Multi Cell Monitoring & Battery Management Systems

All multi cell battery systems require a degree of monitoring to provide an indication of their State of Charge (SoC). In addition, as the energy density of cell chemistries have increased significantly, monitoring has become essential for their safe operation. In particular, all variations of the lithium based secondary cell, whether it is ion, polymer or metal, require careful management to ensure the cell is not subjected to conditions that would result in a safety risk or expose it to conditions that would cause irreversible cell damage and hence shorten battery life.

Monitoring is a generic term used to describe the acquisition and processing of operational cell parameter data which is then used by the management system to initiate further action. These parameters include maximum operating current, maximum cell voltage and cell temperature.

Safety Requirements

From a safety viewpoint, the parameter of principal interest is cell operating temperature, whether it is self generated or caused by the operational environment. The cells internal impedance, combined with the charge and discharge currents flowing through them, produce internal heating and therefore currents should be limited to prevent temperatures that may cause the cell to ignite and/ or explode. Additionally an over voltage condition during charging can also lead to excessive temperatures and potential ignition, therefore the maximum cell voltage must be strictly limited. The current flow and voltage conditions are generated during battery operation and are therefore under the control of the battery management system. However consideration must be given to manufacturing defects which are outwith the control of the management system and can result in internal short circuits leading to exothermic reactions. This can cause cells to spontaneously ignite and a single cell failing in this way can heat neighbouring cells in a battery pack to dangerous levels. A thermal chain reaction results and ultimately the loss of appliance and the possibility of a major fire with serious risk of injury. As a consequence, battery management systems must also address the potential for cell manufacturing defects causing spontaneous heat during operation. Ultimately this is mitigated by the incorporation of appropriate battery cooling systems. Therefore, when designing lithium secondary cell battery management systems, serious consideration must be given to incorporating a battery cooling system as part of the overall battery management regime. Such a system should be designed to minimise the effect of cell overheating and reduce the risk of fire.

Operational Requirements

Operationally, the battery requires cell monitoring to provide an indication of its State of Charge (SoC) and State of Health (SoH) by the acquisition of cell current, cell voltage and cell impedance parameters. A battery SoH can be accurately determined by continually assessing each cell’s history of absolute capacity, internal impedance and keeping a record of depth of discharge on each charge/discharge cycle. In addition to monitoring the SoH, the battery management system should also prevent operating conditions that would otherwise damage the battery, such as excessive discharge. A typical lithium secondary cell would be permanently damaged if its cell voltage was allowed to fall below around 2.5V.

Lithium secondary cells have a near 100% coulometric efficiency which enables accurate determination of their SoC by the integration of charge and discharge currents. The majority of standard, off the shelf battery packs are constructed from a series string of cells and only the overall battery current is integrated on the assumption that since all cells are connected in series each cell sees the same current. However, due to variations in manufacture each cell has a slightly different capacity and cell impedance. A cell balancing circuit is therefore required to prevent the battery management system from disabling the battery during charge or discharge should any single cell reach its maximum or minimum cell voltage. Whether the cell balancing circuit implementation is passive or active, its function is to divert charge current away from one cell (Weak/low capacity) into another (Strong/high capacity). This results in the battery management system being ‘fooled’ into believing it contains the capacity of the strongest/ highest capacity series connected cell. Thus, when only the battery current is integrated, cell balancing can produce a significant source of fuel gauging error. Only by monitoring each cell and determining each individual cells capacity can this error be eliminated.

In summary, battery management systems have become essential for the safe operation of lithium based secondary cells and batteries and extends their operational life. The monitoring of each cell within a battery pack provides greater battery safety, higher fuel gauging accuracy, increased accuracy of SoH prediction, the possibility for preventative maintenance and increased security of supply. The provision of memory within the battery management system also enables historical assessment of SoH as well as storing key critical operating parameters and protection thresholds. In addition there is the opportunity to further enhance battery safety by incorporating a battery cooling system as part of a high power lithium battery management system. Disabling the battery pack by disconnection from the output terminals forms the ultimate electrical protection and consideration may also be given to automated fire extinguishing.

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