Battery Management System

ARCHITECTURE

Effective Battery Management System Design

Considerations:

Safety

Hosts and Batteries

Cell Balancing

System, Battery Gauges

Chargers and Gas Gauges

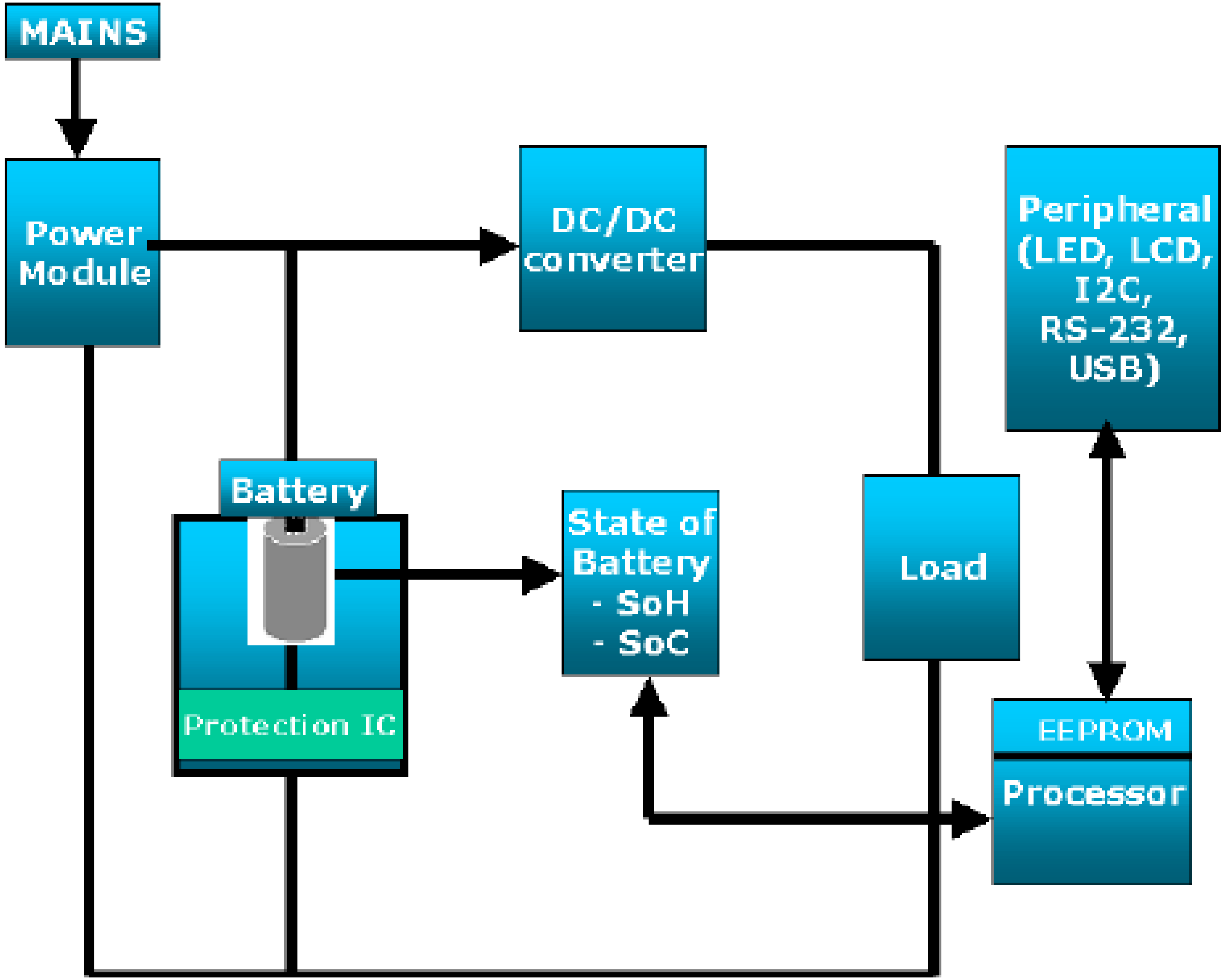
Connecting the Gauges

Capacity Estimates

Runtime Estimation

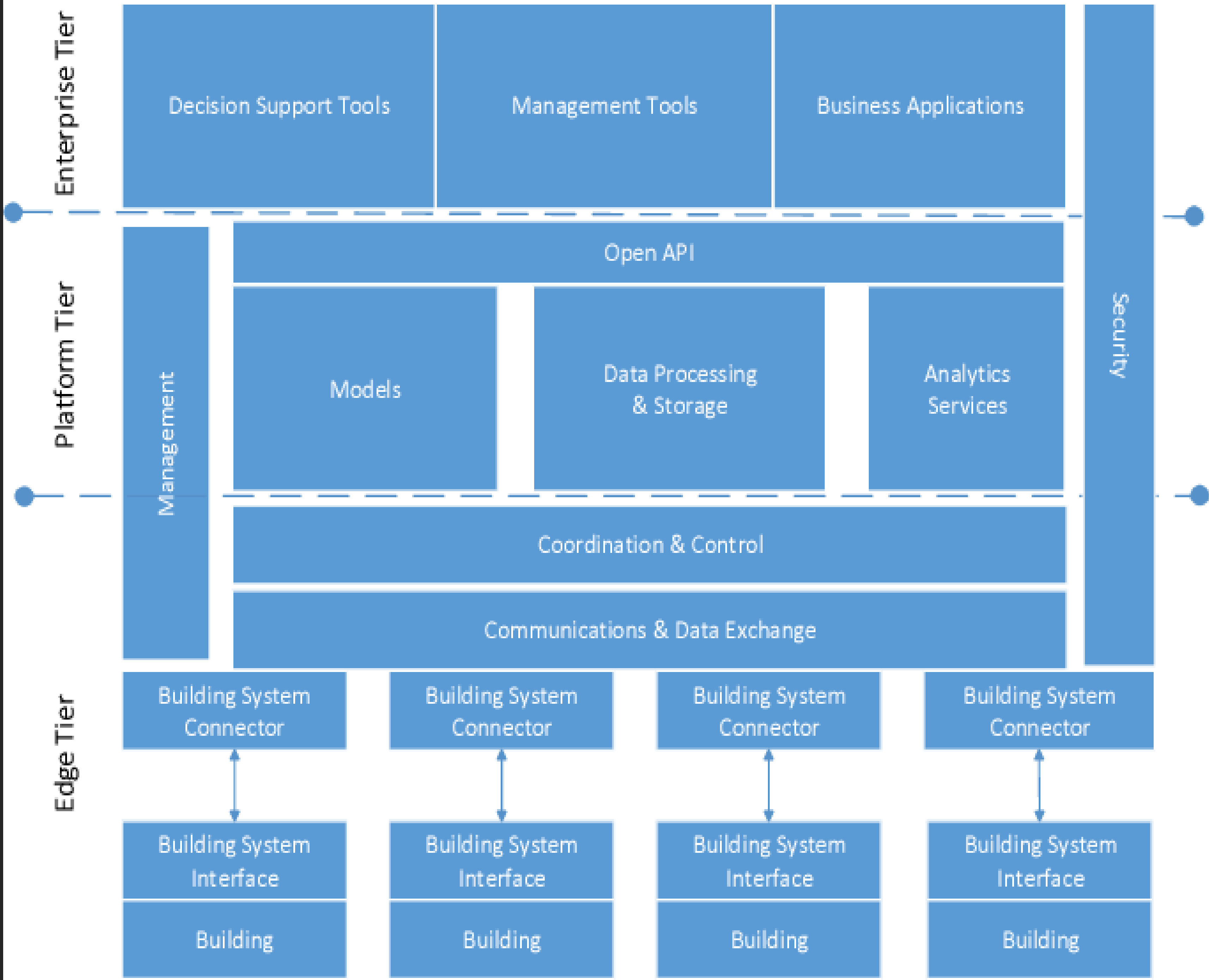
General Architecture of a Battery Management System

A battery management system (BMS) typically consists of several functional blocks, including cutoff field-effect transmitters (FETs), fuel-gauge monitor, cell-voltage monitor, cell-voltage balance, real-time clock, temperature monitor, and a state machine

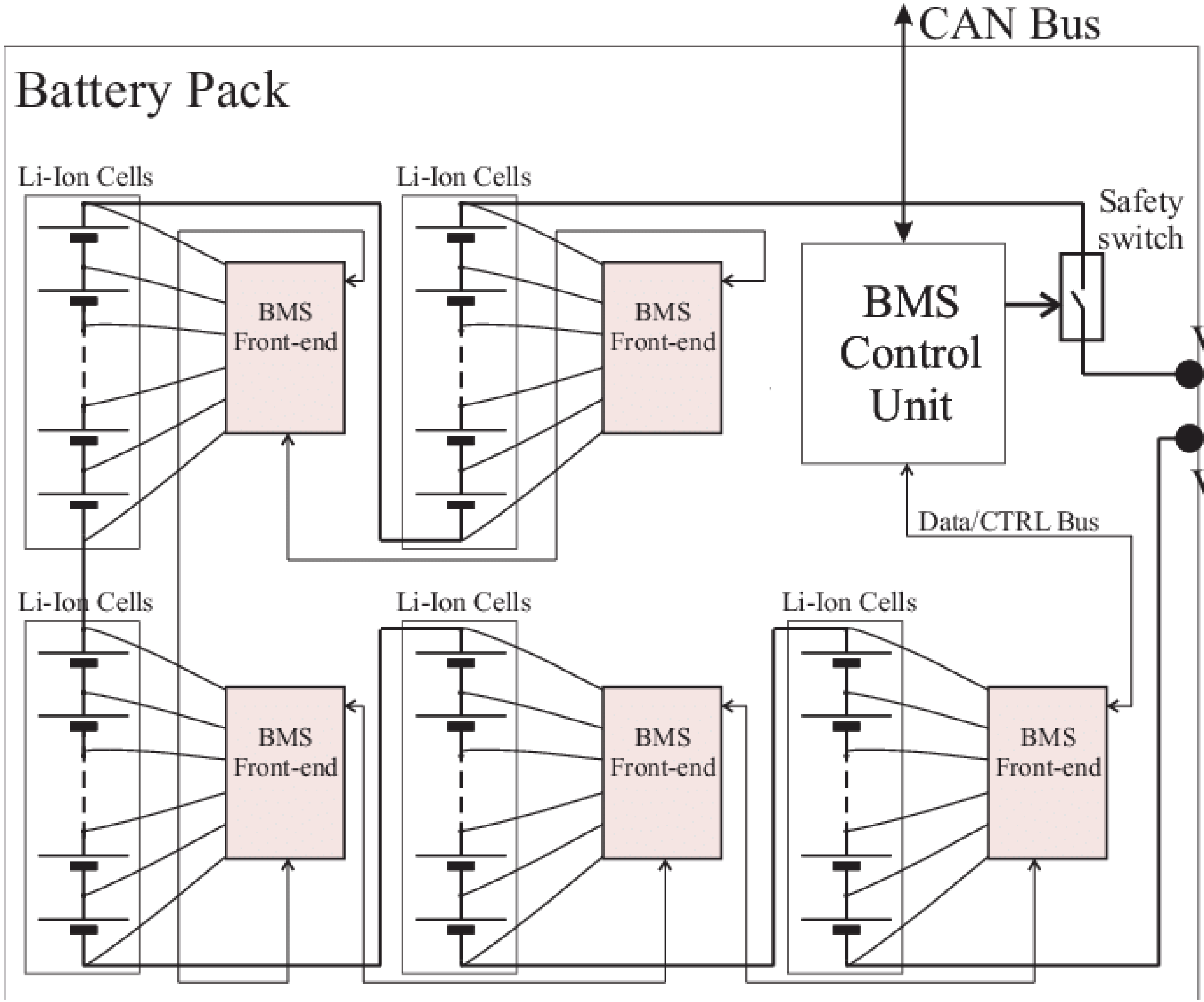


BMS Reference Architecture:

Functional Model

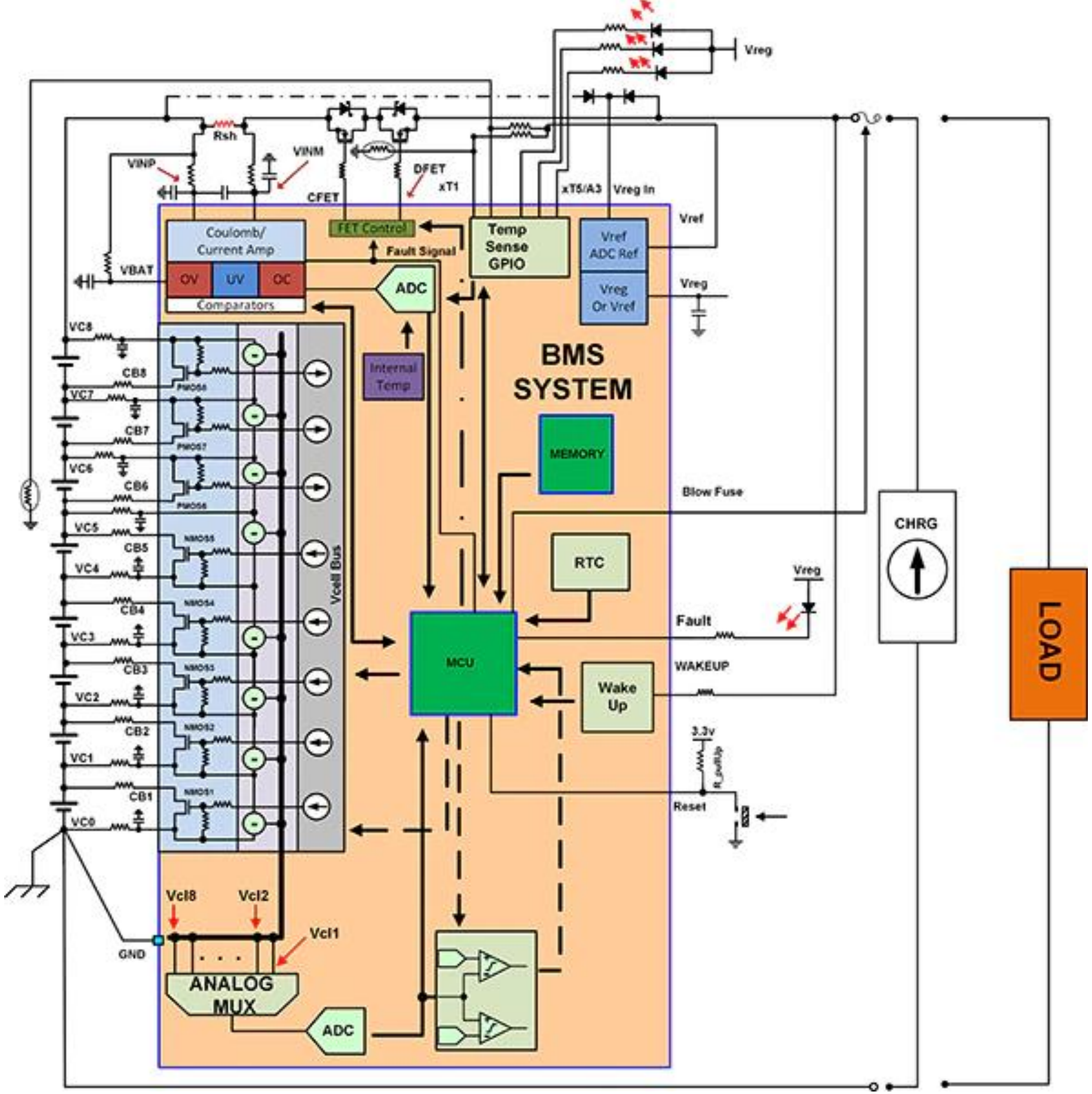


ARCHITECTURE OF A BATTERY MANAGEMENT SYSTEM (BMS) FOR EV/HEV APPLICATIONS.



A battery-management system (BMS) includes multiple building blocks.

The grouping of functional blocks vary widely from a simple analog front end, offers balancing and monitoring and requires a microcontroller, to a standalone integrated solution that runs autonomously.

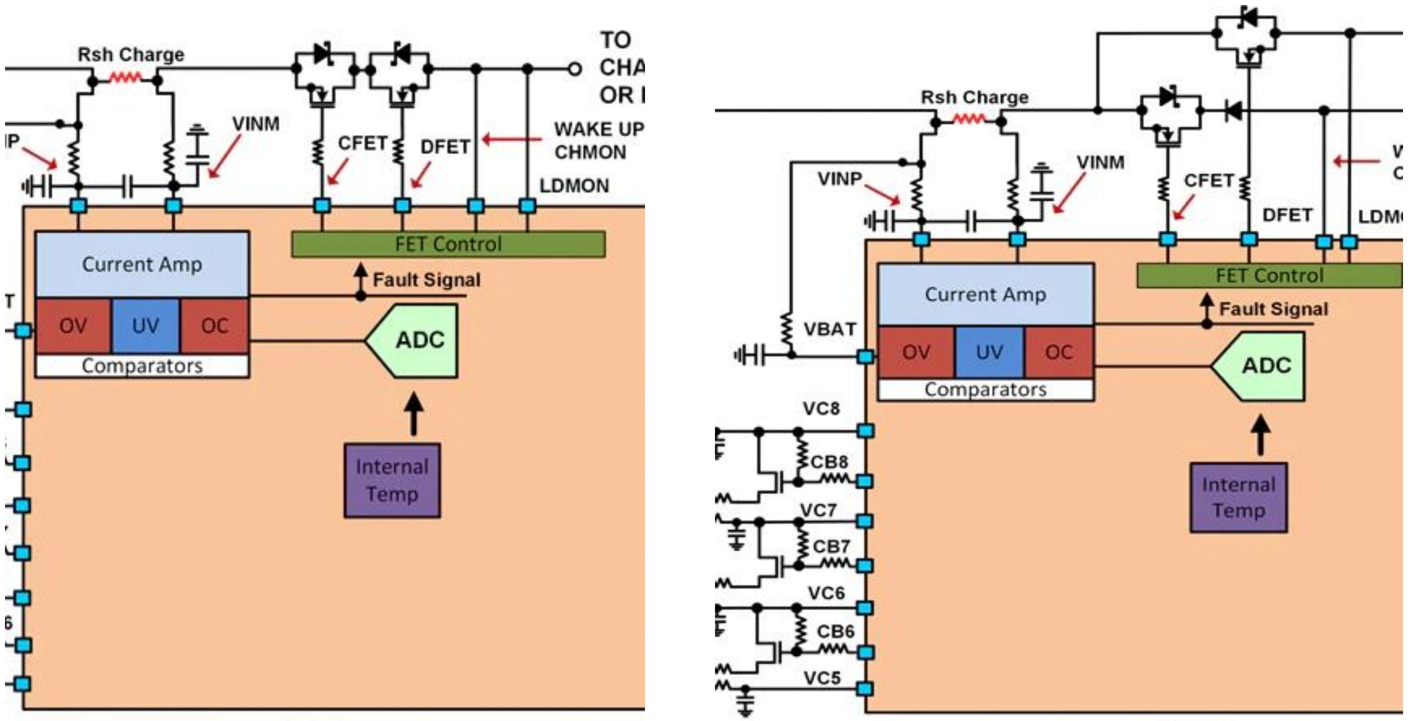


(Fig. 1). Several types of BMS ICs are available.

Cutoff FETs and FET Driver

Shown are cutoff FET schematics for single connection between the load and charger (A), and a two-terminal connection that allows for simultaneous charging and discharging (B).

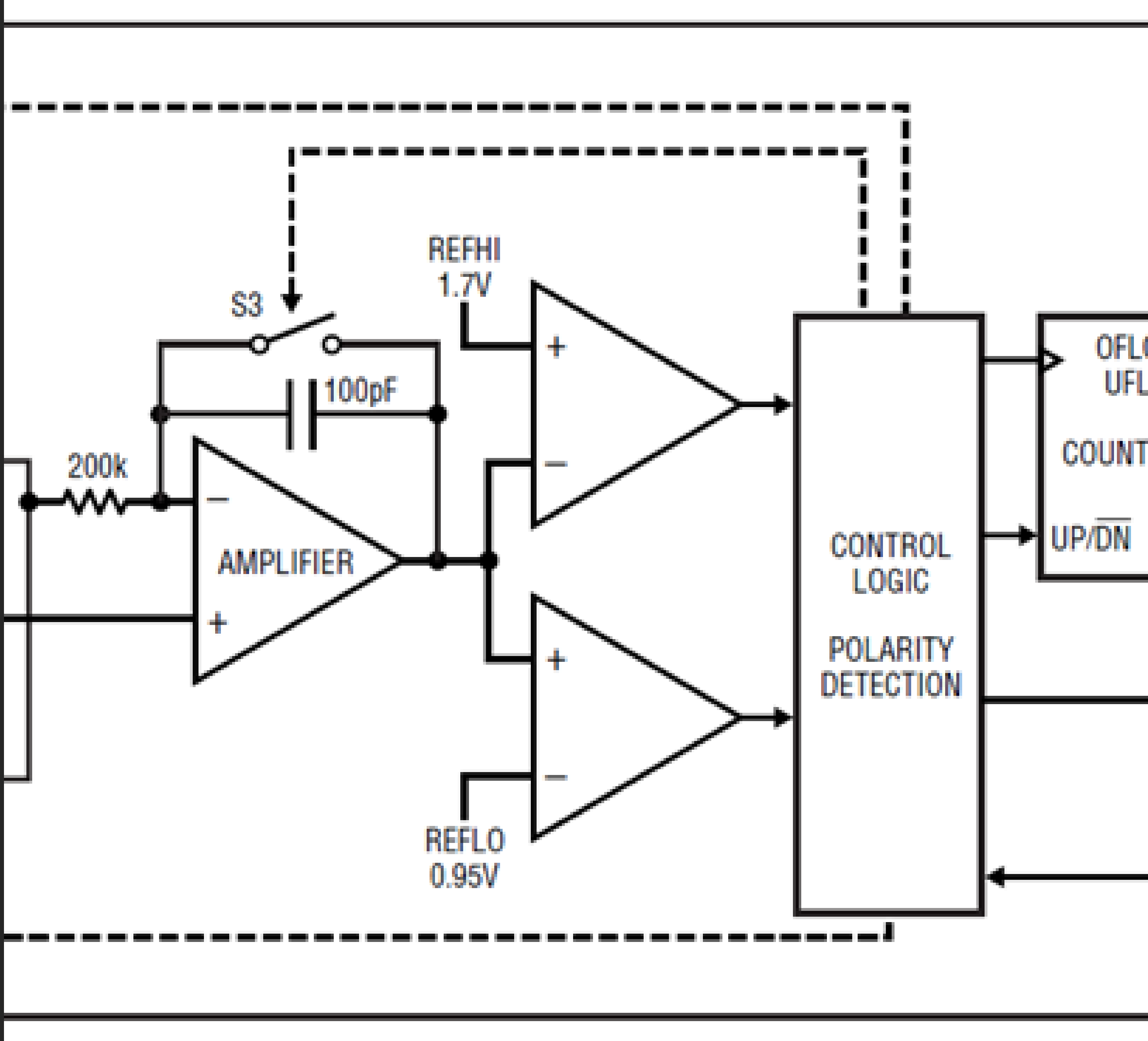
FET-driver functional block is responsible for the battery pack's connection and isolation between the load and charger. The FET driver's behavior is predicated on measurements from battery-cell voltages, current measurements, and real-time detection circuitry. Figure 2 illustrates two different types of FET connections between the load and charger, and the battery pack.



(A) (B)

Fuel-Gauge

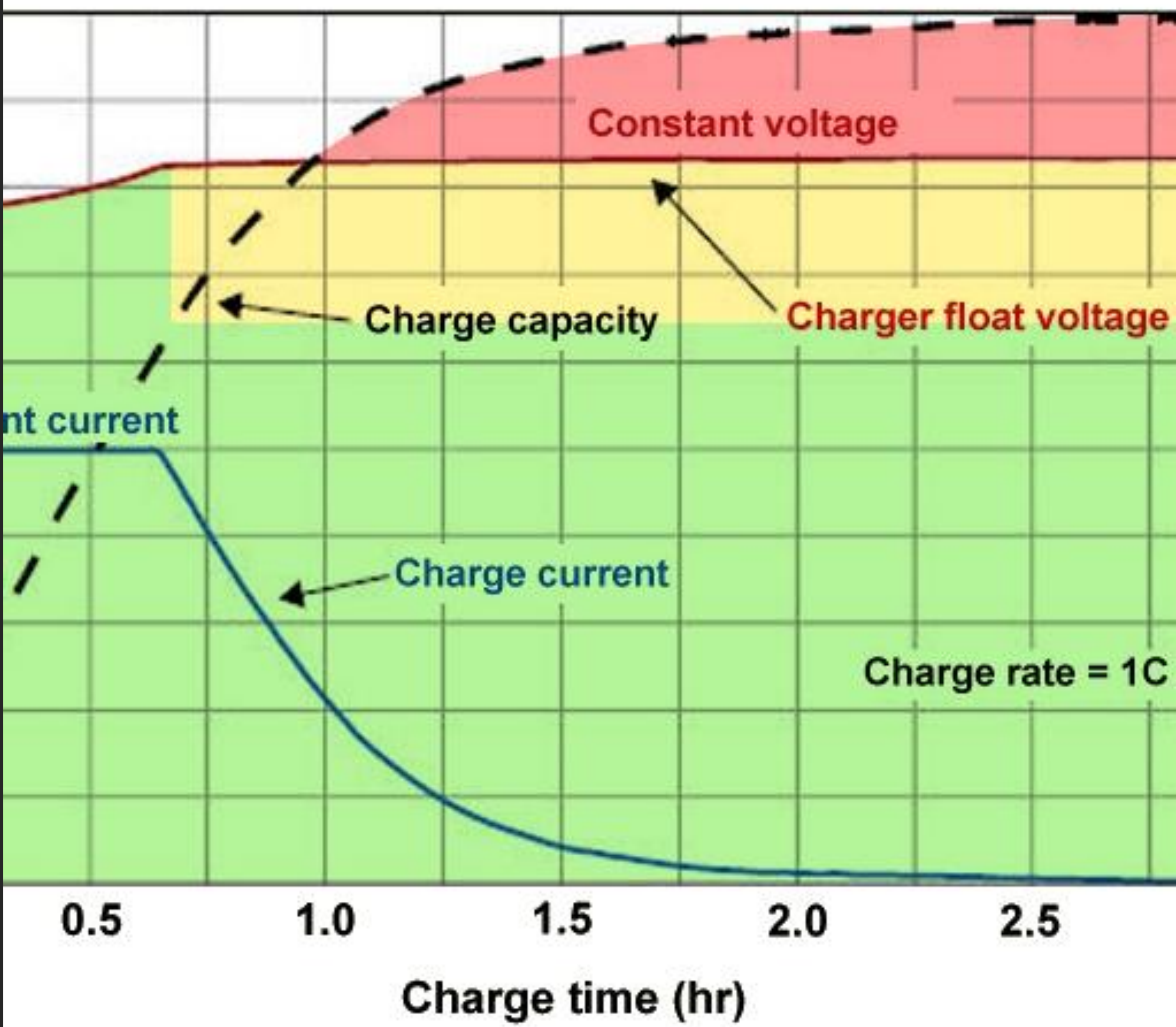
A **battery fuel gauge**, also known as a **battery gas gauge**, determines **battery** state-of-charge (SOC) and state-of-health. A **battery fuel gauge** IC can predict how much longer, under specific operating conditions, the **battery** can continue to provide power. The fuel-gauge functional block keeps track of the charge entering and exiting the battery pack. Charge is the product of current and time. Several different techniques can be used when designing a fuel gauge.



Cell Voltage

Monitoring the cell voltage of each cell in a battery pack is essential to determine its overall health. All cells have an operating voltage window where charging/discharging should occur to ensure proper operation and battery life. If an application is using a battery with a lithium chemistry, the operating voltage typically ranges between 2.5 and 4.2 V. Voltage range is chemistry-dependent. Operating the battery outside the voltage range significantly reduces the lifetime of the cell and can render it useless.

Cells are connected in series and parallel to form a battery pack. A parallel connection increases the battery pack's current drive, while a series connection increases the overall voltage. A cell's performance has a distribution: At time equal zero, the battery-pack cell's charge and discharge rates are the same. As each cell cycles between charge and discharge, each cell's charge and discharge rates change. This results in a spread distribution across a battery pack.



Voltage Measurement

In battery packs assembled from lithium-ion cells, typically each cell voltage, as well as the overall pack voltage, is measured. While the cell voltages are just a few volts, the pack voltage can reach voltages of more than 800 V. Therefore, it has to be distinguished between cell voltage measurement and pack voltage measurement.

Cell Voltage Measurement

The acquisition of cell voltages is usually done by integrated BMS Frontend chips. The chips that are on the market at the time this is written allow connection of cell counts of three up to 16.

Pack Voltage Measurement

The pack voltage acquisition is done by a separate measurement unit, typically consisting of a voltage divider, an impedance converter, a filter, and an Analog-Digital Converter (ADC). The voltage divider is necessary for scaling down the pack voltage to an adequate measuring voltage, which is in the range of the ADC. Depending on the pack voltage and on the electric strength of the resistors, it may be necessary to use several resistors for a safe voltage divider. In addition, a Zener diode should be placed in parallel to the measuring resistor for protecting the following measurement circuits against overvoltage. Since the voltage divider is designed to be highly resistive in order to keep the losses low, the voltage tap of the measuring resistor should be very high-resistance in order not to load the voltage divider. For this reason, an impedance converter that is followed by the filter circuit and the ADC should be used to tap the voltage.

Data Transfer

Communication between individual BMS-modules, as well as between BMS and the overall system, is required. Nowadays, the CAN bus is one of the most prominent buses used in vehicle environments because it is very flexible regarding the number of bus members, as well as offering a good noise resistance. The simpler Local Interconnect Network (LIN)-bus, which is also widely used e.g., has the disadvantages that it is slower, less flexible and non-differential, but, on the contrary, also is less expensive due to reduced hardware efforts. Other buses that are mostly used on short distances, such as chip to chip communication (see above), is the SPI interface, I^2C interface or the Onewire bus. Due to their non-differential signals, they are not robust against disturbances on a longer, more exposed line, such as inter-module buses. For the latter task, the previously mentioned CAN bus is a good choice. If the CAN bus at its highest speed of 1 Mbps is too slow, or the demand for real-time deterministic capability exists, then the FlexRay bus seems adequate. An Ethernet connection is also sometimes used to connect the battery system with the application, especially when high communication speed and large data volumes required.

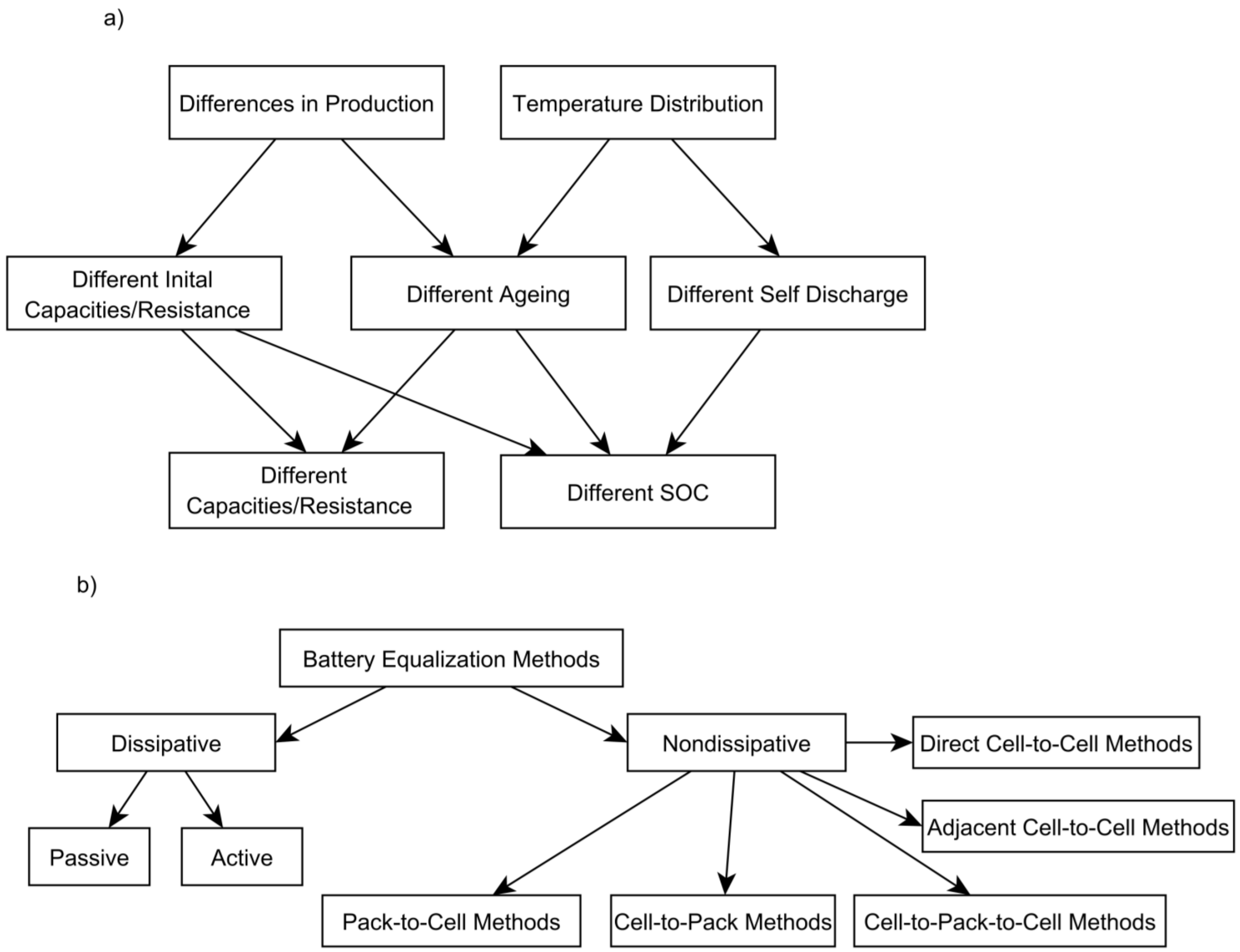
State Machines / Algorithms

Most BMS systems require a microcontroller (MCU) or a field-programmable gate array (FPGA) to manage information from the sensing circuitry, and then make decisions with the received information. In certain devices, an algorithm that is digitally encoded enables a standalone solution with one chip. Standalone solutions are also valuable when mated to an MCU, because the standalone's state machine can be used to free up MCU clock cycles and memory space.

Balancing

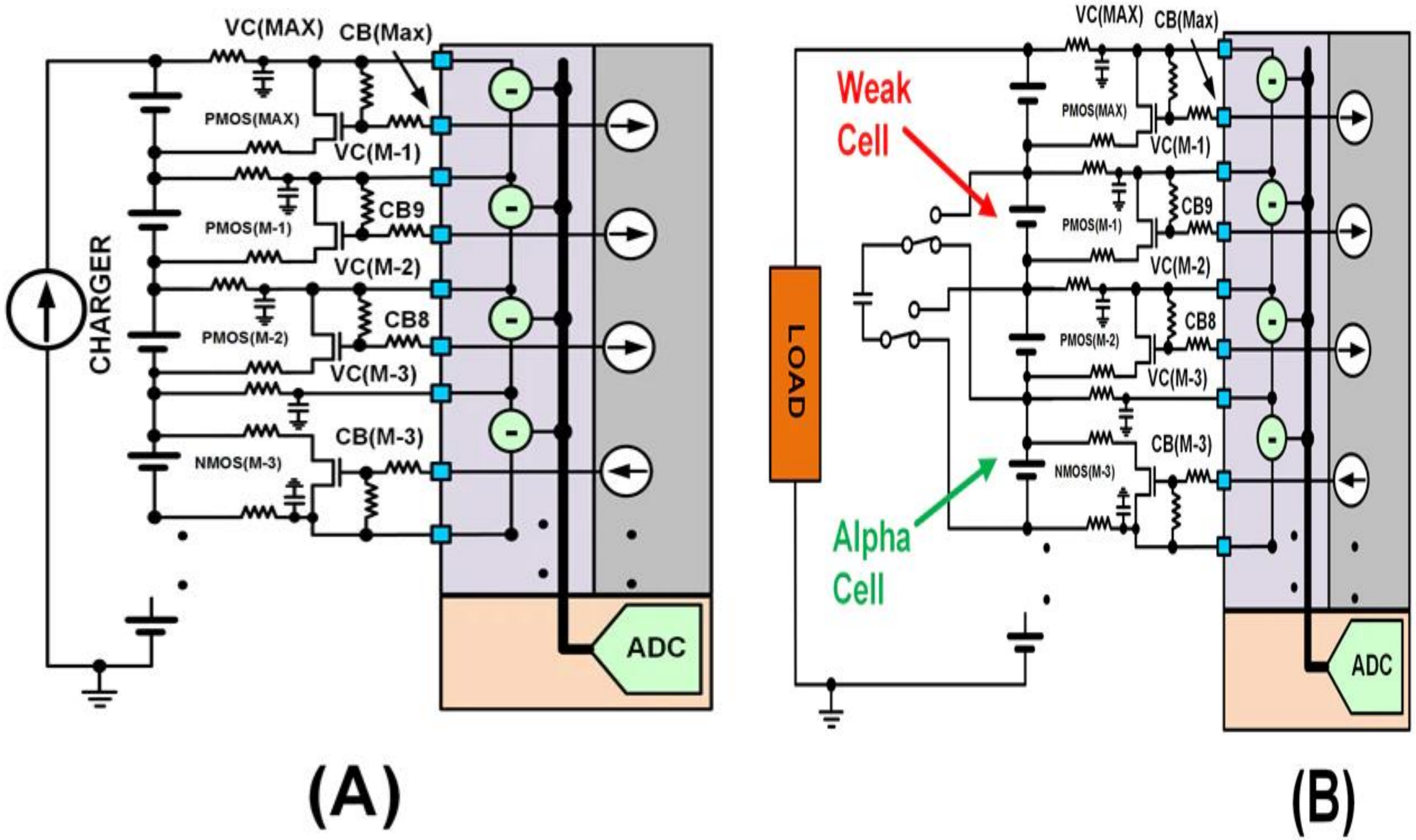
Due to several reasons, at a given time SOC, values can differ in a serial connection of cells. The cause for the inhomogeneities are production related differences on the one hand and different operational and environmental conditions, e.g., temperature, on the other hand. These causes can lead to different initial conditions, different ageing and different self discharge rates, which then result in deviating SOC, capacity and resistance values.

These systems consist of a balancing resistor that can be switched in parallel to a battery cell for each battery cell or parallel connection of battery cells. The main advantage of this approach is its simplicity compared to more complex active and non dissipative solutions. Since the cells can only be discharged with this balancing topology, only SOC changes can be addressed.



Balancing Cell

Bypass cell balancing FETs help slow the charge rate of a cell during the charge cycle (A). Active balancing is used during the discharge cycle to steal charge from a strong cell and give the charge to a weak cell (B).



Temperature Monitoring

Today's batteries deliver lots of current while maintaining a constant voltage. This can lead to a runaway condition that causes the battery to catch fire.

Temperature sensors monitor each cell for energy-storage-system (ESS) applications or a grouping of cells for smaller and more portable applications. Thermistors powered by an internal ADC voltage reference are commonly used to monitor each circuit's temperature.

Common temperature sensors for the measurement of temperatures in the region that is relevant for battery management applications are of Negative Temperature Coefficient (NTC) (metal oxide) or Positive Temperature Coefficient (PTC) (semiconductor) type. These sensors change their resistance as a function of the temperature–for NTC, the resistance decreases with increasing temperature, for PTC .

Other ways of temperature measurement, using metal based PTCs, as the well-known, or making use of the thermoelectric effect (Thermocouple) could provide higher accuracies and a wider temperature range; however, this would involve a higher complexity in terms of electronics

Other BMS Building Blocks

Other functional BMS blocks may include battery authentication, real-time clock (RTC), memory, and daisy chain. The RTC and memory are used for black-box applications—the RTC is used as a time stamp and memory is used for storing data. This lets the user know the behavior of battery pack prior to a catastrophic event. The battery authentication block prevents the BMS electronics from being connected to a third-party battery pack. The voltage reference/regulator is used to power peripheral circuitry around the BMS system. Finally, daisy-chain circuitry is used to simplify the connection between stacked devices. The daisy-chain block replaces the need for optical couplers or other level-shifting circuitry.

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