T630
Process controller

Reference manual
& User guide

Issue 3 July 2000 Part Number HA 082 548 U003

ISSUE STATUS OF THIS MANUAL

Section	Issue
Title page	3
Contents	2
Chapter 1	2
Chapter 2	2
Chapter 3	2
Chapter 4	2
Chapter 5	2
Chapter 6	2
Chapter 7	2
Chapter 8	2
Chapter 9	2
Chapter 10	2
Chapter 11	2
Chapter 12	2
Chapter 13	2
Chapter 14	2
Chapter 15	(not issued)
Chapter 16	2
Chapter 17	2
Chapter 18	2
Appendix A	2
Appendix B	2
Appendix C	2
Parameter index	2
Index	2

Notes

1 Sections are up-dated independently and so may be at different issues.

2 The Title page, and the manual as a whole, always take the issue number of the most recently up-issued section.

3 Within a section, some pages in this manual may be at later issues than others. This happens if those pages have been individually up-issued and retro-fitted into the existing manual to bring it up-to-date — *a policy followed by Eurotherm Process Automation Limited to save paper and minimise harm to the environment*. However, the issue number of the whole section — as listed in the above table — is always the issue number of the most recently up-issued page(s) in that section.

EUROTHERM

Declaration of Conformity

Manufacturer's name:	**Eurotherm Limited**
Manufacturer's address:	**Dominion Way, Worthing, West Sussex, BN14 8QL, United Kingdom.**
Product type:	**Process Controller**
Model(s):	**T630 (Status level E5 or higher)** **T630C (Status level G7 or higher)** **T730 (Status level A2 or higher)**
Safety specification:	**EN61010-1 : 1993 / A2 : 1995**
EMC emissions specification:	**EN50081-2 (Group 1; Class A)**
EMC immunity specification:	**EN50082-2**

Eurotherm Limited hereby declares that the above products conform to the safety and EMC specifications listed. Eurotherm Limited further declares that the above products comply with the EMC Directive 89 / 336 / EEC amended by 93 / 68 / EEC, and also with the Low Voltage Directive 73 / 23 / EEC.

Signed: PRJ de la Nougerède Dated: 23-06-2000

Signed for and on behalf of Eurotherm Limited
Peter de la Nougerède
(Technical Director)

CE

Certificate Part No. IA 249 986 U260 Issue 5 June 2000

Contents PROCESS CONTROLLER REFERENCE MANUAL & USER GUIDE

Chapter 1 INTRODUCTION

Chapter 2 INSTALLATION & STARTUP

Chapter 4 CONFIGURATION

Chapter 5 CONTROL OPERATING MODES

Chapter 6 SINGLE-LOOP CONTROLLER

Chapter 7 DUAL-LOOP CASCADE CONTROLLER

Chapter 8 RATIO CONTROLLER

Chapter 13 CALIBRATION

Chapter 14 SERIAL COMMUNICATIONS

Chapter 16 ERROR CONDITIONS

Chapter 17 SPECIFICATIONS

Appendix A SINGLE-LOOP CONTROLLER

Appendix B DUAL-LOOP CASCADE CONTROLLER

Appendix C RATIO CONTROLLER

PARAMETER INDEX

INDEX

Chapter 1 INTRODUCTION

This chapter introduces you to the Process Controller and summarises its main features.

The main sections in this chapter are:

- Features (§1)
- Applications (§2)
- Inputs & outputs (§3)
- Control configurations (§4)
- Alarm handling (§5)
- User interface (§6)
- Communications (§7)
- Contents of this manual (§8).

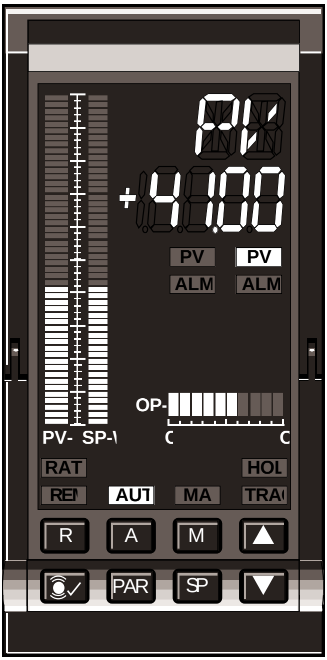


Figure 1-1 Process controller front panel

1 FEATURES

- Manual station, Single-loop, Dual-loop cascade, Ratio, or Override controller
- Incremental 'raise/lower' outputs available with Single-loop, Cascade, and Ratio
- Autotune as standard
- DIN 43700 standard sleeve (72mm × 144mm), IP65/NEMA 4 front panel
- Universal isolated I/O with TC, RTD, high-level plus transmitter PSU
- Modbus communications
- Configuration via front panel or PC
- Passcode protection of configuration parameters
- Minimal hardware options facilitate spares-holding and maintenance

2 APPLICATIONS

The Process Controller is designed for the control of standard process variables — temperature, flow, pressure, and so on — in applications such as industrial boilers, furnaces, kilns, reactors, and mixing vessels.

3 INPUTS AND OUTPUTS

The basic I/O set allows for a single process input and a single process output, both isolated. An isolated transmitter power supply is also built in. Two relays are provided for watchdog and process alarm. An expansion I/O card offers a second process input with a transmitter PSU, a further analogue input and one analogue output. These may be software-configured to connect in a variety of ways to the available internal parameters — e.g. remote setpoint, track input, retransmitted process variable, etc. More flexibility is available via the four digital inputs and four digital outputs, which may be connected to mode-enable and alarm status fields, respectively. All such parameters and status fields, when not connected to the I/O terminals, may be modified from the front panel or a supervisory computer.

4 CONTROL CONFIGURATIONS

The flexibility offered by the I/O configurations available allows the controller to be configured as a manual station (see §4.1), a single-loop controller (§4.2), a dual-loop cascade controller (§4.3), a ratio controller (§4.4), and an override controller (§4.5).

4.1 Manual station

The manual station allows the unit to act as the output device to an externally-implemented hard-wired control signal — e.g. a DDC output. A basic manual station can be configured using only the main I/O board. In this case the input signal is tracked and output to the plant, with manual setting available to the operator. Alternatively, with the optional expansion I/O board fitted, a PV signal can also be monitored, displayed, retransmitted, and have absolute alarms applied to it.

4.2 Single-loop controller

Simple single-loop process control can be achieved with the basic I/O board only. Use of a hardwired remote setpoint requires the expansion I/O board, which also provides the necessary analogue and digital I/O for interlocking between separate master and slave units, to assure bumpless transfers. Alternatively the setpoint trim input allows offset of the process variable — in furnace applications for example.

4.3 Dual-loop cascade controller

This implementation is a classical two-loop cascade pair with full bumpless and procedureless auto/manual/remote switching. All the necessary interlocks are made internally when you select this option, so that wiring and configuration are very simple.

4.4 Ratio controller

The ratio controller implementation allows the controlled variable to follow an external input at a set ratio. The ratio station occupies one of the instrument's front-panel displays ('Loop 2') and the control loop occupies the other one ('Loop 1'). The controlled process variable can be viewed in Loop 1 and the external input — 'uncontrolled process variable' — viewed in Loop 2.

4.5 Override controller

The override controller has two control loops — 'main' and 'override' — working on different setpoints and process variables. Two separate calculated output values are produced, but only a single process output. The process output at any time is automatically supplied by the loop with the lower of the two calculated output values. An expansion I/O board is needed to provide the 'override' loop's process input.

5 ALARM HANDLING

The basic controller has both a watchdog relay output and a relay for process alarms. Use of the expansion I/O board provides additional high and low alarm outputs. Process alarms are indicated to the operator by flashing of the loop 1 and loop 2 alarm LEDs on the front panel. Unacknowledged absolute and deviation alarms cause flashing of the PV and SP bargraphs respectively.

Alarms may be acknowledged by pushbutton for the loop currently on display, and the alarm acknowledge status is also accessible via the communications. Alarm acknowledgement is configurable between automatic acknowledgement of cleared alarms, or pushbutton acknowledgement.

The alarm relay is fully configurable in software to be disabled, or to operate on either absolute alarms or both absolute and deviation alarms, and on either unacknowledged alarms or active alarms.

6 USER INTERFACE

The front panel's ergonomic layout (see Figure 1-1), with its clear alphanumeric displays, bargraphs and indicator lamps, keeps the operator well-informed on the state of the plant being controlled.

In 'operator mode', basic parameters are immediately accessible and adjustable via the pushbuttons, while access to control configuration parameters in 'engineer mode' is protected by two levels of passcode. Parameterisation via the front panel is straightforward and intuitive.

7 COMMUNICATIONS

The controller offers Modbus communications using RS422 (5-wire) or RS485 (3-wire) standards, enabling it to be easily integrated as a slave into a supervisory control environment. Configuration of the controller can also be carried out via the regular Modbus comms, or using a PC and a special RJ11 configuration socket inside the unit.

8 CONTENTS OF THIS MANUAL

Table 1-1 summarises the contents of this *Process Controller Reference Manual & User Guide*. Use the *Table of Contents* at the beginning of the manual for a more detailed breakdown of what's in the individual chapters. Use the *Index* and separate *Parameter Index* at the back to help you locate a particular topic or parameter.

Chapter	Topics
1 Introduction	Summary of the Process Controller's features
2 Installation & startup	Getting the controller up and running, from unpacking to powerup. Example I/O circuits
3 Using the front panel	Using front panel displays & pushbuttons to carry out all basic operations & parameter access
4 Configuration	Front-panel configuration — selecting controller type, configuring I/O, parameterising loops
5 Control operating modes	Control modes supported, explanation of mode priorities and selection
6 Single-loop controller	Overviews of the single-loop controller, I/O, modes, parameters, and setup sheet master
7 Dual-loop cascade controller	Overviews of the cascade controller, I/O, modes, parameters, and setup sheet masters
8 Ratio controller	Overviews of the ratio controller, I/O, modes, parameters, and setup sheet master
9 Manual station	Overviews of the manual station, I/O, modes, parameters, and setup sheet master
10 Incremental control	Incremental control I/O, modes, user interface, parameters, and sensor break action
11 Override controller	Overviews of the override controller, I/O, modes, parameters, and setup sheet masters
12 Tuning	Explanation of tuning, performing automatic tuning, and tuning 'by hand'
13 Calibration	Calibrating the I/O — equipment requirements and parameters used
14 Serial communications	Modbus communications — implementation, latency calculations, connecting to hardware
15 Network communications	(*not yet available*)
16 Error conditions	Instrument errors reported at powerup and by diagnostic parameters, plant alarms handling
17 Specifications	Hardware & software specifications
18 Ordering information	How to order the Process Controller and its options
Appendices A, B, C	Detailed schematics of signal flow via the controller and its interaction with loop parameters
Parameter index	Index of parameter mnemonics
Index	Index of all topics and parameter mnemonics in the manual

Table 1-1 Topics covered by this manual

Chapter 2 INSTALLATION & STARTUP

This chapter presents important safety and EMC information and describes how to install, configure, and power up your controller.

The main topics covered are:

- Safety & EMC information (§1)
- Unpacking (§2)
- Installation (§3)
- Connections & wiring (§4)
- Example I/O circuits (§5)
- Powerup (§6).

1 SAFETY & EMC INFORMATION

Please read this section before installing the controller.

This unit meets the requirements of the European Directives on Safety and EMC. However, it is the responsibility of the installer to ensure the safety and EMC compliance of any particular installation.

1.1 Installation requirements for EMC

This unit conforms with the essential protection requirements of the EMC Directive 89/336/EEC, amended by 93/68/EEC, by the application of a technical construction file.

This unit satisfies the emissions and immunity standards for industrial environments.

To ensure compliance with the European EMC directive certain installation precautions are necessary as follows:

- **General guidance.** For general guidance refer to the Eurotherm Process Automation *EMC Installation Guide* (Part No. HG 083 635 U001).
- **Relay outputs.** When using relay or triac outputs it may be necessary to fit a filter suitable for suppressing the conducted emissions. The filter requirements will depend on the type of load. For typical applications we recommend Schaffner FN321 or FN612.
- **Use with standard mains socket.** If the unit is plugged into a standard power socket, it is likely that compliance to the commercial and light industrial emissions standard is required. In this case to meet the conducted emissions requirement, a suitable mains filter should be installed. We recommend Schaffner types FN321 and FN612.

- **Routing of wires.** To minimise the pickup of electrical noise, the low voltage DC connections and the sensor input wiring should be routed away from high-current power cables. Where it is impractical to do this, use shielded cables with the shield grounded. Refer to the *EMC Installation Guide*, section 5.6, for guidance.

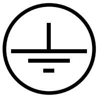
1.2 Installation safety requirements

This controller complies with the European Low Voltage Directive 73/23/EEC, amended by 93/68/EEC, by the application of the safety standard EN61010-1:1993/A2:1995.

1.2.1 Personnel

Installation must be carried out only by authorised personnel.

1.2.2 Protective earth connection



NOTE. A *protective* earth terminal (see symbol inset), in contrast to a *functional* earth terminal, is one that is bonded to conductive parts of an equipment for safety purposes and is intended to be connected to an external protective earthing system.

The following safety measures should be observed:

- Before any other power input connection is made, the protective earth terminal shall be connected to an external protective earthing system.
- Whenever it is likely that protection has been impaired, the unit shall be made inoperative. Seek advice from the nearest manufacturer's service centre.
- The mains supply wiring must be terminated in such a way that, should it slip in the cable clamp, the earth wire is the last wire to become disconnected.

WARNING!

Any interruption of the protective conductor inside the unit, or of the external protective earthing system, or disconnection of the protective earth terminal, is likely to make the unit dangerous under some fault conditions. Intentional interruption is prohibited.

1.2.3 Wiring

It is important to connect the controller in accordance with the wiring data given in this handbook. Wiring installations must comply with all local wiring regulations. Any wiring that is 'Hazardous Live' (as defined in EN61010) must be adequately anchored.

1.2.4 Disconnecting device

In order to comply with the requirements of safety standard EN61010, the unit shall have one of the following as a disconnecting device, fitted within easy reach of the operator, and labelled as the disconnecting device for the equipment:

- A switch or circuit breaker complying with the requirements of IEC947-1 and IEC947-3
- A separable coupler that can be disconnected without the use of a tool
- A separable plug, without a locking device, to mate with a socket outlet in the building.

1.2.5 Overcurrent protection

To protect the unit against excessive currents, the AC power supply to the unit and power outputs must be wired through independent external fuses or circuit breakers. A minimum of 0.5mm^2 or 16awg wire is recommended. Use independent fuses for the instrument supply and each relay output. Suitable fuses are T type, (IEC 127 time-lag type) as follows;

- Instrument supply: 85 to 264Vac, 2A, (T).
- Relay outputs: 2A (T).

1.2.6 Installation category voltages

The unit should not be wired to a three phase supply with an unearthed star connection. Under fault conditions such a supply could rise above 264Vac with respect to ground and the unit would not be safe.

Voltage transients across the power supply connections, and between the power supply and ground, must not exceed 2.5kV. Where occasional voltage transients over 2.5kV are expected or measured, the power installation to both the instrument supply and load circuits should include transient limiting devices, e.g. using gas discharge tubes and metal oxide varistors.

1.2.7 Conductive pollution

Electrically conductive pollution (e.g. carbon dust, water condensation) must be excluded from the cabinet in which the unit is mounted. To ensure the atmosphere is suitable, install an air filter in the air intake of the cabinet. Where condensation is likely, for example at low temperatures, include a thermostatically controlled heater in the cabinet.

1.2.8 Ventilation

Ensure that the enclosure or cabinet housing the unit provides adequate ventilation/heating to maintain the operating temperature of the unit within the limits indicated in the Specification (see Chapter 17).

1.2.9 Electrostatic discharge handling precautions

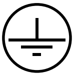
Caution

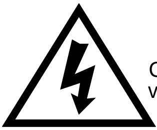
Electrostatic sensitivity. Some circuit boards inside the unit contain electrostatically sensitive components. To avoid damage, before you remove or handle any board ensure that you, the working area, and the board are electrostatically grounded. Handle boards only by their edges and do not touch the connectors.

1.2.10 Safety symbols marked on the unit

Various safety/warning symbols are marked on the unit, which have the following meanings:

 Caution! Refer to the Product Manual

 Protective earth terminal

 Caution! Mains voltages present

 Alternating current

 Direct current

1.3 Keeping the product safe

To maintain the unit in a safe condition, observe the following instructions.

1.3.1 Misuse of equipment

Note that if the equipment is used in a manner not specified in this handbook the protection provided by the equipment may be impaired.

1.3.2 Service and repairs

This unit has no user-serviceable parts. Contact your nearest Eurotherm Process Automation agent for repair.

1.3.3 Cleaning instructions

Use a suitable antistatic vacuum cleaner to keep the unit and all associated air inlets/outlets clear of dust buildup. Wipe the front panel with a damp cloth to keep it clean and the operator legends and displays clearly visible. Mild detergents may be used to remove grease, but do not use abrasive cleaners or aggressive organic solvents.

2 UNPACKING

Unpack the instrument and accessories carefully and inspect the contents for damage. Keep the original packing materials in case re-shipment is required. If there is evidence of shipping damage, please notify the supplier or the carrier within 72 hours and retain the packaging for inspection by the manufacturer's and/or carrier's representative.

2.1 Handling precautions

Caution

Electrostatic sensitivity. Some circuit boards inside the unit contain electrostatically sensitive components. To avoid damage, before you remove or handle any board ensure that you, the working area, and the board are electrostatically grounded. Handle boards only by their edges and do not touch the connectors.

2.2 Package contents

Check the package contents against your order codes, using the labels on the components to help you. Product labelling includes:

- Outer packaging label. Shows the full instrument order code, instrument serial number, and build level.
- Antistatic bag label. Shows the same data as the outer packaging label.
- Sleeve labels. Two labels, one outside and one inside showing the sleeve order code and sales order number.
- Instrument label. One on the instrument, with the same data as the outer packaging label.

3 INSTALLATION

3.1 Dimensions

Figure 2-1 shows the DIN-size aperture needed for panel-mounting the unit. Also shown are the overall dimensions, the mounting clamps, panel section, terminal cover, and the access for cabling.

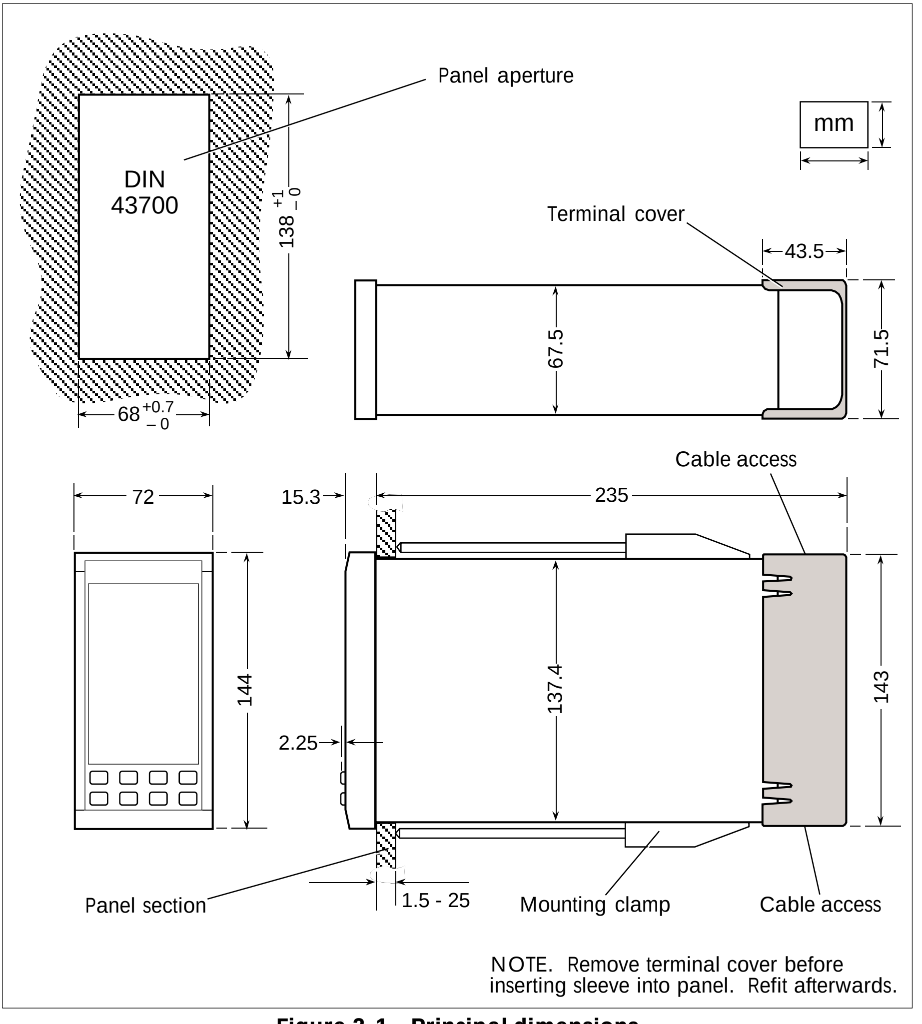


Figure 2-1 Principal dimensions

3.2 Mechanical layout

Figure 2-2 shows an ‘exploded’ overview of the unit’s mechanical layout.

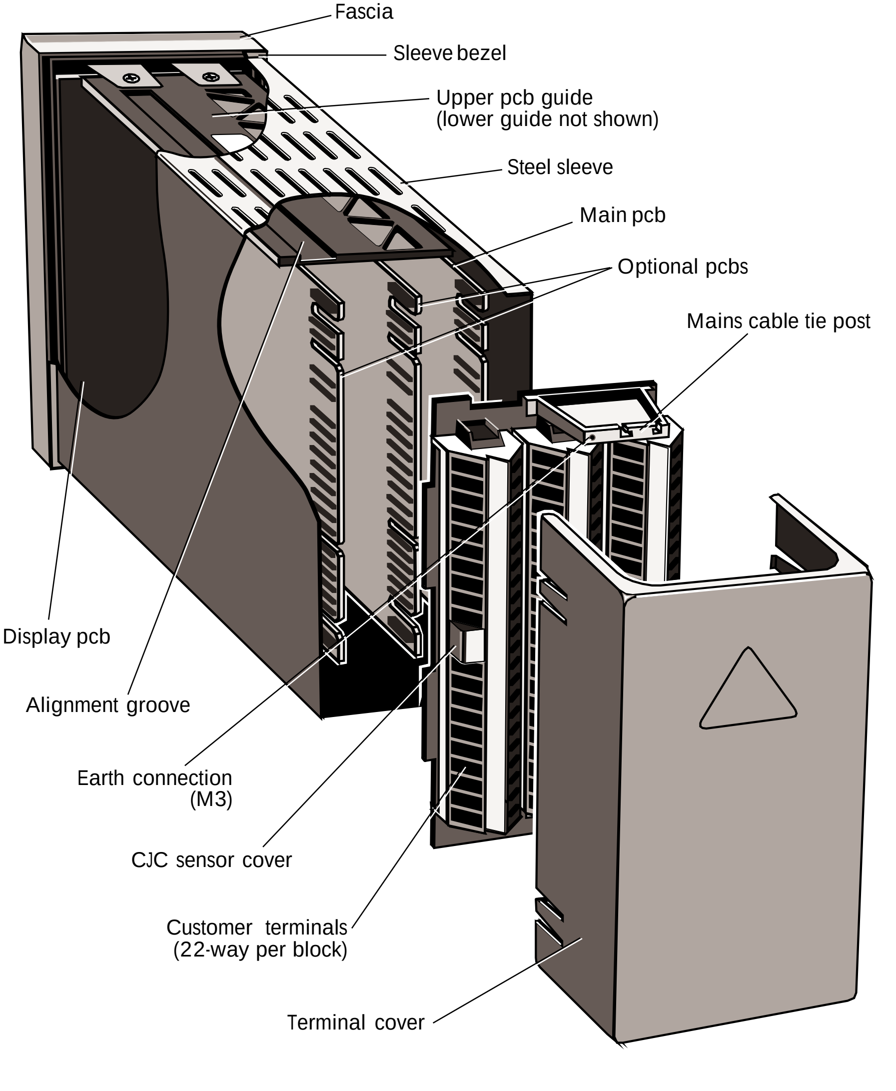


Figure 2-2 Exploded view of unit’s mechanical layout — major components

The instrument's pcbs are held between a pair of plastic pcb guides — upper and lower — which are attached to the fascia/display pcb assembly. The whole assembly slides into a steel sleeve, aligned by a groove in each of the pcb guides. The pcb connectors mate with a set of up to three 22-way customer terminals fitted to the panel at the rear of the sleeve. The terminals are protected by a plastic terminal cover that snap-fits onto the sleeve allowing cable access top and bottom. The main pcb mates with the rightmost terminal block, viewed from the rear, and any further (optional) pcbs mate with the central and the leftmost terminal blocks. Unused block positions may be fitted with blanking plates — see §3.3. Special covers are supplied to protect cold junction compensation sensor terminals where applicable. Two mains cable tie posts are provided, one at the top and the other at the bottom of the terminal blocks. Threaded holes (M3) for earth connections are also provided next to each tie post.

The sleeve is intended for panel- or rack-mounting in a DIN-sized cutout for 144 × 72 mm instruments. The controller can then be removed and replaced from the front of the panel — under power — without disturbing the wiring.

With the sleeve mounted in a panel and the controller in place, the seal from the front of the panel meets IP65 and NEMA4. See §3.3 for more information.

3.3 Panel mounting

Units may be panel-mounted either to IP65 standard (see §3.3.1) or to a non-IP65 standard (see §3.3.2). IP65 standard is achieved by adhering to the permitted instrument spacing and mounting density, panel flatness and finish, blanking plate specification, and by using the approved panel gaskets. This section details these requirements, and describes how to remove the customer terminal cover (§3.3.3), clamp the sleeve in the panel aperture (§3.3.4), and remove a clamp if required (§3.3.5).

3.3.1 Mounting to IP65 standard

To ensure IP65 standard:

- Each sleeve must be mounted in its own singular DIN43700-sized aperture. See Figure 2-3 for details of the aperture dimensions.
- There must be a minimum of 14mm horizontal spacing between adjacent panel apertures, to allow substitution of IP65 standard blanking plates where sleeves are not fitted, and a minimum of 24mm vertical spacing between adjacent apertures.
- A panel gasket must be fitted between the panel and the sleeve to provide adequate sealing when the clamps are tightened to the correct torque (0.6Nm maximum). Figure 2-4 shows the gasket in position, and also a clamping collar.
- A clamping collar (Part No. LA083377) must be used to reinforce thin (<1.5mm) and/or low-strength panels. See Figure 2-4.
- The panel must be flat with a smooth paint finish.
- T962 IP65 blanking plates must be fitted in unoccupied panel apertures.
  Figure 2-3 shows blanking plate dimensions for IP65 (T962) and non-IP65 (T961).

- The fascia lever handle must be snapped completely shut to lock the unit in its sleeve and ensure adequate fascia-to-sleeve sealing. See Figure 2-9 in §3.5.

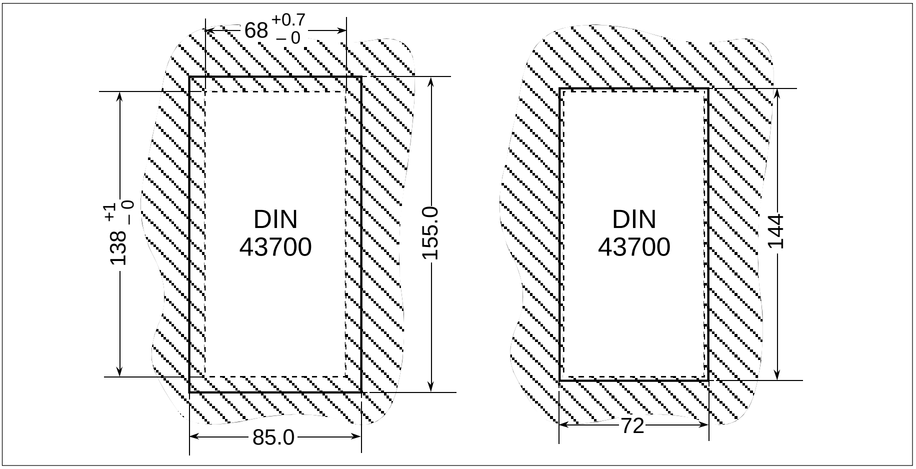


Figure 2-3 Blanking plate dimensions — IP65 (left) & non-IP65 (right)

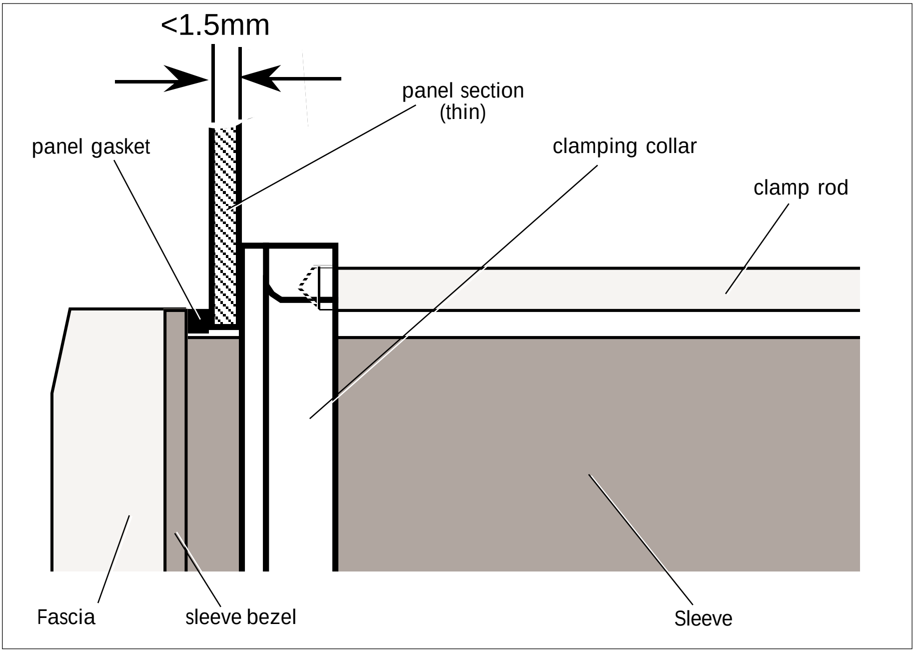


Figure 2-4 Detail of panel gasket and clamping collar (thin panels)

3.3.2 Mounting to non-IP65 standard

For non-IP65 applications:

- Sleeves may be mounted side-by-side in multiple-way apertures. Figure 2-5 shows an example of five DIN43700 instruments and one T961 blanking plate mounted in a T960 19” rack frame adapter.
- Non-IP65 blanking plates (T961) may be used for empty single apertures or empty locations in multiple-way apertures (see Figure 2-5).
- Clamping collars are recommended but not mandatory for thin and/or weak panels (see Figure 2-4).

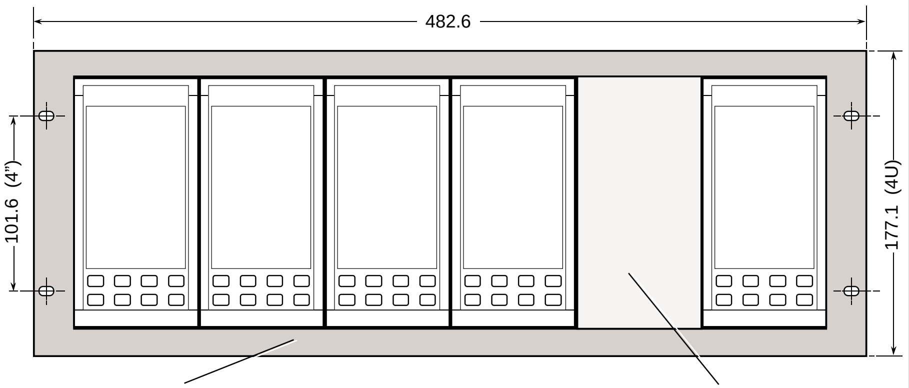


Figure 2-5 Using a multi-way panel aperture for non-IP65 applications

3.3.3 Terminal cover removal

The customer terminal cover at the rear of the sleeve must be removed before the sleeve can be panel-mounted; this is described first.

Refer to Figure 2-6. Grasp the top of the terminal cover at one of its upper corners and pull it firmly to detach one of the four spring clips holding it in position. It will then be easy to remove the entire cover by pulling at its top centre to lever it off. Refitting the cover is the reverse procedure.

3.3.4 Clamping the sleeve in the panel

Insert the sleeve in the aperture and fit the two clamps as shown in Figure 2-7. To fit a clamp, position it flat on the sleeve, locating the hook in the slot. Slide the clamp away from the panel to engage the hook firmly, and snap the two feet into the two small recesses. Screw the clamp rod in to hold the sleeve lightly in position. Fit the second clamp in the same way. Finally, tighten up both clamps to exert a moderate retaining force. To avoid panel distortion, do not overtighten. The maximum recommended torque is 0.6Nm.

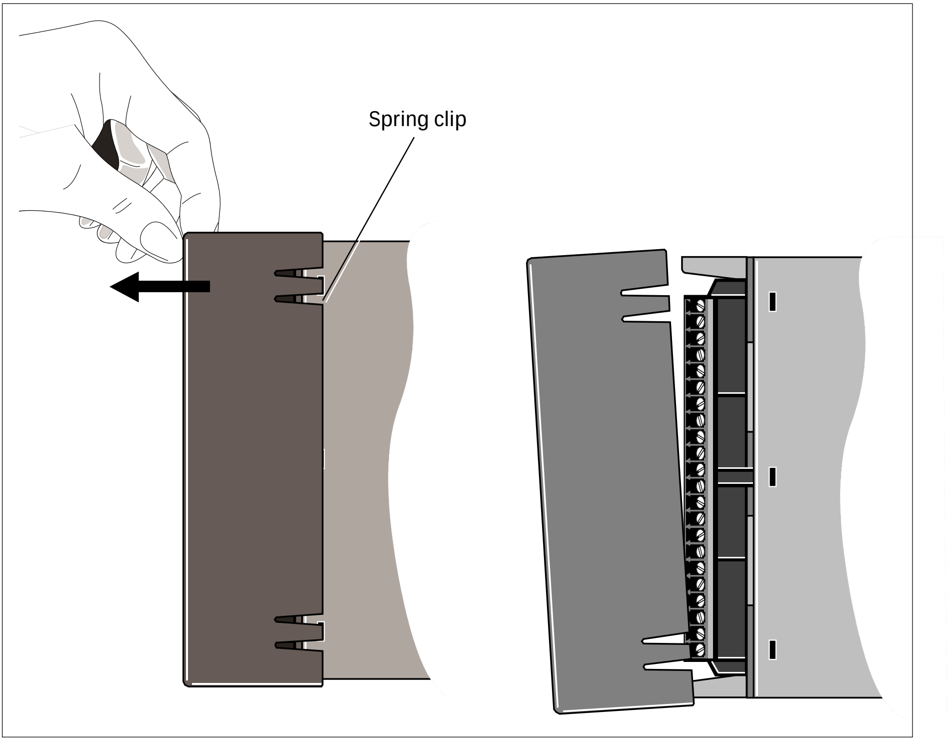


Figure 2-6 Removing the terminal cover

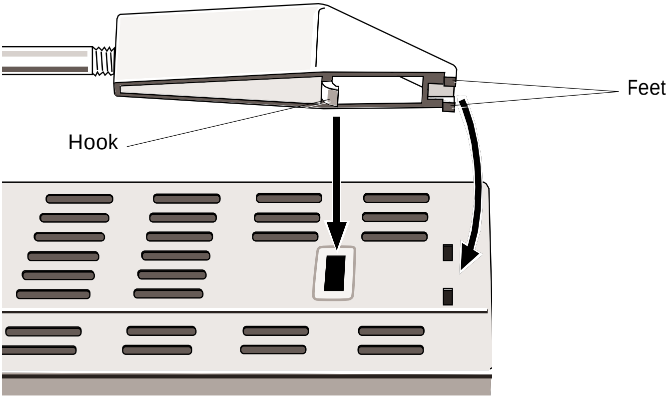


Figure 2-7 Fitting a clamp to the sleeve

3.3.5 Clamp removal

See Figure 2-8. If you want to remove a clamp, slacken it off by at least 2mm and insert a screwdriver blade between the feet at the end of the clamp body. **Lift** the screwdriver handle to lever the clamp towards the panel and disengage it. **Do not press downwards** — this could cause damage!

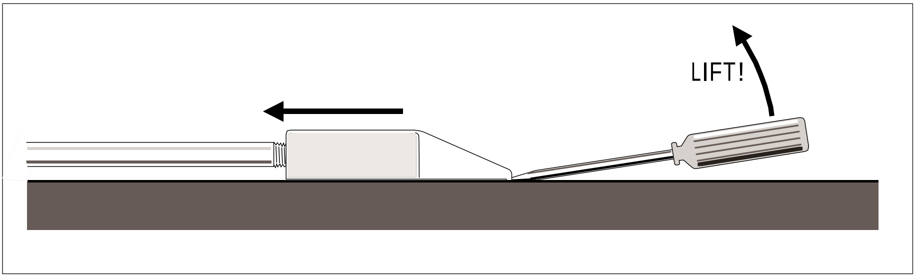


Figure 2-8 Removing a clamp from the sleeve

3.4 Removing the unit from its sleeve

Withdrawing the unit from its sleeve is done entirely from the front of the mounting panel, without disturbing any of the system wiring.

Caution

Repeated removal/replacement of the unit under power erodes the connectors.
Anti-static precautions must be observed when handling the unit out of its sleeve.

See Figure 2-9. To unlock the unit, pull the bottom of the lever handle away from the mounting panel to release it from its spring clips (1), then swing the handle upwards (2) to a nearly horizontal position. This action levers the unit out of its sleeve by about 1cm. Keeping your thumb on the front panel during this operation — see figure — makes it easier and more controllable. Withdraw the unit completely by steadily pulling on the lever handle (3).

3.5 Replacing the unit in its sleeve

See Figure 2-9. Insert the unit into the sleeve, engaging the grooves along the upper and lower plastic guides with the sleeve guides. Slide the unit almost completely into the sleeve until the fascia meets the sleeve hook. Then raise the lever handle and push the unit further into the sleeve to engage the horn at the end of the handle with the sleeve hook. Complete the operation by closing the lever handle and snapping it shut onto its spring clips. Note that a proper IP65 seal will not be established between the unit and sleeve unless this is done.

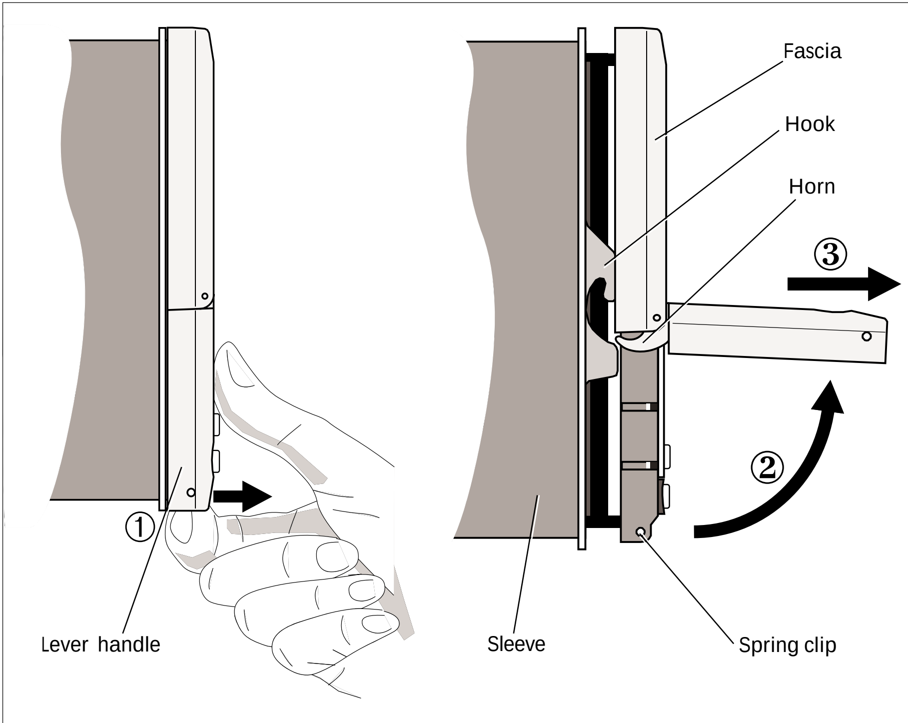


Figure 2-9 Withdrawing the unit from the sleeve

4 CONNECTIONS & WIRING

Electrical connections to the unit are made via (up to) three blocks of customer screw terminals at the rear of the sleeve, protected by a terminal cover — see Figure 2-2. Wiring can pass through the openings in the top and base of the terminal cover. All connections are low current and a 16/0.20 cable size is adequate. The maximum cable size for these terminals is 2.5mm^2. 'Bootlace' type ferrules are strongly recommended.

Power input. The instrument supply should be fused externally in accordance with local wiring regulations. The mains option accepts 90 - 265 Vac, 45 - 65 Hz, the DC option 19 - 55 Vdc. Power input depends on the application and configuration, and on the I/O cards fitted, but is a nominal maximum of 25VA per instrument. Please refer to Chapter 17, *Specifications*, for further details.

4.1 Terminals

Figure 2-10 shows an example of the rear-panel terminals. Other configurations are possible depending on the options ordered. The figure shows the main board terminal block on the righthand side, and an optional Slot 1 I/O terminal block. Slot 2, on the lefthand side of the rear panel, is shown blanked off. Upper and lower supply input cable tie posts and earth screw terminal holes, and terminal identification labels are also shown. Connect a good local earth to the M3 screw terminal(s).

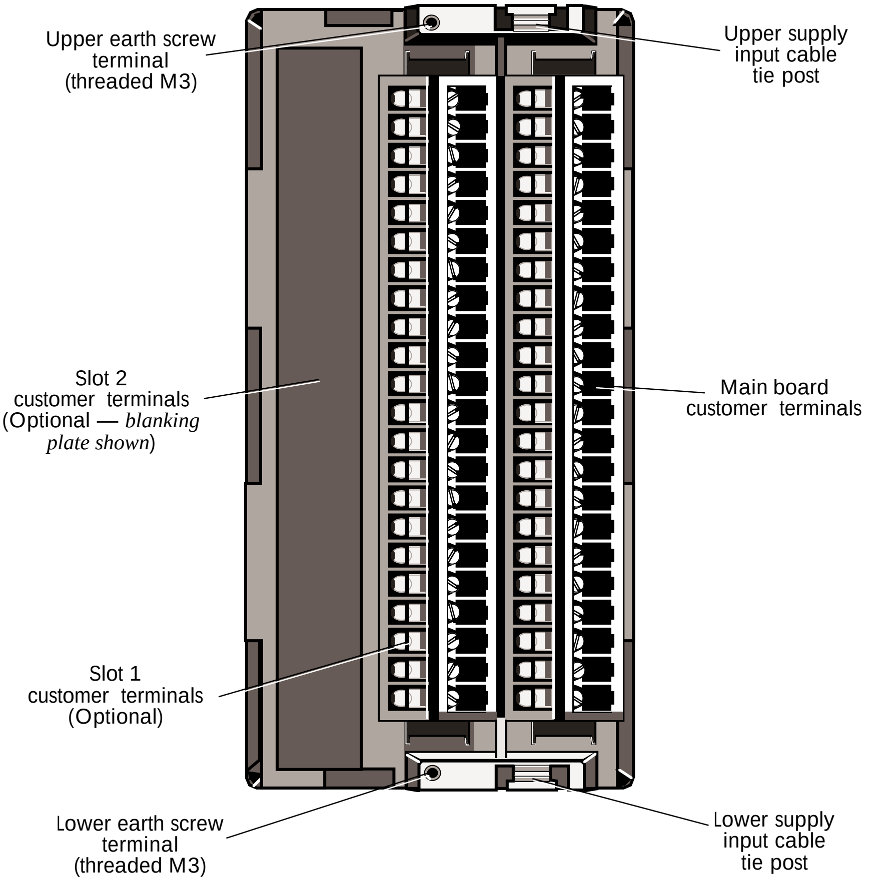


Figure 2-10 Rear-panel terminals (example)

4.2 Terminal designations

4.2.1 Main boards

Tables 2-1 and 2-2 show the terminal designations for the MAINS option main board and the DC option main board, respectively. How these terminals connect to instrument's internal circuitry is shown in §§4.3 to 4.6. Allocating I/O terminals to specific control parameters and configuring action on input break, ranging, linearisation, filtering, and limiting is described in Chapter 4, *Configuration.*

Terminal	Designation
01	Internal ground*
02	Internal ground*
L	Mains live
N	Mains neutral
09	Transmitter PSU +
10	Transmitter PSU –
11	CJC sensor†
12	CJC sensor†
13	Process input V+
14	Process input V–
15	Process input RTD
16	Process output +
17	Process output –
18	Watchdog relay
19	OPEN = fail
20	Alarm relay
21	OPEN = fail
22	(*Not connected*)

**Do not connect!* †*Way occupied by sensor*

Table 2-1 MAINS option main pcb terminals

Terminal	Designation
01	Internal ground*
02	Internal ground*
+	DC input +
–	DC input –
09	Transmitter PSU +
10	Transmitter PSU –
11	CJC sensor†
12	CJC sensor†
13	Process input V+
14	Process input V–
15	Process input RTD
16	Process output +
17	Process output –
18	Watchdog relay
19	OPEN = fail
20	Alarm relay
21	OPEN = fail
22	(*Not connected*)

**Do not connect!* †*Way occupied by sensor*

Table 2-2 DC option main pcb terminals

Terminal	Function
23	
24	Digital I/P Bit 0 — Hold select
25	Digital I/P Bit 1 — Track select*
26	Digital I/P Bit 2 — Remote enable
27	Digital I/P Bit 3 — (*Unallocated user bit*)
28	Digital O/P Bit 4 — NOT(Hold OR Manual)*
29	Digital O/P Bit 5 — NOT(Remote Auto)
30	Digital O/P Bit 6 — NOT(High Alarm)*
31	Digital O/P Bit 7 — NOT(Low Alarm)*
32	Digital ground
33	CJC sensor†
34	CJC sensor†
35	Process input V+
36	Process input V–
37	Process input RTD
38	Analogue input
39	Analogue ground
40	Analogue output
41	Analogue ground
42	Transmitter PSU +
43	Transmitter PSU –
44	

**Altered function if incremental control selected — see Ch10 §2.1* *†Way occupied by sensor*

Table 2-3 Expansion I/O customer terminals

4.2.2 Expansion I/O board option

Table 2-3 shows terminal designations for the expansion I/O board option, fitted to Slot 1 as an option (central terminal block). How these terminals connect to instrument's internal circuitry is shown in §§4.7 and 4.8. See Chapter 4 for details on terminal allocation and I/O configuration.

4.2.3 RS422/485 (MODBUS) communications option

Table 2-4 shows terminal designations for the RS422/485 (MODBUS) half-board option, fitted to Slot 2 — the left-most terminal block. §4.9 shows the option board schematic, and Chapter 14, *Serial communications*, gives information on using Modbus and RS485.

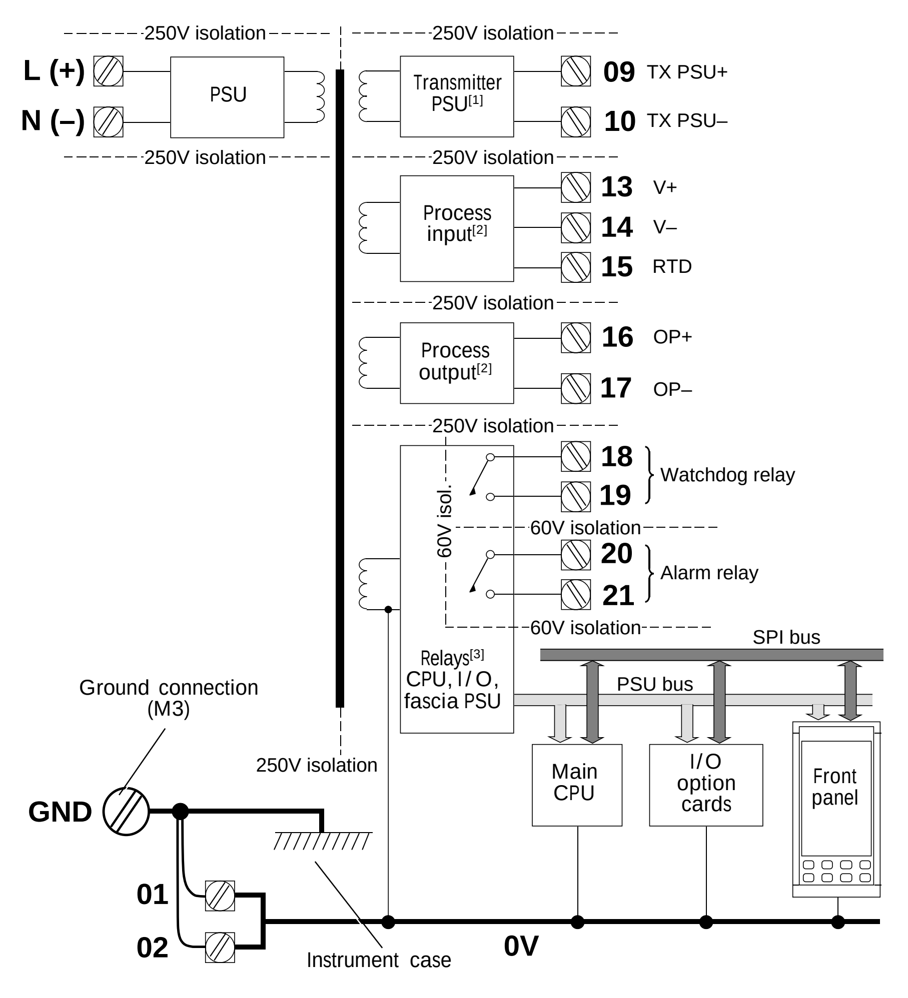
Terminal	Function
58	RFI ground
59	RS422 TX –
60	RS422 TX +
61	
62	RS422 common
63	+5V (@ 5mA±5%)
64	RS422 RX – (& RS485 –)*
65	RS422 RX + (& RS485 +)*
66	RFI ground

*Link for RS485 3-wire operation

Table 2-4 RS422/485 (MODBUS) option board customer terminals

4.3 Zero volts schematic

Figure 2-11 shows schematically the unit's internal zero volts and isolated power supply arrangements, and associated customer screw terminals on the main pcb. Isolated windings feed the transmitter power supply (see Figure 2-12), and process input/output (Figure 2-13). Another winding supplies the main CPU, I/O option card(s), and front panel via a power supply bus. The alarm and watchdog relay outputs (Figure 2-14) are supplied from the same winding. The mains earth terminal connects directly to the instrument case.



[1] *See Figure 2-12.* [2] *See Figure 2-13.* [3] *See Figure 2-14.*

Figure 2-11 Internal zero volts & power supplies schematic

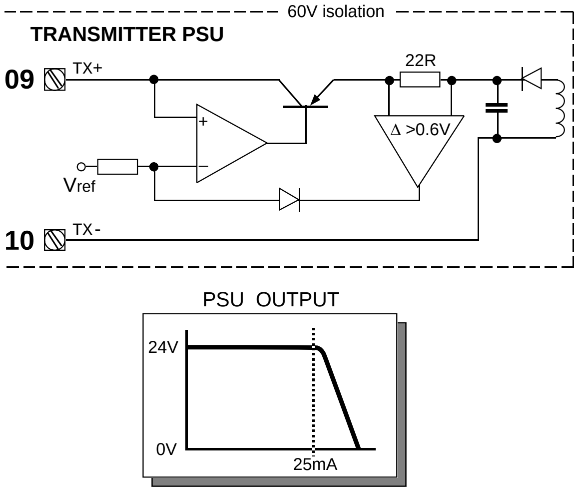


Figure 2-12 Transmitter power supply schematic with output characteristic

4.4 Transmitter power supply schematic

Figure 2-12 shows the transmitter power supply schematically, and associated customer screw terminals. The PSU output characteristic is also shown.

4.5 Main board process I/O schematic

Figure 2-13 shows the main board process inputs/outputs schematically, with associated customer screw terminals. In the schematic, the DSM is a Delta-Sigma Modulator, the IOC is an Input/Output Controller, and the DFC is a Digital Filter Circuit. The SPI bus is the Serial Peripheral Interface communicating with the main CPU, the front panel, and any I/O option cards.

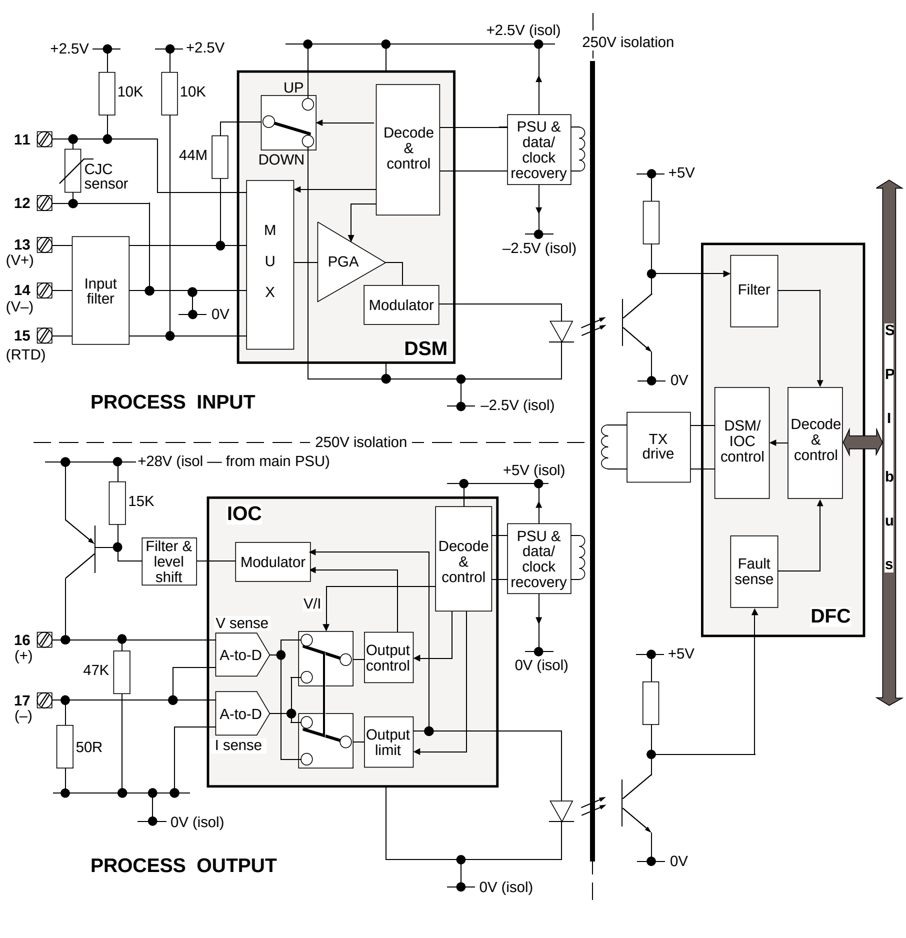


Figure 2-13 Main board process input/output schematic

4.6 Watchdog & alarm relays schematic

Figure 2-14 shows the watchdog and alarm relay schematic, and associated customer terminals. The relays are isolated from the rest of the circuit.

4.7 Expansion board analogue I/O schematic

Figure 2-15 shows the expansion I/O board process inputs and analogue I/O schematically, with associated customer screw terminals. See §4.5 for an explanation of the abbreviations used in the schematic.

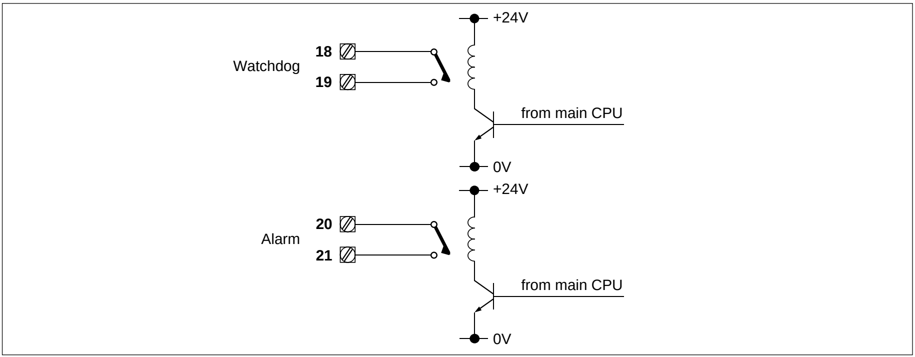


Figure 2-14 Relay outputs schematic

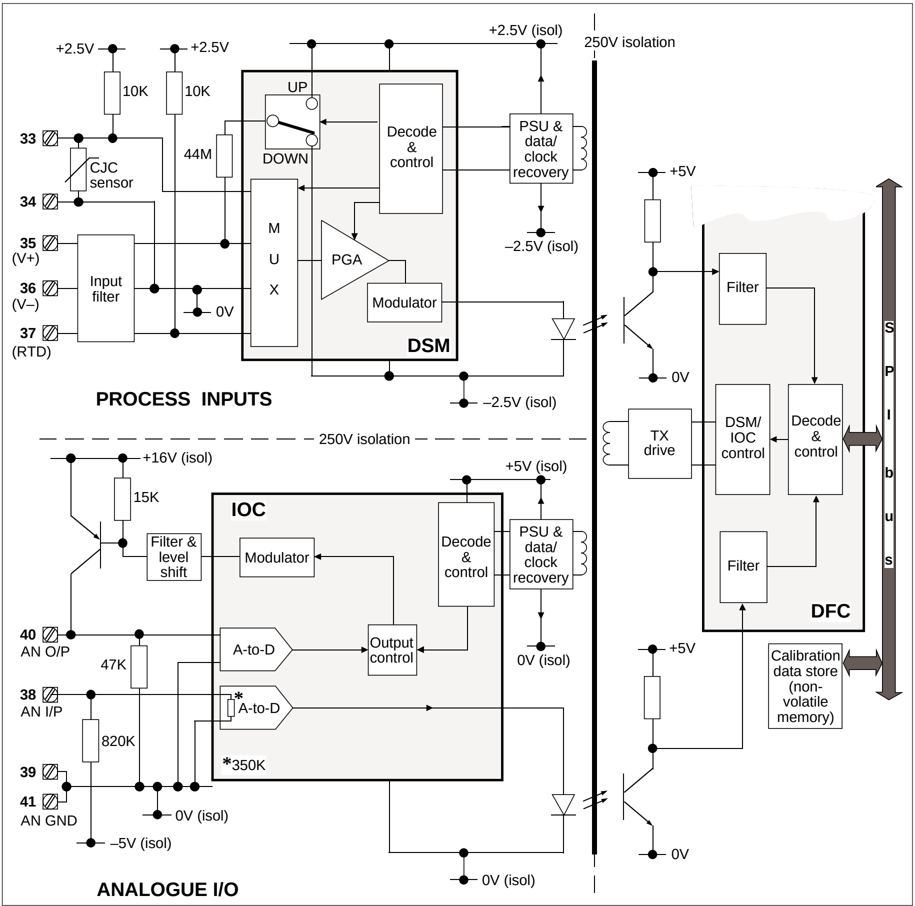


Figure 2-15 Expansion board process inputs & analogue I/O schematic

4.8 Expansion board digital I/O schematic

Figure 2-16 shows the expansion I/O board digital I/O and transmitter power supply schematically, with associated customer screw terminals. See §4.5 for an explanation of the abbreviations used in the schematic. Note that the DFC and SPI bus are shared with those shown in Figure 2-15.

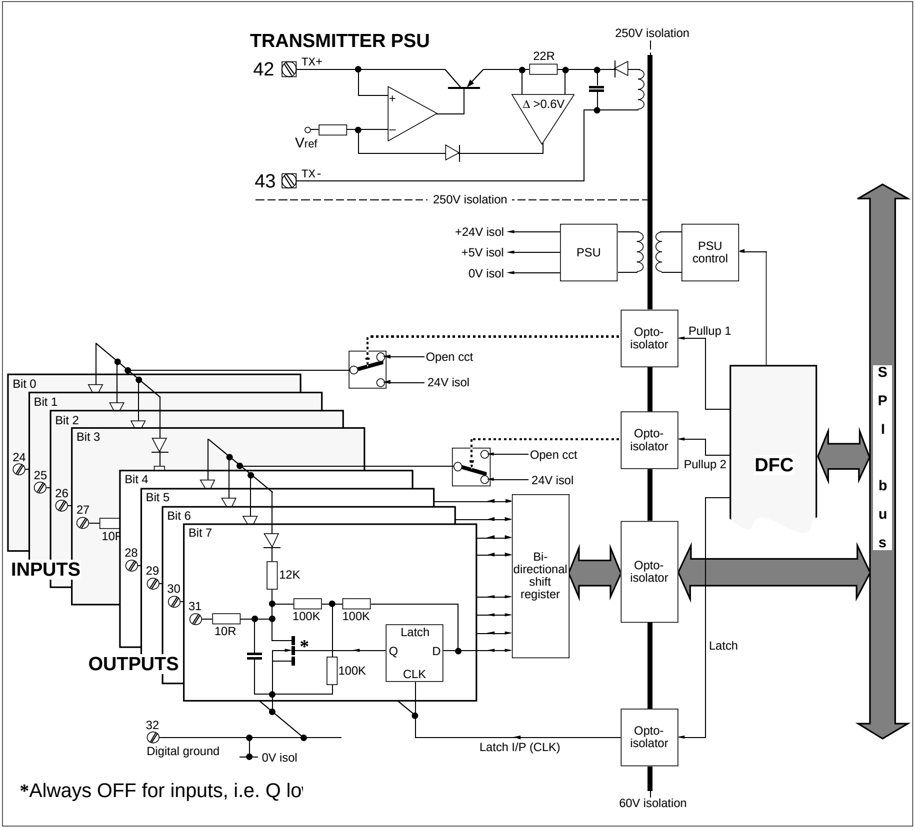


Figure 2-16 Expansion board digital I/O and transmitter power supply schematic

4.9 RS422/485 option board schematic

Figure 2-17 shows the RS422/485 serial communications option board schematic, and associated customer terminals.

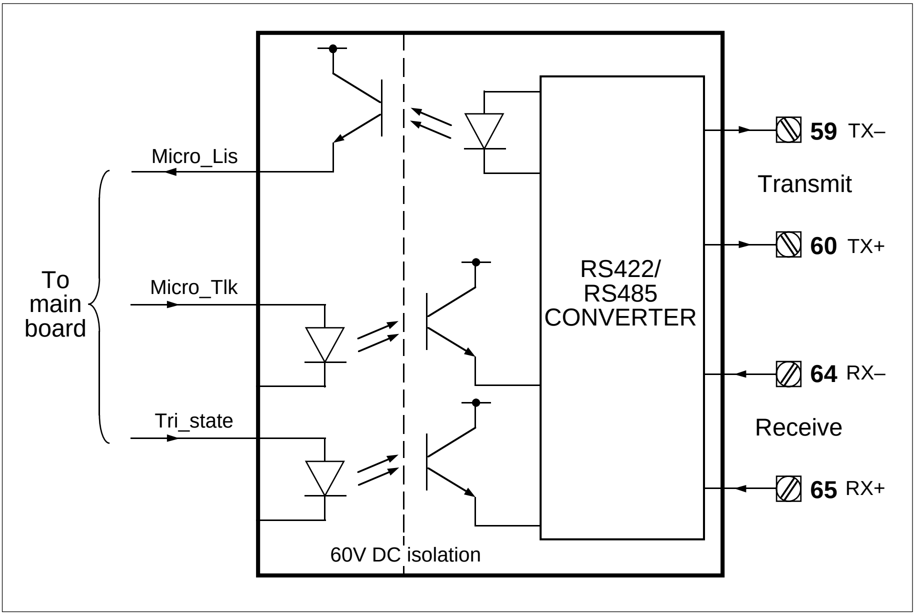


Figure 2-17 RS422/485 option board schematic

5 EXAMPLE I/O CIRCUITS

Figures 2- 18 to 2-31 in this section show you some basic examples of how to connect up the unit's I/O. Note that these are examples only. Where two sets of terminals are available, the bracketed numbers apply to the optional expansion I/O board.

5.1 Process inputs

5.1.1 mV/V/mA inputs

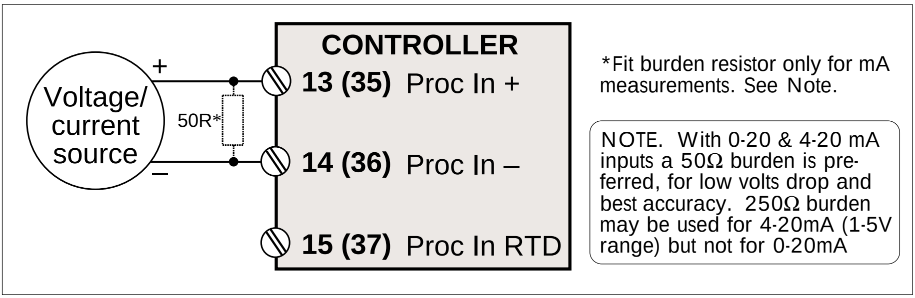


Figure 2-18 mV/V/mA process input example

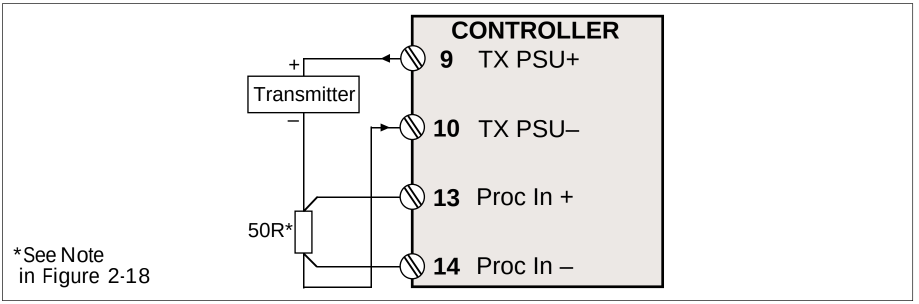


Figure 2-19 Transmitter PSU example

5.1.2 Thermocouple input

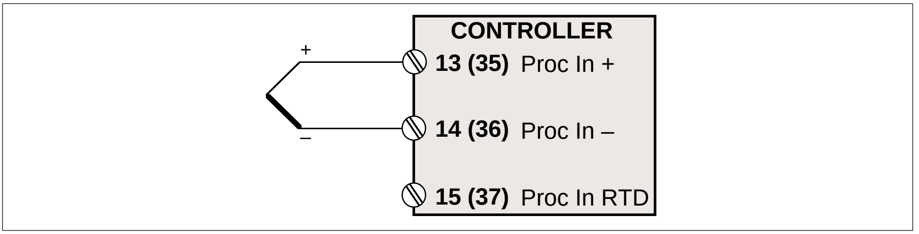


Figure 2-20 Thermocouple process input example

5.1.3 RTD inputs

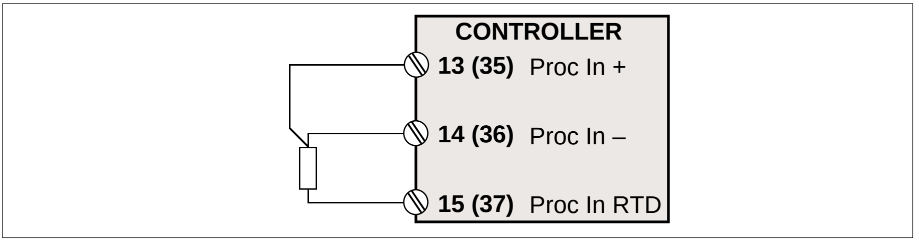


Figure 2-21 RTD (3-wire) process input example

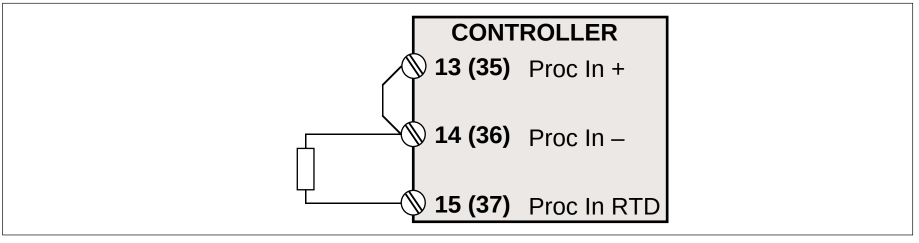


Figure 2-22 RTD (2-wire) process input example

5.2 Process output

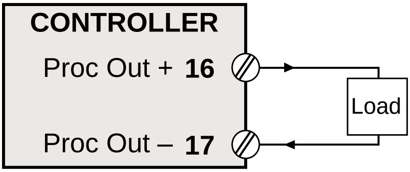


Figure 2-23 Process output example (current output)

5.3 Analogue input

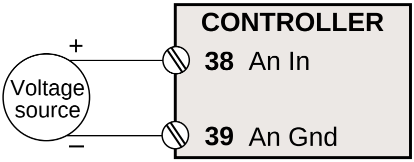


Figure 2-24 Analogue input example (voltage input)

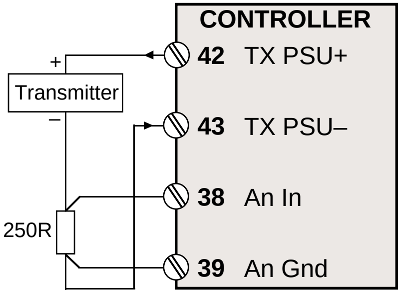


Figure 2-25 Transmitter PSU example — expansion I/O

5.4 Analogue output

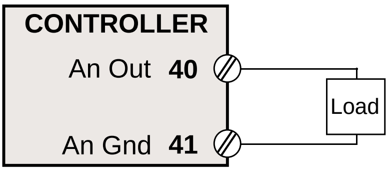


Figure 2-26 Analogue output example

5.5 Digital inputs

5.5.1 Contact sense input

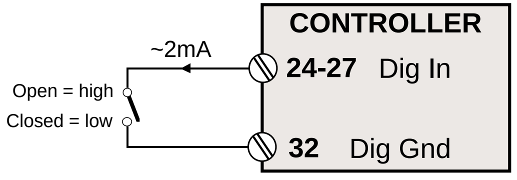


Figure 2-27 Contact sensing input example (software set for internal pullup)

5.5.2 Logic input

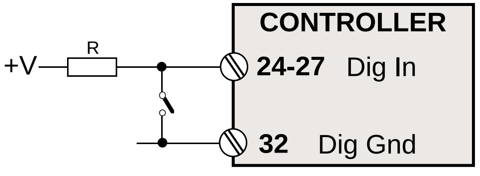


Figure 2-28 Logic input example (software set for external pullup)

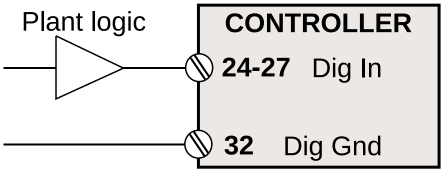


Figure 2-29 Logic input example (software set for external pullup)

5.6 Digital outputs

5.6.1 Logic output

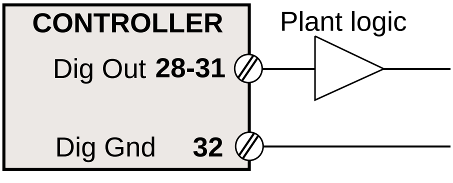
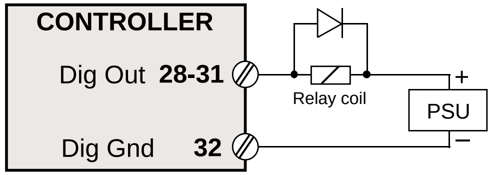


Figure 2-30 Logic output example (software set for internal pullup)

5.6.2 Relay output



NOTE. Low output operates relay

Figure 2-31 Relay output example (software set for external pullup)

6 POWER-UP

This section describes what happens when you power up the instrument. (For full details of all the front-panel displays and controls, refer to Chapter 3, *Using the front panel*.)

1 When you first apply power, the front panel remains blank (no LEDs lit) for a very short period — up to 1 second.

2 Then a series of three self-tests is performed in very quick succession. Progress is indicated by the first three full digits in the red $4^{1}/_{2}$-digit display. The central bars of these digits light up incrementally from left to right as each test is started.

The tests performed are:

- **RAM test** — denoted by the first bar lighting. If this test fails the message **Er01** appears.
- **MASK test** — denoted by the first and second bars being lit. The fail message is **Er02**.
- **ROM test** — denoted by all three bars lit. The fail message is **Er03**.

Figure 2-32 shows the appearance of the $4^{1}/_{2}$-digit display during the ROM test.

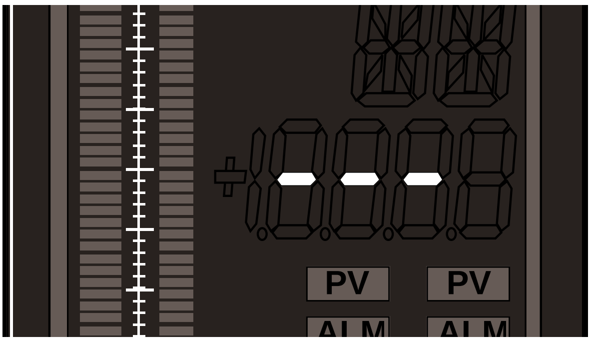


Figure 2-32 Self-test indications on the $4^{1}/_{2}$-digit display — ROM test running

3 Next, all the LEDs on the front panel light up simultaneously for a period of about 2 seconds, during which time you can verify their correct functioning.

NOTE. *If the unit fails any of these tests, contact the factory.*

4 Finally, the unit starts to run the control strategy that was running when it was last powered down, with all the non-volatile parameter settings read from storage in EEP-ROM. Note that 'Loop1' is always displayed by default at power-up.

The operating mode and value of the control output at power-up are determined by the setting of the Configuration Status word SC, found in List 1. If SC bit 0 is FALSE the controller powers up with its last operating mode and control output value. If SC bit 0 is TRUE, Manual mode and a 'failsafe' output are adopted instead. 'Failsafe' is specified by SC bit 1: FALSE = last output value, TRUE = low output value.

Alternatively, if the instrument is being powered up from its as-delivered default state, the default control strategy starts running, i.e. the single-loop controller. Full details of this strategy and its initial parameter values are given in Chapter 6.

Chapter 3 USING THE FRONT PANEL

This chapter describes how to use the instrument's front-panel displays and pushbuttons to carry out all the basic operations. The main topics covered are:

- Operator displays & controls (§1)
- Parameter access (§2).

Figure 3-1 shows the front panel, with a typical display.

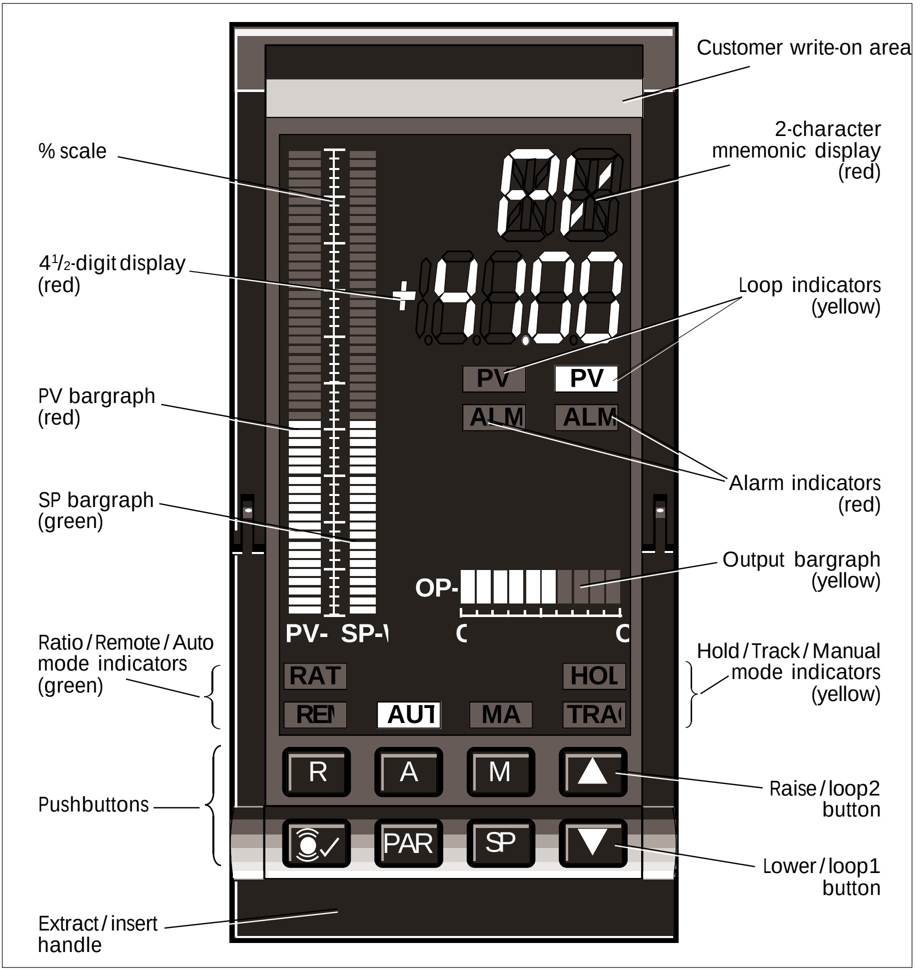


Figure 3-1 Front panel showing typical display

1 OPERATOR DISPLAYS & CONTROLS

This section describes all the displays and pushbuttons on the front panel and their operator functions. Refer to Figure 3-1.

Operator displays give you an overview of the status of each running loop, both graphically and numerically. They also call your attention to alarm conditions. Using the displays and pushbutton controls operators can acknowledge alarms, and inspect and alter (configuration permitting) setpoints and operating modes. With the appropriate passcodes, engineers can inspect and alter any of the control and configuration parameters that define how the instrument functions (see §2).

The front-panel displays are also used to indicate the progress and results of the power-on self-test (POST) that is automatically performed at power-up. Refer to Chapter 2, §6 for details.

Note that when running a two-loop control strategy, the instrument displays only one of the loops at a time on the front panel — selectable via the pushbuttons. However, for reasons of safety the alarm statuses of *both* loops are always clearly annunciated regardless of which loop is currently on display.

> NOTE. This section deals with the general use of the front panel. If your instrument has been configured to run as a ratio controller, or a manual station, some of the controls and displays work in different ways. Refer to Chapter 8, *Ratio controller*, or Chapter 9, *Manual station*, for details.

The front-panel displays comprise:

- alphanumeric displays (see §1.1)
- bargraphs (§1.2)
- loop indicators (§1.3)
- alarm indicators (§1.4)
- operating mode indicators (§1.5).

The pushbuttons (§1.6) include:

- loop control buttons
- a parameter access button
- an alarm acknowledge button.

1.1 Alphanumeric displays

There are two red LED alphanumeric displays — a 2-character parameter mnemonic display, and a $4^1/_2$-digit parameter value display — shown in Figure 3-1.

1.1.1 2-character mnemonic display

The mnemonic display has two functions — indicating parameter mnemonics, and flagging pushbutton errors.

- **Mnemonics.** The display's main purpose is to tell you the name (mnemonic) of the parameter whose value is currently being shown in the 4½-digit display. It is blank during normal running of the controller because PV is the parameter displayed by default, and a blank mnemonic is understood as this. However, when PV's value is initially displayed — or is re-displayed after a different parameter — the mnemonic display does show 'PV' for about six seconds as confirmation. 'PV' also appears briefly after pressing the alarm acknowledge pushbutton. (Note that the display behaves differently when the controller is set up as a manual station. See Ch9 §4 for details.)

  When you select a parameter for display (other than PV), its mnemonic appears for as long as the parameter value is being shown in the 4½-digit display. (See §2 for details on selecting parameters for display.)

  All the control strategy parameter mnemonics are 2-character, e.g. MN, SL, OP, etc. But the special 'list' and 'enter passcode' parameters have single-character mnemonics — L and P respectively. (See §§ 2.1 & 2.2 for information on these parameters).

- **Pushbutton errors.** Another function of the 2-character display is to tell you if you have pressed an illegal pushbutton combination or sequence, which the instrument will ignore. In this case the display shows a pair of 'asterisks'; Figure 3-2 shows an example. You should react to this message by releasing all buttons to clear the error. Until this is done any further button-presses are also ignored. (Valid pushbutton-combinations are given in §§ 1.6 & 2.3.)

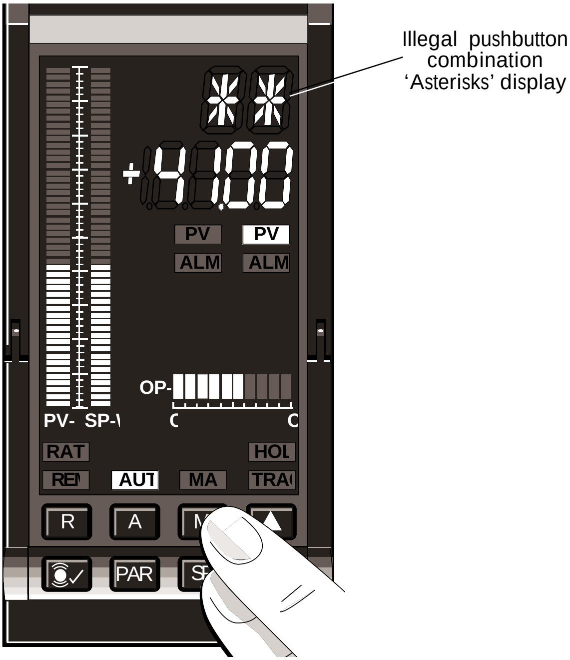


Figure 3-2 Illegal key-combination error 'asterisk' display — example

1.1.2 4½-digit value display

This display has two functions — the main one of showing the value of the current parameter, and the minor one of indicating the progress of the unit's power-on self-test. (See Chapter 2, §6, *Power up*, for details of the POST indications.)

Generally, the parameter value displayed is the one whose 2-character mnemonic is indicated in the mnemonic display — but see §1.1.1. The display can also indicate PV sensor-break or hardware overrange conditions (see below). Parameter values are displayed in a variety of formats — real decimal numbers, integers, hexadecimal words, hexadecimal bytes, and individual bit values. (See §2 for details on selecting parameters for display.)

- **Real numbers.** Parameter values such as PV, SL, etc., are displayed as decimal numbers in the range –19999 to +19999. A decimal point can also appear giving 0-4 decimal places. (The decimal point position is normally set via the loop's DP parameter — see individual chapters on each controller type.) Note that although the *display* is limited to ±19999 plus decimal point, the parameter values themselves are not. If a value exceeds the display limit, the display flags the overflow/underflow error by flashing on and off at the limit of its indication. Such errors usually mean that you have set the number of decimal places too high.
- **Integers.** Some parameters have integral values (e.g. MS, MN, etc.) and these are displayed as such in the range 0-19999, without sign.
- **Hexadecimal words.** 16-bit parameters — 'words' — such as BM, SC, etc., are displayed as four hexadecimal digits preceded by a ''' symbol, e.g. **'400F**. Each hex digit represents the equivalent hex value of a group of four bits. The low-bit group (bits 0 to 3) is represented by the rightmost digit, and the high-bit group (bits 12 to 15) by the leftmost digit. Figure 3-3 explains this representation and shows an example representation of a set of bits as hex 'AbCd'.

  NOTE. Hex digits B and D are displayed as the lower case letters 'b' and 'd', owing to the limitations of the 7-segment LED display.

- **Hexadecimal bytes.** 8-bit parameters — 'bytes' — such as DV, DI, etc., are displayed in the same hex format as word parameters, but differ in having only two hex digits displayed instead of four. Bits 0 to 3 are represented by the rightmost digit, and bits 4 to 7 by the next digit. The leading two digits are not needed and are blank. An example is **' Cd**.
- **Individual bit values.** As well as looking at the total hexadecimal value of a whole byte or word parameter, you can inspect (and sometimes alter) each of its individual bits via the 4½-digit display. A bit is displayed as its bit number — 0 to 15 — occupying the leftmost digit(s), followed by its TRUE/FALSE value occupying the rightmost digit. TRUE is represented as the lower case 't' character, and FALSE as 'F'. Examples: **15 t**, **8 F**.
  (Using the PAR button to inspect and alter bits is described in §2.4.3)
- **PV sensor-break or hardware overrange.** If PV is on display and the PV input goes open-circuit or underrange (i.e. sensor-break), or goes overrange enough to saturate the A-to-D converter, the display flashes '**S_br**' until PV is restored.

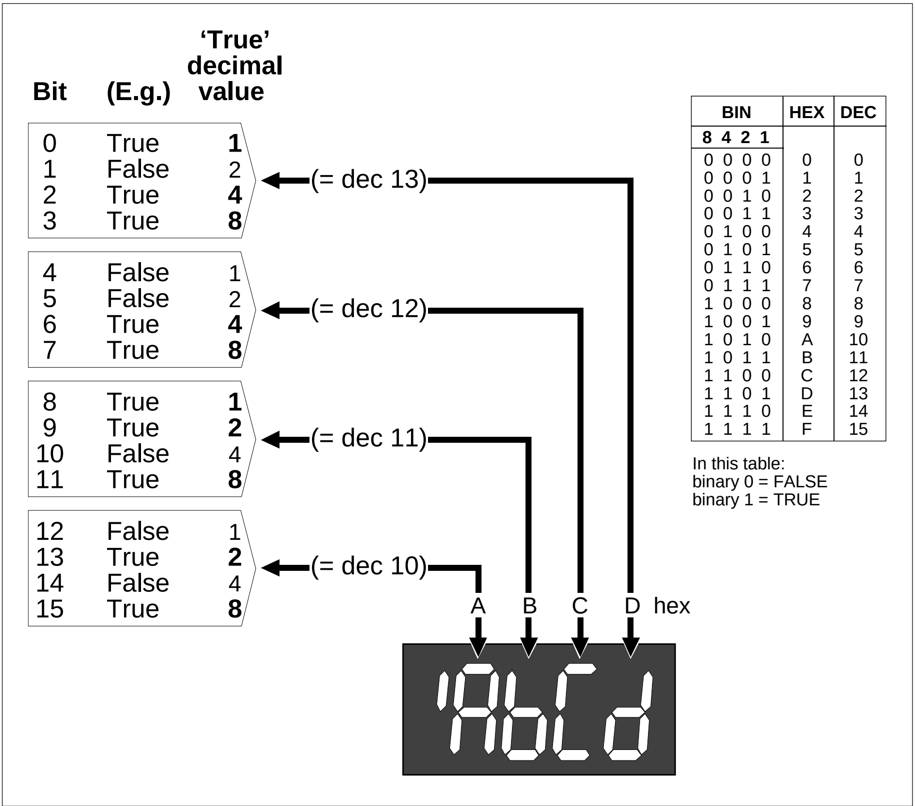


Figure 3-3 Hexadecimal representation of 16-bit 'word' parameter — example 'ABCD'

1.2 Bargraphs

Three colour-coded LED bargraph displays (see Figure 3-1) give operators an instant qualitative picture of the percentage values of the three principal control variables, how they compare with each other, how they may be moving, and the overall stability of the control process. They can also show the configured alarm limits, and automatically flag unacknowledged absolute and deviation alarms in the displayed loop. (See Chapter 16, *Error conditions*, for information on alarms).

The three bargraphs are — a process variable bargraph (PV-X), a setpoint bargraph (SP-W), and an output bargraph (OP-Y).

1.2.1 Process variable bargraph (PV-X)

This red 51-segment vertical bargraph displays the process variable PV as a percentage, in 2% steps. The value displayed is actually PV normalised between its high and low range, i.e. 0% maps to LR and 100% maps to HR. The lowest segment of the display is permanently lit when the instrument is powered and running normally — even when PV is zero.

The bargraph is normally steadily lit, but flashes if an absolute alarm occurs in the currently-displayed loop, that is not acknowledged. The flashing persists until the alarm is acknowledged — automatically or manually. (An absolute alarm is when PV's value moves outside user-set limits. See Chapter 16 for information on alarms.)

You can inspect the currently-configured absolute alarm limits (HA and LA) as percentages on the same normalised scale as PV. Do this by pressing the ▲ and ▼ (raise/lower) pushbuttons together, which causes the limits to appear on the PV-X bargraph as a pair of reverse-lit segments. Figure 3-4 shows an example of this being done, and how the current percentage PV value and alarm limits are read from the bargraph. Note that the deviation alarm limits also appear at the same time (see §1.2.2, next).

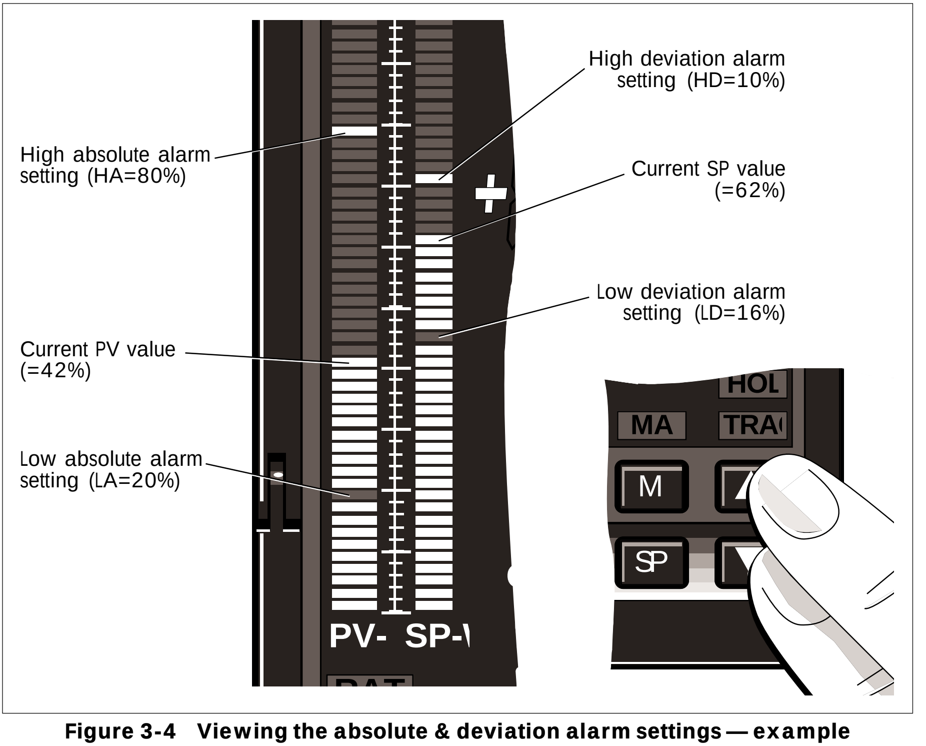


Figure 3-4 Viewing the absolute & deviation alarm settings — example

1.2.2 Setpoint bargraph (SP-W)

This green 51-segment vertical bargraph displays the resultant setpoint SP as a percentage, in 2% steps. The value displayed is actually SP normalised between its high and low range, i.e. 0% maps to LR and 100% maps to HR. The lowest segment of the display is always lit when the instrument is powered and running normally — even when SP is zero.

The bargraph is normally steadily lit, but flashes if an unacknowledged deviation alarm exists in the currently-displayed loop. The flashing persists until the alarm is acknowledged — automatically or manually. (A deviation alarm is when the difference between PV and SP exceeds user-set limits. See Chapter 16 for more information on alarms.)

You can inspect the currently-configured deviation alarm limits (HD and LD) as percentages on the same normalised scale as SP. Do this by pressing ▲ and ▼ together, which causes the limits to appear on the SP-W bargraph as a pair of reverse-lit segments. These segments are positioned above and below the top of the bar, moving up and down with it as SP varies to maintain the set deviations. Figure 3-4 shows an example of this, and how the current percentage SP value and alarm limits are read from the bargraph. Note that the absolute alarm limits also appear at the same time (see §1.2.1, previous).

1.2.3 Output bargraph (OP-Y)

See Figure 3-5. This yellow 10-segment horizontal bargraph displays the control output OP as a percentage, in 10% steps. The first — leftmost — segment lights when the output exceeds 5%, the second lights at >15% output, the third at >25%, and so on in 10% steps until all segments light at >95% output. (Note that with the unit configured as an incremental controller the output bargraph works very differently — Ch10 §4.3 gives details.)

The scale printed below the output bargraph is divided into tenths, with 'C' and 'O' legends denoting 'closed' and 'open' (valves), respectively.

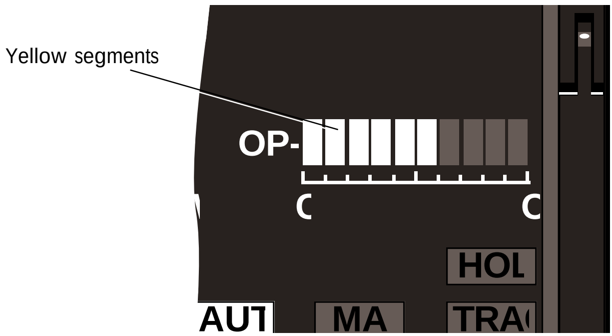


Figure 3-5 The output bargraph (OP-Y) — example showing output between 55% & 65%

1.3 Loop indicators

Two yellow backlit loop indicators (see Figure 3-6), with the legends 'PV 1' and 'PV 2', indicate which of the two loops is currently being displayed on the front panel. 'PV 1' corresponds to loop 1 and 'PV 2' to loop 2. (Selecting a loop for display using the ▲ and ▼ buttons is described in §1.6.3.) If the instrument is configured as a single-loop controller or manual station, neither lamp is lit.

NOTE. 'PV 2' is strictly-speaking not a control *loop* in the ratio control configuration, but rather a *ratio station.*

When a particular loop is on display, flashing bargraphs indicate unacknowledged alarms in the currently-displayed loop only.

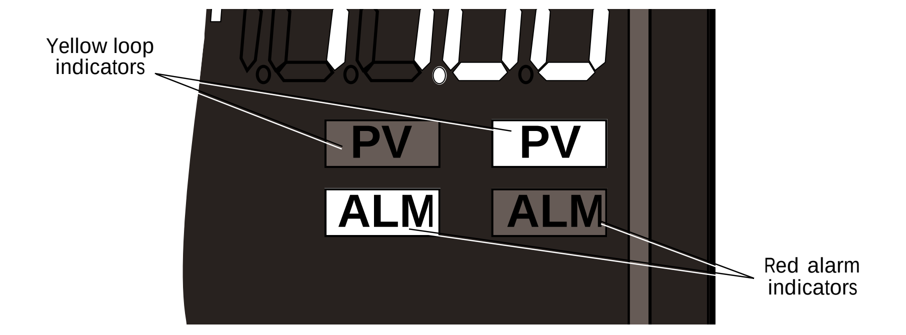


Figure 3-6 Loop & alarm indicators — example showing loop 1 selected & loop 2 in alarm

1.4 Alarm indicators

Two red backlit alarm indicators (see Figure 3-6), with the legends ‘ALM 1’ and ‘ALM 2’, light to indicate an alarm condition in the corresponding loops 1 and 2, respectively. For safety reasons, alarms in *both* loops are indicated on the front panel regardless of which loop is currently on display.

If the alarm condition has not been acknowledged, the indicator flashes to draw your attention to this, and continues to flash until acknowledged. Note that you can configure alarms to acknowledge themselves when the alarm condition clears (set Alarm status word AL bit 12 TRUE).

You can at any time acknowledge (all) alarms in the loop currently on display by pressing the ‘alarm acknowledge’ button (see §1.6.4). Any alarms in the *other* loop are not acknowledged — you must first display that loop then press the button.

If the alarm condition still exists, but has been acknowledged, the corresponding indicator glows steadily. Only when the alarm condition has been both acknowledged and cleared does the indicator go out.

NOTE. There is a hysteresis on leaving an alarm condition. See Chapter 16.

1.5 Operating mode indicators

There are six backlit mode indicators on the instrument’s front panel (see Figure 3-7), which light to tell you the operating mode of the loop currently on display. The indicators are grouped in two areas — the closed-loop modes Ratio, Remote, and Auto on the left, and the open-loop modes Manual, Track, and Hold on the right. The closed-loop modes indicators are green when lit (denoting control), and the open-loop indicators show yellow (as a warning).

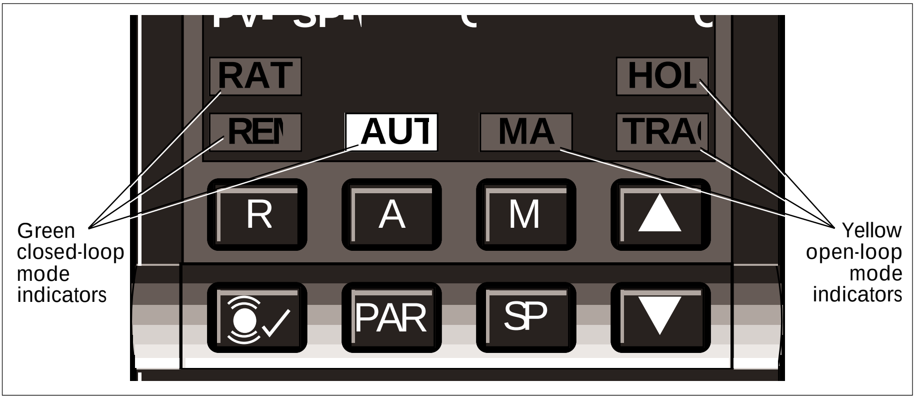


Figure 3-7 Operating mode indicators — example showing Auto(matic) mode operating

In general, mode indicators light steadily to indicate an operating mode. But the Auto and Manual indicators can also flash on and off to indicate Forced Auto (Auto Fallback) and Forced Manual modes, respectively.

NOTE. The operating mode of a loop — and hence the lighting of the mode indicators — is determined by the value of the loop's MN (Mode Number) parameter. MN in turn depends on what mode pushbuttons have been pressed and what mode bits have been set in the control configuration.

(Selecting operating modes via the front-panel R, A, and M pushbuttons is described in §1.6.1. See Chapter 5, *Operating modes*, for details on the interpretation of the MN parameter and the significance of loop operating modes.)

1.6 Operator pushbuttons

The front panel has eight pushbuttons (see Figures 3-1 & 3-7). These allow you to:

- select a loop for viewing/interaction on the front-panel displays
- select the control loop operating mode (but see note below)
- inspect and alter the control output
- inspect and alter the local setpoint
- inspect the absolute and deviation alarm limits
- acknowledge the loop alarm(s)
- using the correct passcode, inspect and alter if possible any user-parameter.

NOTE. The 'R', 'A', and 'M' pushbuttons can be masked to disable their mode-change function. The 'SP' and 'Alarm Acknowledge' buttons can be masked to disable their setpoint-change and alarm-acknowledge functions, respectively. (§1.6.9 describes disabling pushbuttons via the BM button mask parameter.)

Many of these operations are done with a single button-press; others need a 2-button combination. All the buttons act only on the loop currently occupying the front-panel display, and all except the 'alarm acknowledge' button are multi-functional.

Operator functions & engineer functions. The pushbutton functions fall into two groups — 'operator' functions that do not require a passcode, and 'engineer' functions that do. Operator functions include such things as selecting a loop for display, changing control mode, viewing a setpoint, etc. Table 3-1 summarises the operator pushbutton functions, and includes the PAR button for accessing the engineer functions — i.e. 'parameter mode' — via a passcode. Further details on how these buttons work are given in §§1.6.1 to 1.6.9 after the table.

(Engineer functions are described in §2.)

Button legend(s)	Operator function(s)
R	Select Remote mode. View Output OP[1]
A	Select Auto mode. View Output OP[1]
M	Select Manual mode. View Output OP[1]
SP	View Local Setpoint SL (SP in Remote mode)
▲	Display Loop 2
▼	Display Loop 1
	Alarm acknowledge
M + ▲	View and raise Output OP[2] (only in Manual mode)
M + ▼	View and lower Output OP[2] (only in Manual mode)
SP + ▲	View and raise Local Setpoint SL (not remote SP)
SP + ▼	View and lower Local Setpoint SL (not remote SP)
▼ + ▲	View Absolute & Deviation Alarm settings (on bargraphs)
PAR	View 'list' parameter L (to enter 'engineer' mode via passcode)

Incremental control: [1] *only if track input configured* [2] *emit 'raise'/'lower' signal. OP viewed only as per* [1]

Table 3-1 Operator pushbutton functions — summary

1.6.1 Changing mode & inspecting the output

[R] [A] [M] Mode buttons

Mode changes. Pressing one of these three mode buttons may light the corresponding mode indicator above the button, and select the requested mode. But the particular control strategy configuration may inhibit selection of certain modes, so the result could be different. For example, pressing M in Loop 2 of the Override controller leads to the adoption of Track mode — not Manual — because of the way the strategy works. (See Chapters 6 to 11 on the individual control strategies for details of mode selection.)

Inspecting output. While any of the mode buttons are being pressed, OP appears in the mnemonic display, and the control output value is indicated in the $4^{1}/_{2}$-digit display. (It can be altered using the ▲/▼ buttons only if Manual is the operating mode — see §1.6.5.)

> NOTE. With incremental control operating, OP is not the control output and cannot be manually altered using ▲/▼. Instead, ‘raise’/‘lower’ digital signals are generated (see §1.6.5). On pressing a mode button, the OP mnemonic and value do appear, but only if Track input has been configured (see Chapter 10).

1.6.2 Inspecting the setpoint

[SP] Setpoint button

While this button is being pressed, ‘SL’ appears in the mnemonic display, and the local setpoint value shows in the $4^{1}/_{2}$-digit display. You can alter SL’s value using the ▲/▼ buttons.

Note that if the loop is in Remote mode, it is the remote setpoint SP that appears instead — which cannot be altered in this way. SP also appears if SC bit 12 is TRUE for the current loop, and the mode is not Auto. SL tracks PV in this case.

1.6.3 Selecting a loop for display

[▲] & [▼] Raise/lower buttons

Press one of these buttons to select which loop is to occupy the front-panel display. The raise (▲) button selects Loop 2 for display, and the lower (▼) button Loop 1. The corresponding loop indicator (PV 2 or PV 1) lights. If the selected loop is already on display — always true for one-loop configurations — the buttons have no effect.

Note the slight delay before these buttons act. This helps avoid inadvertent loop-changing when pressing the raise and lower buttons together (to view alarm limits, see §1.6.7).

1.6.4 Acknowledging alarms

Alarm acknowledge button

Pressing this button acknowledges all alarms in the loop currently on front-panel display, and stops the loop's alarm indicator and bargraph(s) flashing. Note that any alarms in the other loop are not acknowledged. (See §§1.2 and 1.4 for more information on alarm annunciation.)

1.6.5 Raising & lowering the control output

M + ▲/▼

Adjusting the control output is different for continuous control and incremental control configurations.

- **Continuous control.** To raise or lower the control output OP, first hold down the M button, then press the ▲ or ▼ button (respectively). Doing this normally puts the currently-displayed loop into Manual mode (if not already there), indicates 'OP' in the mnemonic display, and its current value in the $4^1/_2$-digit display. If you keep both buttons pressed the output starts to change, very slowly at first, then at a rapidly accelerating rate until it reaches a limit, or until you release either button. OP can change by 100% in about 12 seconds if no buttons are released.

  NOTE. You can select a very fast non-accelerating ▲/▼ speed by setting List 1 SC bit 15 TRUE. This achieves 100% change in about 5 seconds.

  For precise settings, you should speed to a value near to the one you require, release the ▲/▼ button, then increment or decrement to the precise value one unit at a time by repeated single ▲/▼ presses.

  NOTE. Holding down the raise or lower buttons *before* pressing M is an illegal sequence and elicits the '**' pushbutton error display. If this happens, release all buttons and start again.

  Sometimes, owing to the way a control strategy is configured, pressing M does *not* put the loop into Manual mode. (Loop 2 in the cascade controller is an example — pressing M puts the loop into Track.) In this case you can inspect, but not alter, the control output value.

- **Incremental control.** Incremental control output is in the form of a pair of digital signals — the 'raise' and 'lower' outputs. These signals can be generated using the M and ▲/▼ buttons (see Ch10 §4 for details). But note that OP is not the control output, and is displayed via the M button only if Track input is configured.

1.6.6 Raising & lowering the local setpoint

SP + ▲ / ▼

Raising and lowering the local setpoint SL is done in a similar way to altering OP, described in §1.6.5 — hold down the SP button, then press the ▲ or ▼ button (respectively). ‘SL’ shows in the mnemonic display and its current value in the $4\frac{1}{2}$-digit display. SL’s value changes at a selectable accelerating or fast rate (see §1.6.5), but can be incremented one unit at a time for precise settings.

NOTE. Holding down the raise or lower buttons *before* pressing SP is an illegal sequence and elicits the ‘**’ pushbutton error display.

If your control loop is running with a remote setpoint rather than a local one, or SC bit 12 is TRUE and the mode is not Auto, SP is displayed when you press these buttons — not SL — and you cannot alter its value.

1.6.7 Viewing the absolute & deviation alarm limits

▲ + ▼

Pressing these two buttons *together* displays the currently-configured absolute and deviation alarm limits for the loop. They appear as reverse-lit segments on the PV and SP bargraphs. (See §§ 1.2.1 and 1.2.2 for more information on interpreting these displays.)

1.6.8 Entering engineer (parameter) mode

PAR **Parameter button**

Pressing the PAR button in ‘operator’ mode starts the process by which you can — with the correct passcode(s) — enter ‘engineer’ mode and access complete parameter lists. Note that you can return immediately from engineer mode to normal operator mode by pressing any of the buttons: R, A, M, or SP.

The engineer pushbutton functions, and parameter access, are fully described in §2.

1.6.9 Pushbutton masking via the BM parameter

You can inhibit — ‘mask’ — the mode-select action of any combination of the three mode pushbuttons, R, A, and M. This masking may be advisable in certain control configurations, and can be applied selectively to either or both control loops. Pressing a masked mode button has no effect on the operating mode of the displayed loop, but does still display the control output OP — which can be altered in Manual mode as usual.

You can also mask the ‘alarm acknowledge’ button for a loop, and the setpoint-change action of the SP button. Pressing the masked SP button still displays the loop’s setpoint, but its value cannot be changed using ▲/▼.

Pushbutton masking can be configured via the front panel in engineer mode, by setting the relevant loop's BM (button mask) byte parameter according to Table 3-2. (Accessing and altering parameter values is described in §2.)

BM bit TRUE...	...masks pushbutton...	...which disables
Bit 0	(*not implemented*)	
Bit 1	(*not implemented*)	
Bit 2	SP	Setpoint changes via button[1]
Bit 3	M	Manual mode selection via button
Bit 4	(*not implemented*)	
Bit 5	A	Auto mode selection via button
Bit 6		Alarm acknowledgement via button
Bit 7	R	Remote mode selection via button

[1] *In the Ratio controller, List 1 BM bit 2 masks both loops' SP buttons*

Table 3-2 Button mask parameter (BM) bit settings

2 PARAMETER ACCESS

This section tells you how to access and configure user-parameters via the front panel. These parameters specify instrument control configuration, passwords, communications parameters, I/O allocation and processing, and how each control loop operates. Your instrument is supplied with a default parameter configuration (the single-loop controller, specified in Chapter 6), which lets you use it straight away for basic control.

However, you will want to customise the unit to your own plant requirements, and for that you will need to access a variety of parameters and alter their values. This section deals with parameter access in general terms. Refer to the chapters on individual controller options, and to Chapter 4, *Configuration*, for more information.

2.1 Parameter lists

For convenience and security, parameters are grouped into several separate 'lists' — List 1, List 2, List 3, etc. These lists can be viewed in the mnemonic and $4^{1}/_{2}$-digit alphanumeric displays. Figure 3-8 is an overview of the lists currently available.

- **Lists 1 & 2.** List 1 applies to Loop 1, and List 2 to Loop 2. (In single-loop controllers List 2 is empty). These lists include loop-commissioning parameters such as setpoint ranges and limits, alarm limits, control output limits, local and resultant setpoints, control loop setups, pushbutton mask setup, and others.
- **List 3.** Contains instrument configuration parameters such as model number, control configuration, temperature units, and also the instrument's two parameter access passcodes.
- **List 4.** Specifies the instrument's Modbus serial communications settings.
- **List 5.** Specifies the instrument's main pcb I/O configuration (ranging, linearisation, hardware allocation, etc.).
- **List 6.** Contains similar parameters to List 5, but applies to the optional expansion board's I/O configuration.
- **List 7.** Contains I/O calibration parameters.
- **List 8.** Contains incremental control configuration parameters.
- **List 9.** Contains diagnostic parameters.

(*Further lists are not currently available at this issue of software*.)

Each list also contains at its foot a parameter with the single-character mnemonic 'L'. This is the List Number parameter specifying the number of the list itself. Altering the value of the L parameter accesses other lists, but only via a valid passcode (see §2.2). Note that, apart from the 'enter passcode' parameter 'P', all other mnemonics have *two* characters

For complete parameter listings please refer to Chapter 4, *Configuration*, and also to the chapters on the individual controller options.

2.2 Passcodes

When you first access engineer mode via the PAR key (see §2.3.1) you see a special 'locked' short form of List 1 if you are viewing Loop 1, or of List 2 if you are viewing Loop 2. This locked list contains only two parameters — the List Number L and the 'enter passcode' parameter P. Both parameters are initially set to defaults of zero. You can alter the value of L to select a different list if required, then 'unlock' the selected list by setting P to the correct passcode (§2.3.1). Finally, with the list unlocked and at its full length, you are free to access every parameter it contains (§2.4).

There are two passcodes, stored in parameters P0 and P1 (both in List 3). P0 unlocks only Lists 1 and 2, but P1 can unlock *all* lists. Once List 3 has been unlocked, you can if you wish reset either passcode to another value, by editing P0 and/or P1. You can also disable a passcode (i.e. allow free entry) by giving it a value of zero — the default value adopted on entering engineer mode.

2.3 Engineer (parameter access) mode

Via the front panel you can — with a valid passcode — enter ‘engineer’ mode and select a list for inspection (see §2.3.1). There you can view any parameter value, and alter it provided it is not ‘read-only’. (How parameter values and mnemonics appear on the front panel is described in §§ 1.1.1 and 1.1.2). Note that in engineer mode you can still perform certain ‘operator’ functions, e.g. acknowledge alarms and view alarm settings on the bargraphs (§1.6.1).

You can at any time select a different list for access (§2.3.2), and quit engineer mode when required or automatically after a timeout period (§2.3.3).

How to access and alter the different types of parameter values is described in §2.4.

2.3.1 Entering engineer mode

Refer to Figure 3-8. To enter engineer mode from operator mode, do the following:

1 Press the PAR button. The mnemonic for the List Number parameter ‘L’ appears in the mnemonic display, together with its default value in the $4\frac{1}{2}$-digit display. L is ‘1’ if Loop 1 is the current display, and ‘2’ if Loop 2 is. You are now looking at the list in its ‘locked’ form, with only two items (L and P).

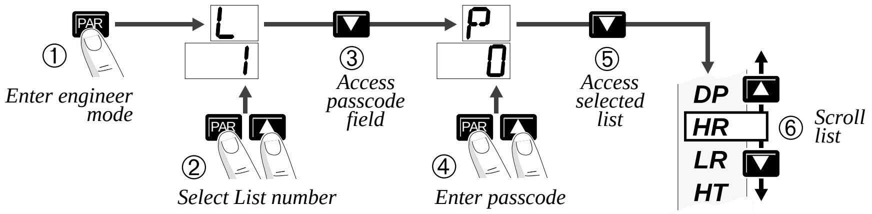
2 If you want to access this list, go directly to step 3. To access a different locked list, hold down PAR and press the ▲ button to increment, or ▼ to decrement, the value of L to the required list number. Release all buttons.

3 Press ▲ or ▼ to scroll to the ‘enter passcode’ parameter P, with its zero default value. Note that if in step 2 you selected the list for the loop not currently displayed, accessing P makes the new loop the current display. If the passcode for your list has been disabled (see §2.2) go directly to step 4. Otherwise, set P to a valid passcode by holding down PAR and pressing the ▲/▼ buttons. The value changes slowly at first, then at an accelerating rate. Speed to a value near the correct one, release the button, then step to the exact passcode with single presses. Release the PAR button.

4 Press ▼ (or ▲) to input and verify the passcode. If the passcode is valid your selected list unlocks and scrolls to its first parameter, or its last parameter if you pressed ▲. (The last parameter is always L.) You can now proceed to step 5. But if your passcode is invalid the list remains locked with only two items, L and P as before, and you must return to step 3.

5 You are now in engineer mode, able to access all the parameters in the selected list (see §2.4).

Note that in engineer mode, some of the pushbuttons have different functions than in operator mode. Table 3-3 summarises the functions of all buttons in engineer mode.



LIST 1 — ALL LOOPS

DP	Decimal point position
HR	Setpoint high range
LR	Setpoint low range
HT	Trim high range/limit
LT	Trim low range/limit
HS	Setpoint high limit
LS	Setpoint low limit
HA	High Absolute alarm
LA	Low Absolute alarm
HD	High Deviation alarm
LD	Low Deviation alarm
HO	High Output limit
LO	Low Output limit
XP	Proportional band
TI	Integral time
TD	Derivative time
TM	Trim value
RM	Remote Setpoint
SL	Local Setpoint
SP	Resultant Setpoint
PV	Process Variable
OP	Control Output
TK	Track value
AL	Alarm status word
SM	Mode status word
SC	Config. status word
BM	Pushbutton mask
MS	Requested mode
MN	Resultant mode
TT*	Motor travel time
PT*	Minimum pulse time
TB	Timebase

LIST 2 — CASCADE

DP	Decimal point position
HR	Setpoint high range
LR	Setpoint low range
HT	Trim high range/limit
LT	Trim low range/limit
HS	Setpoint high limit
LS	Setpoint low limit
HA	High Absolute alarm
LA	Low Absolute alarm
HD	High Deviation alarm
LD	Low Deviation alarm
XP	Proportional band
TI	Integral time
TD	Derivative time
TM	Trim value
RM	Remote Setpoint
SL	Local Setpoint
SP	Resultant Setpoint
PV	Process Variable
OP	Control Output
AL	Alarm status word
SM	Mode status word
SC	Config. status word
BM	Pushbutton mask
MS	Requested mode
MN	Resultant mode
TB	Timebase

LIST 2 — RATIO

DP	Decimal point position
HR	Uncontr. PV high range
LR	Uncontr. PV low range
HS	Ratio setpoint high limit
LS	Ratio setpoint low limit
RS	Ratio setpoint
PV	Uncontrolled PV
MR	Measured ratio
SM	Mode status word

LIST 3 — INSTRUMENT

II	Instrument identity
IV	Instrument version
CC	Controller type
P0	Passcode 0
P1	Passcode 1
TU	Temperature units
B1	Expansion I/O enable

LIST 4 — MODBUS

FS	Fast status byte
AD	Instrument address
BD	Baud rate
PY	Parity
CS	Comms status word

LIST 5 — MAIN I/O

IR	Process Input range
IB	Process I/P break protn.
IL	Process I/P linearisation
IF	Process Input filter TC
OR	Process output range

LIST 6 — EXPANSION I/O

IR	Process Input range
IB	Process I/P break protn.
IL	Process I/P linearisation
IC	Process I/P connections
IF	Process Input filter TC
AR	Analogue input range
AB	An. I/P break protection
AC	An. input connections
AF	Analogue input filter TC
OR	Analogue O/P range
OC	Analogue O/P conns.
DV	Digital I/O values
DI	Digital I/O inv. mask
DC	Dig. I/O conn. mask
DU	Dig. I/O pullup type

LIST 7† — CALIBRATION

CC	Calibration channel
CR	Calibration range
ST	Calibration step
CV	Calibration value

LIST 8* — INCREMENTAL

IN	Inertia compensation
BL	Backlash compensation
VO	Velocity output demand

LIST 9 — DIAGNOSTICS

SI	I/O status word
R1	I/O missed readings
R2	I/O bad readings
R3	Dig. feedb'ck verify fails
R4	Tasks uncompleted
ST	Strategy cycle time
E0	Errors log (newest)
E1	Errors log
E2	Errors log
E3	Errors log
E4	Errors log
E5	Errors log
E6	Errors log
E7	Errors log
E8	Errors log
E9	Errors log
EA	Errors log
EB	Errors log
EC	Errors log
ED	Errors log
EE	Errors log
EF	Errors log (oldest)

**Available only if Incremental control selected (SC bit 8 TRUE)*

†Available only if I/O Calibration enabled (SC bit 13 TRUE)

Figure 3-8 Accessing parameter lists — summary

Button legend(s)	Engineer function(s)	
▲	Scroll / step cyclically up parameter list. Scroll / step up bit list then exit	
▼	Scroll / step cyclically down parameter list. Scroll / step down bit list then exit	
PAR	View bit value	
PAR + ▲	Raise parameter value. Set bit TRUE	
PAR + ▼	Lower parameter value. Set bit FALSE	
▼ + ▲	View Absolute & Deviation Alarm settings (on PV-X & SP-W resp.)	
	Alarm acknowledge	
R	Select Remote	
A	Select Auto	& quit parameter mode
M	Select Manual	
SP	View SL (SP in Remote)	

Table 3-3 Engineer pushbutton functions — summary

2.3.2 Selecting a different list in engineer mode

You can select a different list for parameter access at any time, without leaving engineer mode. To do this:

1 Scroll up or down to the current list's L parameter using ▲ or ▼. The parameter scrolling action is cyclic, so you will eventually get to any parameter going up or down the list. (Figure 3-9 shows this.)

NOTE. You can use the ▲/▼ buttons in two ways. Either hold down a button to 'autoscroll' slowly round the list, or repeatedly press and release it to step round the list as fast as you like.

2 Change L to the required number by holding down PAR and pressing ▲ or ▼. Then release all buttons.

3 Press ▼ (or ▲) to check that the current passcode is valid for the new list. If it is, your selected list unlocks and scrolls to its first (or last) parameter. If the passcode is no longer valid, the new list remains locked and you are instead presented with the parameter P, set at zero, inviting you to input a valid passcode.

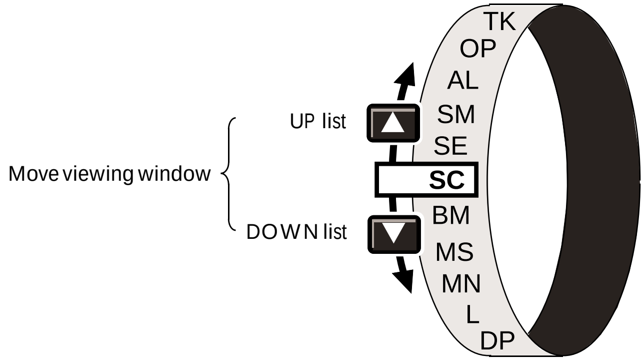


Figure 3-9 Scrolling or stepping cyclically round a list

2.3.3 Quitting engineer mode

You can quit engineer mode, and return to operator mode, in two ways:

- If no pushbuttons are pressed in engineer mode for more than about 5 minutes, the front-panel reverts automatically, for security reasons, back to operator mode.

  A passcode must then be re-input if you wish to return to engineer mode. This time-out facility can be disabled by setting bit 14 in the configuration status word SC, found in List 1. TRUE disables the timeout, and FALSE activates it.

- Pressing a mode button (R, A, M) or the SP button, returns you to operator mode immediately, in addition to having its usual effect (described in §§ 1.6.1 and 1.6.2).

2.4 Viewing & altering parameter values

§1.1.2 described the different types of parameter value seen in the 4½-digit display. This section tells you how to view and alter these values in engineer mode. Refer to the push-button summary in Table 3-3.

2.4.1 Selecting a parameter for inspection / alteration

To do this:

1. Access the required parameter list, as described in §2.3.
2. Hold down or repeatedly press the ▲ or ▼ pushbutton to autoscroll or step cyclically up or down the list to the required parameter. Release the button. Figure 3-9 illustrates how these buttons work to move the viewing 'window' round the continuous parameter list.
3. If the parameter selected is real or integral, you can alter its value directly (§2.4.2). If the parameter is a hexadecimal byte or word, you must access its individual bits to be able to alter any of them (§2.4.3). Note that some parameters are read-only and cannot be altered.

2.4.2 Altering real numbers & integers

To alter the value of a selected real number or integer, hold down the PAR button and press ▲ to raise or ▼ to lower its value, as indicated in the 4½-digit display. These buttons have a selectable accelerating or high speed action, described in §1.6.5. Note that altered parameter values take immediate effect — even while the ▲/▼ buttons are still pressed — and require no special 'input' operation.

Read-only parameters (or ones with inputs that make them effectively read-only) either ignore these key presses, or respond but than rapidly revert to their original values.

2.4.3 Inspecting / altering hexadecimal parameters

1 Access the required hexadecimal byte (8 bits) or word (16 bits), as described in §2.4.1.

2 Press PAR once to view the parameter's bit 0 value in the 4½-digit display. This is shown with the bit number at the left of the display and its value — **t**(rue) or **F**(alse) — at the right. Figure 3-10 shows an example. If bit 0 is the one you want to edit, go straight to step 4.

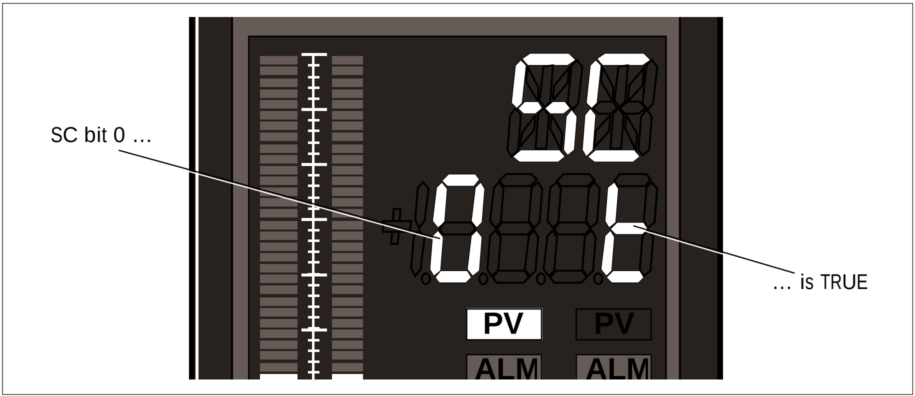


Figure 3-10 Viewing the bits in a hexadecimal parameter — example

3 Hold down or repeatedly press the ▲ button to autoscroll or step up the bit-list until the required bit is displayed. ▼ scrolls *down* the list again. Note that bit-list scrolling is not cyclic. Scrolling beyond either bit 0 or the highest bit (7 or 15) reverts the display to the hexadecimal byte or word format. Figure 3-11 illustrates accessing and scrolling through the 16 bits in a word.

4 To alter the value of the accessed bit, hold down PAR and press ▲ to set the bit TRUE, or ▼ to reset it FALSE. The altered bit-state takes immediate effect in the control strategy or instrument configuration.

5 Revert the display to byte or word format by scrolling the bit-list beyond bit 0 or bit 7/15. You are now ready to access another parameter.

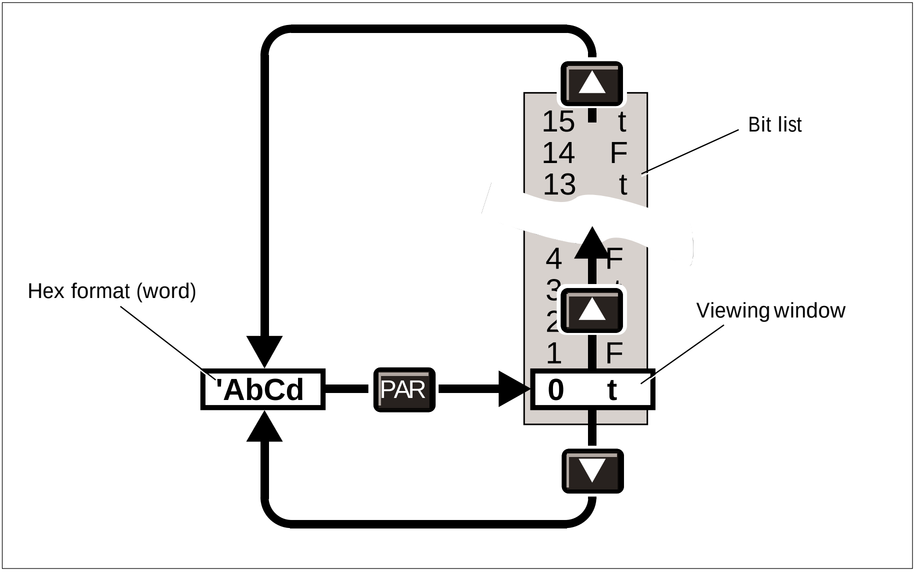


Figure 3-11 Accessing & scrolling bit values in a word

Chapter 4 CONFIGURATION

This chapter tells you how to configure your powered-up controller using the front-panel. It is also possible to configure over the Modbus comms, either internally on the unpowered instrument via the built-in RJ11 configuration socket, or externally via the RS422/485 customer terminals at the rear panel. Modbus addresses are given in the parameter list tables in this chapter, in the '**M'bus**' column. (See Chapter 14, *Serial communications*, for more information.)

To configure a controller you go through the following steps, described in this chapter:

- Selecting the controller type (§1)
- Configuring the I/O (§2)
- Parameterising the control loops (§3).

All these steps involve accessing various configuration parameters, then adjusting their values to specify your particular requirements. Chapter 3 describes how to access and alter parameters.

1 SELECTING THE CONTROLLER TYPE

You can configure an instrument to run as one of the following types of controller. (Refer to the specific chapters mentioned for information on the different controller types.)

- Single-loop controller (see Chapter 6)
- Cascade 2-loop controller (Chapter 7)
- Single-loop controller with Ratio station (Chapter 8)
- Manual station (Chapter 9)
- Override controller (Chapter 11)

Configuration is done by accessing parameter List 3 (shown in Table 4-1), and setting the Control Configuration parameter CC to one of the values shown in Table 4-2. Parameter List 3 contains the 'instrument' parameters and needs passcode P1 for access. (See Chapter 3 §2.2 for information on passcodes.)

L3	Function	Type	Write	M'bus
II	Instrument identity (numeric part of model no.)	Int	✘	122
IV	Instrument version	Int	✘	123
CC	Controller type (0-4) [see Table 4-2]	Int		124
P0	Passcode 0 — Loop commissioning (0-9999) [see Ch3 §2.2]	Int		126
P1	Passcode 1 — Configuration (0-9999) [see Ch3 §2.2]	Int		127
TU	Temperature units (0=°C, 1=°F, 2=K)	Int		132
B1	Expansion I/O board enable (0=disable, 1=enable)	Int		133

✘*Read-only parameter*

Table 4-1 List 3 instrument parameters

For controller type ...	... Set CC parameter to
Manual station	0
Single-loop controller	1
Cascade 2-loop controller	2
Single-loop controller with Ratio station	3
Override controller	4

Table 4-2 Selecting controller type via Control Configuration parameter CC

2 CONFIGURING THE I/O

This section describes how to configure the controller's inputs and outputs to suit your plant requirements. The designations of customer terminals are given in Chapter 2 §4.2.

Figure 4-1 summarises the total I/O available, assuming the optional expansion I/O board is installed. In practice a particular controller type may have less I/O available — refer to chapters on the individual controllers. In the figure, customer terminal numbers in brackets can be assigned to various functions, whereas unbracketed numbers are fixed-function.

Table 4-3 summarises the I/O in terms of its type, isolation, and availability.

I/O	Range/type	Isolation	Main pcb	Expansion pcb
Process input	mA, V, T/C, PRT	Individual	1	1
Process output	mA		1	
Transmitter PSU	24V		1	1
Analogue input	V	By group, common 0V		1
Analogue output	V			1
Digital input	Logic	By group, common 0V		4
Digital output	Logic			4
Alarm relay	SPST		1	
Watchdog relay	SPST		1	

Table 4-3 I/O types, isolation, and availability

To carry out I/O configuration you must specify the following:

- Assignment of inputs and outputs provided by the (optional) expansion I/O board to software functions (see §2.1)
- Hardware ranging and type (§2.2)
- Input break protection (§2.3)
- Sensor break action (§2.4)
- Linearisation (§2.5)
- First-order input filtering (§2.6)

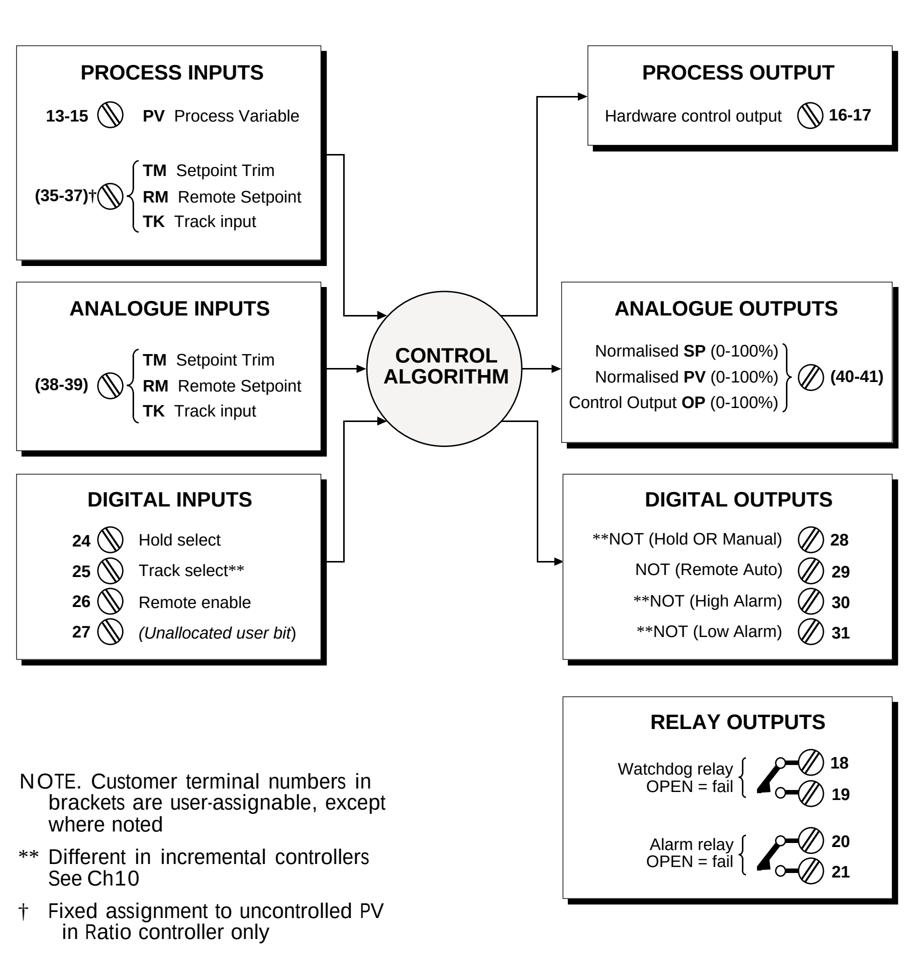


Figure 4-1 I/O summary schematic

- Digital I/O connection and inversion (§2.7)
- Digital I/O pullup types (§2.8)
- Alarm relay output configuration (§2.9)

All the specification is done by setting a variety of parameters to the required values, as described in the sections indicated.

2.1 Assigning optional I/O terminals

You can assign the analogue inputs and outputs provided by the optional expansion I/O board (if fitted) to a variety of alternative software functions, depending on what controller configuration you have selected. For example, in the single-loop controller configuration you can route the process inputs — terminals 35 to 37 — to Loop 1's Track input TK, or its feedforward input, or Remote setpoint RM, or Setpoint trim TM, or effectively disconnect the terminals completely. Figure 4-2 illustrates these options.

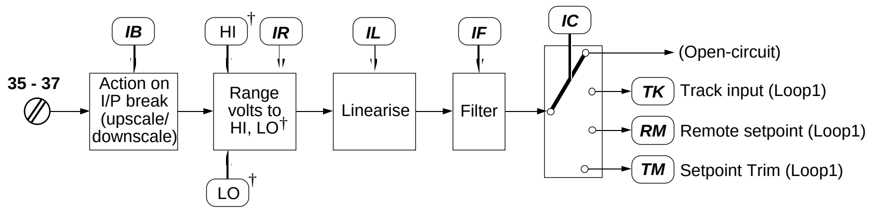
NOTE. You cannot assign the expansion board's digital I/O, or any of the main board's I/O, to customer terminals. They all have fixed functions (see Chapter 2, §§ 4.2.1 & 4.2.2).

Assignments are made by setting three configuration parameters — IC, AC, and OC — to the appropriate integer values. All three parameters are found in parameter List 6, shown in Table 4-4. You must also ***enable*** the expansion I/O board by setting B1 List 3 to TRUE.

2.1.1 Assigning process inputs — terminals 35 - 37

Figure 4-2 shows the available terminal assignments specified via IC when you have configured the instrument as a single-loop controller, and Figure 4-3 shows the fixed assignment for dual-loop controllers. Table 4-5 shows the corresponding IC-values required for the assignments.

The figures also indicate the other input processing occurring — input ranging, break protection, linearisation, and filtering. Specifying ranging is described in §2.2, break protection in §2.3, linearisation in §2.5, and filtering in §2.6.



† Destination	HI =	LO =
TK	100.0	0.0
RM	***HR***	***LR***
TM	***HT***	***LT***

Figure 4-2 Expansion I/O process input schematic — single-loop controllers

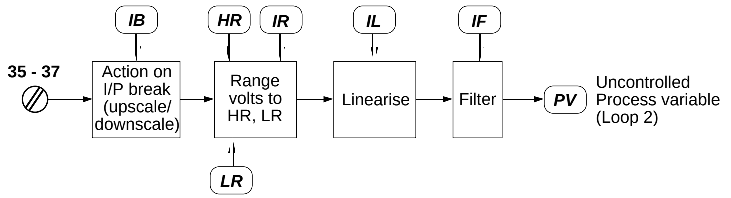


Figure 4-3 Expansion I/O process input schematic — dual-loop controllers

L6	Function	Type	Write	M'bus
IR	Process Input range [see Table 4-9]	Int		150
IB	Process Input break protection [see Table 4-11]	Int		151
IL	Process Input linearisation [see Table 4-13]	Int		152
IC	Process Input connection assignment [see Table 4-5]	Int		153
IF	Process Input filter time constant (0-1999.9 seconds)	Real		154
AR	Analogue input range [see Table 4-10]	Int		155
AB	Analogue input break protection [see Table 4-11]	Int		156
AC	Analogue input connection assignment [see Table 4-6]	Int		157
AF	Analogue input filter time constant (0-1999.9 seconds)	Real		164
OR	Analogue output range [see Table 4-10]	Int		158
OC	Analogue output connection assignment [see Table 4-7]	Int		159
DV	Digital I/O values at customer terminal (TRUE=high, FALSE=low)	CDhex		160
	Digital inputs:		D	
	Bit 0 — Hold select	T/F — 1		
	Bit 1 — Track select (*or unallocated user bit**)	T/F — 2		
	Bit 2 — Remote enable	T/F — 4		
	Bit 3 — (*Unallocated user bit*)	T/F — 8		
	Digital outputs:		C	
	Bit 4 — NOT[Hold OR Manual] (*or 'Raise' output**)	T/F — 1		
	Bit 5 — NOT[Remote Auto]	T/F — 2		
	Bit 6 — NOT[High Alarm] (*or NOT[Alarm] output**)	T/F — 4		
	Bit 7 — NOT[Low Alarm] (*or 'Lower' output**)	T/F — 8		
DI	Digital I/O inversion mask (TRUE=Invert bit, FALSE=copy bit)	CDhex		161
	Digital inputs:		D	
	Bit 0 — Hold select	T/F — 1		
	Bit 1 — Track select (*or unallocated user bit**)	T/F — 2		
	Bit 2 — Remote enable	T/F — 4		
	Bit 3 — (*Unallocated user bit*)	T/F — 8		
	Digital outputs:		C	
	Bit 4 — NOT[Hold OR Manual] (*or 'Raise' output**)	T/F — 1		
	Bit 5 — NOT[Remote Auto]	T/F — 2		
	Bit 6 — NOT[High Alarm] (*or NOT[Alarm] output**)	T/F — 4		
	Bit 7 — NOT[Low Alarm] (*or 'Lower' output**)	T/F — 8		
DC	Digital I/O connection mask (TRUE=connect bit, FALSE=disconnect)	CDhex		162
	Digital inputs:		D	
	Bit 0 — Hold select	T/F — 1		
	Bit 1 — Track select (*or unallocated user bit**)	T/F — 2		
	Bit 2 — Remote enable	T/F — 4		
	Bit 3 — (*Unallocated user bit*)	T/F — 8		
	Digital outputs:		C	
	Bit 4 — NOT[Hold OR Manual] (*or 'Raise' output**)	T/F — 1		
	Bit 5 — NOT[Remote Auto]	T/F — 2		
	Bit 6 — NOT[High Alarm] (*or NOT[Alarm] output**)	T/F — 4		
	Bit 7 — NOT[Low Alarm] (*or 'Lower' output**)	T/F — 8		
DU	Digital I/O pullup type [see Table 4-15]	Int		163

**If incremental control selected*

Table 4-4 List 6 expansion board I/O parameters

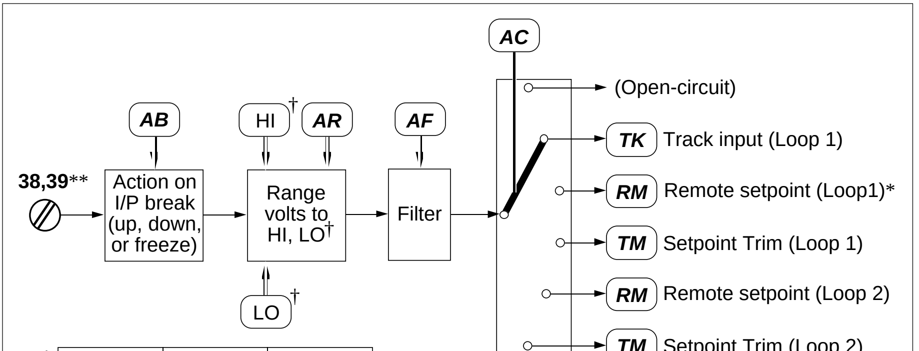
For terminals 35-37 input function ...	Parameter mnemonic	... Set IC List 6 to
Not connected	—	0
Loop 1 Track input	TK	1
(*Unallocated*)	—	(2)
Loop 1 Remote Setpoint	RM	3
Loop 1 Setpoint Trim	TM	4
Loop 2 uncontrolled Process Variable	PV	(*fixed assignment for dual-loop*)

Table 4-5 Process input terminal assignment using IC parameter

2.1.2 Assigning analogue inputs — terminals 38, 39

These are assignable for all controller types via the AC parameter. An exception is the Manual station configuration (CC=0), which does not use terminals 38, 39.

Figure 4-4 shows all the assignments available, and Table 4-6 gives the required AC settings. The figure also shows the other processing applied to the signal — ranging (§2.2), input break protection (§2.3), and filtering (§2.6).



† Destination	HI =	LO =
TK	100.0	0.0
RM	***HR***	***LR***
TM	***HT***	***LT***

Figure 4-4 Expansion I/O analogue input schematic

NOTE. Loop 1's Remote Setpoint (RM) is not assignable to terminals 38, 39 when the instrument is configured as a dual-loop controller.

For terminals 38, 39 input function ...	Parameter mnemonic	... Set AC List 6 to
Open circuit	—	0
Loop 1 Track input	TK	1
(*Unallocated*)	—	(2)
Loop 1 Remote Setpoint*	RM	3*
Loop 1 Setpoint Trim	TM	4
(*Unallocated*)	—	(5)
Loop 2 Remote Setpoint	RM	6
Loop 2 Setpoint Trim	TM	7

**Not assignable in ratio or cascade controllers*

Table 4-6 Analogue input terminal assignment using AC parameter

2.1.3 Assigning analogue outputs — terminals 40, 41

These are assignable for all controller types via the OC parameter. Figure 4-5 shows the options available, and Table 4-7 gives the required OC settings for the assignments. (Ranging via the OR parameter is described below in §2.2.)

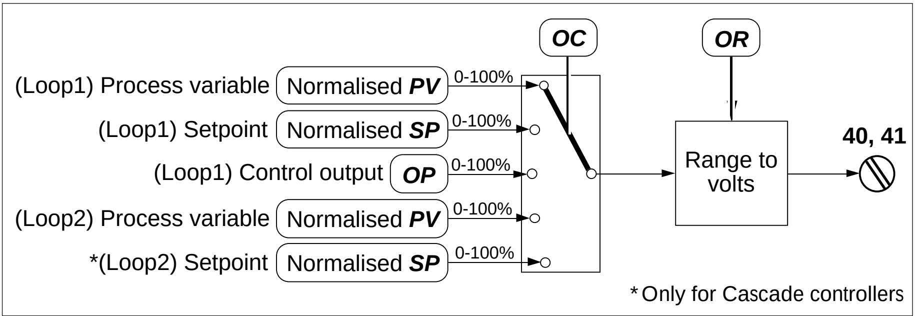


Figure 4-5 Expansion I/O analogue output schematic

Note that PV and SP are available on terminals 40 and 41 in their *normalised* form, not their engineering units form. That is, LR maps onto 0% and HR onto 100%. (Control output OP is always in normalised form anyway.)

For terminals 40, 41 output function ...	... Set OC List 6 to
Loop 1 Normalised Process Variable PV (%)	0
Loop 1 Normalised Setpoint SP (%)	1
Loop 1 Control Output OP (%)	2
Loop 2 Normalised Process Variable PV (%)	3
Loop 2 Normalised Setpoint SP (%)*	4*

**Available only for cascade controllers*

Table 4-7 Analogue output terminal assignment using OC parameter

NOTE. If you set OC to a value that is incompatible with your selected controller type — e.g. OC = 3 for single-loop — the analogue output is forced to zero.

2.2 Specifying hardware ranging & type

Having selected the controller type and assigned its optional I/O (if fitted), you are ready to specify the types of input signal that will be connected to the unit's input terminals, and the types of output signal you require at its output terminals. For example, you may have thermocouple process inputs on terminals 13 to 15, and want 4-20 mA process outputs on terminals 16 & 17. You must specify both the optional I/O provided by any expansion board fitted, and also the main board I/O.

Process input and output specification (see §2.2.1) is done by setting the parameters IR and OR, respectively, to the appropriate integer values. List 5 contains the main board I/O parameters and is shown in Table 4-8. List 6 — which was shown in §2.1 Table 4-4 — contains the expansion board I/O parameters.

L5	Function	Type	Write	M'bus
IR	Process Input range [see Table 4-9]	Int		144
IB	Process Input break protection [see Table 4-11]	Int		145
IL	Process Input linearisation [see Table 4-13]	Int		146
IF	Process Input filter time constant (0-1999.9 secs) [see §2.6]	Real		148
OR	Process output range [see Table 4-9]	Int		149

Table 4-8 List 5 main board I/O parameters

Analogue input and output types are specified via the AR and OR parameters (see §2.2.2). Both of these expansion board I/O parameters are found in List 6.

2.2.1 Specifying process input & output types — terminals 13-17 & 35-37

Process inputs are available on terminals 13-15 and 35-37. Outputs are available on terminals 16-17. Figures 4-2 and 4-3 (§2.1.1) showed the ranging schematically for the expansion I/O board process inputs (terminals 35-37). Figures 4-6 and 4-7 show the processing of the main board process inputs (terminals 13-15) and output (terminals 16 & 17), respectively.

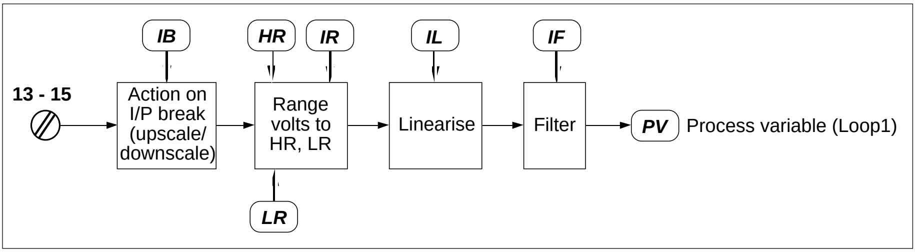


Figure 4-6 Main board I/O process inputs schematic

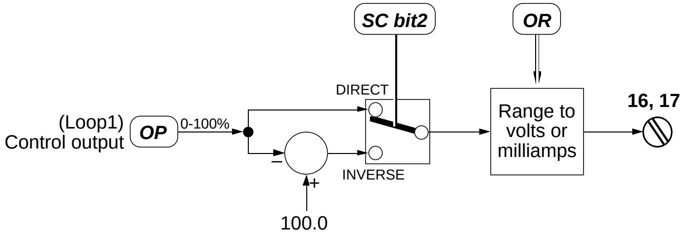


Figure 4-7 Main board I/O process output schematic

Table 4-9 shows the process I/O types available for main and expansion I/O boards, and the corresponding IR and OR settings.

For process I/O type ...	Input terminals 35-37 ... Set IR List 6 to	Input terminals 13-15 ... Set IR List 5 to	Output terminals 16-17 ... Set OR List 5 to
4-20 mA	0	0	0
0-20 mA	1	1	1
1-5 V	2	2	—
0-10 V	3	3	—
Thermocouple	4	4	—
RTD	5	5	—

Table 4-9 Specifying process input & output type via IR & OR parameters

Note that in Figure 4-2 the input signal is ranged to high and low values that depend on the destination assigned to the terminals. The input type selected via IR and the destination selected via IC together determine the correct ranging of the signal. For example, if you configure terminals 35-37 to be the Setpoint Trim (TM) input, with 4-20 mA input selected, then 4mA will map onto the Low Trim (LT) value, and 20mA will map onto the High Trim (HT) value.

The main I/O process inputs (terminals 13-15) are fixed function (Loop 1 PV), so the input signal is always ranged between LR & HR. (See Chapter 6, *Single loop controller*, for more information.)

Inversion of process output. Figure 4-7 shows that the main board process output (i.e. control output OP on terminals 16, 17) can be inverted according to the state of bit 2 of the SC status word. Inverse action means that the hardware control output at the terminals falls from 100% to 0% as the value of OP rises from 0% to 100%, which may be required for fail-safe plant control element operation. Set bit 2 TRUE for inverse output action, or FALSE for direct action.

2.2.2 Specifying analogue input & output types — terminals 38-41

Analogue inputs are available on customer terminals 38, 39 (see Figure 4-4). Outputs are available on terminals 40, 41 (see Figure 4-5). Table 4-10 shows the two analogue I/O types — available for expansion I/O boards only — and the corresponding AR and OR (List 6) settings.

For analogue I/O type ...	Input terminals 38, 39 ... Set AR List 6 to	Output terminals 40, 41 ... Set OR List 6 to
1-5 V	2	2
0-10 V	3	3

Table 4-10 Specifying analogue input & output type via AR & OR parameters

Note that in Figure 4-4 the input signal is ranged to high and low values that depend on the destination assigned to the terminals. The input type selected via AR and the destination selected via AC together determine the correct ranging of the signal. This works in a similar way to process input ranging, described in §2.2.1.

Analogue output ranging — specified via the OR parameter — is indicated in Figure 4-5. For these normalised signals 0% is always mapped onto the low voltage point (0 or 1 volts), and 100% is always mapped onto the high voltage point (5 or 10 volts).

2.3 Specifying input break protection

You can configure what happens to the signal passing into the controller if the real input sourcing that signal goes open-circuit — this is 'input break protection', described in this section. Note that you can also specify what happens to the controller's *output* and *mode* if the PV input fails. This is 'sensor break action', and is described next in §2.4.

For input break protection, you can specify that the signal adopts a high value (upscale break), a low value (downscale break), or — for analogue inputs — freezes at its current value. This is done by setting the IB and AB parameters appropriately. Figures 4-2 to 4-4 (§2.1), and Figure 4-6 (§ 2.2) show this schematically.

Table 4-11 gives the required IB and AB settings for the different break protection options. Note that IB is found both in List 5 for main board I/O, and List 6 for expansion board I/O, which can be set independently. AB is available only in List 6, for the expansion board's analogue input.

WARNING!

If RTD process input is selected (IR=5) with downscale break (IB=2), then on input break the signal may go upscale for ≤0.25 seconds before settling downscale.

For action on input break ...	Input terminals 13-15 ... Set IB List 5 to	Input terminals 35-37 ... Set IB List 6 to	Input terminals 38, 39 ... Set AB List 6 to
Freeze input	(*not available*)	(*not available*)	0
Upscale break	1	1	1
Downscale break	2*	2*	2

**See Warning*

Table 4-11 Specifying input break protection via IB & AB parameters

2.4 Specifying sensor break action

Sensor break action is the way the controller's mode and hardware output respond to failure of the process variable input. PV can 'fail' by going open-circuit, or underrange, or overrange sufficiently to saturate the A-to-D converter. Sensor break action is specified for all configurations by bits 1, 2, and 4 of the SC List 1 configuration status word, and also by bit 4 of the List 2 SC parameter in dual-loop controllers. (SC List 2 bits 1 and 2 are not used.) Table 4-12 summarises the four possible options for controllers in general. (For information specific to incremental controllers, see Ch10 §6.)

NOTE. On PV fail, the message '**S_br**' ('sensor break') flashes in the 4½-digit display, and the mode and output freeze at their current values. Then, after a delay of about 3 seconds, they adopt the values shown in Table 4-12. If PV is restored within this delay, sensor break action is avoided.

SC bit1	SC bit2	SC bit4*	Mode adopted*	Control hardware output
FALSE	X	FALSE	Forced Manual	Left at last value
TRUE	FALSE	FALSE	Forced Manual	Low value (=LO, Low output limit)
TRUE	TRUE	FALSE	Forced Manual	High value (=HO, High output limit)
X	X	TRUE	Maintain existing	Depends on mode & I/P break protection

**In corresponding loop* X = *'don't care'*

Table 4-12 Action on sensor break — available configurations

2.5 Specifying process input linearisation

You may want to linearise an input signal, e.g. square-root the signal from a flow-measuring orifice plate, or characterise a specific thermocouple input. This can be done for the process inputs on both the main board I/O and the expansion board I/O, i.e. terminals 13-15 and 35-37, as schematised in Figures 4-2, 4-3, and 4-6.

To specify a linearisation, set the applicable Input Linearisation parameter IL to the value shown in Table 4-13. Use the List 5 parameter for the main board I/O and List 6 for the expansion board I/O. Note that setting IL to zero disables linearisation.

For input linearisation ...	... Set IL to
(*none*)	0
square root √ [see §2.5.1]	1
J-type thermocouple	2
K-type thermocouple	3
T-type thermocouple	4
S-type thermocouple	5
R-type thermocouple	6
B-type thermocouple	7
N-type thermocouple	8
PT100 resistance thermometer	9

Table 4-13 Specifying process input linearisation using IL parameter

Note that you should select a linearisation appropriate to your process input type:

- **mA and V inputs.** (IR = 0 to 3, see Table 4-9). Set IL to any value in Table 4-13.
- **Thermocouple inputs.** (IR = 4). Set IL in the range 2 to 8.
- **RTD inputs.** (IR = 5). Set IL to 9.

2.5.1 Applying square root linearisation

Square root linearisation is applied by converting the electrical input signal to a number between 0 and 1, extracting the square root, then ranging the result between the appropriate high and low range parameters.

E.g. *Square root linearising a 12mA input signal in the 4-20mA range.* 4mA maps onto 0 and 20mA maps onto 1, so 12mA converts to 0.5. $\sqrt{(0.5)} \approx 0.7$. If LR=100 and HR=200, then mapping LR to 0 and HR to 1 ranges 0.7 to a linearised result of ≈170.

2.6 Specifying process input filtering

You may want to apply first-order filtering to smooth out a noisy input signal, before it passes on into the controller, e.g. to achieve more stable control or to avoid output bumps. This can be done via the Input Filter parameter IF for the process inputs on both the main board I/O and the expansion board I/O, i.e. terminals 13-15 and 35-37, as schematised in Figures 4-2, 4-3, and 4-6, and also via the Analogue Filter parameter AF for the expansion board's analogue input on terminals 38 and 39, schematised in Figure 4-4.

To specify a first-order filter time constant in the range 0-1999.9 seconds, simply set the applicable filter parameter IF or AF to the required value. Use the List 5 parameter (Table 4-8) for the main board I/O and List 6 (Table 4-4) for the expansion board I/O.

NOTE. Setting IF or AF to zero disables filtering.

Figure 4-8 shows how the time constant affects the way a step change in the unfiltered input is followed by the filtered output. Specifically, the output takes IF or AF seconds to rise to about 63% of the new input value. After that, its approach continues exponentially.

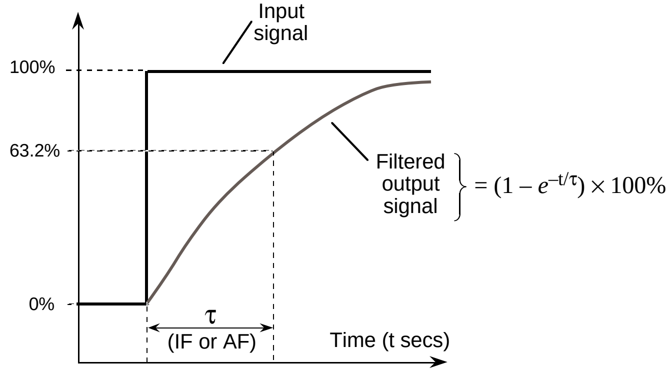


Figure 4-8 Specifying filter action using IF or AF — response to step input

2.7 Specifying digital I/O connection & inversion

Figures 4-9 and 4-10 schematise the parameters involved with processing the expansion board's digital inputs (terminals 24-26) and digital outputs (terminals 28-31), respectively. The parameters are all 8-bit bytes, with bits 0 to 3 relating to the digital inputs, and bits 4 to 7 to the digital outputs. (See Chapter 2 §4.2.2 for details of the terminal designations.)

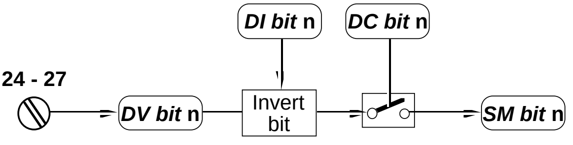


Figure 4-9 Expansion board digital input schematic

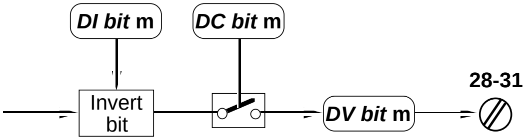


Figure 4-10 Expansion board digital output schematic

Note that, for inputs and outputs, the DV parameter bits reflect the actual digital states existing at the customer terminals.

You can individually connect/disconnect, or invert every digital by setting the bits of the DC and DI parameters, respectively, to appropriate values . Table 4-4 in §2.1.1 lists all these bits, and Table 4-14 summarises their interpretation.

Bit state	(Inputs) DV bits 0-3	(Outputs) DV bits 4-7	(Inputs) DC bits 0-3	(Outputs) DC bits 4-7	(I/O) DI
0	=Low input	=Low output	=Disconnect*	=Disconnect†	=Copy bit
1	=High input	=High output	=Connect	=Connect	=Invert bit

**DV pulled low by hardware †DV holds last value*

Table 4-14 Specifying & interpreting digital I/O parameter bit-states — DV, DC, & DI

2.8 Specifying digital I/O pullup type

You use the Digital Pullup parameter DU to specify the type of pullup — internal or external — required on the digital inputs and outputs. Note that you can specify only one type of pullup for the set of four inputs, and only one type for the set of four outputs — you cannot specify for individual digitals.

If logic inputs are driving customer terminals 24-27, you should specify external pullup on the inputs. For contact sensing applications, however, specify internal pullup on the inputs. If output terminals 28-31 are driving relays you should specify external pullup on the outputs (from an external power supply). Specify internal pullup on the outputs if you want them to drive logic. Table 4-15 summarises the DU parameter settings required for all four possible digital I/O pullup combinations.

(See Chapter 2 §§ 5.5 & 5.6 for examples of digital I/O circuit schematics.)

(terminals 24-27) For input type ...	(terminals 28-31) & output type ...	... Set DU List 6 to
Logic (*external pullup*)	Relay (*external pullup*)	0
Contact sense (*internal pullup*)	Relay (*external pullup*)	1
Logic (*external pullup*)	Logic (*internal pullup*)	2
Contact sense (*internal pullup*)	Logic (*internal pullup*)	3

Table 4-15 Specifying digital I/O pullup types via DU parameter

2.9 Specifying the alarm relay output configuration

You can configure how the alarm relay operates for each loop independently.

Figure 4-11 shows schematically how the relay operates; the outputs are on main board customer terminals 20, 21. The relay is normally closed, but opens if there are any alarms — of a specific type — in a loop. The relay is controlled by bit 9 of the Alarm status word AL, which is found in List 1 and List 2. Either loop's AL bit 9 will operate the alarm relay. (Alarms are described in Chapter 16.)

For each loop, AL bit 14 lets you configure the relay to open either on absolute alarms only (TRUE), or on both absolute and deviation alarms (FALSE) — see the schematic. AL bit 15 lets you specify that the alarm relay remains open only while a valid *unacknowledged* alarm exists in the loop (TRUE), whether or not the actual alarm condition has cleared. Alternatively, you can specify that it remains open only while there is a valid *active* alarm in the loop (bit 15 FALSE).

You can disable the relay completely for each loop by setting AL bit 13 TRUE in the loop. Then, no alarm in that loop is able to set bit 9 and open the relay. Figure 4-11 schematises these actions.

(Chapter 6, *Single-loop controller*, gives the complete List 1 for Loop 1.)

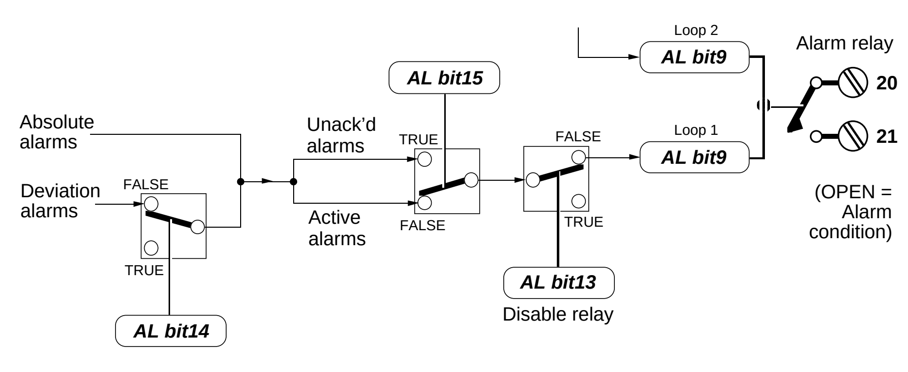


Figure 4-11 Alarm relay schematic

3 PARAMETERISING THE CONTROL LOOPS

Parameterising a control loop specifies how it will operate in your control system. It consists of accessing the loop's commissioning parameters and setting them to appropriate values. For example, you will want to specify setpoint ranges and limits, alarm limits, PID tuning parameters, power-up modes, control action, and so on.

Loop-commissioning parameters are found in List 1 (for Loop 1) and List 2 (for Loop 2, in dual-loop controllers). The list you first access via the PAR button corresponds to the loop currently on display. The parameters contained in a particular loop-commissioning list depend on what controller your instrument is configured as, and whether you are looking at Loop 1 or Loop 2.

To see complete parameter lists and descriptions for the loops in each type of controller, refer to the chapter dealing with that individual controller — Chapter 6, *Single loop controller*, Chapter 7, *Cascade controller*, Chapter 8, *Ratio controller*, Chapter 9, *Manual station*, Chapter 10, *Incremental control*, and Chapter 11, *Override controller*. Additionally, the schematics given in Appendix 1, 2, and 3 show how the loop parameters interact with the signal flows through each controller.

NOTE. To locate information on any parameter in the instrument, consult the *Parameter index* at the back of this manual, just before the *Main index*.

Chapter 5 CONTROL OPERATING MODES

This chapter tells you about the control operating modes supported by the instrument. For information on which of these modes apply to a particular controller option, and how they are implemented, you should refer to the individual chapter on that controller.

The main sections in this chapter are:

- Control modes supported (§1)
- Determining the resultant operating mode — MN (§2)
- Effect of the mode pushbuttons — MS (§3).

1 CONTROL MODES SUPPORTED

Table 5-1 lists all the operating modes supported by the controller. They are listed in order of 'priority', with Hold mode having the highest priority. The table gives for each mode the selection conditions, how you can recognise it from the front-panel LEDs, and how it affects the controller action.

Mode	Selected by	Front panel	Action
Hold	Hold select TRUE	'HOLD' lamp lit	Output frozen
Track	Track select TRUE	'TRACK' lamp lit	Output follows Track value
Forced Manual	PV input or sumcheck failure	'MAN' lamp flashes	As Manual, but lower priority modes cannot be selected until PV restored
Manual	Press 'M' button	'MAN' lamp lit	Output set by operator. Controller acts as manual station. On entry, output adopts last value
Local Auto	Press 'A' button	'AUTO' lamp lit	Automatic control using Local Setpoint
Forced Auto	Press 'R' button, Rem Enable FALSE	'AUTO' lamp flashes	As Local Auto
Remote Auto	Press 'R' button, Rem Enable TRUE	'REM' lamp lit	Automatic control using Remote Setpoint. Local Setpoint tracks RM unconditionally
Ratio	Press 'R' button, CC=3, PV2 OK	'RATIO' lamp lit	As Remote Auto

Table 5-1 Modes supported in descending priority order

1.1 Mode priority

It is possible for more than one mode at a time to be selected for a control loop . However, the loop can only ever adopt a single operating mode — this is the enabled one with the highest priority.

For example, if the Hold select digital input (customer terminal 24) and the Track select input (terminal 25) are both ‘high’, and also if the operator presses the ‘M’ button to select Manual mode, the front-panel displays will light the ‘HOLD’, ‘TRACK’ and ‘MAN’ lamps simultaneously, indicating all the modes currently selected. But the mode actually operating will be Hold mode, because it has the highest priority.

If the operating mode becomes deselected for any reason, the currently-selected mode with the next highest priority takes over. In the above example, if the input to terminal 24 (Hold select) went ‘low’, Track mode would take over as the operating mode because it has the next-highest priority. Only the ‘TRACK’ and ‘MAN’ lamps would remain lit.

NOTE. The digital states mentioned in this example, and throughout this chapter, assume that the bits concerned are not being inverted.

1.2 Modes accessed via the ‘M’, ‘A’, and ‘R’ pushbuttons

It is possible to select Hold, Track, and Forced Manual modes simultaneously if all three entry conditions are met. But the Manual, Local Auto, and the remote modes are mutually-exclusive — pressing any one of the mode buttons ‘M’, ‘A’, and ‘R’ automatically deselects the other two. (This is because pressing each mode button sets the Requested Mode parameter MS to a unique value, as described in §3.)

1.3 Modes accessed via the ‘R’ pushbutton

When you press the front-panel ‘R’ mode button you will select any one of three modes, depending on the state of the Remote Enable input, and what controller type you have selected via the CC parameter (see Ch4 §1). Refer to Table 5-1.

1.3.1 Forced Auto

If remote mode has not been enabled, e.g. because the Remote Enable digital input (customer terminal 26) is ‘low’, pressing ‘R’ selects Forced Auto mode, and the ‘AUTO’ lamp flashes to warn you of this.

NOTE. In the Manual station configuration (CC=0), pressing ‘R’ with Remote not enabled causes a ‘pseudo Forced Manual’ mode to be adopted, and the ‘MAN’ lamp flashes. For details see Chapter 9, §3.

1.3.2 Remote Auto

If remote mode has been enabled, e.g. because the Remote Enable input is ‘high’, pressing ‘R’ selects Remote Auto mode, and the ‘REM’ lamp lights.

1.3.3 Ratio

If you have configured the instrument as a Ratio controller (by setting CC = 3), pressing ‘R’ in Loop 1 selects Ratio mode, provided Loop 2’s PV input — the ‘uncontrolled PV’ — is present. (It is this input that supplies the Remote Enable signal to Loop 1, not the digital input to terminal 26.) The ‘RATIO’ lamp lights to confirm this.

If Loop 2's PV is faulty, the necessary Remote Enable signal will be absent and so Forced Auto will be selected instead.

NOTE. The mode *selected* does not necessarily become the *operating* mode of the loop (see §1.1). It is adopted only if there is no other currently-selected mode of higher priority.

2 DETERMINING THE RESULTANT OPERATING MODE — MN

Each loop has a Resultant Mode parameter MN in its loop-commissioning list, storing an integer value in the range 0-7 to represent the eight possible modes. MN determines the single operating mode adopted by the loop concerned, decided on from the choice of currently-selected modes. Note that there is always at least one currently-selected mode.

Table 5-2 shows how the Resultant Mode parameter MN is derived.

MS	Ratio	Remote	Track	Hold	Forced	MN	Mode
x	x	x	x	T	x	0	Hold
x	x	x	T	F	x	1	Track
0	x	x	F	F	F	2	Manual
1	x	x	F	F	F	3	Local Auto
2	T	T	F	F	F	4	Ratio
2	F	T	F	F	F	5	Remote Auto
0	x	x	F	F	T	6	Forced Manual
2	x	F	F	F	F	7	Forced Auto

T = *TRUE/high.* F = *FALSE/low.* x = *'don't care'*

Table 5-2 Derivation of Resultant Mode parameter MN and corresponding modes

The following six items are taken into account to arrive at the value of MN:

- **MS.** The MS parameter value (0-2), reflecting what mode pushbuttons the operator has pressed. (MS can also be written via the comms.) See Table 5-3 in §3.
- **Ratio.** If the Ratio station has been configured (CC parameter set to 3)
- **Remote, Track, Hold.** The states of the SM status word bits 2-0, corresponding to the mode-select digital inputs — Remote enable, Track select, and Hold select.
- **Forced.** Indications that Forced Manual mode should be selected, owing to PV input or sumcheck failures.

Figure 5-1 illustrates schematically the derivation of MN, and also indicates the priorities of the various operating modes. In the figure, the nearer a 'mode switch' is to the MN parameter on the right, the higher the priority of the corresponding mode — because the state of all 'switches' to the left of it have no effect on MN's value.

For example, if Hold mode has been selected by an input to terminal 24, then MN takes the value '0' regardless of the states of any of the other 'switches' in the schematic. This is why Hold mode has the highest priority.

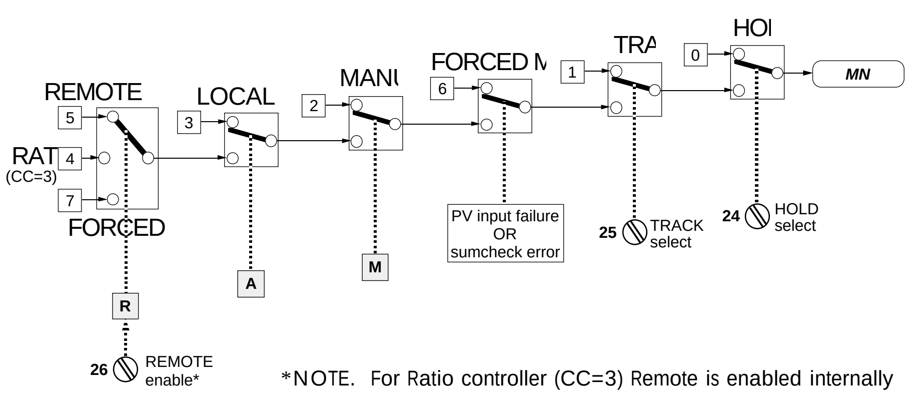


Figure 5-1 Derivation of adopted operating mode — the MN parameter

3 EFFECT OF THE MODE PUSHBUTTONS — MS

As Table 5-2 shows, one of the items taken into account by the loop software in deciding what mode to adopt is the value of the Requested Mode parameter MS. The value of MS is set by pressing the front-panel mode pushbuttons (or via the comms). Also, the adoption of Forced Manual mode forces MS to zero, overriding the pushbuttons.

Table 5-3 shows how pressing the 'R', 'A', and 'M' pushbuttons affects MS.

Pressing the...	...sets MS to...	...corresponding to modes
'M' button	0*	Manual (or Forced Manual*)
'A' button	1	Local Auto
'R' button	2	Remote Auto, Ratio, or Forced Auto

**MS is held at zero if Forced Manual mode is adopted*

Table 5-3 Setting the Requested Mode parameter MS

Note that each loop in a dual-loop controller has its own MN and MS parameters.

Chapter 6 SINGLE-LOOP CONTROLLER

This chapter tells you how to configure and use the instrument when it is set up as a Single-loop controller. The main topics dealt with in this chapter are:

- Overviews of the single-loop controller (§1)
- Single-loop controller inputs and outputs (§2)
- Single-loop controller operating modes (§3)
- Single-loop controller parameters (§4)
- Setup sheet for the single-loop controller (§5).

Appendix A details the loop signal-processing and shows how parameters and data interact through the strategy. Chapter 5 describes controller operating modes in general.

NOTE. If the loop is set up as an incremental controller, the signal-processing is modified — especially control output generation — and some additional parameters are involved. Refer to Chapter 10, *Incremental control*, for details.

1 OVERVIEWS OF THE SINGLE-LOOP CONTROLLER

1.1 General overview

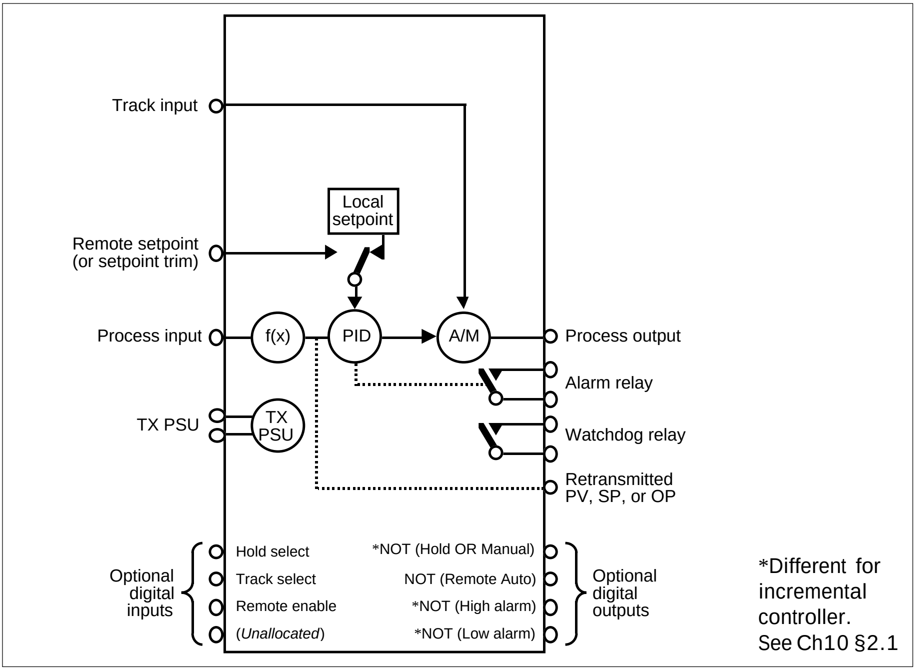


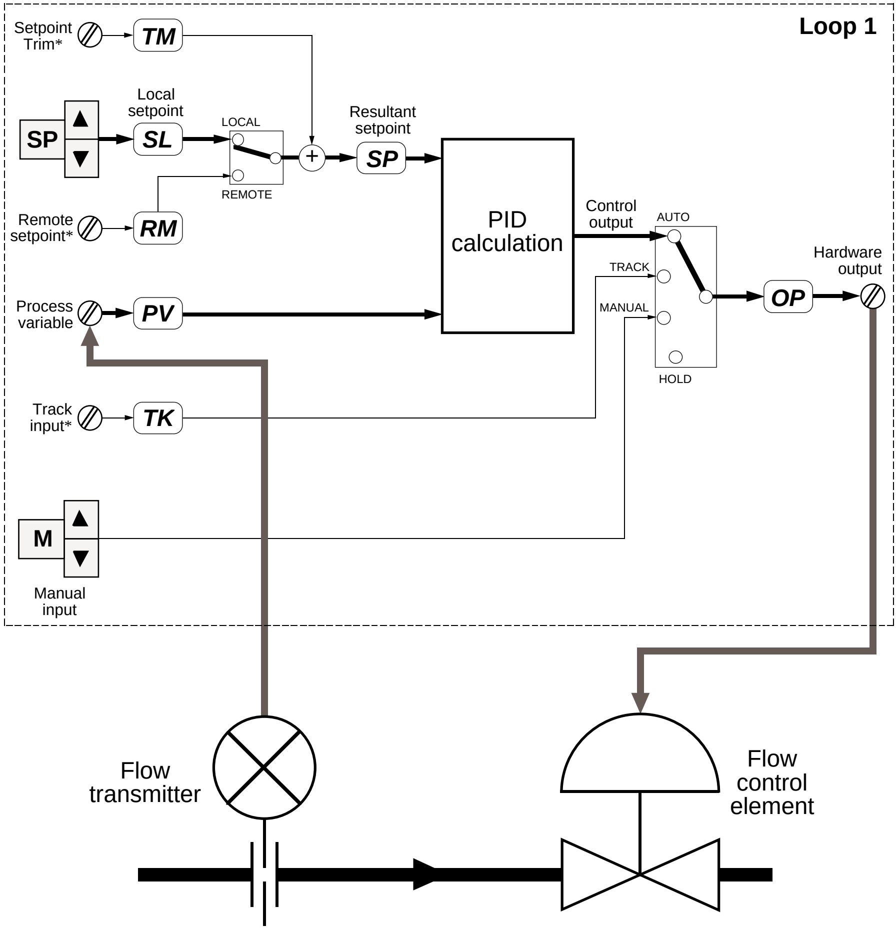
Figure 6-1 Single-loop controller overview

Figure 6-1 is an overview of the controller and its I/O.

A simple single-loop process controller can be configured using the main I/O board only. If the optional expansion I/O board is fitted, a choice of remote setpoint, trim or track signals can be input to the controller as well.

1.2 Flow control example

Figure 6-2 shows an example of the controller being used to control fluid flow in a pipe.



*All possibilities shown; only two available at a time

Figure 6-2 Single-loop controller overview — flow-control example

In automatic operation, the resultant setpoint SP is compared by the PID algorithm to the process variable input PV and a control output OP is generated. OP determines the flow control element's setting. SP can be derived from the Local Setpoint SL, or from an input Remote Setpoint RM. A Trim value TM can be added to the setpoint. The diagram indicates that SL can be adjusted by the operator using the 'SP' and ▲/▼ pushbuttons.

The controller can also operate in other, non-automatic, modes as indicated schematically in the diagram by the 'mode switch' feeding the OP parameter. How these modes are selected is shown in §3.

2 SINGLE-LOOP CONTROLLER INPUTS & OUTPUTS

Figure 6-3 summarises the I/O available for the single-loop controller. Terminal numbers 1-22 refer to the main board I/O, and terminals 23-44 refer to the (optional) expansion I/O board.

In the figure, terminal numbers enclosed in brackets are user-assignable, as described in Chapter 4, *Configuration*. Unbracketed terminal numbers have fixed assignments.

NOTE. If you want to see in more detail exactly where the I/O signals are routed to and from within the control strategy, please refer to Appendix A.

3 SINGLE-LOOP CONTROLLER OPERATING MODES

Table 6-1 summarises the possible operating modes of the single-loop controller. They are listed in descending order of priority. The table gives for each mode the entry conditions, how you can recognise it from the front-panel LEDs, and how it affects the controller action. For more information on operating modes and priorities see Chapter 5.

Mode	Selected by	Front panel	Action
Hold	Hold select input TRUE	'HOLD' lamp lit	Output frozen
Track	Track select input TRUE	'TRACK' lamp lit	Output follows Track value
Forced Manual	PV input or sumcheck failure	'MAN' lamp flashes	As Manual, but lower priority modes cannot be selected until PV restored
Manual	Press 'M' button	'MAN' lamp lit	Output set by operator. Controller acts as manual station. On entry, output adopts last value
Local Auto	Press 'A' button	'AUTO' lamp lit	Automatic control using Local Setpoint
Forced Auto	Press 'R' button, Rem Enable FALSE	'AUTO' lamp flashes	As Local Auto
Remote Auto	Press 'R' button, Rem Enable TRUE	'REM' lamp lit	Automatic control using Remote Setpoint. Local Setpoint tracks RM unconditionally

Table 6-1 Modes supported by the single-loop controller in descending priority order

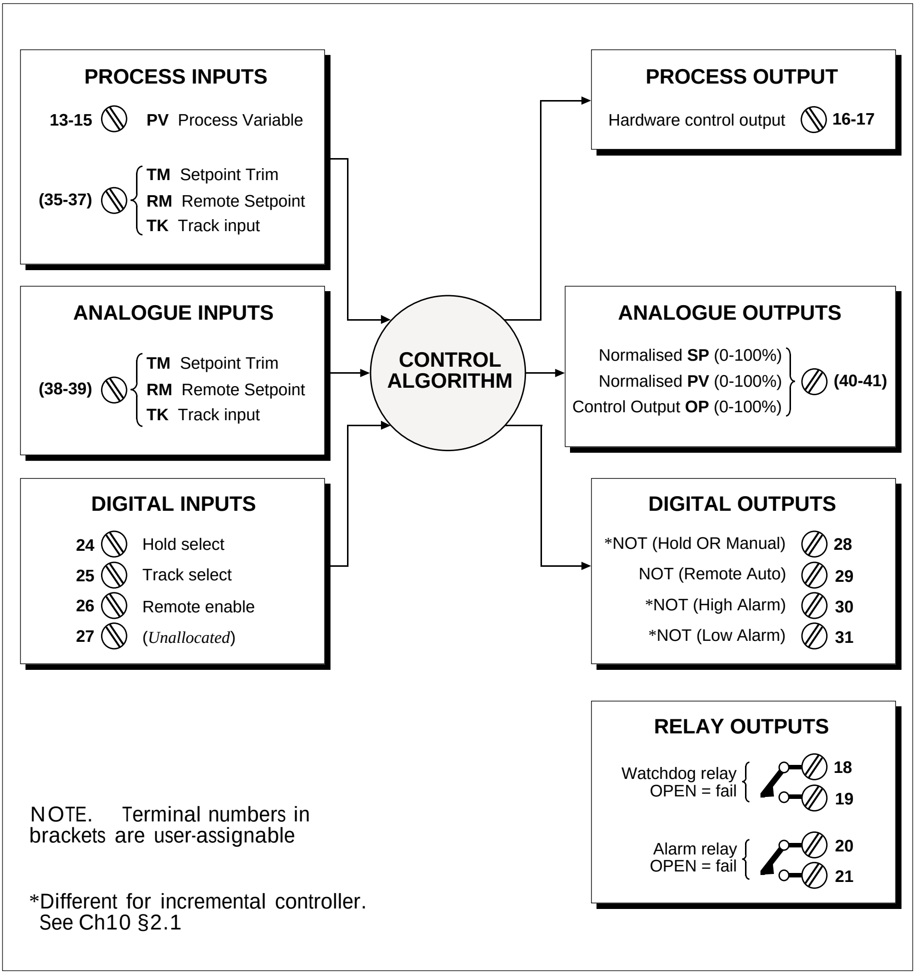


Figure 6-3 Single-loop controller I/O summary

The controller can operate in two distinct types of operating mode — closed-loop (automatic) mode or open-loop (non-automatic) mode.

3.1 Automatic operation

Refer to Table 6-1 and Figure 6-2.

The measured flow rate is sent to the PV input terminal of the controller. This signal is linearised within the controller (see Ch4 §2.5) to be proportional to the flow rate, and is passed into the PID calculation area. Here, it is compared with SP, and a control output OP is calculated by the PID algorithm as a percentage, based on the difference between PV and SP (the error). OP is ranged within the controller (see Ch4 §2.2) then passed via the hardware output terminals to the flow control element. The ranging process converts OP% to a proportional voltage or current value suitable for operating the valve.

In practice, if the measured flow rate PV is higher than the required value SP, the PID calculation automatically adjusts the control output to close the valve by a certain amount, thereby reducing the flow. Or, if the flow rate is too low, OP automatically changes to open up the valve and increase the flow. If the flow rate is on target, OP's value is unaltered. In this way, control is established and the required flow maintained.

The PV signal from the plant to the controller, and the return OP signal from the controller to the plant, together form the closed loop necessary for this type of automatic control.

3.1.1 Local auto & remote auto operating modes

If SP derives from SL, the controller is operating in Local Auto mode. If SP derives from the Remote Setpoint RM, the operating mode is Remote Auto.

3.2 Non-automatic operation

Output signal OP can be derived from sources other than the PID calculation result. This is represented schematically in Figure 6-2 by the 4-way 'mode switch' feeding the OP parameter. In these cases the loop is no longer closed, and so control of the valve is no longer automatic.

3.2.1 Track mode

In Track mode, the hardware output comes from the Track Input parameter value TK, instead of from the PID calculation. This breaks the closed loop and means that the valve position is determined solely by the value of TK.

3.2.2 Manual mode

The valve may be controlled 'by hand' rather than automatically. To do this you select Manual mode — equivalent to setting the 'mode switch' to the Manual position. Now OP can be adjusted via the front-panel 'M' and ▲/▼ pushbuttons as indicated in the figure (Manual input). As in Track mode, PV does not influence the OP-value while the controller is in Manual.

3.2.3 Hold mode

Another possibility is for the control output OP to 'freeze' at its current value, whatever that is, regardless of the values of any input signals or the PID calculation result. To do this you select Hold mode, represented in the figure by a 'mode switch' position with no 'input signal'.

NOTE. Other operating modes are possible with this controller — Forced Manual and Forced Auto. These are shown in Table 6-1.

4 SINGLE-LOOP PARAMETERS — LIST 1

4.1 Parameter lists

Table 6-2 lists all the loop-commissioning parameters associated with the single-loop controller — which are seen in List 1, accessed via passcode ‘P0’. Further information on some of the parameters is found where indicated in the table.

Also listed is the parameter type (format), Modbus address, and whether it is read-only. (For a complete parameter list in order of Modbus address, refer to Ch 14 §3.4.)

L1	Function	Type	Write	M’bus
DP	Decimal point position for List 1 parameters* (0-4 decimal places)	Int		0
HR	Setpoint high range (limits: –19999 to +19999)†	Real		6
LR	Setpoint low range (limits: –19999 to +19999)†	Real		7
HT	Trim high range & high limit (limits: LR–HR to HR–LR)	Real		28
LT	Trim low range & low limit (limits: LR–HR to HR–LR)	Real		29
HS	Setpoint high limit (limits: LR to HR)	Real		14
LS	Setpoint low limit (limits: LR to HR)	Real		15
HA	High Absolute alarm level (limits: LR to HR)	Real		10
LA	Low Absolute alarm level (limits: LR to HR)	Real		11
HD	High Deviation alarm level (limits: 0 to HR–LR)	Real		12
LD	Low Deviation alarm level (limits: 0 to HR–LR)	Real		13
HO	High Output limit (0.00-100.00%)	Real		16
LO	Low Output limit (0.00-100.00%)	Real		17
XP	Proportional band, On/Off control hysteresis (0.0-1999.9) [see §4.2]	Real		18
TI	Integral time (0.00-199.99 TB-units) [TI=0 disables integral term]	Real		19
TD	Derivative time (0.00-199.99 TB-units) [TD=0 disables deriv. term]	Real		20
TM	Trim value (limits: LT to HT)	Real		26
RM	Remote Setpoint value (limits: LS to HS)	Real		25
SL	Local Setpoint (limits: LS to HS)	Real		2
SP	Resultant Setpoint	Real	✘	5
PV	Process Variable	Real	✘	1
OP	Control Output (0.00-100.00%) (limits also: LO to HO)	Real		3
TK	Track value (0.00-100.00%) (limits also: LO to HO)	Real		27
AL	Alarm status word [see Table 6-3]	ABCDhex		4
SM	Mode status word [see Table 6-4]	ABCDhex		23
SC	Configuration status word [see Table 6-5]	ABCDhex		21
BM	Pushbutton mask [see Ch3 §1.6.9]	CDhex		22
MS	Requested mode (0-2) [see Ch5 §3]	Int		8
MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘	9
TT**	Motor travel time (0.5-1999.9 secs) [see Ch10 §5.1.2]	Real		230
PT**	Minimum pulse time (0.1-60.0 secs) [see Ch10 §5.1.3]	Real		31
TB	Timebase (0-1) [0=seconds, 1=minutes]	Int		30

†Subject to relevant decimal point position **Except as indicated in the table*
***Seen only if incremental control selected* *✘Read-only parameter*

Table 6-2 List 1 control loop commissioning parameters — single-loop controller

Table 6-3 lists the bits in the Alarm status word AL, and their meanings. Bit 8 is 'write-only', i.e. it resets automatically to zero after being set to 1. It can be written to directly, but pressing the front-panel alarm acknowledge pushbutton sets it to 1.

	Function		Type			Write
AL	Alarm status word		ABCDhex			
	Bit 0 — High Absolute	Alarm condition (TRUE=active)	T/F —	1	D	✘
	Bit 1 — Low Absolute		T/F —	2		
	Bit 2 — High Deviation		T/F —	4		
	Bit 3 — Low Deviation		T/F —	8		
	Bit 4 — High Absolute	Alarm status (TRUE=unack'd)	T/F —	1	C	
	Bit 5 — Low Absolute		T/F —	2		
	Bit 6 — High Deviation		T/F —	4		
	Bit 7 — Low Deviation		T/F —	8		
	Bit 8 — Alarm acknowledge (TRUE resets bits 4-7)		T/F —	1	B	✎
	Bit 9 — Alarm relay (TRUE=alarm, relay de-energised)		T/F —	2		✘
	Bit 10 —	*(Unused)*	T/F —	4		
	Bit 11 —		T/F —	8		
	Bit 12 — Auto ack. (T: auto-ack cleared alrm, F: needs manual ack)		T/F —	1	A	
	Bit 13 — Relay disable (T: disable alarm relay, F: enable relay)		T/F —	2		
	Bit 14 — Relay on abs. only (T: abs. only, F: abs. & dev. alarms)		T/F —	4		
	Bit 15 — Relay action (T: on unack'd alarm, F: on valid active alarm)		T/F —	8		

Table 6-3 Alarm status word AL (List 1)

Table 6-4 shows the bits of the Mode status word SM. Bits marked * apply to List 1 only.

	Function		Type			Write
SM	Mode status word		ABCDhex			
	Bit 0 — Hold select	Digital inputs	T/F —	1	D	
	Bit 1 — Track select		T/F —	2		
	Bit 2 — Remote enable		T/F —	4		
	Bit 3 — Comms disable*		T/F —	8		
	Bit 4 — NOT [Hold OR Manual]	Digital inputs	T/F —	1	C	✘
	Bit 5 — NOT [Remote Auto]		T/F —	2		✘
	Bit 6 — Raise output*		T/F —	4		
	Bit 7 — Lower output*		T/F —	8		
	Bit 8 — Sensor break (TRUE flags PV fail)		T/F —	1	B	✘
	Bit 9 — Sumcheck error*		T/F —	2		
	Bit 10 — Calibration sumcheck error*		T/F —	4		
	Bit 11 — Hardware conflict* (TRUE=h/ware confign. mismatch)		T/F —	8		
	Bit 12 — Autotune (TRUE starts one-shot tune)		T/F —	1	A	
	Bit 13 — Tune fail (TRUE indicates tuning failure)		T/F —	2		✘
	Bit 14 — Drooptune (TRUE causes 'manual reset')		T/F —	4		
	Bit 15 — Cold started* (TRUE on cold start, FALSE on warmstart)		T/F —	8		✘

Table 6-4 Mode status word SM (List 1)

Table 6-5 shows the bits of the Configuration status word SC. Note that bits 5 and 6 apply only to instruments configured as Ratio controllers. All SC bits are set/reset by the user.

Bit	Name	Function	Dec/Hex	
0	Powerup*	T: Power up in Manual with Failsafe output F: Power up in last mode & last output	1	D
1	Failsafe output*	T: Low output F: Last output	2	D
2	Invert OP*	T: Invert the electrical output [see §4.3] F: No inversion	4	D
3	Invert PID	T: ΔPV & ΔOP same sense [see §4.3] F: ΔPV & ΔOP opposite sense	8	D
4	PV fail mode*	T: On PV fail maintain existing mode [see Ch4 §2.4] F: On PV fail adopt Forced Manual mode with Failsafe output	1	C
5	Inverse Ratio*†	T: Loop1 Remote Setpoint =PV2 × Ratio Setpoint F: Loop1 Remote Setpoint =PV2 ÷ Ratio Setpoint	2	C
6	Ratio Track*†	T: Ratio Setpoint tracks measured Setpoint when Loop1 not in Remote F: Ratio Setpoint does not track	4	C
7	Simulation	T: Connect plant simulation F: Do not connect plant simulation } (*not implemented*)	8	C
8	Incremental Control*	T: Use incremental control (raise/lower) F: Use continuous control	1	B
9	On/Off Control	T: Use On/Off control [see §4.2] F: Use PID control	2	B
10	(*Not used*)		4	B
11	SL Balance	T: Debump on writing to SL (SE bit5 set) F: No debump on SL writes	8	B
12	SL Track	T: SL tracks PV if mode not Auto F: SL remains constant	1	A
13	Calibration enable*	T: Enable I/O calibration F: Normal operation	2	A
14	PAR timeout disable*	T: Disable fallback timeout to normal display F: Enable fallback timeout if no keys pressed (~5 minutes)	4	A
15	Raise/lower speed*	T: Selects high-speed raise/lower of parameter values F: Selects normal raise/lower with acceleration	8	A

**Not applicable in List 2, except where mode affected †For information only — applies to Ratio Controller*

Table 6-5 Configuration status word SC (List 1)

NOTE. In Tables 6-3 to 6-5, the values of the hexadecimal digits 'ABCD' representing the parameters may be derived by adding up the 'TRUE' decimal values indicated for each bit, then converting these to hex numbers, 0-F. FALSE bits count as zero.

4.2 On/off control

In on/off control, in automatic mode, output OP switches between two values only — the High Output Limit HO% and the Low Output Limit LO%. In non-automatic modes OP is held at the LO value, regardless of the setting of SC bit 3 (invert PID).

An asymmetric hysteresis is applied in on/off control, as illustrated in Figure 6-4, specified by the XP parameter. The effect of hysteresis is to delay the switching of OP to its high value until the difference between PV% and SP% exceeds the hysteresis band XP%. As the figure shows, the hysteresis band is applied above or below SP according to whether inverse PID action has or has not been configured, respectively. Hysteresis helps avoid too-frequent output switching with noisy PVs or rapidly-reacting processes.

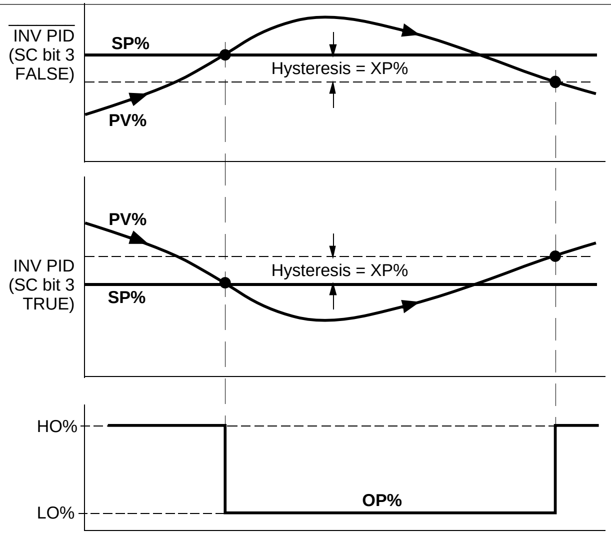


Figure 6-4 On/off control hysteresis

4.3 Invert PID & invert OP

Many processes require the control output OP to *increase* when the process variable PV *decreases* away from the setpoint SP, and vice versa, i.e. ΔOP and ΔPV with opposite senses. Some processes need OP and PV to increase/decrease *together*, i.e. ΔOP and ΔPV with the same senses. SC bit 3 specifies PID action.

Note that OP inversion (SC bit 2) works on the electrical output only, not on OP itself. With OP inversion set, a low OP-value produces a high electrical output, and vice versa.

5 SETUP SHEET FOR THE SINGLE-LOOP CONTROLLER

This section contains a sheet listing all the configurable parameters associated with the single-loop controller, and their default values. You can photocopy the sheet and use it to record for reference your own parameter settings in the spaces provided.

Item	Default	Setting	Description — LOOP 1, LIST 1 COMMISSIONING
DP	2		Decimal point position (0-4 decimal places)
HR	100		Setpoint high range
LR	0		Setpoint low range
HT	0		Trim high range & high limit
LT	0		Trim low range & low limit
HS	100		Setpoint high limit
LS	0		Setpoint low limit
HA	100		High Absolute alarm level
LA	0		Low Absolute alarm level
HD	100		High Deviation alarm level
LD	100		Low Deviation alarm level
HO	100		High Output (OP) limit (0-100%)
LO	0		Low Output (OP) limit (0-100%)
XP	100		Proportional band (0-1999.9)
TI	10		Integral time (0-199.99 mins/secs)
TD	0		Derivative time (0-199.99 mins/secs)
TM	0		Trim value
RM	0		Remote Setpoint value
SL	0		Local Setpoint
TK	0		'OP1' Track value (0-100%)
TT	30.0		Motor travel time (0.5-1999.9 secs)*
PT	0.5		Minimum pulse time (0.1-60.0 secs)*
TB	0		Timebase (0=seconds, 1=minutes)
AL	0000		ALARM STATUS WORD
bit12	FALSE		Auto-ack. (T: auto-ack cleared alarm, F: needs manual ack)
bit13	FALSE		Relay disable (T: disable relay, F: enable relay)
bit14	FALSE		Relay on abs. only (T: abs. only, F: abs. & deviation alarms)
bit15	FALSE		Relay activation (T: on unackd alrm, F: on valid active alrm)
SC	0000		CONFIGURATION STATUS WORD
bit0	FALSE		Powerup (T: Manual, failsafe OP, F: last mode, last OP)
bit1	FALSE		Failsafe output (T: low OP, F: last OP)
bit2	FALSE		Invert electrical output (T: inversion, F: no inversion)
bit3	FALSE		Invert PID (ΔPV & ΔOP — T: same sense, F: opposite)
bit4	FALSE		PV fail (T: no mode change, F: Forced Manual, failsafe OP)
bit5	FALSE		Inverse ratio (T: Loop1 RM=PV2×RS, F: Loop1 RM=PV2÷RS)
bit6	FALSE		Ratio track (T: RS tracks measured SP if Loop1 not Remote)
bit7	FALSE		Simulation (T: connect plant simulation) (*not implemented*)
bit8	FALSE		Incremental control (T: incremental control, F: continuous)
bit9	FALSE		On/off control (T: On/off control, F: PID control)
bit10	FALSE		(*don't care*)
bit11	FALSE		SL balance (On SL writes — T: debump , F: no debump)
bit12	FALSE		SL track (T: SL tracks PV if not Auto, F: SL constant)
bit13	FALSE		Calibration enable (T: enable I/O calib., F: normal op.)
bit14	FALSE		PAR timeout disable (T: disable, F: enable)
bit15	FALSE		Raise/lower speed (T: very fast, F: normal, with acceleration)
BM	00		PUSHBUTTON MASK BYTE
bit0	FALSE		(*don't care*)
bit1	FALSE		(*don't care*)
bit2	FALSE		'SP' pushbutton mask (T: disables setpoint change via button)
bit3	FALSE		'M' pushbutton mask (T: disables mode selection via button)
bit4	FALSE		(*don't care*)
bit5	FALSE		'A' pushbutton mask (T: disables mode selection via button)
bit6	FALSE		'Alm Ack' pushbutton mask (T: disables alm ack via button)
bit7	FALSE		'R' pushbutton mask (T: disables mode selection via button)

**Incremental control only*

Item	Default	Setting	Description — LIST 3, INSTRUMENT PARAMETERS
II	630	—	Instrument identity
IV		—	Instrument version
CC	1	1	Controller type (0=Man St, 1=S-Loop, 2=Cas, 3=Rat, 4=O/ride)
P0	0		Passcode 0 — Loop-commissioning parameters
P1	0		Passcode 1 — Configuration parameters
TU	0		Temperature linearisation units (0=°C, 1=°F, 2=K)
B1	0		Expansion I/O enable (0=disable, 1=enable)

Item	Default	Setting	Description — LIST 4, MODBUS PARAMETERS
FS	00	—	COMMUNICATIONS STATUS BYTE
AD	254		Instrument address (1-254)
BD	0		Baud (0=9600, 1=19200**, 2=4800, 3=2400, 4=1200)
PY	0		Parity (0=none, 1=even, 2=odd)

***Not implemented*

Item	Default	Setting	Description — LIST 5, MAIN PCB I/O PARAMETERS
IR	0		Proc I/P range (0=4-20mA, 1=0-20mA, 2=1-5V, 3=0-10V, 4=T/C, 5=RTD)
IB*	1		Process I/P break protection (1=upscale brk, 2=downscale)
IL	0		Process I/P lin. (0=none, 1=square root, [T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N], 9=PT100 res. therm.)
IF	1		Process input filter time constant (0-1999.9 secs)
OR	0		Process output range (0=4-20mA, 1=0-20mA)

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*

Item	Default	Setting	Description — LIST 6, EXPN. BOARD I/O PARAMETERS
IR	0		Proc. I/P range (0=4-20mA;1=0-20mA;2=1-5V;3=0-10V;4=T/C;5=RTD)
IB*	1		Proc. I/P break protection (1=upscale break, 2=downscale)
IL	0		Proc. I/P lin. (0=none;1=square root;[T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N]; 9=PT100 res. thermom.)
IC	0		Proc. I/P conn. assignt. (0=open cct, 1=TK, 2=feedfwd, 3=RM, 4=TM)
IF	1		Process Input filter time constant (0-1999.9 seconds)
AR	3		Analogue input range (2=1-5V, 3=0-10V)
AB	0		An. I/P break protection (0=freeze, 1=upscale, 2=dnscale.)
AC	0		An. I/P conn. assignt. (0=open cct, 1=TK, 2=feedfwd, 3=RM, 4=TM)
AF	1		Analogue input filter time constant (0-1999.9 seconds)
OR	3		Analogue output range (2=1-5V, 3=0-10V)
OC	0		An. O/P connection assignment (0=PV%, 1=SP%, 2=OP%)
DI	00		DIGITAL I/O INVERSION MASK BYTE (TRUE inverts bit)
bit0	FALSE		Hold select input
bit1	FALSE		Track select input (*or unallocated user bit***)
bit2	FALSE		Remote enable input
bit3	FALSE		(*Unallocated user bit*)
bit4	FALSE		NOT [Hold OR Manual] output (*or RAISE output***)
bit5	FALSE		NOT [Remote Auto] output
bit6	FALSE		NOT [High Alarm] output (*or NOT[Alarm] output***)
bit7	FALSE		NOT [Low Alarm] output (*or LOWER output***)
DC	F0		DIGITAL I/O CONNECTION MASK (TRUE connects bit)
bit0	FALSE		Hold select input
bit1	FALSE		Track select input (*or unallocated user bit***)
bit2	FALSE		Remote enable input
bit3	FALSE		(*Unallocated user bit*)
bit4	TRUE		NOT [Hold OR Manual] output (*or RAISE output***)
bit5	TRUE		NOT [Remote Auto] output
bit6	TRUE		NOT [High Alarm] output (*or NOT[Alarm] output***)
bit7	TRUE		NOT [Low Alarm] output (*or LOWER output***)
DU	0		Digital I/O pullup type: DU / Inputs / Outputs 0 *external* *external* 1 *internal* *external* 2 *external* *internal* 3 *internal* *internal*

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*
*** If incremental control selected*

Item	Default	Setting	Description — LIST 8, INCREM. CONTROL PARAMETERS
IN	0.0		Inertia compensation time (0.0-20.0 secs)*
BL	0.0		Backlash compensation time (0.0-20.0 secs)*

**Incremental control only*

ISSUE	DATE	DRAWN	CHECKED	INSTRUMENT ID
				FUNCTION
				DRAWING NUMBER

SINGLE-LOOP CONTROLLER SETUP SHEET

Chapter 7 DUAL-LOOP CASCADE CONTROLLER

This chapter tells you how to configure and use the instrument when it is set up as a Dual-loop Cascade controller. The main topics dealt with in this chapter are:

- Overviews of the cascade controller (§1)
- Cascade controller inputs and outputs (§2)
- Cascade controller operating modes (§3)
- Cascade controller parameters (§4)
- Setup sheets for the cascade controller (§5).

Appendix B details the loops' signal-processing and shows how parameters and data interact through the strategy. Chapter 5 describes controller operating modes in general.

NOTE. If Loop 1 is set up as an incremental controller, the signal-processing is modified — especially control output generation — and some additional parameters are involved. Refer to Chapter 10, *Incremental control*, for details.

1 OVERVIEWS OF THE CASCADE CONTROLLER

1.1 General overview

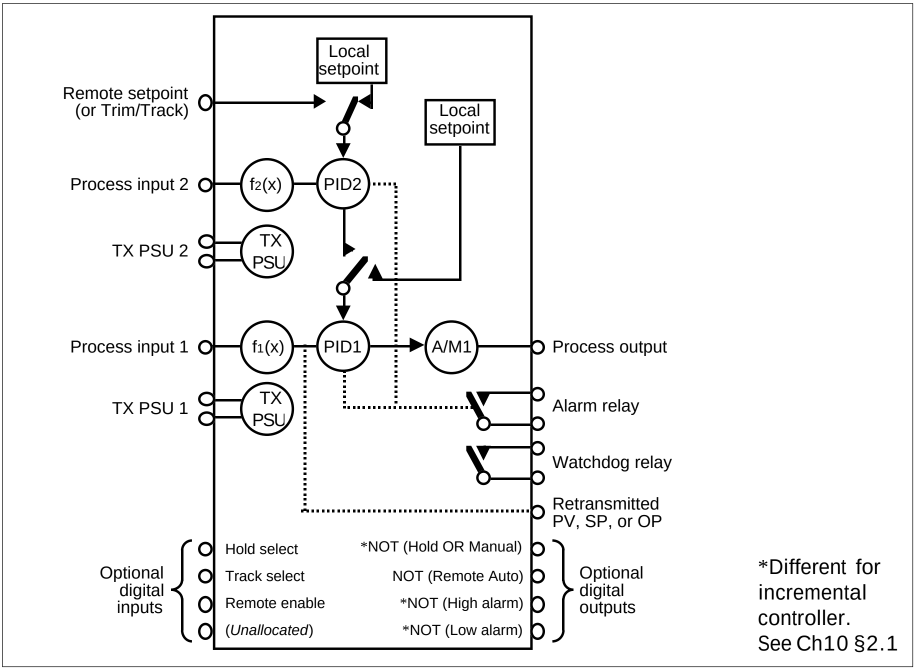


Figure 7-1 Dual-loop cascade controller overview

Figure 7-1 is an overview of the controller and its I/O.

In the master Loop 2 (PID2), process input 2 is compared to the local setpoint and a remote setpoint generated for use in slave Loop 1. In Loop 1 (PID1) the remote setpoint and process input 1 are used to generate a process control output. The expansion I/O board is needed for the Cascade controller to allow Process input 2 to be input to the master loop. It also allows the master loop to use a hardwired remote setpoint or trim input if required. All the necessary mode interlocks between the loops are made internally to ensure bumpless and procedureless auto/manual/remote switching.

1.2 Level control example

Figure 7-2 shows an example of the controller being used to control fluid level in a vessel.

In normal cascade operation the master loop is in automatic mode (Local or Remote), and the slave loop is in Remote Auto mode. Other modes are possible, as described in §2.

The diagram indicates the alternative sources of the setpoint SP in the master loop — either a local setpoint SL, or a remote setpoint RM, input from outside. The local setpoint can be adjusted via the ‘SP’ and ▲/▼ front-panel pushbuttons. The only modes that the master loop can *operate* in are Remote Auto, Local Auto, and Track, though other modes can be *selected*. The slave loop can operate in all the modes supported by the instrument (except Ratio), as described in Chapter 5.

When cascade control is operating, the slave loop derives its setpoint from the master loop’s output OP, which becomes the slave’s Remote Setpoint RM. In non-cascade (local) modes, the slave’s output can derive from a track input or via a manual input, adjustable using the ‘M’ and ▲/▼ buttons.

The mode interlock signals ‘hard-wired’ into the controller between the two loops are indicated in Figure 7-2. They ensure that any mode-changes that affect the cascade action of the loops are communicated between them and appropriate action taken. This is described in §3.

Appendix B gives a more detailed schematic of the dual-loop cascade controller, showing how its parameters interact with the flow of signals through the control strategy.

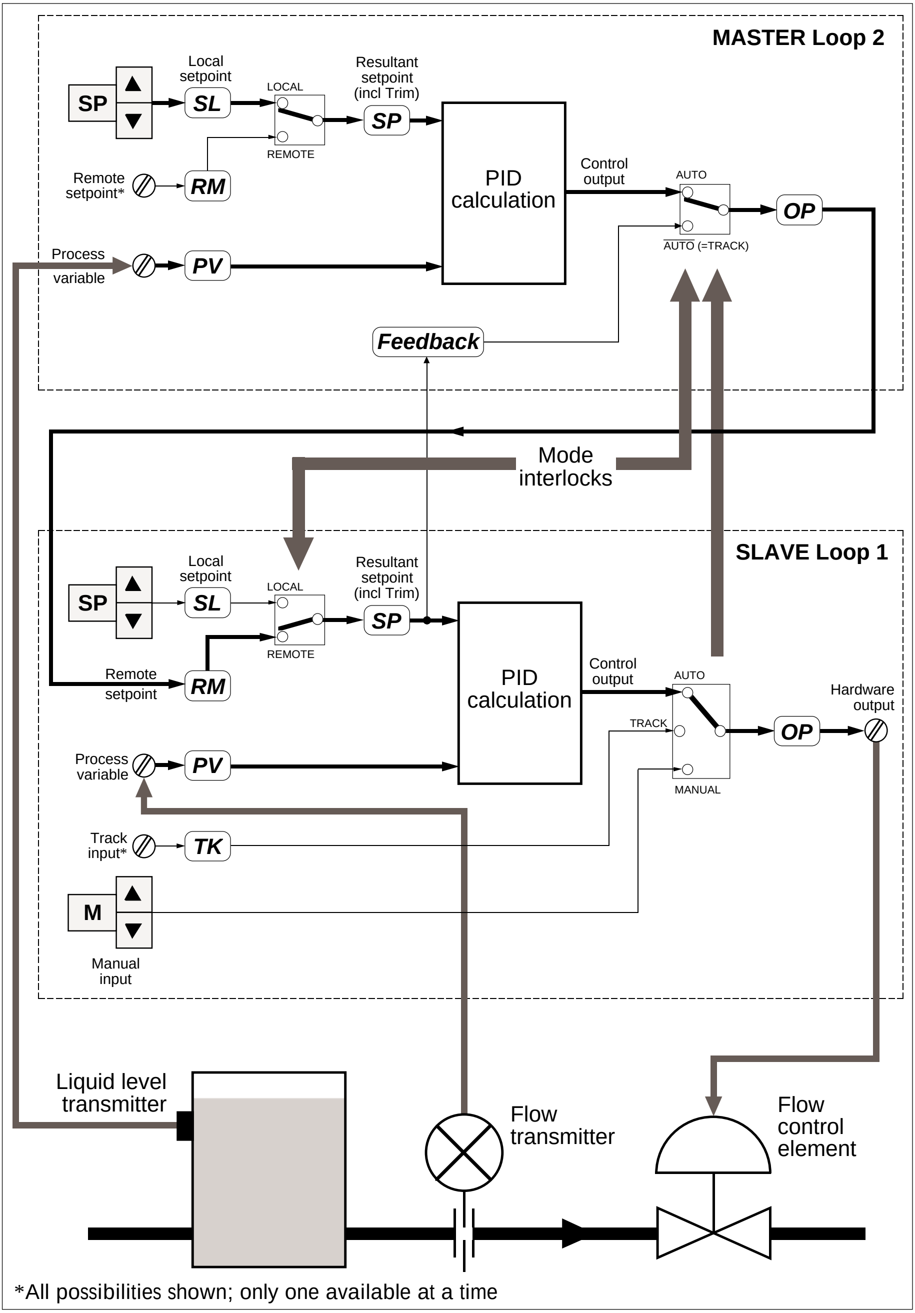


Figure 7-2 Dual-loop cascade overview schematic — level-control example

2 CASCADE CONTROLLER INPUTS & OUTPUTS

Figure 7-3 summarises the I/O available for the cascade controller. Terminal numbers 1-22 refer to the main board I/O, and terminals 23-44 refer to the (optional) expansion I/O board.

In the figure, terminal numbers enclosed in brackets are user-assignable, as described in Chapter 4, *Configuration*. Unbracketed terminal numbers have fixed assignments.

Parameters that are associated with both loops have their mnemonics followed by a '**(1)**' or a '**(2)**' to show which loop is being referred to.

NOTE. If you want to see in more detail exactly where the I/O signals are routed to and from within the control strategy, please refer to Appendix B.

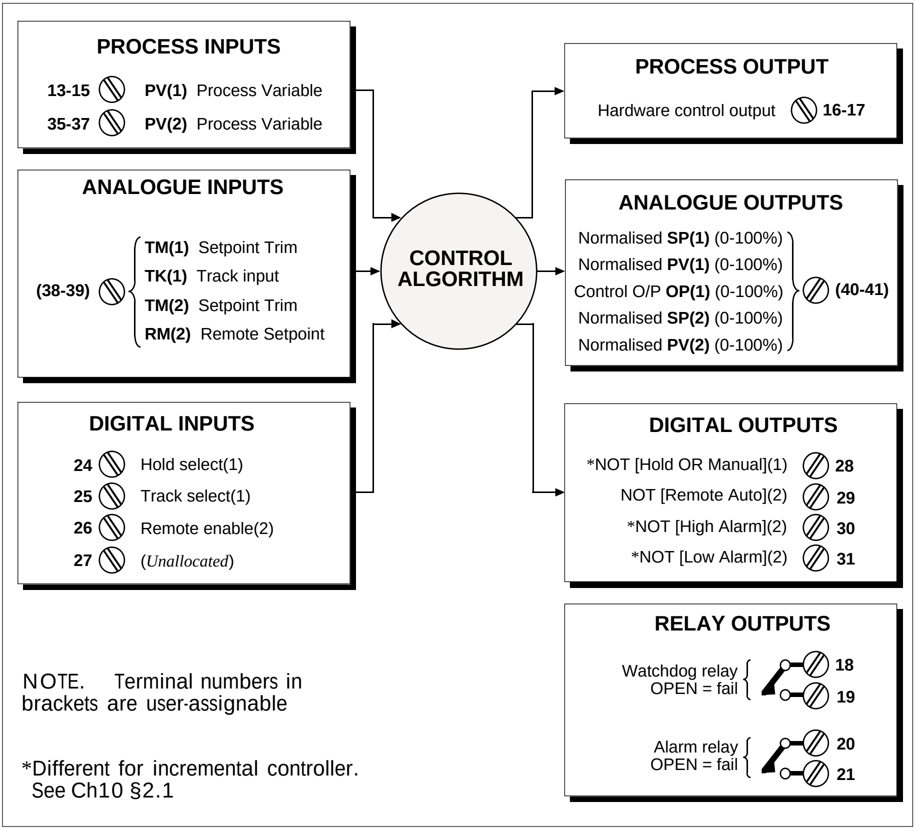


Figure 7-3 Cascade controller I/O summary

3 CASCADE CONTROLLER OPERATING MODES

Tables 7-1 and 7-2 summarise the controller's possible operating modes, their selection, indications, and actions, for slave loop 1 and master loop 2, respectively. For more information on control operating modes see Chapter 5.

Mode	Selected by	Front panel	Action
Hold	Hold select input TRUE	'HOLD' lamp lit	Output frozen. Master loop 2 forced into Track mode
Track	Track select input TRUE	'TRACK' lamp lit	Output follows Track value. Master loop 2 forced into Track mode
Forced Manual	PV input or sumcheck failure	'MAN' lamp flashes	As Manual, but lower priority modes cannot be selected until PV restored.
Manual	Press 'M' button	'MAN' lamp lit	Output set by operator. Controller acts as manual station. On entry, output adopts last value. Master loop 2 forced into Track mode
Local Auto	Press 'A' button	'AUTO' lamp lit	Automatic control using Local Setpoint. Master loop 2 forced into Track mode
Forced Auto	Press 'R' button, master loop 2 in Hold or Manual modes	'AUTO' lamp flashes	As Local Auto
Remote Auto	Press 'R' button, master loop 2 not in Hold or Manual modes	'REM' lamp lit	Automatic (cascade) control using Remote Setpoint from master loop 2. Local Setpoint tracks RM unconditionally

Table 7-1 Modes supported by cascade controller slave loop 1 (descending priority)

Mode	Selected by	Front panel	Action
Hold	(Only selectable via the comms)	'HOLD' lamp and 'TRACK' lamp lit	Output frozen. Slave loop 1 forced into local mode, which forces master loop 2 to select Track mode
Track	Forced into Track by slave loop 1 if slave not in Remote Auto mode	'TRACK' lamp lit	Output tracks slave loop 1's SP value (Slave loop 1 in local mode)
Forced Manual	PV input or sumcheck failure	'MAN' lamp flashes and 'TRACK' lamp lit	As Manual, but lower priority modes cannot be selected until PV restored.
Manual	Press 'M' button	'MAN' lamp and 'TRACK' lamp lit	Slave loop 1 forced into local mode, which forces master loop 2 into Track mode
Local Auto	Press 'A' button	'AUTO' lamp lit	Automatic (cascade) control using Local Setpoint. (Slave loop 1 in Remote Auto mode)
Forced Auto	Press 'R' button, Rem Enable FALSE	'AUTO' lamp flashes	As Local Auto
Remote Auto	Press 'R' button, Rem Enable TRUE	'REM' lamp lit	Automatic (cascade) control using Remote Setpoint. SL tracks RM unconditionally (Slave loop 1 in Remote Auto mode)

Table 7-2 Modes supported by cascade controller master loop 2 (descending priority)

3.1 Automatic cascade operation

Refer to Tables 7-1 and 7-2. In fully automatic mode, the slave loop operates in Remote Auto mode, and the master loop operates in Local Auto or Remote Auto mode.

3.2 Non-cascade operation

3.2.1 Slave loop not in remote mode

It may be required to control the flow rate directly from the slave loop, without using the remote setpoint generated by the master loop. This can be done either by putting the slave into Local Auto mode or, for manual operator control of the valve, putting the slave into Manual mode. (The slave can also be put into Track or Hold mode if required.)

If for any reason the slave loop is not in Remote Auto mode, the master loop is forced to enter Track mode. This is done via an interlock signal passed from Loop 1's NOT [Remote Auto] output to Loop 2's Track Select input. The interlock is 'internally wired' when you select the cascade control option. The effect of this is to cause the master loop's output OP to track the slave loop's setpoint SP, so that when cascade operation is resumed there is no bump in the value of the remote setpoint. Track mode has the second-highest priority of all the modes, and so overrides any other selected mode in the master loop except Hold.

When the slave loop does resume Remote Auto operation, the interlock signal resets to allow the master loop to return from Track to Auto mode.

Figure 7-4 shows the action of this interlock schematically.

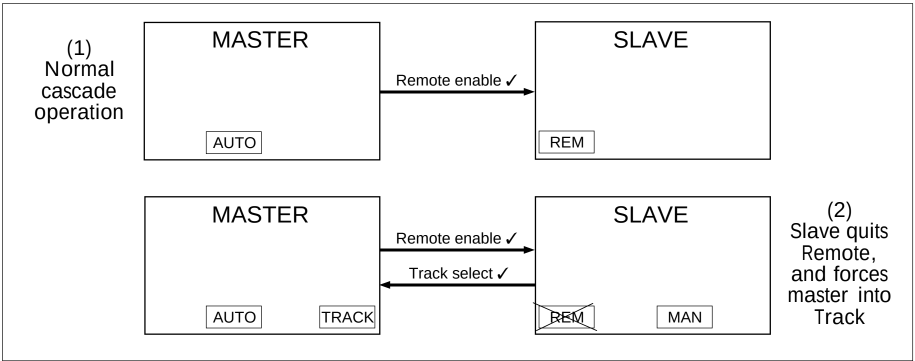


Figure 7-4 Cascade controller interlocks — slave loop 1 quitting Remote mode

3.2.2 Master loop not in auto mode

Cascade operation will be prevented if the master loop enters a non-automatic mode. This can happen if the operator inadvertently selects Manual mode via the front panel, or automatically if the PV input to the master loop fails for any reason. In this case the loop goes into Forced Manual mode initially, then into Manual mode when the PV input is restored.

If for any reason the master loop goes into Hold, Forced Manual, or Manual modes, the slave loop is forced out of Remote mode (into Forced Auto mode). This is done via another 'internally wired' interlock signal passed from Loop 2's NOT [Hold OR Manual] output to Loop 1's Remote Enable input. But as soon as slave Loop 1 quits Remote Auto, the interlock described in §3.2.1 comes into effect and forces master Loop 2 into Track mode, completing the interlock cycle, and preventing bumps when full cascade operation is resumed.

Figure 7-5 shows these interlocks in action.

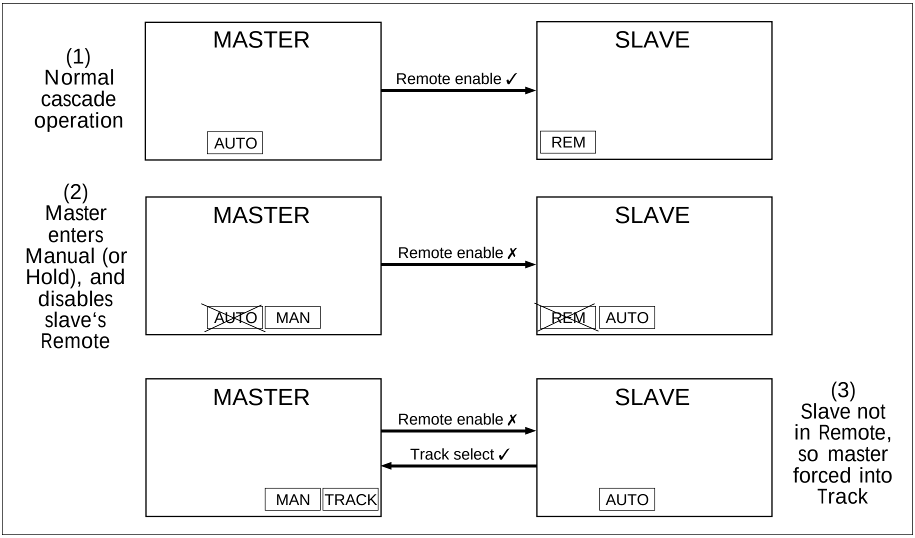


Figure 7-5 Cascade controller interlocks — master loop 2 entering Manual or Hold

NOTE. The effect of these interlocks is that an automatic mode (Remote, Local, or Forced) and Track, are the only modes that the master loop 2 can *operate* in. Other modes may be *selected* at the same time, but they are not allowed to take over as the current operating mode. This is shown in Figure 7-2 and in Table 7-2.

To return to cascade operation, reselect Auto mode in the master loop. With Loop 2 out of Manual/Hold, the interlock signal re-asserts and allows slave Loop 1 to return to Remote Auto mode (from Forced Auto). Once this happens, the other interlock signal resets and allows the master loop to resume automatic operation. Cascade control can then take over again, bumplessly.

4 CASCADE CONTROLLER PARAMETERS — LISTS 1 & 2

Table 7-3 lists the loop-commissioning parameters associated with the slave loop of the cascade controller, which occupies the Loop 1 front-panel display. They are found in List 1, accessed via passcode ‘P0’. Further information on some of the parameters is found where indicated in the table.

Also listed is the parameter type (format), Modbus address, and whether it is read-only. (For a complete parameter list in order of Modbus address, refer to Ch 14 §3.4.)

Table 7-4 lists the loop-commissioning parameters associated with the cascade controller’s master loop, which occupies the Loop 2 front-panel display. They are found in List 2, also accessed via passcode ‘P0’.

L1	Function	Type	Write	M’bus
DP	Decimal point position for List 1 parameters* (0-4 decimal places)	Int		0
HR	Setpoint high range (limits: –19999 to +19999)†	Real		6
LR	Setpoint low range (limits: –19999 to +19999)†	Real		7
HT	Trim high range & high limit (limits: LR–HR to HR–LR)	Real		28
LT	Trim low range & low limit (limits: LR–HR to HR–LR)	Real		29
HS	Setpoint high limit (limits: LR to HR)	Real		14
LS	Setpoint low limit (limits: LR to HR)	Real		15
HA	High Absolute alarm level (limits: LR to HR)	Real		10
LA	Low Absolute alarm level (limits: LR to HR)	Real		11
HD	High Deviation alarm level (limits: 0 to HR–LR)	Real		12
LD	Low Deviation alarm level (limits: 0 to HR–LR)	Real		13
HO	High Output limit (0.00-100.00%)	Real		16
LO	Low Output limit (0.00-100.00%)	Real		17
XP	Prop. band, On/Off control hysteresis (0.0-1999.9) [see Ch6 §4.2]	Real		18
TI	Integral time (0.00-199.99 TB-units) [TI=0 disables integral term]	Real		19
TD	Derivative time (0.00-199.99 TB-units) [TD=0 disables deriv. term]	Real		20
TM	Trim value (limits: LT to HT)	Real		26
RM	Remote Setpoint value (limits: LS to HS)	Real		25
SL	Local Setpoint (limits: LS to HS)	Real		2
SP	Resultant Setpoint	Real	✘	5
PV	Process Variable	Real	✘	1
OP	Control Output (0.00-100.00%) (limits also: LO to HO)	Real		3
TK	Track value (0.00-100.00%) (limits also: LO to HO)	Real		27
AL	Alarm status word [see Ch6 Table 6-3]	ABCDhex		4
SM	Mode status word [see Ch6 Table 6-4]	ABCDhex		23
SC	Configuration status word [see Ch6 Table 6-5]	ABCDhex		21
BM	Pushbutton mask [see Ch3 §1.6.9]	CDhex		22
MS	Requested mode (0-2) [see Ch5 §3]	Int		8
MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘	9
TT**	Motor travel time (0.5-1999.9 secs) [see Ch10 §5.1.2]	Real		230
PT**	Minimum pulse time (0.1-60.0 secs) [see Ch10 §5.1.3]	Real		31
TB	Timebase (0-1) [0=seconds, 1=minutes]	Int		30

†Subject to relevant decimal point position **Except as indicated in the table*
***Seen only if incremental control selected* *✘Read-only parameter*

Table 7-3 Cascade controller slave loop commissioning parameters — List 1

L2	Function	Type	Write	M'bus
DP	Decimal point position for List 2 parameters* (0-4 decimal places)	Int		48
HR	Setpoint high range (limits: –19999 to +19999)†	Real		54
LR	Setpoint low range (limits: –19999 to +19999)†	Real		55
HT	Trim high range & high limit (limits: LR–HR to HR–LR)	Real		76
LT	Trim low range & low limit (limits: LR–HR to HR–LR)	Real		77
HS	Setpoint high limit (limits: LR to HR)	Real		62
LS	Setpoint low limit (limits: LR to HR)	Real		63
HA	High Absolute alarm level (limits: LR to HR)	Real		58
LA	Low Absolute alarm level (limits: LR to HR)	Real		59
HD	High Deviation alarm level (limits: 0 to HR–LR)	Real		60
LD	Low Deviation alarm level (limits: 0 to HR–LR)	Real		61
XP	Prop. band, On/Off control hysteresis (0.0-1999.9) [see Ch6 §4.2]	Real		66
TI	Integral time (0.00-199.99 TB-units) [TI=0 disables integral term]	Real		67
TD	Derivative time (0.00-199.99 TB-units) [TD=0 disables deriv. term]	Real		68
TM	Trim value (limits: LT to HT)	Real		74
RM	Remote Setpoint value (limits: LS to HS)	Real		73
SL	Local Setpoint (limits: LS to HS)	Real		50
SP	Resultant Setpoint	Real	✘	53
PV	Process Variable	Real	✘	49
OP	Control Output (0.00-100.00%)	Real		51
AL	Alarm status word [see Ch 6 Table 6-3]	ABCDhex		52
SM	Mode status word [see Ch 6 Table 6-4]	ABCDhex		71
SC	Configuration status word [see Ch 6 Table 6-5]	ABCDhex		69
BM	Pushbutton mask [see Ch3 §1.6.9]	CDhex		70
MS	Requested mode (0-2) [see Ch5 §3]	Int		56
MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘	57
TB	Timebase (0-1) [0=seconds, 1=minutes]	Int		78

†*Subject to relevant decimal point position* **Except as indicated in the table* ✘*Read-only parameter*

Table 7-4 Cascade controller master loop commissioning parameters — List 2

5 SETUP SHEETS FOR THE CASCADE CONTROLLER

This section contains sheets listing all the configurable parameters associated with the dual-loop cascade controller, and their default values. You can photocopy the sheets and use them to record for reference your own parameter settings in the spaces provided.

Item	Default	Setting	Description — LOOP 2, LIST 2 COMMISSIONING
DP	2		Decimal point position (0-4 decimal places)
HR	100		Setpoint high range
LR	0		Setpoint low range
HT	0		Trim high range & high limit
LT	0		Trim low range & low limit
HS	100		Setpoint high limit
LS	0		Setpoint low limit
HA	100		High Absolute alarm level
LA	0		Low Absolute alarm level
HD	100		High Deviation alarm level
LD	100		Low Deviation alarm level
XP	100		Proportional band (0-1999.9)
TI	10		Integral time (0-199.99 mins/secs)
TD	0		Derivative time (0-199.99 mins/secs)
TM	0		Trim value
RM	0		Remote Setpoint value
SL	0		Local Setpoint
TB	0		Timebase (0=seconds, 1=minutes)
AL	0000		ALARM STATUS WORD
bit12	FALSE		Auto-ack. (T: auto-ack cleared alarm, F: needs manual ack)
bit13	FALSE		Relay disable (T: disable relay, F: enable relay)
bit14	FALSE		Relay on abs. only (T: abs. only, F: abs. & deviation alarms)
bit15	FALSE		Relay activation (T: on unackd alrm, F: on valid active alrm)
SC	0000		CONFIGURATION STATUS WORD
bit0	FALSE		Powerup mode (T: Manual mode, F: last mode)
bit1	FALSE		*(not used)*
bit2	FALSE		*(not used)*
bit3	FALSE		Invert PID (∆PV & ∆OP — T: same sense, F: opposite)
bit4	FALSE		PV fail mode (T: no mode change, F: Forced Manual mode)
bit5	FALSE		*(not used)*
bit6	FALSE		*(not used)*
bit7	FALSE		*(not used)*
bit8	FALSE		*(not used)*
bit9	FALSE		On/off control (T: On/off control, F: PID control)
bit10	FALSE		*(not used)*
bit11	FALSE		SL balance (On SL writes — T: debump , F: no debump)
bit12	FALSE		SL track (T: SL tracks PV if not Auto, F: SL constant)
bit13	FALSE		*(not used)*
bit14	FALSE		*(not used)*
bit15	FALSE		*(not used)*
BM	00		PUSHBUTTON MASK BYTE
bit0	FALSE		*(don't care)*
bit1	FALSE		*(don't care)*
bit2	FALSE		'SP' pushbutton mask (T: disables setpoint change via button)
bit3	FALSE		'M' pushbutton mask (T: disables mode selection via button)
bit4	FALSE		*(don't care)*
bit5	FALSE		'A' pushbutton mask (T: disables mode selection via button)
bit6	FALSE		'Alm Ack' pushbutton mask (T: disables alm ack via button)
bit7	FALSE		'R' pushbutton mask (T: disables mode selection via button)

Item	Default	Setting	Description — LIST 3, INSTRUMENT PARAMETERS
II	630	—	Instrument identity
IV		—	Instrument version
CC	1	2	Controller type (0=Man St, 1=S-Loop, 2=Cas, 3=Rat, 4=O/ride)
P0	0		Passcode 0 — Loop-commissioning parameters
P1	0		Passcode 1 — Configuration parameters
TU	0		Temperature linearisation units (0=°C, 1=°F, 2=K)
B1	0		Expansion I/O enable (0=disable, 1=enable)

Item	Default	Setting	Description — LIST 4, MODBUS PARAMETERS
FS	00	—	COMMUNICATIONS STATUS BYTE
AD	254		Instrument address (1-254)
BD	0		Baud (0=9600, 1=19200**, 2=4800, 3=2400, 4=1200)
PY	0		Parity (0=none, 1=even, 2=odd)

***Not implemented*

Item	Default	Setting	Description — LOOP 1, LIST 1 COMMISSIONING
DP	2		Decimal point position (0-4 decimal places)
HR	100		Setpoint high range
LR	0		Setpoint low range
HT	0		Trim high range & high limit
LT	0		Trim low range & low limit
HS	100		Setpoint high limit
LS	0		Setpoint low limit
HA	100		High Absolute alarm level
LA	0		Low Absolute alarm level
HD	100		High Deviation alarm level
LD	100		Low Deviation alarm level
HO	100		High Output (OP) limit (0-100%)
LO	0		Low Output (OP) limit (0-100%)
XP	100		Proportional band (0-1999.9)
TI	10		Integral time (0-199.99 mins/secs)
TD	0		Derivative time (0-199.99 mins/secs)
TM	0		Trim value
RM	0		Remote Setpoint value
SL	0		Local Setpoint
TK	0		'OP1' Track value (0-100%)
TT	30.0		Motor travel time (0.5-1999.9 secs)*
PT	0.5		Minimum pulse time (0.1-60.0 secs)*
TB	0		Timebase (0=seconds, 1=minutes)
AL	0000		ALARM STATUS WORD
bit12	FALSE		Auto-ack. (T: auto-ack cleared alarm, F: needs manual ack)
bit13	FALSE		Relay disable (T: disable relay, F: enable relay)
bit14	FALSE		Relay on abs. only (T: abs. only, F: abs. & deviation alarms)
bit15	FALSE		Relay activation (T: on unackd alrm, F: on valid active alrm)
SC	0000		CONFIGURATION STATUS WORD
bit0	FALSE		Powerup (T: Manual, failsafe OP, F: last mode, last OP)
bit1	FALSE		Failsafe output (T: low OP, F: last OP)
bit2	FALSE		Invert electrical output (T: inversion, F: no inversion)
bit3	FALSE		Invert PID (∆PV & ∆OP — T: same sense, F: opposite)
bit4	FALSE		PV fail (T: no mode change, F: Forced Manual, failsafe OP)
bit5	FALSE		Inverse ratio (T: Loop1 RM=PV2×RS, F: Loop1 RM=PV2÷RS)
bit6	FALSE		Ratio track (T: RS tracks measured SP if Loop1 not Remote)
bit7	FALSE		Simulation (T: connect plant simulation) *(not implemented)*
bit8	FALSE		Incremental control (T: incremental control, F: continuous)
bit9	FALSE		On/off control (T: On/off control, F: PID control)
bit10	FALSE		*(don't care)*
bit11	FALSE		SL balance (On SL writes — T: debump , F: no debump)
bit12	FALSE		SL track (T: SL tracks PV if not Auto, F: SL constant)
bit13	FALSE		Calibration enable (T: enable I/O calib., F: normal op.)
bit14	FALSE		PAR timeout disable (T: disable, F: enable)
bit15	FALSE		Raise/lower speed (T: very fast, F: normal, with acceleration)
BM	00		PUSHBUTTON MASK BYTE
bit0	FALSE		*(don't care)*
bit1	FALSE		*(don't care)*
bit2	FALSE		'SP' pushbutton mask (T: disables setpoint change via button)
bit3	FALSE		'M' pushbutton mask (T: disables mode selection via button)
bit4	FALSE		*(don't care)*
bit5	FALSE		'A' pushbutton mask (T: disables mode selection via button)
bit6	FALSE		'Alm Ack' pushbutton mask (T: disables alm ack via button)
bit7	FALSE		'R' pushbutton mask (T: disables mode selection via button)

**Incremental control only*

ISSUE	DATE	DRAWN	CHECKED	INSTRUMENT ID
				FUNCTION
				DRAWING NUMBER

CASCADE CONTROLLER SETUP SHEET 1

Item	Default	Setting	Description — LIST 5, MAIN PCB I/O PARAMETERS
IR	0		Proc I/P range (0=4-20mA, 1=0-20mA, 2=1-5V, 3=0-10V, 4=T/C, 5=RTD)
IB*	1		Process I/P break protection (1=upscale brk, 2=downscale)
IL	0		Process I/P lin. (0=none, 1=square root, [T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N], 9=PT100 res. therm.)
IF	1		Process input filter time constant (0-1999.9 secs)
OR	0		Process output range (0=4-20mA, 1=0-20mA)

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*

Item	Default	Setting	Description — LIST 8, INCREM. CONTROL PARAMETERS
IN	0.0		Inertia compensation time (0.0-20.0 secs)*
BL	0.0		Backlash compensation time (0.0-20.0 secs)*

**Incremental control only*

Item	Default	Setting	Description — LIST 6, EXPN. BOARD I/O PARAMETERS
IR	0		Proc. I/P range (0=4-20mA;1=0-20mA;2=1-5V;3=0-10V;4=T/C;5=RTD)
IB*	1		Proc. I/P break protection (1=upscale break, 2=downscale)
IL	0		Proc. I/P lin. (0=none;1=square root;[T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N]; 9=PT100 res. thermom.)
IC	0	—	Proc. I/P conn. assignt. (Fixed: PV2 — Process Variable Loop 2)
IF	1		Process Input filter time constant (0-1999.9 seconds)
AR	3		Analogue input range (2=1-5V, 3=0-10V)
AB	0		An. I/P break protection (0=freeze, 1=upscale, 2=dnscale.)
AC	0		An. I/P (0=o/c, 1=TK, 2=fdfwd1, 4=TM1, 5=fdfwd2, 6=RM2, 7=TM2)
AF	1		Analogue input filter time constant (0-1999.9 seconds)
OR	3		Analogue output range (2=1-5V, 3=0-10V)
OC	0		An. O/P assigmnt. (0=PV1%, 1=SP1%, 2=OP1%, 3=PV2%, 4=SP2%)
DI	00		DIGITAL I/O INVERSION MASK BYTE (TRUE inverts bit)
bit0	FALSE		Hold select input
bit1	FALSE		Track select input (*or unallocated user bit***)
bit2	FALSE		Remote enable input
bit3	FALSE		(*Unallocated user bit*)
bit4	FALSE		NOT [Hold OR Manual] output (*or RAISE output***)
bit5	FALSE		NOT [Remote Auto] output
bit6	FALSE		NOT [High Alarm] output (*or NOT[Alarm] output***)
bit7	FALSE		NOT [Low Alarm] output (*or LOWER output***)
DC	F0		DIGITAL I/O CONNECTION MASK (TRUE connects bit)
bit0	FALSE		Hold select input
bit1	FALSE		Track select input (*or unallocated user bit***)
bit2	FALSE		Remote enable input
bit3	FALSE		(*Unallocated user bit*)
bit4	TRUE		NOT [Hold OR Manual] output (*or RAISE output***)
bit5	TRUE		NOT [Remote Auto] output
bit6	TRUE		NOT [High Alarm] output (*or NOT[Alarm] output***)
bit7	TRUE		NOT [Low Alarm] output (*or LOWER output***)
DU	0		Digital I/O pullup type: DU / Inputs / Outputs 0 *external* *external* 1 *internal* *external* 2 *external* *internal* 3 *internal* *internal*

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*
*** If incremental control selected*

ISSUE	DATE	DRAWN	CHECKED	INSTRUMENT ID
				FUNCTION
				DRAWING NUMBER

CASCADE CONTROLLER SETUP SHEET 2

Chapter 8 RATIO CONTROLLER

This chapter tells you how to configure and use the instrument when it is set up as a Ratio controller. The main topics dealt with in this chapter are:

- Overviews of the ratio controller (§1)
- Ratio controller inputs and outputs (§2)
- Ratio controller operating modes (§3)
- Ratio controller user interface (§4)
- Ratio controller parameters (§5)
- Ratio controller setup sheet (§6).

Appendix C details the loops' signal-processing and shows how parameters and data interact through the strategy. Chapter 5 describes controller operating modes in general.

NOTE. If Loop 1 is set up as an incremental controller, the signal-processing is modified — especially control output generation — and some additional parameters are involved. Refer to Chapter 10, *Incremental control*, for details.

1 OVERVIEWS OF THE RATIO CONTROLLER

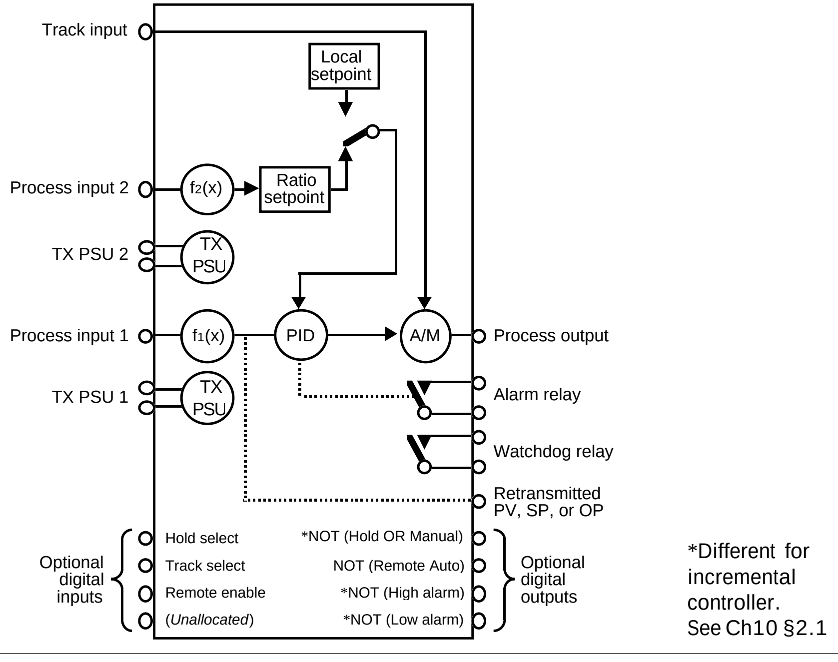


Figure 8-1 Ratio controller overview

1.1 General overview

Figure 8-1 is an overview of the controller and its I/O.

In the Ratio controller, a controlled process variable (Process input 1) is made to follow an external ‘uncontrolled’ process variable (Process input 2) at a set ratio, the Ratio Setting RS.

1.2 Flow control example

Figure 8-2 shows an example of the controller being used to control fluid flow in a pipe. The figure is a simplified schematic and indicates the two-character mnemonics of some of the ratio controller parameters.

The ratio station occupies the Loop 2 display — although it is not actually a ‘loop’ — and the control loop occupies the Loop 1 display. In normal ratio operation, the control loop adopts Ratio (equivalent to Remote Auto) mode.

1.2.1 Ratio station (Loop 2)

Refer to Figure 8-2. In the ratio station an external ‘uncontrolled’ process variable PV is input and either *divided* by the Ratio Setting RS (normal action), or *multiplied* by it (inverse action). This produces the remote setpoint RM for the control loop.

RS can normally be programmed by the operator via the front panel and adjusted using the ‘SP’ and ▲/▼ front-panel pushbuttons. However, RS can also be configured to track the Measured Ratio MR in the event that the control loop quits Ratio mode for any reason, i.e. ceases operating as a ratio controller. MR is the actual ratio of the two process variables, which the controller is attempting to equate to RS. The point of this is to avoid a bump in RM when ratio control is re-established.

1.2.2 Control loop (Loop 1)

In the control loop, a process variable PV is input from the plant, compared by the PID algorithm with the Resultant Setpoint SP, and a control output OP is generated and fed back to the plant.

If the control loop is in Ratio mode, SP is derived from the ratio station’s output RM, and includes any trim and/or limiting. Note that while the loop is in Ratio mode, the Local Setpoint SL — though not being used — is made to track RM. This avoids bumping SP should the loop adopt Local mode. This feature is not shown in Figure 8-2; refer to Appendix C for details.

If the control loop is in Local mode, SL is the source of SP, and the loop behaves as a single-loop controller. The control loop can also operate in Track, Hold, and Manual modes, as for a single-loop controller.

NOTE. Appendix C gives a more detailed schematic of the ratio controller, showing how its parameters interact with the flow of signals through the control strategy.

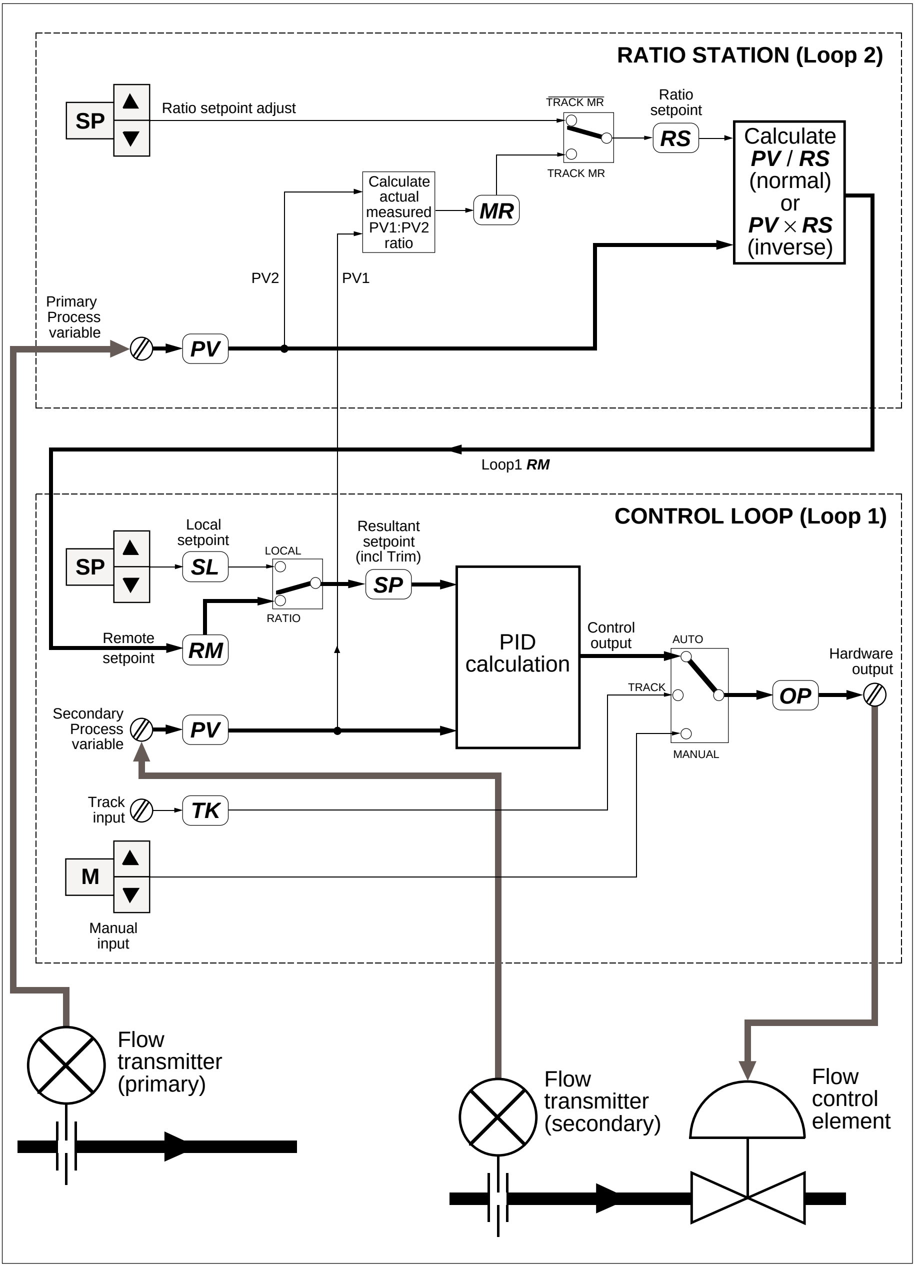


Figure 8-2 Ratio controller overview schematic — flow-control example

2 RATIO CONTROLLER INPUTS & OUTPUTS

Figure 8-3 summarises the I/O available for the ratio controller. Terminal numbers 1-22 refer to the main board I/O, and terminals 23-44 refer to the (optional) expansion I/O board.

In the figure, terminal numbers enclosed in brackets are user-assignable, as described in Chapter 4, *Configuration*. Unbracketed terminal numbers have fixed assignments.

Parameters that are associated with both loops have their mnemonics followed by a '**(1)**' or a '**(2)**' to show which loop is being referred to.

NOTE. If you want to see in more detail exactly where the I/O signals are routed to and from within the control strategy, please refer to Appendix C.

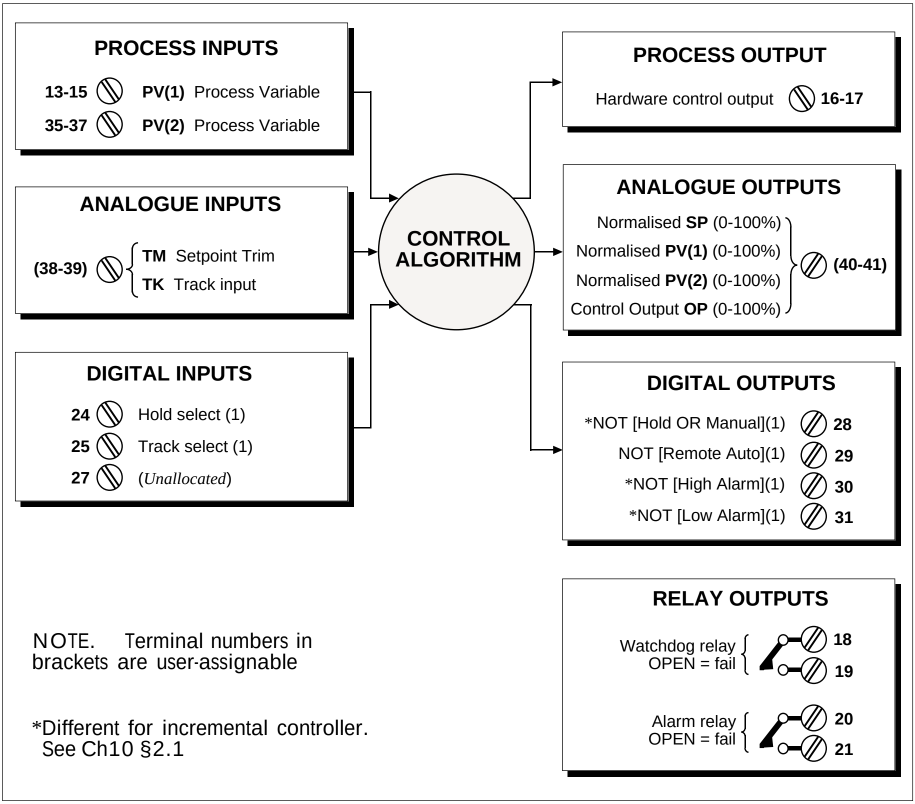


Figure 8-3 Ratio controller I/O summary

3 RATIO CONTROLLER OPERATING MODES

Table 8-1 summarises the controller's possible operating modes, their selection, indications, and actions. These apply only to the control loop (Loop 1), because although the ratio station occupies the Loop 2 display it is not a control loop. For more information on control operating modes see Chapter 5.

Mode	Selected by	Front panel	Action
Hold	Hold select input TRUE	'HOLD' lamp lit	Output (OP) frozen
Track	Track select input TRUE	'TRACK' lamp lit	Output follows Track value (TK)
Forced Manual	PV input or sumcheck failure	'MAN' lamp flashes	As Manual, but lower priority modes cannot be selected until PV restored
Manual	Press 'M' button	'MAN' lamp lit	Output set by operator. Controller acts as manual station. On entry, output adopts last value.
Local Auto	Press 'A' button	'AUTO' lamp lit	Automatic control using Local Setpoint (SL)
Forced Auto	Press 'R' button, PV fail or sumcheck error in ratio station (Loop 2)	'AUTO' lamp flashes	As Local Auto
Ratio	Press 'R' button, PV & sumcheck OK in ratio station (Loop 2)	'RATIO' lamp lit	Automatic ratio control using Remote Setpoint RM output from ratio station. SL tracks RM unconditionally

Table 8-1 Modes supported by ratio controller (descending priority)

4 RATIO CONTROLLER USER INTERFACE

This section shows you how to use the front-panel displays and controls to operate the ratio controller. It assumes you are familiar with the general use of the front panel to view loops, access parameters, etc. This is described in Chapter 3, *Using the front panel.*

4.1 Ratio station — Loop 2 display

To view the controller's ratio station on the front panel, select Loop 2 as the currently-displayed loop. The 'PV 2' lamp lights. Note that the ratio station is not actually a control 'loop'. Figure 8-4 shows the special functions of the ratio station displays and controls. Unused items have been omitted from the diagram.

The display reverts to Loop 1 (the controller display) if no keys are pressed for about five minutes. This timeout can be disabled by setting bit 14 of the SC parameter to TRUE. (SC is found in List 1.)

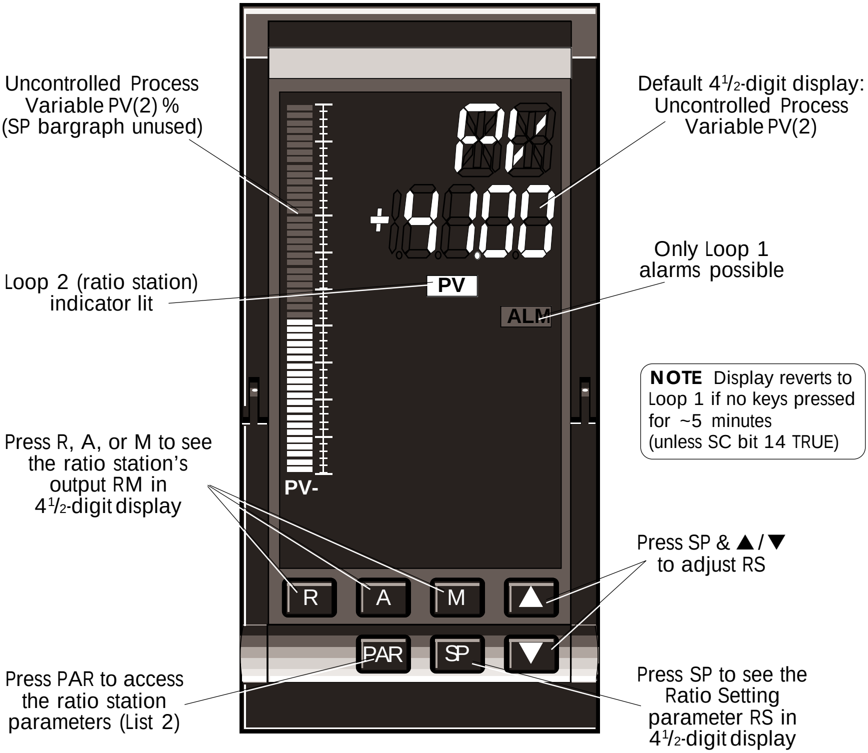


Figure 8-4 Ratio station front panel (Loop 2)

As summarised in the figure, from the ratio station display you can:

- See the uncontrolled Process Variable PV(2) displayed as a percentage on the PV-X bargraph. Note that the SP-W bargraph is unused in this display.
- See PV(2) in engineering units in the 4½-digit display (the default).
- Press 'R', 'A', or 'M' to see the ratio station's output RM in the 4½-digit display.
- Press 'SP' to see the Ratio Setting parameter RS in the 4½-digit display.
- Press 'SP' and ▲/▼ to adjust the value of RS.
- Press 'PAR' to access the ratio station parameters, in List 2.

4.2 Control loop — Loop 1 display

To view the control loop on the front panel, select Loop 1 as the currently-displayed loop. The 'PV 1' lamp lights. Figure 8-5 shows the front-panel functions, which are similar to those of the single-loop controller, described in Chapter 3.

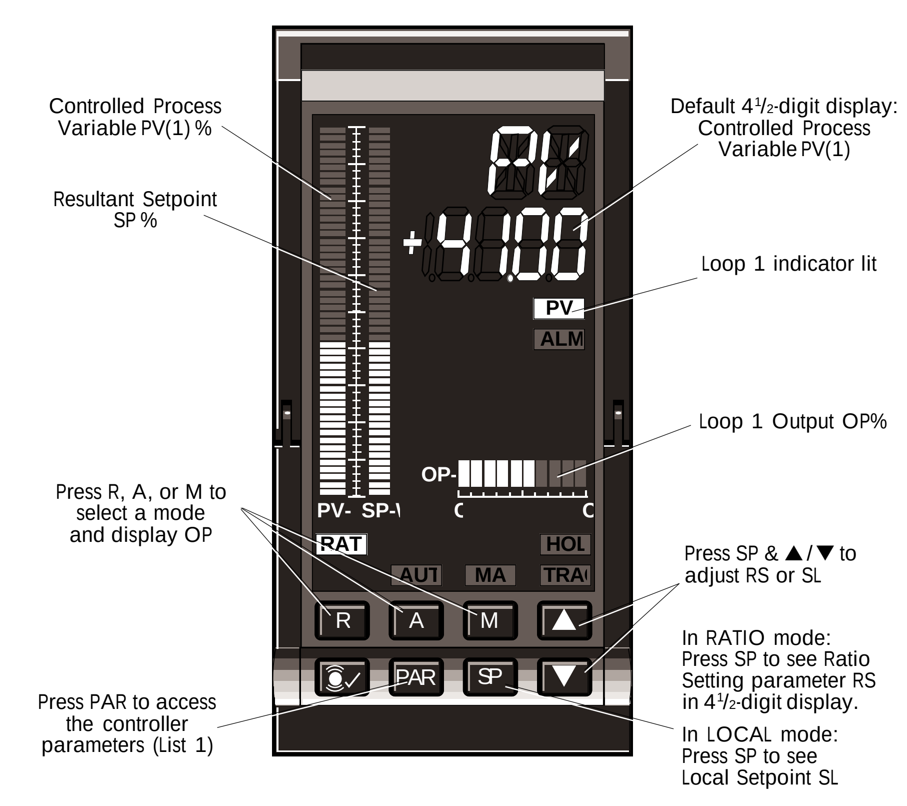


Figure 8-5 Ratio control loop front panel (Loop 1)

As summarised in the figure, from the ratio control loop display you can:

- See the controlled Process Variable PV(1) displayed as a percentage on the PV-X bargraph, and the Resultant Setpoint SP% on the SP-W bargraph.
- See PV(1) in engineering units in the 4½-digit display (the default).
- Press ‘R’, ‘A’, or ‘M’ to see the controller’s output OP in the 4½-digit display, and also select a mode. Note that ‘R’ selects Ratio mode, if the PV(2) input is healthy. Otherwise, Forced Auto is selected.
- Press ‘SP’ to see the Ratio Setting parameter RS in the 4½-digit display, if in Ratio mode, or the Local Setpoint SL if in a local mode.
- Press ‘SP’ and ▲/▼ to adjust the value of RS or SL.
- Press ‘PAR’ to access the ratio control loop parameters, in List 1.

5 RATIO CONTROLLER PARAMETERS — LISTS 1 & 2

Table 8-2 lists the loop-commissioning parameters associated with the control loop of the ratio controller, which occupies the Loop 1 front-panel display. They are found in List 1, accessed via passcode ‘P0’. Further information on some of the parameters is found where indicated in the table.

Also listed is the parameter type (format), Modbus address, and whether it is read-only. (For a complete parameter list in order of Modbus address, refer to Ch 14 §3.4.)

Table 8-3 lists the loop-commissioning parameters associated with the ratio controller’s ratio station, which occupies the Loop 2 front-panel display. They are found in List 2, also accessed via passcode ‘P0’.

L1	Function	Type	Write	M’bus
DP	Decimal point position for List 1 parameters* (0-4 decimal places)	Int		0
HR	Setpoint high range (limits: –19999 to +19999)†	Real		6
LR	Setpoint low range (limits: –19999 to +19999)†	Real		7
HT	Trim high range & high limit (limits: LR–HR to HR–LR)	Real		28
LT	Trim low range & low limit (limits: LR–HR to HR–LR)	Real		29
HS	Setpoint high limit (limits: LR to HR)	Real		14
LS	Setpoint low limit (limits: LR to HR)	Real		15
HA	High Absolute alarm level (limits: LR to HR)	Real		10
LA	Low Absolute alarm level (limits: LR to HR)	Real		11
HD	High Deviation alarm level (limits: 0 to HR–LR)	Real		12
LD	Low Deviation alarm level (limits: 0 to HR–LR)	Real		13
HO	High Output limit (0.00-100.00%)	Real		16
LO	Low Output limit (0.00-100.00%)	Real		17
XP	Prop. band, On/Off control hysteresis (0.0-1999.9) [see Ch6 §4.2]	Real		18
TI	Integral time (0.00-199.99 TB-units) [TI=0 disables integral term]	Real		19
TD	Derivative time (0.00-199.99 TB-units) [TD=0 disables deriv. term]	Real		20
TM	Trim value (limits: LT to HT)	Real		26
RM	Remote Setpoint value (limits: LS to HS)	Real		25
SL	Local Setpoint (limits: LS to HS)	Real		2
SP	Resultant Setpoint	Real	✘	5
PV	Process Variable	Real	✘	1
OP	Control Output (0.00-100.00%) (limits also: LO to HO)	Real		3
TK	Track value (0.00-100.00%) (limits also: LO to HO)	Real		27
AL	Alarm status word [see Ch6 Table 6-3]	ABCDhex		4
SM	Mode status word [see Ch6 Table 6-4]	ABCDhex		23
SC	Configuration status word [see Ch6 Table 6-5]	ABCDhex		21
BM	Pushbutton mask [see Ch3 §1.6.9] (BM List 1 masks both loops’ SP)	CDhex		22
MS	Requested mode (0-2) [see Ch5 §3]	Int		8
MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘	9
TT**	Motor travel time (0.5-1999.9 secs) [see Ch10 §5.1.2]	Real		230
PT**	Minimum pulse time (0.1-60.0 secs) [see Ch10 §5.1.3]	Real		31
TB	Timebase (0-1) [0=seconds, 1=minutes]	Int		30

†Subject to relevant decimal point position **Except as indicated in the table*
***Seen only if incremental control selected* ✘*Read-only parameter*

Table 8-2 List 1 control loop commissioning parameters — ratio controller

L2	Function	Type	Write	M'bus
DP	Decimal point position for List 2 parameters* (0-4 decimal places)	Int		96
HR	Uncontrolled PV high range (limits: –19999 to +19999)†	Real		98
LR	Uncontrolled PV low range (limits: –19999 to +19999)†	Real		99
HS	Ratio setpoint high limit (dec. places — see §5.1) (limits: 0 to 19999)†	Real		102
LS	Ratio setpoint low limit (dec. places — see §5.1) (limits: 0 to 19999)†	Real		103
RS	Ratio setpoint (decimal places — see §5.1) (limits: LS to HS)	Real		101
PV	Uncontrolled Process Variable	Real	✘	97
MR	Measured ratio (decimal places — see §5.1)	Real	✘	100
SM	Mode status word [see Ch 6 Table 6-4]	ABCDhex		105

*†Subject to relevant decimal point position   *Except as indicated in the table   ✘Read-only parameter*

Table 8-3 List 2 ratio station commissioning parameters — ratio controller

5.1 Decimal point position in ratio station parameters

The Decimal Point parameter DP found in List 2 — DP(2) — specifies the number of decimal places for the List 2 parameters, except for those noted in Table 8-3. These are the parameters involving RS. These parameters take their decimal point position from the 'Ratio Decimal Point' parameter, referred to as DP_R.

DP_R is derived from DP List 1 and DP List 2, as follows:

DP_R = DP(2) – DP(1) + 2, for *normal* ratio action, and

DP_R = DP(1) – DP(2) + 2, for *inverse* ratio action.

Note that DP_R is not accessible via the front panel, but is available over the Modbus comms. Refer to Chapter 12 for more information.

6 RATIO CONTROLLER SETUP SHEET

This section contains a sheet listing all configurable parameters associated with the ratio controller, and their default values. You can photocopy the sheet and use it to record for reference your own parameter settings in the spaces provided.

Item	Default	Setting	Description — LOOP 1, LIST 1 COMMISSIONING
DP	2		Decimal point position (0-4 decimal places)
HR	100		Setpoint high range
LR	0		Setpoint low range
HT	0		Trim high range & high limit
LT	0		Trim low range & low limit
HS	100		Setpoint high limit
LS	0		Setpoint low limit
HA	100		High Absolute alarm level
LA	0		Low Absolute alarm level
HD	100		High Deviation alarm level
LD	100		Low Deviation alarm level
HO	100		High Output (OP) limit (0-100%)
LO	0		Low Output (OP) limit (0-100%)
XP	100		Proportional band (0-1999.9)
TI	10		Integral time (0-199.99 mins/secs)
TD	0		Derivative time (0-199.99 mins/secs)
TM	0		Trim value
RM	0		Remote Setpoint value
SL	0		Local Setpoint
TK	0		'OP1' Track value (0-100%)
TT	30.0		Motor travel time (0.5-1999.9 secs)*
PT	0.5		Minimum pulse time (0.1-60.0 secs)*
TB	0		Timebase (0=seconds, 1=minutes)
AL	0000		ALARM STATUS WORD
bit12	FALSE		Auto-ack. (T: auto-ack cleared alarm, F: needs manual ack)
bit13	FALSE		Relay disable (T: disable relay, F: enable relay)
bit14	FALSE		Relay on abs. only (T: abs. only, F: abs. & deviation alarms)
bit15	FALSE		Relay activation (T: on unackd alrm, F: on valid active alrm)
SC	0000		CONFIGURATION STATUS WORD
bit0	FALSE		Powerup (T: Manual, failsafe OP, F: last mode, last OP)
bit1	FALSE		Failsafe output (T: low OP, F: last OP)
bit2	FALSE		Invert electrical output (T: inversion, F: no inversion)
bit3	FALSE		Invert PID (ΔPV & ΔOP — T: same sense, F: opposite)
bit4	FALSE		PV fail (T: no mode change, F: Forced Manual, failsafe OP)
bit5	FALSE		Inverse ratio (T: Loop1 RM=PV2×RS, F: Loop1 RM=PV2÷RS)
bit6	FALSE		Ratio track (T: RS tracks measured SP if Loop1 not Remote)
bit7	FALSE		Simulation (T: connect plant simulation) (*not implemented*)
bit8	FALSE		Incremental control (T: incremental control, F: continuous)
bit9	FALSE		On/off control (T: On/off control, F: PID control)
bit10	FALSE		(*don't care*)
bit11	FALSE		SL balance (On SL writes — T: debump , F: no debump)
bit12	FALSE		SL track (T: SL tracks PV if not Auto, F: SL constant)
bit13	FALSE		Calibration enable (T: enable I/O calib., F: normal op.)
bit14	FALSE		PAR timeout disable (T: disable, F: enable)
bit15	FALSE		Raise/lower speed (T: very fast, F: normal, with acceleration)
BM	00		PUSHBUTTON MASK BYTE
bit0	FALSE		(*don't care*)
bit1	FALSE		(*don't care*)
bit2	FALSE		'SP' pushbutton mask (T: disables setpoint change via button)
bit3	FALSE		'M' pushbutton mask (T: disables mode selection via button)
bit4	FALSE		(*don't care*)
bit5	FALSE		'A' pushbutton mask (T: disables mode selection via button)
bit6	FALSE		'Alm Ack' pushbutton mask (T: disables alm ack via button)
bit7	FALSE		'R' pushbutton mask (T: disables mode selection via button)

**Incremental control only*

Item	Default	Setting	Description — LIST 3, INSTRUMENT PARAMETERS
II	630	—	Instrument identity
IV		—	Instrument version
CC	1	3	Controller type (0=Man St, 1=S-Loop, 2=Cas, 3=Rat, 4=O/ride)
P0	0		Passcode 0 — Loop-commissioning parameters
P1	0		Passcode 1 — Configuration parameters
TU	0		Temperature linearisation units (0=°C, 1=°F, 2=K)
B1	0		Expansion I/O enable (0=disable, 1=enable)

Item	Default	Setting	Description — LIST 4, MODBUS PARAMETERS
FS	00	—	COMMUNICATIONS STATUS BYTE
AD	254		Instrument address (1-254)
BD	0		Baud (0=9600, 1=19200**, 2=4800, 3=2400, 4=1200)
PY	0		Parity (0=none, 1=even, 2=odd)

***Not implemented*

Item	Default	Setting	Description — LOOP 2, LIST 2 COMMISSIONING
DP	2		Decimal point position (0-4 decimal places)
HR	100		Uncontrolled PV high range
LR	0		Uncontrolled PV low range
HS	100		Ratio setpoint high limit
LS	0.01		Ratio setpoint low limit
RS	1		Ratio setpoint

Item	Default	Setting	Description — LIST 5, MAIN PCB I/O PARAMETERS
IR	0		Proc I/P range (0=4-20mA, 1=0-20mA, 2=1-5V, 3=0-10V, 4=T/C, 5=RTD)
IB*	1		Process I/P break protection (1=upscale brk, 2=downscale)
IL	0		Process I/P lin. (0=none, 1=square root, [T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N], 9=PT100 res. therm.)
IF	1		Process input filter time constant (0-1999.9 secs)
OR	0		Process output range (0=4-20mA, 1=0-20mA)

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*

Item	Default	Setting	Description — LIST 6, EXPN. BOARD I/O PARAMETERS
IR	0		Proc. I/P range (0=4-20mA;1=0-20mA;2=1-5V;3=0-10V;4=T/C;5=RTD)
IB*	1		Proc. I/P break protection (1=upscale break, 2=downscale)
IL	0		Proc. I/P lin. (0=none;1=square root;[T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N]; 9=PT100 res. thermom.)
IC	0	—	Proc. I/P conn. assignt. (Fixed: PV2 — Process Variable Loop 2)
IF	1		Process Input filter time constant (0-1999.9 seconds)
AR	3		Analogue input range (2=1-5V, 3=0-10V)
AB	0		An. I/P break protection (0=freeze, 1=upscale, 2=dnscale.)
AC	0		An. I/P connection assignt. (0=open cct, 1=TK, 2=feedfwd, 4=TM)
AF	1		Analogue input filter time constant (0-1999.9 seconds)
OR	3		Analogue output range (2=1-5V, 3=0-10V)
OC	0		An. O/P connection assignt. (0=PV1%, 1=SP%, 2=OP%, 3=PV2%)
DI	00		DIGITAL I/O INVERSION MASK BYTE (TRUE inverts bit)
bit0	FALSE		Hold select input
bit1	FALSE		Track select input (*or unallocated user bit***)
bit2	FALSE		Remote enable input
bit3	FALSE		(*Unallocated user bit*)
bit4	FALSE		NOT [Hold OR Manual] output (*or RAISE output***)
bit5	FALSE		NOT [Remote Auto] output
bit6	FALSE		NOT [High Alarm] output (*or NOT[Alarm] output***)
bit7	FALSE		NOT [Low Alarm] output (*or LOWER output***)
DC	F0		DIGITAL I/O CONNECTION MASK (TRUE connects bit)
bit0	FALSE		Hold select input
bit1	FALSE		Track select input (*or unallocated user bit***)
bit2	FALSE		Remote enable input
bit3	FALSE		(*Unallocated user bit*)
bit4	TRUE		NOT [Hold OR Manual] output (*or RAISE output***)
bit5	TRUE		NOT [Remote Auto] output
bit6	TRUE		NOT [High Alarm] output (*or NOT[Alarm] output***)
bit7	TRUE		NOT [Low Alarm] output (*or LOWER output***)
DU	0		Digital I/O pullup type: DU / Inputs / Outputs 0 *external* *external* 1 *internal* *external* 2 *external* *internal* 3 *internal* *internal*

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*
*** If incremental control selected*

Item	Default	Setting	Description — LIST 8, INCREM. CONTROL PARAMETERS
IN	0.0		Inertia compensation time (0.0-20.0 secs)*
BL	0.0		Backlash compensation time (0.0-20.0 secs)*

**Incremental control only*

ISSUE	DATE	DRAWN	CHECKED	INSTRUMENT ID
				FUNCTION
				DRAWING NUMBER

RATIO CONTROLLER SETUP SHEET

Chapter 9 MANUAL STATION

This chapter tells you how to use the instrument when it is set up as a manual station. The main topics dealt with in this chapter are:

- Overviews of the manual station (§1)
- Manual station inputs and outputs (§2)
- Manual station operating modes (§3)
- Manual station user interface (§4)
- Manual station parameters (§5)
- Setup sheet for the manual station (§6).

NOTE. Incremental control is not available for the manual station.

1 OVERVIEWS OF THE MANUAL STATION

1.1 General overview of the manual station

Figure 9-1 is an overview of the manual station and its I/O.

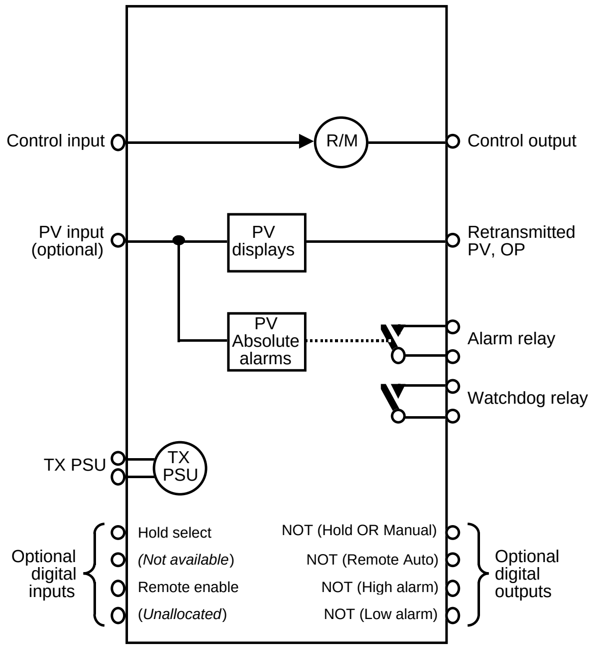


Figure 9-1 Manual station overview

A basic manual station can be configured using only the main I/O board. The process input terminals accept the input control signal (e.g. a DDC output) which — in Remote mode — is tracked and output via the process output terminals to the plant. In Manual mode the operator can intervene and set the control output.

Alternatively, with the optional expansion I/O board fitted, the control input is via the expansion I/O process inputs. This leaves the main board I/O inputs free to monitor a PV signal and apply absolute alarms to it. PV is displayed on the instrument front panel and can be retransmitted via the expansion board's analogue outputs. Additionally, the expansion board provides digital I/O including Hold select and Remote enable.

1.2 Manual station example

Figure 9-2 shows an example of the manual station controlling fluid flow in a pipe.

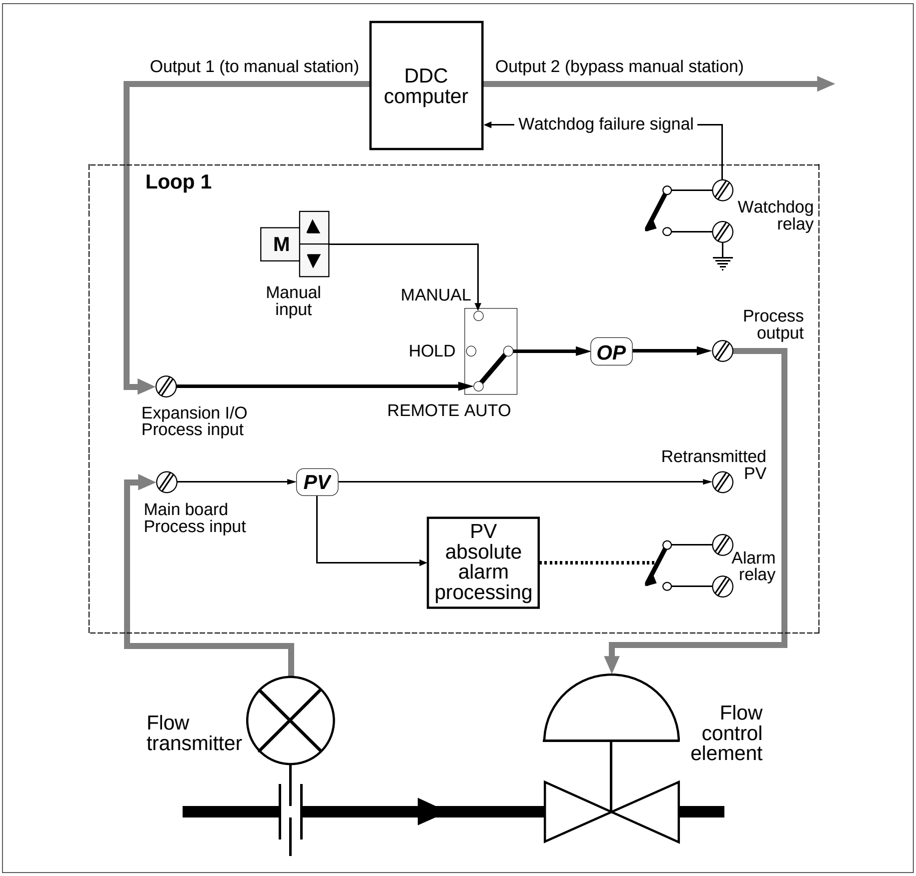


Figure 9-2 Manual station with expansion I/O — flow-control example

In (remote) automatic operation, the manual station output OP tracks the signal input from the DDC computer. At the same time the PV signal from the flow transmitter is displayed on the front panel, processed for alarms and retransmitted. The watchdog relay outputs are wired back to the DDC to allow it to monitor the health of the manual station. On watchdog failure, the DDC is configured to bypass the manual station and send its output signal elsewhere.

The manual station can also operate in manual and hold modes, as indicated schematically in the diagram by the 'mode switch' feeding the OP parameter. §3 describes how these modes are selected and behave.

2 MANUAL STATION INPUTS & OUTPUTS

Figure 9-3 summarises the I/O available for the manual station. Terminal numbers 1-22 refer to the main board I/O, and terminals 23-44 refer to the (optional) expansion I/O board.

In the figure, terminal numbers enclosed in brackets are user-assignable, as described in Chapter 4, *Configuration*. Unbracketed terminal numbers have fixed assignments.

3 MANUAL STATION OPERATING MODES

Table 9-1 summarises the possible operating modes of the manual station. They are listed in descending order of priority. The table gives for each mode the entry conditions, how you can recognise it from the front-panel LEDs, and how it affects the manual station action. For more information on operating modes and priorities see Chapter 5.

Mode	Selected by	Front panel	Action
Hold	Hold select input TRUE	'HOLD' lamp lit	Output frozen
Forced Manual	Track input break or h/w overrange, or sumcheck fail	'MAN' lamp flashes	As Manual, but lower priority modes non-selectable until break/overrange corrected or sumcheck reset
Manual	Press 'M' button	'MAN' lamp lit	Output set locally by operator. On entry, output adopts last value
Pseudo Forced Manual	Press 'R' button, Rem Enable FALSE	'MAN' lamp flashes	As Manual. Press 'M' to restore Manual
Remote Auto	Press 'R' button, Rem Enable TRUE	'REM' lamp lit	Output tracks remote input

Table 9-1 Modes supported by the manual station in descending priority order

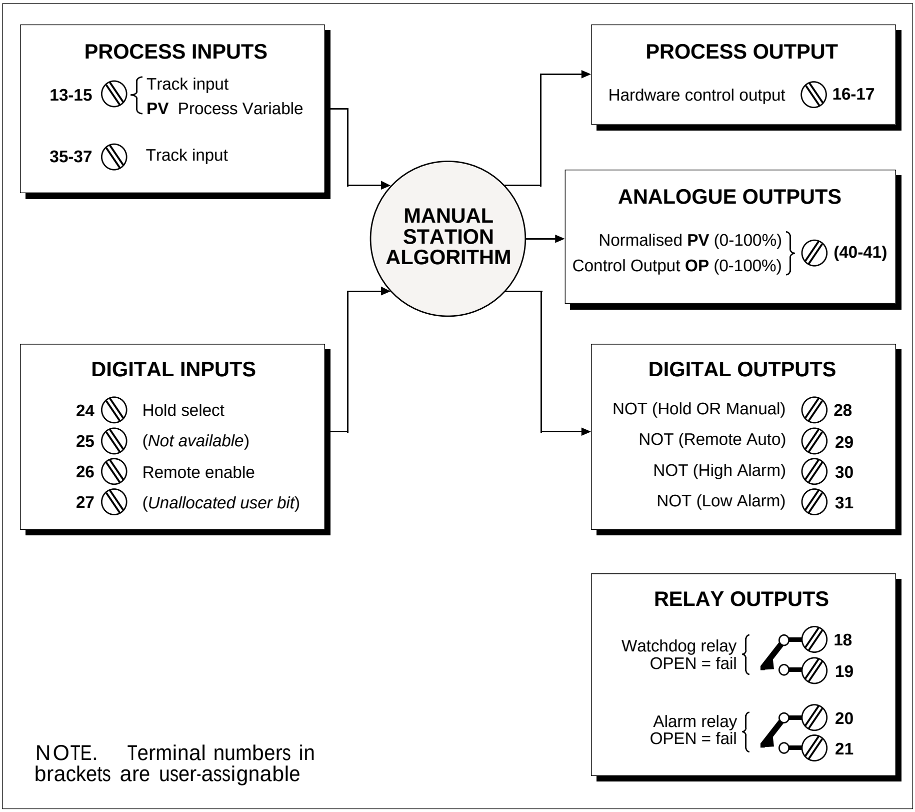


Figure 9-3 Manual station I/O summary

4 MANUAL STATION USER INTERFACE

This section tells you how to use the front-panel displays and controls to operate the manual station. It assumes you are familiar with front-panel use in general (described in Chapter 3).

The user interface differs slightly between the main-board-only manual station and the manual station with optional expansion I/O board.

4.1 Using the manual station with main board only

NOTE. Whether or not an expansion board is fitted, to operate using the main board only you must set List 3 parameter B1 (Expansion I/O enable) to FALSE. The signal to be tracked is connected to process input terminals 13-15, and the hardware output appears on the process output terminals 16 & 17 (see Figure 9-3).

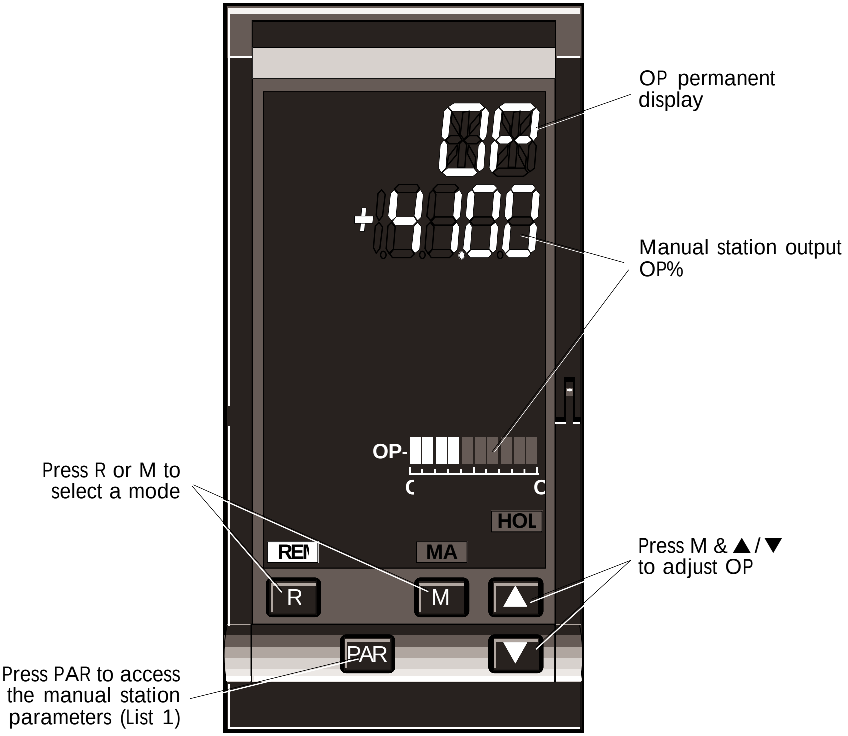


Figure 9-4 Manual station (main board only) front panel displays and controls

Figure 9-4 shows the main-board-only manual station displays and controls. Unavailable displays and keys having no effect have been omitted from the diagram.

As summarised in the figure, from this manual station display you can:

- See the manual station output OP% displayed in the 4½-digit display and on the output bargraph (the only possibilities). The OP mnemonic remains permanently on display.
- Press 'R' or 'M' to select a mode. Note that Remote can be selected only if it has been enabled (by setting List 1 SM bit 2 TRUE).
- Press 'M' and ▲/▼ to adjust the value of OP.
- Press 'PAR' to access the manual station parameters, in List 1. Note that List 1 for the main-board-only manual station is a shortened version of the list for the manual station with expansion I/O board. (List 1 is given in §5.)

4.2 Using the manual station with expansion I/O board

NOTE. To operate with an expansion I/O board fitted you must set List 3 parameter B1 (Expansion I/O enable) to TRUE. The signal to be tracked is connected to process input terminals 35-37, and the hardware output appears on the process output terminals 16 & 17 (see §2). If required, connect a PV signal to terminals 13-15.

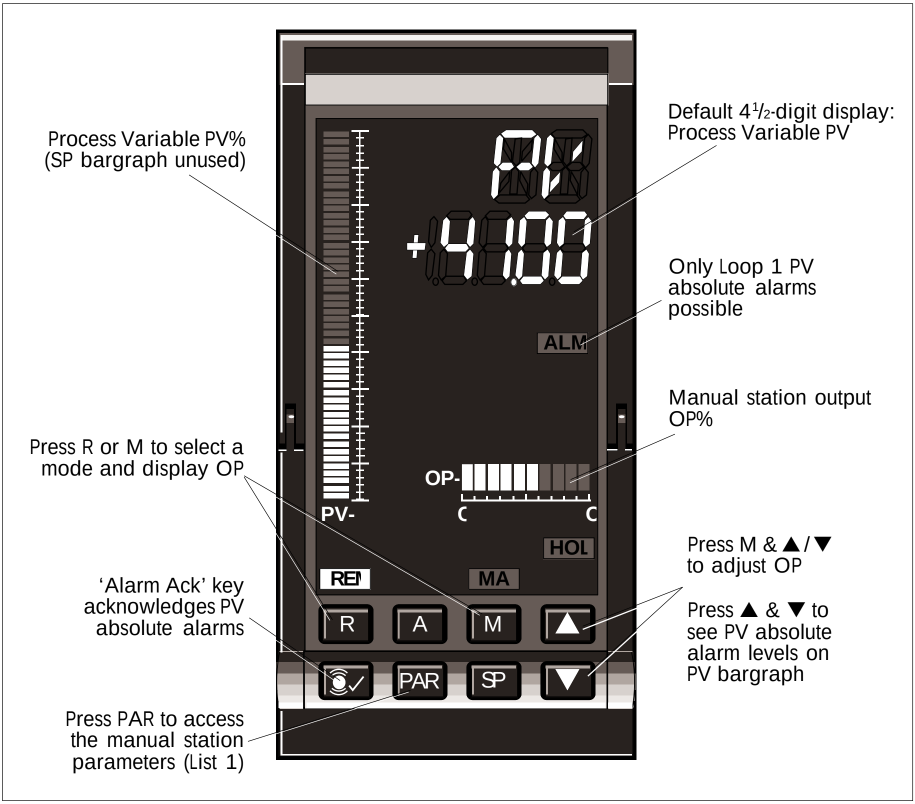


Figure 9-5 Manual station (with expansion I/O board) front panel displays and controls

Figure 9-5 shows the manual station displays and controls. Unavailable items have been omitted from the diagram.

As summarised in the figure, from this manual station display you can:

- See the Process Variable PV displayed in engineering units in the 4½-digit display (the default). Note that the 'PV' mnemonic does not automatically blank out.
- See PV displayed as a percentage on the PV-X bargraph. Note that the SP-W bargraph is unused in this display.

- See OP% displayed on the output bargraph.
- Press ‘R’ or ‘M’ to see the manual station output OP in the 4½-digit display, and also select a mode. Note that Remote can be selected only if it has been enabled; otherwise Pseudo Forced Manual mode is adopted (see §3).
- Press ‘M’ and ▲/▼ to adjust the value of OP.
- Press ▲ and ▼ to inspect PV’s absolute alarm levels on the PV-X bargraph.
- Press the ‘Alarm Acknowledge’ key to acknowledge a PV absolute alarm.
- Press ‘PAR’ to access the manual station’s full list of parameters in List 1. (See §5.)

5 MANUAL STATION PARAMETERS — LIST 1

Table 9-2 lists all the loop-commissioning parameters associated with the manual station — which are seen in List 1, accessed via passcode ‘P0’. Further information on some of the parameters is found where indicated in the table. Note that some of the parameters are available only if the expansion I/O board is in use.

Also listed is the parameter type (format), Modbus address, and whether it is read-only. (For a complete parameter list in order of Modbus address, refer to Ch 14 §3.4.)

L1	Function	Type	Write	M’bus
DP*	Decimal point position for List 1 parameters† (0-4 decimal places)	Int		0
HR*	PV high range (limits: –19999 to +19999, subject to DP)	Real		6
LR*	PV low range (limits: –19999 to +19999, subject to DP)	Real		7
HA*	PV High Absolute alarm level (limits: LR to HR)	Real		10
LA*	PV Low Absolute alarm level (limits: LR to HR)	Real		11
HO	High Output limit (0.00-100.00%)	Real		16
LO	Low Output limit (0.00-100.00%)	Real		17
PV*	Process Variable	Real	✘	1
OP	Manual station Output (0.00-100.00%) (limits also: LO to HO)	Real		3
AL*	Alarm status word [see Ch6 Table 6-3]	ABCDhex		4
SM	Mode status word [see Ch6 Table 6-4]	ABCDhex		23
SC	Configuration status word [see Ch6 Table 6-5]	ABCDhex		21
BM	Pushbutton mask [see Ch3 §1.6.9]	CDhex		22
MS	Requested mode (0-2) [see Ch5 §3]	Int		8
MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘	9

**Available only if expansion I/O in use †Except as indicated in the table ✘Read-only parameter*

Table 9-2 List 1 controller commissioning parameters — manual station

6 SETUP SHEET FOR THE MANUAL STATION

This section contains a sheet listing all the configurable parameters associated with the manual station, and their default values. You can photocopy the sheet and use it to record for reference your own parameter settings in the spaces provided.

Item	Default	Setting	Description — LOOP 1, LIST 1 COMMISSIONING
DP*	2		Decimal point position (0-4 decimal places)
HR*	100		Process Variable high range
LR*	0		Process Variable low range
HA*	100		PV High Absolute alarm level
LA*	0		PV Low Absolute alarm level
HO	100		High Output limit (0-100%)
LO	0		Low Output limit (0-100%)
AL*	0000		ALARM STATUS WORD
bit12	FALSE		Auto-ack. (T: auto-ack cleared alarm, F: needs manual ack)
bit13	FALSE		Relay disable (T: disable relay, F: enable relay)
bit14	FALSE		Relay on abs. only (T: abs. only, F: abs. & deviation alarms)
bit15	FALSE		Relay activation (T: on unackd alrm, F: on valid active alrm)
SC	0000		CONFIGURATION STATUS WORD
bit0	FALSE		Powerup (T: Manual, failsafe OP, F: last mode, last OP)
bit1	FALSE		Failsafe output (T: low OP, F: last OP)
bit2	FALSE		Invert electrical output (T: inversion, F: no inversion)
bit3	FALSE		Invert PID (ΔPV & ΔOP — T: same sense, F: opposite)
bit4	FALSE		PV fail (T: no mode change, F: Forced Manual, failsafe OP)
bit5	FALSE		Inverse ratio (T: Loop1 RM=PV2×RS, F: Loop1 RM=PV2÷RS)
bit6	FALSE		Ratio track (T: RS tracks measured SP if Loop1 not Remote)
bit7	FALSE		Simulation (T: connect plant simulation)**
bit8	FALSE		Incremental control (T: incremental control, F: continuous)
bit9	FALSE		On/off control (T: On/off control, F: PID control)
bit10	FALSE		*(don't care)*
bit11	FALSE		SL balance (On SL writes — T: debump , F: no debump)
bit12	FALSE		SL track (T: SL tracks PV if not Auto, F: SL constant)
bit13	FALSE		Calibration enable (T: enable I/O calib., F: normal op.)
bit14	FALSE		PAR timeout disable (T: disable, F: enable)
bit15	FALSE		Raise/lower speed (T: very fast, F: normal, with acceleration)
BM	00		PUSHBUTTON MASK BYTE
bit0	FALSE		*(don't care)*
bit1	FALSE		*(don't care)*
bit2	FALSE		'SP' pushbutton mask (T: disables setpoint change via button)
bit3	FALSE		'M' pushbutton mask (T: disables mode selection via button)
bit4	FALSE		*(don't care)*
bit5	FALSE		'A' pushbutton mask (T: disables mode selection via button)
bit6	FALSE		'Alm Ack' pushbutton mask (T: disables alm ack via button)
bit7	FALSE		'R' pushbutton mask (T: disables mode selection via button)

**Only with expansion I/O board active   **Not implemented*

Item	Default	Setting	Description — LIST 3, INSTRUMENT PARAMETERS
II	630	—	Instrument identity
IV		—	Instrument version
CC	1	0	Controller type (0=Man St, 1=S-Loop, 2=Cas, 3=Rat, 4=O/ride)
P0	0		Passcode 0 — Loop-commissioning parameters
P1	0		Passcode 1 — Configuration parameters
TU	0		Temperature linearisation units (0=°C, 1=°F, 2=K)
B1	0		Expansion I/O enable (0=disable, 1=enable)

Item	Default	Setting	Description — LIST 4, MODBUS PARAMETERS
FS	00	—	COMMUNICATIONS STATUS BYTE
AD	254		Instrument address (1-254)
BD	0		Baud (0=9600, 1=19200**, 2=4800, 3=2400, 4=1200)
PY	0		Parity (0=none, 1=even, 2=odd)

***Not implemented*

Item	Default	Setting	Description — LIST 5, MAIN PCB I/O PARAMETERS
IR	0		Proc I/P range (0=4-20mA, 1=0-20mA, 2=1-5V, 3=0-10V, 4=T/C, 5=RTD)
IB*	1		Process I/P break protection (1=upscale brk, 2=downscale)
IL	0		Process I/P lin. (0=none, 1=square root, [T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N], 9=PT100 res. therm.)
IF	1		Process input filter time constant (0-1999.9 secs)
OR	0		Process output range (0=4-20mA, 1=0-20mA)

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*

Item	Default	Setting	Description — LIST 6, EXPN. BOARD I/O PARAMETERS
IR	0		Proc. I/P range (0=4-20mA;1=0-20mA;2=1-5V;3=0-10V;4=T/C;5=RTD)
IB*	1		Proc. I/P break protection (1=upscale break, 2=downscale)
IL	0		Proc. I/P lin. (0=none;1=square root;[T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N]; 9=PT100 res. thermom.)
IC	0		*(don't care)*
IF	1		Process Input filter time constant (0-1999.9 seconds)
AR	3		*(don't care)*
AB	0		*(don't care)*
AC	0		*(don't care)*
AF	1		*(don't care)*
OR	3		Analogue output range (2=1-5V, 3=0-10V)
OC	0		An. O/P connection assignment (0=PV%, 1=SP%, 2=OP%)
DI	00		DIGITAL I/O INVERSION MASK BYTE (TRUE inverts bit)
bit0	FALSE		Hold select input
bit1	FALSE		*(don't care)*
bit2	FALSE		Remote enable input
bit3	FALSE		*(Unallocated user bit)*
bit4	FALSE		NOT [Hold OR Manual] output
bit5	FALSE		NOT [Remote Auto] output
bit6	FALSE		NOT [High Alarm] output
bit7	FALSE		NOT [Low Alarm] output
DC	F0		DIGITAL I/O CONNECTION MASK (TRUE connects bit)
bit0	FALSE		Hold select input
bit1	FALSE		*(don't care)*
bit2	FALSE		Remote enable input
bit3	FALSE		*(Unallocated user bit)*
bit4	TRUE		NOT [Hold OR Manual] output
bit5	TRUE		NOT [Remote Auto] output
bit6	TRUE		NOT [High Alarm] output
bit7	TRUE		NOT [Low Alarm] output
DU	0		Digital I/O pullup type: DU 0 = Inputs *external*, Outputs *external*; DU 1 = Inputs *internal*, Outputs *external*; DU 2 = Inputs *external*, Outputs *internal*; DU 3 = Inputs *internal*, Outputs *internal*

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*

ISSUE	DATE	DRAWN	CHECKED	INSTRUMENT ID
				FUNCTION
				DRAWING NUMBER

MANUAL STATION SETUP SHEET

Chapter 10 INCREMENTAL CONTROL

This chapter tells you how to configure and use the instrument as an incremental controller, or 'Motorised valve' controller. The main topics dealt with in this chapter are:

- What is incremental control? (§1)
- Incremental control inputs and outputs (§2)
- Incremental control operating modes (§3)
- Incremental control user interface (§4)
- Incremental control parameters (§5)
- Incremental control sensor break action (§6).

1 WHAT IS INCREMENTAL CONTROL?

1.1 Incremental control basics

In incremental control (also called 'raise/lower' control) the control output is in the form of a pair of digital signals — a 'raise' output and a 'lower' output. These two signals control a bi-directional fixed-speed motor, typically driving a valve open or shut. If the 'raise' output goes high the motor powers up and runs in a direction that opens the valve. The motor stops when the 'raise' output goes low. If the 'lower' output goes high the motor runs in the opposite, valve-closing, direction, stopping when this output goes low.

To achieve finer control of the fixed-speed motor its effective speed can be lowered by 'pulsing' the control outputs. For example, if the 'raise' output is ON for 1 second then OFF for 1 second and so on in a 1:1 mark/space pulse train, the mean speed of the motor is reduced to 50% of normal, and the valve opens only half as much in a given time. Other mark/space ratios reduce the effective motor speed by corresponding amounts.

Figure 10-1 illustrates these actions.

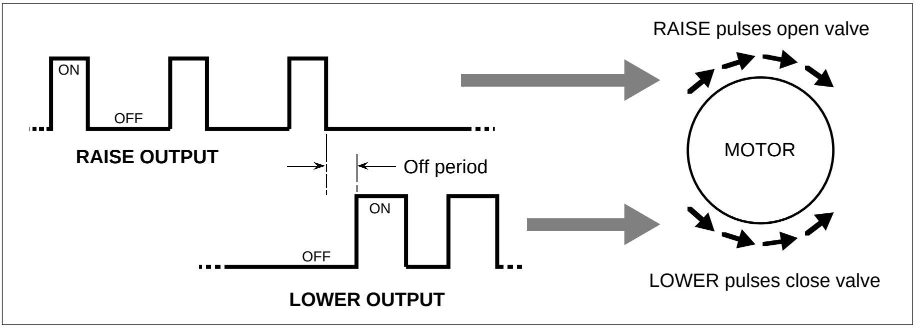


Figure 10-1 Incremental control output pulses

The parameters defining the incremental control output signals are described in §5. Note the ‘off period’ in the figure. This is the time between one control output stopping and the other output starting, i.e. the pause between reversing the motor’s running direction. Maintaining a minimum off period ensures that the motor is never driven in two directions at once. This is described in §5.2.2.

1.2 Understanding the incremental control loop

Figure 10-2 shows schematically how incremental control is implemented in the process controller.

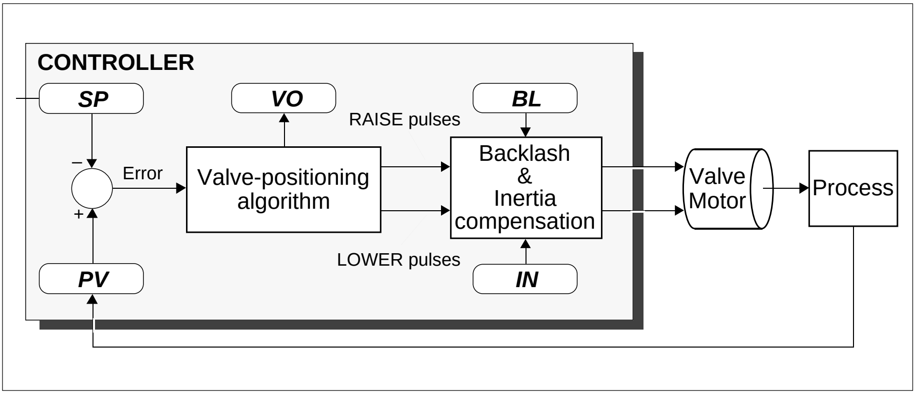


Figure 10-2 Incremental control implementation

1.2.1 Generating the output pulses

The process variable PV from the controlled process is compared with the setpoint SP, and the error signal is passed to the valve-positioning (VP) algorithm. The VP algorithm generates a Velocity Output demand parameter VO, and a pair of corresponding digital pulse trains — the ‘raise’ and ‘lower’ pulse outputs.

1.2.2 Compensating the outputs — inertia & backlash

Before passing on to the controller’s output terminals, the ‘raise’ and ‘lower’ pulses can be adjusted by the algorithm to compensate for two effects that reduce control precision — *motor inertia* and *mechanical backlash*. Figure 10-2 shows this schematically.

- **Inertia compensation.** When the drive signal supplied to a motorised valve halts, the motor does not stop immediately — there is a delay while it decelerates to a standstill. The result of this inertia effect is that each time an output pulse is applied, the motor travels further than required. This can be compensated for by making every output pulse shorter by a time period called the motor inertia time, IN seconds. The motor travels this ‘lost’ time by itself, unpowered.

- **Backlash compensation.** Each time the motor starts up after having changed direction there is a slight delay before the valve starts to move. During this time the mechanical backlash in the drive system between the motor and valve is being taken up. To compensate for backlash, the first pulse after a change of direction can be made longer by a time period called the backlash time, BL seconds.

1.3 Selecting incremental control

Incremental control is selected by setting the List 1 SC parameter bit 8 to TRUE. Note that incremental control can be used only in loop 1; in loop 2, the List 2 SC parameter bit 8 is 'don't care'. An expansion I/O board must be fitted, and enabled by setting List 3 B1 to '1'. There is no need to specially configure the 'raise' and 'lower' digital outputs via the Digital connection parameter DC. These outputs are automatically connected — and DC bits 4 and 7 ignored — when you select incremental control. (§2.1 details the digital I/O).

Some instrument configurations are incompatible with incremental control, as Table 10-1 shows. For these configurations the state of List 1 SC bit 8 is ignored.

Compatible configurations	Incompatible configurations
Single-loop controller (CC=1)	Manual station (CC=0)
Cascade 2-loop controller (CC=2)	Override controller (CC=4)
Single-loop with ratio station controller (CC=3)	'On/off' controller (SC bit 9 TRUE)

Table 10-1 Configurations compatible with incremental control

1.4 Incremental control examples

Incremental control can be used with single- and dual-loop configurations — see previous §1.3. Here are two examples.

1.4.1 Example of incremental control in a single-loop controller

Figure 10-3 shows schematically a simple incremental single-loop controller being used to control the temperature in a gas-fired oven. Note that for clarity not all available parameters are shown (e.g. compensation parameters, etc.). The controller can be operated in automatic or non-automatic modes, as described in §3. For more details on single-loop operation in general, see Chapter 6.

Note that in Manual mode the operator can use the front-panel buttons to emit output raise/lower pulses and drive the motor manually, as suggested in Figure 10-3. More information on front-panel incremental control operations is given in §4.

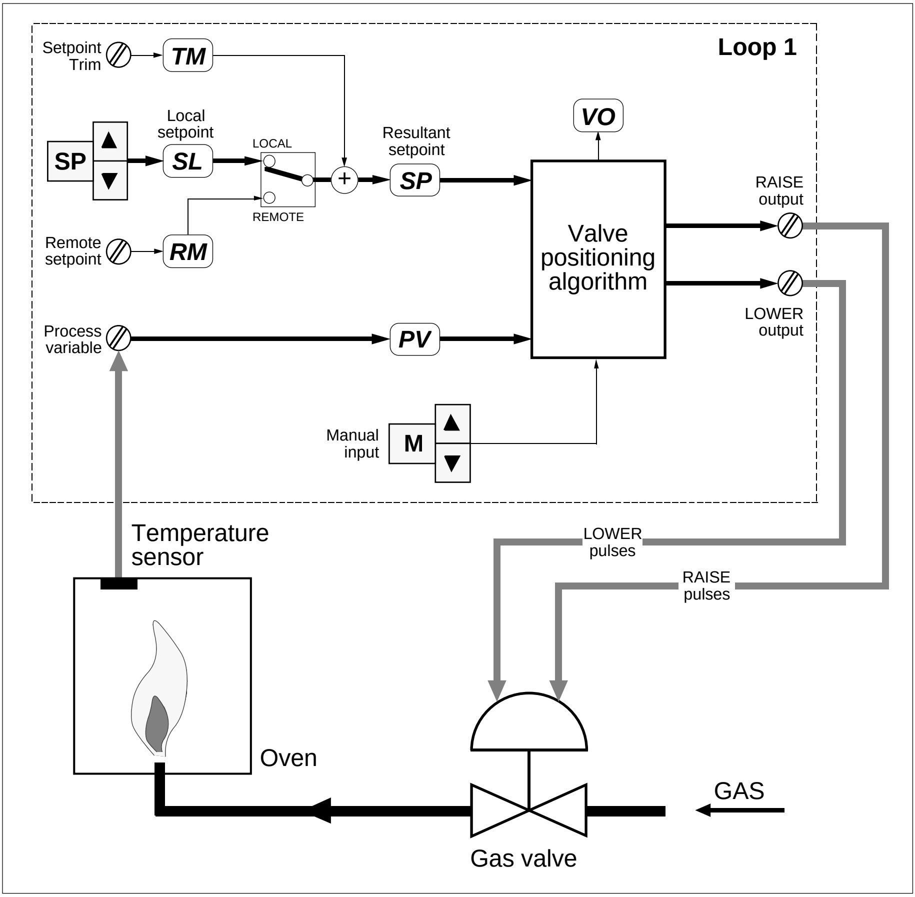


Figure 10-3 Incremental single-loop controller schematic — temperature-control example

1.4.2 Example of incremental control in a dual-loop cascade controller

Figure 10-4 shows schematically a dual-loop cascade controller being used to control an oven, as in the previous example of §1.4.1. Master loop 2 is a continuous controller that compares the required oven temperature with the measured temperature, and calculates the demanded gas flow. This is fed to Slave loop 1 as its remote setpoint. Slave loop 1 compares the demanded gas flow with the measured flow, and controls the gas flow valve accordingly.

For details on cascade operation in general, see Chapter 7.

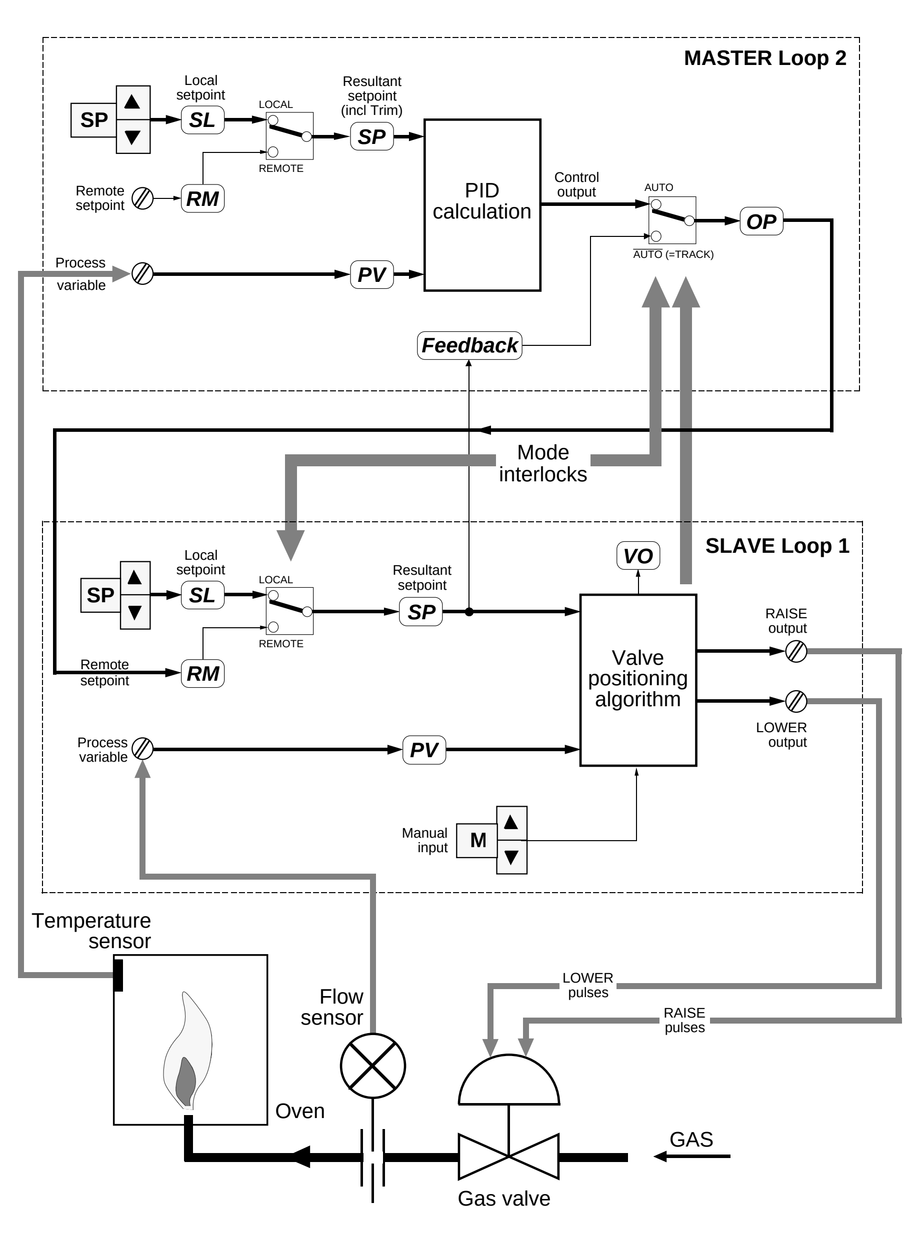


Figure 10-4 Incremental dual-loop cascade controller schematic — example

2 INCREMENTAL CONTROLLER INPUTS & OUTPUTS

Inputs and outputs available when incremental control has been selected are essentially as for the particular controller type configured — i.e. single-loop (see Ch6 §2), cascade (Ch7 §2), or ratio (Ch8 §2) control. Details of the I/O for each controller type are found in the sections of this manual indicated. But with incremental control selected, certain I/O terminals become unavailable or have altered functions, as described in the following sections.

2.1 Digital I/O functions in incremental control

Table 10-2 lists the set of digital expansion I/O rear-panel terminals and compares their functions in analogue output and incremental output configurations.

Terminal	Bit	Analogue outputs	Incremental outputs
⊘ 24 Digital input	DV bit 0	Hold select	Hold select
⊘ 25 Digital input	DV bit 1	Track select	*Unallocated user bit* [1]
⊘ 26 Digital input	DV bit 2	Remote enable	Remote enable
⊘ 27 Digital input	DV bit 3	*Unallocated user bit*	*Unallocated user bit*
⊘ 28 Digital output	DV bit 4	NOT[Hold OR Manual]	RAISE output [3]
⊘ 29 Digital output	DV bit 5	NOT[Remote Auto]	NOT[Remote Auto]
⊘ 30 Digital output	DV bit 6	NOT[High Alarm]	NOT[Alarm] [2]
⊘ 31 Digital output	DV bit 7	NOT[Low Alarm]	LOWER output [3]
⊘ 32 Digital ground	—	—	—

Table 10-2 Digital I/O functions for continuous & incremental control

NOTES to Table 10-2.

[1] Track is an invalid mode in incremental control and cannot be selected. You can wire unallocated user bits to suit your application. The states of the inputs are available via the corresponding DV parameter bits.

[2] For incremental control, the output on terminal 30 combines the functions of terminals 30 and 31 in continuous control configurations.

[3] The DC (Digital connection) parameter bits 4 and 7 settings are ignored when incremental control is selected, and the outputs are automatically connected.

2.2 Analogue I/O functions in incremental control

The fact that the OP parameter is not the control output in incremental controllers means that it can be used for other purposes. Specifically, you can configure the extension I/O process input (terminals 35-37) or the analogue input (terminals 38, 39) as the Track input, and cause OP to display an analogue input on the front panel — e.g. the valve's measured position. This is described in §4.

3 INCREMENTAL CONTROL OPERATING MODES

The operating modes available to a loop when incremental control has been selected are essentially as for the particular controller type configured — i.e. single-loop (see Ch6 §2), cascade (Ch7 §2), or ratio (Ch8 §2) control. Details of the modes available to each controller type are found in the sections of this manual indicated. But with incremental control selected, Track mode is unavailable, and Hold and Manual modes have slightly altered functions, as summarised in Table 10-3.

(For more information on operating modes and priorities see Chapter 5.)

Operating mode	Action in incremental control
HOLD	Raise & Lower digital outputs frozen at zero output, i.e. OFF, so motorised valve being controlled held at current position.
TRACK	Not selectable in a loop operating with incremental control. Mode status word SM bit 1 (Track select) cannot be set TRUE, and Track select digital input terminal 25 becomes unallocated. (You can wire this terminal for any other purpose — its input state is available via the digital input parameter DV bit 1. [See §2.1.])
MANUAL, FORCED MANUAL	Raise & Lower digital outputs cease, halting motor. But operator can cause individual Raise/Lower pulses to be emitted by pressing front-panel ‘M’ button plus ‘raise’/‘lower’ buttons resp., to position valve manually. (Backlash & inertia compensation not applied to output pulses in Manual mode.) [See also §4]

Table 10-3 Action of operating modes specific to incremental control

4 INCREMENTAL CONTROL USER INTERFACE

Guidance on all aspects of using the instrument’s front panel is given in Chapter 3. This section summarises the special features of the user interface when incremental control has been selected, i.e. OP parameter function and display, the output bargraph, and using Manual control mode.

4.1 OP parameter functions in incremental control

With incremental control selected, the analogue OP parameter is no longer the control output, and the hardware output available on terminals 16 and 17 (though present) is not used as a control output. Instead, the incremental raise and lower outputs are digital, via terminals 28 and 31.

Also, in incremental controllers, OP always follows the value of the track input parameter TK regardless of what operating mode is active. This contrasts with continuous control, where OP follows TK only when Track mode is active. (Track mode is not selectable with incremental control.)

Table 10-4 summarises these and other differences in OP function in the two control types.

With continuous control ...	With incremental control ...
OP is the control output (available via terminals 16, 17)	OP is not the control output (but still available via terminals 16, 17). Instead, Raise/Lower digital control outputs are available via terminals 28 & 31
OP value is displayed on the yellow output bargraph	OP value is not displayed on the yellow output bargraph. Instead, bargraph indicates Raise/Lower action [see §4.3]
OP mnemonic & value are always displayed on front panel when R, A, or M button pressed	OP mnemonic & value are displayed on front panel when R, A, or M button pressed only if List 6 IC or AC parameter = 1
OP follows TK only if Track mode active	OP always follows TK (Track mode is invalid)

Table 10-4 Differences in OP function in continuous & incremental controllers

4.2 Displaying OP on the front panel

The fact that in incremental control OP always tracks TK can be exploited to display any signal of interest on the front panel. E.g. you may want to display the controlled valve's measured position, input from a potentiometer fitted to the valve. To do this, either:

- connect the required signal to the expansion I/O board process input (terminals 35, 36) and set List 6 parameter IC (process input terminal assignment) to '1' (Track input), or
- connect the signal to the expansion I/O board analogue input (terminals 38, 39) and set List 6 parameter AC (analogue input terminal assignment) to '1' (Track input).

Now, when any mode button is pressed, the OP mnemonic and its value are displayed on the front panel.

NOTE. To cause OP to display when a mode button is pressed you need only set IC or AC to '1'. No electrical connections to the corresponding input terminals need be made. If *both* IC and AC are set to '1', TK follows the value of the signal input to terminals 35 and 36, overriding any signal on terminals 38 and 39.

4.3 The output bargraph in incremental control

When incremental control is operating, the yellow output bargraph can adopt only three display states — OFF, RAISE, and LOWER. Table 10-5 shows these states and their meanings. Note that the 'raise' and 'lower' displays go on and off in synchronisation with the corresponding pulses supplied to the motor via output terminals 28 and 31.

State	Bargraph display ...		... means
OFF		No segments lit	Output pulse absent/in OFF state. Terminals 28, 31 LO. Motor at rest
RAISE		Rightmost 2 segments lit	‘Raise’ output pulse in ON state. Terminal 28 HI, 31 LO. Motor opening valve
LOWER		Leftmost 2 segments lit	‘Lower’ output pulse in ON state. Terminal 28 LO, 31 HI. Motor closing valve

Table 10-5 Output bargraph displays for incremental control

4.4 Using Manual mode in incremental control

The action of Manual mode in incremental control was summarised in §3. More detail is given here. Manual mode can be used via the front panel (§4.4.1) or via the Modbus comms (§4.4.2).

4.4.1 Using Manual mode via the front panel

To operate the valve in Manual mode via the front panel:

1 With loop 1 on display, and incremental operation selected, enter Manual mode by pressing the ‘M’ button. This halts output pulses, stopping the motor. (Hold mode overrides Manual mode and should therefore be deselected).

2 To open the valve, hold down the ‘M’ button then press the ▲ (‘raise’) button. If you want to ‘nudge’ open the valve, release the buttons promptly. A single ‘raise’ pulse of duration equal to the minimum pulse time (PT parameter) is emitted, if the buttons are released within PT seconds. This can be seen on the output bargraph display.
To operate the motor for longer than PT seconds, keep the two keys pressed for the required time. A continuous ‘raise’ signal is emitted while the keys are pressed, which ceases immediately on their release. (§5 describes PT.)

NOTE. Inertia compensation is not applied to the pulses in Manual mode.

3 To close the valve, proceed as in step 2 but use the ▼ (‘lower’) button.

4 If you try to reverse the motor direction while a pulse is being emitted, the reverse-direction pulse does not start until the current pulse has ceased.

NOTE. Backlash compensation, and the minimum ‘off period’ between reversals, are not applied in Manual mode (but see §5.2.2).

4.4.2 Using Manual mode via the Modbus comms

To do this, the controller must be in Manual or Forced manual mode, and the output must not be in the process of being raised/lowered via the front panel.

A ‘raise’ pulse of duration equal to the minimum pulse time (PT seconds) is output by writing a ‘1’ to the *ManualAction* parameter (Modbus address 237). Writing ‘2’ produces a ‘lower’ pulse of length PT. Writing ‘0’ sets the output to the ‘rest’ state (no pulses).

NOTE. The minimum pulse length signal is always produced via the comms. The longer signals obtainable via the front panel (§4.4.1) are not obtainable via Modbus.

5 INCREMENTAL CONTROL PARAMETERS — LISTS 1 & 8

When incremental control is selected, two extra parameters appear in List 1 — TT (Motor travel time) and PT (Minimum pulse time), and the TD (Derivative time) parameter becomes ‘don’t care’. Also, an extra list appears — List 8 — containing more parameters for configuring the incremental control algorithm. This section explains the action of these extra parameters, and also describes two quasi-parameters that are derived from PT.

For information on the remaining parameters not specific to incremental control, please refer to the sections covering the particular controller type configured — i.e. single-loop (Ch6 §4), cascade (Ch7 §4), or ratio (Ch8 §5) control. (For a complete parameter list in order of Modbus address, refer to Ch14 §3.4.)

5.1 List 1 incremental control parameters

Table 10-6 lists the extra parameters available with incremental control — seen in List 1, accessed via passcode ‘P0’. Further information on the parameters follows the table.

L1	Function	Type	Write	M’bus
TD	(*Not used. Value is ‘don’t care’*)	Real		20
TT	Motor travel time (0.5-1999.9 secs)	Real		230
PT	Minimum pulse time (0.1-60.0 secs)	Real		31

Table 10-6 Extra / modified List 1 incremental control loop commissioning parameters

5.1.1 TD — Derivative time

The TD parameter is not used with incremental control, and its value is ‘don’t care’.

5.1.2 TT — Motor travel time

This is the time (always in seconds) needed for the valve to travel from fully closed to fully open, with the motor powered up continuously. The travel time for the reverse journey is assumed to be the same.

5.1.3 PT — Minimum pulse time

PT specifies the minimum time (always in seconds) that a 'raise' or 'lower' output pulse can be in the ON state — see Figure 10-5. For maximum control precision you should specify as small a PT value as possible, consistent with the inertia characteristics of the controlled motor. Specifically, PT should not be less than 2×IN, the Inertia compensation time, otherwise inertia compensation will not be fully applied (see §1.2.2).

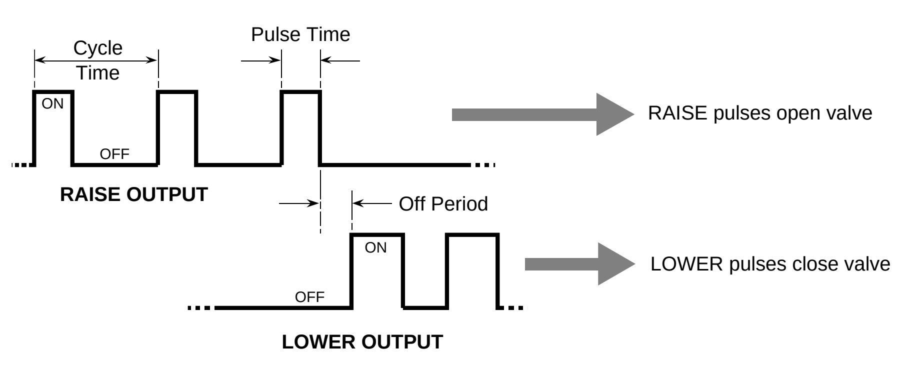


Figure 10-5 Incremental control output pulses — parameters

5.2 Parameters derived from the PT parameter

Two 'quasi-parameters' that derive from PT are used by the valve-positioning algorithm as it generates output pulses. These are the Minimum cycle time, and the Minimum off period.

5.2.1 Minimum cycle time

'Cycle time' for output pulses is equivalent to the period of the pulse train, as indicated in Figure 10-5. During automatic control, the valve-positioning algorithm ensures that the cycle time has a minimum value equal to 4 times the specified PT value.

5.2.2 Minimum off period

'Off period' is the time between the stopping of one control output pulse train and the starting of the other, i.e. the pause between reversing the motor's running direction. This is shown in Figure 10-5. During automatic control, the valve-positioning algorithm ensures that the off period has a minimum value equal to PT, to guarantee that the motor can never be driven in two directions at once. In manual mode, the algorithm applies a reduced minimum off period, equal to 125ms, approximately.

5.3 List 8 incremental control parameters

Table 10-7 shows the List 8 parameters available with incremental control, accessed via passcode ‘P1’. More information on the parameters is found where indicated in the table.

L8	Function	Type	Write	M’bus
IN	Inertia compensation time (0.0-20.0 secs) [see §§1.2.2 & 5.3.1]	Real		235
BL	Backlash compensation time (0.0-20.0 secs) [see §1.2.2]	Real		236
VO	Velocity output demand (–100.00 to +100.00%)	Real	✘	232

✘*Read-only*

Table 10-7 List 8 incremental control loop parameters

5.3.1 Inertia compensation time

For inertia compensation to be applied fully, the IN parameter must be set to a value no greater than PT/2, i.e. half the Minimum pulse time. If the motor has a higher inertia than this, you must increase PT accordingly (see §5.1.3).

6 INCREMENTAL CONTROL SENSOR BREAK ACTION

The way the control output responds to failure of the process variable input (‘sensor break action’) is essentially the same for incremental control as for continuous control configurations. Sensor break action is specified for all configurations by bits 1, 2, and 4 of the SC configuration status word; see Table 6-5 in Chapter 6 for details.

However, because the incremental control outputs are digital rather than analogue, they behave in a special way that is described in this section. Table 10-8 summarises the four possible sensor break action options configurable for incremental control, via SC bits 1, 2, and 4. It lists the mode adopted, the control output response, and the resulting action of the motorised valve being controlled.

NOTE. On PV fail, the message ‘**S_br**’ (‘sensor break’) flashes in the 4½-digit display, and the mode and output freeze at their current values. Then, after a delay of about 3 seconds, they adopt the values shown in Table 10-8. If PV is restored within this delay, sensor break action is avoided.

SC bit1	SC bit2	SC bit4	Mode adopted	Control output	Valve action
FALSE	X	FALSE	Forced Manual	Pulses cease	Left at current position
TRUE	FALSE	FALSE	Forced Manual	‘Lower’ pulse ON for TT+10% [1] secs, then stop	Motored to fully closed [2]
TRUE	TRUE	FALSE	Forced Manual	‘Raise’ pulse ON for TT+10% secs, then stop	Motored to fully open [2]
X	X	TRUE	Maintain existing	Depends on mode & I/P break protection [3]	Depends on control O/P

X = *‘don’t care’*

Table 10-8 Action on PV fail in incremental control — available configurations

NOTES to Table 10-8.

[1] The extra 10% ensures that the valve is indeed fully open or closed.

[2] If PV is restored after Forced Manual mode has been adopted, the loop enters Manual mode and the output pulse ceases immediately. If this happens within TT+10% seconds, the valve could be left in mid-travel. Also, see Caution.

[3] See Ch4 §2.3 for information on configuring input break protection.

Caution

If you have configured SC bit 1 TRUE and bit 4 FALSE, it is possible that on PV fail the valve motor could be powered up at either end of its travel for up to the full motor travel time (plus 10%).
Also, during the autotune process (see Chapter 12) the motor could conceivably be powered up at either end of its travel for up to two hours.
You should ensure that your particular motor setup is tolerant to these conditions.

Chapter 11 OVERRIDE CONTROLLER

This chapter tells you how to use the instrument when it is set up as an override controller. The main topics dealt with in this chapter are:

- Overviews of the override controller (§1)
- Override controller inputs and outputs (§2)
- Override controller operating modes (§3)
- Override controller parameters (§4)
- Setup sheets for the override controller (§5).

NOTE. Incremental control is not available for the override controller.

1 OVERVIEWS OF THE OVERRIDE CONTROLLER

1.1 General overview of the override controller

Figure 11-1 is an overview of the override controller and its I/O.

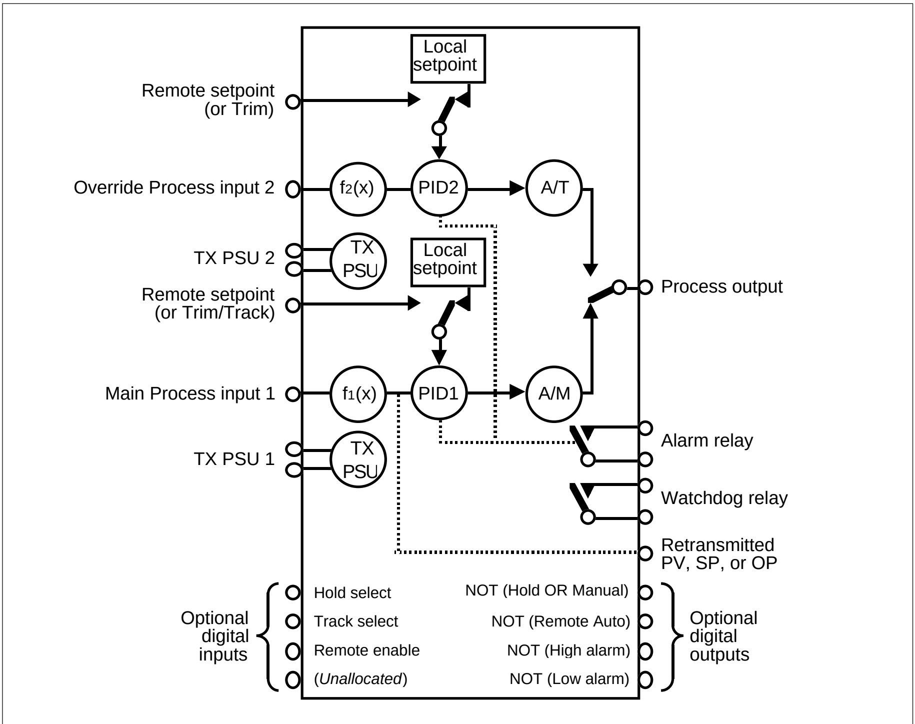


Figure 11-1 Override controller overview

This type of controller has two control loops ('main' and 'override') working on different setpoints and process variables and producing two separate calculated output values, but yielding a single process output to the plant. The process output at any time is automatically supplied by the loop with the lower of the two calculated output values.

The override controller must be configured with an expansion I/O board to provide the second process input.

1.2 Override controller example

Figure 11-2 shows schematically an example of the override controller being used to control the temperature of an ingot heated in an oven.

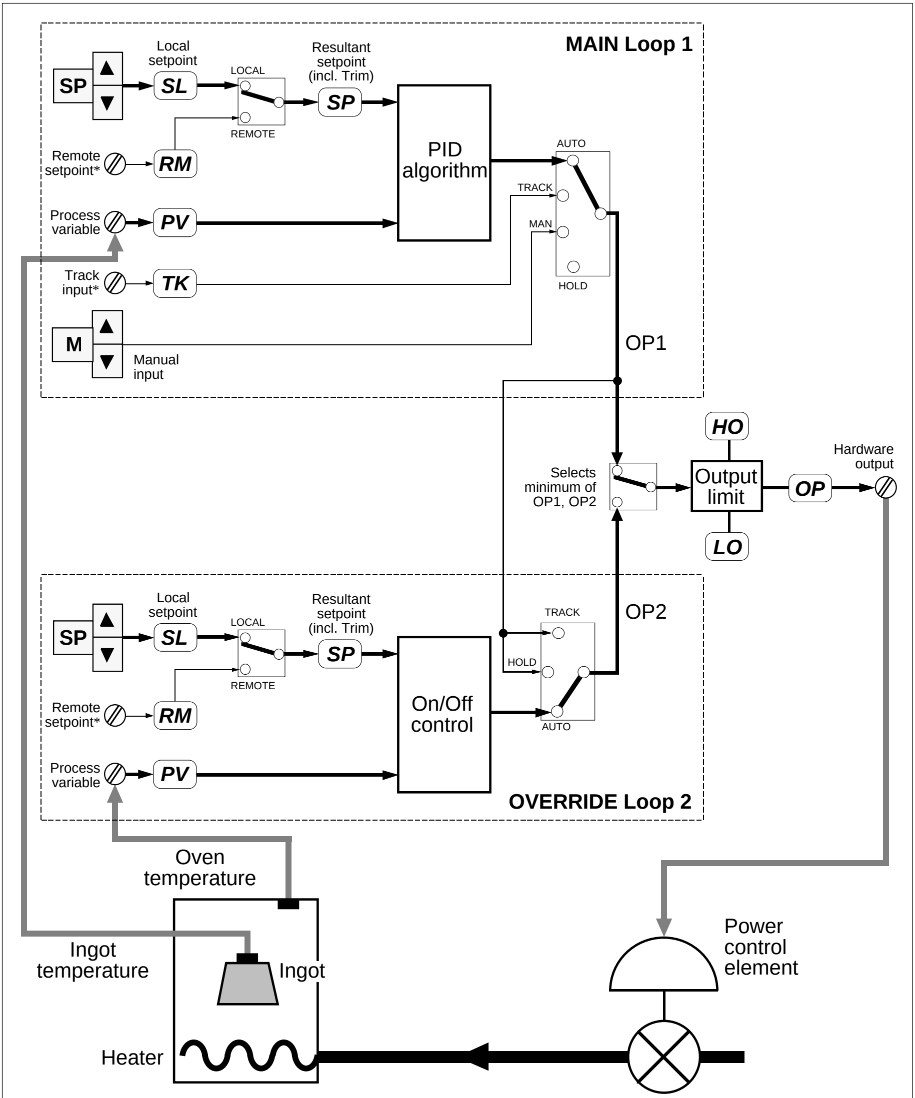
Main Loop 1 is a PID controller monitoring the ingot temperature directly, and override Loop 2 is an on/off controller monitoring the oven temperature. With both loops in automatic mode, the main loop output OP1 controls the ingot temperature without interference from the override loop so long as the oven temperature is below Loop 2's setpoint — which would be set to some upper 'safe' level. If the oven temperature reaches this level, Loop 2's on/off output OP2 falls from 100% to 0%, and so takes over control, shutting off the heater until the oven temperature has fallen to below the 'safe' level. At this point OP1 resumes control of the ingot temperature.

The override controller can also operate in other combinations of modes, as indicated schematically in Figure 11-2 by the 'mode switches' feeding OP1 and OP2. But in all modes the actual output to the plant is always the lower of the two values OP1 and OP2 (subject to output limits). §3 describes how these modes are selected and behave.

2 OVERRIDE CONTROLLER INPUTS & OUTPUTS

Figure 11-3 summarises the I/O available for the override controller. Terminal numbers 1-22 refer to the main board I/O, and terminals 23-44 refer to the expansion I/O board.

In the figure, terminal numbers enclosed in brackets are user-assignable, as described in Chapter 4, *Configuration*. Unbracketed terminal numbers have fixed assignments.



*Not all inputs are available at the same time

Figure 11-2 Override controller schematic — temperature control example

3 OVERRIDE CONTROLLER OPERATING MODES

Tables 11-1 and 11-2 summarise the override controller's possible operating modes, their selection, indications, and actions, for main loop 1 and override loop 2, respectively. For more information on operating modes and priorities see Chapter 5.

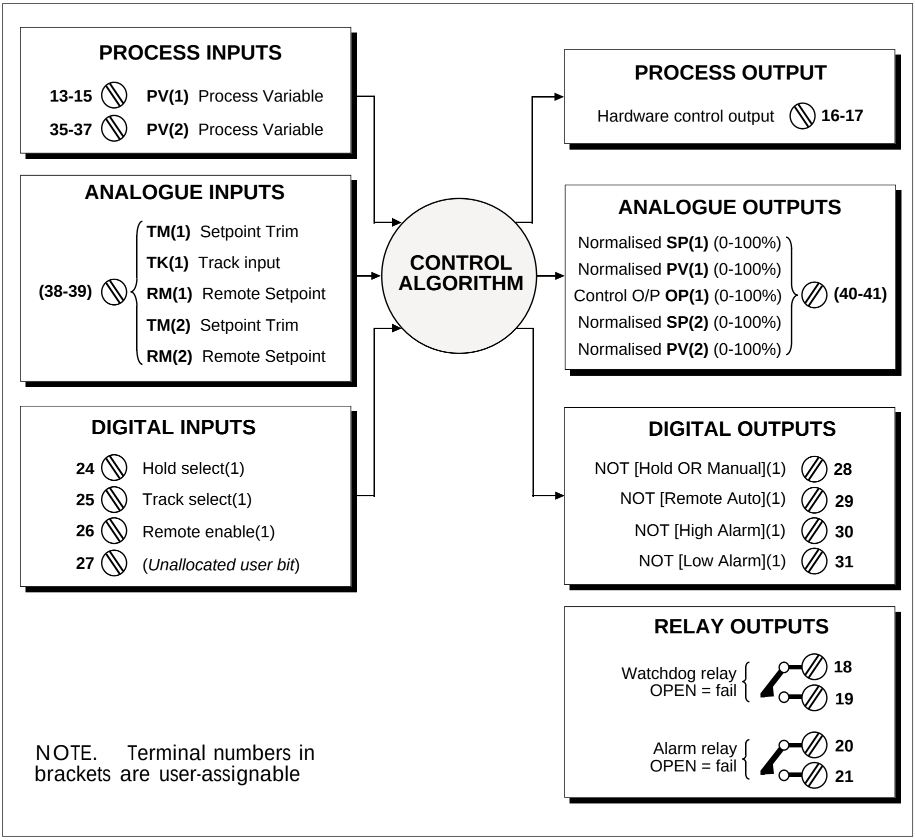


Figure 11-3 Override controller I/O summary

Mode	Selected by	Front panel	Action
Hold	Hold select input TRUE	'HOLD' lamp lit	OP1 frozen
Track	Track select input TRUE	'TRACK' lamp lit	OP1 follows Track value
Forced Manual	PV input break or h/w overrange, or sumcheck fail	'MAN' lamp flashes	As Manual, but lower priority modes non-selectable until break/overrange corrected or sumcheck reset
Manual	Press 'M' button	'MAN' lamp lit	OP1 set locally by operator. On entry, OP1 adopts current OP value
Local Auto	Press 'A'	'AUTO' lamp lit	OP1 generated using local setpoint
Forced Auto	Press 'R' button, Rem Enable FALSE	'AUTO' lamp flashes	As Local Auto
Remote Auto	Press 'R' button, Rem Enable TRUE	'REM' lamp lit	OP1 generated using remote setpoint Local setpoint tracks RM

Table 11-1 Modes supported by the override controller main loop 1 (descending priority)

Mode	Selected by	Front panel	Action
Hold	SM bit 0 TRUE	‘HOLD’ & ‘TRACK’ lamps lit	OP2 tracks OP1
Track	Press ‘M’ button	‘MAN’ & ‘TRACK’ lamps lit	OP2 tracks OP1
Forced Manual	PV input break or h/w overrange, or sumcheck fail	‘MAN’ lamp flashes	As Manual, but lower priority modes non-selectable until break/overrange corrected or sumcheck reset
Manual	Press ‘M’ button	‘MAN’ & ‘TRACK’ lamps lit	OP2 tracks OP1
Local Auto	Press ‘A’	‘AUTO’ lamp lit	OP2 generated using local setpoint
Forced Auto	Press ‘R’ button, Rem Enable FALSE	‘AUTO’ lamp flashes	As Local Auto
Remote Auto	Press ‘R’ button, Rem Enable TRUE	‘REM’ lamp lit	OP2 generated using remote setpoint Local setpoint tracks RM

Table 11-2 Modes supported by override controller override loop 2 (descending priority)

NOTE. The tables show the values adopted by the two loop ‘outputs’ — ‘OP1’ and ‘OP2’. These two quantities are not accessible as parameters, but are used internally by the control algorithm to derive OP, the actual control output. OP is available as a regular parameter in both List 1 and List 2, and is always the lower of OP1 and OP2, limited by the High and Low output limit parameters HO and LO. Figure 11-2 shows this schematically.

4 OVERRIDE CONTROLLER PARAMETERS — LISTS 1 & 2

Table 11-3 lists the loop-commissioning parameters associated with the ‘main’ loop of the override controller, which occupies the Loop 1 front-panel display. They are found in List 1, accessed via passcode ‘P0’. Further information on some of the parameters is found where indicated in the table.

Also listed is the parameter type (format), Modbus address, and whether it is read-only. (For a complete parameter list in order of Modbus address, refer to Ch14 §3.4.)

Table 11-4 lists the loop-commissioning parameters associated with the controller’s ‘override’ loop, which occupies the Loop 2 front-panel display. They are found in List 2, also accessed via passcode ‘P0’.

L1	Function	Type	Write	M’bus
DP	Decimal point position for List 1 parameters* (0-4 decimal places)	Int		0
HR	Setpoint high range (limits: –19999 to +19999)†	Real		6
LR	Setpoint low range (limits: –19999 to +19999)†	Real		7
HT	Trim high range & high limit (limits: LR–HR to HR–LR)	Real		28
LT	Trim low range & low limit (limits: LR–HR to HR–LR)	Real		29
HS	Setpoint high limit (limits: LR to HR)	Real		14
LS	Setpoint low limit (limits: LR to HR)	Real		15

Table 11-3 continued …

… Table 11-3 continued

L1	Function	Type	Write	M'bus
HA	High Absolute alarm level (limits: LR to HR)	Real		10
LA	Low Absolute alarm level (limits: LR to HR)	Real		11
HD	High Deviation alarm level (limits: 0 to HR–LR)	Real		12
LD	Low Deviation alarm level (limits: 0 to HR–LR)	Real		13
HO	High Output (OP) limit (0.00-100.00%)	Real		16
LO	Low Output (OP) limit (0.00-100.00%)	Real		17
XP	Prop. band, On/Off control hysteresis (0.0-1999.9) [see Ch6 §4.2]	Real		18
TI	Integral time (0.00-199.99 mins/secs) [TI=0 disables integral term]	Real		19
TD	Derivative time (0.00-199.99 mins/secs) [TD=0 disables deriv. term]	Real		20
TM	Trim value (limits: LT to HT)	Real		26
RM	Remote Setpoint value (limits: LS to HS)	Real		25
SL	Local Setpoint (limits: LS to HS)	Real		2
SP	Resultant Setpoint	Real	✘	5
PV	Process Variable	Real	✘	1
OP	Control Output (0.00-100.00%) (limits also: LO to HO)	Real		3
TK	'OP1' Track value (0.00-100.00%) (limits also: LO to HO)	Real		27
AL	Alarm status word [see Ch6 Table 6-3]	ABCDhex		4
SM	Mode status word [see Ch6 Table 6-4]	ABCDhex		23
SC	Configuration status word [see Ch6 Table 6-5]	ABCDhex		21
BM	Pushbutton mask [see Ch3 §1.6.9]	CDhex		22
MS	Requested mode (0-2) [see Ch5 §3]	Int		8
MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘	9
TB	Timebase (0-1) [0=seconds, 1=minutes]	Int		30

*†Subject to relevant decimal point position *Except as indicated in the table ✘Read-only parameter*

Table 11-3 Override controller main loop commissioning parameters — List 1

L2	Function	Type	Write	M'bus
DP	Decimal point position for List 2 parameters* (0-4 decimal places)	Int		48
HR	Setpoint high range (limits: –19999 to +19999)†	Real		54
LR	Setpoint low range (limits: –19999 to +19999)†	Real		55
HT	Trim high range & high limit (limits: LR–HR to HR–LR)	Real		76
LT	Trim low range & low limit (limits: LR–HR to HR–LR)	Real		77
HS	Setpoint high limit (limits: LR to HR)	Real		62
LS	Setpoint low limit (limits: LR to HR)	Real		63
HA	High Absolute alarm level (limits: LR to HR)	Real		58
LA	Low Absolute alarm level (limits: LR to HR)	Real		59
HD	High Deviation alarm level (limits: 0 to HR–LR)	Real		60
LD	Low Deviation alarm level (limits: 0 to HR–LR)	Real		61
XP	Prop. band, On/Off control hysteresis (0.0-1999.9) [see Ch6 §4.2]	Real		66
TI	Integral time (0.00-199.99 mins/secs) [TI=0 disables integral term]	Real		67
TD	Derivative time (0.00-199.99 mins/secs) [TD=0 disables deriv. term]	Real		68
TM	Trim value (limits: LT to HT)	Real		74
RM	Remote Setpoint value (limits: LS to HS)	Real		73
SL	Local Setpoint (limits: LS to HS)	Real		50
SP	Resultant Setpoint	Real	✘	53

Table 11-4 continued …

… Table 11-4 continued

L2	Function	Type	Write	M'bus
PV	Process Variable	Real	✘	49
OP	Control Output (0.00-100.00%) [duplicates List 1 OP]	Real		51
AL	Alarm status word [see Ch6 Table 6-3]	ABCDhex		52
SM	Mode status word [see Ch6 Table 6-4]	ABCDhex		71
SC	Configuration status word [see Ch6 Table 6-5]	ABCDhex		69
BM	Pushbutton mask [see Ch3 §1.6.9]	CDhex		70
MS	Requested mode (0-2) [see Ch5 §3]	Int		56
MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘	57
TB	Timebase (0-1) [0=seconds, 1=minutes]	Int		78

*†Subject to relevant decimal point position *Except as indicated in the table ✘Read-only parameter*

Table 11-4 Override controller override loop commissioning parameters — List 2

5 SETUP SHEETS FOR THE OVERRIDE CONTROLLER

This section contains sheets listing all the configurable parameters associated with the override controller, and their default values. You can photocopy the sheets and use them to record for reference your own parameter settings in the spaces provided.

Item	Default	Setting	Description — LOOP 2, LIST 2 COMMISSIONING
DP	2		Decimal point position (0-4 decimal places)
HR	100		Setpoint high range
LR	0		Setpoint low range
HT	0		Trim high range & high limit
LT	0		Trim low range & low limit
HS	100		Setpoint high limit
LS	0		Setpoint low limit
HA	100		High Absolute alarm level
LA	0		Low Absolute alarm level
HD	100		High Deviation alarm level
LD	100		Low Deviation alarm level
XP	100		Proportional band (0-1999.9)
TI	10		Integral time (0-199.99 mins/secs)
TD	0		Derivative time (0-199.99 mins/secs)
TM	0		Trim value
RM	0		Remote Setpoint value
SL	0		Local Setpoint
TB	0		Timebase (0=seconds, 1=minutes)
AL	0000		ALARM STATUS WORD
bit12	FALSE		Auto-ack. (T: auto-ack cleared alarm, F: needs manual ack)
bit13	FALSE		Relay disable (T: disable relay, F: enable relay)
bit14	FALSE		Relay on abs. only (T: abs. only, F: abs. & deviation alarms)
bit15	FALSE		Relay activation (T: on unackd alrm, F: on valid active alrm)
SC	0000		CONFIGURATION STATUS WORD
bit0	FALSE		Powerup mode (T: Manual mode, F: last mode)
bit1	FALSE		*(not used)*
bit2	FALSE		*(not used)*
bit3	FALSE		Invert PID (ΔPV & ΔOP — T: same sense, F: opposite)
bit4	FALSE		PV fail mode (T: no mode change, F: Forced Manual mode)
bit5	FALSE		*(not used)*
bit6	FALSE		*(not used)*
bit7	FALSE		*(not used)*
bit8	FALSE		*(not used)*
bit9	FALSE		On/off control (T: On/off control, F: PID control)
bit10	FALSE		*(not used)*
bit11	FALSE		SL balance (On SL writes — T: debump , F: no debump)
bit12	FALSE		SL track (T: SL tracks PV if not Auto, F: SL constant)
bit13	FALSE		*(not used)*
bit14	FALSE		*(not used)*
bit15	FALSE		*(not used)*
BM	00		PUSHBUTTON MASK BYTE
bit0	FALSE		*(don't care)*
bit1	FALSE		*(don't care)*
bit2	FALSE		'SP' pushbutton mask (T: disables setpoint change via button)
bit3	FALSE		'M' pushbutton mask (T: disables mode selection via button)
bit4	FALSE		*(don't care)*
bit5	FALSE		'A' pushbutton mask (T: disables mode selection via button)
bit6	FALSE		'Alm Ack' pushbutton mask (T: disables alm ack via button)
bit7	FALSE		'R' pushbutton mask (T: disables mode selection via button)

Item	Default	Setting	Description — LOOP 1, LIST 1 COMMISSIONING
DP	2		Decimal point position (0-4 decimal places)
HR	100		Setpoint high range
LR	0		Setpoint low range
HT	0		Trim high range & high limit
LT	0		Trim low range & low limit
HS	100		Setpoint high limit
LS	0		Setpoint low limit
HA	100		High Absolute alarm level
LA	0		Low Absolute alarm level
HD	100		High Deviation alarm level
LD	100		Low Deviation alarm level
HO	100		High Output (OP) limit (0-100%)
LO	0		Low Output (OP) limit (0-100%)
XP	100		Proportional band (0-1999.9)
TI	10		Integral time (0-199.99 mins/secs)
TD	0		Derivative time (0-199.99 mins/secs)
TM	0		Trim value
RM	0		Remote Setpoint value
SL	0		Local Setpoint
TK	0		'OP1' Track value (0-100%)
TB	0		Timebase (0=seconds, 1=minutes)
AL	0000		ALARM STATUS WORD
bit12	FALSE		Auto-ack. (T: auto-ack cleared alarm, F: needs manual ack)
bit13	FALSE		Relay disable (T: disable relay, F: enable relay)
bit14	FALSE		Relay on abs. only (T: abs. only, F: abs. & deviation alarms)
bit15	FALSE		Relay activation (T: on unackd alrm, F: on valid active alrm)
SC	0000		CONFIGURATION STATUS WORD
bit0	FALSE		Powerup (T: Manual, failsafe OP, F: last mode, last OP)
bit1	FALSE		Failsafe output (T: low OP, F: last OP)
bit2	FALSE		Invert electrical output (T: inversion, F: no inversion)
bit3	FALSE		Invert PID (ΔPV & ΔOP — T: same sense, F: opposite)
bit4	FALSE		PV fail (T: no mode change, F: Forced Manual, failsafe OP)
bit5	FALSE		Inverse ratio (T: Loop1 RM=PV2$\times$RS, F: Loop1 RM=PV2$\div$RS)
bit6	FALSE		Ratio track (T: RS tracks measured SP if Loop1 not Remote)
bit7	FALSE		Simulation (T: connect plant simulation) *(not implemented)*
bit8	FALSE		Incremental control (T: incremental control, F: continuous)
bit9	FALSE		On/off control (T: On/off control, F: PID control)
bit10	FALSE		*(don't care)*
bit11	FALSE		SL balance (On SL writes — T: debump , F: no debump)
bit12	FALSE		SL track (T: SL tracks PV if not Auto, F: SL constant)
bit13	FALSE		Calibration enable (T: enable I/O calib., F: normal op.)
bit14	FALSE		PAR timeout disable (T: disable, F: enable)
bit15	FALSE		Raise/lower speed (T: very fast, F: normal, with acceleration)
BM	00		PUSHBUTTON MASK BYTE
bit0	FALSE		*(don't care)*
bit1	FALSE		*(don't care)*
bit2	FALSE		'SP' pushbutton mask (T: disables setpoint change via button)
bit3	FALSE		'M' pushbutton mask (T: disables mode selection via button)
bit4	FALSE		*(don't care)*
bit5	FALSE		'A' pushbutton mask (T: disables mode selection via button)
bit6	FALSE		'Alm Ack' pushbutton mask (T: disables alm ack via button)
bit7	FALSE		'R' pushbutton mask (T: disables mode selection via button)

Item	Default	Setting	Description — LIST 3, INSTRUMENT PARAMETERS
II	630	—	Instrument identity
IV		—	Instrument version
CC	1	4	Controller type (0=Man St, 1=S-Loop, 2=Cas, 3=Rat, 4=O/ride)
P0	0		Passcode 0 — Loop-commissioning parameters
P1	0		Passcode 1 — Configuration parameters
TU	0		Temperature linearisation units (0=°C, 1=°F, 2=K)
B1	0		Expansion I/O enable (0=disable, 1=enable)

Item	Default	Setting	Description — LIST 4, MODBUS PARAMETERS
FS	00	—	COMMUNICATIONS STATUS BYTE
AD	254		Instrument address (1-254)
BD	0		Baud (0=9600, 1=19200**, 2=4800, 3=2400, 4=1200)
PY	0		Parity (0=none, 1=even, 2=odd)

***Not implemented*

ISSUE	DATE	DRAWN	CHECKED	INSTRUMENT ID
				FUNCTION
				DRAWING NUMBER

OVERRIDE CONTROLLER SETUP SHEET 1

Item	Default	Setting	Description — LIST 6, EXPN. BOARD I/O PARAMETERS
IR	0		Proc. I/P range (0=4-20mA;1=0-20mA;2=1-5V;3=0-10V;4=T/C;5=RTD)
IB*	1		Proc. I/P break protection (1=upscale break, 2=downscale)
IL	0		Proc. I/P lin. (0=none;1=square root;[T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N]; 9=PT100 res. thermom.)
IC	0	—	Proc. I/P conn. assignment (Fixed: PV2 — Process Variable Loop 2)
IF	1		Process Input filter time constant (0-1999.9 seconds)
AR	3		Analogue input range (2=1-5V, 3=0-10V)
AB	0		An. I/P break protection (0=freeze, 1=upscale, 2=dnscale.)
AC	0		An. I/P (0=open cct, 1=TK, 3=RM1, 4=TM1, 6=RM2, 7=TM2)
AF	1		Analogue input filter time constant (0-1999.9 seconds)
OR	3		Analogue output range (2=1-5V, 3=0-10V)
OC	0		An. O/P assigmnt. (0=PV1%, 1=SP1%, 2=OP1%, 3=PV2%, 4=SP2%)
DI	00		DIGITAL I/O INVERSION MASK BYTE (TRUE inverts bit)
bit0	FALSE		Hold select input
bit1	FALSE		Track select input
bit2	FALSE		Remote enable input
bit3	FALSE		(*Unallocated user bit*)
bit4	FALSE		NOT [Hold OR Manual] output
bit5	FALSE		NOT [Remote Auto] output
bit6	FALSE		NOT [High Alarm] output
bit7	FALSE		NOT [Low Alarm] output
DC	F0		DIGITAL I/O CONNECTION MASK (TRUE connects bit)
bit0	FALSE		Hold select input
bit1	FALSE		Track select input
bit2	FALSE		Remote enable input
bit3	FALSE		(*Unallocated user bit*)
bit4	TRUE		NOT [Hold OR Manual] output
bit5	TRUE		NOT [Remote Auto] output
bit6	TRUE		NOT [High Alarm] output
bit7	TRUE		NOT [Low Alarm] output
DU	0		Digital I/O pullup type: DU / Inputs / Outputs 0 *external* *external* 1 *internal* *external* 2 *external* *internal* 3 *internal* *internal*

Item	Default	Setting	Description — LIST 5, MAIN PCB I/O PARAMETERS
IR	0		Proc I/P range (0=4-20mA, 1=0-20mA, 2=1-5V, 3=0-10V, 4=T/C, 5=RTD)
IB*	1		Process I/P break protection (1=upscale brk, 2=downscale)
IL	0		Process I/P lin. (0=none, 1=square root, [T/C types: 2=J, 3=K, 4=T, 5=S, 6=R, 7=B, 8=N], 9=PT100 res. therm.)
IF	1		Process input filter time constant (0-1999.9 secs)
OR	0		Process output range (0=4-20mA, 1=0-20mA)

**If RTD selected (IR = 5), with downscale break (IB = 2), see Warning in Ch4 §2.3!*

ISSUE	DATE	DRAWN	CHECKED	INSTRUMENT ID
				FUNCTION
				DRAWING NUMBER

OVERRIDE CONTROLLER SETUP SHEET 2

Chapter 12 TUNING

This chapter tells you how to tune a PID control loop in the instrument. If you do not know how to select and alter parameters, first read Chapter 3, *Using the front panel*.

This chapter has four main topics:

- What is tuning? (§1)
- Automatic tuning (§2)
- Manual tuning (§3)
- Removing steady-state errors — droop compensation (§4).

1 WHAT IS TUNING?

In tuning you match the characteristics of the controller to that of the process being controlled in order to obtain good control. Good control means:

- Stable 'straight-line' control of the process variable at setpoint without fluctuation
- Little or no overshoot or undershoot of the setpoint
- Quick response to deviations from the setpoint caused by external disturbances, thereby restoring the process variable rapidly to the setpoint value.

Tuning involves calculating and setting the value of the loop parameters listed in Table 12-1. These parameters appear in Lists 1 and 2, for Loops 1 and 2 respectively.

Parameter	Mnemonic	Meaning or function
Proportional band	XP	The reciprocal gain of the control loop, as a percentage. Determines the sensitivity of the loop's response to deviations from setpoint
Integral time	TI	Determines the time taken by the controller to remove steady-state error signals
Derivative time	TD	Determines how strongly the controller will react to the rate-of-change of the measured value

Table 12-1 Tuning parameters

2 AUTOMATIC TUNING

This method automatically determines the value of the parameters listed in the Table 12-1.

The instrument uses a 'one-shot' tuner which works by switching the control output on and off to induce an oscillation in the measured process variable value. From the amplitude and period of the oscillation, it calculates the tuning parameter values.

2.1 When to tune

You will normally need to tune each control loop only once, during the initial commissioning of the process. However, if the process under control later becomes unstable (because its characteristics have changed), you can retune for the new conditions at any time.

Note that when tuning the master of a cascade pair, the slave must be in Remote mode.

2.2 How to tune a loop

To initiate one-shot autotuning you must access the Mode Status word SM, found in List 1 or 2 (for loop 1 or 2, respectively).

1. Set the setpoint to the value at which you normally operate the process.
2. In the SM parameter's bit-list, select bit 12 and set it to TRUE to start autotune.
3. Press the 'A' or 'SP' buttons to return to the normal loop display. The display flashes its 'PV 1' or 'PV 2' lamp — according to the loop number being tuned — to indicate that tuning is in progress.

   NOTE. Pressing 'M' halts autotuning until auto mode is restored, at which point autotuning restarts from the beginning of the sequence.

4. The controller induces an oscillation in the process variable by switching the output between high and low values (see Note below). In incremental control, 'high' means a continuous 'raise' signal and 'low' means a continuous 'lower' signal. For normal-action control (SC bit 3 FALSE), if PV is initially below SP, OP is driven high first, then low. If PV is initially above SP, OP is driven low first, then high. For inverse-action control (SC bit 3 TRUE) the reverse happens. The tuning algorithm calculates a target switchpoint based on the error PV–SP. The switching of OP between the high and low states occurs only when the measured PV reaches this switchpoint. Should the target switchpoint not be reached within two hours, tuning is abandoned and the Tune Fail bit is set (SM bit 13).

   NOTE. In continuous controllers, the output is normally switched between the high and low output limits, HO and LO. But if the error PV–SP is small enough (less than an internally set band), the algorithm switches the output between 20% above its initial output value (as Autotune is enabled) and 20% below, subject to the output high/low limits (HO and LO). In incremental controllers, HO and LO have no meaning and this Note does not apply.

   HO and LO default to 100% and 0% respectively. Ensure that your process can tolerate the LO-to-HO-to-LO step changes, and adjust these limits if necessary.*

5. After two cycles of oscillation the tuning is completed and the tuner switches itself off — i.e. SM bit 12 automatically resets to FALSE.
6. The controller calculates the tuning parameters listed in Table 12-1 and then resumes normal control action. Note that if the calculated TI and/or TD values exceed 199.99 seconds (the maximum that can be displayed), the controller automatically selects 'minutes' by setting the Timebase parameter TB to '1' for the loop concerned.

For the master loop of a cascade pair, the output swing is determined by the* ***slave's* *Proportional Band* XP, *not* HO & LO, *and equals* [current control output ±(XP/2)]%.

If you want 'Proportional-only' or 'PD' or 'PI' control, you should set the TI and/or TD parameters to zero before commencing the tuning cycle. The tuner will leave them at zero and will not calculate a value for them.

2.3 Typical automatic tuning cycle

Figure 12-1 shows a process variable-versus-time plot for a typical automatic tuning cycle, with normal-action control (SC bit 3 FALSE).

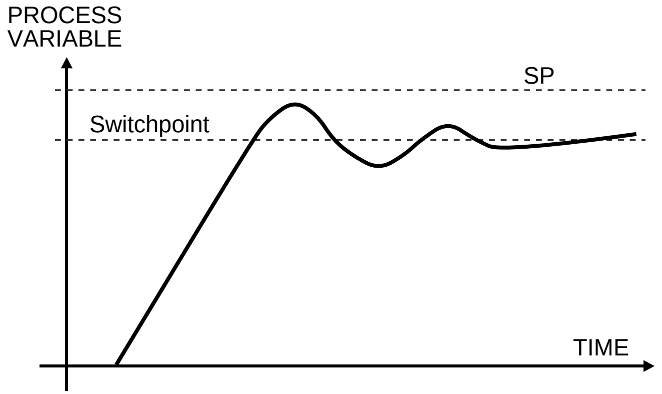


Figure 12-1 Typical process variable-versus-time plot for automatic tuning cycle (PV < SP initially)

Figure 12-2 shows how the output behaves during a typical autotuning sequence.

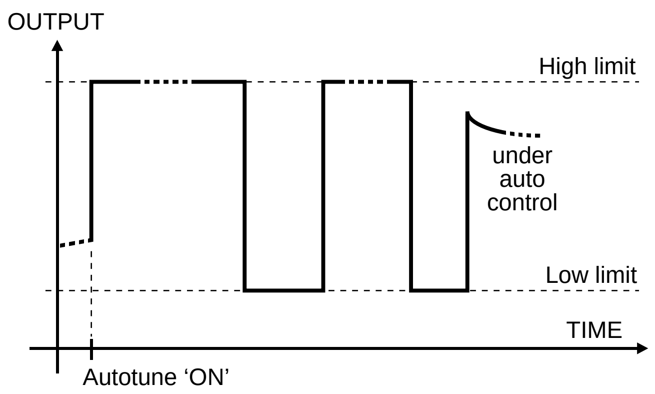


Figure 12-2 Typical output-versus-time plot for automatic tuning cycle (PV < SP initially)

3 MANUAL TUNING

If for any reason automatic tuning gives unsatisfactory results, you can tune the control loop manually. There are a number of standard methods for manual tuning. The one described here is the *Ziegler-Nichols* method.

With the process operating with its normal process variable value:

1. Ignore the fact that the process variable may not settle precisely at the setpoint
2. If the process variable is stable, reduce the proportional band parameter XP so that the process variable just starts to oscillate. If the process variable is already oscillating, increase XP until it just stops oscillating. Allow enough time between each adjustment to see if the loop will stabilise. Make a note of the proportional band value ‘B’ and the period of oscillation ‘T’.
3. Set the XP, TI, and TD parameter values according to the calculations given in Table 12-2.

For control type ...	...Set XP to	...Set TI to	...Set TD to
Proportional-only	$2 \times B$	OFF	OFF
P + I control	$2.2 \times B$	$0.8 \times T$	OFF
P + I + D control	$1.7 \times B$	$0.5 \times T$	$0.12 \times T$

Table 12-2 Tuning values

4 REMOVING STEADY-STATE ERRORS — DROOP COMPENSATION

In a full three-term controller — i.e. a PID controller — the integral term (containing TI) automatically removes steady-state errors. If the controller is set up to work in two-term mode — i.e. PD mode — the value of the TI parameter will be set to zero to disable the integral term. Under these conditions the measured value may not settle precisely at setpoint. The steady-state error from the setpoint that occurs when the integral term is disabled is sometimes referred to as ‘droop’.

A quantity called the ‘manual reset’ represents the value of the control output that will be delivered when the error is zero. ‘Droop compensation’ is the calculation and application of the manual reset value required to remove this droop.

There are two ways to apply manual reset to remove droop — via the droop compensation facility using the SM parameter (§4.1), or via mode selection (§4.2).

4.1 Applying manual reset via the SM parameter

To do this:

1. Allow the process variable to stabilise in automatic mode.
2. Set bit 14 of the SM parameter to TRUE. The controller calculates and applies a new value for manual reset, then automatically switches off droop compensation — i.e. resets SM bit 14 to FALSE.

4.2 Applying manual reset by changing modes

To do this:

1. Allow the process variable to stabilise in automatic mode.
2. Select manual mode (press the ‘M’ button).
3. Reselect auto mode (press the ‘A’ button), which automatically applies the required manual reset. The manual reset value is made equal to the current output value.

Droop compensation can be repeated as often as you require, but between each adjustment you must allow time for the process variable to stabilise.

Chapter 13 CALIBRATION

This chapter tells you how to calibrate the instrument's inputs and outputs, and store the resulting calibration constants to EEPROM. It is assumed that you are familiar with using the front panel to access and alter parameter values. This is described in Chapter 3, *Using the front panel*.

To carry out I/O calibration you enable the process by setting bit 13 of the Configuration Status word SC. You connect the relevant customer terminals to suitable calibration equipment, access and adjust the instrument's calibration parameters via the front panel, and apply and measure voltages, currents, and resistances as described in this chapter.

NOTES. Calibration should be carried out only by qualified personnel using equipment of the required standard. ***The instrument must be allowed to warm up for at least 20 minutes before calibration is begun.***

The main topics dealt with in this chapter are:

- Calibration parameters (§1)
- Calibration equipment required (§2)
- Calibrating inputs (§3)
- Calibrating outputs (§4).

1 CALIBRATION PARAMETERS

The calibration parameters are found in List 7 which is accessed using passcode 'P1'. Note that List 7 is not available unless SC bit 13 (Calibration Enable) is TRUE. These parameters let you specify the particular type of I/O to be calibrated, the step reached in the calibration process, and the measured value of the standard electrical quantity involved.

Table 13-1 lists the calibration parameters. Using them is described in §§ 4 & 5.

L7	Function	Type	Write	M'bus
CC	Calibration channel (0-4) [see Table 13-2]	Int		192
CR	Calibration range (0-5) [see Table 13-3]	Int		193
ST	Calibration step (0-101) [see Note below]	Int	*	194
CV	Calibration value	Real		195

***Alterable only if current step has completed*

Table 13-1 List 7 calibration parameters

NOTE. Under certain error conditions that may arise during calibration, ST can adopt unexpectedly high values (e.g. 100) to flag the error. See Ch16 §5 for more information on calibration error conditions.

Table 13-2 shows the Calibration Channel parameter (CC) settings required for the different types of input and output, and their associated customer terminal numbers.

For calibration channel ...	... Set CC parameter to
Main board process input (terminals 13-15)	0
Main board process output (terminals 16-17)	1
Expansion I/O process input (terminals 35-37)	2
Expansion I/O analogue input (terminals 38-39)	3
Expansion I/O analogue output (terminals 40-41)	4

Table 13-2 Selecting calibration channel via Calibration Channel parameter CC

Table 13-3 shows the Calibration Range parameter (CR) settings required for the different I/O ranges.

For calibration range ...	... Set CR parameter to
4-20 mA process inputs & outputs	0
0-20 mA process inputs & outputs	1
1-5 V inputs & outputs (all types)	2
0-10 V inputs & outputs (all types)	3
Thermocouple process inputs	4
PRT process inputs	5

Table 13-3 Selecting calibration range via Calibration Range parameter CR

2 CALIBRATION EQUIPMENT REQUIRED

Table 13-4 lists the minimum calibration equipment required.

Equipment	Range/value	Accuracy
Voltage sources	0 to 10 V 0 to 150 mV	250µV 4µV
Ammeter	0 to 22 mA	3µA
Voltmeter	0 to 12 V	250µV
Precision resistance calibrator (OR: fixed resistors	0 to 1 kΩ 500Ω & 1kΩ	0.025% 0.025%)

Table 13-4 Minimum calibration equipment required

3 CALIBRATING INPUTS

This section deals with the calibration of analogue inputs (terminals 38-39) and process inputs (terminals 13-15, 35-37). Figure 13-1 reminds you of the relevant terminal designations on the main and expansion I/O boards. (See Chapter 2 for full details.)

NOTE. Process inputs can be configured as either voltage or current inputs, but in both cases the instrument actually measures a voltage. For current-measuring a 50Ω burden resistor is fitted to convert 20mA to 1V at full-scale.

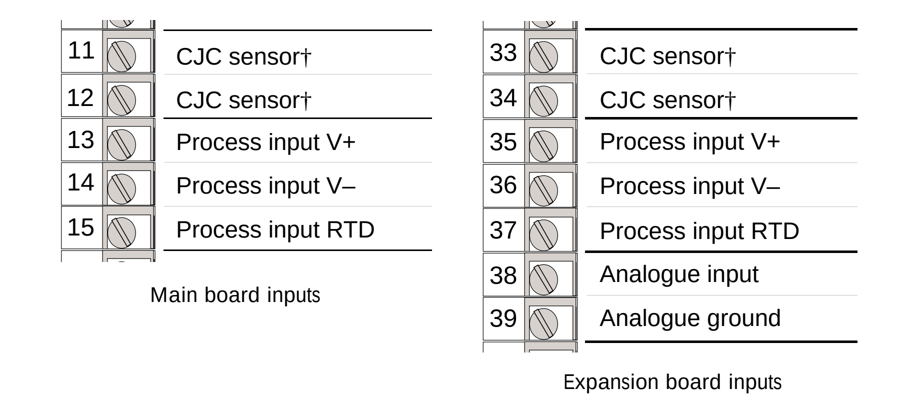


Figure 13-1 Customer terminal designations — inputs

3.1 Calibrating voltage/current inputs

To calibrate a voltage/current input, carry out the following steps:

1 Put the instrument into calibration mode by accessing the SC parameter (found in List 1), and setting bit 13 to TRUE. As soon as this is done the instrument goes effectively into Hold mode, with the output OP frozen (although the HOLD lamp does not light).

Note that in dual-loop controllers you must use the SC found in List 1, not the List 2 parameter, which does not enable calibration.

2 Access the List 7 CC parameter and set its value according to Table 13-2 to specify the input channel you want to calibrate.

3 Then set CR to specify the required calibration range, according to Table 13-3.

4 Check that your CC and CR values are correct, then scroll to the ST (Step) parameter and increment its zero value to ‘1’.

5 Connect the 0-10V voltage source to the appropriate input terminals, observing correct polarity. Figure 13-2 shows the setup, giving both main board and expansion board I/O terminal numbers. Apply either 1V, 5V, or 10V according to the input range being calibrated —use 1V for 0-20mA and 4-20mA ranges, 5V for 1-5V ranges, or 10V for 0-10V ranges. Then increment ST’s value to ‘2’.

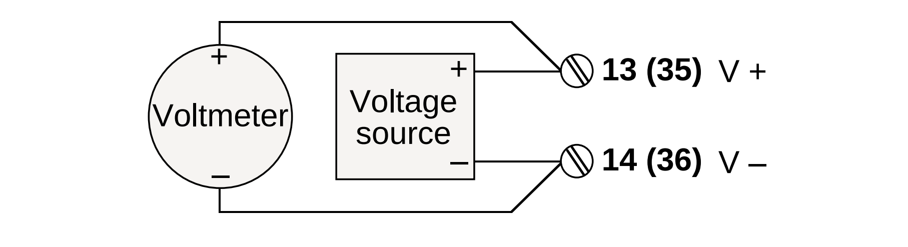


Figure 13-2 Voltage/current input calibration setup

6 Wait a short time (5 seconds at most) for the input scanning to finish, then increment ST to '3'. Note that ST is read-only until scanning is completed, so you cannot increment it too soon.

7 Scroll to the CV parameter and enter the exact value (in *V*) of the voltage you applied in step 5. Then increment ST to '4'.

8 Apply zero volts to the terminals, then increment ST to '5'.

9 Wait for input scanning to finish, and increment ST to '6' as soon as you are permitted.

10 Enter into the CV parameter the exact voltage value (in *V*) applied in step 8. Then increment ST to '7'.

11 If you are satisfied with the calibration and want to store the calibration constants to EEPROM, increment ST once more to '8'. Otherwise, reset ST to '0', or exit from List 7 (which automatically resets ST).

The instrument's voltage inputs are now calibrated.

3.2 Calibrating the thermocouple inputs

To calibrate a thermocouple input completely, you first calibrate the V+ and V– inputs, then the CJC input.

3.2.1 Calibrating the V+ & V– inputs

To do this, carry out the following steps:

1 Put the instrument into calibration mode, as described in §3.1 step 1.

2 Access the List 7 CC parameter and set its value according to Table 13-2 to specify the input channel you want to calibrate.

3 Then set CR to specify the required calibration range, according to Table 13-3.

4 Check that your CC and CR values are correct, then scroll to the ST parameter and increment its zero value to '1'.

5 Connect the 0-150 mV voltage source to the V+ and V– terminals, observing correct polarity. Figure 13-2 shows the setup. Apply 150mV, then increment ST to '2'.

6 Wait for the input scanning to finish, then increment ST to '3'. Note that ST is read-only until scanning is completed.

7 Scroll to the CV parameter and enter the exact value (in *mV*) of the voltage you applied in step 5. Then increment ST to '4'.

8 Apply zero volts to the terminals, then increment ST to '5'.

9 Wait for input scanning to finish, and increment ST to '6' as soon as you are permitted.

10 Enter into the CV parameter the exact voltage value (in *mV*) applied in step 8. Then increment ST to '7'.

3.2.2 Calibrating the CJC input

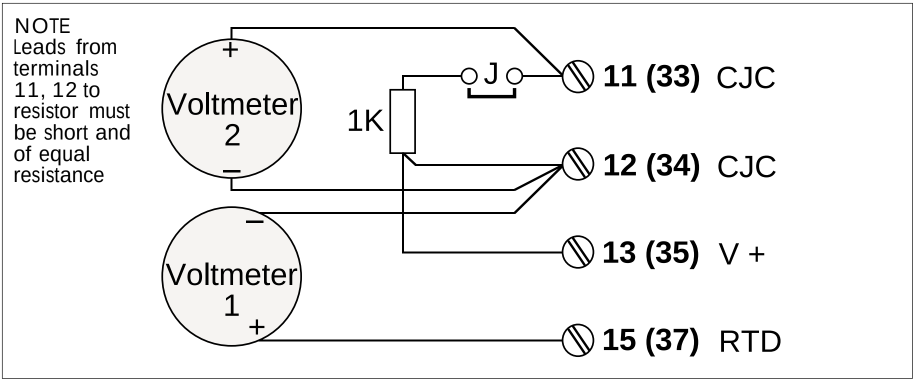


Figure 13-3 CJC calibration setup

To calibrate the CJC input, carry out the following further steps:

11 Connect up the instrument as shown in Figure 13-3, with the jumper link J removed. Then increment ST to '8'.

12 Measure the voltage between terminals 15 & 12 ('voltmeter 1') and enter it (in *V*) into the CV parameter. Then increment ST to '9'.

13 Wait for the input scanning to finish, then increment ST to '10'.

14 Measure the voltage between terminals 11 & 12 ('voltmeter 2') and enter it (in *V*) into CV.

15 Refit the jumper link, *then* increment ST to '11'.

16 Wait for the input scanning to finish, then increment ST to '12'.

17 Measure the voltage between terminals 11 & 12 again, enter it (in *V*) into CV, then increment ST to '13'.

18 If you are satisfied with the calibration and want to store the calibration constants to EEPROM, increment ST once more to '14'. Otherwise, reset ST to '0' (see §3.1).

The instrument's thermocouple inputs are now fully calibrated.

3.3 Calibrating the PRT100 input

To do this, carry out the following steps:

1 Put the instrument into calibration mode, as described in §3.1 step 1.

2 Access the List 7 CC parameter and set its value according to Table 13-2 to specify the input channel you want to calibrate.

3 Then set CR to specify the required calibration range, according to Table 13-3.

4 Check that your CC and CR values are correct, then increment the ST parameter to '1'.

5 Apply 38mV across V+ and V–, then increment ST to '2'.

6 Wait for input scanning to finish, and increment ST to '3'.

7 Enter into the CV parameter the exact voltage value (in *mV*) applied in step 5. Then increment ST to '4'.

8 Apply about 0mV across V+ and V–, then increment ST to '5'.

9 Wait for input scanning to finish, and increment ST to '6'.

10 Enter into the CV parameter the exact voltage value (in *mV*) applied in step 8. Then increment ST to '7'.

11 Now connect up the instrument as shown in Figure 13-4.

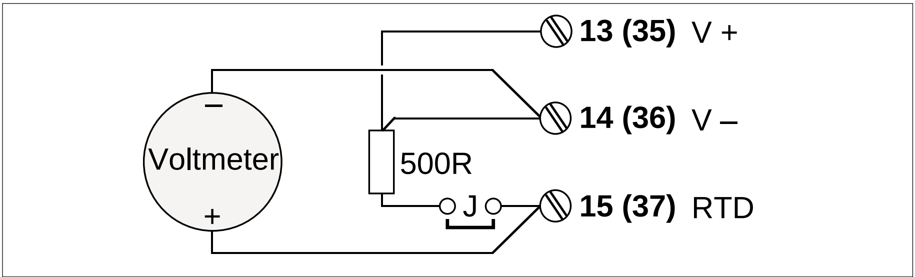


Figure 13-4 RTD calibration setup

12 With jumper link J removed, measure the voltage between terminals 15 & 14, then increment ST to '8'.

13 Enter into the CV parameter the exact voltage value (in *V*) you measured in step 12. Then replace the jumper link and increment ST to '9'.

14 Measure the voltage between terminals 15 & 14, and enter into the CV parameter the exact voltage value (in *V*). Then increment ST to '10'.

15 Wait for the input scanning (of V+, V–, and RTD) to finish, then increment ST to '11'.

16 If you are satisfied with the calibration and want to store the calibration constants to EEPROM, increment ST once more to '12'. Otherwise, reset ST to '0' (see §3.1).

The instrument's PRT100 input is now calibrated.

4 CALIBRATING OUTPUTS

This section deals with the calibration of process outputs (customer terminals 16-17) and analogue outputs (terminals 40-41). Figure 13-5 reminds you of the relevant terminal designations on the main and expansion I/O boards. (See Chapter 2 for full details.)

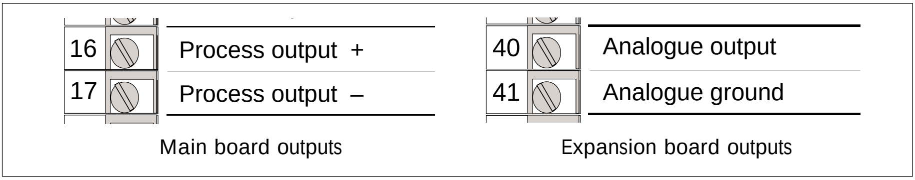


Figure 13-5 Customer terminal designations — outputs

4.1 Calibrating voltage outputs*

To do this, carry out the following steps:

1 Put the instrument into calibration mode, as described in §3.1 step 1.

2 Access the List 7 CC parameter and set its value according to Table 13-2 to specify the output channel you want to calibrate.

3 Then set CR to specify the required calibration range, according to Table 13-3.

4 Check that your CC and CR values are correct, then increment ST to '1'.

5 Measure the output voltage. Figure 13-6 shows the setup. This should approximately equal the top end of the selected range, i.e. 5V or 10V. Then increment ST to '2'.

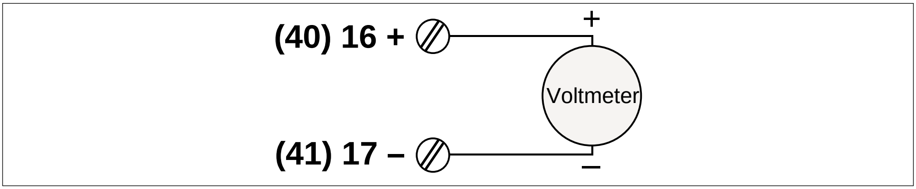


Figure 13-6 Voltage outputs calibration setup

6 Enter the exact value (in *V*) of the output voltage you measured in step 5 into the CV parameter. Then increment ST to '3'.

7 Measure the output voltage again. This should approximately equal the bottom end of the selected range, i.e. 1V for the 1-5V range, or 0V for the 0-10V range. Then increment ST to '4'.

8 Enter the exact value (in *V*) of the output voltage you measured in step 7 into the CV parameter. Then increment ST to '5'.

9 If you are satisfied with the calibration and want to store the calibration constants to EEPROM, increment ST once more to '6'. Otherwise, reset ST to '0' (see §3.1).

The instrument's voltage output is now calibrated.

(**Process voltage outputs not yet offered*)

4.2 Calibrating current outputs

To do this, carry out the following steps:

1 Put the instrument into calibration mode, as described in §3.1 step 1.

2 Access the List 7 CC parameter and set its value according to Table 13-2 to specify the output channel you want to calibrate.

3 Then set CR to specify the required calibration range, according to Table 13-3.

4 Check that your CC and CR values are correct, then increment ST to ‘1’.

5 Measure the output current. Figure 13-7 shows the setup. This should be slightly less than 20mA. Then increment ST to ‘2’.

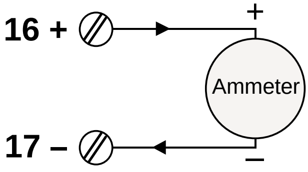


Figure 13-7 Current outputs calibration setup

6 Enter the exact value (in *mA*) of the current you measured in step 5 into the CV parameter. Then increment ST to ‘3’.

7 Measure the output current again. This should approximately equal the bottom end of the selected range, i.e. 0mA for the 0-20mA range, or 4mA for the 4-20mA range. Then increment ST to ‘4’.

8 Enter the exact value (in *mA*) of the current measured in step 7 into the CV parameter. Then increment ST to ‘5’.

9 If you are satisfied with the calibration and want to store the calibration constants to EEPROM, increment ST once more to ‘6’. Otherwise, reset ST to ‘0’ (see §3.1).

The instrument’s current output is now calibrated.

Chapter 14 SERIAL COMMUNICATIONS

This chapter tells you about the instrument's serial (Modbus) communications.

The main topics dealt with are:

- Modbus implementation (§1)
- Transaction times (§2)
- Instrument parameters (§3)
- Connecting a serial comms cable (§4).

1 MODBUS IMPLEMENTATION

To communicate with the instrument via Modbus to RS422/485 standard you must have the RS422/485 serial communications option board fitted. Chapter 2 §4.2.3 shows the terminal designations for this option, and Ch2 §4.9 gives a schematic of the RS422/485 board.

Modbus messages and functions are fully defined in the *Gould Modbus Protocol Reference Guide*, Part No. PI-MBUS-300 (current revision), published by Gould Inc.

The RS485 interface operates as 2-wire half duplex which means that only single-direction communications are possible at any one time. The comms drivers can be connected in a multipoint system, allowing single master and multiple slaves. The controller can function only as a Modbus slave, not a master; the master may be a SCADA system or another device such as a PLC or gateway. Note that Modbus ASCII is not supported.

A subset of the standard Modbus/JBUS driver is implemented, providing read/write access to words and bits. The controller implements Modbus RTU mode only. All parameters relevant to the operation of the instrument are available via comms.

1.1 Modbus functions

Table 14-1 lists the comms functions that are implemented in the controller.

Function	Modbus function code	Maximum length
Read coil / input status	1 or 2	128 bits
Read n words	3 or 4	125 words
Force single coil	5	1 bit
Write 1 word	6	1 word
Read status	7	8 bits
Loopback test	8	4 bytes
Force multiple coils	15	128 bits
Write n words	16	125 words

Table 14-1 Modbus functions implemented

- **Function 1 or 2.** Functions 1 and 2 are identical and return the current status (1/0, i.e. ON/OFF) of a group of bits (i.e. logic coils or discrete inputs).
- **Function 3 or 4.** The instrument allows reads of up to 125 words (250 bytes) in one transaction.
- **Function 5.** This function forces a single bit (i.e. coil) to ‘1’ when the data value requested is 0xFF00, or to ‘0’ when the data value requested is 0x0000. All other data values are illegal.
- **Function 6.** The instrument allows single-word writes. This function limits access to the scaled floating point parameters, 16-bit integers, and bytes.
- **Function 7.** The instrument provides a fast status read. Function 7 returns the status of the instrument in a single byte. (*The content of this byte has not yet been defined*.)
- **Function 8.** The purpose of the loopback test is to test the communications system. The received message is simply echoed back to the sender.
- **Function 15.** This function forces a series of bits (i.e. consecutive logic coils) to defined ‘1’ or ‘0’ states.
- **Function 16.** This is a block write to word data. Up to 125 words can be written in a single transaction.

1.2 Error codes

If an error occurs during a Modbus transaction, the instrument replies only if it is sure that the communication was intended for it. The reply will be the standard Modbus error format, with the MSB of the command function code set. The reply codes are given in Table 14-2.

Code	Error
0	No error
1	Invalid function code
2	Invalid data address
3	Invalid data value
4	(*not allocated*)
7	(*not allocated*)
8	(*not allocated*)
9	(*not allocated*)
10	(*not allocated*)

Table 14-2 Modbus error codes

NOTE. Writing an out-of-limit value to the instrument via Modbus results in the value being rejected and an Error Code 3 response. This is in contrast to writing such values via the front panel, when the value is clipped to the applicable limits and then accepted. E.g. SL, OP, etc.

1.3 Data formats

In this implementation of Modbus, data is 16-bit words. Within the controller there are many different types of data.

1.3.1 Byte

In the instrument a Byte is an 8-bit value. To access a Byte via Modbus the word format must be used. In this case the least significant 8 bits contain the Byte data and the most significant 8 bits are set to zero. All Bytes are unsigned.

1.3.2 Word

In the instrument a Word is a 16-bit value, either signed or unsigned. These values are transmitted MSB first.

1.3.3 Coil (bit)

In the response to a Read coil function, the coil status is packed as one coil per bit of the data field. Status is indicated as ‘1’= ON, ‘0’ = OFF. If the returned coil quantity is not a multiple of 8, the remaining bits in the final data byte will be padded with zeroes (at the high-order end of the byte).

In the Force multiple coils function a logical ‘1’ requests the coil to be ON, and a logical ‘0’ requests it to be OFF. However, in the Force single coil function a value of FF00 requests the coil to be ON and 0000 requests it to be OFF. All other values are illegal.

1.3.4 Scaled integer representation

In scaled integer mode each floating-point value is multiplied by a constant dependent upon its decimal place position. The result of this multiplication is an integer. If the integer requires more than 16 bits the value returned is 8000h.

Table 14-3 gives four examples of scaled integer representation.

E.g.	Internal float value	Scaled integer	Transmitted hex value
(a)	1.001	1001	03 E9h
(b)	10.01	1001	03 E9h
(c)	–1.001	–1001	FC 17h
(d)	40.000	40000	80 00h

Table 14-3 Scaled integer representation — examples

Examples (a) and (b) demonstrate that the SCADA system, as Modbus master, must know the resolution of the parameter when the SCADA screen is designed. Example (c) shows how negative numbers are represented. Example (d) illustrates how ‘large’ numbers are truncated to indicate an over-range value.

1.3.5 Empty space in blocks

Blocks of data being accessed via the Modbus comms may contain empty elements. In read operations these would be parameters that are not configured, or ‘holes’ in the address space, whereas for block writes they could be ‘don’t care’ values. Unused addresses in a block read as 8000 hex, but block elements set to 8000 hex on a write are only ignored if no parameter exists with that Modbus address. 8000 hex might be a valid value for a status word, for example.

1.3.6 Parameter addresses

Figure 14-1 shows a scaled integer region example. The command shown writes a value 1.001 to parameter address 12h in instrument 21.

Instr. address	Modbus function code	First word address MSB	First word address LSB	No. of words to write MSB	No. of words to write LSB	No. of data bytes following	Data MSB	Data LSB	End frame
21	10	00	12	00	01	02	03	E9	CRC

Figure 14-1 Example command — scaled integer region

Figure 14-2 shows three examples of messages involving coils. Example (1) reads coil addresses 16 to 47 from slave device 17. Example (2) sets the Remote Enable bit of Loop 1's SM in slave device 17. Example (3) connects the digital inputs in slave device 17.

(1)

Slave address	Modbus function code	First coil address MSB	First coil address LSB	No. of coils to read MSB	No. of coils to read LSB	End frame
11	01	00	10	00	20	CRC

(2)

Slave address	Modbus function code	Coil address MSB	Coil address LSB	Data MSB	Data LSB	End frame
11	05	00	02	FF	00	CRC

(3)

Slave address	Modbus function code	First coil address MSB	First coil address LSB	No. of coils to force MSB	No. of coils to force LSB	No. of data bytes following	Data	End frame
11	0F	01	60	00	04	01	0F	CRC

Figure 14-2 Example coil messages (see §1.3.6 for details)

2 TRANSACTION TIMES

The time taken for a Modbus transaction comprises three consecutive periods — *request time*, *latency time*, and *response time*. Figure 14-3 illustrates this.

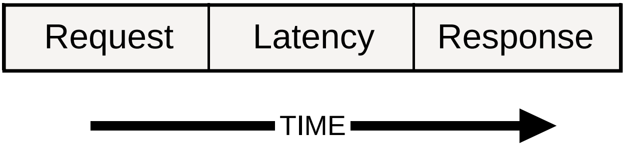


Figure 14-3 Modbus transaction sequence

2.1 Request time

This is the time taken for the master to send the request. It depends on the baud rate being used — the lower the rate the longer the time. The Modbus protocol also allows for a brief delay between characters — which will extend the request time. This depends on the behaviour of the master.

2.2 Latency time

This is the time taken by the instrument to compose a response to a Modbus parameter request, and depends on two factors:

2.2.1 Number of parameters requested

The more parameters requested the longer it takes for the instrument to prepare its response.

2.2.2 Workload of the instrument

An instrument running a single-loop strategy with no extension I/O fitted has more processor-time available for Modbus operations than one running a dual-loop strategy with extension I/O fitted. Consequently it responds more promptly.

2.3 Response time

This is the time taken for the instrument to send the request. It depends on the baud rate being used — the lower the rate the longer the time. The instrument does not normally introduce a delay between consecutive characters in its response.

2.4 Latency time examples at 9600 baud

The figures given in Table 14-4 are a guide to latency times in a variety of circumstances at 9600 baud. To arrive at the corresponding total transaction times, the request and response times must be added to these figures.

Typically the request time, assuming a compact message, is 10 milliseconds. The response time is given by:

$$(5 + (2 \times \text{number of parameters})) \text{ milliseconds.}$$

Strategy workload	No. params. requested	Min. time	Max. time
Single loop, no extension I/O	1	2	7
	10	10	28
	30	28	46
Ratio, with extension I/O	1	3	16
	10	13	25
	30	32	42
Cascade, with extension I/O	1	3	18
	10	10	30
	30	31	62

Table 14-4 Latency timings in milliseconds — examples at 9600 baud

The figures in Table 14-4 were obtained in a simple test environment, using a single PC-based master and single slave instrument. Repeated 'block reads' of the specified number of parameters were made.

3 INSTRUMENT PARAMETERS

Two types of addressing are used — Modbus register addresses (described in §§3.1 to 3.4), and coil addresses (i.e. individual bits, described in §3.5).

3.1 Modbus address allocation

The addressing convention used is JBUS, i.e. the Modbus addresses referred to in this manual are the same as the addresses used in the serial link transactions. Addresses are in the range 0000h to FFFFh.

Modbus addresses are allocated to the instrument's parameters as outlined in Table 14-5. Tables 14-11 to 14-19 in §3.4 list all the parameters sorted by their Modbus addresses.

Note that within each block of addresses there are no 'gaps', and that all parameters are within a limited address range. All operational parameters are accessible via a single multi-parameter poll.

Instrument configuration starts at 120 and finishes at 133. The first 10 loop parameters are those required to animate a faceplate object on a SCADA display. The next 12 are commonly-used commissioning parameters. The last 8 cover the remaining parameters.

Parameter block	Start address
Loop 1	0
Loop 2	48
Ratio station	96
Instrument configuration	120
I/O configuration	144
Diagnostic and calibration	192

Table 14-5 Modbus address blocks

3.2 Setting up the Modbus comms parameters

Setting up the Modbus communications is done via the parameters found in List 4, shown in Table 14-6. You set up the Modbus instrument address, baud rate, and parity using parameters AD, BD, and PY, respectively. Read-only FS is a status byte required by Modbus access code 7 (*FS bits not yet defined*). Comms status word CS indicates receipt of Modbus messages and also flags the presence of a comms board.

Note that the instrument must be powered down then up to implement changes to the baud rate (BD) and parity (PY) parameter values.

See Chapter 2 §4.2.3 for Modbus rear-panel terminal designations, and Ch2 §4.9 for a schematic of the serial comms (Modbus) option board.

L4	Function	Type	Write	M'bus
FS*	Fast status byte, returned on Modbus access code 7	CDhex	✘	120
AD	Instrument address (1-254)	Int		131
BD	Baud rate (0-4) [see Table 14-7]	Int		128
PY	Parity (0-2) [see Table 14-8]	Int		129
CS	Comms status word [see Table 14-9]	(ABC)Dhex	✘	(*none*)

**Bits not yet defined* ✘*Read-only parameter*

Table 14-6 List 4 Modbus comms parameters

For baud rate ...	... Set BD to
9600	0
19200*	1
4800	2
2400	3
1200	4

**Not yet implemented*

Table 14-7 Specifying Modbus baud rate using BD parameter

For parity ...	... Set PY to
None	0
Even	1
Odd	2

Table 14-8 Specifying Modbus parity using PY parameter

	Function	Type	Weight	Nibble	Write
CS	Communications status word	(ABC)Dhex			✘
	Bit 0 — Modbus message received flag (toggles ON / OFF)	T/F —	1	D	
	Bit 1 — (*Unused*)	T/F —	2	D	
	Bit 2 — (*Unused*)	T/F —	4	D	
	Bit 3 — (*Unused*)	T/F —	8	D	
	Bit 4 — (*Unused*)	T/F —	1	C	
	Bit 5 — (*Unused*)	T/F —	2	C	
	Bit 6 — (*Unused*)	T/F —	4	C	
	Bit 7 — (*Unused*)	T/F —	8	C	
	Bit 8 — (*Unused*)	T/F —	1	B	
	Bit 9 — (*Unused*)	T/F —	2	B	
	Bit 10 — (*Unused*)	T/F —	4	B	
	Bit 11 — (*Unused*)	T/F —	8	B	
	Bit 12 — (*Unused*)	T/F —	1	A	
	Bit 13 — (*Unused*)	T/F —	2	A	
	Bit 14 — (*Unused*)	T/F —	4	A	
	Bit 15 — (*Unused*)	T/F —	8	A	

Table 14-9 Communications status word CS (List 4)

3.3 Parameters available via comms

Nearly all the parameters listed throughout this manual are available over both the Modbus communications and also via the instrument's front panel. The Modbus address for each parameter is given in the relevant table (and also in §3.4 listed in address order).

But a small number of parameters are available *only* over the Modbus comms, and are inaccessible to operators via the front panel. These parameters and their addresses are listed in Table 14-10. The ones marked with '*' are dummies that are there only to fill gaps in the Modbus address table. This is necessary to suppress error messages being returned if these addresses are accessed.

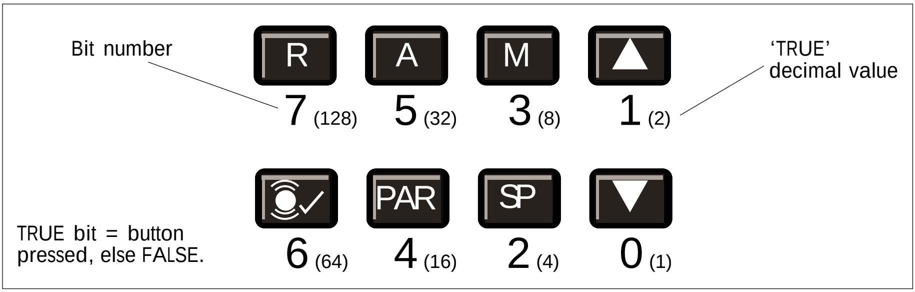


Figure 14-4 Raw_PB pushbutton states — bit numbers & decimal values

Name	Function	Type	Write	M'bus
SE(1)	Control status word for Loop 1 [see AppB §3.3.3]	ABCDhex	✘	24
m1041*	(*Dummy parameter*)	Real		64
m1042*	(*Dummy parameter*)	Real		65
SE(2)	Control status word for Loop 2 [see AppB §3.3.3]	ABCDhex	✘	72
m1052*	(*Dummy parameter*)	Real		75
DP_R	Ratio decimal point position [see Ch8 §5.1]	Int	✘	104
m121*	(*Dummy parameter*)	Int		121
m125*	(*Dummy parameter*)	Int		125
CommsRes	Communications resolution (always=0)	Int	✘	130
ProcIn_c1	(*Dummy parameter*)	Int	✘	147
CalDP	Calibration decimal point posn. (for calibration via comms)	Int	✘	196
LightAll	Light all fascia LEDs (1=LEDs lit ~6s, then bit auto-resets)	Int	✍	197
Raw_PB	Pushbutton states (8-bits, 0-255 decimal) [see Fig 14-4]	Int	✘	198
ManualAction	Manual control of incremental outputs [see Ch10 §4.4]	Int	✍	237

**Fill gaps in Modbus table* ✘*Read-only parameter* ✍*Write-only parameter*

Table 14-10 Parameters available only over Modbus communications

3.4 Parameters in Modbus address order

Tables 14-11 to 14-19 list all the instrument's parameters sorted by their Modbus addresses. With two exceptions (Tables 14-14 & 14-19), each table presents the parameters contained in a single parameter 'list'. But the order you scroll to them within the list via the front panel is not the same as the address order.

NOTE. Parameters marked with an asterisk '*' against their Modbus addresses do not appear in any front-panel list. They are available only over the Modbus comms. (Table 14-10 lists all the 'Modbus-only' parameters.)

You will find these tables helpful when accessing blocks of parameters via the Modbus comms.

M'bus	L1	Function — Loop 1 parameters	Type	Write
0	DP	Decimal point position for List 1 parameters* (0-4 decimal places)	Int	
1	PV	Process Variable	Real	✘
2	SL	Local Setpoint	Real	
3	OP	Control Output (0.00-100.00%)	Real	
4	AL	Alarm status word [see Ch6 Table 6-3]	ABCDhex	
5	SP	Resultant Setpoint	Real	✘
6	HR	Setpoint high range	Real	
7	LR	Setpoint low range	Real	
8	MS	Requested mode (0-2) [see Ch5 §3]	Int	
9	MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘
10	HA	High Absolute alarm level	Real	
11	LA	Low Absolute alarm level	Real	
12	HD	High Deviation alarm level	Real	
13	LD	Low Deviation alarm level	Real	
14	HS	Setpoint high limit	Real	
15	LS	Setpoint low limit	Real	
16	HO	High Output limit (0.00-100.00%)	Real	
17	LO	Low Output limit (0.00-100.00%)	Real	
18	XP	Proportional band (0.0-1999.9)	Real	
19	TI	Integral time (0.00-199.99 mins/secs)	Real	
20	TD	Derivative time (0.00-199.99 mins/secs)	Real	
21	SC	Configuration status word [see Ch6 Table 6-5]	ABCDhex	
22	BM	Pushbutton mask [see Ch3 §1.6.9]	CDhex	
23	SM	Mode status word [see Ch6 Table 6-4]	ABCDhex	
24*	SE(1)	Control status word for Loop 1 [see AppB §3.3.3]	ABCDhex	✘
25	RM	Remote Setpoint value	Real	
26	TM	Trim value	Real	
27	TK	Track value (0.00-100.00%)	Real	
28	HT	Trim high range & high limit	Real	
29	LT	Trim low range & low limit	Real	
30	TB	Timebase (0=secs, 1=mins)	Int	
31	PT	Minimum pulse time (0.1-60.0 secs) [see Ch10 §5.1.3]	Real	

Table 14-11 Loop 1 (list 1) parameters sorted by Modbus address

M'bus	L2	Function — Loop 2 parameters	Type	Write
48	DP	Decimal point position for List 2 parameters (0-4 decimal places)	Int	
49	PV	Process Variable	Real	✘
50	SL	Local Setpoint	Real	
51	OP	Control Output (0.00-100.00%)	Real	
52	AL	Alarm status word [see Ch6 Table 6-3]	ABCDhex	
53	SP	Resultant Setpoint	Real	✘
54	HR	Setpoint high range	Real	
55	LR	Setpoint low range	Real	
56	MS	Requested mode (0-2) [see Ch5 §3]	Int	
57	MN	Resultant mode (0-7) [see Ch5 §2]	Int	✘
58	HA	High Absolute alarm level	Real	
59	LA	Low Absolute alarm level	Real	
60	HD	High Deviation alarm level	Real	
61	LD	Low Deviation alarm level	Real	
62	HS	Setpoint high limit	Real	
63	LS	Setpoint low limit	Real	
64*	m1041	(Dummy parameter)	Real	
65*	m1042	(Dummy parameter)	Real	
66	XP	Proportional band, On/Off control hysteresis (0.0-1999.9) [see §4.2]	Real	
67	TI	Integral time (0.00-199.99 mins/secs) [TI=0 disables integral term]	Real	
68	TD	Derivative time (0.00-199.99 mins/secs) [TD=0 disables deriv. term]	Real	
69	SC	Configuration status word [see Ch6 Table 6-5]	ABCDhex	
70	BM	Pushbutton mask [see Ch3 §1.6.9]	CDhex	
71	SM	Mode status word [see Ch6 Table 6-4]	ABCDhex	
72*	SE(2)	Control status word for Loop 2 [see AppB §3.3.3]	ABCDhex	✘
73	RM	Remote Setpoint value	Real	
74	TM	Trim value	Real	
75*	m1052	(Dummy parameter)	Real	
76	HT	Trim high range & high limit	Real	
77	LT	Trim low range & low limit	Real	
78	TB	Timebase (0=secs, 1=mins)	Int	

Table 14-12 Loop 2 (list 2) parameters sorted by Modbus address

M'bus	L2	Function — Ratio station parameters	Type	Write
96	DP	Decimal point position for List 2 parameters (0-4 decimal places)	Int	
97	PV	Uncontrolled Process Variable	Real	✘
98	HR	Uncontrolled PV high range	Real	
99	LR	Uncontrolled PV low range	Real	
100	MR	Measured ratio (decimal places — see Ch8 §5.1)	Real	✘
101	RS	Ratio setpoint (decimal places — see Ch8 §5.1)	Real	
102	HS	Ratio setpoint high limit (decimal places — see Ch8 §5.1)	Real	
103	LS	Ratio setpoint low limit (decimal places — see Ch8 §5.1)	Real	
104*	DP_R	Ratio decimal point position [see Ch8 §5.1]	Int	✘
105	SM	Mode status word [see Ch6 Table 6-4]	ABCDhex	

Table 14-13 Ratio station (list 2) parameters sorted by Modbus address

M'bus	L3,4	Function — Instr. configuration & serial comms params.	Type	Write
120	FS	Fast status byte, returned on Modbus access code 7	CDhex	✘
121*	m121	(Dummy parameter)	Int	
122	II	Instrument identity (numeric part of model no.)	Int	✘
123	IV	Instrument version	Int	✘
124	CC	Controller type (0-4) [see Ch4 Table 4-2]	Int	
125*	m125	(Dummy parameter)	Int	
126	P0	Passcode 0 — Loop commissioning (0-9999) [see Ch3 §2.2]	Int	
127	P1	Passcode 1 — Configuration (0-9999) [see Ch3 §2.2]	Int	
128	BD	Baud rate (0-4) [see Table 14-7]	Int	
129	PY	Parity (0-2) [see Table 14-8]	Int	
130*	CommsRes	Communications resolution (always=0)	Int	✘
131	AD	Instrument address (1-254)	Int	
132	TU	Temperature units (0=°C, 1=°F, 2=K)	Int	
133	B1	Expansion I/O enable (0=disable, 1=enable)	Int	
(*none*)	CS	Comms status word [see Table 14-9]	(ABC)Dhex	✘

Table 14-14 Instr. config. (list 3) & serial comms (list 4) parameters sorted by Modbus address

M'bus	L5	Function — Main board I/O configuration parameters	Type	Write
144	IR	Process Input range [see Ch4 Table 4-9]	Int	
145	IB	Process Input break protection [see Ch4 Table 4-11]	Int	
146	IL	Process Input linearisation [see Ch4 Table 4-13]	Int	
147*	ProcIn_c1	(Dummy parameter)	Int	✘
148	IF	Process Input filter time constant (0-1999.9 secs) [see Ch4 §2.6]	Real	
149	OR	Process output range [see Ch4 Table 4-9]	Int	

Table 14-15 Main board I/O configuration (list 5) parameters sorted by Modbus address

M'bus	L6	Function — Expansion board I/O configuration parameters	Type	Write
150	IR	Process Input range [see Ch4 Table 4-9]	Int	
151	IB	Process Input break protection [see Ch4 Table 4-11]	Int	
152	IL	Process Input linearisation [see Ch4 Table 4-13]	Int	
153	IC	Process Input connection assignment [see Ch4 Table 4-5]	Int	
154	IF	Process Input filter time constant (0-1999.9 secs) [see Ch4 §2.6]	Real	
155	AR	Analogue input range [see Ch4 Table 4-10]	Int	
156	AB	Analogue input break protection [see Ch4 Table 4-11]	Int	
157	AC	Analogue input connection assignment [see Ch4 Table 4-6]	Int	
158	OR	Analogue output range [see Ch4 Table 4-10]	Int	
159	OC	Analogue output connection assignment [see Ch4 Table 4-7]	Int	
160	DV	Digital I/O values at customer terminal [see Ch4 §2.7]	CDhex	
161	DI	Digital I/O inversion mask [see Ch4 §2.7]	CDhex	
162	DC	Digital I/O connection mask [see Ch4 §2.7]	CDhex	
163	DU	Digital I/O pullup type [see Ch4 Table 4-15]	Int	
164	AF	Analogue input filter time constant (0-1999.9 secs) [see Ch4 §2.6]	Real	

Table 14-16 Expansion board I/O configuration (list 6) parameters sorted by Modbus address

M'bus	L7	Function — I/O calibration parameters	Type	Write
192	CC	Calibration channel (0-4) [see Ch11 Table 11-2]	Int	
193	CR	Calibration range (0-5) [see Ch11 Table 11-3]	Int	
194	ST	Calibration step (0-100)	Int	
195	CV	Calibration value	Real	
196*	CalDP	Calibration decimal point posn. (for calibration via comms)	Int	✘

Table 14-17 I/O calibration (list 7) parameters sorted by Modbus address

M'bus	L9	Function — Diagnostic parameters	Type	Write
197*	LightAll	Light all fascia LEDs (1=LEDs lit ~6s, then bit auto-resets)	Int	-
198*	Raw_PB	Pushbutton states (8-bits, 0-255 decimal) [see Fig 14-2]	Int	✘
199	SI	I/O status word [See Ch14 §2.1]	ABCDhex	✘
200	R1	Count of I/O missed readings	Int	✘
201	R2	Count of I/O bad readings	Int	✘
202	R3	Count of digital feedback verification failures	Int	✘
203	R4	Count of tasks unable to complete in allotted time	Int	✘
205	E1	Errors log stack	Int	✘
206	E2	Errors log stack	Int	✘
207	E3	Errors log stack	Int	✘
208	E4	Errors log stack	Int	✘
209	E5	Errors log stack	Int	✘
210	E6	Errors log stack	Int	✘
211	E7	Errors log stack	Int	✘
212	E8	Errors log stack	Int	✘
213	E9	Errors log stack	Int	✘
214	EA	Errors log stack	Int	✘
215	EB	Errors log stack	Int	✘
216	EC	Errors log stack	Int	✘
217	ED	Errors log stack	Int	✘
218	EE	Errors log stack	Int	✘
219	EF	Errors log stack (oldest error)	Int	✘
220	ST	Strategy cycle time (millisecs)	Int	✘

Table 14-18 Diagnostic (list 9) parameters sorted by Modbus address

M'bus	L1,8	Function — Incremental control parameters	Type	Write
230	TT	Motor travel time (0.5-1999.9 secs) [see Ch10 §5.1.2]	Real	
232	VO	Velocity output demand (–100.00 to +100.00%) [see Ch10 §1.2.2]	Real	✘
235	IN	Inertia compensation time (0.0-20.0 secs) [see Ch10 §5.3.1]	Real	
236	BL	Backlash compensation time (0.0-20.0 secs) [see Ch10 §1.2.2]	Real	
237*	ManualAction	Manual control of incremental outputs [see Ch10 §4.4]	Int	✍

Table 14-19 Incremental control configuration (lists 1 & 8) parameters sorted by Modbus address

3.5 Coil addresses

Coil addresses are allocated in blocks to the instrument's status words as outlined in Table 14-20. Tables 14-21 to 14-24 list all available coil addresses in ascending order.

Parameter block	Start coil address
Loop 1	0
Loop 2	128
Ratio station	256
Digital I/O	320

Table 14-20 Coil address blocks

Coil addr.	Loop 1 bit	Designation	Writeable via Modbus
0	**SM** bit 0	Hold Enable	When not wired to a digital input
1	1	Track Enable	When not wired to a digital input
2	2	Remote Enable	When not wired to a digital input
3	3	Comms. Disable	Always
4	4	NOT [Hold OR Man]	Never
5	5	NOT [Remote Auto]	Never
6	6	Raise	Never
7	7	Lower	Never
8	8	Forced Manual	Never
9	9	Sumcheck	Always
10	10	Calib sumcheck	Always
11	11	Hardware Conflict	Never
12	12	AUTOTUNE	Always
13	13	TUNE_FAIL	Never
14	14	DROOPTUNE	Always
15	15	Cold Started	Never
16	**SC** bit 0	Power Up	Always
17	1	Failsafe OP	Always
18	2	Invert OP	Always
19	3	Invert PID	Always
20	4	PV Fail mode	Always
21	5	Inverse Ratio	Always
22	6	Ratio Track	Always
23	7	(*Not used*)	Never
24	8	Raise/Lower	Always
25	9	On/Off	Always
26	10	(*Not used*)	Never
27	11	SL Balance	Always
28	12	SL Track	Always
29	13	Calibration enable	Always
30	14	Insp timeout disable	Never
31	15	Fast ramp	Never

Table 14-21 continued …

… Table 14-21 continued

Coil addr.	Loop 1 bit	Designation	Writeable via Modbus
32	**AL** bit 0	High Absolute	Never
33	1	Low Absolute	Never
34	2	High Deviation	Never
35	3	Low Deviation	Never
36	4	High Absolute (Unack)	Always
37	5	Low Absolute (Unack)	Always
38	6	High Deviation (Unack)	Always
39	7	Low Deviation (Unack)	Always
40	8	Alarm Acknowledge	Always
41	9	Alarm Relay	Never
42	10	(*Not used*)	Never
43	11	(*Not used*)	Never
44	12	Auto Acknowledge	Always
45	13	Disable Relay	Always
46	14	Relay on Abs. Only	Always
47	15	Relay Action	Always
48	**BM** bit 0	(*Not used*)	Never
49	1	(*Not used*)	Never
50	2	Disable SP button	Always
51	3	Disable M button	Always
52	4	(*Not used*)	Never
53	5	Disable A button	Always
54	6	Disable Alm Ack button	Always
55	7	Disable R button	Always
56	8	(*Not used*)	Never
57	9	(*Not used*)	Never
58	10	(*Not used*)	Never
59	11	(*Not used*)	Never
60	12	(*Not used*)	Never
61	13	(*Not used*)	Never
62	14	(*Not used*)	Never
63	15	(*Not used*)	Never

Table 14-21 Coil addresses for Loop 1 status words

Coil addr.	Loop 2 bit	Designation	Writeable via Modbus
128	**SM** bit 0	Hold Enable	Always
129	1	Track Enable	Never
130	2	Remote Enable	When not wired to a digital input
131	3	(*Not used*)	Never
132	4	NOT [Hold OR Man]	Never
133	5	NOT [Remote Auto]	Never
134	6	(*Not used*)	Never
135	7	(*Not used*)	Never
136	8	Forced Manual	Never
137	9	Sumcheck	Always

Table 14-22 continued …

… Table 14-22 continued

Coil addr.	Loop 2 bit	Designation	Writeable via Modbus
138	10	(*Not used*)	Never
139	11	(*Not used*)	Never
140	12	AUTOTUNE	Always
141	13	TUNE_FAIL	Never
142	14	DROOPTUNE	Always
143	15	(*Not used*)	Never
144	**SC** bit 0	(*Not used*)	Never
145	1	(*Not used*)	Never
146	2	(*Not used*)	Never
147	3	Invert PID	Always
148	4	(*Not used*)	Never
149	5	(*Not used*)	Never
150	6	(*Not used*)	Never
151	7	(*Not used*)	Never
152	8	(*Not used*)	Never
153	9	On/Off	Always
154	10	(*Not used*)	Never
155	11	SL Balance	Always
156	12	SL Track	Always
157	13	(*Not used*)	Never
158	14	(*Not used*)	Never
158	15	(*Not used*)	Never
160	**AL** bit 0	High Absolute	Never
161	1	Low Absolute	Never
162	2	High Deviation	Never
163	3	Low Deviation	Never
164	4	High Absolute (Unack)	Always
165	5	Low Absolute (Unack)	Always
166	6	High Deviation (Unack)	Always
167	7	Low Deviation (Unack)	Always
168	8	Alarm Acknowledge	Always
169	9	Alarm Relay	Never
170	10	(*Not used*)	Never
171	11	(*Not used*)	Never
172	12	Auto Acknowledge	Always
173	13	Disable Relay	Always
174	14	Relay on Abs. Only	Always
175	15	Relay Action	Always
176	**BM** bit 0	(*Not used*)	Never
177	1	(*Not used*)	Never
178	2	Disable SP button	Always
179	3	Disable M button	Always
180	4	(*Not used*)	Never
181	5	Disable A button	Always
182	6	Disable ‘Alm Ack’button	Always

Table 14-22 continued …

… Table 14-22 continued

Coil addr.	Ratio Loop 2 bit	Designation	Writeable via Modbus
183	7	Disable R button	Always
184	8	(*Not used*)	Never
185	9	(*Not used*)	Never
186	10	(*Not used*)	Never
187	11	(*Not used*)	Never
188	12	(*Not used*)	Never
189	13	(*Not used*)	Never
190	14	(*Not used*)	Never
191	15	(*Not used*)	Never

Table 14-22 Coil addresses for Loop 2 status words

Coil addr.	Ratio Loop 2 bit	Designation	Writeable via Modbus
256	**SM** bit 0	(*Not used*)	Never
257	1	(*Not used*)	Never
258	2	(*Not used*)	Never
259	3	(*Not used*)	Never
260	4	(*Not used*)	Never
261	5	(*Not used*)	Never
262	6	(*Not used*)	Never
263	7	(*Not used*)	Never
264	8	Forced Manual	Never
265	9	(*Not used*)	Never
266	10	(*Not used*)	Never
267	11	(*Not used*)	Never
268	12	(*Not used*)	Never
269	13	(*Not used*)	Never
270	14	(*Not used*)	Never
271	15	(*Not used*)	Never

Table 14-23 Coil addresses for Ratio Loop 2 status words

Coil addr.	Digital I/O bit	Designation	Writeable via Modbus
320	**DV** bit 0	Terminal 24	Never
321	1	Terminal 25	Never
322	2	Terminal 26	Never
323	3	Terminal 27	Never
324	4	Terminal 28	When not connected
325	5	Terminal 29	When not connected
326	6	Terminal 30	When not connected
327	7	Terminal 31	When not connected
328	—	(*Not used*)	Never
329	—	(*Not used*)	Never
330	—	(*Not used*)	Never
331	—	(*Not used*)	Never
332	—	(*Not used*)	Never

Table 14-24 continued …

… Table 14-24 continued

Coil addr.	Digital I/O bit	Designation	Writeable via Modbus
333	—	(*Not used*)	Never
334	—	(*Not used*)	Never
335	—	(*Not used*)	Never
336	**DI** bit 0	Terminal 24	Always
337	1	Terminal 25	Always
338	2	Terminal 26	Always
339	3	Terminal 27	Always
340	4	Terminal 28	Always
341	5	Terminal 29	Always
342	6	Terminal 30	Always
343	7	Terminal 31	Always
344	—	(*Not used*)	Never
345	—	(*Not used*)	Never
346	—	(*Not used*)	Never
347	—	(*Not used*)	Never
348	—	(*Not used*)	Never
349	—	(*Not used*)	Never
350	—	(*Not used*)	Never
351	—	(*Not used*)	Never
352	**DC** bit 0	Terminal 24	Always
353	1	Terminal 25	Always
354	2	Terminal 26	Always
355	3	Terminal 27	Always
356	4	Terminal 28	Always
357	5	Terminal 29	Always
358	6	Terminal 30	Always
359	7	Terminal 31	Always
360	—	(*Not used*)	Never
361	—	(*Not used*)	Never
362	—	(*Not used*)	Never
363	—	(*Not used*)	Never
364	—	(*Not used*)	Never
365	—	(*Not used*)	Never
366	—	(*Not used*)	Never
367	—	(*Not used*)	Never

Table 14-24 Coil addresses for digital I/O status words

4 CONNECTING A SERIAL COMMS CABLE

There are two ways to communicate with the instrument via the Modbus comms:

- Via the rear-panel terminals provided by the serial comms board option. This gives full RS422 or RS485 comms.
- Via the RJ11 socket located on the main board inside the instrument. This gives only CMOS (5V) logic level comms — adequate for configuration and over short distances. (*Consult factory for configuration adapter.*)

4.1 Communicating via the rear-panel terminals

Table 14-25 reminds you of the rear-panel terminal designations if you have the serial comms board option installed in the instrument.

Terminal	Designation
58	RFI ground
59	RS422 TX –
60	RS422 TX +
61	
62	RS422 common
63	+5V (@ 5mA±5%)
64	RS422 RX – (& RS485 –)*
65	RS422 RX + (& RS485 +)*
66	RFI ground

*Link for RS485 3-wire operation

Table 14-25 RS422 / 485 option board customer terminals

RS485 (3-wire) comms may be selected by externally linking terminals TX– to RX–, and TX+ to RX+, as shown in Table 14-11.

You set up the communications parameters — AD, BD, and PY — as described in §3.2.

4.2 Communicating via the RJ11 connector

The RJ11 socket mounted on the main board inside the instrument lets you communicate via the serial comms using CMOS logic levels, i.e. 0V = logic 0 and 5V = logic 1. This is adequate for configuring the instrument using a PC, via a relatively short length of cable so that degradation of the signals is not a problem.

Figure 14-5 shows the location of the RJ11 socket and the designations of its six pins.

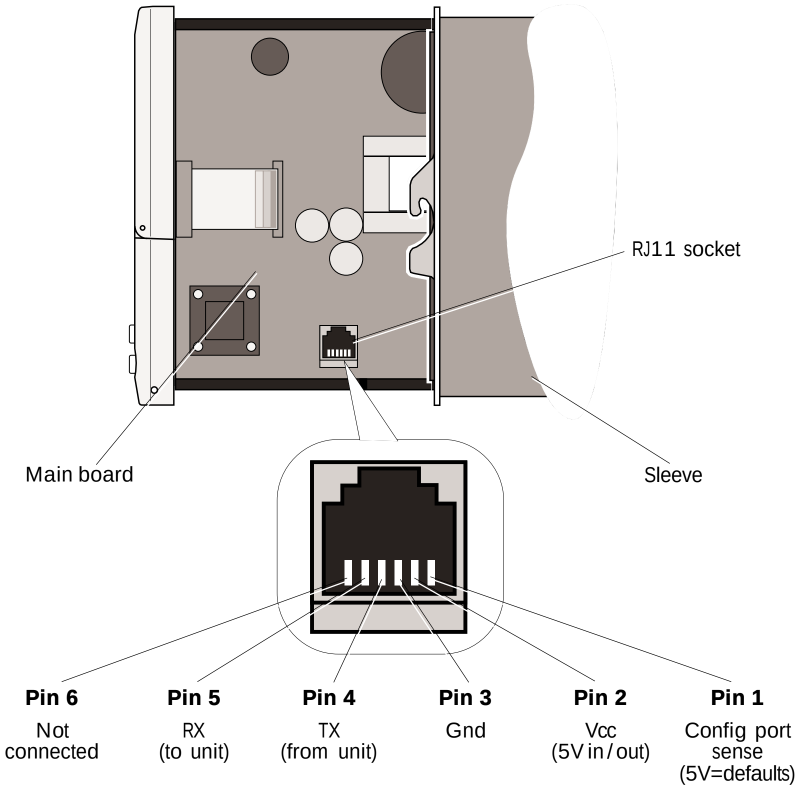


Figure 14-5 RJ11 socket location and pinouts

The RJ11 socket pins are used as follows:

- **Pin 1 — Configuration port sense.** With this pin at 0V or left open-circuit, the Modbus comms are normal and use the address, baud rate, and parity you set up via the AD, BD, and PY parameters (see §3.2).

  If pin 1 is held 'high' — i.e. from 5 to 24V — then although the Modbus protocol is still observed, the instrument now responds to address 255 as well as to the address specified in AD. But it now runs only at 9600 baud, no parity — overriding your BD and PY settings.

  Note that linking pin 1 to pin 2 makes it high.

- **Pins 2 & 3 — Vcc & Gnd.** These pins connect to the internal processor supply rail, and so are at 5V when the instrument is powered up via the sleeve. The I/O and front panel are *not* supplied by this rail. With the instrument out of its sleeve you can power the processor (only) by inputting 5V across pins 2 & 3. Only the processor need be powered for configuration to be carried out.

Caution

Do not connect pins 2 and 3 together if the instrument is externally powered, e.g. via the sleeve. This short-circuits the internal 5V supply and may damage the instrument.

- **Pins 4 & 5 — TX & RX.** Communication is via these two pins using CMOS logic levels, i.e. 0V = logic 0 and 5V = logic 1.
- **Pin 6.** This pin is not connected.

Chapter 16 ERROR CONDITIONS

This chapter tells you about error conditions that may occur within the instrument, and about alarm conditions in the plant.

The main topics dealt with are:

- Instrument errors reported at power-up (§1)
- Instrument errors reported by the diagnostic parameters (§2)
- CPU errors — the watchdog relay (§3)
- Process alarm conditions (§4)
- Calibration errors (§5).

1 INSTRUMENT ERRORS REPORTED AT POWER-UP

At power up the instrument performs several self-tests. The error messages listed in Table 16-1 appear in the 4½-digit display in the event of an error detected at this stage.

For more information on the power-on self-tests, see Chapter 2, *Installation & startup,* §6.

Error	Meaning
Er01	RAM test failed
Er02	MASK test failed
Er03	ROM test failed

Table 16-1 Power-on self-test error messages

2 INSTRUMENT ERRORS REPORTED BY THE DIAGNOSTIC PARAMETERS

List 9 contains a set of diagnostic parameters that may be used to diagnose and pinpoint problems with the instrument. Table 16-2 summarises these parameters. Further details are given where indicated in the table.

L9	Function	Type	Write	M'bus
SI	I/O status word [See §2.1]	ABCDhex	✘	199
R1	Count of I/O missed readings	Int	✘	200
R2	Count of I/O bad readings	Int	✘	201
R3	Count of digital feedback verification failures	Int	✘	202
R4	Count of tasks unable to complete in allotted time	Int	✘	203
ST	Strategy cycle time (ms)	Int	✘	220
E0-EF	Errors log stack (E0 most recent error) [See §2.2]	Int	✘	204-219

Table 16-2 List 9 diagnostic parameters ✘*Read-only parameter*

2.1 I/O status word

Table 16-3 summarises the meanings of the bits in the I/O status word SI. Further details are given in §§ 2.1.1 and 2.1.2.

	Function	Type		Write*
SI	I/O diagnostic status word	ABCDhex		
	Bit 0 — Missed filter [see §2.1.1]	T/F — 1	D	
	Bit 1 — Extra filter [see §2.1.2]	T/F — 2		
	Bit 2 — Nominal calibration data sumcheck failure [see §2.1.3]	T/F — 4		
	Bit 3 — (*Unused*)	T/F — 8		
	Bit 4 — (*Unused*)	T/F — 1	C	
	Bit 5 — (*Unused*)	T/F — 2		
	Bit 6 — (*Unused*)	T/F — 4		
	Bit 7 — (*Unused*)	T/F — 8		
	Bit 8 — (*Unused*)	T/F — 1	B	
	Bit 9 — (*Unused*)	T/F — 2		
	Bit 10 — (*Unused*)	T/F — 4		
	Bit 11 — (*Unused*)	T/F — 8		
	Bit 12 — (*Unused*)	T/F — 1	A	
	Bit 13 — (*Unused*)	T/F — 2		
	Bit 14 — (*Unused*)	T/F — 4		
	Bit 15 — (*Unused*)	T/F — 8		

Table 16-3 I/O status word SI (List 9)

2.1.1 Bit 0 — Missed filter

This bit flags that the lowest level I/O driver failed to read hardware at the expected time. This is a lower-level error than the I/O task overrun error that is reported in the error log (#38). The I/O continues to work, ignoring this error, and the strategy simply uses the previous value again.

A ‘missed filter’ error indicates a severely overloaded instrument, and you should consult the Eurotherm Process Automation factory if this occurs.

2.1.2 Bit 1 — Extra filter

This bit flags that the lowest level I/O driver has tried to read hardware without being set up to do so. Not being expected at higher levels, the reading is not performed, and the strategy is unaffected by this error.

2.1.3 Bit 2 — Nominal calibration data sumcheck failure

In the (unlikely) event that the instrument’s accurate calibration data (see Chapter 13) becomes corrupted, bit 10 of the SM parameter sets TRUE, and ‘nominal’ calibration data held in ROM is automatically substituted. If the nominal calibration data *also* fails its sumcheck, SI bit 2 sets TRUE as well.

2.2 Error logging — E0-EF parameters

The instrument maintains a log of the last sixteen errors to have occurred, storing them in the parameters E0 to EF as hexadecimal numbers. These can be viewed via the front panel or read over the Modbus communications. Table 16-4 defines the error numbers. E0 holds the most recent error logged, E1 the next most recent, and so on, with EF holding the oldest error. Each new error pushes the stack down and deletes the oldest error. The error log is cleared at power up.

Errors marked as ‘Fatal’ in the table cause the instrument to reset. Errors marked ‘Save NV’ cause the non-volatile memory to be saved when the error is detected.

Error	Meaning	Fatal	Save NV
01	Main board DFC failed to communicate at startup	✓	
02	Main board DFC failed to communicate while strategy running	✓	✓
03	Expansion I/O DFC failed to communicate at startup		
04	Expansion I/O DFC failed to communicate while strategy running	✓*	✓*
05	Unrecognised expansion I/O card at startup		
06	Unrecognised expansion I/O card while strategy running	✓*	✓*
30	Internal error — consult factory	✓	✓
31	Internal error — consult factory		
32	Internal error — consult factory		
33	Internal error — consult factory		
38	I/O task unable to complete in allotted time	✓	✓
39	User interface task unable to complete in allotted time		
3A	Control task unable to complete in allotted time		

Table 16-4 Meanings of hexadecimal error numbers stored in E0-EF

**If expansion I/O enabled via B1 parameter*

3 CPU ERRORS — THE WATCHDOG RELAY

Two fail-safe relay outputs are provided on the main board — a watchdog relay and an alarm relay. Each has contacts rated at 60V and 2A. (Refer to Chapter 2 §4.2 for the relevant terminal designations, and Ch2 §4.6 for schematics.) See §4.2 for details of the alarm relay function.

The watchdog relay output indicates the health of the controller’s CPU. While the CPU is functioning correctly the relay is energised and holds the contacts closed. In the event of a CPU failure the relay de-energises and the contacts open.

After a CPU failure the controller attempts repeatedly to restart the CPU. If the restart is successful the watchdog relay closes and normal running resumes. If restart is unsuccessful the relay remains open while further restart attempts are made.

4 PROCESS ALARM CONDITIONS

This section explains how alarms arising in the plant being controlled are specified and handled by the instrument.

4.1 Absolute and deviation alarms

Each control loop has four alarms associated with it, defined in Table 16-5.

Alarm name	Alarm condition
High Absolute	The process variable PV exceeds a user-defined value HA
High Deviation	The process variable PV exceeds the setpoint SP by a user-defined value HD
Low Deviation	The process variable PV is less than the setpoint SP by a user-defined value LD
Low Absolute	The process variable PV is less than a user-defined value LA

Table 16-5 Loop alarm conditions

4.1.1 Setting alarms

The alarm thresholds are set independently for each loop by writing appropriate values to the HA, HD, LD, and LA parameters indicated in the table. These are found in Lists 1 and 2, for Loop 1 and 2 respectively.

Asymmetric hysteresis operates on each alarm at 0.5% of span. That is, although the alarm is triggered as soon as PV crosses the specified threshold, it does not clear until PV has returned within the threshold by an amount equal to 0.5% of span (HR–LR). This helps prevent repeated triggering and clearing of an alarm by a ‘noisy’ PV close to the threshold.

4.1.2 Viewing alarm settings

You can view your absolute and deviation alarm threshold settings (HA & LA, HD & LD) on the front-panel bargraphs, by pressing the ▲ and ▼ pushbuttons together. The settings appear as reverse-lit segments, as described in Chapter 3 §§ 1.2 and 1.6.

4.1.3 Disabling alarms

To disable an alarm you must set an appropriate value for the alarm parameter concerned. To disable the absolute alarms, set LA equal to the low range parameter LR, and HA equal to HR. You can disable deviation alarms HD and LD by setting them equal to the full range of PV, i.e. HR–LR.

4.1.4 Acknowledging alarms

When an alarm initially occurs it adopts the ‘unacknowledged’ state in addition to the ‘in alarm’ state. With *manual acknowledge* configured (Alarm status word AL bit 12 FALSE) the alarm remains unacknowledged — even if the alarm condition itself clears — until the operator acknowledges it by pressing the ‘Alarm Acknowledge’ button on the front panel.

With *auto-acknowledge* configured (AL bit 12 TRUE) the alarm will acknowledge itself when cleared. Alternatively, alarms may be acknowledged by writing to the appropriate bit(s) of the Alarm status word AL, either via the front panel or over the comms. Note that pressing the 'Alarm Acknowledge' button simultaneously acknowledges *all* the alarms in the currently-displayed loop, not individual alarms. Doing this is equivalent to setting AL bit 8 to TRUE.

(See Chapter 3 §1.6 for more information on acknowledging alarms via the front panel.)

4.1.5 Alarm indications

Alarm conditions are annunciated by the instrument in the following ways:

- by the 'ALM 1' and 'ALM 2' front-panel lamps (see Chapter 3 §1.4)
- by flashing front-panel bargraphs (unacknowledged alarms only, see Chapter 3 §1.2)
- by the state of the alarm relay output on the rear panel (see §4.2)
- by the alarm digital outputs on the rear panel (see Appendix A §6)
- by the Alarm status word AL (see Chapter 6 §4).

4.2 Alarm relay output

The alarm relay indicates the health of the plant. Its operation is completely configurable for each loop independently, as described in Ch4 §2.9. The presence in either or both loops of any one of the four alarm conditions described in §4.1 can be configured to operate the alarm relay, i.e. de-energise it and open the contacts.

The *default* configuration of the alarm relay — i.e. with AL bits 12 to 15 FALSE — is to open on any active alarm in the instrument, and close when all active alarms have cleared, whether or not they have been acknowledged. However, by setting a loop's AL bits appropriately, the relay can be made to open selectively on absolute alarms only or on both absolute and deviation alarms, on unacknowledged alarms or on active alarms, or it can be disabled completely for that loop. (See Ch4 §2.9 for details.)

Table 16-6 summarises the *default* front-panel indications and alarm relay states for the four possible combinations of 'In Alarm' and 'Unacknowledged' states.

Alarm(s) present:		**Front-panel indications:**		
In al'm	**Unack'd**	**Alarm LED**	**Bargraph**	**Alarm relay**
Yes	Yes	Flashing	Flashing (Abs: PV bar, Dev: SP bar)	Open
No	Yes	Flashing	Flashing (Abs: PV bar, Dev: SP bar)	Closed
Yes	No	Steady	Normal	Open
No	No	Off	Normal	Closed

Table 16-6 Front-panel indications and alarm relay states — default settings

5 CALIBRATION ERRORS

Two error conditions may arise during the calibration procedure (refer to Chapter 13). Both are signalled by the value adopted by the ST (Step) parameter:

- Invalid input signal (§5.1)
- Internal software error (§5.2).

5.1 Invalid input signal

If the input signal being calibrated is invalid — usually due to a saturated input — the ST parameter flags this error by adopting a value of 100. This tells you that an error has occurred at the input-scanning phase of the calibration.

ST's upper and lower limits are also automatically set to zero, which has no immediate effect. But as soon as you try to alter ST's value via the front panel, it is forced to zero, forcing you in turn to start that particular calibration again.

NOTE. If you are calibrating via the Modbus communications — not the front panel — the procedure is slightly different owing to the way Modbus responds to out-of-limit parameter writes. After the 100 error flag, you can reset ST to zero ***only*** by writing a zero to the parameter; all other values are rejected, not clipped.

5.2 Internal software error

In the unlikely event of an internal calibration software error occurring that lets the ST parameter be incremented past the final (i.e. 'save calibration constants') step, the parameter flags this error by adopting a value of 101. ST's upper and lower limits are also automatically set to zero, as before.

Restoring ST to zero is done as described in §5.1, noting the different procedure for Modbus comms.

NOTE. Consult the factory if this error recurs.

Chapter 17 SPECIFICATIONS

1 PANEL CUT-OUT & DIMENSIONS

Please refer to Chapter 2 §3 for details.

2 MECHANICAL

Fascia dimensions:	height 144mm, width 72mm.
Mounting panel aperture:	height 138 +1 –0 mm, width 68 +0.7 –0 mm.
Behind mounting panel:	depth 235mm (measured from panel front).
Front of mounting panel:	depth 17.55mm (including keypads).
Weight:	1.39kg.
Removal/insertion of unit:	50 operations maximum, with power applied.
MTBF:	20 years.

3 ENVIRONMENTAL

Storage temperature:	–10°C to +85°C, at humidity of 5-95% (non-condensing).
Operating temperature:	0°C to +50°C. The enclosure must provide adequate ventilation, and heating if required to avoid condensation at low temperatures.
Atmosphere:	unsuitable for use above 2000m or in explosive or corrosive atmospheres.
Front panel sealing:	to meet EN60529: IP65.
Controller/sleeve sealing:	IP20 from all directions.
EMC emissions:	to meet EN50081-2 (Group 1; Class A).
EMC immunity:	to meet EN50082-2.
Electrical safety:	to meet EN61010, Installation category II. Voltage transients on any mains power connected to the unit must not exceed 2.5kV. Electrically conductive pollution must be excluded from the cabinet in which the unit is mounted.
Isolation:	EN61010 (1993) — Installation category II, Pollution degree II. All isolated I/O are double-insulated as per EN61010 to protect against electric shock. (For isolation levels of particular I/O types see relevant section of the specification.)
Vibration & shock:	IEC1131-2 for operation.

4 INPUTS & OUTPUTS

I/O technology:	Delta sigma
Boards providing I/O:	Main pcb, and (*optional*) I/O expansion pcb.
Types provided:	Process I/O, analogue I/O, transmitter supply, relays. (*See Table 17-1*).
I/O ranges:	Software-configurable from 4 - 20 mA, 0 - 20 mA, 1 - 5 V, 0 - 10 V, T/C, RTD. (*See Table 17-2*).
Characterisation:	Nil, square root, T/C [J, K, T, S, R, B, N], RTD [PT100].

I/O type*	On main pcb	On expansion I/O pcb	Total available
Process (analogue) input	1	1	2
Transmitter supply	1	1	2
Analogue input		1	1
Process (analogue) output	1		1
Analogue output		1	1
Digital input		4	4
Digital output		4	4
Alarm relay	1		1
Watchdog relay	1		1

Table 17-1 I/O types available on main pcb and (optional) expansion I/O pcb

Table 17-1 I/O types available on main pcb and (optional) expansion I/O pcb

Range	Process inputs	Analogue inputs	Process outputs	Analogue outputs
4 - 20mA	✓*	✘	✓	✘
0 - 20mA	✓*	✘	✓	✘
1 - 5V	✓	✓	✘	✓
0 - 10V	✓	✓	✘	✓
T/C	✓	✘	NA	NA
RTD	✓	✘	NA	NA

**Fit suitable burden resistor — see Note in Chapter 2, Figure 2-18*

Table 17-2 I/O ranges available (✓=available, ✘=not available, NA=not applicable**)**

4.1 Process (analogue) inputs

4.1.1 General

Types available:	V, mA (via external shunt), thermocouple, voltage, 2/3-wire RTD.
Characterisation:	Linear, square root, thermocouple, PRT.
Common mode rejection:	140dB.
Series mode rejection:	50dB (50Hz, 60Hz).
Input isolation:	250V 50/60Hz working. Double-insulated to all other I/O — basic insulation to ground.
PV sample rate:	8Hz.

4.1.2 mA inputs

Ranges:	4 - 20 mA, 0 - 20mA (using 50Ω burden resistor on 1V range).
Break protection:	Up/down scale, software-selectable. Response time < 4s. (overridden by external burden which forces input to zero).
Input impedance:	>10MΩ.
Input bias current:	<5nA.
Resolution (unfiltered):	150µV.
Accuracy @25°C:	0.1% of range (plus external burden resistor accuracy).
Temperature drift:	< ±[75µV + 0.007% of reading]/°C @ 99% confidence. (< ±[8µV + 0.004% of reading]/°C typically). (plus drift of external burden resistor).

4.1.3 Thermocouple inputs

Thermocouples supported:

Thermocouple	Range (°C)	Linearisation accuracy (K)
J	–210 to +1200	±0.02
K	–200 to +1372	±0.05
T	–200 to +400	±0.04
S	–50 to +1767	±0.04
R	–50 to +1767	±0.04
B	25 to 1820	±0.1
N	0 to 1300	±0.05

Break protection:	Up/down scale, software-selectable. Response time < 4s.
Input impedance:	>10MΩ.
Input bias current:	<5nA.
Resolution (unfiltered):	20µV.
Accuracy @25°C:	0.1% of range.
Temperature drift:	< ±[11µV + 0.007% of reading]/°C @ 99% confidence. (< ±[1.2µV + 0.004% of reading]/°C typically).
CJC accuracy:	±0.25°C (@ 25°C ± 5°C).
CJC ambient rejection:	30:1 typically.

4.1.4 Voltage inputs

Ranges:	0 - 10 V.
Break protection:	Fixed, pull-down to zero.
Input impedance:	>250kΩ.
Resolution (unfiltered):	2mV.

Accuracy @25°C:	0.1% of range.
Temperature drift:	< ±[500µV + 0.014% of reading]/°C @ 99% confidence (< ±[20µV + 0.006% of reading]/°C typically) .

4.1.5 Resistance thermometer inputs (PRT)

Input type:	2- or 3-wire.
Sensor type supported:	Pt100.
Range:	–200 to +850 °C.
Lead rejection (3-wire):	8mΩ/Ω of lead resistance.
Sensor current:	250µA.
Input impedance:	>10MΩ.
Resolution:	80mΩ.
Accuracy @25°C:	0.5°C (0.2Ω).
Temperature drift:	< ±[2.4mΩ + 0.003% of reading]/°C. (< ±[0.6mΩ + 0.002% of reading]/°C typically) .

4.2 Process (analogue) outputs

General isolation:	250V 50/60Hz working. Double-insulated to all other I/O — basic insulation to ground.

4.2.1 Current outputs

Range:	0 - 20 mA.
Maximum load:	1kΩ.
Resolution:	12 bits minimum. (5µA).
Accuracy @25°C:	0.5%.
Temperature drift:	< ±[1µA + 0.03% of reading]/°C.

4.3 Transmitter power supply

Voltage:	24V ±1.2V (up to 22mA).
Current:	0-22 mA.
Current limit:	30mA.
Isolation:	250V 50/60Hz working. Double-insulated to all other I/O — basic insulation to ground.

4.4 Analogue inputs — expansion I/O

Range:	0 - 10 V, 1 - 5 V.
Break protection:	Response time < 1 sample period. Fixed pulldown.
Break detect threshold:	–0.4V.

Input impedance:	>250kΩ.
Resolution (unfiltered):	0.7mV.
Accuracy @25°C:	0.1% of range.
Temperature drift:	< ±[0.1mV + 0.022% of reading]/°C.
Isolation:	60Vdc working. Double-insulated to all other I/O — basic insulation to ground.

4.5 Analogue outputs — expansion I/O

Range:	0 - 10 V, 1 - 5 V.
Maximum load:	5mA.
Resolution:	12 bits minimum. (2.5mV).
Accuracy @25°C:	0.1% of range.
Temperature drift:	< ±[0.1mV + 0.022% of reading]/°C.
Isolation:	60Vdc working. Double-insulated to all other I/O — basic insulation to ground.

4.6 Digital inputs — expansion I/O

Pullup voltage:	24V dc via 12kΩ, or open-circuit (selectable).
Input thresholds:	Logic 1: 6.5V minimum. Logic 0: 2.5V maximum.
Isolation:	60Vdc working. Double-insulated to all other I/O — basic insulation to ground.

4.7 Digital outputs — expansion I/O

Pullup voltage:	24V dc via 12kΩ, or open-circuit (selectable). (21V minumum).
Max. low-state current:	100mA.
Max. external pullup voltage:	50V.
Isolation:	60Vdc working. Double-insulated to all other I/O — basic insulation to ground.

4.8 Relays

Watchdog & alarm relays:	SPST, open when de-energised (alarm condition).
Contact rating:	1A at 24V ac/dc. Absolute maximum rating 2A at 60V.
Isolation:	60Vdc working. Double-insulated to all other I/O — basic insulation to ground.

5 POWER SUPPLIES

5.1 Mains version

Input voltage range:	90 - 265 V ac rms.
Input frequency range:	45 - 65 Hz.
Power rating:	25VA.
Holdup time:	10ms.
Fuse:	(*factory replacement only*).

5.2 DC version

Input voltage range:	19 - 55 V dc.
Power rating:	25VA.
Holdup time:	10ms.
Fuse:	(*factory replacement only*).

6 FRONT PANEL

6.1 Displays

PV bargraph:	51-segment red LED vertical % display, labelled PV-X. Bottom segment permanently lit. Displays *PV* in 2%steps. Bargraph flashes when unacknowledged absolute alarm, even if cleared. Displays absolute alarm settings as pair of inverse lit segments if ▲/▼ buttons pressed together.
SP bargraph:	51-segment green LED vertical % display, labelled SP-W. Bottom segment permanently lit. Displays *SP* in 2%steps. Bargraph flashes when unacknowledged deviation alarm, even if cleared. Displays deviation alarm settings as pair of inverse lit segments if ▲/▼ buttons pressed together.
Output bargraph:	10-segment yellow LED horizontal display, labelled OP-Y. (‘C’ and ‘O’ on scale mean ‘closed’ and ‘open’ resp.) 1st segment lights at >5% output, 2nd at >15%, and so on in 10% steps until all segments lit at >95% output.
Mnemonic display:	2 ‘starburst’ 14-segment red LED characters. Displays selected parameter mnemonic, or pushbutton error state — ‘asterisks’. (N.B. ‘PV’ displayed for initial 6 secs only.)
4½-digit display:	4-off 7-segment red LED digits, plus decimal points and leading ‘±1’. Displays value of parameter (last) indicated in the mnemonic display. 19999 maximum readout.

Alarm indicators:	2 red back-lit legends — ‘ALM 1’ (loop 1) and ‘ALM 2’ (loop 2). Legend flashes for unacknowledged alarm, even if cleared. Lit steadily for acknowledged current alarm.
Loop indicators:	2 yellow back-lit legends — ‘PV 1’ (loop 1) and ‘PV 2’ (loop 2). Indicate which loop displayed on front panel. (N.B. Both indicators are OFF in single-loop mode.)
Mode indicators:	6 back-lit legends in two groups of 3 to indicate controller’s operating mode(s) — RATIO, REM, AUTO: green for closed-loop modes. MAN, TRACK, HOLD: yellow for open-loop modes. MAN and AUTO flash when ‘forced’ mode.

6.2 Pushbuttons

8-off elastomeric pushbuttons with orange legends shown below.
‘R’, ‘A’, and ‘M’ pushbuttons can be masked to disable their mode change function only.
‘SP’ and ‘Alarm Acknowledge’ buttons can be masked to disable their setpoint change and alarm acknowledge functions, respectively.

Loop control:	R	Remote mode select / view output *OP* / quit inspect mode
	A	Auto mode select / view output *OP* / quit inspect mode
	M	Manual mode select / view output *OP* / quit inspect mode
	SP	Setpoint inspect or edit / quit inspect mode
	▲	Raise value / scroll or step up list / select Loop 2
	▼	Lower value / scroll or step down list / select Loop 1
Parameters:	PAR	Display ‘list’ (*L*) parameter value / view bit value
Alarms:		Alarm acknowledge in current loop

6.3 Identification

Loop tag/Service ID:	Write-on label (white) at top of front panel.

7 CONTROL CHARACTERISTICS

7.1 General

Loop update time:	125ms total.
Action on sensor failure:	User-selectable — no mode change, or forced manual mode with selectable 'failsafe' output (last or low OP).
Power-fail recovery:	User-selectable — last operating condition, or manual mode with selectable 'failsafe' output.
Central processor (CPU):	H8 family.
Clock speed:	12MHz.
CPU ports:	2 serial — one for SCI bus to I/O and front panel. — one for configuration/serial port.

7.2 Control algorithms

Control types:	User-selectable from — manual station, single loop, dual loop cascade, single-loop with ratio station, override.
Control algorithm:	Selectable for P, PI, PD, PID, or ON/OFF control. Direct- or inverse-acting.
Control output:	0 - 100%, single or split range, for direct- or reverse-acting actuator. Raise/lower output for incremental actuators, available with single-loop, dual-loop cascade, and ratio controllers.

7.3 Autotune facility

Self tune:	Single-shot approach — the instrument perturbs the process then calculates fixed optimal PID tuning constants. Adaptive control / continuous autotune (*not yet available*).

8 COMMUNICATIONS

8.1 Serial communications

Transmission standard:	RS422 (5-wire, 0-5V) or RS485 (3-wire, 0-5V).
Data rate:	Software-selectable from 1200, 4800, 9600, and 19200* bits/second.
Data format:	8 bit, selectable parity, 1/2 stop bits.
Protocols supported:	MODBUS/J-BUS RTU slave.

**Not yet implemented*

Line impedance:	120Ω - 240Ω twisted pair.
Line length:	1220m (4000ft) maximum at 9600 baud.
Units per line:	16 instruments maximum electrical loading. Expandable to 128 electrical maximum by use of buffers.
Isolation:	60Vdc, double insulation.

9 CONFIGURATION

Parameter storage:	Non-volatile EEPROM. (8Kbytes). Allows restart from current operating conditions after indefinite power down.
Via front panel:	Parameter access by list — loop 1, loop 2, instrument, comms, main I/O, expansion I/O, calibration, incremental control, and diagnostics.
Access protection:	Operator parameters — no passcode required. Control and instrument parameters — via two separate user-programmable passcodes.
Via PC:	Configuration adapter plugs into side of unpowered T630. Parameterisation utility with EDIT/LOAD/SAVE.

Chapter 18 ORDERING INFORMATION

1 T630 ORDER CODES

Table 18-1 lists the order codes required for the T630 Process Controller, and gives an example code.

CODE	DESCRIPTION
	Base unit
T630	Process controller
	Power supply
MAINS	Universal mains 90 to 265 V ac rms
DC	19 to 55 V dc
	Expansion I/O (slot 1)
ExpIO	Expansion I/O board fitted
—	Not fitted
	Communications (slot 2)
SER	Serial comms board fitted
(*Consult factory*)	Fieldbus board fitted
—	No board fitted
	Sleeve
T730	Sleeve fitted
—	No sleeve fitted
	Calibration certificate
Cert	Calibration certificate supplied
—	No certificate supplied
	Factory preconfiguration
(*Consult factory*)	Customer configuration
—	Default configuration

Example: T630/MAINS/ExpIO/SER/T730/—/—

Table 18-1 T630 order codes and example

2 T630 ACCESSORIES ORDER CODES

Table 18-2 lists the order codes required for the available T630 Process Controller accessories.

CODE	DESCRIPTION
	Accessories
T960	19" rack frame adapter
T961	Blanking-plate (non-IP65)
T962	Blanking-plate (IP65)
LA083377	Clamping collar for thin (<1.5mm) and/or low-strength panels
(*Consult factory*)	PC configuration tool and adapter cable
LA 246 779 UK25	Terminal-mounted burden resistor 250Ω, for 4-20mA input (1-5V range)
LA 246 779 U50R*	Terminal-mounted burden resistor 50Ω, for 0/4-20mA input (0/0.2-1V range)

**Process inputs only*

Table 18-2 T630 accessories order codes

Appendix A SINGLE-LOOP CONTROLLER

This appendix presents you with a detailed signal-processing schematic, showing how the loop parameters interact with the flow of data through the strategy. This information helps you to gain an in-depth understanding of how the loop works, and is useful when you are adjusting the parameter values to configure the controller for your particular plant needs.

NOTE. If the loop is set up as an incremental controller, the signal-processing is modified — especially control output generation — and some additional parameters are involved. Refer to Chapter 10, *Incremental control*, for details.

The main sections in this appendix are:

- Single-loop controller schematic (§1)
- Setpoint generation (§2)
- PID output (§3)
- Mode selection (§4)
- Output generation (§5)
- Alarm outputs (§6).

1 SINGLE-LOOP CONTROLLER SCHEMATIC

The single-loop controller has a total of about 30 parameters that you can configure to determine exactly the way the controller performs. In some cases you may wish to leave parameter values at their default settings, and your control system may not need all the input and output terminals available.

Figure A-1 shows in some detail how the single-loop controller functions. The principal signal flows in the loop — i.e. for Local Auto mode — are drawn with bold lines to help you see what is happening. The positions of the schematic 'mode switches' are all set to the Local Auto operating positions. Input and output terminals are numbered as they are on the instrument's rear panel — see Ch2 §4.2 for detailed designations.

NOTE. In the figure, terminal numbers enclosed in brackets are assignable to various control parameters, according to your choice — all possibilities are shown. Unbracketed terminal numbers have fixed assignments. (Chapter 4, §2, summarises the instrument's I/O and gives details on how to assign the terminals.)

The schematic does not show all the input and output processing that is applied as signals enter and leave the controller — ranging, linearising, filtering, etc. These are detailed in Ch4 §2. Also omitted for clarity are the watchdog relay terminals (18, 19), alarm relay terminals (20, 21), and transmitter power supply terminals (42, 43).

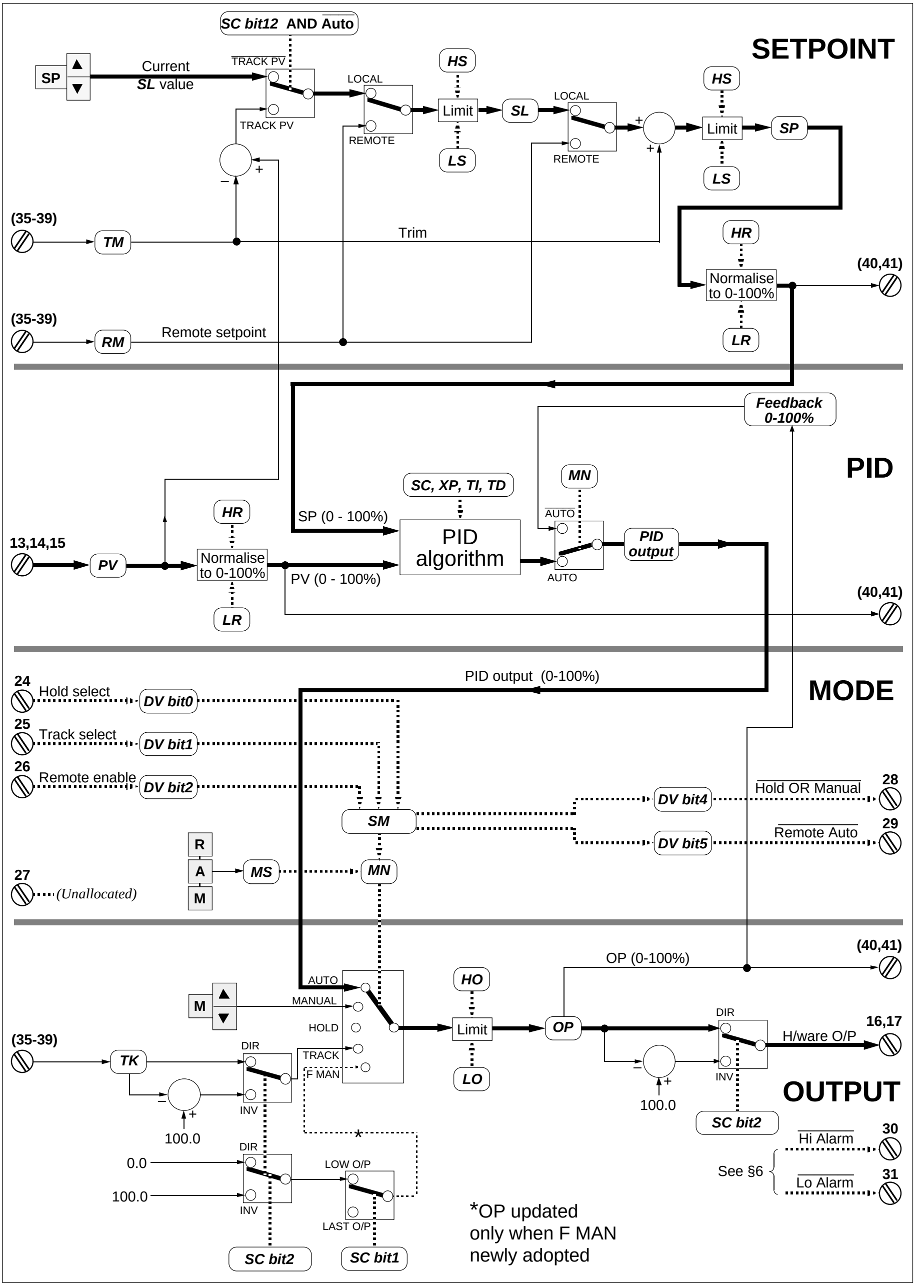


Figure A-1 Single-loop controller schematic

The schematic has been partitioned for convenience into four areas:

- **SETPOINT.** This area is concerned with generating a Resultant Setpoint SP for comparison with the Process Variable PV, in the PID calculation area.
- **PID.** Here, SP and PV are compared as percentages, and used by the PID algorithm to calculate a percentage control output value for passing to the controller's output generation area.
- **MODE.** This area establishes the operating mode of the controller, based on what mode pushbuttons the operator has pressed, and also on the status of the mode-selection and mode-enabling digital inputs. This operating mode data is used in the output generation area to determine the source of the hardware output.
- **OUTPUT.** Here, the hardware control output signal is generated from the appropriate source, depending on the controller's operating mode.

2 SETPOINT GENERATION

The Resultant Setpoint SP is generated from different sources according to the controller's operating mode, and the settings of the SC status word. Refer to Figure A-2, which reproduces the 'SETPOINT' area of the overall schematic in Figure A-1.

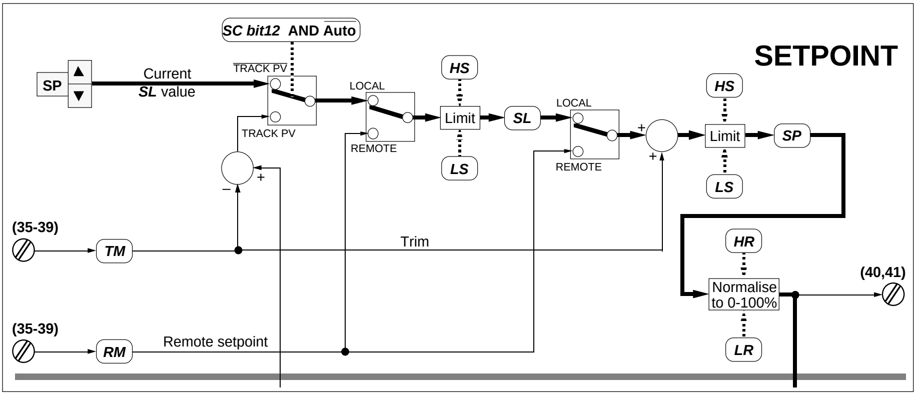


Figure A-2 Single-loop controller schematic — 'SETPOINT' area

2.1 SP generation in Local Auto mode

In Local Auto operating mode SL can be adjusted via the front-panel 'SP' and ▲/▼ pushbuttons, and is subject to limiting by the High and Low Setpoint parameters HS and LS. (The states of the Selected Configuration, SC, and Selected Mode, SM, status words determine the source of SL.) SL then has Setpoint Trim TM added to it, and is limited again by HS and LS to become the Resultant Setpoint SP. SP is normalised before passing on to the PID calculation area. Normalisation converts the engineering value of SP to a percentage, using the mapping of HR to 100% and LR to 0% as the conversion scale. Note that SP% can also be made available as an output signal on terminals 40 and 41 (expansion I/O board analogue output).

2.2 SP generation in Remote mode

If Remote mode is in operation, SP is generated from the Remote Setpoint value RM rather than from SL. RM (input via terminals 35-39) is trimmed and limited, as for local mode, to form SP. Note that while the controller is in Remote mode, SL — although not being used — nevertheless tracks the limited value of RM. This ensures that there is no bump in SP's value when the controller returns to local mode again.

2.3 SP generation in non-automatic modes

If the controller is operating in a local but non-automatic mode, and SC bit12 has been configured TRUE ('Track PV'), SL is made to track the PV input, as shown in Figure A-2. PV has the Trim subtracted from it, and is limited by HS/LS, before updating SL. Note that the Trim is added in again to form SP. Keeping SL, and therefore SP, equal to PV prevents bumps in the PID algorithm output when automatic operation is restored.

3 PID OUTPUT

The way the PID output is derived depends on whether the controller is operating in an automatic or a non-automatic mode. Figure A-3 reproduces the 'PID' area of the overall schematic in Figure A-1.

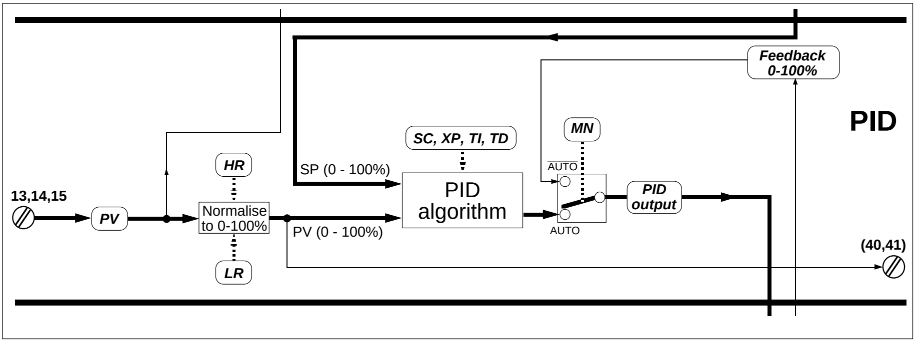


Figure A-3 Single-loop controller schematic — 'PID' area

3.1 PID output in automatic modes

Process Variable PV is input via terminals 13-15, normalised to a percentage, and fed to the PID calculation algorithm. Note that PV% can also be made available as an output signal on terminals 40 and 41. The PID algorithm calculates an output signal from the error (PV–SP), in a way determined by the SC status word and the values held in the Proportional Band parameter XP, and the Integral and Derivative Time constants TI and TD, respectively. SC determines such things as whether PID control or On/Off control is used, if SL balance is applied on SL changes, and the units of the timebase.

3.2 PID output in non-automatic modes

When the controller is operating in a non-automatic mode (determined by the value of parameter MN) the PID output is made to track a value that is fed back from the output parameter OP, rather than being generated by the PID algorithm itself. The point of this is to avoid bumps in the output OP when the controller is restored to automatic mode.

4 MODE SELECTION

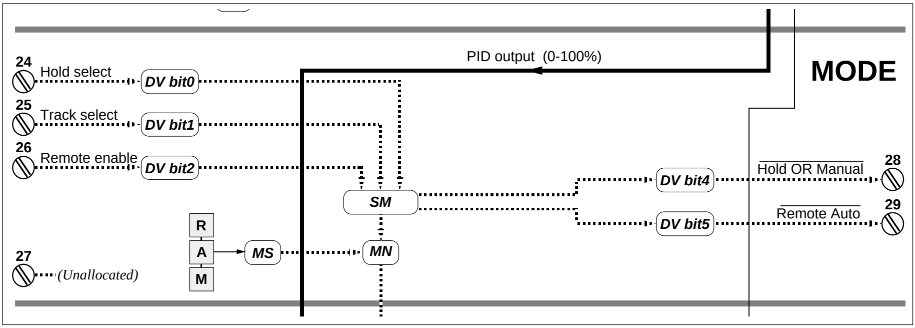


Figure A-4 Single-loop controller schematic — 'MODE' area

Figure A-4 reproduces the 'MODE' area of the overall schematic in Figure A-1. The read-only MN parameter is where the controller's operating mode is stored as an integer value. MN is itself derived from the MS and SM parameters. MS derives from what mode push-buttons have been pressed by the operator, and SM from the states of the Hold select, Track select, and Remote enable digital inputs (terminals 24-26), all of which help determine what mode the controller should be operating in. The operating mode finally resolved in MN is used in the Output area to determine the source of the OP parameter, and therefore the controller's hardware output. Note that the value of SM is also used to provide a pair of digital outputs (terminals 28 and 29) that can be used as 'interlock' signals to a second loop in dual-loop configurations.

How MN is derived, and the priorities and characteristics of the various controller operating modes, is described in Chapter 5, *Control operating modes*.

5 OUTPUT GENERATION

Figure A-5 reproduces the 'OUTPUT' area of the overall schematic in Figure A-1. The source of the control output signal OP depends on the controller's operating mode, as stored in the MN parameter.

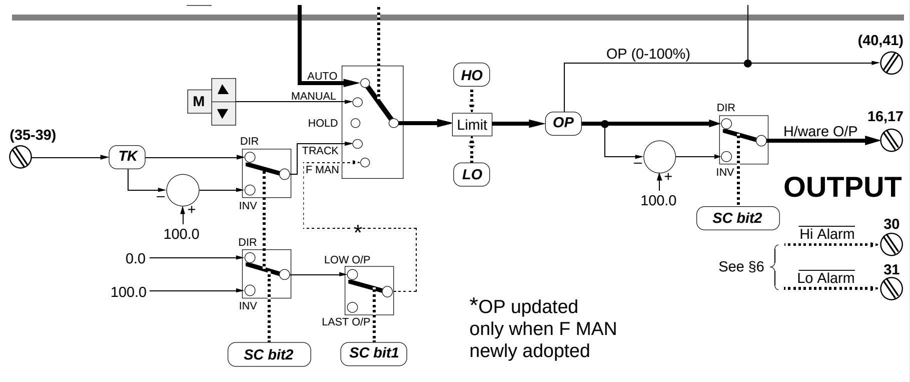


Figure A-5 Single-loop controller schematic — 'OUTPUT' area

5.1 OP output generation in automatic modes

In automatic mode the PID output (as a percentage) is passed to the OP parameter after limiting by the High and Low Output limits HO and LO (both percentages). Note that OP% can be made available as an output signal on terminals 40 and 41. Finally, OP is ranged to the selected voltage or current value, and passed out via terminals 16 and 17 as the controller's hardware output. Before being ranged, OP may be inverted if 'inverse action' has been configured (SC bit2 TRUE). In this case the hardware output decreases when OP increases, and increases when OP decreases. (Ranging is not shown in Figure A-5; refer to Chapter 4, §2.2.1 and Figure 4-6, for details.)

5.2 OP output generation in non-automatic modes

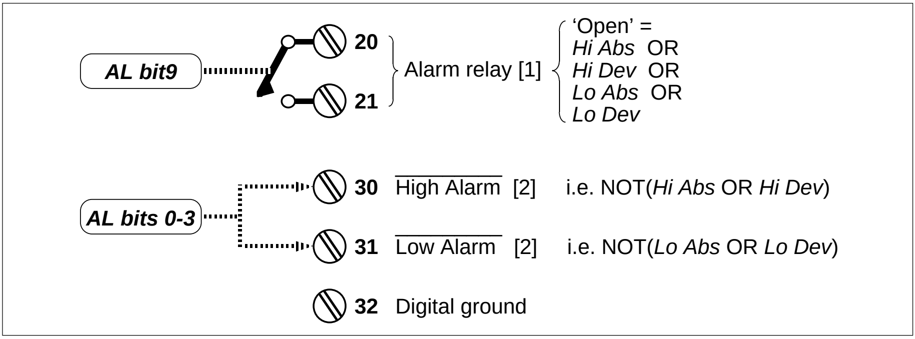
In non-automatic modes the output is generated in a variety of ways:

- **Manual mode.** In Manual mode OP is controlled by the operator using the 'M' plus ▲/▼ pushbuttons. Limiting, inversion, and output ranging are applied as before.
- **Hold mode.** In Hold mode OP is frozen at its current value.

- **Track mode.** In Track mode OP is derived from the Track input TK, which may be input as a percentage via terminals 35-39. Note that if inverse-action has been configured (via SC bit2), TK is inverted *twice* on its way to becoming the hardware output. This means that the output follows the uninverted TK value whether or not inverse action has been configured.
- **Forced Manual mode.** In Forced Manual mode OP is set to either the last value of OP before the mode was adopted, or to a 'low' value, according to how SC bit1 is configured (TRUE for 'low' output, FALSE for last output). A 'low' output equals 0% if direct action has been configured (via SC bit2), but equals 100% for inverse action.

6 ALARM OUTPUTS

Figure A-6 shows the digital outputs associated with alarm conditions.



[1] *Default configuration; see Ch4 §2.9* [2] *Different for incremental control; see Ch10 §2.1*

Figure A-6 Default alarm digital output schematic (main board & expansion I/O)

The alarm relay is completely configurable via AL bits 12 to 15, as described in Ch4 §2.9. Figure A-6 shows only the default conditions. Under these conditions the alarm relay on terminals 20, 21 is normally closed (energised) but opens (de-energises) if there is an absolute or a deviation alarm in any loop. The relay is driven by the state of bit 9 of the Alarm parameter AL. For more information on the operation and configuration of the alarm relay, refer to Ch4 §2.9.

For continuous controllers, terminal 30 outputs a high digital signal provided no high alarm exists, i.e. neither a high absolute nor a high deviation alarm. Terminal 31 does the same for the corresponding low alarms. These terminals are driven by AL bits 0-3, via bits 6 and 7 of digital output parameter DV. You can invert or disconnect these signals if required, as described in Ch4 §2.7.

For incremental controllers terminals 30 and 31 have different functions — see Ch10 §2.1.

Appendix B
DUAL-LOOP CASCADE CONTROLLER

This appendix presents you with detailed signal-processing schematics showing the mode interlocks between the two loops, and how their parameters interact with the flow of data through the strategy. This information helps you to gain an in-depth understanding of how the cascade controller works, and is useful when you are adjusting the parameter values to configure the system for your particular plant needs.

NOTE. If Loop 1 is set up as an incremental controller, the signal-processing is modified — especially control output generation — and some additional parameters are involved. Refer to Chapter 10, *Incremental control*, for details.

The cascade controller is based on the single-loop controller. So, to avoid repetition, where the two controllers operate in the same way you are referred to Appendix A, *Single-loop controller*, for detailed explanations.

The main sections in this appendix are:

- Loop schematics (§1)
- Slave loop 1 (§2)
- Master loop 2 (§3)
- Alarm outputs (§4).

1 LOOP SCHEMATICS

Figure B-1 shows Loop 2, the master controller, and Figure B-2 shows loop 1, the slave controller. The principal signal flows in the loops — i.e. when the controller is operating automatically in cascade — are in bold. Input and output terminals are numbered as they are on the instrument's rear panel — see Ch2 §4.2 for detailed designations.

NOTE. The convention for terminal-numbering is as in Appendix A: bracketed means assignable, unbracketed means fixed assignments. Ranging, etc., is not shown (see Ch4 §2); neither are relay or transmitter PSU terminals.

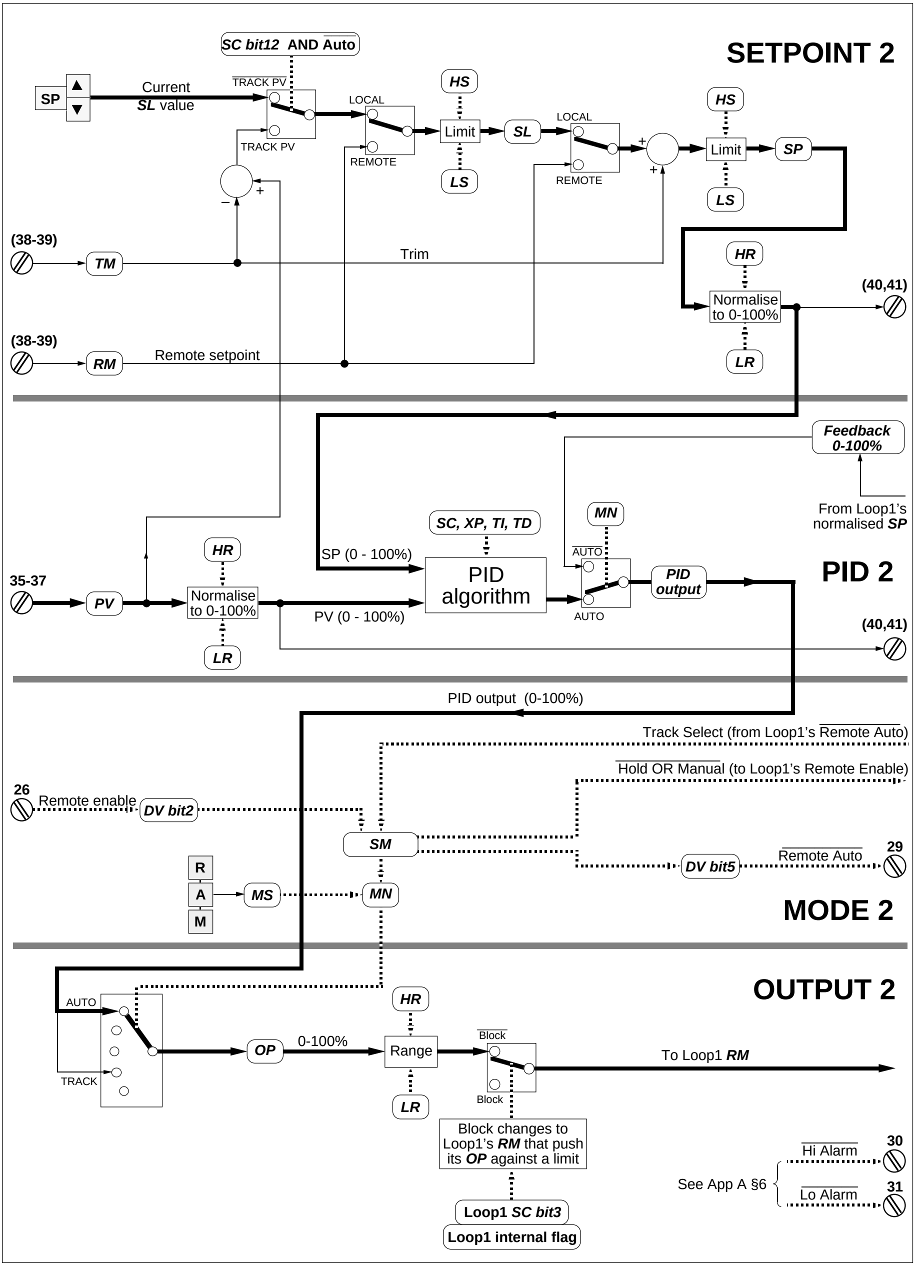


Figure B-1 Dual-loop cascade schematic — Master loop 2

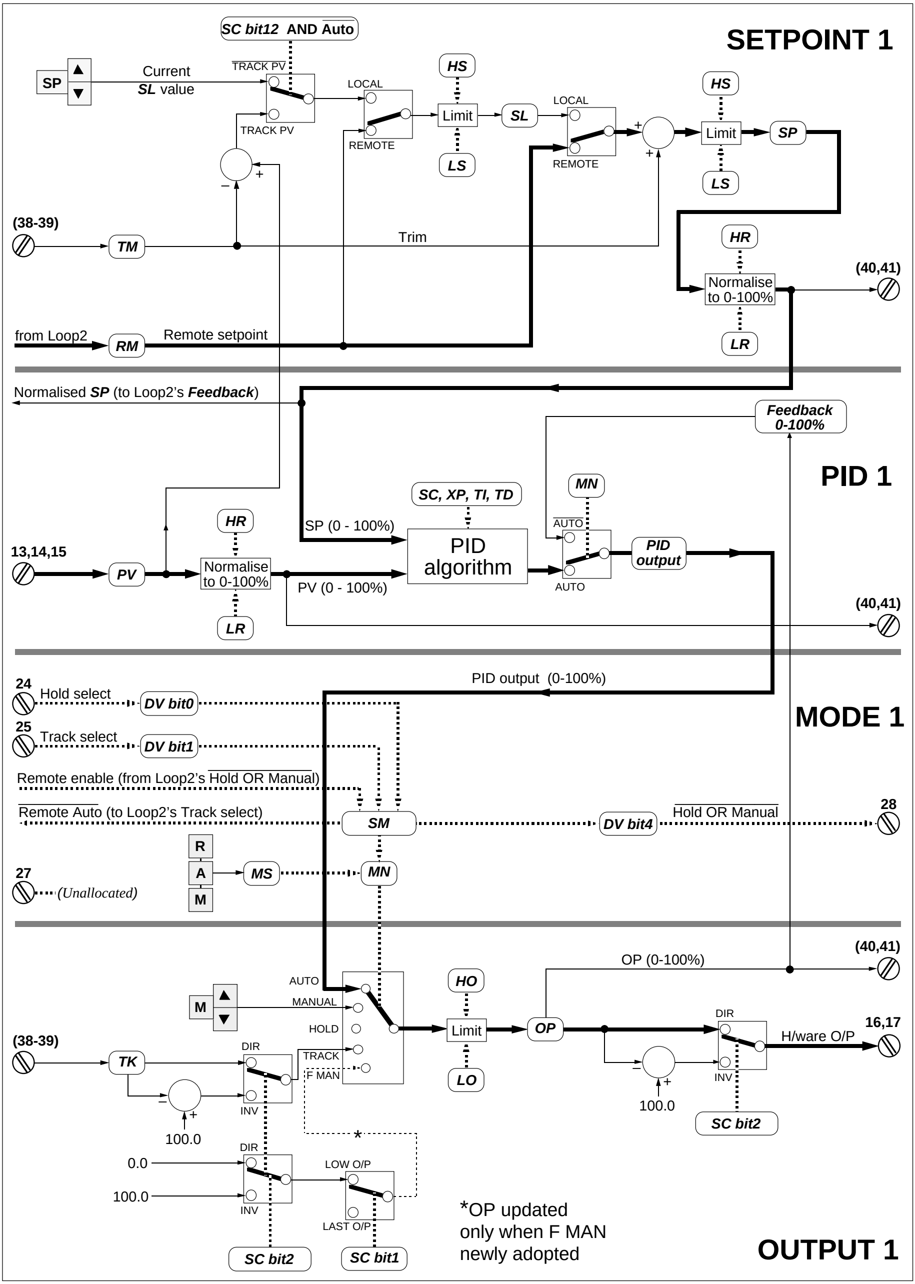


Figure B-2 Dual-loop cascade schematic — Slave loop 1

The schematics are partitioned into four areas, suffixed ‘1’ or ‘2’ for each loop.

- **SETPOINT.** This area is concerned with generating a Resultant Setpoint SP for comparison with the Process Variable PV, in the PID calculation area.
- **PID.** Here, SP and PV are compared as percentages, and used by the PID algorithm to calculate a percentage control output value for passing to the controller’s output generation area.
- **MODE.** This area establishes the operating mode of the controller, based on what mode pushbuttons the operator has pressed, and also on the status of the mode-selection and mode-enabling digital inputs and the interlock signals between the two loops. This data is used in the output generation area to determine the source of the output.
- **OUTPUT.** Here, the control output signal is generated from the appropriate source, depending on the controller’s operating mode.

2 SLAVE LOOP 1

Refer to Figure B-2. Slave loop 1 operates in a very similar way to the single-loop controller, described in Appendix A. The few differences are described for each area in the following sections. Note that the ‘Output’ areas are identical, so no further description is given here. (Please refer to Appendix A for more information.)

2.1 SETPOINT 1 area

The normal mode for cascade operation is Remote Auto, with the Remote Setpoint RM ‘hard-wired’ directly from master loop 2’s output. There is no terminal for inputting RM from an outside source.

2.2 PID 1 area

The normalised Resultant Setpoint SP is hard-wired directly to master loop 2’s Feedback parameter. This is to allow loop 2’s output to track loop 1’s SP when the master is not in an automatic mode.

2.3 MODE 1 area

2.3.1 First mode interlock

The Remote Enable digital input is hard-wired directly from master loop 2’s NOT [Hold OR Manual] output bit. This is the first of the mode interlocks, to prevent the slave from operating from the remote setpoint if the master loop enters Hold or Manual for any reason. There is no Remote Enable terminal input.

2.3.2 Second mode interlock

Slave loop 1's NOT [Remote Auto] digital output is hard-wired directly to master loop 2's Track Select input, as the second mode interlock. The purpose of this interlock is to put the master into Track mode should the slave cease to operate in Remote Auto. In Track mode the master's output tracks the slave's setpoint, which prevents a bump when cascade operation is restored. The NOT [Remote Auto] terminal output is absent.

2.3.3 NOT [Hold OR Manual] digital output

A NOT [Hold OR Manual] digital output terminal is provided in slave loop 1. This can be wired to a second instrument's Remote Enable input to allow two-instrument cascade control.

3 MASTER LOOP 2

Refer to Figure B-1. Master loop 2 also operates in a similar way to the single-loop controller, described in Appendix A, except for the Output area which is very different. The differences are described for each area in the following sections. Note that the Setpoint areas are identical, so no further description is given here. (Please refer to Appendix A.)

3.1 PID 2 area

The Feedback parameter is hard-wired directly from slave loop 1's normalised Resultant Setpoint parameter SP. This is to allow the master loop's output (which acts as the slave's remote setpoint) to track the slave's setpoint when the master is not in an automatic mode, to avoid a bump when cascade control is restored.

3.2 MODE 2 area

Refer to Figure B-3, which reproduces the 'MODE 2' area of the schematic in Figure B-1.

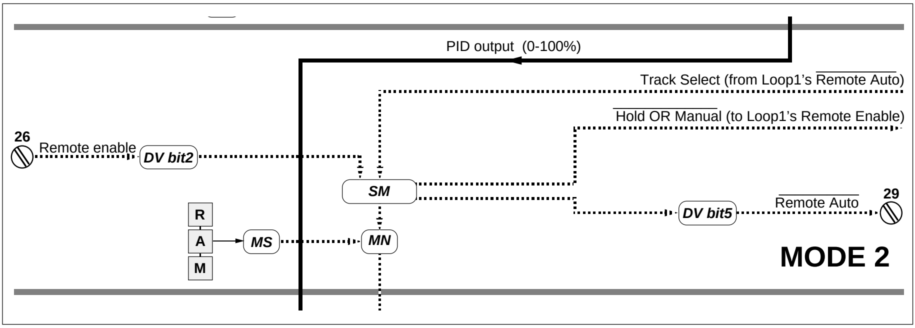


Figure B-3 Dual-loop cascade schematic — 'MODE 2' area of master loop

3.2.1 Hold Select digital input

The Hold Select digital input terminal is absent.

3.2.2 First mode interlock

The NOT [Hold OR Manual] digital signal is hard-wired directly to slave loop 1's Remote Enable digital input. This is the first mode interlock, described in §2.3.1. The corresponding digital output terminal is absent.

3.2.3 Second mode interlock

The Track Select digital input is hard-wired directly from slave loop 1's NOT [Remote Auto] digital output. This is the second mode interlock, described in §2.3.2. The Track Select digital input terminal is absent.

3.3 OUTPUT 2 area

Refer to Figure B-4, which reproduces the 'OUTPUT 2' area of Figure B-1.

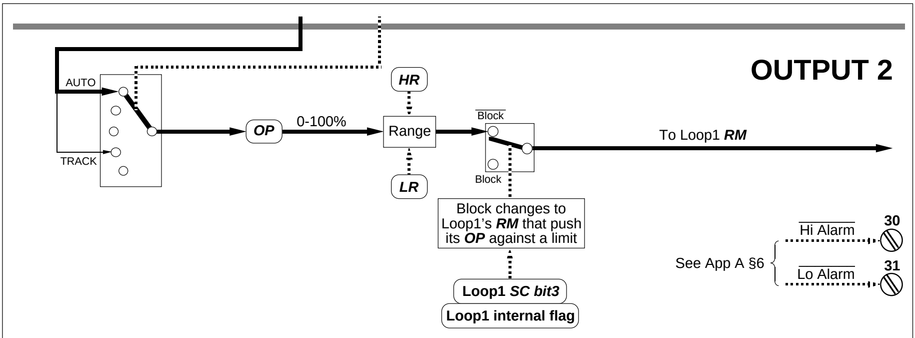


Figure B-4 Dual-loop cascade schematic — 'OUTPUT 2' area of master loop

3.3.1 Permitted operating modes

Because of the mode interlocks between master and slave and the mode priorities, master loop 2 can operate in only three modes — Track, Local Auto, or Remote Auto. Other modes may be selected but are overridden.

- In Track mode the output is sourced from slave loop 1's Resultant Setpoint SP via the Feedback parameter (see §3.1).
- In automatic mode the output is derived by the PID algorithm from the master PV input and either the local or the remote master setpoint.
- Manual mode is not available, and so the operator cannot adjust OP via the pushbuttons.

3.3.2 Track input

The Track input terminal is absent.

3.3.3 Output blocking

There is no simple output limiting by the High and Low Output limit parameters HO and LO — which are absent from Loop 2’s parameter list. This is not needed because slave loop 1’s Setpoint area carries out the required limiting (on Remote Setpoint RM).

However, another type of output-limiting is applied in the master loop, as shown in Figure B-4. If the calculated change in the master’s OP would result in the slave loop’s output being driven against a limit (specified by its HO and LO), then the master’s OP is prevented from changing.

NOTE. Blocking is triggered by a Loop 1 internal flag that detects output-limiting. The way blocking is applied depends on whether or not you have requested PID inversion — specified by the Configuration Status word SC, bit 3.

3.3.4 Control output terminals

Customer terminals for the hardware output and the normalised control output are absent.

3.3.5 Output ranging

The control output OP is ranged from a percentage to engineering units using HR and LR, so that it can act as a remote setpoint for the slave loop.

4 ALARM OUTPUTS

The digital outputs associated with alarm conditions (terminals 20, 21, and 30, 31) are described in Appendix A, §6.

Appendix C RATIO CONTROLLER

This appendix presents you with detailed signal-processing schematics showing how the parameters of the two loops interact with the flow of data through the strategy. This information helps you to gain an in-depth understanding of how the ratio controller works, and is useful when you are adjusting the parameter values to configure the system for your particular plant needs.

NOTE. If Loop 1 is set up as an incremental controller, the signal-processing is modified — especially control output generation — and some additional parameters are involved. Refer to Chapter 10, *Incremental control*, for details.

The ratio controller is based on the single-loop controller. So, to avoid repetition, where the two controllers operate in the same way you are referred to Appendix A, *Single-loop controller*, for detailed explanations.

The main sections in this appendix are:

- Loop schematics (§1)
- Ratio control loop (Loop 1) (§2)
- Ratio station (Loop 2) (§3)
- Alarm outputs (§4).

1 LOOP SCHEMATICS

Figure C-1 shows Loop 2, the ratio station, and Figure C-2 shows loop 1, the control loop. The principal signal flows in the loops — i.e. when the controller is operating automatically in Ratio mode — are in bold. Input and output terminals are numbered as they are on the instrument's rear panel — see Ch2 §4.2 for detailed designations.

NOTE. The convention for terminal-numbering is as in Appendix A: bracketed means assignable, unbracketed means fixed assignments. Ranging, etc., is not shown (see Ch4 §2); neither are relay or transmitter PSU terminals.

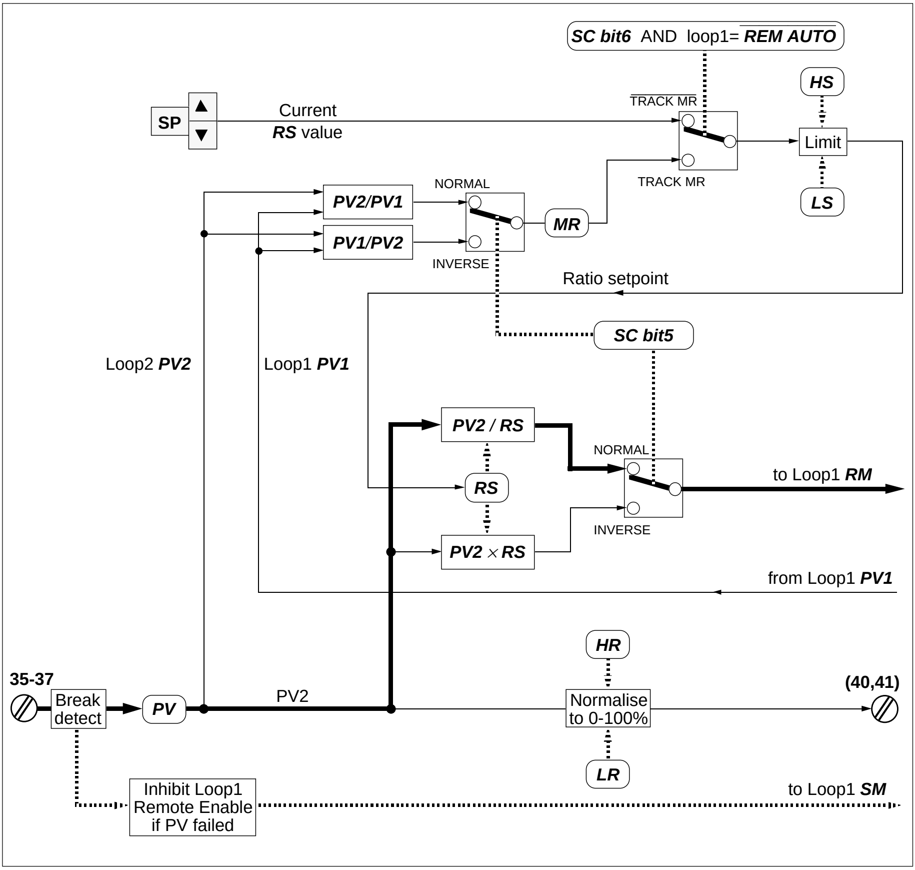


Figure C-1 Ratio station schematic — loop 2

The loop 1 schematic is partitioned into four areas:

- **SETPOINT.** This area is concerned with generating a Resultant Setpoint SP for comparison with the Process Variable PV, in the PID calculation area.
- **PID.** Here, SP and PV are compared as percentages, and used by the PID algorithm to calculate a percentage control output value for passing to the controller's output generation area.
- **MODE.** This area establishes the operating mode of the controller, based on what mode pushbuttons the operator has pressed, and also on the status of the mode-selection and mode-enabling digital inputs. This data is used in the output generation area to determine the source of the output.
- **OUTPUT.** Here, the control output signal is generated from the appropriate source, depending on the controller's operating mode.

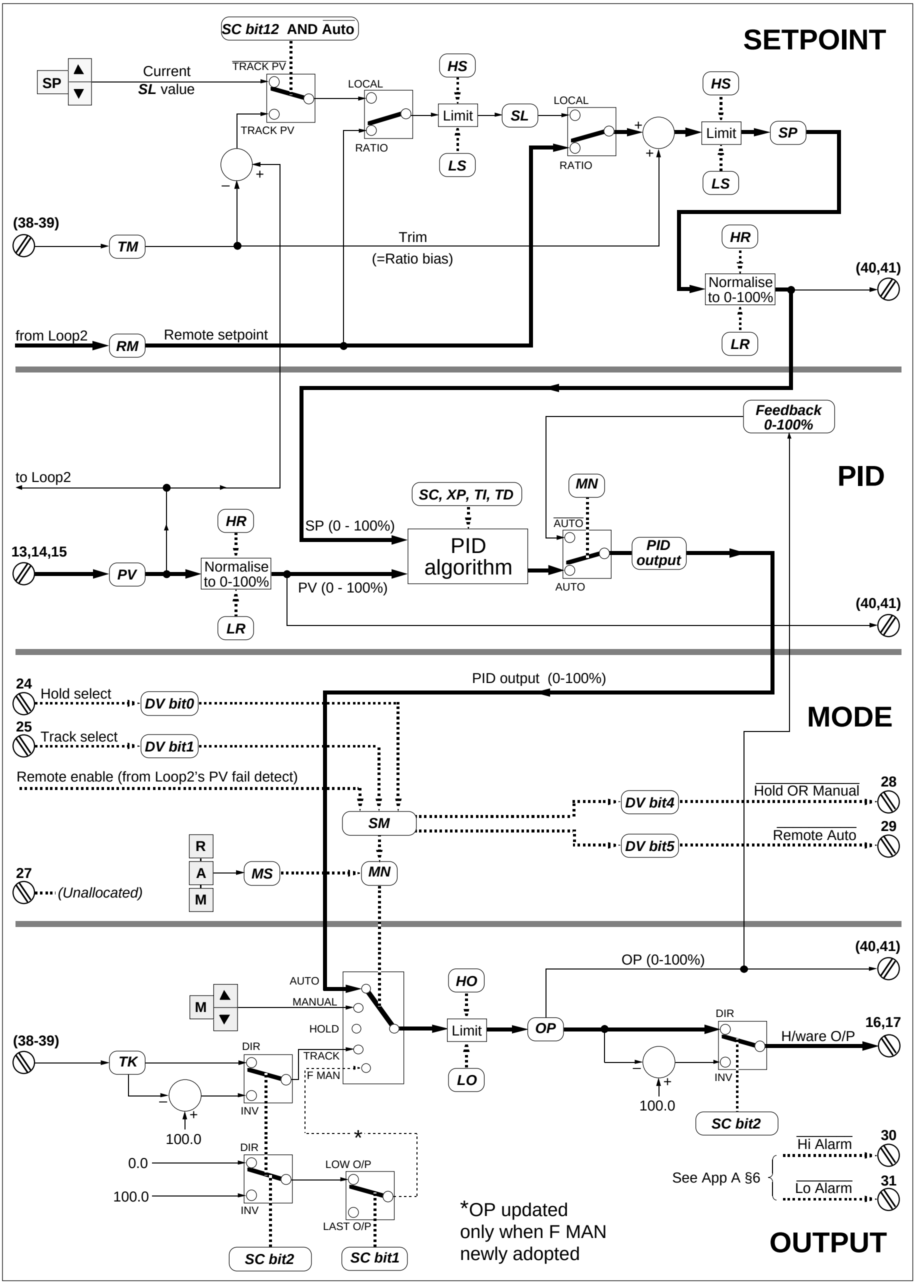


Figure C-2 Ratio control loop schematic — loop 1

2 RATIO CONTROL LOOP (LOOP 1)

Refer to Figure C-2. The ratio control loop (loop 1) operates in a very similar way to the single-loop controller, described in Appendix A. The few differences are described for each area in the following sections. Note that the 'Output' areas are identical, so no further description is given here. (Please refer to Appendix A for more information.)

2.1 SETPOINT area

The normal mode for ratio operation is Ratio, with the Remote Setpoint RM 'hard-wired' directly from the ratio station (loop 2). There is no terminal for inputting RM from an outside source. Note that 'Ratio mode' is effectively the same as Remote Auto mode, in the way loop 1 operates.

2.2 PID area

The Process Variable PV is hard-wired directly to the ratio station (loop 2) where it is used to calculate the Measured Ratio parameter MR.

2.3 MODE area

The Remote Enable digital input to the SM (Mode Status word) parameter is hard-wired directly from the ratio station's PV input fail-detection bit. This bit is normally high, but goes low if the PV input to the ratio station (loop 2) fails, or if there is a sumcheck error. This forces the control loop (loop 1) from Ratio mode into Forced Auto mode in the event of a failure. There is no Remote Enable terminal input.

3 RATIO STATION (LOOP 2)

Refer to Figure C-1. The ratio station is not a control loop at all. It takes in an 'uncontrolled' Process Variable PV via terminals 35-37, and calculates a Remote Setpoint RM which is hard-wired to the control loop (loop 1). RM is controlled to have a specified ratio to the uncontrolled PV.

A normalised (percentage) version of the uncontrolled PV is available at output terminals 40 and 41.

3.1 RM calculation

RM is calculated either as PV *divided* by the Ratio Setpoint parameter RS ('normal' ratio), or PV *multiplied* by RS ('inverse' ratio). The value of the Configuration Status word SC bit 5 specifies the type of ratio — FALSE specifies normal and TRUE specifies inverse ratio.

3.2 RS sources

When the control loop is operating in Ratio mode, RS can be adjusted by the operator using the 'SP' and ▲/▼ pushbuttons, and is limited by the High and Low Setpoint limits HS and LS. But if for any reason the control loop quits Ratio mode (i.e. quits Remote Auto), and you have set SC bit 6 (Ratio Track) to TRUE, then RS tracks the value of the Measured Ratio MR instead. In this case RS is no longer adjustable. The point of this tracking is to prevent a bump in RS when Ratio mode is re-established. Note that in Ratio Track operation RS is still limited by HS and LS.

3.3 MR calculation

MR is the actual measured ratio of the two PV-values, which the controller is attempting to make equal to RS ideally. The controlled Process Variable PV is hard-wired back from loop 1 for use in this calculation. MR is calculated as PV2/PV1 if normal ratio mode has been selected (SC bit 5 FALSE), or PV1/PV2 for inverse ratio (SC bit 5 TRUE).

The rationale of the MR calculation is as follows:

$PV1 = PV2/RS_{NOR}$, therefore $RS_{NOR} = PV2/PV1 = MR_{NOR}$ (ideally), and

$PV1 = PV2 \times RS_{INV}$, therefore $RS_{INV} = PV1/PV2 = MR_{INV}$ (ideally),

where PV1 = Process Variable (control loop in loop 1)
PV2 = Uncontrolled Process Variable (ratio station in loop 2)
RS_{NOR} = Normal Ratio Setpoint
RS_{INV} = Inverse Ratio Setpoint
MR_{NOR} = Normal Measured Ratio
and MR_{INV} = Inverse Measured Ratio.

4 ALARM OUTPUTS

The digital outputs associated with alarm conditions (terminals 20, 21, and 30, 31) are described in Appendix A, §6.

Parameter index

PROCESS CONTROLLER REFERENCE MANUAL & USER GUIDE

Symbols

A

B

C

D

J

K

L

M

N

O

P

Q

R

S

T