User Manual

LucidControl DO4/DO6/DO8

4/6/8 Channel Digital Output USB Module

Table of Content

1 Introduction

This document describes the functionality of the LucidControl DO4/DO6/DO8 USB IO module with 4/6/8 digital outputs controllable by the Universal Serial Bus.

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

2 Setup and Installation

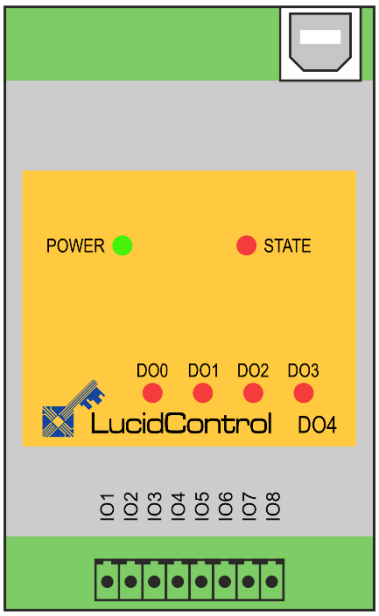

Fig. 1 LucidControl DO4 Module

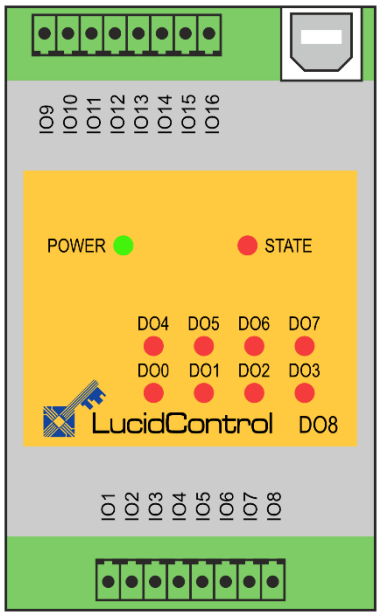

Fig. 2 LucidControl DO8 Module

Fig. 1 and Fig. 2 show drawings of the DO4 and DO8 digital output modules with 4/8 digital outputs channels (DO0 - DO3 and DO4 - DO7).

The IO signals are connected to the lower (IO1 - IO8) and the upper (IO9 - IO16) IO terminals.

The upper IO terminal connector is present at the DO8 module only.

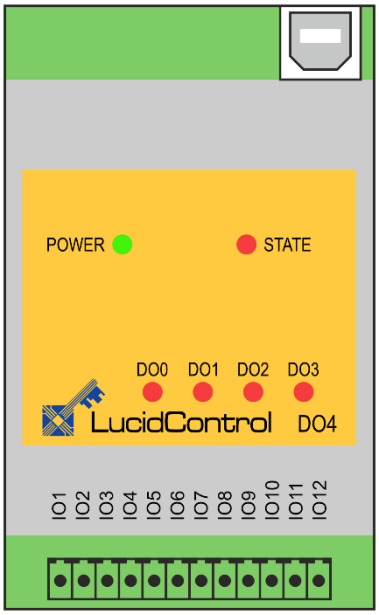

Fig. 3 LucidControl DO4-S Module

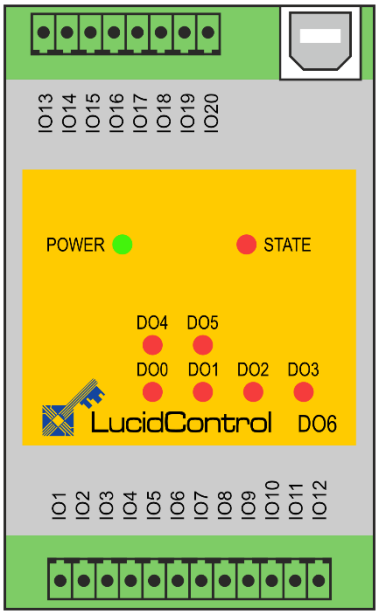

Fig. 4 LucidControl DO6-S Module

Fig. 3 and Fig. 4 show drawings of the DO4-S and DO6-S digital output module with 4/6 SPDT relay output channels (DO0 - DO3 and DO4 - DO5).

The IO signals are connected to the lower (IO1 - IO12) and the upper (IO13 - IO20) IO terminals.

The upper IO terminal connector is present at the DO6-S module only.

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 to any IO terminal. This would damage the device.

All contacts of the modules are protected against ESD but not necessarily against overload, which is especially relevant for output channels.

2.2 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.

Function Class / Type	Current
DO4 (-I, -O)	100 mA
DO8 (-I, -O)	100 mA
DO4-S/DO6-S	250 mA

Tab. 1 USB Current Rating

Tab. 1 shows the USB current rating of the DO4/DO6/DO8 modules.

2.3 Software

LucidControl modules are plug and play and a manual driver installation is not necessary.

First connection:

1. Ensure that no signal is applied to the IO terminals
2. Connect LucidControl via USB with the computer
3. Applies for Microsoft Windows before Windows 10 only: The system requests an installation file. This is not a driver but an information file (INF) only. It can be downloaded from our website https://lucid-control.com/downloads
4. LucidControl switches the green power LED on indicating that the module can be used.

2.3.1 Microsoft Windows

After the installation has finished, the Windows Device Manager lists a new serial port (COM) entry. 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.

2.3.2 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.

2.3.3 LucidIoCtrl Command Line Tool

The LucidIoCtrl command line tool gives full access to all LucidControl modules. It is available for different architectures and can be downloaded from our website:

https://www.lucid-control.com/downloads

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

Please see the general *LucidControl User Manual* for more information.

2.3.4 First Steps

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

The following examples demonstrate the functionality of the module by using the LucidIoCtrl command line tool.

Windows Examples

Setting output channel number 0 to "1"

```
LucidIoCtrl -dCOM1 -tL -c0 -w1
```

Resetting output channel number 0 to "0"

```
LucidIoCtrl -dCOM1 -tL -c0 -w0
```

Reading the output states of the first 4 channels.

```
      LucidIoCtrl -dCOM1 -tL -c0,1,2,3 -r
->    CH0:00  CH1:00  CH2:00  CH3:00
```

Windows requires a different argument for comport numbers 10 and above.

```
      LucidIoCtrl -d\\.\COM10 -tL -c0,1,2,3 -r
->    CH0:00  CH1:00  CH2:00  CH3:00
```

Linux Examples:

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

Setting output channel number 0 to "1"

```
./LucidIoCtrl -d/dev/ttyACM0 -tL -c0 -w1
```

Resetting output channel number 0 to "0"

```
./LucidIoCtrl -d/dev/ttyACM0 -tL -c0 -w0
```

Reading the outputs of the first 4 channels back

```
      ./LucidIoCtrl -d/dev/ttyACM0 -tL -c0,1,2,3 -r
->    CH0:00  CH1:00  CH2:00  CH3:00
```

2.4 IO Configurations

The DO4/DO6/DO8 module is available in different configurations, which are explained in this section.

Function Class	Value	Channels
DO4 (-I, -S- O)	0x1000	4
DO6 (-S only)	0x1020	6
DO8 (-I, -O)	0x1010	8

Tab. 2 Digital Output Function Classes

Function Class Type	Value	Output Type
I	0x1000	Solid State Relay (SSR)
S	0x1100	SPDT Relay
O	0x1200	Open Collector

Tab. 3 Digital Output Function Class Types

Tab. 2 and Tab. 3 list the Function Classes and their types.

The solid state relay and open collector function classes are available with 4 and 8 channels.

The SPDT relay function class is available with 4 and 6 channels.

A closed (active) output is indicated by a red status LED.

2.4.1 4/8 Solid State Relay Outputs (DO4-I/DO8-I)

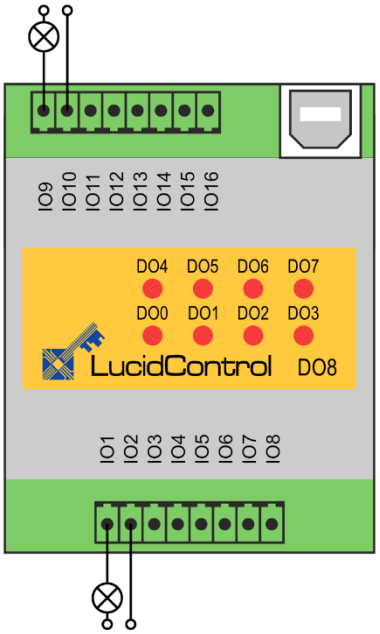

Fig. 5 DO8-I IO Connection

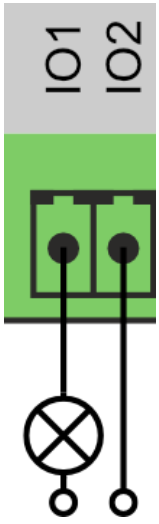

Fig. 6 DO8 Signal

Fig. 5 shows the connection of the DO8-I module in detail.

Power loads (e.g. a lamp) are connected to IO1 and IO2 (DO0) and IO9 and IO10 (DO4).

Fig. 6 shows the lamp connected to the IO terminals IO1 and IO2 (DO0).

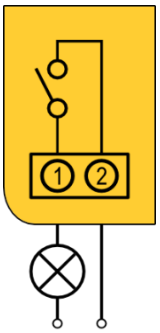

Fig. 7 SSR Output

Fig. 7 shows the principle of a digital output channel with solid state relays (SSR).

When the digital output channel is set to high, the SSR connects IO terminal 1 with IO terminal 2, closing the circuit.

The polarity of the signal is not relevant. The positive or negative potential can be connected to any terminal.

The SSR output channels are opto-isolated, protecting the electronic behind the SSR. The SSR output channels do not share any contacts and are independent.

SSR are not limited in switching cycles and are suited for periodical switching as well as for static switching.

Tab. 4 lists the IO terminals of the DO4-I/DO8-I module and their IO channel numbers.

IO Terminal	Signal	IO Channel Number
1	DO0	0
2		
3	DO1	1
4		
5	DO2	2
6		
7	DO3	3
8		
9	DO4	4
10		
11	DO5	5
12		
13	DO6	6
14		
15	DO7	7
16		

Tab. 4 DO4-I/DO8-I IO Terminal Connector

SSR outputs are not protected against overcurrent and overvoltage. U_{SSRMax} and I_{SSRMax} limits must be considered. Otherwise, the output may be damaged.

If inductive loads are controlled, additional protection may be necessary in order to protect the SSR from excessive high voltage.

SSR outputs support reflect mode, duty-cycle mode and on-off mode.
For duty-cycle and on-off modes the minimum on and off times are limited to T_{SSRMin}.

2.4.2 4/8 Open Collector Transistor Outputs (DO4-O/DO8-O)

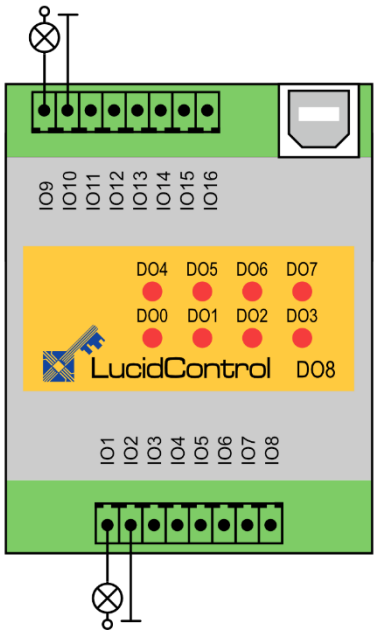

Fig. 8 DO8-O IO Connection

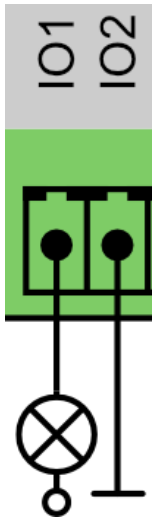

Fig. 9 DO8-O Signal

Fig. 8 shows the connection of the DO8-O module.

Power loads (e.g. a lamp) are connected to IO1 and IO2 (DO0) and IO9 and IO10 (DO4).

Fig. 9 shows the lamp connected to the IO terminals IO1 and IO2 (DO0).

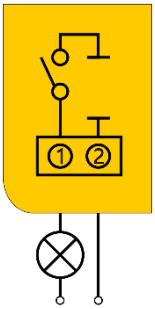

Fig. 10 OC Output

Fig. 10 shows the principle of the digital output channel with open collector transistor outputs.

When the digital output channel is set to high, the transistor connects IO terminal 1 with ground, closing the circuit.

The IO terminals with uneven numbers (e.g. IO1, IO3) are connected to the positive potential.

IO terminals with even numbers (e.g. IO2, IO8) are connected to ground signal.

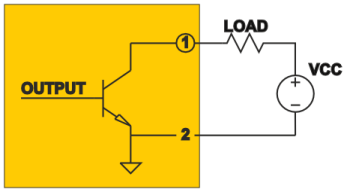

Fig. 11 Open Collector Circuit

The internal circuit of the open collector output is shown in Fig. 11. When the OUTPUT control signal is high, the transistor closes the circuit. This means that IO terminal 1 is connected to ground and the externally applied voltage source VCC powers the load.

The IO terminals of the DO4-O/DO8-O module and their IO channel numbers are listed in Tab. 5.

IO Terminal	Signal	IO Channel Number
1	DO0 +	0
2	GND	
3	DO1 +	1
4	GND	
5	DO2 +	2
6	GND	
7	DO3 +	3
8	GND	
9	DO4 +	4
10	GND	
11	DO5 +	5
12	GND	
13	DO6 +	6
14	GND	
15	DO7 +	7
16	GND	

Tab. 5 DO4-O/DO8-O IO Terminal Connector

Open collector outputs are not protected against overcurrent and overvoltage. I_{OCMax} and U_{OCMax} limits must be considered in. Otherwise, the device may be damaged.

Open collector outputs are not protected against wrong polarization of the applied voltages.

Open collector outputs support reflect mode, duty-cycle mode and on-off mode.

For duty-cycle and on-off modes the minimum on and off times are limited to T_{OCMin}.

2.4.3 4/6 Mechanical Relay SPDT Outputs (DO4-S/DO6-S)

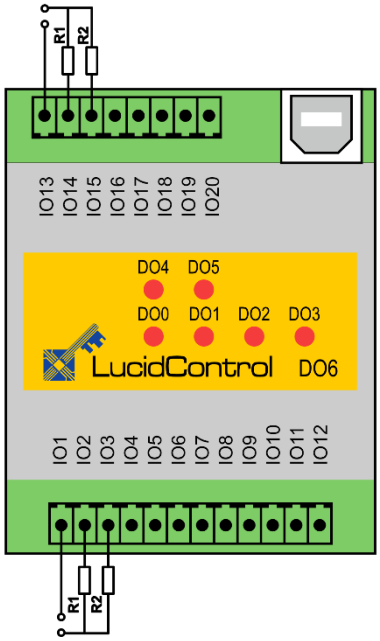

Fig. 12 DO6-S IO Connection

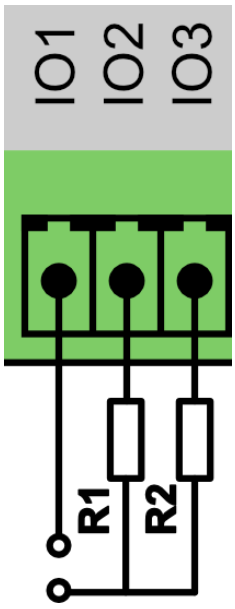

Fig. 13 DO6-S Signal

Fig. 12 shows the connection of the DO6-S module with 6 SPDT relay outputs.

In Fig. 13 two resistors R1 and R2 are connected to the terminals IO2 and IO3 of the digital output channel DO0.

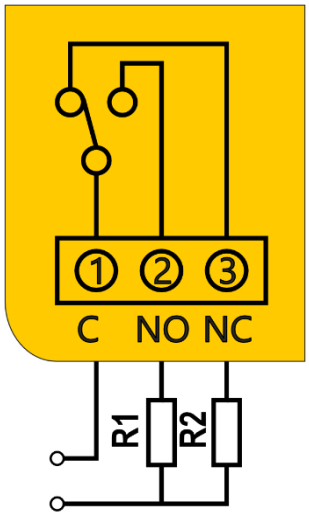

Fig. 14 SPDT Output

Fig. 14 shows the operation principle of the SPDT relay outputs.

The figure shows the inactive active state of channel DO0. In inactive state the common contact (IO1, C) is connected to the normally closed contact (IO3, NC).

If LucidControl is unpowered the relay falls back to the shown state.

If the output is activated, the common contact (C) is connected with the normally open contact (IO2, NO).

IO Terminal	Signal	IO Channel Number
1	C	0
2	NO	
3	NC	
4	C	1
5	NO	
6	NC	
7	C	2
8	NO	
9	NC	
10	C	3
11	NO	
12	NC	
13	C	4
14	NO	
15	NC	
16	C	5
17	NO	
18	NC	
19	Not Connected	
20		

Tab. 6 DO4-S/DO6-S IO Terminal Connector

The IO terminals of the DO4-S/DO6-S module and their IO channel numbers are listed in Tab. 6.

The DO4-S / DO6-S module supports reflect mode and on-off mode.

The DO4-S / DO6-S module should not be used for periodical switching (e.g. PWM) since mechanical relays are limited in number of switching cycles.

The output channels are not protected against overcurrent. It must be ensured that the current does not extend $I_{SPDTMax}$. Otherwise, the output may be damaged.

For On-Off Mode the minimum on and off times are limited to $T_{SPDTMin}$.

3 Module Operation

3.1 Output Signal Value Inversion

Digital output channels have an output signal value and a logical output value. The logical output value is the current state of the output which can be "0" (cleared) or "1" (set). The output signal value is calculated by the output handling.

Read and write commands give access to the logical output value.

In the case that *outDiInverted* (→ 3.5.3.1) is set to "off", the output signal values and logical output values are identical.

In the case that inversion is enabled by setting *outDiInverted* to "on", the output signal value is the inverted logical value. Writing "1" to the output channel value clears the output.

All output modes support output signal value inversion.

3.2 Timing Limits

The different output types of the module make it necessary to limit the timing resolution t_{Res}, which can be found in the specification (→ 4).

The timing resolution specifies the minimum interval for an on-phase or off-phase. If an on-time or off-time is lower than t_{Res} the phase is skipped.

Example:
The output is configured in mode Duty-Cycle with T_{Cycle}=100 ms (100.000 µs) and a DutyCyle of 50‰.

The resulting times are T_{On}=5 ms and T_{Off}=95 ms. Since T_{On} violates the t_{Res} constraint requesting more than 10 ms as minimum, the on-phase of the output is skipped, causing the output staying low permanently.

3.3 Operation Modes

This section describes the operation of the different output modes and gives examples how the outputs can be controlled.

Each of the outputs of the module can work in one of the following modes:

- Reflect Mode
- Duty-Cycle Mode
- On-Off Mode

3.3.1 Reflect Mode

Reflect Mode gives direct access to the logical output value of the output channel.

Writing “1” to the output causes the output being set immediately.

Writing “0” to the output causes the output being cleared immediately.

By setting and clearing outputs in Reflect Mode any pattern of the output signal can be generated, but the timing is limited by the communication protocol and the host computer.

This means e.g., that switching an output on and off every 1ms would need 1000 commands per second. This is not realistic because common operating systems and USB latency do not allow such a fast and deterministic timing.

Duty-Cycle Mode and On-Off Mode improves this by handling the critical timing in the module.

LucidIoCtrl Command Line Tool Example

Configure output channel 0 for Reflect Mode

```
LucidIoCtrl -dCOM4 -c0 -soutDiMode=reflect
```

Set output channel 0 to “1”

```
LucidIoCtrl -dCOM4 -c0 -tL -w1
```

Set the channel 0 back to “0”

```
LucidIoCtrl -dCOM4 -c0 -tL -w0
```

3.3.2 Duty-Cycle Mode and PWM

In Duty-Cycle Mode the module switches outputs on and off in a periodical PWM (pulse-width-modulation) sequence.

By switching an output periodically on and off it is e.g., possible to control the power consumed by a device and can be used for controlling the power of a pump or a heating element.

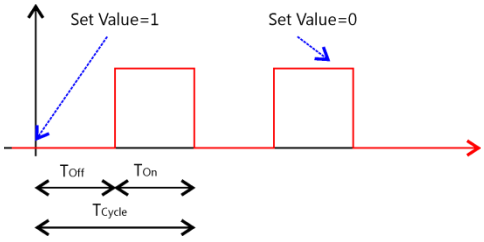

Fig. 15 Duty-Cycle Mode

Fig. 15 shows a periodical signal generated by Duty-Cycle Mode.

Setting the logical output value to “1” starts processing until it is set back to "0".

If the logical output value is set to "0" in off-phase, processing is stopped.

If the value of the output is set to "0" in on-phase, behavior depends on IO Configuration Parameter *outDiCanCancel*.

The timing of the generated signal is configured by two parameters:

- T_{Cycle} defines the cycle time (period) of the signal and can be configured by the IO Configuration Parameter *outDiCycleTime*.
- The IO Configuration Parameter *outDiDutyCycle* defines the relation of the on-time T_{On} and the off-time T_{Off}
  - On-time equals to $T_{On} = \frac{T_{Cycle}}{1000} * DutyCycle$
  - Off-time equals to $T_{Off} = T_{Cycle} - \frac{T_{Cycle}}{1000} * DutyCycle$

The resolution of the generated signal is $\frac{T_{Cycle}}{1000}$ which means that on-time and off-time have a resolution of 1 ‰.

Changing the IO Configuration Parameters *outDiCycleTime* or *outDiDutyCylce* while processing is running updates the values immediately.

The calculated values of T_{on} and T_{off} must be in the limits of t_{Res}. Values outside the limits result in permanent off or on state.

Output Signal Value Inversion:

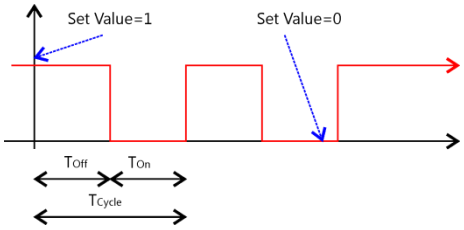

Fig. 16 Duty-Cycle Mode Output Inversion

Fig. 16 shows the output signal value in the case that output signal value inversion is enabled (*outDiInverted* is "on").

Cancelation of On-Phase:

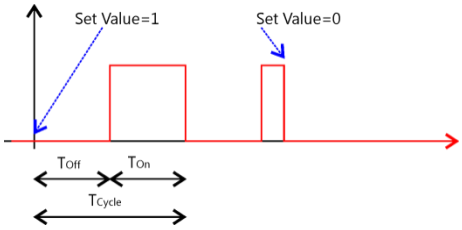

Fig. 17 Duty-Cycle Mode Cancel On-Phase

If output processing is stopped while the output is in on-phase (T_{on}), IO Configuration Parameter *outDiCanCancel* specifies the behavior of stopping.

If *outDiCanCancel* is set to "off" the sequence completes as shown in Fig. 15.

If *outDiCanCancel* is set to "on" the on-phase is interrupted immediately when the output value is set to "0" as shown in Fig. 17.

Updating Parameters
If output processing is running, updates of the IO Configuration Parameters *outDiCycleTime* and *outDiDutyCycle* are applied immediately.

Note:
Mechanical relays have a limited switching capability of approx. 1.000.000 on-off cycles. Because of this the Duty-Cycle Mode is not available for DO4-S module.

LucidIoCtrl Command Line Tool Example
Configure output channel 0 for Duty-Cycle mode

```
LucidIoCtrl -dCOM4 -c0 -soutDiMode=dutyCycle
```

Start processing of PWM signal for output channel 0

```
LucidIoCtrl -dCOM4 -c0 -tL -w1
```

By default, the module is configured with T_{Cycle} = 1 s and DutyCycle = 50%. The output channel is switched 500 ms to “1” and 500 ms to “0”.

Changing T_{Cycle} to 2 s

```
LucidIoCtrl -dCOM4 -c0 -soutDiCycleTime=2000000
```

The output is now 1 s switched on and 1 s switched of

Change DutyCycle to 75%

```
LucidIoCtrl -dCOM4 -c0 -soutDiDutyCycle=750
```

Disable processing of output channel 0

```
LucidIoCtrl -dCOM4 -c0 -tT -w0
```

3.3.3 On-Off Mode

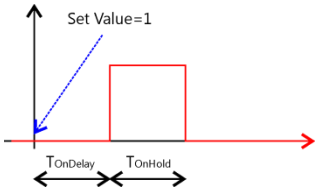

Fig. 18 On-Off Mode

In On-Off Mode the output channel generates a one-time sequence pattern shown in Fig. 18.

By using On-Off Mode time-controlled switching functions (e.g. used in timing relays) can be realized.

Setting the output value to “1” starts processing of the output handling by starting the $T_{OnDelay}$ interval (off-phase). After $T_{OnDelay}$ has passed the output changes to on-phase and T_{OnHold} interval starts. After T_{OnHold} time has passed output changes back to off-phase and the sequence finishes.

Writing "0" to the logical output value while being in off-phase stops the sequence in any case, preventing the output entering on-phase.

If the output value is set to "0" in on-phase, behavior depends on IO Configuration Parameter *outDiCanCancel*.

In On-Off Mode the following two IO Configuration Parameters are relevant for timing configuration:

- Time $T_{OnDelay}$ is specified by the parameter *outDiOnDelay*
- Time T_{OnHold} is specified by the parameter *outDiOnHold*

If the values of T_{OnHold} or $T_{OnDelay}$ are outside the limits of t_{Res} off-phase or on-phase are skipped.

Output Signal Value Inversion

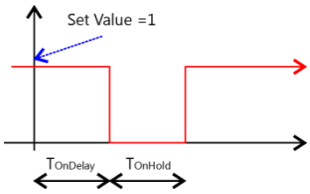

Fig. 19 On-Off Mode Output Inversion

Fig. 19 shows the output signal in case that the output signal inversion is enabled for the output channel (*outDiInverted* set to "on").

Cancelation of On-Phase

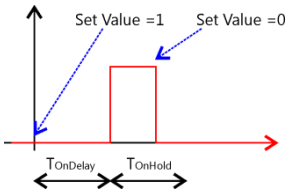

Fig. 20 On-Off Mode Cancel On Phase

If the IO Configuration Parameter *outDiCanCancel* is set to "on", output processing can be stopped by writing "0" to the output channel value. This is shown in Fig. 20 where the on-phase is immediately interrupted before T_{OnHold} has passed.

Writing "0" to the logical output value while being in on on-phase is ignored if *outDiCanCancel* is set to "off".

Retrigger of On-Phase

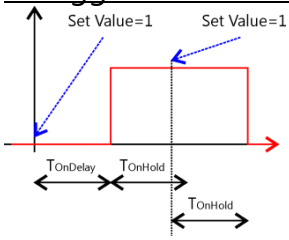

Fig. 21 On-Off Mode Retrigger

Fig. 21 shows the output timing sequence with IO Configuration Parameter *outDiCanRetrigger* set to "on".

This setting allows retriggering the on-phase before the logical output returns to initial "0" value.

Setting the logical output value to "1" before T_{OnHold} has passed restarts the T_{OnHold} interval.

LucidIoCtrl Command Line Tool Example

Configure output channel 0 for On-Off mode

```
LucidIoCtrl –dCOM4 –c0 –soutDiMode=onoff
```

By default, $T_{OnDelay}$ and T_{OnHold} are set to 1s.
After writing a “1” to the output value of channel 0 the output will be set after 1s to “1” returning to “0” after 1s more.

Start processing of output channel 0

```
LucidIoCtrl –dCOM4 –c0 –tL –w1
```

3.4 Commands

LucidControl IO Modules can be accessed by the Frame Protocol which is documented in the general *LucidControl User Manual*.

This section describes in detail the commands which are supported by the DO4/DO6/DO8 modules.

3.4.1 SetIo

This command sets one output value.

Mode	Value
Reflect	Value reflects the logic state to the output
Duty-Cycle	**Value** / 0: Processing disabled / 1: Processing enabled
On-Off	**Value** / 0: Processing disabled / 1: Processing enabled, triggered

Tab. 7 SetIo Output Values

Tab. 7 lists the digital output channel modes and how the IO value is interpreted.

Command	SetIo	**Access**	Write
Opcode	0x40		
LucidIoCtrl Command Line Tool			
Call (-tL)	`LucidIoCtrl -d[COMx] -c[Channel] -tL -w[Value]`		

Tab. 8 SetIo Command

LucidIoCtrl Command Line Tool Example

Set output channel 0 to "1":

```
LucidIoCtrl -dCOM4 -c0 -tL -w1
```

Request Frame

OPC	P1	P2	LEN	Data Field
0x40	Channel	Value Type	Length	Value

Tab. 9 SetIo Request Frame

Value	Description
Channel	Number of input or output channel (Range: 0 - 7)
Value Type	Supported Value Types **Value Type** / **Value Range** / **Length** Digital Logic Value (0x00) / 0 / 1 / 1 Byte
Length	Length of the Values in the Data Field
Value	Values accordingly to the Value Type

Tab. 10 SetIo Request

Response Frame

Status	Length
Status	0

Tab. 11 SetIo Response Frame

Returns Execution Status Code, documented in the general *LucidControl User Manual*.

3.4.2 SetIoGroup

This command sets the output values of a group of outputs.

Tab. 7 lists the digital output channel modes and how the IO value is interpreted.

Command	SetIoGroup	**Access**	Write
Opcode	0x42		
LucidIoCtrl Command Line Tool			
Call (-tL)	`LucidIoCtrl –d[COMx] –c[Channels] –tL –w[Values]` Channels: Comma separated list of channels e.g. –c0,1,3 Values: Comma separated list of values to set e.g. -w1,1,0		

Tab. 12 SetIoGroup Command

LucidIoCtrl Command Line Tool Example

Set output channel 0 to “1”, output channel 2 to “1” and output channel 3 to “0”:

```
LucidIoCtrl –dCOM4 –c0,2,3 –tL –w1,1,0
```

Request Frame:

OPC	P1	P2	LEN	Data Field
0x42	Channel Mask	Value Type	Length	Values

Tab. 13 SetIoGroup Request Frame

<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 present.

<u>Examples:</u>
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 OR 0x80= 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>Length</th></tr>
<tr><td>Digital Logic Value (0x00)</td><td>0x00 oder 0x01</td><td>1 Byte</td></tr>
</table></td></tr>
<tr><td>Length</td><td>Length of the Values in the Data Field (One Value for each channel)</td></tr>
<tr><td>Values</td><td>One or more values to set in channel number ascending order</td></tr>
</table>

Tab. 14 SetIoGroup Request

<u>Response Frame</u>

Status	Length
Status	0

Tab. 15 SetIoGroup Response Frame

Returns Execution Status Code, documented in the general *LucidControl User Manual*.

<u>Example of SetIoGroup</u>

Request frame sets output channel 0 to “1”, channel 1 to “1” and channel 3 to “0”

Request Frame

OPC	P1	P2	LEN	Data Field
0x42	0x0B	0x00	0x03	Byte: 0 = 0x01, 1 = 0x01, 2 = 0x00

Tab. 16 SetIoGroup Request Example

Channel Mask for Param1: 0x01 OR 0x02 OR 0x08 = 0x0B

Response Frame:

Status	Length
0x00	0x00

Tab. 17 SetIoGroup Response Example

3.4.3 GetIo

This command reads the value or state of a digital output channel.

In the case that the output mode is Duty-Cycle or On-Off, the value returns the processing state of the output. "1" indicates processing running, "0" processing stopped.

Command	GetIo	**Access**	Read
Opcode	0x46		
LucidIoCtrl Command Line Tool			
Call (-tL)	`LucidIoCtrl –d[COMx] –c[Channel] –tL –r`		
Return	CHn:LL n: Input Channel LL: Input Digital Value		

Tab. 18 GetIo Command

LucidIoCtrl Command Line Tool Example

Read output channel 0:

```
      LucidIoCtrl –dCOM4 –c0 –tL -r
->    CH0:01
```

Request Frame

OPC	P1	P2	LEN
0x46	Channel	Value Type	0

Tab. 19 GetIoRequest Frame

<table>
<tr><th>Value</th><th>Description</th></tr>
<tr><td>Channel</td><td>Number of input or output channel (Range: 0 - 7)</td></tr>
<tr><td>Value Type</td><td>Supported Value Types
<table>
<tr><th>Value Type</th><th>Value Range</th><th>Response Len</th></tr>
<tr><td>Digital Logic Value (0x00)</td><td>0x00 oder 0x01</td><td>1 Byte</td></tr>
</table>
</td></tr>
</table>

Tab. 20 GetIo Request

Response Frame:

Status	LEN	Data Field
Status	Length	Value

Tab. 21 GetIo Response Frame

Returns Execution Status Code, documented in the general *LucidControl User Manual*.

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

3.4.4 GetIoGroup

This command reads the logic output values of a group of outputs of the same Value Type.

Command	GetIoGroup	**Access**	Read
Opcode	0x48		
LucidIoCtrl Command Line Tool			
Call (-tL)	`LucidIoCtrl –d[COMx] –c[Channels] –tL –r` Channels: Comma separated list of channels e.g. –c0,1,3		
Return	List of values sorted from lower to higher channels CHn:LL n – Channel LL – Digital Value		

Tab. 22 GetIoGroup Command

LucidIoCtrl Command Line Tool Example

Read output values of channel 0, 1 and 3:

```
      LucidIoCtrl –dCOM4 –c0,1,3 –tL –r
->    CH0:00  CH1:01  CH3:01
```

Request Frame

OPC	P1	P2	LEN
0x48	Channel Mask	Value Type	0

Tab. 23 GetIoGroup Request Frame

<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.

<u>Examples:</u>
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>Response Len</th></tr>
<tr><td>Digital Logic Value (0x00)</td><td>0x00 or 0x01</td><td>1 Byte</td></tr>
</table></td></tr>
</table>

Tab. 24 GetIoGroup Command

<u>Response Frame:</u>

Status	LEN	Data Field
Status	Length	Value(s)

Tab. 25 GetIoGroup Response Frame

Returns Execution Status Code, documented in the general *LucidControl User Manual*.

In case of successful execution, the command returns the read values of the channels specified in the Channel Mask in channel number ascending order.

<u>Example of GetIoGroup Request:</u>

Request frame reads output channels 0, 1 and 7.

OPC	P1	P1A	P2	Length
0x48	0x83	0x01	0x00	0x00

Tab. 26 GetIoGroup Request Example

Response Frame:
For output 0 = “0”, output 1 = “1” and output 7 = “1”

Values in Data Field are in ascending order Channel 0, Channel 1, Channel 7.

Header Field		Data Field		
Status	LEN	CH 0	CH1	CH7
0x00	0x03	0x00	0x01	0x01

Tab. 27 GetIoGroup Response Example

3.5 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 *LucidControl User Manual*.

Parameter values can be made persistent in the non-volatile memory of the microcontroller e.g., by adding the -p argument to LucidIoCtrl or by setting the persistent parameter in the API function to true. Values of persistent parameters are restored when LucidControl is powered on.

The number of write cycles to the non-volatile memory is limited. Write operations wear out the non-volatile memory and periodical updates of persistent parameter values should be avoided in order not to destroy the device over time.

3.5.1 outDiValue

This IO Configuration Parameter reflects the value or the state of the output.

In the case that the output is in Reflect mode the *outDiValue* contains the value of the output.

In the case that the output is operating in Duty-Cycle or On-Off mode, *outDiValue* contains "1" when the output processing is running and "0" when the output processing is stopped.

Parameter	*outDiValue*	**Access**	Read / Write
Address	0x1000		
Values	Output Value		
Default Value	0x00	**Parameter Type**	1 Byte unsigned
LucidIoCtrl Command Line Tool			
Parameter Name	*outDiValue*	**Parameter Values**	0 / 1
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –soutDiValue=[Value] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –goutDiValue`		

Tab. 28 IO Configuration Parameter outDiValue

LucidIoCtrl Command Line Tool Example

Set value of output channel 0 to "1" and make the setting persistent:

```
LucidIoCtrl –dCOM4 –c0 –soutDiValue=1 –p
```

Read value or state of output channel 0:

```
      LucidIoCtrl –dCOM4 –c0 –goutDiValue
->    outDiValue=1
```

Setting *outDiValue* allows to assign a persistent value by means that the output value is restored after the module is restarted.

3.5.2 outDiMode

This IO Configuration parameter configures the operation mode of the output.

<table>
<tr><td>Parameter</td><td>outDiMode</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">Output Mode<table><tr><th>Byte</th><th>Mode</th></tr><tr><td>0x00</td><td>Inactive</td></tr><tr><td>0x01</td><td>Reflect</td></tr><tr><td>0x08</td><td>On-Off</td></tr><tr><td>0x0A</td><td>Duty-Cycle</td></tr></table></td></tr>
<tr><td>Default Value</td><td>0x01</td><td>Parameter Type</td><td>1 Byte unsigned</td></tr>
<tr><td colspan="4">LucidIoCtrl Command Line Tool</td></tr>
<tr><td>Parameter Name</td><td>outDiMode</td><td>Parameter Values</td><td>incactive / reflect / onoff / dutyCycle</td></tr>
<tr><td>Call (Set)</td><td colspan="3"><code>LucidIoCtrl -d[COMx] -c[Channel] -soutDiMode=[Value] {-p} {--default}</code></td></tr>
<tr><td>Call (Get)</td><td colspan="3"><code>LucidIoCtrl -d[COMx] -c[Channel] -goutDiMode</code></td></tr>
</table>

Tab. 29 IO Configuration Parameter outDiMode

LucidIoCtrl Command Line Tool Example

Set operation mode of channel 0 to Duty-Cycle Mode and make the setting persistent.

```
      LucidIoCtrl -dCOM4 -c0 -soutDiMode=dutyCycle -p
```

Read the operation mode of channel 0

```
      LucidIoCtrl -dCOM4 -c0 -goutDiMode
->    outDiMode=dutyCycle
```

3.5.3 Bit Parameter outDiFlags

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

Parameter	*outDiFlags*	**Access**	Read / Write
Address	0x1101		
Values	The value consists of these bit parameters **Bit Parameter** / **Bit Position** *outDiCanRetrigger* / Bit 0 *outDiCanCancel* / Bit 1 *outDiInverted* / Bit 2		
Default Value	0x00	**Parameter Type**	1 Byte unsigned

Tab. 30 IO Configuration Parameter outDiFlags

The parameter *outDiFlags* cannot be accessed directly by using the Command Line Tool. The Bit Parameters should be used instead.

If *outDiFlags* is changed by the SetParam command this must be done in a read-modify-write sequence in order to prevent overwriting other bit parameters.

3.5.3.1 outDiInverted

This Bit Parameter configures the output signal value inversion.

Parameter	*outDiFlags*	**Access**	Read / Write
Address	0x1101	Bit Parameter outDiFlags	
Values	**Bit Parameter** / **Bit Position** *outDiInverted* / Bit 2		
Default Value	Off	**Parameter Type**	1 Bit
LucidIoCtrl Command Line Tool			
Parameter Name	*outDiInverted*	**Parameter Values**	on / off
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –soutDiInverted=[Value] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –goutDiInverted`		

Tab. 31 IO Configuration Parameter Bit outDiInverted

LucidIoCtrl Command Line Tool Example

Enable output signal value inversion of output channel 0 and make the setting persistent.

```
LucidIoCtrl–dCOM4 –c0 –soutDiInverted=on –p
```

Read output signal value inversion flag of output channel 0.

```
      LucidIoCtrl –dCOM4 –c0 –goutDiInverted
->    outDiInverted=on
```

3.5.3.2 outDiCanCancel

This Bit Parameter configures the output on-phase cancelation.

Parameter	*outDiFlags*	**Access**	Read / Write
Address	0x1101	Bit Parameter outDiFlags	
Values	**Bit Parameter**: *outDiCanCancel* — **Bit Position**: Bit 1		
Default Value	Off	**Parameter Type**	1 Bit
LucidIoCtrl Command Line Tool			
Parameter Name	*outDiCanCancel*	**Parameter Values**	on / off
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –soutDiCanCancel=[Value] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –goutDiCanCancel`		

Tab. 32 IO Configuration Parameter Bit outDiCanCancel

LucidIoCtrl Command Line Tool Example

Enable output cancelation output channel 0 and make the setting persistent.

```
LucidIoCtrl –dCOM4 –c0 –soutDiCanCancel=on –p
```

Read configuration of output cancelation of output channel 0

```
LucidIoCtrl –dCOM4 –c0 –goutDiCanCancel
->  outDiCanCancel=on
```

3.5.3.3 outDiCanRetrigger

This Bit Parameter configures the on-phase retrigger function of the output.

Parameter	*outDiFlags*	**Access**	Read / Write
Address	0x1101	Bit Parameter outDiFlags	
Values	**Bit Parameter**: *outDiCanRetrigger* — **Bit Position**: Bit 0		
Default Value	Off	**Parameter Type**	1 Bit
LucidIoCtrl Command Line Tool			
Parameter Name	*outDiCanRetrigger*	**Parameter Values**	on / off
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –soutDiCanRetrigger=[Value] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –goutDiCanRetrigger`		

Tab. 33 IO Configuration Parameter Bit outDiCanRetrigger

LucidIoCtrl Command Line Tool Example

Enable output retrigger of channel 0 and make the setting persistent.

```
LucidIoCtrl –dCOM4 –c0 –soutDiCanRetrigger=on –p
```

Read output retrigger configuration of output channel 0

```
LucidIoCtrl –dCOM4 –c0 –goutDiCanRetrigger
```

```
->    outDiCanRetrigger=on
```

3.5.4 outDiCycleTime

This IO Configuration Parameter specifies the cycle time T_{Cycle} of an output in Duty-Cycle Mode.

Parameter	*outDiCycleTime*	**Access**	Read / Write
Address	0x1110		
Values	T_{Cycle} in µs (micro seconds) $t_{Res} \leq T_{Cycle} \leq 1$ h		
Default Value	1,000,000 (1 s)	**Parameter Type**	4 Bytes unsigned
LucidIoCtrl Command Line Tool			
Parameter Name	*outDiCycleTime*	**Parameter Values**	Time [µs]
Call (Set)	`LucidIoCtrl -d[COMx] -c[Channel] -soutDiCycleTime=[Time] {-p} {--default}`		
Call (Get)	`LucidIoCtrl -d[COMx] -c[Channel] -goutDiCycleTime`		

Tab. 34 IO Configuration Parameter outDiCycleTime

LucidIoCtrl Command Line Tool Example

Set T_{Cycle} of output channel 0 to 1.5s.

```
      LucidIoCtrl -dCOM4 -c0 -soutDiCycleTime=1500000
```

Read T_{Cycle} parameter of output channel 0

```
      LucidIoCtrl -dCOM4 -c0 -goutDiCycleTime
->    outDiCycleTime=1500000
```

If the cycle time is changed frequently, the value must not be made persistent in order to avoid wear-out of non-volatile memory.

Note:
Timing limits for t_{Res} (→ 3.2) have to be considered.

3.5.5 outDiDutyCycle

This IO Configuration Parameter specifies the duty-cycle of an output in Duty-Cycle mode.

Parameter	*outDiDutyCycle*	**Access**	Read / Write
Address	0x1111		
Values	Duty Cycle in ‰ (1 / 1000)		
Default Value	500 (50%)	**Parameter Type**	2 Bytes unsigned
LucidIoCtrl Command Line Tool			
Parameter Name	*outDiDutyCycle*	**Parameter Values**	Duty Cycle [‰]
Call (Set)	`LucidIoCtrl -d[COMx] -c[Channel] -soutDiDutyCycle=[Value] {-p} {--default}`		
Call (Get)	`LucidIoCtrl -d[COMx] -c[Channel] -goutDiDutyCylce`		

Tab. 35 IO Configuration Parameter outDiDutyCycle

LucidIoCtrl Command Line Tool Example

Set Duty Cycle of output channel 0 to 20%.

```
      LucidIoCtrl –dCOM4 –c0 –soutDiDutyCycle=200
```

Read Duty Cycle setting for output channel 0

```
      LucidIoCtrl –dCOM4 –c0 –goutDiDutyCycle
->    outDiDutyCycle=200
```

If the duty-cycle is changed frequently, the value must not be made persistent in order to avoid wear-out of non-volatile memory (→ 3.5).

Note:
Timing limits (→ 3.2) have to be considered.

3.5.6 outDiOnDelay

This IO Configuration Parameter specifies the on-delay time $T_{OnDelay}$ of an output in On-Off Mode.

Parameter	*outDiOnDelay*	**Access**	Read / Write
Address	0x1112		
Values	$T_{OnDelay}$ in µs (micro seconds) $t_{Res} \leq T_{OnDelay} \leq 1$ h		
Default Value	1,000,000 (1 s)	**Parameter Type**	4 Bytes unsigned
LucidIoCtrl Command Line Tool			
Parameter Name	*outDiOnDelay*	**Parameter Values**	Time [µs]
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –soutDiOnDelay=[Time] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –goutDiOnDelay`		

Tab. 36 IO Configuration Parameter outDiOnDelay

LucidIoCtrl Command Line Tool Example

Set $T_{OnDelay}$ of output channel 0 to 520 ms and make the setting persistent.

```
      LucidIoCtrl –dCOM4 –c0 –soutDiOnDelay=520000 –p
```

Read $T_{OnDelay}$ setting for output channel 0

```
      LucidIoCtrl –dCOM4 –c0 –goutDiOnDelay
->    outDiOnDelay=520000
```

Note:
Timing limits (→ 3.2) have to be considered.

3.5.7 outDiOnHold

This IO Configuration Parameter specifies the on-hold time T_{OnHold} of an output in On-Off Mode.

Parameter	*outDiOnHold*	**Access**	Read / Write
Address	0x1113		
Values	T_{OnHold} in µs (micro seconds) $t_{Res} \leq T_{OnHold} \leq 1$ h		
Default Value	1,000,000 (1 s)	**Parameter Type**	4 Bytes unsigned
LucidIoCtrl Command Line Tool			
Parameter Name	*outDiOnHold*	**Parameter Values**	Time [µs]
Call (Set)	`LucidIoCtrl –d[COMx] –c[Channel] –soutDiOnHold=[Time] {-p} {--default}`		
Call (Get)	`LucidIoCtrl –d[COMx] –c[Channel] –goutDiOnHold`		

Tab. 37 IO Configuration Parameter outDiOnHold

LucidIoCtrl Command Line Tool Example

Set T_{OnHold} of output channel 0 to 1200 ms and make the setting persistent.

```
LucidIoCtrl –dCOM4 –c0 –soutDiOnHold=1200000 –p
```

Read T_{OnHold} setting of output channel 0

```
LucidIoCtrl –dCOM4 –c0 –goutDiOnHold
->  outDiOnHold=1200000
```

Note:

Timing limits (→ 3.2) have to be considered.

4 Specification

Parameter		Condition	Value	
Outputs				
	No of Output Channels			4/6/8
Outputs - Electrical Characteristics @ 25°C				
	Maximum Rated Load Current [Note1]	DO4-I/DO8-I	I_{SSRMax}	750 mA
		DO4-O/DO8-O	I_{OCMax}	750 mA
		DO4-S/DO6-S	$I_{SPDTMax}$	750 mA
	Maximum Rated Load Voltage	DO4-I/DO8-I	U_{SSRMax}	24 V
		DO4-O/DO8-O	U_{OCMax}	24 V
		DO4-S/DO6-S	$U_{SPDTMax}$	24 V
	Maximum On Resistance	DO4-I/DO8-I	R_{SSR}	0.25 Ω
		DO4-O/DO8-O	R_{OC}	tbd
		DO4-S/DO6-S	R_{SPDT}	0.1 Ω
Outputs – Timing Characteristic				
	Minimum Resolution	DO4-I/DO8-I	t_{Res}	10 ms
		DO4-O/DO8-O		0.5 ms
		DO4-S/DO6-S		100 ms
	T_{Cycle}, $T_{OnDelay}$, T_{OnHold}		t_{Res} < T < 3600 s	
Module – Communication				
	USB			2.0 Full Speed CDC Profile
Module – Electrical Characteristics				
	Power Supply			Supplied with +5V by USB No additional Power Supply needed.
	Maximum Rated Supply Current	DO4-I/DO8-I		40 mA
		DO4-O/DO8-O		40 mA
		DO4-S/DO6-S		250 mA
Module – Environment				
	Temperature	Storage		-20 °C … +70 °C
		Operation		0 °C … +55 °C
	Humidity			< 85 % RH, non-condensing
Module – Housing				
	Dimension 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

Software		
	Supported Systems	MS Windows 7 and higher Ubuntu, Raspbian, Debian

Tab. 38 Device Specification

Note1 Output channels are able to control resistive loads only. For inductive loads additional protection is necessary.

Module is specified at environmental temperature of 25°C.

5 Order Information

Order Code	Product
LCTR-DO4-I	LucidControl Digital Output USB Module with 4 Channels of Solid State Relays (SSR)
LCTR-DO4-O	LucidControl Digital Output USB Module with 4 Channels of Open Collectors (OC)
LCTR-DO4-S	LucidControl Digital Output USB Module with 4 Channels of Relays (SPDT)
LCTR-DO8-I	LucidControl Digital Output USB Module with 8 Channels of Solid State Relays (SSR)
LCTR-DO8-O	LucidControl Digital Output USB Module with 8 Channels of Open Collectors (OC)
LCTR-DO6-S	LucidControl Digital Output USB Module with 6 Channels of Relays (SPDT)

Tab. 39 Digital Output Module Order Codes

6 Document Revision

Date	Rev.	
2018/08/04	2.0	• Added documentation of DO8 module • Added documentation of USB Isolation
2020/08/27	2.1	• Updated On-Off and Duty-Cycle Mode
2024/08/19	2.2	• General Review • Added DO6-S

Tab. 40 Document Revision

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