User Manual

LucidControl AI4/AI8

4/8 Channel Analog Input USB Module

Table of Content

1 Introduction

This document describes the functionality of the LucidControl AI4/AI8 USB module measuring 4/8 analog voltages or currents controllable via Universal Serial Bus.

This document explains functions which are specific to the AI4/AI8 module.

2 Setup and Installation

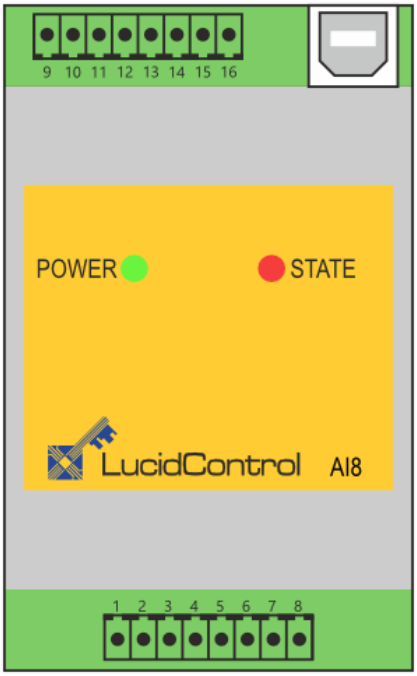

Fig. 1 Analog Input Module AI8

Fig. 1 shows the sketch of the AI8 analog input module with 8 analog voltage or current input channels.

Each IO connector has 8 terminals, one positive and one negative pin.

The lower IO connector is used for channels 0 to 3. It is present on the AI4 and AI8 modules.

The upper IO connector available on the AI8 analog input module only. It is used for the channels 4 to 7.

2.1 Safety Information

LucidControl complies with regulations and industrial standards active in the EU. To keep the device functional, the following safety and maintenance information must be adhered.

The device must only be used for the intended purpose.

The device must not be used under the following conditions:

- It is obviously damaged
- An error was detected
- Outside humidity and temperature limits
- Unauthorized personnel

Never apply voltages higher than 30V (or lower than -30V) to any IO terminal. This would damage the device.

2.2 Configurations

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

Tab. 1 Input Range

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

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

2.3 Interface and Interconnection

2.3.1 USB Connection

LucidControl USB modules are connected to the computer by using a USB 2.0 cable which must not extend a length of 5 m. They are “bus powered” what means that the host computer supplies the module with power.

LucidControl AI4/AI8 module is rated with a maximum current of 40 mA.

2.3.2 IO Connection

2.3.2.1 Voltage Inputs

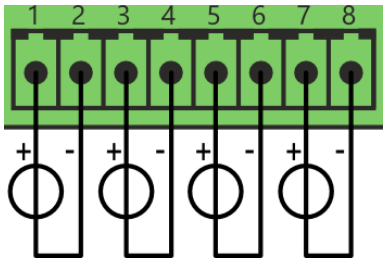

Fig. 2 shows the connection of the channels 0 to 3 of the AI4/AI8 module.

Fig. 2 AI4/AI8 Voltage Inputs

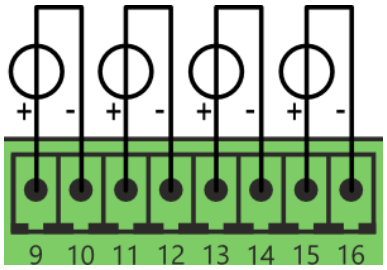

Fig. 3 shows the connection of the channels 4 to 7 of the AI8 module.

Fig. 3 AI8 Voltage Inputs

2.3.2.2 Current Inputs

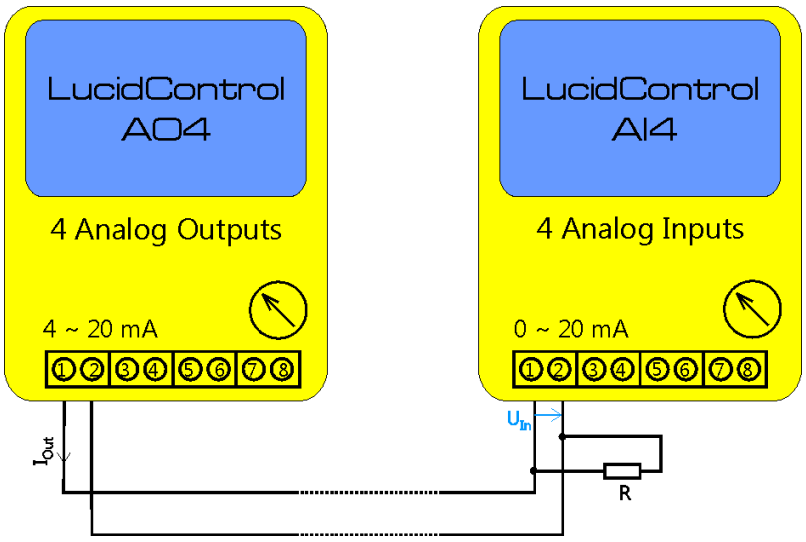

Fig. 4 shows how the analog inputs of the AI4-20M0 are used as current inputs. The module is able to measure currents in the range of 0 to 20mA.

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

Fig. 4 Analog Current Input Module Connection

The AI4/AI8-20M0 module is supplied with 4/8 pcs of 500 Ω precision burden resistors. The resistors can be connected to the input terminals in parallel to the input signal.

The AI4/AI8-20M0 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.

2.4 Setup of Hard- and Software

Setting up LucidControl hardware is straight forward:

1. Ensure that no signal is applied to the IO Connector
2. Connect LucidControl via USB with the computer
3. Applies for Microsoft Windows older than Windows 10 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. LucidControl switches the green power LED on. The module can be used.

2.4.1 Windows

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

If more than one module is connected to a computer, the operating system ensures that the same serial port number is assigned to the module(s) after restart.

2.4.2 Linux

The module is immediately installed as /dev/ttyACM**n** device where n is a number referring to the index of the device.

Note
If more than one module is connected to a computer, Linux does by default not ensure that a module is permanently linked to the same /dev/ttyACM**n** device.

2.4.3 LucidIoCtrl Command Line Tool

The 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.

Please see the section 3 of the general *LucidControl User Manual* for more information about LucidIoCtrl.

2.4.4 First Steps

After the module was successfully installed, the green Power LED is switched on signaling that the module is ready for use.

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 USB IO module is connected to COM1.

Reading the voltages of 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 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/AI8 Analog Input Module measures the voltages or currents and converts it to a digital representation.

3.1 Operation Modes

3.1.1 Inactive

In inactive mode the module returns a value of 0.

Inactive channels are skipped from processing, speeding up the conversion of the remaining active input channels.

3.1.2 Standard

Input signals are converted in a round robin sequence.

3.2 Offset Compensation

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 3.4.5.

3.2.1.1 Oversampling

The AI4/AI8 modules use a precision 12 bit hardware ADC.

The hardware ADC oversamples the measured input signal at minimum by a factor of 256 (hardware oversampling) before the result is returned.

The AI4/AI8 firmware does additional firmware oversampling which can be configured by the IO Configuration Parameter *inAnNrSamples* (see 3.4.4).

The default firmware oversampling is 16 (*inAnNrSamples* = 16). This gives a total factor of 4096 (hardware oversampling x firmware oversampling = 256 x 16). This is a good compromise between accuracy and speed.

3.3 Commands

3.3.1 GetIo

This command reads a value of an analog input channel.

Command	GetIo	**Access**	Read
Opcode	0x46		
LucidIoCtrl 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		

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 to 8)</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>

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 case of an error, the command returns the Execution Status Code documented in the general *LucidControl User Manual*.

3.3.2 GetIoGroup

This command reads the input values of a group of analog input channels of the same Value Type.

<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">LucidIoCtrl Command Line Tool</td></tr>
<tr><td>Call (-tV)</td><td colspan="3"><code>LucidIoCtrl –d[COMx] –c[Channels] –tV –r</code>
<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
<code>CHn:vv</code><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"><code>LucidIoCtrl –d[COMx] –c[Channels] –tC –r</code>
<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
<code>CHn:vv</code><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"><code>LucidIoCtrl –d[COMx] –c[Channels] –tA –r</code>
<u>Channels:</u>
Comma separated list of channels e.g. –c0,1,3</td></tr>
<tr><td>Return</td><td colspan="3"><code>CHn:dd</code><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>
<tr><td>4</td><td>4</td><td>0x10</td></tr>
<tr><td>5</td><td>5</td><td>0x20</td></tr>
<tr><td>6</td><td>6</td><td>0x40</td></tr>
<tr><td>7</td><td>P1A 0</td><td>P1=0x80
P1A = 0x01</td></tr>
</table>
Values are bitwise OR combined
Size of P1 is 1 or 2 bytes. If Bit 7 of P1 is set, a subsequent P1A is expected.

Examples:
Accessing channel numbers:
0 and 3 Value = 0x01 OR 0x08 = 0x09
1 and 2 Value = 0x02 OR 0x04 = 0x06
1, 2 and 7 Value P1 = 0x02 OR 0x04 = 0x86
Value P1A = 0x01 (for channel 7)
</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>

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 channel number ascending order.

In case of an error, the command returns the Execution Status Code documented in the general *LucidControl User Manual*.

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

3.4 IO Configuration Parameters

LucidControl modules are configured by a set of System Configuration Parameters and IO Configuration Parameters.

The parameters are accessible by the SetParam and GetParam command which are described in the general *LucidControl User Manual*.

3.4.1 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
LucidIoCtrl 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 (3.3.1) in order to read the input value. The parameter provides the ADC Value (Value Type 0x10) only.

3.4.2 inAnMode

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

Parameter	inAnMode	**Access**	Read / Write
Address	0x1100		
Values	Input Mode **Byte** 0x00 = **Mode** inactive 0x01 = standard		
Default Value	0x00	**Parameter Type**	1 Byte unsigned
LucidIoControl Command Line Tool			
Parameter Name	inAnMode	**Parameter Values**	inactive / standard
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –sinAnMode=[Mode] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –ginAnMode`		

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
```

3.4.3 Bit Parameter inAnFlags

This IO Configuration Parameter groups Bit Parameters which are represented by one bit e.g. having an “on” or “off” state only).

All values are reserved for future use.

3.4.4 inAnNrSamples

This IO Configuration Parameter specifies the number of oversampling cycles for an input channel.

Oversampling increases the quality of the converted result. The algorithm calculates an average signal and adds additional precision bits if possible.

Valid oversampling cycles are 2, 4, 8, 16, 128 or 256.

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
```

3.4.5 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
LucidIoCtrl 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		4/8	
Input - Electrical Characteristics				
	Measurement Method		Analog to Digital Conversion	
	Resolution		12 bit hardware, 14 bit oversampled	
	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 Profile	
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			

Tab. 2 AI4/AI8 Specification

5 Order Information

Order Code	Product
LCTR-AI4-5	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-AI4-5S	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.
LCTR-AI8-5	LucidControl Analog Input USB Module with 8 channels 0 ~ 5 V.
LCTR-AI8-10	LucidControl Analog Input USB Module with 8 channels 0 ~ 10 V.
LCTR-AI8-24	LucidControl Analog Input USB Module with 8 channels 0 ~ 24 V.
LCTR-AI8-5S	LucidControl Analog Input USB Module with 8 channels -5 ~ 5 V.
LCTR-AI8-10S	LucidControl Analog Input USB Module with 8 channels -10 ~ 10 V.
LCTR-AI8-24S	LucidControl Analog Input USB Module with 8 channels -24 ~ 24 V.
LCTR-AI8-20M0	LucidControl Analog Input USB Module with 8 channels 0 ~ 20 mA.

Tab. 3 Order Codes

6 Document Revision

Date	Rev.	
2013/02/24	1.0	
2016/01/28	1.1	
2016/04/26	1.2	
2023/04/06	1.3	Added documentation of AI8 module

Tab. 4 Document Revision

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