporary protection disable

COMMUNICATION and ERROR MANAGEMENT

?HELP	Query list of available commands
?ERRMSG	Query last command error message
ECHO	Select serial line echo
NOECHO	Cancel serial line echo