TO: LFEV Team

FROM: Drew Jeffrey

DATE: 10 May 2014

SUBJECT: Accumulator Container FEV Compliance Memo

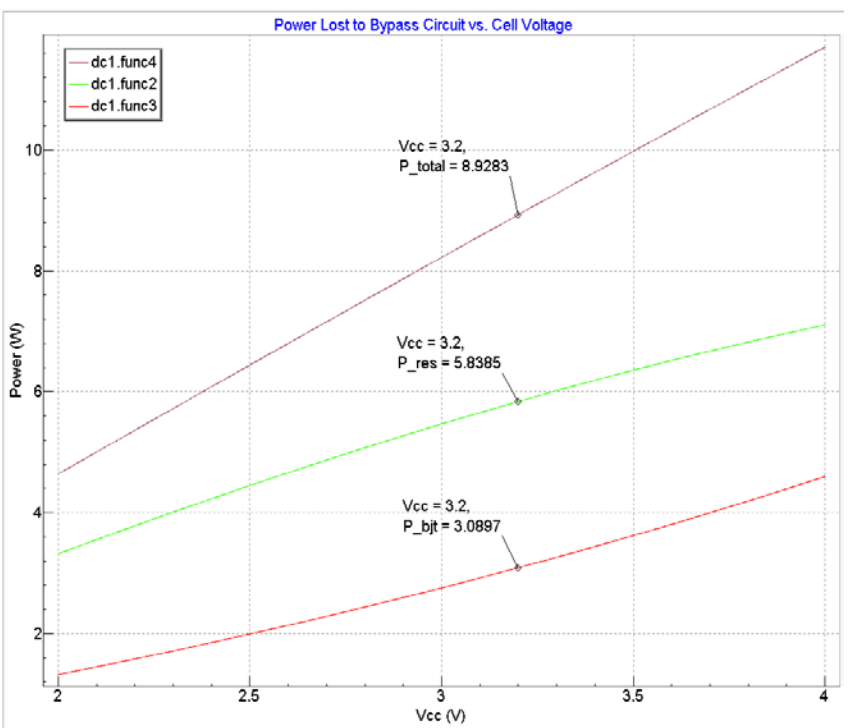
ABSTRACT:

This memo details how the analysis requirements relating to the accumulator container have been met in our system's final design. This document outlines how requirements R004-6, EV 3.3.3, EV 3.4.3, EV 3.5.5 and EV 3.6.8 have or have not been met by the current design.

REQUIREMENTS:

R004-6 - Cooling - The AMS requires a simple, small, manufacturable heat sink cooling system for the bypass switch. Performance of cooling system shall be proved by computer modeling and empirical measurements

The 2013 design utilized a larger heat sink for the bypass circuitry as this was deemed able to dissipate the heat produced by the bypass resistor and transistor. In our 2014 design, a smaller heat sink was utilized along with a cooling fan.



The 2013 team's bypass circuitry is identical to the one used in the 2014 AMS boards. As such their SPICE analysis results can be used by us and applied to the 2014 AMS boards. During charging, the battery cells will be at about 3.5VDC while bypassing. According to the 2013 analysis, about 10W of heat will be dissipated by the resistor and power transistor of the bypass circuitry. The heat sink used for the AMS boards was rated for 2.9 °C/W. At that thermal resistance, the velocity of air necessary for cooling is 190 FPM. The fan within our accumulator container can move 100 CFM. We can assume for this analysis the air flow produced by our fan is a cylinder with a diameter the size of the fan and each heat sink on the AMS boards is encountering the same air velocity since they are all in line with the fan. The fan's diameter is 0.41 feet, giving it an area of 0.13 square feet. To find the speed of the air in FPM, we divide the CFM rating by the area of the fan to get 757 FPM. This is well above the 190 FPM necessary for forced air cooling and will therefore meet this requirement.

EV 3.3.3 - All batteries or capacitors that make up the accumulator must be divided into accumulator segments. Maintenance plugs, additional contactors or similar measures must be taken to allow electrical separation of the internal accumulator segments such that the separated segments contain a maximum voltage of less than 120 VDC fully charged and a maximum energy as specified in Table 10. This separation method must be used whenever the accumulator containers are opened for maintenance and whenever accumulator segments are removed from the container. Maintenance separation requiring tools to isolate the segments will not be accepted.

For our design, one accumulator container contains seven 60Ah cells. Each cell fully charged contains 3.2V * 60Ah = 192 Wh = 691200 joules. There are 7 cells, so each accumulator container contains 7 * 691200 joules = 4.84 megajoules. The maximum number of energy for each accumulator container is 12MJ, so our design is within this limit. In addition, each segment has a voltage of around 22.4V which is much less than the 120VDC maximum allowed in each separated accumulator segment.

EV 3.4.3 - All accumulator containers must lie within the surface envelope as defined by IC1.5.1

Although integration with the LFEV car will not begin until either 2015 or 2016, the battery pack delivered by the 2014 team was designed to be fit like saddle bags on the sides of the car in between the wheels. The SAE car dimensions specify a wheel to wheel distance of 46". The 2014 team's battery pack will measure approximately 36" in length, which is small enough to fit in between the wheels of the car.

EV 3.5.5 - The fuse protecting the accumulator circuit must have a rating lower than the voltage and current ratings of the isolation relays.

Currently, the fuse protecting the accumulator circuit is rated for 200A and 160VDC. The AIRs are rated for 350A and up to 800VDC, so the fuse ratings are lower than the AIR ratings.

EV 3.6.8 - Team-Designed Accumulator Management Systems: Teams may design and build their own Accumulator Management Systems. However, microprocessor-based accumulator management systems are subject to the following restrictions: (a) The processor must be dedicated to the AMS function only. However it may communicate with other systems through shared peripherals or other physical links. (b) The AMS circuit board must include a watchdog time (Maxim MAX6373 or similar) which is physically separate from the CPI. (c) The external watchdog time must be hardwired to the AIRs through an electro-mechanical relay such that a watchdog timeout or lost of power to the circuit board will result in the AIRs opening (d) The watchdog "tickle" input must be driven high and low in separate routines (i.e. no "compliment port pin" code) At least one watchdog input transition must be driven inside a foreground routine, i.e. both transitions may not be contained in timer or externally-triggered interrupt routines. (e) The code that drives the watchdog input may not be located such that a malfunction resulting in continuous internal watchdog timeouts could prevent the external watchdog timer from timing out. (f) The external watchdog time must be demonstrable.

The 2014 battery pack uses a custom built AMS. It does use a microprocessor based solution, however, it is dedicated to AMS functionality alone as it only continually monitors the voltage and temperature of the individual battery cells, measures the voltage and current of the entire battery pack, engages the safety system if it detects unsafe readings, and provides an RS-485 link to allow the AMS to communicate battery pack details to the central SCADA computer. On the Pack Manager breakout board, an ADM1232 watchdog timer is provided. The safety loop relay on the breakout board is normally open, so if power is lost, the relay will naturally be open and break the safety loop, opening the AIRs. In addition, a watchdog timeout will also cause the safety loop relay on the breakout board to open, thereby opening the AIRs. Within the software running on the TS-8160-4200 in the pack manager, the watchdog input is driven in the foreground and no complement port pin code is used. The code is arranged to force the watchdog input pin low then high, so if continuous internal watchdog timeouts occur, the code will force the input pin to be low and then not force the pin high before another internal timeout occurs and restarts the board and the program. In order to demonstrate the watchdog, the pack manager's program supports a command to disable or enable the watchdog input pin. This command can be sent to the pack manager during tech inspection to demonstrate the watchdog chip.