

CEBO-LC

CEBO-LC is a universal measurement and automation device. It has a plug-and-play USB interface which is isolated to prevent mutual interference between the computer and all the many things you want to connect to.

Its electronics is capsuled in a rugged aluminum housing, which has rubber fittings for a secure grip.

Connecting sensors and actuators can be achieved easily using the built-in screw terminals. Custom extensions can simply be plugged in to its extension DB25 connector.

There is no AC adapter required. High accuracy and extreme reliability are hallmarks of this device.

The mainboard is also available as an OEM version. You can embed it in your devices, machines or equipment and save the time and costs of designing your own electronics. Contact us to find out details.

Applications

- Measuring voltages and resistances
- Detecting sensor signals and digital states
- Automate experiments and tests,
- Control of special machines
- Monitoring of processes
- Setting analog values from a PC or Mac
- Switch of digital signals
- Event counting

Features

Analog inputs

- 14 single-ended or seven differential or any combination
- 16bit resolution
- Software programmable gains: x1, x10, x100, x1000
- Analog input ranges: $\pm 10V$, $\pm 1V$, $\pm 100mV$, $\pm 10mV$
- Instrumentation amplifier inputs
- SAR 65.000 - 85.000 Samples/s (depending on the number of enabled inputs)

Analog outputs

- Two single-ended
- 12bit resolution
- $\pm 10V$ output swing
- 50Ω impedance
- Short-circuit proof

Digital IO

- 20 general purpose I/O
- Individually configurable as input or output
- CMOS voltage levels (3,3V nominal)
- 5V tolerant
- Short-circuit proof

Additional

- Built-in temperature sensor
- One trigger input / output
- One counter input
- Two constant-current outputs ($200\mu A$ / $10\mu A$)
- Two power outputs (5V)

- Two status LEDs

USB interface

- USB1.1 and USB2.0 compatible
- Full-Speed (12Mbit)
- Isolated to improve measurement performance and protect host computer
- High retention USB connector to prevent unintended disconnection

Supported operating systems

- Microsoft Windows (Vista, 7, 8) (32bit + 64bit)
- Microsoft Windows XP (32bit)
- Mac OS X, 10.6 or higher
- Linux (PC/Desktop), tested on Ubuntu 12.04 LTS (32bit + 64bit)
- Linux on Raspberry Pi (Wheezy)

Supported programming languages/interfaces

- C++
- Java
- .NET
- Python
- LabVIEW (on Windows platforms)
- ProfiLab (on Windows platforms)

Hardware description

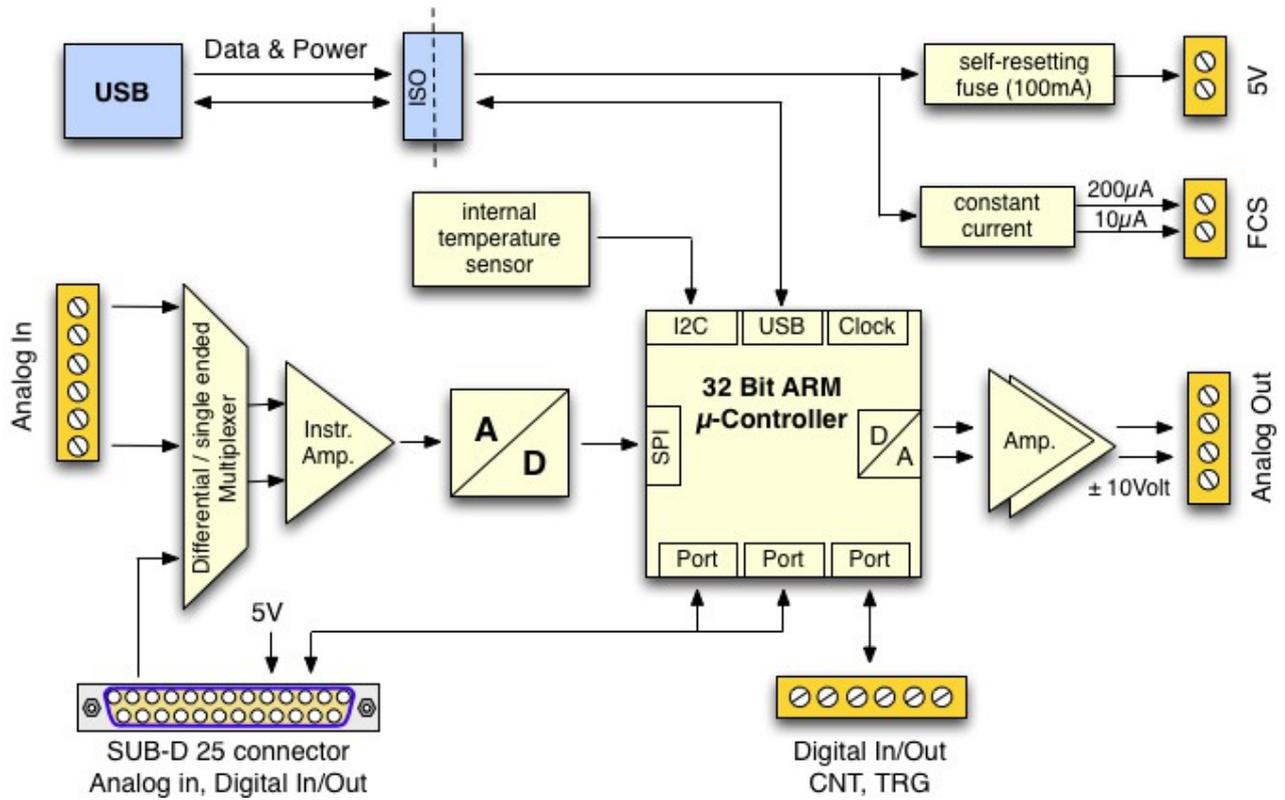


Figure 1: Simplified block diagram

Parameter	Min.	Typ.	Max.	Unit
Dimensions (B x W x H)		75 x 113 x 36		mm
Operating temperature range	0	23	70	°C
Typical power consumption		250		mA

Screw terminals

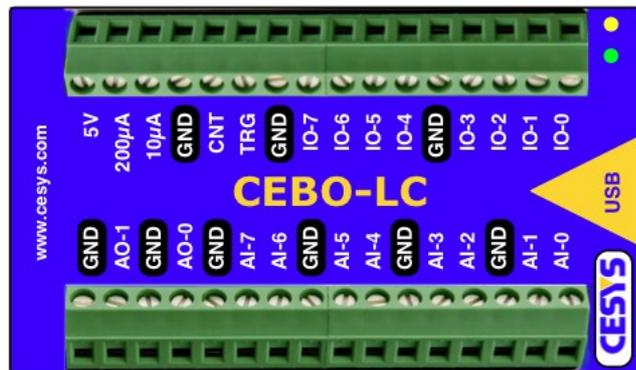


Figure 2: Screw terminal pin assignment

A selection of CEBO-LC signals is available on industry standard 5mm screw terminals:

- Eight single-ended analog inputs
- Two single-ended analog outputs
- Eight digital input/output signals
- Trigger input/output signal
- Counter input signal
- Two constant-current outputs (200µA/10µA)
- Power output (5V)
- Nine GND terminals

Signal	Comment	Signal	Comment
GND¹		5V²	Power output
AO-1	Analog output 1	200 μ A	Constant-current output
GND¹¹		10 μ A	Constant-current output
AO-0	Analog output 0	GND¹¹	
GND¹¹		CNT	Counter input
AI-7	Analog input 7	TRG	Trigger input/output
AI-6	Analog input 6	GND¹¹	
GND¹¹		IO-7	Digital input/output (PORT0, IO7)
AI-5	Analog input 5	IO-6	Digital input/output (PORT0, IO6)
AI-4	Analog input 4	IO-5	Digital input/output (PORT0, IO5)
GND¹¹		IO-4	Digital input/output (PORT0, IO4)
AI-3	Analog input 3	GND¹¹	
AI-2	Analog input 2	IO-3	Digital input/output (PORT0, IO3)
GND¹¹		IO-2	Digital input/output (PORT0, IO2)
AI-1	Analog input 1	IO-1	Digital input/output (PORT0, IO1)
AI-0	Analog input 0	IO-0	Digital input/output (PORT0, IO0)

1 All GND terminals are internally connected to the same signal.

2 All 5V power outputs are internally connected. A total of 100mA of current can be sourced.

Protective circuit of digital signals on screw terminals

All digital signals are short-circuit proof³ and protected against temporary over-voltage.

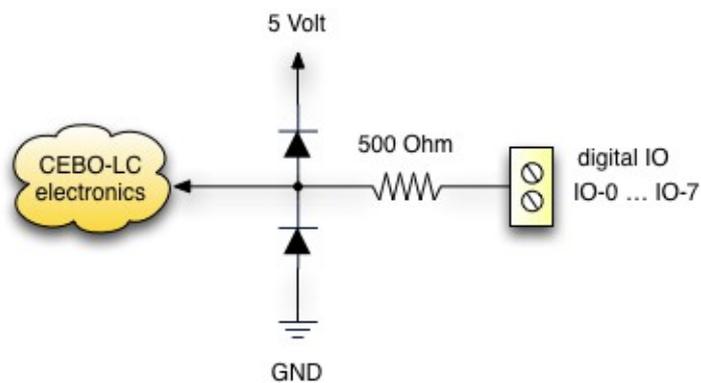


Figure 3: Protective circuit of digital signals on screw terminals.

Please note the different value of the series resistors for inputs/outputs located on screw terminals and those available at D-Sub pins.

³ Single IO only. Keep total current below 25mA.

Expansion connector (DB25)

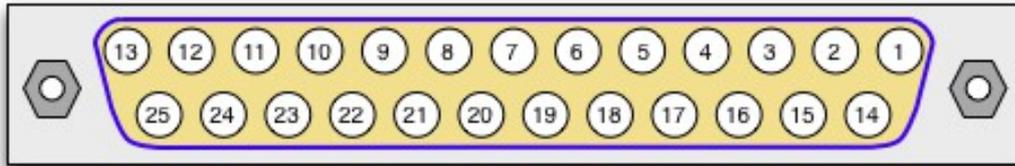


Figure 4: Expansion connector DB25

Additional to the industry standard 5mm screw terminals, CEBO-LC comes with a 25pin D-Sub jack of female type. A lot of CEBO-LC Input/Output signals not available on the screw terminals are routed to this expansion connector:

- Six Single-Ended Analog Inputs
- Twelve Digital I/O signals
- 5V Power Output
- Six GND signals

Pin	Signal	Comment	Pin	Signal	Comment
1	GND¹¹		14	5V²²	Power output
2	IO-8	Digital input/output (PORT1, IO0)	15	IO-9	Digital input/output (PORT1, IO1)
3	IO-10	Digital input/output (PORT1, IO2)	16	IO-11	Digital input/output (PORT1, IO3)
4	IO-12	Digital input/output (PORT1, IO4)	17	GND¹¹	
5	GND¹¹		18	IO-13	Digital input/output (PORT1, IO5)
6	IO-14	Digital input/output (PORT1, IO6)	19	IO-15	Digital input/output (PORT1, IO7)
7	IO-16	Digital input/output (PORT2, IO0)	20	IO-17	Digital input/output (PORT2, IO1)
8	IO-18	Digital input/output (PORT2, IO2)	21	IO-19	Digital input/output (PORT2, IO3)
9	GND¹¹		22	GND¹¹	
10	AI-13	Analog input 13	23	AI-12	Analog input 12
11	AI-11	Analog input 11	24	AI-10	Analog input 10
12	AI-9	Analog input 9	25	AI-8	Analog input 8
13	GND¹¹				

Protective circuit of digital signals on DB25

All digital signals on connector DB25 are short-circuit proof² and protected against temporary over-voltage.

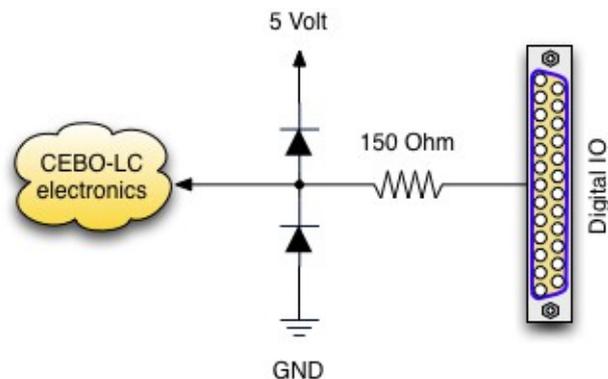


Figure 5: Protective circuit of digital signals on screw terminals.

Please note the different value of the series resistors for inputs/outputs located on D-Sub pins and those available at screw terminals.

Driving a Led with a digital output on DB25

You can use digital outputs on connector DB25 to drive a Led without the need for an additional series resistor. The internal protection resistor then will act as a current limiter.

Example:

Output Voltage when "high": 3,3V

Typical forward voltage of a red Led: 1,8V (2,1V typical for green Led)

Current flow: $(3,3V - 1,8V) / 150 \text{ Ohm} = 10\text{mA}$

USB interface

CEBO-LC is a full-speed USB 2.0 device. USB connection provides communication and power. CEBO-LC GND signal is isolated from USB/PC ground. Hence, mutual interference between host system and CEBO-LC I/O signals is avoided.

In other words: The CEBO-LC signals labeled GND are **not** connected to the host computer chassis or the host computer GND. This is a big advantage when precise and noise-free measurements are desired.

Because it is already built-in, there is no need to use an additional external USB-ISOLATOR:

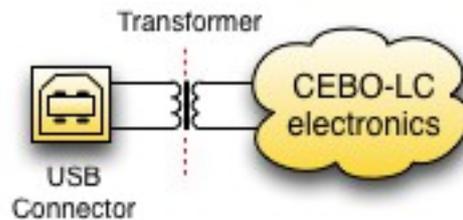


Figure 6: CEBO-LC comes with integrated USB isolation

CEBO-LC USB features
USB1.1 and USB2.0 compatible
Full-Speed (12Mbit)
Isolated to improve measurement performance and protect the host computer
High retention USB connector to prevent unintended disconnection
Isolation rated for 500V / 60Hz (1000VDC for one second)

Important: CEBO-LC is not approved for medical use.

Power and status LEDs

CEBO-LC comes with two status LEDs. The yellow LED indicates USB connection and traffic while the green LED indicates power status or helps identifying a special CEBO-LC device optically.



Figure 7: CEBO-LC power and status LEDs

Green LED

Primarily the green LED signals power supply connection status. If CEBO-LC is powered (i.e. is plugged to a host or to an USB hub) the LED will turn on.

Additionally, the green LED can be switched off and on via software command. This way, when you use more than one CEBO-LC device with a single host system, you can identify a special device by setting/resetting the LED.

Yellow LED

The yellow LED signals USB connection status and traffic. Default status after successfully establishing the USB link is on. With every USB transfer a short blink is initiated. Therefore blinking speed can be a measure of USB traffic.

Analog inputs

- Eight single-ended (AI-0 to AI-7) or four differential on screw terminals
- Six single-ended (AI-8 to AI-13) or three differential on expansion connector DB25
- 16bit resolution
- Software programmable gains: x1, x10, x100, x1000
- Analog input ranges: $\pm 10V$, $\pm 1V$, $\pm 100mV$, $\pm 10mV$
- Instrumentation amplifier inputs
- SAR 65.000 - 85.000 Samples/s (depending on the number of enabled inputs)

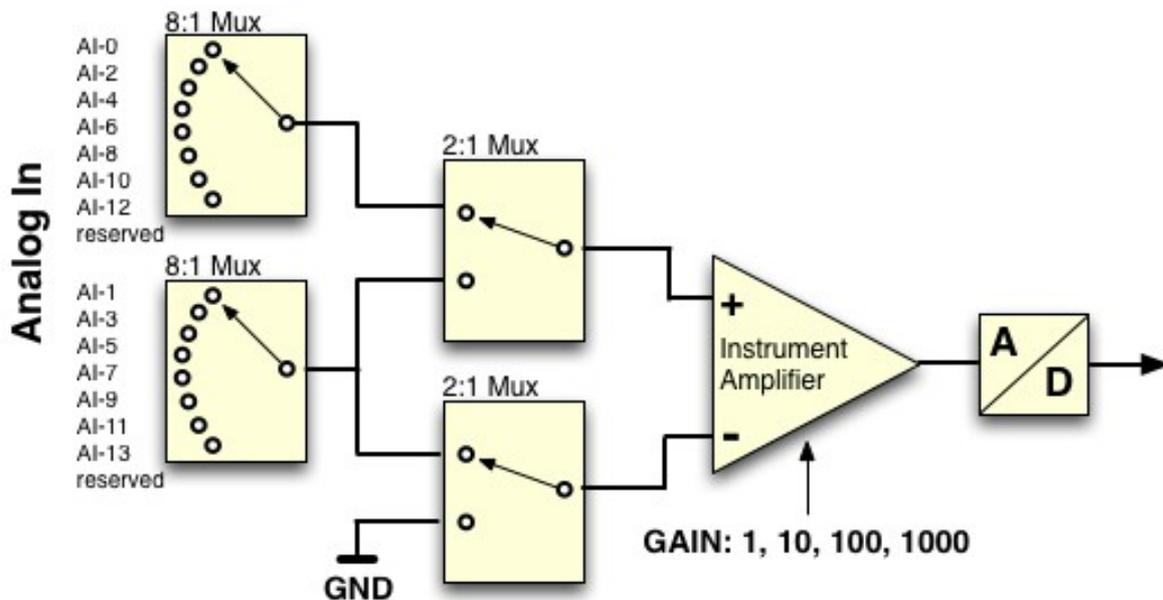


Figure 8: CEBO-LC's analog input stage

Floating inputs

To keep input resistance at a maximum, all Analog Inputs are left floating and are not artificially pulled to 0,0V. Readings from a floating input depend on sample rate and adjacent channels and will return undefined results.

Over-voltage protection

CEBO-LC's analog inputs are rated for $\pm 10\text{V}$ with respect to GND. Keep voltages on any analog input within $\pm 12,3\text{V}$ to guarantee valid readings on adjacent channels. To limit current flow in case of over-voltage an internal series resistor is added at all input channels. Make sure voltages are within $\pm 20\text{V}$ at any time to prevent CEBO-LC from damage. This is also true if CEBO-LC is unpowered.

Input signal range

CEBO-LC's analog inputs are designed for signals in the range of $\pm 10\text{V}$, with the option to amplify small signals with a gain factor of up to 1000, resulting in the four different analog input ranges: $\pm 10\text{V}$, $\pm 1\text{V}$, $\pm 100\text{mV}$, $\pm 10\text{mV}$. These are true for single-ended input signals.

However, due to the 3-op-amp architecture of CEBO-LC's instrumentation amplifier, in differential mode the input signal range also depends on the common-mode voltage (V_{CM}) of the applied signals. To guarantee valid readings, keep input voltage (V_{IN}) within the regions as indicated in *Figure 9* and *Figure 10*.

$$\text{(EQ1)} \quad V_{\text{CM}} = \frac{(V_{\text{POS}} + V_{\text{NEG}})}{2}$$

$$\text{(EQ2)} \quad V_{\text{IN}} = V_{\text{POS}} - V_{\text{NEG}}$$

V_{POS} : even channel of differential pair

V_{NEG} : odd channel of differential pair

Example 1:

$$V_{\text{POS}} = 5\text{V}; \quad V_{\text{NEG}} = -5\text{V}; \quad \text{gain} = 1 ?$$

$$\Rightarrow \quad V_{\text{CM}} = \frac{(5\text{V} + (-5\text{V}))}{2} = 0\text{V}; \quad V_{\text{IN}} = 5\text{V} - (-5\text{V}) = 10\text{V}$$

As shown in *Figure 9*, $V_{\text{IN}} = 10\text{V}$ at a common-mode voltage $V_{\text{CM}} = 0\text{V}$ is inside the allowed analog input signal range. No problems will arise with a gain setting of 1.

Example 2:

$$V_{\text{POS}} = 7\text{V}; V_{\text{NEG}} = 6\text{V}; \text{gain} = 10?$$

$$\Rightarrow V_{\text{CM}} = \frac{(7\text{V} + 6\text{V})}{2} = 6,5\text{V}; V_{\text{IN}} = 7\text{V} - 6\text{V} = 1\text{V}$$

Although $V_{\text{IN}} = 1\text{V}$, using analog input range $\pm 1\text{V}$ will give unsatisfactory results. As shown in *Figure 10*, $V_{\text{IN}} = 1\text{V}$ at a common-mode voltage $V_{\text{CM}} = 6,5\text{V}$ is outside the allowed analog input signal range for a gain setting of 10. However with gain = 1 this will work fine.

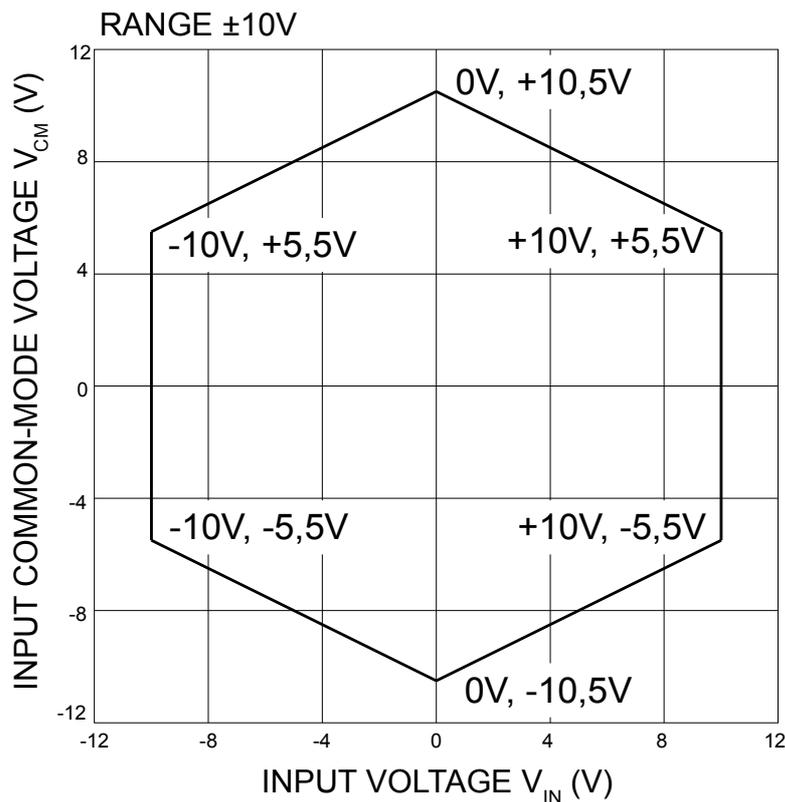


Figure 9: Analog input voltage range for gain = 1

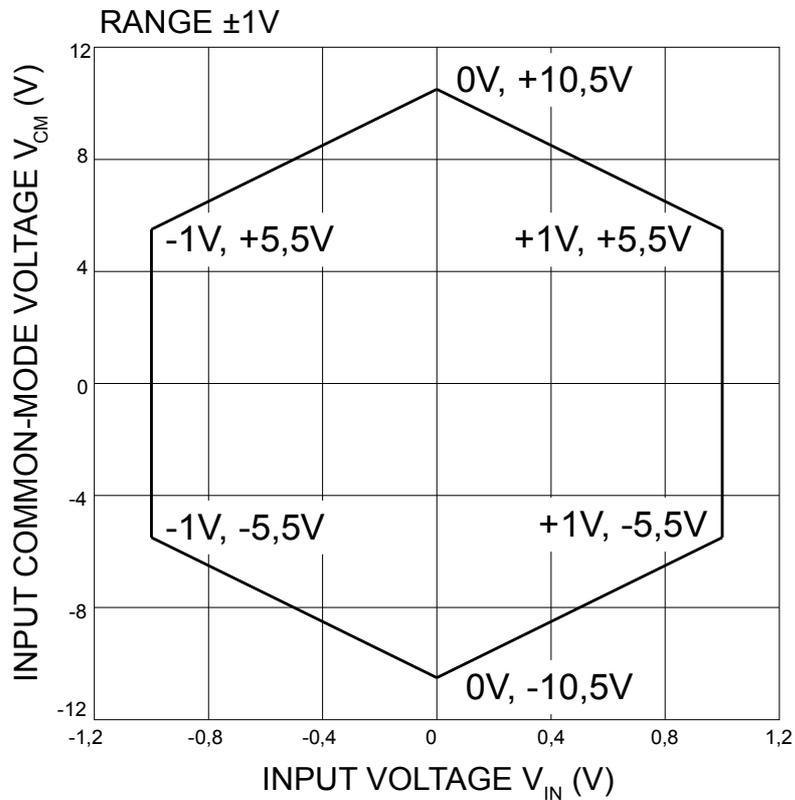


Figure 10: Analog input voltage range for gain = 10

Settling time

In general, settling time is the time needed for the analog signal to reach a stable state at the ADC input after a step change occurred. With CEBO-LC such a step change occurs every time when input multiplexers change from one channel to another. Therefore this time is called interchannel delay time. With increasing gain settings a higher interchannel delay time may be required. With default interchannel delay times CEBO-LC meets specifications at all gains for source impedances up to 1 k Ω at the least.

Factory preset interchannel delay times		
Gain	Interchannel delay time	Unit
1	16	μs
10	28	μs
100	150	μs
1000	500	μs

All CEBO-LC noise and resolution tests were measured with factory-preset interchannel delay times. Normally, there is no need to change these settings. However, it is possible if desired.

Noise and resolution

The following table provides typical noise levels measured with CEBO-LC under ideal conditions. Resolution is calculated based on these levels. If not otherwise noted, measurements were taken with AI-0 connected to GND with a short wire.

Range	Peak-to-peak Noise [24bit counts]	Peak-to-peak resolution [bits]	Noise-free resolution [μV]	RMS noise [24bit counts]	Effective resolution [bits]	Effective resolution [μV]
±10V	942	14,1	1123,3	219,8	16,2	262,0
±1V	1252	13,7	149,2	286	15,8	34,1
±0,1V	6252	11,4	74,5	1448,2	13,5	17,3
±0,01V	19484	9,8	23,2	4039,6	12,0	4,8

For noise-free resolution, 128 measurements were taken, subtracting the minimum value from the maximum value. RMS and effective data were calculated based on the standard deviation of 128 readings. Equations (3) and (4) were used to determine signal-to-noise ratio (SNR) and corresponding effective number of bits (ENOB).

$$(EQ3) \text{ SNR}_{\text{dB}} = 20 * \log\left(\frac{\text{noise}}{\text{full - scale input}}\right)$$

$$(EQ4) \text{ ENOB}_{\text{bit}} = \frac{\text{SNR}_{\text{dB}} - 1,76 \text{ dB}}{6,02 \text{ dB}}$$

Equation (5) gives a representation of noise in counts (24bit aligned).

$$(EQ5) \text{ Noise}_{\text{counts_24bit}} = 2^{(24 - \text{ENOB})}$$

To calculate a corresponding 16bit value, counts data needs to be divided by 2^8 :

$$(EQ6) \text{ Noise}_{\text{counts_16bit}} = \frac{\text{Noise}_{\text{counts_24bit}}}{2^8}$$

Calculate peak-to-peak resolution (μV) & effective resolution (μV) with equation (7):

$$(EQ7) \text{ Resolution}_{\mu\text{V}} = \frac{\text{full - scale input}}{2^{\text{Resolution}_{\text{bit}}}}$$

Parameter	Comment	Min. ⁴	Typ. ⁴	Max. ⁴	Unit
Typical input voltage range ⁵	Gain = 1	-10,5		+10,09	Volts
Maximum input voltage range	Valid readings ⁶	-12,3		+12,3	Volts
	No damage ⁷	-20		+20	Volts
Input bias current		5		30	nA
Input impedance			1		G Ω
Source impedance ⁸			1		k Ω
Absolute accuracy (23 °C) ⁹	Gain = 1		$\pm 0,01$		% FS
	Gain = 10		$\pm 0,01$		% FS
	Gain = 100		$\pm 0,01$		% FS
	Gain = 1000		$\pm 0,04$		% FS
Noise	Peak-to-peak			<23,2	μV
Effective resolution	RMS		16,2		Bits
Noise-free resolution			14,1		Bits
Crosstalk ¹⁰	1kHz		100		dB
	10kHz		86		dB

4 Based on characterization, not production tested.

5 Signals outside the typical input voltage range will result in over-/underflow.

6 Maximum voltage on any analog input referred to GND for valid measurements on adjacent channels.

7 Voltages beyond the maximum input voltage range may damage CEBO-LC.

8 Keep source impedance below the given value to ensure proper readings with default settling times.

9 $f_{\text{total}} = f_{\text{measure}} + f_{\text{calibration device(max)}}$

$$f_{\text{measure}} = \frac{x_d - x_r}{x_r}$$

f : relative error

x_r : value from calibration device

x_d : mean of n measurements from Device Under Test

n = 1000 / 1000 / 500 / 100 at ranges $\pm 10\text{V}$ / $\pm 1\text{V}$ / $\pm 100\text{mV}$ / $\pm 10\text{mV}$

10 AI-0 connected to GND, AI-1 sourced by a sinusoidal voltage of 10V amplitude. Measurement data collected and compared for AI-0 and AI-1 with varying gain settings.

Analog outputs

- Two single-ended on screw terminals
- 12bit resolution
- $\pm 10V$ output swing
- 50Ω impedance
- Short-circuit proof

CEBO-LC provides two 12bit analog outputs. Both outputs are available at screw terminals, labeled AO-0 and AO-1, respectively. CEBO-LC's analog outputs are rated for $\pm 10V$ output swing and short-circuit proof. With firmware releases up to v1.3, outputs support software timed DAQ modes, only. Maximum update rate for analog outputs therefore strongly depends on host performance regarding processing of requests targeting the USB interface. The typical minimum time frame varies between one and four microseconds, resulting in maximum frame rates between 250Hz up to 1000Hz.

Parameter	Comment	Min. ³	Typ. ³	Max. ³	Unit
Nominal output range	No load	-10		+10	Volts
	@ $\pm 2,5mA$	-9,875		+9,875	Volts
Resolution			12		Bits
Absolute accuracy	5% to 95% FS		$\pm 0,1$		% FS
Integral linearity error				± 4	Counts
Differential linearity error				± 2	Counts
Error due to loading	@ 100uA		0,16		%
	@ 1mA		0,6		%
Source impedance			50		Ω
Short-circuit current ¹¹	Max to GND		45		mA

Power on behavior

When connecting CEBO-LC to a host system, a positive voltage might occur on analog outputs. Pulse length typically is about 6ms, peak voltage is about 1,5V. Maximum short-circuit current during this period is about 20mA. Please make sure that connected equipment is not negatively affected by this.

The same behavior is true when updating CEBO-LC firmware. Please remove all connections prior to initiating firmware update process.

¹¹ Continuous short-circuit will not cause damage.

Digital inputs/outputs

- 20 general purpose input/outputs
- Individually configurable as input or output
- CMOS voltage levels (3,3V nominal)
- 5 Volt tolerant
- Short-circuit proof

Digital inputs					
Parameter	Comment	Min.³	Typ.³	Max.³	Unit
Low level input voltage		-0,3		0,8	Volts
High level input voltage					Volts
Maximum input voltage range ¹²	Screw terminals ¹³	-10		10	Volts
	Connector DB25 ³	-6		6	Volts

Digital outputs					
Parameter	Comment	Min.³	Typ.³	Max.³	Unit
Low level output voltage	No load		0,0	0,8	Volts
	Screw terminals, Sinking 1mA ¹³		0,5		Volts
	Connector DB25, Sinking 1mA ¹³		0,2		Volts
High level output voltage	No load	2,0	3,3		Volts
	Screw terminals, Sourcing 1mA ¹³		2,8		Volts
	Connector DB25, Sourcing 1mA ¹³		3,0		Volts
Short-circuit current ²	Screw terminals ¹³		6,5		mA
	Connector DB25 ¹³		18		mA
Output impedance	Screw terminals ¹³		507		Ω
	Connector DB25 ¹³		183		Ω

¹² Voltages beyond the maximum input voltage range may damage CEBO-LC.

¹³ Protective circuits of digital inputs/outputs on screw terminals differ from that on connector DB25.

Trigger

CEBO-LC provides one dedicated trigger input/output pin which is located at the TRG screw terminal. With firmware releases up to v1.3, the trigger is available for multi frame DAQ modes only. With the trigger signal you can use an external event to start data acquisition or you can synchronize multiple CEBO-LC devices. After startup the trigger TRG is configured as input signal, but remains inactive. To use TRG as trigger input, the corresponding peripheral needs to be enabled, first. This is done by software calls (API).

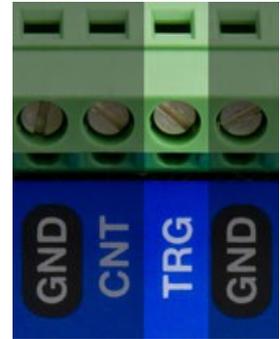


Figure 11: TRG screw terminal

Trigger input

In trigger input mode, an external signal must be supplied to the TRG screw terminal. CEBO-LC supports three different ways of trigger recognition.

Rising edge mode

In rising edge mode, every transition from low to high level on the TRG screw terminal is considered a trigger event.

Falling edge mode

In falling edge mode, every transition from high to low level on the TRG screw terminal is considered a trigger event.

Alternating mode

In alternating mode, both edges are considered trigger events.

Parameter	Comment	Min. ³	Typ. ³	Max. ³	Unit
Low level input voltage		-0,3		0,8	Volts
High level input voltage		2,0		5,8	Volts
Maximum input voltage range ¹²		-10		10	Volts
Input total edge rate ¹⁴	No streaming				Edges/s
	While streaming ¹⁵			75.000	Edges/s

¹⁴ Keep the total number of edges per second below the given value to avoid missing edges.

¹⁵ InputFrame contains AI-0.

Parameter	Comment	Min. ³	Typ. ³	Max. ³	Unit
Latency ¹⁶	External timed ¹⁷		10,5		us
	Hardware timed ¹⁸		21,5		us

Trigger output

You can use trigger output for hardware timed DAQ modes. The TRG signal then becomes an actively driven digital output. Depending on your setup (pulse mode or alternating mode) TRG signal level either toggles on every acquisition of a frame or a short pulse in the range of some 100ns is output.

Alternating mode

In alternating trigger output mode, every acquisition of a frame toggles the level of the TRG output signal. Consequently, the resulting signal is a square wave with 50% duty cycle at half the frequency of the data acquisition frame rate.

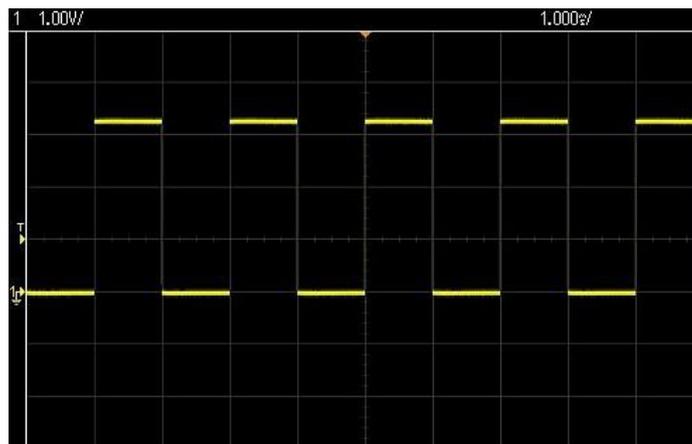


Figure 12: Alternating trigger output at 1kHz frame rate

Pulse mode

In pulse trigger output mode, every trigger event initiates a short pulse of several 100ns on TRG screw terminal. In this mode the TRG signal rate equals the data acquisition frame rate, but duty cycle depends on frame rate and will be less than 50%.

16 Time interval from edge of TRG signal to conversion start for the first analog input in InputFrame.

17 External timed data acquisition mode.

18 Hardware timed data acquisition mode with trigger set to rising edge input mode.

Parameter	Comment	Min. ³	Typ. ³	Max. ³	Unit
Low level output voltage			0	0,8	Volts
High level output voltage		2,0	3,3		Volts
Short-circuit current			12,8		mA
Output impedance			257		Volts
Maximum frame rate ¹⁹	No streaming				Frames/s
	While streaming ¹⁵			75.000	Frames/s
Latency ^{16,20}			9,5		us

Trigger application example

To get higher frame rates or channel counts, you can use two or more CEBO-LC devices in parallel. In many cases, an identical acquisition rate is desired for all CEBO-LC devices. With the help of the trigger output in alternating output mode, you can easily synchronize connected CEBO-LC devices.

To setup for this scenario, connect together the TRG screw terminals of all CEBO-LC devices to be synchronized. As CEBO-LC is isolated from the host ground, additionally connect one GND screw terminals of each device.

Configure one device - this one will be the master device - for alternating trigger **output** mode and all other devices - which are the slave devices - for alternating trigger **input** mode. With every frame start, the master device will toggle the level on the TRG screw terminal, tripping a trigger event on the attached slave devices. So all devices are synchronized and use the same frequency for data acquisition.

¹⁹ Keep frame rate below the given value to avoid buffer overflow/underflow within CEBO-LC hardware.

²⁰ Hardware timed data acquisition mode with trigger set to alternating output mode.

Counter

CEBO-LC has one dedicated external counter input. It is located at the screw terminal labeled CNT.

On every rising edge on CNT, a 32bit register is incremented. This counter requires the firmware to jump to a small interrupt service routine on each rising edge. Therefore maximum edge rate without missing counts depends on available processing resources. When the CNT counter is used exclusively, maximum input edge rate will be in the range of 35.000 Samples/s, while continuously polling counter value. With multi frame DAQ enabled at the same time, maximum input edge rate will be less. And since each rising edge on CNT needs processing time, maximum multi frame DAQ input frame rate will be reduced, too. By default CNT counter peripheral is disabled and the counter register is initialized to 0. Prior to starting to collect counter data, the peripheral needs to be enabled. This is done by software calls (API).

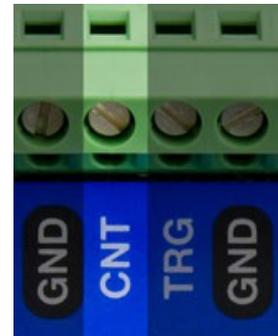


Figure 13: CNT screw terminal

Parameter	Comment	Min. ³	Typ. ³	Max. ³	Unit
Low level input voltage		-0,3		0,8	Volts
High level input voltage		2,0		5,8	Volts
Maximum input voltage range ¹²		-10,0		10,0	Volts
Input total edge rate ¹⁴	No polling ²¹		300.000		Edges/s
	Continuously polling		35.000		Edges/s
	While streaming ²²		25.000		Edges/s

21 Counter value is only checked, after counting events have been disabled.

22 InputFrame consists of AI-0 and counter value.

Temperature sensor

Inside the CEBO-LC device, the I²C temperature sensor ADT7410 from Analog Devices is used to provide $\pm 0,5^{\circ}\text{C}$ accurate, 16bit digital data.

Reading the temperature is initiated by a software call (API). A 16bit value is returned immediately. Please note, that temperature data is not available while streaming mode is active.

Because the temperature sensor resides inside CEBO-LC's enclosure, temperature readouts deliver values that are somewhat higher than the temperature of the screw terminals. Typically this offset is about 1-2 °C at room temperature.

Constant-current sources

CEBO-LC has two built-in accurate current sources (200 μA /10 μA). Both are available at screw terminals.

The exact values of the constant-current outputs are measured during factory calibration process and stored in onboard flash within CEBO-LC hardware. These values are available through software calls (API).

Application example

The following application example will show you the process of determining the value of a resistor with the help of one of the constant-current sources and one of the analog input channels.

Connect one terminal of the resistor under observation to one of the constant-current sources, for example the screw terminal 200 μA . The resistor's other terminal connect to one of the screw terminals labeled GND. Then connect the constant-current source's terminal to an analog input channel, e.g. AI-0.

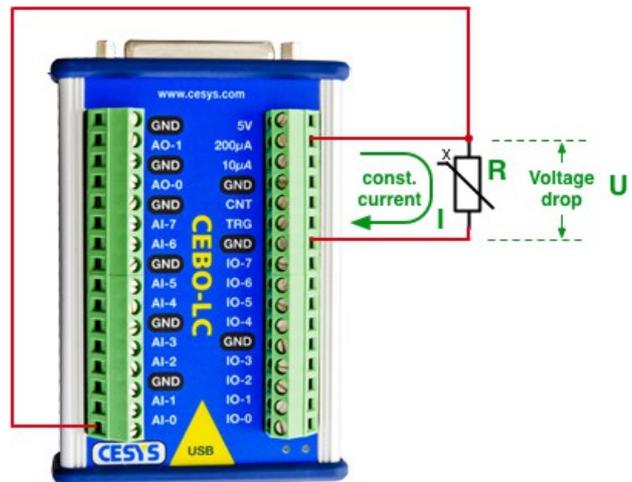


Figure 14: Measuring a resistor's value with the help of one of CEBO-LC's constant-current sources

With the knowledge of the voltage drop across the resistor under question, and the known value of the constant-current source, you can determine the resistance using Ohm's law (EQ8).

$$(EQ8) \quad R = \frac{U}{I} = \frac{\text{Voltage drop across resistor}}{\text{Fixed current source value}} = \frac{\text{Value of AI-0}}{200 \mu\text{A}}$$

Resistive sensors are very common to measure various physical quantities. With the help of a temperature-dependent resistor (PTC, NTC), a temperature can be measured indirectly by measuring the voltage drop across the resistor.

The constant-current sources can drive voltage levels up to about 3 Volt. Please make sure, that within your measurement range the resistor's value, and therefore the voltage drop across the resistor, respect this limit.

For the 200µA source, the maximum resistance should not exceed 15 kOhm (= 3 Volt / 200µA). With the 10µA source the limit is about 300 kOhm (= 3 Volt / 10µA).

Multiple analog channels with current sources

Please note, that the default interchannel delay times will not suffice for reading multiple analog channels when one of the constant-current sources is used as one of the sources. Channel-to-channel switching inevitably produces some disturbance on signal lines. Due to the nature of the constant-current sources, the driving capabilities are very limited (200µA or 10µA). Interchannel delay times beyond 1000µs (recommended: 1500µs) should be used for analog channels being "driven" by constant-current sources to ensure proper settling. Please also note, that it is not necessary to increase interchannel delay times for analog inputs that are being driven by other sources, as long as the recommendations for the [maximum source impedance](#) are met.

200µA constant-current source					
Parameter	Comment	Min. ³	Typ. ³	Max. ³	Unit
Absolute accuracy ²³	R < 12kΩ			±0,4%	
Temperature coefficient					ppm/°C
Maximum voltage			3,0		Volts

²³ 25°C ambient air temperature.

10µA constant-current source					
Parameter	Comment	Min.³	Typ.³	Max.³	Unit
Absolute accuracy ²³	R < 40kΩ			±0,4%	
Temperature coefficient					ppm/°C
Maximum voltage			3,0		Volts

5 Volt power supply output

CEBO-LC comes with two 5V power supply outputs. You can use these to supply external sensors, signal conditioners or any other circuit to save an additional battery or wall-plug. The first output is located at the screw terminal labeled "5 Volt", the second one is available at pin 14 of the D-Sub expansion connector DB25. Both outputs are internally connected to the same potential. A self-resetting PTC fuse limits the total current available to about 100mA at an ambient air temperature of 23°C.

Please note, that the 5 Volt power output is not identical to the USB power supply output. An isolated DC/DC converter inside CEBO-LC is used to generate the output voltage with reference to CEBO-LC GND terminals. The PC/host ground is isolated.

Do not connect an external 5V power supply to CEBO-LC's 5 Volt power outputs. CEBO-LC is sourced from USB and does not need an additional power supply.

Parameter	Comment	Min.³	Typ.³	Max.³	Unit
Typical output voltage			5,0		Volts
Accuracy			±5		%
Load voltage regulation	10% to 100% full load.			15	%
Output ripple and noise			50		mV
Maximum current	-40°C ²⁴		140		mA
	0°C ²⁴		110		mA
	+23°C ²⁴		100		mA
	+40°C ²⁴		80		mA
	+70°C ²⁴		50		mA

²⁴ Hold current of onboard PTC fuse.

CEBO-LC/OEM²⁵

CEBO-LC is also available as "OEM-version" without the enclosure and without screw terminals. The screw terminal signals are located on a standard 2x20 pin 0,1" (2,54mm) header instead.

Use the OEM version to embed CEBO-LC functionality into your machines or devices.



Figure 15: CEBO-LC OEM version

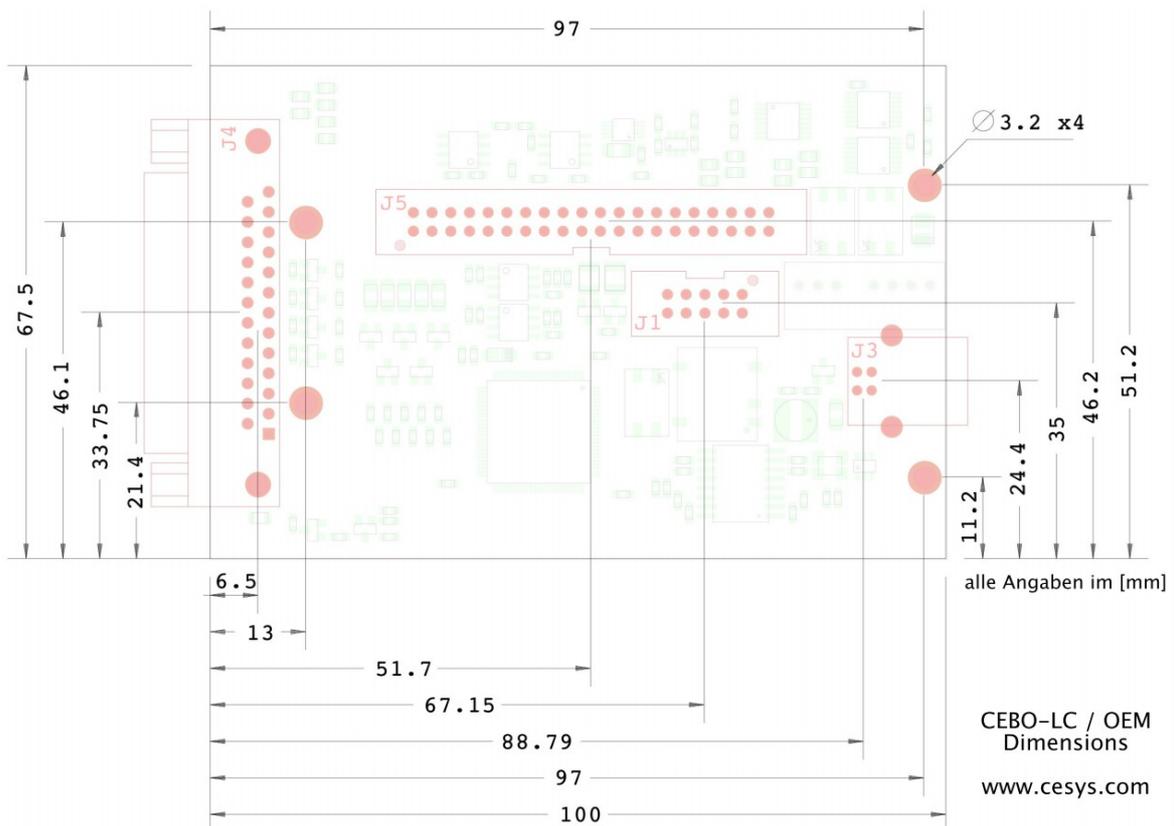


Figure 16: CEBO-LC OEM - dimensions

²⁵ Please note the minimum order quantity of 10 pieces for CEBO-LC OEM.

CEBO-LC OEM connector J5					
Pin	Signal	Comment	Pin	Signal	Comment
1	GND ²⁶	CEBO-LC ground reference	2	5 Volt ²⁷	5V power output
3	10µA	Constant-current output	4	200µA	Constant-current output
5	GND ²⁶	CEBO-LC ground reference	6	CNT	Counter input
7	TRG	Trigger input/output	8	IO-7	Digital input/output (Port0, IO7)
9	IO-6	Digital input/output (Port0, IO6)	10	IO-5	Digital input/output (Port0, IO5)
11	GND ²⁶	CEBO-LC ground reference	12	IO-4	Digital input/output (Port0, IO4)
13	IO-3	Digital input/output (Port0, IO3)	14	IO-2	Digital input/output (Port0, IO2)
15	IO-1	Digital input/output (Port0, IO1)	16	IO-0	Digital input/output (Port0, IO0)
17	GND ²⁶	CEBO-LC ground reference	18	GND ²⁶	CEBO-LC ground reference
19	AO-1	Analog output 1	20	GND ²⁶	CEBO-LC ground reference
21	AO-0	Analog output 0	22	GND ²⁶	CEBO-LC ground reference
23	AI-6	Analog input 6	24	AI-7	Analog input 7
25	AI-4	Analog input 4	26	AI-5	Analog input 5
27	GND ²⁶	CEBO-LC ground reference	28	GND ²⁶	CEBO-LC ground reference
29	AI-2	Analog input 2	30	AI-3	Analog input 3
31	AI-0	Analog input 0	32	AI-1	Analog input 1
33	GND ²⁶	CEBO-LC ground reference	34	GND ²⁶	CEBO-LC ground reference
35	VCC ²⁸	+12V output	36	VSS ²⁸	-12V output
37	GND ²⁶	CEBO-LC ground reference	38	T-LED ²⁹	USB status and traffic
39	P-LED	Power supply status and indicator	40	GND ²⁶	CEBO-LC ground reference

Specifications for VCC/VSS output					
Parameter	Comment	Min. ³	Typ. ³	Max. ³	Unit
Typical VCC output voltage	No load		+12,0		Volts
	@ 2,5mA				Volts
Typical VSS output voltage	No load		-12,0		Volts
	@ 2,5mA				Volts
Maximum current ³⁰			±2,5		mA

26 All GND terminals are internally connected to the same signal.

27 All 5V power outputs are internally connected. A total of 100mA of current can be sourced.

28 VCC/VSS are the power supplies for the analog stage within CEBO-LC. Any distortions coupled into these lines might decrease overall accuracy.

29 T-LED and P-LED are general purpose digital I/O signals driven by CEBO-LC hardware. With default firmware setup both are used to drive LEDs located on the screw terminal expansion board to signal some status information.

30 Drawing excessive current on VCC/VSS lines might have a negative impact on measuring performance.

Data acquisition

Data acquisition is the process of measuring data. It is abbreviated DAQ. With CEBO-LC there are several ways to collect data - analog and/or digital. We call them "DAQ modes".

This section will show you how easy it is to measure data with CEBO-LC.

DAQ modes

Some measurement problems require more effort than reading one single input.

Depending on the circumstances, a fixed number of measurements with well defined timing or an endless stream of measurements is desired. Sometimes, data acquisition should take place only when there is a trigger event (i.e. a external digital signal switches from low to high).

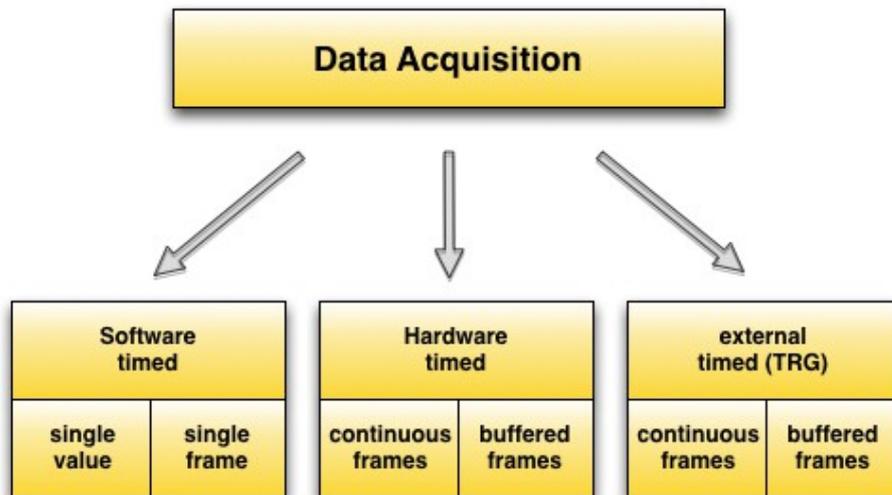


Figure 17: Data acquisition modes

Software timed - single value input/output

The most basic form to sample an input or modify an output. Exact timing is not predictable, as it strongly depends on host system processing of requests targeting the

USB interface.

Software timed - one single frame

Capture and return one frame, which may consist of several input or output signals. Exact frame timing is not predictable, as it strongly depends on host system processing of requests targeting the USB interface. Therefore frame to frame timing might vary. With a typical system minimum time frames are between one and four microseconds, hence the maximum sample rate will be about 250 up to 1.000 frames per second.

Hardware timed - continuous frames

Capture and return an unlimited number of frames. The frame to frame timing is completely done by CEBO-LC hardware and only stopped upon user request. If you need well defined sample rates at the highest data transfer levels use this mode. The achievable maximum frame acquisition frequency is limited by the available data transfer rate between CEBO-LC and the host system. With a fast host system total sample rates up to 85.000 Samples per second are possible.

Hardware timed - buffered frames

Frame data is captured to onboard memory of CEBO-LC and stops automatically, when a given number of frames has been stored. The frame to frame timing is completely done by CEBO-LC hardware. Use this mode, if you need a well defined sample rate at the highest data transfer levels, but your host system is not capable to sustain such high data rates. The number of acquisitions is limited by the buffer size of the CEBO-LC.

When **external trigger** is enabled, an edge on the TRG input is required to start capturing.

External timed - continuous/buffered frames

These acquisition modes are like the hardware-timed modes but with one difference: Timing is not done by CEBO-LC hardware, but an adequate clock signal has to be provided on the trigger input. Edges on TRG, configured as trigger input, start the acquisition of one frame. Edge rate therefore defines the frame rate used for data capturing. You can [configure the trigger input](#) to trip trigger events on falling, rising or both edges.

Frames

With CEBO-LC various sources and sinks of data are available. Besides 14 analog inputs and two analog outputs there exist 20 general purpose digital IOs, one trigger input/output and one 32bit counter input.

To reduce transmission overhead when accessing the peripherals, rather than assigning an individual address to each peripheral, data flow from and to CEBO-LC is organized as blocks of data. These have known size and structures and are referred to as "frames".

Depending on the transmission direction, there are InputFrames and OutputFrames. An InputFrame contains the results of data acquisition, digital inputs and/or counter values, while an OutputFrame contains data to be sent to analog or digital outputs.

Before you can use a frame, you have to define its contents by using the methods `setupInputFrame` or `setupOutputFrame`, respectively.

InputFrame

Setting up an InputFrame is a two-step process: First, build a list of inputs that should be sampled. This can be any analog input, digital port or counter. Any input can be selected only once. CEBO-LC uses a fixed sequence for the processing of selected inputs, therefore the order of elements within the list does not matter.

Second, set up the InputFrame using the aforementioned list calling `setupInputFrame` of the class instance.

OutputFrame

Similarly to the process for InputFrames, the first step for defining an OutputFrame is to set up a list of all outputs that should be modified using a single write. With CEBO-LC an OutputFrame can include one or both analog outputs and up to three digital ports (do not forget to set the output enable masks for the selected digital IOs). Call `setupOutputFrame` using this list to set up the OutputFrame.

DAQ timing

Data acquisition of all channels takes place sequentially in a fixed order. Channel-to-channel switching times can be adjusted through the parameter "interchannel delay" to attune to different source impedances and necessary minimum settling times. Longer [interchannel delay times](#) decrease frame rate, but might improve accuracy with high source impedances.

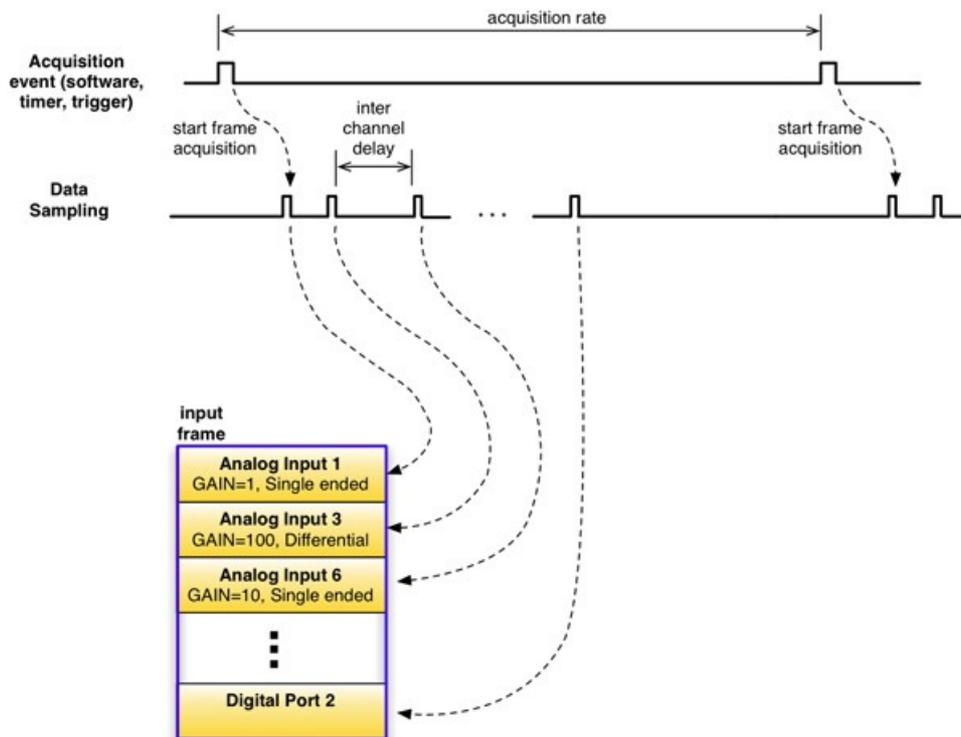


Figure 18: DAQ example with frames

Single value IO

Single value IO is the most basic form to sample an input or modify an output. The call is synchronous, so invoking a method processes the request always immediately, which means:

- In case of sampling: The result of the called method is the sampled value, the method call lasts as long as sampling and data transmission from device to host is active.
- In case of modify: The method call sends the value to the peripheral directly and returns.³¹

Single value command and response times				
	Min. ^{3,32}	Typ. ^{3,3}	Max. ^{3,3}	Unit
Analog input ³³		1,40	6,00	ms
Digital input ²		0,93	4,00	ms
Digital output ³⁴		tbd		ms

Single frame IO

As using single value IO transfer is easy, there are also some drawbacks. For example, if you want to read more than one analog input at a time, some overhead will occur, reducing the maximum achievable update rate.

A better approach in this case would be to define a list of input signals to be sampled, tell the device to sample them and then get the values with only one USB reading. With the help of single frame IO transfers you can achieve exactly this behavior, reducing necessary USB transfers to a minimum.

And as channel-to-channel timing now is done completely in CEBO-LC hardware, host latency no longer affects timing between channels, but only between concurrent frames.

Read single InputFrame

Use single frame reading if you want to read more than one input at once. Specify a list of all inputs to read and call the method `setupInputFrame` of the device in use. Note,

31 Actually, the method returns earlier than the output will show the result, as some latency from host system to the device's peripheral exist.

32 Timing depends on host computer and USB peripheral.

33 Interval between subsequent readings.

34 Pulse-length when writing high and low levels subsequently.

that list type varies between different programming languages. Please refer to the specific language documentation for more detail.

All subsequent calls to `readFrame()` will sample the specified inputs and return an instance of type `InputFrame`, which contains the sampled values. `InputFrame` has convenient methods to access these values.

Single frame command and response times				
	Min. ^{3,3}	Typ. ^{3,3}	Max. ^{3,32}	Unit
1x analog input		0,90	4,00	ms
1x digital port		0,90	4,00	ms
1x analog input + 1x digital port + 32bit counter		1,15	4,00	ms

Write single `OutputFrame`

If you want to update various outputs at once, use the method `writeFrame()`. Similar to input direction, start with defining a list of outputs. After this call the method `setupOutputFrame()` using this list.

To access the outputs, create an instance of type `OutputFrame`, whose set-up fits to the respective device. This is easily done by calling the Method `createOutputFrame()`. Use the various methods of `OutputFrame` to fill the structure with the values you intent to output. Then call `writeFrame()` on the device instance to update all previously specified outputs.

Multi frame data acquisition

While single frame accesses are a convenient way to read multiple input signals all at once, maximum achievable sample rate is limited due to timing limits of USB. With a typical host system minimum time frames are between 1ms and 4ms, hence the maximum sample rate will be about 250 up to 1.000 frames per second. Besides, latency of most host systems cannot be guaranteed and therefore frame to frame timing might vary. If you want to do measurements with well defined sample rates or need the highest possible frame rate, use the multi frame DAQ methods of CEBO-STICK.

Methods

CEBO-LC supports four methods for multi frame data acquisition:

1. `startBufferedDataAcquisition()`
2. `startContinuousDataAcquisition()`
3. `startBufferedExternalTimedDataAcquisition()`
4. `startContinuousExternalTimedDataAcquisition()`

These four modes can be classified as two groups: the hardware timed modes (1. + 2.), where timing is done by CEBO-LC, and the external timed modes (3. + 4.), where an adequate clock signal has to be provided on TRG, which has to be [configured as trigger input](#), then. Hardware timed modes also support a triggered mode, where data acquisition is delayed until a valid trigger event has been detected.

Continuous data acquisition

Each group supports continuous as well as buffered data acquisition. In continuous modes, once you start data acquisition, data is captured continuously until you stop it. To compensate for host system timing issues, CEBO-LC provides an onboard buffer. Make sure to read frames as fast as possible to avoid buffer overflows.

Buffered data acquisition

With buffered modes, data is captured to onboard memory of CEBO-LC and stops automatically, when a given number of frames has been stored. Use these modes, if you need a high sample rate, but your host system is not capable to sustain such high data rates. The maximum number of samples you can capture using buffered modes is limited by the amount of onboard memory and depends on frame size. Use `calculateMaxBufferedInputFrames()` to get the maximum number of frames that fit into onboard memory for a given frame setup. With only one analog input enabled, you can sample up to 8.191 frames. See the following table for further details.

Frame setup	Maximum number of frames for buffered modes
1x analog input	8.191
1x digital port	8.191
3x digital port + 32bit counter	1.638
14x analog input	585
14x analog input + 3x digital port + 32bit counter	431

Frame setup	Maximum frame rate ³⁵
1x analog input	70.000
2x analog input	39.000
14x analog input	6.000
1x digital port	90.000
3x digital port + 32bit counter	32.000
14x analog input + 3x digital port + 32bit counter	5.500

³⁵ Interchannel delay time was 11us. Continuous data acquisition mode.

Workflow

Use the the following steps to setup CEBO-LC for multi frame data acquisition:

1. Open device.
2. Create a list of input signals.
3. Setup the InputFrame using `setupInputFrame()` together with this list.
4. Call one of the Multi Frame DAQ methods:
 - a) `startBufferedDataAcquisition()`
 - b) `startContinuousDataAcquisition()`
 - c) `startBufferedExternalTimedDataAcquisition()`
 - d) `startContinuousExternalTimedDataAcquisition()`
5. Read the captured frames using either `readBlocking()` or `readNonBlocking()`.
6. Stop the data acquisition using `stopDataAcquisition()`.
7. Close device.

Calibration data

CEBO-LC devices are tested and calibrated before delivery. All corrections to measurement data based upon the calibration data are done automatically within API. Additionally, the actual values for both constant-current sources - 200 μ A and 10 μ A - are measured during fabrication test and stored inside onboard flash. You can access these with the help of some software calls. For more details, please see the section "info" inside the programming reference guide for the language of your choice.

Firmware and software update

For latest information on firmware and software releases, please visit the [download section](#) at www.cesys.com. There you will find release notes, drivers and newest software and firmware available for CEBO compatible devices. Additionally CeboMsr-API developer packages for Microsoft Windows, Mac OS X, Linux and others are available, supporting various programming languages, including C++, Java, .NET, Python.

Specifications

General

Parameter	Min.	Typ.	Max.	Unit
Dimensions (B x W x H)		75 x 113 x 36		mm
Operating temperature range	0	23	70	°C
Typical power consumption		250		mA

Analog inputs

Parameter	Comment	Min. ³⁶	Typ. ³⁶	Max. ³⁶	Unit
Typical input voltage range ³⁷	Gain = 1	-10,5		+10,09	Volts
Maximum input voltage range	Valid readings ³⁸	-12,3		+12,3	Volts
	No damage ³⁹	-20		+20	Volts
Input bias current		5		30	nA
Input impedance			1		GΩ
Source impedance ⁴⁰			1		kΩ
Absolute accuracy (23 °C) ⁴¹	Gain = 1		±0,01		% FS
	Gain = 10		±0,01		% FS
	Gain = 100		±0,01		% FS
	Gain = 1000		±0,04		% FS

36 Based on characterization, not production tested.

37 Signals outside the typical input voltage range will result in over-/underflow.

38 Maximum voltage on any analog input referred to GND for valid measurements on adjacent channels.

39 Voltages beyond the maximum input voltage range may damage CEBO-LC.

40 Keep source impedance below the given value to ensure proper readings with default settling times.

41 $f_{\text{total}} = f_{\text{measure}} + f_{\text{calibration device(max)}}$

$$f_{\text{measure}} = \frac{x_d - x_r}{x_r}$$

f : relative error

x_r : value from calibration device

x_d : mean of n measurements from Device Under Test

n = 1000 / 1000 / 500 / 100 at ranges ±10V / ±1V / ±100mV / ±10mV

Parameter	Comment	Min.	Typ. ³⁶	Max. ³⁶	Unit
Noise	Peak-to-peak			<23,2	μV
Effective resolution	RMS		16,2		Bits
Noise-free resolution			14,1		Bits
Crosstalk ⁴²	1kHz		100		dB
	10kHz		86		dB

Analog outputs

Parameter	Comment	Min. ⁵⁵	Typ. ⁵⁵	Max. ⁵⁵	Unit
Nominal output range	No load	-10		+10	Volts
	@ ±2,5mA	-9,875		+9,875	Volts
Resolution			12		Bits
Absolute accuracy	5% to 95% FS		±0,1		% FS
Integral linearity error				±4	Counts
Differential linearity error				±2	Counts
Error due to loading	@ 100uA		0,16		%
	@ 1mA		0,6		%
Source impedance			50		Ω
Short-circuit current ⁴³	Max to GND		45		mA

42 AI-0 connected to GND, AI-1 sourced by a sinusoidal voltage of 10V amplitude. Measurement data collected and compared for AI-0 and AI-1 with varying gain settings.

43 Continuous short-circuit will not cause damage.

Digital inputs/outputs

Digital inputs						
Parameter	Comment	Min.⁵⁵	Typ.⁵⁵	Max.⁵⁵	Unit	
Low level input voltage		-0,3		0,8	Volts	
High level input voltage					Volts	
Maximum input voltage range ⁴⁴	Screw terminals ⁴⁵	-10		10	Volts	
	Connector DB25 ⁴⁵	-6		6	Volts	

Digital outputs						
Parameter	Comment	Min.⁵⁵	Typ.⁵⁵	Max.⁵⁵	Unit	
Low level output voltage	No load		0,0	0,8	Volts	
	Screw terminals, Sinking 1mA ⁴⁵		0,5		Volts	
	Connector DB25, Sinking 1mA ⁴⁵		0,2		Volts	
High level output voltage	No load	2,0	3,3		Volts	
	Screw terminals, Sourcing 1mA ⁴⁵		2,8		Volts	
	Connector DB25, Sourcing 1mA ⁴⁵		3,0		Volts	
Short-circuit current ⁴⁶	Screw terminals ⁴⁵		6,5		mA	
	Connector DB25 ⁴⁵		18		mA	
Output impedance	Screw terminals ⁴⁵		507		Ω	
	Connector DB25 ⁴⁵		183		Ω	

44 Voltages beyond the maximum input voltage range may damage CEBO-LC.

45 Protective circuits of digital inputs/outputs on screw terminals differ from that on connector DB25.

46 Single IO only. Keep total current below 25mA.

Trigger input/output

Trigger input					
Parameter	Comment	Min.⁵⁵	Typ.⁵⁵	Max.⁵⁵	Unit
Low level input voltage		-0,3		0,8	Volts
High level input voltage		2,0		5,8	Volts
Maximum input voltage range ⁴⁴		-10		10	Volts
Input total edge rate ⁴⁷	No streaming				Edges/s
	While streaming ⁴⁸			75.000	Edges/s
Latency ⁴⁹	External timed ⁵⁰		10,5		us
	Hardware timed ⁵¹		21,5		us

Trigger output					
Parameter	Comment	Min.⁵⁵	Typ.⁵⁵	Max.⁵⁵	Unit
Low level output voltage			0	0,8	Volts
High level output voltage		2,0	3,3		Volts
Short-circuit current			12,8		mA
Output impedance			257		Volts
Maximum frame rate ⁵²	No streaming				Frames/s
	While streaming ⁴⁸			75.000	Frames/s
Latency ^{49,53}			9,5		us

47 Keep the total number of edges per second below the given value to avoid missing edges.

48 InputFrame contains AI-0.

49 Time interval from edge of TRG signal to conversion start for the first analog input in InputFrame.

50 External timed data acquisition mode.

51 Hardware timed data acquisition mode with trigger set to rising edge input mode.

52 Keep frame rate below the given value to avoid buffer overflow/underflow within CEBO-LC hardware.

53 Hardware timed data acquisition mode with trigger set to alternating output mode.

Counter input

Parameter	Comment	Min. ⁵⁵	Typ. ⁵⁵	Max. ⁵⁵	Unit
Low level input voltage		-0,3		0,8	Volts
High level input voltage		2,0		5,8	Volts
Maximum input voltage range ⁴⁴		-10		10	Volts
Input total edge rate ⁴⁷	No polling ⁵⁴		300.000		Edges/s
	Continuously polling		35.000		Edges/s
	While streaming ⁵⁵		25.000		Edges/s

Constant-current sources

200 μ A constant-current source					
Parameter	Comment	Min. ⁵⁵	Typ. ⁵⁵	Max. ⁵⁵	Unit
Absolute accuracy ⁵⁶	R < 12k Ω			$\pm 0,4\%$	
Temperature coefficient					ppm/ $^{\circ}$ C
Maximum voltage			3,0		Volts

10 μ A constant-current source					
Parameter	Comment	Min. ⁵⁵	Typ. ⁵⁵	Max. ⁵⁵	Unit
Absolute accuracy ⁵⁶	R < 40k Ω			$\pm 0,4\%$	
Temperature coefficient					ppm/ $^{\circ}$ C
Maximum voltage			3,0		Volts

5 Volt power output

Parameter	Comment	Min. ⁵⁵	Typ. ⁵⁵	Max. ⁵⁵	Unit
Typical output voltage			5,0		Volts
Accuracy			± 5		%
Load voltage regulation	10% to 100% full load.			15	%
Output ripple and noise			50		mV

54 Counter value is only checked, after counting events have been disabled.

55 InputFrame consists of AI-0 and counter value.

56 25 $^{\circ}$ C ambient air temperature.

Parameter	Comment	Min. ⁵⁵	Typ. ⁵⁵	Max. ⁵⁵	Unit
Maximum current	-40°C ⁵⁷		140		mA
	0°C ⁵⁷		110		mA
	+23°C ⁵⁷		100		mA
	+40°C ⁵⁷		80		mA
	+70°C ⁵⁷		50		mA

VCC/VSS power output

Specifications for VCC/VSS output					
Parameter	Comment	Min. ⁵⁵	Typ. ⁵⁵	Max. ⁵⁵	Unit
Typical VCC output voltage	No load		+12,0		Volts
	@ 2,5mA				Volts
Typical VSS output voltage	No load		-12,0		Volts
	@ 2,5mA				Volts
Maximum current ⁵⁸			±2,5		mA

Ordering information

Order Number	Device	Comment
C028152	CEBO-LC	Universal 16Bit multi-I/O DAQ with isolated USB interface.
C028195	CEBO-LC OEM ⁵⁹	OEM version of CEBO-LC without enclosure or screw terminals.

57 Hold current of onboard PTC fuse.

58 Drawing excessive current on VCC/VSS lines might have a negative impact on measuring performance.

59 Minimum order quantity: 10 pieces.

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v1.2	07.04.14	Header added, Footer Modified, Layout modified. (jk)
V1.3	09.11.15	Added information on typical power consumption.

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