



## Features

- Precision closed loop inertial sensor with optical position feedback and fluid damping
- Dual axis measurement range  $\pm 5^\circ$  to  $\pm 45^\circ$
- High resolution measurement ( $<0.0002^\circ$ )
- High accuracy over full measurement range ( $<0.003^\circ$ )
- Low temperature drift ( $<0.005^\circ$  over  $0-40^\circ\text{C}$ )
- ModBus TCP/IP Ethernet interface.
- Supports assignable fixed IP, or DHCP
- Fully isolated power supplies, 19-30V dc input
- Rigid machined Anodised Aluminium housing (IP67)
- Two IP67 M8 connectors for network and power



## Description

The DCL inclinometer utilises a precision closed loop inertial inclinometer sensor to give extremely accurate and high resolution angle measurement. It has fully isolated power supplies, with a ModBus over TCP/IP Ethernet interface. The anodised Aluminium housing is sealed to IP67 making it suitable for use in the most demanding environments. A pair of industry standard IP67 sealed M8 connectors connect the network and power supply separately. Communication is via a ModBus TCP/IP protocol on a 10Mbit Ethernet physical

layer. The sensors have extremely low inherent temperature drift, and this is improved further by individual temperature compensation. The sensing element is the latest generation closed loop type with liquid damping and optical position feedback. This enables very high accuracy measurement with very low temperature drift, excellent long term stability, and excellent performance in applications with high vibration. These devices are manufactured and calibrated in our UK factory to guarantee performance to the stated specification.

## General Specifications

Parameter	Value	Unit	Notes
<b>Supply Voltage</b>	19-30	V dc	Supply is fully isolated internally, and protected against transients. Internal power modules are CE certified.
<b>Operating Current</b>	90	mA	Maximum value at 24V supply
<b>Operating Temperature</b>	-20 to 70	$^\circ\text{C}$	Maximum operating temperature range.
<b>Storage Temperature</b>	-40 to 80	$^\circ\text{C}$	Maximum storage temperature range.
<b>Weight</b>	1025	g	
<b>Sealing</b>	IP67		Seal rating applies to housing and connectors.
<b>Frequency Response</b>	1	Hz	This is the low pass cutoff frequency of the second order digital filter. This is adjustable between 0.125 and 7Hz via the ModBus control commands
<b>Physical Interface</b>	Ethernet 10baseT		Utilises 10Mbit Ethernet interface (compatible with 10/100/1000Mbit devices)
<b>Data Protocol</b>	ModBus over TCP/IP		For more details see section 'Control Command Set' and <a href="http://www.modbus.org">http://www.modbus.org</a>
<b>Default IP address</b>	192.168.16.130 :502	g	Shipping default static IP address. Can be changed with custom ModBus command. Port used for ModBus is port 502



## Performance Specifications

Parameter	DCL2-05	DCL2-20	DCL2-45	Unit
Measuring range	±5	±20	±45	°
Zero Bias Error	±0.0025	±0.0025	±0.0025	°
Accuracy (@20°C)	±0.0025	±0.005	±0.01	°
<b>Temperature Errors</b>				
Zero Drift	±0.0002	±0.0002	±0.0002	°/°C
Sensitivity Drift	±0.002	±0.002	±0.002	%/°C
Accuracy 0 to 40°C	±0.006	±0.01	±0.02	°
Long Term Stability	±0.01	±0.01	±0.01	°
Resolution (@1Hz BW)	0.0002	0.0005	0.001	°

Parameter	Notes
Measuring range	Defines the calibrated measurement range.
Zero Bias Error	This is the <b>maximum</b> angle from the device when it is placed on a perfectly level surface. The zero bias error can be removed from measurement errors either by mechanical adjustment, or as a fixed offset value after installation.
Accuracy (@20°C)	This is the <b>maximum</b> error between the measured and displayed value at any point in the measurement range when the device is at room temperature (20°C).
<b>Temperature Errors</b>	Temperature change can cause a drift of the zero position and the sensitivity of the inclinometer. These parameters are defined below:
Zero Drift	If the device is mounted to a level surface in the zero position, this value is the <b>maximum</b> drift of the output angle per °C change in temperature.
Sensitivity Drift	When the temperature changes there is a change in sensitivity of the sensor's output. The error this causes in the measurement is calculated from the formula: $E_{sd} = SD \times \Delta T \times \theta$ Where: $E_{sd}$ is the change in output (in degrees) due to sensitivity temperature change $SD$ is the sensitivity drift specification from the above table $\Delta T$ is the change in temperature in °C $\theta$ is the current angle of the inclinometer axis in question in degrees.
Accuracy 0 to 40°C (with compensation)	This is the <b>maximum</b> error between the measured and displayed value at any point in the measurement range at any temperature over the calibrated temperature range (devices are individually characterised and compensated for optimum temperature performance).
Long Term Stability	Stability depends on environment (temperature, shock, vibration and power supply). This figure is based on being powered continuously in an ideal environment.
Resolution (@1Hz bandwidth)	Resolution is the smallest measurable change in output.



Connector and Connection Details

There are two M8 connection sockets on the inclinometer sensor. The power cable is 3 pin, the Ethernet network connector is 4 pin. The mating connector details are shown below. All mating connectors, cables and accessories are available from us on request.

Ethernet Connections

M8 Pin No.	Wire Colours	Function	Ethernet RJ45 Pin
1	Brown	Tx D1+	1
2	White	Tx D1-	2
3	Blue	Rx D2+	3
4	Black	Rx D2-	6

Power Connections

M8 Pin No.	Wire Colours	Function
1	Brown	+ve Supply (24Vdc)
2	Blue	Not Connected
3	Black	0v Supply

Binder M8 Straight Connector



3 pin : EL-CON-99-3402-00-03  
4 pin : EL-CON-99-3376-00-04

Binder M8 Moulded 2m PUR Cable



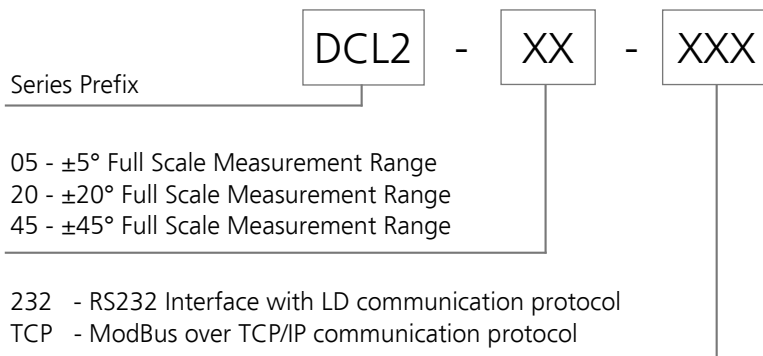
3 pin : EL-CAB-79-3406-52-03  
4 pin : EL-CAB-79-3382-52-04

Binder M8 Moulded 5m PUR Cable



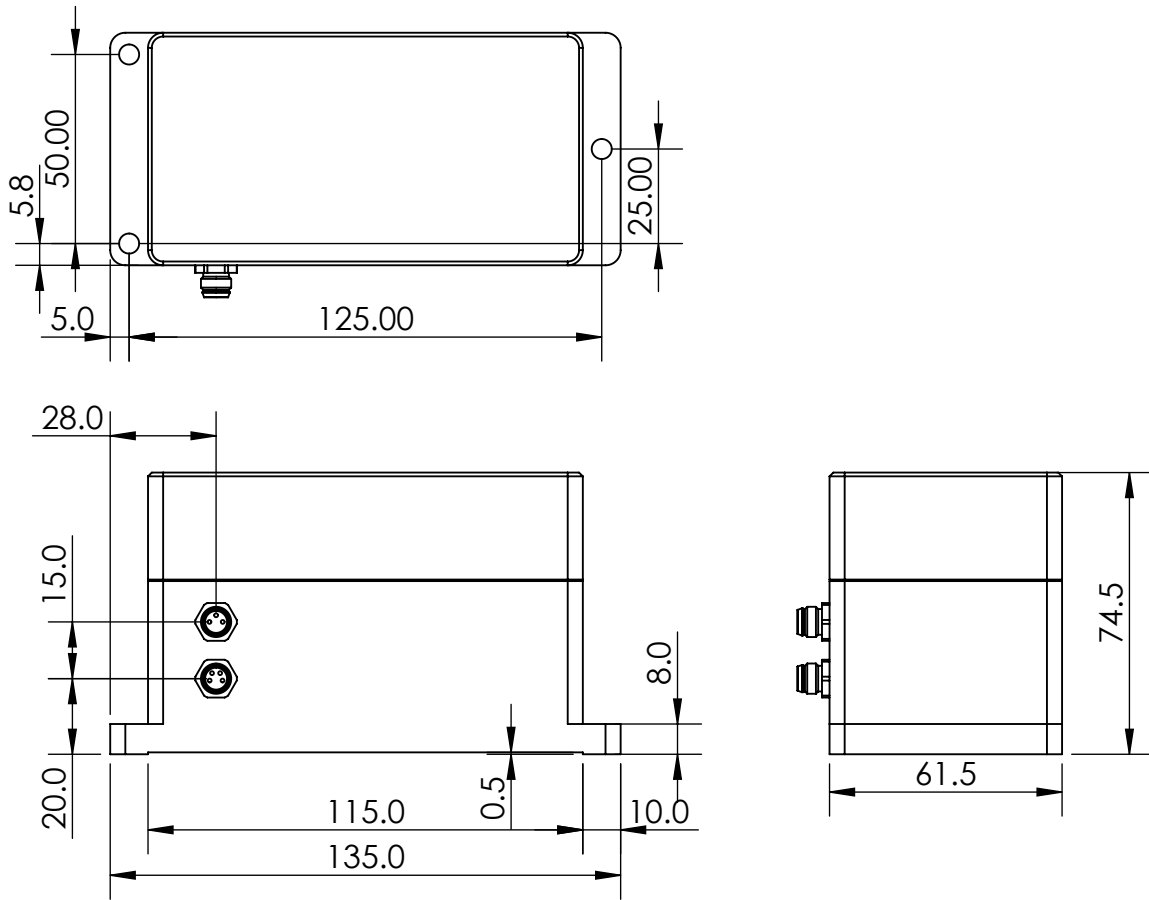
3 pin : EL-CAB-79-3406-55-03  
4 pin : EL-CAB-79-3382-55-04

Part Numbering



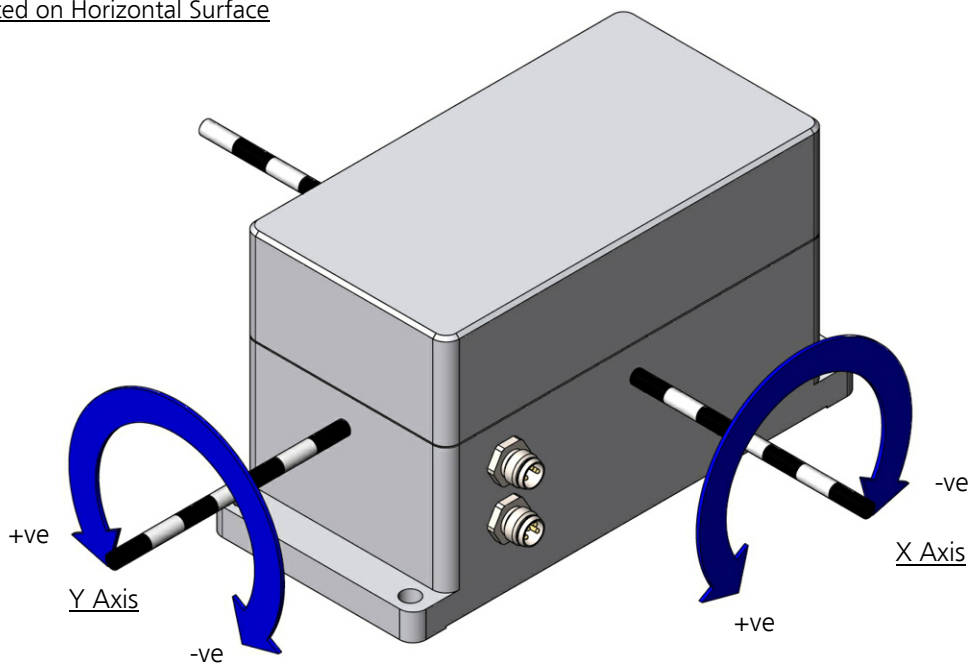


Housing Drawing



Axis Direction and Mounting Orientation

Mounted on Horizontal Surface



**Control Command Set**

Data is transmitted and received over a 10baseT Ethernet interface using the ModBus TCP/IP protocol. The following section provides some basic information about the communication between the host PC or PLC and the SMCL. The full ModBus on TCP/IP specification can be obtained from:

[http://www.modbus.org/docs/Modbus\\_Messaging\\_Implementation\\_Guide\\_V1\\_0b.pdf](http://www.modbus.org/docs/Modbus_Messaging_Implementation_Guide_V1_0b.pdf)

The device (the inclinometer) acts as a server. The PC or PLC acts as the client. The client needs to open a valid TCP/IP socket with the device before communication can take place. The default IP address of the devices at the time of shipping is 192.168.16.130. This can be changed using the software application provided. It can also be changed to DHCP mode where the device will negotiate a dynamic IP address with the DHCP server. To switch to DHCP mode the IP address is changed to 0.0.0.0.

The byte order for all 16-bit values is Big Endian (most significant byte first).

Read and write access to the device is done using ModBus Function Code 3 (read holding registers) and ModBus Function Code 6 (write single register) commands. These two function codes provide the basic functionality needed by most users.

Parameter	Address	ModBus Register Address	Description	Read/Write
Sensor X Angle	0x00	40,001	Address 0x00 returns the upper 16 bits of the closed loop sensor X axis angle. This combines with address 0x01 to form a 32 bit signed integer value equal to the measured angle x 10,000.	Read Only
	0x01	40,002		
Sensor Y Angle	0x02	40,003	Address 0x02 returns the upper 16 bits of the closed loop sensor Y axis angle. This combines with address 0x03 to form a 32 bit signed integer value equal to the measured angle x 10,000.	Read Only
	0x03	40,004		
Sensor Temperature	0x06	40,007	Returns a 16 bit signed integer value equal to the temperature of the sensor in degrees C x 100	Read Only
Filter Index	0x09	40,010	Returns a 16 bit integer value between 0 and 8 which relates to a table of filter responses from 0.125 to 7Hz	Read / Write
X Angle Offset	0x12	40,019	Address 0x12 returns the upper 16 bits of the X axis angle offset. This combines with address 0x13 to form a 32 bit signed integer value equal to the offset angle x 10,000. The offset is used for zeroing the output after installation.	Read / Write
	0x13	40,020		
Y Angle Offset	0x14	40,021	Address 0x14 returns the upper 16 bits of the Y axis angle offset. This combines with address 0x15 to form a 32 bit signed integer value equal to the offset angle x 10,000. The offset is used for zeroing the output after installation.	Read / Write
	0x15	40,022		



## Frequency Response Filter Indexes

The frequency response of the inclinometer output can be changed to any of the response times shown in the table by setting the filter index value in the relevant ModBus parameter (0x09).

The closed loop sensors has a built in mechanical and electronic filter with a 15Hz cutoff frequency. The outputs are then passed through an analogue second order 5Hz Butterworth anti-aliasing filter. Finally there is a digital 2nd order Butterworth low pass filter implemented in a FIR algorithm. It is this digital filter which is controlled by this parameter. For structural monitoring applications it is normal to use the slowest filter response (0.125Hz) as it is not likely there will be sudden changes in output, and the slow response will give the best measurement resolution.

Filter Index	Frequency Response (Hz)	Damping Time (ms)
0	0.125	8000
1	0.25	4000
2	0.5	2000
3	1	1000
4	2	500
5	3	333
6	4	250
7	5	200
8	7	143

## Reading a Holding Register

The data from the device is stored in holding registers as detailed on page 4. Function code 0x03 is used to read these registers. Below is the command and response message format, including the error response in the even there is an error.

	Byte Data	No Of Bytes	Description
Command	0x03	1	Function code for read register
	0x0000	2	Starting register (0x0000 is X axis angle)
	0x0002	2	Number of registers to read
Response	0x03	1	Function code for read register
	0x04	1	Byte count (2 x number of registers)
	0x0000	2	First and second register data : 0x0000705D = 28765 (decimal) = 2.8765°
	0x705D	2	

## Writing to a Holding Register

Data can be written to some registers, such as the registers that store the filter indexes for each axis frequency response. Function code 0x06 is used to write these registers as detailed below.

	Byte Data	No Of Bytes	Description
Command	0x06	1	Function code for write register
	0x0009	2	Register to write (0x0009 is filter coefficient)
	0x0001	2	Data to write (16 bit). 0x0001 = 0.125Hz
Response (same as command)	0x06	1	Function code for write register
	0x0009	2	Register to write (0x0009 is filter index)
	0x0001	2	Data to write (16 bit). 0x0003 = 1Hz



**Examples of Reading Angle**

Example 1: Read the X axis angle

Command

```
function code
| starting reg. to read (0x0000)
| | number of reg. to read (0x0002)
| | |
03 00 00 00 02
```

Response (positive angle)

```
function code
| byte count
| | angle (0x0000705d = 28765 decimal (2.8765 degrees)
| | |
03 04 00 00 70 5d
```

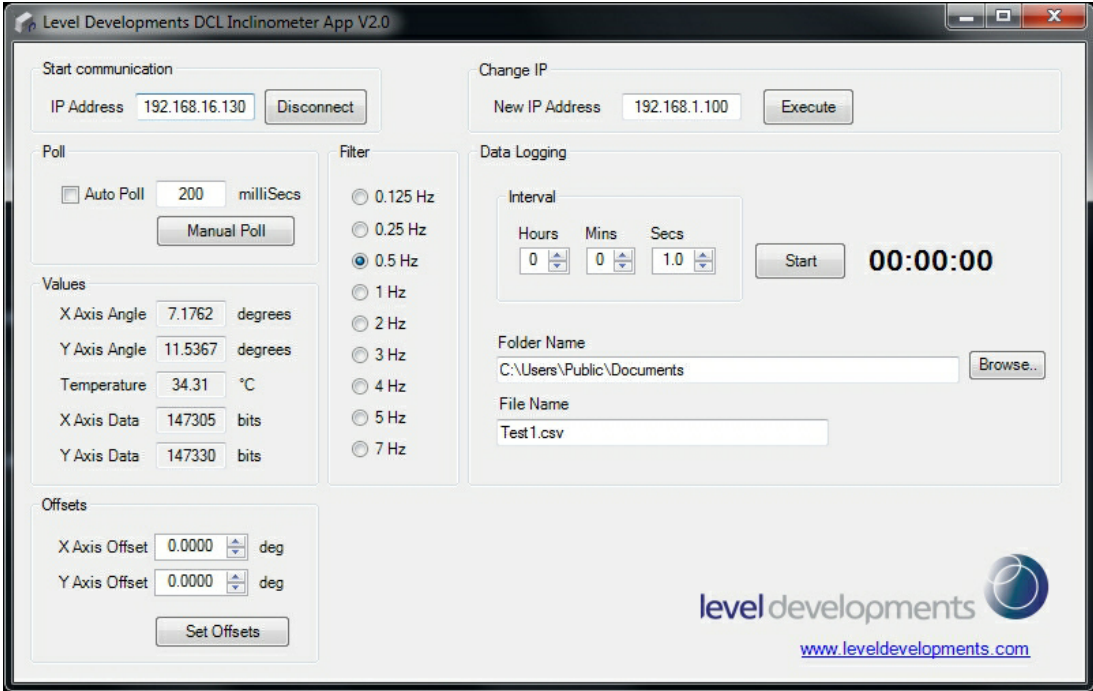
Response (negative angle)

```
function code
| byte count
| | angle (0xffffa54d = -23219 decimal (-2.3219 degrees)
| | |
03 04 ff ff a5 4d
```



## Configuration Application

The device ships with a small Windows based application for displaying and logging the inclinometer data, and for network configuration. Using this application it is possible to read data from the device, log it to a csv file, change the static IP address, switch to DHCP mode, and change the filter coefficients and the zero offset values.



The device is shipped by default with the static IP address of 192.168.16.130. It should only be connected to a network where this address is free or reserved. After connection to the network and powering up the device, click the 'Connect' button to open the TCP/IP socket to the device. The angle and temperature values can then be retrieved by clicking the 'Poll' button. Checking the 'Auto Poll' check box will poll the device at regular intervals as specified in the relevant text box.

To change the IP address, type the new IP address into the 'Change IP' text box and click 'Execute'. This will close the current connection, change the device's IP address. The device can then be re-connected using the new IP address.



Please take care to record any change in the IP address. If the modified IP address is not recorded then it will not be possible to communicate with the device and it will need to be returned to the factory for resetting.

To change to DHCP mode, change the IP address to 0.0.0.0. Internally the device will switch to DHCP mode, and attempt to connect to a DHCP server. If it is successful the DHCP server will assign an IP address to the device. In order to connect to it at this stage check the DHCP server to see which IP address it has assigned, and then connect as before using this IP address.

The current filter setting is read from the device when the connection is made, and shown in the corresponding radio button. Clicking a different value will update the setting in the device accordingly. This setting is saved after power down.

The X and Y offset values are also read from the device when the connection is made (default value is 0.0). To change the offset values type the desired offset values into the relevant boxes and click the 'Set Offsets' button. These offsets can be used to zero out any initial zero point errors after installation. The values are stored after power down.