LD5/LE5 Series Large Digit Display Output Addendum

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1 Introduction

This addendum to the main LD5/LE5 instrument manuals contains information for the operation of output options plus the PI control mode for relay . Refer to the main manual for all other information regarding these instruments.

The standard and optional outputs available are as follows:-

- Optional relays plus single analog output. This addendum covers the use of the optional analog output as a PI control output and shows wiring details. Refer to the standard manual for details of analog output 1 as a retransmission output. This section also covers the electrical connections for the 4 extra relay option.

- Four output relays are fitted as standard. This addendum covers the use of relays 1 and 2 as PI control relays. Refer to the standard manual for details of the standard on/off alarm or control operation.

- Optional isolated single or dual analog output, 4-20mA only in 12 bit version or 4-20mA, 0-1VDC or 0-10VDC in 16 bit version. This addendum covers the use of output 1 and 2 as retransmission or PI control outputs and shows wiring details.

- Optional serial communications. This addendum covers the use of the optional isolated RS232 or RS485 serial communications in both standard ASCII and Modbus RTU modes.

- Datalogger. This addendum covers the datalogger commands for use with polling software other than the supplied download software. For information on using the datalogger with the download software issued with the datalogger consult the separate "Download Software User Guide".

2   4 Relay and Analog output option board

Optional relays and/or analog output can be fitted to this instrument. The plug in board is factory configured to one of the following options:

LD5-OPT-I - single current sourcing 4-20mA output 12 bit
LD5-OPT-A - single 4-20mA (current sourcing), 0-1VDC or 0-10VDC (user selectable) output 16 bit
LD5-OPT-IRRRR - single current sourcing 4-20mA output 12 bit plus 4 extra relays
LD5-OPT-ARRRR - single 4-20mA (current sourcing), 0-1VDC or 0-10VDC (user selectable) output 16 bit plus 4 extra relays
LD5-OPT-RRRR - Four extra relays

The location of the electrical connectors for these options and wiring example are shown below.
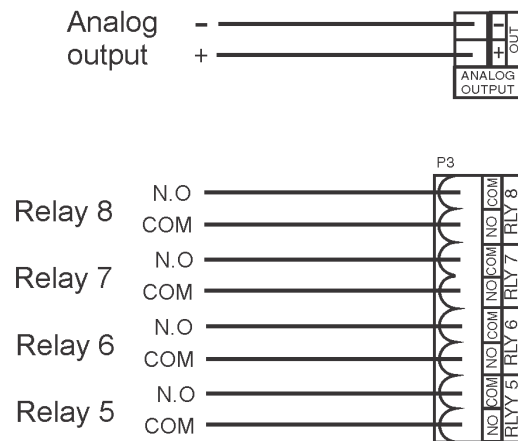
3 Dual Analog output option board

Optional Dual Analog output is available for these instruments. The plug in board is factory configured to one of the following options:

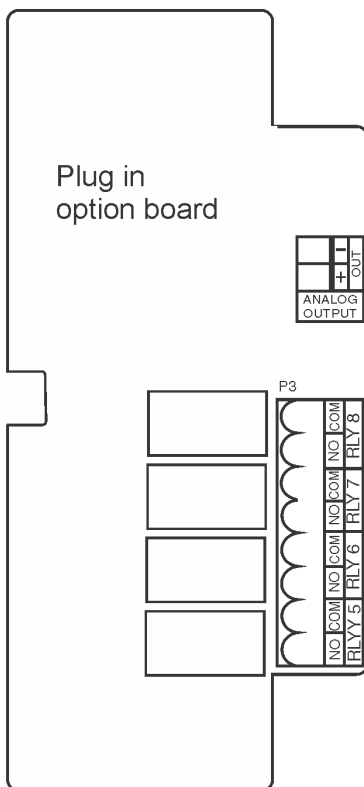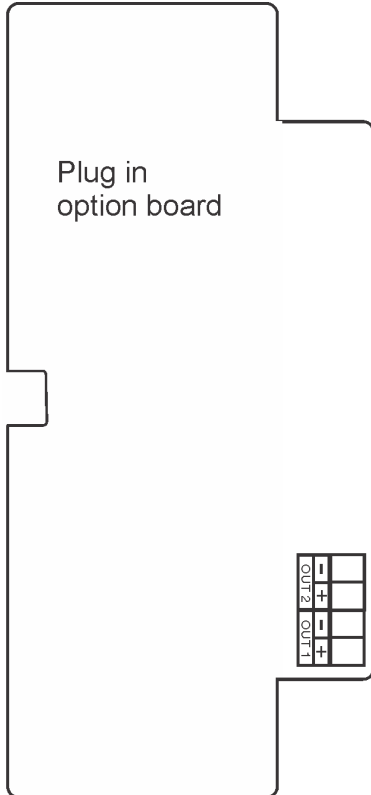LD5-OPT-II - dual current sourcing 4-20mA outputs 12 bit
LD5-OPT-AA - dual 4-20mA (current sourcing), 0-1VDC or 0-10VDC (user selectable) outputs 16 bit

The location of the electrical connectors for these options and wiring example are shown below.

4 Serial and USB output option board

Optional RS232, RS485 and USB communications is available for these instruments. The plug in board is factory configured to one of the following options:

LD5-OPT-S - isolated RS232 and RS485
LD5-OPT-U - USB communications
LD5-OPT-SU - isolated RS232 and RS485 and USB

Note: both RS232 and RS485 are fitted fitted in two of the options above and either can be used but only one at a time. With the LD5-OPT-SU option the USB and either RS232 or RS485 can be used at the same time. Note if these options are fitted the standard non isolated RS485 port on the main board will be disabled.

Several communications options are available for the RS232 and RS485 communications. For USB communications the **A.buS** mode must be chosen. Refer to the relevant chapter in this manual for a description of the serial operation modes.

The location of the electrical connectors for these options and wiring example are shown below.

Plug in
option board

Wiring example showing USB, RS485 and RS232 options

Note for RS232 Rx at this instrument connects to Tx at the mating terminal and Tx at this instrument connects to Rx at the mating terminal.
For RS485 the A terminal connects to other A terminal and the B terminal connects to other B terminals. Use twisted pair shielded cable for RS485.

USB type B connector
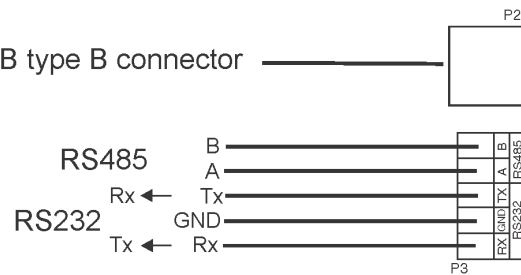
RS485
RS232

5 4 relay, Serial and USB output option board

Optional 4 relay, RS232, RS485 and USB communications is available for these instruments. The plug in board is factory configured to one of the following options:
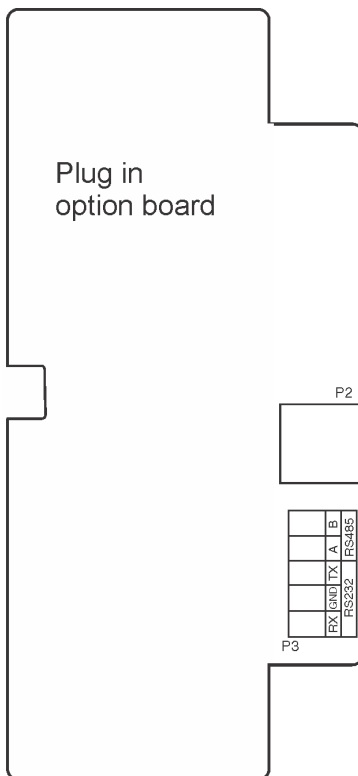
LD5-OPT-S - isolated RS232 and RS485
LD5-OPT-U - USB communications
LD5-OPT-SU - isolated RS232 and RS485 and USB
LD5-OPT-SRRRR - isolated RS232 and RS485 plus 4 extra relays
LD5-OPT-URRRR - USB communications plus 4 extra relays
LD5-OPT-SURRRR - isolated RS232 and RS485 and USB plus 4 extra relays

Note: both RS232 and RS485 are fitted fitted in two of the options above and either can be used but only one at a time. With the LD5-OPT-SU and LD5-OPT-SURRRR options the USB and either RS232 or RS485 can be used at the same time. Note if these options are fitted the standard non isolated RS485 port on the main board will be disabled.

Several communications options are available for the RS232 and RS485 communications. For USB communications the **A.bu5** mode must be chosen. Refer to the relevant chapter in this manual for a description of the serial operation modes.

The location of the electrical connectors for these options and wiring example are shown below.

Wiring example showing 4 Relay, USB, RS485 and RS232 options

Note for RS232 Rx at this instrument connects to Tx at the mating terminal and Tx at this instrument connects to Rx at the mating terminal.
For RS485 the A terminal connects to other A terminal and the B terminal connects to other B terminals. Use twisted pair shielded cable for RS485.
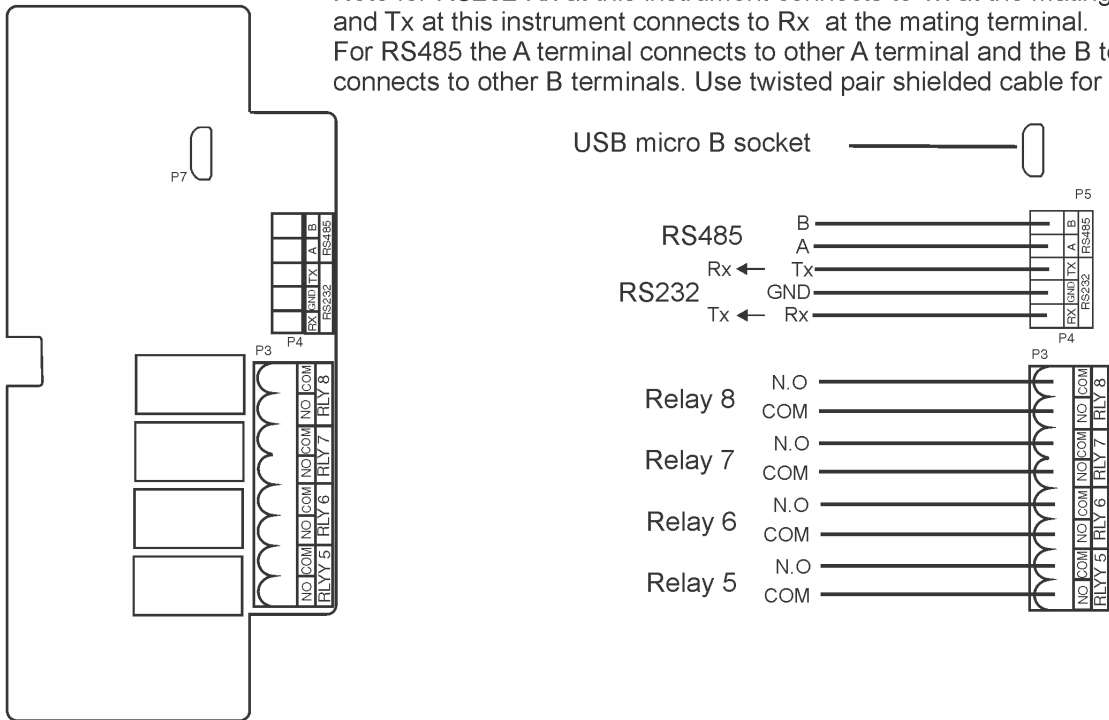
6 Serial communications commands

This chapter details the serial communications modes when using RS232 or RS485 communication. If no siolated serial output option is fitted the standard non isolated RS485 communications port can be used. Refer to the appropriate chapter in this manual for wiring connection when the optional serial output board is fitted. If the optional serial communications board is fitted the standard non isolated RS485 port will be disabled. Refer to the main instruction manual for wiring detail using the non isolated RS485.

Serial Functions:

bAud - Set baud rate. Select the baud rate from **300**, **600**, **1200**, **2400**, **4800**, **9600**, **19.2** or **38.4**

PrtY - Set parity. Select either **NONE**, **EUEN** or **Odd**

O.Put - Select serial output mode. Select **NONE**, **Cont**, **Poll**, **A.buS**, **diSP** or **m.buS**. The **diSP**, **Cont** and **Poll** modes are described in more detail in this chapter. **A.buS** is used when communicating with the Windows compatible download software available in short form for download or supplied in full form with the Ethernet plus data logger option, refer to the handbook supplied with the software. See the "Modbus Communications" chapter for details of the **m.buS** option.

The choices for communications mode are.

- **NONE** - Turns off serial communications

- **Cont** - Sends ASCII form of display data every time display is updated

- **Poll** - Controlled by computer or PLC as host. Host sends command via RS232/RS485 and instrument responds as requested.

- **A.buS** - Communication mode used with Windows compatible download software

- **diSP** - Sends image data from the display without conversion to ASCII - used when connecting a slave display or displays from the same manufacturer as the master instrument

- **m.buS** - Modbus RTU serial comms.

Addr - Set unit address for polled (POLL) mode (1 to 31). Allows several units to operate on the same RS485 interface reporting on different areas etc. The host computer or PLC may poll each unit in turn by supplying the appropriate address. The unit address ranges from 1 to 31 (DEC) but is offset by 32 (DEC) to avoid clashing with ASCII special function characters such as $< STX >$ and $< CR >$. Therefore 32 (DEC) or 20 (HEX) is address 0, 42 (DEC) or 2A (HEX) addresses unit 10.

Notes: Multi drop operation is only valid for instruments fitted with the RS485 output option.

6.1 Serial operation and commands

diSP - Image Display Mode:

In image display mode the display value is sent via RS232/RS485 as raw data in the format:

$$< ESC > \text{IXYYYY}$$

Where: $<ESC>$ is the ESCAPE character (27 Dec, 1B Hex, ∧[ASCII)
        I is the character "I" (73 Dec, 49 Hex)
        X is the number of image bytes in ASCII (31 to 38 Hex)
        $YYYY$ is the raw, 8 bit display data.

This information is output at the same rate as the sample rate. The number of image bytes sent depends on the number of display digits present. This mode is suitable only when the receiving unit is produced by the same manufacturer as this instrument. The data sent is seven segment display image i.e. Bit 0 is segment A, Bit 1 is segment B etc.

Cont - Continuous Transmit Mode:

In this mode the display value is continually transmitted out via the RS232/485 interface in ASCII format with 8 data bits + 1 stop bit. Data will be updated at approximately the same rate as the sample rate.

The format for this mode is:

$$<STX>XAAAA,XBBBB,XCCCC,.......XHHHH<CR>$$

Where: $<STX>$ is start of text character (2 Dec, 02 Hex, ∧B ASCII)
        X SPACE (32 Dec, 20 Hex) for a positive value or
        X "-" (45 Dec, 2D Hex) for a negative value
        $AAAA$ is the display value for Channel 1 in ASCII
        $BBBB$ is the display value for Channel 2 in ASCII
        $CCCC$ is the display value for Channel 3 in ASCII
        $HHHH$ is the display value for Channel 8 in ASCII
        $<CR>$ is a Carriage Return (13 Dec, 0D Hex, ∧M ASCII)

Notes: Display values will only be sent for active channels i.e. the channels selected at the **CONF CHAN Cnt** function. Leading spaces (32 Dec, 20 Hex) will be transmitted if the display value is less than 4 digits long. If the decimal point is non zero then it will be sent in the appropriate place as "." (46 Dec, 2E Hex) and will use the space normally set for positive numbers ("X" value above) if the number has 4 digits plus a decimal point. If a negative sign is sent it will be sent next to the value with no leading spaces e.g. "-23" rather than "- 23".

Poll - Host Controlled Transmit Mode:

This mode requires a host computer, PLC or other device to poll the instrument to obtain display or other information or reset various setpoint parameters. Communications software is required when using **Poll** mode. Data is in ASCII format with 8 data bits + 1 stop bit. When polling the instrument it is essential that the command characters are sent with less than a 10mS delay between them. This normally means that each command line must be sent as a whole string e.g. $<STX>PA<CR>1<CR>$ is sent as one string rather than $<STX>$ on one line followed by P etc. Whenever the function key is operated the whole string is sent. The format used is ASCII (8 data bits + 1 stop bit).

The format for the command requesting a value from the instrument is:

$$<STX>CA<CR>D<CR>$$

Where: $<STX>$ is the start of text ASCII character (∧B, 02 Dec, 02 Hex)
        C is the command character (see following poll commands available)
        A is the unit address (Range: 32 to 63 Dec, 20 to 3F Hex, "SPACE" to ? ASCII the address is offset by 32 Dec, 20 Hex)
        $<CR>$ is the ASCII character for CR (∧M, 13 Dec, 0D Hex)
        D is the Channel number required e.g. 1 (49 Dec, 31 Hex) for Channel 1

The format for data returned from the instrument is:

$$< ACK > CANXYYYY < CR >$$

Where:
$< ACK >$	is the Acknowledge c haracter (6 Dec, 06 Hex, ∧B ASCII)
C	is the command character (see following poll commands available)
A	is the unit address (Range: 32 to 63 Dec, 20 to 3F Hex, "SPACE" to ? ASCII the address is offset by 32 Dec, 20 Hex)
N	is the Channel number in ASCII
X	SPACE for positive or "-" for negative
$YYYY$	is the value requested in ASCII

Notes: Leading spaces (32 Dec, 20 Hex) will be transmitted if the display value is less than 4 digits long. If the decimal point is non zero then it will be sent in the appropriate place as "." (46 Dec, 2E Hex) and will use the space normally set for positive numbers ("X" value above) if the number has 4 digits plus a decimal point.

The format for the host in sending a relay setting to the instrument is:

$$< STX > CA < CR > N < CR > XYYYY < CR >$$

Where:
$< STX >$	is Start of Text Character (2 Dec, 02 Hex, ∧B ASCII)
C	is the command character (see following poll commands available)
A	is the unit address (Range: 32 to 63 Dec, 20 to 3F Hex, "SPACE" to ? ASCII the address is offset by 32 Dec, 20 Hex)
$< CR >$	is Carriage Return (13 Dec, 0D Hex, ∧M ASCII)
N	is the relay number in ASCII e.g.: 1 for alarm 1 etc.
X	SPACE for positive or "-" for negative
$YYYY$	is the sent relay value in ASCII

The format for the returned data for a relay setting to the instrument is:

$$< ACK > CANXYYYY < CR >$$

Where:
$< ACK >$	is the Acknowledge c haracter (6 Dec, 06 Hex, ∧B ASCII)
C	is the command character (see following poll commands available)
A	is the unit address (Range: 32 to 63 Dec, 20 to 3F Hex, "SPACE" to ? ASCII the address is offset by 32 Dec, 20 Hex)
$< CR >$	is Carriage Return (13 Dec, 0D Hex, ∧M ASCII)
N	is the relay number in ASCII e.g.: 1 for alarm 1 etc.
X	SPACE for positive or "-" for negative
$YYYY$	is the returned relay value in ASCII

Notes: Leading spaces (32 Dec, 20 Hex) will be transmitted if the display value is less than 4 digits long. If the decimal point is non zero then it will be sent in the appropriate place as "." (46 Dec, 2E Hex) and will use the space normally set for positive numbers ("X" value above) if the number has 4 digits plus a decimal point.

The POLL commands available and instrument responses are as follows:

1. **Transmit Primary display value:** $< STX > PA < CR > D < CR >$
   e.g. ∧BP!∧M2∧M using a terminal program (channel 2, address 1). Instructs unit to return the primary display value for the selected channel. Format of returned data is:

   $$< ACK > PAXYYYY < CR >$$

Where: $<ACK>$ is Acknowledge (6 Dec, 06 Hex)
         P echo command received "P" (80 Dec, 50 Hex)
         A is the responding units address
         X SPACE for positive or "-" for negative
         $YYYY$ is the value in ASCII
         $<CR>$ is a Carriage Return (13 Dec, 0D Hex)

2. **Transmit secondary (calculated channel) value:** $<STX>SA<CR>D<CR>$
   e.g. $\wedge BS!\wedge M2\wedge M$ using a terminal program (channel 2, address 1). Instructs unit to return the display value for the selected calculated channel. If the display has no secondary display value i.e. no calculated channels have been enabled then a "?" will be returned. Format of returned data is:

   $<ACK>SAXYYYY<CR>$

Where: $<ACK>$ is Acknowledge (6 Dec, 06 Hex)
         S echo command received "S" (83 Dec, 53 Hex)
         A is the responding units address
         X SPACE for positive or "-" for negative
         $YYYY$ is the value in ASCII
         $<CR>$ is a Carriage Return (13 Dec, 0D Hex)

3. **Transmit all active channel display values:** $<STX>PA<CR>0<CR>$
   e.g. $\wedge BP!\wedge M0\wedge M$ using a terminal program (address 1). Instructs unit to return the display values for channel zero (0) which is the instruction to return all active channels i.e. the channels selected a the **CONF CHAN Cnt** function. Format of returned data is:

   $<ACK>PA0XBBBB,........XIIII<CR>$

Where: $<ACK>$ is Acknowledge (6 Dec, 06 Hex)
         P echo command received "P" (80 Dec, 50 Hex)
         A is the responding units address
         0 0 (ZERO) (48 Dec, 30 Hex)
         X SPACE (32 Dec, 20 Hex) for a positive value or
         X "-" (45 Dec, 2D Hex) for a negative value
         $BBBB$ is the display value for Channel 1 in ASCII etc.
         $IIII$ is the display value for the highest active channel in ASCII
         $<CR>$ is a Carriage Return (13 Dec, 0D Hex, $\wedge$M ASCII)

Example: If all 8 channels are active then the returned data format would be:
$<ACK>PA0XBBBB,XCCCC,XDDDD,XEEEE,XFFFF,XGGGG,XHHHH,XIIII<CR>$

4. **Read low alarm setpoint:** $<STX>LA<CR>N<CR>$
   e.g. $\wedge BN!\wedge M2\wedge M$ to read alarm 2 low setpoint using a terminal program (address 1). Instructs unit to return the low alarm setpoint value. Format of returned data is:

   $<ACK>LANXYYYY<CR>$

Where: $<ACK>$ is Acknowledge (6 Dec, 06 Hex, $\wedge$F ASCII)
         L echo command received "L" (76 Dec, 4C Hex)
         A is the responding units address
         N is the relay number in ASCII
         X SPACE for positive and "-" for negative

$YYYY$ is the setpoint value in ASCII

$< CR >$ is a Carriage Return (13 Dec, 0D Hex, ∧M ASCII)

5. **Read high alarm setpoint:** $< STX > HA < CR > N < CR >$

e.g. ∧HN!∧M2∧M to read alarm 2 high setpoint using a terminal program (address 1). Instructs unit to return the high alarm setpoint value. Format of returned data is:

$$< ACK > HANXYYYY < CR >$$

Where: $< ACK >$ is Acknowledge (6 Dec, 06 Hex, ∧F ASCII)

                H echo command received "H" (72 Dec, 48 Hex)

                A is the responding units address

                N is the relay number in ASCII

                X SPACE for positive and "-" for negative

                $YYYY$ is the setpoint value in ASCII

                $< CR >$ is a Carriage Return (13 Dec, 0D Hex, ∧M ASCII)

6. **Set low alarm setpoint:** $< STX > lA < CR > N < CR > XYYYY < CR >$

e.g. ∧lN!∧M1∧M1000∧ to set alarm 1 low setpoint to 1000 using a terminal program (address 1). Instructs unit to set the low alarm setpoint value.

Format of returned data is:

$$< ACK > lANXYYYY < CR >$$

Where: $< ACK >$ is Acknowledge (6 Dec, 06 Hex, ∧F ASCII)

                l echo command received "l" (108 Dec, 6C Hex)

                A is the responding units address

                N is the relay number in ASCII

                X SPACE for positive and "-" for negative

                $YYYY$ is the setpoint value in ASCII

                $< CR >$ is a Carriage Return (13 Dec, 0D Hex, ∧M ASCII)

7. **Set high alarm setpoint:** $< STX > hA < CR > N < CR > XYYYY < CR >$

e.g. ∧hN!∧M1∧M5000∧ to set alarm 1 low setpoint to 5000 using a terminal program (address 1). Instructs unit to set the high alarm setpoint value. Format of returned data is:

$$< ACK > hANXYYYY < CR >$$

Where: $< ACK >$ is Acknowledge (6 Dec, 06 Hex, ∧F ASCII)

                h echo command received "h" (104 Dec, 68 Hex)

                A is the responding units address

                N is the relay number in ASCII

                X SPACE for positive and "-" for negative

                $YYYY$ is the setpoint value in ASCII

                $< CR >$ is a Carriage Return (13 Dec, 0D Hex, ∧M ASCII)

8. **Transmit instrument model and software version:** $< STX > iA < CR >$ e.g. ∧Bi!∧M using a terminal program (address 1). Instructs unit to return the instrument model and software version.

Format of returned data is: $< ACK > iAAIC\ BBB - BBB\ CCX.X < CR >$

Where: $< ACK >$ is Acknowledge (6 Dec, 06 Hex, ∧F ASCII)
              i echo command received "i" (105 Dec, 69 Hex)
              A is the responding units address (offset by 32 Dec e.g. "!" is address 1)
              AIC is the manufacturers name
              $BBB - BBB$ is the model number of the instrument e.g. LD5-RT8
              CC a 2 character identifier e.g. RT means RTD input
              $X.X$ is the software version number e.g. 4.6
              $< CR >$ is a Carriage Return (13 Dec, 0D Hex, ∧M ASCII)

9. **Invalid command:** If the command received from the host is invalid the unit will return the following: $< ACK >?A < CR >$, where:

Where: $< ACK >$ is Acknowledge (6 Dec, 06 Hex, ∧F ASCII)
              ?   echo command received "?" (63 Dec, 3F Hex)
              A is the responding units address (offset by 32 Dec e.g. "!" is address 1)
              $< CR >$ is a Carriage Return (13 Dec, 0D Hex, ∧M ASCII)

7 Modbus RTU functions

When using Modbus RTU communications the instrument must be set up electrically for RS232 or RS485 communications and the **SErı OPEr** function must be set to **ñ.buS**. For Ethernet communications Modbus TCP can be used. The maximum recommended baud rate for Modbus RS232 or RS485 operation is 9600. Functions 1 and 3 are available with register and address ranges as shown below:

Functions 1 and 3 register and address ranges

Func Code	Description	Register Range	Address Range
0x01	Read Coil Status	1 - 9999	0x0000 - 0x270E
0x03	Read Holding Registers	40001 - 49999	0x0000 - 0x270E

Modbus Function 1 - Read coil status
Reads the ON/OFF status of the relay coils. Broadcast is not supported. Relay addresses are offset by 1 e.g. relay 1 is addressed as 0, relay 2 is addressed as 1 etc. Logic 1 = ON, Logic 0 = OFF. To read the coil status a query is sent to the instrument, the instrument then responds to the query. An example of a query to read coils 1 to 8 from the instrument at address 2 is given below.

Field name	RTU Example(Hex)	TCP Example(Hex)
Transaction ID Hi	Not used	00
Transaction ID Lo	Not used	01
Protocol ID Hi	Not used	00
Protocol ID Lo	Not used	00
Message length Hi	Not used	00
Message length Lo	Not used	06
Unit address	02	02
Function	01	01
Starting address Hi	00	00
Starting address Lo	00	00
Number of points Hi	00	00
Number of points Lo	08	08
Error check (LRC or CRC)	– (e.g. 3d ff)	Not sent

In Modbus RTU this would be sent as 02 01 0000 0008 followed by the CRC e.g. 3dff
In Modbus TCP this would be sent as 0001 0000 0006 02 01 0000 0008
Transaction ID value increments by one each time a new transmission is sent in a session.
Protocol ID for Modbus TCP is always 0000

An example of a response is given below:

Field name	RTU Example(Hex)	TCP Example(Hex)
Transaction ID Hi	Not used	00
Transaction ID Lo	Not used	01
Protocol ID Hi	Not used	00
Protocol ID Lo	Not used	00
Message length Hi	Not used	00
Message length Lo	Not used	06
Unit address	02	02
Function	01	01
Byte count	01	01
Data (coils 8 to 1)	B6	B6
Error check (LRC or CRC)	–	Not used

The status of the relay coils is shown in the Data B6 (hex) or binary 10110110. Relay 1 is indicated by the least significant binary bit. The status of the relays is therefore:

Relay 1 - OFF, Relay 2 - ON, Relay 3 - ON, Relay 4 - OFF, Relay 5 - ON, Relay 6 - ON, Relay 7 - OFF and Relay 8 - ON.

Function 3 register table

Register	Name	Data Type	Units	Func	Address	R/W
40001	Channel 1	16 bit Integer		0x03	0x0000	R
40002	Channel 2	16 bit Integer		0x03	0x0001	R
40003	Channel 3	16 bit Integer		0x03	0x0002	R
40004	Channel 4	16 bit Integer		0x03	0x0003	R
40005	Channel 5	16 bit Integer		0x03	0x0004	R
40006	Channel 6	16 bit Integer		0x03	0x0005	R
40007	Channel 7	16 bit Integer		0x03	0x0006	R
40008	Channel 8	16 bit Integer		0x03	0x0007	R
40009	Alarm 1 High	16 bit Integer		0x03	0x0008	R
40010	Alarm 2 High	16 bit Integer		0x03	0x0009	R
40011	Alarm 3 High	16 bit Integer		0x03	0x000a	R
40012	Alarm 4 High	16 bit Integer		0x03	0x000b	R
40013	Alarm 5 High	16 bit Integer		0x03	0x000c	R
40014	Alarm 6 High	16 bit Integer		0x03	0x000d	R
40015	Alarm 7 High	16 bit Integer		0x03	0x000e	R
40016	Alarm 8 High	16 bit Integer		0x03	0x000f	R
40017	Alarm 1 Low	16 bit Integer		0x03	0x0010	R
40018	Alarm 2 Low	16 bit Integer		0x03	0x0011	R
40019	Alarm 3 Low	16 bit Integer		0x03	0x0012	R
40020	Alarm 4 Low	16 bit Integer		0x03	0x0013	R
40021	Alarm 5 Low	16 bit Integer		0x03	0x0014	R

Register	Name	Data Type	Units	Func	Address	R/W
40022	Alarm 6 Low	16 bit Integer		0x03	0x0015	R
40023	Alarm 7 Low	16 bit Integer		0x03	0x0016	R
40024	Alarm 8 Low	16 bit Integer		0x03	0x0017	R
40025	Ch1 Decimal Pt	16 bit Integer		0x03	0x0018	R
40026	Ch2 Decimal Pt	16 bit Integer		0x03	0x0019	R
40027	Ch3 Decimal Pt	16 bit Integer		0x03	0x001a	R
40028	Ch4 Decimal Pt	16 bit Integer		0x03	0x001b	R
40029	Ch5 Decimal Pt	16 bit Integer		0x03	0x001c	R
40031	Ch7 Decimal Pt	16 bit Integer		0x03	0x001e	R
40032	Ch8 Decimal Pt	16 bit Integer		0x03	0x001f	R
40040	Ch6 Decimal Pt	16 bit Integer		0x03	0x0027	R

Function 3 - Read holding registers

This function reads the binary contents of the holding registers in the instrument being addressed. The value for this function is stored as a 32 but two's compliment number in two 16 bit registers per channel. Note; a value of 32000 represents a positive overrange and -32000 a negative overrange.

Registers 4001 to 4008 are addressed as 0x0000 to 0x0007.

Registers 4009 to 4016 hold the alarm high values for relays 1 to 8. Note a value of 0x8000 means that the relay is set to OFF and has no high value. Registers 4009 to 4016 are addressed as 0x008 to 0x00f.

Registers 4017 to 4024 hold the alarm low values for relays 1 to 8. Note a value of 0x8000 means that the relay is set to OFF and has no low value. Registers 4017 to 4024 are addressed as 0x0010 to 0x0017.

Registers 4025 to 4032 represent the decimal point settings for channels 1 to 8. Registers 4025 to 4032 are addressed as 0x0018 to 0x0020.

An example of a query to read input channels 1 to 3 from an instrument at address 5 is given below.

Field name	RTU Example(Hex)	TCP Example(Hex)
Transaction ID Hi	Not used	00
Transaction ID Lo	Not used	01
Protocol ID Hi	Not used	00
Protocol ID Lo	Not used	00
Message length Hi	Not used	00
Message length Lo	Not used	06
Unit address	05	05
Function	03	05
Starting address Hi	00	00
Number of points Hi	00	00
Number of points Lo	03	03
Error check (LRC or CRC)	–	Not sent

Transaction ID value increments by one each time a new transmission is sent in a session. Protocol ID for Modbus TCP is always 0000

An example of a response is given below:

Field name	RTU Example(Hex)	TCP Example(Hex)
Transaction ID Hi	Not used	00
Transaction ID Lo	Not used	01
Protocol ID Hi	Not used	00
Protocol ID Lo	Not used	00
Message length Hi	Not used	00
Message length Lo	Not used	06
Unit address	05	05
Function	03	03
Byte count	06	06
Data Hi(register 1)	00	00
Data Lo(register 1)	33	33
Data Hi(register 2)	00	00
Data Lo(register 2)	25	25
Data Hi(register 3)	00	00
Data Lo(register 3)	17	17
Error check (LRC or CRC)	–	Not used

The value of register 1 is 0033 Hex which is 51 Dec. The value of register 2 is 0025 Hex which is 37 Dec. The value of register 3 is 0017 Hex which is 23 Dec.

8 Setting up the relay PI controller

Standard alarm relay functions (non PI control functions) are covered in the main instrument manual.

Alarms 1 and/or 2 can be assigned to relay PI control operation. When selected for PI control Alarm 1 will have Relay 1 dedicated to its operation and Alarm 2 will have Relay 2 dedicated to its operation. Once selected for relay PI control these relays will not be available for assignment to other alarms.

The Relay Proportional + Integral Controller can be made to operate in either pulse width control or frequency control mode via the function. The best results are usually achieved by initially configuring as a "Proportional Only" controller and then introducing the Integral functions when stable results are obtained.

The function allows three choices of operating mode for the chosen relay, namely **Hi.Lo**, **Ctrl** or **Freq**. If **Hi.Lo** is selected the chosen relay will operate as a setpoint relay whose operation is controlled by the , etc. settings and the PI control settings will not be seen.

If **Ctrl** is selected then the chosen relay will operate in pulse width control mode. If **Freq** is selected then the chosen relay will operate in frequency control mode.

Pulse width control - operates by controlling the on to off time ratio of the relay. In a typical application this would be used to control the length of time for which a dosing pump is switched on during a control cycle i.e. the pump or other device will continuously operate for the length of time the relay is activated and will stop operating when the relay is de-activated.

Frequency control - operates by changing the rate at which the relay switches on and off. In a typical control application the frequency control operation is particularly suited for use when one shot dosing is used i.e. the pump or other device puts out a fixed dosing quantity for every pulse received.

8.1 Relay pulse width modulation control mode

To use pulse width modulation control **Ctrl** must be selected at the function.

Pulse width control
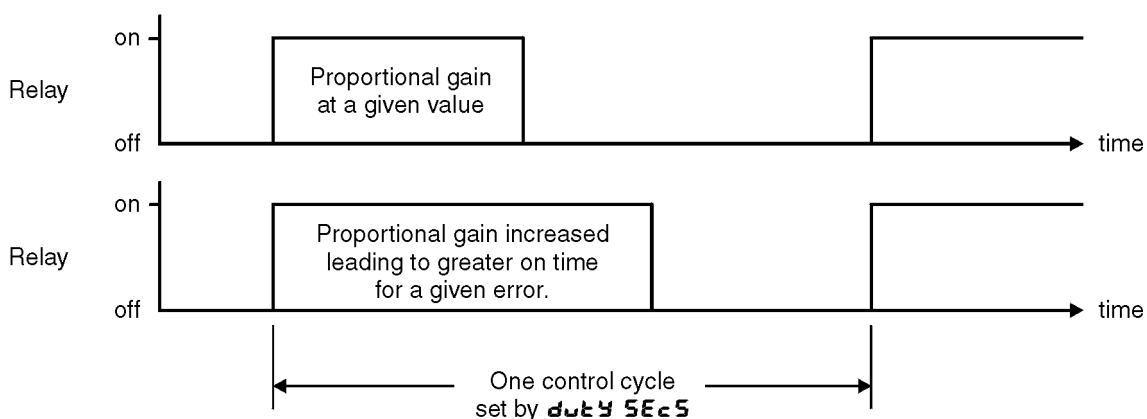
8.2 Relay frequency modulation control mode

To use frequency PI control **FrEq** must be selected at the **OPEr** function. In frequency modulation mode the relay on time is fixed, see function **on SECS**. The duty cycle time can also be set. The control program will vary the actual off time to suit the error seen between the setpoint and the measured temperature at the time. For example if extra dosing is needed to reach the setpoint then the off time will be reduced resulting in more on pulses per period of time i.e. the frequency of the pulses is controlled to allow the setpoint to be maintained.

Frequency control - pulse frequency varies according to settings and control requirement
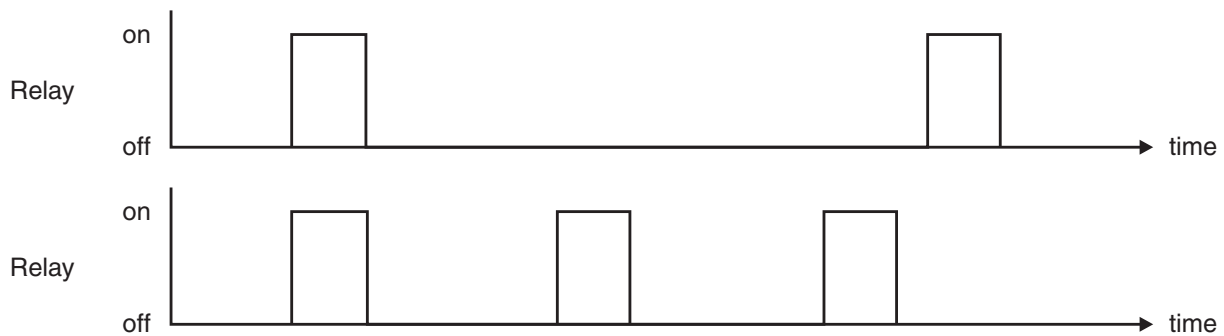
PI control functions and setup procedure

8.3 Alarm relay operating mode

Section:	**AL 1** to **AL 8**
Display:	**OPEr**
Range:	**Hi.Lo**, **Ctrl**, **FrEq**
Default Value:	**Hi.Lo**
Default Access Level	**4**
Function number	**4160** to **4167**

Sets the operating mode for the selected relay; Choices are:

- **Hi.Lo** will cause the relay to operate in on/off mode using the setting in the and functions.

- **Ctrl** will cause the relay to operate in pulse width PI control output mode.

- **FrEq** will cause the relay to operate in frequency PI control output mode.

8.4 Relay PI control span

Section:	**AL 1** to **AL 8**
Display:	**SPAN**
Range:	Any display value
Default Value:	**1000**
Default Access Level	**4**
Function number	**4290** to **4297**

The function of the control span is to define the limit to which the PI control values will relate. The control span value will be common to all control relays i.e. if more than one control relay output is being used then each of these relays operates from the same control span setting. The span value defines the range over which the input must change to cause a 100% change in the control output when the proportional gain is set to 1.000. This function affects the overall gain of the controller and is normally set to the process value limits that the controller requires for normal operation. For example if the control setpoint (**SEtP**) is 70 and the **SPAN** is 20 and **P.9** is set to 1.000 then an error of 20 from the setpoint will cause a 100% change in proportional control output. For example with **SEtP** at 70, **SPAN** at 20, **P.9** at 1.000 and **b.AS** at 0.0 a display reading of 50 or lower (**SEtP** minus **SPAN**) the control output will be at 100% i.e. the relay will be on continuously. The control output will then gradually adjust the on/off time as the display value reaches the setpoint.

8.5 Relay PI control setpoint

Section:	**AL 1** to **AL 8**
Display:	**SEtP**
Range:	Any display value
Default Value:	**1000**
Default Access Level	**4**
Function number	**4200** to **4207**

The control setpoint is set to the value in measurement units required for the control process. The controller will attempt to vary the control output to keep the process variable at the setpoint.

8.6 Relay PI control proportional gain value

Section:	**AL 1** to **AL 8**
Display:	**P.9**
Range:	Any display value
Default Value:	**0.010**
Default Access Level	**4**
Function number	**4210** to **4217**

The proportional value will determine the degree to which the controller will respond when there is a difference (error) between the measured value and the process control setpoint. If the propor-

tional gain is increased then for a given error the relay on time will be increased (or decreased if the error is on the other side of the setpoint). The proportional gain action can be reversed by setting a negative gain i.e. with a negative gain the on time will reduce as the error increases. With a proportional gain of 1.000 and an error of 10 or more (with control span set at 10) the controller will increase the frequency by 100% if possible. With a proportional gain of 0.500 an error of 10 or more (with control span set at 10) will cause the controller to increase the frequency by 50%, if possible. Too much proportional gain will result in instability due to excessive overshoot of the setpoint. Too little proportional gain will lead to a slow response.

			This table shows the effect on the pulse width on changing proportional gain and bias with the following settings: $SPAN = 20.0$, $duty$ $SECS = 1.0$, $I.9 = 0.000$
SEtP	**P.9**	**b.AS**	**Effect on relay operation**
70.0	1.000	0.0	Reading of **50.0** or below - relay permanently on.
			Reading of **50.0** to **70.0** - relay pulses with off time increasing as value approaches **70.0**.
			Reading **70.0** or above - relay permanently off.
70.0	1.000	100.0	Reading of **70.0** or below - relay permanently on.
			Reading of **70.0** to **90.0** - relay pulses with off time increasing as value approaches **90.0**.
			Reading **90.0** or above - relay permanently off.
70.0	1.000	50.0	Reading of **60.0** or below - relay permanently on.
			Reading of **60.0** to **70.0** - relay pulses with off time increasing as value approaches **70.0**.
			Reading **70.0** - relay pulses at 50% on and 50% off.
			Reading **70.0** to **80.0** - relay pulses with off time increasing as value approaches **80.0**.
			Reading **80.0** or above - relay permanently off.
70.0	0.500	50.0	Reading **50.0** or below - relay permanently on.
			Reading **50.0** to **70.0** - relay pulses with off time increasing as value approaches **70.0**.
			Reading **70.0** - relay pulses at 50% on and 50% off.
			Reading **70.0** to **90.0** - relay pulses with off time increasing as value approaches **90.0**.
			Reading **90.0** or above - relay permanently off.
70.0	- 1.000	50.0	Reading of **60.0** or below - relay permanently off.
			Reading of **60.0** to **70.0** - relay pulses with on time increasing as value approaches **70.0**.
			Reading **70.0** - relay pulses 50% on and 50% off.
			Reading **70.0** to **80.0** - relay pulses with on time increasing as value approaches **80.0**.
			Reading **80.0** or above - relay permanently on.

8.7 Relay PI control integral gain value

Section:	**RL 1** to **RL 8**
Display:	**1.9**
Range:	Any display value
Default Value:	**0.000**
Default Access Level	**4**
Function number	**4220** to **4227**

Note: the range value may be restricted if the number of display digits does not allow viewing of the full range.

The Integral action will attempt to correct for any offset which the proportional control action is unable to correct (e.g. errors caused by changes in the process load). When the integral gain is correctly adjusted the control output is varied to maintain control by keeping the process variable at the same value as the control setpoint. Since the integral gain is time based the output will gradually increase if the error does not decrease i.e. if the measured value remains constant and there is an error (a difference between the measured value and the setpoint) then the frequency will be increased compared to the previous frequency output. The higher the proportional gain, the greater the degree by which the on to off ratio will be affected i.e. the response will be greater at higher integral gain settings. With an integral gain of **1.000** an error of **1.0** or more with control span set at **1.0** will cause the integral action to try to correct at the rate of 100% minute. With an integral gain of **0.200** an error of **1.0** or more will cause the integral action to try to correct at the rate of 20% per minute. Too high an integral gain will result in instability. To low an integral gain will slow down the time taken to reach the setpoint. The optimum setting will depend on the lag time of the process and the other control settings. Start with a low figure (e.g. **0.200**) and increase until a satisfactory response time is reached. The integral gain figure has units of gain/minute. The integral action can be reversed by setting a negative gain figure, note that the sign of the integral gain must match the sign of the proportional gain. The integral control output follows the formula:

$$Integral\ control\ output = \frac{error \times Ig \times time\,(seconds)}{60} + previous\ integral\ control\ output$$

Where Ig is the integral gain set via the function.
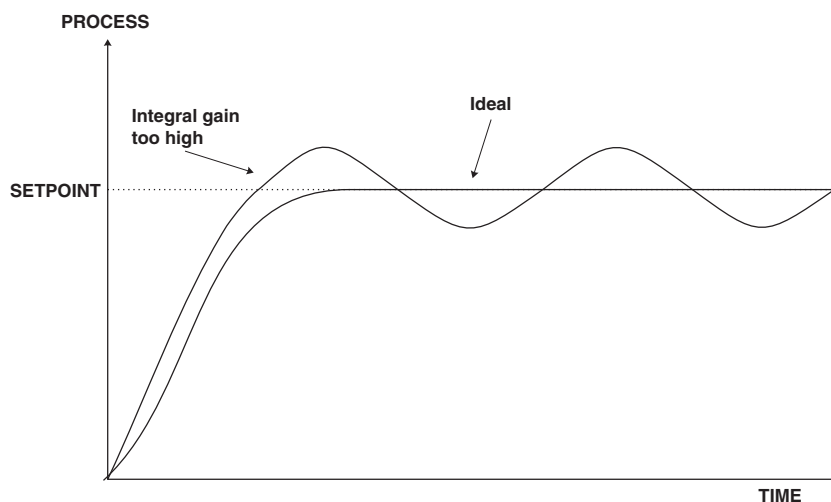
8.8 Relay PI control integral high limit value

Section:	**AL 1** to **AL 8**
Display:	**I.H**
Range:	**0** to **100.0** %
Default Value:	**0.000**
Default Access Level	**4**
Function number	**4240** to **4247**

The maximum limit can be used to reduce overshoot of the control setpoint when the control output is increasing i.e. rising above the setpoint. Other than this the limit operates in the same manner as the low limit described in the following function.

8.9 Relay PI control integral low limit value

Section:	**AL 1** to **AL 8**
Display:	**I.L**
Range:	**0** to **100.0** %
Default Value:	**100.0**
Default Access Level	**4**
Function number	**4250** to **4257**

The low limit can be used to reduce overshoot of the control setpoint when the control output is being reduced i.e. falling below the setpoint. The low limit reduces the available output swing by a percentage of the maximum output. Without a limit the integral output can be very large at the time the setpoint is reached and a large overshoot of the will then result. Settings available are from 0.0 to 100.0 (%). If the limit setting is too high then overshoot will result. If the setting is too low then the integral output can be limited to such an extent that the setpoint cannot be maintained. Start with a low value such as 20.0 and increase or decrease the value until a satisfactory result is obtained.

The advantage of using separate low and high limits is that in many applications the response is very one directional e.g. the system may respond very quickly to a heat input but may cool down at a much slower rate. Separate high and low limit settings allow independent limiting of the integral control swing below and above the setpoint so a smaller minimum limit can be set to limit swings below the setpoint to compensate for the slower cooling time. The minimum and maximum limits are used in conjunction with the output bias setting to maintain the control process setpoint value. For example with a **b.AS** set at 50%, minimum limit set at 20% and a maximum limit of 30% the actual bias when the process is at the setpoint may be anywhere between 30% and 80% i.e. Integral control is being used to alter the bias setting in order to maintain the process at the setpoint. In this case the minimum term will allow the bias to drop to a value between 50% and 30% in order to maintain the setpoint. The maximum term will allow the bias point to rise to a value between 50% and 80% in order to maintain the setpoint.

8.10   Relay PI control bias

Section:	**AL 1** to **AL 8**
Display:	**b, AS**
Range:	**0** to **100.0** %
Default Value:	**50.0**
Default Access Level	**4**
Function number	**4260** to **4267**

The control bias sets the ideal steady state output required once the setpoint is reached. Settings are in % from 0.0 to 100.0. When set at 0.0 the relay will be de-activated for the entire control period when the measured input is at the setpoint (depending on proportional and integral gain settings). If set at 50.0 then the relay operation frequency will on for 50% and off for 50% of the duty cycle time when the measured input is at the setpoint. If set at 100.0 then the relay will activated for the whole time whilst the measured input is at the setpoint.

8.11   Relay PI control duty cycle

Section:	**AL 1** to **AL 8**
Display:	**duty SECS**
Range:	**0** to **6553.5** secs
Default Value:	**10.0**
Default Access Level	**4**
Function number	**4270** to **4277**

Displays and sets the control duty cycle (period) from **0.0** to **5000.0** seconds. The control period sets the total time for each on/off cycle. This time should be set as long as possible to reduce wear of the control relay and the controlling device.
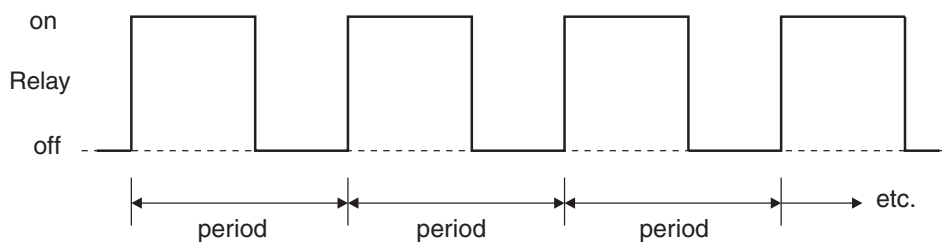
8.12   Relay PI frequency control "on" time

Section:	**AL 1** to **AL 8**
Display:	**on SECS**
Range:	**0** to **6553.5** secs
Default Value:	**1.0**
Default Access Level	**4**
Function number	**4280** to **4287**

Displays and sets the control pulse width ("on" time) from **0.0** to **5000.0** seconds. If set to 0.0 the relay will be disabled. The duration should be long enough to ensure that the device being controlled receives an acceptable on pulse.

8.13   Setting up the PI pulse width controller

Settings in the procedure below are intended as a basic guide to setting up the controller where there required settings are not known.

1. Set the **OPEr** function to **Ctrl** .

2. Set the control setpoint **SEtP** to the required setting.

3. Set the control span **SPAn** to the required setting.

4. Set the proportional gain **P.9** to an arbitrary value e.g. **0.500**.

5. Set the integral gain **I.9** to **0.000** (i.e. off).

6. Set the low and high integral **I.L** and **I.H** limits to an arbitrary value e.g. **20.00**.

7. Set the bias **bi AS** to **50.0**.

8. Set the cycle **duty SECS** period to **20** seconds.

Initialise the control system and monitor the control results. If the original settings causes process oscillations then gradually decrease the proportional gain until the oscillations decrease to an acceptable steady cycle. If the original settings do not cause process oscillations then gradually increase the proportional gain until a steady process cycling is observed.

Once the steady cycling state is achieved note the difference between the display value and the control setpoint value. Gradually increase or decrease the bias value until the displayed value matches (or cycles about) the control setpoint value.

Gradually increase the integral gain until the process begins to oscillate. Then reduce the integral gain slightly to regain the control without this added oscillation.

Create a step change to the process conditions and observe the control results. It may be necessary to fine tune the settings and use integral limits to obtain optimum results.

Set up sequence	Symptom	Solution
Proportional gain	Slow response	Increase proportional gain
Proportional gain	High overshoot or oscillation	Decrease proportional gain
Proportional bias	Process above or below setpoint	Increase or decrease bias as required
Integral gain	Slow response	Increase integral gain
Integral gain	Instability or oscillations	Decrease integral gain

This table shows the effect on the output frequency on changing proportional gain and bias with the following settings:

SPAN = 20.0, **duty SECS** = 1.0, **I.9** = 0.000

SEtP	P.9	bi AS	Effect on relay operation
70.0	1.000	0.0	Reading of **50.0** or below - relay pulses at maximum frequency. Reading of **50.0** to **70.0** - relay pulses with frequency decreasing as value approaches **70.0**. Reading **70.0** or above - relay permanently off.
70.0	1.000	100.0	Reading of **70.0** or below - relay pulses at maximum frequency. Reading of **70.0** to **90.0** - relay pulses with frequency decreasing as value approaches **90.0**. Reading **90.0** or above - relay permanently off.
70.0	1.000	50.0	Reading of **60.0** or below - relay pulses at maximum frequency. Reading of **60.0** to **80.0** - relay pulses with frequency decreasing as value approaches **80.0**. (period increased by 50% at **70.0** compared to minimum period e.g. if minimum period is 4 seconds the period at **70.0** will be 6 seconds) Reading **80.0** or above - relay permanently off.
70.0	0.500	50.0	Reading **50.0** or below - relay pulses at maximum frequency. Reading **50.0** to **90.0** - relay pulses with frequency decreasing as value approaches **90.0**. (period increased by 50% at **70.0** compared to minimum period e.g. if minimum period is 4 seconds the period at **70.0** will be 6 seconds) Reading **90.0** or above - relay permanently off.
70.0	- 1.000	50.0	Reading of **60.0** or below - relay permanently off. Reading of **60.0** to **80.0** - relay pulses with frequency decreasing as value approaches **80.0**. (period increased by 50% at **70.0** compared to minimum period e.g. if minimum period is 4 seconds the period at **70.0** will be 6 seconds) Reading **80.0** or above - relay pulses at maximum frequency.

8.14   Setting up the PI frequency controller

Settings in the procedure below are intended as a basic guide to setting up the controller where there required settings are not known.

1. Set the **OPEr** function to **FrEq**.

2. Set the control setpoint **SEtP** to the required setting.

3. Set the control span **SPAN** to the required setting.

4. Set the proportional gain **P.9** to an arbitrary value e.g. **0.500**.

5. Set the integral gain **I.9** to **0.000** (i.e. off).

6. Set the low and high integral **I.L** and **I.H** limits to an arbitrary value e.g. **20.00**.

7. Set the bias **bIAS** to **50.0**.

8. Set the cycle **dutY SECS** period to **20** seconds.

9. Set the relay on time **on SECS** to an arbitrary value e.g. **1.0**

Initialise the control system and monitor the control results. If the original settings causes process oscillations then gradually decrease the proportional gain until the oscillations decrease to an acceptable steady cycle. If the original settings do not cause process oscillations then gradually increase the proportional gain until a steady process cycling is observed.

Once the steady cycling state is achieved note the difference between the display value and the control setpoint value. Gradually increase or decrease the bias value until the displayed value matches (or cycles about) the control setpoint value.

Gradually increase the integral gain until the process begins to oscillate. Then reduce the integral gain slightly to regain the control without this added oscillation.

Create a step change to the process conditions and observe the control results. It may be necessary to fine tune the settings and use integral limits to obtain optimum results.

Set up sequence	Symptom	Solution
Proportional gain	Slow response	Increase proportional gain
Proportional gain	High overshoot or oscillation	Decrease proportional gain
Proportional bias	Process above or below setpoint	Increase or decrease bias as required
Integral gain	Slow response	Increase integral gain
Integral gain	Instability or oscillations	Decrease integral gain

9 Analog output option functions

The optional analog outputs can be configured to operate in either retransmission or PI control modes.

Functions seen when set for retransmission output are:
OutP , **InPt** , **P.Ctl** , **Lo** and **HiGh**

Functions seen when set for PI control output are:
OutP , **InPt** , **P.Ctl** , **SEtP** , **SPRn** , **P.G** , **I.G** , **I.H** , **I.L** and **biRS**

These functions are described below.

9.1 Analog retransmission outputs

Section:	**rO1** to **rO2**
Display:	**OutP**
Range:	**4-20**, **0-1.0**, **0-10**
Default Value:	**4-20**
Default Access Level	**4**
Function number	**4140** to **4141**

One or two analog outputs are optionally available in either 12 or 16 bit versions. The 12 bit version output is fixed at 4-20mA. With the 16 bit version the user can select 4-20mA, 0-1VDC or 0-10VDC output at this function.

9.2 Analog retransmission input channel

Section:	**rO1** to **rO2**
Display:	**InPt**
Range:	Any available channel
Default Value:	**CH1**
Default Access Level	**4**
Function number	**43E0** to **43E1**

This function allows selection of which channel the selected analog output is to follow. The output can follow any input channel or and calculation channel. For example to select analog output 1 to follow input channel 3 set the **rO1 InPt** function to **CH3**. Alternatively when **d.SEL** is chosen the output channel can be set to selected via the remote inputs. See the remote input functions and electrical installation chapter remote input details. Note that if the **d.SEL** mode is selected all input channels and calculated channels selected for retransmission must have the same decimal point setting. If two analog outputs are available and both are set to operate in the **d.SEL** mode then both outputs will be controlled by the same remote input selection, i.e. they are not independent. It is not possible to use the remote input selection method on both analog outputs independently.

9.3 Analog output PI control

|	
Section:	**ro 1** to **ro 2**
Display:	**P.Ctl**
Range:	**NO** or **YES**
Default Value:	**No**
Default Access Level	**4**
Function number	**4600** to **4601**

This function allows the analog output to be set to retransmission or PI control. To use the analog output as retransmission set the **P.Ctl** function to **No**, the PI control functions will not be seen if the **P.Ctl** function is set to **No**.

To use the analog output as a PI control output set the **P.Ctl** function to **YES**, the PI control functions will be seen if the **P.Ctl** function is set to **YES** and the retransmission functions will not be seen.

9.4 Analog output PI control setpoint

Section:	**ro 1** to **ro 2**
Display:	**SEtP**
Range:	Any display value
Default Value:	**0.0**
Default Access Level	**4**
Function number	**4610** to **4611**

This function allows selection of the PI control setpoint. The control setpoint is set to the value in displayed units required for control of the process. The controller will attempt to vary the control output to keep the process variable at the setpoint.

PROCESS

Process above
setpoint

Process at
setpoint

SETPOINT

Process below
setpoint

TIME
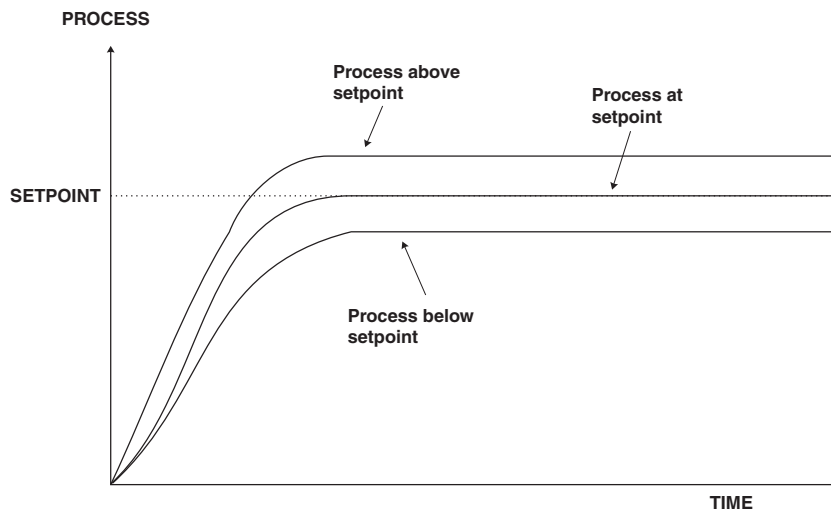
9.5 Analog output PI control span

Section:	**ro 1** to **ro2**
Display:	**SPAn**
Range:	Any display value
Default Value:	**100.0**
Default Access Level	**4**
Function number	**4618** to **4619**

This function allows selection of the PI control span. The control span determines the points at which the control process cuts in and cuts out. For example a control setpoint of 100 with a control span of 40 with zero integral gain and a proportional gain of 1.000 will have its output fully on at 80 or below and fully off at 120 or above. Between the values of 80 and 120 the output will change to try to maintain the setpoint.

9.6 Analog output PI control proportional gain

Section:	**ro 1** to **ro2**
Display:	**P.9**
Range:	Any display value
Default Value:	**1.000**
Default Access Level	**4**
Function number	**4620** to **4621**

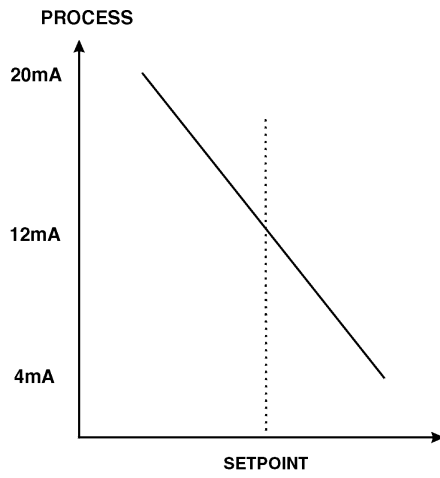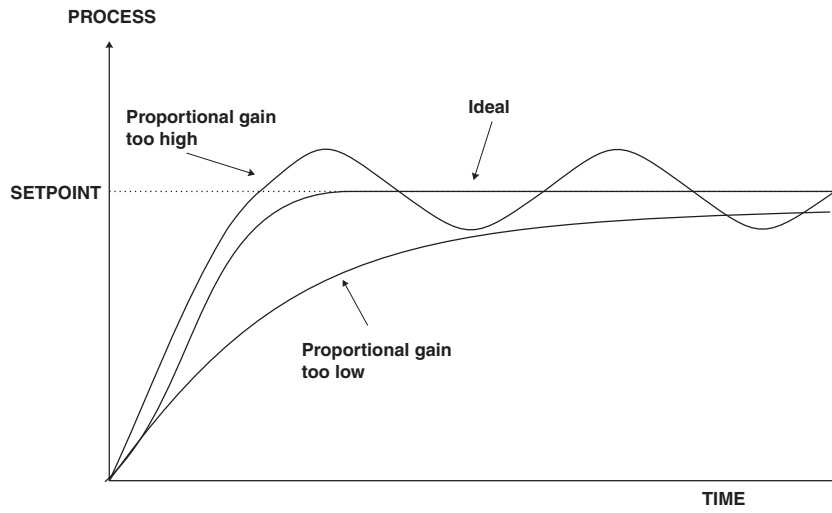Allows selection of the PI control proportional gain.

The proportional gain is the ratio between the change in measured input and change in control output. Too much proportional gain will result in instability.

Example 1 - if the proportional gain is set to **1.000** and the measured input changes by 100% of the span set in **SPAn** then the output will change by 100%.
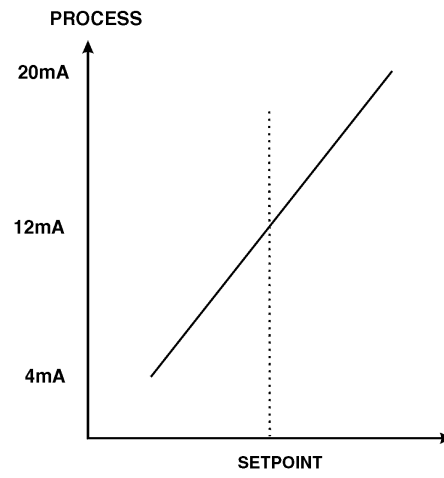
Example 2 - if the proportional gain is set to **2.000** and the measured input changes by 50% of the range set in **SPAn** then the output will change by 100%.

Example 3 - if the proportional gain is set to **2.000** and the measured input changes by 25% of the range set in **SPAn** then the output will change by 50%.

Setting a negative proportional gain will reverse the control output.

PROCESS

Proportional gain too high

Ideal

SETPOINT

Proportional gain too low

TIME

PROCESS

20mA

12mA

4mA

SETPOINT

Positive *P.9* value e.g. *1.000*

PROCESS

20mA

12mA

4mA

SETPOINT

Negative *P.9* value e.g. *-1.000*

SEtP	P.9	b, AS	Effect on analog output (4-20mA used in this example)
This table shows the effect of the output current of changing proportional gain and offset with the following settings: $SPAn = 20.00$, $I.9 = 0.000$			
70.00	1.000	0.000	Reading of 50.00 or below - 20mA output
			Reading of 50.00 to 70.00 - mA output decreasing as reading approaches 90.00
			Reading 70.00 or above - 4mA output
70.00	1.000	1.000	Reading of 70.00 or below - 20mA output
			Reading of 70.00 to 90.00 - mA output decreasing as reading approaches 9.00
			Reading 90.00 or above - 4mA output
70.00	1.000	0.500	Reading of 60.00 or below - 20mA output
			Reading of 60.00 to 80.00 - mA output decreasing as reading approaches 80.00 with 12mA output at 70.00
			Reading 80.00 or above - 4mA output
70.00	0.500	0.500	Reading 50.00 or below - 20mA output
			Reading 50.00 to 90.00 - mA output decreasing as reading approaches 90.00 with 12mA output at 70.00
			Reading 90.00 or above - 4mA output
70.00	- 1.000	0.500	Reading of 60.00 or below - 4mA output
			Reading of 60.00 to 80.00 - mA output increasing as reading approaches 80.00 with 12mA output at 70.00
			Reading 80.00 or above - 20mA output

9.7 Analog output PI control integral gain

|	
Section:	$r01$ to $r02$
Display:	$I.9$
Range:	Any display value
Default Value:	0.000
Default Access Level	4
Function number	4628 to 4629

The integral control action will attempt to correct any offset which the proportional control action is unable to correct (e.g. errors due to a changing load). When the integral gain is correctly adjusted the control output is ramped up or down to maintain control by keeping the process variable at the same value as the control setpoint. An integral gain which is too large will cause a rapid response to any error but can also lead to overshooting and oscillation. An integral gain which is too small

will slow the time taken to reach the setpoint. The optimum value chosen will depend on the lag time of the process and other control settings. Start with a low figure and increase until a satisfactory response time is reached. The integral gain figure has units of gain/minute. Setting a negative integral gain will reverse the integral control action. If introduction of an integral gain figure causes the error to increase i.e. the process value is moving further away from the setpoint then check the sign of the integral gain e.g. if it is negative change it to a positive value. Note that the sign of the integral gain value should be the same as the proportional gain value i.e. they should either both be positive or both be negative.

The integral control output can be found from:

$$Integral\ control\ output = \frac{Error \times I.G \times time(secs)}{60} + previous\ integral\ control\ output$$

Where $I.G$ is the integral gain is set by the $\mathit{I.9}$ function.
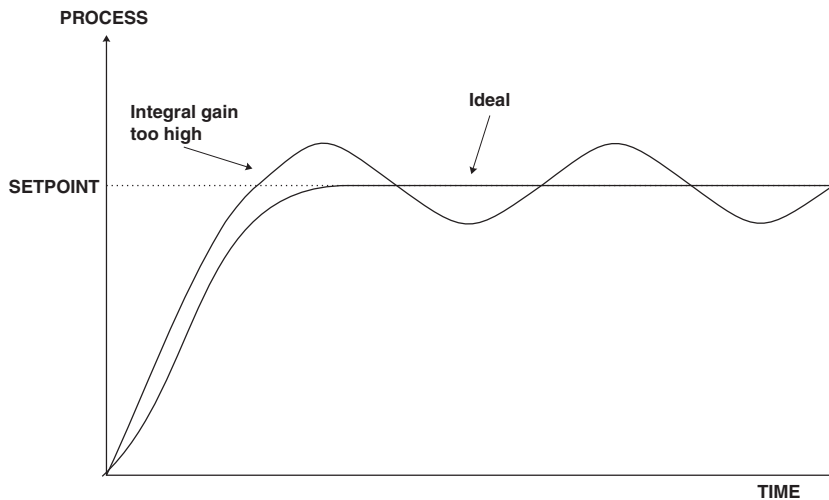
9.8   Analog output PI control integral high limit

Section:	$\mathit{r01}$ to $\mathit{r02}$
Display:	$\mathit{I.H}$
Range:	$\mathit{0}$ to $\mathit{100.0}$ %
Default Value:	$\mathit{100.0}$
Default Access Level	$\mathit{4}$
Function number	$\mathit{4638}$ to $\mathit{4639}$

Allows selection of the PI control integral high limit.

The high limit sets the maximum control output for the integral term i.e. puts a high level limit to the integral control current or voltage output. The limit is used to reduce available output swing and hence limit the effect of integral control output build up which can cause overshoot and instability in the system. If the process value is not close to the setpoint value then the integral control will see a large error. Since integral control output increases with time, the longer an error is seen the more the integral control output will build up. Unless the output is limited then once the process reaches the setpoint the integral control output can be very large (e.g. 100%) causing the process value to overshoot the control setpoint. A setting which is too high will result in allowing the integral control output to cause overshooting. A setting which is too low will result

in the integral control output being limited to an extent which means that the setpoint cannot be reached. Start with a low figure e.g. 10.0 and increase the value until a satisfactory response is reached. Maximum setting is 100.0 (100%). Having separate high and low limits is particularly useful if the process response is very one directional. For example in temperature control a heater may be used to give a fast response in heating a tank of liquid when the temperature falls below the setpoint. The heat of the liquid rises quickly but any overshoot will mean that the temperature is too high. The heater will be switched off but the tank of liquid will take a long time to cool to the setpoint level.

9.9   Analog output PI control integral low limit

|	
Section:	⌐0 ¦ to ⌐0 2
Display:	¦ .L
Range:	0 to 100.0 %
Default Value:	100.0
Default Access Level	4
Function number	4640 to 4641

Allows selection of the PI control integral low limit.

This function sets the minimum control output for the integral term value and works in the same manner as ¦ .H described above except that the setting controls the low swing.

9.10   Analog output PI control bias

Section:	⌐0 ¦ to ⌐0 2
Display:	b¦ AS
Range:	0 to 100.0 %
Default Value:	50.0
Default Access Level	4
Function number	4648 to 4649

Allows selection of the PI control bias. The bias is initially used to set the output value when operating the instrument as a proportional only controller. The bias determines what % of the proportional control output will be given when the process value reaches the setpoint value. If set to 0.000 then there will be zero output (e.g. 4mA for a 4-20mA output) when the process value reaches the setpoint value. If set to 0.500 then there will be a 50% output (e.g. 12mA for a 4-20mA output) when the process reaches the setpoint value. If set to 1.000 then there will be a 100% output (e.g. 20mA for a 4-20mA output) when the process reaches the setpoint value. If using proportional only control then when stable control is established there may be a difference between the process and the setpoint values. By altering the bias value the difference may be minimised.
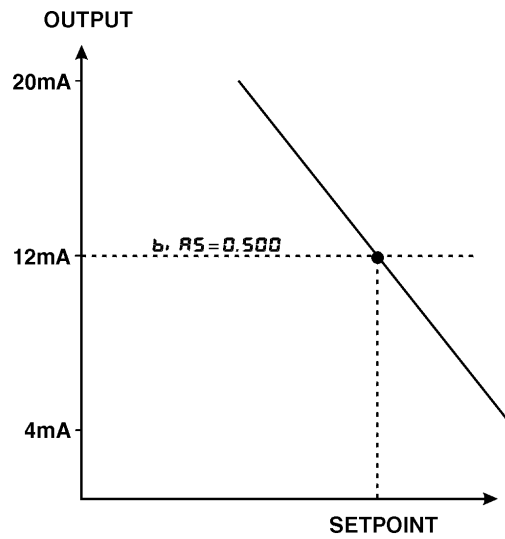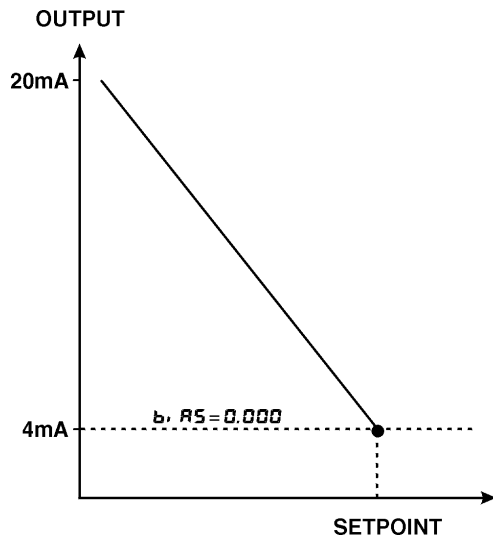
9.11 Analog retransmission low display value

Section:	`rO1` to `rO2`
Display:	`Lo`
Range:	Any display value
Default Value:	`0.0`
Default Access Level	`4`
Function number	`4120` to `4121`

This function can be used to set the analog retransmission signal output low value in displayed engineering units. For example to set analog output 1 to retransmit 4mA (or 0V if available) for a display value of zero set `rO1 Lo` to `0`.

9.12 Analog retransmission high display value

Section:	`rO1` to `rO2`
Display:	`Hi9h`
Range:	Any display value
Default Value:	`100.0`
Default Access Level	`4`
Function number	`4130` to `4131`

This function can be used to set the analog retransmission signal output high value in displayed engineering units. For example to set analog output 1 to retransmit 20mA (or 1V or 10V if available) for a display value of 200 set `rO1 Lo` to `200`.