LV Battery & BMS

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Project Description / Justification

A few sentence description of the system/project.

Designing a low voltage (lv) battery pack for MKV's LV electronics system, including Pack configuration and BMS PCB.

There are two Low Voltage systems on our MKV Formula Car - the Cooling LV and the Ground LV (GLV) system. Currently we are working on the GLV system, to . Both systems run at the same voltage, they have entirely different operational requirements and thus need to be specced totally differently.

Project Links

ALL Design Documents, Specifications, and Information

- **We are currently using this spreadsheet to record final specifications for LV Packs, BMS systems, etc.**
- **https://docs.google.com/spreadsheets/d/1jNzmEW8gYzVo2ICA-lvgvPik2UgGUVpqzuyDUMSRFGE/edit?usp=sharing**

Resources

- We are primarily using imrbatteries.com and 18650batterystore.com to spec and source our batteries.
- Battery Datasheet

Relevant Rules (If any which they're usually are)

EV.5 Tractive System - Monitoring

EV.5.1.2 The AMS must continuously measure the cell voltage of every cell, in order to keep the cells
inside the allowed minimum and maximum cell voltage levels stated in the cell data sheet. If
single cells are directly connected in parallel, only one voltage measurement is needed.

EV.5.1.3 The AMS must continuously measure the temperatures of critical points of the accumulator to
keep the cells below the allowed maximum cell temperature limit stated in the cell data sheet
or 60°C, whichever is lower.

Currently Working on testing:

Over-voltage testing of components on the GLV system. With the introduction of the new battery pack, our max voltage exceeds most of the components on the system are rated for. This table reflects the results of testing these components at higher voltages in isolation:

Component	Testing Notes	Pass?

AIRs (GIGAVAC GV242BAB)	▪ Coil functions as intended outside of rated voltage range. (Coils close and open at range from 13V - 17V).
	▪ 30 min stress test:
	  ▪ Subjected AIR to 17V for 30 minutes
	  ▪ Noticed AIR heating up very slowly
	  ▪ Coil Temp rose from 30C at resting to 39C at the 18 minute mark
	  ▪ Coil Temp ended up at 41C at 30 minutes
	▪ Coil Current draw was measured to be 0.3A - higher than the datasheet specified 0.23A
	  ▪ Can be attributed to sourcing 17V instead of the expected 12V
		Pass

Brakelight	• At 12V, Current draw of the brakelight is 0.05A
	• At 17V, current draw of 0.09A
	• Stress Test:
	  • 5 min on, 5 min off, 5 min on, 5 min off, 5 min on
	  • Making sure the light still works when over-volted (at 17V)
	  • Took it like a champ
	  • Got pretty warm ~45C after the 3rd round of being on
	  • Brakelight will never be on at this voltage for such a long time. Should be fine.
		Pass

Motor Controller	At 16V on the roadkill harness, the total current draw was 0.590V. The MC was communicating fine on the CAN bus. After unplugging the MC the roadkill harness was drawing 0.2V.	Pass

Design/updates Log

Keep notes of design decisions here. What was chosen, why it was and what was disregarded and why. Should be updated at least weekly. Quick and dirty documentation.

09 Apr 2020

Updates on work that's been happening over the last month

- Gone through a couple iterations of layout design (updated design screenshot included below)
- Layout revisions will continue in the upcoming week(s)
- Initial testing complete for to test/determine State of Charge and discharge capacity for LV Battery pack (view updates on this confluence page) (View Plotted Testing Results here)

Design Reviews

DR1 - This took place very early in the project progression and the notes were very 'early-stage'

DR2 - notes from electrical Leads Design Review 2

Design Review Slides link

Big Picture - They roasted the PCB Schematic but confirmed we were on track

Key notes from the review

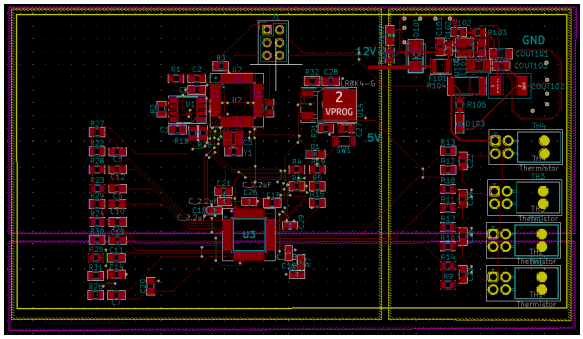
- Programming LED's
- UARTS
- Internal Regulation? Does this chip have it?
- External Relays and how this board interacts with them
- Naming conventions - need to fix
- Battery + , Battery - need two separate connections?
- Different Grounds - DVDD, AVSS, etc.
- NFAULT pin - need an LED
- LDOIN pin - Consider the battery / capacitor connection
- Thermistor Connectors - micromatch?
- How we will trigger WAKEUP pin?
- Do UART connections need pull up resistors?

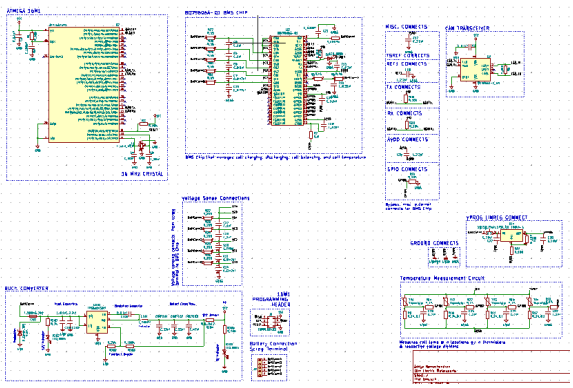
Large Design Decision (Heading 2)

We have no large design decisions to document yet.

- Additional schematic & PCB layout design review planned in the upcoming week

Update Screenshots below:



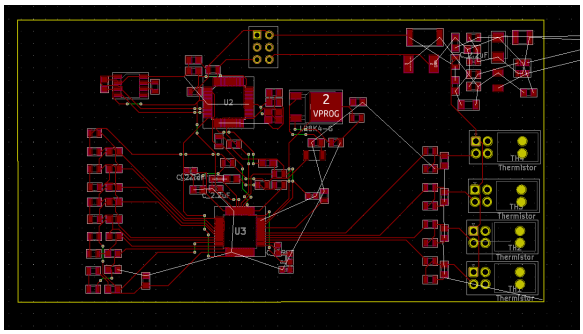


09 Mar 2020

(Post meeting confluence update) - **began testing LV Battery SOC-Voltage relationship**

- 8.17 V total pack voltage (2 V / cell) pack was over discharged
- .336 mA vampire draw current load on top + terminal of cell
- 2 uA vampire draw current load on mid and low positive terminals of cell
- .340 mA Total Vampire draw current load on battery
- By end of meeting, charged pack up to 12.3 V open circuit voltage
    - Charged on 3-4A, 4-5 minutes of charge

(Prior to Meeting Confluence Update): **Completed Layout V2 -**



Still need to work on adding in 4 Ground Planes, fixing buck setup, adding CAN connector, adding screw terminal connection, and adding WAKEUP circuitry to trigger WAKEUP pin on powering board.

08 Mar 2020

List of GLV components that may be sensitive to a 16.8V maximum GLV.

1. Motor Controller (Max 16V)
2. COTS CAN Logger (Max 36V)
3. IMD (Max 24V)

4. RTD Buzzer (Max 13V)
5. Brakelight
6. AIRs (16V)
7. 12v Shutdown circuit relays (~20V)
8. IMU (18V)
9. Emeter (60V)
10. Precharge Relay
11. Discharge Relay

01 Mar 2020

PCB schematic design nearly completed for LV BMS PCB.

Board has passed 1 Design Review and is transitioning into Layout Phase

Features Included

- Overvoltage protection
- Undervoltage protection
- Cell balancing (passive or active)
- Over and under temperature protection

Quick Reference Links

Design Review Slides

BMS Chip Datasheet

BMS Chip Software programming datasheet

Linear Regulator Datasheet

PCB schematic core sections

- BMS Chip Connects
- Misc. Connects
- Can Tranciever
- Buck Converter
- AtMega 16M1
- Voltage Sense Connections
- 16M1 Programming Header
- Battery Connection Screw Terminal
- GPIO Connects
- Temperature Measurement Circuit
- VProg linear regulator Connect
- Ground Connects

(Major fixes from the design review are covered on the left.)

Most serious design questions we faced when designing the board:

- What kind of cell balancing current do we need for this board to be capable of?
- How do we trigger wakeup?
- How do we think about individually testing different features / components on this board?
- Whats the best communication protocol for this board to talk to the ATMEGA?

Handy images

Table 6. Available Functions by Power Mode

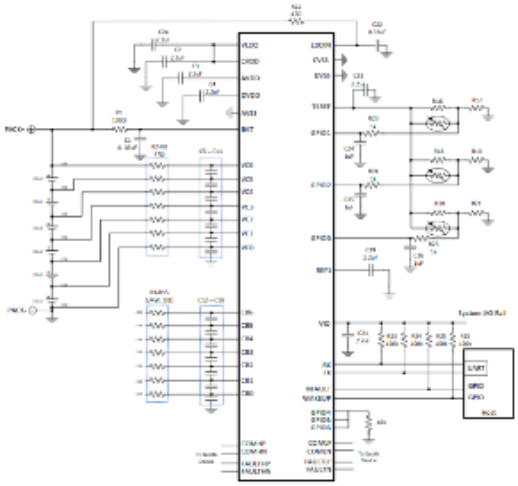
	SHUTDOWN	SLEEP	ACTIVE
OV/UV Comparators		X	X
OT/UT Comparators		X	X
Communications			X
Cell Balancing		X	X
WAKE Tone	X	X	X
WAKEUP Detection	X	X	X
SLEEPtoACTIVE Detection		X	X
SHUTDOWN Detection		X	X
ADC Reads			X
FAULTDET Tone		X	X
GPIO FAULT		X	X
SPI Master			X
Communication Timeout			X

9.2.1.2.11.1 Selecting Cell Balance Resistors

The cell balancing current, I_{EQ} , is set using the resistors, R_{EQ}. All cell balancing resistors must be the same value. The value for R_{EQ} is calculated as:

$$R_{EQ} = \frac{1}{2} \times \left(\frac{V_{BAT}}{I_{EQ}} - R_{DS(ON)} \right) \quad (17)$$

9.2.1 Base Device with Measurement Applications Circuit



02 Feb 2020

Multiple cycles of testing completed - OTS BMS works, prevents overcharge & prevents discharge. Ran through AD & TI BMS chip options, chose this this BMS Chip, beginning work on custom BMS PCB design via KiCad.

Features we want in our custom BMS:

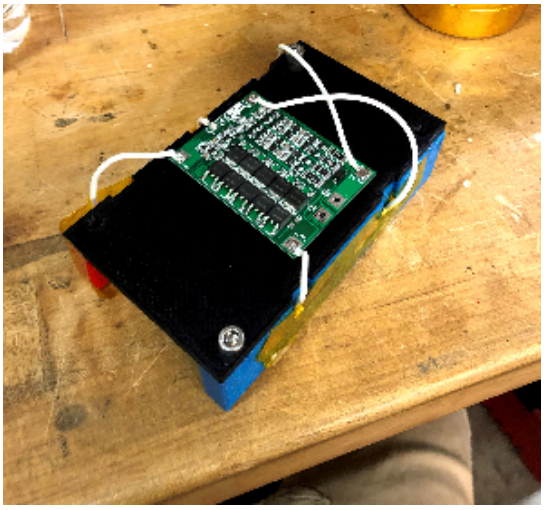
- Must Have: overvoltage & undervoltage protection
- Must Have: overttemp and undertemp protection
    - Nice to Have: Cell Balancing

23 Jan 2020

Will complete 2 charge and discharge cycles of the GLV battery pack this week. Our setup uses these parts linked below.

BMS link

Battery link



05 Dec 2019

Worked out usable battery configuration for the LV Cooling battery - the LG MJ1 in a 4s11p setup, coming out to a total pack capacity of 38500 mAh, max discharge current of 110 amps, and specs of 2156 grams, 727 cm^3, and $219 per pack.

Began work on KiCad documentation

02 Dec 2019

Picked an OTS bms solution

ordered batteries and ots bms from 18650batterystore and amazon respectively

began work choosing batteries and config for Cooling LV

24 Nov 2019

OTS (off-the-shelf) solutions to compare to benefit of making our own.
Option 1 - $9

Option 2 - $11

19 Nov 2019

Inrush when LV is on is 1.99A
Steady state when LV is on is 1.41A
The green GLV light consumes about half that
That number will be a bit higher when the TSAL is on as well

11.14.18 - today began working on speccing a BMS system for the GLV configuration. talked to mechanical design team about mechanical constraints. Didn't get too far w/ speccing the BMS boards, only looked at boards and chips from AD & TI manufacturing sites.

11.11.19 - today talked to others about system recs and will be working during the upcoming week

11.7.19 - previously was assigned this project

today built from scratch the comparison spreadsheet framework, and specced a cell and config for the GLV pack.