System Maintenance Manual

ECE 492 – Spring 2014

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Abstract

This document discusses the low-level details of design, construction, operation, repair and maintenance of hardware and software subsystems in the LFEV-ESCM 2014 deliverables (battery pack, charger).

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Pack overview and component ID

Mechanical Design

Overall Dimensioning and Packaging

Airflow/Heating

Pack Assembly Instructions

This section describes the procedure to be followed to assemble a complete battery pack. Each assembly should be constructed before overall pack assembly can take place.

Notes on Torque: How Tight is "Tight"?

Notes on Current Path

Resistance of Path
Using Grease at joints

Assembly 1

Parts required: Battery Cell x7, BMS assembly x7, Battery Bridge P/N 49 x5, U-Strap Battery Bridge P/N 50

1. Line up cells width-wise (4.9 inch side) with rubber dividers in between
2. Ensure the terminals on top of the cells alternate between red and metal (positive and negative - see picture)
3. Using Battery Terminal Connectors (P/N 49) connect the terminals of cells 2-6 (see picture) to the adjacent cells, leaving one positive and one negative terminal open on each side of the 7-cell unit. Instead of P/N 49, use the U-Strap Battery Bridge P/N 50 for the connection between the first and second Battery Cell from the right (negative side).
4. Using banana jacks, fasten the assembled AMS assembly into each cell. Ensure that all AMS assemblies are oriented in the correct direction (see picture).

Assembly 2

Parts required: Fuse Holder, 1 Relay (AIR), 1 Battery Holder Small (P/N 23), 1 Fuse Airs Bridge (P/N 71), AIR Spacer, Fuse Clamp Bolt, Fuse

1. Fasten AIR to AIR Spacer using screws on diagonal of black panel of AIR
2. Attach L71 to AIR using washer and bolt.
3. Attach other side of L71 to Fuse Holder and screw in Fuse Clamp Bolt to hold in place.
4. Attach Fuse Holder and AIR spacer to Battery End using screws.
5. Attach Fuse to Fuse Holder.

Assembly 3

1. Fasten AIR to Battery Holder End L23 using screws on diagonal of black panel of AIR (see picture)
2. Fasten Charging AIR to Battery Holder End L23 using screws on ends of Charging AIR

Assembly 4

Parts Required: Fan Filter Assembly, DIN Rail Assembly, End Plate

1. Attach DIN Rail Assembly using two screw holes in the middle of the plate (not near the edges)
2. Slide Fan Filter Assembly into top opening of the End Plate, flush with both edges of the End Plate. Fasten with screws
3. When the pack is fully assembled, the bulk of the DIN Rail Assembly will be facing inward.

Assembly 5

Parts Required: Fan, End Plate, DIN Rail Assembly, Fan Guard

1. Attach DIN Rail Assembly using two screw holes in the middle of the plate (not near the edges)
2. Slide Fan into the top opening of the End Plate, flush with the side opposite of the DIN Rail Assembly.
3. The Fan should be oriented so that it blows air in the same direction as the DIN Rail Assembly sticks out. This will be the inward facing side of the End Plate.
4. Fasten Fan Guard on the outward side of the End Plate and fasten the Fan to the Fan Guard using screws.

Assembly 6

Parts required: Top Plate, Blue Connector, Gray Connector, Input plate 1 assembly, Input plate 2 assembly, LCD Display

1. Orient the Top plate so that the side with three openings is on the right, and the majority of the holes on top.
2. Fasten the input plate 1 assembly to the upper right corner of the plate with the fuses on the bottom.
3. Fasten the LCD Display in the rectangular opening directly below the input plate 1 assembly.
4. Bring the blue connector up through the bottom of the plate in the opening directly to the left of the LCD Display and Input Plate1 Assembly and fasten with bolts
5. Fasten the Input Plate 2 Assembly to the opening in the upper left corner of the Top Plate.
6. Bring the gray connector up through the bottom of the plate in the opening directly below the Input Plate 2 Assembly and fasten it to the Top Plate and fasten with bolts.

Assembly 7

Parts needed: Pack Base Plate L1, Negative Side Charging Relay, Charging Relay Screws, PCB Mount Board, Pacman Breakout Board, Single Board Computer

1. We will be calling the side with more holes on it the right side of L1. Fasten the PCB Mount Board onto L1 using the screws farthest to the right.
2. Fasten the Negative Side Charging Relay to L1 using the screws second to the right.
3. Attach the Pacman Breakout Board to the right side of the PCB Mount Board.
4. Attach the Single Board Computer to the left side of the PCB Mount Board.

Assembly 8

Parts needed: Pack Back, Wire Duct

1. Attach Wire Duct to the Pack Back with the long end on top.

Overall Pack Assembly

1. Fasten Assembly 4 to the bottom plate on the end with the PCB Mount Board. We will call this the right side of the pack.
2. Fasten Assembly 5 to the bottom plate on the opposite end.
3. Fasten Assembly 3 to the bottom plate using the screw holes closest to the left end plate. The AIR side should be facing the left end plate as well
4. Put the positive end of Assembly 1 flush with Assembly 3.
5. Squeeze Assembly 1 together using Assembly 2 until you can screw Assembly 2 into the bottom plate.
6. Screw top plate onto the two End Plate Assemblies with the gray connector side on the left.
7. Screw Assembly 8 (back wall with wire route) to the back side and wire up the system. Make sure the power to the PM Board is the last wire to be connected.
8. Attach the last remaining side wall onto the pack.

Electrical Design

Current Path

AIRs

Fusing

External Connectors

PacMan BoB

Schematic

PCB Layout

Connectors

Pinouts

Sensors

Current

Voltage

Temperature

Sense wire protection

PacMan Computer

System States

Reset/Startup

Configuration

Troubleshooting

Error Codes

Re-imaging the system

BMS board

Schematic

See Appendix A.

PCB

See Appendix B.

Design Notes

The BMS may be thought of as a piece of drop-in hardware. Although it contains a microcontroller, the firmware performs a fixed set of functions that cannot be altered or configured. One BMS board is attached to each cell and monitors cell's voltage and temperature. Each BMS board also controls the cell's charging bypass circuit.

The entirety of the board's status can be observed and controlled by three LEDs and one pushbutton. The power LED (D4, labelled "PWR") is green, and is on as long as the voltage regulator is functioning. The activity LED (D3, labelled "ACT") is yellow, and blinks at a rate of 0.5-1.0 Hz to indicate that the firmware in the uC is operating properly and is not hung up. The bypass LED (D2, labelled "BYP") indicates that the cell's bypass circuit is active. The "RESET" button (SW1) resets the uC in case of code failure. The uC may also be reset remotely by placing 3.3VDC (>1mA) across pins 1 (-) and 6 (+) of either J2 or J3 on the board. This activates a phototransistor which shorts the same connection as the pushbutton.

Having a full uC on each board may seem overkill, but there are several reasons for this. First, the legacy design incorporated more functionality that was moved off-board in this year's design. Second, the cell data must be aggregated and digitized at some lower level than the central SCADA. It is impractical to run 32 voltage sense lines, 40 temperature sense lines, and 28 bypass control lines to the cells from the central SCADA system. Digitizing the data at the lowest level (i.e. on each BMS board) results in the fewest interconnections. A bus communication line is really is the only choice, as point-to-point communication lines take just as many wires as the analog sense lines. From an economic standpoint, the cost of a uC is significantly lower even than discreet A/D ICs with digital communication interfaces. Furthermore, discreet A/Ds are limited in address space. For these reasons it was advantageous to keep the uC in the design.

The firmware must be loaded on the uC before it is installed in the pack. This is done by way of a PICkit3 in-circuit programming cable connected to header J1 on the BMS board. Instructions for programming are found in the 2013 PICkit 3 Manual.

The firmware assigns each board a default address of 0x00. Each BMS board in the pack must have this default address changed to a unique 8-bit address. The address must be an even number, as required by I2C protocol, and it must not overlap with any other devices on the PacMan board. The PacMan computer will automatically detect all BMS boards in the range 0x02 to 0x1F, and other I2C sensors as specified in the configuration file. We recommend using a logical ordering of successive board addresses such as 0x02, 0x04, 0x06, etc for sanity, and labelling the board in some fashion once the address is set. The addresses will be retained even if power is lost or the uC is reset.

Because each BMS board sources its power from the cell to which it is attached, the ground reference is not consistent from board to board. Therefore any communication interface which leaves the board must be electrically isolated. Both the I2C signals and the remote reset signals are isolated between the pin header and the uC.

Troubleshooting

The BMS board contains no consumable or service-replaceable parts. In case a BMS board is malfunctioning, the following steps can be used to diagnose the problem:

1. The board should be removed from the cell and secured in a vise or other stand.
2. The board should be inspected for obviously damaged or missing components. If damage is observed, repair the component or replace the board. If no damage is visible, continue with the troubleshooting steps.
3. The banana jacks on the bottom can be connected directly to a lab supply output with hook-up leads. Turn on the lab supply and set the output to 3.3VDC.
4. The power LED should immediately light. If the power LED is not lit, the problem is likely within the voltage regulator circuit. In this case, the easiest solution is to replace the entire board.
5. If the activity LED is not flashing (i.e. stuck on or completely off), first try to reset the processor. If this does not work, the firmware could be corrupted. The uC should be re-programmed. (See the 2013 PICkit 3 Manual for details.) If the activity LED still does not flash after re-programming, the uC is likely damaged. In this case, the easiest solution is to replace the entire board.
6. If the bypass is not being activated, try to reset the board and verify the address of the board. (See the BMS Firmware memo for commands and connections to a PC for diagnostics.) If this does not work, it could be that the firmware is configured for a bypass time limit of 0 minutes. In this case, the firmware should be set to a non-zero bypass time limit. If this does not resolve the issue, the easiest solution is to replace the entire board.
7. If the voltage or temperature commands are not returning sane values, try to reset the board and verify the address. If this does not work, the easiest solution is to replace the entire board.

Charger

Charger Specifications

The charger is a TDK-Lambda Genesys series GENH30-25 programmable power supply. As a commercial, UL-listed power supply, the case must not be opened under any circumstances. There are no user serviceable parts inside. The power supply is capable of producing 30VDC at 25A.

Because of relatively high currents involved, the resistance of the current path(s) is not negligible. For this reason, the pack voltage as reported by the PacMan, the sum of the individual cell voltages, and the charger input voltage may not agree.

Charge Algorithm

The charging algorithm uses constant-current combined with a bypass mechanism to balance individual cells. The maximum cell charging voltage is specified by the cell manufacturer to be 3.65V per cell when

multiple cells are used in a pack. The charger output voltage is then found by summing the cell voltages and the resistive losses in the current path. Although the algorithm is current-based (not dependent on voltage), the voltage limit is useful as an added layer of safety.

Pigtail

The power output terminals on the GENH30-25 are designed to accept bolted connections, and are not designed to be connected and disconnected frequently. This is the reason for the inclusion of a pigtail on the charger. The pigtail provides an Anderson connector which combines all signals into one connector. This pigtail can and should remain connected under normal circumstances, but may be removed if necessary.

1. Unplug the charger from AC power.
2. Remove the hood protecting the output terminals.
3. Remove the bolts holding the ring terminals to the output terminals.

Troubleshooting

If the pack will not charge, identify the symptom:
The LCD does not display "charging" when the charge cable is plugged in.
The LCD displays "charging" but the current is zero.
The LCD displays "charging" but the current is negative.

1. Try to re-seat CW2 (charge cable).
2. Check continuity between CW2:P1-5 and CW2:P1-6. These two pins are the "charge sense" pins and must provide a short circuit for the pack to charge.
3. Check the voltage between A1:J0-5 and A1:J0-6 (pack charge sense pins). The voltage should be ( ).

Ensure the charger is plugged into the wall and switched on. If the charger display shows an error message, refer to the charger manual for details.
Ensure the charge cable is securely seated on both ends.
Ensure the charger is set to sufficient voltage to allow current to flow into the pack, not out.