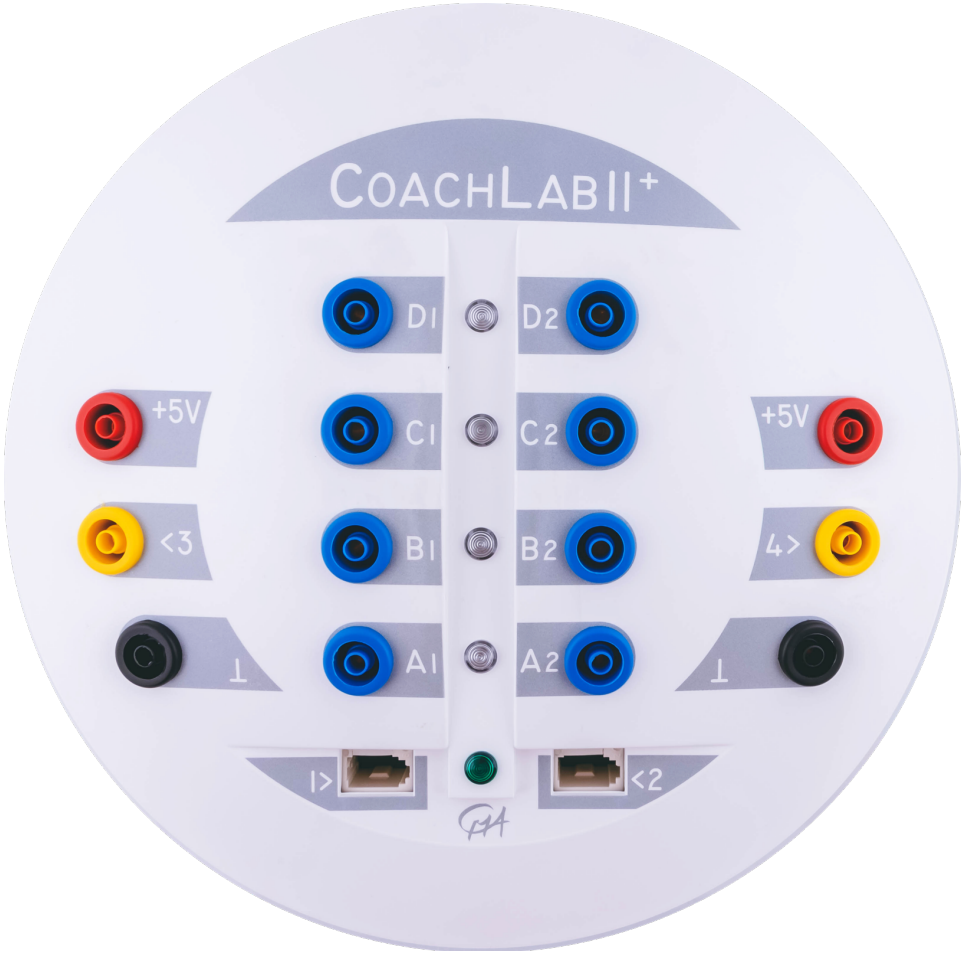
COACHLAB II+ INTERFACE 006P

USER GUIDE



CENTRE FOR MICROCOMPUTER APPLICATIONS

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I. INTRODUCTION

1. About CoachLab II+

CoachLab II+ is a versatile lab interface designed for computerized measurement and control in STEM[1] Education. It features its own processor and memory, allowing for high sampling rates of up to 100,000 Hz with precise independent timing. The interface also includes FLASH memory, making it easy to upgrade the internal operating system.
The interface supports six sensor inputs:
- two BT (right-handed) inputs
- two 4-mm inputs, and
- two BT (left-handed) inputs for CMA Motion Detectors 0664.

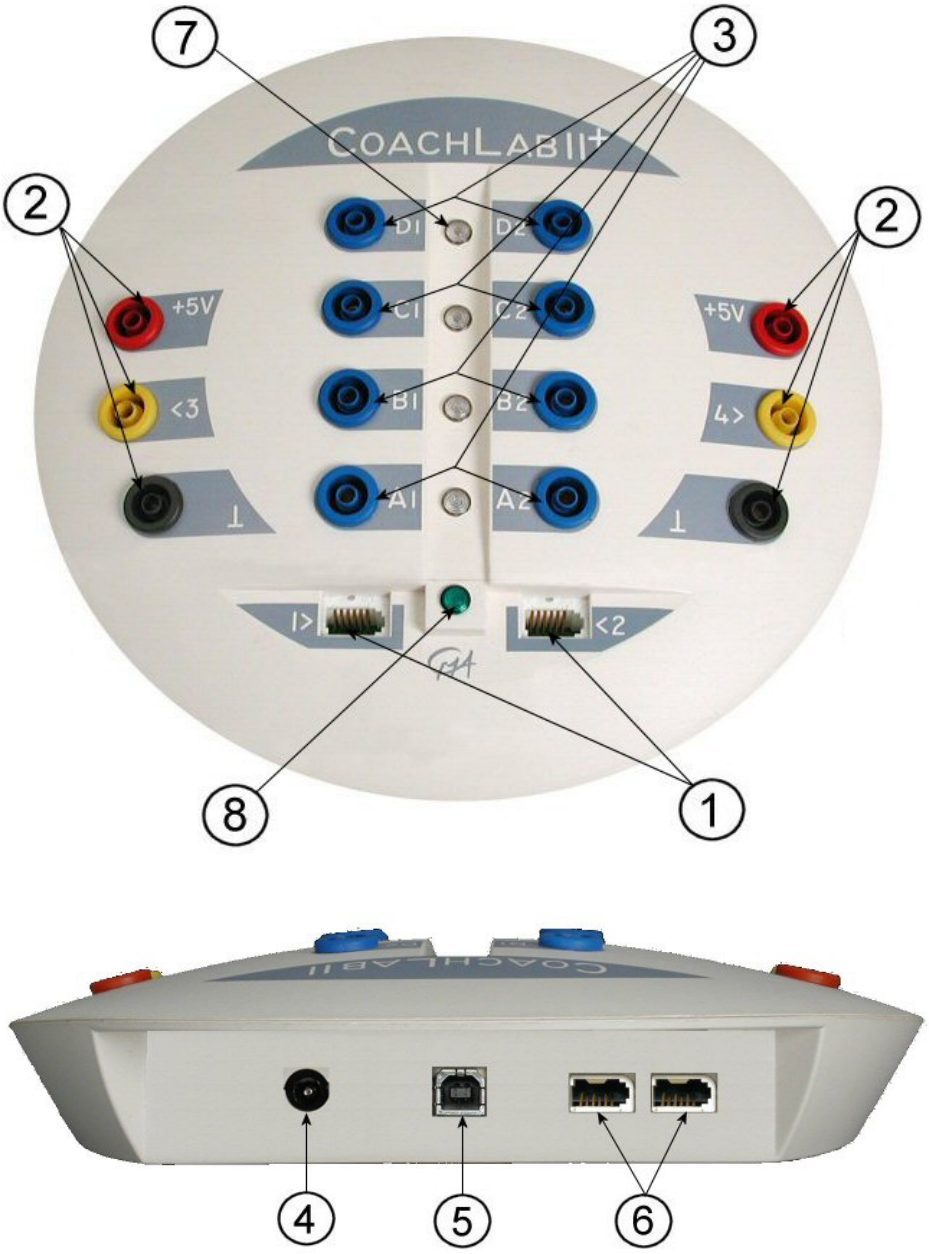
Additionally, it has four control outputs for connecting actuators.

CoachLab II+ connects to a computer via a USB port and is powered by a mains adapter.

The CoachLab II+ package contains the following items:
- CoachLab II+ interface
- Mains adapter
- USB cable, and
- User's Manual (English).

[1] Science, Technology, Engineering and Mathematics

2. CoachLab II+ Overview



1) Two analog BT inputs (1 and 2) to connect sensors with BT connectors.
2) Two analog 4-mm inputs (3 and 4) to connect sensors with 4-mm plugs.
3) Four control output channels A-D to connect various actuators.
4) A bus for the external mains adapter.
5) A bus for USB connection.
6) Two digital BT inputs (input 5 and 6) to connect motion detectors 0664.
7) Four red/orange/green LEDs showing the status of each of the digital output channels.
8) A green LED which lights up when CoachLab II+ is properly powered.

II. GETTING STARTED

1. Turning CoachLab II+ on

To turn on the CoachLab II+, follow these steps:

- Plug the round plug of the 12 V power supply into the socket (4) located on the rear side of CoachLab II+.
- Plug the power adapter into the outlet.
- The green LED (8) will light up, indicating that the interface is properly powered and initiating a test program. During the test, all LEDs will light up in sequence.

Warning:

*Use **ONLY** the included 12-V power main adapter otherwise CoachLab II+ can be damaged.*

To reset CoachLab II+

Occasionally, the communication between CoachLab II+ and the computer may be lost. If this happens, you can reset CoachLab II+ in two ways using the Coach software:

1. If there is no communication when opening a Coach Activity/Results and the program displays a message that the CoachLab II+ panel cannot be initialized:
   - Ensure that the interface is properly connected to the computer (i.e., it worked previously). Reset the interface by disconnecting and reconnecting the plug of the external mains adapter, and
   - Press ***Retry*** in Coach.
2. If communication with the interface is lost while working in a Coach Activity/Result:
   - Right-click the CoachLab II+ screen panel.
   - Select the option *Reset Hardware*.

2. Embedded system

Operating systems such as Microsoft Windows have the disadvantage that "real-time" measurements can be interrupted at any time by other tasks the operating system has to perform (multitasking). This is particularly problematic with high sample frequencies. The solution is to control the processes using a separate microcontroller and store the data in the interface's memory. This technology is utilized in CoachLab II+, which has its own processor and memory. When the software sends a measurement command to CoachLab II+, it performs the measurement independently, and stores the data in its local memory. The data is

then sent to the computer via the USB port. If this process is interrupted by other tasks of the operating system, the data is not lost; it only appears on the screen with a slight delay.

2.1. RAM memory

For buffering sampled data, CoachLab II+ is equipped with 64 kB of RAM, which can store up to 32000 samples. This means that when using one sensor, you can collect 32,000 data points, and when using two sensors, you can collect 16,000 data points per measurement. This applies to **frequencies higher than 10 000 Hz**. At such frequencies, the measurements stops automatically when the memory is full, which may occur before the measurement time is reached.
For **frequencies lower than 10 000 Hz**, the buffer operates in a cyclic manner, allowing measurement runs of up to 500,000[2] points. Data is transferred in real-time as long as data transfer can keep up with data generation. This depends on the used USB.
The measurement time can be extended by using the 'Repeat'[3] option in the Coach program.

2.2. Flash memory

CoachLab II+ is equipped with Flash (non-volatile) memory, which stores the internal operating system (firmware). Flash memory is rewritable, allowing you to update your CoachLab II+ as new functionality becomes available.

To update firmware

To utilize new features for CoachLab II+, it is necessary to update its firmware. You can update the firmware of your interface using the **Firmware Update** option provided under **Tools** in the main menu of the Coach program.
Note that the Coach program automatically detects when a connected CoachLab II+ needs an update and provides a direct update option.

3. Sensor inputs

For connecting sensors CoachLab II+ has:

- Two analog inputs (input 1 and 2) for sensors with BT (British Telecom)-style plugs with a right-hand connector.
- Two analog inputs (input 3 and 4) for sensors with 4-mm plugs.
- Two digital inputs (input 5 and 6) for sensors with BT (British Telecom)-style plugs with a left-hand connector.

[2] The limit of the Coach program

[3] Option: Measurement Settings, Tab Advanced,

Adapters are available to convert:

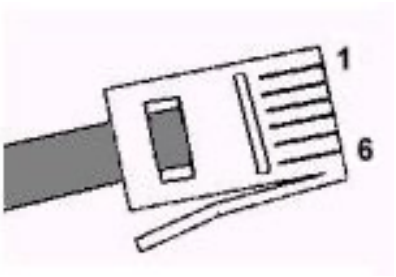
- BT connector to three 4-mm plugs suitable for 4-mm inputs (Art. nr 0520).
- 4-mm plugs to a BT connector suitable for BT analog inputs (Art. nr 0519).

CMA Adapters 0520 (left) and 0519 (right)

3.1. Analog BT sensor inputs

Sensors with BT (right-handed) plug can be connected to BT inputs 1 and 2 of CoachLab II+. The right-handed BT plug has 6 pins with the following connections:

Pin	Connections
1	Vin
2	Ground
3	Vres[1]/I2C[3] data
4	Auto-ID[2]/I2C[3] clock
5	5 V DC
6	Vin-low



[1] V_{res} - Output reference voltage (pull-up resistor 15 kΩ) for resistance measurements.

[2] Auto ID (pull-up resistor 10 kΩ)- Auto ID sensor detection input.

[3] For (I^2C) communication between CoachLab II+ and intelligent sensors.

	Vin	Vin-low
Inputs	1, 2	1, 2
Input range	-10 .. 10 V	0 .. 5 V
Resolution (12 bit)	4.9 mV	1.2 mV
Input impedance	100 kΩ	100 kΩ

The BT inputs **have** the possibility for automatic sensor recognition.

3.2. Analog 4-mm sensor inputs

The 4-mm inputs 3 and 4 of CoachLab II+ allow for direct measurement of any voltage between -10 V and +10V or between 0 and +5V (depending on software settings). They allow sensors with 4-mm plugs to be connected in the following manner:

4mm input	Connections
Red	+5 V DC sensor supply voltage
Yellow	Vin
Black	Ground

	Vin
Inputs	3, 4
Input range	-10 to +10 V or 0 to +5 V (software controlled)
Resolution (12 bit)	4.9 mV (-10 to +10 V range) or 1.2 mV (0 to +5V range)
Input impedance	100 kΩ

Warning: The 4-mm inputs **do not** have the possibility of automatic sensor recognition.

3.3. Analog inputs used as digital counters

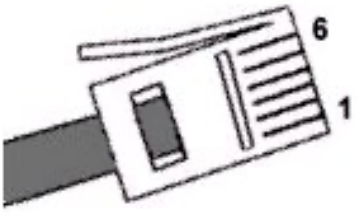
Sometimes it is beneficial to count signal changes from an analog sensor as pulses, for example, to measure the heart rate using a heart-rate sensor.
With CoachLab II+, it is possible to convert an analog sensor to function as a counter, a 1-bit digital meter, a frequency meter, or a time-interval meter (these settings can be adjusted in the Coach software).
For a converted sensor, the input signal is internally monitored at 10 000 Hz, which imposes a maximum frequency limit of 5000 Hz or a count rate limit of 5000 counts per second. All converted sensors utilize conversion settings such as a threshold value and a direction of the signal passing through the threshold.

3.4. Digital BT Inputs

Two digital BT inputs, 5 and 6, are located on the rear side of CoachLab II+. The CMA BT digital (left-handed) Motion Detectors 0664 can be directly connected to these sensor inputs. It's important to note that analog and digital sensors are "keyed" differently to prevent them from being connected to the wrong port.

The left-handed BT plug has 6 pins with the following connections:

Pin	Connections
1	Echo (input) [1] / I/O[3]
2	Init (output) [2] / I/O[3]
3	Auto - ID / I/O[3]
4	+5 V DC
5	Ground
6	I/O[3]



[1] Echo - Ultrasonic motion detector input, TTL signal
[2] Init - Distance initialization signal, TTL signal
[3] I/O: these 4 pins can be configured for digital input or output

3.5. Automatic sensor detection

CoachLab II+ automatically detects sensors when they are connected to the BT inputs and attempts to identify them. Most CMA sensors will be recognized automatically. However, some older BT CMA sensors, sensors connected via the sensor adapter (e.g. CMA 4-mm to BT adapter 0519) or older sensors with 4-mm plugs will not be identified automatically and will need to be manually selected from the Sensor Library in the Coach software.
For sensors connected to the 4-mm inputs, CoachLab II+ does not offer automatic sensor recognition. Sensors connected via these inputs, including those equipped with EEPROM sensor memory, must be manually selected from the Sensor Library in the Coach software.

4. Outputs

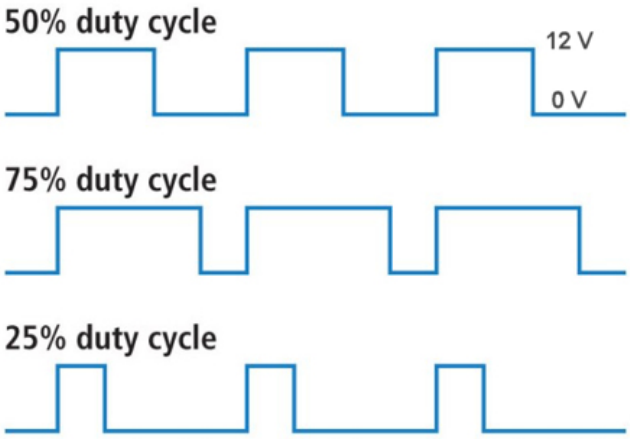
CoachLab II+ features four output channels labeled A to D, designed to control various actuators. Each output channel is equipped with a push-pull channel driver capable of being set in four controllable states. A 'push-pull' output channel consists of two wires, each capable of switching between the poles of the power supply (+12 V and Ground). This configuration allows for selecting the direction of current flow through the actuator, resulting in four distinct controllable states per output.
The output LED indicates the states of each output channel using different colors: Green, Orange, Red, or Off.

The maximum output current for each channel is 0.6 A, with a total combined output current across all channels not exceeding 1.2 A. This allows for driving two bi-directional motors of up to 0.5 A each.
The output channels support 16 different power levels achieved through Pulse Width Modulation (PWM). PWM reduces power by toggling the 12 V supply on and off at a rate of 625 Hz. Here's how the PWM operates:

- At level 1, the output channel is on for 1/16th of the cycle time and off for the rest, repeating at 625 Hz.
- At level 2, the output channel is on for 2/16th of the cycle time and off for the remainder, also repeating at 625 Hz.

In practical terms:

- A 100% duty cycle (output fully on throughout the cycle time) equates to setting the voltage at 12 Volts.
- A 50% duty cycle (output on for half of the cycle time) is equivalent to setting the voltage at 6 V.
- A 0% duty cycle (output fully off throughout the cycle time) is akin to grounding the signal.



50%, 75%, and 25% Duty Cycles

The maximum power level for an actuator can be adjusted in the Coach program.

Note:

To minimize the risk of damage from overloading, the outputs of CoachLab II+ do supply any power when no actuator icon is placed on the screen panel in the Coach software.

CMA offers various actuators, which can be used with the CoachLab II+ interface:

- Actuator set (Art. code 062) includes simple actuators as lamps, a motor, and a buzzer.
- Heating coil (Art. code 018) for heating liquids.

- Immersion heater (Art. code 019) for heating liquids or metal Calorimeter Blocks (Art. code 074)
- Step-motor Burette (Art. nr 061) precise control of liquids, used in titration experiments.
- Switch Module (Art. nr 063) for controlling 110/220V devices.

5. Sampling rate

CoachLab II+ can sample data from up to 6 sensors simultaneously. The maximum sampling rate is determined by the number of channels in use and the configuration of those channels during data collection.

Number of inputs used	Maximum sample rate
One analog input	100 kHz[1]
Two analog inputs	50 kHz
Three analog inputs	3.3 kHz
Four analog inputs	2.5 kHz
One or two converted sensors (counter, frequency, period)	signal sampled at 10 kHz[2]
One motion detector (+ other inputs)	100 Hz
Two motion detectors (+ other inputs)	50 Hz

[1] For higher sample rates, the maximum number of samples is constrained by the internal memory capacity of the interface. This limitation depends on the number of sensors used simultaneously, as they share the same memory buffer.

[2] The signal of the sensor(s) is internally sampled at a frequency of 10000 Hz. Analog signals are sampled every 100 µs and evaluated to determine if they are above or below a specified threshold. Therefore, the analog input signal must remain above the threshold for at least 100 µs and below the threshold for at least 100 µs. This condition sets a maximum pulse or event frequency of 5,000 Hz, assuming the signal is perfectly symmetrical. If the input signal contains noise or is not symmetrical, the maximum pulse frequency will be lower.
When used as a counter, due to these signal requirements, the maximum count rate is 5,000 counts per second (for symmetrical signals).
The maximum sampling frequency of a *converted* signal is 2500 Hz. It's important to note that while the maximum frequency of the signal itself may be higher (up to 5,000 Hz), the interface's sampling capabilities set this limit for data acquisition.

III. USING COACHLAB II+

CoachLab II+ can be connected to various types of host devices, including:
- Windows computers and laptops
- Mac computers and laptops
- Android tablets with a USB port (via Micro USB OTG cable)
- Chromebooks[4].

1. Connecting CoachLab II+ to a host device

CoachLab II+'s USB connection port is located on its rear side.
- Plug the square end of the USB cable into the USB port on CoachLab II+.
- Connect the other end of the USB cable to the USB port on your computer.

For Windows: CoachLab II+ utilizes HID[5] USB, which is supported by a standard driver already available in Windows. The driver installation occurs automatically the first time CoachLab II+ is connected to the PC computer[6]. The Coach program automatically detects the USB connection for CoachLab II+; it is not necessary to specify any hardware settings.

2. Coach programs

The Coach 7 and Coach 7 Lite programs (for Windows and Mac computers) and Coach 7 and Coach 7 Lite Apps (for tablets equipped with the USB port) support measurements with CoachLab II+. During such measurement CoachLab II+ stays connected to a host device via a USB cable. Data collected in real-time are transferred directly to the host device, allowing users to monitor the measurement progress directly on the screen. It's important to note that recorded data are not stored in CoachLab II+'s internal memory and should be saved within the Coach program itself.

2.1. Coach 7[7]

Coach is a multimedia learning and authoring software environment designed for STEM education. It provides tools to:
- collect data using interfaces and sensors,
- control systems,
- measure on digital videos and images,
- model dynamical systems and processes,

[4] More detailed information on use with Chromebooks is given on the CMA website.
[5] Human Interface Device
[6] No administrator rights are needed to install this driver under all Windows versions.
[7] Has to be purchased separate (license code needed for installation).

- process and analyze data.

As an authoring system, Coach enables the creation of multimedia activities for CoachLab II+. Examples of such activities, intended for student use, are accessible within the program. For more detailed information about Coach's functionalities and usage, please refer to the CMA website.

2.2. Coach 7 Lite

Coach 7 Lite is a streamlined version of Coach 7 that supports measurement and control with CMA's interfaces, including CoachLab II+. The program provides a limited set of data processing and analysis tools. Coach 7 is available for free but **requires a license code**. To obtain your free license code, please register on the CMA website at https://cma-science.nl/coach-7-lite.

2.3. Typical measurement procedure in Coach

To collect data with CoachLab II+ (a typical procedure)[8]:

- Connect CoachLab II+ to the computer.
- Launch Coach on the computer.
- Open an Activity/Result for CoachLab II+ in Coach.
- Connect sensor(s) to the sensor input(s) on CoachLab II+.
- CoachLab II+ automatically detects the connected sensor(s) and displays their icons on the CoachLab II+ screen panel. Sensors that are not automatically identified must be selected from the Coach Sensor Library.
- The measurement is executed according to the specified measurement settings. Click the **Measurement Settings** button to review these settings: measurement type, measuring time, sampling frequency, and number of collected samples.
- Follow the instructions in the Activity or start the measurement directly by clicking the green **Start** button.
    - In most cases, Coach automatically initiates the measurement.
    - If triggering is enabled, the measurement starts automatically when the trigger conditions are met.
    - When the type of measurement is set to **Manual**, the green **Manual Start** button appears in the Toolbar. Click this button to collect a single measurement. If keyboard input(s) is specified enter the value(s) for one or more quantities as required.
- The measurement stops when the specified measurement time (for time-based measurements) or the specified number of samples (for manual measurements) has been reached. If you need to interrupt the measurement process, click the red **Stop** button or press <***Esc***>.

[8] This procedure does not describe the Event-based type of measurement.

- Save your result to a file using the **File** menu options **Save** or **Save As…**.

2.4. Control of outputs

Actuators connected to CoachLab II+ outputs can be controlled via the CoachLab II+ screen panel or through a control program in the Coach program.
The CoachLab II+ screen panel, displayed in the Measurement and Control Activities, shows empty output spaces. If no actuator is placed on an output, that output is not powered.

To select an actuator

- Click an output (the cursor changes to a hand) and select **Choose and Actuator**.
- Select an actuator from the list.
- Click **OK** to accept. The icon of the selected actuator will be placed on the output.
- The status of the actuator is shown on the icon.
- To manually control the actuator, click circles representing LEDS located in the middle of the screen panel. Depending on the type of the selected actuator, 2 or 4 bits, you will have 2, 3 or 4 possibilities.
- To control the actuators via a control program run your program.

APPENDIX. MEASUREMENT AND CONTROL COMMANDS OF COACHLAB II+

1. Measurement methods

The following measurement techniques are implemented in CoachLab II+:

Single reading

A direct sample (data point) from a given channel is collected.

Time-based measurements

Data from each connected channel (analog and/or digital) are collected at a regular time interval. The sampling frequency and total measurement time can be selected.
One of the channels can serve as a trigger channel. The pre-trigger time, trigger level and trigger direction can be predefined.
For measurements with selected pre-trigger time before it is checked or the signal fulfills the trigger conditions the measured data are stored in the pre-trigger buffer. Because of this the data collected during the pre-trigger time are always available.

Event-based measurements

Before an event-based measurement can be performed a counter, or a converted analog sensor (counter, frequency, 1-bit digital, or period) must be assigned to an analog or a digital input. Data from all connected channels are collected each time an external event is registered by the counter. Next to the sensor values also time stamps are recorded (with a resolution of 100 μs).
The measurement process stops after a specified number of events.

Start-stop measurement

By using the event-based mode it is possible to perform time measurements for example when a falling object passes across two light gates.

Response-time measurement

This method is used for measurements with ultrasonic motion detectors. The distance between an object and a motion detector is determined in the following way. CoachLab II+ initiates a measurement by sending a trigger pulse to an ultrasonic motion detector. At the same moment the 16-bits timer of the micro-controller is reset and the ultrasound detector sends an ultrasonic pulse. When the sensor detects the pulse reflected from an object the time is recorded. Based on the time and the speed of sound in air the distance between the detector and the object is determined. The resolution of the measured time is 1.33 μs. This corresponds to a resolution of 0.23 mm in the determination of the distance.

Counting 'events' / 'pulses'

In this method a counter is incremented by one unit when an event is registered at an analog or a digital channel. The counting range is 0 - 65535.

Up/down counter

There are sensors (e.g. a bi-directional pulley) that generate a counting signal on two different pins of the connector. One of the signals is used to increase the counter, the other one to decrease the counter. CoachLab II+ is able to handle the signals from these kinds of sensors. The interface is also able to handle signals where the counting direction (up or down) depends on the value of a second pin (e.g. 0 is count up, 1 is count down). The counting range lies between -32768 and 32767.

2. Control commands

Analog or digital actuators can be controlled through the outputs of CoachLab II+. For this purpose the following commands are implemented:

SetOutputs On/Off

All outputs are set in the specified state at the same time

SetBit(s)

One or more outputs (specified by the parameter **s**) are set to 'High' at the same time.

ResetBit(s)

One or more outputs (specified by the parameter **s**) are reset to 'Low' at the same time.

GetOutputs

Returns the actual state of the outputs.

SetPowerLevel

Sets the power level of an output to one of the 16 available levels. The power is reduced by switching the 12 V on an output channel on and off at a rate of 625 Hz for certain part of the time period (ranging from 1/16 to 16/16 period). This is called PWM - Pulse Width Modulation.

OnFor (one-shot)

An output can be switched on for a given time interval. Time resolution is 0.8 ms. Maximum time is 52 s.

Flash

An output can be periodically switched on or off. Maximum period time is 13 s.

When two outputs, which are adjusted to the same power level, are combined as one analog channel, it is possible to control for example a DC motor, which turns in two directions.

3. Measurement and control at the same time

All control commands can be executed while a measurement is running for sampling frequencies up to 10000 Hz.

Note:
It is possible to develop own software (for example in LabVIEW or Java) to control CoachLab II+. For this reason the description of command list and the data formats for CoachLab II+ are available on request from CMA.

TECHNICAL SPECIFICATIONS

1. Key features

PROCESSOR	PIC18F66J50
MEMORY	64 kB RAM
POWER	Mains Adapter (110 V US version, 220 V European version AC/DC 12V/1.25A) 2.1 mm DC-plug. Polarity: inside positive (+), outside negative (−)
STATUS INFORMATION	Green LED indicates proper powering Red/Orange/Green LEDs indicate the 4 states of the output channels
ADC RESOLUTION	12 bits
SAMPLING FREQUENCY	Max 100 000 Hz, via one channel
SENSOR INPUTS	Two analog BT (right-handed) inputs Two analog 4-mm inputs Two digital BT (left-handed) inputs
CONTROL OUTPUTS	Four output channels with variable power levels
CONNECTION TO A HOST DEVICE	Via USB, data transfer depends on the used device
COMPUTER SOFTWARE	Coach 7 Lite (free) or Coach 7

2. Working conditions and maintenance

For your safety and that of your equipment, follow these rules for handling, for cleaning CoachLab II+, and for working more comfortably.

- Your CoachLab II+ is designed to be operated on a desk.
- Your CoachLab II+ is not waterproof. Precautions must be taken to ensure that liquid cannot enter the unit.
- Do not expose CoachLab II+ to extreme heat or cold sources and to direct sunlight for extended periods of time.
- Operating CoachLab II+ outside the following ranges may affect performance:
    - Temperature: 5° to 40° C.
    - Relative humidity: 0 % to 90 % (noncondensing)
- Never force a connector into a port. When connecting a sensor, make sure that the sensor cable connector matches the sensor input, and that you have positioned the connector correctly.
- When cleaning CoachLab II+, first turn it off and unplug the connected sensors and USB cable. Then clean with a soft, lint-free cloth. Avoid getting moisture in any openings. Do not spray liquid directly on CoachLab II+.
- Use **ONLY** the included 12-V power main adapter otherwise CoachLab II+ can be damaged.

3. Warranty

CoachLab II+ is warranted to be free from defects in materials and workmanship for a period of 24 months from the date of purchase provided that it has been used under normal laboratory conditions. This warranty does not apply if CoachLab II+ has been damaged by accident or misuse.

4. Safety Information

CoachLab II+ is developed and produced in conformity with CE regulations.
This product shall be handed over to your local community waste collection point for recycle of the products.

This product is to be used for educational purposes only.
It is not appropriate for industrial, medical, research, or commercial applications.