On a charge

Lithium ion batteries are finding automotive applications, but managing them is a tricky business. By **Graham Pitcher.**

Batteries for hybrid and electric powered vehicles have made significant advances since the days of the electric milk float.

Electric powered vehicles have been around for many years; the milk float being one of the more obvious examples. But the problem has been the weight of the lead-acid batteries and the limited range and speed which the batteries enable.

Lead-acid batteries have a low capacity, expressed as Whr/kg. Picking up on trends in the consumer world, automotive battery developers have moved to nickel metal hydride technology, which provides twice the capacity available from lead-acid. More recently, lithium ion technology has been applied, potentially tripling the capacity of lead-acid.

This larger capacity either allows for a battery pack one third the size of the lead-acid predecessor for the same power or three times the power from the same size battery.

This is all very well, but whatever technology is selected, a large number of cells need to be connected to provide the required levels of power. And each cell needs to be managed, because anything other than optimal charging and discharging regimes will reduce the battery's life significantly and, in some instances, create dangerous conditions.

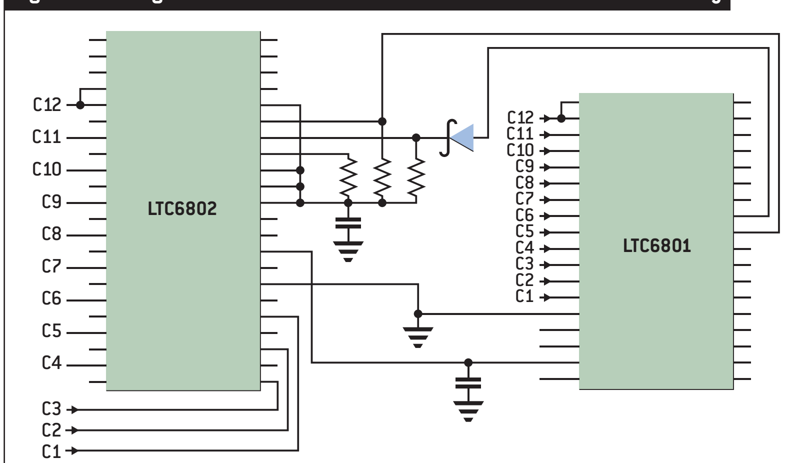
Tim Regan, applications manager with Linear Technology, said: "For high power applications, such as electric vehicles, hundreds of batteries are stacked to create a high voltage source, resulting in less current through thinner and lighter wiring. There is significant motivation to provide safe and reliable long term operation and, to that end, the charge on each and every cell must be monitored continually to maintain the optimum level for years of use."

To do this, the voltage on each cell in the stack must be measured. This is typically acquired using an a/d converter, which passes the information to a microcontroller. The controller then manages the charge and discharge of all the cells such that they are not operated outside of a tight range. "With hundreds of individual cells in a system," Regan noted, "an integrated measuring circuit can significantly save on component count." Linear has recently unveiled the LTC6802, which can measure the voltage on up to 12 cells and monitor two temperature sensors through an integral 12bit a/d converter.

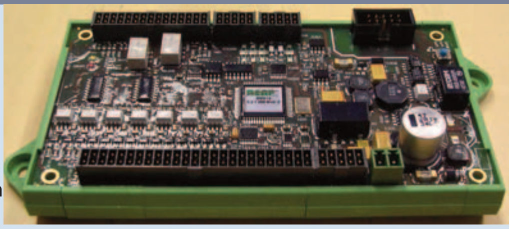
"Any number of cells can be linked together, with the measured voltages of each group of 12 streamed serially to a host microcontroller," Regan continued. "These measuring devices and the controller form the heart of the battery management system."

Regan points out that careful control of the state of charge of each cell is

Fig 1: Combining cell measurement with fault detectionfor enhanced reliability



REAPing the benefits



Southampton based REAP Systems specialises in lithium ion battery management systems. According to the company, its systems make lithium ion battery systems safer and adds the technology is 'not as easy as it sounds'.

One of the challenges of such systems is thermal runaway. Shre Kumar Chatterjee, technical sales engineer, pointed out that lithium ion has a small operating range. "Our battery management system keeps cells 'in the zone' if temperature or voltage change and each cell is monitored."

Stephanie Pielot, a REAP director, said the system allowed around 40 parameters to be monitored. "There's a microcontroller at the heart of the system, but the software is the most important aspect." Currently, the system uses an Atmel 8bit microcontroller, but the company is looking to upgrade this part.

One module can control up to 14 cells and multiple modules can be connected using a CAN bus. REAP has developed a custom battery management system for use in heavy vehicles. The battery pack features 168 cells arranged in eight modules.

Because of the high voltage and power levels in the system, a different approach was needed. Using standard battery management modules, REAP developed a closed loop control system that responds as quickly as systems featuring a smaller numbers of cells.

essential if the usable lifetime of the cells is to be maximised. "But it may not be enough to satisfy the ever demanding automotive customer," he added. "The automobile presents a harsh and perilous operating environment. For long term satisfaction, 'what if' analysis of the system is necessary."

He says questions to consider include:

- What if a wire to a cell gets disconnected?
- What if the voltage measurement accuracy shifts?
- What if internal register bits get stuck in a way that could always indicate a good cell voltage reading?
- What if the measuring ic is somehow damaged by system voltage transients?

"The most insidious fault would trick the controller into determining that a cell or group of cells is in perfect condition, when in fact, they are not being measured properly. These cells could then fully discharge or get dangerously overcharged while the system is completely unaware. Something is needed to 'monitor the monitor' for a higher level of reliable operation."

As an alternative to a fully redundant measuring approach, a fault monitoring circuit can be wired in parallel with the measuring device and serves to double check the basic functionality of the system. Figure 1 shows 12 Li-ion cells being monitored using an LTC6802, which provides precise measurements, while an LTC6801 checks for over/undervoltage conditions on each cell.

The LTC6801 performs a simple undervoltage and overvoltage comparison on each cell periodically. If all is okay, the LTC6801 provides a differential clock signal at the status output lines. If something is wrong, this clock stops, allowing the controller to perform diagnostics. Any number of LTC6801s can be stacked to monitor hundreds of cells.

"Preserving the proper charge level of all batteries in a system will add years of service to a costly battery pack," Regan concluded. "This is essential for customer satisfaction in automotive systems such as electric powered vehicles."

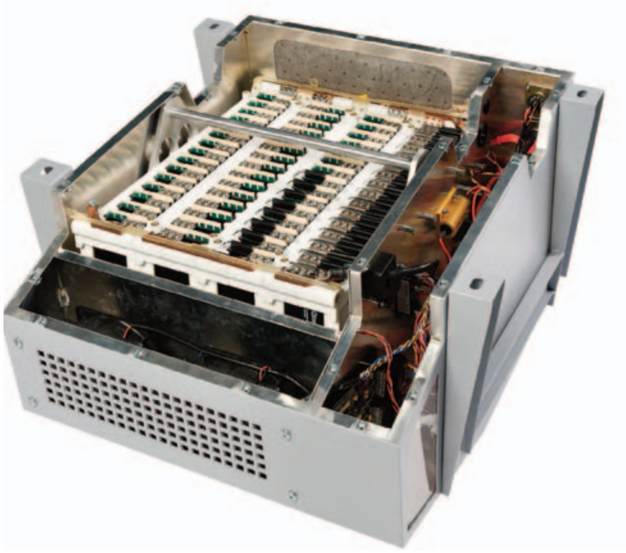
Meanwhile, a two year collaboration has created a battery pack using QinetiQ's iron sulphide based cell chemistry and Ricardo's battery management system.

The RED-LION project set out to replace the battery pack used in the Efficient-C prototype hybrid electric vehicle (HEV) with one using cells capable of demonstrating suitable material cycle life, capacity, specific energy, rate capability and safety. Custom cells – designed and manufactured by QinetiQ – were integrated within a bespoke battery pack designed by Ricardo to directly replace the existing unit. Part of the process required a new battery management system to manage the iron sulphide chemistry.

The prototype cells have been shown to deliver a life of more than 1000 cycles at a limited depth of discharge.

A key innovation of the RED-LION project is said to be the battery management system. Based on a bespoke architecture, the system is adaptable to a range of cell chemistries and battery architectures.

The project has demonstrated the potential of the cell chemistry within an HEV environment. Whilst the current cell's high charge/discharge rate makes it more suited to HEVs and low range plug in HEVs, its cost versus energy density ratio is likely to make it attractive for all electric vehicles.



The Ricardo designed HEV battery pack and management system, developed as part of the RED-LION project, incorporates QinetiQ's iron sulphide Li ion cell chemistry.