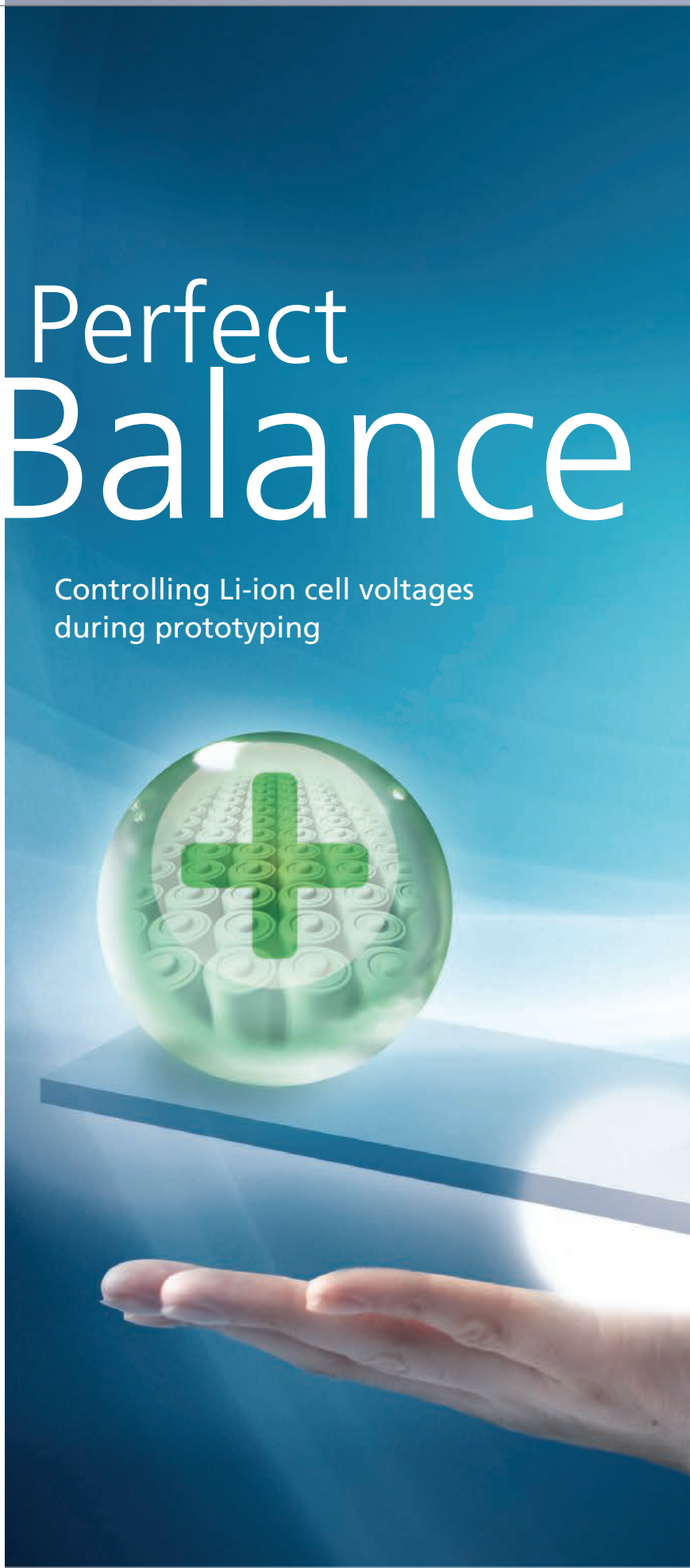
Perfect Balance

Controlling Li-ion cell voltages during prototyping



To benefit fully from the high energy density of Li-ion batteries, the state of charge of the individual cells must be monitored precisely. dSPACE has developed a battery management system that performs this task throughout the development process, from the first model to in-vehicle testing. Its main focus is on measuring and controlling Li-ion batteries.

Electromobility Needs Powerful Batteries

One reason for the combustion engine's great success in the 20th century is gasoline's high energy density. While one liter of gasoline can run for many kilometers, a modern battery of the same mass or volume takes an electric vehicle only a fraction of the distance. As this comparison clearly shows, developing powerful, high-density batteries is key to the breakthrough of electrical vehicles.

Li-Ion Batteries as the Solution

One type of high-density power storage is batteries based on Li-ion technology. A Li-ion battery consists of numerous single cells with voltages in a typical range of 3.3 … 4.2 V, depending on the battery type. To reach the necessary voltages of sev-

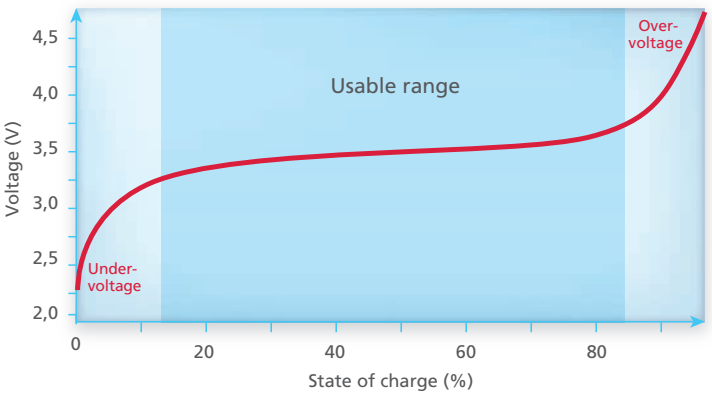


Figure 1: Typical load curve of a Li-ion cell. The usable voltage range is limited to several 100 mV.

eral hundred volts, a large number of single cells are combined to build a cell stack.

Li-Ion Batteries Need Monitoring

Li-ion batteries have to be constantly monitored and controlled because the usable voltage range of a Li-ion cell is limited to several 100 mV (figure 1). The further the voltage moves out of this ideal range, the more the life span of the cell is impaired. In extreme cases, the cell can even be destroyed. Instances of battery fires in telephones, laptops, and last but by no means least, the Boeing Dreamliner, emphasize just how important it is to monitor the battery state. Protecting the cells against undervoltage and overvoltage is therefore a top priority. This is where a battery management system (BMS) comes in. This system has the challenging task of measuring cell voltages with galvanic isolation at a precision of only a few millivolts, when the voltage of the overall cell stack usually reaches several hundred volts. A BMS also has to monitor the temperature, because this has a major impact on the cell state.
Using algorithms, the BMS continuously monitors the individual cells to determine values such as the battery's state of charge (SoC), state of health (SoH), and so on. The BMS also performs what is known as 'cell balancing' to keep the voltages of all the single cells at the same level. In passive balancing, superfluous charge is drawn off by switching an ohmic resistance in parallel to any cells whose voltage is too high. The voltage balance between the cells in a stack is one of the most important factors that influence the life span of Li-ion batteries.

The Battery Management System from dSPACE

Because standard solutions fail to meet the requirements described above, at dSPACE we developed our own battery management system for rapid control prototyping, called Battery Cell Voltage Measurement and Balancing. This system lets users measure and control the cell voltages of Li-ion batteries during rapid control prototyping, and also supports the development of battery management algorithms.
Li-ion batteries with a total voltage of up to 846 V can be connected to this dSPACE BMS (battery management and balancing system). The system measures the voltage of each cell with high precision and provides the ability to reduce it, if

> With the battery management system from dSPACE, high-voltage batteries can be managed at cell level with high accuracy.

Figure 2: The modular structure of the dSPACE battery management system allows tailor-made configurations of up to around 200 cells and can also be installed directly in a vehicle.

required, by means of a switchable resistor.
The system is modular and can be assembled to create configurations of between 6 and approx. 200 cells. It can also be installed directly in a vehicle. The modules are connected via Ethernet with a dSPACE prototyping system such as MicroAutoBox II.
One module can measure the voltage and temperature of up to 24 cells and passively balance each cell separately. The balancing resistances are located on a separate carrier board so that different resistance values can be tried out quickly. Because the voltage and temperature measurement inputs are galvanically isolated, a real battery can also be connected to the system.
All the properties of a prototyping system have to be more powerful than those of the final product. The dSPACE BMS achieves a precision of ±3 mV at a measurement frequency of up to 1 kHz, regardless of the number of cells. This makes it possible to study the cell chemistry as well. The cell voltage measurement processes in the individual modules can also be synchronized.

Features at a Glance:

Max. no. of cells	Approx. 200
Max. voltage	846 V
No. of cells per module	24
Cell voltage	0 … 5 V
Measurement frequency	Max. 1 kSPS
Precision	±3 mV at 3.3 V ±300 mV
Resolution	0.61 mV
Synchronized measurement	For all cells
BMS IC	Intersil ISL78600
Temperature measurement	For each cell, by thermistor (NTC)
Balancing method	Passive balancing
Isolation	Complete galvanic isolation
Isolation monitoring	Interface for isolation monitoring device
Safety features	Watchdog, diagnostics options, temperature monitoring
Hardware interface	Ethernet
Software interface	Simulink® blockset

In 'manual balancing' mode, the system gives users all the freedom they need to develop battery management algorithms, letting them balance cells individually or collectively, and at any intervals. The `automatic balancing' mode is a comfort function that performs the less important ask of specifying target voltages and switch-off times so that developers can give their full attention to the more important BMS algorithms.

Seamless System Monitoring

To continuously monitor the overall system state, the dSPACE BMS has extensive error detection and alarm features:

- Warnings on hardware faults and communication/synchronization errors
- Temperature warnings
- Warnings on isolation faults
- Warnings on cell undervoltage and overvoltage

To ensure the safety of the overall system, the isolation resistance is monitored by a separate device that constantly provides information on the state of the isolation and immediately outputs an alarm when it detects an isolation leak.

For safety reasons, dSPACE supplies the BMS only as a turnkey system in an engineering project. ■

Figure 3: The isolation concept of the dSPACE battery management system makes it safe to use high battery voltages.