Installation and user's guide
M-8003-4529-03-B

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HC20 Installation Guide

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Care of equipment

Renishaw HC20 compensation system and associated products are precision components and must therefore be treated with care.

Changes to Renishaw products

Renishaw plc reserves the right to improve, change or modify its products and documentation without incurring any obligation to make changes to Renishaw equipment previously sold or distributed.

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Safety

The Renishaw HC20 compensation system is designed for integration into the primary position feedback loop of a motion system. It is essential that the system is installed in accordance with the instructions in this installation guide and it is the responsibility of the system integrator to ensure that, in the event of a failure of any part of the Renishaw system, the motion system remains safe.

In the case of motion systems with powers or speeds capable of causing injury, it is essential that appropriate safety protection measures are included in the machine design. Further guidance on this can be found in the European Standard EN ISO 12100 “Safety of machinery - general principles for design - risk assessment and risk reduction”. It is the sole responsibility of the OEM/system integrator to select the safety measures appropriate for their application.

Electrical safety

Do not remove any part of the housing; to do so may expose a danger of high voltage electric shock. Defective products should be returned to Renishaw for service.

Safety information

The following symbol is used in this manual wherever important safety information is present.

Before proceeding with any electrical connection or operation of the laser system, refer to the General safety information in the introduction.

Warranty

Renishaw plc warrants its equipment provided that it is installed exactly as defined in associated Renishaw documentation.

FCC

Information to the user (FCC section 15.105)

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the HC20 installation guide, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Information to user (FCC section 15.21)

The user is cautioned that any changes or modifications not expressly approved by Renishaw plc or authorised representative could void the user’s authority to operate the equipment.

EC compliance

Renishaw plc declares that the HC20 compensation system complies with the applicable directives, standards and regulations.

HC20 compensation system relevant patents and patent applications

The following patents and patent applications relate to this and other products:

EP 0397289

JP 2,630,345

US 5,026,163

EP 0668483

JP 3,502,178

US 5,638,177

GB 2337339B

DE 19980326 T1

US 6,473,250 B1

JP 3,388,738

US 5,341,702

JP 2001-194184A

US 6,934,641 B2

JP 2005-37,371

WEEE

The use of this symbol on Renishaw products and/or accompanying documentation indicates that the product should not be mixed with general household waste upon disposal. It is the responsibility of the end user to dispose of this product at a designated collection point for waste electrical and electronic equipment (WEEE) to enable reuse or recycling. Correct disposal of this product will help to save valuable resources and prevent potential negative effects on the environment. For more information, please contact your local waste disposal service or Renishaw distributor.

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Section 1 - Operation overview

Contained in this section

1.1 Introduction

The Renishaw HC20 compensation system is designed as far as possible to be a drop in replacement for the original HC10. The HC20 has been used to integrate the use of multiple Renishaw single axis compensator units (RCU10) into a single system that has the same physical architecture as the HC10 and therefore requires minimal machine changes when upgrading.

Please note however the following:

- The HC20 components cannot be used as individual replacements to an existing HC10 system, the HC20 compensation rack and the HC20 PSU will only function correctly when installed together.
- When upgrading a system from a HC10 to a HC20 it is required that the sensors are also upgraded.This includes material and air temperature sensors, the pressure sensor is integrated into the HC20 compensation rack as standard.
- Some previously supported output status lines are no longer supported in the implementation of HC20. This may require changes to the integration with the machine tool NC.
- HC20 cable connectivity may not be compatible with some early HC10s (see the warning in Section 1.6).

1.2 Additional Documents

Before starting an installation of a HC20 compensation system the following additional documents should be reviewed, these are supplied on the Laser scale technical documentation CD (A-9904-2407).

M-8003-3192 - HS20 installation guide - This manual covers the installation of the HS20 laser head along with the integration into the machine tool.

M-9904-1122 - RCU10 quadrature compensation unit - This manual covers the use of RCU10 units which are used within the HC20 compensation rack. It also covers the use of RCU-CS, the software used in the setup and monitoring of the HC20 system.

1.3 General safety information

The Renishaw HC20 compensation system is designed for integration into the primary position feedback loop of a motion system. It is essential that the system is installed in accordance with the instructions in the installation manuals and it is the responsibility of the system integrator to ensure that, in the event of a failure of any part of the Renishaw laser or compensation system, the motion system remains safe.

In motion systems with powers or speeds capable of causing injury, safety protection measures must be included in the design. It is recommended that satisfactory operation of these protection measures is verified **before** the feedback loop is closed. The following are examples of safety protection measures that can be used. It is the sole responsibility of the system integrator to select appropriate measures for their application.

1. The HS20 quadrature will go into a tri-state condition (open circuit) under a fault condition. The HC20 must be configured to tri-state on error as this is the primary safety mechanism. The machine controller must detect the tri-stated condition and stop the axis moving.

   Four status lines are provided from each HS20 which should be connected directly to the HC20. These include /UNSTABLE, /BEAM BLOCK, /BEAM LOW and /OVERSPEED.

   Three OUTPUT status lines are provided as follows for each axis on the HC20. These signals should be connected and monitored by the machine controller.

   - **/ERROR** – Errors which may affect the integrity of the feedback system. The axis must be stopped and disabled immediately. Errors can be cleared by removing the source of the fault and then asserting the /Reset line to allow normal operation to be restarted. After a single error event is detected, the error condition is latched until the Reset signal is asserted, and the condition that caused the error has disappeared.

- **/SUSPEND** – Medium-level errors which may affect the accuracy or operation of the machine. Processes/part machining should not be allowed until this error has cleared. Suspend conditions indicate states where the compensator has not fully completed the compensation adjustment, such as waiting to reference the axis, injecting pulses after a compensation process or a compensation failure. Error clear or system reset is not required to deactivate the /Suspend line.
- **/WARNING** – A Warning condition indicates any other error condition that requires attention, but will not compromise the safety or the accuracy of the feedback signals. The warning condition is not persistent and will disappear when the reason for causing it is cleared. Error clear or system reset is not required to deactivate the /Warning line.

2. The axis must include physical limit switches which, when tripped, will stop axis motion before damage occurs (soft limits alone are insufficient). Note that in the case of thermally compensated systems, positional corrections of several hundred ppm are possible. This should be taken into account when defining the relative positions of soft and hard axis limits.
3. Cable breakage detection (encoder disconnect). The position feedback and error signal lines are all provided as differential line driven pairs. Failure in the cable or of the line drivers can be detected by checking these differential pairs are always being driven in opposing states. If the lines are not in opposing states, the motion **must be** stopped.
4. Motor torque monitoring. If the motor torque exceeds an expected limit, the axis of motion **must be** stopped.
5. The machine must include an emergency stop button.
6. Following error detection. If the difference between the controller demand position and the axis feedback position exceeds an expected limit, the axis motion must be stopped.
7. Guards, viewing windows, covers and interlocks may be used to prevent user access to hazardous areas, and to contain ejected parts or materials.
8. If the machine includes an independent tacho (velocity) feedback system, this should be cross-checked with the position feedback. For example, if the tacho indicates the axis is moving, but the position feedback doesn't the axis motion must be stopped.
9. In the case of synchronised parallel motion systems (for example twin rail gantry drive systems), the relative positions of master and slaves axes should be monitored. If the difference in their positions exceeds an expected limit, axis motion must be stopped.

Important note: In the case of measures 6 to 9, the limit needs to be selected carefully depending on the application and the type of position compensation selected to avoid false alarms.

For further advice, consult the appropriate machine safety standards.

Secondary fault protection measures

It is the responsibility of the system integrator to ensure that in the event of a failure of any part of the Renishaw laser or compensation system that the motion system remains safe. In the case of motion systems with powers or speeds capable of causing injury, secondary protection measures must be included in the design. Refer to the General Safety information in the introduction for details of suitable secondary safety measures. It is recommended that such secondary measures be tested during system integration by deliberately introducing single faults into the system. (Obviously such tests need to be carried out carefully to ensure injury cannot occur if such secondary systems fail to operate).

Battery disposal symbol and statement

Note: The HC20 uses RCU10 which contains a lithium battery. Please contact Renishaw for details of battery replacement. Typical battery replacement life is ten years. At the end of life, the RCU10 must be disposed of in accordance with local regulations.

The use of this symbol on batteries, packaging or accompanying documents indicates that used batteries should not be mixed with general household waste. Please dispose of the used batteries at a designated collection point. This will prevent potential negative effects on the environment and human health which could otherwise arise from inaproppriate waste handling. Please contact your local authority or waste disposal service concerning the separate collection and disposal of batteries. All lithium and rechargeable batteries must be fully discharged or protected from short circuiting prior to disposal.

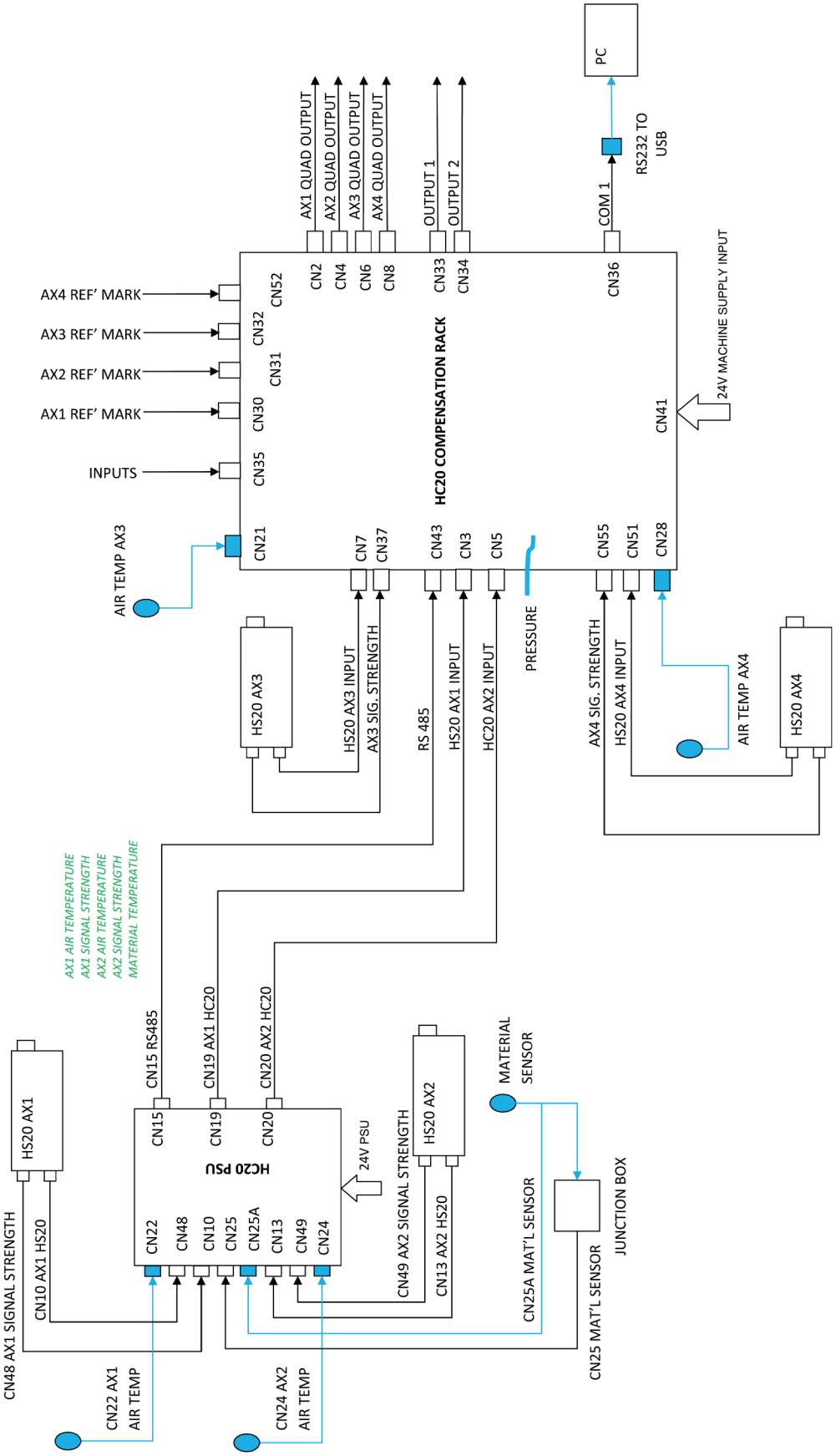
1.4 System Overview

The HC20 system is available in a number of different axis options for which the details are available below:

- HC20 2-axis compensation system (A-8003-4565)
- HC20 3-axis compensation system (A-8003-4530)
- HC20 4-axis compensation system (A-8003-4540)

These systems consist of the following parts:

	HC20 2-axis compensation system (A-8003-4565)	HC20 3-axis compensation system (A-8003-4530)	HC20 4-axis compensation system (A-8003-4540)
HC20 2-axis compensation rack	1 off	-	-
HC20 3-axis compensation rack	-	1 off	-
HC20 4-axis compensation rack	-	-	1 off
HC20 PSU	1 off	1 off	1 off
RCU-CS Software	1 off	1 off	1 off
Material temperature sensors	1 off	1 off	1 off
Air temperature sensors	2 off	3 off	4 off
Sensor cables	3 off	4 off	5 off
Sensor connector kit	3 off	4 off	5 off
Serial USB adaptor kit	1 off	1 off	1 off
Cable RS232 serial	1 off	1 off	1 off



4-Axis HC20 compensation system layout

(only items shown in blue require new cables)

1.5 HC20 input and output logic levels

Within the HC20 system some of the logic levels of the RCU units are inverted to ensure the HC20 inputs and outputs match those of the HC10 system.

Output logic levels

Status Lines	Logic levels	Source/sink	Pullups
Error	24 V, active low	20 mA	1.1 kΩ
Suspend	24 V, active low	20 mA	1.1 kΩ
Warning	24 V, active low	20 mA	1.1 kΩ

Input logic levels

Inputs	Logic levels	Threshold
Seek reference	24 V active high	7.5 V
Work-piece comp enable	24 V active high	7.5 V
Work piece comp temp freeze	24 V active high	7.5 V
Reset	24 V active low	7.5 V
Reference mark switch	5 V normally open	2.0 V

1.6 HC20 System Components

HC20 compensation rack

Part No: A-8003-4566 *(2-Axis)*, A-8003-4535 *(3-Axis)*, A-8003-4545 *(4-Axis)*

The HC20 will contain a corresponding number of RCUs to the axes of compensation available. The type of RCU10 compensation unit used for each axis is shown below:

Axis 1	RCU10-PX-XX - RCU10 compensation unit with pressure sensor
Axis 2	RCU10-XX-XX - RCU10 compensation unit
Axis 3	RCU10-XX-XX - RCU10 compensation unit
Axis 4	RCU10-XX-XX - RCU10 compensation unit

The envelope and mounting positions of the HC20 compensation rack have been designed to match the HC10 compensation rack. The HC20 compensation rack contains the main communication links between the machine controller and the laser encoder system. It also links the third and fourth axis into the complete system.

Warning: On some earlier HC10 models, D-type connectors were used for all connectors on the rear HC10 panel instead of the circular M23 connector style. These units are not directly compatible with the current version of the HC20 system and further modification will be required. If you have a system that uses only D-type connectors to interface to the HC10, it is recommended that you contact your local Renishaw subsidiary before commencing the upgrade.

HC20 PSU Unit

Part No: A-8003-4570

The HC20 PSU is the same for each of the available HC20 systems. The HC20 PSU acts as the communication from axis 1 and 2 laser heads, air temperature sensors and material temperature sensor. This is then linked to the main HC20 compensation unit via the original cables used by the HC10 system.

RCU10 Configuration Software

Part No: RCU10-CS-XX

The HC20 compensation system uses the same software as the RCU10. This software is used for configuring the HC20 on initial setup. It can also be used to monitor the signal strength and laser status while the machine is running if required.

Sensor Cable Assembly (5m)

Part No: RCU10-TC-X5

The sensor cable is required to connect the new style air and material sensors to the HC20 PSU and compensation unit.

Air Temperature Sensor

Part No: RCU10-AT-XX

The air sensor is used in applications that require refractive index compensation. The sensor contains a calibrated thermistor to monitor ambient air temperature in the range of 0˚C to 40˚C. The temperature reading is converted is converted into a digital signal inside the sensor, which reduces susceptibility to noise when the reading is transmitted to the RCU10.

Material Temperature Sensor

Part No: RCU10-MT-XX

The material temperature sensor is used in applications that require scale, work-piece or machine structure compensation. The sensor contains a calibrated thermistor to monitor material surface temperature in the range of 0˚C to 55˚C. The temperature reading is converted into a digital signal inside the sensor, which reduces susceptibility to noise when the reading is transmitted to the RCU10.

Section 2 - Differences between HC20 and HC10

2.1 Pre installation requirements

- Power requirements

2.2 Hardware changes from the HC10 system

- HC20 compensation unit (overview)
- HC20 power supply unit (overview)

2.3 HC20 and HC10 system control I/O comparison

- HC20 status lines (outputs)
- Previous HC10 machine controller input (status lines)
- HC20 machine controller inputs (status lines)
- HC20 machine controller outputs (control lines)
- HC20 status/control lines during normal operation

2.4 HC20 and HC10 operation on power up

- HC10 operation on system power up
- HC20 operation on system power up

2.5 Compensation activation

- Machine home operation and compensation activation
- Workpiece compensation selection (M-codes)

2.1 Pre installation requirements

The installation process for the different HC20 variants (2-axis, 3-axis and 4-axis) are similar, the only difference is the number of lasers and sensors that will require connecting.

Power requirements

The HC20 requires a 24v power supply conforming to the following specification:

HC20 compensation rack

24 V DC +/- 1V @ 3.5A 24 V DC +/- 1V @ 2.5A	Warm-up (~10 mins) Operation at room temperature (20 ˚C)

HC20 power supply unit

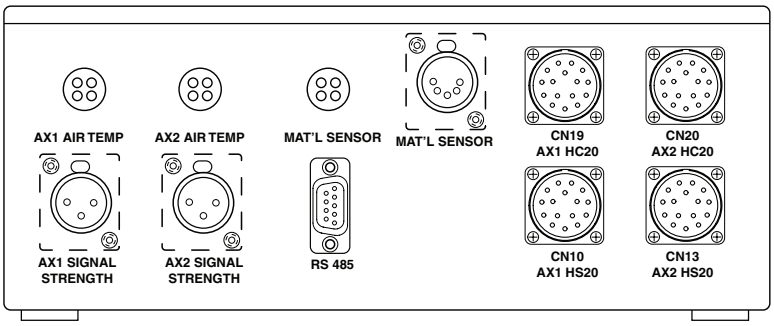
24 V DC +/- 1V @ 2.5A 24 V DC +/- 1V @ 1.5A	Warm-up (~10 mins) Operation at room temperature (20 ˚C)

The 24 V power supply used for both the HC20 compensation rack and HC20 power supply unit should be a single fault tolerant supply certified to EN (IEC) 60950-1.

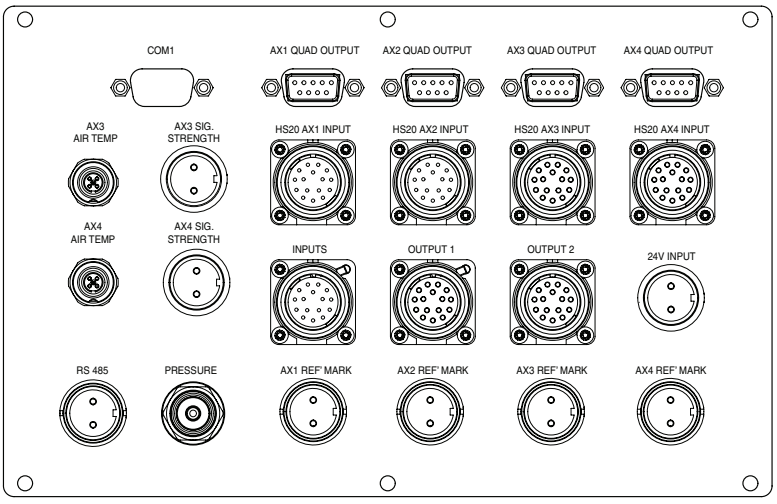
A suitable in-line power supply for the HC20 power supply unit (PSU) is provided as part of the system.

2.2 Hardware changes from the HC10 system

This section covers the differences between the HC10 and the HC20.



HC20 PSU (front face)



HC20 compensation unit (Rear panel)

HC20 compensation unit (overview)

Part changes	Details of changes
Axis 3 & 4 air temperature sensor connectors	These have been changed for the binder style connector that is compatible with the new style air sensor. It is required that the original air sensors are replaced with the new style air sensors.
Humidity sensor	The humidity sensor has been removed. The HC20 system now requires the humidity level to be set through the RCU-CS software.
Pressure sensor	The RCU10 on axis 1 contains a pressure sensor with a tube connected to the rear panel of the HC20 compensation rack. Therefore it is necessary for the push-lock connector to be kept clear, to achieve this it may be required that a 4mm air tube is connected and run to a suitable position where a valid pressure reading can be achieved.
HC20 fuse	The 24v fuse has been removed from the front panel. This is due to the HC20 design containing a thermal fuse which is self resetting.
Communication with the HC20	The previous system was essentially a PC. Therefore when interfacing to the original HC10 system to make changes to the configuration, this was done by connecting a monitor and keyboard. Because the HC20 system uses RCUs, they will need to be configured through a laptop computer with RCU-CS installed.

HC20 power supply unit (overview)

Part changes	Details of changes
Axis 1 & 2 air temperature sensor connectors	These have been changed for the binder style connector that is compatible with the new style air sensor. It is required that the original air sensors are replaced with the new style air sensors.
Material temperature sensor connectors	There are two material sensor connectors available. One is a binder connector compatible with the new style temperature sensors and cabling. The other is a XLR connector the same as the HC10, so that existing cabling can be used. The existing HC10 material temperature sensor is not compatible with HC20, therefore the sensor end of the existing cable will require rewiring into a binder connector to accept the new material sensor. Both connectors should not be used simultaneously.

2.3 HC20 and HC10 system control I/O comparison

The laser scale requires a number of input and output control lines from the machine controller I/O modules. These are required as follows:

HC20 status lines (outputs)

The outputs from the HC20 do differ from the HC10, this is due to the HC20 using RCU10 compensators inside and the functionality of these compensators. The error and warning lines have been maintained and are wired into the same pins to maintain safety functionality. However the HC10 also had dedicated lines for diagnostics whereas the HC20 does not have the same functionality - the differences are outlined below for Output 1 connection of the HC10/HC20, Output 2 connection mirrors this but for AX3 and AX4.

Pin	HC20 function	HC10 function	Comments
1	Not in use	/AX1 UNSTABLE	Due to no dedicated outputs from the RCU10 for these errors these lines no longer exist on HC20
2	Not in use	/AX1 BEAM BLOCK	
3	Not in use	/AX1 OVERSPEED	
4*	/AX1 SUSPEND	/AX1 BEAM LOW	Functionality changed
5	/AX1 WARNING	/AX1 WARNING	Functionality identical
6	/AX1 ERROR	/AX1 ERROR	Functionality identical
7	Not in use	/AX2 UNSTABLE	Due to no dedicated outputs from the RCU10 for these errors these lines no longer exist on HC20
8	Not in use	/AX2 BEAMBLOCK	
9	Not in use	/AX2 OVERSPEED	
10*	/AX2 SUPEND	/AX2 BEAM LOW	Functionality changed
11	/AX2 WARNING	/AX2 WARNING	Functionality identical
12	/AX2 ERROR	/AX2 ERROR	Functionality identical
13	Not in use	Not in use	-
14	Not in use	Not in use	-
15	Not in use	Not in use	-
16	Not in use	Not in use	-

* The pin previously used for /BEAM LOW now indicates /SUSPEND. Please refer to the RCU10 manual for details of what causes /SUSPEND to be active. A beam low situation will, as before trigger the warning line to become active but now has no additional dedicated output.

For a full description of what causes the warning, error or suspend lines to become active please refer to the RCU10 manual, please note however that the logic of the RCU10 may be the reverse of the HC20 as some signals are inverted to maintain backwards compatibility with HC10.

Previous HC10 machine controller inputs (status lines)

The HS10 Laser head and the HC10 compensation rack, in conjunction with the system software provide a set of outputs lines, which switch between 0V (low level) and 24V (high level).

All signals are active low.

Output line asserted	Causes	Action by control
/UNSTABLE	Indicates that the HS10 laser head is unstable (or in warm-up). When the HS10 laser head becomes stable, this error will clear automatically.	Whilst /UNSTABLE is asserted low the machine motion must be disabled.
/BEAM_BLOCKED	Indicates that the return signal strength has fallen below 5% of full signal strength.	Whilst /BEAM_BLOCKED is asserted low the machine motion must be disabled.
/BEAM_LOW	Indicates that the return signal strength has fallen below 15% of full signal strength.	Machining can continue, however the source of the alarm should be investigated and maintenance performed.
/OVERSPEED	Indicates that invalid quadrature transitions have been detected.	Whilst /OVERSPEED is asserted low the machine motion must be disabled.
/WARNING	HC10 Compensation Rack generated active low status line. Full details of causes of WARNING being asserted are given in the HS10 manual, Appendix D.	Machining can continue
/ERROR	HC10 Compensation Rack generated active low status line. Full details of causes of ERROR being asserted are given in the HS10 manual, Appendix D	If /UNSTABLE & ERROR are both asserted, machine motion must be disabled. If ERROR is asserted on its own then parts must not be cut, however, the machine should be configured to move via the ‘JOG’ function or within a homing sequence.
FATAL ERROR	A fatal error is generated when both WARNING and ERROR are asserted simultaneously. Full details of causes of a fatal error being asserted are given in the HS10 manual, Appendix D	Whilst a FATAL ERROR It is asserted the machine motion must be disabled.

HC10 system status lines (machine I/O inputs)

HC20 machine controller inputs (status lines)

Three levels of error are available to the machine control as follows:

Warning Low-level errors which do not affect system accuracy but indicate that maintenance is required.

Suspend Medium-level errors which may affect the accuracy or operation of the machine. Processes/part machining should not be allowed until this error has cleared.

Error Errors which may affect the integrity of the feedback system. The axis must be stopped and disabled immediately.

The resulting machine handling of these extended error functions should be as follows:

Output line asserted	Causes	Action by control
WARNING	• HS20 laser signal strength has reached Beam low level. • Unassigned or unallocated sensor detected. • Other minor RCU10 condition.	• Display a message. • Schedule maintenance.
SUSPEND	• Sensor rate of change exceeded. • Sensor reading out of range. • Following error (Accuracy) detected. • Axis not yet referenced (homed). • Sensor failure. • Compensation failure. • Parameter table select failure. • Compensation buffering enabled. • Currently injecting to re-establish position.	• Stop the machining operation (part program). • Display a message. • Jog movements may be allowed. • Sensor reading unfrozen
ERROR	• Internal RCU10 error. • Input/output counter errors. • Laser encoder in preheat. • RCU10 in configuration mode. • Error from external input. • System configuration invalid or corrupt. • Axis communication link failure. • Following error (Safety) detected. • Excessive compensation detected	• Stop axis motion immediately and disable drive.

HC20 system status lines (machine I/O inputs)

NOTE

When either an /UNSTABLE, /BEAM_BLOCKED or /OVERSPEED condition is present on the laser, the Aquad and Bquad feedback signals are disabled and the lines configured into a high impedance state (Tri-state). Under this condition the machine receives no position feedback and the machine motion must be immediately disabled.

HC20 machine controller outputs (control lines)

The Laser Scale system also requires four control lines (per axis) from the machine controller output modules. These lines need to switch between 0 and 24 V DC. The purpose of these lines is to provide control signals to the Laser Scale system, to change modes and initialise the system. Most of the operations are achieved by using combinations of these lines together via a 'handshaking' type operation between the machine controller and the HC20 compensation unit:

The function of these lines is to:

- Define the wavelength compensation reference position (machine home).
- Define the workpiece offset reference point for workpiece expansion compensation.
- Deactivation or suspension of workpiece expansion compensation.
- Reset the HS20 lasers in the event of an error.

System control lines

HC20 terms	RCU-CS terms	HC10 terms
Seek reference	Seek ref (SR)	Seek_ref
Workpiece comp enable (see note 2)	Workpiece request comp. (WR)	Workpiece_ref
Workpiece comp temp freeze (see note 1)	Sensor update freeze (SF)	Disable_matcomp
/Reset	Error clear (ER)	/Machine_reset

Fatal error: This occurs within the HC10 when 'Warning' and 'Error' are triggered together. This functionality does not exist within the HC20. This is represented by '/Error' within the HC20.

Note 1

Descriptions of the two modes are described below:

- /Workpiece _compensation_temperature_freeze (RCU10/HC20) - *freezes the value of the work piece temperature at the current value when requested.*
- Disable_material_comp (HC10) - *Allows the controller to select work piece compensation update on request mode.*

The differences between the two modes are described below:

Disable_matcomp within the HC10 was to hold a work piece temperature value whilst this mode is active. This is completed with the aim of ensuring that whilst the machining operation is underway, any change in the material sensor reading does not affect the accuracy of the operation. This mode is replicated by using /Workpiece_compensation_tempeature_freeze, within the RCU10/HC20.

Note 2

The HC10 (workpiece_ref) mode enabled multiple material temperature sensors to be used and compensation enabled for different points along the axis. This function is not supported in the HC20 system.

‘/Workpiece_compensation_enable’ (RCU10/HC20) defines the point at which the work piece compensation is enabled. There are two possible ways in which this feature is enabled.

- Controller signals: Workpiece thermal compensation is activated by a signal through the J7 Auxiliary I/O connector from the machine control using a configured ‘M’ code.
- Axis reference: Workpiece thermal compensation is activated automatically at the machine reference when the RCU10 references, so work piece themal compensation is effectively on permanently.

The mode by which ‘/Workpiece_compensation_enable’ is enabled is set through RCU-CS by selecting ‘System configuration’/’Parameters’/’Workpiece thermal compensation’/’Actuation method’.

The table below details these control lines.

Signal Name	Function
SEEK_REF	Used during wavelength compensation reference (machine axis home) sequence, workpiece offset reference position determination and deactivation of workpiece compensation. (Active HIGH)
WORKPIECE_REF	Used during wavelength compensation reference (machine axis home) sequence, workpiece offset reference position determination and deactivation of workpiece compensation. (Active HIGH)
DISABLE_MATCOM	Allows the controller to select workpiece compensation update on request mode. (Active HIGH)
MACHINE_RESET	Reset line via which the machine control can directly reset HS20 laser heads. Normally this line must be held high (24V). (Active LOW)

System control lines (Machine I/O outputs)

HC20 status / control line levels during normal operation

Under normal machine operation the system status lines will be in the following states:

/ERROR	Inactive (High)
/WARNING	Inactive (High)
/SUSPEND	Inactive (High)

Controller output lines should be set to be normally in the following states:

SEEK_REF	Inactive (Low)
WORKPIECE_REF	Inactive (Low)
DISABLE_MATCOMP	Inactive (Low)
MACHINE_RESET	Inactive (High)

2.4 HC20 and HC10 operation on power up

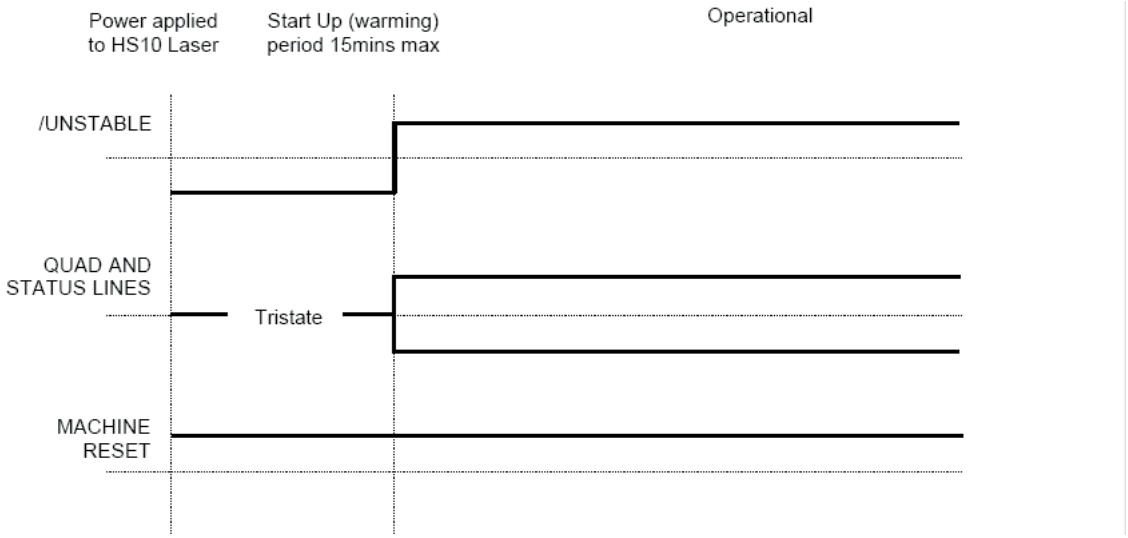
HC10 operation on system on power-up

Following an initial power up, the HS20 laser heads take a period of between 10 and 15 minutes to stabilise. This unstable period is communicated to the controller via each of the laser head /UNSTABLE (active low) lines. For a standard installation with three HS20 heads, three separate /UNSTABLE lines must be routed via the HC10 Compensation Rack to the controller.

For this reason it is advisable that the HS20 lasers be powered from a supply that remains on even when the machine controller is powered-down. This will avoid a 15 min delay each time that the machine control is powered-up.

The diagram below depicts this /UNSTABLE period in Start-up.

Note that the MACHINE RESET controller output line MUST be held high (24V) during this time. Ideally each HS20 Laser Head will have its own independent machine generated reset line which is connected to the HS20 Laser head via the HC10 Compensation Rack.



HS20 power up conditions

Once the HS20 Laser Heads become stable, indicated by the /UNSTABLE line being at 24V, the quadrature lines and HS20 status lines have the tri-state (high impedance) state removed and are activated.

If the HS20 Lasers are subsequently powered whilst still warm then the start-up time will be considerably less (typically 2 mins).

NOTE: If the MACHINE_RESET line is not held in a high (24v) state during the laser warm-up period, then the lasers can be prevented from starting correctly. This can be caused when the machine control is not powered before the lasers. To correct this situation, it will be necessary to remove power from the lasers for a short period of time, ensuring that the MACHINE_RESET line is high (24v).

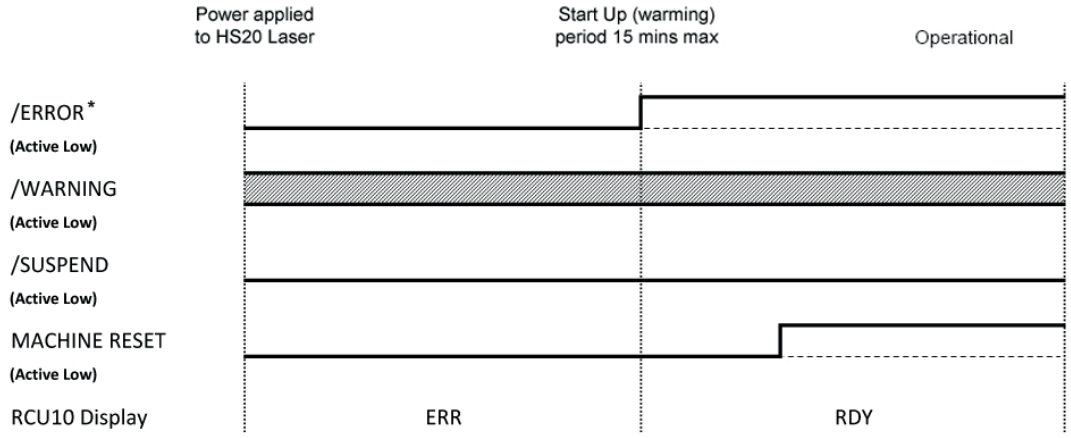
HS20 operation on system power-up

Following an initial power up, the HS20 Laser Heads take a period of between 10 and 15 minutes to stabilise.

For this reason it is advisable that the HS20 Lasers be powered from a supply that remains on even when the machine controller is powered-down. This will avoid a 15 min delay each time that the machine control is powered-up.

The diagram below depicts this /ERROR period in Start-up.

Note that the MACHINE RESET controller output line SHOULD be held low (0V) during this time. Ideally each HS20 Laser Head will have its own independent machine generated reset line which is connected to the HS20 Laser head via the HC20 Compensation Rack.



HS20 power up conditions

Operation of system on power-up

Step 1	The controller sets the Reset output line low (Active)
Step 2	The controller monitors for /ERROR input line to be high (24v) [delay 100ms]
Step 3	The controller sets Reset output line high (Not Active)

Once the HS20 laser heads become stable, indicated by the /ERROR line being at 24V, the quadrature lines and HS20 status lines have the tri-state (high impedance) state removed and are activated.

* /ERROR - The /ERROR line should clear after a maximum of 15 minutes once the /UNSTABLE error from the HS20 has cleared and no other error exists.

2.5 Compensation activation

To enable the HC20 laser scale system to be fully integrated into the machine control requires the development of machine control logic. This software must perform the following functions:

- Handling of the HC20 wavelength compensation reference position routine within the machines standard home cycle.
- Enabling, deactivating and selecting workpiece compensation, by using I/O line provided. These operations are normally configured as ‘M’ codes.

The requirement for handshaking between the HC20 Compensation Rack and the machine controller exists primarily for two reasons:

Firstly, since these control lines are used to initialise, or fundamentally effect the operation of the compensator, it is very important that control signals are not issued at the wrong time. This is avoided by providing a sequence of actions that must occur before a command is recognised.

For example, the reference mark switch may be activated during routine machining. Without the use of additional conditioning this would cause the machine to reset it’s home position each time that the reference switch is passed over. Handshaking in this case is provided to ensure that referencing is a controlled operation that cannot randomly occur.

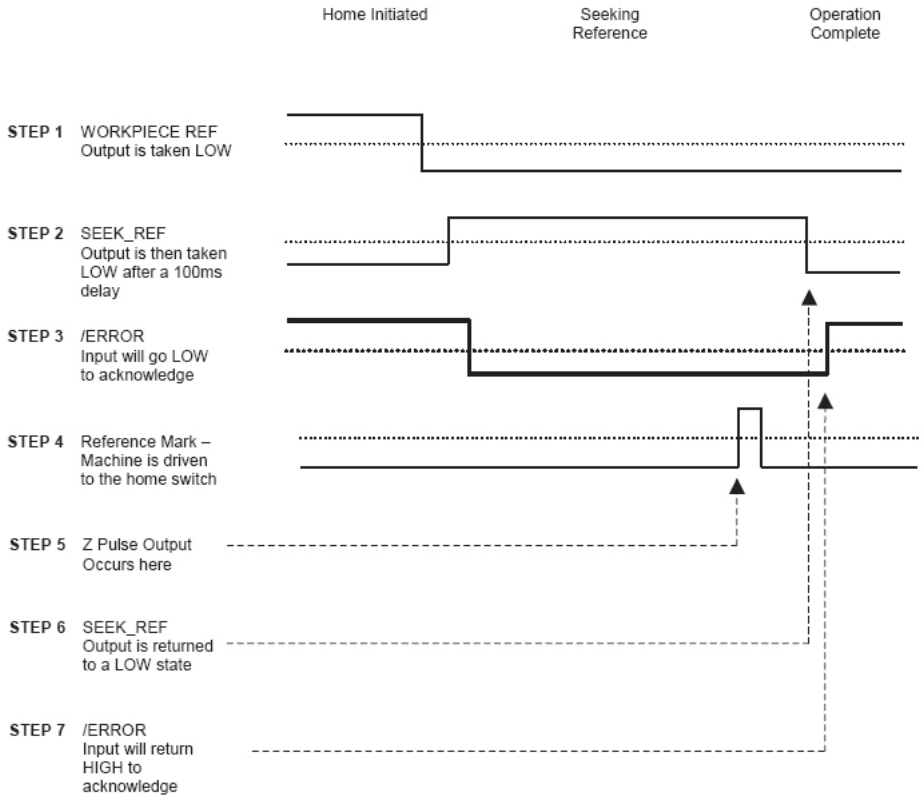
Secondly, there are two different reference positions which need to be established; one for wavelength compensation (machine home) and one for workpiece offset (workpiece compensation reference position). The use of the handshaking sequence allows either of these points to be defined, whilst using the minimum number of machine output lines per axis.

Machine home operation and compensation activation

In addition to the requirements for the machine controller to be given a reference (or Z) pulse, the Laser Scale must also know which point is to be defined as the origin for wavelength compensation. These two requirements are satisfied in operation. The method by which this is achieved is as a handshaking operation between machine controller and HC20 Compensator.

The following diagram shows the required handshaking routine once the machine home operation has been initiated. The machine control must be programmed to give the appropriate outputs and monitor the responses.

HC10 homing operation

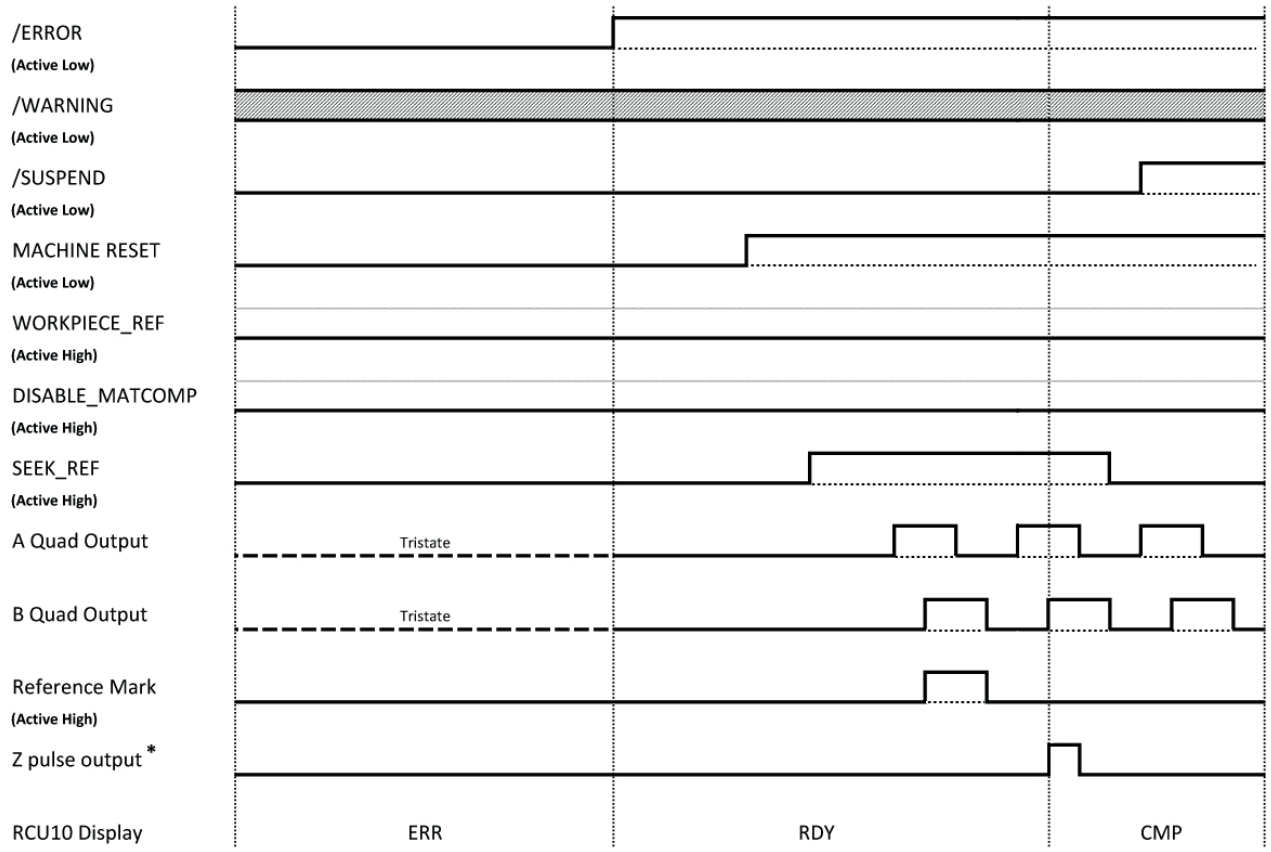


HC10 machine axis home sequence

Step 1	The controller must set the WORKPIECE_REF output line low. [delay 100ms]
Step 2	The controller sets the SEEK_REF output line high. [delay 100ms]
Step 3	The /ERROR input will go low at this point to acknowledge that a home sequence is in progress. This can be checked by the control program. **Note:** If this is the first homing sequence from initial power up, the ERROR line will be set low from start-up, before the controller sets WORKPIECE_REF low and SEEK_REF high.
Steps 4 & 5	The machine is then driven to the reference switch, and when it is reached the compensator will issue a reference mark pulse (Z pulse) on the quadrature lines.
Step 6	Once the machine control has received the Z pulse, the SEEK_REF output line can be returned to a low state. [delay 100ms]
Step 7	This will then be acknowledged by the /ERROR Input line returning to a high state. This signifies that this axis has been homed successfully.

Note: The delays are included to ensure that the system has time to respond to input lines being changed. This value is not critical, 100ms is an arbitrary value.

HC20 homing operation



HC20 machine home operation

Step 1	The controller monitors for /ERROR input line to be high.
Step 2	The controller must set the WORKPIECE_REF output line low. [delay 100ms]
Step 3	The controller must set the DISABLE_MATCOMP output line low. [delay 100ms]
Step 4	The controller sets the SEEK_REF output line high.
Step 5	The machine is then driven to the reference switch , and when it is reached the compensator will issue a reference mark pulse (Z pulse) on the quadrature lines.
Step 6	Once the machine control has received the Z pulse, the SEEK_REF output line can be returned to a low state. [delay 100ms]
Step 7	This will be acknowledged by the /SUSPEND Input line returning to a high state. This signifies that this axis has been homed successfully.

Note: The delays are included to ensure that the system has time to respond to input lines being changed. This value is not critical, 100ms is an arbitrary value.

*** Digital Quadrature Output:** The Z pulse output is produced when A is high and B is high. The re-synchronisation process ensures a reference output will occur at 5 ±1 output quadrature counts later than the reference input.

***Analogue Quadrature Output:** The output is produced between –45° and +135° and is valid when the amplitude of sine and cosine are equal. The re-synchronisation process ensures a reference output starts nominally 256 output counts later than the reference input and is valid at 320 ±1.

Workpiece compensation selection (M-codes)

During machining operations, it will be necessary for the machine controller to enable and disable the workpiece thermal compensation function. This is achieved on the HC20 compensator by using two of the control lines (/WORKPIECE COMPENSATION REQUEST and /SEEK WORKPIECE REFERENCE) in a defined sequence. This sequence needs to be programmed into the machine as an M-code operation.

Two M-codes are required to enable and disable the function, and these are traditionally programmed as M91 & M92:

M91 Activate / Define the workpiece offset (enable workpiece compensation).

M90 Deactivate workpiece compensation.

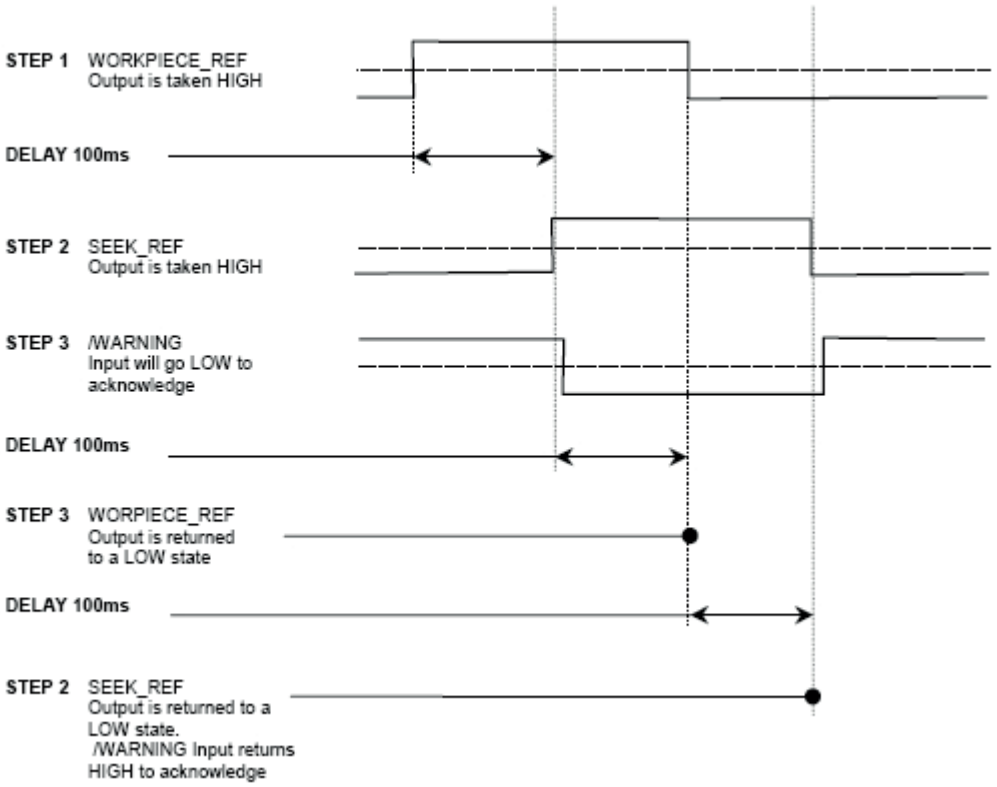
Additionally, a third control line (DISABLE_MATCOM) is used to ‘freeze’ the reading update of the material temperature sensor. This function can also be implemented as machine M-codes:

M92 Freeze the workpiece temperature sensor reading.

M93 Un-freeze workpiece temperature sensor reading.

HC10 M91 Define WORKPIECE_REFERENCE position.

The workpiece offset (workpiece compensation reference point) is described below as a handshaking operation between machine controller and compensator, signal activity for the operation is shown below:



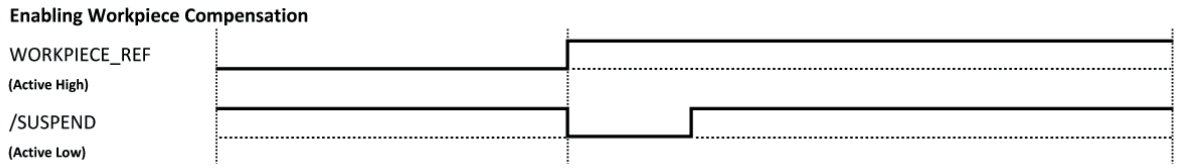
HC10 workpiece reference origin / enable sequence

Once workpiece compensation is enabled all moves relative the workpiece reference position are appropriately compensated for the effects of thermal expansion/contraction. In some applications it is possible to fixture multiple parts on the machine table. In such cases workpiece compensation is enabled at a location (workpiece reference) around which the part is predicted to expand and the part is then machined as normal.

HC20 enabling workpiece compensation

The workpiece compensation function is enabled when the Workpiece compensation enable line is held in a high state. The M91 code should be programmed to set the output line high (on).

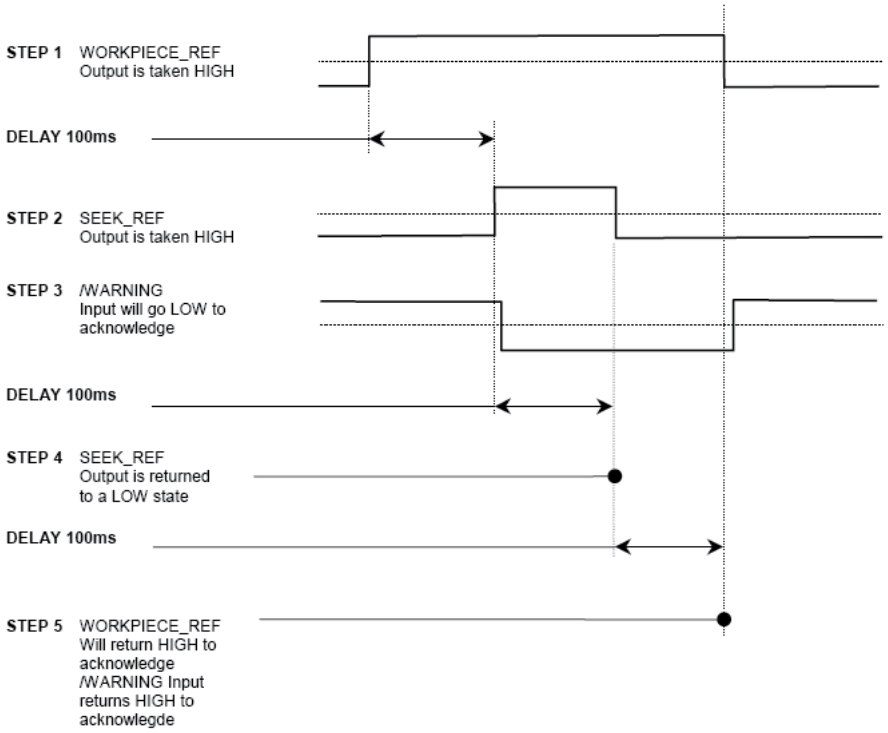
Once workpiece compensation is enabled, all moves relative to the workpiece reference position are appropriately compensated for the effects of thermal expansion or contraction. In some applications it is possible to fixture multiple parts on the machine table. In such cases workpiece compensation is enabled at a location (workpiece reference) around which the part is predicted to expand and the part is then machined as normal.



Step 1	The controller should set the WORKPIECE_REF output line high. The /SUSPEND line will go low while the appropriate number of compensation pulses are injected into the machine control.
Step 2	The controller should monitor the /SUSPEND input signal to return high. Workpiece compensation is now enabled.

HC10 M90 deactivate workpiece compensation.

The procedure below details the sequence of events for deactivating workpiece compensation and returning to wavelength compensation only.



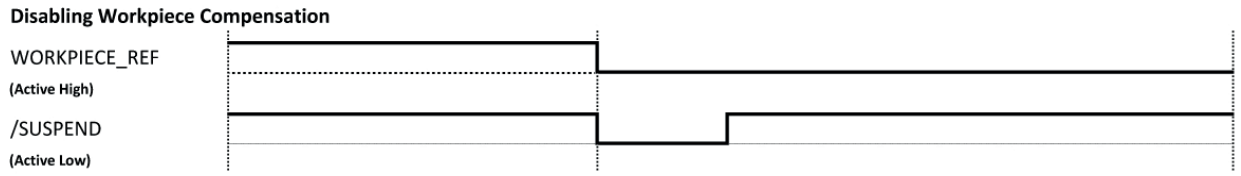
HC10 deactivate workpiece compensation sequence

Workpiece compensation is now deactivated. Until re-activated compensation will only be applied to counteract the effects of wavelength variation.

HC20 disabling workpiece compensation

Conversely, the workpiece compensation function is disabled when the **Workpiece compensation enable** line is returned to the low state. M90 should be programmed to set this line low (off).

Workpiece compensation is now deactivated. If M90 is used at a machine position which is away from the workpiece origin, the appropriate number of compensation pulses will be re-injected into the machine control to bring the machine back into a position that is compensated only for the effects of wavelength variation (if laser encoders are used). For this reason, a short delay should be programmed in before machining is allowed to continue.



Step 1	The controller should set the WORKPIECE_REF output line low. The /SUSPEND line will go low while the appropriate number of compensation pulses are injected into the machine control. If 'Disable Workpiece Compensation' is performed at a machine position which is away from the workpiece origin, the appropriate number of compensation pulses will be re-injected into the machine control to bring the machine back into a position that is compensated only for the effects of wavelength variation.
Step 2	The controller should monitor the /SUSPEND input signal to be high. Workpiece compensation is now disabled.

HC10 M92/M93 Enable/Disable material temp update

The function Disable Material Compensation is included to enable the user to update the reference temperature for material compensation purposes at selected intervals.

This function effectively ‘freezes’ the last reading that has been taken on the material temperature sensor, whilst workpiece expansion compensation remains active.

This is achieved by setting the state of the DISABLE_MATCOM as follows:

HIGH (24v) (M92) The material temperature is frozen at the last reading.

LOW (0v) (M93) The material temperature is read constantly.

In practice these lines are usually controlled with M-codes, where M92 is used to freeze readings and M93 reactivates readings.

HC20 suspending workpiece compensation

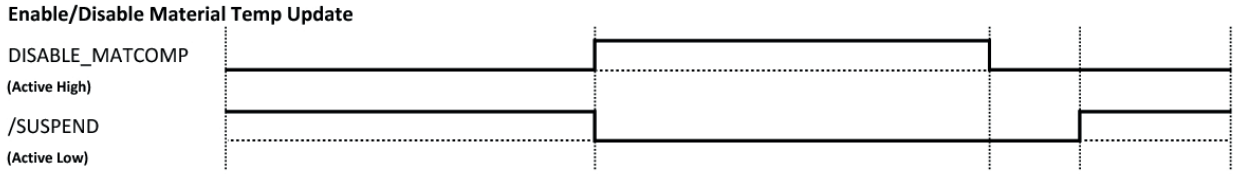
The function **Disable material compensation** (sensor update freeze) is included to enable the user to update the reference temperature for material compensation purposes at selected intervals.

This function effectively ‘freezes’ the last reading that has been taken on the material temperature sensor, whilst workpiece expansion compensation remains active.

This is achieved by setting the state of the **Workpiece compensation temperature freeze** line as follows:

HIGH (M92) The material temperature is held at the last reading

LOW (M93) The material temperature is read constantly



To Suspend Workpiece Temperature Sensor Reading

Step 1	The controller should set the DISABLE_MATCOMP output line high.
Step 2	The controller should monitor the /SUSPEND input signal to be low. While the / SUSPEND line is low, the workpiece temperature is held at the last reading and machining must not be started.

To Resume Workpiece Temperature Sensor Reading

Step 1	The controller should set the DISABLE_MATCOMP output line low.
Step 2	The controller should monitor the /SUSPEND input signal to be high. Once /SUSPEND returns high the workpiece temperature is read constantly and machining can begin.

HC20 multiple fixturing with workpiece compensation

If, because of multiple fixturing, the machine now moves to the next part with workpiece compensation active, then compensation for the total move relative to the workpiece reference of the previous part is applied and will continue to be applied during machining. Clearly this could introduce inaccuracy in the features machined in the second and subsequent parts. In this case it is necessary to disable and then re-enable the workpiece reference at the new parts' reference position.

The correct way to use workpiece compensation in cases with multiple fixturing capability is detailed below:

1. Home the machine axes (if not already done).
2. Move the machine to the workpiece expansion origin position. When in position, use M91 to enable workpiece compensation.
3. Machine the part.
4. Switch back to wavelength compensation only using M90.
5. Change the required parameter table.
6. Home the machine axes.
7. Move the machine to the second workpiece expansion origin. When in position, use M91 to enable workpiece compensation.
8. Machine the part.
9. Switch back to wavelength compensation only using M90.
10. Move to the next workpiece origin etc.

Section 3 - HC20 installation

3.1 HC10 settings

3.2 Laser head installation

- Laser head installation in accordance with the HS20 manual
- System check in accordance with the HS20 manual

3.3 HC20 PSU installation

- Mounting of the PSU
- Mounting of the power supply
- Installation of the material temperature sensors
- Installation of the air temperature sensors
- Laser head signal strength pin changes (Axis 1, Axis 2)

3.4 HC20 compensation unit installation

- Mounting of the unit
- Unit power supply
- Laser head signal strength pin changes (Axis 3, Axis 4)
- Installation of the air temperature sensors (Axis 3, Axis 4)
- Installation of the signal strength cable (Axis 3, Axis 4)

3.5 HC20 system configuration

- Connect to the HC20
- Configuration set up

3.6 HC20 system testing

- Pre machine hand over tests
- Post machine hand over tests

3.1 HC10 settings

It is recommended that before any work has commenced to upgrade the system a back up of the HC10 system configuration is taken and kept in a suitable location. The following information will be required from the HC10 for the installation of the HC20, these are listed below:

- axis names
- environmental compensation status
- material compensation status
- expansion coefficient used

3.2 Laser head installation (HS10 to HS20)

Laser head installation in accordance with the HS20 manual

If HS20 laser heads are being installed as part of the upgrade process it is recommended that these are installed first. These should initially be aligned with the HC10 system that currently exists on the machine.

HS20 is fully compatible with HC10.

Ensure that during the installation of the HS20 laser heads that the 'HS20 installation guide' is followed.

It is recommended that the serial numbers of the HS20 laser heads are recorded during the installation, as these will be required as part of the HC20 installation.

It is recommended that the installation of the HS20 laser heads are verified in accordance with the tests detailed in 'HS20 installation guide'.

3.3 HC20 PSU Installation

Mounting of the PSU

The HC20 PSU exterior dimensions and mounting positions are identical to that of the standard HC10 PSU.

The following steps should be followed to install the HC20 PSU:

Step	Description
1.	Ensure the power is isolated from the HC10 PSU.
2.	Remove all the cables from the HC10 PSU ensuring that the origin of each cable is recorded.
3.	Remove the four screws that secure the HC10 PSU in place.
4.	Remove the HC10 PSU then place the HC20 PSU in its place and secure using the four screws previously used.
5.	Connect the HS20 axis 1 and axis 2 lasers to the PSU (CN10 and CN13).
6.	Connect the HC10/HC20 axis 1 and axis 2 communication cables (CN19 and CN20). **Do not connect to power at this stage.**

Warning: Do not connect the power to the HC20 PSU at this stage.

Mounting of the power supply unit

As per the HC10, the HC20 power supply unit (A-8003-4821) should be mounted in a vertical orientation so the main input connector (IEC 320-C14) faces downwards and is secured with the retention clip. This is to avoid the possibility of coolant drips entering the connector.

Laser head signal strength pin changes (axis 1 and 2)

If the system you are upgrading does not use signal strength monitoring then proceed to the next step.

To change the signal strength from an analogue to digital signal the following wiring changes are required. In some instances, it may be easier to manufacture a new cable and run it in line with the previous cable.

Step	Description
1.	On the HS20 end of the signal strength cables the pins on the connector need to be changed. * Pin 1 (0V DC) needs to be changed to Pin 8 (/Status), * Pin 2 (Beam strength) needs to be changed to Pin 7 (Status).
2.	Complete the wiring changes on both the axis 1 and 2 signal strength cables.
3.	Connect the cables to the HS20 and the appropriate axis 1 or 2 port on the HC20 PSU.

Installation of the material temperature sensor

It is required that the material sensor is changed over to the new style sensor that is supplied. The original HS10 material temperature sensor is not compatible.

Step	Description
1.	Where possible use the 5m cable supplied with the kit, if this is not possible then a new cable will need to be created with the use of the connector kits supplied. This cable will need to be wired as follows: * Pin 1 (Data -) to Pin 1 (Data -) * Pin 2 (0V) to Pin 2 (0V) * Pin 3 (5V) to Pin 3 (5V) * Pin 4 (Data +) to Pin 4 (Data +)
2.	Connect the material sensor to the cable and position in suitable place.
3.	Once the material sensor is in place then connect the sensor to the HC20 PSU.

In applications where more than five metres of cable is required it is recommended that a custom cable is manufactured. This should be manufactured from the following specification cable.

- Recommended conductor size: 0.25mm^2 (24 awg)
- Cable O.D: 3.5mm - 5mm (0.14 in - 0.2 in)

Renishaw recommends the use of a cable with overall shield and twisted pair wire cores for the data signals. An example of this would be Belden 88102 transmitter cable connector kit, A-9904-1636, is supplied for making up custom cables.

If it is not possible to remove the old sensor cable and replace this with the new sensor cable then, this cable will need to be modified to accommodate the new sensor. This can be done by using the following steps and the 5-pin XLR connector on the front of the HC20 PSU.

Step	Description
1.	Modify the existing cable as follows: * XLR-Pin 1 (5V) to Binder-Pin 3 (5V) * XLR-Pin 2 (0V) to Binder-Pin 2 (0V) * XLR-Pin 3 (Data +) to Binder-Pin 4 (Data +) * XLR-Pin 4 (Data -) to Binder-Pin 1 (Data -)
2.	Connect the material sensor to the cable and position in suitable place.
3.	Once the material sensor is in place then connect the sensor to the HC20 PSU.

Installation of the air temperature sensors

The installation of the air temperature sensors is very similar to that of the material temperature sensor.

Step	Description
1.	Where possible use the 5m cable supplied with the kit. If this is not possible then a new cable will need to be created with the use of the connector kits supplied. This cable will need to be wired as follows: * Pin 1 (Data -) to Pin 1 (Data -) * Pin 2 (0V) to Pin 2 (0V) * Pin 3 (5V) to Pin 3 (5V) * Pin 4 (Data +) to Pin 4 (Data +)
2.	Connect the air temperature sensors to the cable and position in suitable place. Ensure that this is completed for axis 1 and 2.
3.	Once the air temperature sensors is in place then connect the sensor to the HC20 PSU.

In applications where more than five metres of cable is required it is recommended that a custom cable is manufactured. This should be manufactured from the following specification cable.

- Recommended conductor size: 0.25mm^2 (24 awg)
- Cable O.D: 3.5mm - 5mm (0.14 in - 0.2 in)

Renishaw recommends the use of a cable with overall shield and twisted pair wire cores for the data signals. An example of this would be Belden 88102 transmitter cable connector kit, A-9904-1636, supplied for making up custom cables.

3.4 HC20 compensation unit installation

Mounting of the HC20 compensation rack

The HC20 compensation rack exterior dimensions and mounting positions are identical to that of the standard HC10 compensation rack.

The following steps should be followed to install the HC20 compensation rack:

Step	Description
1.	Ensure the power is isolated from the HC10 compensation rack.
2.	Remove the cables from the HC10 compensation rack ensuring that the origin of each cable is recorded.
3.	Remove the four screws that secure the HC10 compensation rack in place.
4.	Remove the HC10 compensation rack and replace with the HC20 compensation rack within its place and secure using the four screws previously removed.
5.	Connect the HS10/HS20 axis 3 and 4 lasers to the compensation rack (where applicable).
6.	Connect the HC10 PSU/HC20 PSU axis 1 and 2 communication cables.
7.	Connect the RS485 cable between the HS20 PSU and HC20 compensation unit.
8.	Connect the ‘INPUTS’ and ‘OUTPUTS’ connectors from the machine control.
9.	Connect the appropriate number of reference switches to the system using the ‘AX* REF MARK’ connectors.
10.	Connect the quad output connectors (AX* QUAD OUTPUT) to the HC20 compensation system for the appropriate number of axes.

Laser head signal strength pin changes (axis 3 and 4)

If the system you are upgrading does not use signal strength monitoring then proceed to the next step.

To change the signal strength from an analogue to digital signal the following wiring changes are required. In some instances, it may be easier to manufacture a new cable to replace the previous cable.

Step	Description
1.	On the HS20 end of the signal strength cables the pins on the connector need to be changed. * Pin 1 (0V DC) needs to be changed to Pin 8 (/Status), * Pin 2 (Beam strength) needs to be changed to Pin 7 (Status).
2.	Complete the wiring changes on both the axis 3 and 4 signal strength cables.
3.	Connect the cables to the HS20 and the appropriate axis 3 or 4 port on the HC20 PSU.

Installation of the air temperature sensors

The installation of the air temperature sensors is very similar to that of the material temperature sensor.

Step	Description
1.	Where possible use the 5m cable supplied with the kit, if this is not possible then a new cable will need to be created with the use of the connector kits supplied. This cable will need to be wired as follows: * Pin 1 (Data -) to Pin 1 (Data -) * Pin 2 (0V) to Pin 2 (0V) * Pin 3 (5V) to Pin 3 (5V) * Pin 4 (Data +) to Pin 4 (Data +)
2.	Connect the air temperature sensors to the cable and position in suitable place. Ensure that this is completed for axis 1 and 2.
3.	Once the air temperature sensors is in place then connect the sensor to the HC20 PSU.

In applications where more than five metres of cable is required it is recommended that a custom cable is manufactured. This should be manufactured from the following specification cable:

- 24 AWG EcoMini 2 pair
- Nominal Diameter 4.22mm (0.166”)

An example of this cable is **‘Alpha Wire’** - Mfr. Part No. 78172

This cables Nominal Diameter correctly fits the recommended Binder cable back shell clamp (max allowed dia. 5mm)

Final system connections

To complete the system installation then the final connectors will be required to be connected.

Step	Description
1.	Connect any remaining cables to the HC20 compensation rack, excluding the power supply cable.
2.	Connect the 24V power supply to the HC20 PSU.
3.	Connect the RD20 cable to the ‘Com 1’ port on the HC20 compensation rack if required.
4.	Connect the power supply to the HC20 compensation rack..

3.5 HC20 system configuration

HC20 configuration setup

The configuration of the HC20 systems is to be completed after the system has been installed.

Some of the configuration file settings will need to be adjusted to match that of the HC10 system previously installed. The majority of these settings are set to a default to match the HC10 system.

Because the HC20 uses a series of RCU10 units, they are connected in a network via high speed link cables. These will already be configured as a network before the unit leaves the factory.

If the HC20 is being configured to use the analogue output for integration with a Siemens 840D control, then please find additional notes within appendix 2.

Set to HC10 default	Set by customer on site
Encoder type	Direction sense
Wavelength	Update rate
Resolution	Sensor configuration
Sample rate	Compensation settings
Reference mark source	Compensation parameters
Signal format	
Tristate on Error	
Controller logic	

Other information that will also be required will be the serial numbers for the following units:

- RCU10 with the pressure sensor
  (this will be indicated on the serial number label located on the HC20)
- HS20 laser heads
- Material temperature sensor
- Air temperature sensors

Connecting to the HC20 system

To be able to configure or communicate with the HC20, this will need to be completed with the RCU-CS software.

For the main instructions on how to use the software and details relating to the configuration settings then please refer to the RCU10 quadrature compensation unit manual.

To connect to the HC20 connect a PC to the HC20 with the RCU-CS software installed.

Each are required to be connected using the ‘COM 1’ port located on the front of the HC20 compensation rack. The HC20 system kit comes with a converter from RS232 to USB to allow modern PC’s to be connected.

Step	Description
1.	Connect the PC to the HC20 compensation rack using the ‘COM 1’ port.
2.	Identify which port number on the HC20 is connected to on the PC using the device manager.
3.	Once the port has been identified then set the serial port in RCU-CS using the following steps: * Open RCU-CS * Login as ‘Configurator’ using the password ‘config’ * Select ‘OK’ on the ‘Connection Wizard’ * Select ‘Tools’ from the drop down menu followed by ‘Serial Port’ * Select the appropriate ‘Port Number’ and select ‘OK’ * Then select the ‘Receive’ button bar to connect to the RCU10 units

Setup the configuration settings for the HC20 system

Ensure that you login in as configurator to be able to adjust the RCU10 configuration. The RCU10 units will also need to be in ‘Configuration mode’, if they are not then use the ‘Mode’ button to set this.

To set the configuration settings for the HC20 select the ‘Configuration’ button to open the configuration window.

- **System** - this is where the initial machine related information is set within the machine.
- **Sensors** - this is where the sensor information is required.
- **Compensation** - this is where the input and output machine settings are set.
- **Parameters** - this is where the compensation details are defined.

For specific details relating to the setup then please refer to the RCU10 quadrature compensation unit, installation and user guide.

Due to the way the HC20 sensor network specific sensors will have to be assigned to different RCU10’s when configuring the system. This is due to the way that the system is internally wired in the HC20. Therefore the specific sensors will be required to be assigned to specific RCU10’s which are described below.

RCU10 -XX-PX - Axis 1	Axis 1 - laser head signal strength
	Axis 2 - laser head signal strength
	Axis 1 - air temperature sensor
	Axis 2 - air temperature sensor
	Material temperature sensor
RCU10-XX-XX - Axis 2	Axis 3 - laser head signal strength
	Axis 4 - laser head signal strength
	Axis 3 - air temperature sensor
	Axis 4 - air temperature sensor

No sensors are required to be configured to the RCU10 units for axes 3 and 4.

Transmitting the configuration to the HC20

Once the configuration has set then it will need to transmitted to the HC20.

To transmit the settings to the HC20 then select the ‘Transmit’ button and follow the on screen steps.

Creating a back-up of the configuration settings

To create a backup of the configuration settings, then select ‘File’ and ‘Save’ from the drop down menu. This will create a .rcf file which can be uploaded to the RCU10 via RCU-CS at a later date.

Change between configuration and compensation mode

Once the configuration file has been uploaded then the RCU10 units will then need to be changed into compensation mode. This can be done by using the ‘Mode’ button.

Different system modes within RCU-CS

There are different modes of the system. These modes are described below:

Configuration (CONF)	This mode allows for the configuration of the system to be adjusted.
Ready (RDY)	This mode is when the system is configured and ready to start the machine operation. No compensation will be applied until the machine reference is found.
Compensation (COMP)	Once the machine reference has been found then the wavelength and material / structural compensation would be found.
Error (ERR)	Axis has registered an error.

3.6 HC20 system testing

Pre machine hand over tests

Ensure that before the HC20 is given control of the machine through feedback of the HS20 laser heads that the ‘Pre HS20 feedback testing’ has been completed. This is available in the HS20 installation guide.

Post machine hand over tests

Also ensure that once the machine has been switched over the HS20 feedback that the ‘Switching machine control to HS20 feedback’ and ‘Machine under HS20 feedback testing’ has been completed. This is also available in the HS20 installation guide.

Section 4 - System Maintenance

Contained in this section

4.1 HC20/HS20 system maintenance

This section describes the maintenance that is required to the HC20 system.

There is minimal maintenance that is required within the HC20 system. The checks described below should be completed as part of the machines scheduled maintenance.

- **Signal strength**: The machine should be run along its axis and the signal strength should be monitored. If a beam low warning is indicated along the length of the axis the HS20 should be realigned. The procedure on how this should be completed can be found within the ‘HS20 installation guide’.
- **Air and material temperature sensors**: The readings of the air and material temperature sensors should be checked as part of the routine maintenance on the machine. These should be checked by ensuring that the reading they are providing is valid. If these are found to be faulty then they should be immediately replaced and the machine should not be run until this has been completed.

Section 5 - Troubleshooting

Contained in this section

5.1 HC20 troubleshooting

If a problem is identified within the HC20 system then the following section can be used to highlight the potential cause of the problem.

Issue Identified	Potential Cause	Recommended Action
HC20 system power failure - There is no power supply present within the HC20 system.	This can either be caused by a failure in the power supply to the main HC20 or the main PCB board within the HC20	1. Firstly ensure that 24v is present at the input to the HC20. 2. Check there are no lose connections between the external power connector and the PSU unit. 3. If there is power going onto the PCB check to see if there is power coming off the PCB to one of the RCU10's. If there is not any power coming off the PCB then the PCB is at fault. If there is power coming off the PCB to the RCU-10's then contact LCPD product support for more information.
The power has failed for one of the RCU10's - This will be identified by the RCU10 not showing any error on the screen or being found in RCU-CS.	This can either be caused by a power failure on the PCB board or within the RCU10.	1. Firstly identify if power is present on the link cable between the PCB within the HC20 and the RCU10. 2. If no power is present then the fault is either with the PCB or the power cable linked to that RCU10. 3. If power is being provided to the RCU10 and it is not starting up then the fault is with the RCU10. To change the RCU10 please contact LCPD product support.
There are limited or no input signals coming from the machine controller to the HC20.	This could be related to one of the link cables that either comes from the PCB to the rear panel of the HC20. Or the inputs cables that link each RCU10 to the PCB.	1. Firstly using the RCU-CS interface identify if the inputs cannot be seen on all of the axes or if it is just specific axes. 2. If the inputs cannot be seen on any of the axes then this would suggest that this cause of the problem would be related to the inputs cable that links the PCB to rear panel of the HC20. 3. If the inputs have failed for one specific axis then this would suggest that the fault lies in the cable linking the RCU10 to the main PCB machine axis.
There are limited or no output/error signals coming from the HC20 to the machine controller.	If no error signals are being received then this is related to the two 16-way output connectors. If the error is with the quadrature out of the HC20 then this will relate to the each of the axis outputs.	1. If no error signals are being received from the HC20, then identify which axis this is occurring on. 2. If it is occurring from one axis then the fault could lie with either the link cable from the RCU10 output to the PCB or from the PCB to either one of the two 16-way outputs connectors (Output 1 = Axis 1 & 2, Output 2 = Axis 3 & 4). 3. If the issue is related to the quadrature output then, the fault could lie within the link cable from the RCU10 to the rear panel or the RCU10 unit for that axis.

A sensor failure is present within the system.	If it is one sensor that has failed within the system then it is likely that this is a genuine sensor failure. If multiple sensors fail within the system it is likely that this is as a result of a failure within the sensor network.	1. If one sensor has failed within the network and the LED is not flashing on the sensor, then the sensor is required to be replaced. 2. If the LED is not flashing on a number of sensors then this is likely to be due to a power failure within the sensor network. 3. If this is the case with the sensors connected to the PSU, then ensure that the 5V is present on the 16-way connector coming from the HC20 (refer to HC20 & HC20 PSU pin outs in appendix 3)
Incorrect sensor readings are being received or no communication is being received.	Incorrect sensor readings can be caused by direct heat or cooling sources near the sensors. If there is a failure in the sensor communication then this is likely to be caused by a break in the sensor network.	1. First check for any external sources that can cause an unexpected change in the operating temperature. 2. Change the sensor for a different sensor on the network to establish if the fault is with that specific sensor. 3. If there is a specific sensor that has lost communications then ensure that the connections are correctly fitted along the cable length. 4. If the air sensors for axis 1 & 2 and the material sensor have lost their communication then check the RS485 link cable between the HC20 and the PSU as this carries the network comm's between the two units.
No power is present on the lasers for Axis 1 & 2.	This is likely to be caused by a power supply failure in the HC20 PSU.	1. If there is no power on the laser heads for axis 1 and 2 then ensure that the connections on the cables are checked. 2. Change the PSU power supply. *Note: the sensors will still be active even if there is a failure within the HC20 power supply as these are powered from by a 5V supply from the HC20.*

Note: The guide detailed above can vary depending on the system integration into the machine. Therefore if the problem you are seeing is not described above then it is recommended that you contact:

LCPD Technical Support on either +44 (0) 1453 855440 or lcpdtechnicalsupport@renishaw.com

Appendix 1 - System specification

HC20 system performance

The compensation completed by the HC20 compensation unit is completed through the RCU10 units within the assembly. Therefore the system performance is directly related to that of the RCU10.

Input resolutions*	Laser encoder:	79nm, 158nm, 316nm and 633nm (digital format)
	Encoder:	0.1µm, 0.5µm, 1µm and 5µm (digital format)
Output resolutions*	Digital:	10nm to 5µm
	Analogue:	20µm, 25µm, 40µm, 50µm and 100µm *(actual resolutions available depend upon encoder input resolution)*
Accuracy	+/- 1ppm**	(refractive index compensation only) This assumes a working environment that falls within a 0˚C to 40˚C temperature range, 650mB to 1150mB pressure range and a %RH entered within +/-20%.
	+/- 2ppm**	(with 10ppm/˚C material compensation) This assumes a working environment that falls within a 0˚C to 40˚C temperature range and a %RH entered within +/-20%.
Maximum velocity	5m/s	at resolutions >400nm
	0.2m/s	at 10nm resolutions
Compensation update rate	200µs	
Delay through compensator	<1µs (digital output)	
	<2µs (analogue output)	
Output update rate (digital) (selectable)	20 MHz (50 ns)	(minimum edge-edge separation)
	10 MHz (100 ns)	
	5 MHz (200 ns)	
	2.5 MHz (400 ns)	
Output update rate (analogue)	10 MHz (100 ns)	
Input sample rate (selectable)	40 MHz / 20 MHz / 10 MHz / 5 MHz / 2.5 MHz	**Note:** Minimum quadrature edge to edge separation 50 ns (i.e. 20 MHz) The quadrature decode logic contains a digital filter which is used to remove noise spikes from the incoming signals. This filter is only operational for input sample clocks of 10 MHz and below.

* - Valid input/output resolution combinations are pre-defined (refer to section 2.4.2 of the RCU10 quadrature compensation unit manual for further details.

** - plus the greater of +/-3 input counts and +/- output counts for digital outputs and a velocity-dependant following error for analogue outputs.

Note: RCU10 performance specifications are only guaranteed in a working environment that falls within a 0˚C to 40˚C temperature range, 650 mbar to 1150 mbar and a relative humidity entered to within +/-20% of actual.

HC20 component specification

HC20 compensation unit

Dimensions	
Length:	528mm*
Width:	295mm*
Depth:	190mm*
Weight:	15kg *(4-axis system)*
Power Supply	
Voltage:	24V +/-1V
Current:	<3.5A
Maximum power:	84W *(with 2off HS20's, 2off sensors and 4off RCU10's connected)*
Operating Environment (indoor use only)	
Pressure:	Normal atmospheric (650 mbar - 1150 mbar)
Humidity:	0 - 95% RH *(non condensing)* Maximum relative humidity 80% *(for temperatures up to 31˚C decreasing linearly to 50% relative humidity at 40˚C)*
Temperature (storage):	-20˚C - 70˚C
Temperature (operating):	0˚C - 50˚C
Altitude:	0 to 2000m

HC20 power supply unit

Dimensions	
Length:	280mm*
Width:	220mm*
Depth:	250mm*
Weight:	2kg
Power Supply	
Voltage:	24V +/-1V
Current:	<2.5A
Maximum power:	60W *(with 2off HS20's and 3off sensors connected)*
Operating Environment (indoor use only)	
Pressure:	Normal atmospheric (650 mbar - 1150 mbar)
Humidity:	0 - 95% RH *(non condensing)* Maximum relative humidity 80% *(for temperatures up to 31˚C decreasing linearly to 50% relative humidity at 40˚C)*
Temperature (storage):	-20˚C - 70˚C
Temperature (operating):	0˚C - 50˚C
Altitude:	0 to 2000m

** - dimensions match those of the HC10*

Air temperature sensor

Accuracy*:	+/- 0.2˚C (k=2)
Measurement range:	0˚C - 40˚C
Update rate:	1 Hz

Material temperature sensor

Accuracy*:	+/- 0.1˚C (k=2)
Measurement range:	0˚C - 55˚C
Update rate:	1 Hz

Pressure sensor

Accuracy*:	+/- 2mbar (k=2)
Measurement range:	650mbar to 1150mbar
Operating temperature:	0˚C - 60˚C
Update rate:	1 Hz

* - sensors calibrated over operating temperature range by immersion in a temperature controlled fluid bath.

Appendix 2 - Using the analogue quadrature signal from the RCU10

The HC20 using the RCU10 single axis compensators can be configured to produce a 1Vpp analogue quadrature output which can be used with a Siemens 840D control.

HC10 analogue quadrature outputs

When configured with an HS10, the HC10 was able to offer the following analogue signal periods:

HS10 output resolution	Minimum feedrate	HC10 analogue signal period
0.079 µm	0.1 m/s	25.6 µm
0.158 µm	0.25 m/s	64 µm
0.316 µm	0.5 m/s	128 µm
0.633 µm	1 m/s	256 µm

HC20 analogue quadrature outputs

When configured with an HS20, the HC20 is able to offer the following analogue signals periods:

HS20 output resolution	Maximum feedrate		HC20 analogue signal period
	From the HS20	Into the HC20	
0.079 µm	1.0m/s	1.582m/s	20 µm
			25 µm
			40 µm
			50 µm
			100 µm
0.158 µm	2.0m/s	3.164m/s	40 µm
			50 µm
			100 µm
0.316 µm	2.0m/s	5.000m/s	100 µm

It can be seen that the output from the HC10 and RCU10 vary with their outputs. Therefore some of the configuration settings for the RCU10 and parameters for the machine control will need to be altered to accommodate for these differences.

RCU10 analogue quadrature settings

This section describes the settings required to configure an HS20 together with an RCU10 to produce an analogue quadrature.

HS20 laser head settings

The HS20 needs to be configured to produce a digital quadrature signal with a resolution of 79nm (158nm can also be used, please consult the HS20 installation guide for further information). Therefore, the HS20 dip switches should be set as follows:

Dip switch	Function	Status	Switch setting
1	No function	-	Off
2	Quadrature hysteresis	Disabled	On
3	Quadrature resolution	79nm	On
4		79nm	On
5	Quadrature clock frequency	16MHz	On
6		16MHz	Off
7		16MHz	Off
8	Parity	-	On

For further information on using the dip switch or the individual functions, please refer to the HS20 installation guide.

RCU10 compensation unit settings

The settings for the RCU10 need to be configured to take the digital quadrature input from the HS20 and produce a compensated analogue quadrature. The tables below highlight how it is recommended that these settings are set.

Note: These settings can be application dependant, therefore a detailed understanding of each setting and its effect is required before creating the RCU10 configuration.

RCU10 encoder input	
Description	Setting
Signal format	HS10
Pitch	0.07910235580 µm
Direction sense	Normal
Sample rate	40.0 MHz
Reference mark source	External port

RCU10 output to controller	
Description	Setting
Signal format	Analogue
Pitch	40 µm
Direction sense	Normal
Update rate	10.0 MHz
Tristate on error	Enabled
Controller logic	24 V

Siemens 840D parameters and settings

If the HC10 to HC20 upgrade is being completed on a machine which uses a Siemens 840D controller, it is possible that the following settings may need to be reviewed and changed to accommodate the difference in signal period between the HC10 and HC20.

The parameters listed below are by no means a complete list of parameters that may require adjustment, but represent some of the encoder based settings.

Note: The changing of machine parameters should only be completed by someone who is experienced in machine control integration, understands the operation of the machine and the effect of changing parameters within the machine control.

Parameter name	Definition	HC10 example (256 µm)	HC20 example (40 µm)
ENCODER_IS_LINEAR	Selects a linear encoder	=1	=1
ENC_GRID_POINT_DIST	Selects the encoder sine period	=0.256	=0.040
ENC_RESOLUTION	Interpolation factor	=2048	=2048
GANTRY_POS_TOL_ WARNING	An alarm setting which monitors the difference between gantry axes after each has been homed, but before synchronisation. If exceeded, an error is raised which allows the operator to manually synchronise axes. Must be set to at least 1.5x the sinusoid period (see note 1).	=0.384	=0.060
GANTRY_POS_TOL_REF	This setting also monitors axis difference after homing. When exceeded, the synchronisation process is halted **without** synchronising. This setting will depend on how much skew can be tolerated in the machine during reference, beofre damage could occur.	=1.00	=1.00
GANTRYPOS_TOL_ ERROR	An alarm setting that monitors gantry axis difference after synchronisation has been completed, i.e during normal machine operation. Can be set to a much smaller value, as once synchronisation is complete, no skew should occur.	=0.1	=0.1

Note 1: This parameter may need to be set to a larger value if the machine normally tends to have an amount of skew before homing. For example, if gantry ‘relaxes’ into skew on a power-down.

For ENC_GRID_POINT_DIST it is important that the original HC10 settings are understood correctly so that the modified machine settings can be applied correctly.

Appendix 3 - Spares parts list

HC20 PSU

It is recommended that if any parts of the HC20 PSU fail during operation then the complete HC20 PSU unit is replaced. This is due to the nature of the internal components within the HC20.

Part Number	Description
A-8003-4570	HC20 PSU
A-8003-4821	24V Power supply for HC20 PSU

HC20 Compensation Unit

The HC20 compensation unit contains RCU10 units which are able to be interchanged within the HC20 if a unit was to fail. The part numbers which are available as spares for the HC20 compensation unit are detailed further below:

Part Number	Description
A-8003-4566	HC20 Compensation System - 2-Axis
A-8003-4535	HC20 Compensation System - 3-Axis
A-8003-4545	HC20 Compensation System - 4-Axis
RCU10-PX-XX	RCU10 with Pressure Sensor (used for axis 1)
RCU10-XX-XX	RCU10 with No Pressure Sensor (used for axis 2, 3, 4)
RCU10-DB-XX	RCU Sensor Distribution Block
A-9904-1451	RCU Fast Link Cable

HC20 system - Additional spares

The following spares are not directly part of the HC20 and HC20 PSU but maybe required as part of the HC20 system upgrade.

Part Number	Description
RCU10-AT-XX	Air temperature sensor
RCU10-MT-XX	Material temperature sensor
RCU10-TC-X5	Sensor cable
RCU10-CS-XX	RCU10 CS software
A-9904-1636	Sensor connector kit
A-9904-2407	Laser encoder systems manuals CD
A-8014-0670	Serial-USB adaptor
RCU10-AC-X5	Armoured sensor cable (5m)
A-8003-6000	HS20 laser head
P-CA82-0054	Cable RS232 serial
A-8003-2777	HC20 single axis connector kit
A-8003-2778	HC20 two axis connector kit
A-8003-2779	HC20 three axis connector kit
A-8003-2780	HC20 four axis connector kit

HC20 system - Recommended spares

The following spares are recommended by Renishaw to have available in the unlikely event that the system was to fail. These are only recommended and it is up to the customer as to the level of spares required for the machine.

Part Number	Description	Qty
RCU10-PX-XX	RCU10 with Pressure Sensor	1
RCU10-AT-XX	Air temperature sensor	1
RCU10-MT-XX	Material temperature sensor	1
RCU10-TC-X5	Sensor cable	1
A-9904-2407	Laser encoder systems manuals CD	1
A-8003-4821	24V Power Supply for HC20 PSU	1
A-8003-6000	HS20 laser head	1
A-8014-0670	Serial USB adaptor kit	1
P-CA82-0054	Cable RS232 serial	1

It maybe required that an additional HC20 system is required as a spare instead of an individual RCU10, if minimal machine down time is required in case of failure. These part numbers can be found below:

- HC20 compensation unit (2-axis system) - A-8003-4566
- HC20 compensation unit (3-axis system) - A-8003-4535
- HC20 compensation unit (4-axis system) - A-8003-4545

Appendix 4 - HC20 system pin out

This section details the pin outs on the front of the HC20 power supply unit and HC20 compensation system.

HC20 PSU

The table below details the pin out for each connector on the front of the HC20 PSU.

Connector Description	Connector Type	Pin	Purpose
AX1 Air Temp & AX2 Air Temp	Binder, Panel Mount, 4-Way, female (24 AWG)	1	DATA-
		2	0V
		3	5V
		4	DATA+
Material Sensor	Binder, Panel Mount, 4-Way, female (24 AWG)	1	DATA-
		2	0V
		3	5V
		4	DATA+
Material Sensor (Old Style)	XLR 5-Way Female	1	5V
		2	0V
		3	DATA+
		4	DATA-
		5	0V
AX1 Signal Strength & AX2 Signal Strength	Connector, XLR, 3-Way, Male	1	DATA-
		2	DATA+
		3	*Not in use*
RS485	9-Way 'D' Type socket	1	DATA+
		2	*Not in use*
		3	*Not in use*
		4	*Not in use*
		5	*Not in use*
		6	DATA-
		7	*Not in use*
		8	*Not in use*
		9	*Not in use*
AX1 HC20 & AX2 HC20	LAPP EPIC Circular 16-Way Insert Male	1	*Not in use*
		2	0V
		3	CHASSIS_GND
		4	AQUAD
		5	/AQUAD
		6	BQUAD
		7	/BQUAD
		8	RESET
		9	*Not in use*
		10	*Not in use*
		11	*Not in use*
		12	/BEAMBLOCK + OVERSPEED
		13	5V
		14	/UNSTABLE
		15	/BEAMLOW
		16	*Not in use*

AX1 HS20 & AX2 HS20	LAPP EPIC Circular 16-Way Insert Female	1	24V DC
		2	0V
		3	CHASSIS_GND
		4	AQUAD
		5	/AQUAD
		6	BQUAD
		7	/BQUAD
		8	RESET
		9	*Not in use*
		10	*Not in use*
		11	*Not in use*
		12	/BEAMBLOCK
		13	/OVERSPEED
		14	/UNSTABLE
		15	/BEAMLOW
		16	*Not in use*
24V INPUT	2-Way Plug Male, Panel	1	24V
		2	0V

HC20 Compensation Unit

The table below details the pin out for each connector on the front of the HC20 compensation unit.

Connector Description	Connector Type	Pin	Purpose
COM1	9-Way 'D' Type plug Male	1	*Not in use*
		2	TXD
		3	RXD
		4	*Not in use*
		5	0V
		6	*Not in use*
		7	*Not in use*
		8	*Not in use*
		9	*Not in use*
AX3 Air Temp & AX4 Air Temp	Binder, Panel Mount, 4-Way, Female (24 AWG)	1	DATA-
		2	0V
		3	5V
		4	DATA+
AX3 Signal Strength & AX4 Signal Strength	Connector, XLR, 2-Way Socket, Female	1	DATA-
		2	DATA+
RS485	Connector, XLR, 2-Way Socket, Female	1	DATA+
		2	DATA-
AX1 Quad Output, AX2 Quad Output, AX3 Quad Output, AX4 Quad Output	9-Way 'D' Type socket Female	1	0V
		2	/BQUAD
		3	/Z
		4	/AQUAD
		5	*Not in use*
		6	*Not in use*
		7	BQUAD
		8	Z
		9	AQUAD
HS20 AX1 INPUT & HS20 AX2 INPUT	LAPP EPIC Circular 16-Way Insert Male	1	*Not in use*
		2	0V
		3	CHASSIS_GND
		4	AQUAD
		5	/AQUAD
		6	BQUAD
		7	/BQUAD
		8	RESET
		9	*Not in use*
		10	*Not in use*
		11	*Not in use*
		12	/BEAMBLOCK + OVERSPEED
		13	5V
		14	/UNSTABLE
		15	/BEAM LOW
		16	*Not in use*

HS20 AX3 INPUT & HS20 AX4 INPUT	LAPP EPIC Circular 16-Way Insert Female	1	24V
		2	0V
		3	CHASSIS_GND
		4	AQUAD
		5	/AQUAD
		6	BQUAD
		7	/BQUAD
		8	RESET
		9	*Not in use*
		10	*Not in use*
		11	*Not in use*
		12	/BEAMBLOCK
		13	/OVERSPEED
		14	/UNSTABLE
		15	/BEAM LOW
		16	*Not in use*
INPUTS	LAPP EPIC Circular 16-Way Insert Male	1	AX1 WORKPIECE COMP ENABLE
		2	AX1 WORKPIECE COMP TEMP FREEZE
		3	AX1 RESET
		4	AX1 SEEK REF
		5	AX2 WORKPIECE COMP ENABLE
		6	AX2 WORKPIECE COMP TEMP FREEZE
		7	AX2 RESET
		8	AX2 SEEK REF
		9	AX3 WORKPIECE COMP ENABLE
		10	AX3 WORKPIECE COMP TEMP FREEZE
		11	AX3 RESET
		12	AX3 SEEK REF
		13	AX4 WORKPIECE COMP ENABLE
		14	AX4 WORKPIECE COMP TEMP FREEZE
		15	AX4 RESET
		16	AX4 SEEK REF
OUTPUT 1	LAPP EPIC Circular 16-Way Insert Female	1	*Not in use*
		2	*Not in use*
		3	*Not in use*
		4	/AX1 SUSPEND
		5	/AX1 WARNING
		6	/AX1 ERROR
		7	*Not in use*
		8	*Not in use*
		9	*Not in use*
		10	/AX2 SUSPEND
		11	/AX2 WARNING
		12	/AX2 ERROR
		13	*Not in use*
		14	*Not in use*
		15	*Not in use*
		16	*Not in use*

OUTPUT 2	LAPP EPIC Circular 16-Way Insert Female	1	*Not in use*
		2	*Not in use*
		3	*Not in use*
		4	/AX3 SUSPEND
		5	/AX3 WARNING
		6	/AX3 ERROR
		7	*Not in use*
		8	*Not in use*
		9	*Not in use*
		10	/AX4 SUSPEND
		11	/AX4 WARNING
		12	/AX4 ERROR
		13	*Not in use*
		14	*Not in use*
		15	*Not in use*
		16	*Not in use*
AX1 REF MARK, AX2 REF MARK, AX3 REF MARK, AX4 REF MARK	Connector, Panel Mount, 2-Way, Plug Male	1	DATA+ / SWITCH (Normally Open)
		2	0V
24V INPUT	Connector, Panel Mount, 2-Way, Plug Male	1	24V
		2	0V

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