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Notebook Batteries Diminish in a Few Months, Where Similar Batteries Last a Decade in Electric Vehicles (EVs)!

If you ever wonder about the reason behind this, or if you simply thought these batteries are not the same, this is for you.

35 years after commercialization of Li-Ion batteries, the workhorse behind every portable equipment and EVs, one would think everything has been figured out, the technology is mature and this is as good as it gets. Although the search for improvements to Li-Ion batteries or replacements has been a constant almost since the beginning, with number of startups that have come and gone looking for the holy grail, the basic Li-Ion technology seems to be the winner, potentially due to the existing enormous infrastructure already in place for manufacturing them. So, is there no room for improvement? Are we at the end of the rope, and have to live with what we have, and give up on further advancements? The short answer is “definitely not”. In reality there is a lot of money left on the table, mainly due to the poor or lack of effective battery management in a large number of these end equipment. The battery life in these equipment could profoundly improve by implementing effective battery management, with no change to their chemistry or structure.

In this age of social media and internet, things that so profoundly affect our user experience, are broadly discussed and everyone is aware of the “whys” and the “hows”, but the fact that most of our everyday battery-powered equipment lack effective battery management, seem to be an exception to the rule. If we asked the entire Notebook owners why their unit loses battery capacity so quickly, the common answer would be well batteries age. You may also hear that the same is true in cell phones, so this does not come as a surprise. The fact is that the reason behind the Cell phone batteries loss of capacity and the Notebook’s are not the same. Cell phone batteries actually age, and that is mainly due to the need for multiple charges per day, as well as topping off the battery to its near absolute maximum to improve the at least initial runtime, which has a highly adverse effect on the battery life. On the contrary, most of us do not charge our laptops multiple times a day, or at least not from complete empty to complete full. Because of the large capacity of the Notebook batteries, it is also easy to give up a couple of percent of the charge capacity, for a major improvement in battery life. So why do we see this short life phenomena in Notebook and other consumer equipment batteries, and how would battery management fix this issue?

Li-Ion batteries are highly sensitive to over voltage (catastrophic failure and fire hazard), as well as under voltage (severe loss of capacity). For this, every battery pack requires a protection circuit to ensure cell voltages are kept between these thresholds. Aside from the voltage level limits, protection circuits also prevent over current and over temperature. Since the voltage of each cell directly relates to its state of charge, ability to set these thresholds accurately is key in getting maximum capacity, while maintaining safety. Common low-cost protection circuits have high tolerances, resulting in much broader threshold settings than desired.

Fundamentally no two batteries are identical, mainly due to the manufacturing tolerances, as well as temperature variation among cells. These variations will result in different cell capacity and self-discharge among cells in multi-cell packs that will result in different cell voltages. Since Li-Ion batteries are sensitive to over voltage and under voltage, the protection function will cut off charge and or discharge to the entire pack prematurely, when any single cell reaches a min. or a max. voltage threshold. Forced cell balancing is the only way to assure longevity and full capacity of a battery pack throughout its life. The error due to the differences in capacity will accumulate over charge and discharge cycles, resulting in severe out of balance cells. The more unbalanced the cells become, the lower the battery pack capacity. This is how a notebook computer battery, as an example, can exhibit a fraction of the original charge capacity, sometimes after only a short few month of operation.

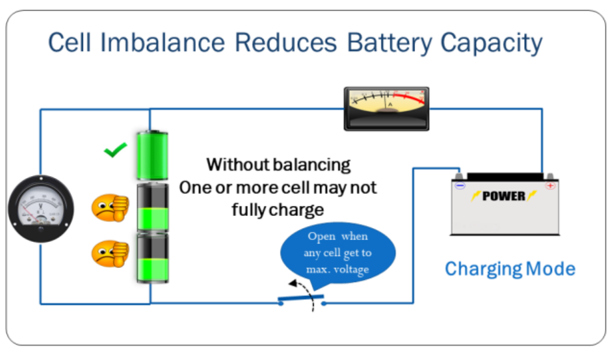

FIG 1: As soon as one cell is fully charged, the protection function cuts the charge to the pack

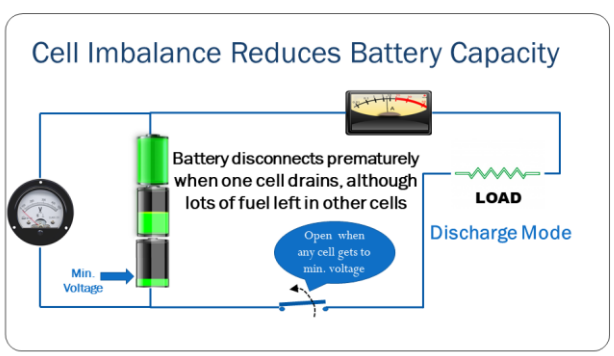

FIG 2: As soon as one cell is fully discharged, the protection function cuts the discharge to the pack

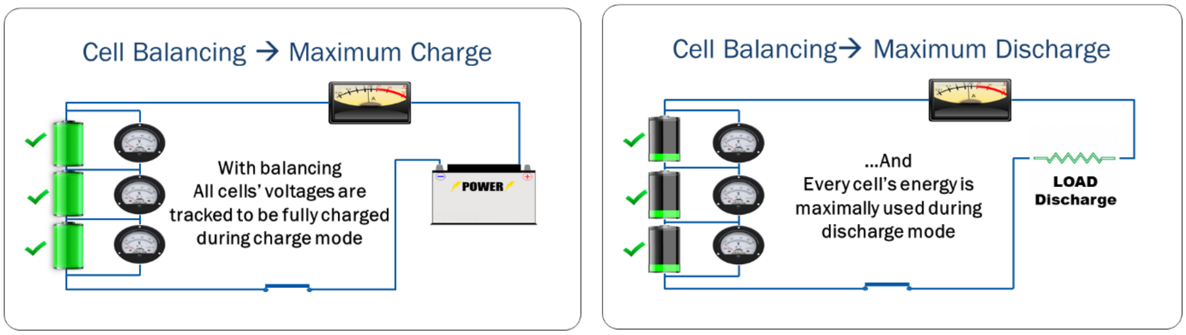

FIG 3 & 4: Fully balanced cells result in complete charge and discharge, allowing maximum effective capacity

So why effective battery management, and more specifically cell balancing, not implemented across such broad range of products? With all the advancements in technology, historic low cost of semiconductor devices, due to fierce competition, what keeps the OEMs from utilizing these devices? These battery management devices clearly exist, as we see their utilization in high-end products, such as EVs, so why not in most consumer devices? If you guessed cost, you are correct. Yes, as surprising as this sounds, the industry has not been able to take the cost out of these functions and commoditize them, as most other power management devices have. This is not by accident, nor is it a decision. This has simply been a fact of life, high cost of manufacturing => high ASP; high ASP => reduced usage; reduced usage => no R&D investment; no R&D => no change => status quo! You could see how this vicious cycle, has been self-defeating, resulting in no measurable improvement in decades. It is not quite clear how and when, this became a fact of life and people learned to live with it, and simply ignore it. Again, since majority of the consumers are unaware of this, and no one complains, why try to solve it?

So how expensive are these solutions, and what makes them so expensive? There is a range of answers for the first part of this question, as it depends on the size of the batteries, the grade of the batteries and finally the solution itself. As a ballpark, the cost of effective battery management could be equal to a major portion of the cost of the batteries in a pack, and at the upper end, could be as expensive as the batteries themselves, meaning such implementation could possible double the cost of the battery pack, which would make it completely unaffordable in low profit margin equipment. The answer to why so expensive is a bit more complicated, but it comes down to the extreme need for accuracy.

Clearly, the measurement accuracy is the most important element in all aspects of battery management. For various reasons, including the flat curve of Li-Ion cell voltage vs. state of charge, ~5mV tolerance has become the standard accuracy target. A simple math puts this target at about 0.1%, which is monumentally difficult to achieve, especially when done using brute force, all analog approaches. To make things even more challenging, for best performance, this accuracy needs to be maintained throughout the entire temperature, as well as cell voltage range. Brute force approaches have historically failed to make this possible! To put things in perspective, a typical power management solution, which regulates a voltage at usually one fine point, often has a tolerance of 1%. This 10x better accuracy of measurement requirement across a range, is a tall order. This is especially true when batteries are sitting on top of one another when in series, therefore not even sharing a reference point. This poses new problems that are not common with any other power management solutions, so basically a one-off. Historically high-resolution ADCs have been utilized, and for various reasons only one ADC is time multiplexed to measure all or a number of the cells. This forces the use of analog level-shifters, which are another source of inaccuracy. The fact that the measurement is time multiplexed, means that the change in load current changes the measurement, if the current changes from one reading to the next. This is inevitable in most applications, and hence another major source of inaccuracy and unreliability of each measurement.

And the solution….. Nova Semiconductor's patented technology provides a breakthrough solution to this old problem. Instead of brute force approaches, a new Digitally Assisted Analog (DAA) provides an unprecedented 1mV accuracy or 0.02% overall operating conditions (5x to 30x improvement), but most importantly this is done with elegance and therefore at low cost. DAA is a powerful method to bring performance and accuracy to simple and inaccurate analog functions, using algorithms that are done all in digital domain. Unlike analog blocks, digital blocks are simple, unaffected by the environment, such as heat and therefore completely stable and repeatable. Each DAA application is Unique, and is a new invention, as this is.

Lack of effective and affordable balancing solutions, has pushed many low-cost consumer products to shy away, and not implement such important and necessary functions, leading to severe short life of the battery packs. Often a dead battery results in an end of life for the whole unit, creating unnecessary waste, affecting the consumer and the environment alike. We have set out to change this by providing true solutions to these old problems, but more importantly make them affordable so every end equipment could afford them. No battery pack should lose capacity before its time!

Nova is poised to dramatically reduce the need for over manufacturing of Li-Ion batteries, resulting in reduction of the poisonous materials in our landfills,

saving the planet, one battery pack at a time!

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