EVtv SAFE-T-BMS

Product Specification

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This document describes the basic functionality of a non-incendiary Battery Monitoring/Management System designed to determine electric vehicle battery pack state of charge, cell health, and temperature during vehicle operation. It should prevent overcharging and overdischarging of an electric vehicle battery pack.

The product is designed to monitor battery systems and provide operational safety interlocks and communications regarding pack health. It specifically does not perform maintenance tasks such as balancing and minimizes wiring in the vehicle. The concept is to provide information and in some cases take action to protect the pack, but “first do no harm” to battery and vehicle systems.

The basic design philosophy incorporates the following.

1. No spaghetti wiring
2. No parasitic loads
3. Don't burn anything to the ground
4. Don't screw up a battery pack

The device functionality falls into the following categories:

1. Current Measurement
2. Voltage Measurement
3. Temperature Measurement
4. State of Charge Calculation
5. Cell Health Calculations
6. Control RELAY Functions
7. Communications Functions
8. SAE J1772 Management

CURRENT MEASUREMENT

In most Battery Management Systems, current is measured using inexpensive Hall Effect Current measurement devices. While handy, these devices are notoriously inaccurate and subject to temperature drift and zeroing problems. The SAFET BMS will take advantage of a chip released in April of 2013 by SENSDYNE termed the SPF100.

Current measurement is accomplished using a very low resistance 1200A 50mv shunt Iconnected to the negative terminal of the vehicle high voltage battery pack. All currents into or out of the battery pack must go through this shunt. Two current sense wires are connected to the BMS Control Unit which measures the voltage drop across the very low resistance of 0.00004166666667 ohms or 41.6 microohms.

This current measurement requires very close accuracy and calibration to be capable of measuring both high current levels for vehicle operation of up to 2000 amperes and very low current levels of 2-3 amperes often encountered during regenerative braking and charging operations. The device uses the SENSDYNE SPF100 chipset to make these measurements and provide them over an I2C interface to the microcontroller in the BMS Controller. In this way the reference of the current sense resistor is isolated from the BMS Controller microprocessor and the associated 12v vehicle power system. Measurement is bidirectional from zero to 2000 amperes.

VOLTAGE MEASUREMENT

Voltage measurement is accomplished using up to five voltage sensor bolts used on the anodes of cells. These sensor bolts are cored to provide both voltage and temperature taps down inside the bolt to most closely approximate anode temperature and voltage. They are connected by CAT5 ethernet cable to the BMS control unit.

Inside the BMS control unit, the voltages are scaled by precision voltage dividers and converted to an I2C serial stream through an isolated Analog to Digital converter.

The pack will normally be divided into four segments using five taps or three segments using four taps depending on the total number of cells as the pack must be evenly divided between segments.

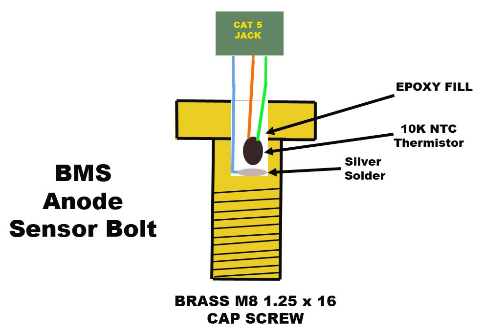
In this way, we can calculate both the total pack voltage and the individual voltage of each pack segment for comparison.

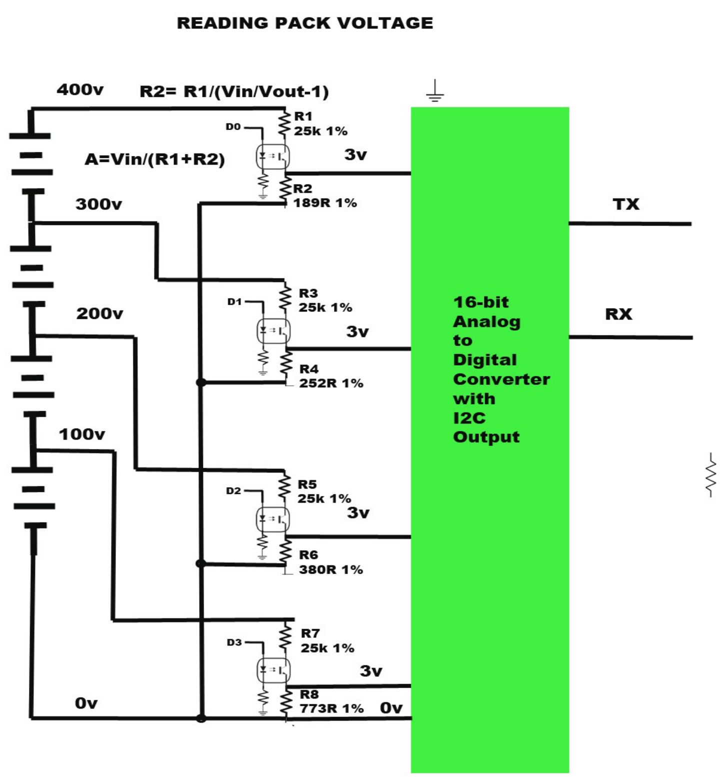
To minimize parasitic loads, each voltage divider for each pack segment will be strobed by a digital output (D0-D3) which will turn on that specific voltage divider segment in turn. In software, we will strobe the optocoupler for that segment on, and then poll the ADC for that voltage. These will be done in turn. This will cause current flow through the pack segments only during the read phase.

Refer to the attached diagram. There is an inherent problem with this design. It requires current through the entire pack for the 400v measurement, but only ¾ of the pack for 300v input and ½ the pack for 200v measurement. Even for the brief strobing described, these imbalances will be cummulative over time and are unacceptable.

This might be solved by having individual A/D converters with their own isolated supply for each voltage tap. Which would point up the advantage of not having very many of them.

The point is, be conscious of these kinds of low level drains and imbalances. This is one of the reasons Battery Management Systems tend to damage battery packs.





TEMPERATURE MEASUREMENT

Cell temperatures are measured at up to five anode locations, again using the sensor bolts. These bolts contain 10k NTC thermistors. The BMS Control Unit provides a 5v voltage across the thermistor as well as a parallel reference resistor to derive an input voltage 0-5v representing cell temperature. This is converted by an ADC to I2C serial stream data, providing both isolation and temperature data. Accuracy of +/- 1.5C would be adequate.

STATE OF CHARGE CALCULATION

State of charge calculation is determined by calculating the total size of the pack in the fully charged state in kilowatt hours by multiplying the nominal voltage of the pack by its amphour capacity.

Software in the multicontroller thèn takes pack voltage and current data periodically to calculate and integrate kWh consumption which is subtracted from cell capacity. Values are stored in both ampere hours and kilowatt hours.

The system automatically resets to zero AH/kWh during normal charging when the charge voltage exceeds normal operating voltage. SOC countdown will begin at 0 when voltage falls below the charging threshold voltage.

A manual reset button will also be provided to zero SOC indication.

The SAFET BMS will provide a PWM output indicating State of Charge that can be used to drive a normal automotive fuel gage.

CELL HEALTH CALCULATIONS

Cell health is determined by monitoring temperature and voltage under various conditions of operation.

As both temperature and voltage vary enormously during vehicle operation, and actual values will vary from vehicle to vehicle, absolute values are not considered terribly important here.

The overriding determinant of health here will be done by comparing the voltage of either three or four battery pack segments. With good cell health, these values should be essentially identical in ALL operational scenarios. Both at rest and under load. Dead or dying cells would often exhibit with unusually high or low voltage, either statically or under load.

The overriding premise is that cells with problems will basically not be able to maintain their voltage under high currents and would exhibit this problem under that scenario somewhat earlier than they would at rest with no load.

The voltage of almost any size segment of any conceivable cell pack will be within a few tenths of a volt of any other segment if all cells are healthy.

It would be a statistically unlikely event for two cell segments to each have an identically failing cell or cells. But it becomes statistically ludicrous to have three or four pack segments with identical failures.

This system will not indicate WHICH cell has failed or is unhealthy and likely to fail in the near future. That determination is not needed while driving or charging the vehicle. The specific cells needing attention can be determined in the garage in a maintenance scenario. The theory here is that while operating the vehicle, we need to know THAT we are experiencing cell failure or likely to soon. WHAT the specific failure is is simply useless information to the driver of the vehicle.

The sensitivity of the comparison and the action taken on error can be configured by the end user.

CONTROL RELAY FUNCTIONS

The Safe-T-BMS can perform a variety of functions based on measured voltages, temperatures, state of charge indications or cell health determinations. To interlock or perform these functions, four programmable relays are provided, K1 through K4 and the Normally Open (NO), Normally Closed (NC) and control arm (C) terminals of those relays are exposed for connection with other vehicle systems.

For example, a 240vac relay could be controlled by a 12v signal normally routed through K1C-NO. The battery pack is normally charged to 126.5v by the charger with charge terminating at that point.

The SAFETYBMS can be configured so that K1 closes when the voltage reaches 129v and releases subsequently when the voltage falls below 120v.

In this way, the BMS acts as a backup safety interlock in the event of charger failure, and if the voltage rises beyond the normal 126.5v, the relay is energized applying 12v through the now closed NO contacts to the AC relay, disconnecting AC power from the charger.

Indeed, a SECOND relay could be used to accomplish the same act if a measured pack temperature rose above a user configurable temperature. By using the NO contacts of two relays, the AC power would be removed by EITHER a high voltage indication OR a high temperature indication.

Other scenarios could involve decreasing throttle input to the controller to effect a “limp” mode in the event that two battery pack segments were more than 0.4v different under load and this could be configured to LATCH the relay requiring some form of reset function to unlatch it.

COMMUNICATIONS FUNCTIONS

The SafeTBMS should provide several separate communications functions. These to include:

USB Serial Port Communications
CANbus Communications
Bluetooth BLE Wireless Link

USB Serial Port Communications.

A very basic ASCII text string will be available via USB serial port connection at 19200 bps or higher containing voltage, temperature, amperes, and kWh in a single string repeating once per second.
By sending an ASCII character, the end user can interrupt this flow to display a simple numeric menu allowing entry of very basic configuration choices for the operation of the unit.

CANBUS COMMUNICATIONS

The device will feature a Controller Area Network (CAN) connection with extended addressing at 250 kbps. Device address will be configurable. Device will broadcast messages which will include:

Pack voltage
Pack current
Instantaneous power output in kW.
4 segment voltages
current SOC percentage
kWh used
4temperatures
4 relay states

BLUETOOTH BLE COMMUNICATIONS

The SafeTBMS will provide Bluetooth BLE communications capability to communicate with handheld smart phones and tablets including both Android and Apple IOS devices.

It is envisioned that this will lead to application development to both display attractively battery current and voltage and SOC as well as power output etc. Additionally a configuration menu will allow access to all configuration options of the device.

SAE J1772 EVSE FUNCTIONS

The SAFE-T BMS will perform all functions for SAE J1772 communications for Level I and Level II charging.

Most notably proximity switch and pilot signal management. The BMS will provide the resistance and diode logic to turn on the EVSE and begin the charging sequence.

But it will also monitor voltages and temperatures of the pack.

1. If total pack voltage exceeds a maximum charge voltage value, the BMS will disconnect the EVSE, removing power from the charger. This voltage will normally be slightly higher than the voltage set in the charger for charge termination – providing a failsafe backup to the charger to prevent overcharging.

2. If the disparity in voltage between one measured pack segment and any other exceeds a threshold percentage, the BMS will disconnect the EVSE, removing power from the charger.

3. If Anode temperature is below 32F/0C the BMS will disconnect EVSE, removing power from the charger.

4. If any monitored pack anode temperature exceeds 55C at any time, the BMS will disconnect EVSE removing power from the onboard charger.