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 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 Hardware

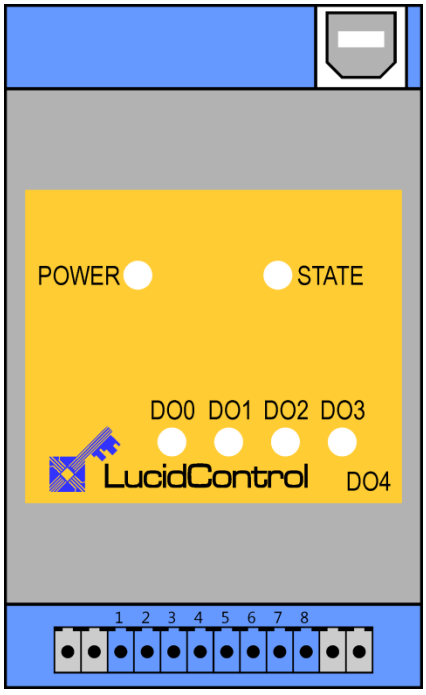

Fig. 1 Analog Input Module

Fig. 1 shows the sketch of the Analog Input AI4 module with 4 analog voltage 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.

2.1 Configurations

Module Type	Type Number	Input Voltage Range	
		V_{Min}	V_{Max}
Positive Inputs	LCTR-AI4-5	0 V	5 V
	LCTR-AI4-10	0 V	10 V
	LCTR-AI4-24	0 V	24 V
Symmetrical Inputs	LCTR-AI4-5S	-5 V	5 V
	LCTR-AI4-10S	-10 V	10 V
	LCTR-AI4-24S	-24 V	24 V

Tab. 1 Input Voltage Range

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

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

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

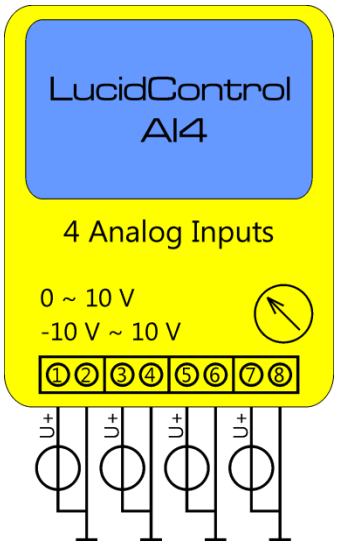

Fig. 2 Analog Input Module Connection

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.

The terminals 2, 4, 6 and 8 are internally connected to ground.

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 for Take-Off

Once 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 Usage

The AI4 module measures the voltages of connected input signals.

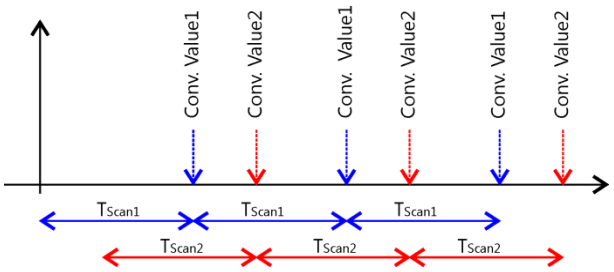

Fig. 3 Input Processing

Fig. 3 illustrates the processing of the analog input signals in Standard Mode.

In order to keep the diagram simple it shows only two active channels.

The blue lines are related to input channel 1, the red lines to input channel 2.

The figure illustrates the periodical capture of both input channels within the scan interval time T_{Scan}.

T_{Scan} can be configured by changing the IO Configuration Parameter *inAnScanTime*. This could be done for faster measurement intervals.

3.1 Input Calibration

The LucidControl AI4 module measures analog signals (more precisely voltages) which are captured, conditioned and converted to digital values.

In contradiction to logic signals where by nature only two states LOW and HIGH are possible for analog signals all voltages within a given range are converted to their representing digital value.

The signal conditioning which is part of the measurement circuit contains components which are not free from tolerances (e.g. offset voltages of amplifier). These have to be compensated in order to measure a correct value.

The calibration function of the AI4 module described in the following corrects these measurement tolerances.

Note:
All modules are calibrated before shipping and it is not necessary to recalibrate a new module nor is it necessary to calibrate it regularly!

3.1.1 Calibration Procedure

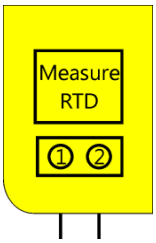

Fig. 4 Analog Input Sort Calibration

For short input calibration the inputs must be shortcut as it is shown in Fig. 4. After creating a shortcut e.g. by connecting the terminals 1 and 2 for input channel 0 the short input calibration can be executed by using the LucidIoCtrl command line tool. For detailed information see section 3.2.3.

Example

The short input calibration should be done for channel 0 and the result should be stored for further usage.

```
LucidIoCtrl –dCOM1 –c0 –a --short –p --quiet [ENTER]
```

In combination with the I/O Calibration command (-a) the short input calibration is specified (--short). Passing Parameter --quiet causes LucidIoCtrl skips user confirmation before the command is started. Using Parameter –p makes the calibration setting persistent so that is used after a restart of the module.

The short input calibration for channel 0 is finished and the remaining input channels can be calibrated the same way afterwards.

Reading the input voltage after short input calibration was done should return a voltage of 0 V (assuming that the shortcut between the terminals was not removed)

```
      LucidIoCtrl –dCOM1 –c0 –tV –r [ENTER]
->    CH0:0.000
```

3.1.2 Offset Compensation

In some cases it is necessary to compensate an offset voltage 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.

A detailed description can be found in section 3.3.4.

3.2 Commands

After an input was set up correctly and configured it is possible to read the input value by using the commands GetIo for a single value or GetIoGroup in order to read a group of input values of the same type.

Accessing inputs and outputs is a very common task which is mostly identical for all Lucid Control modules. Please refer to the section 3.2.1.1, 3.2.1.2 and 4.3 of the general LucidControl manual for comprehensive information covering reading and writing of inputs and outputs in general.

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

3.2.1 GetIo

This command reads a value from an input.

<table>
<tr><td>Command</td><td>GetIo</td><td>Access</td><td>Read</td></tr>
<tr><td>Opcode</td><td>0x46</td><td></td><td></td></tr>
<tr><td colspan="4">LucidIoControl Command Line Tool</td></tr>
<tr><td>Call (-tV)</td><td colspan="3"><code>LucidIoCtrl –d[COMx] –c[Channel] –tV –r</code></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>vv</td><td>Input Voltage</td></tr></table></td></tr>
<tr><td>Call (-tA)</td><td colspan="3"><code>LucidIoCtrl –d[COMx] –c[Channel] –tA –r</code></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 Voltage</td></tr></table></td></tr>
</table>

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:

```
      LucidIoCtrl –dCOM4 –c0 –tV -r [ENTER]
->    CH00:5.000
```

Read digital ADC value from input channel 0:

```
      LucidIoCtrl –dCOM4 –c0 –tA -r [ENTER]
->    CH00:0x0064 (100)
```

Request Frame

OPC	P1	P2	LEN
0x46	Channel	Value Type	0

Value	Description
Channel	Number of input or output channel (Range: 0 ~ 3)
Value Type	Supported Value Types

Value Type	Value Range	Size
Signed Voltage Resolution 1 µV (0x1D)	-100,000,000 µV ~ 100,000,000 µV (-100 V ~ 100 V)	4 Bytes
Signed Voltage Resolution 1 mV (0x0C)	-30,000 mV ~ 30,000 mV (-30 V ~ 30 V)	2 Bytes
ADC Value (0x10)	0 ~ 65,535	2 Bytes

Fig. 5 GetIo Request

Response Frame:

Status	LEN	Data Field
Status	Length	Value(s)

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.

3.2.2 GetIoGroup

This command reads the input values of a group of inputs of the same Value Type. See also section 3.2.1.

<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 (-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

Value	Description
Channel Mask	Channel Mask Specifies the output channels to access **Channel / Bit Position / Value** 0 / 0 / 0x01 1 / 1 / 0x02 2 / 2 / 0x04 3 / 3 / 0x08 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
Value Type	Supported Value Types **Value Type / Value Range / Size** Signed Voltage Resolution 1 µV (0x1D) / -100,000,000 µV ~ 100,000,000 µV (-100 V ~ 100 V) / 4 Bytes Signed Voltage Resolution 1 mV (0x0C) / -30,000 mV ~ 30,000 mV (-30 V ~ 30 V) / 2 Bytes ADC Value (0x10) / 0 ~ 65,535 / 2 Bytes

Fig. 6 GetIoGroup Request

Response Frame:

Status	LEN	Data Field
Status	Length	Value

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.

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, Channel3.

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

3.2.3 CalibrateIO

This command performs the short input calibration as it is described in section **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Command	CalibrateIo	Access	-
Opcode	0x52		
LucidIoControl Command Line Tool			
Call	`LucidIoCtrl –d[COMx] –c[Channel] –a {--quiet} {–p} {--short}`		

Examples for open input and short input calibration can be found in section **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Request Frame

OPC	P1	P2	LEN
0x52	Channel	0x00	0x00

Value	Description
Channel	Number of analog input channel (Range: 0 ~ 3)

Response Frame

Status	LEN
Status	0x00

The command does not return any data. In the case of an error the command returns Execution Status Code documented in section 4.4 of the LucidControl User Manual.

3.3 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.

3.3.1 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**	0x00 or 0x01
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 (3.2.1) in order to read the input value. The parameter provides the ADC Value (Value Type 0x10) only.

3.3.2 inAnMode

Parameter	inAnMode	**Access**	Read / Write
Address	0x1100		
Values	Input Mode **Byte** / **Mode** 0x00 – 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
```

3.3.3 inAnScanTime

This IO Configuration Parameter configures the scan time T_{Scan} of the analog input.

Parameter	inAnScanTime	**Access**	Read / Write
Address	0x1111		
Values	T_{Scan} in ms (milli seconds) 50 ms ≤ T_{Scan} ≤ 10 s		
Default Value	200 (200 ms)	**Parameter Type**	2 Bytes unsigned
LucidIoControl Command Line Tool			
Parameter Name	inanScanTime	**Parameter Values**	Time [ms]
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –sinAnScanTime=[Time] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –ginAnScanTime`		

LucidIoCtrl Command Line Tool Example

Set T_{Scan} of input channel 0 to 0.5 s and make the setting persistent.

```
LucidIoCtrl –dCOM4 –c0 –sinAnScanTime=500 –p [ENTER]
```

Read T_{Scan} parameter of input channel 0

```
LucidIoCtrl –dCOM4 –c0 –ginAnScanTime [ENTER]
->    inDiScanTime=500
```

3.3.4 inAnOffset

This IO Configuration Parameter configures the Input Offset Compensation Value which is described in section 3.1.2.

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

3.3.5 inAnCal

This IO Configuration Parameter configures the short calibration value which is described in section **Fehler! Verweisquelle konnte nicht gefunden werden.**. The value does not have a unit and even if it possible it is not recommended to set this value manually.

Parameter	inAnCal	**Access**	Read / Write
Address	0x1130		
Values	Short Calibration Value 0 ~ 65,535		
Default Value	0	**Parameter Type**	2 Bytes unsigned
LucidIoControl Command Line Tool			
Parameter Name	inAnCal	**Parameter Values**	0 ~ 65,535
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –sinAnCal=[Value] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –ginAnCal`		

LucidIoCtrl Command Line Tool Example

Read Short Calibration Value of input channel 0

```
      LucidIoCtrl –dCOM4 –c0 –ginAnCal [ENTER]
->    inAnCal=760
```

4 Specification

Parameter		Condition	Value	
Inputs				
	No of Input Channels		4	
Input - Electrical Characteristics				
	Measurement Method		Analog to Digital Conversion	
	Resolution		14 bit	
	Max. Measuring Error		1 %	
	Input Resistance		> 100 kΩ	
Input – Timing Characteristic				
	Measurement Interval		T_{Scan}	50 ms ≤ t ≤ 10 s
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.

The following accessories are available:

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