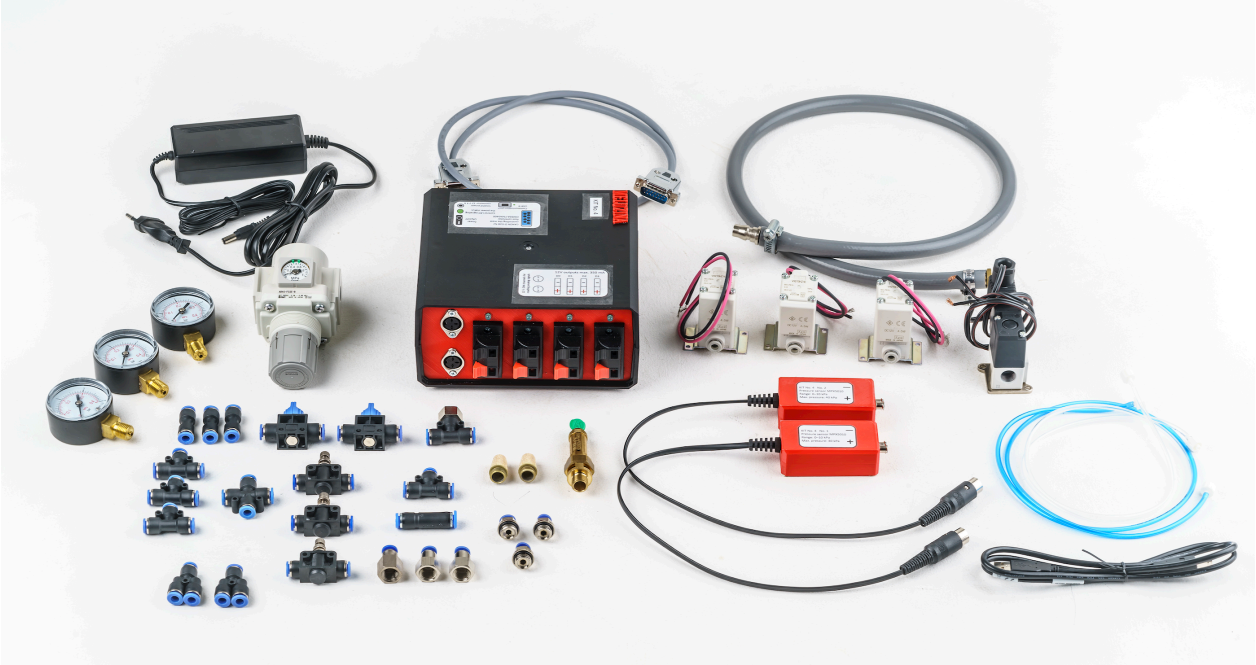
PNEHYKUR manual

PNEHYKUR is a pneumatic and hydraulic kit specially developed by Non-conventional Ventilatory Team (NVT) at the Faculty of biomedical engineering (FBME) CTU in Prague for teaching Fluid Mechanics and Plumbing. PNEHYKUR kit contains the main computer called Meluzína, connectors and adapters, pressure sensors, electromagnetic solenoids, and pneumatic components.



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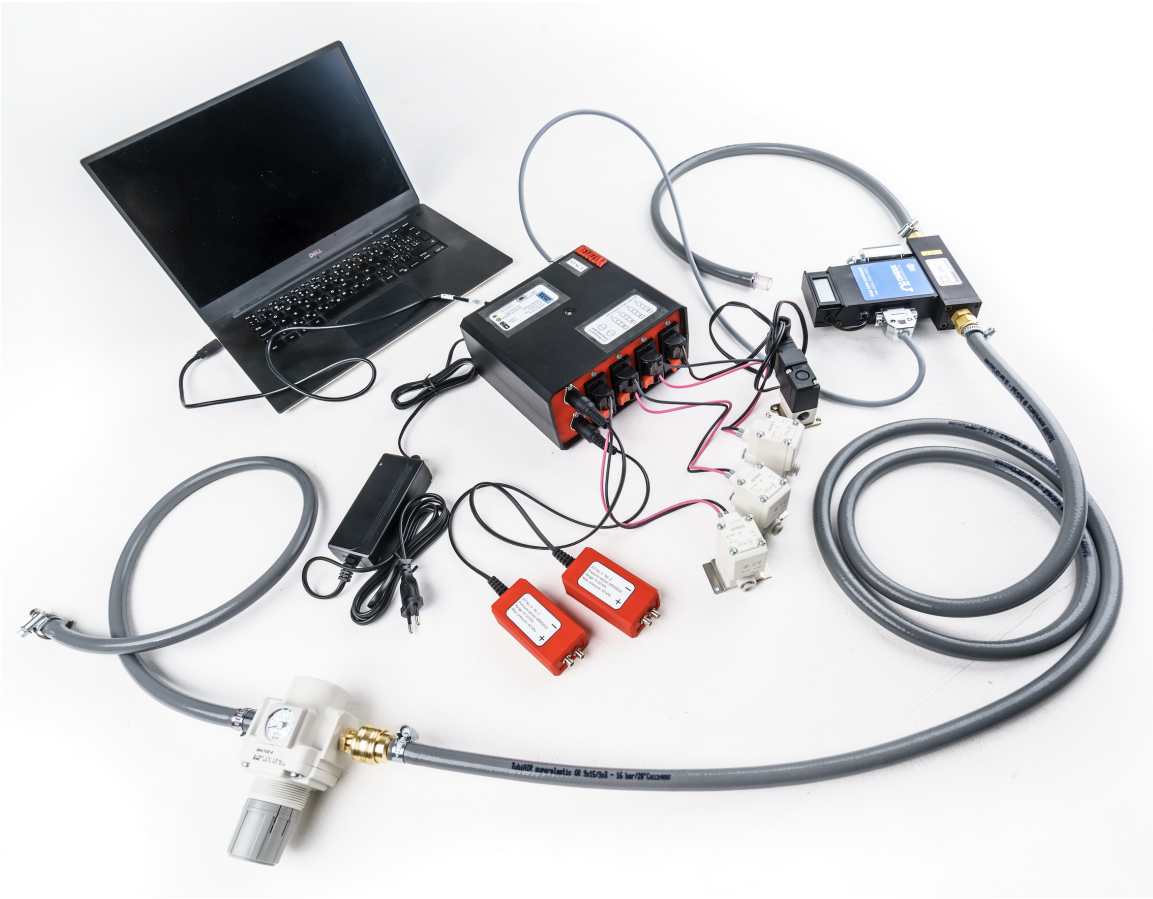


Fig. 1: Completely connected PNEHYKUR kit 1.0 with OMEGA FMA5400 flow controller

1. Every PNEHYKUR kit 1.0 contains:

1. Meluzína
2. 2x pressure sensor
3. Connector between Meluzína and OMEGA FMA5400 controller
4. Connector between Meluzína and PC
5. Power supply 12V
6. 3x 2/2 electromagnetic solenoid
7. 1x Pressure reducing valve
8. 1x 3/2 electromagnetic solenoid
9. Connector between air distribution system and pressure reducing valve
10. 2x connector between pressure sensor and other sampling point
11. 3x Manometer
12. 1x Pressure relief valve
13. 2x muffler
14. 3x straight internal fittings
15. 3x straight external fittings
16. 4x T–connector
17. 3x straight connector
18. 2x Y–connector
19. 1x X–connector
20. 3x throttle valve
21. 1x self-closing straight fitting
22. 2x ball valve
23. 1x T–connector with internal fittings

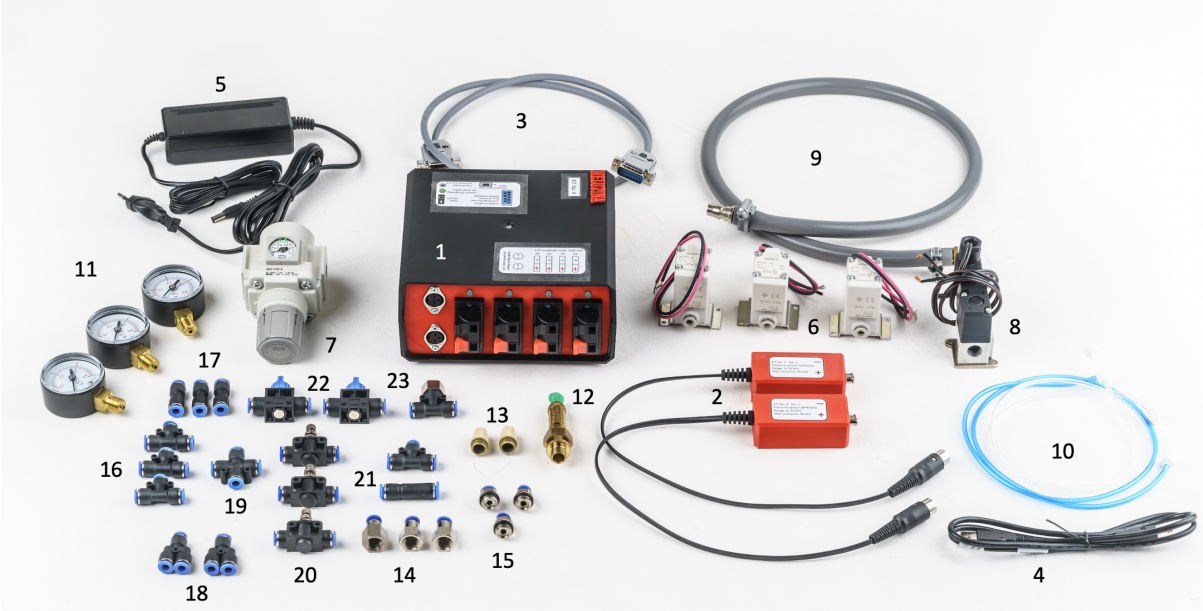


Fig. 2: All the components of the PNEHYKUR kit 1.0

2. Every PNEHYKUR kit 2.0 contains:

1. PC
2. Meluzína
3. Pressure reducing valve
4. 2x pressure sensor
5. Air flowmeter 0–100 L/min with G1/4 or 6mm connector
6. Connector between Meluzína and OMEGA FMA5400 flow controller
7. Power adapter
8. Power supply 12V
9. Connector between Meluzína and PC
10. 2x extension cable for the air flowmeter
11. Manometers (2x 0–1 Bar, 2x 0–4 Bar, 0–8 kPa, 0–100 mbar, 0–100 cmH_2O)
12. Thermometer with 4mm connector
13. 3x 2/2 electromagnetic solenoid
14. Throttling scissors
15. 2x teflon tape
16. 6mm particulate filter
17. 6mm pressure indicator
18. 6mm ball valve with release
19. 2x internal G3/8 connector
20. Push-in coupler with external G1/4 connector
21. Push-in coupler with internal G1/4 connector
22. Push-in quick coupler (Asian type)
23. Push-in quick coupler (European type)
24. 6x 6mm straight coupler with external G1/4 connector
25. 2x 6mm T-connector with internal G1/4 connector
26. 6x 6mm straight coupler with internal G1/4 connector
27. Pressure relief valve
28. Muffler
29. 4x sealing ring
30. 2x internal reduction
31. Female quick coupler with external G1/4 connector (European type)
32. 2x 6mm straight connector
33. 3x 6mm–4mm straight connector
34. 6mm Y-connector
35. 4x 6mm T-connector
36. 6mm X-connector
37. 2x 6mm ball valve
38. 2x 6mm throttle valve

Fig. 3: All the components of the PNEHYKUR kit 2.0

3. Meluzína

Meluzína is a universal device that was specially developed for the PNEHYKUR educational kit. The control is mediated by the LabView program interface. Using the Meluzína device, **it is primarily possible to control the OMEGA FMA5400 flow controller, read analog signals from sensors or control solenoid valves and pumps.**

Fig. 4: Back view of the Meluzína device

Fig. 5: Front view of the Meluzína device

3.1 Accessories

You will need the following connectors to take the full advantage of the Meluzína device:

Fig. 6: Power supply with a nominal voltage of 12 V and a maximum current of 4 A

Fig. 7: Connector between Meluzína and OMEGA FMA5400 flow controller – 14 channel cable for communication

Fig. 8: Connector between Meluzína and PC – USB cable (male–male) type B – type A

3.2 Front view

On the front, there are four 12V outputs for controlling valves or motors or pumps with a maximum current consumption of 350 mA. The red marked socket is for positive voltage polarity and the black socket is for negative polarity. In the left part of the front panel there are two DIN female connectors with 12V output and a channel for reading analog signals (three DIN female connectors in the Meluzína 2.0).

Fig. 9: Front view with two DIN connectors and four 12V outputs

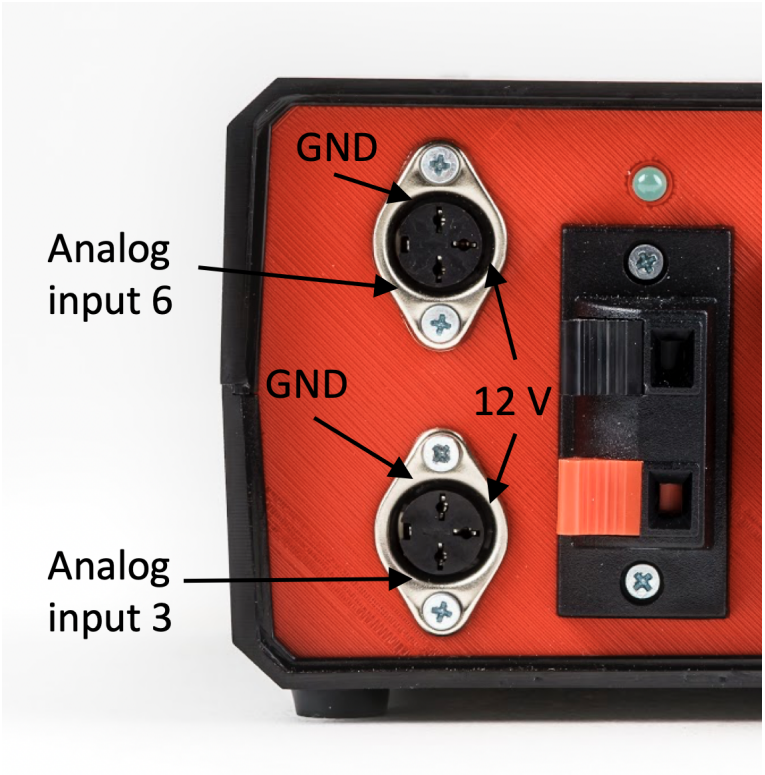


Fig. 10: Detailed front view of pinouts of DIN connectors

3.3 Back view

On the back, there is a coaxial power connector (12 V, 4 A), a switch for powering the device, a control LED for signaling the power status, one CANON D–SUB for controlling the flow controller OMEGA FMA5400 and a USB–B communication port for connection DAQ cards with LabView software environment on the computer.

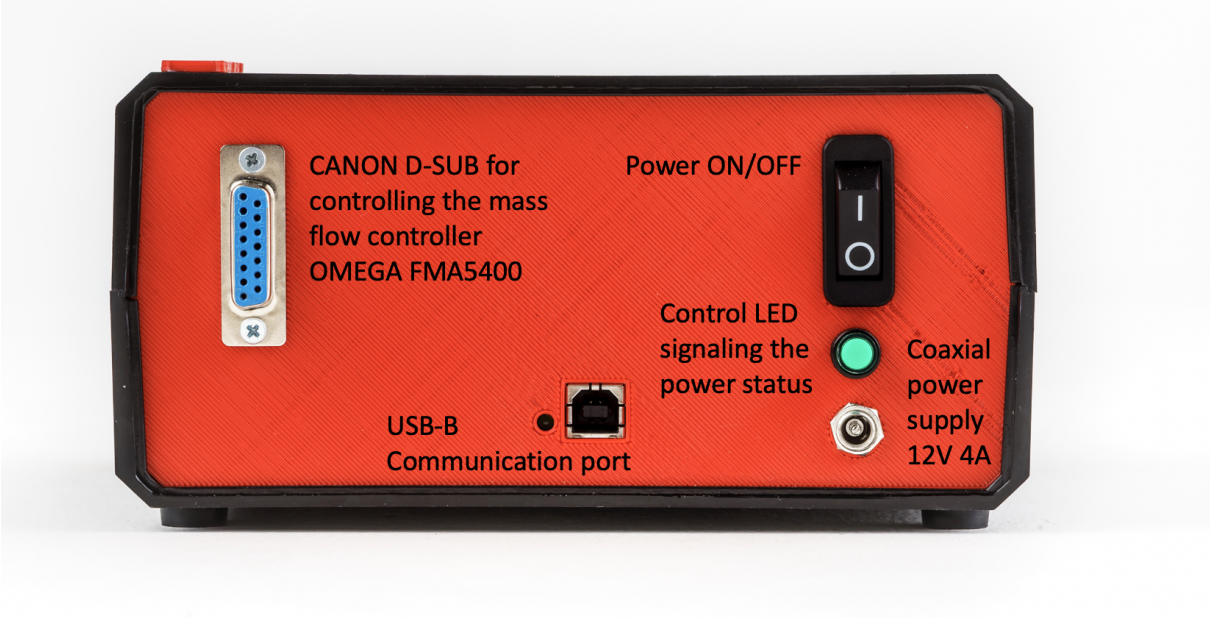


Fig. 11: Back view with inputs for connectors

3.4 Maximum load

Meluzína's internal circuits are protected by a 4A fuse located inside. At full load of all outputs, a current consumption of 350 mA to one of the digital outputs (D0–D3) is calculated. Power supply for Omega FMA5400 flow controller with a value of 650 mA.

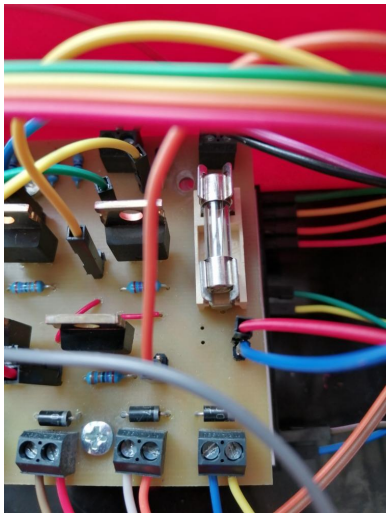


Fig. 12: Fuse location detail

4. Typical connecting to the air-distribution system

Use a pressure reducing valve to reduce the pressure from the air-distribution system to a **maximum of 2 bar**. Another hose is connected to the flow controller OMEGA FMA5400 and the hose is ending with a 15 mm I.D. adapter. Do not forget to connect the OMEGA FMA5400 to the Meluzína device.

It is also possible to use a pressure reducing valve to reduce the pressure from the air-distribution system and then connect a 6mm hose to the pressure reducing valve without using OMEGA FMA5400 and Meluzína. The flow can be adjusted by a throttle valve.

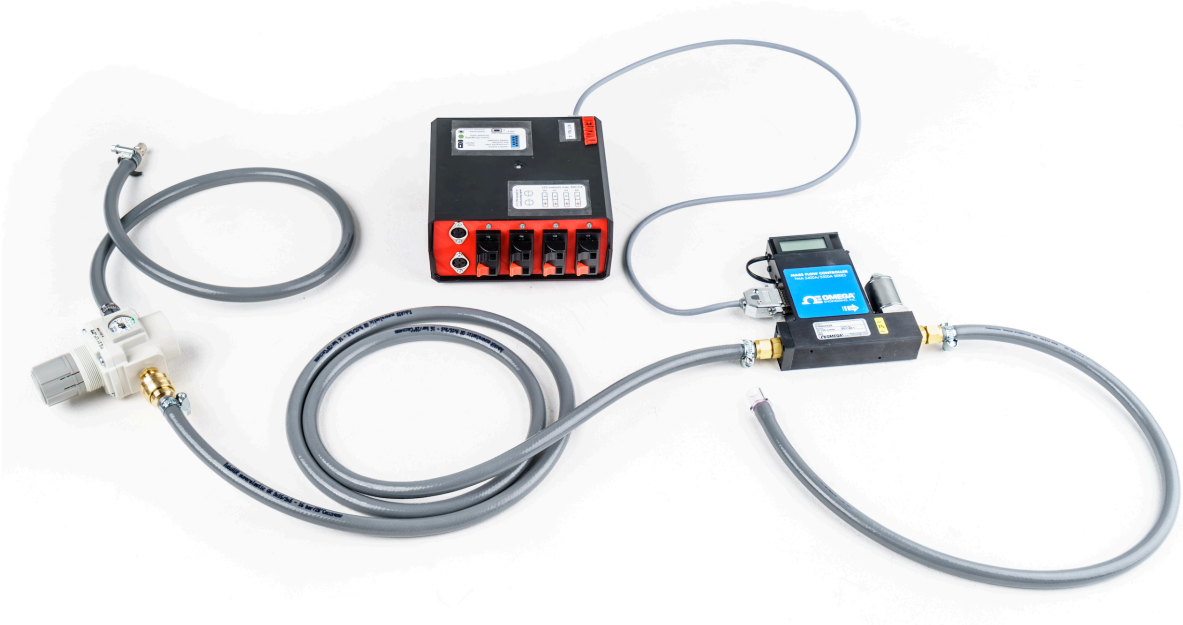


Fig. 13: Typical connecting to the air-distribution system

5. SOFTWARE

Software for signal readings from the sensors, for controlling the flow rate and for controlling the solenoid valves and pumps is made in LabVIEW (National Instrument, Austin, Texas, USA). The basis for all these applications is a DAQ device driver. Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, vibration, or sound with a computer. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with application software.

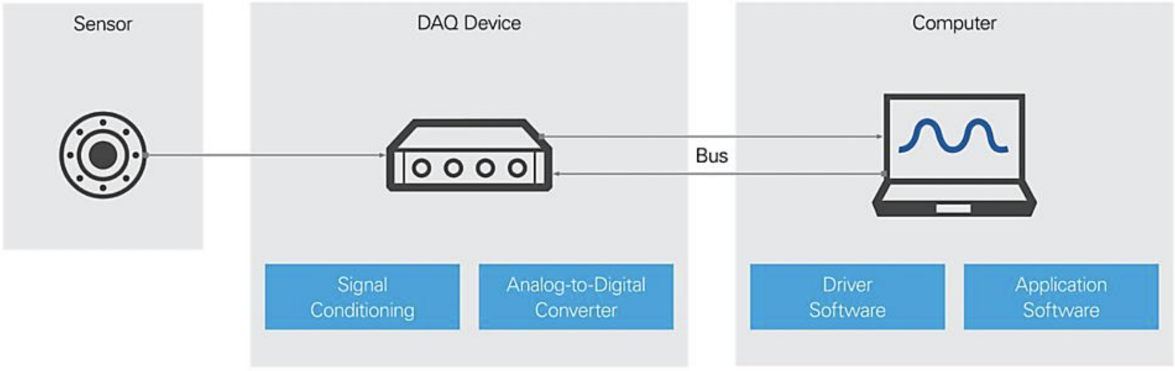


Fig. 14: A scheme of converting signal into computer

The designed SW in LabVIEW primarily enables to:

1. control OMEGA FMA5400 flow controller
2. read analog signals from sensors
3. control solenoid valves or pumps

5.1 Setup

a) First, switch on a computer and power the Meluzína device.
b) Next, connect the Meluzína with the computer.
c) Other connections depend on the laboratory task.
d) At the computer select the one needed exe file.
e) Then, select the connected Meluzína device you are using.

Fig. 15: Dialog panel for selecting connected Meluzína device

5.2 OMEGA FMA5400 control

For the laboratory task No. 1 in Fluid Mechanics and No. 3 in Plumbing, you will need to control the OMEGA FMA5400 to control the flow. You connect the Meluzína with the OMEGA FMA5400. The flow between 0–100 L/min is set by the cursor on the graph or by adding a number into the white box under the graph. When you click on the button "Full open", the OMEGA will give a maximal flow. When you click on the button "Close", the OMEGA will stop working.

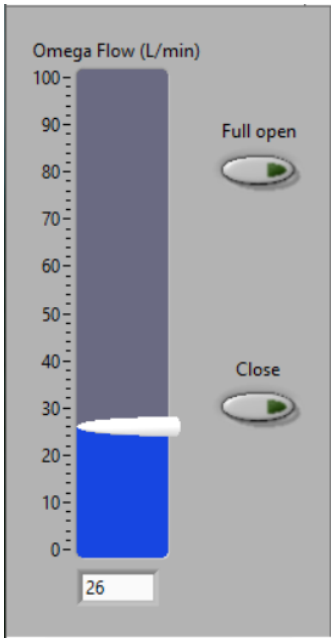


Fig. 16: Controlling the flow on the OMEGA FMA5400

5.3 Manual measurement of the P–Q characteristic

For a part of the laboratory task No. 2 and No. 3 in Fluid Mechanics and No. 5 in Plumbing, you will need to control the OMEGA FMA5400 and read an analog signal from the sensor. You connect Meluzína with the OMEGA FMA5400 and with the pressure sensor. You can choose between 10kPa pressure sensor MPX5010 and +/- 2kPa pressure sensor MPX7002 in the left down corner. Under this box, it is possible to make **zeroing of the sensor**. Especially for the MPX7002 sensor it is important. The flow between 0–100 L/min is set by the cursor on the graph or by adding a number into white box under the graph. When you click on the button "STOP", the OMEGA will stop working. On the graph, there is pressure in kPa on the Y coordinate and time on the X coordinate. Under the graph, there is a box showing the actual pressure in numbers.

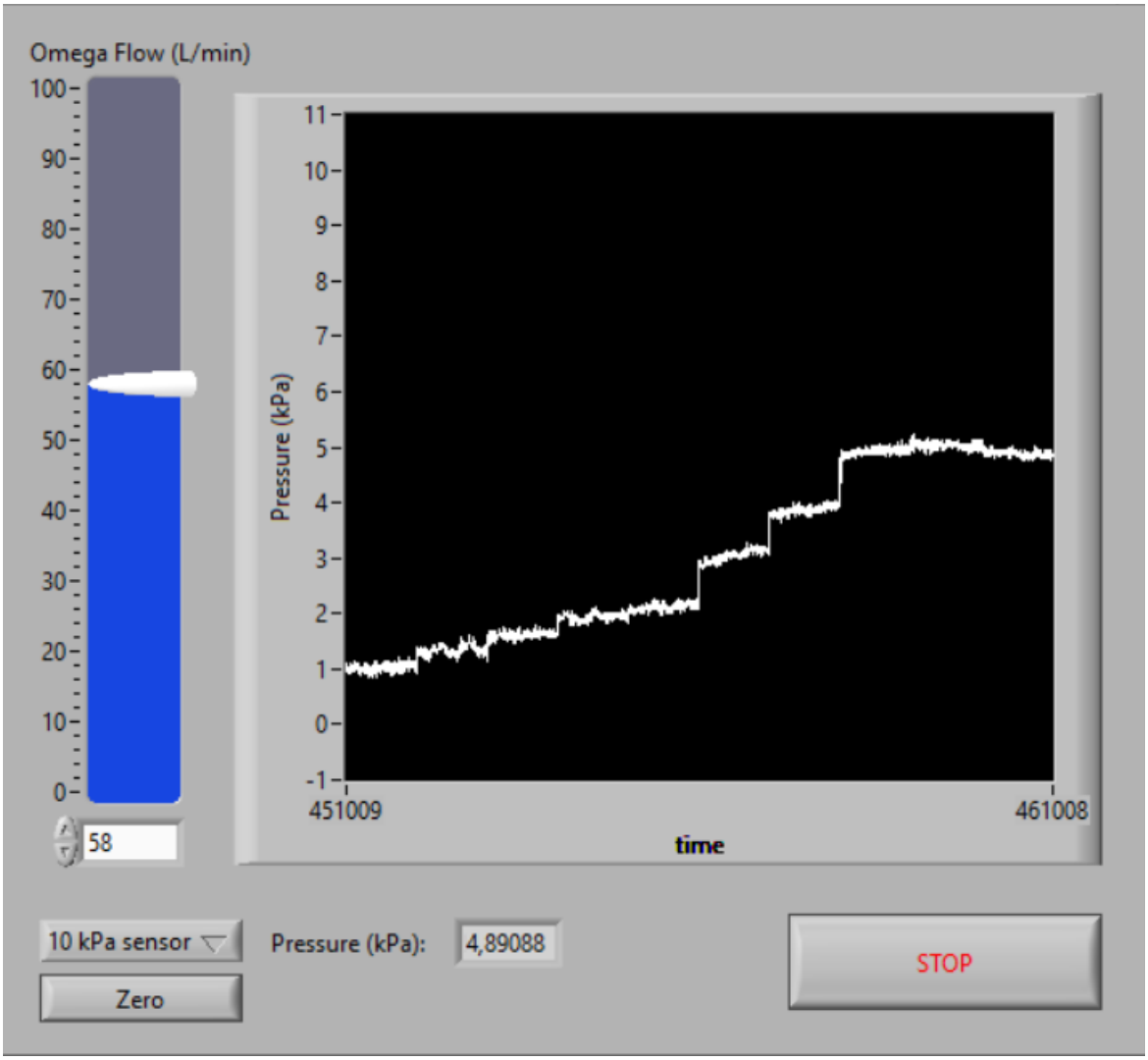


Fig. 17: Controlling the flow on the OMEGA FMA5400 and reading a signal from the pressure sensor

5.4 Automatic measurement of the P-Q characteristic

For a part of the laboratory task No. 2 and No. 3 in Fluid Mechanics, you will need to control the OMEGA FMA5400 and read an analog signal from a sensor. You connect Meluzína with the OMEGA FMA5400 and with the pressure sensor or with the flow meter. You can choose between 10kPa pressure sensor MPX5010, +/- 2kPa pressure sensor MPX7002, Hotwire sensor and Turbine sensor in the left-up corner. The measurement goes from the highest flow to the lowest flow. The first step always takes at least 10 seconds.

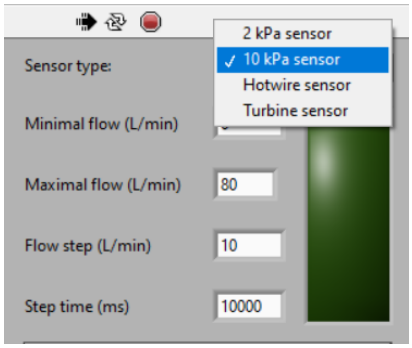


Fig. 18: Choosing the right sensor or flowmeter

In the left part of the application, you can set the minimal and maximal flow, flow step and step time (it takes some time to the OMEGA FMA5400 to stabilise the flow). Do not forget to zero the pressure sensor before the measurement. On the graph, you see the measured pressure. It is possible to see the actual set flow under the graph. When you click on the button "Export data" after the measurement, the data will be copied (CTRL C) and you can insert them into another document for further analysis. In the right part of the graph, there will show the measured pressures after the measurement. When you click on the button "STOP", the OMEGA FMA5400 will stop working.

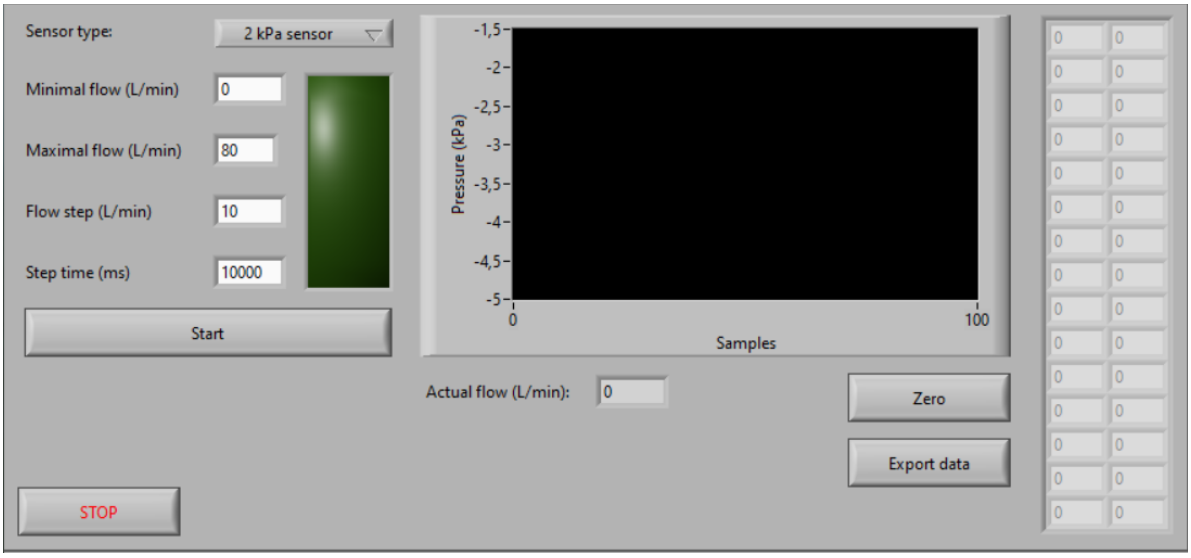


Fig. 19: The whole application for automatic measurement of P-Q characteristic

5.5 Valve cycling

For laboratory tasks No. 4 and No. 8 in Fluid Mechanics and No. 3, No. 7, No. 8 and No. 10 in Plumbing, you will need to control electromagnetic solenoid valves or pumps and/or read a signal from a sensor. You connect Meluzína with the pressure sensor or with the flow meter and with a maximum of four electromagnetic solenoid valves. You can choose between 10kPa pressure sensor MPX5010, +/- 2kPa pressure sensor MPX7002, Hotwire sensor and Turbine sensor in the left-up corner.

The right part of the application is designed for controlling electromagnetic solenoid valves or pumps. You can decide how many valves you are going to use and down in the application; you decide the time duration of each step of the iteration. On the left, there is a white box for choosing a number of iterations. You have got a maximum of four steps for one iteration. By clicking on the button of the chosen valve, you choose this valve to be open in that step. You can open all the valves in one step, close all the valves in the other step or choose one to be open for the whole time, it is up to you.

Do not forget to zero the pressure sensor before the measurement. On the graph, you see the measured pressure. When you click on the button “Export data” after the measurement, the data will be copied (CTRL C) and you can insert them into another document for further analysis. When you click on the button “STOP”, the measurement will stop.

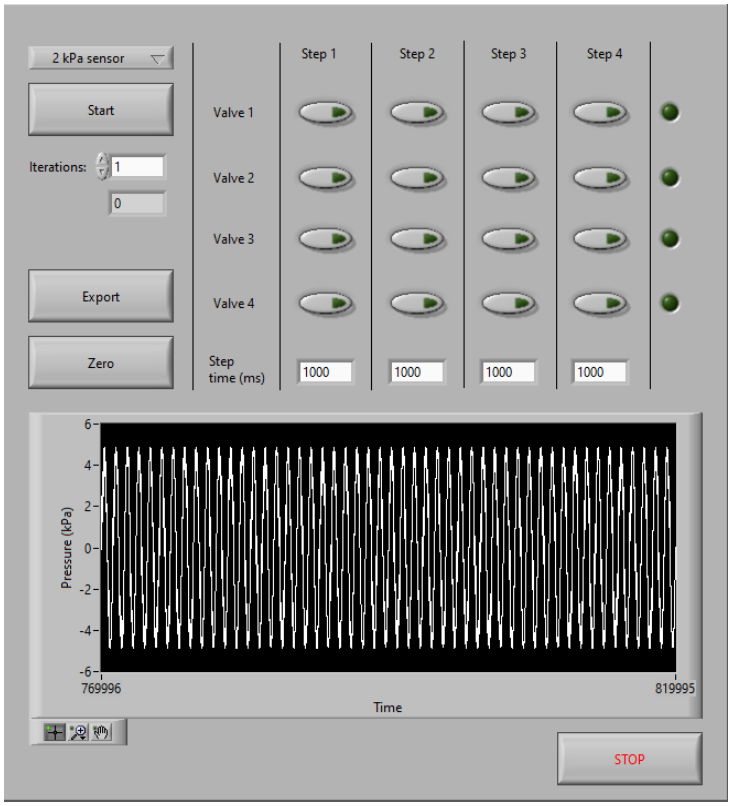


Fig. 20: The whole application for controlling the solenoid valves and reading a signal from pressure sensor

5.6 Pressure measurement

For laboratory tasks No. 5 in Fluid Mechanics and No. 6 and No. 7 in Plumbing, you will need to read a signal from a sensor. You connect Meluzína with the pressure sensor. You can choose between 10kPa pressure sensor MPX5010, +/- 2kPa pressure sensor MPX7002.

Do not forget to zero the pressure sensor before the measurement. On the graph, you see the measured pressure. When you click on the button “STOP”, the measurement will stop.

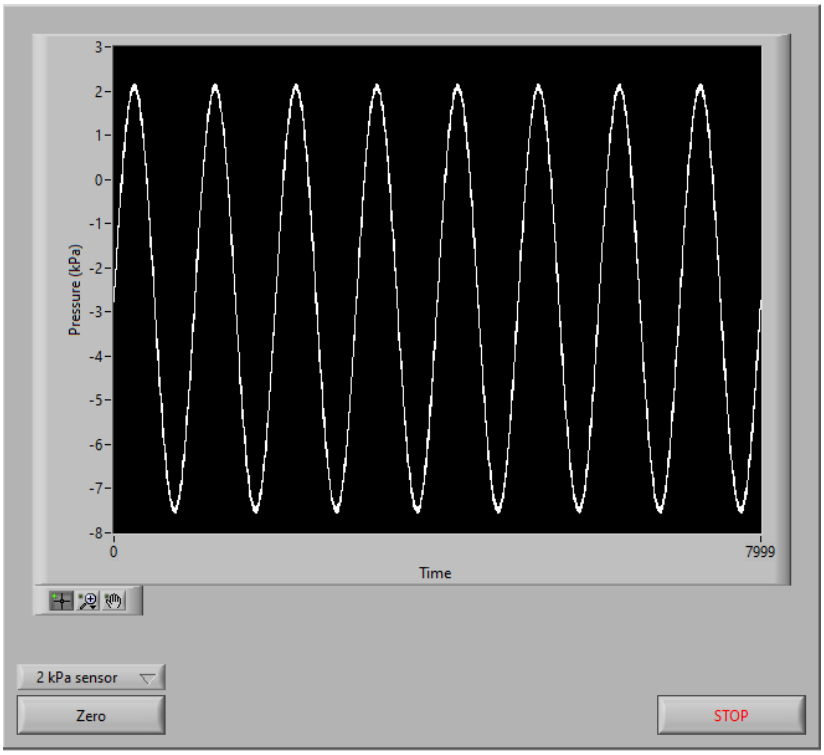


Fig. 21: The application for reading a signal from pressure sensor

5.7 Automatic measurement of compliance

For the laboratory task No. 6 in Fluid Mechanics, you will need to control the OMEGA FMA5400, read an analog signal from the sensor and control solenoid valves. You connect Meluzína with the OMEGA FMA5400 and with the pressure sensors. Also, you put the wires from the solenoids into the red marked socket (for positive voltage polarity) and into the black socket (for negative polarity). You will use the 10kPa pressure sensor MPX5010. In the left-up part of the application, you choose the Meluzína device. The flow between 0–100 L/min is set by the cursor on the graph or by adding a number into white box under the graph. You have got a maximum of five steps to measure the compliance of the demijohn. By clicking on the button of the chosen valve, you choose this valve to be open in that step. You can open all the valves in one step, close all the valves in the other step or choose one to be open for the whole time, it is up to you. Down in the application, you decide the time duration of each step. When you click on the button “Export data” after the measurement, the data will be copied (CTRL C) and you can insert them into another document for further analysis. On the graph, you see the measured pressure. Do not forget to zero the pressure sensor before the measurement. When you click on the button “STOP”, the OMEGA will stop working.

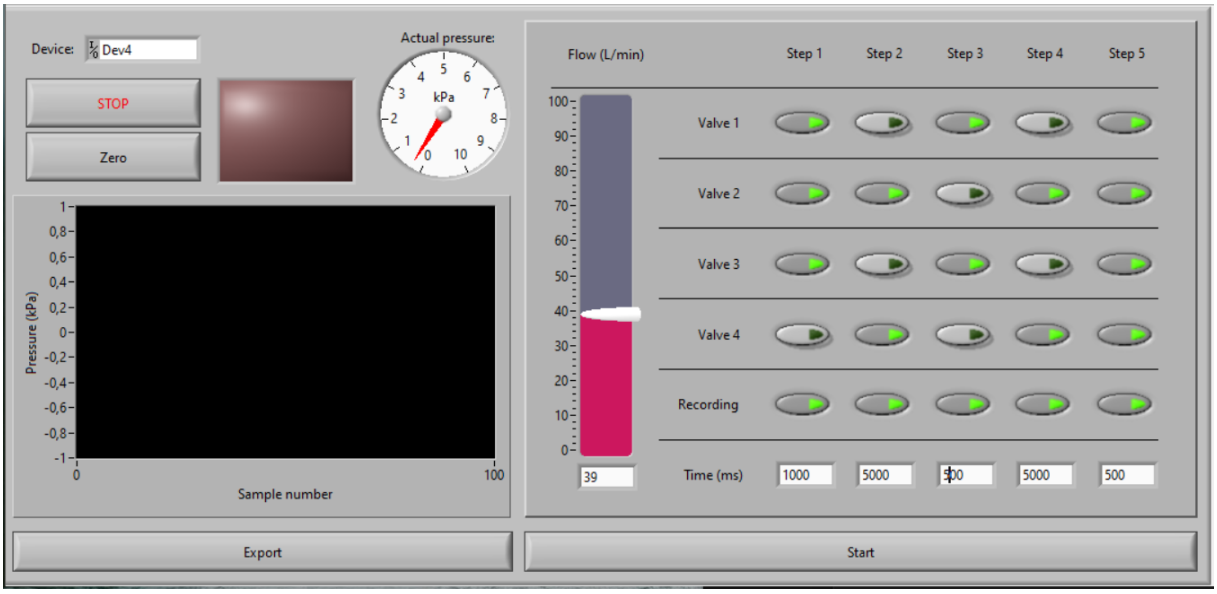


Fig. 22: The whole application of automatic measurement of compliance

6. Additional modules

The following prepared modules for sensing non–electrical quantities can be connected to the DIN connectors: Pressure sensor 10kPa MPX5010, accurate pressure sensor +/- 2 kPa MPX7002, anemometer with a hot wire, flowmeter with Hall sensor and digital air flowmeter.

6.1 Pressure sensor MPX5010 0–10 kPa

The pressure sensor has a range of 0–10 kPa, which senses the pressure using the MPX5010 sensor.

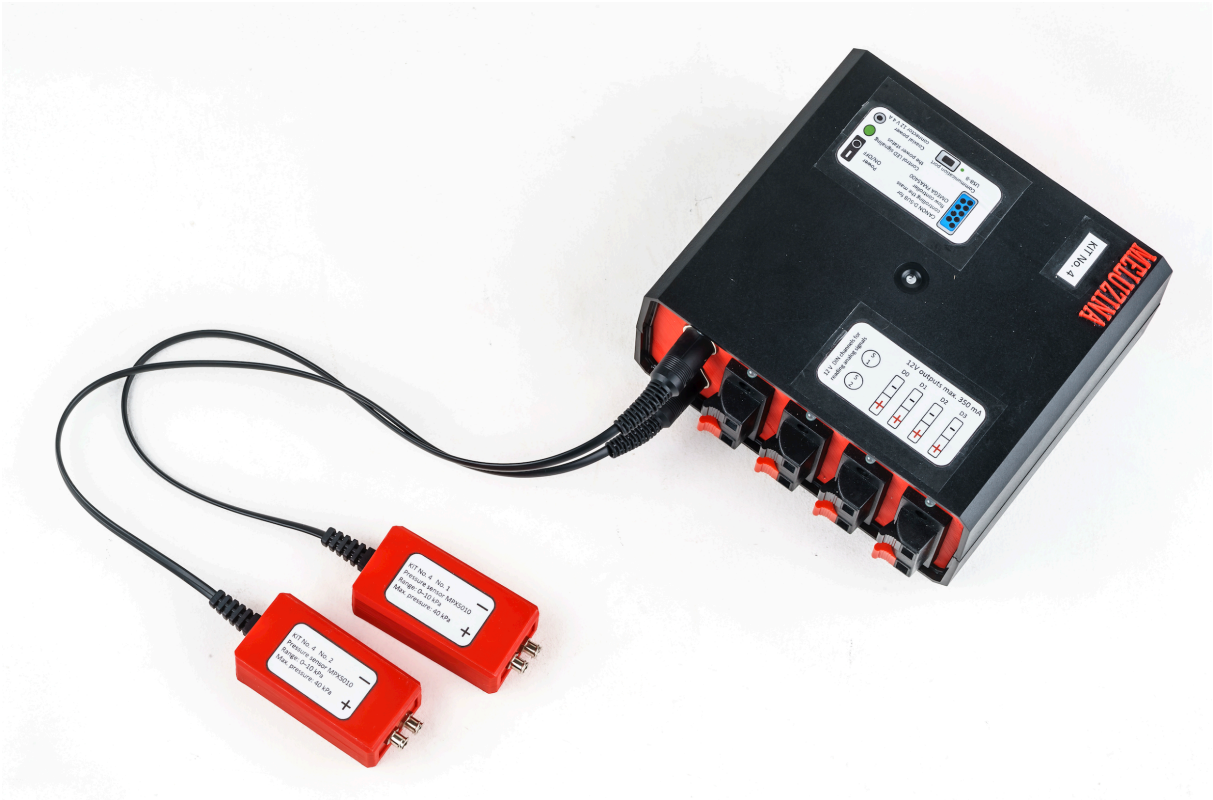


Fig. 23: Connection between Meluzína and two 10kPa pressure sensors

Technical parameters are in the following table:

Pressure sensor MPX5010	
Parameter	**Value**
Power supply	12 V
Signal	0–5 V
Range	0–10 kPa
Max. pressure	40 kPa

Fig. 24: 10kPa pressure sensors

6.2 Pressure sensor MPX7002DP +/- 2 kPa

This pressure sensor is for sensitive measurements and its measuring range is +/- 2 kPa. The pressure is measured by the MPX7002DP sensor.

Fig. 25: Connection between Meluzína and two +/- 2kPa pressure sensors

Technical parameters are in the following table:

Pressure sensor MPX7002DP	
Parameter	**Value**
Power supply	12 V
Signal	0–5 V
Range	-2 to +2 kPa
Max. pressure difference between ports	75 kPa

Fig. 26: +/- 2kPa pressure sensors

6.3 Anemometer with a heating wire

Another module is an anemometer with a hot wire. The measuring bridge must be balanced with the potentiometer before measuring the flow.

Technical parameters are in the following table:

Anemometer with a heating wire	
Parameter	**Value**
Power supply	12 V
Signal	0–3 V
Range	~0–15 L/min

Fig. 27: Hot wire anemometer

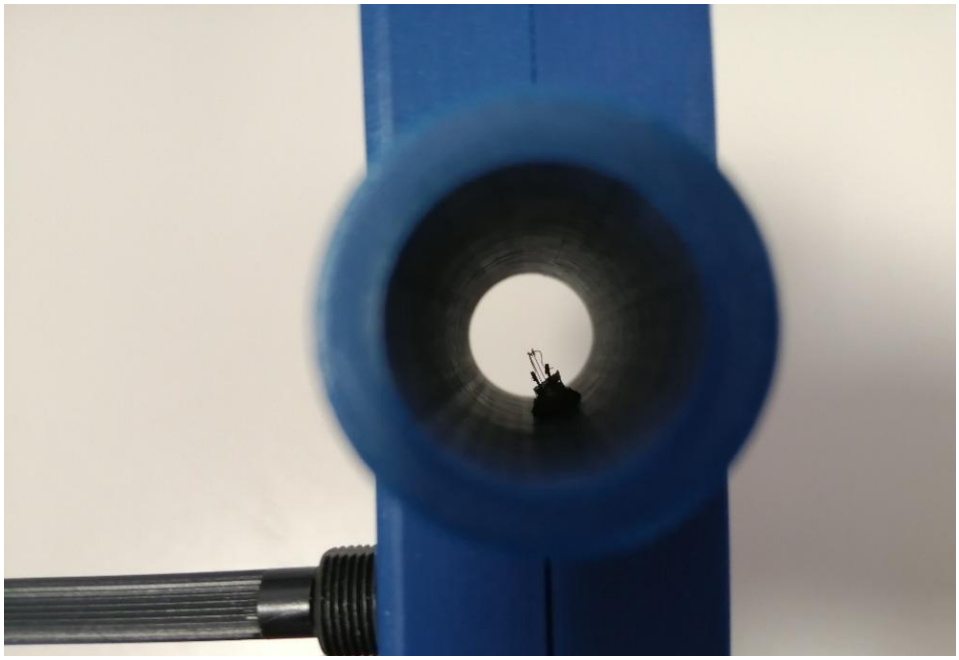


Fig. 28: Detail of the heating wire

6.4 Flow Meter with Hall sensor

Next module is a mechanical element with a Hall probe, which measures the flow in the range of ~5–30 L/min. The output of the flow meter is a rectangular signal with a frequency corresponding to the flow.

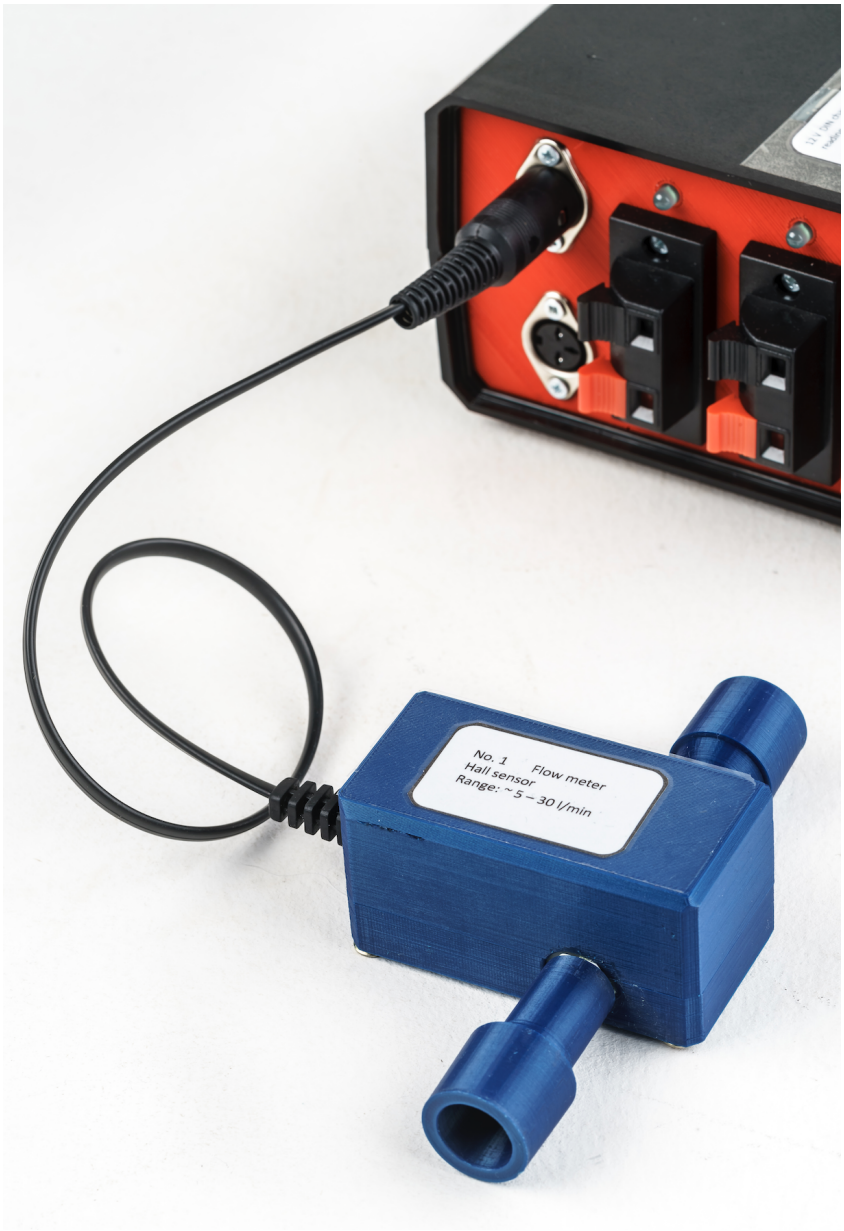


Fig. 29: Connection between Meluzína and flow meter with Hall sensor

Technical parameters are in the following table:

Flowmeter with Hall sensor	
Parameter	**Value**
Power supply	12 V
Signal	0–12V
Range	~ 5–30 L/min

6.5 Digital Air flowmeter

Digital air flowmeter PFM7 SMC is a device with which you can measure the flow rate in the range of 0–100 L/min. It has a voltage analog output 1–5 V. If you connect it with the Meluzína device, it works only in the range of 0–50 L/min. For the full measuring scale, you have to use the extension cable with 24V power supply.

Fig. 30: 12V supply from Meluzína for measuring range of 0–50 L/min of the flowmeter or 24V supply from the distribution network for measuring range of 0–100 L/min.

7. Electromagnetic solenoids

Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix fluids. They are found in many application areas. Solenoids offer fast and safe switching, high-reliability, long service life, good medium compatibility of the materials used, low control power and compact design. The valve can use a two-port design to regulate a flow or use a three or more-port design to switch flows between ports.

7.1 2/2 electromagnetic solenoid

For the laboratory tasks, you will be using 12V 2/2 electromagnetic solenoids with a maximum pressure of 2 bar.

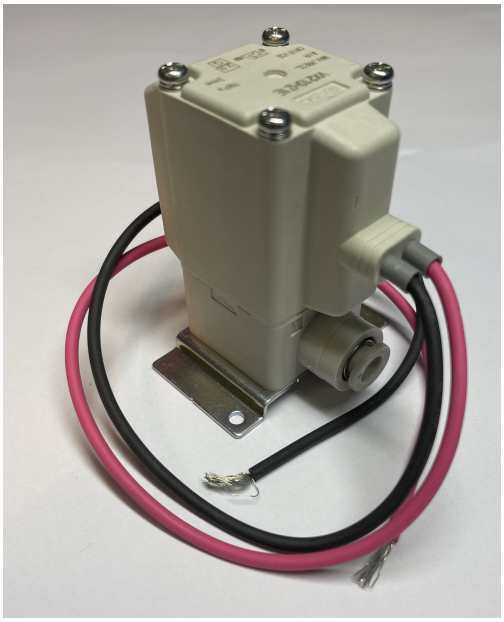


Fig. 31: 2/2 electromagnetic solenoid valve

7.2 3/2 electromagnetic solenoid

The PNEHYKUR kit 1.0 also includes 12V 3/2 electromagnetic solenoid with a maximum pressure of 7 bar.

Fig. 32: 3/2 electromagnetic solenoid valve

7.3 Extension module

As a prolongation for the electromagnetic solenoids or pumps, you can use an extension module which also indicates present voltage.

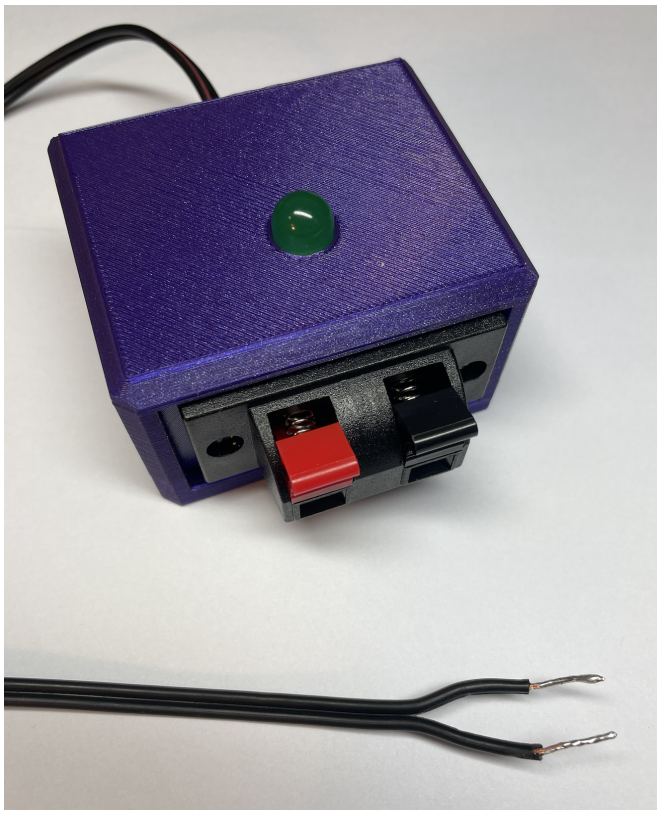


Fig. 33: Extension module

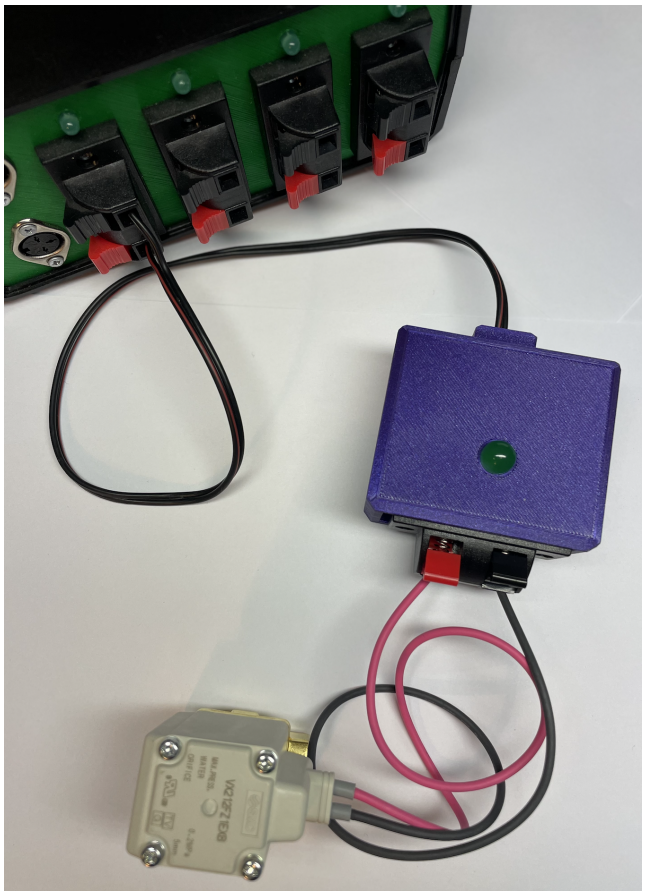


Fig. 34: Connection between Meluzína, extension module and electromagnetic solenoid valve

8. Measuring devices for the laboratory tasks

To pass all the laboratory tasks, you will need to measure flow, pressure, size, or diameter. For this reason, you have got several devices allowing you to measure these quantities.

8.1 Flow measurements

For measuring the flow, you can use the flow controller OMEGA FMA5400 or the flow meter MF5712.

8.1.1 Flow controller OMEGA FMA5400

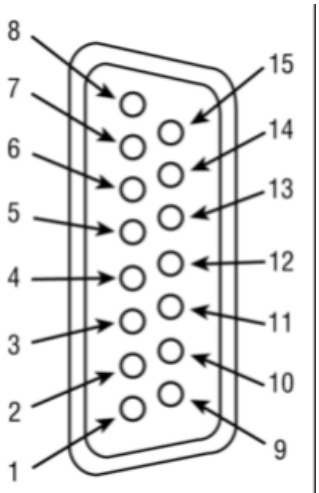
Use the OMEGA FMA5400 flow controller to set the flow in the range 0–100 L/min. It works as a mass flow controller with LCD display showing the real flow, where the flow is set by voltage between 0–5 V.

Fig. 35: OMEGA FMA5400 mass flow controller

Pinout connector D–SUB

In the case of Meluzína, only pins 3, 4, 5, 7, 8, 10, 11, 12 are fitted. For analog control of OMEGA FMA5400, the Analog Output 0 pin is used on the DAQ card. For digital control of Purge, Digital 6 and Valve OFF Digital 7 are used.

PIN	FUNCTION
1	0 to 5 VDC Flow Signal Common
2	0 to 5 VDC Flow Signal Output
3	Common
4	Open (Purge)
5	Common, Power Supply
6	(unassigned)
7	+12 VDC (+24 VDC*) Power Supply
8	Remote Setpoint Input
9	4 to 20 mA (-) Flow Signal Return (use with 14)
10	Remote Setpoint Common (use with 8)
11	+5VDC Reference Output for Remote Setpoint
12	Valve Off Control
13	Auxiliary +12 VDC (+24 VDC*) Power Output (For Loads <100 mA)
14	4 to 20 mA (+) Flow Signal Output
15	Chassis Ground



1 & 2	0-5 VDC OUTPUT	5 & 7	+12 VDC (+24 VDC*) POWER SUPPLY
3 & 4	PURGE	8 & 10	0-5 VDC OR 4-20 mA REMOTE SETPOINT
3 & 12	VALVE OFF CONTROL	9 & 14	4-20 mA OUTPUT
5 & 13	AUXILIARY +12 VDC (+24 VDC*) POWER OUTPUT (FOR LOADS <100 mA)	10 & 11	+5 VDC CONTROL SOURCE

Fig. 36: OMEGA FMA5400 flow controller Connector configuration

8.1.2 Flow Meter MF5712

The flow meter MF5712 with LCD display measures in the range 0–200 L/min. It can work on batteries or with the power supply.

Fig. 37: Flow meter MF5712

8.2 Pressure measurements

During the laboratory tasks, you will usually use the 10kPa or +/- 2kPa pressure sensors but in some moments, you will need different methods to measure the pressure in the tubing.

8.2.1 Testo 512

An easy and accurate option is to use Testo 512 pressure gauge. You have got two types of pressure gauges for use. One of them has the range of measurement 0–200 hPa and the other one 0–20 hPa. With this device, you can choose if you want to measure a maximum pressure, a minimum pressure, or a mean pressure. It is also possible to zero the sensor.

Fig. 38: Testo 512 pressure gauge

7.2.2 Manometer

When you are working with big pressures it is not always necessary to know the pressure accurately. This manometer measures the pressure in the range of 0–4 bar. One good advantage is that it does not need any batteries.

Fig. 39: 0–4 bar manometer and a typical connecting to the tubing

8.3 Length/Diameter/Size measurements

It is usually necessary to know the length of the tube or what is the diameter of the tube for calculating pressures or resistance or something else. For accurate measurements you can use a caliper with the range of 0–15 cm. Another option is to use a folding rule for ordinary measurements.

Fig. 40: Caliper and folding rule

9. Adapters

During the following laboratory tasks, it will be needed to use adapters of different diameters for connecting tubes and hoses between each other or it will be necessary to use them as a sampling place for pressure measurements.

Between tubes and sampling points or pressure sensors:

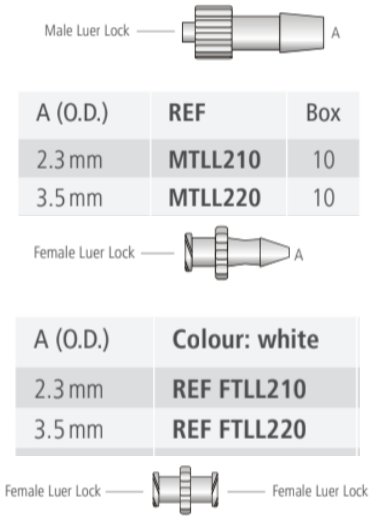
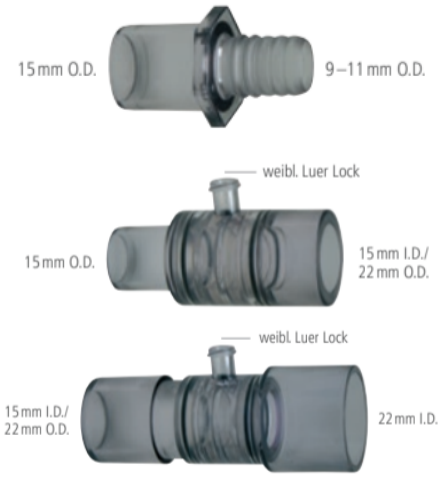


Fig. 41: Male/Female Luer lock

For connecting hoses or tubes and as a sampling point for pressure measurements:

Made by injection-moulding machine:



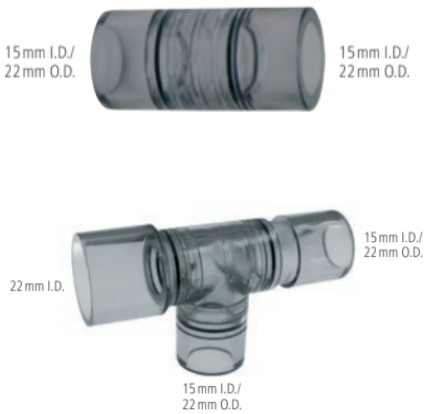


Fig. 42: Connectors for tubing with different diameters

Made by 3D printing:

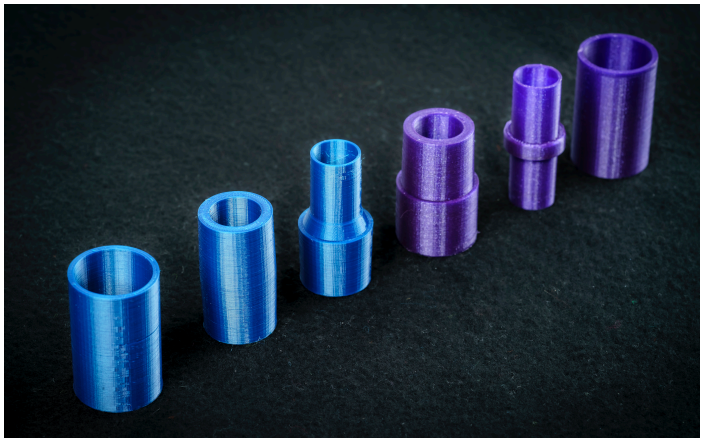


Fig. 43: 3D printed adapters

For connecting a 6mm tube and 15mm I.D. adapter:

Fig. 44: An adapter between 6mm tube and 15mm I.D.

For connecting tubes of different diameters and 15mm I.D. adapter:

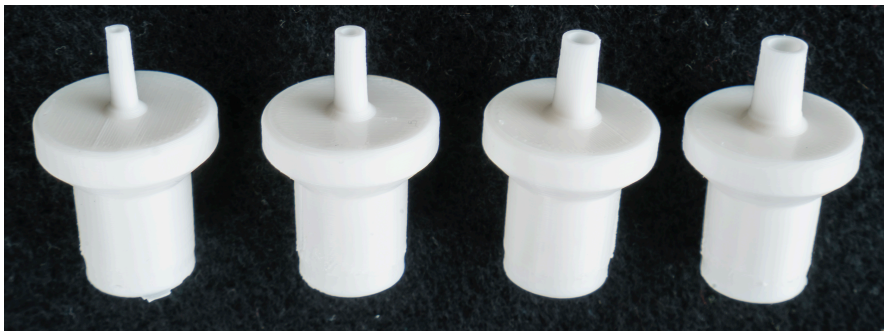
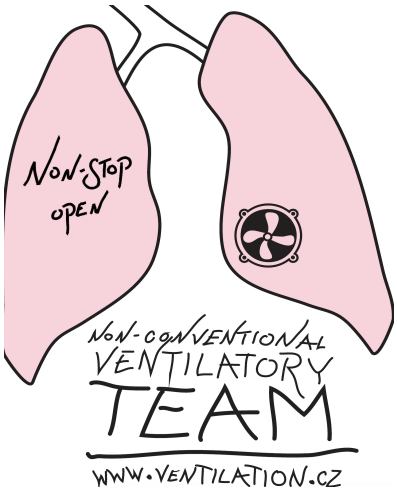


Fig. 45: Adapters for connecting between 15mm I.D. and tubing of different diameters



CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE
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