



FES BATTERY PACK GEN4 16S 84Ah

With integrated BMS and G sensor

User Manual, Version 1.0



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1. Important notices

It is important to read this manual carefully before using the FES battery pack! It contains important information about FES GEN4 Battery pack, having a vital importance to the flight safety. If you need more information, please contact FES manufacturer - LZ design.

Information in this document is subject to change without notice. LZ design reserves the right to change or improve their products and to make changes in the content of this material without obligation to notify any person or organization of such changes or improvements.



WARNING means that the non-observation of the corresponding procedure leads to an immediate or important degradation of the flight safety.



CAUTION means that the non-observation of the corresponding procedures leads to a minor or to a long-term degradation of the flight safety.



NOTE draws the attention on any special item not directly related to safety, but which is important or unusual.

1.1 Limited Warranty

This product is warranted to be free from defects in materials or workmanship for one year from the date of purchase. Within this period, LZ design will, at its sole option, repair or replace any components that fail in normal use. Such repairs or replacement will be made at no charge to the customer for parts and labour. The customer shall be responsible for any transportation cost. This warranty does not cover failures due to abuse, misuse, accident, or unauthorised alterations or repairs.

The warranties and remedies contained herein are exclusive and in lieu of all other warranties expressed or implied or statutory, including any liability arising under any warranty of merchantability or fitness for a particular purpose, statutory or otherwise.

In no event shall LZ design be liable for any incidental, special, indirect or consequential damages, whether resulting from the use, misuse, or inability to use this product or from defects in the product.

LZ design retains the exclusive right to repair or replace the unit or software, or to offer a full refund of the purchase price, at its sole discretion. To obtain warranty service, contact your local LZ design dealer or contact LZ design directly.

2. General info

This is a FES GEN4 16S 84Ah battery pack, developed especially for FES application in double-seat sailplanes. Battery pack contains 480 Li-ion cells of 18650 type. There are 30 cells wired in parallel and 16 of such blocks wired in serial - 16S 30P configuration. For FES application, always a pair of such battery pack is required. Each pair of battery packs is marked as A and B.

Battery pack is equipped with internal BMS (Battery Management System) circuit board and e-ink display showing battery state of charge - SOC.

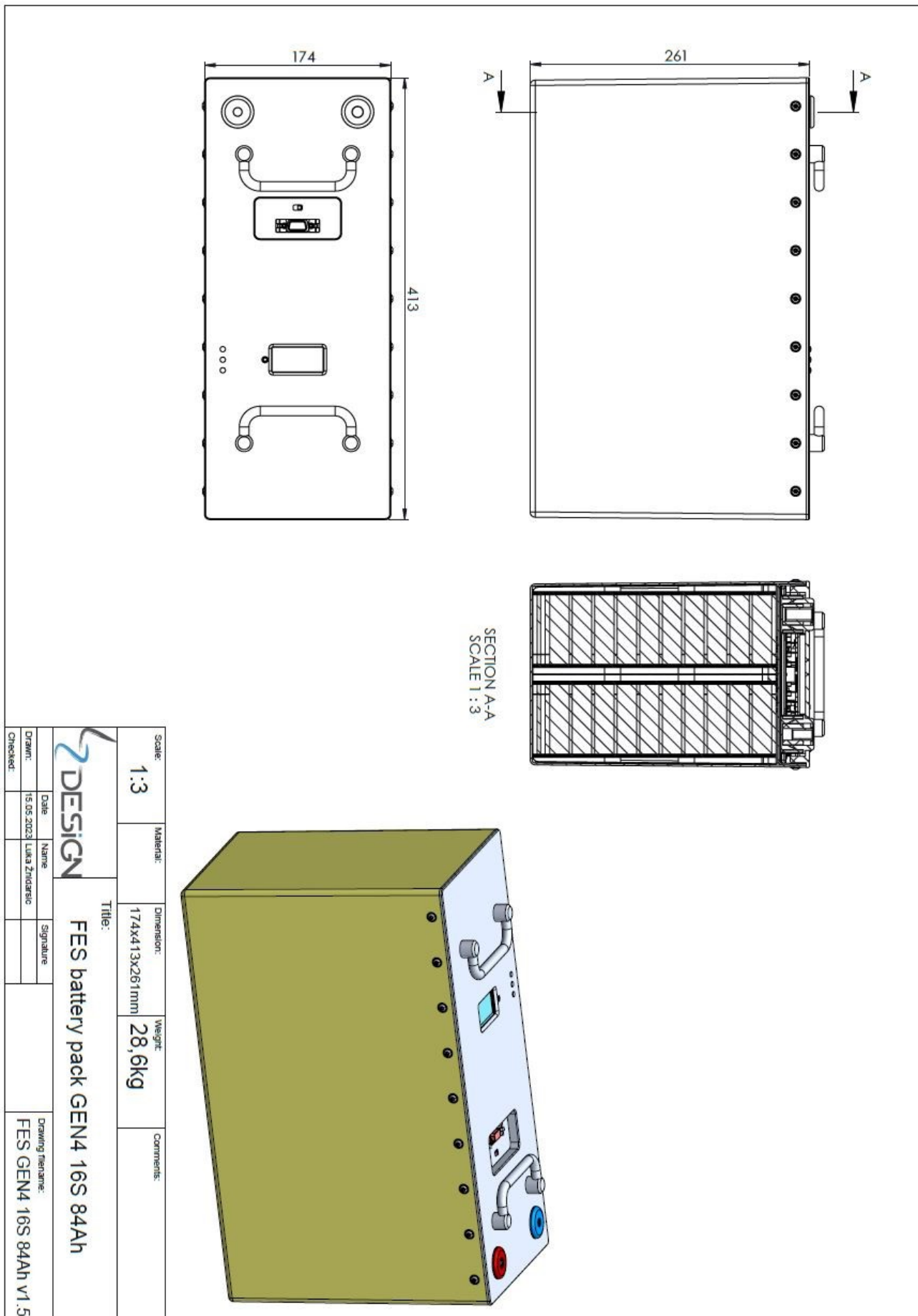
For + and - terminals we chose to use Amphenol Radsok hyperbolic high-power contact technology. Socket terminals are hidden inside of the pack. To avoid wrong connections there is an 8 mm contact for – pole and a 10,3 mm contact for + pole.

FES GEN4 Battery packs have additionally **built-in G-load sensor** which measure the accelerated motions. In case of excessive loads, is triggered an error message which appears on the e-ink display: Battery not operational, Contact service. The battery pack is unoperational and needs to be inspected.

2.1 Technical data:

FES Battery pack GEN4 16S 84Ah	
Weight of single battery pack	28,6kg
Box dimensions (W x L x H), without terminals	174 x 413 x 261mm
Cells producer	E-One Moli Energy Corp.
Electrochemical system	NMC (LiMnNiCoO ₂)
Cells type	INR-18650-P28A
Average capacity of each cell	2,8Ah
Number of cells	480
Energy storage capacity	4,8kWh
Maximum total voltage	66,5V
Minimum total voltage	49,5V
Maximum current	250A
Max balancing current per cell block	1A
Internal BMS type	FES BMS 2Q
Standard 600W small charger	FES KOP602E
Optional 1200W bigger charger	FES KOP1001E
Optional 360W travel charger (also supports US 110V~)	FES travel 16S

2.2 Drawing



Scale:	1:3	Material:	174x413x261mm	Weight:	28,6kg	Comments:
Title: FES battery pack GEN4 16S 84Ah						
DESIGN	Date:	Name:	Signature:	Drawing Name: FES GEN4 16S 84Ah v1.5		
Drawn:	15.05.2023	Luka Znidarsic		Checked:		

2.3 General layout of the pack:



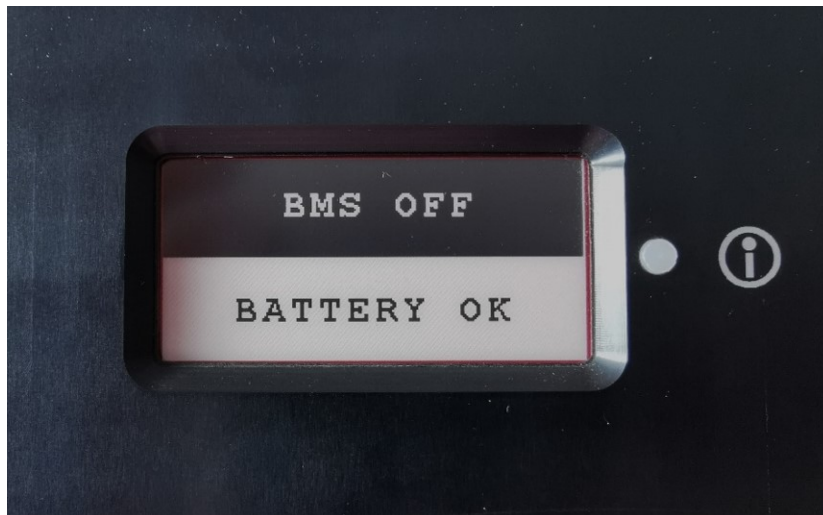
Top view of FES GEN4 16S 84Ah Battery pack

2.4 Introduction of the e-ink display:

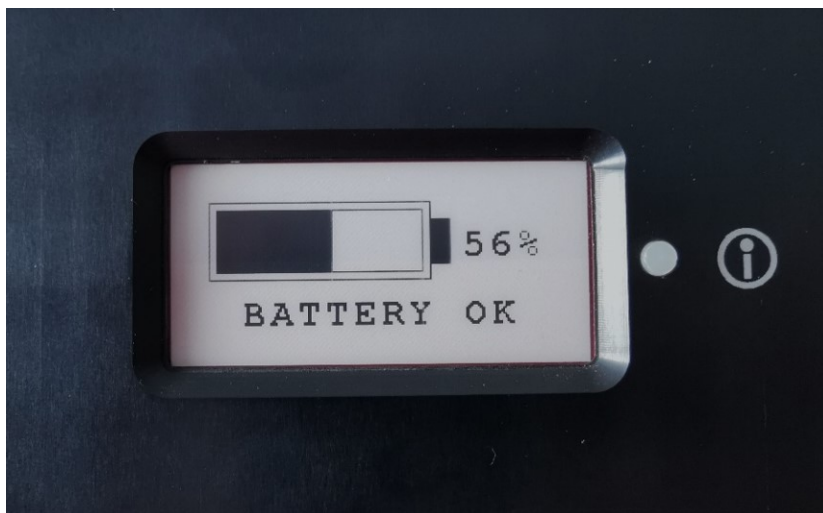
With FES GEN4 Battery pack, new e-ink display is introduced. This is a low power consumption display, showing the following data:

- State of BMS (ON / OFF),
- State of charge (SOC),
- Battery pack total voltage,
- Battery pack temperature,
- BMS temperature (top cover),
- Cell voltage in mV (min, delta, max, graphic presentation of relative values)
- Errors (warnings),
- G - load sensor error message.

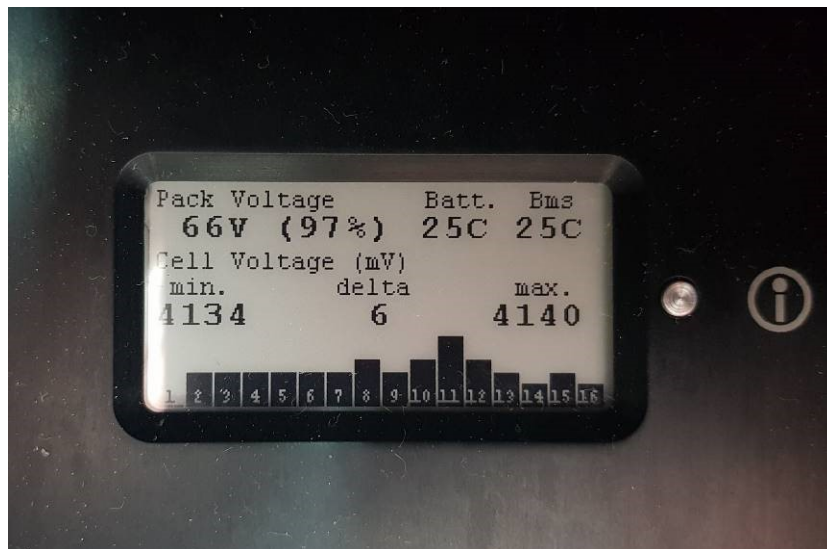
Switching between menus (on the pictures below) is possible by pressing the button next to the screen.



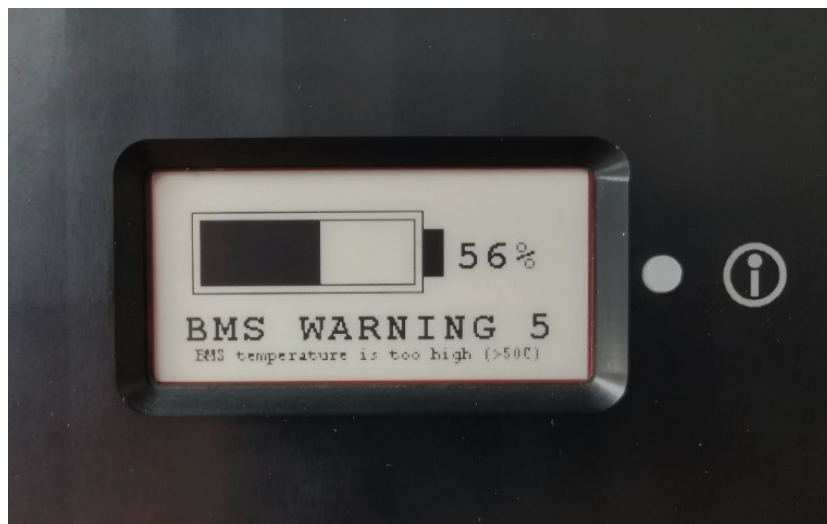
Initial menu when BMS is OFF



State of charge menu when BMS is ON



Battery pack data Menu



The number of an error (warning) shown on the display.



G - load sensor error message

2.5 Internal BMS

FES GEN4 battery pack is equipped with BMS (Battery Management System) electronic circuit.

How BMS works?

The BMS electronic measures and controls the voltage level of each cell in the battery pack. During charging and discharging, battery cells differ in voltage levels, due to slightly different capacity of the cells. Cells with lower capacity charge faster than cells with higher capacity. Cells that reach maximum pre-set voltage faster than the others, are discharged through resistors inside of the BMS. The redundant energy is dissipated as heat through the upper cover plate, which is milled from Aluminium and anodized in black.



Note: BMS starts balancing cells only during charging, and above pre-set balancing start voltage (4.10 V)

BMS data and initial settings

Parameter	Value	Unit
Maximum charging current**	9, 18	A
Maximum balancing current	1	A
Single cell end of charge voltage*	4.16	V
Single cell balance voltage start*	4.1	V
Single cell balance voltage end*	4.16	V
Single cell under-voltage protection*	3.1	V
Single cell over-voltage protection*	4.18	V
Max battery pack temperature*	55	°C
Max BMS temperature	50	°C

*Initial settings may be changed with BMS Control software.

**Max charging current depends on type of charger.

3. Battery pack chargers

Charging of FES battery packs is permitted only with special FES chargers, that are listed below. A suitable voltage step-up transformer must be used for chargers that require 230 V~ 50/60 Hz input, in countries with 110 V~ grid.



Note: Chargers are pre-set with suitable settings for FES GEN4 16S and starts charging only if a communication with the BMS can be established.

3.1 Available chargers

FES KOP602E – standard equipment

- Maximum power consumption: **600W**
- Maximum charging current: 9A
- Required input voltage: 230 V~ 50/60Hz
- Weight: 2.2kg
- Two FES KOP602E chargers are included with FES system (for 16S configuration), so both battery packs can be charged at the same time.
- Modern, fully automatic charger.
- Logging of charging times and capacity



FES KOP602E Charger

FES KOP1001E – optional charger

- Maximum power consumption: **1200 W**
- Maximum charging current: 18 A
- Required input voltage: 230 V~ 50/60 Hz
- Weight: 3.9kg
- Modern, fully automatic charger.
- Logging of charging times and capacity.



FES KOP1001E Charger

FES travel charger 16S – optional

- Maximum power consumption: **360 W**
- Maximum charging current: 5 A
- Required input voltage: 100V-240V AC / 50 - 60Hz
- Weight: 1.5kg
(more details in dedicated manual)



FES travel charger 16S

4. Charging (standard charger)



Caution: Place charger on a safe, secure position. Keep away from dust, direct sunlight, fire, smoke, children, and any unattended person!



Warning: Before charging, physical condition of the battery packs should be inspected. Any signs of mechanical damage, such as punctures, dents, scratches or similar must be evaluated and reported to manufacturer before charging.

4.1 Battery to charger connection procedure

1. Connect RED + and BLUE - cables from charger to first battery pack.
2. Connect charger and Battery pack with BMS-Charger communication cable.



BMS-Charger communication cable (FES KOP601E, FES KOP1001E)

3. Plug in the charger to the outlet (220V AC, 50-60Hz).
4. Turn on the BMS switch on top of the battery pack cover.

Immediately after BMS is switched ON, the BMS starts a test procedure - a check of all 16 cells, one by one. Red »Error LED« turns ON during system's test procedure and turns OFF again when the test is completed without error.

5. When the test procedure is completed the green »Power LED« starts blinking, indicating that the BMS is working in the normal mode, and BMS sends a signal to the charger to start charging. Orange LED on front panel of the charger lights up, which indicates charging. It is also possible to hear the contactor "click" inside of the charger. Charging current increases slowly to the maximum value of 9A (or 18A at 1200W) and charger cooling fans turn on after a while.

6. In normal mode, the green »BMS Power« LED is flashing. This means that the BMS is turned ON, but not necessary balancing. Balancing starts when one cell reaches a pre-set balancing voltage value, usually 4.1 (this can be changed using BMS Control Software).
 - If one or more cells have higher voltage than the others, they will be discharged and the BMS temperature rise will be minimal.
 - In case that one cell has lower voltage than the others, all cells with higher voltage will need to be discharged to reach a balanced stat. This leads to higher BMS temperature rise, even if the voltage difference is only 0.010V (10mV).
7. The red »Error LED« is ON only during the initial test procedure. After the test is finished it turns OFF. If a system error is detected the LED blinks a certain number of times followed by a pause. The number of blinks identifies the error as per table in chapter 4.1.
8. When the first cell reaches 4.160V, charging current is reduced. If there is a big difference between the cells (more than 50mV), it can take long for all of them to reach 4.160V, as charging current is reduced to 1 A.
9. When all cells reach 4.160V (+/- 2mV), **BMS sends a signal to the charger to stop charging.**

The **Green** OK "Thick mark" LED starts **glowing Green**.

This indicates that the charging cycle was completed properly.

10. Switch OFF BMS on top of the Battery pack. Unplug charger from the outlet. Unplug charging cables and signal cable from the battery pack.



Warning: Both battery packs **must have** approximately the same cell voltage levels (close to 4.160V per cell), before usage. Using two packs with too much difference in voltage is not allowed!

Maximum 1V difference between total voltages of both packs is acceptable. For instance, Pack 1: 66.4V (average 4.150V per cell), Pack 2: 65.4V (4.087V per cell), this is just acceptable! Bigger voltage difference is not acceptable!



Caution: If there is a risk of a lightning strike by an approaching thunderstorm, stop charging immediately and disconnect the charger from the outlet.

4.2 Error description

System errors are indicated in two ways:

- specific number of an error, with short description, indicated on the e-ink display.



- red »Error LED« blinking, followed by a longer pause. Number of red blinks identifies the error.

List of system errors

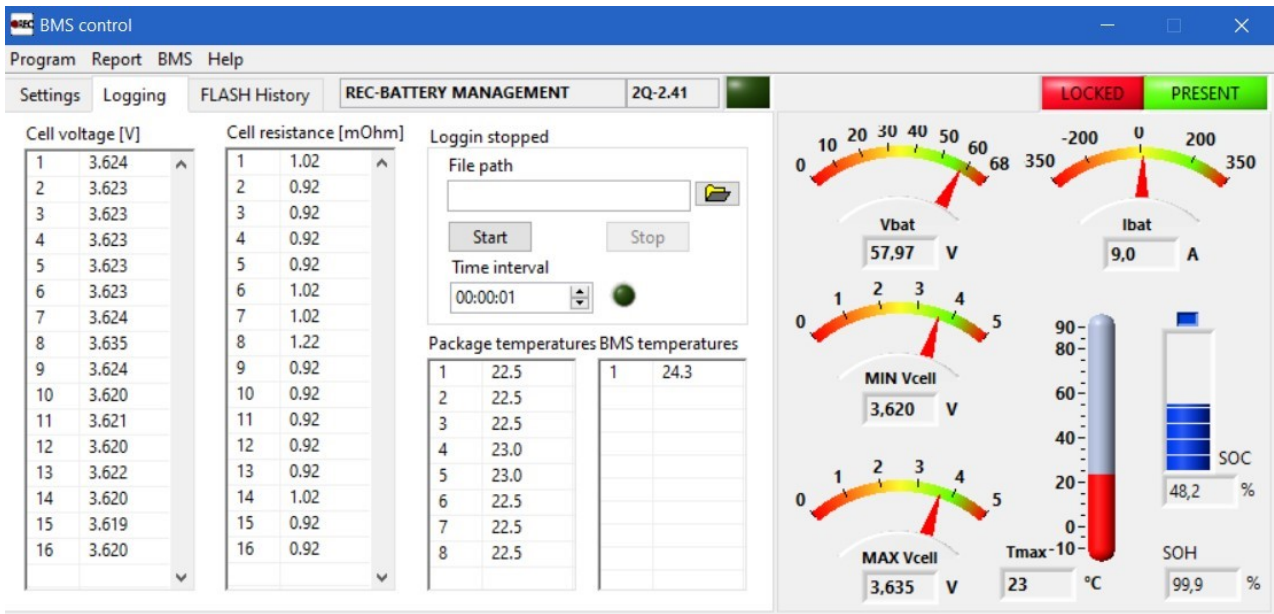
Number of red blinks	Error description
1	Single or multiple cell voltage is too high (4.18V) *
2	Single or multiple cell voltage is too low (3.1V) *
3	Cell voltages differ more than pre-set value (0.5V) *
4	Battery pack temperature is too high (>55°C) *
5	BMS temperature is too high (>50°C) *
6	Number of cells is not set properly
7	Too low temperature for charging < -1°C
8	BMS do not recognize temperature sensor
9	Communication error
10	Measurement of cell below 0,1V or above 4,8V
13	Wrong chemistry set by BMS control software
14	Bad cell contact
15	Balancing transistor failure
16	BMS internal communication error

*Initial settings may be changed with BMS Control Software.

4.3 FES BMS Control software

If you want to monitor and log how voltage levels of each cell in the battery pack are rising during charging, you can use dedicated FES BMS Control software on the PC (or via optional FES LCD display – for monitoring only).

In case there are problems detected during charging, a log file can be created and sent to us by email. This can help us to discover the problem and find a suitable solution. Installation and setup of the FES BMS Control Software is described step by step in a dedicated FES BMS Control manual, which can be downloaded from our website.



SOC, SOH, total, lowest and highest cell voltage levels

5. Before flight

Valid for FES Self-launchers:

FES battery packs must be always recharged for self-launching, so that maximum power is available to obtain a good climb rate. This is especially important when:

- batteries are cold and voltage drop under high load is increased,
- taking off from a short runway,
- taking off at high altitude or
- in hot summer conditions.

Valid for FES Self-sustainers:

Battery packs should be recharged before each flying day, especially if the motor was used significantly during previous flights, and/or a long cross-country flight is planned. This ensures maximum energy will be available when needed.



Note: *It is recommended to recharge the battery packs just a day or two before flight is planned. However, enough time must be planned in for charging process to complete fully.*

5.1 Installing the batteries



Warning: Make sure that both battery packs are fully charged before installation into sailplane. Both battery packs **must have** approximately the same voltage level of each cell (close to 4.16 V per cell). The difference between the total voltage levels of the packs should be **less** than 1V.

1. Check batteries for any visual damage.



Warning: Even small, visually detectable damage implies, that the affected battery is not airworthy.

2. Open battery compartment cover.
3. Check: "Power switch" OFF.
4. Check: Sailplane Master switch is OFF.
5. Insert the first pack (terminals facing forward) and slide it backwards.
6. Insert the second pack (terminals are facing rearward).
7. Both battery packs should be correctly secured with the fixation plates and the fastening knob – **please see next chapter 5.1.1!**
8. Lift power cables from side support.
9. Plug in the shorter cable, with 8 mm pin in the BLUE (or BLACK) housing, into a minus marked 8 mm socket of the front battery pack.
10. Plug in longer cable with 10 mm pin in the RED housing, into a plus marked 10 mm socket of rear battery pack.
11. Insert DATA cable connectors, into each battery pack DATA connector.



Caution: Before inserting the DATA cable connector, make sure that the orientation is correct. Connector should be plugged in straight, otherwise pins could be damaged.

12. Close battery compartment cover.



Warning: The battery compartment cover must be sealed with tape in flight. If there is a possibility of water entering the battery compartment on the ground (e.g. rain shower or during cleaning), the battery compartment cover must be kept sealed. Water could damage the batteries even in small quantities.

5.1.1 FES battery packs fixation



When you put the batteries in the battery compartment, evenly align the strap for holding – it should be equally folded over the edge of the battery pack on both sides!



Lay the lower fixation plate on the holding strap.



Lay the upper fixation plate on the lower fixation plate. Put the pin (fi 4 mm) of the knob in the centering hole on the bottom plate and fasten the knob.



The strap is evenly aligned.



Lower fixation plate and the centering hole.

5.2 Pre-flight test run

After installation of battery packs, it is advised to perform short motor test run on the ground. Short motor run is also recommended before the first flight of a flying day.

1. Remove propeller cover and tail dolly.
2. Open battery compartment cover.
3. Check: Power switch OFF.
4. Switch ON the BMS on each battery pack and wait until initial check is completed.
5. Insert the connecting cable between the front pack + terminal and rear pack – terminal.
6. Close the battery compartment cover and seal it with tape.
7. Seat into the cockpit of the glider and close the canopy.
8. Check that nobody is in the line of the propeller disk or in front of the sailplane.
9. Switch ON the FCU and wait a few seconds until a normal screen appears.
10. Switch ON the Power switch.
11. Gently rotate throttle knob clockwise to start the motor. Use only small RPM, just to check if the system works normally.
12. Check if automatic positioning is working properly.
13. Switch OFF the Power switch.

6. After landing



Warning: After last landing of the flying day (or if you decided not to fly), it is mandatory:

- switch OFF Master switch
- switch OFF both BMS's on top of the battery packs
- unplug the "Connecting cable", from the battery packs

6.1 Removing the batteries

When the total voltage of the battery packs drops below 125 V, it is sensible to remove them from of the glider and recharge them shortly before next flight is planned.

To remove batteries the procedure below should be followed:

1. Check: Sailplane Master switch OFF.
2. Open battery compartment cover.
3. Remove the Connecting cable from terminals of battery packs.
4. Remove red and black power plugs from battery packs.
5. Fix both power cables on right side of battery compartment wall.
6. Remove DATA connectors from each battery pack.
7. Fix DATA cable to side of battery compartment.
8. Unscrew battery pack fastening knobs.
9. Take all retaining plates out.
10. Firmly grip the front battery by a carrier strap.
11. Lift the battery pack out of the fuselage and put it in a safe place.
12. Firmly grip the rear battery pack by the carrier strap und slide it forward along the bottom of the compartment.
13. Lift the battery pack out of the fuselage and put it in a safe place.
14. Close battery compartment cover.



Caution: Always use a transport box or similar for transport and storage of the batteries to protect them from mechanical damage. Make sure you store battery packs in a dry and safe place. Read FES Battery pack manual section 7 and 8 for further instructions.

7. Maintenance

With proper and careful use of FES battery packs, there is practically no maintenance required. FES battery packs are designed with the best cells available, so that they can provide high power, good endurance and will serve you for many years and charging cycles.



Note: Unfortunately, some capacity deterioration will occur due to aging of the cells whether the battery packs are in use or not. The useful life of a lithium cells is based on several factors which can prevent the battery from providing sufficient current draw due to increased internal resistance.

Poor condition of the cells can be recognized during powered flight by these symptoms:

- bigger voltage drops at max power settings than usual,
- significantly reduced maximum achievable power (with fully charged packs),
- significantly reduced usable capacity – lower altitude gain and range of level flight,
- steeper temperature rise gradient of the battery pack.



Note: We suggest replacing FES battery packs, when maximum available range of level flight is reduced to half of the range achieved when they were new. Probably there would be not much sense to utilize them further in such state.

Please handle FES battery packs very carefully to avoid mechanical damage of the housing. Only if battery packs are free of any damage it is allowed to charge them and use them in the glider. They must be always visually inspected before each charging and use in the glider. This is even more important when the glider is used by a syndicate of pilots or in aeroclubs. If the housing is found to be damaged, cells inside could also be damaged, which can be dangerous. In such case, please contact the manufacturer, for evaluation of damage and further steps.

7.1 Suitable uses and treatments to reduce deterioration

Suitable uses and treatment that will reduce deterioration include:

1. Use low power settings as much as possible and practical during flight.
2. Do not discharge cells below 3.4V (109V total voltage), if it is not necessary.
3. Store battery packs at suitable temperatures when they are not in use (see chapter 7. Storage)
4. Store battery packs at suitable charge levels (around 50% SOC, see chapter 7. Storage)

7.2 SOH – State of Health

Good indication of the battery pack condition is SOH – State of Health % parameter, which can be read in lower right corner of BMS control software. It is calculated from average internal resistance of the cells, measured during charging, and number of charging cycles.

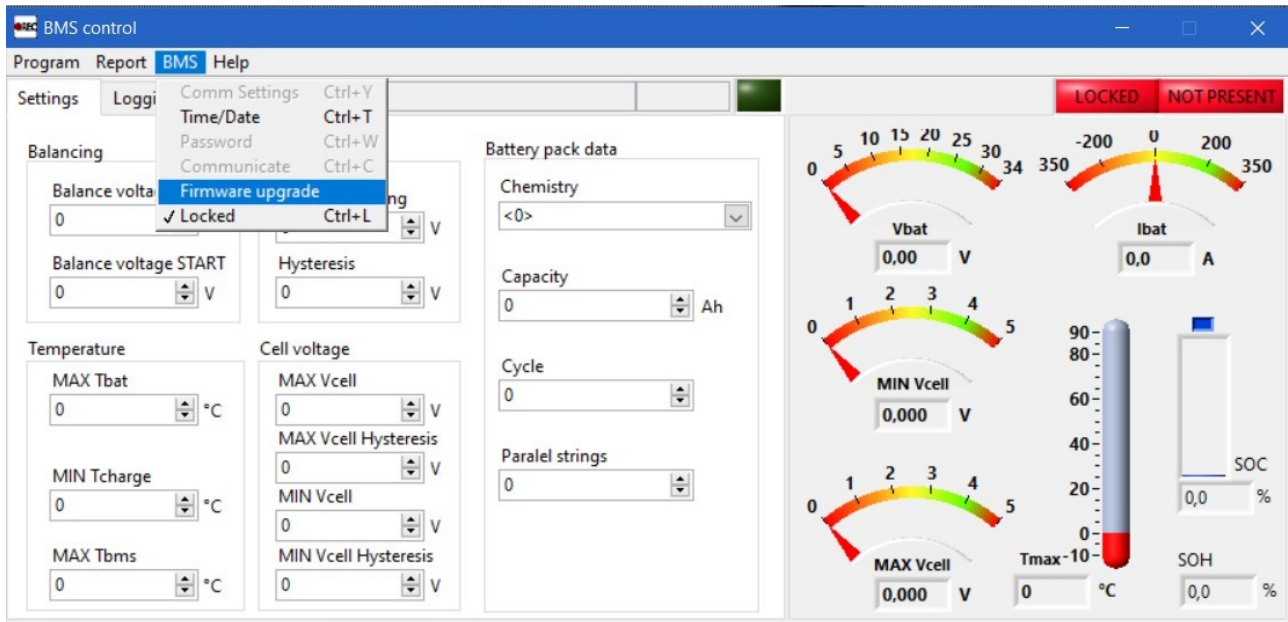
With poor treatment of the battery packs, their cells internal resistance will be increasing faster, and the calculated SOH % level will reduce.

7.3 BMS firmware upgrade

If a new and improved version of BMS firmware is available, it is easy to perform an upgrade, by using the provided BMS-Charger-PC cable, and BMS Control software which is available for download from the FES website.

If there is any strange behaviour of BMS, upgrade usually resolves the problem.

To perform the upgrade, a suitable .bin file is required, which we can send to the customer by email. Please save it to the chosen location on PC disk.



Connect BMS-Charger-PC cable to BMS and to USB port of PC. Run BMS Control Software, cancel any initial error messages which might appear (note that for firmware upgrade green PRESENT indication is not required). From upper menu choose BMS, then Firmware upgrade and browse for .bin file where you save it on PC (named like: BMS_2Q-2.22.bin). Switch ON the BMS switch on top of the battery pack. Wait until programming will reach 100% in progress window. BMS will restart itself and start working normally.

8. Transport

8.1 Car transport

FES battery packs must be protected against mechanical damage and moisture, during transport in the car. We strongly recommend using a pair of FES Stainless steel boxes for advanced protection.



FES stainless steel storage box



FES GEN4 Battery pack placed into FES Stainless steel box

For safety reasons, transport box should be placed into the luggage compartment, if possible, pushed forward up to the back of the back seats. Transportation box should be secured additionally, so that it cannot move during acceleration or braking.



Warning: For safety reasons it is not allowed to transport battery packs in the cabin of the car, behind driver's or co-driver's seat for instance, or in front of the co-driver seat. This could be very dangerous in case of an accident.



Warning: Do not leave battery packs in the parked car under the sun, as they can be exposed to high temperatures.

8.2 In glider trailer



Warning: It is not allowed to transport battery packs in the front area of glider trailer.

When transporting the glider in a trailer, the FES battery packs must be placed in the battery compartment of the glider and properly secured using the retainer plates, the same as during flight.



Warning: When glider is stored in trailer the "Connecting cable" must always be removed.

8.3 Ship/train transport

When your glider is transported by RORO ship (or train) in its trailer, or in a shipping container, with or without its trailer, we suggest placing and fastening the FES battery packs into the battery compartment of the glider, so they are properly secured, the same as during flight.

Another possibility is to place the battery packs into the FES Stainless steel boxes and secure them in a corner of the container.

It is recommended that gliders are shipped using light coloured shipping containers, where internal temperature on hot days at the sea might be lower. It is also possible to paint the top of or the whole container in white to reduce the internal temperature.



Glider trailer placed in the container

9. Discharging and storage

When you stop flying for a longer time, for instance during winter, **it is mandatory** to discharge FES battery packs to 50% SOC. This is to middle of the allowed total voltage range: 3.7V per cell, approximately 59V per pack, or 118V total as indicated on the FCU instrument, when the motor is stopped.

Discharging of the packs can be done in two ways:

- you can discharge them during the last flight of the season, or
- you can use FES discharging assistant (standard equipment) or FES Discharger 2 (optionally available).

9.1 FES Discharger 2 – standard equipment

- End of discharge (50% SOC): 59 V
- Standalone device – **no need to connect external DC load** (oil radiator).
- **Touch LCD display.**
- Higher discharging power, shorter total time of discharging.
- Delivered already properly adjusted for usage with 16S Battery packs.



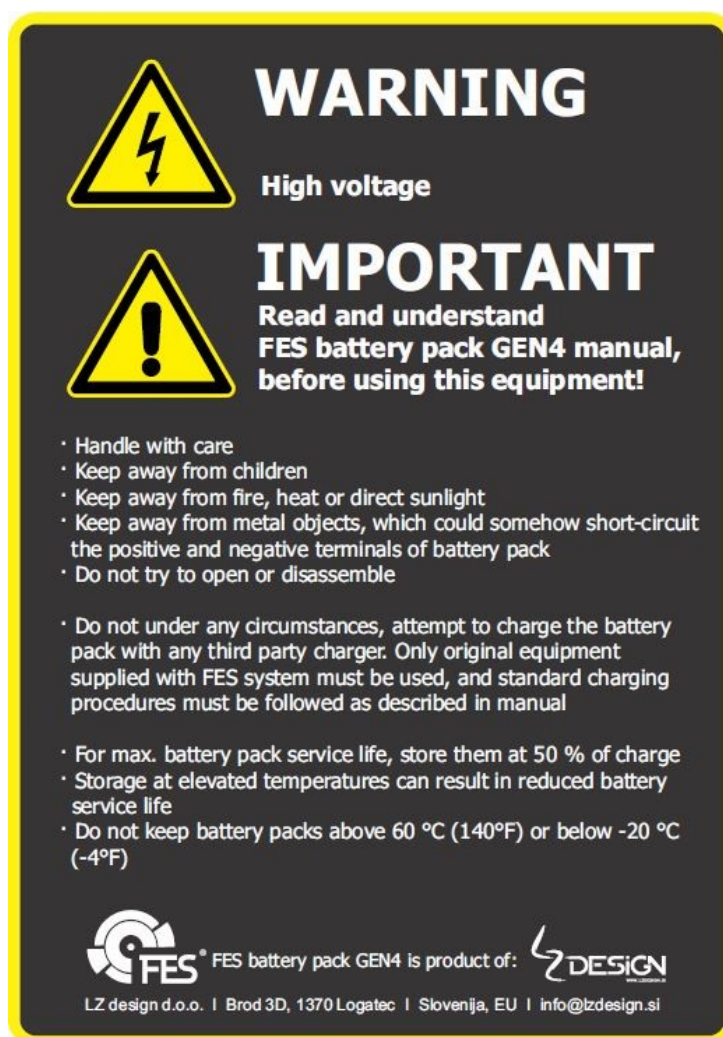
FES Discharger 2

The most important environmental factor for slower aging, is the temperature at which the battery packs are stored. Store them between 10°C to 20°C and normal humidity. Do not store batteries at high or below freezing temperatures and/or in humid environments (like in an old all metal glider trailer).



Note: Always try to avoid exposing battery packs to high temperature, as this is the most significant to the longevity of cells.

9.2 Warning sticker



Note: Above warning sticker, with some basic information regarding storage and charging, is located on rear vertical wall of each FES GEN4 battery pack!

10. Used packs

Check document "Handling instruction for used battery".

11. Revision history

May 2023	Initial version of manual for 16S packs, Version 1.00
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