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Cost Effective and Customizable Battery Management System (BMS) for Li-Ion Batteries

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Agenda

- Introduction

- BMS – Common and New Features

- BMS for Flight Termination System (FTS)

- BMS Customization

- Over/Under Voltage Protection

- Over-Current Protection

- Sleep Mode

- Temperature Control

- Cell Balancing and Cell Connectivity

- Heater Functionality

- Environmental Testing

Battery Management System (BMS) - Introduction

Lithium-Ion (Li-Ion) cells have been the predominant building block for many Li-Ion batteries in consumer electronics and in applications such as

- Vehicle traction packs

- Energy storage systems

- **Military** (focus of interest)

Li-Ion batteries perform very effectively but only if they are treated well. Therefore, they require an effective Battery Management System (BMS).

It is the job of a BMS is to ensure that the battery pack is operated safely.

Battery Management System (BMS) - Introduction

Over the past many years of working with different BMS's for different applications, not all BMS's are the same. They <u>must</u> be tailored for a specific application. We developed and deployed BMS's for:

- Telecommunication industry

- Outside surveillance cameras

- Automotive

- Military (BB2590, Silent Watch, Wearable Electronics)

There are pros and cons in each applications, some features are more important than others. Even though the safety of the battery pack has always been the main concern in any application, customers also ask for a cost effective BMS without major and prolonged re-designs. Our focus in this discussion will be on **military.**

Battery Management System (BMS) – Common Features

While all BMS's may provide:

- Over- and Under-Voltage Protections

- Perhaps Cell Balancing

- Over-current Protection

- Short Circuit Protection

- Temperature Control and Output

But, they will not tell you everything...

Chg	PrCh	Dsch
Current Cntr		Cell Bln
Over/Under Voltage Ptct		
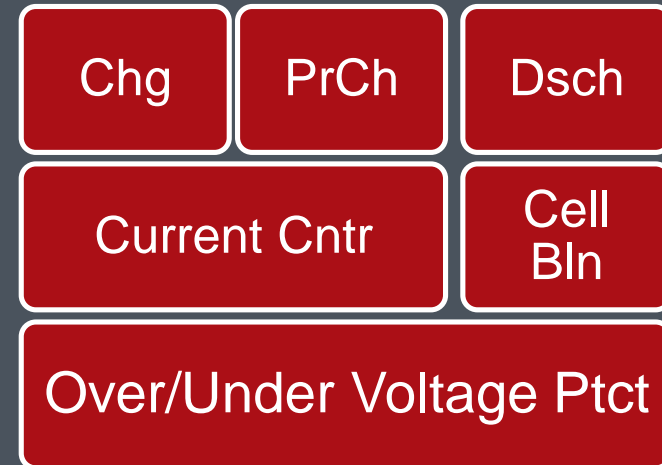
Battery Management System (BMS) – New Features

Not all BMS's inform the user about a detected failure:

- What if the balancing stopped working?

- Cell Failure detection

- Sleep mode

- Can some features be turned on and off depending on the applications?

Such cost effective BMS's are not available off-the-shelf. The cost effective BMS will periodically check all its main functions and provide the status and specific alert to the user.

Battery Management System (BMS) – Military

- Designed for and used in new Flight Termination Systems (FTS)

- Monitors and protects between 3 – 8 cells connected in series

- Supports Li-Ion -CoO2, -MnO4, -FePO4 and other chemistries

- Driven by and meets RCC-319 specification and requirements (RSO witnessed)

Comparison Table (next slide) between a good acceptable BMS and the one required for FTS Li-Ion battery per RCC-319.

Battery Management System (BMS) – FTS

Description	Standard BMS	RCC-319
Over-voltage	Yes	Yes
Under-voltage	Yes	No
Over-current (charging)	Yes	Yes
Over-current (discharging)*	Yes	No
Short circuit protection*	Yes	No
Reverse Polarity	Yes	Yes
Temperature Control	Yes	Yes
Cell Balancing	Yes	Yes
Cell Connectivity Lost	Yes	Yes
Customized Alerts	Yes	No
Firmware*	Yes	No

Note:

Over-current (discharging) - No fuses allowed inside FTS batteries

Firmware - If Yes, Additional testing requires per RCC-319

External each cell voltage monitoring is available

Battery Management System (BMS) – FTS Battery

Li-Ion FTS Battery
(Device No. G3203C1)

Performance
Voltage (V): 24 to 33.6
Current (A): 5 Discharge
1.0 Charge
Rated Capacity (Ah): 2.8 at 77ºF (25 ºC)
Internal Heater: Yes
Operating Temp. Range (F):
Charge: 32º to +113º
Discharge: -4º to +160º
Storage Temp. Range (F): <95º

Physical Characteristics
Chemistry: Li-Ion
Size: 6.26" x 3.56" x 1.34"
Weight (lb.): 2.05

Environmental
RCC319-10 FTS Battery Requirements

Battery Management System (BMS) – Customization

How do we smoothly transition from a standard BMS to the one required for the FTS application without a major re-design?

Description	Acceptable BMS	RCC-319	Default	Versatility
Over-voltage	Yes	Yes	On	On/Off
Under-voltage	Yes	No	Off	On/Off
Over-current (charging)	Yes	Yes	On	On/Off
Over-current (discharging)*	Yes	No	Off	On/Off
Short circuit protection*	Yes	No	Off	On/Off
Reverse Polarity	Yes	Yes	Off	Always On
Temperature Control	Yes	Yes	Off	On/Off
Cell Balancing	Yes	Yes	On	Always On
Cell Connectivity Lost	Yes	Yes	On	Always On
Customized Alerts	Yes	No	On	Always On
Firmware*	Yes	No	Off	On/Off
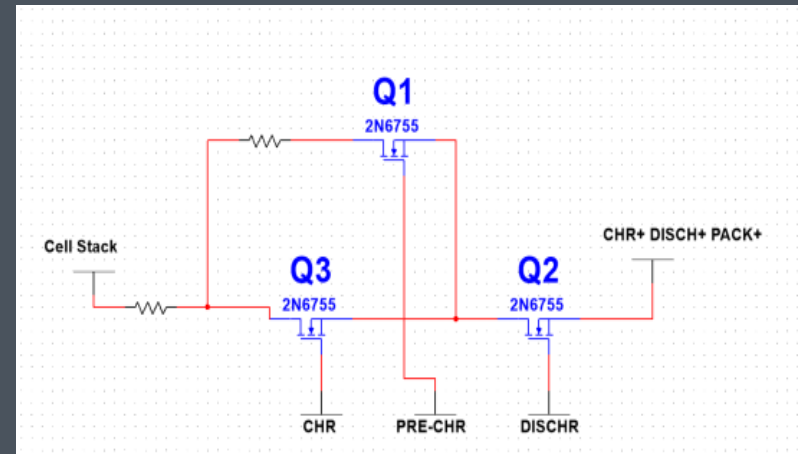
Battery Management System (BMS): Under-Voltage Protection

- Due to RCC-319, there is no under-voltage protections permitted during discharge. Also, there are no fuses. Traces are sized for 10A of continuous discharge current.

- However, the BMS can be implemented as a charger with the under-voltage protection enabled. Therefore, the low voltage cut-off would be 24V for the LCO chemistry.

Battery Management System (BMS): Over-Current Protection

The charge and discharge current are monitored on high side all the time, except during the sleep mode.

The BMS has different current threshold (and time) depending on application. Thresholds are set by EAS.

- Over-Current condition (Charging) – Example, multiple batteries connected in parallel
- Over-Current condition (Discharging) – Example, fuse clearing in Telecommunication
- Short Circuit condition (Discharge) – Example, external short
- Charge and Discharge paths can be separated. Currently, set as one path
- Pre-charge control possible. Designed with the intent to use during charging at cold temperature

Battery Management System (BMS): Sleep Mode

- The battery pack goes into the sleep mode if there has been no current flow for a certain period of time. That time duration is set by EAS.

- Sleep mode condition adds **prolonged storage** of the batteries. The re-charge can be done once a year instead of every 6 months (typical).

- The battery gets out of sleep mode immediately once a charger is connected or a current flow is detected (wake-up condition).

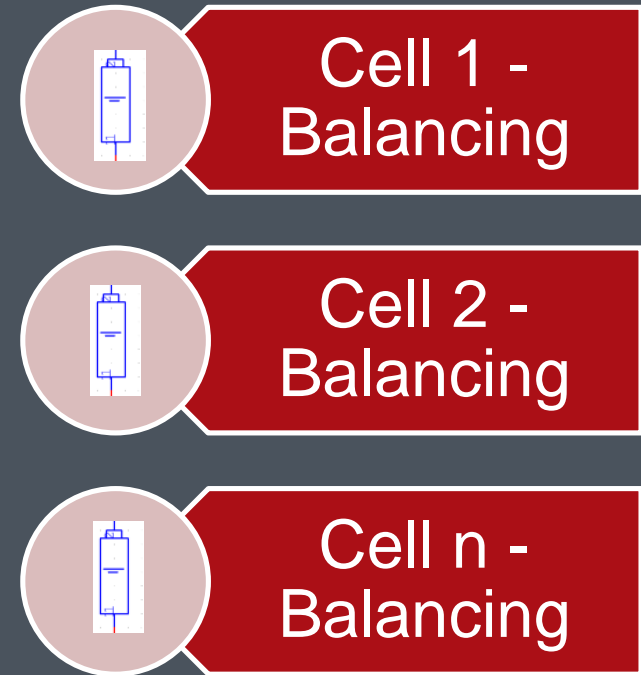## Battery Management System (BMS): Temperature Control

- One RTD for external use. It is physically placed on the cell #4.

- Two thermistors for internal BMS use. They can be used to monitor FET temperature, battery pack temperature or additional cell temperature.

- Over-temperature condition is set by EAS. The battery pack would shut down if the over-temperature condition is detected.

- Normal condition will return once the condition is cleared. Currently, this feature is not used. It can be enabled at any time, or when used as a charger.
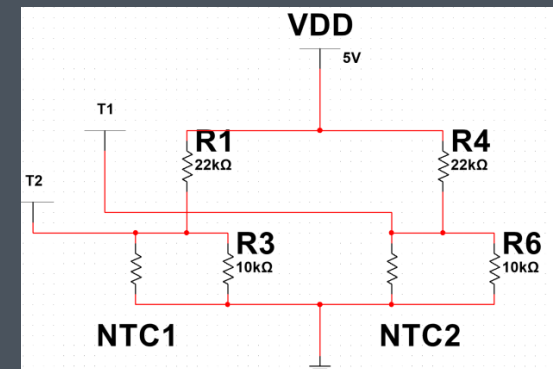
+80C	0.15V
+50C	0.29V
+25C	0.46V
0C	0.62V
-20C	0.71V
-40C	0.75V

Battery Management System (BMS): Cell Balancing

- Each cell balancing FET turns automatically once the cell voltage reached 4.2V (LCO chemistry). This voltage can be changed by EAS depending on the cell chemistry used

- It is passive balancing. Balancing resistors are sized to sink 100 mA of current

- Balancing stops when the cell voltage drops below 4.2V (LCO chemistry)

Cell 1 - Balancing

Cell 2 - Balancing

Cell n - Balancing

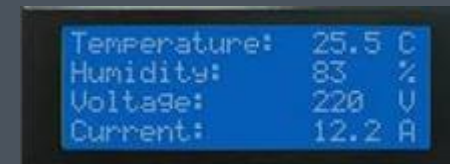## Battery Management System (BMS): Cell Connectivity Lost

- As an additional safety feature, Cell Connectivity (Open-Wire) detection has been implemented. The main goal of this feature is to turn off the power FETs if there is an open wire to prevent the cells being excessively charged or discharged.

- Over-voltage and under-voltage protection will not detect if cell balancing has been compromised. Therefore, cell(s) can still be damaged despite over-voltage and under-voltage protections functioning properly.

- Cell Connectivity (Open-Wire) detection checks connectivity of the cell to the balancing circuitry and checks balancing FETs connectivity.

Battery Management System (BMS): Customized Alerts

At the battery level, there are no visual alerts (i.e. LEDs, displays). There is RS-485 output for the external charger/analyzer. The external charger would have customized visual indicators for as many or as little alerts as desired. Current design would have an LED indicating the following events:

- Battery charging and discharging

- Battery pack shutting down

- Open-wire detection

- Over-current protection, Over-, Under-voltage protection

- Over-temperature protection

- More alerts can be easily implemented

Battery Management System (BMS): RTD Output

Precision RTD output mounted on the cell #4. This output is used during flight:
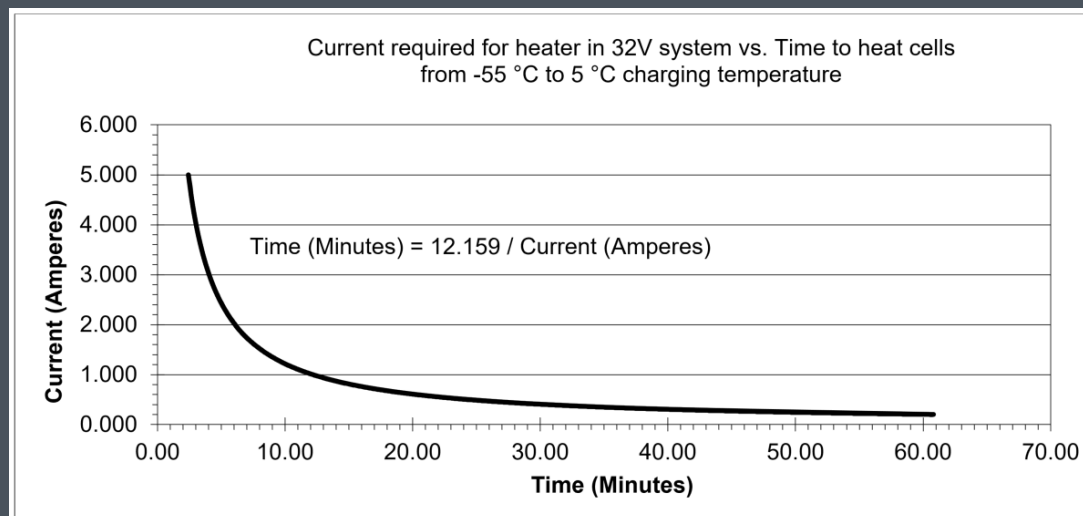
A sample is listed below:

- 1,236 Ohms for 61 degrees C

- 1,097 Ohms for 25 degrees C

- 1,020 Ohms for 5 degrees C

- 961 Ohms for -10 degrees C

- 882 Ohms for -30 degrees C

- 843 Ohms for -40 degrees C

Cell 1
Cell 2
Cell 3
Cell 4 +RTD
Cell 5
Cell 6
Cell 7
Cell 8
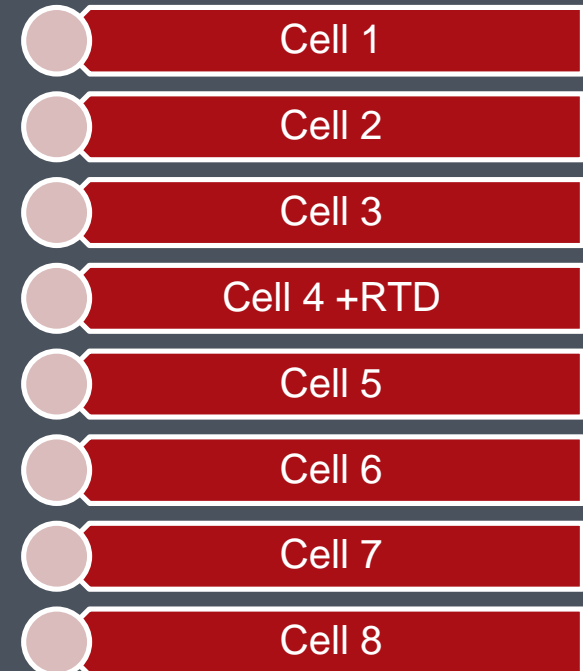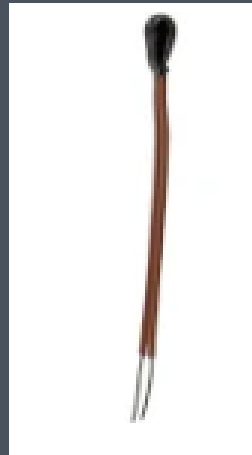
Battery Management System (BMS): Heater Functionality

Battery BMS has an integrated heater for cold discharge applications:

- EAS programs the desired On and Off temperatures

- Automatic On/Off switching

- Requires external power supply (32V, 16W)

Current required for heater in 32V system vs. Time to heat cells
from -55 °C to 5 °C charging temperature

$$Time (Minutes) = 12.159 / Current (Amperes)$$

Battery Management System (BMS): Charger/Analyzer

Because of the flexibility and versatility of the BMS in the Li-Ion battery, the board can be easily integrated into a portable charger. All the important features for the charger can be easily enabled:

- Plot of each cell voltage
- Plot of the total battery voltage
- Current flowing in and out of the battery
- RTD measurement

Battery Management System (BMS): Environmental Testing

BMS boards passed various vibrations and shock testing up to 10db as part of the FTS battery qualification at <u>hot</u> and <u>cold</u> extremes:

- Board did not crack or break

- Components on the boards did not crack or break

- No signs of fatigue or failures

Battery Management System (BMS): Questions

- **Questions?**

- **Thank you for your attention!**