Battery Pack & Electrical Examples

What other teams saw that you don’t need to see

Steve McMullen

Battery Pack Design

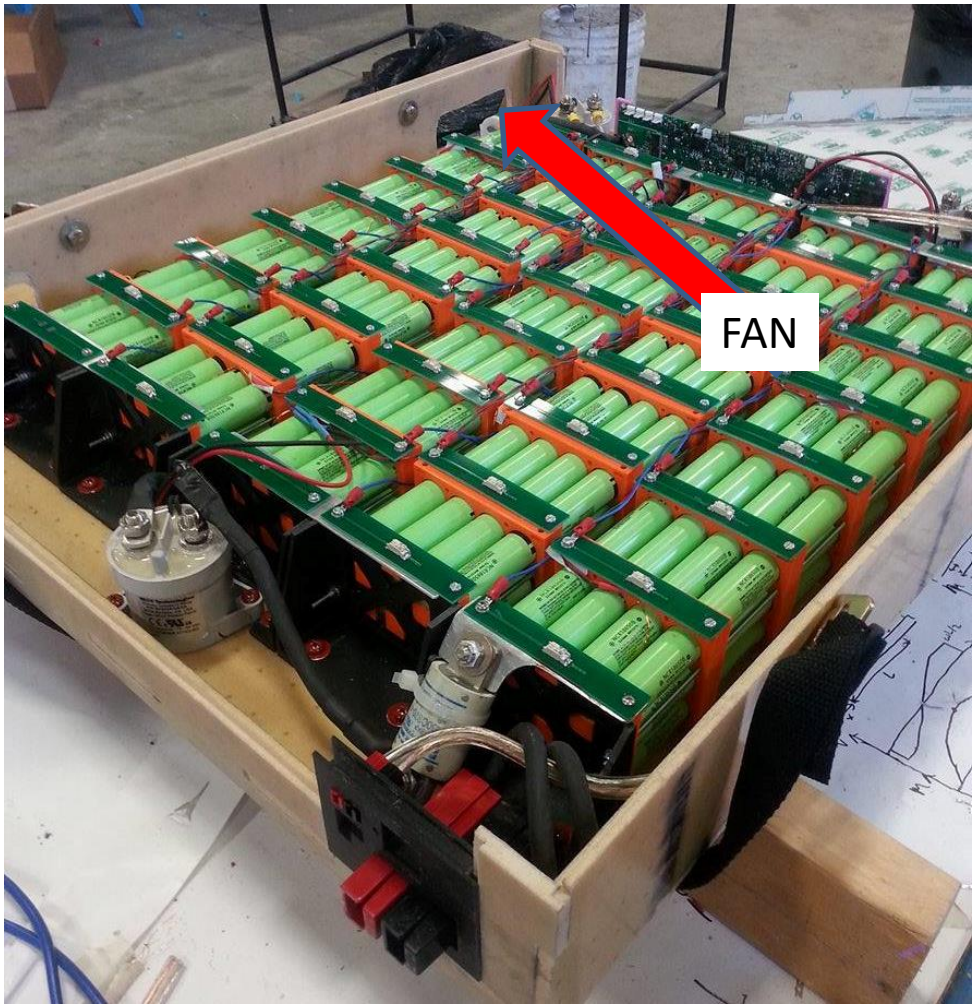
- Some **Functions** of the **Pack Design**
  - Provide electrical Connection
    - Cells to Module
    - Modules to Pack
    - Pack to Vehicle Grid
  - Provide mechanical restraint to Cells
  - Provide Thermal Cooling
    - Fan Mounting stationary to pack
    - Ventilation for equivalent cell temperatures
  - Provide Location and Mounting for Fuse
  - Provide Location and Mounting for Battery Relays
  - Provide Location and Mounting for Motor Relay
  - Provide Location and Mounting for Battery Protection System
  - Provide the ability to Isolate all High Voltage exiting the pack.
  - Provide a structure that contains the cells, relays, fuse and BPS.

Battery Pack Design

- **Example: Module to Pack Connections**
  - Here we see the compression of the copper tabs using Aluminum plates with 4 small screws that also held the sense boards. This proved to be inadequate to carry the pack current during the Qualifier and was replaced with Copper Bars and larger screws on some of the connections.

Battery Pack Design

- **Example**
  - Once can see that the fan location does NOT offer adequate air distribution to the pack given its position relative to the cells and the air flow.
  - Fuse weight is supported by the Aluminum Buss which can fatigue the battery tab
  - The Pack to Vehicle Grid is very good using Anderson connectors for quick Impound ability
  - Even after the copper buss modifications at the Qualifier, additional copper was needed during the Rayce
  - Team suffered from reduced range and detected this as the cause of the imbalance

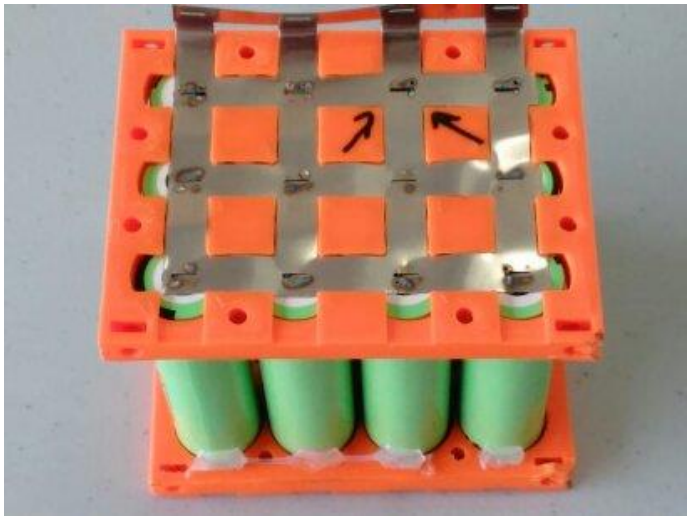


Battery Pack Design

- The prior example did not accomplish all the requirements equally in the pack design area
- Let’s walk through some other designs and further elaborate how all this can actually be done.

Battery Pack Design

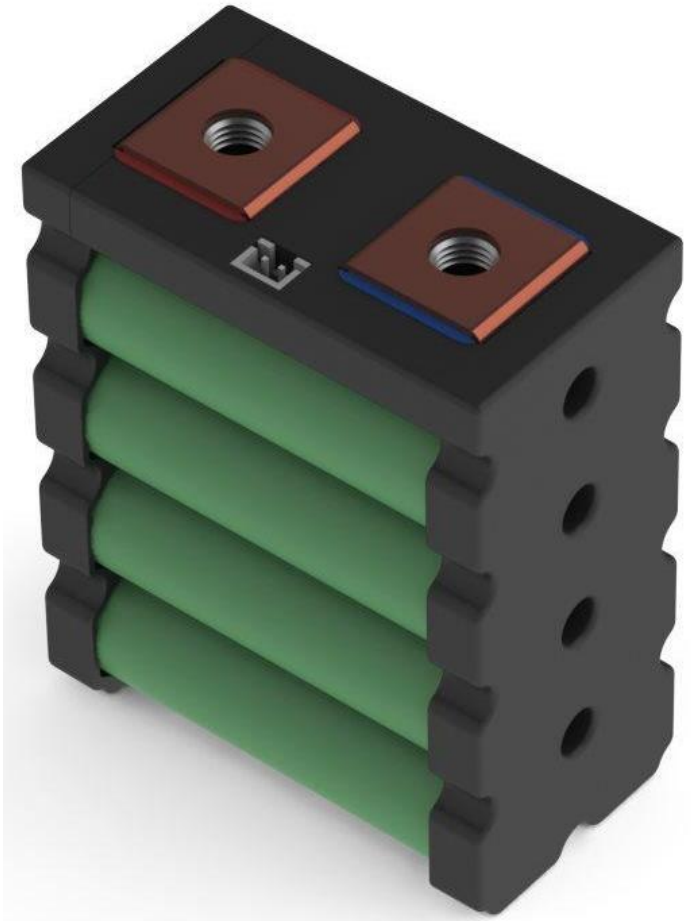
- **Function: Cells to Module Mechanical and Electrical**
  - Here is an better example of cells being held relative to each other.
  - Additional reaming was used to hold the cells to the grid structure precisely beyond the 3-D printing
  - They were also electrically connected as a module very well with Spot Welded Nickel buss by the team after some spot weld development.



Battery Pack Design

- Function: **Cells to Module Mechanical and Electrical**
  - Here's a different example of Cell Retention
  - Again, 3-D printed, this time where hidden nuts and internal copper buss served as the terminal to this module.
  - Note the embedded Sense connector for easy sense
  - Not aware of how to hold to pack though and appears heavier than previous designs.

Energus Power Solutions,
Baltic Institute of Advanced Technologies (BPTI)



Battery Pack Design

- **Function: Module to Pack Electrical**
  - Cell holders which aligned connections to stand proud between Modules.
  - Nickel plated Copper Tabs on each module were clamped together to provide Pack Current and Pack Voltage with very low resistance.
  - There is no load on the cells using this method
  - Another concern is the ability of the Nickel buss structure to carry pack current.

Battery Pack Design

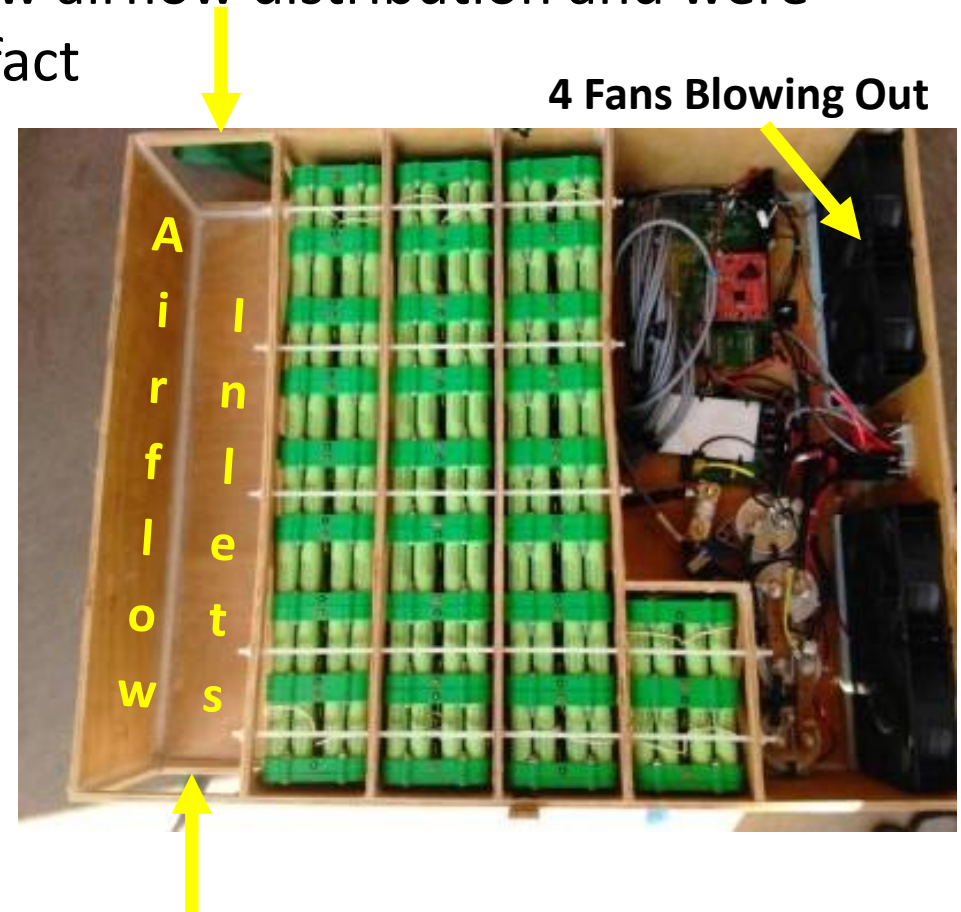
- Function: Module to Pack Electrical
  - End 3-D Aluminum end cap was designed to terminate the string and provide connection to the rest of the strings.
  - This is aluminum end cap provided a Tab to conduct out to the Fuse and Relays

Battery Pack Design

- Function: Module to Pack Mechanical
  - Modules fit between dividers and Plastic rods are bolted across above the cells
  - This contains the modules in all directions to limit motion
  - Motion is the enemy of electrical connections held in pressure contact

Battery Pack Design

- Function: Pack Thermal
- Batteries distributed to allow for equal airflow throughout
- Partitions designed to allow airflow distribution and were easily modified after the fact
- 12V DC/DC converter within battery box allows pack charging without vehicle chassis.
- Relays, fuse and BPS all in hotter airstream will add to the life and durability of the pack itself



Battery Pack Design

- Function: System Design
  - Power Switch and main Fuse easily reached should it be necessary
  - No Extra wire
  - Battery Protection close and inside
  - Independent Low Voltage Connection and DC Connection out to Drive Inverter

Battery Pack Design

- Function: Mounting and Connectivity
- Here an 18650 Cell Package is used to provides mounting and connectivity for up to 8 cells.
- They provide reasonable spacing if airflow is designed to pass thru
- Upside: Very Quick Pack Assembly, Robust to Weak Pack designers, safe and easily.
- Downsides: Weight and Cost.

Tyva Energie out of France

Pack insights from a 2016 Team

Hello Steve,

I have attached some thoughts below.

We made a few errors we think contributed to our performance:

- Using thick nickel tabbing (0.010") meant cells were harder to Spot weld – Weaker spot welds that failed
- Using wide (0.500") copper bus bar soldered to the tabbing made the tabs too stiff to adequately spot weld to batteries with ends that were slightly out of plane – Stress on the terminals
- Using wide copper bus bar did not allow for enough area for good welds on the cells directly under the copper – Assembly/manufacturability
- Bolting modules together put a constant tension on the spot welds – Pack Vibration
- Lack of compliant material under the cells caused all vibration to be transmitted to spot weld joints

Our solutions to these problems, which we will likely use on our next pack:

- Consider using thinner (0.005) nickel tabbing
- Use thinner bus bar or copper braid between the tabbing, perhaps soldered or crimped to bolted lugs via copper braid
- Use compliant material under cells to provide vibration isolation

You are welcome to attribute these to our team and direct questions about our problems to us.

Team with Motor Lead issues

In Conclusion

- Most Images represented in this slide show were from actual 2016 teams designs.
- It was the teams who offered to share this learning with the rest of you to improve your pack designs.
- It is my goal that teams not have connectivity, thermal or packaging issues associated with any solar raycing event.