User Manual

LucidControl AI4

4 Channel Analog Input USB Module

1 Introduction

This document describes the functionality of the LucidControl AI4 USB module measuring 4 analog voltages or currents controllable via Universal Serial Bus.

A basic description of the complete LucidControl product family can be found in the document *LucidControl User Manual*.

This document concentrates on the specific topics of the analog input module which is described here with all its details. In order to set up the module in a fast way please see the

LucidControl AI4 One Sheet Manual

which provides all information necessary to start working with the module out of the box without reading lots of documentation.

2 Setup and Installation

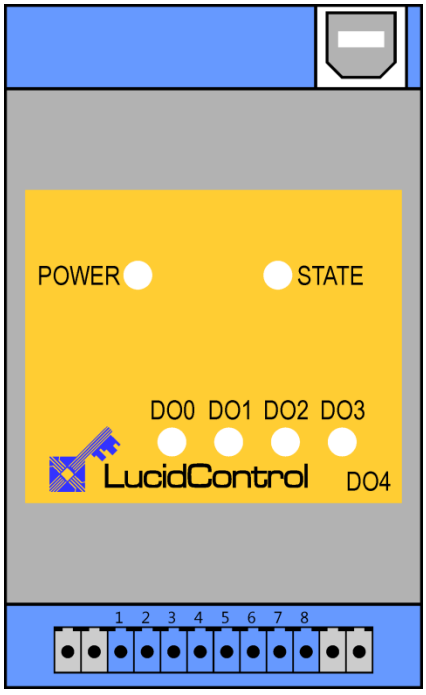

Fig. 1 Analog Input Module

Fig. 1 shows the sketch of the Analog Input AI4 module with 4 analog voltage or current inputs (AI0 ~ AI3).

All LucidControl modules have two connectors, one USB connector and an IO- Connector which makes it easy to setup them.

While the upper USB connector is used for interconnection with the computer, the lower IO-Connector is used for inputs and outputs.

The IO-Connector provides 8 terminals in total - two for each input.

The intended use of the analog input module is the acquisition of analog signal lines. The module must only be used for the intended use.

For the analog input module it is explicitly stated that no potential of more than 30V must be applied to any connector of the module. The modules must only be used within the specified conditions.

2.1 Configurations

Module Type	Type Number	Input Voltage Range	
		V_{Min}, I_{Min}	V_{Max} / I_{Max}
Positive Voltage Inputs	LCTR-AI4-5	0 V	5 V
	LCTR-AI4-10	0 V	10 V
	LCTR-AI4-24	0 V	24 V
Symmetrical Voltage Inputs	LCTR-AI4-5S	-5 V	5 V
	LCTR-AI4-10S	-10 V	10 V
	LCTR-AI4-24S	-24 V	24 V
Current Inputs	LCTR-AI4-20M0	0 mA	20 mA

Tab. 1 Input Voltage Range

Tab. 1 shows the available module types with their input range.

The analog input module can measure voltages in the range $V_{Min} \leq V_{IN} \leq V_{Max}$ and $I_{Min} \leq I_{IN} \leq I_{Max}$

2.2 Interface and Interconnection

2.2.1 USB Connection

LucidControl USB modules are connected to the computer by using a standard USB cable which must not extend a length of 5 m. They are “bus powered” which means that the host computer supplies the module with power.

LucidControl AI4 module is rated with a maximum current of 40 mA.

Note:
Supplying USB devices with power is not critical using a desktop computer or notebooks but it must be considered that the total power of one USB port is limited to 500 mA.

Note:
The USB ports of the Raspberry Pi® are limited to 100 mA. This means that maximum two devices can be connected to a port directly.

Note:
Using an active USB-Hub with its own power supply allows the connection of additional devices in the case that the host is not able to supply them.

2.2.2 IO Connection

2.2.2.1 Voltage Inputs

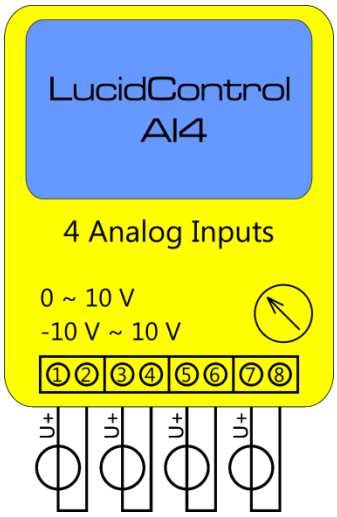

Fig. 2 Analog Voltage Input Module Connection

Fig. 2 shows the interconnection of the module in a typical application.

The analog input voltages are represented by voltage sources with a voltage within the valid range.

Note:
In previous versions of the Analog Input Module the terminals 2, 4, 6 and 8 were connected to ground.

2.2.2.2 Current Inputs

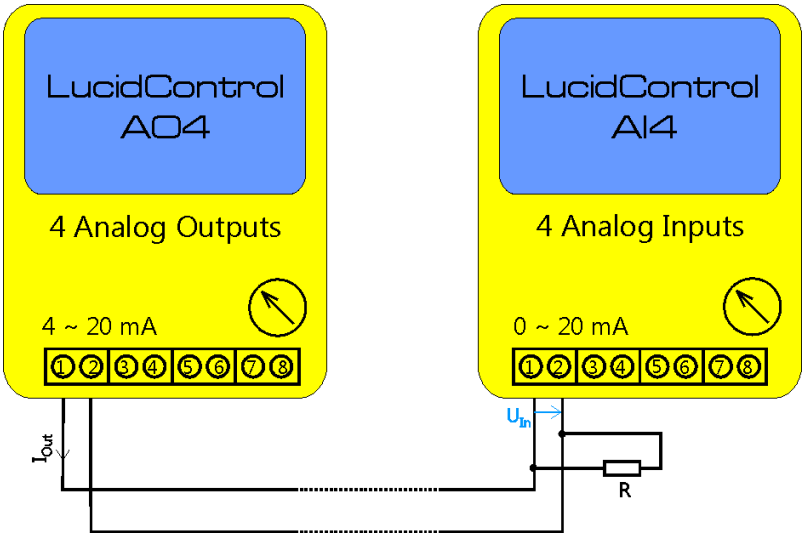

Fig. 3 Analog Current Input Module Connection

Fig. 3 shows how the analog inputs of the AI4-20M0 are used as current inputs. The module is able to measure currents in the range of 0 to 20mA.

In Fig. 3 the analog input module measures a 4-20mA signal is created by the LucidControl analog output module.

The AI4-20M0 module is supplied with 4 pcs of 500 Ω precision burden resistors. The resistors can be connected to the input terminals in parallel to the input signal.

The AI4-20M0 is able to measure both, 0-10 V signals as well as 0-20 mA signals. The burden resistor is only necessary for 0-20mA current inputs.

The burden resistor transforms the 0-20mA current into a voltage:

$$U_{In} = R \,||R_{In} * I$$

In this formula I is the measured current. R is the 500 Ω burden resistor. Most of the current I is flowing through R but a small part is flowing through the input resistance of the analog input circuit. This causes that the maximum measured voltage is lower than

$$U_{In} = 500\Omega * 20\text{mA} = 10\text{V}$$

The maximum voltage at a current of 20mA is 9,985V caused by the input resistance of approx. 300kΩ.

For the current value types (e.g. CUS4) this calculation is done by the module.

All applied signals must be in the supported range. Under no circumstances the applied signals must exceed +30 V resp. -30 V.

2.3 Setup of Hard- and Software

Setting up LucidControl hardware is extremely easy:

1 Ensure that no signal is applied to the IO Connector
2 Connect LucidControl via USB with the computer
3 Applies for Microsoft windows only: The system asks for an installation file. This is not a driver but only an information file (INF). The file can be downloaded from our website www.lucid-control.com/downloads
4 That's all. LucidControl switches the green power LED on and the module is ready for usage.

2.3.1 Windows

As mentioned the installation under Microsoft Windows requires the information file.

After finished installation the Windows Device Manager contains a new serial port (COM). The module can be accessed using this port.

Note:
Even if more than one module is connected to a computer Windows ensures that the same serial port number is assigned to the module(s) after restart.

2.3.2 Linux

Despite to Windows installation under Linux the module is usable immediately after connection without any additional steps. Linux installs /dev/ttyACM devices for any module connected to the computer.

Note:
By default Linux cannot ensure that the same /dev/ttyACM device is assigned to the same module on restart. But as long as only one module is connected to the computer it is ensured that it is accessible via /dev/ttyACM0.

This problem can be solved by the LucidIoCtrl command line tool which can create static devices always pointing to a specific module. Moreover the device can be given useful names e.g. dev/digitalIoKitchen.

Please see the section … of the general LucidIo User Manual for more information.

2.3.3 Get command line LucidIoCtrl

LucidIoCtrl command line tool can be downloaded from our website:

www.lucid-control.com/downloads

This page provides the command line tool LucidIoCtrl for different architectures.

After downloading the program can be stored in a folder of choice.

Please see the section … of the general LucidControl User Manual for more information about this helpful tool.

2.3.4 Ready to Start

After the module was installed successfully (if it was necessary at all) the green Power LED is switched on signaling that the module is ready for use.

Since the module was preconfigured for standard input mode (see ...) it can be used without further configuration. The following examples demonstrate the functionality of the module by using the LucidIoCtrl command line tool.

Windows Examples
For all examples it is assumed that the module is connected to COM1.

Reading the voltages of all 4 input channels

```
      LucidIoCtrl -dCOM1 -tV -c0,1,2,3 -r [ENTER]
->    CH00:5.000  CH01:5.000  CH02:5.000  CH03:5.000
```

Linux Examples:
For all examples it is assumed that the module is connected to /dev/ttyACM0.

Reading the voltages of all 4 input channels

```
      LucidIoCtrl -d/dev/ttyACM0 -tV -c0,1,2,3 -r [ENTER]
->    CH00:5.000  CH01:5.000  CH02:5.000  CH03:5.000
```

3 Module Operation

The LucidControl AI4 Analog Input Module measures the voltage or currents of input signals.

The input signals are converted to a digital value. The acquisition time (T_{Scan}) is 5 ms. After T_{Scan} has passed a new value is available for all activated channels.

3.1 Operation Modes

3.1.1 Inactive

In inactive mode the module returns a value of 0. The input processing is suspended in this mode.

3.1.2 Standard

3.2 Offset Compensation

In some cases it is necessary to compensate an offset value by adding a value to the measured result.

The value of the IO Configuration Parameter *inAnOffset* is added to the measured result. This allows offset correction of ± 3 V or ± 3 mA.

A detailed description can be found in section 3.5.5.

3.3 Range Overflow Detection

If the converted result is outside the measurement range the input value indicates range overflow.

Analog Input Modules which have a positive voltage or current input range only can detect voltages higher than the upper limit (V_{+Range}, I_{+Range}). Input values below 0 are returned as small negative values for signed value types and 0 for unsigned value types. A negative overflow is not detected.

Analog Input Modules with positive and negative voltage range can detect voltages higher than the upper (V_{+Range}) and lower than the lower limit (V_{-Range}).

Values of the supported value types indicating overflow of an input:

Value Type	Condition	Returned value
VOS4	$V < V_{-Range}$	0x80000000

	$V > V_{+Range}$	0x7FFFFFFF
VOS2	$V < V_{-Range}$	0x8000
	$V > V_{+Range}$	0x7FFF
VOU4	$V < 0$	0
	$V > V_{+Range}$	0xFFFFFFFF
VOU2	$V < 0$	0
	$V > V_{+Range}$	0xFFFFF
CUS4	$I < I_{-Range}$	0x80000000
	$I > I_{+Range}$	0x7FFFFFFF

3.4 Commands

Accessing inputs and outputs is a very common task which is mostly identical for all LucidControl modules. For this task input modules provide the commands GetIo for reading of a single value and GetIoGroup for reading of a group of values of the same type.

For more comprehensive information covering reading and writing of inputs and outputs please see the sections 3.2.1.1, 3.2.1.2 and 4.3 of the general LucidControl manual.

The following sections describe in detail the commands which are supported by the AI4 module.

3.4.1 GetIo

This command reads a value from an input.

Command	GetIo	**Access**	Read
Opcode	0x46		
LucidIoControl Command Line Tool			
Call (-tV)	`LucidIoCtrl –d[COMx] –c[Channel] –tV –r`		
Return	`CHn:VV` n – Input Channel VV – Input Voltage		
Call (-tC)	`LucidIoCtrl –d[COMx] –c[Channel] –tC –r`		
Return	`CHn:VV` n – Input Channel VV – Input Current		
Call (-tA)	`LucidIoCtrl –d[COMx] –c[Channel] –tA –r`		
Return	`CHn:DD` n – Input Channel DD – ADC Value		

Note

When using the LucidIoCtrl command line tool the distinction between GetIo and GetIoGroup commands is not necessary since the program handles this automatically.

LucidIoCtrl Command Line Tool Example

Read voltage from input channel 0 (value is 5V):

```
      LucidIoCtrl –dCOM4 –c0 –tV –r [ENTER]
->    CH0:5.000
```

Read current from input channel 0 (value is 15mA):

```
      LucidIoCtrl –dCOM4 –c0 –tC –r [ENTER]
->    CH0:15.000
```

Read digital ADC value from input channel 0:

```
      LucidIoCtrl –dCOM4 –c0 –tA –r [ENTER]
->    CH0:0x0064 (100)
```

Request Frame

OPC	P1	P2	LEN
0x46	Channel	Value Type	0

<table>
<tr><th>Value</th><th>Description</th></tr>
<tr><td>Channel</td><td>Number of input or output channel (Range: 0 ~ 3)</td></tr>
<tr><td>Value Type</td><td>Supported Value Types
<table>
<tr><th>Value Type</th><th>Value Range</th><th>Size</th></tr>
<tr><td>Signed Voltage
Resolution 1 µV
(0x1D)</td><td>-100,000,000 µV ~
100,000,000 µV
(-100 V ~ 100 V)</td><td>4 Bytes</td></tr>
<tr><td>Signed Voltage
Resolution 1 mV
(0x1C)</td><td>-30,000 mV ~
30,000 mV
(-30 V ~ 30 V)</td><td>2 Bytes</td></tr>
<tr><td>Signed Current
Resolution 1nA
(0x23)</td><td>-100,000,000 nA ~
100,000,000 nA
(-100 mA ~ 100mA)</td><td>4 Bytes</td></tr>
<tr><td>ADC Value
(0x10)</td><td>0 ~ 65,535</td><td>2 Bytes</td></tr>
</table></td></tr>
</table>

Tab. 2 GetIo Request

Response Frame:

Status	LEN	Data Field
Status	Length	Value

In case of successful execution the command returns the value of the specified channel number.

In the case of an error the command returns Execution Status Code documented in section 4.4 of the LucidControl User Manual.

Please see 3.3 explaining values reserved for Range Overflow Detection.

3.4.2 GetIoGroup

This command reads the input values of a group of inputs of the same Value Type. See also section 3.4.1.

<table>
<tr><td>Command</td><td>GetIoGroup</td><td>Access</td><td>Read</td></tr>
<tr><td>Opcode</td><td>0x48</td><td></td><td></td></tr>
<tr><td colspan="4">LucidIoControl Command Line Tool</td></tr>
<tr><td>Call (-tV)</td><td colspan="3">LucidIoCtrl –d[COMx] –c[Channels] –tV –r

<u>Channels:</u>
Comma separated list of channels e.g. –c0,1,3</td></tr>
<tr><td>Return</td><td colspan="3">List of values sorted from lower to higher channels
CHn:vv
<table><tr><td>n</td><td>Input Channel</td></tr><tr><td>vv</td><td>Input Voltage</td></tr></table></td></tr>
<tr><td>Call (-tC)</td><td colspan="3">LucidIoCtrl –d[COMx] –c[Channels] –tC –r

<u>Channels:</u>
Comma separated list of channels e.g. –c0,1,3</td></tr>
<tr><td>Return</td><td colspan="3">List of values sorted from lower to higher channels
CHn:vv
<table><tr><td>n</td><td>Input Channel</td></tr><tr><td>vv</td><td>Input Current</td></tr></table></td></tr>
<tr><td>Call (-tA)</td><td colspan="3">LucidIoCtrl –d[COMx] –c[Channels] –tA –r

<u>Channels:</u>
Comma separated list of channels e.g. –c0,1,3</td></tr>
<tr><td>Return</td><td colspan="3">CHn:dd
<table><tr><td>n</td><td>Input Channel</td></tr><tr><td>dd</td><td>ADC Value</td></tr></table></td></tr>
</table>

<u>LucidIoCtrl Command Line Tool Example</u>

Read voltages from all input channels:

```
      LucidIoCtrl –dCOM4 –c0,1,2,3 –tV –r [ENTER]
->    CH0:6.000  CH1:2.500  CH2:0.000  CH3:-2.500
```

Request Frame

OPC	P1	P2	LEN
0x48	Channel Mask	Value Type	0

<table>
<tr><th>Value</th><th>Description</th></tr>
<tr><td>Channel Mask</td><td>Channel Mask
Specifies the output channels to access
<table>
<tr><th>Channel</th><th>Bit Position</th><th>Value</th></tr>
<tr><td>0</td><td>0</td><td>0x01</td></tr>
<tr><td>1</td><td>1</td><td>0x02</td></tr>
<tr><td>2</td><td>2</td><td>0x04</td></tr>
<tr><td>3</td><td>3</td><td>0x08</td></tr>
</table>
Values are bitwise or combined

Examples:
Accessing channel 0 and 3 Value = 0x01 OR 0x08 = 0x09
Accessing channel 1 and 2 Value = 0x02 OR 0x04 = 0x06</td></tr>
<tr><td>Value Type</td><td>Supported Value Types
<table>
<tr><th>Value Type</th><th>Value Range</th><th>Size</th></tr>
<tr><td>Signed Voltage
Resolution 1 µV
(0x1D)</td><td>-100,000,000 µV ~
100,000,000 µV
(-100 V ~ 100 V)</td><td>4 Bytes</td></tr>
<tr><td>Signed Voltage
Resolution 1 mV
(0x1C)</td><td>-30,000 mV ~
30,000 mV
(-30 V ~ 30 V)</td><td>2 Bytes</td></tr>
<tr><td>Signed Current
Resolution 1nA
(0x23)</td><td>-100,000,000 nA ~
100,000,000 nA
(-100 mA ~ 100mA)</td><td>4 Bytes</td></tr>
<tr><td>ADC Value
(0x10)</td><td>0 ~ 65,535</td><td>2 Bytes</td></tr>
</table></td></tr>
</table>

Tab. 3 GetIoGroup Request

Response Frame:

Status	LEN	Data Field
Status	Length	Value(s)

In case of successful execution the command returns the read values of the channels specified in the Channel Mask.

In the case of an error the command returns Execution Status Code documented in section 4.4 of the LucidControl User Manual.

Please see 3.3 explaining values reserved for Range Overflow Detection.

Example of GetIoGroup Request:
The following request frame reads voltage inputs 0 and 1

Opcode	P1	P2	Length
0x48	0x03	0x00	0x00

Channel Mask (P1): 0x01 OR 0x02 = 0x03

Response Frame:
For input 0 = 5.000 V, input 2 = 2.500V
Values in Data Field are in ascending order Channel 0, Channel 1.

Header Field		Data Field							
Status	LEN	Value Channel 0				Value Channel 1			
0x00	0x08	0x40	0x4B	0x4C	0x00	0xA0	0x25	0x26	0x00

3.5 Parameters

LucidControl modules allow configuration by a set of System Configuration Parameters and IO Configuration Parameters.

The Parameters are accessible via the SetParam and GetParam command which are described in sections 4.3.5 and 4.3.6 of the LucidControl User Manual.

3.5.1 inAnValue

This IO Configuration Parameter contains the ADC value of the input.

Parameter	inAnValue	**Access**	Read
Address	0x1000		
Values	ADC Input Value		
Default Value	0x00	**Parameter Type**	2 Bytes unsigned
LucidIoControl Command Line Tool			
Parameter Name	inAnValue	**Parameter Values**	0 ~ 65,535
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –ginAnValue`		

LucidIoCtrl Command Line Tool Example
Read value of input channel 0:

```
      LucidIoCtrl –dCOM4 –c0 –ginAnValue [ENTER]
->    inAnValue=0
```

Note:
For normal operation it is recommended to use the function GetIo (3.4.1) in order to read the input value. The parameter provides the ADC Value (Value Type 0x10) only.

3.5.2 inAnMode

This IO Configuration Parameter configures the operation mode of the input.

<table>
<tr><td>Parameter</td><td>inAnMode</td><td>Access</td><td>Read / Write</td></tr>
<tr><td>Address</td><td>0x1100</td><td colspan="2"></td></tr>
<tr><td>Values</td><td colspan="3">Input Mode<table><tr><th>Byte</th><th>Mode</th></tr><tr><td>0x00</td><td>inactive</td></tr><tr><td>0x01</td><td>standard</td></tr></table></td></tr>
<tr><td>Default Value</td><td>0x00</td><td>Parameter Type</td><td>1 Byte unsigned</td></tr>
<tr><td colspan="4">LucidIoControl Command Line Tool</td></tr>
<tr><td>Parameter Name</td><td>inAnMode</td><td>Parameter Values</td><td>inactive / standard</td></tr>
<tr><td>Call (Set)</td><td colspan="3"><code>LucidIoCtrl -d[COMx] -c[Channel] -sinAnMode=[Mode] {-p} {--default}</code></td></tr>
<tr><td>Call (Get)</td><td colspan="3"><code>LucidIoCtrl -d[COMx] -c[Channel] -ginAnMode</code></td></tr>
</table>

LucidIoCtrl Command Line Tool Example

Set operation mode of input channel 0 to Standard Mode and make the setting persistent.

```
LucidIoCtrl -dCOM4 -c0 -sinAnMode=standard -p [ENTER]
```

Read the operation mode of input channel 0

```
LucidIoCtrl -dCOM4 -c0 -ginAnMode [ENTER]
->  inAnMode=standard
```

3.5.3 Bit Parameter inAnFlags

This IO Configuration Parameter groups parameters which are represented by one bit e.g. having an “on” or “off” state only). All values are reserved for future use.

3.5.4 inAnNrSamples

This parameter defines the number of oversampling cycles.

This parameter configures the oversampling of the analog values.

By oversampling the measured result is more precise. The algorithm calculates an average and when possible additional bits increase precision.

Valid oversampling cycles are 2, 4, 8, 16, 128 or 256. The acquisition time T_{Scan} is increased by the oversampling cycle factor and can become e.g. 1.3s for 256 oversampling cycles.

Parameter	inAnNrSamples	**Access**	Read / Write
Address	0x1112		
Values	2, 4, 8, 16, 128 or 256 oversampling cycles		
Default Value	16	**Parameter Type**	2 Bytes unsigned
LucidIoControl Command Line Tool			
Parameter Name	inAnNrSamples	**Parameter Values**	Cycles
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] -sinAnNrSamples=[cylces] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –ginAnNrSamples`		

LucidIoCtrl Command Line Tool Example

Set number of oversampling cycles to 128 and make the setting persistent.

```
LucidIoCtrl –dCOM4 –c0 –sinAnNrSamples=128 –p [ENTER]
```

Read number of oversampling cycles of input channel 0

```
LucidIoCtrl –dCOM4 –c0 –ginAnNrSamples [ENTER]
->  inAnNrSamples=128
```

3.5.5 inAnOffset

This IO Configuration Parameter configures the Input Offset Compensation Value which is described in section 3.2.

Parameter	inAnOffset	**Access**	Read / Write
Address	0x1120		
Values	Offset Compensation in 100 µV steps (-3 V ~ 3 V) Offset Compensation in 100 nA steps (-3 mA ~ 3 mA) -30,000 ~ 30000		
Default Value	0	**Parameter Type**	2 Bytes signed
LucidIoControl Command Line Tool			
Parameter Name	inAnOffset	**Parameter Values**	Voltage [100 µV] Current [100 nA]
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –sinAnOffset=[Value] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –ginAnOffset`		

LucidIoCtrl Command Line Tool Example

Set Input Offset Compensation value of input channel 0 to -500µV and make the setting persistent.

```
LucidIoCtrl –dCOM4 –c0 –sinAnOffset=-5 –p [ENTER]
```

Read Offset Compensation value

```
LucidIoCtrl –dCOM4 –c0 –ginAnOffset [ENTER]
->  inAnOffset=-5
```

4 Specification

Parameter		Condition	Value	
Inputs				
	No of Input Channels		4	
Input - Electrical Characteristics				
	Measurement Method		Analog to Digital Conversion	
	Resolution		14 bit	
	Accuracy		typ. ±0,25 % of full scale range	
	Max. Measuring Error		± 5 LSB	
	Input Resistance		R_{In}	> 100 kΩ
Input – Timing Characteristic				
	Acquisition Interval / Channel		T_{Scan}	5 ms
Module – Communication				
	USB		2.0 Full Speed CDC Profil	
Module – Electrical Characteristics				
	Power Supply		USB Bus Powered with +5V No additional Power Supply needed.	
	Maximum Rated Supply Current		40 mA	
Module – Environment				
	Temperature	Storage	-20 °C … +70 °C	
		Operation	0 °C … +55 °C	
	Humidity		< 85 % RH, non-condensing	
Module – Housing				
	Dimensions L x W x H		90 x 54 x 62 mm	
	Weight (in total)		120 g	
	Assembly		Rail-Mount (EN 50022, TS35)	
	Protection Class (DIN 40050)		IP20	
Module - Indicators				
	• Operation and Error Indicator • Communication Indicator			

5 Order Information and Accessories

Digital Input Product Family

Order Code	Product
LCTR-AI4-05	LucidControl Analog Input USB Module with 4 channels 0 ~ 5 V.
LCTR-AI4-10	LucidControl Analog Input USB Module with 4 channels 0 ~ 10 V.
LCTR-AI4-24	LucidControl Analog Input USB Module with 4 channels 0 ~ 24 V.
LCTR-AI4-05S	LucidControl Analog Input USB Module with 4 channels -5 ~ 5 V.
LCTR-AI4-10S	LucidControl Analog Input USB Module with 4 channels -10 ~ 10 V.
LCTR-AI4-24S	LucidControl Analog Input USB Module with 4 channels -24 ~ 24 V.
LCTR-AI4-20M0	LucidControl Analog Input USB Module with 4 channels 0 ~ 20 mA.

The following accessories are available:

Order Code	Product
LCTR-AK1710-8	Plug-In Terminal 8-way 1,5 mm^2 wire