

Active Vs. Passive Cell Balancing

What is the difference and why choose one over the other?

If you don't know what Cell-Balancing is, or why one should implement the function in a Li-Ion battery pack, you might want to read on that subject in another [whitepaper](#).

As a quick recap, cell balancing is required to assure maximum capacity of the battery pack throughout its useful life. The imbalance occurs due to self-discharge, temperature variance amongst cells and other factors, such as variations in cell capacity that can lead to imbalance cells, which results in premature charge and discharge termination, done by the protection circuit. For this, every multi-cell battery pack should have a balancing function to assure best performance and long life.

Now the question become, how to make this balancing work? In an ideal world, we would be able to add just enough energy to the lower charged cells to bring them up to the same level as the other cells. This means having to implement a very complex charger, which can charge each cell individually and keep a tab on all the cells to bring them to the same charge point. Alternatively, many have suggested, and implemented methods to do an active balancing. Active balancing refers to a system where it can remove the extra charge from the high-charged batteries, and put that in a low-charged batteries to bring them to a balance point. And finally, there is a third method called passive balancing. This is to simply bleed the high charge cells to bring them to the same level as the lowest cells, so balancing is achieved.

At a glance, one can easily and quickly reach the simple conclusion that if the goal of the cell balancing is to provide higher capacity, then dissipating the energy in the high-charged cell can be defeating. However, a closer look at the details can prove otherwise.

It is known that a few millivolts of difference in the flat portion of any Li-Ion battery voltage curve, can translate to a large amount of energy. Depending on the chemistry and the make of the battery, such as in LiFePO₄, the difference between 80% charged and 20% charged cell can be as little as 20mV. Considering most cell balancing products out in the market have the best accuracy at around 5mV, this means by the time the circuit detects an imbalance and tries to make the correction, it is very well possible that we can potentially have 50% energy difference among any two batteries in the pack. Accepting this possibility, who could logically think dissipating this difference to achieve balancing is the right choice, or acceptable? Considering this scenario, there is no other way than to try and implement active balancing, and take this possibly large

amount of energy, from one cell to the others instead of throwing it away. Hard to argue with that, right? Well, as they say the devil is in the details.

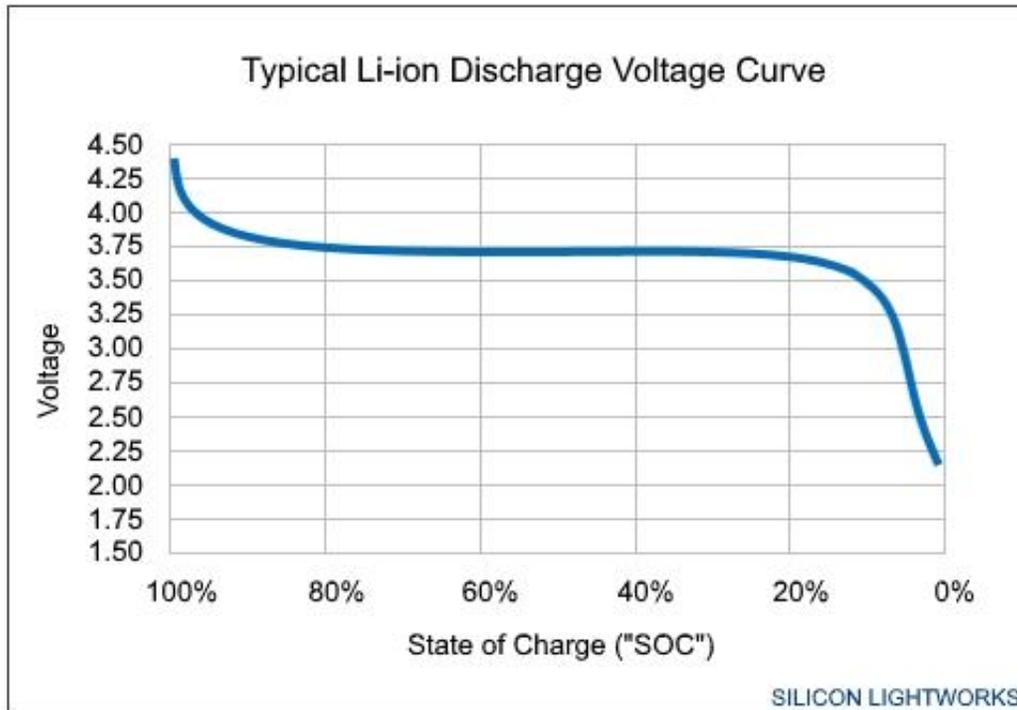


Fig. 1, Courtesy of Silicon Lightworks™

You might have noticed that the issue with the scenario above was the fact that the measurement accuracy could almost not catch the imbalance until it was too late. Since the inaccuracy and offset can go either way, it is conceivable that I attempted to catch the issue early, the detection circuit can erroneously detect a low-charged battery as a high-charged battery and attempt to balance them in a reverse order, worsening the problem. Traditional approaches have resulted in less than desired accuracy for most solutions to make a great passive or even active balancing system. Automotive batteries need to overcome these issues, or there would be severe penalties in terms of battery life and driving range. For this the automakers go through extensive and therefore expensive calibration steps to get better accuracy. It is also worth mentioning that in the past few years, some BMS IC makers have also enabled non-automotive customers to perform their own calibration, in an attempt to being accuracy to solutions that inherently lack enough accuracy to do an effective job. The calibration step is generally an expensive proposition, which might be considered as passing the Buck, so someone else deals with the issue. Although

these solutions cost considerably less than the more accurate solutions, the cost of the calibration, which usually happens at the pack assembly step, negates the cost savings and the lower cost of these solutions. The overall accuracy achieved is also questionable, as the act of calibration generally happens at one temperature and one voltage, so does little or nothing to correct for temperature coefficient, INL, DNL and moving offsets over temperature.

Now consider if the detection was much more accurate, therefore much earlier in determining the charge differences, such that the act of balancing would only dissipate a small amount of energy, far less than the total capacity of the batteries it tries to balance. Would this still be thought of as waste of energy? Perhaps not. Just like anything in life, there are tradeoffs amongst choices. Active balancing entails complex circuits, some with multitude of Inductors, transformers, many switches and passive components to provide the flexibility to take the energy from any cell and put it in any other cells. If our only alternative is to throw away a major portion of the charge to achieve balancing, then the complexity of the active balancing seems inevitable. Afterall, much investment goes into battery engineering and a battery pack to give it the best possible capacity. Wasting huge amount of energy to simply get to a balance point, does not seem acceptable.

Related Article: [**"A Modular Cell Balancer Based on Multi-Winding Transformer and Switched-Capacitor Circuits for a Series-Connected Battery String in Electric Vehicles"**](#)

Thuc Minh Bui, Chang-Hwan Kim, Kyu-Ho Kim and Sang Bong Rhee

Considering the history of traditional balancing circuits, majority of consumer products have shied away from using them due to high cost. Now imagine adding the cost of the complex active balancing. Sounds like putting gas on a fire to put it out! Basically, would not be achievable for any consumer products.

Now what has stopped chip makers from making better accuracy products, such that small discharge at a time can lead to perfectly balanced cell? Again for more detail on this, you can refer to another [whitepaper](#). Using brute-force approaches makes such solutions completely cost prohibitive.

It would be game changing to provide 5-10x the accuracy of the conventional solutions at an affordable price. This is what Nova's innovative technology promises. With the new tight accuracy, not only effective balancing is possible, beyond anything that was achievable in the past, passive balancing is the only method that would make sense. This is true, as with the heightened accuracy levels, constant monitoring and balancing, the amount of energy wasted

will be negligible. This would make balancing possible for all end equipment, even those with low profit margin and low budget, which historically have not implemented cell balancing.

Nova's breakthrough technology, for the first time, makes it possible to implement effective, affordable passive balancing for any end equipment. With low power consumption, as well as better than 1mV accuracy over all conditions, passive balancing is far simpler, lower cost and fully implementable for any size battery, knowing that we will not have to do large discharges to make cell balancing work. When the balancing act is constant and small, it happens in the background, and assures perfect balancing and maintenance at all times. With this, the battery cells never get a chance to fall far apart from each other, so the discharge is never more than a small amount, which does not cause measurable charge degradation. Keep in mind that Li-Ion cells don't fall out of balance at once, it accumulates through charge and discharge cycles, and happens over time.

With Nova's simple and low complexity approach, every battery pack will have a chance to outlast the equipment it powers. The charge capacity of such battery pack will mostly be maintained throughout its life, and battery replacement can become a thing of the past. Since protection functions also rely on accurate measurements, those functions are also improved and maximum as well as minimum cell voltages can be finely set, to keep the best balance for battery life vs. capacity. Simultaneous voltage measurement of all cells, overcome current noise, and assures clear and accurate reading of all cell voltages. This can make profound improvement in accuracy, even in noisy systems, such as in systems with electric motors, in EVs, eBikes and power tools.

In conclusion, although active balancing seems like a reasonable approach, as it promises efficient reallocation of the energy, in practice it is expensive, and therefore cost prohibitive in most applications. With the accuracy and low cost offered through Nova's digitally assisted analog scheme, passive cell balancing is not only affordable, it is the only method that makes sense across all products and platforms. With the continuous measurement, smart algorithms to consider cell impedance, aging and other characteristics, cell balancing happens in the background without any user interaction or interventions. Smart cell balancing assures long and healthy life of the battery pack, where it can perform at its peak capacity at all times. Since Li-Ion batteries intrinsically have a long life, it is most likely that the batteries will outlast the equipment such as a Notebook computer or an eBike, such that a battery replacement can be a thing of the past, thus reducing waste and over manufacturing,

Saving our planet, one battery pack at a time!