# DCell & DSC Miniature, Hi–Precision Strain Gauge Converters - Version 2

**DCell**


**DSC**

**Converts a strain gauge sensor input to a digital serial output**

**www.mantracourt.co.uk**

User Manual Instructions

MANTRACOURT
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Contents

# Chapter 1 Introduction

This chapter provides an introduction to DCell/DSC products, describing the product range, main features and application possibilities.

## Overview

The DCell and DSC products are miniature, high-precision Strain gauge Converters; converting a strain gauge sensor input to a **digital** serial output. They allow multiple high precision measurements to be made over a low-cost serial link. Outputs can be accessed directly by PLCs or computers, or connected via various types of network, telephone or radio modem, all without compromising accuracy.

## Key Features

**Ultra-miniature**
The DCell 'puck' format can be fitted inside most load cell pockets, and similar restricted spaces. The DSC cards are similarly very small, optimised for mounting as a component onto custom PCBs.

**High-precision**
10ppm basic accuracy (equates to 17 bit resolution) with comparable stability – far exceeds standard instrument performance.

**Low-power**
Low-voltage DC supply (8.5V min), typically 40mA per device. (including 350R strain gauge)

**Adjustable sensitivity**
Configured for standard 2.5mV/V full-scale strain gauges as supplied.
A single additional resistor configures the input between 1 and 100 mV/V full-scale.

**Temperature sensing and compensation**
Built-in temperature sensor and advanced 5-point temperature-compensation of measurement.

**Linearity compensation**
Advanced 7-point linearity compensation

**Serial output**
Lower-cost cabling, improved noise immunity, and longer cable runs with no accuracy penalty.
Device addressing allows up to 253 devices on a single bus, drastically reducing cabling cost and complexity.
Two-way communications allow in-situ re-calibration, multiple outputs and diagnostics.
No separate measuring instruments needed.

**Digital calibration**
Completely drift-free, adjustable in-system and/or in–situ via standard communications link.
Two independent calibration stages for load cell- and system-specific adjustments.
Programmable compensation for non-linearity and temperature corrections.
Calibration data is also transferable between devices for in-service replacement.

**Self-diagnostics**
Continuous monitoring for faults such as strain overload, over/under-temperature, broken sensors or unexpected power failure.
All fault warnings are retained on power-fail.

**Multiple output options**
Choice of 2 communications standards: RS232 or RS485.
Choice of 3 different protocols: ASCII, MODBUS or MANTRABUS, for ease of integration.
All variants provide identical features and performance.

## Special Facilities

**Output Capture Synchronisation**
A single command instructs all devices on a bus to sample their inputs simultaneously, for synchronised data capture.

**Output Tare Value**

An internal control allows removal of an arbitrary output offset, enabling independent readings of net and gross measurement values.

**Cell Excitation Sensing**
For increased accuracy and sensor malfunction detection

**Dynamic Filtering**
Gives higher accuracy on stable inputs, without increased settling time.

**Programmable Output Modes**
Output rate control enables speed/accuracy trade-off.
ASCII output version provides decimal format control and continuous output mode for 'dumb terminal' output.

**Unique Device Identifier**
Every unit carries a unique serial-number tag, readable over the communications link.

**Communications Locking**
A private key locking scheme can restrict device access to the suppliers own software, giving suppliers or systems integrators control over 3rd-party re-supply.

**Communications Error Detection**
An interruption of normal communications due to drop-outs or noise is detected as badly formatted receive data, which triggers a diagnostic warning flag.

**External Temperature Sensing**
The internal temperature sensor can be replaced with an external device in contact with the sensor, for improved accuracy (especially tracking changing temperature conditions).

**Software Reset**
A special communications command forces a device reboot, as a failsafe to ensure correct operation.

## The Product Range

Devices are available in two physical formats.

The **DCell** (puck) products consist of a Digital Strain gauge Signal Conditioner with RS485 bus output in an ultra-miniature cylindrical "puck" format.
This is suitable for installation in very small spaces, including load cell pockets.
External connections are made by wiring to solder-pads.

The **DSC** (card) products are very similar to the DCell but in a different physical form for mounting standalone or on a board.
The DSC is also available with an RS232 output.
External connections are via header pins which can plug into connectors, or be soldered to wires or into a host PCB.

## Which Device To Use

It is important to select the correct product for your application.

- First choose DCell or DSC based on your physical installation needs
- Choose the communications protocol depending on performance/integration requirements
- the RS232 output option may be simpler if your system only uses a *single* DSC card

**Common Features**
Both physical formats offer identical control and near-identical measurement performance
Both are available in all three output protocols: MODBUS, ASCII or MANTRABUS

**Differences**
DCell (puck) has a 4 wire gauge connection for mounting very close to the sensor
The DSC (card) has a 6 wire gauge connection allowing a short cable run.
Only the DSC (card) is currently available with the RS232 output option

**Special Aspects To Consider**
The DCell fits neatly into a strain gauge pocket
The DSC lends itself to PCB mounting
The RS485 output version *must* be used for multiple devices on the same bus

## Additional DSC Variants Available

A separate DSC variant is available with CANbus output, using a CANOpen-compliant protocol.
A DSC variant with 3 bits of digital i/o is available for simple control interfacing
(These variants are sufficiently different to require their own manuals)

**Future Planned Versions**
DCell (puck) form with RS232 output
DCell (puck) form with CANbus output
Ethernet connection
Radio connection

**Contact Mantracourt for latest details.**

## Some Application Examples

**Simple Distributed Measurement**
Pressure loads are taken at a number of keys points in a manufacturing process, distributed over a large area.
Each pressure sensor contains a DCell unit, and all the sensors are connected by a single cable carrying power and RS485 communications. A central PC allows continuous display, monitoring and logging of all values from a central control room. This displays a control-panel and current display window, and logs information to an Excel spreadsheet for future analysis.
Further monitoring checks and displayed information can easily be added when required to the system where up to 253 ‘nodes’ can be installed.

**Low cost dedicated weighing station**
A basic load cell weighing-pad device has a cable leading to a wall mounted weight display.

**Digital Load Cell**
Load cell products are offered with a high-precision digital communications option.
A DCell is fitted into the gauge pocket of each load cell in manufacture. During product testing, each unit undergoes a combined load test and temperature cycle. Each unit is then programmed with individually calculated gain, offset, linearity and temperature compensation tables. All units perform to a very tight specification without the use of any trimming components.

**High Reliability Load Sensing**
A road bridge has a dedicated load monitoring and active control computer system. System calibration adjustments are only established during construction, so sensors must be replaceable without recalibration.
Each load monitoring point has a digital load cell fitted, with calibration values set during construction. Self-diagnostics aid detection of failures.
When a failed load cell is replaced it will produce identical force measurements. The old load cell set-up data values are programmed into the separate user-level calibration store in the unit, to produce an identically performing replacement.

**Remote radio weigher**
A variety of lifting machines in a loading yard can be used with a weighing link to display weight in tonnes on a remote hand-held readout.
A heavy duty strain gauge load-link is fitted with a battery-powered radio modem and DCell. The independent handheld display unit communicates with the DCell over a transparent radio link, providing a simple LCD readout and tare button operation.

**Load balance monitor**
A lorry loading weighpoint monitors left/right load balance and sounds a warning if loading is too uneven for safety.
A drive-on weighing platform is provided with load cells at each of four corners. Each cell is wired to a DSC unit, and these are cabled to a 3rd-party LCD display and control unit, producing a complete turnkey system. A digital I/O card is wired to the same bus to control the warning alarm. Application software running on the control unit provides a % left/right balance readout with a graphical tipping display, and a total weight indication.
The balance indication is calculated by comparing the different corner readings. If it exceeds a programmed limit, a command to the I/O card turns the relay on.
Total weight is calculated by summing the individual results mathematically.
Automatic re-zeroing occurs when the total is near zero for more than a few seconds.
A control button enables a set-up mode for recalibration (protected by operator password), which displays individual readings and total. Corner compensation can be checked by observing the changing total as a weight is moved around. Simple button presses control two point recalibration for any cell.

**Weighing subsystem for process control**
Several strain gauge loads are monitored as part of a larger data acquisition/monitoring system, based around a high-speed Profibus network.
The load measurements occur in groups of physically related signals which relate to specific ‘area modules’ along with a number of other measurements and control outputs.
The strain gauges are wired to DSC cards, controlled and interrogated via MODBUS protocol commands on an RS485 bus. The DSCs and other 3rd-party MODBUS-compliant devices which govern the area module are all connected to a single RS485 ‘spur’. The devices in each area-module spur are controlled from the main Profibus backbone, using an off-the-shelf bus gateway unit.

# Chapter 2 Getting Started with the Evaluation Kit

This chapter explains how to connect up a DCell/DSC for the first time and how to get it working. For simplicity, this chapter is based on the standard DCell/DSC Evaluation Kit, which contains everything needed to communicate with a puck or card from your PC.
It is advised that first time users wishing to familiarise themselves with the product use Mantracourt's Evaluation Kit. This provides a low cost, easy way to get started.
If you do not have an Evaluation Kit, the instructions in this chapter mostly still apply, but you will need to wire up the device (and possible bus-converter) and have some means of communicating with it. See *Communications* Protocols in *Chapter 11 Communication* as appropriate to the protocol type.
See also *Chapter 13 Installation* for details on wiring up the device.

## The Evaluation Kit

### Contents

- An Evaluation PCB which comprises of
  - A 7 Way Screw Connector for the Strain Gauge
  - A 4 Way Screw Connector for Power & RS485 Comms
  - A 9 Way 'D'Type for Direct RS232 Connection to PC
  - Link Headers for 4 Wire Strain Gauge Option (DCell)
  - Link Headers for RS232 or RS485 Comms Selection
  - Terminating resistor for RS485

- An Evaluation DCell or DSC of your choice
- A CD ROM containing VisualLink Evaluation Software
- A 9 to 25 Way 'D'Type Adaptor for the PC Comms Port
- A 9 Way 'D'Type Extension Lead

- **For RS485 ONLY** an RS232 to RS485 converter and connecting cable
- **For RS232 ONLY** a power connection cable

See the following diagram.

### *Figure 2.1 Evaluation Kits for the DCell & DSC*

**Evaluation Kit for the RS485, with the DCell**


**Evaluation Kit for the RS232 with the DSC**


## Other Things you will need

- A regulated power supply, capable of providing 10 -15V at 100mA (10v is minimum requirement for RS485 converter)
- A PC running Windows 95 or above, with a spare RS232 communications port and 35Mb free disk space

**and, ideally**

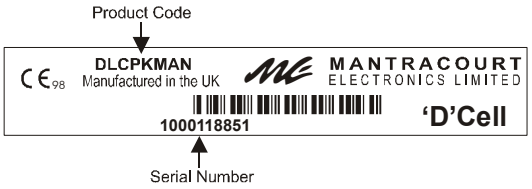
- A strain gauge, load cell or simulator, 350-1000 ohms impedance.
  (**NOTE:** the devices use ac excitation, so a dc mV source will not work)

## Checking the Device Protocol Type and Station Number

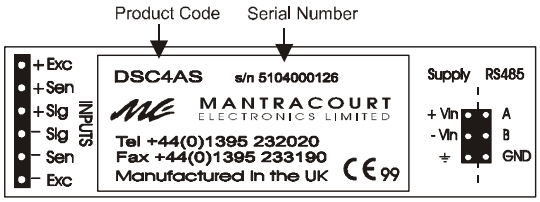
Before running the communications application, you should check both the protocol to use and the device station number.

The product label shows the product code which determines the protocol and its serial number which determines initial station number.

**Example DCell label**




**Example DSC label**




**For a DCell, the Product Code is one of the following 3 types**

| | |
|---|---|
| DLCPKASC | ASCII output |
| DLCPKMAN | MANTRABUS output |
| DLCPKMOD | MODBUS output |

**For a DSC card, the Product Code is one of the following 6 types**

| | |
|---|---|
| DSC4AS | RS485 output card with ASCII protocol |
| DSC4MA | RS485 output card with MANTRABUS protocol |
| DSC4MB | RS485 output card with MODBUS protocol |
| DSC2AS | RS232 output card with ASCII protocol |
| DSC2MA | RS232 output card with MANTRABUS protocol |
| DSC2MB | RS232 output card with MODBUS protocol |

**NOTE:** For evaluation purposes, the electrical output standard RS485 or RS232 is not important: Your kit should contain the correct equipment to connect the device to a PC.
The product code should match your original order.
The serial number of the device is also shown.

## The *station number* of a new DCell/DSC device is set up to have the same last 2 digits as its serial number

**E.G. 817752 gives station 52, while 103800 gives station 100.**

(N.B. this is only the *factory set* value; and its value changed by a previous user)

Make a note of both the protocol and station number now. The communications application needs to be told both the protocol to use and the station number to communicate with.

## Connecting Up The Evaluation Kit For RS485

Connect the PC using the 9 way 'D'Type to the RS232/RS485 converter. Plug the cable provided into the converter and connect the other end to the 4 way screw connector on the PCB using the colour codes indicated on the PCB ident.
Ensure LK4 & LK5 are set to pins 1 & 2. Fit LK3 which terminates the RS485 comms. Connect the power cable to your power supply, which has been set to deliver between 10 & 15 volts, then switch on.

***Figure 2.2 DCell - RS485 Versions Evaluation Kit Communications***

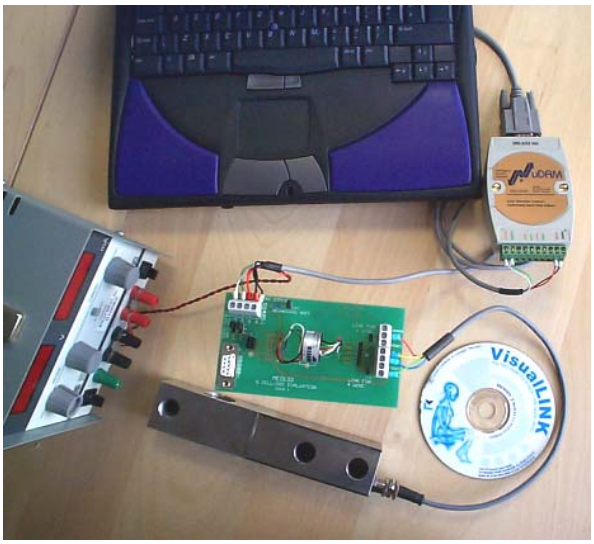
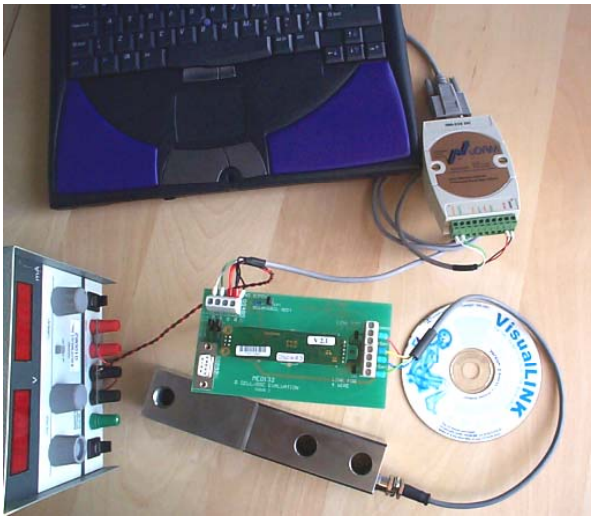


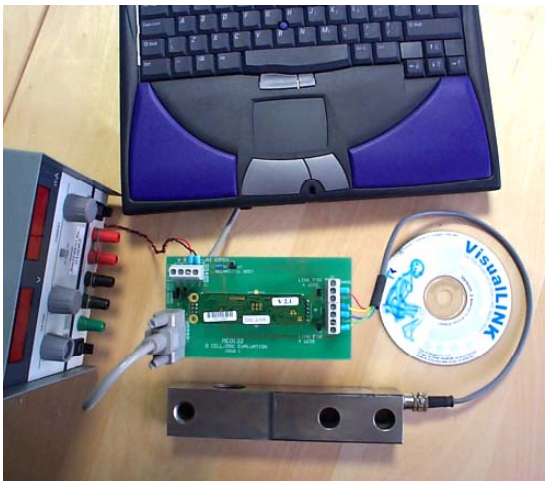

***Figure 2.3 DSC4-RS485 Versions Evaluation Kit Connections***




### *Connecting Up The Evaluation Kit For RS232*

Connect the supplied power cable (Red & Black twisted) to the 4 way screw noting the colours indicated on the PCB.
Connect the 9 way 'D'Type extension lead to the J1 of the evaluation board marked (RS232) and the other end to the comms port of the PC.
Ensure LK4 & LK5 are set to pins 3 & 2 again see PCB indent for the markings of these links.
Now connect power cable to your power supply, which has been set to deliver between 10 & 15 volts, and switch on.

***Figure 2.4 DSC2-RS232 Versions Evaluation Kit Connections***




Note that if your PC serial port has a 25 way serial port connector, you should use the 9 to 25 way 'D' type adaptor provided to connect to the evaluation hardware.

## Installing VisualLink

The DCell/DSC evaluation communications application is written for the VisualLink environment. VisualLink is Mantracourt's own rapid development software platform for PC SCADA applications. It provides communications drivers for the DCell/DSC products (amongst many others). An evaluation copy is provided on CD-ROM with the DCell/DSC Evaluation Kit.

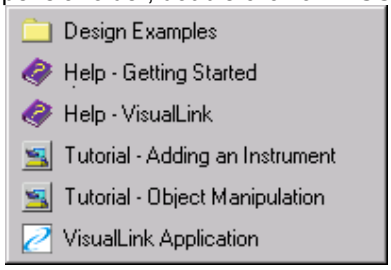
Uninstall any previous versions of VisualLink before proceeding.
Install the VisualLink demonstration application by inserting the CD in the CD ROM drive. This should start the 'AutoRun' process, unless this is disabled on your computer.
(If the install program does not start of its own accord, run SETUP.EXE on the CD by selecting '*Run'* from the '*Start Menu*' and then entering *D:\SETUP*, where *D* is the drive letter of your CD-ROM drive).

The install program provides step-by-step instructions. The software will install into a folder called *VisualLink* inside the *Program Files* folder. You may change this destination if required.
After installation you may be asked to restart the computer. This should be done before proceeding with communications.

For further information, refer to *Chapter 15 The VisualLink Application*

## Running the VisualLink Evaluation Application

Having installed VisualLink, you can now run the special evaluation application, which the rest of this chapter is based around.
From the windows 'Start' button, select *Programs*, then *VisualLink*, select Design Examples. This opens a folder, double click on 'DSC & DCell Evaluation.vld'.




Will open the design example folder

The on-line help for VisualLink

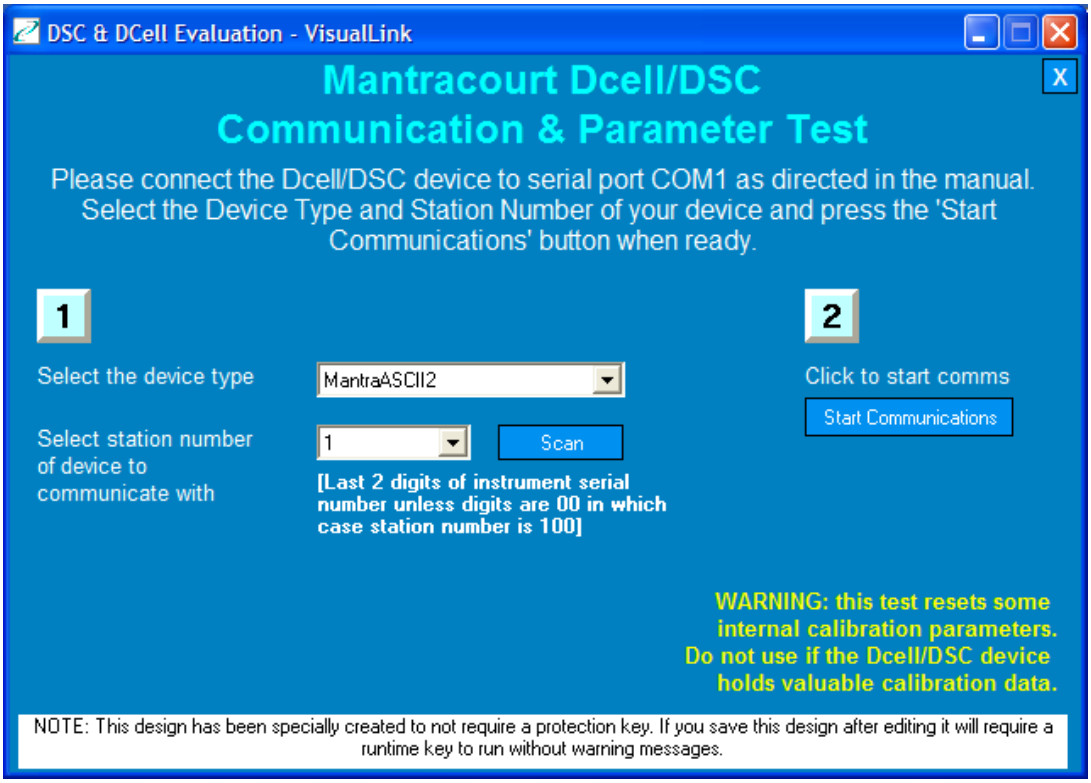
A brief animated tutorial about adding an instrument

A brief animated tutorial about manipulating objects

The VisualLink application

The following window should appear:–

***Figure 2.5 Communication & Parameter Test Page***




The ‘type’ drop-down selects the protocol to communicate with.
The ‘station number’ selects the correct device on the bus.

Use the selection controls to make appropriate selections, from the data you noted down in the earlier section *Checking the Device Protocol Type and Station* Number

- Select the protocol appropriate to the product code
- Select the station-number according to the device serial number (as described above)

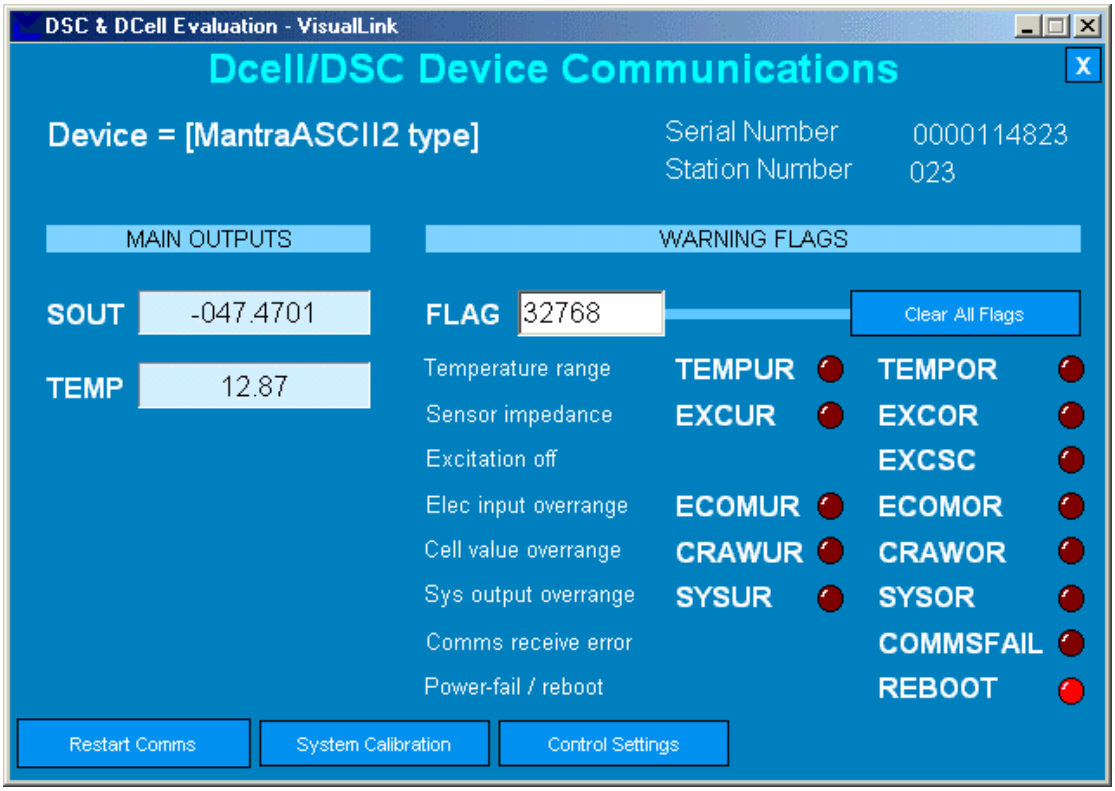
If you need to use a serial port other then COM1. See *Chapter 15 The VisualLink Application*

Now hit the ‘Start Communications’ button…

## Viewing Device Data

The following, main 'Communications Page' should now appear

***Figure 2.6 Device Communications Page***




At the top are shown the device type, serial number and current communications station number.

The main device output values are shown on the left.

The diagnostics flags are shown on the right

**If there is a communications problem, a separate 'Error' window will appear after a few seconds – check all settings, and *Chapter 14 Troubleshooting* for additional advice.**

Once communications are established, the screen displays current information values read from the DCell/DSC device :–

- The 'SOUT' value is the main device output –this is probably currently near zero as there is no input connected.
- The 'TEMP' value is the internal temperature measurement reading – this will probably be changing slowly as the device warms up.

The application refreshes these two displays at a reasonably fast rate, about 3 times a second, while the other data is read less frequently (every 1 or 2 seconds).

On the right, the 'FLAG' value shows the device diagnostic warning flags. Individual bits of this 16-bit parameter register represent specific warning conditions.
This value is generally zero in normal use, but at present will have at least bits 15 and 1 set (value 32768+2=32770).

The application also displays the current bit settings as individual indicators: Bits 15 and 1 are shown as the REBOOT and EXCOR flag indicators.
REBOOT means the device has been reset (usually powered down).
EXCOR means the excitation measurement is above a warning 'high' limit ("**EXC**itation **O**ver-**R**ange"): This is a sensor high-impedance warning, i.e. the input gauge is broken or disconnected.

If you now hit the 'Clear All' button next to the FLAG value, the REBOOT warning (and any others) should clear, but the EXCOR flag will remain set (assuming that there is still no load cell connected), and the FLAG value will be 2.

Now you have successfully established communications with your evaluation device, future chapters concentrate on specific feature areas.

# Chapter 3 Basic Setup and Calibration

This chapter explains the most common setup and maintenance operations for operating DCell/DSC devices. This includes initial calibration, and communications settings.

## Connecting a Load Cell

You can now connect a strain gauge bridge, load cell or simulator to the DCell/DSC.

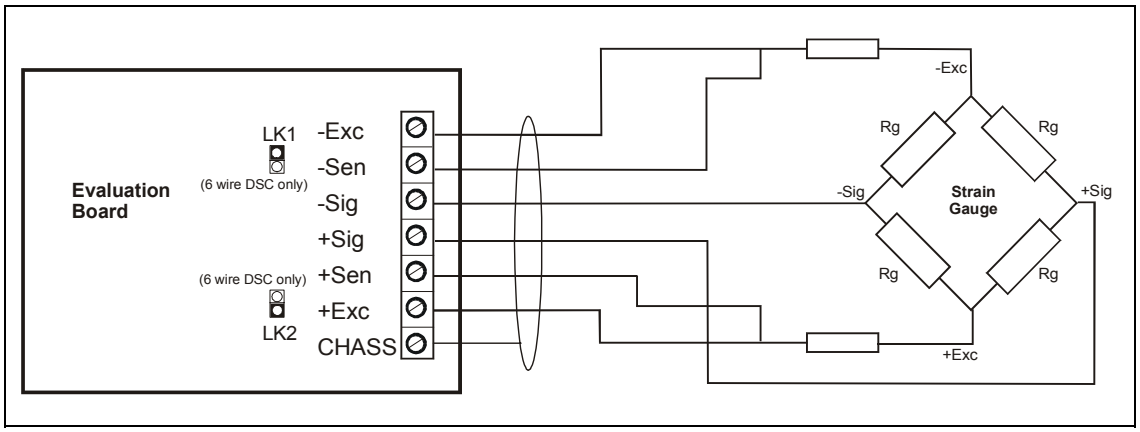
A suitable strain gauge should have an impedance of 350-1000ohms and (at least for now) a nominal output of around 2.5mV/V.

**NOTE: You can't just simulate a cell input with a small voltage.**
**This is because DCell/DSC devices use an AC bridge excitation, so the input is an AC signal changing in phase with the excitation.**

Note the following

1. If using the DCell or a 4 wire strain gauge then ensure LK1 & LK2 are fitted. Connections to +Sen & -Sen will not be made.
2. The cable length from strain gauge to evaluation PCB should be as short as possible and not exceed 3 meters.
3. The screen should be connected to the body of the load cell and terminated at 'CHASS'.

### *Figure 3.1 Evaluation Board Sensor Connections*




Once you have connected the load cell, you should see 'believable' output values on the main reading "SOUT" indicator, that change with the input level between about –100.0 and +100.0.

The readings are scaled in "percent full-scale", i.e. it reads 100.0 for a 2.5mV/V input.

If you hit the 'Clear All Flags' button, the EXCOR warning flag should now clear, and the FLAG value will just be zero.

## Adjusting the System Calibration

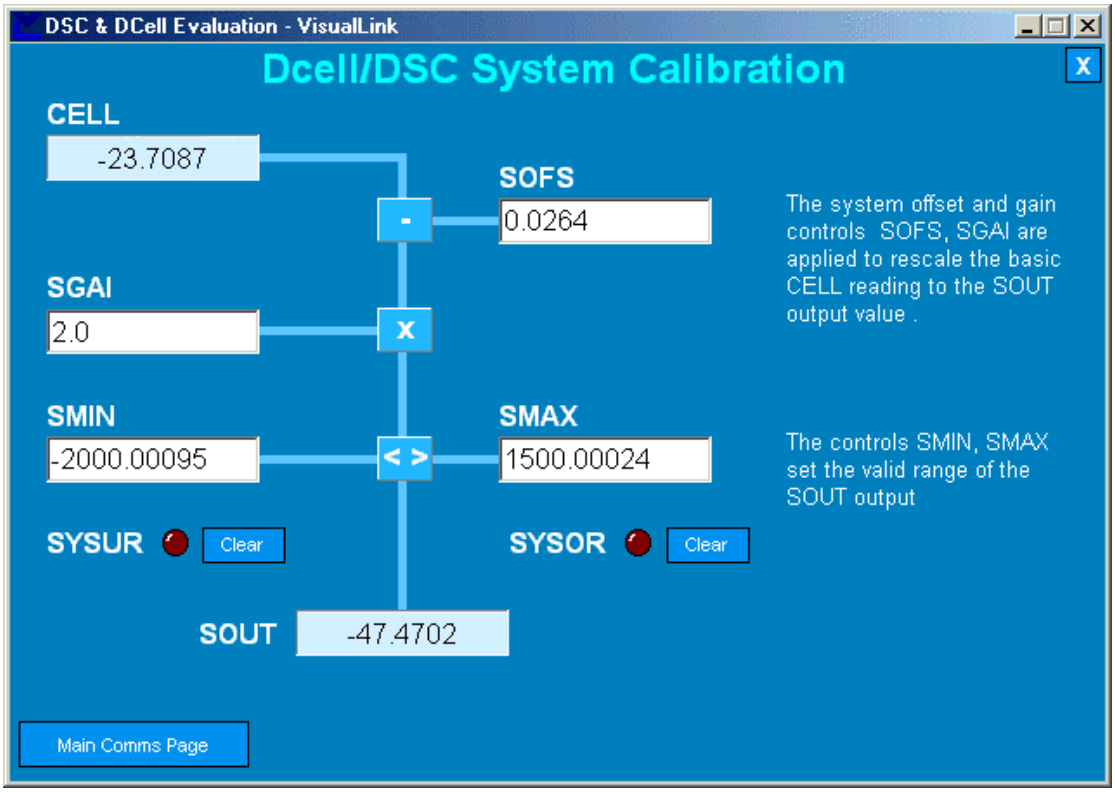
The values obtained so far are simple 'electrical' readings, in %-full-scale (where 100% is the basic 2.5mV/V output level).
These are produced by the device 'electrical' calibration, which is factory-fixed to within about 0.2% accuracy.

This inbuilt calibration cannot be changed, however the device also contains separate user-adjustable calibration controls. These allow you to rescale the output value to read in units of your choice, and to calibrate precisely to your load cell / system hardware for much more precise results.

To see this, from the main 'Communications' page, hit the 'System Calibration' button

The following page should now appear :–

***Figure 3.2 System Calibration Page***




The boxes labelled SOFS, SGAI, SMIN and SMAX show the current values of control parameters stored in the device.

To change a setting, just click in the relevant box and enter the new value. The new value is sent to the device immediately.

This application page shows how the SOUT output is produced from the basic CELL reading value by the following steps

1. The input is the CELL reading value
2. This then has SOFS (the **s**ystem **offs**et) subtracted from it
3. The result of this is multiplied by SGAI (the **s**ystem **gai**n)
4. After applying GAIN the result is limited to the range SMIN..SMAX (**s**ystem **min**imum to **s**ystem **max**imum)
5. This gives the new SOUT output value

The system over-range flags are also shown (SYSUR,SYSOR = **sys**tem **u**nder-**r**ange / **o**ver-**r**ange): If the scaled result was bigger than SMAX or smaller than SMIN, then the SYSOR or SYSUR flag is set.
**NOTE:-** SMIN & SMAX also clamp the output SOUT to exceeded value!

Try changing the SOFS and SGAI parameters to different values :–

The SOFS parameter is used to remove the cell output offset.
**E.G. If CELL reads 0.1253 when the load cell is unloaded, set SOFS=0.1253 to make SOUT=0 with no load.**
The SGAI parameter scales the results, so changing the output units.
**E.G. if you have a 2.5mV/V output, 5 tonne load cell, then the CELL output should be 100 for a nominal 5-tonne load. So setting SGAI=0.05 causes the cell to read approximately in**

**tonnes**
Note that when you change SGAI, you change the output 'units', so SMIN and SMAX may also need to be adjusted.
**E.G. if, in the previous example, you wanted an output in Kg, you would set SGAI=5.0. But the valid output range will then be ±5000 (Kg), so you also need to set SMIN=-5000 and SMAX=5000 as well –otherwise the output will still be limited to ±100.**

The boxes show the current values of **parameters** in your device: The applications page reads data from the device to display the values, and allows you to enter new values which are then sent back to the device. It thus acts as a 'window' on the data within the device you are currently communicating with.

To return to the previous page, just hit the 'Main Comms Page' button.

## Device Communications

Most interactions with DCell/DSC devices actually involve reading and writing 'parameter' values,

- Device outputs are read from 'read-only' parameters
- Control values (such as the calibration controls above) are read/write parameters
- Some fixed values (such as device serial-number) are also read-only

However, some commands can simply cause a one-off action to be performed, e.g. the SNAP command takes a 'snapshot' sample of the current output value (see in *Chapter 10 Additional Software Features*), and the RST command causes a device reboot (see *Changing Device Communications Settings*, below).

The commonest use of DCell/DSC devices in an overall system involves several devices on one bus, with a 'host' controller reading the main output value from each device in turn. Less frequently, the host also checks the devices' warning flags. Other, occasional activities may use other commands.
In this situation, the permanently-stored control parameters for calibration and communications setup are normally set up in the initial installation process, and then never (or rarely) touched.

### *WARNING: Finite Non-Volatile Memory Life*

The DCell and DSC use EEPROM-type memory as the storage for non-volatile controls (i.e. all the settings that are retained even when powered down).
The device EEPROM itself is specified for 100,000 write cycles (for any one storage location).
Therefore –
**When automatic procedures may write to stored control parameters, it is important to make sure this does not happen too frequently.**

So you should not, for example, *on a regular basis* adjust an offset calibration parameter to zero the output value. However, it *is* reasonable to use this if the zeroing process is initiated by the operator, and won't normally be used repeatedly.

For the same reason, automatically cancelling warning flags must also be implemented with caution: It is okay as long as you are not getting an error recurring *repeatedly*, and resetting it every few seconds.

## Setting a Precise Calibration

**NOTE:** ***the full calibration facilities are considerably more complex than the basic calculations described here. See*** **Chapter 5 Readings Processing and Calibration** ***for fuller details.***

In order to get correct measurement values from a device, you need to establish precise values for the calibration controls. This generally depends on the combined performance of the measuring device, load cell and (often) the mechanical system it is installed in.

Once you have worked out correct values for SGAI and SOFS, these values are simply written into the parameters, as shown above. This then gives precise readings in the required output units. The SMIN and SMAX controls are then set to the expected normal range of the output value.

(One of the advantages of digital calibration is that the results of changing the calibration are always precisely known –i.e. you can calculate exactly what results you will get with a particular change to the calibration setup, there is no 'cut and try' needed)

If you have a load cell connected, and a suitable test weight, you can calibrate the cell in the simplest way as follows

1. Run up the VisualLink DCell/DSC Evaluation Design Application, and select the 'System Calibration' page, as above
2. Set SGAI back to the default 1.0, SOFS to 0.0 and SMIN/SMAX to –/+100.0
3. Remove all load so the inputs see's the desired 'zero' calibration point and allow to settle
4. Note the CELL reading value, and copy this into SOFS.
   SOUT should then read zero.
5. Apply your test weight, and allow to settle, ideally this would be about full range for best accuracy over the measurement range.
6. Take the known weight of your test weight (in the required engineering units), and divide by the current SOUT value – i.e. calculate (weight)/(SOUT) Put this value into SGAI.
7. Set SMIN and SMAX to an appropriate output value range.
   SOUT should now show the value of the test weight, as required

The next section briefly reviews different methods of establishing the calibration values.

## *Calibration Methods*

There are a number of ways of establishing the correct control values

**Method 1 - Nominal (data sheet) performance values**

This is the simplest method, where the given nominal mV/V sensor output is used to calculate an approximate value for SGAI (as described in the above example).

**E.G. a 50 kN (i.e. approx 5-tonne) load cell has nominal sensitivity of 2.2mV/V full-scale. The standard DCell/DSC sensitivity is 2.5mV/V, giving an output value of 100, so to get 50.0 for an input of 2.2mV/V, we set SGAI to 50/100*(2.5/2.2)≈0.568182.**
**( N.B. 6 figures is a suitable accuracy to work to )**
**It is also useful to set SMIN/SMAX=–/+50.0, to show when the input goes out of the normal range, because the electrical signal will now never exceed the normal range.**

**Method 2 - Device Standard (Calibration) Values**

With some load cells you may have a manufacturer's calibration document. This gives precise cell-output gain and offset specifications for the individual cell. These values can be used to set the SGAI and SOFS values to be used.

**E.G. a 10 tonne load cell has a calibration sheet specifying 2.19053mV/V full-scale output, and -0.01573mV/V output offset.**
**SOFS is set to the input offset in %-of-2.5mV/V, which is –0.01573/2.5*100 ≈ –0.629200**
**SGAI is set to (10/100)*(2.5/2.19053) ≈ 0.114128**
**SMAX and SMIN can be set to 10.0 and –0.1 (if negative loads are not expected in this case)**

**NOTE:**

Methods 1 and 2 require no load tests. This means that systematic installation errors cannot be removed, such as cells not being mounted exactly vertical. The accuracy is also limited by the DCell/DSC electrical calibration accuracy, which is about 0.2%.
The remaining methods require testing with known loads, but are therefore inherently more reliable in practice, as they can remove unexpected complicating factors relating to installation.

**Method 3 - Two-Point Calibration Method**

This is a simple in-system calibration procedure, and probably the commonest method in practice (as in the previous example).
Two known loads are applied to the system, and reading results noted, then calibration parameters are set to provide exactly correct readings for these two conditions.

**E.G. a 10kN (1-tonne) load cell has a CELL reading of +0.120721 with no load, and -87.2077 with a known 100Kg test-weight.**
**To calibrate this to read in a –1.0 to +1.0 tonne range, set SOFS=0.120721, SGAI=0.1/(-87.2077 – +0.120721)≈–0.00114510 and SMAX/SMIN=+/-1.10**

**NOTE:**
The usual method for weighing systems is to make point (1) the unloaded state, which should read zero, and point (2) with a known test weight on, which should read the value (in required units) of the test weight. This approach is simpler, because you can remove the offset *first*, as explained in the previous section.

**Method 4 - Multi-point Calibration Test**
For ultimate accuracy to a whole series of point measurements may be taken to determine the best linear scaling of input output: Effectively, a 'best line' through the data is then chosen, and the calibration is set up to follow the line.
Testing of this sort is also used to establish linearity corrections, and similar tests at different temperatures are used to set up temperature compensation (see *Chapter 6 Temperature Compensation and Chapter 7 Linearity Compensation).*

## Changing Device Communications Settings

This section explains the other most commonly used settings – those used to control device communications.

The device bus standard and protocol type are specified by the product code, and fixed during manufacture. However, the communications 'station number' (bus address) and baudrate are programmable via communications parameters. Care is needed when changing these, to avoid losing communications with the device, so this section demonstrates how to do this correctly.

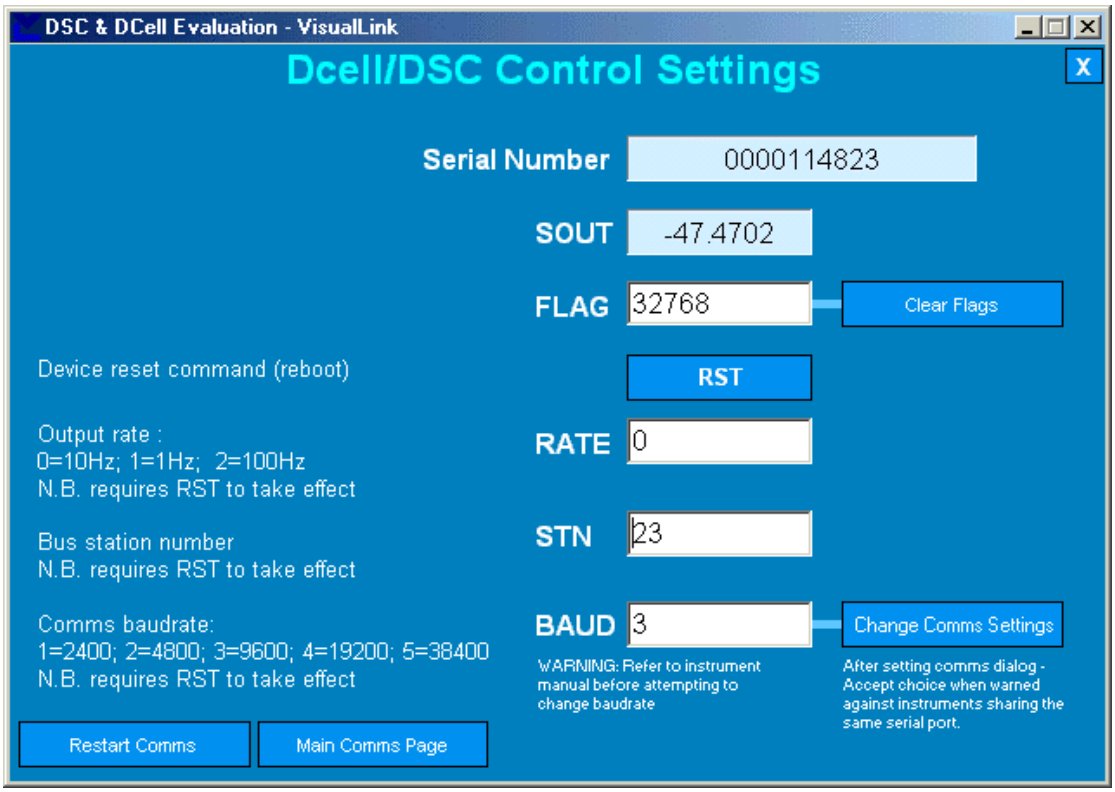
If you lose all communications with the device, see *Chapter 14 Troubleshooting* to solve the problem.

The section also shows you how to adjust the device output rate, and how this affects the output readings.

From the main 'Device Communications' page in the VisualLink evaluation application, hit the 'Control Settings' button.

The following page should now appear :–

*Figure 3.3 Control Settings Page*




The SOUT and FLAG info are shown here for reference only.

The RATE, STN and BAUD settings control
output rate, station number and comms baudrate.

The 'RST' button sends a device reboot command.
This is needed for changes to RATE, STN and BAUD to take effect.

## *Output Rate Control*

The RATE parameter is used to select the output update rate, according to the following table of values –

| RATE value | 0 | 1 | 2 |
|---|---|---|---|
| update rate (readings per second) | 10 | 1 | 100 |

The normal rate is 10Hz (RATE=0): The other settings give a different speed/accuracy trade-off. Invalid RATE values are treated as if it was set to 0.

**To change the output rate**

1. Set RATE to the new value
2. Hit the 'RST' button to reboot the device
3. Wait for 3 seconds for the reset procedure to complete and measure cycle to start

The value displays will 'freeze' for 2-3 seconds, as VisualLink interrupts communications for a while whenever a device is rebooted, to avoid spurious errors when the device does not respond.

With RATE set to 1, you should be able to see the SOUT update rate slow to once a second, and the noise level should also noticeably decrease.

With RATE=2, you won't see any difference in rate because VisualLink can't display the results much quicker than 10 a second, but increased noise can be seen.

All the main-reading output values are updated at this rate. See *Figure 5.1 Readings Processing* – for an overview of readings processing.

## *Baud Rate and Station-Number Controls*

**Station Number, STN**
The STN parameter controls the 'station number', which specifies the device address for bus communications.
As supplied, devices have the station-number set according to the device serial number, as described previously in *Checking the Device Protocol Type and Station* Number.

**To change the station number of your device**
1. First set STN to a suitable new value (making sure that no other device of the same number is also connected!)
2. Now hit the 'RST' button to reboot (needed before the device begins to use the new value)
3. Wait for a VisualLink 'Errors' window to appear.
   (because it is no longer getting responses to commands addressed to the old number)
4. Return to the startup page, by hitting the 'Restart Comms' button
5. Clear the errors, and close the Errors window
6. Select the new Station Number in the dropdown list
7. Hit 'Start Communications' button again. You should now find you can talk to the device again

To connect *multiple* devices on the same bus, it is first vital to set all the station numbers to different values.
This is because if two devices with the same station number are connected to the same bus, it is not possible to talk to them individually: So in particular, you cannot correct the problem by changing the station number of one of them!
If a bus connects to two devices with the same station number, the only solution is to remove one of them and connect it to a one-to-one link to reprogram it.

**NOTES:**
- The valid range of STN depends on the protocol, but it is always at least 1-253.
- All the protocol types have a 'bus address' type device identifier, which is known as the 'station number' for MANTRABUS, 'address' for ASCII and 'node id' for MODBUS.
- The valid ranges for different protocols are: 1-253 for MANTRABUS, 1-999 for ASCII and 1-255 for MODBUS.
- In all cases, if STN is set outside the valid range, it behaves as if set to a default of 1.

**Baudrate Control, BAUD**
The BAUD parameter is a read/write byte value specifying a standard communications baudrate according to the following table –

| BAUD value | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| baud rate (bps) | 2400 | 4800 | 9600 | 19200 | 38400 |

BAUD can only take the values shown above. If set <1 or >5, the baud rate defaults to 9600.

**Warning: When changing this setting it is possible to lose communication with the device. As well as keeping track of the correct baudrate, it is also essential in this case to be sure that your hardware supports the rate you are changing to.**
**The evaluation kit supports all possible DCell/DSC baudrate settings.**

When changing baudrates, you should not see any noticeable difference, except maybe slight changes in responsiveness when changing parameter values. However, if you design your own communications applications (with VisualLink, or otherwise), higher baudrates will allow faster readout rates etc.

Lowering the baudrate is generally only needed where very long cable runs are used, to improve communications reliability.

**To change the baudrate, follow a similar sequence to changing the STN value**

1. First set BAUD to the new value
2. Now hit the 'RST' button to reboot (needed to make the device start using the new value)
3. Wait for the VisualLink 'Errors' window to appear
4. Return to the startup page, by hitting the 'Restart Comms' button
5. Clear the errors, and close the Errors window
6. Hit the 'Change Comms Settings' button: A new popup window appears
7. Select the new VisualLink communications baudrate with the popup menu controls
8. Hit 'Ok' to confirm and hide the window
9. Hit 'Start Communications' button again. You should now find you can talk to the device again

# Chapter 4 Summary of Software Features

This chapter gives a complete overview of all the software functions.
Each item has only a brief description here, consult the references for detailed information.

**User Calibrations**
The devices have sophisticated digital calibrations, which can be adjusted via communications.
See *Chapter 5 Readings Processing and Calibration*.

**Diagnostic Warnings**
Checks are continually made on correct operation, and warning flags record any problems found.
See ***Chapter 6 Self Diagnostics***.

**Temperature Compensation**
An internal temperature measurement can be used to correct for sensor drifts with temperature.
See *Chapter 6 Temperature Compensation*.

**Linearity Compensation**
Corrections can be applied to correct for non linearities in the input measurement.
See *Chapter 7 Linearity Compensation*

**Communications Lock**
A 'security' scheme enables a supplier to ensure that devices they sell can only be used with their software, and vice-versa.
See Chapter 9 Device Locking.

**Factory Calibration**
The calculations for the basic electrical reading and the temperature measurement are described in *Electrical Calibration* and *Temperature Calibration* in *Chapter 10 Additional Software Features*.

**Input Filtering**
The input Electrical calibration processing involves a dynamic filtering technique, explained in Chapter 10 Additional Software Features.

**Result Snapshot**
Multiple inputs can be sampled simultaneously with a single bus command.
See *Reading Snapshot* in *Chapter 10 Additional Software Features*.

**Continuous Output**
(ASCII protocol only): Devices can be made to transmit continuously for output on slave display.
See Continuous Output in *Chapter 10 Additional Software Features*.

**Output Formatting**
(ASCII protocol only): The decimal formatting of the output value is adjustable.
See Output Format Control in *Chapter 10 Additional Software Features*.

**Output Tracking**
A flag mechanism allows every output result to be sampled once and once only.
See Output Update Tracking in *Chapter 10 Additional Software Features*.

**Output Selection**
The main output can be switched between different internal values.
See SOUT Output Selection in *Chapter 10 Additional Software Features*.

**Information Parameters**
The device serial-number and software version can be read back over the communications.
See Informational Parameters in *Chapter 10 Additional Software Features*.

**EEPROM access**
Special commands to access internal storage are used to adjust the factory calibration.
See EEPROM Controls in *Chapter 10 Additional Software Features*. Software Reset
A 'reboot' command is also used to implement communications settings changes.
See Software Reset in *Chapter 10 Additional Software Features*.

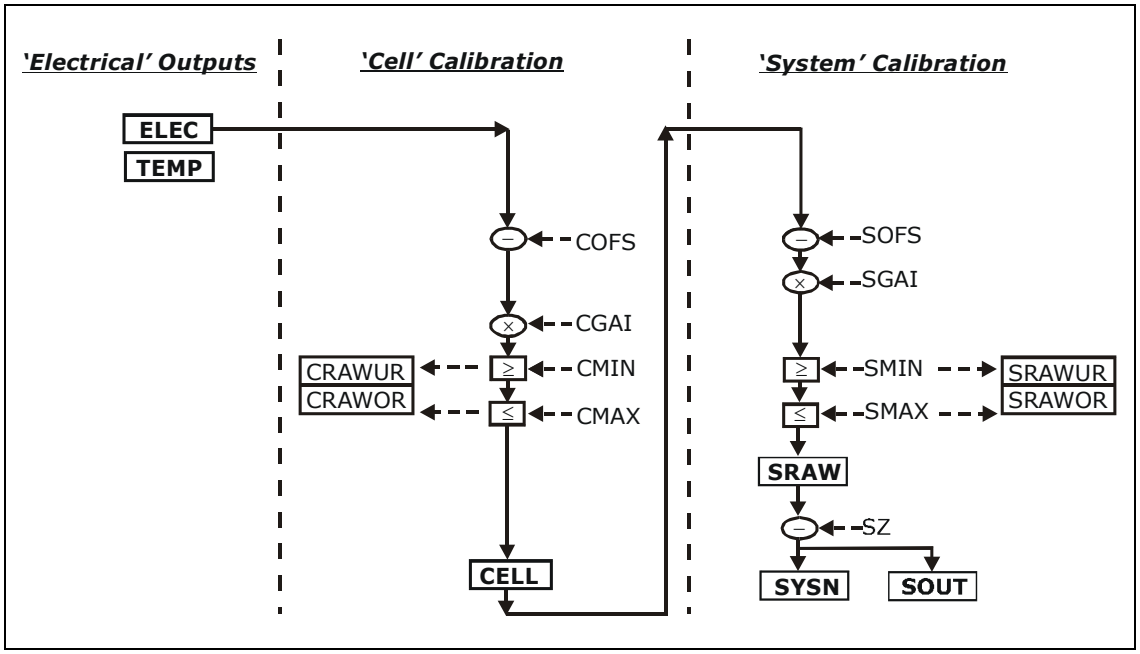
# Chapter 5 Readings Processing and Calibration

This chapter gives a complete account of the calibration controls and processing of input readings *except* for the linearity-and temperature-compensation processes (which have their own chapters later on).

## Main Reading Calculations

The following figure shows a simplified view of the whole of the readings processing calculations, omitting the compensation calculations (see *Figure 5.2* for the complete version).

### *Figure 5.1 Readings Processing – Main Features*




This 'chain' of calculations is performed on every input reading.
The named values shown in the boxes are all output parameters, which can be read back over the comms link.
These calculations are updated continually, at the update rate set by the RATE control (see *Output Rate Control* in *Chapter 3 Basic Setup and Calibration*).

The diagram shows ***three separate calibration stages,*** called the 'Electrical', 'Cell' and 'System'. This allows independent calibrations to be stored for the device itself, the load cell and the installed system characteristics –

**Electrical**
The 'Electrical' calibration produces corrected electrical readings from the internal measurements. This is factory-set by Mantracourt during the production process.
(There are effectively *three* electrical calibrations, one for each output rate setting)

The main outputs from this are –

- ELEC is the raw electrical output, in "% full scale" units.
- TEMP is a device temperature measurement, in °C.

There are also two flags, ECOMUR and ECOMOR (not shown on the diagram), which indicate an input electrical under- or over-range.

The electrical calibration is not covered in detail here, because it normally never changes after manufacture, and is not controlled by communications parameters.
(A fuller account is given in *Electrical Calibration* in *Chapter 10 Additional Software Features*)

**Cell**
The 'Cell' calibration converts the raw electrical output into a cell-force reading.
This can be used by an OEM sensor manufacturer to provide a standard, calibrated output in force units, which could be based on either typical or device-specific calibration data.
(This stage also includes the temperature- and linearity-corrections, not covered here)

The outputs from this are
CELL is a load cell force reading in "Force" units (e.g. kN)
CRAWUR and CRAWOR are two flags indicating under or, over range for the force measurement.

**System**
The 'System' calibration converts the Cell output into a final output value, in the required engineering units.
This is normally be set up by a systems installer or end user, to provide whatever kind of output is needed, independently of device-specific information in the Cell calibration.
(Making this split allows in-service replacement without re calibration).

The outputs from this are
- SRAW is a re-scaled and offset adjusted output
- SYS is the final output value, after removing a final user output offset value (SZ) from SRAW
- SRAWUR and SRAWOR are output warning limit flags.

In practice, SRAW and SYS can be used to represent something like gross and nett values.

## Results Value Scaling
Both the Cell and System calibrations are simply linear rescaling calculations –i.e. they apply a gain and offset.

In both cases, four parameters define the scaling, offset and min and max limit values. These calculations are applied in the following way:
Output = (input – OFS) × GAI
Output = min(output, MAX)
Output = max(output, MIN)
(In addition, if the value exceeds either limit, one of two dedicated error flags is set)

The control parameters thus have the following characteristics: –
- OFS is the input value that gives zero output, set in "input units"
- GAI is the multiplying factor, set in "output-units per input-unit"
- MAX and MIN are output limit values, set in "output units"

The units and functions of the main scaling controls can thus be summarised as –
Cell Calibration

| | | |
|---|---|---|
| COFS | [%fs] | ELEC value offset (ELEC value giving CELL=0) |
| CGAI | [force/%fs] | CELL/ELEC gain factor |
| CMIN | [force] | Minimum value for CRAW |
| CMAX | [force] | Maximum value for CRAW |

**System Calibration**

| | | |
|---|---|---|
| SOFS | [force] | CELL value offset (CELL value giving SRAW=0) |
| SGAI | [eng/ force] | SYS/CELL gain factor |
| SMIN | [eng] | Minimum value for SRAW |
| SMAX | [eng] | Maximum value for SRAW |
| SZ | [eng] | SRAW value offset (SRAW value giving SYS=0) |

(where "%fs" is "per-cent full scale", "force" is force units, and "eng" is engineering units)

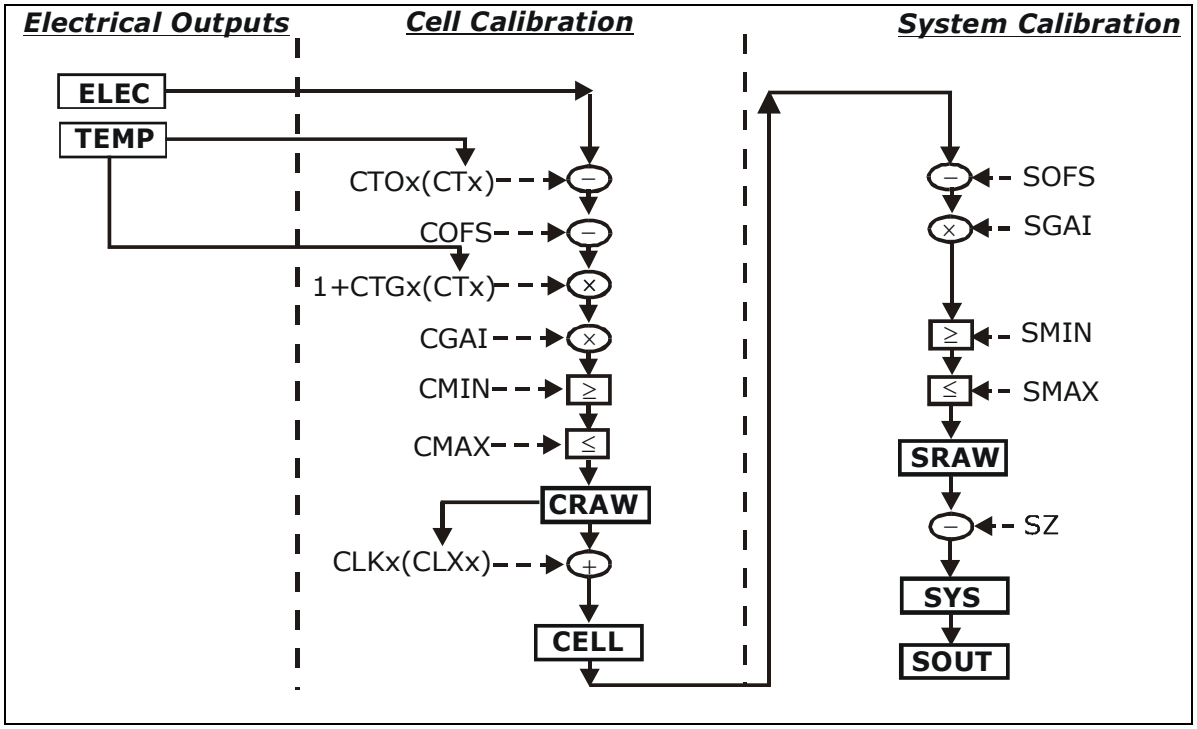
## The SOUT Main Output Value

The "main" output value, SOUT, is *normally* an identical copy of the final system output, SYS. In fact, however, SOUT can be 'selected' to track any of a whole group of different output parameters. Details for this are given in *SOUT Output* in *Chapter 10 Additional Software Features*.

## A Complete Picture of Readings Processing

For completeness, the following diagram shows a total overview of the calibration processes

### *Figure 5.2 Readings Processing – Full*




The detailed operation of the 'Cell' calibration stage, as shown above, as follows

- The raw 'ELEC' input is rescaled by the 'Cell' controls and temperature compensated (based on current TEMP value) to give the CRAW value.
- CRAW is then linearity-compensated to give the final CELL output

**NOTES:**

1. Temperature-compensation is integrated with the basic cell scaling calculations, so there is no 'uncompensated cell output' value available.
2. The cell range limits, CMIN and CMAX are applied to the CRAW result, not the linearised value
3. The system range limits are applied to SRAW, not SYS, so the range errors SYSUR and SYSOR are independent of the SZ setting.

This more complete picture is used for the discussion of the compensation facilities in the following chapters.

## Calibration Parameters Summary and Defaults

The various control parameters are listed for each stage.
This also includes the compensation parameters, not covered in this chapter, but shown in Figure 5.2 Readings Processing – Full
The 'default' values shown set the device back to its nominal default calibration (%-full-scale output)

**Cell Control Defaults**

| Command | Action | Default Values |
|---|---|---|
| COFS | basic cell offset | 0.0 |
| CGAI | basic cell gain | 1.0 |
| CTN | number of temp points | 2 |
| CT1..5 | temp point values | 0.0, 25.0, 0,0… |
| CTO1..5 | offset adjusts | 0.0, 0.0, 0,0… |
| CTG1..5 | gain adjusts | 0.0, 0.0, 0,0… |
| CMIN | craw min limit | –150.0 |
| CMAX | craw max limit | +150.0 |
| CLN | number of linearity points | 2 |
| CLX1..7 | linearity raw-value points | 0.0, 100.0, 0,0… |
| CLK1..7 | linearity adjusts | 0.0, 0.0, 0,0… |

**System Control Defaults**

| Command | Action | Default Values |
|---|---|---|
| SOFS | basic offset | 0.0 |
| SGAI | basic gain | 1.0 |
| SMIN | raw min limit | –150.0 |
| SMAX | raw max limit | +150.0 |
| SZ | output zero offset | 0.0 |

## Two-Point Calibration Calculations and Examples

Values for both the Cell and System calibrations can be set up in any of the ways described under *Calibration Methods* in *Chapter 3 Basic Setup and Calibration*.
Examples are given here for two-point calibration, as this is by far the most common method.

**Cell Calibration**

The scaling parameters are COFS, CGAI, CMIN and CMAX –
COFS is in '%' (nominal percent-full-scale from electrical calibration)
CGAI is in 'cell-units per %'
CMIN, CMAX are in cell units.

The cell output calculation is (in the absence of temperature and linearity corrections) –
CELL = (ELEC – COFS) × CGAI
If we have two electrical-output (ELEC) readings for two known force loads, we can convert the output to the required range. So if –

test load = fA → ELEC reading = cA
test load = fB → ELEC reading = cB

– then calculate the following gain value
CGAI = (fB – fA) / (cB – cA)
and the offset is
COFS = cA – (fA / CGAI)

The outputs should then be CELL = fA,fB true force values, as required.

**System Calibration**

For system calibration, the arrangement is very similar
The parameters are SGAI, SOFS, SMIN and SMAX. So –
SOFS is in cell units
SGAI is in 'engineering units per cell unit'
SMIN, SMAX are in engineering (output) units.

The system calculations are —
SRAW = (CELL – SOFS) × SGAI
SYS = SRAW – SZ

If we have two cell-output (CELL) readings for two known test loads, we can convert the output to the required range. So if –
test load = xA → CELL reading = cA
test load = xB → CELL reading = cB

– then we calculate the following gain value
SGAI = (xB – xA) / (cB – cA)
and then the offset
SOFS = cA – (xA / SGAI)

The outputs should now be SRAW = xA, xB true load values, as required.

**Example:**
**A 2500Kgf load cell installation is to be calibrated by means of test weights.**
**The cell calibration gives an output in Kgf ranging 0–2000.**
**A system calibration is required to give an output reading in the range 0–1.0 tonnes.**

**Calculations**
**Take readings with two known applied loads, such as –**
**For test load of xA = 99.88Kg : CELL reading cA = 100.0112**
**For test load of xB = 500.07Kg : CELL reading cB = 498.7735**

**Calculate gain value. In this case put SGAI = (xB – xA) / (cB – cA)**
**= (0.50007 – 0.09988) / (498.7735 – 100.0112)**
**≈ 0.001003580 = $1.003580 \bullet 10^{-3}$**

**Calculate offset value. In this case SOFS = (cA – xA/SGAI)**
**= (100.0112 – (0.09988 / $1.003580 \bullet 10^{-3}$))**
**≈ 0.487495**

**Set SMIN, SMAX to include the expected output range**
**say SMAX = +1.0, and SMIN = –0.1 to allow for small negative loads**
**Check**
**Putting the values back into the equation, results for the two test loads should then be —**
**For x = 99.88Kg, CELL = 100.0112, so**
**SRAW ≈ (100.0112 – 0.487495) × $1.003580 \bullet 10^{-3}$ ≈ 0.0998799**
**For x = 500.07Kg, CELL = 498.7735, so**
**SRAW ≈ (498.7735 – 0.487495) × $1.003580 \bullet 10^{-3}$ ≈ 0.5006987**

**The remaining errors are due to rounding the parameters to 7 figures.**
**Internal parameter storage is only accurate to about 7 figures, so errors of about this size can be expected in practice.**

# Chapter 6 Temperature Compensation

This chapter explains how to use the Temperature Compensation facilities, to compensate for changes in the measurement with ambient temperature.

## Purpose and Method of Temperature Compensation

Most measurement methods are affected by changes in temperature, and (uncompensated) load cells are especially sensitive, having a large overall temperature coefficient.

Temperature compensation adjusts the measured value in a way that depends on a temperature measurement, so that (ideally) the output does not depend on the current temperature.
In practice, it is usual to refer to a calibration 'reference' temperature: The ideal output value is then what the reading 'would have been' if made at the reference temperature.

The DCell/DSC temperature compensation facilities make adjustments to the 'Cell' calibration parameters (i.e. gain and offset) which depend on temperature, according to a digitally programmed curve.
These adjustments are automatically applied, based on the current device temperature measurement. With some care, this can remove the need for the usual electrical compensation components altogether.

## Control Parameters

The temperature compensation parameters define a pair of lookup tables that contain adjustments to the cell calibration gain and offset over temperature.

The parameters concerned are the following

| | | |
|---|---|---|
| CTN | [-] | number of temperature table points |
| CT1…CT5 | [°C] | indicated TEMP value at table point |
| CTO1…CTO5 | [ppm-fs] | ELEC offset ($\times 10^4$) adjustment at table point |
| CTG1…CTG5 | [ppm] | cell gain ($\times 10^6$) adjustment at table point |

**They work like this**

- The number of temperature calibration points is set by CTN (from 2 up to 5).
- The temperature values are set by CT1, CT2 .. CT5 (or to the number set by CTN). These ***must*** be arranged in order of increasing temperature.
- The gain adjustments at these temperatures are set by CTG1, CTG2 .. CTG5
- The offset adjustments at these temperatures are set by CTO1, CTO2 .. CTO5
- Gain adjustments are specified in parts-per-million (ppm)
- Offset adjustments are specified in "parts-per-million full-scale", or 0.0001%

## Internal Calculation

A working table index, i, is derived from the current measured temperature, T, as follows —

(n = number of points used, as set by CTN)

When $(T < T_1)$ then $i = 1$

When $(T > T_{n-1})$ then $i = (n-1)$

Otherwise $i$ is chosen so that $T_i \le T \le T_{i+1}$

The resulting current gain and offset adjustment values are then

$$ctg = CTG_i + (CTG_{i+1} - CTG_i) \times (T - T_i) / (T_{i+1} - T_i)$$

$$cto = CTO_i + (CTO_{i+1} - CTO_i) \times (T - T_i) / (T_{i+1} - T_i)$$

The compensated cell value is then calculated as
$CELL = (ELEC - COFS - 10^{-4} \times cto) \times (1.0 + 10^{-6} \times ctg) \times CGAI$

## How to Set Up a Temperature Compensation

There are a number of ways of setting up a temperature compensation curve.
The best possible compensation for a given piece of physical hardware can only be achieved by performing detailed experiments on that particular unit, to characterise the measurement output at a variety of different, stable temperatures in the required operating range.
The cost, time, expertise and equipment needed to do this can be considerable: The basic choice of methods thus depends on trading off ideal accuracy against the expense of the calibration procedure.

**Method 1**
Apply a simple linear drift correction (i.e. for known constant gain and offset changes per degree), by specifying zero correction at the calibration temperature, and appropriately adjusted correction values at extreme temperatures above and below this.
This can be used when the measurement or sensor has known temperature coefficients.

**Method 2**
Where the temperature characteristics of the measurement are known, but not linear, a similar scheme to Method 1 can be used, with a multi-point table defining an approximation to the known, ideal temperature curves of offset and gain variations.

**NOTE:** Both of the above methods are based on 'known' characteristics, which could come from datasheets. This is fairly easy, but also brings into question the actual accuracy of the TEMP measurement – see *Temperature Measurement Accuracy* below.
The remaining methods assume some calibration testing.

**Method 3**
Do a series of measurements at different temperatures and install the appropriate correction values to give exactly correct results at those same temperatures –i.e. calculate ideal gain and offset corrections at the tested temperatures.
(*This method is the most common)*.

**Method 4**
Use a set of test results to plan a 'best correction' curve (not necessarily perfect at test temperatures, but slightly better overall).

**NOTES:**
All of these methods can be applied *either* to data from individual devices *or* to an 'average' correction for a particular type of sensor hardware.
During testing, temperatures should be measured using the internal TEMP measurement, as this is the measurement used to do the corrections.
For in-system tests, the environment of the DCell/DSC must always be as near as possible to the exact conditions of the eventual in-system use.

## Potential Problems

It is worth always bearing in mind some *unavoidable* limitations of the compensation scheme
1. Equipment physical characteristics may drift over time
2. The internal temperature measurement may drift over time
3. The temperature measurement will experience a time-lag in tracking the actual temperature of the measuring device during changes in temperature
4. The relationship between internal device temperature and that at the sensor is complicated by the fact that the device itself emits heat in use.
   See *Temperature Measurement Accuracy*.

**These problems can be addressed as follows**
1. No real solution.
2. Should be adequately repeatable if random noise is acceptable: The temperature measurement is typically not that stable anyway, due to fluctuating cooling conditions.
3. Do not rely on large temperature compensation factors where temperature may change *quickly*. Or use external temperature sensor bonded to the input sensor (see next section)

4. Always operate with a fixed, stable power supply voltage.

## Temperature Measurement Accuracy

The TEMP reading is a taken from a sensor within the DCell/DSC device. With a DCell placed directly in the sensor pocket it will measure – as near as practical – the sensor temperature. A DSC should at least be mounted close to the sensor, and preferably in good thermal contact.

The TEMP reading can be expected to track that at the sensor, but with an offset: The offset is due to the device itself giving off heat – i.e. the internal temperature is always above the ambient temperature it finds itself in.

Luckily, the temperature compensation process only needs a reasonably *repeatable* measurement which relates to actual conditions at the sensor.
However, any tests to establish temperature corrections must *always* be carried out as close to normal operational conditions as possible –and this includes operation at the same power-supply voltage. Changes in power-supply voltage must also be avoided.

Of course, the measurement may be inadequate if a nominal temperature correction is wanted (i.e. a known calibration change per-degree), or if a temperature measurement is wanted for its own sake.
In these cases, the temperature calibration can be adjusted, if required – see *Temperature Calibration* in *Chapter 10 Additional Software Features*.
The absolute accuracy of the TEMP measurement would not exceed 1°C at best, due to the relatively simple sensor used.

Temperature accuracy problems can mostly be eliminated by fitting an external temperature sensor near to the sensor. See also *Fitting an External Temperature Sensor* in *Chapter 13 Installation*:

## Parameter Calculations and Example

This is based on **Method 3** above –i.e. compensation is designed so that the measured test results will be exactly compensated at the test temperatures.

Suppose load tests are performed at a series of different temperatures,

$T_i$ (i=1..n)

Known loads, xA,xB are applied, and the resulting electrical readings at each temperature are

ELEC = $eA_i$, $eB_i$ (for each $T_i$)

'Ideal' offset and gain factors can then be derived for each temperature –

$gai_i = (xB - xA) / (eB_i - eA_i)$

$ofs_i = eA_i - (xA + COFS/CGAI) / gai_i$

( as described in *Two-Point Calibration Calculations and Examples*, in *Chapter 5 Readings Processing and Calibration*
– note that this is easier if you put COFS=0 to start with )

Choosing one of the $T_i$ , say $T_k$ , as the 'most usual' operation temperature (the reference), we then use the gain and offset for that temperature as the basic 'Cell' gain and offset parameters –

$CGAI = gai_k$ , $COFS = ofs_k$

The lookup tables are then set up to contain the ppm-differences from these 'centre' values –

CTN = n

$CT_i = T_i$

$CTG_i = 10^6 \times (gai_i / CGAI - 1)$

$CTO_i = 10^4 \times (ofs_i - COFS)$

(last factor is $10^{-4}$ because 100.0 full-scale gives 1ppm f.s. = 0.0001)

**NOTES:**

1. The $T_i$ values are temperatures **as measured by the device** (i.e. TEMP values). The *actual* temperatures are not important.
2. The calculation yields *exact* results (except for rounding errors) at **all** the calibration points $e1_i$, $e2_i$ (at the appropriate temperatures).
3. For the 'centre' temperature, $T_k$, the correction values disappear, i.e. $CTG_k = CTO_k = 0$. This is less wasteful than it appears, as the calculation needs to be "told" the temperature that the basic gain and offset apply at.
4. Any subsequent calibration changes to CGAI and COFS will probably not require the table values to change, unless the change is fairly large.

**Example**
**Suppose electrical readings are taken with two known loads –**
**xA=99.88Kg , xB=500.07Kg**
**at different three temperatures, giving the following ELEC values –**

**at $T_1$ = –15.3°C : ELEC readings are $eA_1$=14.25537, $eB_1$=70.18944**

**at $T_2$ = 20.7°C : ELEC readings are $eA_2$=14.31633, $eB_2$=70.50611**

**at $T_3$ = 35.2°C : ELEC readings are $eA_3$=14.40616, $eB_3$=71.00749**

**at $T_4$ = 51.9°C : ELEC readings are $eA_4$=14.39212, $eB_4$=71.05322**

**Calculations**
**applying the formulae for gain and offset values then gives –**

**$gai_1 = (xB-xA)/(eB_1-eA_1) \approx 7.154673$ , $ofs_1 = eA_1-(xA/gai_1) \approx 0.295263$**

**$gai_2 = (xB-xA)/(eB_2-eA_2) \approx 7.122114$ , $ofs_2 = eA_2-(xA/gai_2) \approx 0.292404$**

**$gai_3 = (xB-xA)/(eB_3-eA_3) \approx 7.070329$ , $ofs_3 = eA_3-(xA/gai_3) \approx 0.279519$**

**$gai_4 = (xB-xA)/(eB_4-eA_4) \approx 7.062870$ , $ofs_4 = eA_4-(xA/gai_4) \approx 0.250560$**

**taking $T_2$=20.7°C as 'normal' operating temperature, we then set**

**CGAI = $gai_2 \approx 7.122114$ , COFS = $ofs_2 \approx 0.292404$**

**the temperature correction tables are then set relative to this, as follows –**

**CTN = 4**

**CT1 = $T_1 \approx -15.3$**

**CT2 = $T_2 \approx +20.7$**

**CT3 = $T_3 \approx +35.2$**

**CT4 = $T_3 \approx +51.9$**

**CTG1 = $10^6 \times ((gai_1 / CGAI) - 1) \approx 4571.536$**

**CTG2 = $10^6 \times ((gai_2 / CGAI) - 1) \approx 0$**

**CTG3 = $10^6 \times ((gai_3 / CGAI) - 1) \approx -7271.015$**

**CTG4 = $10^6 \times ((gai_4 / CGAI) - 1) \approx -8318.317$**

**CTO1 = $10^4 \times (ofs_1 - COFS) \approx 028.5900$**

**CTO2 = $10^4 \times (ofs_2 - COFS) \approx 0$**

**CTO3 = $10^4 \times (ofs_3 - COFS) \approx -128.850$**

**CTO4 = $10^4 \times (ofs_4 - COFS) \approx -418.440$**

**Checking**
**the CELL result is now correct for all these temperatures and loads, e.g. –**

**for TEMP=20.7, ELEC=14.31633, result is**

**CELL = $((ELEC - 10^{-4} \times cto) \times (1.0 + 10^{-6} \times ctg) - COFS) \times CGAI$**
**$\approx (14.31633 - 0.292404 - 10^{-4} \times 0) \times (1.0 + 10^{-6} \times 0) \times 7.122114$**
**$\approx 99.8799$**

**for TEMP=20.7, ELEC=70.50611, result is**
**$\approx (70.50611 - 0.292404 - 10^{-4} \times 0) \times (1.0 + 10^{-6} \times 0) \times 7.122114$**
**$\approx 500.070$**

**for TEMP= –15.3., ELEC=14.25537, result is**
**$\approx (14.25537 - 0.292404 - 10^{-4} \times 28.59) \times (1.0 + 10^{-6} \times 4571.536) \times 7.122114$**
**$\approx 99.8800$**

**for TEMP= –15.3., ELEC=70.18944, result is**
**$\approx (70.18944 - 0.292404 - 10^{-4} \times 28.59) \times (1.0 + 10^{-6} \times 4571.536) \times 7.122114$**
**$\approx 500.069$**

# Chapter 7 Linearity Compensation

This chapter describes the Linearity Compensation features and how to use them.

## Purpose and Method of Linearisation

Load cell sensor outputs are never precisely proportional to the input (applied load).
If the graph of the measurement output against the true value shows slight deviations from the ideal straight-line, then slight errors remain even when the basic calibration (offset and gain) is as good as possible.
Linearity compensation adjusts the raw measurement by a small amount that is calculated as a function of the raw measurement value itself. Ideally this will adjust the output response, for any given input load, by exactly the right amount to place the final result onto the ideal straight line.

The DCell/DSC non-linearity compensation uses a single 'lookup table', similar to those used for temperature compensation (see previous chapter). This provides a linearly-interpolated compensating value with up to 7 control points, which is then added to the output result.

Generally, linearisation is a finer level of compensation than temperature compensation.
It should only be applied after the basic Cell calibration and temperature compensation (if any) have been set up.
Although the tests are generally simpler than testing over temperature, the accuracy requirement is often greater. See below for notes of possible difficulties to be avoided.

## Control Parameters

Refer to *Figure 5.2 Readings Processing – Full*
The lookup table (based on parameters CLXi, CLKi) defines an offset adjustment based on the CRAW value, which is then added in to give the final CELL output.
(So linearity correction is applied after any temperature compensation.)

**The parameters involved are**

| | |
|---|---|
| CLN | sets the number of linearisation points (from 2 up to 7). |
| CLX1..7 | raw input (CRAW) value points |
| CLK1..7 | output (CELL) adjustments to apply at these points |

**They are used like this**

- The number of calibration points is set by CLN (from 2 up to 7).
- Raw input value points are set by CLX1, CLX2 .. CLX7 (or up to the number set by CLN)
  These ***must*** be arranged in order of increasing input value.
- The output corrections at these points are set by CLK1, CLK2 .. CLK7
- Corrections are specified in "thousandths of a cell unit"
  (so a CLKi of 1.0 actually adds 0.001 to the CELL output)

## Internal Calculation

This uses the same basic 'interpolated table lookup' method as for temperature compensation.
First, a working table index, i, is derived from the current raw input CRAW=x, as follows

(n = number of points used, as set by CLN)

When $(x < CLX_1)$ then $i = 1$

When $(x > CLX_{n-1})$ then $i = (n-1)$

Otherwise i is chosen so that $CLX_i \le x \le CLX_{i+1}$

The resulting interpolated adjustment value is then calculated as –

$$ofs = CLK_i + (CLK_{i+1} - CLK_i) \times (x - CLX_i) / (CLX_{i+1} - CLX_i)$$

Then the compensated cell value is calculated as –
$CELL = CRAW + 10^{-3} \times ofs$

## How to Set Up Linearity Compensation

A linearity correction can be set up either from sensor specification/calibration data, or more commonly from in-system testing results.
Assuming we do not have any prior information on linearity errors, the usual approach is to do a series of controlled tests with accurately known test loads.
Just as with temperature compensation, it is *possible* to obtain a detailed graph of linearity error and then choose a 'best-fit' piecewise linear curve for the compensation table.
However, it is generally good enough, and much simpler, to simply test at several different points and then apply an exact correction at those points. If the error curve is reasonably smooth, this should give exact results at the test points, and reasonably accurate values in between.

**NOTES:**
Linearisation tests should only be done ***after*** the cell calibration is set, because the correction values are dependent on the cell calibration.
Similarly, linearisation testing should only be done at the calibration 'reference' temperature, or after temperature compensation is installed, to avoid temperature effects from distorting the results.
The linearisation tests should not reveal any significant remaining linear trend in the errors.
If errors do appear to lie on a definite line, this could drastically reduce the accuracy of the correction.
If this does happen, it shows that the cell calibration is wrong and should be redone.
The table points must always cover more-or-less the whole range of output values to be used, because corrections are extrapolated outward beyond the first and last points.
It is always worthwhile including more test-points than will be used in the correction table, because this gives confidence that no regions of rapidly changing error have been missed.
Tests should be done both with steadily increasing ***and*** decreasing load values, as hysteresis effects (for load cells) are often of a similar size to non-linearities.

## Parameter Calculations and Example

Based on the simple method outlined above, we suppose that we have obtained test results for a series of precisely known load values –

test loads $X_i$ give readings of CRAW = $C_i$, for ($i = 1..n$)

Then calculate the errors that need to be removed at these points –

$E_i = X_i - C_i$

Now just enter these values into the correction table, remembering to scale the errors –

CLN = n
$CLX_{i=} X_i$

$CLK_i = 1000 \bullet E_i$

**Example**
**Suppose we have a load cell and Cell calibration giving a result in the range 0-500 KgF.**
**The following test results were obtained using a series of known test loads –**

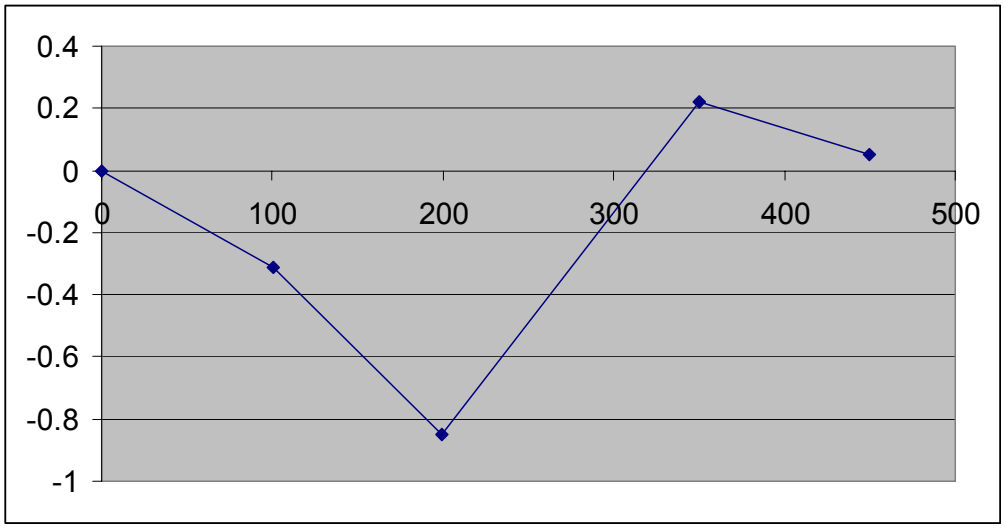
**For test load of x1 = 0Kg : CELL reading c1 = 0.0010**
**For test load of x2 = 100.13Kg : CELL reading c2 = 100.44**
**For test load of x3 = 199.72Kg : CELL reading c3 = 200.57**
**For test load of x4 = 349.97Kg : CELL reading c4 = 349.75**
**For test load of x5 = 450.03Kg : CELL reading c5 = 449.98**

**We choose these precise test points as our linearisation reference points, so**
**CLN = 5**
**CLX1 = 0.0010**
**CLX2 = 100.44**
**CLX3 = 200.57**
**CLX4 = 349.75**
**CLX5 = 449.98**
**(Note that these are the raw reading values, not the known true values.)**
**Now calculate all the residual errors, and set up the correction factors –**
**CLK1 = $10^3 \times (x1 - c1) \approx 1000 \times (000.00 - 0.0010) = -1.0$**
**CLK2 = $10^3 \times (x2 - c2) \approx 1000 \times (100.13 - 100.44) = -310.0$**
**CLK3 = $10^3 \times (x3 - c3) \approx 1000 \times (199.72 - 200.57) = -850.0$**

**CLK4 = $10^3$×(x4 – c4) ≈ 1000×(349.97–349.75) = +220.0**
**CLK5 = $10^3$×(x5 – c5) ≈ 1000×(450.03–449.98) = +320.0**

**The CELL output values will now have the required values at all these 5 points.**

**Note on the Example**
If you graph the errors from the above example, the results look like this




This doesn't show any very definite linear trend, so the calibration is okay.
However there ***is*** a big jump between points 3 and 4, which might be worth a more detailed investigation: Some important features of the error curve could have been missed by the test.

# Chapter 8 Self-Diagnostics

This chapter describes the use of the in-built self diagnostics.

All the self-diagnostics rely on the FLAG parameter, which is a 16-bit integer register in which different bits of the value represent different diagnostic warnings.

## Monitoring Warning Flags

The flags are normally used something like this
FLAG is read at regular intervals by the host (like the main output value, but generally at longer intervals)
If some warnings are active, i.e. FLAG is non-zero, then the host tries to cancel the warnings found by writing FLAG= 0
The host then notes whether the error then either remains (i.e. couldn't be cancelled), or if it disappears, or if it re-occurs within a short time, and will take action accordingly.

The warning flags are generally latched indicators of transient error events: By resetting the register, the host both signals that it has seen the warning, and readies the system to detect any re-occurrence (i.e. it resets the latch).

What the host should actually do with warnings depends on the type and the application:
Sometimes a complete log is kept, sometimes no checking at all is needed.
Often, some warnings can be ignored unless they recur within a short time.

Warning flags survive power-down, i.e. they are backed up in non-volatile (EEPROM) storage. Though useful, this means that repeatedly cancelling errors which then shortly recur can wear out the device non-volatile storage – see *WARNING: Finite Non-Volatile Memory Life* in *Chapter 3 Basic Setup and Calibration*.

The flags EXCSC and OLDVAL are ***exceptions*** to the above scheme:
These are both set *and* unset by the device software, and are not stored in EEPROM. See below for more details.

## Meaning and Operation of Flags

The various bits in the FLAG value are as follows

| Bit | Value | Description | Name |
|---|---|---|---|
| 0 | 1 | Excitation under-range | EXCUR |
| 1 | 2 | Excitation over-range | EXCOR |
| 2 | 4 | Temperature under range ( TEMP) | TEMPUR |
| 3 | 8 | Temperature over-range (TEMP | TEMPOR |
| 4 | 16 | Strain gauge input under-range | ECOMUR |
| 5 | 32 | Strain gauge input over-range | ECOMOR |
| 6 | 64 | Cell under-range (CRAW) | CRAWUR |
| 7 | 128 | Cell over-range (CRAW) | CRAWOR |
| 8 | 256 | System under-range (SRAW) | SYSUR |
| 9 | 512 | System over-range (SRAW) | SYSOR |
| 10 | 1024 | Communication error | COMMSFAIL |
| 11 | 2048 | (unused – reserved) | |
| 12 | 4096 | (unused – reserved) | |
| 11 | 8192 | Stale output value | OLDVAL |
| 14 | 16384 | Excitation Short circuit (cell currently off) | EXCSC |
| 15 | 32768 | Reboot warning | REBOOT |

**NOTE:**
The mnemonic names are used by convenience properties in VisualLink, but are otherwise for reference only –the flags can only be accessed via the FLAG parameter.

**The various warning flags have the following meanings**
The EXCSC and EXCUR/EXCOR warnings are triggered by measurements of the bridge excitation voltage:
EXCOR is set when the excitation measures high (sensor open-circuit).
EXCUR is set when the excitation measures low (sensor short-circuit)
EXCSC is set while excitation is turned off (to reduce over currents), but this flag is self-resetting: See *Cell Excitation Management* below

TEMPUR and TEMPOR indicate temperature under- and over-range. The temperature minimum and maximum settings are part of the temperature calibration, fixed at –50.0 and +90.0 ºC
ECOMUR and ECOMOR are the basic electrical output range warnings. These are tripped when the electrical reading goes outside fixed ±120% limits: This indicates a possible overload of the input circuitry, i.e. the input is too big to measure.
The tested value, ECOM is an unfiltered precursor of ELEC
CRAWUR and CRAWOR are the cell output range warnings. These are tripped when the cell value goes outside programmable limits CMIN or CMAX.
The tested value, CRAW is the cell output prior to linearity compensation.
SYSUR and SYSOR are the system output range warnings. These are triggered if the SYS value goes outside the SMIN or SMAX limits.
COMMSFAIL indicates that a serial communications framing error was detected, which indicates that improperly formatted data was detected on the bus. If this occurs 3 times in 100 output times this causes a communications reset). See *Communications Errors* in *Chapter 11 Communication*.
OLDVAL indicates that the value SOUT (used for various special purposes) has not been updated since last read. This flag is not reset by the host in the usual way. See *Output Update Tracking* in *Chapter 10 Additional Software Features*.
REBOOT is set whenever the DCell/DSC is reset. The possible causes are power loss, the RST command or a software watchdog timeout (should never happen!).

## Cell Excitation Management

The EXCSC and EXCUR/EXCOR warnings are triggered by measurements of the bridge excitation voltage.
EXCUR/EXCOR are reset in the usual way, by host action only, but EXCSC is a self-resetting warning indication (not a normal, latching flag value).

EXCOR is set when the excitation measures high, so that the apparent bridge impedance is considerably greater than 1kOhm.
This can mean that the sensor or wires are broken (open-circuit).
EXCUR is set when the excitation measures low, so that the apparent bridge impedance is considerably less than 350ohm.
This normally means a short-circuit. For a DSC only (with 6-wire cell connection) it may also be due to a wiring failure.

Whenever EXCUR is triggered, the device also sets the EXCSC flag and *turns off the bridge excitation*, in order to protect itself against a possible overcurrent.

About every 10 seconds, EXCSC is cancelled and the excitation turned back on again, in case the problem has cleared itself: If the excitation still measures low, after a few milliseconds EXCSC will be set and the excitation turned off again. Otherwise, normal operation resumes with EXCSC cancelled, but the EXCUR warning will remain set until cancelled by the host.

When the excitation is turned off, of course, some readings may be invalid (usually near zero). This can be important if the data are being logged as a continuous stream. To ensure good readings, it will probably be necessary to reject all data up to a few readings around (and especially after) the time EXCSC is reported. Also note that EXCSC will always be clear for a short period every few seconds even if the apparent short-circuit persists.

# Chapter 9 Device Locking

This chapter describes the security 'locking' scheme.

All devices contain a 'lock' that prevents unauthorised usage. This is not intended as a data security feature, but to insure DCell/DSC resellers against being undercut by third-party resellers.

In order to access a device's data outputs, it must first be in an 'unlocked' state. This is achieved by programming it to *either* disable locking completely *or* to release the lock when a specific coded command is received.

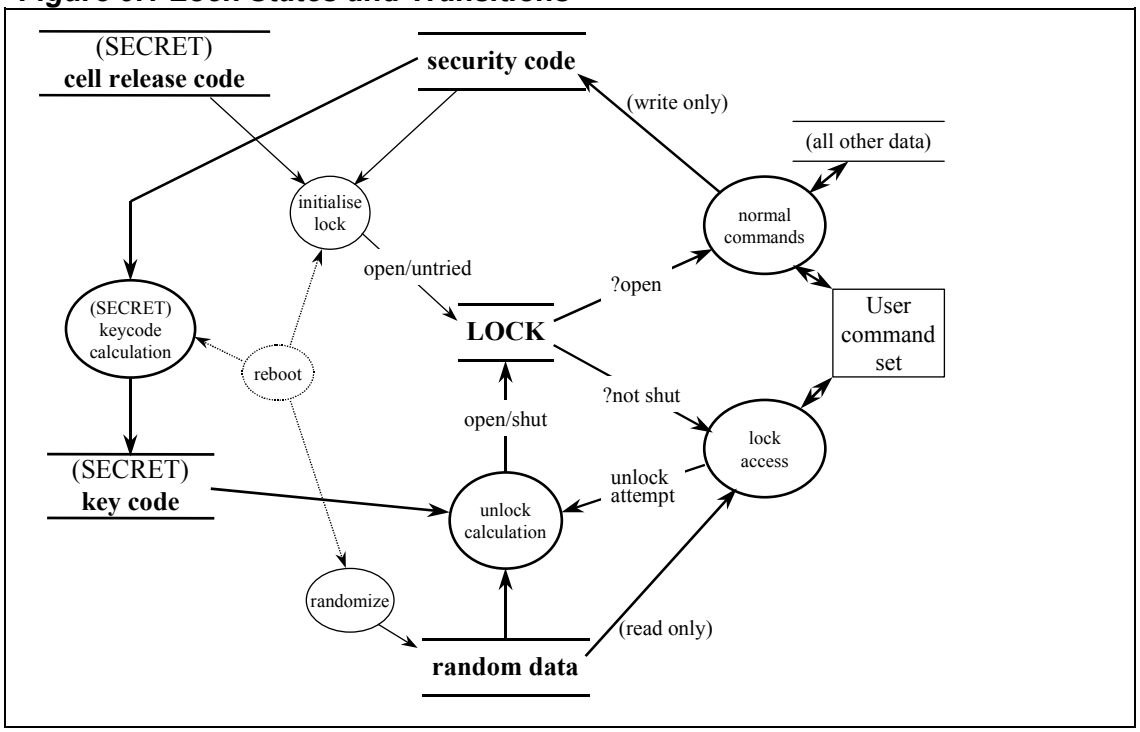
**The locking scheme has the following general features**

- A device can be tied exclusively to supplied software, and vice-versa
- Access requires knowledge of a secret 'security code', unique to the supplier
- All communications are normal, uncoded data, including the unlock operation
- The lock can be completely disabled when required, by programming in a separate secret code number

## Lock Operation

The device lock is always in one of the states shown

***Figure 9.1 Lock States and Transitions***




**The behaviour in the different states can be summarised as follows**

- When the device is rebooted it is in the OPEN or UNTRIED state, depending on whether locking is currently disabled or enabled (controlled by lock 'security code' parameter)
- In the 'lock open' state, the device behaves as normal
- In the 'lock untried' state, no data can be read from the device, but parameter writes and action commands (including the 'unlock' command) are permitted.
- In the 'lock shut' state all access is forbidden.
  The only way out of the 'shut' state is to reset the device.
- When the lock is open, it can still be deliberately (+permanently) shut by sending a bad unlock value.

## Ways of Using the Lock

Locking is controlled by setting the stored '**security code**' in each device, to enable use in one of two ways (refer also to *Figure 9.2 Lock Operations*)

**Locking Disabled**

The security code is set to the '**cell release code**'. This disables locking, allowing access to the full set of commands.
As the security code cannot be read out, and the release code is different for each device, this information can be restricted as required.
Devices are supplied in this state, which can be reinstated at any time simply by rewriting the security code. Mantracourt will only reveal a Cell's release code to the original supplier.

**Locking Active**

In this case the security code is set to a '**supplier code**', issued to authorised suppliers by Mantracourt. The device must then be specifically 'unlocked' for use after every device reboot (i.e. following powerdown or a reset command).
To unlock the device for use, the user first reads back some data which is randomly produced on reboot, and then issues an 'unlock' command passing an '**unlock value**' calculated using this random data.

Calculating the 'unlock value' requires the matching '**supplier key**', issued by Mantracourt with the supplier code. This prevents anyone from reusing a device by setting an unauthorised security code – they will need the appropriate key value as well.

## Purpose of the Security Scheme

It is fairly easy to gain access to any device, simply by using the supplier's approved software to access it, and then reconnecting the device to communicate with something else.
It is also possible to 'get in' by trying random unlock values: The unlock value is only one byte, so this will usually succeed in around 1-200 tries. However, this is not practical as a general get-around as the device must also be repeatedly reset, taking around 2-3 seconds per attempt.

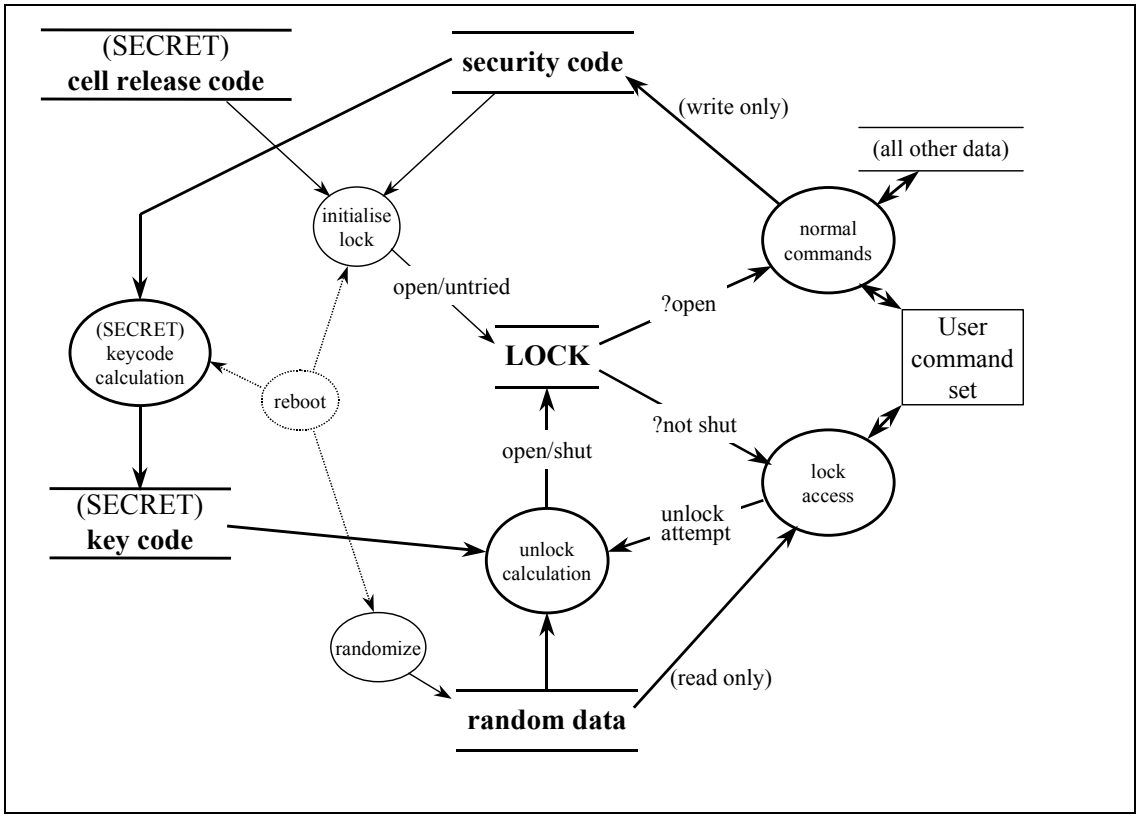
In view of this, the scheme does ***not*** attempt to make unlocking hard. Instead, it makes it hard ***to determine the unlock key***.
This is done by making the unique release code device-specific, using random data in the calculation, making the security code write-only, and deriving the unlock key from the security code by a secret algorithm.

To defeat locking, you need *either* the device-specific release code, *or* a valid code/key pair. Such information will only be released to authorised suppliers.

## Lock Calculation Details

The lock operations are summarised in the following diagram

### *Figure 9.2 Lock Operations*




**The components of this system are as follows**

- The security code, key and random data all consist of sequences of four bytes.
- The random data bytes are accessed as a pair of read-only integer parameters LKD1..2. Each contains 2 bytes of the four-byte sequence (like SERL and SERH): The lower byte of the LKD1 value is the first data byte.
  These are the only values that can be read back before the device is unlocked. They are rewritten randomly on every reboot.
- The security code is stored in the EEPROM. It is written to by first writing the two integer parameters LKK1, LKK2 and then sending the LKD1 value (as a check) to the command LKWR. The lower byte of the LKK1 value is the first code byte.
- The internal 'key code' is derived from the security code by a secret algorithm
- The 'cell release code' is a special value unique to each device. Setting the security code to this value disables the lock.
- The "ULCK" command requires an 'unlock value' as its argument. This must match the value calculated by the device from its security key code and the random data. If the wrong value is sent, the device becomes completely locked and can then only be reset.

The unlock value itself is a single byte, calculated as follows –

```
/* a bit-jumbling routine */
unsigned char Scramble_Bits(unsigned char data) {
  int i, bit, rotate;
  rotate = data & 7;           /* extract lower 3 bits (MOD 8) .. */
  for (i=0; i<rotate; i++) {   /* .. and 'rotate' by this many */
    if (data >= 128)
      data = 2*(data - 128);
    else
      data = 2*data + 1;
  }
  return data;
}

/* the main calculation */
unsigned char Unlock_Value(unsigned char data[4], unsigned char key[4]) {
  int i, unlock;
  unlock = 0;
  for (i=0; i<4; i++) {   /* do for each of 4 bytes .. */
    unlock ^= key[i];               /* XOR with one byte of key */
    unlock = Scramble_Bits(unlock);  /* jumble up */
    unlock ^= data[i];              /* XOR with one byte of data */
    unlock = Scramble_Bits(unlock);  /* jumble up */
  }
  return unlock;
}
```

## Lock Commands Examples

To unlock a device, the command sequence looks like this (note: examples are described using ASCII protocol commands) –

read out random data using, E.G.

!001:LKD1? → +03123 (e.g.)
!001:LKD2? → +11723 (e.g.)

now calculate the unlock value + send it to turn the lock off, using (e.g.)

!001:ULCK=173

To rewrite security code, you would send (e.g.)

!001:LKK1 = 7207
!001:LKK2 = 42219
!001:LKWR = 3123 (matching LKD1)

**NOTE:**
The value sent to LKWR value must match the current LKD1 value.
This is to prevent accidental writes.

The VisualLink protocols for DCell/DSC devices also provide convenience functions for performing these operations.
If 'device' is a VisualLink instrument object of an appropriate type, then –

"device.PerformUnlock k1,k2,k3,k4"
unlocks the device, where k1-k4 are the key-code byte values, k1 the low-order byte

"device.RewriteSecurityCode k1,k2,k3,k4"
installs a new security-code value, where k1-k4 are the four bytes of the code.

# Chapter 10 Additional Software Features

This chapter describes a variety of features not covered elsewhere.

## SOUT Output Selection

The control **ICNT** can be used to make the SOUT value 'track' any one of several different output parameters.
Every time a new main reading value is processed, the SOUT parameter is updated to contain a copy of the current 'selected' output reading.

**This is important for a number of other operations, as described in the following sections**

- Continuous output: SOUT is the value that is transmitted.
- Snapshot: SOUT is the result latched into SYSN by a SNAP command.
- Result update: the OLDVAL flag is reset only when SOUT is read

In order to choose the 'selected' output result, ICNT is set to an indexing value.
The following values are currently supported (see *Figure 5.2 Readings Processing – Full* and *Figure* 10.1 Electrical Calibration Process for details of these parameters)

| ICNT setting | Selected output | Description |
|---|---|---|
| 0 | SYS | main System output |
| 1 | TEMP | temperature reading |
| 2 | SRAW | System output before SZ ('Gross' value) |
| 3 | CELL | Cell (force) output |
| 4 | FLAG | fault diagnostics |
| 5 | CRAW | cell output before linearisation |
| 6 | ELEC | raw electrical reading (%fs) |
| 7 | ECOM | unfiltered electrical reading |
| 8 | ERAW | raw input value before |
| 9 | EXC | excitation measure |
| 10 | FILT | dynamic filter time-constant |
| 11 | OFFS | input channel in use (=1 near to zero) |
| 12 | SZ | Final System output offset (Tare) |
| 13 | SYSN | Snapshot value |

The usual 'default' setting is ICNT=0, which makes SOUT=SYS.
New devices are always shipped with this setting.

## Output Update Tracking

The **OLDVAL** flag is cleared every time new reading values are produced, and set when the SOUT output value is read.

This allows sampling each result exactly once: SOUT is read (and possibly other results), and then the host waits, polling the FLAG value, until OLDVAL is cleared to indicate a new output is ready.

This scheme works as long as the communications speed is fast enough to keep up. With faster update rates and slower baud rates, it may not be possible to read out the data fast enough.

## Reading Snapshot

The action command **SNAP** samples the selected output by copying SOUT to the special result parameter **SYSN**.
The main use of this is where a number of different inputs need to be sampled at the same instant. Normally, multiple readings are staggered in time because of the need to read back results from separate devices in sequence: By broadcasting a SNAP command at the required time, all devices on the bus will sample their inputs within a few milliseconds. The resulting values can then be read back in the normal way from all the devices' SYSN parameters.

## Output Format Control (ASCII ONLY)

The parameters **DP** and **DPB** are used to control the formatting of floating-point values in the ASCII protocol.

DP controls the number of decimal places after the point and DPB controls the number of decimal places before the point. Values of 1..8 are appropriate in both cases.
All output values are then transmitted in this same format. As values are limited to a normal 4-byte accuracy (about 7 digits), it may sometimes be necessary to alter the formatting for best accuracy in reading/writing values.

**E.G. if DP=5 and DPB=2, the value 1.257 is output as "+01.25700"**

Changes to DP and DPB only take effect when the device is rebooted (as for BAUD and STN).

## Continuous Output (ASCII ONLY)

For the ASCII protocol only, there is a 'continuous output' mode:

The SOUT value is continually broadcast at the output rate (or as fast as possible if limited by communications speed).
The output is switched on and off by sending the standard ASCII 'XON/XOFF' control bytes (ctrl-Q = 0x11 and ctrl-S = 0x13).

This feature is intended for output to a single, simple serial display devices and printers.

**It has certain special limitations as follows**

- It can only be used in one-to-one operation, i.e. only one unit on a bus (as otherwise collisions can occur).
- On a RS485 bus it is not always easy to switch off, as the stop instruction must be transmitted when the device itself is not transmitting: If the output rate is limited by communications speed, then output is virtually continuous and may be impossible to stop.
  (N.B. this does not apply to RS232, which has separate transmit and receive connections)
- The operation does not start automatically, i.e. an initial Ctrl-Q must be sent. This means that if there is (for instance) a brief power interruption, output will stop.

To avoid possible problems, continuous-output operation is only enabled when the station-number (STN) is set to the special value of 999.

## EEPROM Controls

The special commands **EEAD, EEV, EEWR, EERD** are provided for accessing the built-in non-volatile storage (EEPROM).
This is potentially dangerous, as all non-volatile settings are stored in the EEPROM.
At present, the only expected end-user use of these commands would be to adjust the Temperature Calibration see *Figure* 10.1 Electrical Calibration Process.

EEAD is a read/write integer holding an EEPROM address (0-495).
EEV is a read/write byte value holding the read/write value.
EERD/EEWR are action commands triggering a read/write operation.

To read a byte, set EEAD to the address, execute EERD and read the result from EEV.
To write, set EEAD to the address, write the value required to EEV and execute EEWR.

There are 496 bytes of EEPROM data which can be addressed.
After use, EEAD is always reset to 65535 for safety (an invalid address, which prevents a write).

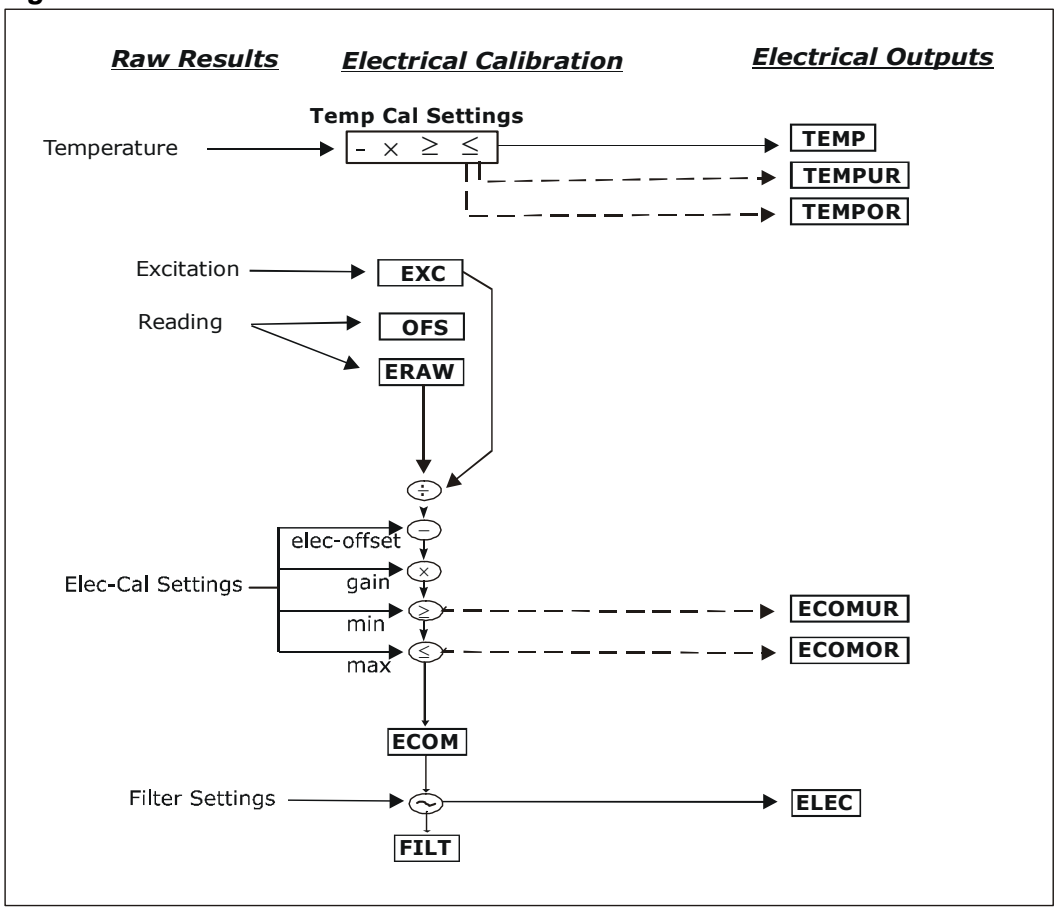
## Electrical Calibration

The 'Electrical' calibration stage is the initial phase of results processing, responsible for producing the basic TEMP and ELEC value outputs. This contains factory-set calibration information which should never need to be changed, and therefore has no control parameters.

Details are included here for explanation only, as none of these facilities can be adjusted.

The operation of the Electrical Calibration is illustrated by the following diagram.

### *Figure 10.1 Electrical Calibration Process*




In the same way as *Figure 5.2 Readings Processing – Full* this diagram shows the initial phase of results processing.

**The basic internal reading processes result in the following initial outputs**
**ERAW** is the basic reading value
**OFFS** is set to 1/0, indicating a reading on the 'offset'/'main' channel (readings near to zero are read on a separate channel for noise reasons)
**EXC** is the excitation voltage measurement
**TEMP** is the temperature reading

All of these except TEMP are debug-only values.
The other outputs are of no particular use to the ordinary user as their values may depend on the selected output rate, and may change between software releases.

In the next stage of calculation, ERAW is divided by EXC to give a corrected reading value.
This value is adjusted by stored calibration constants and block-averaged (depending on output rate setting), to give rise to **ECOM**, the first guaranteed, calibrated output value.
The electrical limit values (fixed at about ±120%) are also applied here, which are connected to the ECOMUR and ECOMOR flags.

Finally, ECOM is dynamically filtered to give the main Electrical Output, ELEC, as described in the next section. ECOM *can* safely be used, if an unfiltered electrical output value is needed.

## Dynamic Filtering

(See also previous section, including *Figure 10.1 Electrical Calibration* Process)

The dynamic filter produces the basic ELEC result by passing the evenly sampled ECOM value through a low-pass filter with a variable amount of averaging.
With a static input, this averages the input over a fairly large number of readings, smoothing the signal value to significantly improve noise performance. When the input changes, however, the filter responds to the increased rate of change by reducing its averaging time-constant, to better track the change.
The FILT parameter shows the current time-constant setting. This is 1 after a sharp step-change, and increases up to a fixed maximum (depending on RATE) while the input is steady.

This approach produces a better trade-off between steady-state output noise and response to input changes. However, the output noise on ELEC (and all subsequent values) increases during an input level change, and for some time after (it takes time for the filter time constant to ramp up again).
The filter settings are optimised for each rate setting, assuming a relatively 'clean' input signal. However, dynamic filtering is inherently sensitive to noise. Extra noise on the input can thus have a disproportionate effect on the output reading noise (something like a square-law).

## Temperature Calibration

While the basic 'Electrical' calibration stage is factory-set and not suitable for adjustment by the user, the TEMP calibration can be modified if needed.
This might be necessary if a more precise temperature reading value is required, or the measured temperature doesn't track the sensor temperature well enough to perform a desired nominal temperature compensation.

The temperature calibration is an adjustable linear rescaling and limiting process similar to those for the Cell and System reading calibrations. There are no communications parameters provided to access this, but the controls are stored with the other control settings in the non-volatile memory (EEPROM) and can be accessed via the EEPROM read/write commands.

These values are formatted as IEEE 4-byte floating-point values (as described for the MANTRABUS protocol, see *The Mantrabus-II Protocol* in *Chapter 11 Communication*).
They are stored from the LSB at the lowest address to the exponent byte at the highest.
**NOTE:**
These storage addresses may change between software releases.
These addresses are valid for Version 2

As with any use of the temperature measurement, any tests must be done using the exact intended operating conditions, including power-supply voltage, for any useful accuracy – see *Temperature Measurement Accuracy* in *Chapter 6 Temperature Compensation* for more details.

## Informational Parameters

The **VER** parameter (read-only byte) returns a value identifying the software release number, coded as 256*(major-release)+(minor-release)

**E.G. current version 2.2 returns VER=514**

**SERL** and **SERH** are read-only integer parameters returning the device serial-number.
This is decoded as serno = 65536*SERH + SERL.
The VisualLink DCell/DSC protocols include a convenience 'Serial Number' property that automatically does this.

The nine parameters **USR1..9** are read/write real values: These can be freely used for non-volatile storage of customer information, such as OEM serial-numbers or calibration dates.

## Software Reset

The RST command forces a device reset, equivalent (as near as possible) to power cycling.
The reset action may take up to about a second to take effect, followed by the normal start-up pause (another 1-2 seconds).

The VisualLink protocols' 'RST' property imposes a 3 second application delay to avoid communications failure during a reset operation.

The command is mostly used when a device reboot is required to changes to certain parameters take effect, such as STN and BAUD.

# Chapter 11 Communication Protocols

This chapter gives details of communication protocols and bus connections.

There are effectively three 'layers' to DCell/DSC communications

1. Internally, all devices support the same 'command set', as described in *Chapter 12 Software Command Reference*.
2. Command-accesses are coded into actual byte sequences according to a communications protocol. Several different protocols are available.
3. Serial communications are carried out over a bus, which operates according to the usual RS232 or RS485 standards.

The bus standard and protocol type are fixed for a given device during production.
The communications baudrate and station number (the "bus address") are configured for each device by the ordinary control parameters STN and BAUD (see *Baud Rate and Station-Number Controls* in *Chapter 2 Getting Started with the Evaluation Kit*).

## Bus Standards

## Serial Data Format

Serial data formatting is the same for all the protocols and is fixed to

- one start-bit
- one stop-bit
- 8 data bits
- no parity

### *Communications Flow Control*

Bus flow control is managed as part of the protocol (managed differently by each).
No hardware or software flow control signals are to be used for any of the bus standards.

### *Communications Errors*

Serial data which does not conform to the expected format causes a 'serial framing error' to be registered, which sets the COMMSFAIL flag see *Chapter 8 Self-Diagnostics*.
What this actually means is that, following a starting (1 to 0) transition, a 'stop' (1) bit was not seen in the expected place. This is obviously baudrate dependent; the commonest cause being data transmitted at a lower baudrate than the unit was configured for.

### *Choice of Bus Formats*

Essentially, the RS232 bus is *only* suitable where the application will only ever need a single DCell/DSC device.
The only real advantage of RS232 output is that no data converter is required to connect the device to a PC.

The RS485 bus is the simplest and most flexible choice from the wiring point of view. It enables multi-drop operation and much longer cable lengths.
However, it usually requires a bus converter, which must be chosen to suit the equipment in use.

### *The RS232 Bus Standard*

RS232 has separate, dedicated transmit (Tx) and receive (RX) wires. Each wire is permanently driven by the sending end, with no transmit enable/disable controls, so RS232 is only suitable for one-to-one communications.

The connection is basically 3-wire, in that the Tx and RX signals are related to a common ground potential. For DCell/DSC connections, this ground is shared with the power return (VIN–).
(It is therefore especially important for RS232 devices to connect the earth ***at the device end***, to avoid noise from communications degrading the reading accuracy).

The RS232 standard specifies operation over line lengths of 15M (50 ft) or less, more or less independent of baudrate.
The drive capability of RS232 compatible hardware varies a great deal, but most exceed this comfortably, at least at the baudrates used by DCell/DSC devices.

## The RS485 Bus Standard

RS485 differs from RS232 in two important respects:

1. It uses differential signalling on pairs of signal wires. With small voltage detection thresholds and a large amount of common-mode rejection, this improves performance over longer distances.
2. It uses driver enable/disable controls to allow the same wires to be shared between several devices. This enables multidrop operation.

The RS485 standard is a two-wire bus. For good noise immunity, the two wires are normally twisted together and shielded.
There is no defined ground connection: All attached devices load the A and B lines so as to normally pull the grounds of floating devices to within a few volts of each other. The common-mode tolerance (effectively about +/–7 Volts) then allows communications without any further grounding provision.

An RS485 bus of any length also behaves like a transmission line, and so must be terminated to avoid reflections. This is done by connecting a 120 Ohm resistor between the A and B lines at each end of the bus.

**The RS485 standard is specified for operation up to 4000 feet (1200 metres) at any rate below 9600 baud, and proportionately less at higher rates.**
However, this assumes an ideal straight cable run with termination at both ends.
In practice, a bus with many devices along its length can fall short of this, especially if any connected devices are on long ‘stubs’ leading off the main bus. This may mean that the bus has to run at a slower speed than expected for reliable communications.

For practical details, see *RS485 Bus* in *Chapter 13 Installation*.

## Communications Protocols

All communications take place according to a specific protocol. All devices on a bus must use the same protocol to avoid confusion.
The protocol specifies the structure and meaning of data exchanged, and how access is controlled so as to avoid collisions.
The various DCell/DSC variants support a variety of different protocols, allowing integration with various other types of devices on a network.

### *Choosing a Protocol*

The current choices are

| | |
|---|---|
| ASCII | printable characters, easy to drive, direct output to printers/displays |
| MODBUS RTU | binary industry standard, inter-compatible with other devices such as PCBs |
| MANTRABUS-II | efficient binary protocol, checksums give better security than ASCII |

**NOTE:**
In a VisualLink communications application, a DCell/DSC is represented by an object with a property for each available command. As VisualLink supports all the DCell/DSC protocols, this is a convenient way of designing portable, protocol-independent applications.

## *Communications Software for the Different Protocols*

To access a DCell/DSC, you will need a communications application running on your PC or PLC, in addition to the appropriate hardware connections.
The simplest approach for initial experiments is to use the VisualLink evaluation application.
A purchased version of VisualLink can be used for more much more complex control and monitoring applications. VisualLink Lite can be used providing a 'window' into intended parameters and variables. This can be downloaded from our website http://www.mantracourt.co.uk/vllitre.htm

A great advantage of using VisualLink is that it is protocol-independent, so that the same application can be used with different types of DCell/DSC if required. This is possible because the command set itself is the same for all devices, regardless of the communications protocol used (see *Chapter 12 Software Command Reference* for the complete list).
Commands are generally referred to by their mnemonic names, as used in the ASCII protocol: VisualLink uses these same names for the instrument properties which access the commands, so this makes the property set of a DCell/DSC device (as a VisualLink 'instrument' object) the same for all product types.

**Other simple ways of using the different protocols are as follows**

1. The ASCII protocol only uses basic printable characters, and so can be accessed with a simple terminal program like Windows 'HyperTerminal'.
2. The MODBUS protocol can be accessed via a proprietary generic MODBUS application. For evaluation purposes, we suggest the free shareware demo of 'ModScan32' from Win-Tech software (visit www.win-tech.com).
3. MANTRABUS needs a purpose-designed program to handle full 8-bit data bytes and the proprietary checksum calculations, VisualLink and VisualLink Lite provides this.

## *Common Features of All Protocols*

The communications protocols are all of the master/slave type: A central 'host' device (normally a PC or PLC) acts as a bus master, in control of all communications.
Communications consist of the master transmitting **command messages** addressed to particular DCell/DSC 'slave' devices. The target slave may then transmit a 'response message' back to the master.
Because there is only one bus master, and slaves never initiate communications, the master is in control of all communications. This enables multidrop operation, i.e. a single master can control any number of slave devices at a time.
In practice, the master usually 'polls' the attached slaves, interrogating them in a fixed rotation.

**Command Types**
A single command sent to a device can instruct it to read from or write to an internal 'parameter' value, or to execute a 'Control Action'.
The device responds by returning data (for a parameter read) or a simple acknowledge (for write or action): Precise details depend on the protocol in use.

**Each command message contains the following information**

1. The intended slave address (or broadcast)
2. The command to access
3. The access type, one of read / write /execute
4. (for write accesses only) the write value

**The command response will then be one of the following three types**

1. An error indication
2. A simple acknowledge
3. A read data-value (implicit acknowledge)

The various protocols differ quite a lot in the available types of error and acknowledgements. The distinction between different access types is also protocol-dependent, in that some use a dummy read or write command for execute access.

**E.G. the following are example commands of the ASCII protocol –**
**"!001:BAUD?" is to read the value of the BAUD parameter**
**"!001:CLX3=3.74" is a write to the CLX3 parameter**
**"!001:SNAP" is to execute the SNAP action**
**N.B. all these are addressed to station number 1 only.**

**Slave Addressing and Broadcast**
Every slave device on the bus is identified by a unique address value, known variously as its 'station number', 'node id' etc. depending on the protocol.
Each command message contains an address specifying to which slave device it is directed. A slave will ignore all communications that are not addressed to it.
All the protocols also define a special address value (normally 0) which is reserved for broadcast commands, which all slaves act on.
No response is allowed to broadcast commands, as multiple replies would collide with one another.

**E.G. "!037:BAUD?" is an ASCII-protocol command asking station 37 for its BAUD value**
**"!000:SNAP" is an ASCII-protocol broadcast command telling all devices to sample their data**

**Parameters**
Parameters are the values used for all control settings and output values. They have an associated storage type (byte, integer or real-value), and may be either read/write, read-only or write-only. Output or 'result' values are mostly read-only.
Configurable parameters are held in non-volatile storage, so control settings are retained permanently even when power is removed.

**E.G. "SYS" is the main system output value: It is a read-only real (floating-point) value.**
**E.G. "BAUD" controls the serial communications rate: It is a read/write byte value.**

## *Data Type Conversions and Rounding*

**Type Conversion**
Depending on the protocol, an integer/byte parameter may need to be converted to or from a floating-point representation for reading or writing.
**The rules are as follows**
For reading, integer and byte parameters are treated as unsigned, and never read negative – i.e. read value ranges are 0 to 65535.0 and 0 to 255.0.
For writing, values written to integer and byte parameters are truncated to the nearest integer, and negative or positive values are acceptable
**NOTE:** Floating-point data is not always exact, even when reading integral data

**E.G. could get 3.999974 instead of 4**
**E.G. for a byte write 240, 240.1 and 239.66 are all the same value**

**Rounding**
Although rounding is applied when writing to integral values, data read from a device is ***not*** rounded off.

## The ASCII Protocol

The ASCII protocol uses only printable characters and carriage-return ('<CR>'), which allows a "dumb" terminal device or a PC programme like Hyper-Terminal to interrogate the device.Host Command Message Format
The basic command request structure is shown in the following example, illustrating the message "!001:SGAI=123.456<CR>", meaning write 123.456 to parameter SGAI on station 1:

| Framing Character | Station Address | Separator | Command Identifier | Access Code | Data | End of frame |
|---|---|---|---|---|---|---|
| ! | 001 | : | SGAI | = | -99.9999 | <CR> |

**An explanation of each field is as follows**

- **Framing character** A "!" character is used to signal the start of a new message. This character is only ever transmitted by the host, for framing purposes
- **Station Address** A 3-digit ASCII decimal number (0-999), determining which slave device(s) the command is intended for. All 3 digits must be sent
  Address 000 is reserved for broadcast addressing.
- **Separator** Always present. As no checksum or message verification technique is used, slaves use this as an extra check on message validity
- **Command Identifier** Up to 4 alpha-numeric characters, case insensitive, giving the name of the required command.
- **Access Code** Defines what sort of response is expected :–
  '**=**' means write data is expected to follow
  '**?**' means the host is expecting to receive read data back
  <CR> (i.e. nothing more before end) means the command is an action type (execute)
- **Data** An ASCII decimal-formatted number, can include 0..9, '**+**','–', '**.**' and spaces.
  This field can have a maximum length of 15 characters
- **End of frame** A <CR> is always present to indicate the end of the message

**Summary**

- A command message begins with '**!**', followed by a 3-digit station address, then a '**:**', and finishes with a <CR>.
- The '**!**' and <CR> *only* appear at the beginning and end of commands respectively
- From the '**:**' to the final <CR> is the command 'instruction' (of read, write or execute type)
- All instructions begin with an alphanumeric command identifier of up to 4 characters, and end with a non-alphanumeric (which may be the final <CR>).

**Slave Response Message Formats**

Each slave monitors the bus for command messages. It responds to any message that is addressed to it by sending a response message.

To be accepted by a slave device, a message must start with '**!**', the correct 3-digit slave address and '**:**', and end with <CR>, with no intervening extra '!'.
The slave will then *always* respond.

**There are three possible types of response: acknowledge (ACK), acknowledge with data (for a read), and not-acknowledge (NAK)**

ACK is a single <CR> character. This confirms an execute or write command.
ACK-with-data is a decimal number, followed by <CR>. This confirms a read and returns the data value.
NAK is an '?' <CR> sequence. The device rejected the command.

**There are several possible reasons for a NAK response**

Command identifier not recognised
Badly formatted command: Missing command identifier, unrecognised access-code character, or unexpected character somewhere else
Access attempted not supported by this command.

**NOTES:**

- From receipt of the host's terminating <CR> to a response from the device (if any) will be at most 50mS. After this, it can be assumed there is no response.
- There is no value-checking: A slave can *not* NAK a command because a write data value is 'unsuitable' in some way, only if write access itself is disallowed.

For the Ack-with-data (i.e. a successful read command), the returned value consists of printable ASCII characters finishing with a <CR>, formatted according to the DP and DPB settings as follows

**Write Command**
If the command is accepted by the device then a <CR> is transmitted. There is no error checking on the data received by the device.

**Example:**
**A command to set the BAUD parameter to 3 on station 1 could look like this –**
**!001:BAUD=3<CR>**
**assuming a device with STN=1 is present, it will respond with –**
**<CR>**

**Read Command**
Returns the requested value specified by the command.
The returned value is formatted according to the DP and DPB values: The response consists of a sign character (±), DPB decimal digits before a decimal point, DP digits after the point and a terminating <CR>:
The length of the response is thus fixed at DP+DPB+3 characters.

**Example:**
**A command to read the SOUT output could look like this –**
**!001:SOUT?<CR>**
**if the value=32.1, and format settings are DP=3 and DPB=5, the response string will be –**
**+00032.100<CR>**

**Action Command**
If the command is accepted by the device then a <CR> is transmitted.

**Example:**
**A command to reset device 14 would look like –**
**!014:RST<CR>**
**the response string will be just –**
**<CR>**

**Broadcast Commands**
If the station address in a command message is "000", this means a broadcast command:.
*All* slaves act as normal on a broadcast command, but do not respond.

**Example:**
**A command to all devices on the bus to sample their inputs would look like this –**
**!000:SNAP<CR>**
**- there is no response**

**Bad Commands**
If any command is not understood by the device then a "?" is transmitted followed by a <CR>.

**Example:**
**A unrecognised command, correctly addressed to station 173 –**
**!173:XYWR?<CR>**
**produces the general error response –**
**?<CR>**

**Continuous Output Stream**
When the STN is set to 999, the ASCII protocol also provides a 'continuous output' stream facility. The new SOUT value is transmitted on every result update – see *Chapter 10 Additional Software Features*.

## The MODBUS-RTU Protocol

MODBUS is a proprietary standard of Modicom Inc.
The full specification is quite complex, including a timeout-based framing strategy and polynomial CRC calculation, so full details are not given here.Refer to Modicom documentation. Knowledge of the MODBUS protocol is therefore assumed.

The MODBUS protocol is a partial implementation of the “RTU” (binary) form of the MODBUS standard, sufficient to allow DCell/DSC units to coexist on a serial bus with other MODBUS-compliant devices.

**NOTE:**
Third-party applications for MODBUS communications are readily available (e.g. ModScan from Win-Tech software, www.win-tech.com, who offer a free trial version).

**Modbus Messages**
All messages and responses are formatted and checksummed according to the normal RTU rules. The slave number is the device station number: Slave ‘0’ may also be used for broadcast writes.

The device command-set is mapped into the MODBUS ‘Output’ or ‘Holding Registers’ –
***Parameters*** (read or write) are mapped onto a pair of registers containing a 4-byte floating-point value
***Action commands*** are implemented as dummy parameters: Writing activates the command and reading returns a dummy value (with no action)

**Only two valid message function codes are supported**

| | | |
|---|---|---|
| Function 03 | ‘Read Holding Registers’ | - to read a register-pair |
| Function 16 | ‘Preset Multiple Registers’ | - to write a register-pair |

The start address must always be a valid parameter address, which is always an odd number (see below).

The ***only*** permitted data length is 2 registers, i.e. 4 bytes.
Registers ***can not*** be read or written singularly, in larger groups or using other addresses (i.e. even-numbered registers cannot be addressed directly).

**Parameter Addresses**
All MODBUS parameter addresses are derived from the equivalent MANTRABUS register number by a simple “times 2 plus 1” calculation.
For example, the ‘FLAG’ parameter is Mantrabus register#14, so this occupies MODBUS holding registers 29 and 30 (because $2 \times 14 + 1 = 29$).

See the command table in *Chapter 12 Software Command Reference* for the starting register numbers.

**Parameter Values**
All exchanged values (read and write parameters) are in the standard IEEE 4-byte floating-point format :

**The 32 bits of the number are distributed as follows**

| | | | |
|---|---|---|---|
| MSB | 31 | **Sign** bit , | 1=negate |
| | 30-22 | **Exponent**, | 7-bit excess-127 |
| LSB | 21-0 | **Mantissa**, | 23-bit fraction with implicit 1 |

The value of the number is thus
$\{ (-1)^{Sign} * 2^{(Exponent-127)} * 1.Mantissa \}$,

Note the ‘assumed 1’ before the mantissa. The exception to this is the special value 0.0, which is represented as 4 zeroes.
**E.G. a floating point number of -12345.678 is represented as – [hex] C6 40 E6 B6**
These 32 bits are mapped onto a register pair in the following way: The lower register holds bits 15-0 and the upper register bits 31-16.
These values are coded according to normal Modbus conventions, so the actual byte sequence in a read/write message is thus –
$R1_{hi}$, $R1_{lo}$, $R2_{hi}$, $R2_{lo}$
– which in terms of bits is (rather oddly!) –
15:8, 7:0, 31:24, 23:16

**Error codes**

**Only three Modbus error codes are supported, which are used as follows**

01 'Illegal Function' request for function other than 3 / 16
02 'Illegal Data Address' attempt to read an unsupported register address
03 'Illegal Data Value' attempt to write a read-only parameter, or message too long for buffer (valid messages have a known maximum length)

**Write Command Example**

Write value 1.23 (represents as hex 3F9D70A4) to registers 57,58 on slave#4
by sending

[hex] 04 station address
10 function code
00 38 start-reg hi,lo (NB h38=56 addresses register 57)
00 02 quantity = 2 registers
04 byte-count = 4
70 A4 first=lower register (17) value = hi,lo
3F 9D second=upper register (18) value = hi,lo
6B AB checksum = hi,lo

**A correct response would then be**

[hex] 04 station address
10 info copied from command ...
00 38
00 02
C0 50 checksum = hi,lo

**Read Command Example**

Read a value from registers 13,14 on slave#52
by sending –

[hex] 34 station address
03 function code
00 0C start-reg hi,lo (NB h14=20 addresses register 21)
00 02 quantity = 2 registers
01 AD checksum = hi,lo

**A correct response, with a value -55.2317 (hex C25CED51), would then be**

[hex] 34 station response
03 function
04 byte-count
ED 51 C2 5C data
AA D4 checksum = hi,lo

**Execute Command Example**

Execute command 101 on slave#17
by sending –

[hex] 11 station address
10 function code
00 64 start-addr h64=100 → register 101
00 02 quantity = 2 registers
04 byte-count
00 00 00 00 data (value irrelevant)
A0 B4 checksum = hi,lo

**The acknowledge response is then**

[hex] 11 station response
10 info copied from command ...
00 64
00 02
02 87 checksum = hi,lo

## The Mantrabus-II Protocol

Mantrabus-II is a 2 wire system where data is transmitted & received over a common pair of wires. For this reason the framing character must not be sent in a reply from the responding DCell. The protocol ensures this does not occur by splitting byte data into nibbles with the exception of the framing character & station number.

**Framing Character**

The framing character for Mantrabus-II is **FEh**, (this being different from the older Mantrabus-I **FFh** to allow the two protocols to be mixed on one bus).

**Checksum**

Both Host & Device send their EXOR checksum of all data sent, excluding framing character, in nibble format the MS nibble being first.

**E.G. EXOR Checksum of data is A7h. Checksum characters sent = 0Ah, 07h**

**Data Transfer**

Data is both sent and received as 4 bytes split into 8 nibbles following the station number, plus two nibbles of checksum.

**Floating-Point Data Format**

***All*** data sent & received in Mantrabus-II is in the IEEE floating point format, this being a 4 byte floating-point number. The byte containing the sign & exponent is sent first, with the LS byte of the mantissa being last.

**The memory layout of the 4-byte floating-point numbers is:**

| | | | |
|---|---|---|---|
| MSB | 31 | **Sign** bit , | 1=negate |
| | 30-22 | **Exponent**, | 7-bit excess-127 |
| LSB | 21-0 | **Mantissa**, | 23-bit fraction with implicit 1 |

The value of the number is thus

$\{ (-1)^{Sign} * 2^{(Exponent-127)} * 1.Mantissa \}$,

Note the 'assumed 1' before the mantissa. The exception to this is the special value 0.0, which is represented as 4 zeroes.

**E.G. a floating point number of -12345.678 is represented as – [hex] C6, 40, E6, B6**
**This is transmitted in nibble format as – [hex] 0C, 06, 04, 00, 0E, 06, 0B, 06.**

**End of Data Identifier**

As the protocol has no fixed length or length identifiers the ***last*** nibble of ***data*** sent to the device has its ***MS nibble set***. This indicates to the device that all data has been received & the next 2 bytes will be checksum data.

**ACK & NAK**

Mantrabus-II supports ACK & NAK, sending ACK (06h) at the end of a successful operation, and NAK (15h) for an unknown command or failed operation. These are always preceded by the station number (see examples below).

N.B. Mantrabus-II will ***not*** transmit a NAK for invalid checksum data, but instead remains silent. (This is different from the behaviour of the older Mantrabus-I).

**Writing to Variables**

Station number and command number are followed by 8 bytes of nibble data (the last having its MS bit set), followed by the 2 checksum nibbles.

**E.G. To write the value 100.0 (Floating point 100.0 = 42h, C8h, 00h, 00h) to variable** CGAI **(command number 40) at station 20, send the following**

**FEh, 14h, 28h, 04h, 02h, 0Ch, 08h, 00h, 00h, 00h, 80h, 0Bh, 0Eh**
**| | | [ DATA | ] [EXOR CS]**
**Frame char | Station number | Cmd number | MS bit of last Byte set**

**the response is then –**
**14h, 06h i.e. 'station number', 'ACK'.**

**Reading of Variables**
To read an individual variable, the command number is sent with the MS bit set (i.e. no data following).

**E.G. To read *CGAI* (command number 40) from station number 20, send the following –**

```
FEh,      14h,      A8h,          0Bh, 0Ch
|         |         [ |  ]        [EXOR CS]
Frame     Station   Cmd with
char      number    MS bit set
                    of last byte
```

**Assuming the value was -12345.678 (coded as C640E6B6h, representing -1 * $2^{13}$* 12345.678 / 8192), the response will be –**

```
14h,      0Ch, 06h, 04h, 00h, 0Eh, 06h, 0Bh, 06h,      01h, 0Fh
|         [                DATA                  ]    [EXOR CS]
Station
number
```

**Action Commands**
These are transmitted like read commands, i.e. no data sent. The response is as for write commands.

**E.G. To reset station 3 (command 100), send the following.–**

```
FEh,      03h,      E4h,                    0Eh, 07h
|         |         |                       [EXOR CS]
Frame     Station   Cmd with
char      number    MS bit set
```

**The response is then –**
**03h, 06h**

**Dump Commands**
Mantrabus-II supports commands 1 (data-dump) and 2 (read display), similar to the older Mantrabus-I.

Command 2 is treated exactly like a read command for the SYS value (command 10).

Command 1 returns a set of data outputs in the normal nibble format –

**Response to command 1**

| **Byte** | |
|---|---|
| 1 | Station number |
| 2-9 | SYS |
| 10-17 | TEMP |
| 18-25 | SRAW |
| 26-33 | CELL |
| 34-41 | FLAG |
| 42-49 | VER |
| 50-57 | SERL |
| 58-65 | SERH |
| 66-73 | STN |
| 74-81 | BAUD |
| 82-89 | RATE |
| 90-97 | DP |
| 98-105 | DPB |
| 106-113 | SGN |
| 114-121 | SOFS |
| 122-129 | SMIN |
| 130-137 | SMAX |
| 138-145 | SHST |
| 146-147 | XOR Checksum |

# Chapter 12 Software Command Reference

This chapter contains tables of all DCell/DSC commands, with brief details of each.

***Table 12.1 Commands in Access Order***

| ASCII name | description | datatype | access | MB reg | MD reg |
|---|---|---|---|---|---|
| SOUT | selected output | float | RO | 9 | 19 |
| SYS | main output | float | RO | 10 | 21 |
| TEMP | temperature | float | RO | 11 | 23 |
| SRAW | raw system output | float | RO | 12 | 25 |
| CELL | cell output | float | RO | 13 | 27 |
| FLAG | error flags | int | RW | 14 | 29 |
| CRAW | raw cell output | float | RO | 15 | 31 |
| ELEC | electrical output | float | RO | 16 | 33 |
| ECOM | unfiltered ELEC | float | RO | 17 | 35 |
| ERAW | raw reading | float | RO | 18 | 37 |
| EXC | raw excitation | float | RO | 19 | 39 |
| FILT | filter averaging | byte | RO | 20 | 41 |
| OFFS | offset channel flag | char | RO | 21 | 43 |
| SZ | system zero | float | RW | 22 | 45 |
| SYSN | snapshot result | float | RO | 23 | 47 |
| VER | software version | byte | RO | 30 | 61 |
| SERL | serial number low | int | RO | 31 | 63 |
| SERH | serial number high | int | RO | 32 | 65 |
| STN | station number | int | RW | 33 | 67 |
| BAUD | baud rate select | byte | RW | 34 | 69 |
| ICNT | output select | byte | RW | 35 | 71 |
| RATE | reading rate select | byte | RW | 36 | 73 |
| DP | digits after point | byte | RW | 37 | 75 |
| DPB | digits before point | byte | RW | 38 | 77 |
| CTN | tempco n-points | byte | RW | 110 | 221 |
| CT1..5 | tempco TEMPs | float | RW | 111..115 | 223..231 |
| CTG1..5 | tempco gain-adjust | float | RW | 116..120 | 233..241 |
| CTO1..5 | tempco offset-adjust | float | RW | 121..125 | 243..251 |
| CGAI | cell gain | float | RW | 40 | 81 |
| COFS | cell offset | float | RW | 41 | 83 |
| CMIN | cell range min | float | RW | 44 | 89 |
| CMAX | cell range max | float | RW | 45 | 91 |
| CLN | lin n-points | byte | RW | 50 | 101 |
| CLX1..7 | lin raw-values | float | RW | 51..57 | 103..115 |
| CLK1..7 | lin corrections | float | RW | 61..67 | 123..135 |
| SGAI | system gain | float | RW | 70 | 141 |
| SOFS | system offset | float | RW | 71 | 143 |
| SMIN | system range min | float | RW | 74 | 145 |
| SMAX | system range max | float | RW | 75 | 151 |
| USR1..9 | g.p. storage values | float | RW | 81..89 | 163..179 |
| EEAD | EEPROM address | int | RW | 90 | 181 |
| EEV | EEPROM value | byte | RW | 91 | 183 |
| LKK1..2 | new lock code data | int | WO | 92..93 | 185..187 |
| RST | reboot | – | X | 100 | 201 |
| EERD | read EEPROM | – | X | 101 | 203 |
| EEWR | write EEPROM | – | X | 102 | 205 |
| SNAP | take snapshot | – | X | 103 | 207 |
| ULCK | unlock | byte | W | 104 | 209 |
| LKD1..2 | lock random data | int | RO | 105..6 | 211..213 |
| LKWR | write new lock code | int | WO | 107 | 215 |

**Table Key**
".." - Denotes a range (e.g. CLK1..7 means "CLK1" to "CLK7")
Access RW/RO/WO/X = read-write / read-only / write-only / execute
Datatype float/int/byte/– = 4-byte real / 2-byte integer / 1-byte integer / none
MB reg = register number for MANTRABUS protocol
MD reg = start register address (always odd) for MODBUS protocol

**NOTES:**
All Modbus accesses are in register pairs, Modbus addresses are just (2*MANTRABUS)+1
ICNT output-index values correspond to the position in this table (SOUT=0, SYS=1, ...)

### *Table 12.2 Commands in Alphabetic Order*

| ASCII name | datatype | access | description | Mantrabus II Command | Modbus register |
|---|---|---|---|---|---|
| SOUT | float | RO | selected output | 9 | 19 |
| SYS | float | RO | main output | 10 | 21 |
| TEMP | float | RO | temperature | 11 | 23 |
| SRAW | float | RO | raw system output | 12 | 25 |
| CELL | float | RO | cell output | 13 | 27 |
| FLAG | int | RW | error flags | 14 | 29 |
| CRAW | float | RO | raw cell output | 15 | 31 |
| ELEC | float | RO | electrical output | 16 | 33 |
| ECOM | float | RO | unfiltered ELEC | 17 | 35 |
| ERAW | float | RO | raw reading | 18 | 37 |
| EXC | float | RO | raw excitation | 19 | 39 |
| FILT | byte | RO | filter averaging | 20 | 41 |
| OFFS | char | RO | offset channel flag | 21 | 43 |
| SZ | float | RW | system zero | 22 | 45 |
| SYSN | float | RO | snapshot result | 23 | 47 |
| VER | byte | RO | software version | 30 | 61 |
| SERL | int | RO | serial number low | 31 | 63 |
| SERH | int | RO | serial number high | 32 | 65 |
| STN | int | RW | station number | 33 | 67 |
| BAUD | byte | RW | baud rate select | 34 | 69 |
| ICNT | byte | RW | output select | 35 | 71 |
| RATE | byte | RW | reading rate select | 36 | 73 |
| DP | byte | RW | digits after point | 37 | 75 |
| DPB | byte | RW | digits before point | 38 | 77 |
| CTN | byte | RW | tempco n-points | 110 | 221 |
| CT1..5 | float | RW | tempco TEMPs | 111..115 | 223..231 |
| CTG1..5 | float | RW | tempco gain-adjust | 116..120 | 233..241 |
| CTO1..5 | float | RW | tempco offset-adjust | 121..125 | 243..251 |
| CGAI | float | RW | cell gain | 40 | 81 |
| COFS | float | RW | cell offset | 41 | 83 |
| CMIN | float | RW | cell range min | 44 | 89 |
| CMAX | float | RW | cell range max | 45 | 91 |
| CLN | byte | RW | lin n-points | 50 | 101 |
| CLX1..7 | float | RW | lin raw-values | 51..57 | 103..115 |
| CLK1..7 | float | RW | lin corrections | 61..67 | 123..135 |
| SGAI | float | RW | system gain | 70 | 141 |
| SOFS | float | RW | system offset | 71 | 143 |
| SMIN | float | RW | system range min | 74 | 145 |
| SMAX | float | RW | system range max | 75 | 151 |
| USR1..9 | float | RW | g.p. storage values | 81..89 | 163..179 |
| EEAD | int | RW | EEPROM address | 90 | 181 |
| EEV | byte | RW | EEPROM value | 91 | 183 |

| | | | | | |
|---|---|---|---|---|---|
| LKK1..2 | int | WO | new lock code data | 92..93 | 185..187 |
| RST | – | X | reboot | 100 | 201 |
| EERD | – | X | read EEPROM | 101 | 203 |
| EEWR | – | X | write EEPROM | 102 | 205 |
| SNAP | – | X | take snapshot | 103 | 207 |
| ULCK | byte | W | unlock | 104 | 209 |
| LKD1..2 | int | RO | lock random data | 105..6 | 211..213 |
| LKWR | int | WO | write new lock code | 107 | 215 |

# Chapter 13 Installation

This chapter gives detailed information on integrating DCell and DSC devices into a production system – including mounting, protection, adjustments, wiring and electrical requirements.

## Before Installation

Carefully remove the DCell/DSC device from its shipment box. Check that the device is complete and undamaged.
Check the Product Type Code – on the product label is that which you ordered.

The DCell/DSC can operated in any industrial environment providing the following limits are not exceeded

| | |
|---|---|
| Operating Temperature | -40 ºC to +80 ºC |
| Humidity | 95% non condensing |
| Storage temperature | -40 ºC to +80 ºC |

For precise details of environmental approvals, see Chapter 16 Specifications.

**It is advisable to follow the following installation practice where possible**

- Minimise vibration.
- Do not mount next to strong electrical or magnetic fields (transformers, power cables)
- Ensure easy access to the module
- Install electrical protection device as the unit is not internally fused.
- Always ensure the package is secure and protected

## Physical Mounting

**DCell** is normally sealed in the pocket of the load cell, which provides mechanical and moisture protection, and electrical screening.
The case is a flexible nylon “sheath”, which can be secured with a suitable flexible adhesive: An ordinary silicone sealant works well. Rigid glues or cements are not suitable.
Connecting wires are soldered directly to the pads on the top and bottom of the ‘puck’. Care must be taken to electrically insulate the connection pads from the surrounding metal.

**DSC** is normally installed in a protective enclosure, such as a metal box.
The pins can be plugged into standard (0.1” pitch) PCB header sockets, or soldered directly into a host board or to connecting wires.
It can be mounted either way up. Unwanted pins projecting on one side may be cropped off.
For extra vibration resistance, the three mounting holes provided can be used.
If not required, the protruding end with the single hole can be cut off to make the board smaller.

## Electrical Protection

No additional electrical screening is normally needed.
Electrostatic protection is sufficient for installation purposes only.
Devices are protected up to 25V against reverse-polarity supply, shorting of communications lines to power supply, and shorting of sensor inputs.
No over-current protection is provided in case of faults, so the supply arrangements should ensure adequate power limiting or fusing.

## Moisture Protection

Both DCell and DSC must only be operated in a dry environment, as moisture can dramatically degrade the measurement performance.

**DCell**

Will normally be sealed into a load cell pocket.
While flexible silicone sealant can be used to completely embed the unit, this is not adequate moisture protection in itself.

If required, the entire unit can be embedded in a potting compound: A two-part epoxy compound can be used, but bubbles and gaps must be avoided to prevent mechanical stresses which could break the device –compound can be injected into the outer sheath with a syringe.
The compound used must be specified for electrical use, and have sufficient thermal conductivity to cope with the heat given off (up to 1W on a 15V supply).

**DSC** no additional electrical screening is required, but moisture and/or mechanical protection is often required. Any simple box or enclosure can be used. If metal, the enclosure should be earthed to the CH connection (see *Communications Cabling and Grounding Requirements* below).

## Soldering Methods

Take care soldering cables to the pads. Use a temperature controlled soldering iron set to a maximum 330ºC, for no longer than 2 seconds per pad. Excessive heat or increased soldering time may result in damage to the PCB.

**NOTES:**

1. Solder with water-soluble flux should not be used (even low-residue), as this can leave a surface film which attracts atmospheric moisture, degrading measurement performance.

2. DCell units are ***especially*** easily damaged by poor soldering, due to the use of thin, flexible circuit boards: Overheating or applying any pressure to a pad can de solder components on the other side of the board, or cause the pad itself to become detached.

## Power Supply Requirements

The power supply needed is nominally 8.5 to 15V DC, but any possible droop or ripple must be included: The devices contain 'brown-out' detection, which may trigger if the supply voltage at the device drops below the 8.5 volts.

A single device consumes typically 35mA with a 350Ω gauge connected (except RS232-output units, which use about 10mA more).
An installation should therefore assume at least 50mA per unit, and allow for extra current being taken at power-on (though supply voltage can safely drop temporarily), and for possible voltage drops in long cables.

Any power-supply ripple should be below 30mV, and supply arrangements should provide current limiting for fault conditions (see *Electrical Protection,* above).

## Identifying Sensor-End Connections

### *Figure 13.1 DCell Input Connections*

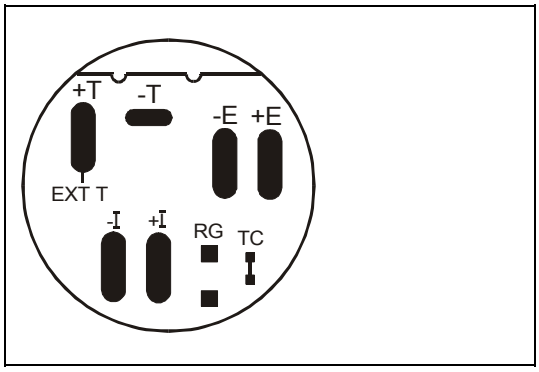
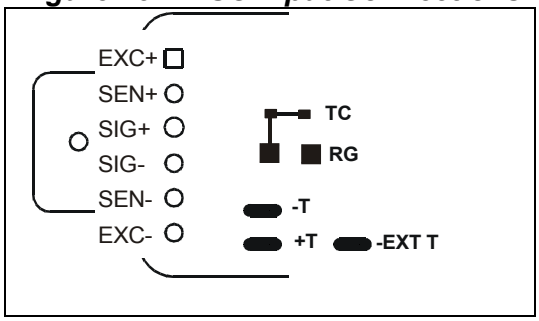


***Figure 13.2 DSC Input Connections***




**Strain gauge bridge connections are as follows**

- **EXC+/–** positive/negative excitation (supply)
- **SNS+/–** *DSC ONLY* positive/negative excitation sense
- **SIG+/–** positive/negative output signal

**Other Connections**

- Resistor **RG** and track-cut **TC** are used to adjust the mV/V sensitivity (see *Input Sensitivity Adjustment,* below).
- Connections **T+/–** and track-cut **EXTT** are used to connect an external temperature sensing device (see *Fitting an External Temperature Sensor* below).

## Identifying Bus-End Connections

***Figure 13.3 DCell Bus Connections***

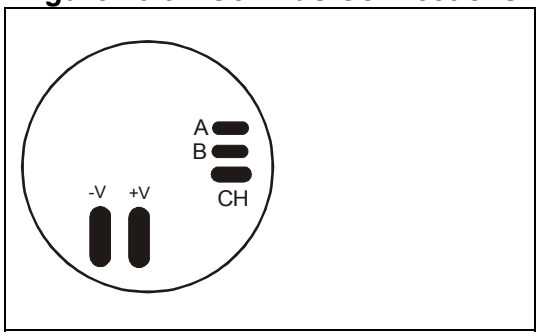
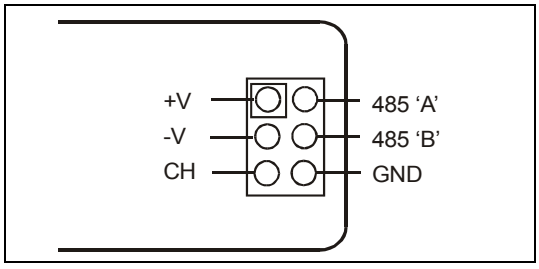
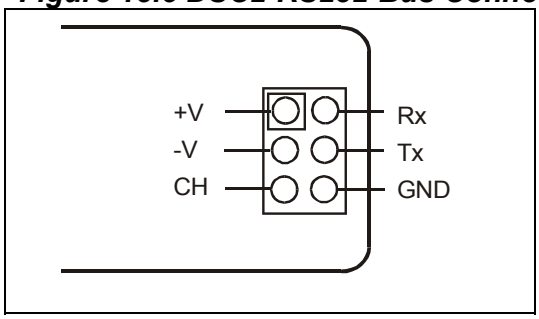



***Figure 13.4 DSC4-RS485 Versions-Bus Connections***



### *Figure 13.5 DSC2-RS232-Bus Connections*




- **VIN+/–** are the DC power-supply and return connections
- **A** and **B** are *RS485* communications connections
- **RX** and **Tx** are *RS232* communications connections
- **GND** is a communications ground connection (*not DCell*, use VIN–)
- **CH** is the chassis ground, used for shielding and earthing only

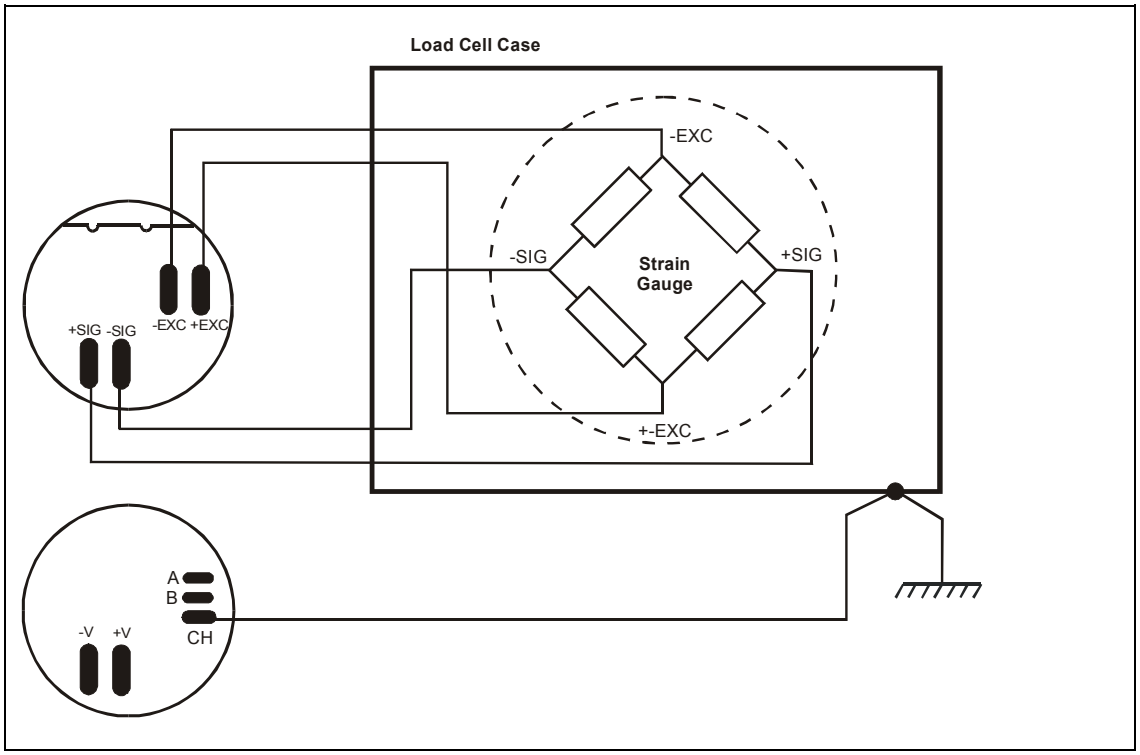
## Sensor Cabling and Grounding Requirements

**To achieve full performance specifications and conform to environmental approvals, it is important to follow the wiring procedures outlined in this section.**

## DCell Sensor Wiring

The following diagram illustrates how to wire up a puck to a strain gauge

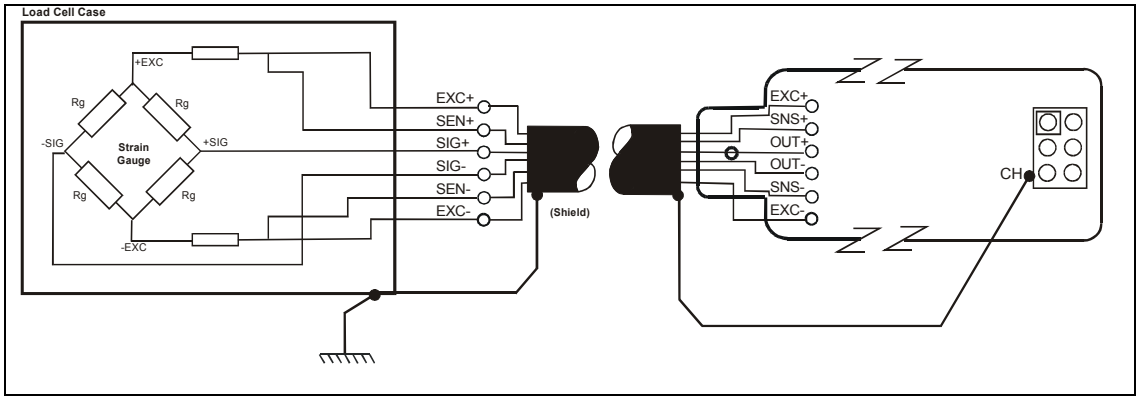
### *Figure 13.6 DCell Input Wiring Arrangement*



**Key Requirements**
All the load cell wires should be kept as short as feasible, at most 10cm.
The EXC+/– wires should be twisted together, also the SIG+/– pair, and the two pairs kept apart. It is also recommended to secure the wires from moving due to shock or vibration.
The CH pad must be grounded to the load cell body.
For specified performance, this should be less than 10cm of at least 16/0.2 solid wire.

**DSC Sensor Cabling**
The following diagram illustrates how to connect a DSC card to the load cell sensor

### *Figure 13.7 DSC Input Cabling Arrangement*



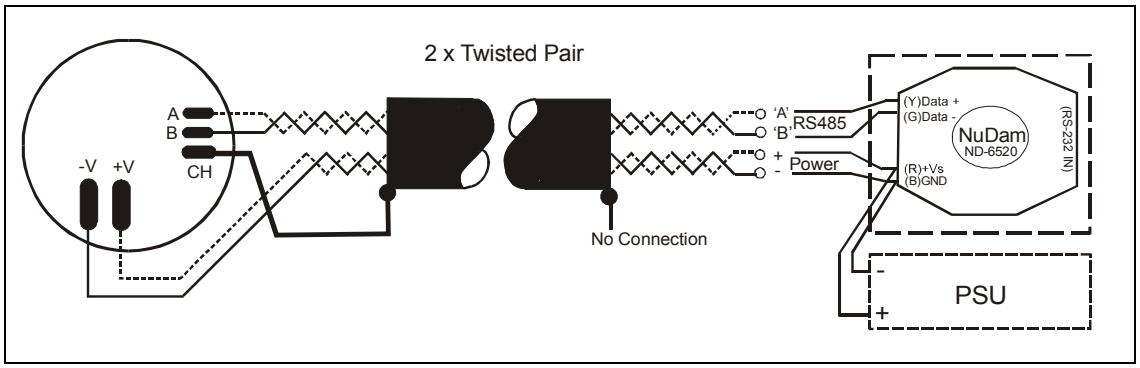

**Key Requirements**
The load cell cable should be a triple twisted pair with independent screens, with the three pairs used for the EXC, SNS and SIG signal-pairs.
The cable should be as short as possible, up to 5 meters for a low capacitance cable when connected to a 350 ohm bridge.
For specified performance, the load cell must be grounded to the CH pin using a separate conductor (***not*** via the load cell cable screen).
This should be a solid wire, at least 16/0.2, again as short as possible and at most 2m.
The cable screen must be grounded at the cell end, and ***not*** at the DSC end.

## Communications Cabling and Grounding Requirements

**To achieve full performance specifications and conform to environmental approvals, it is important to follow the wiring procedures outlined in this section.**

**DCell Power and Communications Wiring**
The following diagram illustrates how to connect a puck to the communications and power supply ("bus") cable.

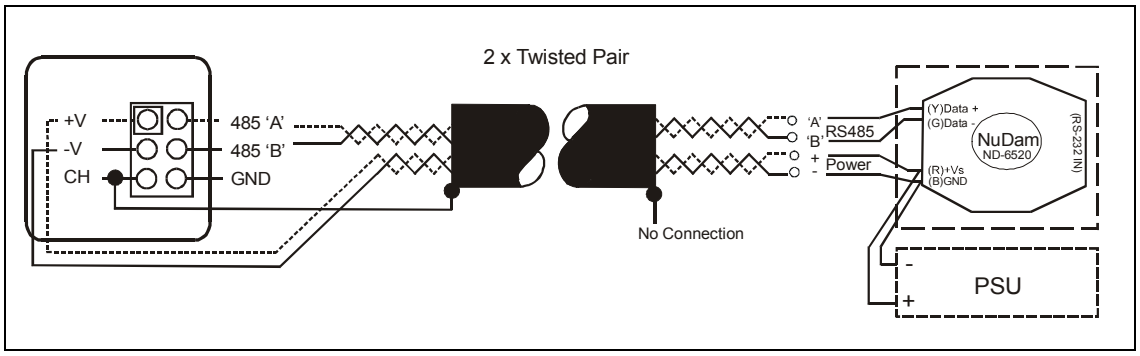
### *Figure 13.8 DCell Bus-End Arrangement*




**Key Requirements**
The cable must enter the load cell via an EMC cable gland which connects the cable screen to the load cell body.
The cable must be a twin twisted pair with independent screens, with one pair used for the communications and the other for the power wires.
The cable screen must be grounded to the CH pad of the DCell, and ***not*** at the host end.

**DSC4-RS485 Versions- Power and Communications Wiring**
The following diagram illustrates how to connect a DSC4 card to the communications and power supply ("bus") cable.

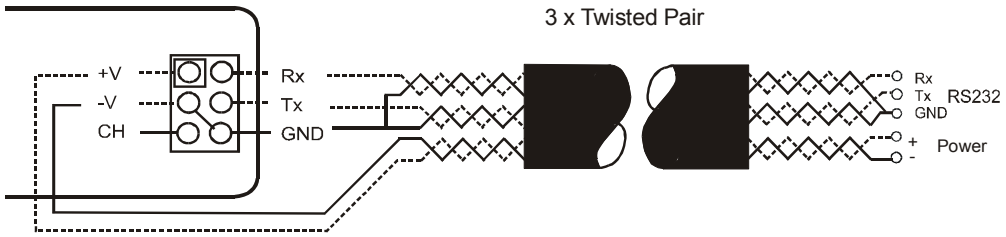
### *Figure 13.9 DSC4-RS458 Versions-Bus-End Arrangement*




## Key Requirements
The cable should be a twin twisted pair with independent screens, with one pair used for the communications and the other for the power wires.
The cable screen must be grounded to the CH pin at the DSC end, and ***not*** at the host end.
Any further metal housing should also be grounded to the DSC CH pin, and should ***not*** be connected to the bus cable screen (or the sensor cable).

**DSC2-RS232 Versions (RS232 output) Power and Communications Wiring**
The following diagram illustrates how to connect a DSC2 card to the communications and power supply ("bus") cable.

*Figure 13.10 DSC2-RS232 Versions Bus-End Arrangement*




**Key Requirements**
The cable should be a triple twisted pair with independent screens. Each of the Rx, Tx and VIN+ wires is paired with a VIN- wire.
The cable screen must be grounded to the CH pin at the DSC end, and ***not*** at the host end.
Any further metal housing should also be grounded to the DSC CH pin, and should ***not*** be connected to the bus cable screen (or the sensor cable).

## Suitable Cable Types

**DCell/DSC4-RS485 Versions-RS485 Bus Cable**
**Requires**

- 2 × twisted-pair with independent screens
- Characteristic impedance 50-150 ohms.
- Core to core and core to screen capacitance below 300pF/m

A suitable type is BICC Brand-Rex BE56723 (also equivalent to Belden type 8723).
In the UK, this is available from Farnell, part number 148-539.

**DSC Sensor Cable and DSC2-RS232 Versions RS232 Cable**
Both of these require 3 × twisted-pair version, otherwise similar to the above.
A suitable type is BICC Brand-Rex PD3003 (also equivalent to Belden type 8777).
In the UK, this is available from Farnell, part number 148-540.

## Warning: Special Problems with Portable Computers

Many portables use double insulated power supplies with no ground connection, and in this case a considerable voltage can appear on the port pins/chassis when the PC is powered off the mains. When such a system hosts a DCell/DSC bus, the whole arrangement may be connected to the mains ground only via the external power-supply or the ground connections to the data-converter or the DCell/DSC units.

Electrical damage due to the brief presence of high voltages can easily occur when such a system is connected up.

***Permanent harm can easily be done to the PC serial port, the data converter and/or DCell/DSC devices***.

This is not simply a theoretical risk. We have seen several converters, and some DCell devices, destroyed in this way.

Also note that this kind of damage may often not be immediately obvious, appearing as erratic operation rather than outright failure.

## To Avoid These Problems

1. Any portable should be separately grounded (e.g. via the converter supply) before connecting it to the mains supply, or to a DCell/DSC bus.

2. We always recommend the use of externally powered rather than port powered data converters (see below for details of suitable converters)

## RS232 Bus Layout

Essentially, the only limitation here is on the cable length.
As described in *The RS232 Bus Standard in Chapter 11 Communication*, this is supposedly up to **15m independent of baudrate**.

This is not a very realistic figure for typical modern hardware: For genuine RS232 compatible hardware, the length might be at least twice this at 9600 baud, and perhaps more at lower speeds.

However, some PCs have serial ports that are *not* truly RS232 hardware compatible, and may not have sufficient drive for specified operation.
In these cases, the port will probably still be usable with a "short enough" cable. It would be far safer, though, to replace the suspect hardware with something more suitable.

## RS485 Bus Layout

See also the general discussion of RS485 characteristics, *The RS485 Bus Standard* in *Chapter 11 Communication*.

Multiple devices are connected "in parallel" to the communications and power supply wire pairs, as shown in the following diagrams.

### *Figure 13.11 RS485 Bus Connections for Multiple DCells*

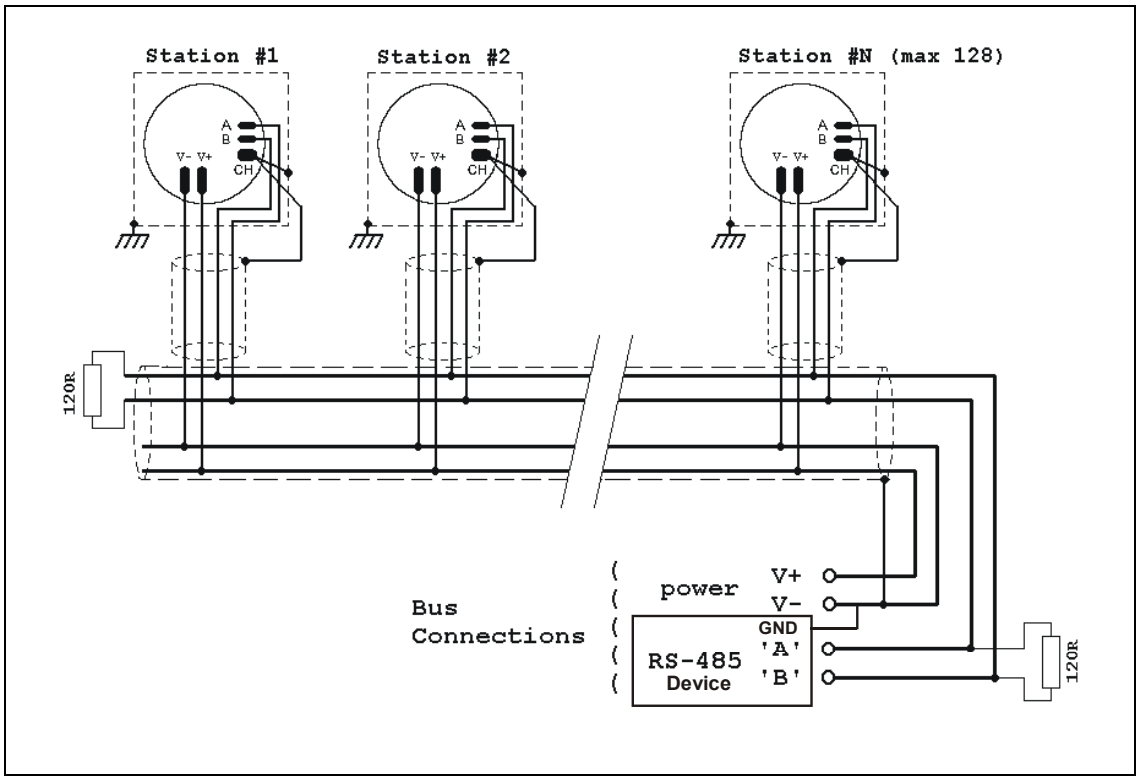
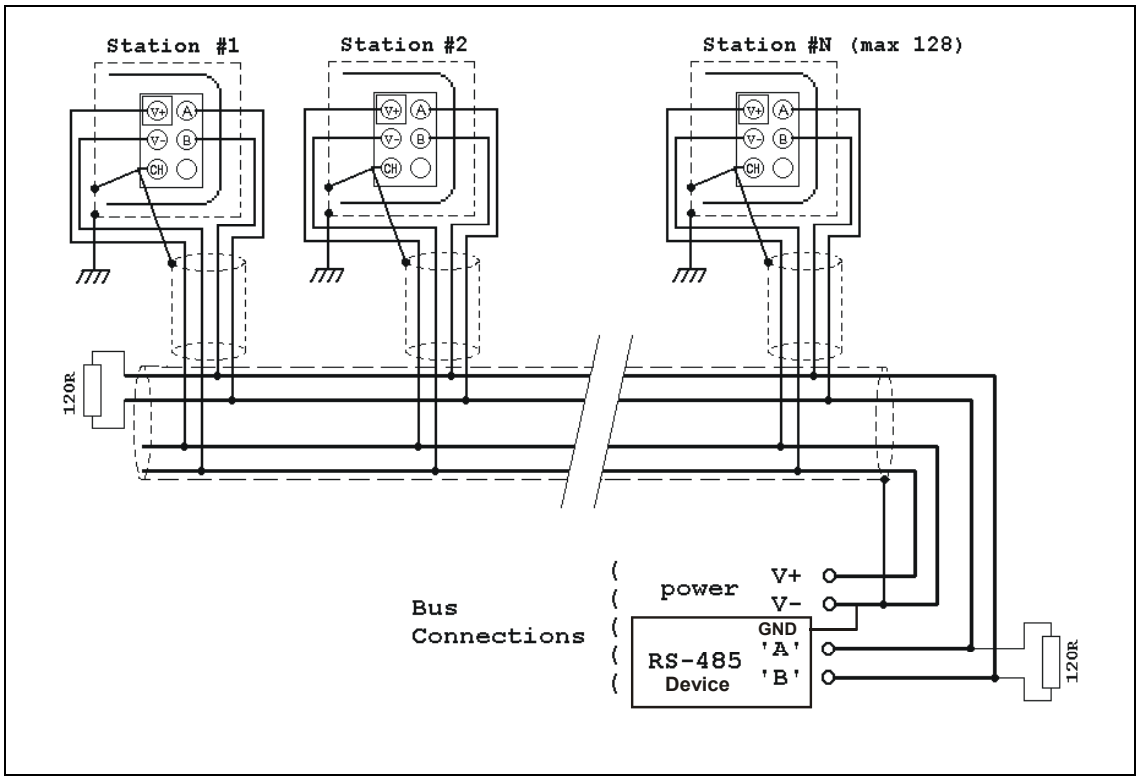


*Figure 13.12 RS485 Bus Connections for Multiple DSC4-RS485 Versions*




**Key Requirements**

- The main bus cable must be terminated at either end.
- Where the bus does not go directly to each attached device, each 'stub' cable connecting to the bus should have just one device on it.
- Stub branches should be kept as short as possible, less than 10m at most.
- The 'stub' cables should be grounded at each device, and the main cable grounded at the data-converter end. *None of these should connect.*
- Stubs are not terminated.

**Bus Layout and Termination**

The ideal bus is a single length of cable, terminated at either end. Each end connects to a communicating device, while other devices are connected as near as possible directly to the main bus as it passes them (i.e. not on long side-branches).
The bus must be terminated at both ends to avoid reflections. This is done by connecting a 120 Ohm resistor between the A and B lines.

**Loading**

In addition to reflections, each connected device places a load on the bus. According to the RS485 standard, a maximum of 32 'standard-load' devices can be simultaneously connected. The DCell/DSC devices are each one quarter standard load, so ***a maximum of 128 devices may be connected at once to a single length of bus***.
It is possible to increase this with bus repeaters, but the bi-directional nature of RS485 means it is usually simpler to add extra communications ports at the host, driving completely separate busses.

**Grounding**

The RS485 standard does not specify any particular ground connection.
If two external devices are both externally grounded (i.e. not floating), the grounds must be within the bus common-mode range (±7 volts) to connect safely and communicate. Beyond this, an isolating converter may be needed.

**2 Wire & 4 Wire Connections**
DCell/DSC devices only use 2 wire RS485 connections.
A 2 wire RS485 connection uses the same pair for transmit and receive, so the master has no special rights to the bus, and only the rules of the protocol used prevent two devices transmitting at once.

## RS232 & RS485 Bus Converters

Typical DCell/DSC applications use a PC or PLC host, connecting via an RS232 port. This then requires an RS232 to RS485 bus converter to communicate with the bus.
The following features are of importance-

**2 Wire RS485 Connection**
**Baudrate Support**
Must support at least the rates to be used
**Driver-enable Control**
Can be ***either*** hardware control-line driven (normally via DTR), ***or*** automatic (host transmitting enables driver).
**Hardware Control** requires special host software (especially under Windows), and the serial port hardware must be suitable. VisualLink provides support for this, on most PCs.
**For Automatic Control**, the converter detects host transmissions: It usually needs to be set to the correct baud rate, and may only support certain specific baudrates.
**Power Options**
Can be self-powered (i.e. from the RS232 port, maybe RTS, DTR or Tx data-pin), or require an external power-supply.
Although a self powered converter seems attractive, it will usually have a limited drive capability: It will thus only drive a reasonably short bus with a few devices on it.

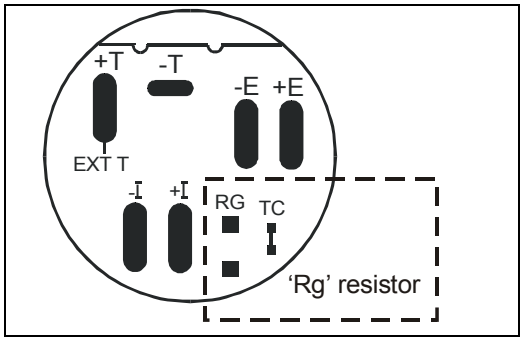
The RS232 & RS485 bus converter Mantracourt supplies as standard is an externally powered device, supporting all the DCell/DSC data rates.
It features completely automatic data-rate detection (no setup switches), and automatic enable-control switching with opto isolation.

GND PSU must be connected to GND of the RS485 device.

## Input Sensitivity Adjustment

If your strain gauge does not deliver a 2.5mV/V full scale output, you may want to adjust the sensitivity of the electronics (hardware) and/or the software gain controls.
If you want to test with an input of *more* than 2.5mV/V, you will have to adjust the hardware sensitivity to avoid saturating the input. If it is less, you can correct in software alone, but increasing sensitivity will generally improve accuracy.
To adjust the mV/V of a DCell or DSC, an extra resistor 'Rg' is fitted across the pads RG, as shown above, in

### *Figure 13.13 Identifying the DCell 'Rg' Resistor*




**Identifying Sensor End Connections**
The link across TC can be cut to disconnect the internal 100R gain resistor: This is needed for lowering the sensitivity.

The resistor is 0805 size surface mount chip.
A 0.1%, 15ppm resistor must be used to maintain performance.

**Reducing Sensitivity**
To accommodate a maximum sensor output *larger* than 2.5mV/V, it is necessary to reduce the electrical sensitivity of the input circuitry.

To decrease sensitivity, the link **TC** is cut, and the value of the resistor fitted, in kΩ, should be –

$R_g$ = (required mV/V) x 40

- where 'S' is the required sensitivity in mV/V.

**Increasing Sensitivity**
When the full scale output is *smaller* than 2.5 mV/V, it may be desired to increase sensitivity. However, it is often possible instead to compensate partly or entirely in software, by increasing a software gain control (CGAI or SGAI – see *Main Reading Calculations* in *Chapter 5 Readings Processing and Calibration*).

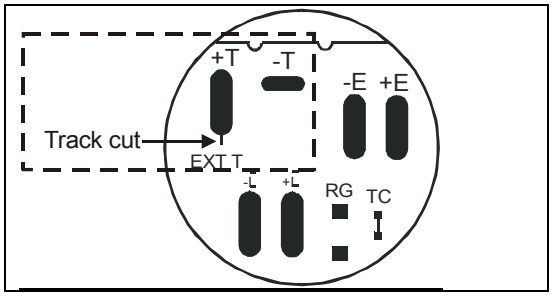
To *increase* sensitivity, **TC** is left in place, so that the fitted Rg appears in parallel (this gives better temperature stability). It's value should then be

$$R_g = \frac{1}{\frac{0.025}{\text{(required mV/V)}} - 0.01}$$

**Two effects should be noted**
1. The purpose of increasing sensitivity is to reduce reading *noise*, which governs the effective resolution. Using software gain alone obviously gives reduced performance.
2. The sensitivity should, however, not be set greater than typically 1mV/V: Beyond this, input noise usually dominates and no extra benefit can be achieved.

## Fitting an External Temperature Sensor
An external temperature sensing diode can be fitted in place of the one on-board by cutting the link **EXTT**, and wiring the sensor anode/cathode to pads **+T** and **–T**

### *Figure 13.14 Identifying the DCell T+ and T- Track Cut*




Contact your supplier for suitable devices and further information.

The sensor itself is a small surface-mount device, approximately 0603 resistor size. It will need to be secured in good thermal contact with the sensor, typically with adhesive.

See *Temperature Measurement Accuracy* in *Chapter 6 Temperature Compensation* for more details of when this might be useful.

# Chapter 14 Troubleshooting

This chapter gives a quick guide to problem solving for DCell/DSC devices.
Bear in mind that the quickest way to pin down problems is to usually replace items with 'known good' alternatives. This also applies to cables, power supplies, devices etc.

## No Communications

The majority of problems involve a failure to communicate, as there are a fair number of optional settings that must be set the same at both ends of the link.
For this reason, any communications application should always check command responses, and flag a problem when there these responses are not activated.

Possible problems can be categorised according to where in the 'chain' of communication the problem may be. The typical chain runs as follows,

- PC software (port connection, baudrate, station number, protocol)
- PC serial port (working)
- Serial lead to converter
- RS232/RS485 data converter (power supply, PC port, wiring, transmit enable, baudrate setting)
- Bus wiring
- Device (wiring, station number, baudrate, protocol, working)

A quick checklist elaborates on these requirements, in the case that you are using the VisualLink evaluation software (other software may have different requirements at the PC end): Check that –

**PC End**

1. PC software settings: right serial port, baudrate and protocol
   (standard data setup is 1 start bit+ 1 stop bit, no flow control)
2. PC serial port okay: check with other serial device, e.g. wire 2 PCs together with Hyperterminal running on both

**(RS232 Versions) RS232 Evaluation Cable**

3. Evaluation Kit cable: on right serial port; end *without* power supply wires connects to PC

**(RS485 Versions) Cable + Data Converter**

4. Cable to data converter: right serial port, standard 9 pin straight-through cable (***not*** 'null modem' type, with Tx/Rx crossed).
5. Power connected to data converter
6. Data converter baudrate setting ***(if not Evaluation Kit type)***: DIL switches for this, may be essential for automatic enable-switching
7. Data converter enable switching ***(if not Evaluation Kit type)***: If done by control line, check the serial port connects this correctly. If by transmission detect, how is baudrate set?

**Evaluation Board or Device**

8. Power reaches the device
9. ***(RS485)*** connections the right way round.
   with comms idle, 'B' should be a few tenths of a volt higher than 'A'
10. Device settings: correct station-number, baudrate
    (How do you know these are correct? A substitute device is very useful here!)
11. Device protocol: double-check product label
12. Device running okay:
    devices take 20-30mA supply current without sensor attached, 30-50 with
    device should produce 4-5V AC across sensor end EXC connections

## Bad Readings

The cause can be either hardware or software related.

**Software**

1. Check the ELEC reading first and ensure it is correct. This figure is the RAW input and is not affected by the user configurable calibration settings.
2. If ELEC looks correct, check the calibration settings step by step.
   Consider resetting all the calibration controls to default values – see *Calibration Parameters Summary and Defaults* in *Chapter 5 Readings Processing and Calibration*. This should make SOUT=ELEC at all times.

**Hardware**

3. Excitation problems – should be obvious from the flags value.
   If the input *appears* (to device) to be shorted, the device only applies excitation briefly every 10secs or so. This can look like a disconnected sensor (results read near zero all the time).
   Check excitation voltage (~4V AC)
   With DSC cards, broken/missing excitation sense connections will cause similar problems.
4. Genuine hardware problems usual show up as **total** failure – i.e. no reading = always unchanging, usually near zero, sometimes always full-scale.
   Check wiring, take voltage level readings and again if possible use a known good device and set up.
5. Check the sensor is connected properly, and has some resistance across excitation wires, and around 350 Ohms across output wires (when disconnected from device).
6. Check for damaged DCell/DSC device by replacement

## Unexpected Warning Flags

Remember that all ordinary warning flags (i.e. ***not*** EXCSC, OLDVAL) must be explicitly reset –they do not clear themselves when a problem is resolved.
If a flag cannot be cleared, the cause must be persistent –i.e. it keeps happening again. This can be immediate, regular (every few seconds) or irregular (occasional).
See *Chapter 6 Temperature Compensation Self Diagnosis* for precise details of how the individual warnings operate.

**Bear in mind the following possible problems**

1. REBOOT or COMMSFAIL may indicate intermittent connections.
2. Where ECOMUR/OR or EXCUR/EXCOR are triggered, suspect input wiring.
3. Various 'range' errors (CRAWUR/OR, SRAWUR/OR) are also likely to be set if the excitation was interrupted (EXCUR/OR).
4. For DSC cards, EXCUR/OR may also be due to bad excitation-sense connections.
5. For range errors, check the associated limit parameters (CMIN/MAX, SMIN/MAX).
6. Problems are likely if any calibration MIN/MAX parameters are set the wrong side of zero (i.e. MIN>0 or MAX<0).

## Problems with bus baud rate

There are a number of special difficulties to be considered here

- Systems with very long cabling may not work with higher baud rates
- When using an RS232/RS485 converter, it may be necessary to change some converter settings when changing baud rate. Some baud rates may not be supported by some converters.
- Always remember you need to reboot devices before the change takes effect
- A bus with two devices talking at different baud rates may become unusable.
  So always change ***all at once*** by powering down or issuing a broadcast reset command (RST).

Difficult problems can always be overcome, if necessary, by isolating individual devices and trying the different baud rates in turn. This deals with all possible problems, as long as your hardware can deliver all the supported baud rates.

## Recovering a "lost" DCell/DSC

For baud rate problems, see previous section.

You can try all 3 protocols if confused (but this should be indicated by the product code on the product label, if it has not been removed).

If a station number is unknown, it can be reset via *broadcast* command, as long as the device is the only one on the bus.

If two devices on the same bus end up set to the same ‘bus address’, they can no longer be commanded separately:
The only solution is to remove one device from the bus and connect it exclusively to a PC to change its STN.

Always remember that a reboot (power-off or RST command) is needed to change settings!

# Chapter 15 The VisualLink Application

**Introduction**
An evaluation version of VisualLink, the SCADA package from Mantracourt, is available with special designs constructed to communicate with the supplied DCell and DSC instruments. This will enable you to test and program the instrument.

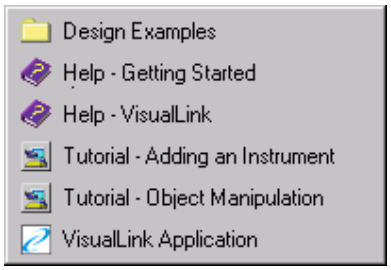
**Limitations**
The evaluation version of VisualLink allows you to do everything that can be achieved with the full version except that a pop-up notice will appear every minute. The example designs mentioned in this manual are special designs that will **not** display this notice. If you save one of these designs in your version of VisualLink you will no longer be able to run it without the notice being displayed. (Save it to another filename if you want to retain the original designs.)

**Hardware Requirements**
Recommended minimum PC specification:
- Pentium 200 with Windows 95 or better
- Mouse
- 64 MB RAM
- CD ROM
- 45MB hard disk space

A lower specified PC will still run the software but speed will be reduced.

**Installing the Software**
Uninstall any previous versions of VisualLink before proceeding.
Placing the CD in the CD ROM drive should start Auto Install.
If not, run SETUP.EXE from the CD drive by selecting '*Run'* from the '*Start Menu*' and typing *D:SETUP* where *D* is the drive letter of your CD ROM drive.
The software will install into a folder called *VisualLink* inside the *Program Files* folder. You may change this destination if required. After installation you may be asked to restart the computer. This should be done before proceeding with communications.

Once installation is complete a new item will be placed in the '*Programs'* section of your '*Start Menu'* called *VisualLink*. This will contain the following items, see below:




Will open the design example folder

The on-line help for VisualLink

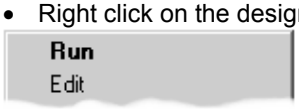
A brief animated tutorial about adding an instrument

A brief animated tutorial about manipulating objects

The VisualLink application

**Running Designs**
Click on the '*Design Examples'* item within the VisualLink program group to open the examples folder. Within this, the file 'DSC & DCell evaluation is the DCell/DSC evaluation software.

**You can select and run DSC & DCell evaluation by using any one of the following methods**
- Double click on the design file. This will launch VisualLink and load and run the design with no access to the editor.
- Right click on the design file and select **Run** from the pop-up menu. This will perform the same




action as above.

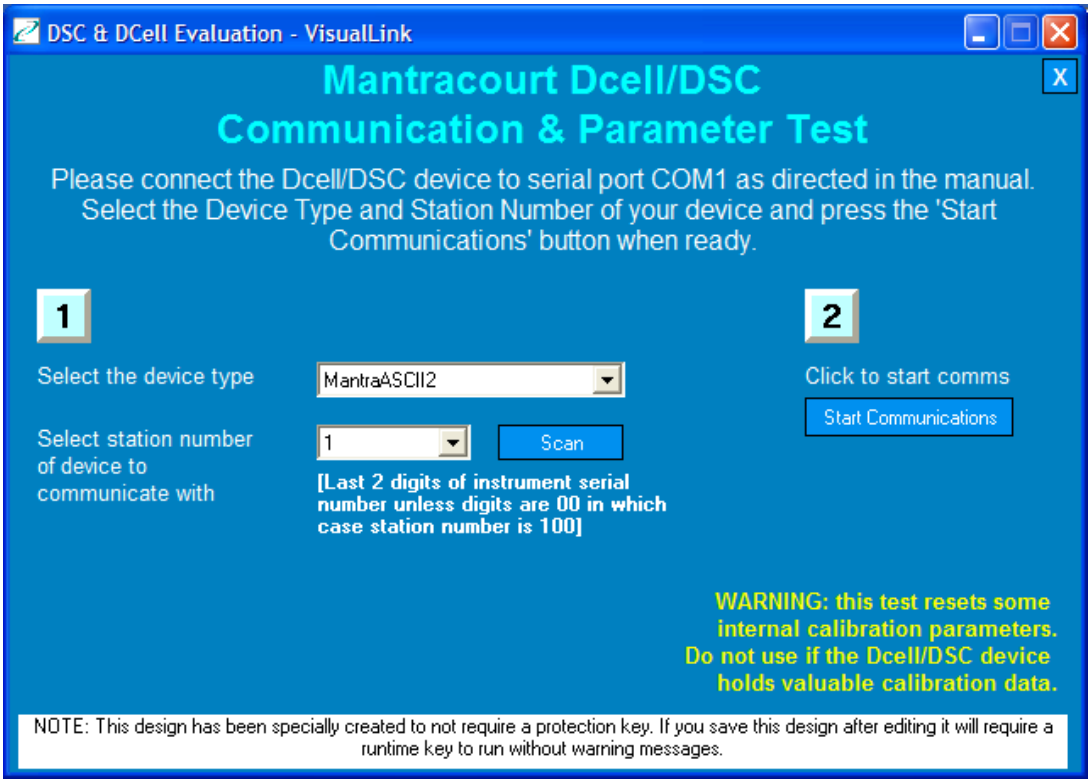
- Right click on the design file and select **Edit** from the pop-up menu. This will launch VisualLink

and load the design in edit mode. You can then experiment with editing the design. To run press ▶ on the Toolbar.

- Launch VisualLink and open the design file using the Open button on the Tool Window. To run press ▶ button on the Toolbar.

**DCell/DSC Evaluation Application Notes**
This is the first screen you will see in the Evaluation

### *Figure 15.1 Communication & Parameter Test Page*




Select the instrument type from the drop down menu & the station number.

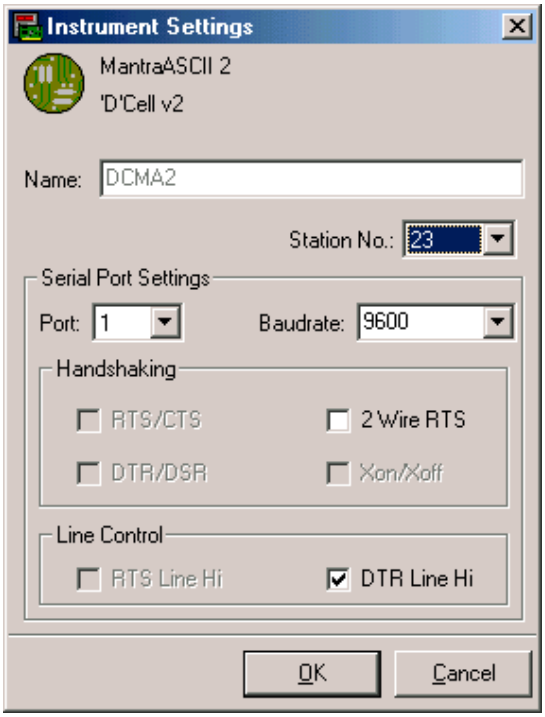
If you have changed the serial number and lost track of it's setting, click on the "Scan" button and VisualLink will search from 1 to 253 producing a list of found devices. This may take some time!

When you are happy with your selection and the instrument is connected to COM1, click the 'Start Communications' button. This will now attempt communications with the instrument – see *Device Communications* in *Chapter 3 Basic Setup and Calibration*.

The layout has been designed to use the COM1 serial port, at 9600 baud.

If these settings are not appropriate, you can change them via the following pop-up window that appears when you hit the 'Change Comms Settings' button –

### *Figure 15.3 Instrument Settings Window*




You should never need to change any of the other settings.
When finished, hit 'OK' to confirm and close the window.

If message boxes indicate that instruments cannot reside on the same serial ports just press OK to accept.

Note that the next time you use the design, the communications will revert to the defaults (COM1 and 9600 baud).

**Evaluation Version Limitation**
Without a full licence, VisualLink will display a pop-up message about registration once a minute while in 'run' mode.
The designs provided have been specially processed to remove this restriction, but in any device you save to disk this limitation will reappear.

# Chapter 16 Specifications

### *Table 16.1 Technical Specifications*

'D'Cell is nominally set for 2.5mV/V sensitivity.

| Parameter | Min | Typical | Max | Units |
|---|---|---|---|---|
| Strain Gauge Excitation System | | 4 Wire | | |
| Strain Gauge Excitation Voltage | - | 4.5 | 5 | VAC |
| Strain Gauge Drive Capability | 320 | - | 1200 * | Ohms |
| Strain Gauge Sensitivity | 1 | 2.5 | 20 ** | mV/V |
| Internal Resolution | | 24 | | Bits |
| Output Resolution - 1Hz readings | | 19 *(17)* | | Bits |
| 10Hz readings | | 17 *(16)* | | Bits |
| 100Hz readings | | 15 *(14)* | | Bits |
| Signal Filter | | Dynamic recursive type | | |
| Non Linearity before Linearization | | 0.0005 | 0.001 | %FSD |
| Offset Temperature coefficient , before compensation | | 0.0005 | 0.001 | %C |
| Gain Temperature coefficient, before compensation | | 0.001 *(0.002)* | 0.003 *(0.005)* | %C |
| Offset long term drift | | 0.0005 | 0.001 | % month |
| Gain long term drift | | 0.002 | 0.005 | % month |
| Common mode imbalance offset | | 0.001 | | %FSD |
| Common mode imbalance gain | | 0.001 | | %FSD |
| Temperature resolution | | 0.1 | | C |
| Temperature accuracy | | 1 | | C |
| Power Supply voltage | 8.5 | 10 | 14 | Vdc, 60mA max |
| Power Supply current | | 35 | 60 | mA |
| Power Supply ripple | | | 30 | mVAC |
| Output Data terminal | | RS485 | | |
| Data transmission rate | 2,400 | 9,600 | 38,400 | bps |
| Output cable length (speed dependant) | | | 1000 | m |
| Operating temperature range | -40 | | +85 | C |
| Storage temperature | -40 | | +85 | C |
| Humidity | 0 | | 95 | %RH |
| Housing | | Black nylon sleeve | | |
| PCB Dimensions | | Diameter 20.7mm, Height 12mm | | |

Notes: *Italics figures in (brackets) refer to the low cost version*

* For reporting of excitation open circuit. Able to drive up to 10K Ohms, but will continually report excitation open circuit.

** By setting of the gain resistor.

### *Table 16.2 DSC Technical Specifications*

DSC Conditioner is nominally set for 2.5mV/V sensitivity.

| Parameter | Min | Typical | Max | Units |
|---|---|---|---|---|
| Strain Gauge Excitation System | | 6 Wire | | |
| Strain Gauge Excitation Voltage | | 4.5 | 5 | VAC |
| Strain Gauge Drive Capability | 320 | | 1200 * | Ohms |
| Strain Gauge Cable length | **see note Power & Communications | | | m |
| Strain Gauge Sensitivity | 1 | 2.5 | 20 *** | mV/V |
| Internal Resolution | | 24 | | Bits |
| Output Resolution - 1Hz readings | | 19 *(17)* | | Bits |
| 10Hz readings | | 17 *(16)* | | Bits |
| 100Hz readings | | 15 *(14)* | | Bits |
| Signal Filter | | Dynamic recursive | | |
| Non Linearity before Linearization | | 0.0005 | 0.001 | %FSD |
| Offset Temperature coefficient, before compensation | | 0.0005 | 0.001 | %C |
| Gain Temperature coefficient, before compensation | | 0.001 *(0.002)* | 0.003 *(0.005)* | %C |
| Offset long term drift | | 0.0005 | 0.001 | % month |
| Gain long term drift | | 0.002 | 0.005 | % month |
| Common mode imbalance offset | | 0.001 | | %FSD |
| Common mode imbalance gain | | 0.001 | | %FSD |
| Temperature resolution | | 0.1 | | C |
| Temperature accuracy | | 1 | | C |
| Power Supply voltage | 8.5 | 10 | 14 | Vdc, 60mA max |
| Power Supply current | | 35 | 60 | mA |
| Power Supply ripple | | | 30 | mVAC |
| Output Data terminal | | RS232/485 | | |
| Data transmission rate | | | | |
| Output cable length (speed dependant) | | | 1000 | m |
| Operating temperature range | -40 | | +85 | C |
| Storage temperature | -40 | | +85 | C |
| Humidity | 0 | | 95 | %RH |
| Housing | | PCB with metal shield case if required | | |
| Connectors - Input | | 6 pins | | |
| Connectors - Output | | 6 pins including dc power | | |
| Environmental protection | | IP40 | | |
| PCB Dimensions L x W x H | | 87.4mm x 20mm x 8.5mm | | |

Notes: *Italics figures in (brackets) refer to the low cost version*

* For reporting of excitation open circuit. Able to drive up to 10K Ohms, but will continually report excitation open circuit.

** Power & Communications Connections: For a 350R Bridge, a cable length of 5 meters will give no more than 80ppm gain shift.

*** By setting of the gain resistor.

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*In the interests of continued product development, Mantracourt Electronics Limited reserves the right to alter product specifications without prior notice.*

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