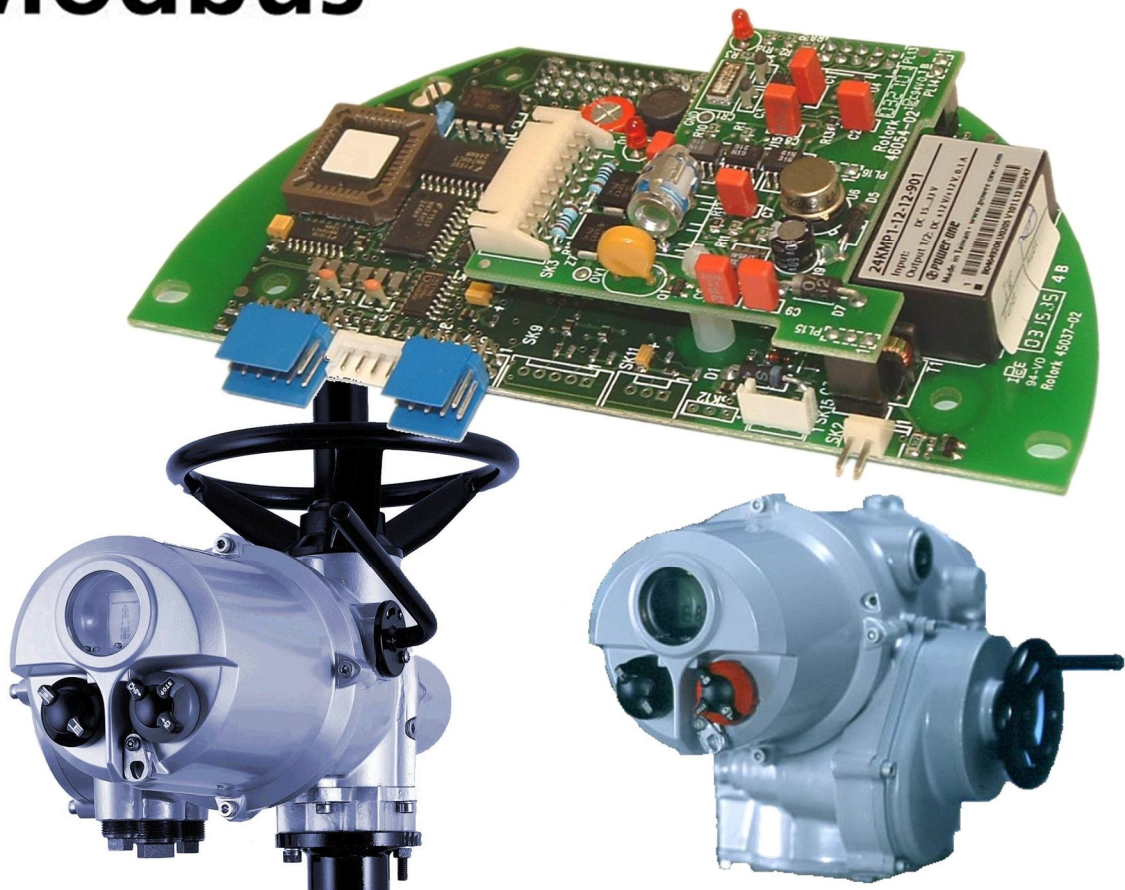


rotork

Modbus®



**Modbus RTU Actuator Control
Mk2 Option Card
Technical Manual**
(IQ Pro, IQT Pro, SI Pro, EH Pro, ROMpak and Q)

Publication PUB091-003-00_0219

The Modbus card described in this manual contains static-sensitive devices. Suitable precautions, such as wearing an earthed anti-static wrist strap, should be taken before handling the card. The card should be kept in an anti-static bag or box while it is not fitted within an actuator.

Note 1: The Modbus Modules described in this manual are suitable for inclusion in Rotork IQ Pro, IQT Pro, ROMpak, SI Pro, EH Pro and Q range actuators. The Modbus Modules may also be fitted to earlier versions of the IQ range of actuators.

Note 2: Although the same Modbus module is fitted to the different ranges of actuators, there will be different numbers of valid inputs and outputs for each range, depending on the actuator capabilities. For example, actuators not fitted with a battery cannot report Battery Low.

Note 3: The information in this manual relates to the following Modbus module firmware release - M207 or newer.

Note 4: Throughout this manual the Modbus Module may simply be referred to as the module or MFU (Modbus Field Unit – the circuit board fitted to the actuator in the field).

Note 5: Inputs are the status messages from the actuator and outputs are the command messages to the actuator.

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Glossary of Terms:

Address	The unique address for a node on the fieldbus, range 1-247.
Fieldbus	The digital, two-way, multi-drop communication links.
Field Unit	The Modbus option card fitted to the actuator
Master/Slave	The method of communication used by the Modbus Module. The fieldbus requires a Modbus master to control the data exchange on the highway.
Modbus	The communication protocol used for data exchange.
Modbus RTU	The version of the protocol available from the Rotork module.
Node	A single device on the fieldbus.
RS-485	The electrical properties of the data highway as defined by the IEC standard, copper conductors, 2 wire twisted pair.
Segment	A section of an RS-485 fieldbus that is terminated in its characteristic impedance. Each Segment can include up to 32 devices.

Abbreviations:

ACTCON	Actuator Control (Register).
CRC	Cyclic Redundancy Check (error detection).
DV	Desired Value.
ESD	Emergency Shut Down.
IEC	International Electrotechnical Commission.
MFU	Modbus Field Unit.
MV	Measured Value.
NIC	Network Interface Card.
PCB	Printed Circuit Board.
PLC	Programmable Logic Controller.
RAM	Random Access Memory.
ROM	Read Only Memory.
RTU	Remote Terminal Unit.
SIL	Safety Integrity Level
SW	Software.

1 INTRODUCTION

The Rotork Modbus Module Actuator Control option card (MFU) uses 2-wire (half-duplex) RS-485 and the Modbus RTU protocol to allow for information exchange and control over the data highway between the actuator and a suitable host system with a Modbus capability.

The module is an integral part of the actuator in which it is housed and is fitted within the main electrical housing. For the IQ Pro, IQT Pro, SI Pro, EH Pro and Q products this electrical housing is double sealed and need never be opened once the actuator leaves the assembly plant. The ROMpak actuators do not have double sealing and the electrical cover is required to be entered for connecting to the Field connections.

All adjustments to the settings for the module may be made via the Modbus data highway using a Modbus master tool or via the Infra-red setting tools for the IQ Pro, IQT Pro, SI Pro and EH Pro products. (If the data highway speed was not specified at time of order, or it is changed, it may be necessary to change the links on a Single Highway plus Repeater option, see Section 4.5.3.)

The Modbus Module circuits do not impinge on the actuator control electronics; the actuator itself remains fully self-protecting. The module performs the tasks of network interface, actuator data collection and the issuing of actuator commands.

The Modbus Module may command the actuator into which it is fitted to open, stop, close, perform an ESD operation or move to a set position. Commands to the module come from the network and will have been generated in a master controller. The module operates in Master/Slave communication mode only using Modbus RTU protocol. For SI and EH actuators, where a SIL approved safety function is required, the hard wired ESD control should be used and not the Modbus ESD function.

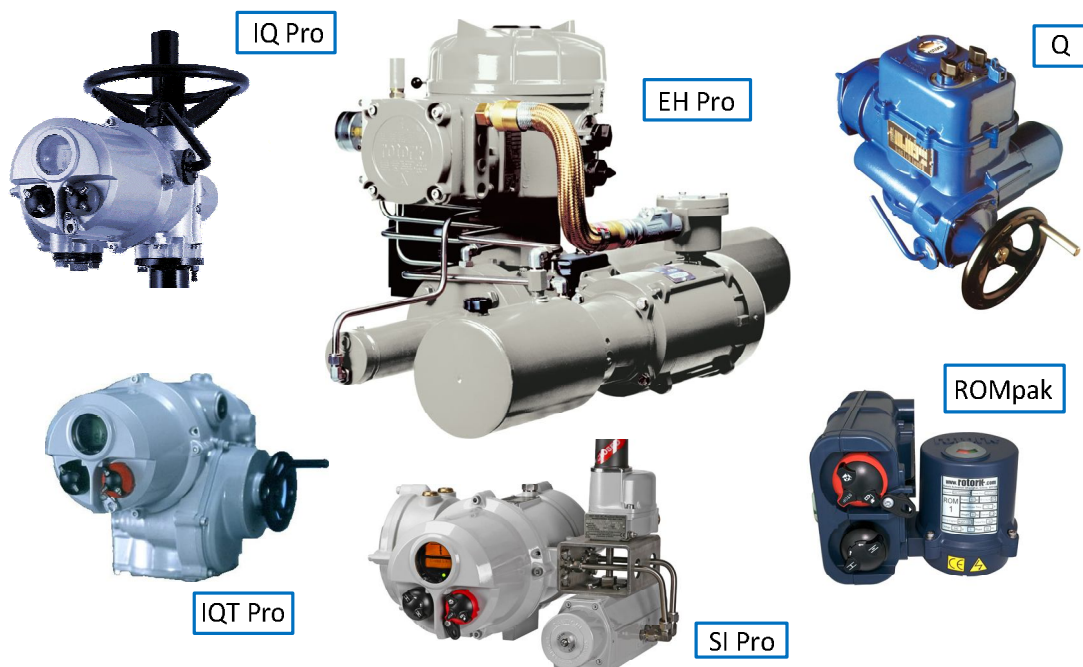


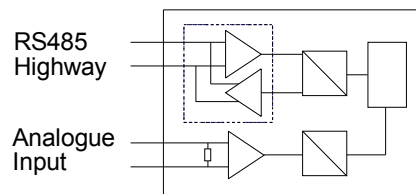
Fig 1: The Modbus Module Option Card Actuator Compatibility

1.1 General

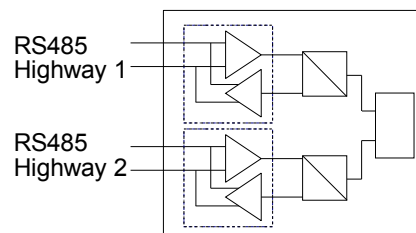
The Modbus Module has three variants:

- Single RS-485 highway plus one analogue input channel
- Dual Independent isolated RS-485 highways
- Single RS-485 highway with inbuilt isolating repeater

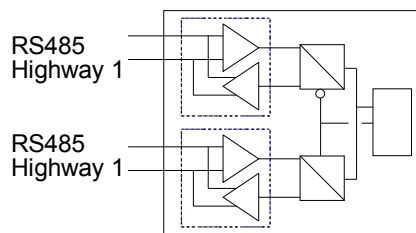
Communication Medium	RS4-85 2-wire highway (single or dual), half duplex
Protocol	Modbus RTU
Mode	Master/Slave, module is a slave



Single Highway + Analogue Input



Dual Highway



Single Highway + Repeater

Fig 2: The Types of Modbus Module Mk2 Option Card

2 MODBUS OPTION CARD PROPERTIES

2.1 Mechanical properties

The MFU module consists of a network interface card, that either fits directly to the main actuator printed circuit board (ROMpak) or fits to an interface card; where the two board assembly is then fitted inside the actuator electrical housing (IQ Pro, IQT Pro, SI Pro, EH Pro and Q).

All the connectors are polarised to prevent incorrect insertion.

□ Network Interface Card (NIC)

This small printed circuit board carries the Modbus, RS-485 highway connections and protection circuits. There are two versions of the Network Interface Card, one for a single highway and a second for two highway (or one highway with repeater) use.

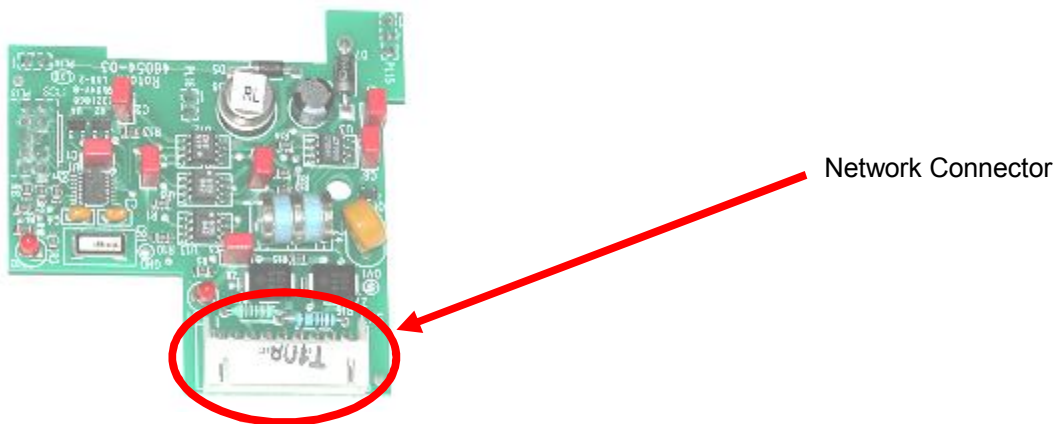


Fig 3: The Modbus single channel NIC, showing the network connector.

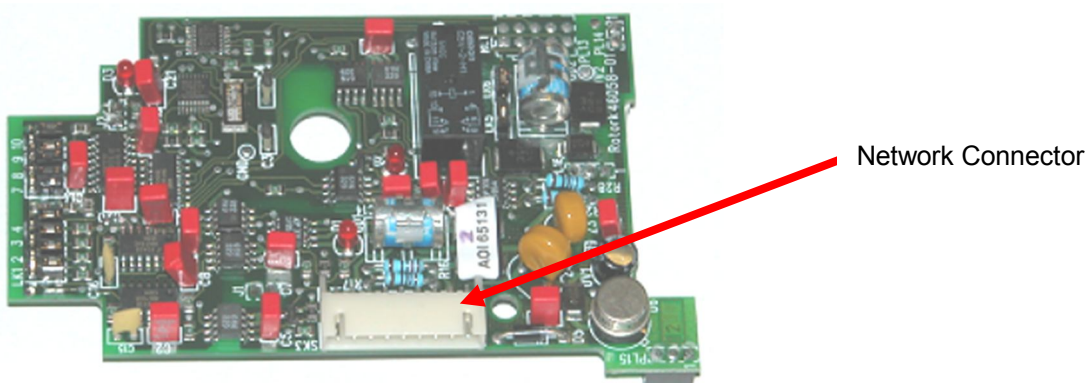


Fig 4: The Modbus dual channel NIC.

❑ **Interface Card (IQ Pro, IQT Pro, SI Pro, EH Pro and Q)**

The ROMpak does not require an additional interface card.

The interface card is profiled and assembled to fit an IQ Pro, IQT Pro, SI Pro, EH Pro or Q actuator. For the SI Pro, EH pro and Q, it carries the processor for collecting the data from the actuator main board and passing this data to the Network Interface card. For the IQ Pro and IQT Pro it is used simply for physical connection to the main card.

The primary connection to the actuator circuits is by a multi-pin connector on the Interface Card that, due to its physical shape may only be fitted in the correct polarisation. Internal wiring harnesses connect to the Interface card for other signals and options within the actuator. The Interface card is powered from within the actuator.



Fig 5: The Interface Card (SI Pro and EH Pro actuators, Q is similar, see Section 3.2)

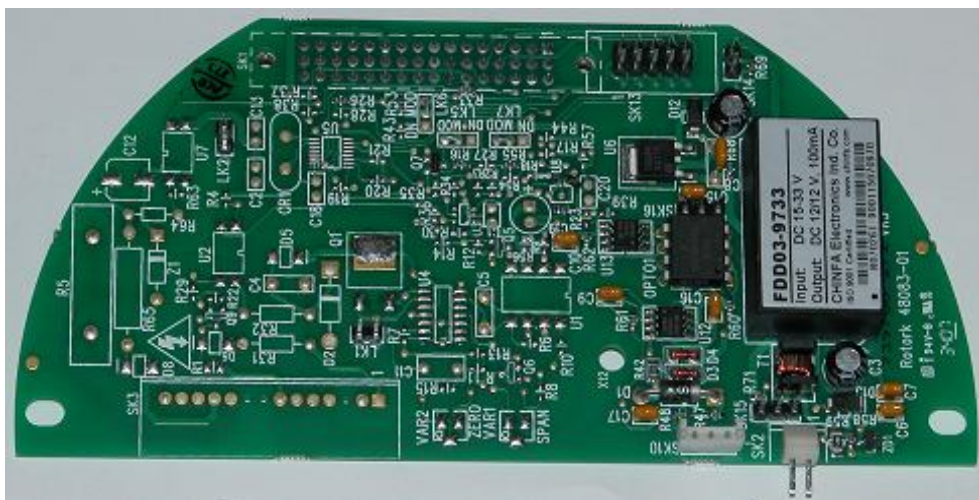


Fig 6: The Interface Card (IQ Pro and IQT Pro actuators)

Early assemblies of NIC and Interface Cards were physically joined by their electrical connectors and a push-fit spacing pillar. Later versions use a threaded pillar, which is useful for higher vibration environments.

2.2 Electrical Properties

The MFU connects directly to the Interface Card of the actuator. The MFU does not sit in the main control path for the actuator and does not affect the actuator control integrity.

The Modbus RS-485 fieldbus data highway connections are fully isolated from the actuator electronics.

2.3 Operation and Storage

The MFU is designed to be stored in the actuator and operated within the same environment as the actuator. The constraints are:

- Operating temperature: -40degC to +70degC
- Storage temperature: -50degC to +85deg C
- Relative Humidity: 5% to 95% (<50degC) non-condensing

3 FITTING THE MODBUS MODULE OPTION CARD

3.1 Inside an IQ Pro or IQT Pro actuator

The MFU is suitable for fitting into IQ Pro actuators with 3000 or 5000 series wiring diagrams and IQT Pro with 6000 or 7000 series wiring diagrams. The connections and fitting in an IQT Pro is similar to that for an IQ Pro and the following information effectively relates to both actuator types. The MFU is normally located in the first option board slot inside the electrical housing using connection SK1 to the Main pcb.

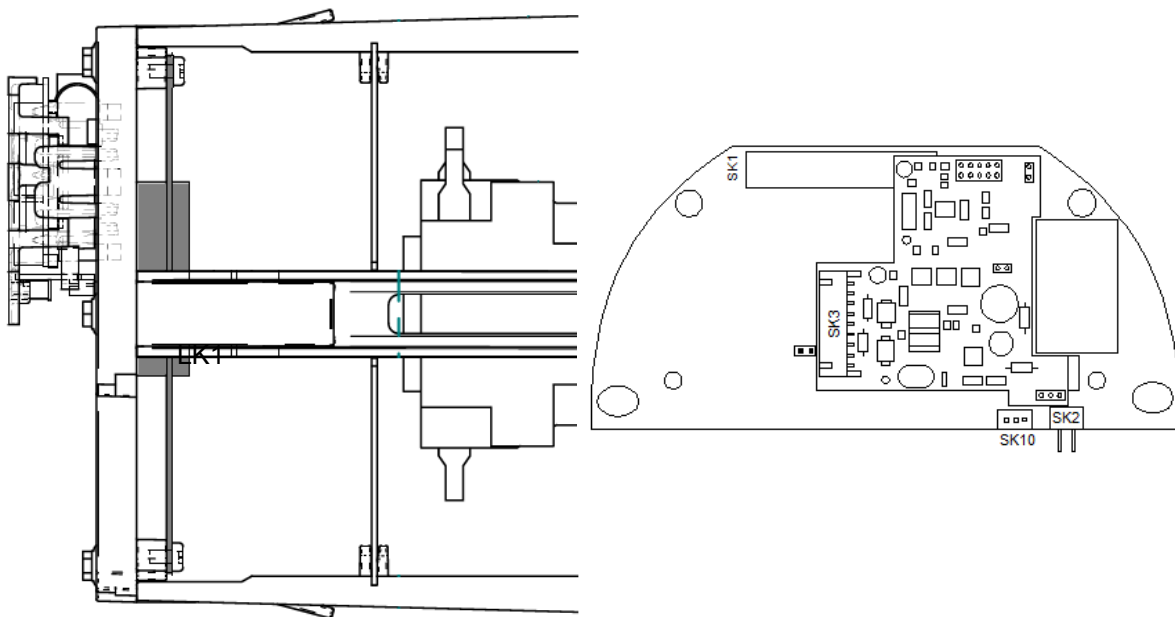


Fig 7: The IQ Pro and IQT Pro MFU and its location in an IQ Pro or IQT Pro actuator

With the IQ Pro and IQT Pro actuators the remote inputs are always present (they are conditioned by the MFU) and there is an option to include Digital Outputs from relay contacts. If the MFU is required to operate the 4 digital outputs that can be controlled from the card then the Extra Relay Indication card associated with these outputs must be fitted into the actuator. The following table describes the wiring harnesses and their function in the IQ and IQT actuator.

MFU Socket	Wiring Harness
SK2	24V power supply input from actuator
SK3	Modbus RS-485 Fieldbus connection
SK10	Analogue Input connection ①

Note: ① Only available on Single Channel module, wiring diagram 3000-400 or 6000-400

3.2 Inside a Q actuator

The MFU is fitted in the option board position in this actuator. Only one option board may be fitted at any one time. The necessary internal components must also be present; in this case a potentiometer and auxiliary limit switches at end of travel must be fitted to the actuator.

The illustration (Fig 8) shows the Q version of the circuit board.

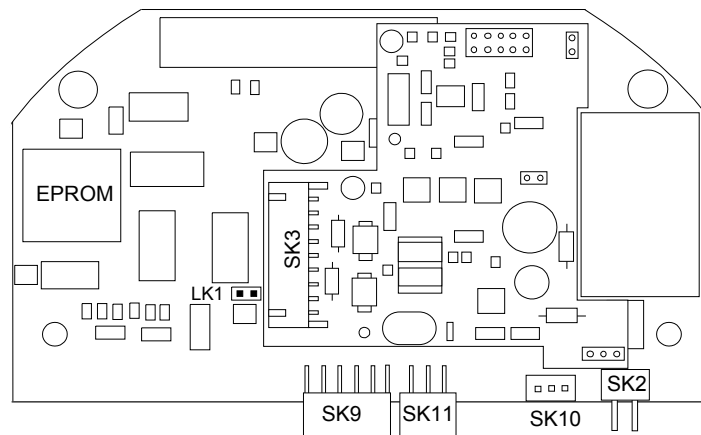


Fig 8: The MFU module profiled for the Q actuator

Digital Outputs from relay contacts are not supported from the Q actuator, nor is the ability to report the status of the remote control inputs as Digital Inputs. The following table shows the wiring harnesses that must be fitted and the function of each loom for the Q range actuator.

MFU Socket	Wiring Harness
SK2	24V power supply input from actuator
SK3	Modbus RS-485 Fieldbus connection
SK9	Limit switches
SK10	Analogue Input connection ①
SK11	Potentiometer

Note: ① - Only available on Single Channel module

In a Q actuator there is a direct connection from PL2 on the Modbus Module to SK5 of the actuator main board.

To restore the card to its default of Modbus Mk2 and the associated default parameter settings, LK1 should be fitted and the actuator power cycled. In normal operation LK1, shown above in Figure 8, should not be fitted.

3.3 Inside ROMpak actuator

The MFU is suitable for fitting into ROMpak actuators, wiring diagram RX0X-4X0 (where X can be any value) details the option card connections on the terminal strip. The MFU module is fitted in the only option board slot inside the ROMpak electrical housing.

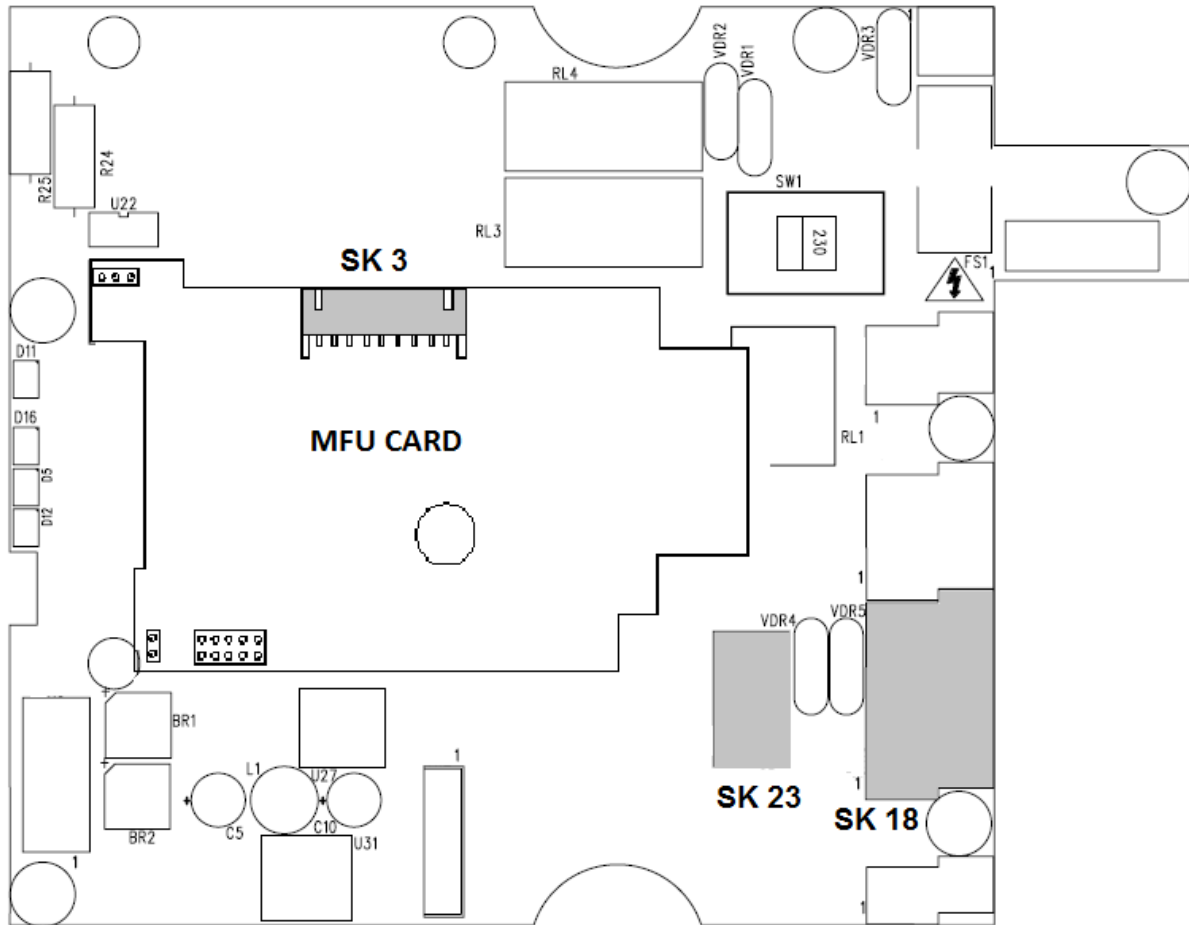


Fig 9: The MFU located in a ROMpak actuator

SK3 is the connection to the Modbus Fieldbus Data Highway; this is connected to SK23 on the main PCB assembly via an internal loom. The user wires the Modbus connections to the main PCB assembly at the terminal block SK18 as per the wiring diagram.

The MFU card fitted in the ROMpak actuator cannot be defaulted by the LK1 method previously described for the Q actuator, as there is no interface card fitted between the MFU card and the actuator Main PCB.

3.4 Inside an SI or EH actuator

The MFU is suitable for fitting into SI Pro and EH Pro actuators, wiring diagram SWM SI-001. The MFU is normally located in the first option board slot inside the electrical housing using connection SK1 to the Main pcb.

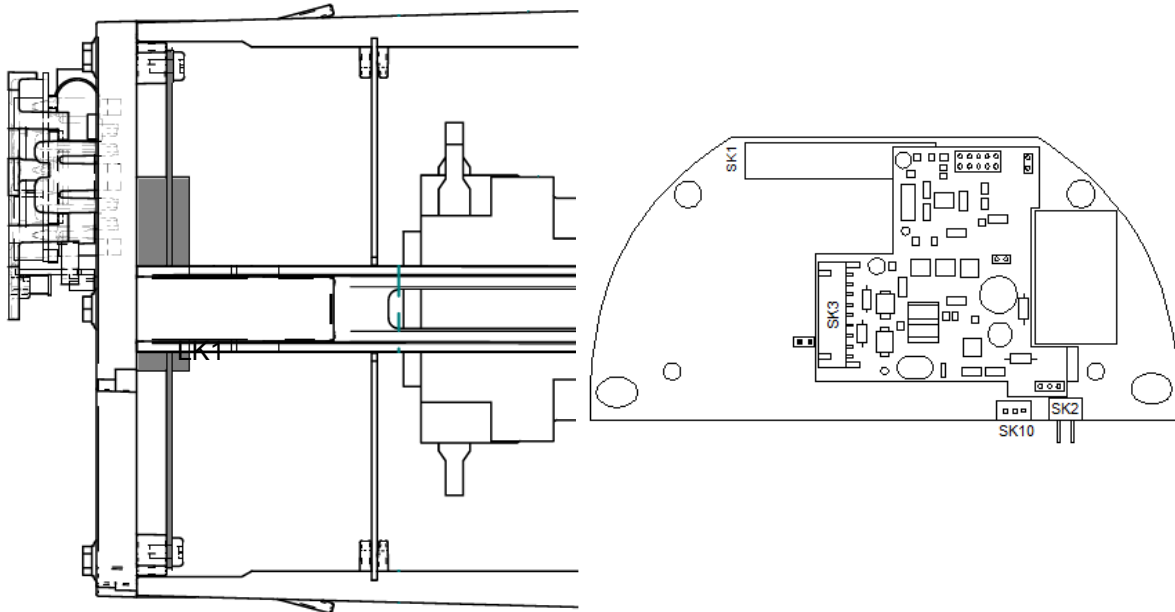


Fig 10: The MFU and its location in an SI Pro or EH Pro actuator

With the SI Pro and EH Pro actuators the remote inputs are always present (they are conditioned by the MFU) and there is an option to include Digital Outputs from relay contacts.

The following table describes the wiring harnesses and their function in the SI Pro and EH Pro actuators.

MFU Socket	Wiring Harness
SK 2	24V power supply input from actuator
SK 3	Modbus RS-485 Fieldbus connection
SK 10	Analogue Input connection ①

Note: ① - Only available on Single Channel module

3.5 Replacing or Fitting a Modbus Module Option Card

The MFU should be replaced or fitted only in a suitable environment. The actuator must be made electrically safe before opening any covers.

The Modbus card described in this manual contains static-sensitive devices. Suitable precautions, such as wearing an earthed anti-static wrist strap, should be taken before handling the card. The card should be kept in an anti-static bag or box while it is not fitted within an actuator

The electrical housing cover should be removed and the existing MFU carefully unplugged from its main connector. Once removed from the main connector, the wiring loom connectors should be removed. The replacement board is fitted in the reverse order to removal. The wiring harnesses are polarised so that only the correct one will fit its mating part on the circuit board.

If the operation is to fit an MFU for the first time then the necessary wiring looms must be added to the internal wiring harness of the actuator. The actuator wiring diagram shows the connectors and harnesses used. The wiring harnesses are fitted inside the actuator before attempting to fit the MFU. Once the looms are in place connect them to the MFU, then fit the MFU to the actuator main board connector.

Once the module is fitted, the actuator should be re-assembled.

Once power is applied the field unit parameters should be checked and corrected where necessary, see Section 9.

4 RS-485 DATA HIGHWAY, CONNECTIONS AND MFU SETUP

4.1 Data Highway

The MFU uses RS-485, 2-wire, half duplex, Modbus RTU communications at various data rates. The rules governing the installation and connection of an RS-485 highway should be observed at all times to produce a successful installation. The RS-485 highway does not allow power to be transferred and the MFU is powered from the actuator itself. The MFU can only report data when the actuator is powered up.

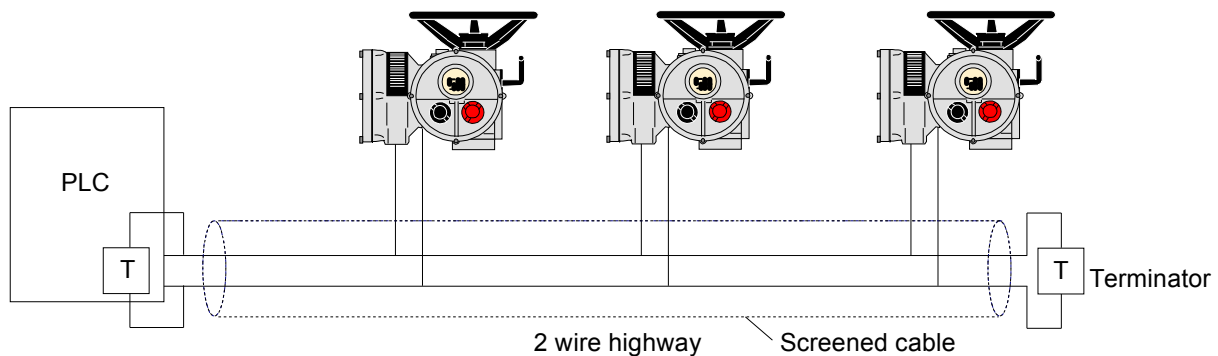


Fig 11: Typical RS-485 Data Highway

The data highway must be terminated with a proper termination resistor at each end. The highway itself can use tapped spur or stub connections to the actuators but it is recommended to keep any stub lengths to a minimum for successful operation. Alternatively, the connection can be made in and out of each actuator in a daisy chain arrangement. The length of the highway and number of devices connected will vary from project to project. The standard permits up to 32 devices to be connected on a section, though one of these will be the PLC. If more devices are needed (up to the maximum addressable of 247) then RS-485 repeaters may be added after each group of 32. The standard default address used by the Modbus Module is 247.

The length of the highway will determine the maximum speed for the data transmission. The greater transmission speeds are obtained at the lower lengths.

Although RS-485 requires only 2 wires for data transmission the standard also requires that all the nodes on the network have a maximum common mode differential of ± 7 volts. This requires the ground potential at all points to be within the 7 volt limit. If the equipment is distributed over a wide area, or an area with poor ground conductivity, it may be necessary to connect a third wire between all the nodes. Most successful installations use 3 wires and Rotork provides a 'common' terminal on the actuator.

Since the data passes over a single 2 wire cable there are periods between messages when no devices are actively driving the lines. In order to ensure that data continues to flow correctly after these periods it is advisable to ensure the lines are biased to suitable voltage levels during the time the line is idle. This is usually achieved by biasing at the PLC. The MFU contains internal biasing circuits that ensure suitable levels are maintained on the line even with no device transmitting.

4.2 Highway Topology

Two different connection topologies can be used for RS-485. The first system is to use a trunk line with various spurs or drop lines from it. This system will require the location of the taps in junction boxes near to the actuators. With the second the actuators can be directly connected to the trunk line in a daisy chain. All the configurations require the cumulative total of the drop lines and stub lines to be kept within the permitted maximum for the network speed to be used.

It is good practice to avoid spurs wherever possible.

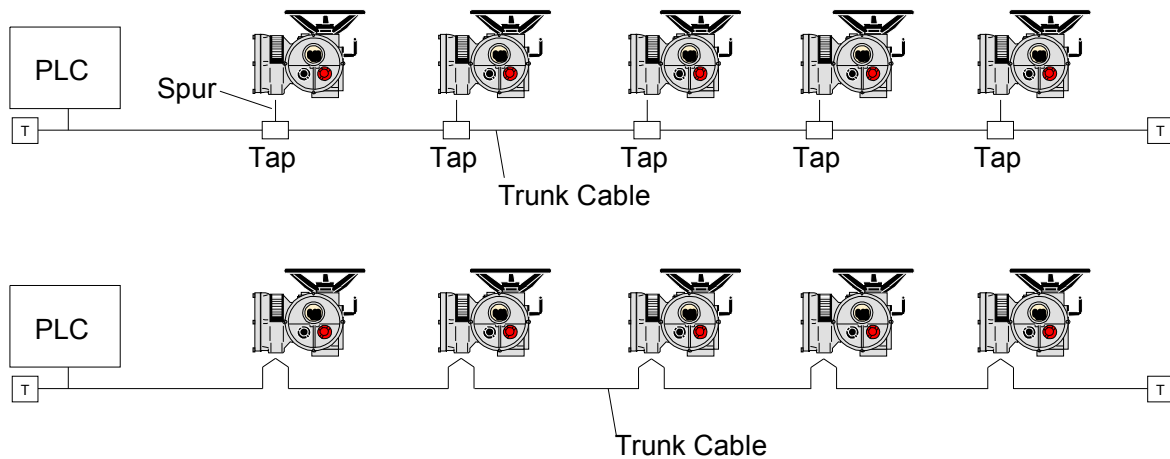


Fig 12: RS-485 Data Highway Topology

The maximum Trunk length and that for each spur and the cumulative total are dependent on the system speed in use. The table below suggests the maximum figures for cable type A, also defined below. The segment length is the total of the trunk and all the spurs added together.

Data Rate (Baud)	Maximum Segment Length	Total Spur Length
300	24.0 km	2.0 km
600	12.0 km	1.0 km
1k2	12.0 km	1.0 km
2k4	6.0 km	500 metres
4k8	3.0 km	500 metres
9k6	1.2 km	500 metres
19k2	1.2 km	500 metres
38k4	1.0 km	300 metres
57k6	750 metres	200 metres
115k2	500 metres	100 metres

(Note that each actuator includes up to 0.6 metres of Drop length)

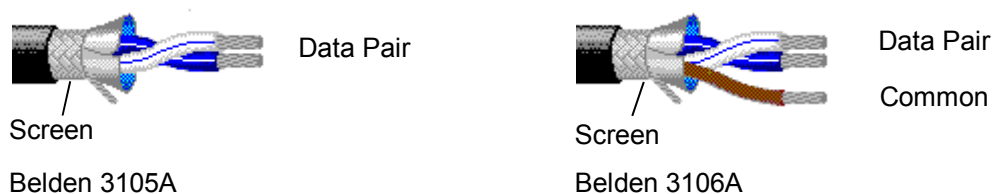
Actuator Type	IQ / IQT	SI / EH	ROMpak / Q
Internal Drop length (metres)	0.6	0.6	0.3

Within each actuator there is a short drop line or stub connection wire from the terminals to the MFU itself. This length must be included in any calculation for total and individual drop lengths. A more robust network generally has cable length (metres) times data rate (bits per second) less than 10 million.

4.3 Cable Types

The network must be connected using a suitable cable. Two conductors plus a shield and drain wire are required as a minimum, though Rotork recommends the use of a 3 wire cable to ensure the common mode voltage between all the actuators and the PLC is kept within the RS-485 specified limits.

Amongst the cable manufacturers Belden have the PVC jacketed 3105A single pair 2 core cable, which meets the minimum requirement. Belden 3106A has an extra core and therefore has sufficient conductors to include a common wire between all the nodes on the network and meets the Rotork recommendation. Information on Belden cable may be found on the Belden web site (www.belden.com) or at <http://bwcecom.belden.com/>, where a search on RS-485 will reveal technical papers and cable information.



Belden Part No.	Total Number of Conductors	AWG (stranding) dia. Inches	Nom. DCR	Insulation material	Nominal O.D.	Nom Impedance (ohms)	Nominal Capacitance
3105A Paired - EIA Industrial RS-485 PLTC/CM	2	22 AWG (7 x 30)	48.2 ohm/km	Overall PVC jacket Datalene insulated twisted pair	7.26 mm	120	11.0 pF/ft.
3106A Composite - EIA Industrial RS-485 PLTC/CM	3	22 AWG (7 x 30)	48.2 ohm/km	Overall PVC jacket Datalene insulated twisted pair	7.67 mm	120	11.0 pF/ft.

Fig 13: Typical RS-485 cable

Cables for European installations must comply with the Construction Products Regulation.

The terminals to which the wires connect in the each actuator type will be different and the actuator wiring diagram must be consulted to establish the connections.

4.4 Termination Network

In order to operate correctly all RS-485 highways must be terminated at each end of the main trunk line using a suitable resistor (120 ohms nominal). These will usually be near the scanner PLC and near the furthest actuator. The resistors are connected between data line A and data line B. If the termination resistors are not fitted there is a possibility that the network communications will be unsatisfactory. In some cases network data line biasing may also be necessary, however to minimise this requirement the actuator transceiver chips include secure turn round components.

For IQ / IQT, SI / EH and Q actuators that use the MFU, there is a termination resistor inside each actuator. One side of the resistor is brought to a terminal whilst the other is already connected to data line A. Linking the Terminator terminal to data line B completes the connection to place the resistor across the data lines.

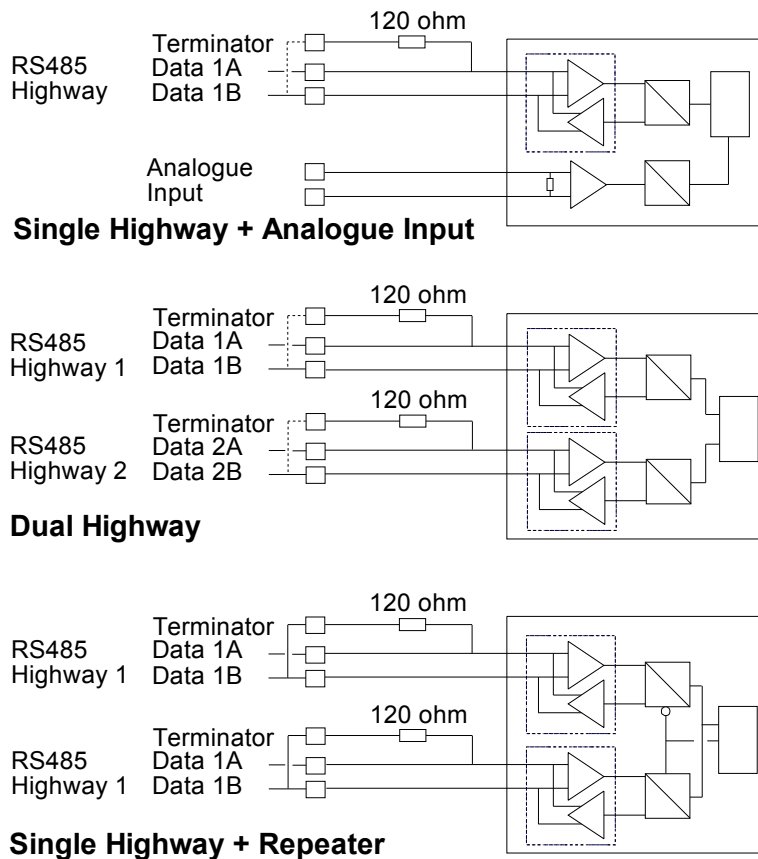


Fig 14: Termination for RS-485 highway

In the ROMpak, there are moveable links, LK1 & LK2, next to SK23. These should connect pins 1 and 2 for termination, or remain at pins 2 and 3 for no termination:

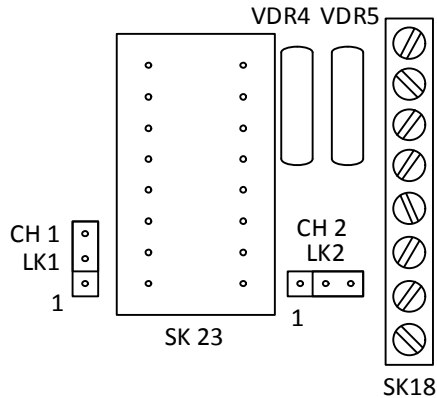


Fig 15: Termination for RS-485 highway in ROMpak actuators. The links are shown in the non-terminated position.

4.5 Inter-connecting the Highway and Setting up the MFU

The three MFU variations (Single, Dual and single repeater) allow for various different highway connections. The 'single channel version' can be used for simple highways, and where there is an analogue transmitter connected it will also return the value from the transmitter signal. The 'dual channel version' is used for redundant highway applications where the highway integrity is important and the 'single highway with repeater version' can be used for either ring topology connections or applications where distances are extended.

In those cases where the single highway with repeater is applied in a ring connection, the communications can travel either way around the ring. In this mode the number of devices that can be interconnected will depend on the speed of operation of the highway as each unit introduces a small propagation delay.

Note: When using the single highway with internal repeater the termination should always be fitted on both sides of the repeater since there are no other devices on the highway

4.5.1 Single Highway with Analogue Input

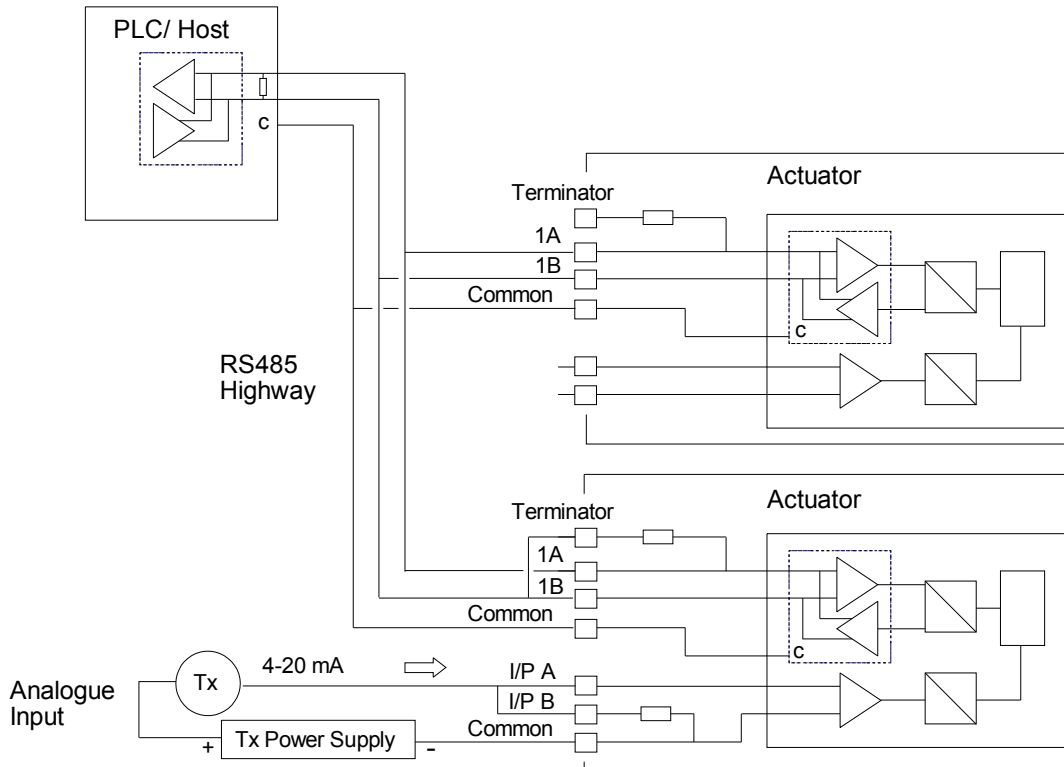


Fig 16: Single Highway + Analogue Input Connections

With the single channel option the actuator is connected to only one highway. An additional input is provided for measuring and reporting an analogue variable to the Modbus controller. The connection of the actuator to the highway uses terminals 1A and 1B. The terminal numbers depend on the actuator type and are indicated on the actuator wiring diagram. The last actuator on the highway should have the termination resistor connected by linking the highway 1B terminal to the Terminator terminal. Take care to ensure that the correct polarity is observed on the data highway connection, all the 1A terminals must be connected together on one data line and all the 1B terminals on the other.

- ❑ Data line 1A is positive with respect to data line 1B when the MFU is transmitting a '1'.

If an analogue input is being used it is connected to the analogue input terminals. The MFU caters for both current and voltage analogue signals. There is no power supply on the card for the analogue transmitter and an external power supply must be used to power it.

- ❑ For voltage inputs connect I/P A to the positive signal and analogue Common to the negative signal from the transmitter
- ❑ For current inputs connect I/P A to I/P B (to insert the conditioning resistor). The current input positive is to I/P A and I/P B whilst the current input negative is connected to the analogue Common.

There are no links or settings required on the MFU card when this version is being used.

4.5.2 Dual Highway

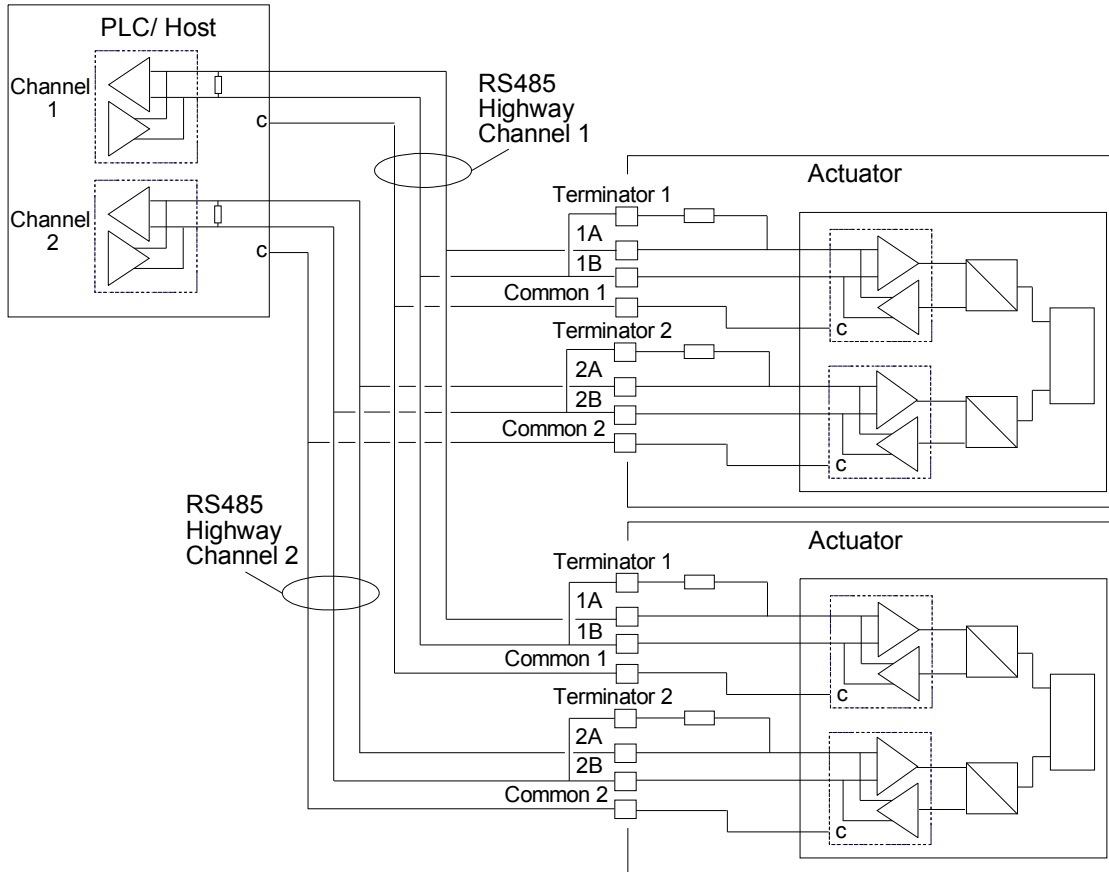


Fig 17: Dual Highway Connections

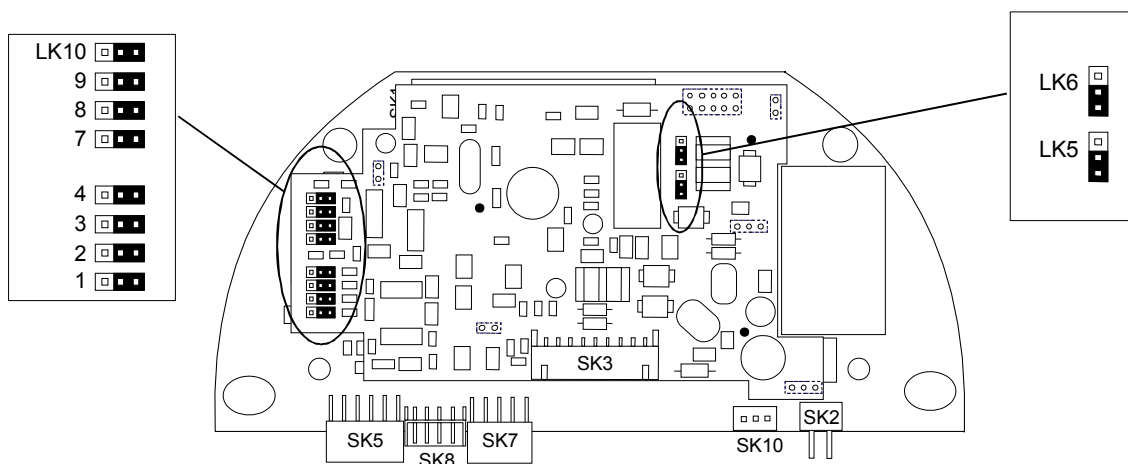


Fig 18: Jumper Settings for Dual Highway Option. Or, LK5 & LK6 not fitted.

The actuator can be connected to two highways when redundant communication links are required. The connection of the actuator to the highways uses terminals 1A and 1B for highway 1 and 2A and 2B for highway 2, the terminal numbers depend on the actuator type and are indicated on the actuator wiring diagram. The last actuator on the highway should have the termination resistors connected by linking Terminator terminal to the B terminal on the appropriate highway connection. Take care to ensure that the correct polarity is observed on the connection on each data highway, all the 1A terminals must be connected together on one data line and all the 1B terminals on the other for highway 1, all the 2A terminals are connected together on one data line and all the 2B terminals on the other for highway 2.

- Data line A is positive with respect to data line B when the MFU is transmitting a '1'.

The dual channel MFU uses a single Modbus address common to both channels, so it is not possible to run the same highway to both channels on the card.

- One Modbus address for the card common for both channels.

There are a number of jumper links on the Network Interface Card, which must be in the correct position. These links determine the function of the card and when in the dual channel mode they must be positioned as shown in the diagram. LK5 and LK6 may, in some cases, not be fitted. This is also correct.

4.5.3 Single Highway with Internal Repeater

With this option a single highway passes through the Modbus Module and an internal repeater regenerates the data signals. The input to output connection is also isolated and this then allows the next section of cable to reach the maximum specified distance and the number of connected devices on the section to be 32. Termination resistors will be required at all repeater connection points.

In addition to allowing for signal regeneration with the internal repeater it is also possible to connect the last device on the network back to the PLC in a ring configuration. As each highway section is isolated from its neighbours the ring topology affords a degree of redundancy. The PLC channels must not be used simultaneously unless there is a section of the network that is broken.

- Data line 1A is positive with respect to data line 1B when the MFU is transmitting a '1'.

There are a number of jumper links on the Network Interface Card that must be in the correct position for the card to function as a single channel module. The repeater section is able to wait for the correct period after transmitting data before changing to receive mode, this is important to ensure communications on the highway is good. The time for the delay is set by jumpers on the mezzanine and varies according to the data transmission speed chosen.

- The internal repeater supports data speeds from 2,400 to 115,200 baud.

Jumper Settings:

Speed (Baud)	LK1	LK2	LK3	LK4	LK5	LK6	LK7	LK8	LK9	LK10
2,400	Left	Left	Left	Left	Top	Top	Left	Left	Left	Left
4,800 / 9,600	Left	Left	Left	Left	Top	Top	Left	Right	Left	Right
19,200 / 38,400	Left	Left	Left	Left	Top	Top	Right	Left	Right	Left
57,600 / 115,200	Left	Left	Left	Left	Top	Top	Right	Right	Right	Right

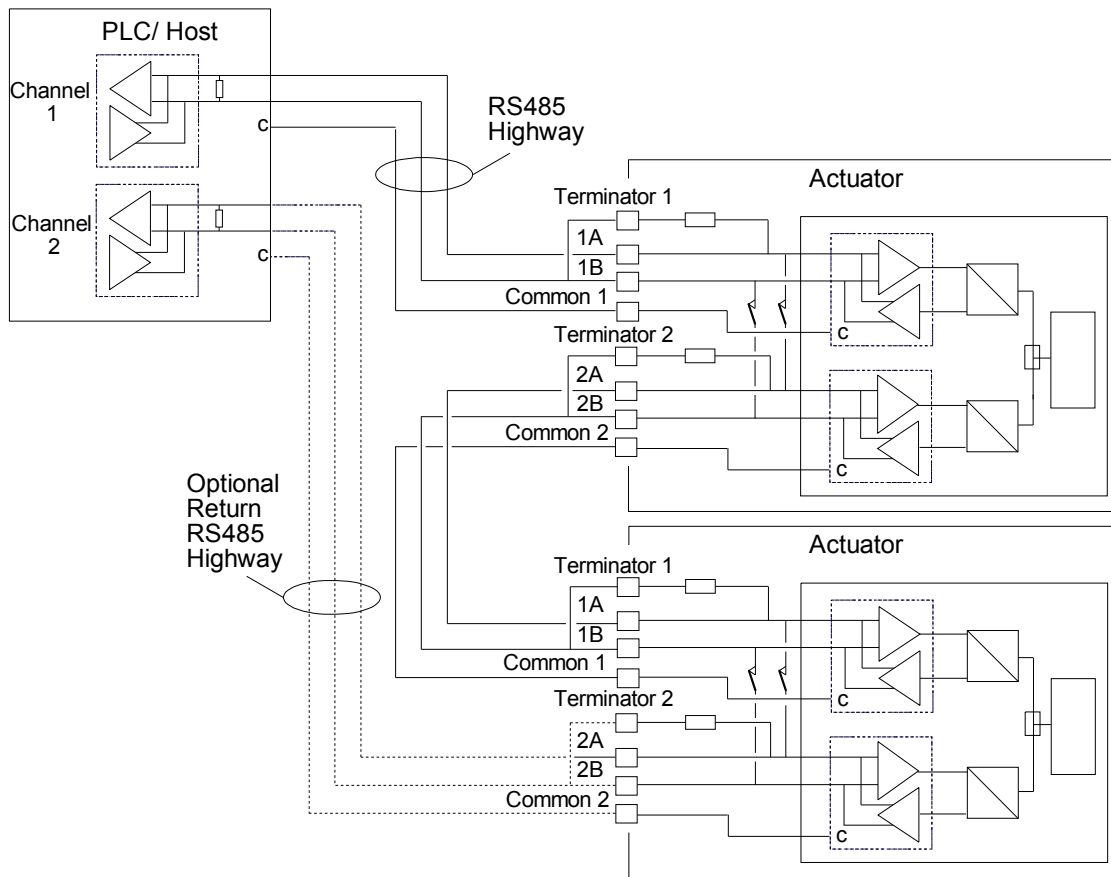


Fig 19: Single Highway with Internal Repeater Connections

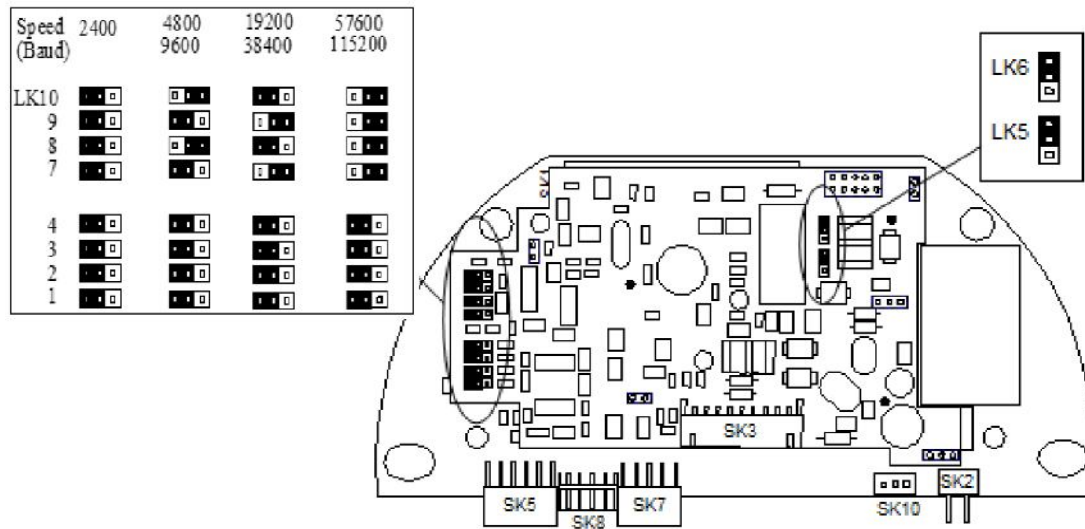


Fig 20: Jumper Settings for Single Highway with Internal Repeater Option

5 THE ACTUATOR INPUT AND OUTPUT SIGNALS

The Modbus Module allows the actuator to be controlled by, and to report data to, a suitable host device using Modbus RTU protocol. This section explains the data signals that are available for exchange and their meaning in relation to the actuator functionality. The data locations used for the Modbus registers and coils are given later in this manual.

This section also gives information on the other control inputs available for moving the actuator.

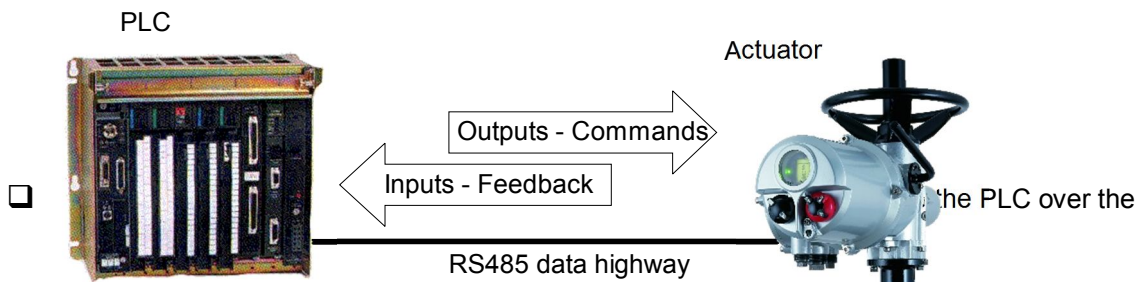


Fig 21: Input and Output Data Direction

- ❑ **Outputs** are defined as signals originating at the PLC and operating the actuator controls.

In general, the SI Pro and EH Pro actuators will behave in a similar manner to each other when controlled by the MFU. The IQ Pro will be similar to the IQT Pro and the ROMpak will be similar to the Q.

5.1 Control Outputs

The Modbus Module can be used to control the actuator and position the valve. The valve may be moved fully closed, fully open or to an intermediate position. Additionally, the actuator can make the valve adopt an Emergency Shut Down position. The actuator may also be operated from its local controls or by hard wired direct contact inputs (in the case of the IQ and IQT the Auxiliary Input Mask must be correctly set).

As well as controlling the actuator the MFU can also be used to operate 4 discrete output relays when fitted to an IQ/IQT actuator with the relay card fitted.

The control commands have three potential sources:

- ❑ Modbus RS-485 network generated commands
- ❑ Actuator Local Controls
- ❑ Direct contact input controls

The full list of commands is shown in the table. The actuator types show whether the command is applicable to that actuator type.

Command	IQ / IQT actuator	SI / EH actuator	ROMpak / Q actuator
Modbus over the network			
Open	✓	✓	✓
Close	✓	✓	✓
Stop	✓	✓	✓
Emergency Shut Down	✓	✓	✓
Relay output DO-1*	✓①	x	x
Relay output DO-2*	✓①	x	x
Relay output DO-3*	✓①	x	x
Relay output DO-4*	✓①	x	x
Analogue Position Demand	✓	✓	✓
Local Controls			
Open	✓	✓	✓
Close	✓	✓	✓
Stop	✓	✓	✓
Direct Hard Wired Inputs			
Open	✓	✓	✓②
Close	✓	✓	✓②
Stop/Maintain	✓	✓	x②
Emergency Shut Down	✓	✓	✓②
Open Interlock (active prevents opening)	✓	x	x
Close Interlock (active prevents closing)	✓	x	x

Note: ① – Requires Extra Relay Indication board to be fitted

② – Push to Run action only. Maintained action not available if analogue positioning is used

The Modbus RS-485 network commands will operate the actuator provided -

- Local/Local Stop/Remote selector is in 'Remote',
- On IQ or IQT actuators, Modbus commands are not inhibited by the 'Inhibit/DI-4' input parameter setting and DI-4 condition
- No interlock is active on IQ or IQT actuators.
- There is no standing hard wired control input active
- No alarm condition prevents it from moving

Open A digital command to cause the actuator to open to the fully open position as indicated by the Open limit switch. Under correct operation the actuator stops either when the open limit switch is reached, when the torque exceeds the value set and the open limit switch has been reached, or a new command is sent over the network.

Close A digital command to cause the actuator to close to the fully closed position as indicated by the Close limit switch. Under correct operation the actuator stops either when the close limit switch is reached, when

the torque exceeds the value set and the close limit switch has been reached, or a new command is sent over the network.

Note: *Many IQ multi-turn actuators are set to open until the open limit switch is reached and, close until the closing on torque switch trips, but it is dependent on the type of valve. The IQT and Q normally operate 90-degree valves, use stop bolts on the actuator or gearbox, and stop when these are reached. The control room indication is always taken from the end of travel limit switch settings*

- Stop** With no other command present this digital command causes an actuator motor that is running to stop.
- Emergency Shut Down** A digital command that causes the actuator to drive to its Emergency position. There are settings within the actuator to determine if this is a closed, open or stay put action.

For SI and EH actuators, this should not be used for SIL applications. The hard wired ESD input should be used.
- Relay Output DO-1 to DO-4** These 4 commands are used to energise and de-energise the internal relays on the additional relay board in an IQ / IQT or SI / EH actuator. (These outputs are referred to as S5-S8 in the standard actuator documentation when there is no MFU in the actuator.) The resulting outputs can be used for operating other equipment such as a pump or indication light. The IQ/IQT actuator is not able to control these relays directly from the main board when the MFU is fitted. They will maintain their last state if power is removed from the actuator. On restoration of power the relays will be reset to their de-energised condition and the coils will report '0'.
- Analogue Position Demand** This function is only available over the Modbus RS-485 network. To initiate Analogue Position Control a value must be written the Position DV register (range 0-100.0%, resolution 0.1%). The valve will open to the appropriate amount and stop in that position (within the deadband setting). If a subsequent digital command to open or close the valve is issued, from any source, this will take priority over the analogue position command. Once the setpoint is reached the positioning controller is switched off. A new write to the Position DV register will initiate positioning mode once more. The register location is listed later in this manual.

Provided limited range positioning is not invoked the values 0% and 100% written to this register produce a special case output where the command is revised so as to fully close the valve to its tight shut off position (0%) and fully open the valve (100%).
- Hard Wired Stop** The hard wired stop input acts as a change of state input. If the actuator is moving, opening the Stop input will stop the actuator. If the Stop input is already open and a Modbus command is sent to the actuator, the Modbus command will be initiated. To stop the actuator the hard wired input must be closed and opened again.

5.1.2 Modbus Control using Individual Coil commands

The open, close, stop, ESD and DO-1 to DO-4 controls can be written using function code 05 or 15 to write to single or multiple coils. Writing the value FF00 turns a coil on and 0000 turns it off. The MFU provides a degree of intelligence in operating the coils for the open, close, stop and ESD functions. When one coil is turned on, all the others are turned off, so only one can be on at a time. The actuator will obey the last command it receives, so if two writes using function code 05 follow each other closely the last one will win.

A multiple coil write by function code 15 to turn on more than one of the open, close, stop and ESD coils in the same command is not permitted. If an attempt to energise more than one of these coils in one command is made an exception response is generated and the multiple write ignored.

With the open and close coils these will turn off once the actuator completes the command, a new command is sent, the actuator is placed in local or some other interruption occurs. For example the close coil will de-energise once the actuator reaches the close position and stops. The stop and ESD coils remains latched once turned on and are cleared by another command or writing 0 to the coil.

The ESD action works slightly differently in that even if the coil is reset to 0, the action remains latched in the actuator. This is because a network ESD command overrides the actuator local controls. In order to remove the ESD action it is necessary to write a new command and if the actuator has local selected then the only command that will clear the latch is a write to the stop coil.

In the case of the DO-1 to DO-4 relays they will follow the command, energising when turned on and de-energising when turned off. These relays also maintain their status if the actuator power is removed and reset to the de-energised state only when the power is restored.

5.1.3 Modbus Control using the ACTCON Register

A single register is provided to allow the digital control of the actuator. Writing a value to the register with function code 06 or 16 causes the actuator to open, close, stop or ESD and at the same time cancels any other command set. This method of control removes the need to reset commands written with a code 05 coil write with a second write to the same location. The number written changes any coil states already set to the new value.

ACTCON Register (Register 5)				
Value	Stop	Close	Open	ESD
0	✓	✗	✗	✗
1	✗	✓	✗	✗
2	✗	✗	✓	✗
3	✗	✗	✗	✓
4 – 255	No action	No action	No action	No action

5.1.4 Modbus Control using the Actuator Position DV register

The analogue position control function will take priority over an earlier coil or ACTCON register command to open, stop, close or ESD the actuator when a value is written to the Actuator Position DV register. The controller will then position the actuator to the desired value.

The analogue position control function is cancelled either by the actuator achieving the desired position or a coil or ACTCON register write to one of the open, stop, close, ESD coils.

Note that when limited range positioning is used and the actuator is in the fully closed position a DV value of 0%, or when the actuator is in the fully open position a DV value of 100%, are not acted upon.

5.1.5 The IQ ‘S’ contacts (Modbus DOs).

The IQ/IQT actuator has four ‘S’ contact outputs that may be configured to report the status of the actuator with signals such as Open Limit, Closed Limit etc. These are identified as S1 to S4.

In addition, an optional additional relay board can be fitted with four more relays. The status of these relays is then adjusted by Modbus commands on outputs DO-1 to DO-4. Note that these relays are latching and, if energised, will not change state when the actuator power is removed. On restoration of power the relays will be reset to their de-energised condition and the coils will report ‘0’.

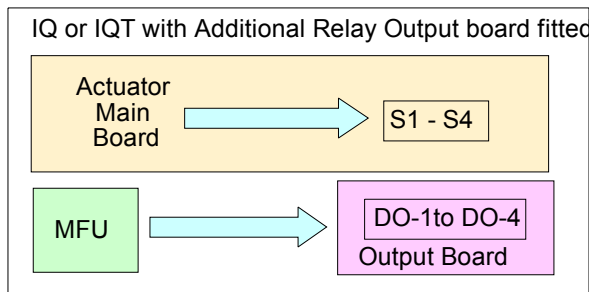


Fig 24: IQ and IQT relay outputs DO-1 to DO-4

5.1.6 IQ Modbus Network Control Disable feature

It is possible to set the IQ or IQT ESD/DI-4 input so that the IQ/IQT actuator ignores open, stop, close, ESD and position control signals sent over the Modbus network. If the ESD DI-4 / Net Disable parameter is set to Active then when the ESD input is connection is made (i.e. 24 volts applied to ESD), Modbus control is not allowed. This feature is independent of the Auxiliary mask setting. When the ESD DI-4 / Net Disable parameter is set to active, no ESD will be available.

5.2 Actuator Digital Input Status Feedback

The Modbus Module can report over the network a comprehensive data set relating to the status of the valve and actuator as indicated in the table below. The conventional contact indications are also available from the actuator limit switches and indication contacts.

Status Feedback	IQ / IQT actuator	SI / EH actuator	ROMpak / Q actuator
Actuator Moving	✓	✓	✓
Close Limit	✓	✓	✓
Open Limit	✓	✓	✓
Running Closed	✓	✓	✓
Running Open	✓	✓	✓
Remote selected	✓	✓	✓
Local Stop selected	✓	✓	✓
Local selected	✓	✓	✓

Status Feedback	IQ / IQT actuator	SI / EH actuator	ROMpak / Q actuator
Thermostat Tripped	✓	✓ ^③	✓ ^②
Monitor Relay	✓	✓	✓
Valve Obstructed	✓	✓ ^④	✓
Valve Jammed	✓	✓ ^④	✓
Valve Moving by Hand	✓	x	✓
Moving Inhibited	✓	✓	✓
Position Control Enabled	✓	✓	✓
Watchdog Recovery	✓	✓	✓
Battery Low	✓	x	x
Open Interlock input	✓	x	x
Close Interlock input	✓	x	x
DI -1	✓	x	x
DI -2	✓	x	x
DI -3	✓	x	x
DI -4	✓	x	x
Slow Mode	① □ □ ✓	x	①

Note: ① – This bit is reported when within the slow mode band, but does not affect the actuator.

② - a torque alarm when motor fails to turn after thermostat trips.

③ - this will show up as a general fault on the SI actuator.

④ - these will show up as either over pressure or stall on the SI actuator.

5.2.1 Digital Inputs from All Actuator Types

- Actuator Moving** Whenever the actuator position is changing due to the motor running or in the case of the IQ or IQT if the output drive is moving, this bit will be set true (1).
- Close Limit** This data bit indicates that the actuator has reached the closed position. The limit switch should be set slightly within the actual valve stroke to allow for torque seating or overshoot on closing without damaging the valve. The data bit will remain true (1) even if the position is passed through or exceeded.
- Open Limit** This data bit indicates that the actuator has reached the open position. The limit switch should be set slightly within the actual valve stroke to allow for torque seating or overshoot on opening without damaging the valve. The data bit will remain true (1) even if the position is passed through or exceeded.
- Running Closed** Whenever the actuator motor contactor used to drive the actuator in the closing direction is energised this bit will be true (1).

- Running Open** Whenever the actuator motor contactor used to drive the actuator in the opening direction is energised this bit will be true (1).
- Remote Selected** This bit is true (1) when the actuator three position remote/local stop/local selector is in the Remote position. The selector must be in this position for Modbus control to be permitted.
- Local Stop** The actuator three position selector passes from Local to Remote or Remote to Local through the Local Stop position. The switch can also be placed in Local Stop. When the switch is in the Local Stop position this bit will be true (1). Remote control of the actuator is not possible when the selector is in this position.
- Local Selected** This bit is true (1) when the actuator three position remote/local stop/local selector is in the Local position. Remote control of the actuator is not possible when the selector is in this position.
- Thermostat** If the temperature of the motor windings rises above the thermostat trip value, the thermostat contact will open and this signal will be present (1). There are no adjustments for the temperature at which the thermostat trip operates. The motor will be stopped if the thermostat trips. Only once the motor has cooled down and the thermostat has reset itself can a new Remote, Host or Local command to move the actuator be carried out. A setting on the actuator main board allows the ESD command to override the thermostat. The bit will remain set at logic 1 until the motor cools down and the thermostat resets itself.
- Monitor Relay** This signal is true (1) when actuator remote control is not available. The actuator Monitor Relay status is a composite signal for several alarms. This signal will be set true if the actuator selector is in Local or Local Stop (not in Remote) or if the thermostat trips. The mains supply is also monitored and if one of the three phases is lost this bit is set. If the actuator is operated from a single phase supply and this is lost then communications with the actuator will also be lost. Where a 3 phase supply is used, if the phase associated with the control circuits is lost then communications with the actuator will be lost.
- Valve Obstructed** This bit will be true (1) if the actuator stops in mid travel when not expected to do so after receiving a command to move. If the actuator torque exceeds the trip value set during commissioning then the motor will stop and motion will cease. The reason for the actuator stopping will be the high torque due to an obstruction and not a 'Stop' signal or reaching the desired setpoint position. (This could indicate a thermostat trip in a ROMpak actuator).

The bit will remain true (1) until the actuator position changes by 2% or more.

Note: *Attempting to restart the actuator to move towards the obstruction (even if the obstruction no longer exists) is not possible, the actuator will not restart. The actuator must be electrically reversed away from the obstruction before attempting to continue in the original direction.*

- Valve Jammed** This bit will be true (1) if the actuator is stationary at the end of travel and fails to move away from the seat of the valve when a network command requests it to do so. The actuator will trip on excessive

Note: *Attempting to restart the actuator to move out of the seated position is not possible. The actuator must be reversed before it will run in the same direction again. The jammed seat must first be released manually before electrical control is attempted. The problem may be overcome by adjusting the actuator torque setting which is designed to provide extra power on leaving the seated position.*

torque due to the valve being jammed in the seat. The MFU fails to see movement and reports this status after the time set in the associated parameter during the MFU set up. (This could indicate a thermostat trip in a ROMpak actuator).

The bit will remain true (1) until the actuator position changes by 2% or more.

- Valve Moving by Hand** The manual movement of the valve is reported as true (1) if the actuator is moved by the handwheel away from the last position. The percentage of travel required to trip the indication is set in the associated parameter during MFU set up. The bit will remain true (1) until the actuator is moved electrically by either the local controls or a network command.
- Moving Inhibited** This bit will be true (1) when the Motion Inhibit Timer is active or the Interrupter Timer is active (IQ/IQT only), or both are active. The Motion Inhibit Timer is used in position control to prevent the actuator from exceeding its prescribed number of starts per hour, or to reduce the effects of hunting during closed loop control. The Interrupter Timer in the IQ/IQT can be used over part or the entire actuator stroke to slow down the effective speed of valve travel. When under network control, the control signal does not need to be re-applied when this bit is true, as the control action will continue once the time has elapsed.
- Position Control Enabled** This bit will be true (1) when a Position command is being actioned. This data can be used to indicate that positioning mode has control of the actuator.
- Watchdog Recovery** The MFU watchdog automatically resets the processor if it is tripped. This bit will be true (1) following a watchdog trip for the time period set in the associated watchdog timeout parameter.

5.2.2 Digital Inputs from IQ and IQT Actuator

- Battery Low** Applicable to IQ and IQT actuators only. The status of the internal battery is monitored and should it fall below a critical level this signal will become true (1). The battery is used to power the circuits used to keep track of the valve position when the actuator mains power is switched off. This battery is used only when the actuator has no power feed and the valve is actually moved.
- Open Interlock** Applicable to IQ and IQT actuators only. The input contact to the Open Interlock is monitored by the MFU. Whenever the input contact is closed this bit will be true (1). If the actuator is not using the interlock function then this input can be used as a digital status feedback for a plant signal not associated with the actuator. If the interlock circuit is being used then this bit will indicate the existence of an interlocking input that can prevent the actuator from opening.
- Close Interlock** Applicable to IQ and IQT actuators only. The input contact to the Close Interlock is monitored by the MFU. Whenever the input contact is closed this bit will be true (1). If the actuator is not using the interlock function then this input can be used as a digital status feedback for a plant signal not associated with the actuator. If the interlock circuit is being used then this bit will indicate the existence of an interlocking input that can prevent the actuator from closing.
- Digital Input DI-1** Applicable to IQ and IQT actuators only. This bit reports the status of the contact connected to the actuator hard wired **Open** terminals. The input can be used to control the actuator or simply to report the status of a plant feedback signal. The function is set in the Auxiliary Input Mask parameter which determines whether the bit is reported as true (1) for a closed contact or an open contact and whether the input controls the actuator or not. Note that the input is always reported even when it is also controlling the actuator.
- Digital Input DI-2** Applicable to IQ and IQT actuators only. This bit reports the status of the contact connected to the actuator hard wired **Close** terminals. The input can be used to control the actuator or simply to report the status of a plant feedback signal. The function is set in the Auxiliary Input Mask parameter which determines whether the bit is reported as true (1) for a closed contact or an open contact and whether the input controls the actuator or not. Note that the input is always reported even when it is also controlling the actuator.
- Digital Input DI-3** Applicable to IQ and IQT actuators only. This bit reports the status of the contact connected to the actuator hard wired **Stop/Maintain** terminals. The input can be used to control the actuator or simply to report the status of a plant feedback signal. The function is set in the Auxiliary Input Mask parameter which determines whether the bit is reported as true (1) for a closed contact or an open contact and whether the input controls the actuator or not. Note that the input is always reported even when it is also controlling the actuator.

- Digital Input DI-4** Applicable to IQ and IQT actuators only. This bit reports the status of the contact connected to the actuator hard wired **ESD** terminals. The input can be used to control the actuator or simply to report the status of a plant feedback signal. The function is set in the Auxiliary Input Mask parameter which determines whether the bit is reported as true (1) for a closed contact or an open contact and whether the input controls the actuator or not. Note that the input is always reported even when it is also controlling the actuator.
 A configuration feature also allows DI-4 to be set to act as a 'Disable Fieldbus Control' input. In this mode when the input is made (irrespective of the Auxiliary Mask setting) the actuator cannot be controlled over the network. This can be useful during plant commissioning to prevent unwanted valve movement.

5.2.3 Digital Inputs from IQT Actuator

- Slow Mode** Applicable to IQT actuators only. In positioning mode, when the IQT actuator approaches its setpoint the motor automatically switches to 'slow mode' and the actuator runs at a lower speed. This allows any developed inertia to be dissipated and a better positional accuracy to be achieved without overshoot. The deviation from the setpoint at which slow mode is adopted is set in the associated parameter. When slow mode is in use this bit will be true (1). The IQ and Q actuators also report this bit, but these actuators do not have a slow mode capability.

5.3 Actuator Analogue Input Feedback

The Modbus Module makes available over the network a number of analogue variables. These contain information about the valve and actuator. If the single highway with analogue input variant of the Modbus Module is used, one associated plant measurement is also available.

Analogue Feedback	IQ / IQT actuator	SI / EH actuator	ROMpak / Q actuator
Actuator Instantaneous Torque	✓	✓ ^②	✗
Valve Position	✓	✓	✓
Analogue Input ^①	✓	✓	✓

Note: ^① – Requires the Single Highway + Analogue Input Modbus Module.

^② - SI and EH actuators report hydraulic pressure instead of torque.

- Torque** The currently developed torque value is reported as an Integer Value in the range 0 to 120 (0-78 hex) representing the percentage of actuator rated torque generated.
- Valve Position** The current valve position is reported as an Integer Value in the range 0 to 1000 (0 – 3E8 hex) representing the percentage position to 0.1% resolution.
 The IQ and IQT actuator automatically scales the valve position value reported from the setting of the limit switches.
 The Q actuator requires the valve to be stroked fully between the closed and open limit switches for the value to be automatically

scaled. This scaling is retained in EEPROM when the actuator power is removed.

If Limited Range Positioning is invoked by setting the appropriate parameters, then the reported valve position 0 to 100% follows the limited range of valve travel.

- Analogue Input** The current value of the analogue input is reported as an Integer Value in the range 0 to 1000 (0 – 3E8 hex) representing the percentage value to 0.1% resolution.
The input may be 0 to 5V or 0 to 20mA d.c. from an externally powered field transmitter (the actuator does not provide the power for the transmitter).
The input must be calibrated during the set-up of the MFU using the Analogue Input Max parameter. Apply a 100% signal and write a value to the parameter, the current value will then be reported as 100%. The scaling is retained in EEPROM when the actuator power is removed.

5.4 IQ Data Logger Information

The Modbus Module also makes available some of the IQ and IQT data logged information from registers in the data base. The data available is updated when the actuator reaches the end of travel and stops moving, provided the actuator selector is in the 'Remote' position.

- Close Torque Set** One register records the actuator setting for the maximum generated torque value permitted when the actuator is moving towards the closed position.
- Open Torque Set** The actuator setting for the maximum generated torque value permitted when the actuator is moving towards the open position is recorded in this register.
- Torque at x% when opening** There is a set of registers that each record the last value for the torque generated when the actuator is moving from closed to open and reaches a particular position (x%). The registers contain 11 values of torque generated in 10% position increments between 0% and 100% of valve travel.
- Torque at x% when closing** There is a set of registers that each record the last value for the torque generated when the actuator is moving from open to closed and reaches a particular position (x%). The registers contain 11 values of torque generated in 10% position increments between 100% and 0% of valve travel.
- Motor Starts – Closing Direction** Two registers (one double register) contain the total number of times the motor contactor to close the valve has been operated. The first register contains the low order 16 bits. The counter cannot be reset to zero.
- Motor Starts – Opening Direction** Two registers (one double register) contain the total number of times the motor contactor to open the valve has been

operated. The first register contains the low order 16 bits. The counter cannot be reset to zero.

6 MODBUS COMMUNICATION

6.1 Electrical Specification

Line Electrical Specification: RS-485, two-wire, half duplex

6.2 Outer Protocol

Modbus Transmission Mode RTU (8 bit Binary data)
Supported Baud Rates 300, 600, 1k2, 2k4, 4k8, 9k6, 19k2, 38k4, 57k6, 115k2
(2k4, 4k8, 9k6, 19k2, 38k4, 57k6, 115k2 when using the internal repeater option)

Number of bits per character
Start bits 1
Data bits (LSB first) 8
Parity (configurable) Odd, Even, None
Stop bits (configurable) 1 or 2

Error checking CRC

Message turn round time/delay time
Minimum period between request and response:

Data Speed (Baud)	300	600	1k2	2k4	4k8	9k6	19k2	38k4	57k6	115k2
Turn Round Time (ms)	188	100	60	40	28	24	20	20	20	20
Repeater Delay ^① (μs)	NA ^②	NA ^②	NA ^②	3.5	3.5	3.5	3.5	3.5	3.5	3.5

Note: ① – In the Single Highway with Internal Repeater Modbus Module option there is a propagation delay in the repeater.

② – NA = not applicable, the repeater function cannot be used below 2,400 baud.

Maximum period between request and response: 190 ms.

6.3 Repeaters

A single segment supports up to 32 nodes, one of which is usually the PLC. The addition of repeaters allows the segment to be extended in length or increase the number of nodes connected or both. The maximum lengths at different speeds are discussed in Section 4.2. The number of repeaters in a single highway should be kept to a minimum, as this can seriously extend the delay between a message being sent and the response arriving at the PLC.

The Single highway with Inbuilt Isolating Repeater version of the Modbus Module introduces propagation delays as mentioned above. Care must be taken in any system design to allow for these delays.

6.4 Dual Channel Mode

The dual channel version of the Modbus Module has two ports and allows two data highways to be used for communication from the host system to the module. These highways operate independently with a limit of 32 devices per segment and the ports on the module communicate with their associated highway. There is some interaction between the ports since a single processor serves them and the following points must be noted.

- The module only has one setting for the unit's address, communication speed and format. Both the communications ports share one set of common values for these parameters.
- When communication is active, every device on the highway reads all the data request or command messages. Each unit then responds only those messages aimed at its address.
- Port 1 has priority over Port 2. Since every message is read the host system must allow an idle time on Port 1 to allow Port 2 time to read its messages completely.
- A minimum time gap equivalent to 11 bytes of data should be left between data requests on both highways. This will ensure that the processor has sufficient time to respond to messages directed at Port 2. Without this idle period messages directed at Port 2 may not be acknowledged and a response may not be generated.

7 MODBUS DATA BASE

The data in the Modbus Module may be collected using a number of different Modbus function codes. Similarly the commands to the MFU can be either register or discrete based. This inbuilt flexibility is designed to allow for any host device to be able to access the actuator over a Modbus network in the simplest way.

This section provides information on the function codes supported and the data that may be collected or commands issued using those codes.

In all cases registers and discrete locations are numbered from 0 and do not include any offsets.

7.1 Modbus RTU Message Frame

Message synchronisation is maintained by simulation, the receiving MFU monitors the elapsed time between receipt of characters. If 3 and one-half character times elapse without a new character or frame completion, then the next byte received will be the start of a new message and begin with the address.

Modbus Address	Function Code	Register or Discrete Address	Number of Registers or Bits	Data Field	CRC Check
8 bits	8 bits	16 bits	16 bits	N bits	16 bits

Fig 25: Modbus transaction format

7.2 Modbus Address

The Modbus Module allows slave addresses in the range 1 to 247 to be used for devices; the addresses above 247 are reserved for special functions. Address 0 is recognised by all the slaves and is used for global Broadcast messages only. This leaves 247 addresses for use by the connected Modbus Modules on the data highway.

Note that the dual highway unit uses a single address for both highway connections.

- Single RS-485 highway plus one analogue input channel
Address range supported = 0 to 247 (0 for broadcast)
- Dual Independent Isolated –RS-485 highways
Address range supported = 0 to 247 (0 for broadcast)
Both channels must share the same address
- Single RS-485 highway with inbuilt isolating repeater
Address range supported = 0 to 247 (0 for broadcast)

7.3 Function Code Support

Details of the Request and Reply formats for messages can be found in the Modbus Application Protocol Specification V1.1b3, found at <http://www.modbus.org>. The following table lists the function codes supported by the Modbus Module.

Function Code	Modbus Name	Addressing
01	Read Output Coil Status	Discrete
02	Read Input Status	Discrete
03	Read Holding Registers	Register
04	Read Input Registers	Register
05	Force Single Coil	Discrete
06	Preset Single Register	Register
07	Read Exception Status	
08	Loopback Diagnostic Test	
15	Force Multiple Coils	Discrete
16	Preset Multiple Registers	Register
17	Report Slave ID	

Exception Response Code	Meaning
01	Illegal function code or incorrect message length
02	Illegal data address (Register or discrete address invalid)
03	Illegal data value
06	Busy

To read data the function code to use will depend on whether the data is to be read as single bits or as 16 bit registers. For example, code 01 reads data as discrete bits, whereas code 03 reads the data as registers. In many cases Discrete and Register access reads the SAME data.

Code 01 - Read Coils

This is used to read discrete (bit) data from the data base to obtain information about the status of the output coils (commands).

Code 02 - Read Input Status Requests

This is used to read discrete (bit) data from the data base to obtain information about the actuator current status such as open or closed positions achieved.

Code 03 - Read Holding Register Requests

All the data in the MFU can be read using function code 03. Discrete data is mapped into registers that are available for this command.

Code 04 - Read Input Register Requests

Actuator position and torque registers, plus the status bits are accessible with function code 04.

- Code 05 and 15 - Force Single Coil or Multiple Coils**

The output coils are the discrete outputs from the actuator or its digital control commands. Code 05 writes one coil per message whilst code 15 can write values to several at once.
- Code 06 and 16 - Preset Single Register or Multiple Registers**

Registers are used for position control and also for digital control and can be accessed singly, or in multiples with these codes. Function code 06 writes a single 16 bit register whilst function code 16 can write several in one transaction.
- Code 07 – Read Exception Status**

This is a specific short message function code which returns predetermined discrete data from the MFU. The message is used to allow fast transfer of a small data packet.
- Code 08 - Loopback Diagnostic Test**

The purpose of the Loopback Test is to test the communication system between the Modbus Module and the host. The MFU supports this test when used with diagnostic code 00, Return Query Data, and 02, Return Diagnostic Register. No other diagnostic test codes are supported.
- Function Code 17 – Report Slave ID**

This function code generates a response that contains specific information about the MFU and actuator (providing the data has been entered on setup).
- Exception Response Codes**

Error code 01 will be presented back to the host if the function code in the data message is not one of those supported by the Modbus Module or the message length is not as expected.

Error code 02 will be presented back to the host if the Data Address is not valid for the Modbus Module.

Error code 03 will be presented back to the host if the value to be written in a coil or register write is not valid for the register or coil location chosen in the MFU.

Error code 6 will be presented back to the host if the MFU is unable to respond with a correct message because it is busy.

7.4 Broadcast Commands

Broadcast commands are only supported for specific registers, coils and commands.

- Stop and ESD** Code 05 writes to coils 0 (Stop) and 3 (ESD) are supported for address 0 broadcast.

Code 06 writes to register 5 (Actuator Digital Control) with values 0 (Stop) and 3 (ESD) are supported for address 0 broadcast.

7.5 Data Location Offsets

The locations given in the data base are those, which should appear in the messages as they are transmitted on the Modbus link. Some host systems offset the addresses so far as the user is concerned. In such cases the address programmed into the host would be different to those listed. All data locations listed start from 0. Please check the host system documentation carefully to determine if any offsets are required.

Typical Offsets are:

Function Code	Offset to be added to formulae result
1	1
2	10001
3	40001
4	30001
5	1
6	40001

7.6 Data Locations

The data locations in the following tables are all numbered from 0. For a definition of the actuator functions listed refer to Section 5. Not all the listed signals are available from every actuator type. For the DO-1 to DO-4 options on IQ and IQT the relay output board must be fitted.

Note: *All data locations listed start from 0, it may be necessary to add an offset to match the number required for the PLC.*

7.6.1 Data Accessed with Function Code 01 - Read Coils

Location (Bit)	R/W	Data	Range
0	R/W	Stop command output coil status	0-1
1	R/W	Close command output coil status	0-1
2	R/W	Open command output coil status	0-1
3	R/W	ESD command output coil status	0-1
4	R/W	DO-1 output coil status	0-1
5	R/W	DO-2 output coil status	0-1
6	R/W	DO-3 output coil status	0-1
7	R/W	DO-4 output coil status	0-1

Note: Coil 'on' when the state is true, reports as a '1'.

7.6.2 Data Accessed with Function Code 02 - Read Discrete Inputs

Location (Bit)	R/W	Data	Range
0	RO	Actuator moving	0-1
1	RO	Closed limit	0-1
2	RO	Open limit	0-1
3	RO	Running closed	0-1
4	RO	Running open	0-1
5	RO	Remote selected	0-1
6	RO	Local Stop selected	0-1
7	RO	Local selected	0-1
8	RO	Thermostat tripped	0-1
9	RO	Monitor relay	0-1
10	RO	Valve obstructed	0-1
11	RO	Valve jammed	0-1
12	RO	Valve moving by hand	0-1
13	RO	Moving inhibited	0-1
14	RO	Position control enabled	0-1
15	RO	Watchdog recovery	0-1
16	RO	Battery low	0-1
17	RO	Open interlock active	0-1
18	RO	Close interlock active	0-1
19	RO	DI-1	0-1
20	RO	DI-2	0-1
21	RO	DI-3	0-1
22	RO	DI-4	0-1
23	RO	Slow mode	0-1

Note: When the input is true the status reports as a '1'.

7.6.3 Data Accessed with Function Code 03 - Read Holding Registers

The accessible registers that can be read with this function code also include the Input registers.

Location (Reg/Bit)		R/W	Data	Range
0	0	RO	Actuator moving	0-1
0	1	RO	Closed limit	0-1
0	2	RO	Open limit	0-1
0	3	RO	Running closed	0-1
0	4	RO	Running open	0-1
0	5	RO	Remote selected	0-1
0	6	RO	Local Stop selected	0-1
0	7	RO	Local selected	0-1
0	8	RO	Thermostat tripped	0-1
0	9	RO	Monitor relay	0-1
0	10	RO	Valve obstructed	0-1
0	11	RO	Valve jammed	0-1
0	12	RO	Valve moving by hand	0-1
0	13	RO	Moving inhibited	0-1
0	14	RO	Position control enabled	0-1
0	15	RO	Watchdog recovery	0-1
1	0	RO	Battery low	0-1
1	1	RO	Open interlock active	0-1
1	2	RO	Close interlock active	0-1
1	3	RO	DI-1	0-1
1	4	RO	DI-2	0-1
1	5	RO	DI-3	0-1
1	6	RO	DI-4	0-1
1	7	RO	Slow mode	0-1
1	8	RO	Reserved	0
1	9	RO	Reserved	0
1	10	RO	Reserved	0
1	11	RO	Reserved	0
1	12	RO	Reserved	0
1	13	RO	Reserved	0
1	14	RO	Reserved	0
1	15	RO	Reserved	0
2	-	RO	Actuator Instantaneous Torque ①	0-78 hex (0 – 120%)
3	-	RO	Valve Position	0-3E8 hex (0.0 – 100.0%)
4	-	RO	Analogue Input	0-3E8 hex (0.0 – 100.0%)

Location (Reg/Bit)	R/W	Data	Range	
5	-	R/W	Actuator Digital Control	0-3 0 = stop, 1 = close 2 = open 3 = ESD
6	-	R/W	Actuator Position DV (desired value)	0-3E8 hex (0.0 – 100.0%)
26-31	-	R/W	Actuator Tag name	12 bytes ASCII char

Note: ① Pressure instead of Torque in SI Pro and EH Pro.

The following Data Logger information is also accessed by function code 03. Torque values are in the range 0 – 120%. The registers are updated with new data a short period after the actuator stops moving provided the actuator selector is in remote. The values may not contain the updated information for up to 2 minutes.

Location (Reg/Bit)	R/W	Data	Range	
32	-	RO	Close Torque set	0-78 hex
33	-	RO	Open Torque set	0-78 hex
34	-	RO	Torque at 0% - open direction	0-78 hex
35	-	RO	Torque at 10% - open direction	0-78 hex
36	-	RO	Torque at 20% - open direction	0-78 hex
37	-	RO	Torque at 30% - open direction	0-78 hex
38	-	RO	Torque at 40% - open direction	0-78 hex
39	-	RO	Torque at 50% - open direction	0-78 hex
40	-	RO	Torque at 60% - open direction	0-78 hex
41	-	RO	Torque at 70% - open direction	0-78 hex
42	-	RO	Torque at 80% - open direction	0-78 hex
43	-	RO	Torque at 90% - open direction	0-78 hex
44	-	RO	Torque at 100% - open direction	0-78 hex
45	-	RO	Torque at 0% - close direction	0-78 hex
46	-	RO	Torque at 10% - close direction	0-78 hex
47	-	RO	Torque at 20% - close direction	0-78 hex
48	-	RO	Torque at 30% - close direction	0-78 hex
49	-	RO	Torque at 40% - close direction	0-78 hex
50	-	RO	Torque at 50% - close direction	0-78 hex
51	-	RO	Torque at 60% - close direction	0-78 hex
52	-	RO	Torque at 70% - close direction	0-78 hex
53	-	RO	Torque at 80% - close direction	0-78 hex
54	-	RO	Torque at 90% - close direction	0-78 hex
55	-	RO	Torque at 100% - close direction	0-78 hex
56	-	RO	Close Contactor counts low order	0-FFFF hex
57	-	RO	Close Contactor counts high order	0-FFFF hex
58	-	RO	Open Contactor counts low order	0-FFFF hex
59	-	RO	Open Contactor counts high order	0-FFFF hex

7.6.4 Data Accessed with Function Code 04 - Read Input Registers

Location (Reg/Bit)		R/W	Data	Range
0	0	RO	Actuator moving	0-1
0	1	RO	Closed limit	0-1
0	2	RO	Open limit	0-1
0	3	RO	Running closed	0-1
0	4	RO	Running open	0-1
0	5	RO	Remote selected	0-1
0	6	RO	Local Stop selected	0-1
0	7	RO	Local selected	0-1
0	8	RO	Thermostat tripped	0-1
0	9	RO	Monitor relay	0-1
0	10	RO	Valve obstructed	0-1
0	11	RO	Valve jammed	0-1
0	12	RO	Valve moving by hand	0-1
0	13	RO	Moving inhibited	0-1
0	14	RO	Position control enabled	0-1
0	15	RO	Watchdog recovery	0-1
1	0	RO	Battery low	0-1
1	1	RO	Open interlock active	0-1
1	2	RO	Close interlock active	0-1
1	3	RO	DI-1	0-1
1	4	RO	DI-2	0-1
1	5	RO	DI-3	0-1
1	6	RO	DI-4	0-1
1	7	RO	Slow mode	0-1
1	8	RO	Reserved	0
1	9	RO	Reserved	0
1	10	RO	Reserved	0
1	11	RO	Reserved	0
1	12	RO	Reserved	0
1	13	RO	Reserved	0
1	14	RO	Reserved	0
1	15	RO	Reserved	0
2	-	RO	Actuator Instantaneous Torque	0-78 hex (0 – 120%)
3	-	RO	Valve Position	0-3E8 hex (0.0 – 100.0%)
4	-	RO	Analogue Input	0-3E8 hex (0.0 – 100.0%)

7.6.5 Data Accessed with Function Code 05 and 15 – Force Single and Multiple Coils

Location (Bit)	R/W	Data	Range
0	R/W	Stop command output coil status	0-FF00 hex
1	R/W	Close command output coil status	0-FF00 hex
2	R/W	Open command output coil status	0-FF00 hex
3	R/W	ESD command output coil status	0-FF00 hex
4	R/W	DO-1 output coil status	0-FF00 hex
5	R/W	DO-2 output coil status	0-FF00 hex
6	R/W	DO-3 output coil status	0-FF00 hex
7	R/W	DO-4 output coil status	0-FF00 hex

Using code 05 write FF00 (hex) to turn on the command, DO-1 to DO-4 are turned off by writing '0'. The other coil commands are cleared by various means as explained in Section 5.1.2. Using code 15 write 1 to turn on the command and 0 to turn off the command.

The commands to open, close, stop or ESD the actuator are not cancelled by writing a '0'. The actuator latches the instruction and will complete the action unless a subsequent counter command is received before the action is completed.

7.6.6 Data Accessed with Function Code 06 and 16 – Preset Single and Multiple Registers

Location (Reg/Bit)	R/W	Data	Range
5	-	R/W Actuator Digital Control	0-3 0 = stop, 1 = close 2 = open 3 = ESD
6	-	R/W Actuator Position DV (desired value)	0-3E8 hex (0.0 – 100.0%)

The Actuator Digital Control register allows one of the four commands to be selected by writing the appropriate value.

Provided limited range positioning is not invoked, the Actuator Position DV register assigns a special importance to the values 0% and 100% written to this register. The command is revised so as to fully close the valve to its tight shut off position (0%) and fully open the valve (100%).

7.6.7 Data Accessed with Function Code 07 – Read Exception Status

Code 07 reads a predefined data set with minimal overheads and is used for fast data transfer. A single byte is returned.

Location (Bit)	R/W	Data	Range
0	RO	ESD coil status	0-1
1	RO	Open coil status	0-1
2	RO	Close coil status	0-1
3	RO	Stop coil status	0-1
4	RO	Closed position limit	0-1
5	RO	Open position limit	0-1
6	RO	Monitor relay	0-1
7	RO	Reserved	0-1

7.6.8 Data Accessed with Function Code 08 – Loopback Diagnostic Test

The Loopback Test is used to test communications only. In a correctly working unit the return message is the same as the query sent. Two codes are supported.

Code	Data
00	Return query data
02	Return diagnostic register

The Diagnostic Register contains the following data.

Location (Reg/Bit)	R/W	Data	Range
- 0	RO	Memory Status Fault	0-1
- 1	RO	Auxiliary control input active	0-1
- 2	RO	Position controller enabled	0-1
- 3	RO	Highway ESD active	0-1

7.6.9 Data Accessed with Function Code 17 – Report Slave ID

The Slave ID data response includes 20 registers, (40 bytes) of ASCII data to give the device name, software version and service tag number.

Byte	Data
1 – 23	'Null Null Rotork MODBUS MODULE.'
24 – 28	Software version: 'Mxxx ' (where xxx is the revision number)
29 – 40	Tag Number (12 bytes)

7.7 Data Base Summary:

Data	Location (Reg / Bit)	Function	Accessed by MODBUS function code							
			01	02	03	04	05	06	15	16
Stop	0	Digital Output	01				05		15	07
Close	1	Digital Output	01				05		15	07
Open	2	Digital Output	01				05		15	07
ESD	3	Digital Output	01				05		15	07
Output DO-1 (extra relay S5)	4	Digital Output	01				05		15	
Output DO-2 (extra relay S6)	5	Digital Output	01				05		15	
Output DO-3 (extra relay S7)	6	Digital Output	01				05		15	
Output DO-4 (extra relay S8)	7	Digital Output	01				05		15	
Actuator moving	0 / 0	Digital Input		02	03	04				
Close position limit	0 / 1	Digital Input		02	03	04				07
Open position limit	0 / 2	Digital Input		02	03	04				07
Valve running close	0 / 3	Digital Input		02	03	04				
Valve running open	0 / 4	Digital Input		02	03	04				
Selector in remote	0 / 5	Digital Input		02	03	04				
Selector in local stop	0 / 6	Digital Input		02	03	04				
Selector in local	0 / 7	Digital Input		02	03	04				
Thermostat tripped	0 / 8	Digital Input		02	03	04				
Monitor relay	0 / 9	Digital Input		02	03	04				07
Valve obstructed	0 / 10	Digital Input		02	03	04				
Valve jammed	0 / 11	Digital Input		02	03	04				
Manual movement	0 / 12	Digital Input		02	03	04				
MIT/Interrupter timer	0 / 13	Digital Input		02	03	04				
Position control enabled	0 / 14	Digital Input		02	03	04				
Watchdog	0 / 15	Digital Input		02	03	04				
Battery low	1 / 16	Digital Input		02	03	04				
Open Interlock input active	1 / 17	Digital Input		02	03	04				
Close Interlock input active	1 / 18	Digital Input		02	03	04				
Hard wired input DI-1	1 / 19	Digital Input		02	03	04				
Hard wired input DI-2	1 / 20	Digital Input		02	03	04				
Hard wired input DI-3	1 / 21	Digital Input		02	03	04				
Hard wired input DI-4	1 / 22	Digital Input		02	03	04				
Slow mode	1 / 23	Digital input		02	03	04				
Instantaneous torque	2 / -	Input register			03	04				
Valve position	3 / -	Input register			03	04				
Analogue input	4 / -	Input register			03	04				
Actuator digital control	5 / -	Output register			03		06		16	
Position demand output	6 / -	Output register			03		06		16	
Action on loss of signal	7 / -	Parameter reg			03		06		16	
Min position	8 / -	Parameter reg			03		06		16	
Max position	9 / -	Parameter reg			03		06		16	
Deadband	10 / -	Parameter reg			03		06		16	
MIT	11 / -	Parameter reg			03		06		16	
Aux mask	12 / -	Parameter reg			03		06		16	
Communications lost position	13 / -	Parameter reg			03		06		16	
Hysteresis	14 / -	Parameter reg			03		06		16	
Slow mode range	15 / -	Parameter reg			03		06		16	
Jammed time	16 / -	Parameter reg			03		06		16	
Manual movement travel	17 / -	Parameter reg			03		06		16	
Watchdog timeout	18 / -	Parameter reg			03		06		16	
ESD DI-4/Net disable	19 / -	Parameter reg			03		06		16	
Analogue input max	20 / -	Parameter reg			03		06		16	
Communications fault timer	21 / -	Parameter reg			03		06		16	
Address	22 / -	Parameter reg			03		06		16	
Baud rate	23 / -	Parameter reg			03		06		16	
Parity, Stop bits	24 / -	Parameter reg			03		06		16	

Data	Location (Reg / Bit)	Function	Accessed by MODBUS function code									
			01	02	03	04	05	06	15	16	Other	
Database format	25 / -	Parameter reg			03				06		16	
Actuator Tag number	26 – 31 / -	Parameter reg			03				06		16	
Data logger data	32 – 59 / -	Input register			03							
Memory status OK/Fault	- / 0	Diagnostics										08 (02)
Aux control input active	- / 1	Diagnostics										08 (02)
Positioner enabled	- / 2	Diagnostics										08 (02)
Highway ESD active	- / 3	Diagnostics										08 (02)

8 CONFIGURATION REGISTERS

In order to make the best use of the MFU, the module has a number of configurable parameter registers that may be adjusted to optimise the performance of the actuator. All the parameter registers have factory default setting designed to meet the most common requirements for the actuator. If these are not suitable for a particular application then by using a Modbus communication tool the values can be changed.

The Modbus Module contains 20 configurable parameter registers; with the IQ and IQT actuator some of these can be altered by using the infra-red communications link and the setting tool. By using a Modbus communication tool connected to the RS-485 highway all the registers may be reviewed and altered to suit the particular application for the actuator.

Care must be exercised with access to these parameter registers as they can alter the complete performance of the actuator, including selecting a different operating data base.

This section of the manual describes each variable parameter register and should be used for reference when using the configuration tools. All the registers can be read using function code 03 (Read Holding Registers). The contained values may be altered using function code 06 (Preset Single Register) or function code 16 (Preset Multiple Registers).

☐ Actuator Related Network Configurable Parameter Registers

Description	Value/Range	Default Value	Location (Register)	R/W Access		
				03	06	16
Action on Loss of Communications	0 = Nothing (No Action) 1 = Open 3 = Close 5 = Stop 7 = Position Any other value = Off	0 = Nothing (0000 hex)	7	03	06	16
Limited Range Position Minimum	0 – 100% 0000 – 0064 hex	0% 0000	8	03	06	16
Limited Range Position Maximum	0 – 100% 0000 – 0064 hex	100% 0064 hex	9	03	06	16
Deadband ①	0.0 – 25.5% ② 0000 – 00FF hex	5.0% 0032 hex	10	03	06	16
Motion Inhibit Time	0 – 255 sec 0000 – 00FF hex	5 sec 0005 hex	11	03	06	16
Aux Input Mask	0 – 255 0000 – 00FF hex	15 000F hex	12	03	06	16
Communications Lost Position	0 – 100% 0000 – 0064 hex	0% 0000 hex	13	03	06	16
Hysteresis ①	0.0 – 25.5% 0000 – 00FF hex	2.0% 0014 hex	14	03	06	16
Slow Mode Range	0 – 100% 0000 – 0064 hex	5% 0005 hex	15	03	06	16

Description	Value/Range	Default Value	Location (Register)	R/W Access		
Valve Jammed Time	0 – 255 sec 0000 – 00FF hex	5 sec 0005 hex	16	03	06	16
Manual Movement Travel	0 – 100% 0000 – 0064 hex	10% 000A hex	17	03	06	16
Watchdog Timeout	0 – 255 sec 0000 – 00FF hex	10 sec 000A hex	18	03	06	16
ESD DI-4/Net Disable	DI-4 is ESD = 0 DI-4 is Net Disable = 1	ESD 0000 hex	19	03	06	16
Analogue Input Max	0 – 1023 0000 – 3FF hex	0 0000 hex	20	03	06	16
Communications Fault Timer	0 – 255 sec 0000 – 00FF hex	10 sec 000A hex	21	03	06	16

Note: ① - Setting the deadband lower than the hysteresis, or the hysteresis greater than the deadband causes the hysteresis to be set to 0.1%

② - IQ Setting tool only allows 0.0 to 9.9% deadband to be set

❑ Modbus Network Related Network Configurable Parameter Registers

Description	Value/Range	Default Value	Location (Register)	R/W Access		
Modbus Address	1 – 247 0001 – 00F7 hex	247 00F7 hex	22	03	06	16
Baud Rate (baud) ①	0 = not used 1 = 300 6 = 9k6 2 = 600 7 = 19k2 3 = 1k2 8 = 38k4 4 = 2k4 9 = 57k6 5 = 4k8 A = 115k2 (values in hex)	9k6 (0006 hex)	23	03	06	16
Parity/Stop bits①	0 = No parity, 1 stop bit 1 = No parity, 2 stop bits 2 = Even, 1 stop bit 3 = Even, 2 stop bits 4 = Odd, 1 stop bit 5 = Odd, 2 stop bits	None/1 (0000 hex)	24	03	06	16
Data Base Format①	Modbus Mk1/Mk2 0 = Mk1 1 = Mk2	Mk2 (0001)	25	03	06	16
Actuator Tag Name	Any ASCII char (12 characters max)	(blank) all = 0000	26 to 31	03	06	16

Note: ① - When altered, the new value will only take effect after the actuator power has been cycled.

8.1 Actuator Related Configurable Parameter Registers

These parameter registers set up the response of the actuator will take to various control and network actions.

8.1.1 Action on Loss of Communications (Register 7)

This register is used in conjunction with register 13 (Communications Lost Position) and 21 (Communications Fault Timer).

The Action on Loss of Communications register defines the actuator action that will result after the time set for the Communications Fault Timer (register 21) if there is no network communication activity detected by the MFU.

The action may be

- Nothing** (0) No action, actuator will complete any command in process (the default setting)
- Open** (1) The actuator will open the valve
- Close** (3) The actuator will close the valve
- Stop** (5) The actuator stops
- Position** (7) The actuator will adjust the valve position to the setting given in the Communications Lost Position (register 13).

8.1.2 Limited Range Position Minimum and Maximum (Registers 8 and 9)

These parameter registers are used to define the positions in the range of valve travel that will be reported as 0 to 100% if it the whole travel from the closed position to the open position is not used. In addition, the position demand setpoint output value will also be modified to follow this limited range.

It is possible to make the position data reported and the position controller relate to a reduced span of actual valve travel. In this mode the position data relates to the reduced portion of the valve stroke. This is sometimes used where the valve is required to have a 0% position (or 100% position) that is not the same as the fully closed position (or fully open position). These parameters define the actual limited range of valve travel that will be used for the position reporting and control by the positioner.

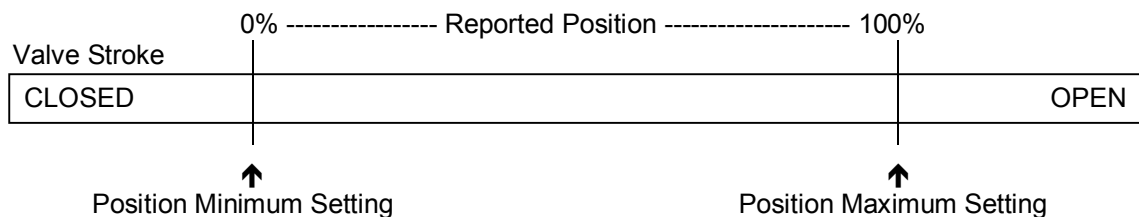


Fig 26: Limited Range Position Control and Reporting

Note that the digital open and close commands will still make the valve travel over its full stroke. The special case analogue commands of 0% and 100% that would otherwise cause the actuator to travel to the limit switch or torque off positions are inhibited if values other than 0 and 100 are set in these parameters.

The values inserted relate to the maximum total valve travel between closed and open and represent the point in the full stroke which will now be used for the limited stroke 0 and 100 values.

8.1.3 Deadband and Hysteresis (Registers 10 and 14)

When using position control by sending a value to the Actuator Position DV setpoint there are a number of parameter registers used to tune the position controller and reduce the possibility of damage to the actuator. These two registers are set to prevent hunting around the setpoint due to high inertia of the valve. They will require adjustment for each specific application. In addition, the Motion Inhibit Timer is used to ensure the actuator does not carry out an excessive number of starts in a given period.

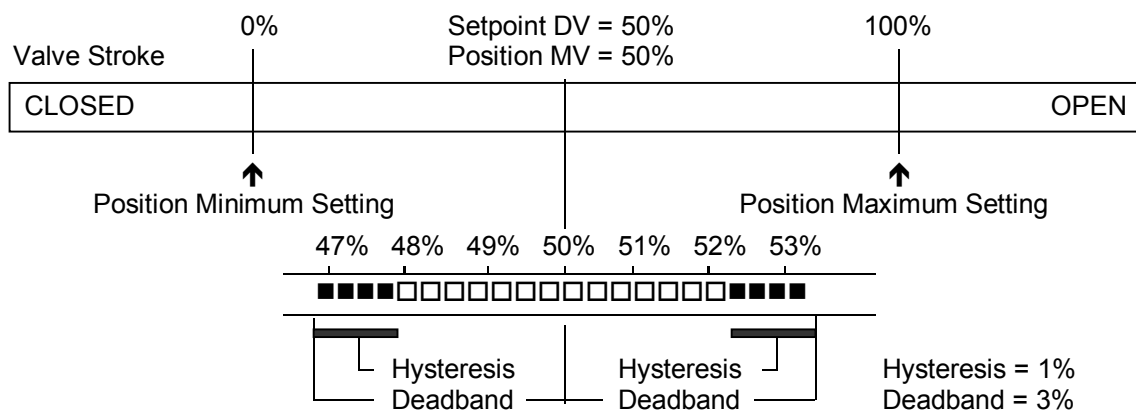
Deadband

The control used for the positioner is proportional only. The MFU will run the actuator to the desired position and then it stops. As the actuator and valve combination have some inertia there is a possibility that the desired position may be overrun and the positioner will then reverse the direction of travel to make the valve adopt the desired position. This overshoot and return may continue for a number of cycles and is known as hunting, the valve and actuator combination will hunt around the setpoint if the inertia is high. To prevent this from happening there is a Deadband setting whereby once the actuator enters the deadband the motor will be stopped. For example a 5% deadband will cause the motor to be stopped once the actual position is within 5% of the desired position. The inertia will then bring the actual position nearer the desired position.

The deadband is the allowable error around the setpoint.

Hysteresis

In addition to the deadband a second setting, hysteresis, further refines the performance of the position controller. The positioner will run the actuator towards the setpoint DV until the actual position is within the deadband minus the hysteresis setting. This has the effect of instructing the actuator to stop when it is nearer the DV. The actuator will not restart unless it overshoots and runs outside the deadband or a new command places the new desired position outside the deadband.



The Hysteresis is the amount of movement inside the deadband permitted before the motor stops.

Fig 27: Deadband and Hysteresis settings

8.1.4 Motion Inhibit Timer (Register11)

The Motion Inhibit Timer setting is the period that must elapse between consecutive starts of the actuator motor when in positioning mode. The idle period will prevent the actuator motor from exceeding its rated number of starts per hour.

In addition, when tuning the valve positioner the setting can be used to allow the plant dynamics to stabilise between valve movements.

8.1.5 Auxiliary Input Mask (Register 12)

This parameter register relates to the IQ and IQT actuators only and allows the auxiliary inputs (open, stop, close, ESD) to be set to control the actuator or simply report their status. In addition, it allows the sense of the input (open or closed contact) that is reported as true (1) to be set. Actuator control always requires a true (1) input signal. The status of the inputs is always reported over the network and they can be used to report associated plant inputs instead of controlling the actuator.

The register should be considered in its binary format using the low order byte. The number has the binary form $x^7x^6x^5x^4, y^3y^2y^1y^0$, requiring 8 bits. Each bit in the high order nibble, $x^7x^6x^5x^4$, either enables or disables the associated input for control of the actuator. The bits in the low order nibble, $y^3y^2y^1y^0$, determines if the input reports a closed contact as a '1' or an open contact as a '1'. Only when the input is a '1' as set by the mask and the contact state will the actuator respond to the input if it is also set to control the actuator.

To allow an input to act as a control signal its associated bit in the high order nibble must be set to a '1' in the mask. To allow a closed contact to be reported as a '1' then its associated bit in the low order nibble must be set to '1' in the mask.

Bit	Position	Value	Function
7	X^7	0	Disable ESD input as command
		1	Enable ESD input as command
6	X^6	0	Disable Stop/Maintain input as command
		1	Enable Stop/Maintain input as command
5	X^5	0	Disable Close input as command
		1	Enable Close input as command
4	X^4	0	Disable Open input as command
		1	Enable Open input as command
3	Y^3	0	Report closed contact on ESD input as '0'
		1	Report closed contact on ESD input as '1'
2	Y^2	0	Report closed contact on Stop/Maintain input as '0'
		1	Report closed contact on Stop/Maintain input as '1'
1	Y^1	0	Report closed contact on Close input as '0'
		1	Report closed contact on Close input as '1'
0	Y^0	0	Report closed contact on Open input as '0'
		1	Report closed contact on Open input as '1'

The following examples show how the Auxiliary Input Mask settings can be applied.

	Most Significant Bit				Least Significant Bit			
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	X ⁷	X ⁶	X ⁵	X ⁴	Y ³	Y ²	Y ¹	Y ⁰
	Enable DI-4 ESD	Enable DI-3 Stop	Enable DI-2 Close	Enable DI-1 Open	Invert DI-4	Invert DI-3	Invert DI-2	Invert DI-1
Example 1	0	0	0	0	1	1	1	1
Example 2	1	1	1	1	1	1	1	1
Example 3	0	0	0	0	0	0	0	0

- Example 1 The default value of '15' (0000,1111 binary or 0F hex) makes all 4 inputs report closed contacts as true (1) and none of the inputs will operate the actuator.
- Example 2 The value 255 (1111,1111 binary or FF hex) makes all 4 inputs report closed contacts as true (1) and all the inputs control the actuator in their predefined way.
- Example 3 The value 0 (0000,0000 binary or 00 hex) makes all 4 inputs report open contacts as true (1) and none of the inputs will operate the actuator.

8.1.6 Communications Lost Position (Register 13)

The setting in this parameter register determines the position in the range 0 to 100% that the actuator will move to if the Modbus network communications stops being received, provided the Fault Mode (Register 1) is set to 'Position'. No action will be taken unless the communications stops for a period equal or greater than the setting in the Communications Fault Timer (Register 21).

8.1.7 Slow Mode Range (Register 15)

This parameter register is only applicable to IQT actuators. The Slow Mode Range sets the deviation between the setpoint and current position in positioning mode inside which the actuator motor will slow to minimum speed.

If the setpoint (DV) is 50% and the setting for this parameter is 10%, then when the actuator moves within the range 40% to 60% the motor will adopt low speed. The actuator does not use slow mode for digital (Open/Close) commands.

8.1.8 Valve Jammed Time (Register 16)

Parameter register 16 sets the time delay that must elapse without any actuator movement before deciding the Valve Jammed status bit must be set. Valve Jammed is only announced if the actuator is asked to move and fails to respond when it should. The time must be long enough to ensure that the valve is not moving at all.

8.1.9 Manual Movement Travel (Register 17)

Manual Movement Travel sets the amount of valve travel not under motor action that is permitted before being considered 'Manual Movement'. The setting must be sufficiently large to cover over run of position control due to valve inertia. Too small a setting will result in Manual Movement alarms each time the valve is positioned, particularly if the deadband is small.

8.1.10 Watchdog Timeout (Register 18)

If the watchdog trips to reset the processor the Watchdog Recovery data bit is set. The data bit will automatically reset to '0' after the time period set in this parameter register.

8.1.11 ESD DI-4/Net Disable (Register 19)

In the IQ/IQT actuator this input determines the mode of operation for the ESD/DI-4 remote input. The input can be used either to disable control of the actuator from the network, or to act as an ESD/digital input. When this setting is made 'Active' the input will disable network control of the IQ/IQT when the contact input is closed irrespective of the Aux Mask setting.

8.1.12 Analogue Input Max (Register 20)

The MFU includes an analogue input channel for a process input. This input will require calibration to ensure it is accurately reported.

This parameter can only be set when the MFU is on line and the analogue input should be connected to a calibration source. When the register is set this causes the analogue input to be sampled and the value read to be used for the input to be reported as 100.0%. If the parameter register is simply read then the value displayed is the raw analogue input value.

Apply a 100% input and write any number between 1 and 1023, but different from the currently register value, write the new value and read back from the MFU. The number in the register will change to the raw A/D value equivalent to the currently applied analogue signal and the reported value for the Analogue Input in register 4 will read 1000 decimal, 03E8 hex (100.0%).

8.1.13 Communications Fault Timer (Register 21)

Parameter register 21, the Communications Fault Timer setting, determines the number of seconds that network communication must be absent before the setting for the Fault Mode will be carried out.

8.2 Modbus Network Related Configurable Parameter Registers

These parameter registers set up the MFU for network communications.

8.2.1 Modbus Address (Register 22)

The Modbus Address is the address on the network that the Modbus Module will respond to. The address can be in the range 1 to 247, though 247 is generally not used as this is the default address and may be used by any newly introduced device on the network.

With a dual channel unit both channels use the same address. Changes to the register altering the address will become effective only after the actuator power is cycled.

8.2.2 Baud Rate (Register 23)

Register 23 sets the communication baud rate. Note that the new setting for this register will not become active until the actuator power is cycled. On a dual channel unit both channels operate at the same baud rate.

8.2.3 Parity and Stop Bits (Register 24)

The parity and number of stop bits used in the communications is selected by altering the content of this register. Note that the new settings for this register will not become active until the actuator power is cycled. On a dual channel unit both channels operate using the same parity and stop bit setting.

8.2.4 Data Base Format (Register 25)

The Modbus Module can use different data base formats, the one to use is selected by the content of this register. Note that the new settings for this register will not become active until the actuator power is cycled. On a dual channel unit both channels operate using the same data base.

The Mk2 data base is as detailed in Section 7. Where the MFU is being used as a spare part to replace the earlier design it is possible to select Mk1 data base where data and performance are as the older unit. Appendix A gives the data base locations used by the Mk1 protocol.

8.2.5 Actuator Tag Name (Register 26 to 31)

The MFU may be programmed to contain a 12 character tag name string in these registers. Each byte contains one character.

8.3 Return to Defaults

The card may be restored to the default settings for the configuration parameters, protocol and address if necessary. To carry out this procedure will require the board to be fitted with a suitable shorting link on LK1 (take care to select the link on the Interface Card and not the one on the NIC) and the power to the card to be cycled. Note that the default data base format is Mk2.

- Switch the actuator off
- Access the Interface card and fit a shorting link across LK1
- With the card in the actuator, switch the power on and off
- Access the Interface card and remove the shorting link from LK1

The link LK1 must not be fitted under normal operating conditions.
This feature is not available for the ROMpak.

9 SETTING UP AND MAINTAINING THE MODBUS MODULE

In most applications the majority of the default settings in the Modbus Module will be suitable for the operation of the valve and need not be altered. However, in every case it will be necessary to alter the address since the default should never be used within a live system (the default value is 247).

9.1 Using a Network Configuration Tool

Any device capable of writing register values can be used to configure the Modbus Module. Changes to the actuator related parameter registers become active immediately they are altered. Changes to the network related parameters usually require a power cycle of the actuator. In order to establish communications to do this, the default network settings of address = 247, Baud rate = 9,600 and Parity = none should be set in the Modbus Network Configuration tool. The individual register values required may be different for each actuator and will depend on the application and process being controlled as well as the actuator size, speed and other design features. Because the ROMpak and Q actuators do not have a display, they can't be configured using the infra-red setting tool, so they should be set up over the network using a suitable configuration tool.

9.2 Setting up an IQ or IQT with the Setting Tool

The IQ / IQT and SI / EH actuators include an infra-red communication port for setting the actuator performance, limit switches and so on. This communication link can be used to set some, but not all, of the MFU parameter registers. The registers should still be checked with a Modbus host device to ensure optimum actuator and network compatibility. The diagram illustrates the access route through the actuator menu screens to reach the settings that affect the MFU. Note that the **[Od]** function must be set to **[OP]**; if it is not then the card will not be able to control the actuator. For SI and EH actuators there is another setting for **[OD]** to allow an additional direct hard-wired ESD, which is not affected by the Auxiliary Input Mask setting. This setting for **[Od]** is **[OE]**.

The parameters that may be set by using the Setting Tool and the infra-red link are listed below. The available range for the deadband setting when using the setting tool is less than the range found using the configuration tools. Parameters may only be altered if the actuator control knob is set to the Local or Local Stop position.

Register No.	Description	Range	Default Value
7	Action on Loss of Communications	Nothing (No Action), Stop, Close, Open, Position	Nothing
8	Limited Range Position Minimum	0 – 100%	0%
9	Limited Range Position Maximum	0 – 100%	100%
10	Deadband	0.0 – 9.9%	5.0%
11	Motion Inhibit Time	0 – 255 sec	3 sec
12	Aux Input Mask	0 – 255 (00 – FF hex)	15 (0F)
13	Communications Lost Position	0.0 – 100.0%	0.0%
22①	Address	0 – 247	247
23①	Baud Rate (baud)	300, 600, 1k2, 2k4, 4k8, 9k6, 19k2, 38k4	9k6
24①	Parity (1 stop bit)	Odd, Even, None	None

Note: ① - When altered, the new value will only take effect after the actuator power has been cycled.

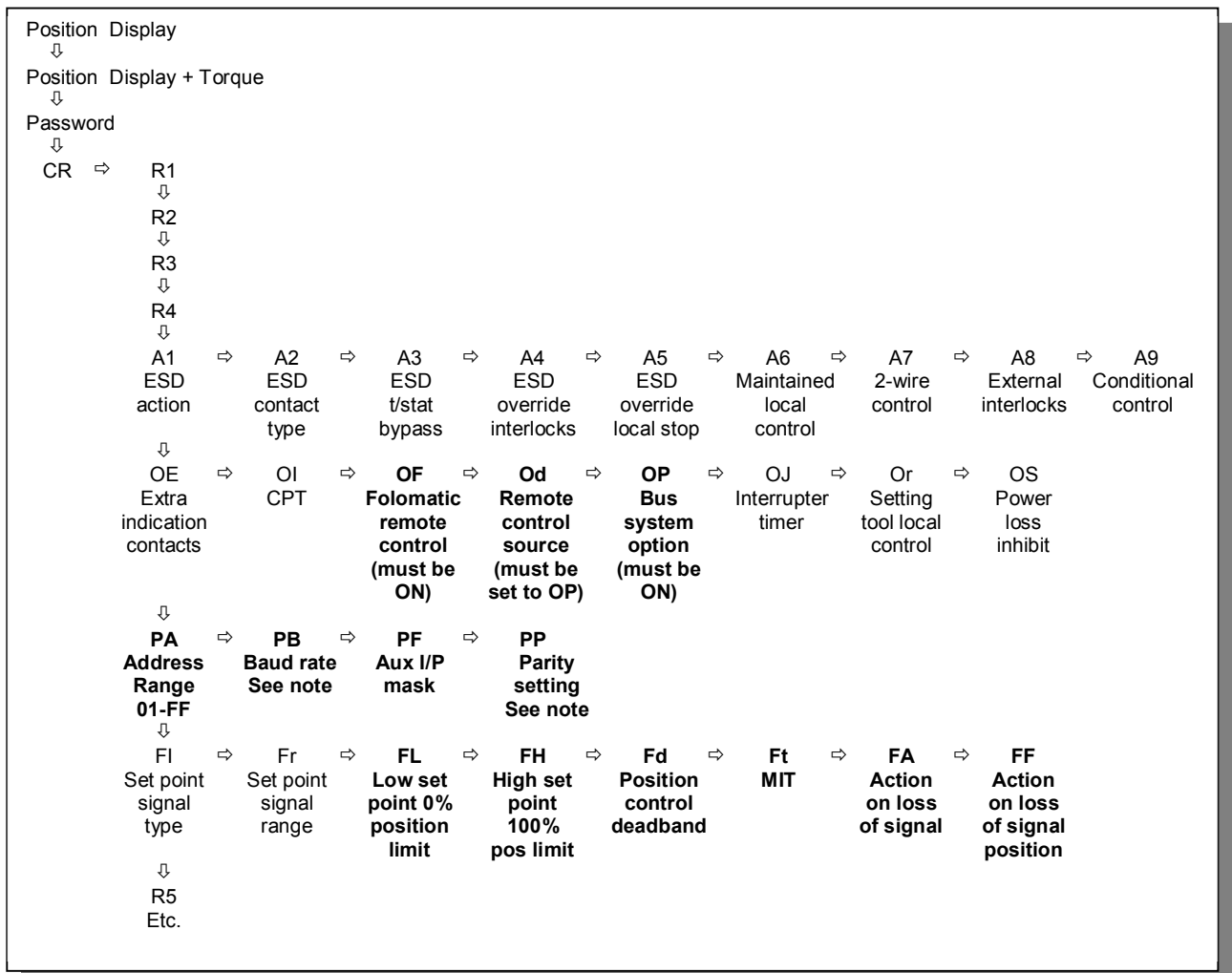


Fig 28: Setting tool menu structure and MFU settable parameters for IQ/IQT

Note: Baud rate settings:

- 01** = 110 (Mk1 protocol only)
- 03** = 300
- 06** = 600
- 12** = 1,200
- 24** = 2,400
- 48** = 4,800
- 96** = 9,600
- 19** = 19,200
- 38** = 38,400

Parity settings:

- No** = No parity
- En** = Even parity
- Od** = Odd parity
- Stop bits always = 1

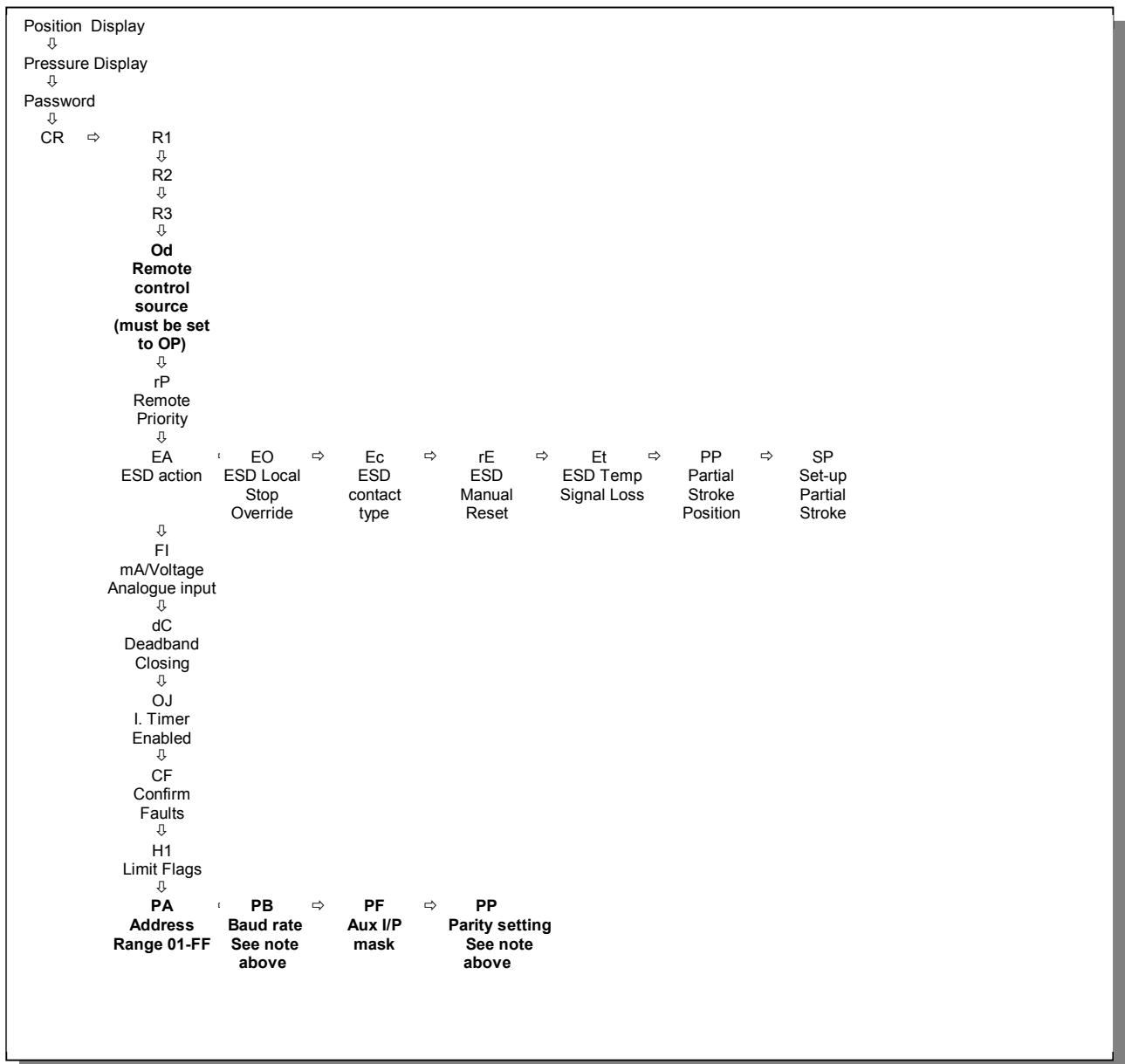


Fig 29: Setting tool menu structure and MFU settable parameters for SI/EH

10 MAINTENANCE AND REPAIR

There is no periodic service requirement for the MFU.

Repairs should not be attempted on the module. The Network Interface Card and Interface Card are a pair and should never be separated. Replacing the complete MFU assembly with a new replacement device should rectify any failure. Static sensitive devices are used in the MFU, it is therefore mandatory to observe anti-static precautions when handling or working on the unit.

10.1 Records

In order that a replacement can be easily introduced in the event of a device failure it is very important to record and keep safe all the settings made for the variable registers. The table lists all the registers that must be checked and set up for each Modbus Module on a network. The data should be recorded for each module.

Note: *Make a note of all changes to register settings to ensure that, in the case of a failure, the replacement device can be swiftly set to the correct values.*

Actuator Configurable Registers

Parameter No.	Description	Setting	Notes
7	Action on Loss of Communications		
8	Limited Range Position Minimum		
9	Limited Range Position Maximum		
10	Deadband		
11	Motion Inhibit Time		
12	Aux Input Mask		
13	Communications Lost Position		
14	Hysteresis		
15	Slow Mode Range		
16	Valve Jammed Time		
17	Manual Movement Travel		
18	Watchdog Timeout		
19	ESD DI-4 / Net Disable		
20	Analogue Input Max		
21	Communications Fault Timer		

Network Configurable Registers

Parameter No.	Description	Setting	Notes
22	Address		
23	Baud Rate (baud)		
24	Parity and Stop bits		
25	Data Base Format		
26-31	Actuator Tag Name		

11 TROUBLESHOOTING

In general, most of the problems that are seen with actuators fitted to a Modbus network are due to wiring errors and are simple to test and fix.

Often, the problem is that the network is connected to the wrong actuator terminals. The correct terminal numbers are given in the wiring diagram that comes with each new actuator. If this diagram has been lost, then a new one can be found on the Rotork web site. The wiring diagram number is usually given on the actuator name plate.

The terminal connections can be confirmed with a multimeter. With the actuator powered-down, a resistance of approximately 270,000 ohms should be measured across the correct terminals. This will also confirm that the actuator internal loom is correctly connected to a working MFU.

If the reading is open circuit, then there may be a loom problem (only to be seen in a retrofitted actuator – all actuators are factory tested before shipping), there may not be an MFU fitted, or the MFU may be damaged.

If the network is attached to the correct terminals and there are no communications, then perhaps the A and B connections are reversed. These could be swapped, again with the actuator powered down, and communications checked again with the actuator powered up.

If there are still issues with communications, then please confirm that the correct address, baud rate and parity have been set in the actuator and that they correspond with the settings in the known working DCS.

If there are still issues with communications, please contact Rotork Technical Support at the telephone numbers given on the back page of this manual.

The following information helps with the investigation:

1. Actuator Serial number from the actuator name plate.
2. Wiring Diagram number from the actuator name plate.
3. Software version. If the actuator has a display, the software versions of the fitted PCBs may be obtained by following the instructions in the actuator manual. If there is no software version given for the MFU, then it may not be fitted. If the actuator has no display and no communications, you will not be able to obtain the software version of the MFU.
4. Type of actuator.
5. Feedback from DCS.

12 APPENDIX A – MODBUS MODULE MK1 DATA BASE

12.1 Introduction

The Modbus Module Mk2 has the ability to replicate the data base used in the Mk1 design. This permits the use of the Mk2 card as a spare part to replace Mk1 cards in most applications. For exact compatibility please check the original system configuration.

When the module is used to replicate the Mk1 the main difference from the Mk2 is in the data base for collecting data and issuing commands. The electrical and physical properties remain as the same. This section describes the Mk1 data base.

12.2 Input and Output Signals

12.2.1 Control Outputs

Command	IQ actuator	IQT actuator
Modbus over the network		
Open	✓	✓
Close	✓	✓
Stop	✓	✓
Emergency Shut Down	✓	✓
Relay output DO-1 ^①	✓ ^①	✓ ^①
Relay output DO-2 ^①	✓ ^①	✓ ^①
Relay output DO-3 ^①	✓ ^①	✓ ^①
Relay output DO-4 ^①	✓ ^①	✓ ^①
Analogue Position demand (DV)	✓	✓
Local Controls		
Open	✓	✓
Close	✓	✓
Stop	✓	✓
Direct Wired Inputs		
Open	✓	✓
Close	✓	✓
Stop/Maintain	✓	✓
Emergency Shut Down	✓	✓
Open Interlock (active prevents opening)	✓	✓
Close Interlock (active prevents closing)	✓	✓

Note: ^① – Requires relay output board to be fitted

12.2.2 Digital Input Status Feedback

Status Feedback	IQ	IQT	Definition
Actuator Moving	✓	✓	Centre column moving for any reason
Close Limit	✓	✓	End of travel position, closed position achieved
Open Limit	✓	✓	End of travel position, open position achieved
Thermostat Tripped	✓	✓	Motor temperature thermostat operated
Monitor Relay	✓	✓	Local or Local stop selected or Phase loss or thermostat tripped
Local selected	✓	✓	Selector in local control position
Remote selected	✓	✓	Selector in remote control position
Battery Low	✓	✓	Battery power low
Running Closed			Actuator close contactor energised
Running Open	✓	✓	Actuator open contactor energised
Interrupter Timer	✓	✓	Interrupter Timer operating
MIT Active	✓	✓	Motion Inhibit Timer active
Open Interlock input	✓	✓	Open Interlock present
Close Interlock input	✓	✓	Close Interlock present
Position Control Enabled	✓	✓	Actuator in positioning mode
Error	✓	✓	Device Fault, use Loopback Test to determine the error.
S1 ^①	x	x	Setting for S1 on the actuator
S2 ^①	x	x	Setting for S2 on the actuator
S3 ^①	x	x	Setting for S3 on the actuator
S4 ^①	x	x	Setting for S4 on the actuator
DI -3	✓	✓	Remote input for Stop condition
DI -2	✓	✓	Remote input for Close condition
DI -1	✓	✓	Remote input for Open condition
DI -4	✓	✓	Remote input for ESD condition

Note: ^① – The ‘S’ contacts are no longer monitored by the hardware

12.2.3 Analogue Input Status Feedback

Analogue Feedback	IQ	IQT	Definition
Actuator Instantaneous Torque	✓	✓	Current torque value, Scale: 0-120% = 0-65536
Valve Position	✓	✓	Current position, Scale: 0-100% = 0-65536

12.3 Modbus Communication

The electrical properties of the MFU in Mk1 mode are the same as in Mk2 mode:

Line Electrical Specification:	RS-485, two-wire, half duplex (4 wire not supported)
Modbus Transmission Mode	RTU (8 bit Binary data)
Supported Baud Rates	300, 600, 1k2, 2k4, 4k8, 9k6, 19k2, 38k4, 57k6, 115k2 (2k4, 4k8, 9k6, 19k2, 38k4, 57k6, 115k2 when using the internal repeater option)
Number of bits per character	1 start bit, 8 data bits, Parity bit, 1 or 2 stop bits
Parity (configurable)	Odd, Even, None
Variants	Single highway plus analogue input Dual highway (one common address and baud rate) Single highway with repeater

12.4 Modbus Data Base

Message format:	RTU
Modbus Address:	1 to 247 (Dual channel version both channels must have the same address.)

12.4.1 Function Code Support

Function Code	Modbus Name	Addressing
01	Read Output Coil Status	Discrete
02	Read Input Status	Discrete
03	Read Holding Registers	Register
04	Read Input Registers	Register
05	Force Single Coil	Discrete
06	Preset Single Register	Register
07	Read Exception Status	
08	Loopback Diagnostic Test	
15	Force Multiple Coils	Discrete
16	Preset Multiple Registers	Register
17	Report Slave ID	

12.4.2 Broadcast Messages

Broadcast messages using code 05 and 06 are allowed to the following functions

- Open command
- ESD command

12.4.3 Data Locations

Note: All data locations listed start from 0, it may be necessary to add an offset to match the number required for the PLC.

Read Output Status – Function code 01

Write Output Coil – Function code 05 and 15

Location (Bit)	R/W	Data	Range
0	R/W	Stop command output coil status	0-1
1	R/W	Close command output coil status	0-1
2	R/W	Open command output coil status	0-1
3	R/W	ESD command output coil status	0-1
4	R/W	DO-1 output coil status	0-1
5	R/W	DO-2 output coil status	0-1
6	R/W	DO-3 output coil status	0-1
7	R/W	DO-4 output coil status	0-1

Read Input Status – Function code 02

Location (Bit)	R/W	Data	Range
0	RO	Actuator moving	0-1
1	RO	Closed limit	0-1
2	RO	Open limit	0-1
3	RO	Thermostat Tripped	0-1
4	RO	Monitor Relay	0-1
5	RO	Local selected	0-1
6	RO	Remote selected	0-1
7	RO	Battery Low	0-1
8	RO	Running Closed	0-1
9	RO	Running Open	0-1
10	RO	Interrupter Timer	0-1
11	RO	MIT Active	0-1
12	RO	Open Interlock input	0-1
13	RO	Close Interlock input	0-1
14	RO	Position control enabled	0-1
15	RO	Error	0-1
16	RO	S1①	0
17	RO	S2①	0
18	RO	S3①	0
19	RO	S4①	0
20	RO	DI –3	0-1
21	RO	DI –2	0-1
22	RO	DI –1	0-1
23	RO	DI –4	0-1

Note: ① – The 'S' contacts are no longer monitored by the hardware

Read Output Registers – Function code 03**Write Output Registers – Function code 06 and 16**

Location (Register)	R/W	Data	Range
0	R/W	Actuator Digital Control	0-3 0 = stop, 1 = close 2 = open 3 = ESD
1	R/W	Analogue Position Demand (DV)	0-FFFFhex (0.0 – 100.0%)
2	R/W	Deadband	0-4147 hex (0 – 25.5%)
3	R/W	Motion Inhibit Time	0-00FF hex (0 – 255 sec)
4	R/W	Minimum position	0-FFFF (0 – 100%)
5	R/W	Maximum position	0-FFFF (0 – 100%)
6	R/W	Data Base Format (power must be cycled for change to take effect)	0-1 (0 = Mk1 data 1 = Mk2 data)

Read Input Registers – Function code 04

Location (Register)	R/W	Data	Range
0	RO	Actuator Instantaneous Torque	0-FFFF hex (0 – 120%)
1	RO	Valve Position	0-FFFF hex (0.0 – 100.0%)

Read Exception Status – Function code 07 (one byte response)

Location (Bit)	R/W	Data	Range
7 (msb)	RO	S1 ^①	0
6	RO	S2 ^①	0
5	RO	S3 ^①	0
4	RO	S4 ^①	0
3	RO	DI-3 (Stop)	0-1
2	RO	DI-2 (Close)	0-1
1	RO	DI-1 (Open)	0-1
0 (lsb)	RO	DI-4 (ESD)	0-1

Note: ^① – The 'S' contacts are no longer monitored by the hardware

Loopback Test – Function code 08

Supported Diagnostic Codes

Diagnostic Code	Function
00	Return query data
01	Restart communications
02	Return diagnostic register
04	Force slave listen only
10	Clear diagnostic counts
11	Return bus message count
17	Return slave busy count

Diagnostic Register contents

Location (Bit)	Description
0	EEPROM timeout error
1	Checksum error
2	Checksum error
3	Checksum error
4	Watchdog recovery
5	Reserved
6	Reserved
7	Reserved
8	Reserved
9	Reserved
10	Reserved
11	Reserved
12	RS-485 highway ESD active
13	Auxiliary control input active
14	Positioner MIT active
15	Positioner enable flag

Bits 0 to 7 generate the “error” bit in the digital status register.

- Bit 0 indicates an EEPROM timeout has occurred.
- Bit 1 to 3 indicates that a checksum error has occurred
- Bit 4 indicates whether the module has been reset by the watchdog.
- Bit 12 indicates that an ESD has been received via the RS-485 highway.
- Bit 13 shows that an auxiliary input, (enabled for control), is active.
- Bit 14 when set the MIT is active.
- Bit 15 when set the actuator is operating in positioning mode

Report Slave ID – Function code 17

Byte	Data
0 – 25	‘00Rotork IQ Modbus Module.’
26 – 47	‘Software version: Mxxx’ (where xxx is the revision number)

Exception Reporting – Supported codes

Exception Response Code	Meaning
01	Illegal function code or incorrect message length
02	Illegal data address (Register or discrete address invalid)
03	Illegal data value
06	Busy

12.5 Configuration

The module should be placed into Mk2 mode to set up all the configurable registers. Once these are set the mode can be returned to Mk1 for use on the Mk1 network. The complete list of configurable registers is given in Section 8.

Some registers may be altered using the IQ Setting Tool – Figure 19 shows the functions that are accessible in this way.

12.6 Records

A complete set of records as indicated in Section 9 should be retained for each installed actuator.



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