Packing in the power

Creating a high energy battery system for electric vehicles is a challenge. By **Greg Zimmer**.

There are a number of reasons why the electric car presents a huge green opportunity. Electric cars operate from grid power, instead of petrol. Grid electricity is generated efficiently and is available from a range of sources.

Meanwhile, electric cars use energy more efficiently than the internal combustion powered car. Most automobiles operate through a continuous cycle of acceleration, deceleration and idling. Variable loading, such as accelerating or decelerating, favours the electric motor over the combustion engine since it offers high torque at low speeds.

Combustion engines operate most efficiently within a narrow speed/load range and, in order to meet peak acceleration demands, must be oversized. The resulting engine efficiency for converting gasoline energy to motion is typically 20%. Electric motors, by contrast, have a typical efficiency of 90%. The electric motor does not have to waste energy idling at stops and an electric system offers the potential to recover mechanical energy through regenerative braking.

Unfortunately, an all electric automobile is not a viable solution today because its range is limited by the amount of energy that can be stored on board. Today's typical battery pack could provide an electric vehicle with a 100 mile range after an 8hr charge. A typical petrol tank provides a standard car with a 300mile range and can be refuelled in minutes. For widespread acceptance in the US, the electric automobile must have an increased range and/or a decreased recharge time.

The solution is a 'hybrid' vehicle that combines the combustion engine with the electric drive train to offer the range, while still providing most of the green benefits. Hybrid vehicles use an on board petrol engine for battery charging and operate this engine when needed and at the most efficient speed/torque range.

Multiplying the green effect

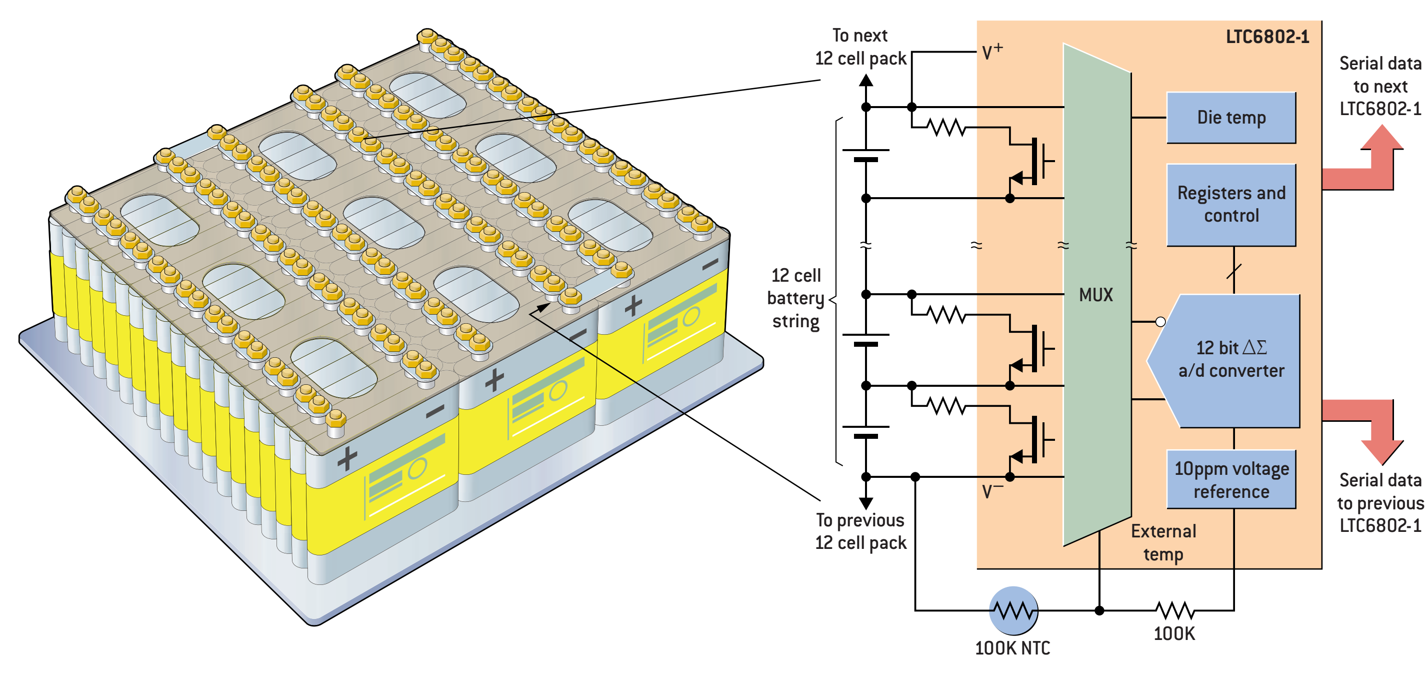
The success of the electric vehicle will support high performance battery systems for other applications, driving both price and performance. For localised generation, including small photovoltaic or wind generation systems, batteries serve a critical balancing function and when the grid is available, serve as a backup power system. Current battery systems are significantly costly and large, with reliability and safety concerns. Next generation battery systems will offer higher energy density for a smaller, less costly, more reliable and safer solution.

Lithium-Ion (Li-Ion) is poised to be the battery chemistry of choice for high power battery applications, primarily for its high energy density: switching to Li-Ion from today's NiMH technology will improve energy storage density by 400%. However, for Li-Ion batteries to be reliable over thousands of cycles, the battery system must address a number of technical challenges.

Li-Ion battery performance depends on battery temperature and age, battery charge and discharge rates and the state of charge (SOC). These factors are not independent. For example, Li-Ion batteries generate heat when discharged, which can increase discharge current. This has the potential of creating thermal runaway and catastrophic failure. Meanwhile, charging a Li-Ion battery to 100% SOC or discharging to 0% SOC will degrade its capacity quickly. As a result, Li-Ion operation needs to be restricted to an SOC range, such as 20% to 80%, where the usable capacity is only 60% of the specified capacity. Furthermore, Li-Ion cells have a flat discharge curve, in which a 1% change in SOC may only be indicated by a few mV. To exploit fully the useable range of the battery, the battery system must monitor this cell voltage (which corresponds directly to the SOC) accurately.

In addition to the sensitive nature of Li-Ion cells, the method for combining batteries together is also an important consideration. To

Fig 1: Block diagram of the LTC6802



deliver significant power from an electrical system, such as during acceleration, hundreds of volts are required. Remember that delivering 1kW at 1V requires 1000A; delivering 1kW at 100V requires only 10A. Inherent resistance in system wiring and interconnects translates to IR loss, so designers use the highest voltage and lowest current that's practical.

For a battery based system, where the typical Li-Ion cell has a fully charged voltage of 4.2V, many battery cells must be connected in series in long strings. Any single cell failure will disable the entire stack and each additional cell in the string increases this risk.

The challenge of creating a high voltage battery stack using Li-Ion batteries is not trivial. A Li-Ion battery stack cannot be charged and discharged as if it were a single power source. For those cells with slightly less capacity than the others, their SOC will gradually deviate from the others over multiple charge and discharge cycles. If the SOC for each cell is not equalised – or balanced – periodically, some cells will eventually be over charged or over discharged, leading to damage and, eventually, complete battery stack failure.

As a result, a battery control system must manage each battery cell carefully. This problem can be divided into data acquisition and control. The control aspect involves algorithms and techniques to charge and discharge each cell, based on the system data. This is dependent on the specific application and often involves closely guarded IP. Data acquisition is accomplished via the battery stack interface, which must measure quickly and accurately each single cell voltage along the high voltage stack. This requires the ability to extract a small differential voltage from a common mode voltage ranging from 0 to more than 1000V. This is a tough challenge, requiring the combination of a number of high performance analogue functions.

Linear Technology's LTC6802 handles the data acquisition task for large battery stacks and is particularly well suited for Li-Ion batteries. The LTC6802 connects directly to each cell in a string of batteries, up to 12 individual cells.

Using a level shifting serial interface, multiple LTC6802s can be stacked in series without optocouplers or isolators, allowing precision voltage monitoring of every cell in very long strings of series connected batteries. When multiple LTC6802 devices are connected in series, they can operate simultaneously, permitting quick and accurate voltage measurement of all cells.

Voltages measurement accuracy is better than 99.75% and all cell voltages in a stack can be measured within 13ms. Each cell is monitored for under- and over voltage conditions and each cell input has an associated mosfet switch, which can be used to discharge over charged cells.

Each LTC6802 communicates via a 1MHz serial interface that supports both broadcast and addressed commands. Also included are two thermistor inputs, two GPIO lines and a 5V regulator. The device has been designed to operate over industrial temperatures with high immunity to ESD, EMI and noise.

This part solves a number of problems confronting today's battery systems. High precision measurements over the full operating temperature range allow the batteries to be used over their full useable SOC range, with confidence that the batteries will not exceed these limits. Robustness will allow the part to operate reliably in the automotive environment and the integration will enable battery systems to meet challenging cost, space and manufacturability constraints.

After years of effort and steady progress, high energy battery systems will soon be practical for everyday use, especially as part of the electric and hybrid electric vehicle.

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