Model 392

Continuous-trace circular-chart recorder

Controller and Setpoint Generator Manual

invensys
EUROTHERM

CONTROLLER AND SETPOINT GENERATOR MANUAL

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(Continued)

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CONTROLLER AND SETPOINT GENERATOR

CONFIGURATION AND OPERATION

1 INTRODUCTION

This manual is intended as a supplement to the Installation and Operation manual supplied with the recorder, and explains the connection, configuration and operation of the loop controller and the setpoint generator (SPG). All information and warnings from the above manual must be observed.

Configuration of channels, alarms, totalisers etc. should be carried out before control configuration is started.

2 INSTALLATION

The loop controller and SPG require the fitting of a retransmission card (used for CAT control outputs and for contact inputs), and / or a relay output card (DAT). For current design instruments, these boards are recognised by the recorder, and the only hardware set up is to define retransmission outputs as Voltage or Current.

On previous versions of the boards, it was also necessary to set links to define whether the board was board one or board two. For convenience, all these links are shown in figure 2, below. A fuller description appears in the Installation and Operation manual supplied with the recorder.

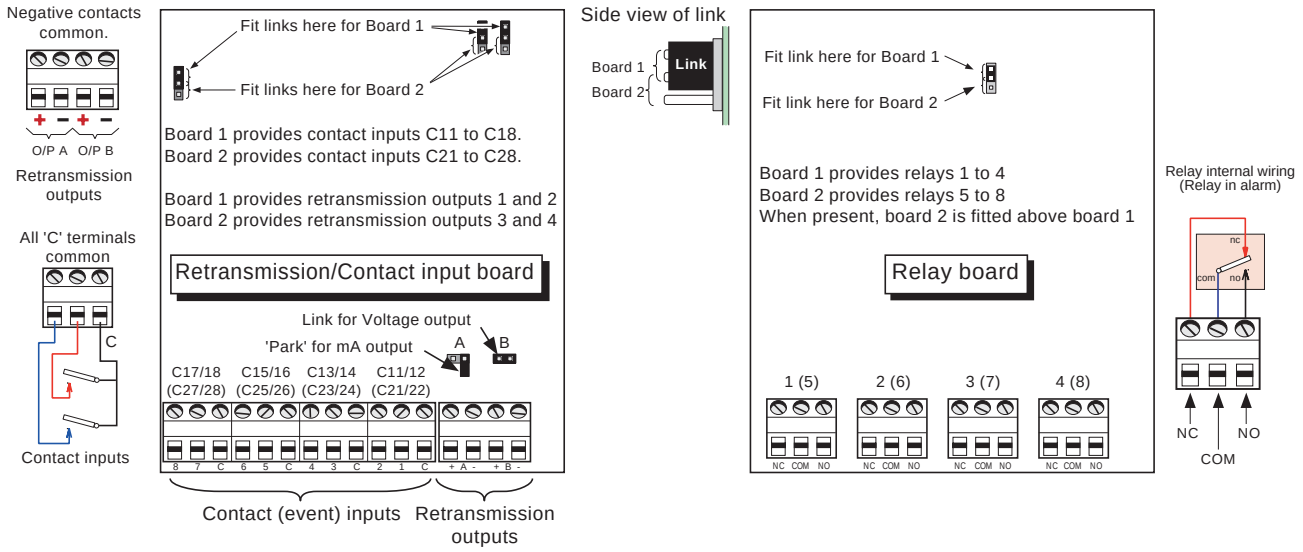

Figure 2 Hardware configuration for option boards

3 CONTROL OVERVIEW

3.1 OUTPUT TYPES

There are two output types available, *viz* Current adjusting (CAT) and Duration Adjusting (DAT).

CAT outputs take the form of a 0 to 20 or 4 to 20 mA signal (as configured) from the retransmission board, and are used to drive elements such as valves

DAT outputs take the form of a relay contact closure commonly used to drive heaters/coolers etc. The output value is converted to a % of cycle rate. For example, a one-minute cycle rate with an output value of 25% means that the relay will close for 15 seconds, and open for 45 seconds.

Each loop can have a single or dual (Duplex) output.

Duplex outputs can be both CAT, both DAT, or one of each, depending on the type of load being driven. Duplex outputs involve driving two physical outputs from one control loop. The output value is generally set with ranges of -100% to +100%, allowing the controller to maintain an output resolution of 0.1% over the full 200% output span.

Figure 3.1 shows how duplex outputs can be scaled to overlap (both outputs are active near zero for more precise control). Also shown is the setting of a deadband between the two outputs by scaling the low ends away from zero.

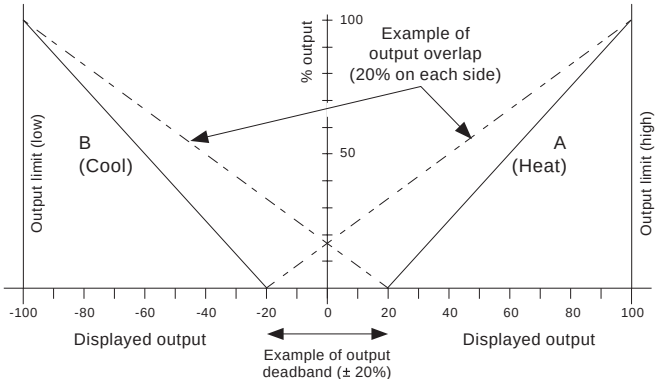

Figure 3.1 Duplex Operation

3.2 PID ALGORITHM

The control algorithm used is a classic three-action PID scheme with enhancements. Figure 3.2 shows the structure of the two loops. See also Annex A for a more detailed discussion of PID.

3.2.1 PID Definitions

BUMPLESS TRANSFER

The controller output remains stable after a transfer from manual to automatic, providing there is a non-zero reset tuning parameter (i.e. the integrator is not turned off). Transfer from auto to manual sets the manual output value in the settings menu (section 5.2) to the current automatic output value, as the transfer takes place.

ANTI-RESET WINDUP

The integration of the 'I' term stops whenever the output value reaches the low or high programmed output limits.

3.2 PID ALGORITHM (Cont.)

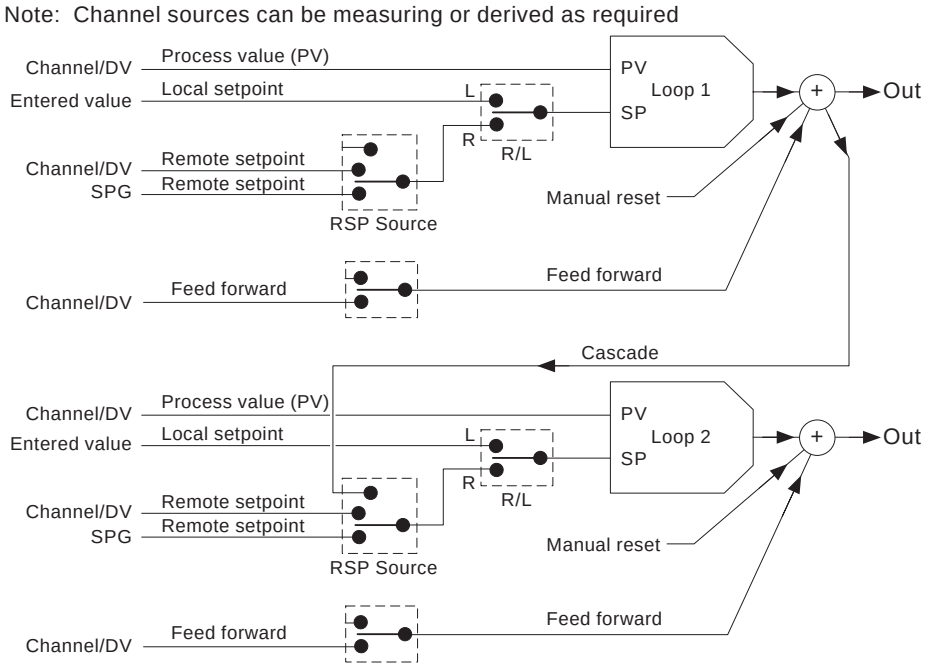

Figure 3.2 Loop structure

3.2.1 PID DEFINITIONS (Cont.)

CUTBACK

Cutback is a mechanism which helps to balance a process, at its operating point, quickly from start-up conditions. It does this by causing the 'I' term integrator to be set at its normal operating level faster than at the rate dictated by the selected reset time. This allows a fast start up even when a long reset time (for slow processes) has been configured. It also helps to eliminate 'overshoot' at start up. Cutback operates as follows:

1. The basic PID control settings cause the output value to reach one of the output limits (this is normal during start up)
2. Cutback is activated if the value of the deviation exceeds the configured cutback setting. Once cutback is activated, the output stays at its extreme value until the deviation falls below the cutback setting. This happens even if the normal PID control would decrease the output earlier.
3. When the cutback setting is reached, and cutback deactivated, the controller is put through a bumpless transfer operation, using the extreme output value. This causes the 'I' term to be initialised at the level:

   I = (extreme o/p) - (new 'P' term) - (new 'D' term).

   The result of this is that the 'I' term is set very close to the level at which it normally operates, without it having had to ramp there under the constraints of the configured reset time.

There are two cutback settings, one for positive deviations (Cutback high), the other for negative deviations (Cutback low). Normally, the optimum settings for these parameters are:

$$\text{Cutback high} = \frac{\text{Proportional band}}{100} \times \text{loop span} \qquad \text{Cutback low} = \pm \frac{\text{Proportional band}}{100} \times \text{loop span}$$

Cutback settings can, however, be widened (when a second time constant is involved) or turned off (during configuration).

3.2.1 PID DEFINITIONS (Cont.)

FEED FORWARD

Each loop can have an input channel, a derived channel or a derived variable value as a feed forward signal, for use with the bumpless transfer algorithm. Feed forward is not used during manual operation.

Feed forward is applied directly to the loop output and is scaled at 0 to 100% to work with the loop output of 0 to 100%.

REMOTE SETPOINT

Each loop will accept a remote setpoint value from a setpoint generator (trace 1 or trace 2), an input or derived channel, a derived variable (DV) value or (for loop 2) from the output of loop 1. In the latter case, the control loops are said to be in Cascade.

Notes:
1. If the remote setpoint for a loop is switched off, the R/L (Remote/Local) key will not function.
2. If a channel is used as the source, it should be ensured that that channel is not also selected as a loop PV input, nor as a remote setpoint for another loop.
3. The scaling of a remote setpoint channel must be in the same units as those of the channel used for the loop PV.

CASCADE

If the remote setpoint source for loop 2 is selected as controller 1, the two loops are automatically placed into a Cascade configuration (e.g. figure 3.2.1). In such a case:

1. The auto/manual controls of the two loops are linked. If loop 2 is placed in manual mode, then loop 1 is forced into manual mode. (This prevents loop 1 experiencing a large deviation when loop 2 output affects the process value.)
2. When both loops are in manual mode, the output of loop 1 is forced to track the process value of loop 2, thus keeping the loop 2 deviation at zero. When Loop 2 is returned to automatic, the transfer takes place at balance, thus causing the minimum disturbance to the process. Loop 1 is then returned to automatic control.
3. Since the cascade configuration causes loop 1 output to follow the loop 2 PV, the loop 1 output cannot be adjusted even when it is in manual mode, unless loop 2 is in automatic mode.

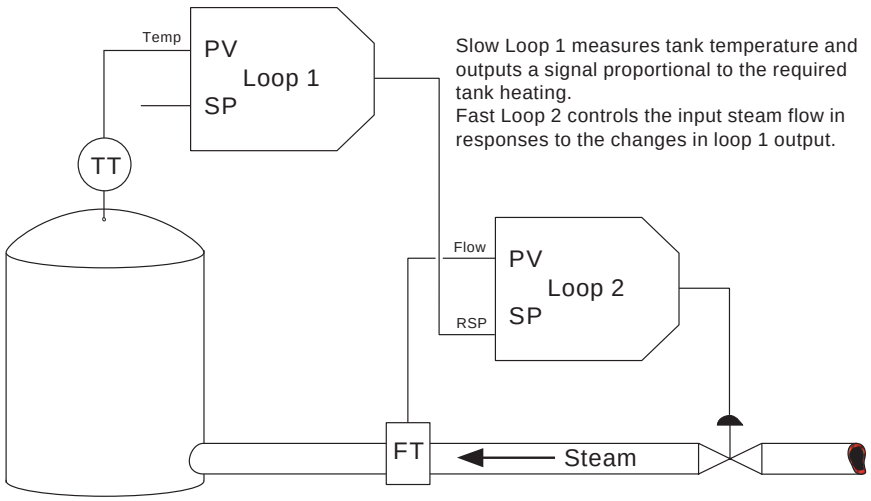

Figure 3.2.1 Cascade connection example

3.2.1 PID DEFINITIONS (Cont.)

SETPOINT TRACKING

When enabled, then if the loop is in manual mode, the local setpoint for the loop follows the process value. This helps to ensure that the transfer from manual to automatic is done at balance.

Notes:
1. The local setpoint can be adjusted only when the relevant loop is in automatic mode
2. Setpoint tracking is enabled/disabled independently for each loop

RATE SOURCE

The rate term source can be either the Process Value (PV) or the Deviation. The taking of the derivative of the PV helps to avoid large rate terms when setpoint changes are made. Taking the derivative of the Deviation can be more effective when the setpoint is following a programmed input.

ADJUSTABLE LOOP SPAN

The span of each loop is configurable, making the loop span independent of both the input span and the chart span. Changes can thus be made to the PV span without such changes affecting the loop tuning.

3.3 TUNING PARAMETERS

3.3.1 Tuning parameter definitions

PROPORTIONAL BAND

The percentage of loop span that the Deviation must equal to cause the Proportional term to change by 100%. See Annex A for more details.

RESET TIME

The output due to the integral term reaches 100% when the deviation value has been equal to the proportional band for the Reset Time. Reset Time is usually set to the fundamental time constant of the Process. See Annex A for more details.

RATE TIME

If $\frac{\text{d Dev}}{\text{dt}} = \frac{\text{Proportional band}}{\text{Rate time}}$ (or $\frac{\text{d PV}}{\text{dt}} = \frac{\text{Proportional band}}{\text{Rate time}}$), then the derivative term will have changed by 100%,

where $\frac{\text{d Dev}}{\text{dt}}$ is the rate of change of Deviation Value, and $\frac{\text{d PV}}{\text{dt}}$ is the rate of change of Process Value.

The Derivative term helps to compensate for the secondary dominant time constant of the process. It initially opposes the ‘P’ and ‘I’ terms. See Annex A for more details.

DEVIATION VALUE

Deviation value is the difference between the Process Value and the Setpoint value : Dev = PV - SP

CONTROL DIRECTION

Direct acting controllers increase output if the Deviation Value is positive, and decrease output if the Deviation value is negative. Used with exothermic processes.

Reverse acting controllers increase output if the Deviation Value is negative, and decrease output if the Deviation value is positive. Used with endothermic processes.

PRIMARY/SECONDARY TUNING

These are two sets of tuning constants (Proportional band, Reset time, Rate time) available for use with each loop, called Primary and Secondary. If Secondary is configured ‘Off’, no secondary values need to be entered, and the process uses only the Primary set of constants.

Secondary tuning constants are used in cases where it is convenient to have one set of constants to provide course control when the process value lies far from the setpoint, and another set of constants to provide fine control at or near the setpoint. Alternatively, (case 3, below), primary and secondary tuning can be used, for example, when control dynamics vary widely for the two sides of a Duplex heat/cool process

The secondary set can be invoked by

1. PV, SP or Deviation reaching/exceeding a specified value. In such cases, both high and low limits must be entered. Primary tuning is used within these limits; Secondary tuning outside these limits.
2. An action equation (see installation and Operation manual for details)
3. Output direction. In this case:
   a Primary tuning is used for any Single output
   b Primary tuning is used for positive Duplex outputs
   c Secondary tuning is used for negative Duplex outputs.

4 CONTROL LOOP OPERATION

4.1 CONTROL LOOP OPERATOR INTERFACE

The operator interface for loop 1 is shown in figure 4.1 below. The display for loop 2 is identical, except that the upper and lower lines are reversed. It is assumed that the user is familiar with the keys to the right of the display. If not, please refer to the Installation and Operation Manual as necessary.

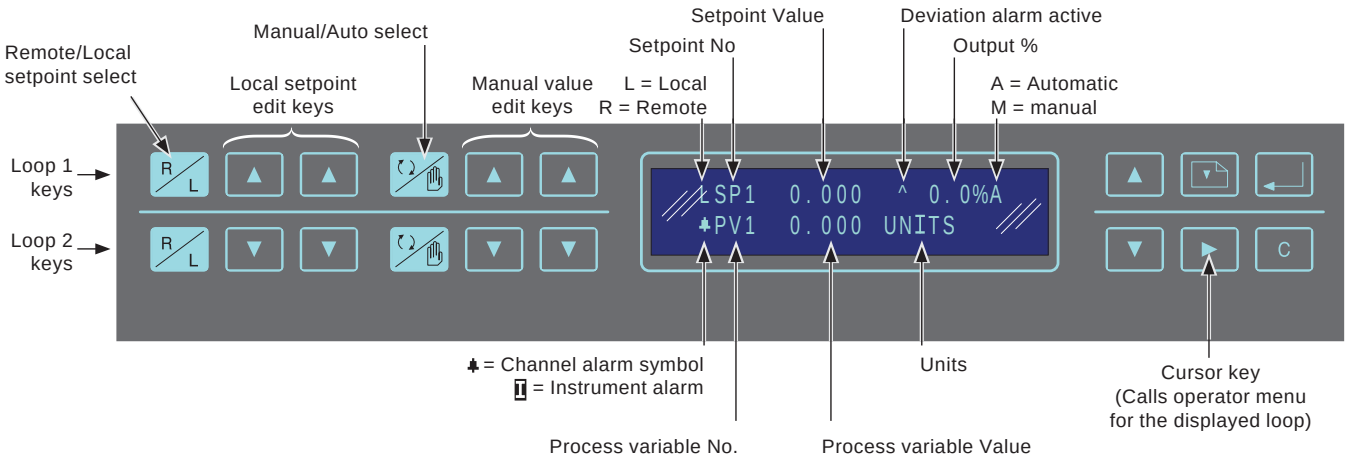

Figure 4.1 Control loop operator interface (Loop 1)

4.2 CONTROL LOOP OPERATOR MENUS

The loop displays, such as that depicted above, form part of the scroll sequence of the recorder background display, with Loop 1 appearing after input channel 1, and loop 2 appearing after input channel 2.

Touching any of the keys to the left of the display overrides the scroll sequence and immediately calls the Loop display for loop 1 (by touching one of the upper six keys), or for loop 2 (by touching one of the lower six keys). Once the required loop is displayed, and if access is permitted (Ctl Access on - section 5.8) then operating the cursor key calls the top level operator display for that loop.

4.2.1 Top level menu

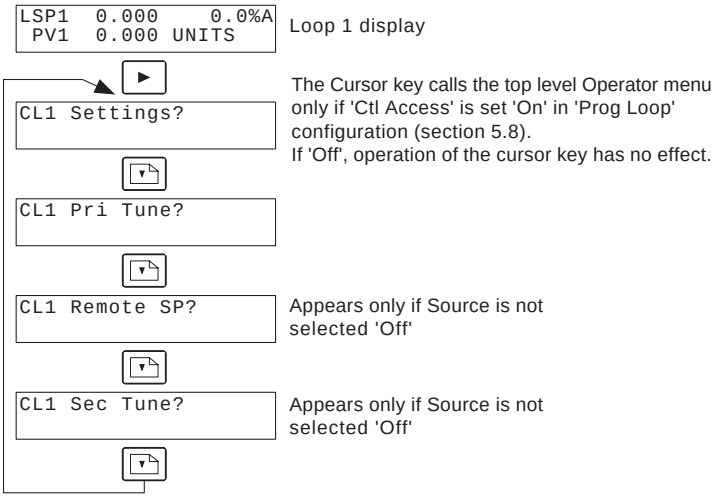

Figure 4.2.1 Top level Operator menu (Control loops)

4.2.2 Loop settings operator menu

Figure 4.2.2 shows the Loop Settings operator sub menu

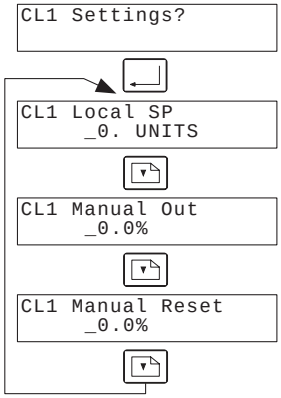

Figure 4.2.2 Settings Operator menu

CONFIGURABLE ITEMS

Local SP	Use the up/down/cursor keys of the right-hand keyboard, or the setpoint edit keys to enter a value for the local setpoint
Manual Out	Use the up/down/cursor keys of the right-hand keyboard, or the manual edit keys to enter a manual output value. Initially displays previous automatic value, when switching to manual.
Manual Reset	Use the up/down/cursor keys of the right-hand keyboard, or the manual edit keys to enter a manual reset value to be added, as a fixed percentage, to the manual or automatic output value.

4.2.3 Primary tune operator menu

Figure 4.2.3 shows the Primary Tune operator submenu

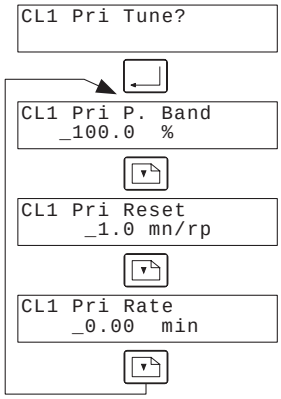

Figure 4.2.3 Primary Tune Operator menu

CONFIGURABLE ITEMS

Pri P.Band	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.1 and 2000 for the proportional band, representing gain settings from ×1000 to ×0.05.
Pri Reset	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.0 and 999.9 minutes per repeat. (0.00 = Reset off)
Pri Rate	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.00 and 99.99 minutes. (0.00 = Rate off)

4.2.4 Remote Setpoint (RSP) operator menu

Figure 4.2.4 shows the Remote Setpoint (RSP) operator sub menu

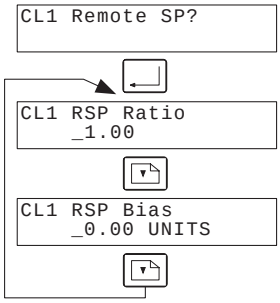

Figure 4.2.4 Remote Setpoint Operator menu

CONFIGURABLE ITEMS

RSP Ratio — Use the up/down/cursor keys of the right-hand keyboard to enter a value for Remote Setpoint ratio. Values <1 decrease the setpoint value; values >1 increase the setpoint value. RSP ratio (along with the RSP Bias, below) scales the remote setpoint value before it is used as a loop setpoint.

Note: The RSP ratio affects the setpoint generator when selected as a remote setpoint. RSP Ratio should be left with a value of 1 when not in use

RSP bias — Use the up/down/cursor keys of the right-hand keyboard to enter a value for Remote Setpoint bias. This value is added to or subtracted from the RSP value. RSP bias (along with the RSP ratio, above) scales the remote setpoint value before it is used as a loop setpoint.

4.2.5 Secondary tuning operator menu

Figure 4.2.5 shows the operator submenu for Secondary tuning.

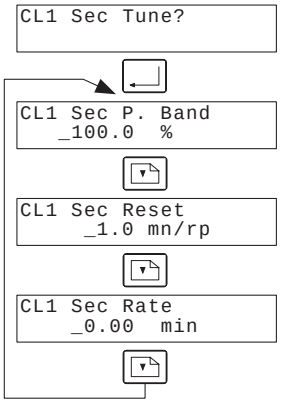

Figure 4.2.5 Secondary Tune Operator menu

CONFIGURABLE ITEMS

Sec P.Band — Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.1 and 2000 for the proportional band, representing gain settings from ×1000 to ×0.05.

Sec Reset — Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.0 and 999.9 minutes per repeat. (0.00 = Reset off)

Sec Rate — Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.00 and 99.99 minutes. (0.00 = Rate off)

5 CONTROL LOOP CONFIGURATION

It is assumed that the user knows how to gain entry to the top level Controller Menu, and is familiar with the concept and use of action equations. If necessary, the Installation and Operation Manual supplied with the recorder should be referred to.

5.1 TOP LEVEL CONTROLLER MENU

Figure 5.1 shows the top level menu and gives guidance as to where to find descriptions of the various sub menus.

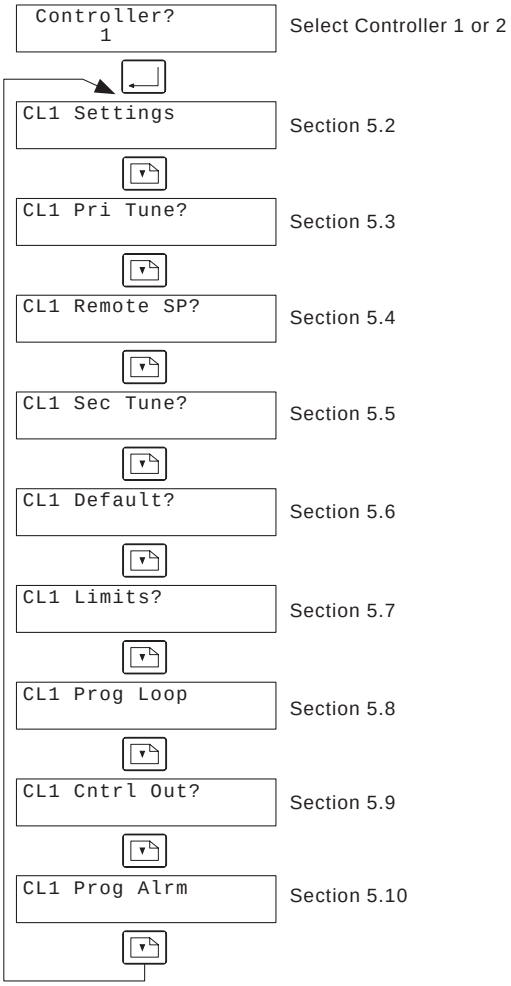

Figure 5.1 Top level controller configuration menu

5.1.1 Submenus

Settings	Entry of Local Setpoint, Manual Output and Manual Reset values. See section 5.2
Pri Tune	Entry of Primary Proportional, Integral and Derivative constants. See section 5.3
Sec Tune	Entry of Secondary Proportional, Integral and Derivative constants. Also action equation and enable/ disable selection. See section 5.5
Remote SP	Used to set the remote setpoint ratio and bias. Also to enable/disable Remote Setpoint. See section 5.4
Default	Choose 1 out of 10 default configuration templates - See section 5.6
Limits	Entry of min. and max. values allowed for measured and calculated variables. See section 5.7
Prog Loop	Entry of RSP choices, Secondary tuning selections and action equations for Manual output and Local setpoint. See section 5.8
Cntrl Out	Set Control direction, DAT cycle rates, DAT limits and Slew rate. See section 5.9.
Prog Alrm	Set up deviation alarm for the program. See section 5.10.

5.2 SETTINGS CONFIGURATION

Figure 5.2 shows the Settings sub menu

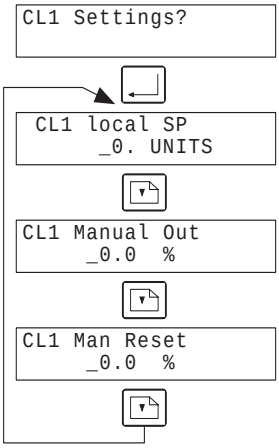

Figure 5.2 Settings configuration menu structure

5.2.1 Configurable items

Local SP	Use up/down/cursor keys or the Local setpoint edit keys (figure 4.1) to enter required values
Manual out	When in Manual operation, the Manual Output value can be changed using the up/down/cursor keys or the Manual value edit keys (figure 4.1)
Man Reset	Use the up/down/cursor keys to enter a value for Manual Reset. This is a fixed % value to be added to the automatic or manual output

5.3 PRIMARY TUNING CONFIGURATION

Figure 5.3 shows the Primary tuning sub-menu

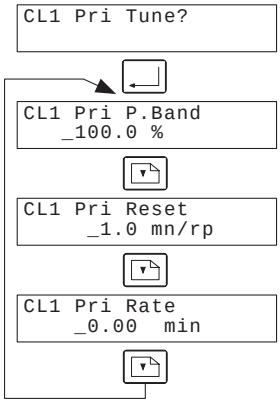

Figure 5.3 Primary Tuning configuration menu structure

5.3.1 Configurable items

Pri P.Band	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.1 and 2000 for the proportional band, representing gain settings from ×1000 to ×0.05.
Pri Reset	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.0 and 999.9 minutes per repeat. (0.00 = Reset off)
Pri Rate	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.00 and 99.99 minutes. (0.00 = Rate off)

5.4 REMOTE SP CONFIGURATION

Figure 5.4 shows the Remote Setpoint (RSP) configuration sub-menu

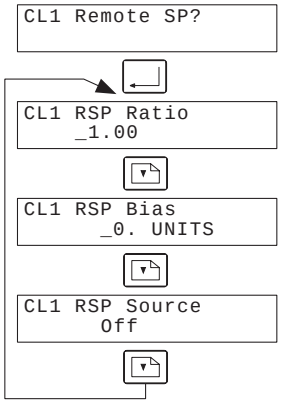

Figure 5.4 Remote setpoint configuration menu structure

5.4.1 Configurable items

RSP Ratio — Use the up/down/cursor keys of the right-hand keyboard to enter a value for Remote Setpoint ratio. Values <1 decrease the setpoint value; values >1 increase the setpoint value. RSP ratio (along with the RSP Bias, below) scales the remote setpoint value before it is used as a loop setpoint.

Note: The RSP ratio affects the setpoint generator when selected as a remote setpoint. RSP Ratio should be left with a value of 1 when not in use

RSP Bias — Use the up/down/cursor keys of the right-hand keyboard to enter a value for Remote Setpoint bias. This value is added to or subtracted from the RSP value. RSP bias (along with the RSP ratio, above) scales the remote setpoint value before it is used as a loop setpoint.

RSP Source — Used to select the signal to be used as an RSP source. This source can be any input or derived channel, a derived variable value, or an SPG trace, if the setpoint generator option is fitted. Loop 2 can also have the output of controller 1 as an RSP source, setting the two controllers into Cascade configuration.

5.5 SECONDARY TUNING CONFIGURATION

Figure 5.5 shows the secondary tuning configuration sub-menu.

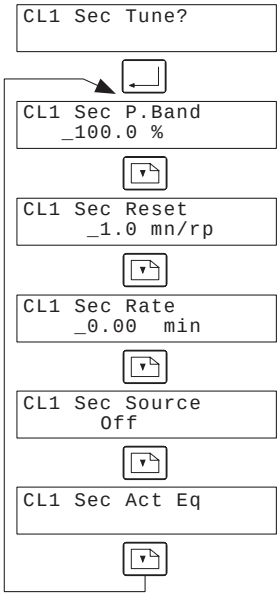

Figure 5.5 Secondary tuning configuration menu

5.5.1 Configurable items

Sec P.Band	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.1 and 2000 for the proportional band, representing gain settings from ×1000 to ×0.05.
Sec Reset	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.0 and 999.9 minutes per repeat. (0.00 = Reset off)
Sec Rate	Use the up/down/cursor keys of the right-hand keyboard to enter a value of between 0.00 and 99.99 minutes. (0.00 = Rate off)
Sec Source	Used to select the signal to be used as a Secondary tuning source. This source can be any input or derived channel, a derived variable value, or an SPG trace, if the setpoint generator option is fitted. If 'Sign' is selected it is possible, in a duplex system, to configure the Primary tuning to be active during positive output and Secondary tuning to be active during negative output. See section 3.3 for more details.
Sec Act Eq	Allows one or more triggers to be entered which, when any one or more is active cause the secondary tuning parameter set to become active. See the Installation and operation manual for details of Action equation entry.

5.6 DEFAULT CONFIGURATIONS

There are 10 'template' configurations available for selection, as follows:

1	Single	CAT	Reverse acting
2	Single	DAT	Reverse acting
3	Single	CAT	Direct acting
4	Single	DAT	Direct acting
5	Duplex	CAT	Reverse acting
6	Duplex	DAT	Reverse acting
7	Duplex	CAT	Direct acting
8	Duplex	DAT	Direct acting
9	Cascade	CAT	Reverse acting (2 loops)
10	Cascade	DAT	Reverse acting (2 loops)

Figure 5.6 below shows these configurations in graphical form. Section 5.6.1 details default parameter values.

5.6 DEFAULT CONFIGURATIONS (Cont.)

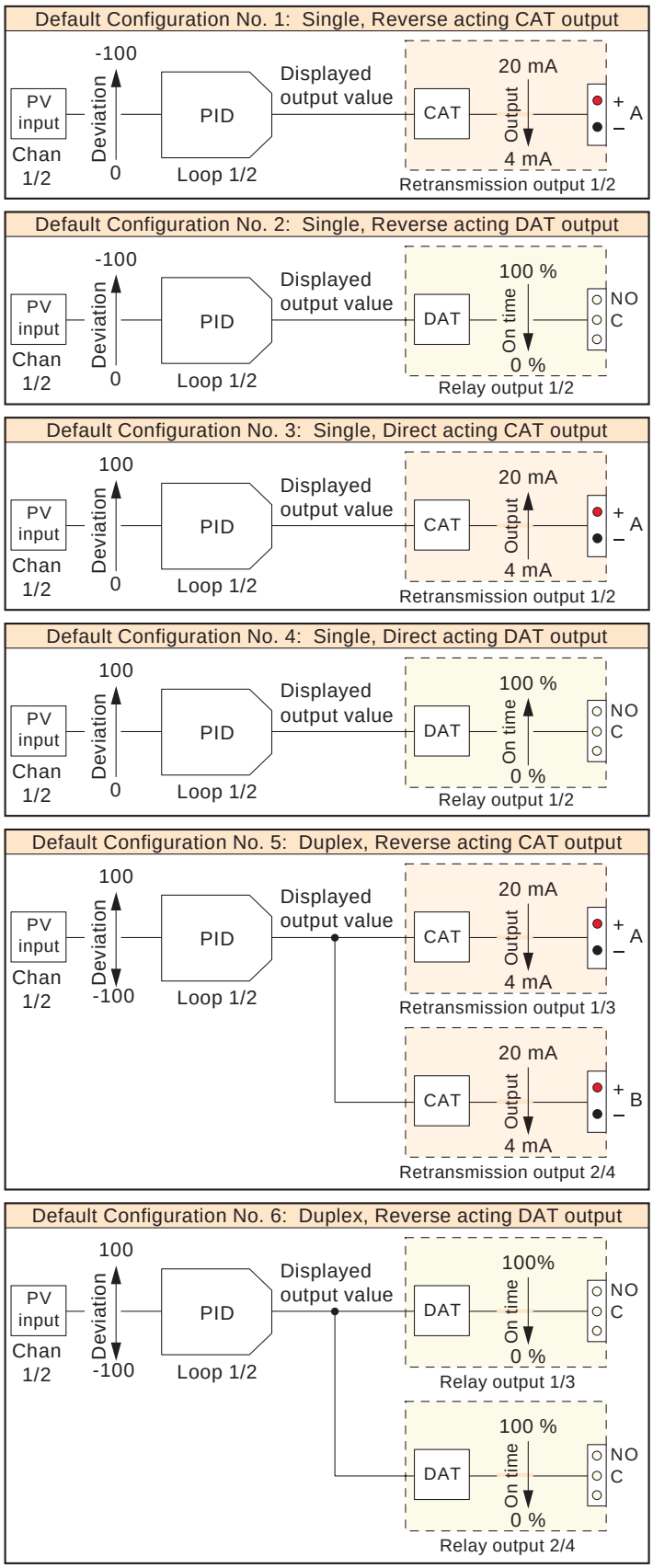

Figure 5.6 sheet 1. Default configurations 1 to 6

5.6 DEFAULT CONFIGURATIONS (Cont.)

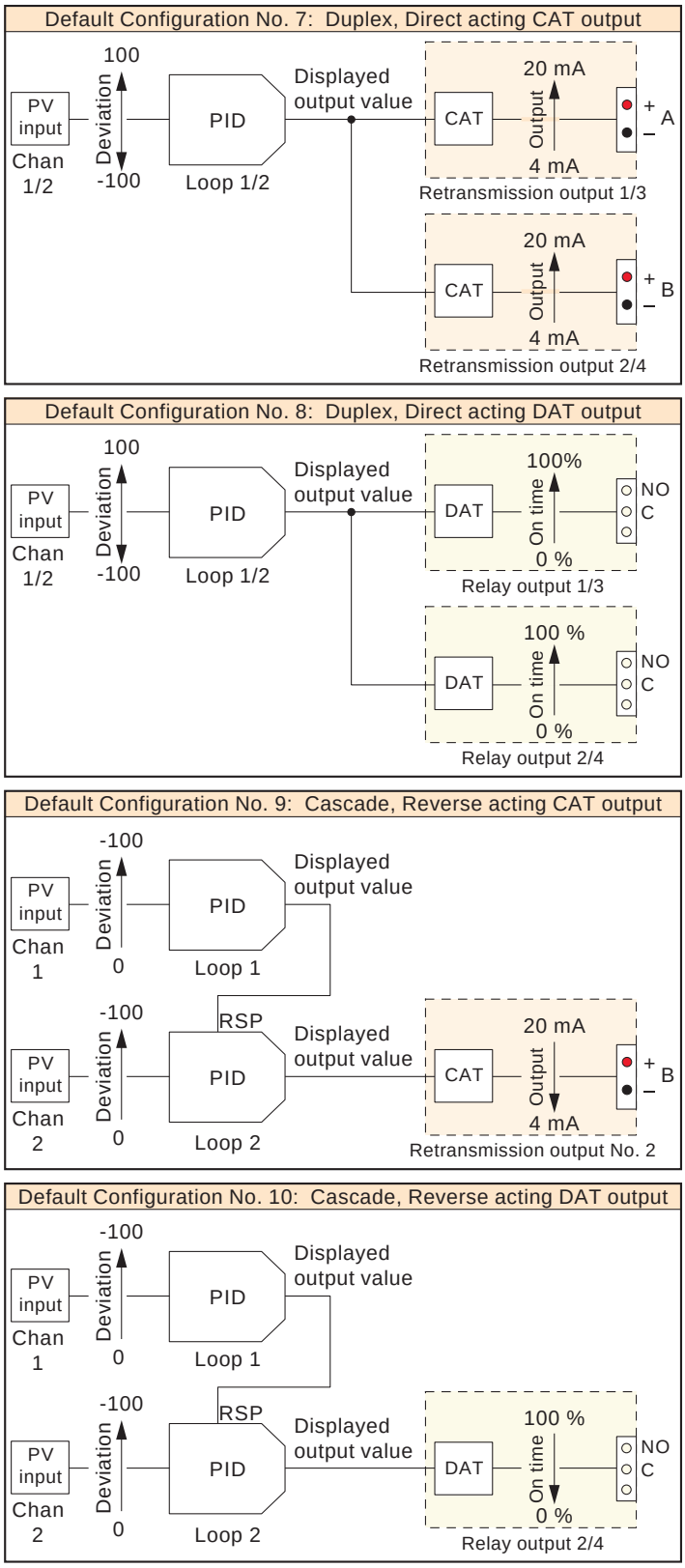

Figure 5.6 sheet 2. Default configurations 7 to 10

5.6.1 Default parameter values

The following list is generalised, and some items in it (e.g. 'Direction') depend on the actual default configuration selected.

Notes:
1 When a default configuration is selected, output choices are automatically made. There can be up to four retransmission outputs fitted to the recorder. Control outputs must be included in this maximum. Control loops ordered as CAT will automatically be supplied with the required number of retransmission outputs.
2. Control loops ordered as DAT will automatically be supplied with the required number of relay outputs.
3. Further retransmission and relay outputs must be ordered separately

Local SP	0.00
Manual Out	0.0%
Man Reset	0.0%
Pri P Band	100%
Pri Reset	1.0 min/repeat
Pri Rate	0.00 min
RSP Ratio	1.00
RSP Bias	0.00
RSP Source	Ch 3 for loop1; Ch 4 for loop 2
Sec P Band	100%
Sec Reset	1.0 min/repeat
Sec Rate	0.00 min
Sec Source	Off
Input low	Ch1 for loop 1; Ch 2 for loop 2
Input high	Ch1 for loop 1; Ch 2 for loop 2
SP low	0.00
SP High	100.0
Output lo	0.00
Output Hi	100.0
Cutback Lo	-100.0
Cutback Hi	100.0
Sec Trip Lo	Ch1 for loop 1; Ch 2 for loop 2
Sec Trip Hi	Ch1 for loop 1; Ch 2 for loop 2
FForwrd Lo	0.00
FForwd High	100.0
Rate Mode	Dev
SP Tracking	Off
PV Source	Ch1 for loop 1; Ch 2 for loop 2
FFwd Src	Off
Cutback	Off
Control Acc	On
Man Act Eq	None
Local Act Eq	None

Direction	Reverse
Out Type	Single
A cyc Rate	10 sec/c
B cyc Rate	10 sec/c
DAT A Low	0.00%
DAT A High	100%
DAT B Low	0.00%
DAT B High	-100%
Slew Rate	0% / min
Retrans 1 Source	CL1 (Single or Duplex) CL2 (Cascade)
Retrans 1 Type	4 to 20 mA
Retrans 1 Low	0.0
Retrans 1 High	100.0
Retrans 2 Source	CL2 (Single) CL1 (Duplex)
Retrans 2 Type	4 to 20 mA
Retrans 2 Low	0.0
Retrans 2 High	100.0
Retrans 3 Source	CL2 (Duplex)
Retrans 3 Type	4 to 20 mA
Retrans 3 Low	0.0
Retrans 3 High	100.0
Retrans 4 Source	CL2 (Duplex)
Retrans 4 Type	4 to 20
Retrans 4 Low	0.00
Retrans 4 High	-100.0
Relay 1 Type	DAT
Relay 1 Source	CL1
Relay 2 Type	DAT
Relay 2 Source	CL2 (Single); CL1 (Duplex)
Relay 3 Type	DAT
Relay 3 Source	CL2 (Duplex)
Relay 4 Type	DAT
Relay 4 Source	CL2

5.7 LIMITS CONFIGURATION

Figure 5.7 shows the limits configuration submenu.

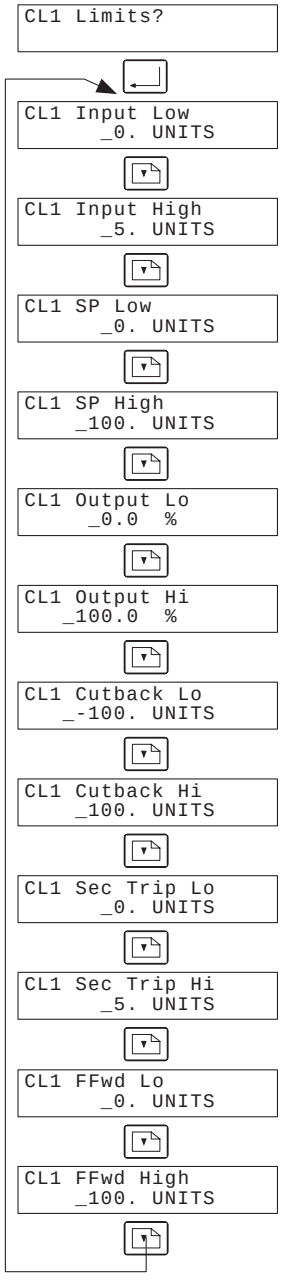

Figure 5.7 Limits configuration menu

5.7.1 Configurable items

Input Low/High	For gain calculation only. The proportional band is based on these two values, rather than on the input channel range, though it is normal to set the channel and control values equal. The controller input is not limited to these values. The ratio between the Input Channel and Loop spans acts as a multiplier for the gain. For example, if the Control Input Low/High span is twice the Channel Input span, the loop gain is halved. The up/down arrow and cursor keys are used to enter the required values.
SP Low/High	These settings can be used to restrict setpoint changes to a specific operating range. The up/down arrow and cursor keys are used to enter the required values.
Output Lo/Hi	These settings can be used to restrict the current loop output to a specific range. The up/down arrow and cursor keys are used to enter the required values.
Cutback Lo/Hi	It is normal for only one Cutback trip point to be set, with the other limit at an extreme value so as to make it non-active. Cutback is activated in the Program Loop menu (section 5.8). The up/down arrow and cursor keys are used to enter the required values.
Sec Trip Lo/Hi	If secondary tuning is enabled in the Program Loop menu, then the secondary tuning parameters become active when the value rises above the Sec Trip hi value or below the Sec Trip Lo value. There is a fixed 2% hysteresis value applied, in order to prevent nuisance tripping when the value is 'hovering' near the trip points. The up/down arrow and cursor keys are used to enter the required values.
FFwd Lo/High	If Feed forward is enabled in the Program Loop menu (section 5.8), the 0 to 100% output value is scaled here. The up/down arrow and cursor keys are used to enter the required values. Example: If the feed forward signal is applied to an input channel which has Input High/Low settings of 0 and 100, and the feed forward lo/high settings are 0 and 400, then the feed forward component at the output cannot exceed 25%.

5.8 PROGRAM LOOP CONFIGURATION

Figure 5.8 shows the program loop configuration submenu.

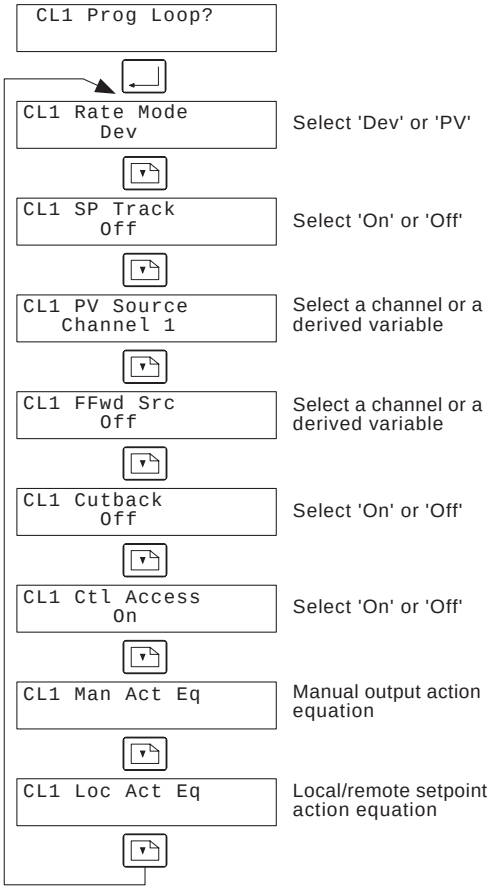

Figure 5.8 Program loop configuration menu

5.8.1 Configurable items

Rate Mode	Use the up/down arrow/cursor keys to select the rate (derivative) action based on the changes in the Deviation or process value.
SP Track	Use the up/down arrow keys to enable/disable setpoint tracking.
PV Source	Use the up/down arrow keys to select process value source as input channel 1 to 4, Derived channels 5 or 6 or derived variable value 1 to 9.
FFwd Source	Use the up/down arrow keys to select the feed forward source as input channel 1 to 4, Derived channel 5 or 6 or derived variable value 1 to 9. Selecting 'Off' disables feed forward.
Cutback	Use the up/down arrow keys to enable/disable cutback
Ctl Access	Use the up/down arrow keys to enable/disable operator access to control settings. When set 'On', the Settings, Pri Tuning, Remote SP and secondary tuning menus can be accessed from the operator menu without a password being needed. When Off, these items do not appear in the Operator menu.
Man Act Eq	Allows one or more triggers to be entered, which, when active, force the control loop to Manual. See the installation and operation manual for details of Action Equations.
Loc Act Eq	Allows one or more triggers to be entered, which, when active, force the control loop from using a remote setpoint to using a local setpoint. See the installation and operation manual for details of Action Equations.

5.9 OUTPUT CONFIGURATION

Figure 5.9 shows the output configuration submenu.

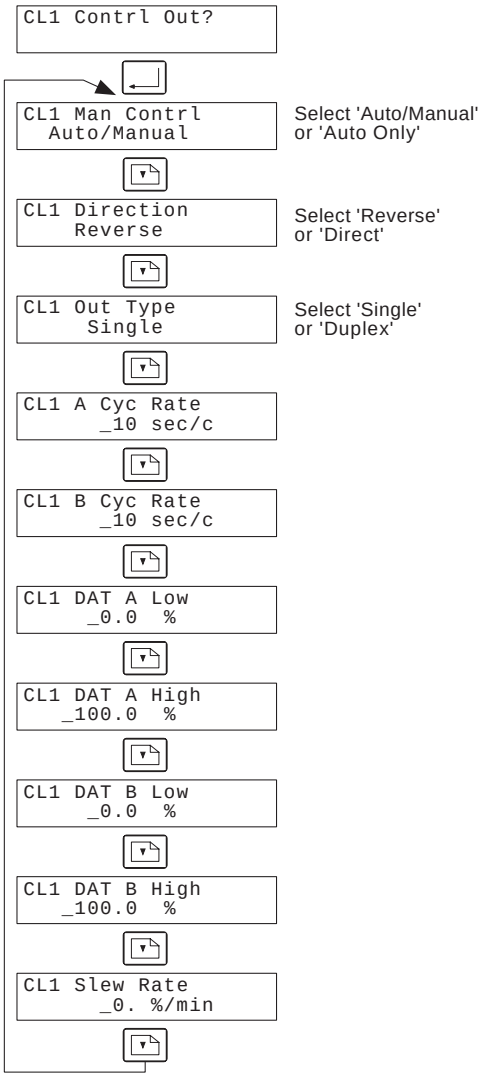

Figure 5.9 Output configuration menu

5.9.1 Configurable items

Man Contrl — Select ‘Auto only’ or ‘Auto/Manual’. If set to ‘Auto only’, the loop cannot be set to manual by action equation or from the keypad.

CAUTION

After power loss, the recorder initialises to Auto mode. The password is required before the above ‘Man Contrl’ selection can be set to Auto/Manual, allowing the recorder to be switched to manual mode.

Direction — Select Reverse or Direct. Reverse is used for processes (e.g. heating) in which the input is required to decrease as the process value (PV) exceeds the setpoint (SP). Direct is used for processes (e.g. cooling) where the input is required to increase as the PV exceeds the SP.

Out Type — Select Single or Duplex. A single output provides one CAT or DAT connection which can operate from 0 to 100% of its scaled output values. A Duplex output provides a loop with two CAT/DAT connections normally used where two different devices are to be connected to the loop output which usually operates from -100 to +100%.

A/B Cyc Rate — A DAT output operates by turning an output relay on and off for periods of time based on the output signal from the control loop. For example, a 1 minute cycle with 25% output will be on for 15 seconds, then off for 45 seconds and so on. The cycle rate can be set to suit the type of element connected to the output - for example, a large resistance heater requires a long cycle time in order to react during its ‘On’ time. The ‘A’ and ‘B’ sides of a Duplex DAT output are set separately.

A/B Low/High — DAT outputs can be scaled to respond to the 0 to 100% controller output as required. For example an unscaled output would have a low setting of 0% and a high setting of 100% and would track the controller output exactly. A typical scaling example would be if the output went from 25% to 75% in response to the controller output of 0% to 100%. The ‘A’ and ‘B’ sides of a Duplex DAT output are scaled separately.

Slew Rate — Used to slow down the controller output signal for elements that would be damaged by too fast a turn-on rate. An entry of 20% per minute, means that an unscaled output takes 5 minutes to reach 100%. An entry of 0% turns ‘Slew Rate’ off.

5.10 PROGRAMMABLE ALARM CONFIGURATION

Figure 5.10 shows the Programmable (deviation) alarm sub-menu

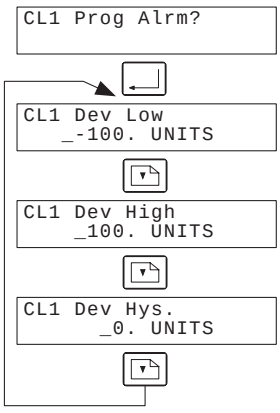

Figure 5.10 Programmable alarm configuration menu

5.10.1 Configurable items

Dev Low/Dev High — Use the up/down arrows and cursor key to enter low and high values for the deviation alarm. Internal triggers D1L, D1H, D2L and D2H are generated if the deviation falls below the Low value or rises above the High value, for loops 1 and 2 respectively. These triggers can be used as action equation sources for operating relays etc.

Dev, Hys — Use the up/down arrows and cursor key to enter a hysteresis value for the alarm to prevent nuisance triggering when the deviation value is hovering near one of the trigger points.

6 SETPOINT GENERATOR (SPG)

This option provides a precise, digital replacement for cam programmers. The SPG provides two analogue traces on a common time base. These traces can be initialised at the value of any recorder channel or at a fixed value. Eight event outputs are available in each segment.

6.1 SPG OVERVIEW

The setpoint programmer works like a cam programmer. There are two programmable wheels on the cam drive to produce two traces on a common time base. Holding one trace holds them both; resetting one trace resets them both. The On/Off state of each trigger can be set for each segment. This is analogous to there being eight tabs on each cam to make/break eight switches. When the program is held, the event status stops changing. The eight outputs (SP1 to SP8) can be used as action equation sources.

6.1.1 Recipes and segments

A recipe (or program) consists of a set of Segments and the means of sequencing them. For this recorder, the maximum number of segments in a recipe is 20. The recorder can store a maximum of four recipes, only one of which may be active at any one time. All four recipes start from a common set of initial conditions.

The basic unit of the SPG is the ‘segment’. The segment contains target values for the traces, event states etc. one segment for both traces is active at any given time. Any change in the operation of the SPG requires a transition to another segment.

There are four types of segment: Target segments, Cycle segments, End segments and Repeat segments.

TARGET SEGMENTS

A Target segment consists of a target value for each trace, a segment Duration value, the on/off status for the eight event outputs. The Target value is in the same units as those of the control loop process value, and is the value that the segment reaches by the end of its Duration.

Duration may be set between 0 and 9999 minutes (166 hours). For ramps longer than this, multiple segments must be used and the intermediate target values calculated by the user. Zero duration segments are used to provide step changes in Setpoint. Event outputs are not available with zero duration segments.

Notes:
1. There is no entry for ramp rate, as this is calculated by the SPG.
2. There is no Soak time entry, as a ‘soak’ is a segment with the target value set to the final value of the previous segment.

CYCLE SEGMENTS

A cycle segment is placed at a point in a recipe where it is desired to repeat a portion of that recipe. Cycle recipe segments contain a ‘Number of cycles’ count, and a ‘destination cycle segment number’. Cycle segments can be programmed to repeat up to 999 times. If further repeats are required, a second cycle segment can be placed in series.

Cycle segments must always cycle to a segment number less than the cycle segment number

Cycles can be ‘nested’ up to 5 deep. For example, if a cycle were defined from segment 10 to segment 2, with a nested cycle of segment 8 to segment 4, the sequence would be:
10, 9, 8, (7, 6, 5, 4), 7, 6, 5, 4, 3, 2

6.1.1 RECIPES AND SEGMENTS (Cont.)

END SEGMENTS

An end segment stops the recipe and displays the message: 'Done'

REPEAT SEGMENTS

A repeat segment causes the recipe to restart at a specified segment number. The segment should be placed immediately before the 'End' segment.

6.1.2 Elapsed time

The elapsed time is the sum of the durations of the segments so far. The value is reset to zero by 'Repeat' segments.

6.2 SPG OPERATION

6.2.1 SPG Operator displays

Figure 6.2.1a shows operator interface, with the normal SPG run display, and figure 6.2.1b just the SPG status display. These two displays are part of the normal scroll sequence described in the Installation and Operation Manual.

Note: The Elapsed Time indication on the bottom line of the status display reads 0 for times up to 1 minute, 1 for times between 1 and 2 minutes, and so on.

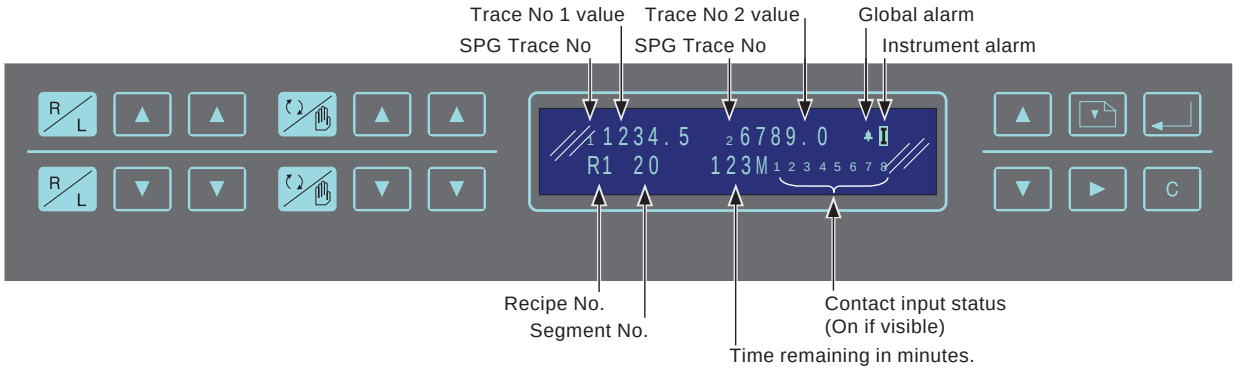

Figure 6.2.1a SPG Run display

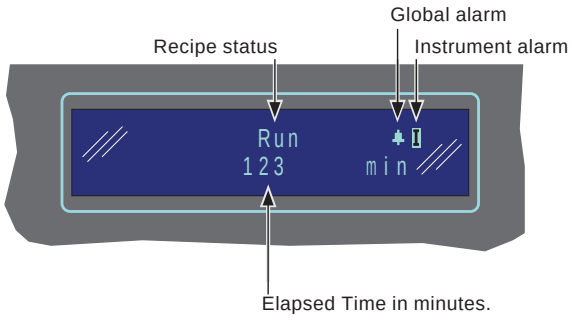

Figure 6.2.1b SPG Status display

6.2.2 SPG Operator menu

Figure 6.2.2 shows the SPG Operator menu which is accessed from either the Run display or the Status display, by operation of the right arrow (cursor) key.

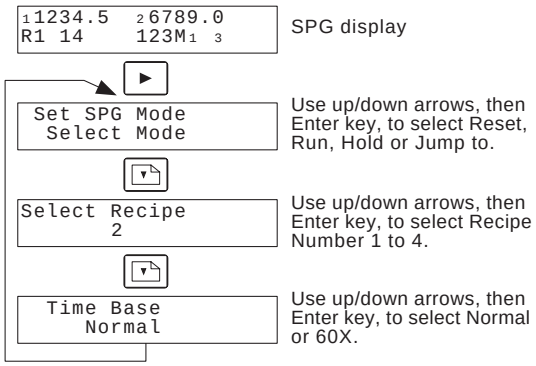

Figure 6.2.2 SPG Operator menu

OPERATOR ACCESSIBLE ITEMS

Set SPG Mode — Allows the user to select 'Run', 'Hold', 'Reset' or 'Jump to' as the operating mode.

- **Run mode** — The SPG starts at the values defined in the 'Setpoint Gen' menu and advances one segment at a time to the End segment. Each target segment starts at the final value of the preceding segment. Elapsed time is counted as the sum of all segments. When a cycle segment (with a non-zero cycle count) is encountered, both traces jump to the target segment defined in the Segment Type menu. The traces then ramp to the target value of the jumped-to segment in that segments duration time.
- **Hold mode** — The operation of the SPG can be paused by action equation, or by setting the SPG mode to 'Hold' from the Operator menu. Both traces stop; current values and elapsed time are held constant; events do not change state.
- **Reset mode** — When a reset is initiated by setting the SPG mode to 'Reset' in the Operator menu, the recipe goes into Hold at segment 1, or at the first segment with a non-zero duration (if segment 1 is of zero duration). Events are initialised as defined for this segment. All times are set to zero, and the recipe remains in Hold mode until started.
  A reset initiated by a contact closure is similar, but the recipe remains in Hold mode only until the contact closure is reopened.
- **Jump to** — When SPG mode is set to 'Jump to' both traces jump to the target segment defined in the Segment Type menu. The traces then ramp to the target value of the jumped-to segment in that segments duration time.

Select Recipe — Use the up/down arrow keys to select a recipe to run.

Time base — When set to 'Normal' in the SPG operator menu, the menu timing runs as configured.
When set to '60X', durations configured in minutes will act in seconds instead. Zero-duration segments will not show a segment number nor add to the elapsed time, even though they may take a second or two to execute.

7 SPG CONFIGURATION

7.1 INTRODUCTION

This allows the user to edit the four available setpoint generator recipes. Figure 7.1, below, shows the top level Configuration menu.

Section 7.2 describes the Edit recipe configuration, which allows segments to edited, inserted or deleted.
Section 7.3 describes trace configuration, which allows the initial source to be entered for each trace, and the decimal point position to be entered.
Section 7.4 describes how to copy a recipe.

The final two entries in the top level configuration menu are the Reset and Hold action equations for the segment. Action equations are described in the Installation and Operation manual.

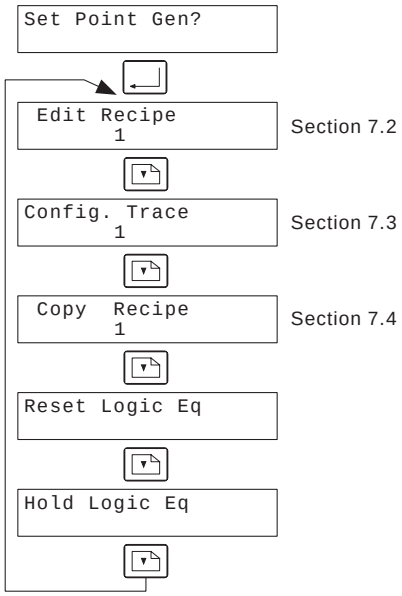

Figure 7.1 SPG Configuration menu: Top level

7.2 EDIT RECIPE

This part of the recorder configuration allows the user to Add, Delete and/or Edit, target, cycle or reset segments for each of the four recipes. Figure 7.2, below gives an overview of the SPG Edit menu.

7.2.1 SPG EDIT RECIPE CONFIGURABLE ITEMS (Cont.)

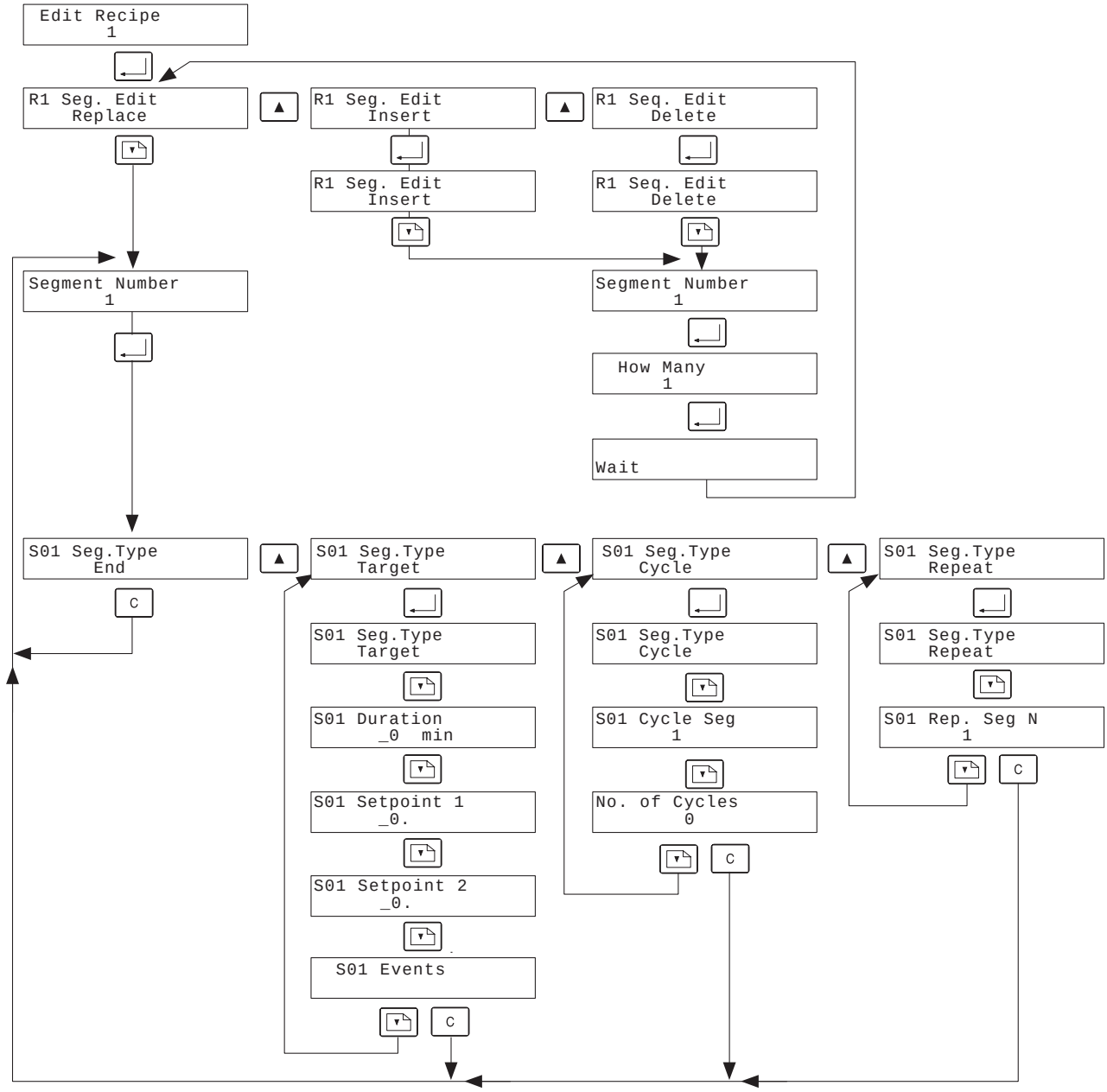

Figure 7.2 SPG Edit Recipe menu structure

7.2.1 SPG Edit menu configurable items

Edit Recipe — The Up/Down arrow keys are used to select recipe 1 to recipe 4 for editing.

Seg. Edit — The Up/Down arrow keys are used to select Replace, Insert or Delete

Replace

SEGMENT NUMBER: Select segment number which is to be edited.

SEG. TYPE: Use up arrow and Enter keys to select segment type.

End — No configurable attributes. It is recommended that the last segment in all recipes be an End segment. This ensures that the message 'Done' appears in the status display, and that the recipe has to be reset before being run again.

Target — **DURATION:** Enter a duration for both traces of the segment of up to 9999 minutes (166.7 days). (See note 1 below.)
SETPOINT 1: Enter the target value for Trace 1 of this segment
SETPOINT 2: Enter the target value for Trace 2 of this segment
EVENTS: Up to 8 events can be made active for each segment. These events are used to trigger action equations.

Cycle — A cycle segment permits the repetition, of a section of the recipe, up to 999 times. To repeat the whole recipe use a Repeat segment (below) instead.
CYCLE SEG: This is the lower number Segment to which to cycle.
NO. OF CYCLES: Enter the number of times the cycle is to be repeated (up to 999).

Repeat — A Repeat segment returns the recipe to a specified segment, indefinitely.
REP. SEG N: Enter the number of the segment that is to be returned-to.

Insert

SEGMENT NUMBER: The segment number in front of which new segments are to be inserted. If, by inserting segments, the total number will exceed 20, then all segments that would have numbers greater than 20 are permanently lost. All new segments are 'End' segments.
HOW MANY: The total number of segments to be inserted before the Segment number selected previously. An entry of 20 will insert new segments from the insertion point to the end of the recipe.

Delete

SEGMENT NUMBER: The segment number of the first segment that is to be deleted.
HOW MANY: The number of segments to be deleted. An entry of 20 deletes all segments from the selected Segment Number to the end of the recipe. 'Deleted' segments are all converted to 'End' segments.

Notes

1 Durations apply to both traces. It may be necessary to use more than one segment for the ramp on one trace to satisfy the changes on the other trace. In such a case, the user must calculate intermediate target values for the trace. In figure 7.2.1, Trace 1 reaches its target before Trace 2, and must then 'wait' for Trace 2 to catch up. It is therefore necessary to use a second segment and to calculate a new intermediate setpoint for trace 2, as shown.

2 Repeat and Cycle segments must be re-defined after any insertion or deletion affecting segments with numbers lower than theirs.

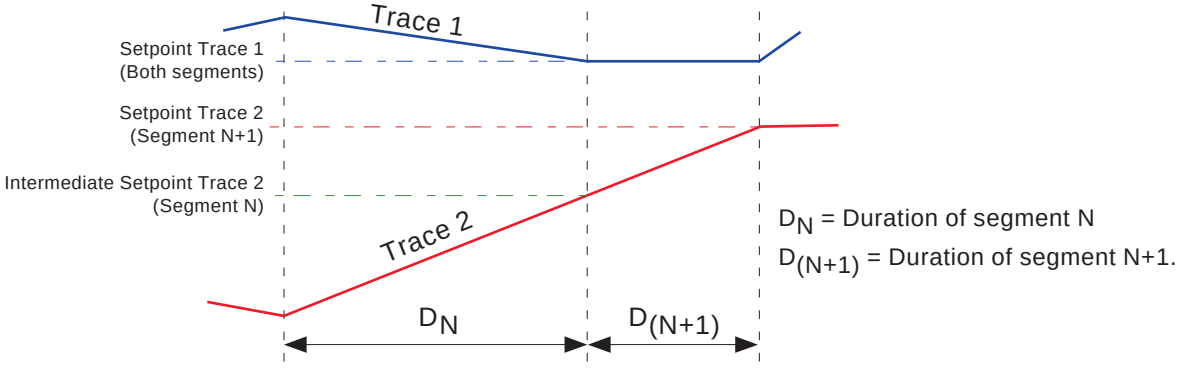

Figure 7.2.1 Dual segment ramping

7.3 SPG CONFIG TRACE CONFIGURATION

Figure 7.3 shows the Config Trace sub menu.

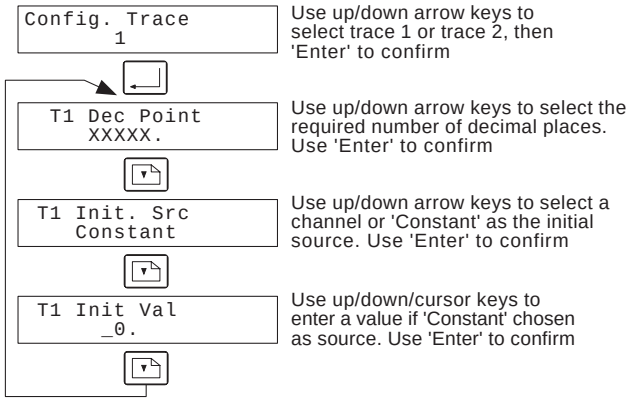

Figure 7.3 SPG Config Trace menu structure

7.3.1 Configurable items

Config Trace	The up/down arrow keys are used to select trace 1 or trace 2 for configuration.
Dec Point	The up/down arrow keys are used to select the number of decimal places for the SPG display.
Init. Src	The up/down arrow keys are used to select an input channel (channels 1 to 4), a derived channel (channels 5 and 6), a derived variable (DV1 to DV9) or a constant to supply the initial value for the trace..
Init Val	For Init. Src = Constant, the up/down arrow /cursor key are used to enter the value of the constant here.

7.4 SPG COPY RECIPE

Figure 7.4 shows the Copy Recipe sub menu. Copy is used where a number of similar recipes are required, and copying/editing is more time efficient than creating a new recipe from scratch.

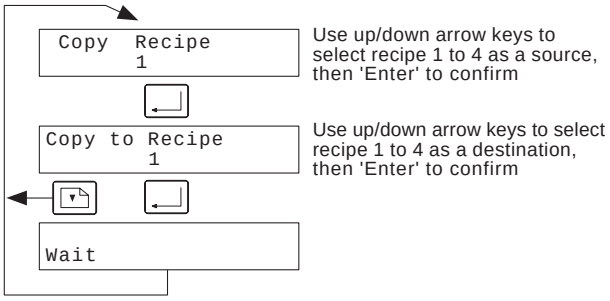

Figure 7.4 SPG Copy Recipe menu structure

7.4.1 Configurable items

Copy Recipe	Use the up/down arrows to select a (source) recipe to be copied.
Copy to Recipe	Use the up/down arrows to select a (destination) recipe number to which the source recipe is to be copied.

ANNEX A PID OVERVIEW

A1 PID CONTROLLERS INTRODUCTION

The controller implemented in this recorder is a full featured PID controller providing Proportional, reset (Integral) and Rate (Derivative) control actions.

A2 PROPORTIONAL ONLY CONTROL

The basic control strategy in conventional feedback control is to compare an actual Process Variable value (PV) with a desired value (Setpoint or SP) for that variable. When a difference (deviation) exists, the controller output is adjusted to bring the PV back to the setpoint. Ideally, the continuous, proportional, corrective action keeps the process value at the setpoint.

The sensitivity with which the controller reacts to the deviation can be controlled by the 'Proportional Band'. This is defined as the percentage of input span that the deviation must equal to cause a 100% change in controller output. A small value for Proportional Band means that a small deviation causes a large output response and *vice versa*. In brief: Gain = 100%/PB

EXAMPLE 1
Input Span = 200 units.
PB setting = 10%
Output changes by 100% for a 20 unit deviation (i.e. 10% of 200)

EXAMPLE 2
Input Span = 200 units.
PB setting = 50%
Output changes by 100% for a 100 unit deviation (i.e. 50% of 200)

EXAMPLE 3
Input Span = 200 units.
PB setting = 100%
Output changes by 100% for a 200 unit deviation (i.e. 100% of 200)

Proportional control assumes that the load is constant. If the load changes the controller is unable to maintain the process at the setpoint, as there is only one output value for each process variable value. The only way that a proportional controller can compensate for a change in process load is by adding a bias value (manual reset) into the controller output.

A3 PROPORTIONAL PLUS INTEGRAL (PI) CONTROL

The addition of the automatic reset control action allows for changes in process load. Reset action senses that an 'error' (offset) is present after proportional action has taken place, and continues to change the output further in order to eliminate the error. The rate at which the output moves due to reset action, is proportional to the size of the error and the Reset Time adjustment.

Reset Time adjustment allows the setting of the rate at which the controller changes the output to correct the offset. The value is entered in 'minutes per repeat', where 'minutes per repeat' refers to the amount of time for Reset Action to ramp the controller output by an amount equivalent to that produced by Proportional action. A large value for Reset Time causes a slow Ramp; a small Reset Time causes a fast ramp. Figure A3, below, defines Reset Time graphically. For clarity, the figure assumes that the error remains constant.

A3 PROPORTIONAL PLUS INTEGRAL (PI) CONTROL (Cont.)

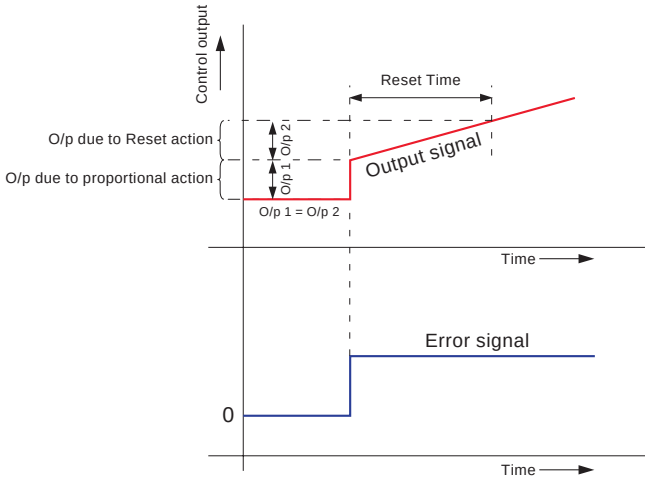

Figure A3 Reset Time definition

A4 PROPORTIONAL PLUS INTEGRAL PLUS DERIVED (PID) CONTROL

The need for Rate action (derived action) arises when the closed loop response of the process variable as a result of PI control would cause the output to 'overshoot' the correct value, and then start an oscillation as the result of the error signal going negative, then positive (as the result of over correction), and so on. This situation is typical of an application where a short reset time is required to respond rapidly to a new load situation, but the process response is of necessity too slow to respond to rapid changes. In order to overcome this problem, a 'cutting back' of the controller output is applied to ensure minimum overshoot. Figure A4 shows a sample comparison of two process responses, one with PI control (curve 1); the other with PID control (curve 2).

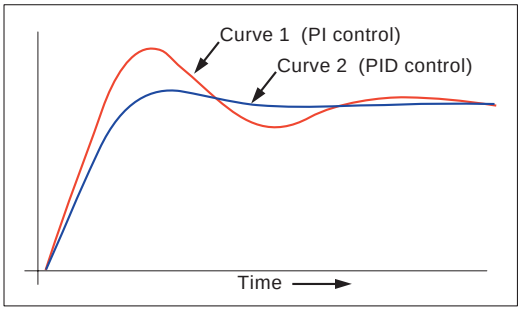

Figure A4 Tuning effect of Rate Action

The amount of rate action that is applied to the output of the controller is determined by the rate-of-change of the error signal and by the Rate time setting. The greater the rate-of-change in error signal, the greater the effect of the Rate action.

The Rate time setting is entered in minutes, and represents the time period in which the error signal must repeat itself for the output component due to rate action to be equivalent to the proportional component. Assuming a constant ramp rate on the error signal, larger values of Rate Time cause larger changes in the Rate Action component.

Decreasing the Rate Time decreases the effect of the addition of Rate Action on the closed loop response.

A5 CONTROL PERFORMANCE

A5.1 INTRODUCTION

Good control performance requires the controller to be tuned to the process by adjusting the Proportional band, the Rate and the Reset actions. The definition of 'good control performance' will vary from process to process, but in general the goals can be stated as:

1. Minimum disruption following a process 'upset'.
2. Minimum time interval before return to setpoint
3. Minimum offset resulting from changes in operating conditions.

There are a number of different manual methods for finding controller settings to satisfy these goals. All result in a good approximation which then has to be fine-tuned for optimum control performance. Two methods are described below: the 'ultimate cycle method' (Zieglar & Nichols) and the 'process reaction curve method' (Cohen & Coon).

A5.1.1 Ultimate Cycle Method

This tuning procedure is as follows:

1. Set the controller as follows:
   Reset Time = 99.99 Min/Repeat
   Rate time = 0.0
   Proportional band to 100.0
2. With the controller in Automatic mode, slowly decrease the Proportional band until the Process Value starts to oscillate. Write down the Proportional Band setting which just results in oscillation. This is called 'the ultimate Proportional band' (PBu).
3. Measure the time period of the oscillation, by determining the time between successive PV peaks. This time period is called the 'Ultimate Period' (PU)
4. Compute the tuning parameters as follows:

PI CONTROL

PB = 2.22 x PBu
Reset = PU/1.2

PID CONTROL

PB = 1.66 x PBu
Reset = PU/2
Rate = PU/8

A5.1.2 Process reaction Curve method

Refer to figure A5.1.2 as necessary.

1. Place the controller in Manual Mode. Step change the output by a known amount (Md) which is sufficient to make the process value change. Write down the amount of output % change.
2. Examine the chart record of the Process Value change, and note the times taken for the PV to reach 28% (Td) and 63.2% (Tr) of its new steady state value, and the total size of the change (Cd).
3. Calculate the following:

   Gain = Kp = Cd/Md

   Time constant = Tp = 1.5(Tr - Td)

   Dead time = a = 1.5(Td - 0.33Tr)/Tp
4. Calculate the tuning parameters as follows

PI CONTROL

$$PB = \frac{Kp}{\frac{0.9}{a} + 0.082}$$

$$Reset = \frac{Tp(3.33a + 0.333a^2)}{1 + 2.2a}$$

PID CONTROL

$$PB = \frac{Kp}{1.35a + 0.270}$$

$$Reset = \frac{Tp\,(2.5a + 0.5a^2)}{1 + 0.6a}$$

$$Rate = \frac{Tp\,(0.37a)}{1 + 0.2a}$$

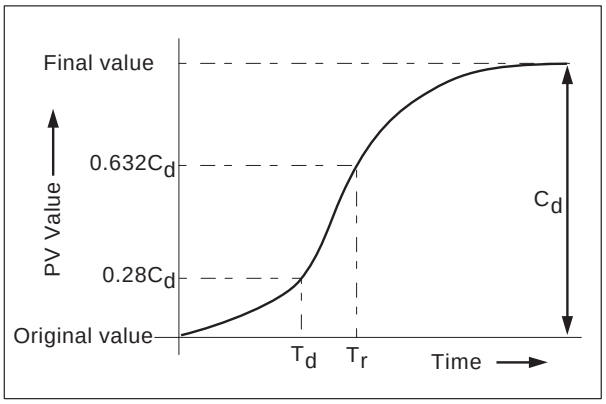

Figure A5.1.2 Reaction curve definitions

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