ILLSEC
Handbook

(Institut Laue-Langevin Sample Environment Controller)

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1. Overview

The ILL Sample Environment Controller (ILLSEC) is designed specifically to the needs of the ILL Sample Environment Laboratory and the apparatus currently in use on the instruments. It has the following characteristics:

- Four 4-wire resistance inputs - excitation current continuously variable between 0 and ±1000µA
- Two precision voltage inputs (±2.5V max.)
- Heater output 75V, 2A max.

2. Configuration

It is possible to configure the ILLSEC many different ways depending on the apparatus being controlled. In the following descriptions the parts of the titles in parenthesis show which menu item on the front-panel display is used to perform the configuration, as well as the corresponding computer interface command. Some configurations can only be set up by using computer commands.

2.1 Input Functions (menu-CHANNEL ; chan command)

Each input can be assigned to one of the logical functions shown below.:

- **Regulation channel**

  The channel is used for temperature regulation. Up to two channels can be assigned this function at the same time. Normally one will be a high temperature thermometer (e.g. Platinum resistance thermometer), and the other a low temperature thermometer (e.g. Carbon or Germanium). An overlap region can be defined for two thermometers (see `sensor` below). From this an automatic weighted mean temperature is calculated from the two values when the temperature of both sensors lies within the defined overlap region. *At least one channel has to be assigned to regulation for temperature control to operate.*

- **Sample channel**

  The channel is used to measure the sample temperature. In the same way as for regulation, up to two channels can be assigned to this function. If regulation of sample temperature is enabled (not yet available) then it is this temperature that is maintained at the requested set-point.

- **Measurement channel**

  The channel is simply used for temperature monitoring. No limitation is placed on the number channels set to this function, and no automatic thermometer overlap calculations are made for high and low temperature thermometers.

- **Not used (off)**

  The channel is not used for any purpose, and can be left with nothing connected to it.

2.2 Input Sensors (menu - SENSOR ; ip and sensor commands)

The characteristics and calibration of sensors are defined using the *`sensor`* computer command. The separate description of the command gives further details. Once a sensor has been declared, with either the menu item SENSOR or the *`ip`* command, it can be assigned as being connected to a given input channel using the reference number used in the declaration.

Some common types are pre-defined in the ILLSEC software. Although their characteristics are known internally they still have to be declared when starting up the ILLSEC from "cold" -i.e. when no configuration has yet been introduced. This normally is only necessary when a new version of the software EPROMs is introduced and the internal data base held in non-volatile RAM has to be erased. A special start-up file (called *sensinit*)held on the internal RAM disc will do this automatically. The following sensor types can be declared using the `sensor` command and then assigned to a given channel:

- OC Open-Circuit (no sensor connected)
- V Voltage (only a voltage can be measured)
- R Resistance (can only be assigned to the resistance channels A,B,C,D)
- PTDIN Platinum resistance of the DIN43760,BS1904,NFC43-330 standard
- PT Platinum resistance for cryogenic use (α = 0.00392506)
- AB 100Ω Allen-Bradley Carbon (old series: $R_{4.2K} \approx 1500\ \Omega$)
- C 100Ω Allen-Bradley Carbon (new series: $R_{4.2K} \approx 1050\ \Omega$)
- CG Carbon Glass (Lake Shore)
- CTG Carbon Glass (CENG)
- RHFE Rhodium Iron resistance thermometer ($R_{273K} = 27\Omega$)
- TYPE-K Type K thermocouple (Ni-Cr/Ni-Al) DIN 43710
- TYPE-W Type W5 thermocouple (W-Re5%/W-Re26%)
- TYPE-S Type-S thermocouple (Pt/Pt-Rh10%)
- GE Germanium resistance thermometer
- CNX Cernox(®Lake Shore) resistance thermometer

2.3 Input Multiplexers (menu MUX ; mux command)

Each of the four resistance measurement channels (A, B, C, and D) has an internal multiplexer that allows it to be connected to the front panel connector or to one of three internal reference resistors. These resistors have values of 10kΩ(±0.1%), 100Ω(±0.01%) and 0Ω. These internal standards are used to systematically re-calibrate the measurement electronics for maximum accuracy. It takes place every ten minutes and is usually invisible to the user except when the temperature has changed from very low values (<10K) to high values over a short period of time. This is due to the way the excitation current is optimised for the temperature being measured and the very large change in value of semiconductor sensors (3 or 4 orders of magnitude). It may be noticed under these circumstances that 10 minutes after a new set-point has been requested there it a small jump in the measured temperature. This should not be a problem since after making a large change in set-point the system will not have reached equilibrium within ten minutes.

Under normal circumstances the multiplexers will be set to measure the external sensors but they can be set to read one of the internal reference resistors to check on the correct operation of the instrument.

2.4 PID set-up (menu-MODIFY/PID ; nvpid & pid commands)

The PID (Proportional-Integral-Differential) control algorithm used on the ILLSEC is the same one that has been used on the old ILL PTC(Precision Temperature Controller). It has been proved to be very robust and not too sensitive to the PID parameter values. These values are used slightly differently to those used in classical numerical PID controllers found on the market in that they do not relate to any specific time parameter. Their action is different also since the larger a gain parameter (GP-Proportional gain, GI-Integral gain, GD-Differential gain) the bigger its action. (In a classical PID the smaller the P parameter the higher the gain; the smaller the I parameter the faster the integral term reacts.)

At present there is no auto-tuning option on the ILLSEC but there is a system of auto-selection of PID parameters depending on the set-point temperature. Each time a new set-point is selected the PID parameters are taken from a table of values depending on the target value of temperature. These tables are selected using the MODIFY/PID/NAME menu option or the `pid` command. The tables are defined using the `nvpid` computer command.

If it is required to adjust the PID parameters this can be done using the pid command but will be more practical using the MODIFY/PID menu. Normally the PID parameters will be set to manual (MODIFY/PID/MAN) so that when different set-point temperatures are tried the PID parameters will not be automatically modified by the system to the values held in the current PID table. This automatic parameter selection can be selected with the MODIFY/PID/AUTO menu.

2.5 Limits (menu-MODIFY/LIMITS ; lim command)

Two sets of limits can be modified by the operator; the minimum and maximum set-point temperatures, and the minimum and maximum heater output power. The minimum limits for both variables is zero. The maximum values are determined by the "hardware" limits set in the current PID table. For example the ORANGE PID table will not allow the set-point maximum limit to be set above 325 Kelvin and the heater power maximum limit to be set above 40% (0.4 x 75 = 30V).

2.6 Auto-identification system (menu-AUTOIDENT)

The ILLSEC incorporates a novel system for automatically identifying the equipment to which it is connected. Each of the two resistance measurement connectors (inputs A/B and C/D) has a wire dedicated to this function. At the cryostat end of the sensors cable is an adapter plug constructed from a standard Jæger plug and a Fischer socket. Inside this adapter is a small integrated circuit that transmits a unique serial number back to the ILLSEC. The ILLSEC can then look up this number in an internal table to determine the sensors' types and reference numbers, the PID characteristics (if appropriate), etc. If all the appropriate information is present in the internal data-base then the ILLSEC will reconfigure the measurement inputs appropriately. This function is initiated with the AUTOIDENT menu command. If there is no properly programmed adapter connected to the ILLSEC then an error message is displayed after a few seconds.

3. Commands

3.1 General syntax

```
<command name> [<options>] {parameters} [<options>]
```

where:

- `[]` = enclosed items are optional
- `{}` = enclosed items may be used 0, 1 or more times
- <> = enclosed item is a description of the parameter to use.

All commands return a status line of the form:

```
<command name> returned status <nn>
```

where `<nn>` is a signed decimal integer. A value of 0 (zero) indicates successful execution of the command with no detected errors. Any other value indicates some sort of error documented under the description of each command.

For most commands this status line can be inhibited by using the *-q* option, but this is not recommended except for those commands that only return the value of internal parameters, such as *rt*.

When the ILLSEC is first switched on, both of the RS232 serial interfaces default to 9600 baud (8 data bits, no parity, 1 stop bit) with XON/OFF flow control. Since it is intended for each interface to be usable with an ordinary VT100-type terminal, anything typed on the interface will be echoed to the screen. When using a computer to interface with the ILLSEC this is undesirable so the following commands should be sent when initialising the interface for use with a computer:

```
tmode noecho<CR>
initio -<CR>
```

(the character after the word "initio" is a minus sign - ASCII 2D hex)

From then on only characters sent by the ILLSEC will be visible, any typing of commands will be "blind". To restore the echoing of commands simply give the following:

```
initio<CR>
```

Output from the commands depends on individual commands, the number of lines of output being variable. After any output has been typed the status line as described above is output (unless it has deliberately been suppressed).
All lines are separated by the `<CR><LF>` pair, and the system indicates its readiness to accept another command by issuing the following prompt:

```
<CR><LF>ILLSEC:<path>><SPC>
```

where `<path>` is the current OS-9 directory path. Thus a typical prompt string will be:
"`<CR><LF>ILLSEC:/dd/CMDS><SPC>`"
(not including the quotation marks).

When writing software to communicate with the ILLSEC a fairly safe character string to wait for before issuing a command would be first to wait for the <CR><LF> combination and then for the "`><SPC>`" ('greater-than' sign followed by a space character). If required, the prompt string can be changed using the following command:

```
-p="new prompt string"<CR>
```

The new prompt string only has to be enclosed in quotes if it includes one or more space characters. A string commonly used by ILLSEC operators is "`:<SPC>`" (colon followed by a space), so that communication software only has to wait for the four characters "*`<CR><LF>: `*".

Finally, multiple commands can be placed on the same line, separated by semicolons, if required. Thus an example of a command line sent to the ILLSEC when initialising communications software is:

```
tmode noecho;initio -;-p=": "<CR>
```

3.2 chan define channel function

Syntax: `chan [<options>] [parameters]`

Function: `chan` defines the functionality of a given channel. A maximum of two channels can have the same function, in which case the two temperatures will be used according to their range of application and their cross-over region (e.g. the progressive transfer from Platinum to Carbon as the temperature descends).
The possible functions are:

- Regulation - the sensor is mounted on the regulation block
- Sample - the sensor is mounted on the sample holder; this is the temperature that would be controlled by the second PID loop.
- Measurement - the sensor is used for monitoring only and is never associated with a control function.
- Nothing - the channel is not used; no reading is made even if a sensor has been defined for that channel. It corresponds to an OFF state.

Parameters:

r[=]<channel number> - channel is for regulation
s[=]<channel number> - channel is for sample measurement
m[=]<channel number> - channel is for temperature monitoring only
n[=]<channel number> - channel not used (OFF)

If no parameters are given then `chan` will give a list of the functions assigned to each channel. (same as -l).

Options:

`-l`	list the functions of all the currently active channels (default).
`-q`	Quiet - suppress status text.
`-qq`	Quiet - suppress status line (not recommended).
`-?`	Display help message for `chan`.

Status returns:

0	No error, limits changed as requested.
1	Unknown option
2	Attempt to define more than two regulation channels
3	Attempt to define more than two sample channels

3.3 data define thermometer calibration data

Syntax: `data [<opts>] s[=]<sensor ID> [<opts>]`

Function: `data` is used to define the calibration data for the calculation method of a thermometer previously declared using the `sensor` command. This data is only required for sensors that have been individually calibrated; typical data predefined in the ILLSEC memory is used for all sensors having the serial number zero.
The data are read from *`stdin`* and can thus be read from a file using the "<" redirection symbol, or be typed in at a terminal.

Options:

- `-n` used to define or redefine a set of data for a specific sensor and store it in the non-volatile memory of the ILLSEC. If data already exists for the given sensor it is over-written, unless an error in the new definition is detected, in which case the old data remains untouched.
- `-l` display data and calibration method for the given sensor.
- `-q` Quiet - suppress status text.
- `-qq` Quiet - suppress status line (not recommended).
- `-?` display help message.

Parameters : `s[=]<sensor ID>` sensor type & serial number (e.g. AB114)

Status returns:

- `0` No error detected, data stored as requested.
- `1` Unknown option.
- `2` error in the `s=` parameter.
- `3` Sensor not found or cannot be redefined (e.g. PT_DIN).
- `4` Insufficient memory to hold the data; memory can be freed by deleting other sensors (and their calibration data) using `sensor`.
- `5` Number of zones or data lines equals zero (see appendix A).
- `6` Unexpected end of file (not enough data).
- `7` Bad data.
- `8` No data defined or not available for given sensor.

NOTE: See appendix A, page 45 for a description of the data format for each calibration method.

See also: `sensor` command.

3.4 ip define a sensor for an input channel

Syntax: `ip [<opts>]`

Function: `ip` is used to define what sensor is connected to each input channel. One of three methods can be used:

(1) **by specifying the `-b` option with a measurement block number** which is the number that would be returned by the auto-identification system. The block characteristics have to have already been defined using the `nvblock` command. The first sensor on the block will be assigned to the given channel and the second sensor of the block will be assigned to the given channel number + 1. Either of these channel definitions can then be overridden by using the individual assignment option `-s` if necessary.

(2) **by simply specifying a cryostat number using the `-c` option.** This will cause the ILLSEC data base to be searched for a block defined as belonging to the given cryostat (either a regulation block if `<place number>` = 0, or a sample holder having with the same serial number as `<place number>`). For example `-c=69,0` would refer to the regulation block of cryostat 69ILHV25; `-c=69,1` refers to sample holder (porte échantillon) number 1 of the same cryostat. If found the block is assigned as if it had been specified using `-b` option as above.

(3) **by specifying an individual sensor reference using the `-s` option.** If both *`-n=<chan>`* and *`-s=<ID>`* options are given then channel *`chan`* is defined as having sensor type *`ID`* connected to it. If only one of these two options is given then `ip` will search the channels to find a match for the one specified and will list the results (providing the `-l` option is given). If no sensor of the designated ID is connected anywhere then an error status is returned.

If no options are given then `ip` will list the ID of the sensor connected to each channel.

Only sensors that are already known to the ILLSEC can be specified. (A list can be obtained with the `-?` option), otherwise an error status is returned.

Options:

`-n[=]`	`<channel number>`
`-s[=]`	`<sensor ID>`
`-c[=]`	`<cryostat number>,<place number>`
`-b[=]`	`<block number>`
`-l`	list sensor types for each channel
`-q`	Quiet - suppress status return values (not recommended).
`-?`	Display help message for `ip`.

Status returns:

`0`	No error.
`1`	Unknown option
`2`	Channel number invalid.
`3`	Sensor not found.
`4`	Sensor type missing.
`5`	Given sensor not assigned to any channel.
`6`	Impossible sensor type for the given channel
`7`	Incompatible options
`8`	Block not found.
`9`	Value missing for -n, -s, -c or -b options.
`10`	Not enough options given

3.5 lim set user limits

Syntax: `lim [<options>] [{sph}{spl}=<temperature>] [{oph}{opl}=<power>]`

Function: `lim` sets the various limits available to the user. They include those for the temperature set-point and those for the output power.

All user limits are checked against the "hardware" limits imposed by the apparatus being controlled. If an attempt is made to set a user limit outside a hardware limit then no action is taken and an error message is returned.

If there are no parameters on the command line, or the -l option is given, `lim` returns the current limit settings on a single line in the form:

sph=dddd.ddd spl=dddd.ddd oph=dddd.ddd opl=dddd.ddd

where *sph* means set-point high-limit (K)
where *spl* means set-point low-limit (K)
where *oph* means output power high-limit (%)
where *oph means* output power low-limit (%)
where *dddd.ddd* is the decimal value

Options:

`-l`	list user limits.
`-h`	display the 'hardware' limits.
`-q`	Quiet - suppress status text.
`-qq`	Quiet - suppress status line (not recommended).
`-?`	Display help message for `lim`.

Status returns:

`0`	No error, limits changed as requested.
`1`	Unknown option.
`2`	*spl* greater than *sph.*
`3`	*oph* less than *opl.*
`4`	*spl* (or *opl*) less than 'hardware' minimum limit.
`5`	*sph* (or *oph*) greater than hardware' maximum limit.

3.6 mux set up input multiplexers for channels A, B, C and D

Syntax: `mux [<opts>] [parameters] [<opts>]`

Function: connects one of channels A, B, C or D to an external sensor or to one of three internal reference resistors. It is recommended that each unused input be set to the 0 Ω internal reference.

Options:

`-l`	list the input connected to each measurement channel (default).
`-q`	Quiet - suppress status text.
`-qq`	Quiet - suppress status line (not recommended).
`-?`	Display help message for `mux`.

Parameters:

`e[=]<chan>`	set <chan>(0 .. 3) to external sensor
`a[=]<chan>`	set <chan>(0 .. 3) to internal 0 Ω reference
`b[=]<chan>`	set <chan>(0 .. 3) to internal 100 Ω reference
`c[=]<chan>`	set <chan>(0 .. 3) to internal 10000 Ω reference

Status returns:

`0`	No error detected.
`1`	Unknown option.
`2`	Internal error reading current state.
`3`	Internal error setting multiplexer.
`4`	Internal error communicating with HC11.

Note: Errors 2, 3 and 4 are due to hardware faults. If they occur the ILLSEC will have to be repaired.

3.7 nvblock define a measurement block and its characteristics

Syntax: `nvblock [<opts>] [parameters] [<opts>]`

Function: define the characteristics of a so called "measurement block". A block has a logical function of either a regulation block or a sample measurement block. It is assigned a unique identification number (issued by the Sample Environment Laboratory) which is used by the auto-identification system when configuring the ILLSEC. The characteristics that are defined are the type and serial numbers of the sensors mounted on the block and the PID table identifier if appropriate. Once defined the auto-id system can set up the channel inputs whenever the block ID is referenced.

Options:

`-n`	create a new block
`-d`	delete a block
`-l`	display the characteristics of a block
`-q`	Quiet - suppress status text.
`-qq`	Quiet - suppress status line (not recommended).
`-?`	display help message

Parameters:

`i[=]<block identification number>`
`n[=]<PID structure name>`
`p[=]<place number>` 0:regulation >0:sample holder
`s[=][<sensor 1 ID>][,<sensor 2 ID>]` (e.g. s=AB123,PT0)

Status returns:

`0`	No error, limits changed as requested.
`1`	Unknown option
`2`	One of `i=`, `n=` or `s= missing`
`3`	Unknown block ID
`4`	Not enough non-volatile memory
`5`	Conflicting options
`6`	Block already exists
`7`	Unknown PID name
`8`	Sensor 1 not found
`9`	Sensor 2 not found

See also: chapter 4.7.2 **Selecting channel thermometers by block**, page 36

3.8 nvpid define PID structure

Syntax: `nvpid [<opts>] <PID name> [<opts>]`

Function: define the PID data for a measurement block. The data consists of a table of temperatures for each of which the values of Proportional gain, Integral gain and Differential gain are given. When a new regulation setpoint is requested the ILLSEC searches in its current PID table for the temperature band containing the new setpoint value. When found the tabulated gains for P, I and D are inserted into the PID control loop algorithm.
The data are read from the *stdin* path of the program so they can be typed directly into the program using the input device, or read from a file on the internal RAM disk using the "<" redirection operator.
The format of the data is as follows:

<max. "hardware" temperature>
<max. "hardware" power>
<number of PID table entries to follow(N)>
<PID table entry 1>
.
.
<PID table entry N>

where each <PID table entry> consists of the following 5 values:

```
Temperature,
Proportional gain, Integral gain, Differential gain,
Differential filter constant.
```

Each value is separated by any number of white-space characters which includes the <CR> character so they can be all on one line or spread over a number of lines as shown above.

Options:

`-n`	Create a new PID table structure.
`-d`	Delete a PID table.
`-l`	Display the data for the named PID table.
`-q`	Quiet - suppress status text.
`-qq`	Quiet - suppress status line (not recommended).
`-?`	Display help message.

Status returns:

`0`	No error, limits changed as requested.
`1`	Unknown option
`2`	Name missing
`3`	Named PID data not found
`4`	Not enough non-volatile memory to store the table
`5`	Conflicting options
`6`	Named PID table already exists
`7`	Unexpected End Of File (not enough data)
`8`	Bad data (non-numeric character)

3.9 pen set up pen recorder outputs

Syntax: `pen [<options>] [parameters] [<options>]`

Function: `pen` sets up the two analogue outputs to follow the value of one of a number of possible internal parameters. An output of 0V can be assigned a minimum value and would correspond to the left-hand edge of the chart-recorder paper. The maximum output is 5V and can be assigned a value that will correspond to the right-hand edge of the paper if the pen-recorder is set to have a full-scale span of 5V. If an output has already been assigned to monitor a particular variable, it is not necessary to redefine it when only the scale is being changed; the previous variable is assumed.
If more than one output parameter is given only the last one to appear on the line is taken into account.
`pen` with no parameters or options will list the current configuration of the pen recorder outputs (same as -l option).

Parameters:

min[=]<min value>	Define minimum scale value
max[=]<max value>	Define maximum scale value

Options:

`-1`	output number 1
`-2`	output number 2
`-rt`	monitor regulation temperature.
`-st`	monitor sample temperature.
`-r<n>`	monitor resistance on channel <n>. (n=0 .. 3)
`-t<n>`	monitor temperature, in Kelvin, of input channel <n> (n=0 .. 5)
`-v<n>`	monitor raw ADC reading for channel <n>. (n=0 .. 7) (min = -524288, max = 524287).
`-pw`	monitor heater power (per cent).
`-off`	disable pen recorder output.
`-l`	display the configuration of the pen recorder outputs.
`-q`	suppress status line.
`-?`	display help message for `pen`.

Status returns:

`0`	No error detected.
`1`	Unknown option.
`2`	Attempt to cross the left & right values (max < min).
`3`	No output number given (either -1 or -2 must be given).

3.10 pid set PID parameters

Syntax: `pid [<opts>] [parameters] [<opts>]`

Function: Set pid parameters. The parameters can be for the regulation control loop (default if neither `-r` nor `-s` options are specified) or for the sample control loop.

Options:

`-r`	parameters are associated with the regulation loop (default)
`-s`	parameters are associated with the sample control loop
`-ar`	automatic PID parameter selection (regulation block)
`-mr`	manual PID parameter selection (regulation block)
`-as`	automatic PID parameter selection (sample block)
`-ms`	manual PID parameter selection (sample block)
`-n[=]<name of PID structure>`	
`-l`	display PID parameters (default).
`-q`	suppress status line.
`-?`	display help message.

Parameters:

`gp[=]value`	Set PID GP to value
`gi[=]value`	Set PID GI to value
`gd[=]value`	Set PID GD to value
`td[=]value`	Set PID TD to value
`wi[=][value]`	Set PID WI to value (default zero)

Status returns:

`0`	No error detected
`1`	Unknown option
`2`	Incompatible options

3.11 ramp define a temperature ramp with time

Syntax: `ramp [<opts>] <final temperature(K)> <time(min)>`

Function: `ramp` changes the temperature linearly over the given time from its present value to that given as the first parameter in the command line. The `ramp` command will give an error if the target temperature is outside the current set-point limits. However once the ramp is started a limit can be changed and if this temperature is ever reached the ramp will be aborted, leaving the set-point at the limit value.
Normally the ramp starts at the current temperature, but it can be forced to start at some other temperature using the -s option. It must be born in mind, though, that 'stability' at this forced starting temperature is not waited for, so the start of the ramp when using the -s option may be a long way from the expected value.

Options:

`-s[=]<T>`	Force starting temperature to T (Kelvin)
`-q`	Quiet - suppress status text.
`-qq`	Quiet - suppress status line (not recommended).
`-?`	Display help message.

Status returns:

`0`	No error detected.
`1`	Unknown option.
`2`	Illegal starting temperature given with -s
`3`	Missing parameter
`4`	T > maximum limit
`5`	T < minimum limit
`6`	control loop not running (ILLSEC will have to be restarted)

3.12 reg define which temperature to control; either regulation or sample

Syntax: `reg [<opts>]`

Function: `reg` defines which type of temperature control to use: either simple control of the regulation block or a double loop controlling the sample temperature.

Options:

`-r`	Control regulation temperature.
`-s`	Control sample temperature.
`-l`	Display current regulation type (default if no option given).
`-q`	Quiet - suppress status text.
`-qq`	Quiet - suppress status line (not recommended).
`-?`	Display help message.

Status returns:

`0`	No error detected.
`1`	Unknown option.
`2`	No channel has been designated for regulation measurement.
`3`	No channel has been designated for sample measurement.
`4`	Conflicting options.

3.13 `rt` read temperature and heater values

Syntax: `rt [<opts>]`

Function: Read temperature & heater values. If no options are given `rt` returns four decimal values on a single line as follows (all are given with 3 digits after the decimal point):

```
sp=<setpoint> reg=<regulation> sam=<sample> pwr=<heater>
```

Options -e and -f will add the absolute voltage values applied to input channels E and F respectively.
If the -v option is given then no labels precede each value:

```
<setpoint> <regulation> <sample temp.> <% heater power>
```

This allows an easier analysis of the returned data by another computer programme.

Options:

-e	Print input E voltage
-f	Print input F voltage
`-q`	Suppress error return values
`-v`	Suppress labels
`-?`	Display this help message

Status returns:

`0`	No error detected
`1`	Unknown option

3.14 sensor declare a new thermometer and its characteristics

Syntax: `sensor [<opts>] [parameters] [<opts>]`

Function: `sensor` introduces a new thermometer to the ILLSEC database. It defines its type and serial number as well as an overlap temperature if required (overlap is used to calculate a weighted mean when traversing the temperature zone covered by two different thermometers such as carbon & platinum). `sensor` also defines how the temperature is calculated by defining a method or function name. It does not specifically define any calibration data for the sensor, that is done with the `data` command.

Normally it is only necessary to remove a sensor from the database when the non-volatile memory is full and space is required for a new one. This is done with the `-d` option which will delete all references to the thermometer including its calibration data. If the thermometer is currently in use it cannot be deleted until it is released from the channel to which it is allocated.

The overlap temperature can be changed with the `-m` option, but it is not possible modify the calculation method for a given sensor once it is defined because of any possible data associated with it; the sensor must be deleted first and then redefined as using the new method.

The `sensor` command with no options or parameters will give a list of all sensors in the ILLSEC database.

Options:

- `-n` create a new sensor.
- `-m` modify the overlap temperature of a given sensor.
- `-d` delete all references to a given sensor.
- `-l` display characteristics of a given sensor.
- `-q` Quiet - suppress status text.
- `-qq` Quiet - suppress status line (not recommended).
- `-?` display help message.

Parameters :

`s[=]`<sensor ID> Type and serial number (e.g. AB102)

`o[=]`<overlap temperature>

if overlap<0 then temperature is taken as a minimum limit.

if overlap>0 then it is assumed to be a maximum value.

`m[=]`<method> name of the calibration method used to calculate the temperature.

Valid names are:

cheby	:	Chebychev polynomial
poly	:	Classical polynomial
poly_pt	:	Polynomial used for platinum sensor
pt_din	:	Polynomial used for Pt DIN sensors
poly_th	:	Interpolating polynomial used for thermocouples
rhfe85	:	Rhodium Iron 1985 with 3-point calibration

Status returns:

- `0` No error detected.
- `1` Unknown option.
- `2` either `s=` or `m=` missing.
- `3` Sensor not found (`-l`, `-m` or `-d` options).
- `4` No enough room in non-volatile memory.
- `5` Incompatible options.
- `6` Sensor already exists.
- `7` Unknown method.
- `8` Unknown sensor type.
- `9` Sensor in use (-d option)

See also: `data` command.

3.15 sp set temperature set-point

Syntax: `sp [<options>] <temperature> [<options>]`

Function: `sp` sets the ILLSEC set-point to `<temperature>` given in Kelvin. The value is checked to be within the current limits set by the user.

If the PID values are set to auto, then new values of PID parameters will be selected from the current table depending on the value of the requested target temperature.

If `sp` is executed with no parameters then it will display the current value of the set-point (same as `-l` option).

Options:

`-l`	Display the current set-point temperature
`-q`	Quiet - suppress status text.
`-qq`	Quiet - suppress status line (not recommended).
`-?`	Display help message for `sp`.

Parameters : setpoint temperature in Kelvin

Status returns:

`0`	No error, set-point changed as requested.
`1`	Unknown option
`2`	Attempt to move set-point above the current maximum. The set-point is not changed.
`3`	Attempt to move the set-point below the current minimum. The set-point is not changed.

4. Menus

The front panel LCD and its associated keyboard are used for setting up the ILLSEC and monitoring its function without the need for any external terminals or computer links. Most functions can be controlled from the front panel but some can only be achieved using the serial links, such as introducing new sensor calibrations or PID data files.

When first switched, on the LCD display a welcome screen for a few moments while it is initialising itself and then displays the main operating menu as shown in Figure 1 below.

DISPLAY	MUX
MODIFY	SENSOR
CONTROL	AUTOIDEN
RECORDER	RE_ZERO
CHANNEL	

Figure 1 - Main Menu

Menu items are selected by simply pressing the button next to the desired menu item. A short beep indicates that the button press has been registered. If a relatively long operation, such as re-zeroing the input amplifiers, is in progress then the button will not be accepted and no beep will occur. Simply try again when the operation has been completed.

The commands are organised into a hierarchical structure where selecting a main menu item displays a sub-menu with its own sub-menus. For those commands where data is selected from menu choices the new values have to entered into the instrument database by pressing the button opposite the **ENT** legend. To leave a sub menu the **ESC** legend has to selected. If changes are made on the screen and **ESC** is pressed without first having pressed **ENT** then any changes will be ignored.

The rest of this chapter will describe each of the main menu items in turn.

4.1 DISPLAY

The **DISPLAY** command contains seven display options to monitor various parameters. They are selected using the six buttons situated just below the screen. When leaving the **DISPLAY** command the current option is memorised and re-displayed the next time **DISPLAY** is selected.

4.1.1 DISPLAY TEMPERATURE

```
              DISPLAY
            TEMPERATURE

       REGULATION:  273.16 K
       SAMPLE    :  273.17 K
       SET-POINT :  300.00 K

       HEATER    :    0.000%


          SET-POINT LIMITS

        LOW LIMIT:    0.00 K
       HIGH LIMIT:  325.00 K

 TEMP CHAN Reg<-PID->Sam ESC  ->
```

Figure 2 - Display Temperature screen

This is the first screen to be displayed the first time **DISPLAY** is selected after the instrument has been switched on. It provides a live display of the regulation and sample temperatures. The values displayed are those obtained after any sensor overlap calculation has been performed (see `sensor`, page 21). The heater output is derived from the main control algorithm and constantly updated. The other parameters, set-point and its high and low limits are also constantly updated but they will only be seen to change if altered by one of the serial port commands.

This is the screen displayed after pressing the **TEMP** button on the bottom row.

4.1.2 DISPLAY CHANNEL TEMPERATURES

```
              DISPLAY
       CHANNEL TEMPERATURES

     REGULATION:  273.159 K
     SAMPLE    :  273.163 K

     CHANNEL A :    1.727 K
     CHANNEL B :  273.159 K

     CHANNEL C :    1.723 K
     CHANNEL D :  273.163 K

     CHANNEL E : off
     CHANNEL F : off

 TEMP CHAN Reg<-PID->Sam ESC  ->
```

Figure 3 - Display Channel Temperatures

This screen gives a live display of each individual measurement channel A,B,C,D,E and F. It also displays the calculated regulation and sample temperatures as before.

This is the screen displayed after pressing the **CHAN** button on the bottom row.

4.1.3 DISPLAY REGULATION PID PARAMETERS

```
                 DISPLAY
        REGULATION PID PARAMETERS

 GP:   400000    NAME: displex
 GI     40000    MODE: Auto-select
 GD:   50000    SAMPLE PID INACTIVE
 TD:       80    REG TEMP:  273.155 K

          WP:       6553600
          WI:             0
          WD:            27
      HEATER:             0.000%

REGULATION SET_POINT:   300.000 K

    TEMP CHAN Reg<-PID->Sam ESC  ->
```

Figure 4 - Display Regulation PID parameters

This screen is used to monitor the PID algorithm controlling the regulation temperature. As well as showing the PID parameters (GP, GI, GD, TD) it also displays the individual terms (WP, WI, WD) that contribute to the final heater power which is also shown.

The name of the current PID table in use is shown, together with the operating mode; either manual or auto select. The state of the sample PID loop, either active or inactive, is also shown. Finally the regulation temperature and set-point are displayed for reference.

This is the screen displayed after pressing the **Reg** button.

4.1.4 DISPLAY SAMPLE PID PARAMETERS

```
                 DISPLAY
          SAMPLE PID PARAMETERS

 GP:      400    NAME: unknown
 GI     50000    MODE: Auto-select
 GD:       30    SAMPLE PID INACTIVE
 TD:        5    REG TEMP:  273.155 K

          WP:         10736
          WI:             0
          WD:             0
      HEATER:             0.000%

REGULATION SET_POINT:   300.000 K

    TEMP CHAN Reg<-PID->Sam ESC  ->
```

Figure 5 - Display Sample PID parameters

This screen is essentially the same as the previous one except that it displays the sample PID loop values. It is selected by pressing the **Sam** button.

4.1.5 DISPLAY CHANNEL VOLTAGES

```
             DISPLAY
        CHANNEL VOLTAGES

    REGULATION:  273.159 K
    SAMPLE    :  273.163 K

    CHANNEL A :    1.731 mV
    CHANNEL B :   34.599 mV

    CHANNEL C :    1.684 mV
    CHANNEL D :   35.697 mV

    CHANNEL E : off
    CHANNEL F : off

 <- VOLT RES       K/C  ESC
```

Figure 6 - Display Channel Voltages

This display is similar to Display Channel Temperatures except that it displays the voltages actually appearing on the voltage input pins of the connector. This can be useful for debugging purposes or when resistance thermometers are not being used.

In order to access this screen, first the right-arrow (`->`) button, as seen on the previous screens, has to be pressed to make the rest of the menu choices appear as shown in Figure 6, then the **`VOLT`** button has to be pressed. To redisplay the initial menu items press the left-arrow (`<-`) button.

4.1.6 DISPLAY CHANNEL RESISTANCES

```
             DISPLAY
      CHANNEL RESISTANCES

    REGULATION:  273.159 K
    SAMPLE    :  273.163 K

    CHANNEL A : 9987.984 Ohm
    CHANNEL B :  100.009 Ohm

    CHANNEL C :10004.782 Ohm
    CHANNEL D :  100.010 Ohm

    CHANNEL E : unreadable
    CHANNEL F : off

 <- VOLT RES       K/C  ESC
```

Figure 7 - Display Channel Resistances

This screen is similar to the previous one except the resistances measured at each of the four resistance measurement channels are displayed. Since channels E and F are not capable of measuring resistance, if either of these are configured to measure voltage then with this screen the associated value will be marked as "unreadable" as shown in Figure 7.

This screen is accessed from the extended menu options using the "**`->`**" and **`RES`** buttons.

4.1.7 Displaying temperature in Kelvin or degrees Celsius

```
              DISPLAY
       CHANNEL RESISTANCES

     REGULATION:    0.009 C
     SAMPLE    :    0.013 C

     CHANNEL A : 9987.984 Ohm
     CHANNEL B :  100.009 Ohm

     CHANNEL C :10004.782 Ohm
     CHANNEL D :  100.010 Ohm

     CHANNEL E : unreadable
     CHANNEL F : off

  <- VOLT RES       K/C  ESC
```

Figure 8 - Displaying temperature in deg. Celsius

The **`K/C`** button shown in Figure 8 allows all temperatures displayed in the LCD to be toggled between either Kelvin or degrees Celsius. This function only affects the **displayed** values on the front panel LCD. All **internal values are always** in Kelvin, notably with the shell commands accessed via the serial interfaces.

4.2 MODIFY

```
            PID       PID
  SP  LIM   Reg       Sam  ESC
```

Figure 9 - Modify Menu

Figure 9 shows the four options available when the **`MODIFY`** menu option is selected from the main menu shown in Figure 1, page 23.

4.2.1 Modifying the set-point temperature

```
              SET POINT
0                                        5
      CURRENT VALUE :  300.000 K
          NEW VALUE :          K
1                                        6


2                                        7
          REGULATION:  273.159 K
          SAMPLE    :  273.158 K
3                                        8


4                                        9
      .   -   BS        ENT   ESC   K/C
```

Figure 10 - Modifying the Set-Point

The set-point can be modified using the screen shown in Figure 10. Digits are entered using the ten buttons at the sides of the screen marked **`0-9`**. A decimal point is entered using the button marked with a dot, and negative values (Celsius display only) with the button marked with a dash. Erroneous entries can be corrected using the **`BS`** (Back-Space) button. The **`K/C`** button allows the temperature units to be toggled between Kelvin and Celsius.

Any new value that is entered, which must fall between the minimum and maximum set-point limits (see below), is not stored until the **`ENT`** button is pressed. If **`ESC`** is pressed without first pressing **`ENT`** the new value is ignored.

4.2.2 Modifying Limits

```
            SPL :    0.00 K
            SPH :  325.00 K

            OPL :    0.00 %
            OPH :   30.00 %






     SPL SPL   OPL       OPH   ESC
```

Figure 11 - Modification of Limits

Two sets of limits can be changed with the **`MODIFY/LIM`** option. They are the set-point maximum and minimum allowable values and the heater power output maximum and minimum limits.

The set-point limit restricts the values that can be given to the set-point by any means, whether using manual commands from the front panel as shown in *4.2.1 Modifying the set-point temperature* above, or using the `sp` shell command, page 22, or implicitly by using the `ramp` command, page 18. The maximum set-point limit (**`SPH`**) can have any value between 0K and the "hardware" limit determined by the PID parameters currently in use (see `nvpid`, page 15). The minimum set-point limit (**`SPL`**) must be between 0K and the maximum set-point limit.

Similarly, the minimum and maximum allowable heater power values are determined using **`OPL`** and **`OPH`**. The highest value for **`OPH`** is limited by the PID parameters and the highest value for **`OPL`** is **`OPH`**. Note that if **`OPL=OPH`** the heater power will be forced to that value no matter what the control loop attempts to set.

Under all circumstances, if the regulation temperature exceeds the maximum set-point value the heater will be automatically switched off. An attempt to switch the heater back on is made every ten minutes after the input amplifiers are re-zeroed. If the temperature falls below the limit the heater can be manually re-armed by switching the front panel heater switch to off and then back to on again.

```
          SET POINT HIGH LIMIT
0                                       5
      CURRENT VALUE :  325.000 K
          NEW VALUE :          K
1                                       6


2                                       7
          REGULATION:  273.159 K
          SAMPLE    :  273.158 K
3                                       8


4                                       9
      .   -   BS       ENT  ESC  K/C
```

Figure 12 - Modifying Set-point upper limit

Since all the screens for modifying the limits are very similar, only one has been reproduced in Figure 12. As usual, the new value is not stored unless the **`ENT`** button is pressed.

4.2.3 Modifying Regulation PID parameters

```
        REGULATION PID PARAMETERS

 GP:   400000    NAME: displex
 GI     40000    MODE: Auto-select
 GD:   500000    SAMPLE PID INACTIVE
 TD:       80    REG TEMP:  273.155 K

         WP:       6553600
         WI:             0
         WD:            27
     HEATER:              0.000%

REGULATION SET_POINT:   300.000 K

     GP  GI  GD       TD  ESC  ->
```

Figure 13 - PID parameter modification

This screen is almost the same as Figure 4 - Display Regulation PID parameters, except that the bottom line gives access to various parameters. The GP, GI and GD options permit the Proportional Gain, Integral Gain and Differential Gain to be altered. In "classical" PID controllers the proportional gain (often referred to as the proportional band) has an inverse action on the system i.e. the smaller the proportional band parameter the higher the gain and the higher the risk of instability. In the ILLSEC the value for the Proportional Gain, GP, has a positive action so that reducing its magnitude also reduces the response of the proportional term, WP.

This is also true for the other two parameters. If GI is made bigger then the integral term, WI, will change quicker. In order to stop the integral term from changing the value of GI should be 0; i.e. it will block WI at its current value.

Increasing GD will make the differential term, WD, react more to changes in temperature. Thus when making relatively large changes in temperature by changing the set-point a large value of GD will cause WD to attempt to slow down the rate of change. This has the effect of "anticipating" the arrival at the desired set-point and thus reduce the overshoot. However when at equilibrium if the GD term is too large this will tend to introduce noise into the heater value causing poor regulation. As a general rule, the value of GD should be chosen so that the noise appearing on the WD term is less than 100th of that of the WI term at equilibrium (the WP term at this point should theoretically be zero).

TD is a time constant for an RC-type filter used to remove the sharp peaks from the WD term. The larger its value the longer is the time constant of the filter. If GD is zero then TD has no effect.

Pressing the right-arrow button gives access to four other values. These are WI, PID manual, PID autoselect and PID table name.

`WI` allows any value to be set into the WI term. This is useful if during tuning of the PID parameters it is required to hold the average heater power at some arbitrary value. It may also be required if the WI needs to be quickly set to zero when small values of GI are being used. In general this is only necessary when adjust the PID values for a particular application, and is never needed during normal control applications.

The button marked **`MAN`** is used to select manual PID parameter selection. In this mode the PID parameters are not changed by the control algorithm when a new set-point is selected.

Pressing the **`AUT`** button puts the PID parameters into auto-select mode. In this mode whenever a new set-point is introduced into the ILLSEC the control algorithm selects the GP, GI, GD and TD values from the lookup table identified as NAME on the second line of the display.

The **NAME** button on the bottom line gives access to the screen shown in Figure 14 below.

```
          REGULATION PID NAME

       CURRENT NAME: displex
           NEW NAME: orange




  ^    v    ENT             ESC
```

Figure 14 - Selecting a PID table

The up-arrow and down-arrow buttons on the bottom line cycle the "NEW NAME" parameter through all the PID tables held in the ILLSEC memory. These tables are introduced into the ILLSEC memory using the `nvpid` command, page 15.

Pressing the **ENT** button will store the new table for future auto-select values of PID parameters.

4.2.4 Modifying Sample PID parameters

Modifying the sample PID parameters is exactly the same as for the regulation control loop, so it will not be repeated here. It should however be noted that at the time of writing the sample PID loop had not been fully tested, and may not be operating as expected.

4.3 CONTROL

This menu option is used to select whether the PID control is operating on the regulation temperature or on the sample temperature. If sample temperature is selected a second control loop is activated, the output of which becomes the set-point for the regulation control loop.

After pressing the button marked **CONTROL** a sub-menu allows either regulation (**REG**) or sample (**SAM**) control to be active.

It should be repeated here that sample control has not yet been fully tested.

4.4 RECORDER

The rear panel pen recorder outputs (see Figure 38, page 44) can be configured to monitor various internal parameters within the ILLSEC. These are regulation temperature, sample temperature, heater power, individual channel temperatures, channels A, B, C and D measured resistance values, the raw ADC reading for each of the input channels, and two internal reference voltages. When first selected from the main menu, the pen recorder set-up displays the screen shown in Figure 15 below. To configure pen 1 press the button marked **PEN1** which will display the menu shown in Figure 16.

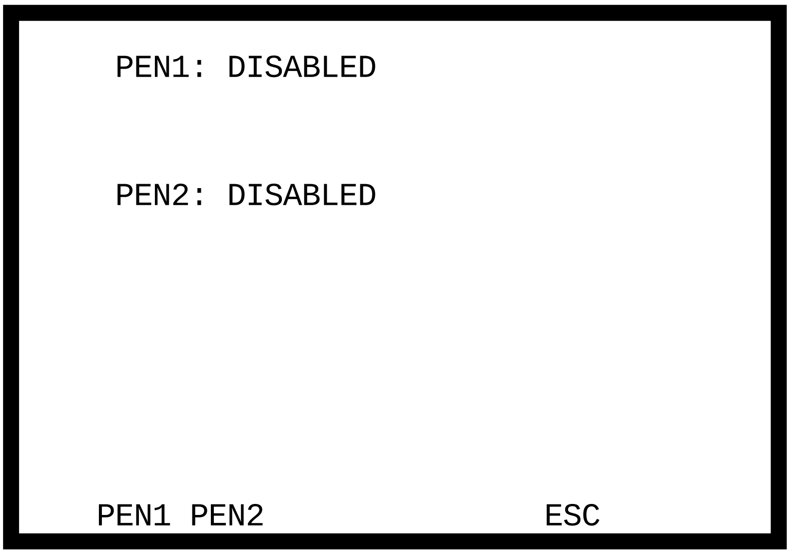


Figure 15 - Pen Recorder menu

The first step is to select the parameter to be monitored by pressing the button marked **PAR**. The currently selected parameter is displayed together with the new one. The new parameter is changed by pressing the up-arrow and down-arrow buttons until the required parameter is displayed. In order to select it **ENT** has to be pressed before leaving the sub-menu.

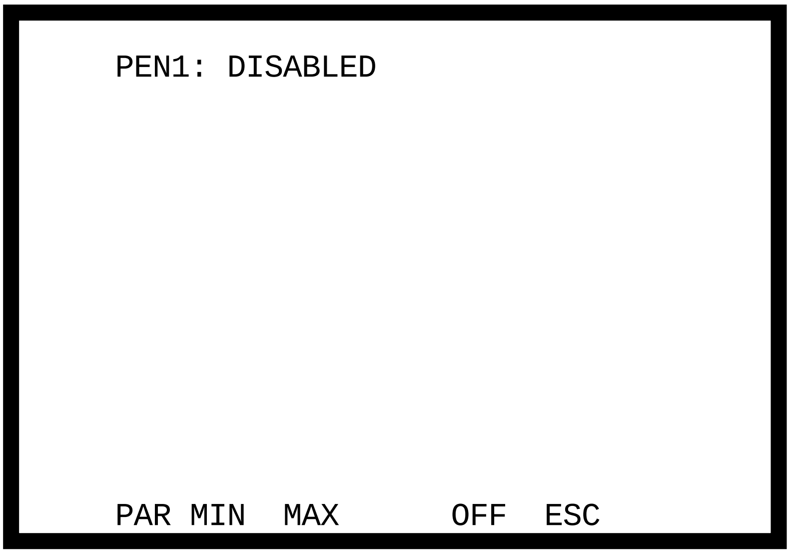


Figure 16 - Pen 1 with no parameter assigned

```
     PEN1: REGULATION TEMPERATURE
           scale min:    0.00 K
           scale max:   10.00 K






     PAR MIN  MAX      OFF  ESC
```

Figure 17 - Pen 1 with parameter selected

The screen will now display the sub-menu similar to Figure 17. The minimum scale value corresponds to the left-hand edge of the paper or 0V, and the maximum scale value corresponds to the right-hand edge or 5V. These two values can be changed to any required value by pressing the buttons marked MIN or MAX.

Pressing the OFF button will disable the corresponding pen output and display the screen shown in Figure 16 once again.

Setting up pen 2 is done in exactly the same manner.

4.5 CHANNEL

```
^        -> SENSOR A: REGULATION
            SENSOR B: REGULATION

v           SENSOR C: SAMPLE
            SENSOR D: SAMPLE

            SENSOR E: MEASURE
            SENSOR F: OFF



     REG SAM MEAS       ENT ESC OFF
```

Figure 18 - Affecting a function to a channel

Each measurement channel has to be assigned a logical function. It can be either a regulation channel, a sample temperature channel or simply a measurement for monitoring purposes.

The regulation function is usually assigned to those thermometers closest to the heating element so that there is the minimum time delay between heat input changes and the effect being detected by the thermometer(s). Thus a much tighter temperature control can be maintained, allowing fast temperature changes with the minimum of overshoot.

In order to control temperature, at least one channel has to be designated as a regulation thermometer. If this is not done the PID loop will be disabled and the heater supply switched off. A maximum of two channels can be assigned the regulation function. If two are used it is assumed that one is a high temperature thermometer such as platinum and the other a low temperature thermometer such as carbon. When these sensors are defined using the `sensor` command (page 6) each one is assigned an "overlap" temperature that together define a region over which the two temperatures indicated by each thermometer are used to calculate a weighted mean temperature. For example a platinum sensor would be assigned a (minimum) overlap of 20K and a carbon sensor a (maximum) overlap of 50K. Between 20K and 50K the temperature from each thermometer is used to calculate the weighted mean with 100% of the value of the platinum being used at 50K and above, 50% Pt/50% C at 35K, and 100% carbon at 20K and below. If only one channel is designated regulation or if one of the two designated channels becomes unreadable for whatever reason then the single good value is used on its own.

The sample function is used in a similar way to the regulation function. The temperature displayed as the sample temperature will be the calculated weighted mean if appropriate. This requires up to two channels being designated as sample channels, but a sample thermometer is not obligatory for the regulation control loop to operate. Only the sample control loop requires a sample temperature, and if one is not available the sample loop is disabled.

If a channel is assigned the measurement function it is simply displayed without any special significance being attached to its value. In particular no overlap calculation is ever done with measurement channels even if the sensors have been defined with an overlap temperature. For this reason more than two channels can be designated as measurement channels.

To select a channel press on the up-arrow or down-arrow to position the right-arrow opposite the required channel. The function for the selected channel can then be chosen using the appropriate button: **`REG`**, **`SAM`**, **`MEAS`**, or **`OFF`**. As usual, changes made are not taken into account until the **`ENT`** button is pressed.

4.6 MUX

```
^     -> SENSOR A: EXTERNAL SENSOR
         SENSOR B: EXTERNAL SENSOR

v        SENSOR C: 10K Ohm REFERENCE
         SENSOR D: 100 Ohm REFERENCE







           0  100              10K
     EXT Ohm Ohm        ENT ESC Ohm
```

Figure 19 - Selecting the internal multiplexer

Each of the four resistance measurement channels has a four way multiplexer to connect the measurement electronics to either an external sensor via the front panel Fischer connector (see page 40), or to one of three internal resistance references. These internal resistances are used to maintain the measurement accuracy during normal operation. It is sometimes useful to be able to select them manually to check the correct operation of the instrument or to set unused channels to some fixed value. A number of the screen examples shown in this handbook correspond to the channel multiplexers being set to these internal references. The three values available are 0Ω (mainly used for re-zeroing the input amplifiers), 100Ω and 10000Ω. To change a channel first select it with the up or down arrows then press the appropriate **`Ohm`** button. In normal operation a channel will be set to use the external sensor by pressing the **`EXT`** button.

4.7 SENSOR

```
           SENSOR A: C0
           SENSOR B: PT0

           SENSOR C: C0
           SENSOR D: PT0

           SENSOR E: V0
           SENSOR F: UNKNOWN



   SENSOR    BLOCK          ESC
```

Figure 20 - SENSOR menu

The **`SENSOR`** option is used to define which of the internally known sensors is connected to each channel in use. The first screen of the **`SENSOR`** menu is shown in Figure 20. This shows the current configuration and offers two possible methods for changing it, either by **`SENSOR`** or by **`BLOCK`**.

4.7.1 Selecting channel thermometers by sensor

```
          SELECTION BY SENSOR
^
        -> SENSOR A: C0
           SENSOR B: PT0
v
           SENSOR C: C0
           SENSOR D: PT0

           SENSOR E: V0
           SENSOR F: UNKNOWN



      <   >           ENT  ESC
```

Figure 21 - Channel selection by sensor

This method of defining sensors allows each individual channel to be assigned a sensor on a one to one basis. The channel to be assigned a sensor is selected in the usual way with the up or down arrow buttons. The sensor is the chosen from the internal list using the left-arrow button or the right-arrow button which change the sensor reference displayed against the selected channel. The choice is stored when the **`ENT`** button is pressed.

4.7.2 Selecting channel thermometers by block

```
           SELECTION BY BLOCK
^
           SENSOR A: C0
           SENSOR B: PT0
v
        -> SENSOR C: C0
           SENSOR D: PT0

           SENSOR E: V0
           SENSOR F: UNKNOWN




      <   >            ENT  ESC
```

Figure 22 - Channel selection by block

The term block here is used to refer to a physical object on which are mounted one or more thermometers and possibly a heating element. A block usually corresponds to a regulation temperature or a sample temperature. Also blocks are distinct from each other and are relatively loosely connected thermally.

This method of assigning sensors to channels is much simpler than the previous one since the individual sensor references do not have to be known by the operator and the PID table is set up when a regulation block is chosen. It does require, however, that the characteristics for a given block have been previously defined using the `nvblock` command described on page 14.

Within the ILL the Sample Environment Laboratory has adopted a simple standard for assigning block numbers. Each cryostat in use at the institute has a unique identification serial number. These numbers are assigned in numerical order as each new cryostat is put into service. For assigning a block number to the body of the cryostat itself the serial number is multiplied by 10. Thus the regulation block of cryostat 109IL HV 49 has a block number of 1090 (the serial number always the first one in a cryostat reference ID). Each cryostat has one or more sample holders called *porte échantillon*. These sample holders are always associated with a given cryostat and are themselves numbered upwards starting at 1. This sample holder number is added to the cryostat regulation block number to produce the sample block number. So sample holder number 2 (*P.ECH 2 - porte échantillon 2*) of the above cryostat will be assigned the number 1092. It is very unusual for a given cryostat to have more than two or three sample holders, so this numbering system should not fail!

Normally the block reference number is engraved in the adapter plug used to connect the ILLSEC cables to the cryostat or sample holder.

Figure 22 shows the screen displayed after pressing the BLOCK button. The channel (sensor) is selected using the vertical arrow buttons, but care should be taken to select either sensor A or sensor C since the block function assigns sensors to the selected channel and the one immediately below it. Selecting channel B would assign sensors straddling the two Fischer plugs (see page 40) and would not normally be meaningful.

```
          SELECTION BY BLOCK

          SENSOR A: C0
          SENSOR B: PT0

       -> SENSOR C: C72
          SENSOR D: PT114

          SENSOR E: V0
          SENSOR F: UNKNOWN

          BLOCK 1092
          CRYOSTAT 109  P.ECH 2

      <   >            ENT  ESC
```

Figure 23 - Choosing a block number

Having chosen a channel the block number is selected using the left and right arrow buttons. The block number is displayed together with the cryostat information defined by the `nvblock` command (page 6). The reference numbers of the corresponding sensors are also displayed opposite the appropriate channels as shown if Figure 23. Notice also that it is no longer possible to change the channel selection at this stage.

Pressing the **ENT** button will store the chosen block, assigning the sensors and the PID parameter table if it is a regulation block.

4.8 AUTOIDEN

```
vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
>>>>>>>      WARNING      <<<<<<<
^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^

THIS MAY CHANGE THE CURRENT SETUP

             PROCEED ?


       YES                  ESC
```

Figure 24 - Initiating autoidentification

If the **AUTOIDEN** option is chosen from the main menu the screen shown in Figure 24 is displayed to warn the operator that major changes to the operating configuration are likely to occur if the autoidentification function is executed. This could have drastic changes being made to the operating temperature due to changes in sensor type and calibration as well as PID parameters. For this reason the autoidentification should only be performed when changing the apparatus connected to the ILLSEC and when the heater is switched off.

However this is the most convenient way of reconfiguring the ILLSEC when connecting it to a different cryostat or changing the sample holder. In order for it to operate correctly the blocks being connected must have been defined in the ILLSEC data base (see `nvblock`, page 14), and the cable adapters to have been correctly programmed for the blocks they are attached to.

If the **`YES`** button is pressed at this point the ILLSEC activates the autoidentification electronic circuitry housed in the cable adapters. These adapters then send back the block numbers which are checked against the internal data base. If the blocks are found then the ILLSEC is reconfigured in the same way as manually selecting the block numbers as described in the previous section **Selecting channel thermometers by block**, page 36.

4.9 RE-ZERO

```
DISPLAY                                MUX

MODIFY                              SENSOR
        RE_ZEROING INPUTS...*

CONTROL                           AUTOIDEN

RECORDER                           RE_ZERO

CHANNEL
```

Figure 25 - Main menu while zeroing inputs

In normal circumstances the input amplifiers are re-zeroed every ten minutes to maintain maximum long term accuracy and eliminate drift. Sometimes this can cause problems, when changing samples from example; while the sample holder is out of the cryostat it is often disconnected from the ILLSEC. If in the meantime the ILLSEC re-zeros its amplifiers the zero offset can be completely erroneous on the sample channel(s). When eventually the sample holder is reconnected the readings obtained on the sample temperature will either be wrong or even unreadable. This will be corrected at the next scheduled re-zero which could of course take up to ten minutes to occur. For this reason a manual re-zero option is available from the main menu. While the re-zero is in process the ILLSEC has to stop the control loop while maintaining the heater output at its current value until the re-zeroing is completed. Because of this the temperature and heater readings appear to freeze momentarily when continuously monitoring them either via the LCD screen or by computer commands via the serial links.

The effect of re-zeroing is normally invisible when the temperature is at equilibrium either at a fixed value or while changing in a controlled manner using a ramp. The only time it is noticeable is when the temperature is changing in an uncontrolled manner at high speed such as when the set-point has just been changed to a new value relatively far away from the present temperature.

Pressing the **`RE-ZERO`** button does not change the menu screen but does display a message to show the operation is in progress as shown in Figure 25.

5. Connectors

5.1 Front Panel Connectors

Figure 26 shows the general layout of the connectors available on the front panel. All drawings of the individual connectors are shown as seen when viewed from the front of the apparatus with the front panel in the closed position. Pin numbers are shown in their correct positions as marked on the connectors themselves (usually only visible on the solder side of the connector).

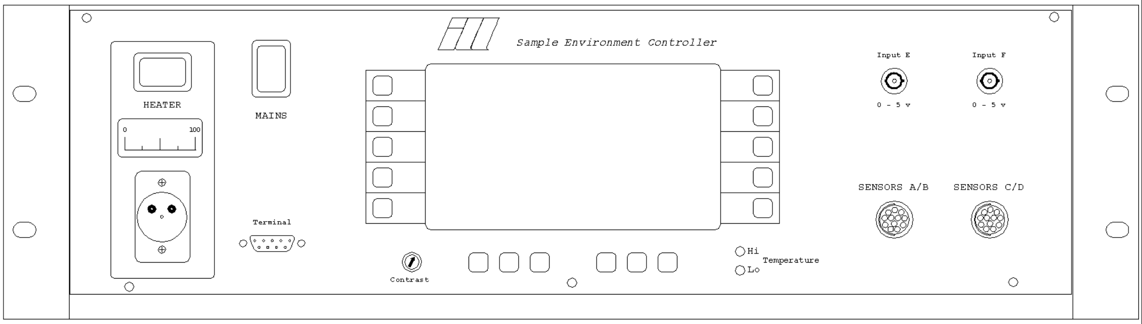


Figure 26 - Front panel layout

5.1.1 Heater Connector

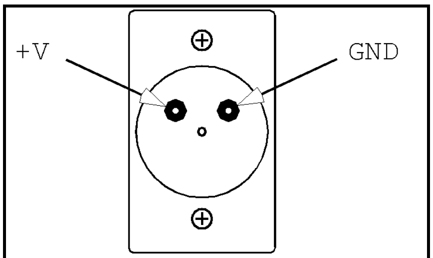


Figure 27 - Heater connector

The heater connector supplies the heater output power from the PID control algorithm. The maximum power available is 150W (75V, 2A) for an optimum load of 50Ω. A suitable plug is from the LNE-series manufactured by Neutrik, type LNEFC or LNE11C. (RS Components ref. 466-444).

5.1.2 Front panel RS232 terminal connector

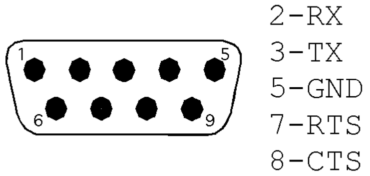


Figure 28 - RS232 9-pin connector

The front panel terminal socket can be used for connecting either a simple VT100-type or as a computer link. The RS232 set-up is 9600 baud, 8 data bits, 1 stop bit, no parity, XON/OFF flow control (hardware CTS/RTS not used). These parameters can be changed, but since the set-up is fixed in ROM code the procedure is relatively complicated. The default set-up has been found to be satisfactory in all cases encountered up to now, even using long cable runs of 50 metres or so.

The terminal is permanently connected to an internal OS-9 command shell will allows access to the built in commands as described in chapter 3, **Commands**, page 7. Since the default set-up is for use with an interactive terminal, characters typed at the keyboard are echoed on the terminal screen. This can cause problems if using an external computer to dialogue with the ILLSEC, but it is a simple matter to change the set-up so that no echoing takes place. See chapter 3.1, **General syntax**, page 7 for details.

5.1.3 Voltage Input Connectors

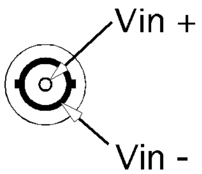


Figure 29 - BNC connector pinout

The two high precision voltage input connectors are intended for use with ancillary equipment such as AC bridges or capacitance bridges with an analog output. The differential inputs have a FSR of 5v. Each input (Vin+ and Vin-) has a resistance of 1MΩ to ground.

5.1.4 Resistance Measurement Connectors

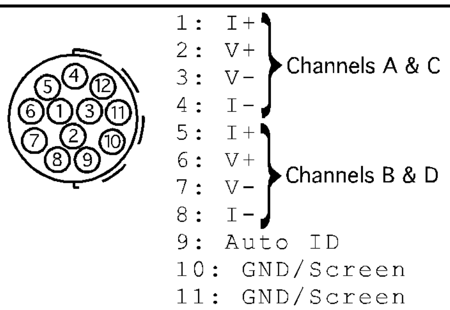


Figure 30 - Fischer connector pinout

Each resistance measurement input connector carries two complete 4-wire resistance measurement channels. The left-hand connector carries channels A and B, and the right-hand connector carries channels C and D.

The current generator (I+/I-) can supply currents of up to ±1mA (±15bit resolution). The FSR of high impedance differential voltage inputs (V+/V-) is ±156mV.

These connectors also carry the signal required to automatically obtain the serial number of the measurement "block" connected at the other end of the cable (see **Auto-identification system**, page 6).

5.2 Rear Panel Connectors

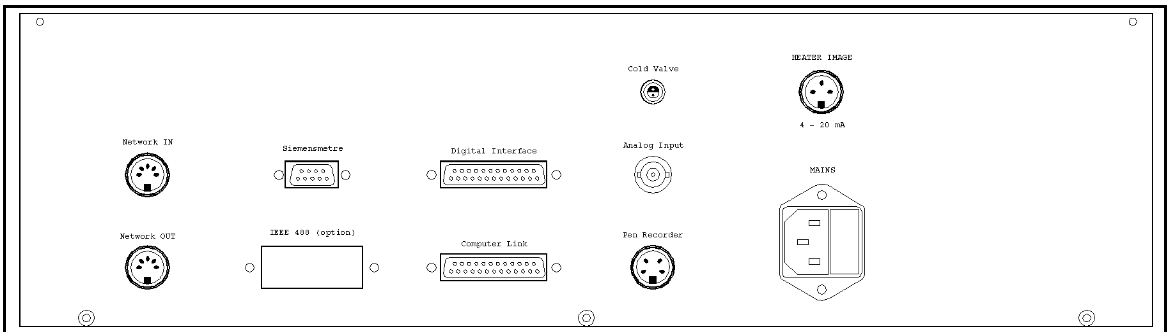
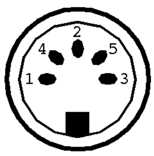


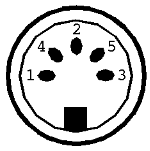
Figure 31 - Rear Panel layout

5.2.1 Network connectors



1-No Connection
2-No Connection
3-No Connection
4-IN:input
5-IN:loop return

Figure 32 - Network IN



1-THRU: output
2-Screen
3-THRU:loop ret.
4-OUT:output
5-OUT:loop return

Figure 33 - Network OUT

These two connectors are intended to allow the connection of two or more ILLSECs together so that one can act as a master and the other a slave. A host computer with only one serial interface could this control more than one temperature at a time. Although the electronic hardware exists no software has yet been integrated into the ILLSEC to implement this function.

The interface is based on the industry standard MIDI system.

5.2.2 Siemensmeter connector

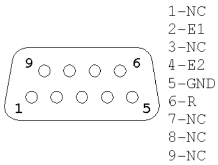


Figure 34 - Siemensmeter connector

This interface is provided to be able to connect the "Ohmmètre Régulateur PX1" (ORPX) directly to the ILLSEC. This is a specialised very low temperature controller used mainly with ILL dilution refrigerators.

5.2.3 Rear Panel RS232 computer interface connector

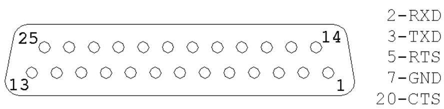


Figure 35 - Computer Link pinout

This connector has the same function and configuration as the front panel terminal connector (see page 40). It provides a totally independent OS-9 shell interface capable of issuing different commands concurrently with the other interface. It is thus possible to use one interface for communicating with an external computer while using the other as a monitoring or debugging terminal.

The only difference between the two interfaces is that the rear panel one is the "console" terminal and thus issues a sign-on message at start-up time and provides a low-level debugging interface should hardware problems present difficulties in booting the system.

5.2.4 Digital Input/Output interface connector

The digital I/O interface connector is the same type as that shown in Figure 35. The pins are directly connected to a Parallel Interface Adapter type MC68B21. This will allow the TTL-compatible lines to be programmed as inputs or outputs as required (see separate MC6821 data sheet for further information). At present this function has not been pre-programmed into the ILLSEC firmware, but special requirements can be satisfied using programmes stored in battery RAM. Contact the author for details.

The pin assignments for the digital I/O interface are shown in Table 1, page 43.

pin	signal
1	GND
2	CA1
3	CA2
4	PA0
5	PA1
6	PA2
7	PA3
8	PA4
9	PA5
10	PA6
11	PA7
12	GND
13	GND
14	GND
15	CB1
16	CB2
17	PB0
18	PB1
19	PB2
20	PB3
21	PB4
22	PB5
23	PB6
24	PB7
25	GND

Table 1 - Digital I/O connector pinout

5.2.5 Cold Valve output

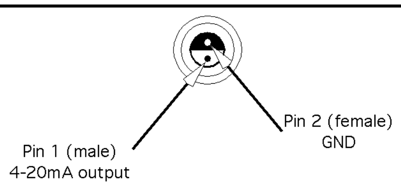


Figure 36 - Cold Valve connector

This connector provides the necessary signal to drive the automatic "cold valve" used on most ILL cryostats. At this time it is unused, but its function will be incorporated into the new auto-adaptive control algorithm when this becomes available, probably during 1998.

5.2.6 Rear panel Analog Input (BNC)

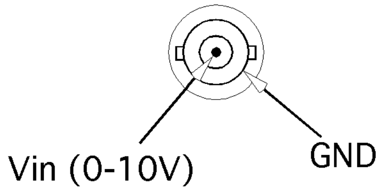


Figure 37 - Rear panel analog input

This is a general 10V, 12-bit analog voltage input which can be used to monitor external systems such as cryo-fluid levels.

5.2.7 Pen Recorder output

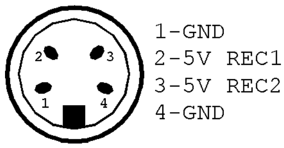


Figure 38 - Pen Recorder connector

The pen recorder connector provides output drive for two independent pen recorder channels (or other monitoring equipment). The two channels can be independently programmed to monitor various internal parameters including different channel temperatures, heater output, PID algorithm terms, etc. See **set up pen recorder** outputs, page 16 for details.

5.2.8 Heater Image Output (4-20mA)

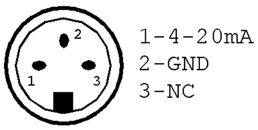


Figure 39 - Heater Image connector

This output provides 4-20mA image of the heater output voltage. 4mA corresponds to 0V and 20mA corresponds to 75V.

Note that this is a voltage image of the output, so if the load resistance goes open circuit or the output relay opens it will not be reflected in the signal produced at this connector.

6. Appendix A - data file formats

6.1 "cheby" file format.

The cheby method for calculating temperatures uses two main categories of sensor:

1) semiconductor types such as C, AB, CG, Ge and Cernox, and
2) metallic types such as Rhodium/Iron.

For the first type the Chebychev coefficients have to be generated using 1/T vs $\log_{10}$(R), and for the second type T vs R. In both cases the file format is the same as shown below:

```
NZONES
NCOEFF[ZONE(1)]
.
.
NCOEFF[ZONE(NZONES)]
Rmin(ZONE[1])
Rmax(ZONE[1])
ZL(ZONE[1])  ZU(ZONE[1])
coeff[1](ZONE[1])
.
coeff[NCOEFF[ZONE[1]](ZONE[1])
Rmin(ZONE[2])
Rmax(ZONE[2])
ZL(ZONE[2])  ZU(ZONE[2])
coeff[1](ZONE[2])
.
coeff[NCOEFF[ZONE[2]](ZONE[2])
.
.
.
.
.
Rmin(ZONE[NZONES])
Rmax(ZONE[NZONES])
ZL(ZONE[NZONES])  ZU(ZONE[NZONES])
coeff[1](ZONE[NZONES])
.
coeff[NCOEFF[ZONE[NZONES]](ZONE[NZONES])
```

where `NZONES` is the number of temperature zones (usually 2 or 3),
`NCOEFF(n)` is the number of coefficients in each zone,
`Rmin(ZONE(n))` and `Rmax(ZONE(n))` are the minumum and maximum values of resistance for `ZONE(n)`,
`ZL(ZONE(n))` and `ZU(ZONE(n))` are the ZL and ZU values for `ZONE(n)`, and
`coeff[1](ZONE[n])` to `coeff[NCOEFF[ZONE[n]](ZONE[n])` are the coefficients for `ZONE(n)`.

Individual values can be separated using spaces or newlines.

6.1.1 Example data file for "cheby" method sensor calibration

```
3                                  <--  3 zones
6                                  <--  6 coeffs. in zone 1
6                                  <--  6 coeffs. in zone 2
10                                 <-- 10 coeffs. in zone 3
650. 40755.                        <-- Rmin=650Ω, Rmax=40755Ω
2.61207357547107 4.61021286497437  <-- ZL=2.6120735, ZU=4.610212
 0.456102241183535                 <-- coeff.1 zone 1
 0.356395581171768                 <-- coeff.2 zone 1
 0.01916396051357
-0.00127449997150562
 0.000285302914010889              <-- coeff.5 zone 1
 0.000062773521774113              <-- coeff.6 zone 1
160. 650.                          <-- Rmin=160Ω, Rmax=650Ω
2.16423385469261 2.99179294734342  <-- ZL=2.16423, ZU=2.99179
 0.118806553047151                 <-- coeff.1 zone 2
 0.103961675050546                 <-- coeff.2 zone 2
 0.00741283591119771
-0.000999337789467689
 0.000203949802939958              <-- coeff.5 zone 2
-0.000059106162740603              <-- coeff.6 zone 2
100.82 160.
2.00354669310213 2.238898879222784
 0.0189709359462902                <-- coeff.1 zone 3
 0.0153013147788692                <-- coeff.2 zone 3
 0.00137056973044102
 0.000072910105858375
-0.000059897314186395
 0.000036970780894934
-0.000021846146644448
 0.000014245656430173
-0.000006897760062618              <-- coeff.9 zone 3
-0.000002271885929335              <-- coeff10 zone 3
```

6.2 "rhfe85" file format.

The "rhfe85" data format usually consists of just 3 fixed-point temperature/resistance values at 273.15K, 77.348K and 4.222K. These are the so-called 3-point calibration points given by the sensor supplier. They are used to fit a typical Rhodium/Iron resistance curve for the alloy that was manufactured in 1985 and is still in use today. Unfortunately the extrapolation below 4.2K is not good, so if possible it is better to give a few measured values at these low temperatures. In any case this still does not constitute a true calibration and so errors of up to 1K can occur midway between the three temperatures given above.

6.2.1 Example data file for "rhfe85" method sensor calibration

6	6 temperature/resistance values pairs in the file
1.2200 1.5090	T=1.2200K R=1.5090Ω (extra calibration point)
2.1000 1.6620	T=2.1000K R=1.6620Ω (extra calibration point)
3.5000 1.8790	T=3.5000K R=1.8790Ω (extra calibration point)
4.222 1.9749	<-- liquid helium fixed point
77.348 6.879	<-- liquid nitrogen fixed point
273.16 27.03	<-- water triple-point fixed point

7. Appendix B - regenerating the non-volatile RAM

Sometimes it may be necessary to regenerate the data held in the non-volatile RAM. This can happen if either the NiCad battery becomes discharged because of long periods of non-use, or because of a ROM version change.

The NVRAM holds two types of data. The first is a small ram-disc which stores the startup files and the source files for sensor and PID data. The second is a memory heap where the actual data calibrations, ILLSEC set-up configuration, last set-point temperature, etc. are stored.

If the NVRAM is lost a special debug flag will have to be reinitialised. If this is not done then the system debugger is started on the system terminal which is the one on the rear panel. If the flag does not have the correct value(24_{hex}) then every time the ILLSEC is restarted the system debugger will be called and execution halted.

If a standard VT100-type terminal or a terminal emulator such as Versaterm® set to 9600baud is connected then when the ILLSEC is switched on the following message will appear:

```
    Institut Laue-Langevin
Sample Environment Controller
called debugger

Rel: 00000000
Dn: 00000000 00002000  00000000 00000000   00000000 00000001
FFFFE000 000017F8
An: 10000942 10000478  10100000 10100000   00002800 00000800
00000800 000017F8
SR: 2709  (--S--7----N--C)                     SSP: 000017F8
USP: 00000000
PC: 10000856   - 43FAFC40            lea.l $FC40(pc),a1
debug:
```

The flag resides at address $300C000C. To set it to $24 type the change memory command:

```
debug:c 300c000c<CR>
```

the debugger replies with:

```
300C000C  00 : 24<CR> <-- typed by user
300C000D  00 : . <-- typed by user
debug:
```

The boot process is then continued by typing the go command:

```
debug:g<CR>
```