DEROGY Sàrl
Avenue du Théâtre, 7
c/o Fid & Trust SA
1005 Lausanne
CH-550.1.184.586

Yves-Anne Gouffon de Kerdellech

Multiplexed Analog Front End (AFE) for Cell Voltage and Temperature Measurement

Measuring cell voltage can get complex since it requires high accuracy and might also inject switching noises from mux apart from this every cell is connected to a resistor through a switch for cell balancing. To overcome these problems an AFE – Analog Front end IC is used. An AFE has built-in Mux, buffer and ADC module with high accuracy. It could easily measure the voltage and temperature with common mode and transfer the information to the main microcontroller.

"How to measure pack current for BMS?"

EV Battery Pack can source a large value of current upto 250A or even high, apart from this we also have to measure the current of every module in the pack to make sure the load is distributed evenly. While designing the current sensing element we also have to provide isolation between the measuring and sensing device. The most commonly used method to sense current are the Shunt method and the Hall-sensor based method. Both methods have their pros and cons. Earlier shunt methods were considered less accurate, but with recent availability of high-precision shunts designs with isolated amplifiers and modulators they are more preferred than the hall-sensor based method.

Battery state Estimation

The major computational power of a BMS is dedicated to estimate the Battery state. **This includes the measurement of SOC and SOH**. SOC can be calculated using the cell voltage, current, charging profile and discharging profile. SOH can be calculated by using the number of charge cycle and performance of the battery.

"How to measure the SOC of a Battery?"

There are many algorithms to measure the SOC of a battery, each having its own input values. The most commonly used method for SOC is called **the Coulomb Counting a.k.a**

book keeping method. We will discuss more on that later. Apart from that there are many other advanced and more sophisticated algorithms that are listed below.

Basic Methods

- Coulomb Counting method
- Ampere-hour (Ah) method
- Open-Circuit Voltage (OCV) method
- Impedance / IR Measurement Method

Machine Learning Based Algorithms

- Neural Network Fuzzy Logic
- Support Vector Machine

Advanced Method

- State-Space Model Estimation using Kalman Filter

Coulomb Counting Technique

By far the coulomb counting Technique is the most used and easy to understand algorithm. It is based on the fact that the **ratio between the Total charge Input and the Maximum capacity of the battery will give us the SOC value**. The formula for the same is given below.

```
SOC = Total Charge Input / Maximum Capacity
```

While the Maximum capacity of the battery will be mentioned in the datasheet of the battery, calculating the **Total charge Input** requires some mathematical approach. The total charge input is nothing but the product of the current and time, but the value of current varies based on time and hence we have to use current integration method to determine the Total charge Input. Discrete values of current are taken at regular internal and the integral of these values will give us the value of Total Charge Input.

For understanding purpose if we consider that the value of current is constant say 2A for 4 hours then the value of Total charge input will be 8Ah and if the maximum capacity of the battery is 25Ah then the SOC value is simply ((2*4)/25) 32%. But this method is not very reliable because the maximum capacity of the battery will get reduced as the battery ages. Hence many other algorithms were developed.

Battery Modeling

To use any of the above-discussed algorithms or to verify if your BMS is working as expected we need to develop a mathematical model for our battery pack.

"Why do we need Battery Modeling?"

A typical battery pack takes about 6 hours to get charge and another 6 hours to get discharged. The voltage and current profile of the cells will be different during charging and discharging based on the load, age, temperature and many such conditions. It is not practically possible to charge and discharge a battery in all required condition for the entire life cycle of the Battery pack to check if the BMS is working as expected. This is why Battery model is developed. This model can act as a virtual battery (Hardware in loop) during the developmental stage of the BMS.

The accuracy of the SOC and SOH also depends on the accuracy of the battery model; hence it should always provide high fidelity and robustness. A typical usage of battery model is shown below using the below image

In an ideal Battery model, the input voltage should be equal to the output voltage and the error value should be zero. But in practical this scenario is hard to achieve since there are many parameters like temperature, age etc which can affect the system. There are many battery models available they can be broadly classified as Lumped-Parameter Model, Equivalent Circuit Model and Electro-chemical model out all three the Electro-chemical model is the most hard and most accurate model.

BMS – Thermal Management

Apart from measuring the voltage, current and temperature and calculating SOC, SOH etc the BMS has another important task of **regulating the battery temperature**. A battery pack would drain faster if operated in higher or lower temperatures. To prevent this cooling systems are used in the battery. The Tesla for example uses liquid cooling where a tube is passed through the battery pack to get in contact with all the cells. A coolant like water or Glycol is then passed through the tubes. The temperature of the coolant is controlled by the BMS based on the cell temperatures. Apart from this the batteries also use air or chemicals to maintain the required temperature.

With this let us conclude the article here, there are still lots to know about BMS and how they work. Today many silicon companies like Renesas, Texas Instruments etc. have their own series of **BMS IC**'s and Tool kits which could do the hardware pulling for you and you can use it without diving deep into all this. With every new EV in the market the BMS evolves to get much smarter and easy to use.