FUEL CELL DEVELOPER KIT – 30W

ASSEMBLY GUIDE

Model no.: FCDK-30

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1. PREFACE

The "Fuel Cell Developer Kit – 30 W" FCDK-30 (further – kit) enables the user to easily design and build fuel cell systems using a fuel cell stack with up to 30 W capacity.

An Arduino open-source platform supported by an online developer forum encourages rapid customisation of the control system and user interface for a wide range of applications from toy trains, airplanes and automobiles, to remote monitoring systems.

Abbreviations:
FC – fuel cell;
FCS – fuel cell stack;
SPE – solid polymer electrolyte;
MEA – a membrane-electrode assembly, the most essential part of a single FC, comprising the anode, the cathode and the ionomer proton-exchange membrane, alongside with sealing.

Depending on a considered topic and its required depth of comprehension, the kit could be operated within the school subjects boundaries (physics, chemistry, some sections of mathematics), as well as in higher educational programs. During the experiments, students will acquire a certain set of professional technical knowledge and some common technical skills.

This manual covers shield PCBs of v.2.0 or above. If you have a shield PCB of a lower version number please contact us directly at support@horizoneducational.com.

2. SAFETY REQUIREMENTS

In this section you will find information on safe handling of the kit equipment. It is important that you read and understand the contents of this section.

Be sure to read this manual and familiarize yourself with the kit contents and operating principle before starting and using it.

2.1. General safety information

- Keep this manual in a safe and accessible place. Operating person must read it carefully and thoroughly.
- Use only original parts of equipment.
- Any modifications of kit design, unaffiliated repairs or disassembly are strictly prohibited. Any of these actions could dangerously affect kit operation and safety.
- Avoid exposure to fumes of acids, alkalis and other chemically active substances.

2.2. Safety measures during working with the kit

- The room in which works with the kit are carried out should be well ventilated and equipped with primary means of fire extinguishing according to requirements of GOST 12.4.009-93.
- Maintain the polarity of auxiliary electrical load. Do not short-circuit output terminals.
- Kit must be operated under supervision of specially trained personnel (age 18+). Supervisors must familiarize themselves with operation manual beforehand and receive appropriate instructions.
- Persons who work with the kit must familiarize themselves with operation manual beforehand and receive appropriate instructions.
- Do not disconnect the cables and gas lines connecting the components of the kit during operation of the FCS.
- Do not leave the kit equipment running unattended.

2.3. Safety measures during work with hydrogen

WARNING: Fire Hazard!

- The fuel cell stack of the kit uses hydrogen. Hydrogen leakage and mixing with air could lead to explosion hazard.
- HYDROSTIK PRO cartridge is under pressure.
- Do not place the equipment near heat or open flame sources. Avoid direct sunlight and heating of the equipment above 50 °C.
- Ensure the right installation position of the hydrogen cartridge into the pressure regulator.
- Check that cables, terminals and gas supply lines are intact before starting the operation.
- Do not use the equipment above designed capacity and in potentially explosive areas.
- Discharged hydrogen cartridges may contain some residual hydrogen inside in a bound state, NEVER throw them into a fire.
- NEVER breach or disassemble the hydrogen cartridge!

3. FUEL CELL STACK OPERATING PRINCIPLE

Hydrogen fuel cell power system provides energy to various applications. At the same time, use of FCs allows to reach new levels of power supply capacity.

A fuel cell stack is designed for power generation by a chemical reaction between active agents on electrodes (the anode and the cathode). In these reactions hydrogen acts as fuel while air oxygen is an oxidizer.

An FC does not suffer from self-discharge and does not require electricity to recharge. It could produce energy as long as there are hydrogen and oxygen available.

Unlike other power generators (i.e. based on internal combustion engines or turbines) FC does not burn the fuel, hence no noise and vibration during the process. Power produced by an FC is a result of a silent electrochemical reaction. The main feature of an FC is the direct power generation from oxygen and hydrogen.

An FC has high electrical efficiency and its operation does not spawn by-products like CO or greenhouse gases. Water is the only exhaust of FC operations.

Figure 1 shows operating principle of a fuel cell.

The electrolyte (membrane) between the anode and the cathode conducts protons. The chemical reaction starts after hydrogen contacts the anode and oxygen contacts the cathode. This reaction generates electricity, heat and water.

Here you can see the chemical reactions flow:

Reaction at the anode: $2H_2 => 4H_+ + 4e_-$

Reaction at the cathode: $O_2 + 4H_+ + 4e_- => 2H_2O$

Overall reaction of the FCS: $2H_2 + O_2 => 2H_2O$

Molecular hydrogen dissociates on the catalyst of the anode and releases electrons. Hydrogen ions (protons) pass through the electrolyte to the cathode, while electrons flow via the external circuit, producing direct current that could be used for power supply of external equipment. Oxygen molecule gains the electron (from the external circuit) on the catalyst, which generates water as a liquid or steam. It is the only product of this chemical reaction.

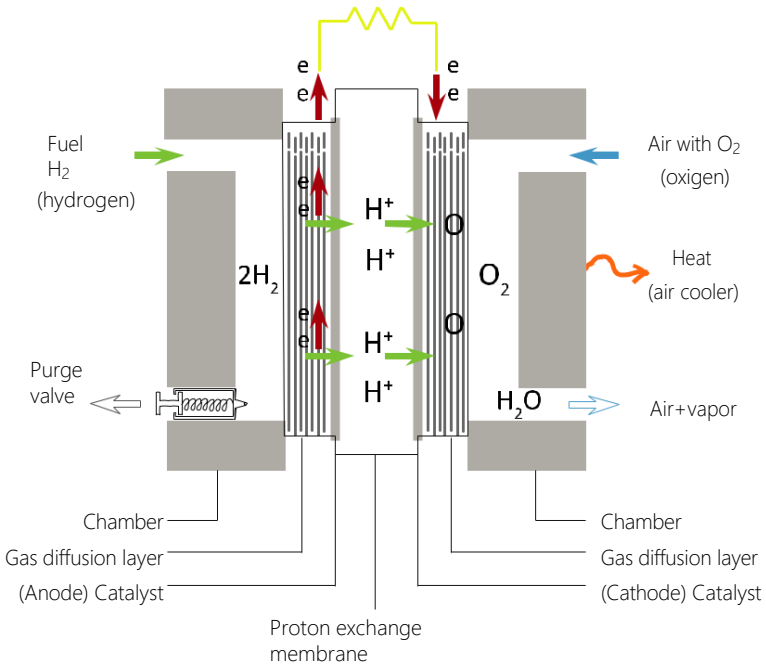


Fig. 1. Fuel cell operating principle

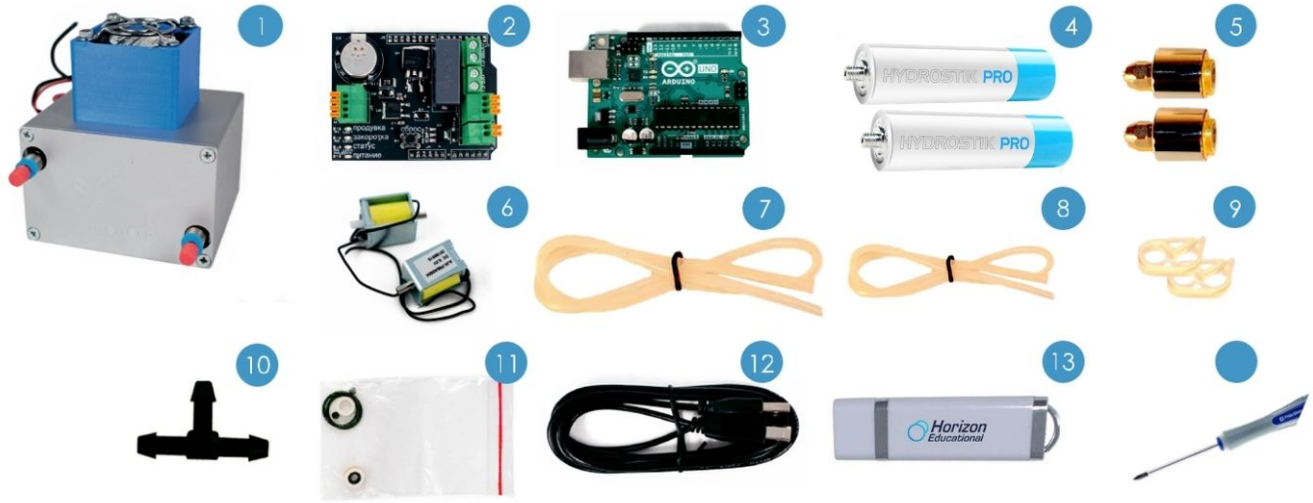
4. KEY TECHNICAL PERFORMANCES

FCS type	Hydrogen-air
FCS rated capacity, W	30
FCS rated voltage, V	8 – 12
FCS idle voltage, V	12 – 14,5
FCS weight, kg, max	0,4
FCS dimensions (L × W × H), mm	76 × 82 × 70*
FCS fuel type	Hydrogen
Hydrogen purity (assay of pure hydrogen, grade A, as per GOST 3022-80), %	99,99
Time to reach normal output, min.	~ 10
Number of MEAs in a FCS, pcs	15
HYDROSTIK PRO hydrogen cartridge capacity, l	10
HYDROSTIK PRO intermetallide alloy grade	AB5
Purge valve type	Electromagnetic
Operating temperature conditions, °C	+15 ... +40

* Dimensions may vary slightly depending on the components.

5. KIT CONTENTS AND OPERATING PRINCIPLE

Kit contents



1. FCS
2. Arduino shield for FCDK-30
3. Arduino Uno
4. Two HYDROSTIK PRO hydrogen cartridges
5. Two pressure regulators
6. Two purge valves
7. Silicon tubing (L = 0,5 m)
8. Plastic tubing (L = 0,3 m)
9. Two plastic tube clips
10. Silicon tubing T-splitter
11. Two repair kits for pressure regulator
12. USB-cable
13. USB flash drive with software
14. Screwdriver

The kit requires fuel (hydrogen) and oxidizer (oxygen from air) for operation.

Hydrogen from the HYDROSTIK PRO goes to the FCS via the pressure regulator.

Oxygen is fed to the reaction zone moving through the open channels of the cathode surfaces by means of the axial fan. In the FCS with an open cathode, air is used not only as the oxidizer, but also as a part of the cooling system. The electrochemical reaction running in the active zone of the FCS is exothermic and due to internal resistance the additional heat is released when the current passes through an FC. Therefore, the FCS is heated during operation depending on the load. Due to the constant flow of air from the active zone of the cathode, a continuous process of evaporation of water is maintained, which leads to removal of excess heat from the device.

To clean the system from the gaseous by-products of the reaction that accumulate during operation in the anode chamber, a purge has to be periodically performed.

The reaction of hydrogen and air produces potentials difference on the terminal plates, which generates direct current in the circuit if there is an electrical load.

FCS control (set purging time and duration) is carried out through the Arduino. The Serial Monitor in the Arduino Environment displays the status of the FCS (FCS voltage, current and temperature, fan speed as well as readouts of the purge process).

LED "Status" flashes when the capacitor located on the Arduino shield is charging and glows continuously when the capacitor is charged. LED "Purge" lights up when there runs a process of purge. LED "Power" lights up when power is connected to the Arduino shield. (See the inscriptions for LED on the Arduino shield).

6. KEY FUNCTIONS AND RATED PARAMETERS

6.1. Key functions:

- Measurements of current, voltage and temperature of FCS.
- Adjustment of purging time and duration, and purge intervals of FCS.
- Adjustment of fan speed.
- External load connection indicator.

6.2. Rated parameters:

- FCS current, voltage and temperature.
- Fan speed.

7. BEFORE THE WORK STARTS; OPERATING MANUAL

ATTENTION! Always place the FCS with the hydrogen outlet to be located in the lowest position. It is necessary to ensure that the water released from the membrane in the anode (hydrogen) path as well as other by-products able to interfere with the normal flow of the electrochemical reaction do not accumulate inside the FCS and could be easily removed by the periodic purges.

The preferred location of the FCS is with the hydrogen inlet/outlet fittings downwards, as shown in the lowest position of figure 2.

IMPORTANTLY! The FCS requires an unobstructed flow of air through all the air holes, since oxygen entering through these holes is involved in the electrochemical reaction. Even partial blocking of the air flow to the FCS (clogging with dust or blocking by external objects) reduces the performances and the fuel cell stack lifespan.

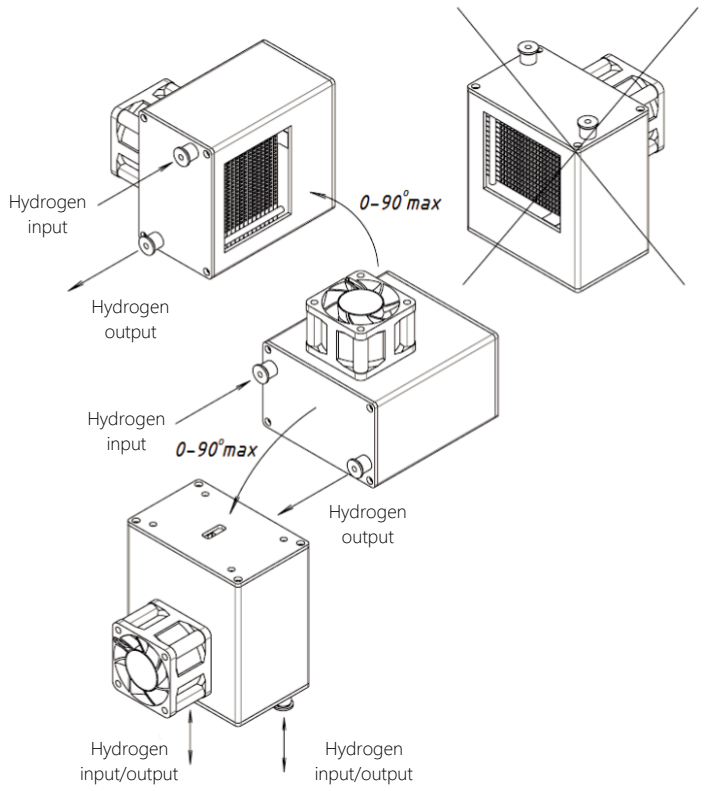


Fig. 2. Possible positions of the FCS during operation

7.1. How to unfold the kit

When you are unpacking the kit follow the order as below:

- Inspect the case, check its integrity, and possible signs of physical damage.
- Open the case, take out the manual and read it carefully.
- Check the contents with the datasheet and inspect the kit components for signs of physical damage. If damage is exposed, contact the forwarder and the manufacturer.

7.2. How to assemble an electrochemical generator using the kit components, and how to work with it

Connect a pressure regulator and a purge valve:

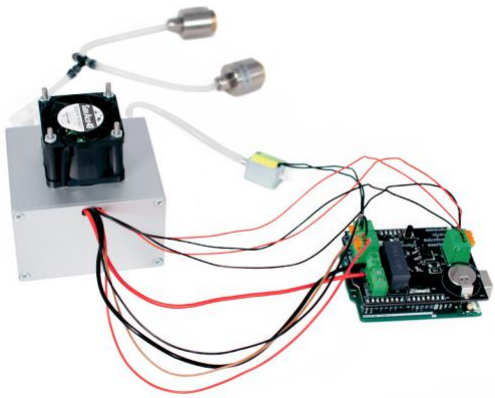
1. Cut two short pieces of the plastic tube (approximately 2.5 cm long).
2. Insert the two cuts into fittings of the fuel cell stack.
3. Cut a short piece of the silicone tube (approximately 3 cm long).
4. Push one end of the short piece onto the white nozzle of the purge valve.
5. Push the other end of this tube onto any plastic tube, which is inserted into the fitting of the fuel cell stack.
6. Cut a longer piece of the silicone tube (approximately 8 cm long).
7. Pass the longer cut of the silicone tube through the plastic tube clip. This clip will be used later to open or close the flow of hydrogen whilst the regulator and HYDROSTIK PRO are connected.
8. Unscrew the nut from the regulator and pass one end of the tube through the nut before pulling the tube onto the regulator and tightening the nut over the tube (there is no need to use a spanner – finger-tight torque is sufficient).
9. Pull the other end of this tube onto the free plastic tube, which is inserted into the fitting of the fuel cell stack.

If you want to use two HYDROSTIK PRO use the silicon tubing T-splitter.

Electrical connections to the Arduino shield:

1. Connect the black wire from the fuel cell stack to the terminal on the Arduino shield labeled "FCS IN –".
2. Connect the red wire from the fuel cell stack to the terminal on the Arduino shield labeled "FCS IN +".
3. Connect two wires from the purge valve to the terminals on the Arduino shield labeled "Purge" (polarity does not matter).
4. Connect two wires from the one thermistor to the terminals on the Arduino shield labeled "T1" (polarity does not matter).
5. Connect two wires from the other thermistor to the terminals on the Arduino shield labeled "T2" (polarity does not matter).
6. Connect the black wire from the fan to the terminal on the Arduino shield labeled "FAN –".
7. Connect the red wire from the fan to the terminal on the Arduino shield labeled "FAN +".
8. Connect the brown wire from the fan to the terminal on the Arduino shield labeled "FAN P".
9. You can connect an electrical load to the terminals on the Arduino shield labeled "FCS OUT –" and "FCS OUT +" observing the polarity.

Prepare Arduino and fuel cell control shield:



1. If you do not yet have the Arduino Environment and drivers installed on your computer, follow these instructions, relating to your operating system (http://arduino.cc/en/Guide/HomePage).
2. Before proceeding make sure you can open an example Arduino sketch (e.g. blink), compile it and upload. If so, you can proceed to work.
3. Plug the fuel cell control shield into the Arduino Uno taking care that all the pins on the underside of the shield slot into the holes in the Arduino Uno stackable header.
4. Connect your Arduino to your computer using the USB cable.
5. Download the version 2.0 of the FCDK-30 Arduino library from the USB flash drive.
6. Launch the Arduino Environment software on your computer.
7. In the "Tools" menu check that you have the correct Board selected (Arduino Uno) and the correct Serial Port.
8. Open the file in the Arduino Environment: "File", "Open", "FCDK_V2_ARDUINO.ino". Please note that for correct operation of the software all three of the files "FCDK_V2_ARDUINO.ino", "second_v2.h" and "TimerOne.h" must be in the same folder called "FCDK_V2_ARDUINO".
9. If required, change the set values for the purge duration and the purge delay, as well as the fan speed.
10. Click the "Check/Compile" button to check and compile the software.
11. Click the "Upload" button to upload the software to the Arduino.
12. Open the Serial Monitor from the Tools menu in the Arduino Environment.
13. Check that the baud rate (bottom-right of the window) is set at 9600. You should see text appear in the Serial Monitor window to indicate that the software is running.

Notice. You can calibrate the current yourself. The calibration procedure is described in the file "second_v2.h".

Notice. The assembled system can be disconnected from the personal computer. In this case you will not be able to observe the performances of the FCS, but it will continue to work in the established mode.

Connect HYDROSTIK PRO and an electrical load:

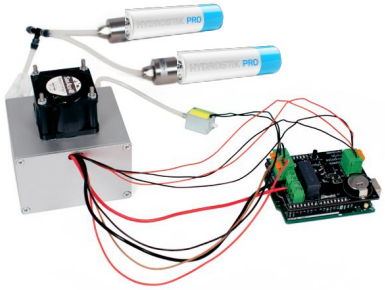
1. Ensure the plastic clip on the tube between the regulator and the inlet valve is closed.
2. Screw the HYDROSTIK PRO into the regulator.
3. Ensure the stack is mounted or positioned so that the vents on both sides are open to air.
4. Open the clip on the tube to allow hydrogen to flow into the fuel cell stack. The fan on the fuel cell should start spinning.

Notice. If the FCS does not start and the interval between the purges is large, it is necessary to manually purge the hydrogen input, since after the assembling of the scheme the FCS could have been filled with air, which prevents the flow of hydrogen to the anodes of the FCS. To do this temporarily disconnect the silicone tube from the purge valve and immediately put it back on.

Notice. The HYDROSTIK PRO is cooled in the process of work – the intensity of cooling and, therefore, the temperature of the hydrogen storage depends on a number of factors, including hydrogen consumption and the ambient temperature.

5. Connect two wires from an electrical load to the terminals on the Arduino shield labeled "FCS OUT –" и "FCS OUT +", observing the polarity.
6. When you wish to turn off the system, first disconnect your load from the terminal on the Arduino shield labeled "FCS OUT +".
7. Close the clip on the hydrogen supply tube to stop the flow of hydrogen.
8. Wait for the fan to turn off.

Care should be taken not to overload the stack. Ensure that the maximum current drawn by your equipment cannot exceed 5 A (the voltage on the FCS should not fall below 6.5 V).



8. MORE SAFETY INSTRUCTIONS

IMPORTANT!

- It's not recommended to use excessive force when you are screwing the HYDROSTIK PRO into the pressure regulator, but at the same time it should be screwed tightly to ensure the flow of hydrogen from the cartridge to the FCS.
- For correct fuel cell stack operation you should periodically turn the kit on, every 7-10 days for 5-10 minutes and operate it with a low load (5 W) to ensure sufficient membrane moisturization.
- For the best moisture retention of the FCS membrane it is recommended to store and use the kit in rooms with a humidity of minimum 20%.
- Channels for the inlet of air through the FCS are small. It is necessary to ensure a uniform flow of air without impurities and massive dust (fluff and other volatile particles that contribute to clogging channels) in the FCS. It is forbidden to close the air intake area on the FCS and the air outlets from the fan with any objects.
- Do not expose the kit to CO (carbon monoxide): Do not store and use the kit in rooms with smoke.
- It is recommended not to place the end of the tube connected to the outlet of the FCS near the air intake area, it may reduce the lifespan of the FCS.
- The manufacturer recommends the use of the FCS with the following nominal settings:

  --the duration of the purge – 200 ms,

  --the delay between purges – 20 s.
- When you are connecting the FCS to the control system on the Arduino shield, you should observe the polarity.
- It is not allowed to turn off the inflow of hydrogen to the FCS without preliminary disconnecting the entire external load.

9. TRANSPORTATION AND STORAGE

1. Transportation of the kit inside a case protected from direct physical impact or moisture effects is tallowed by any type of transport with the permitted speed to any distance as per Ж requirements of GOST 23216-78.
2. During transportation it is necessary to comply with the general rules of forwarding goods by the selected type of transport. Placement and fastening of the case in vehicles should ensure its stable position, excluding the possibility of overturning, falling and hitting other goods and walls of vehicles.
3. During loading and unloading do not throw the case.
4. Transportation and storage temperature conditions: the lowest temperature is 0 °C, the highest temperature is +45 °C. The kit should be stored in a packing case.