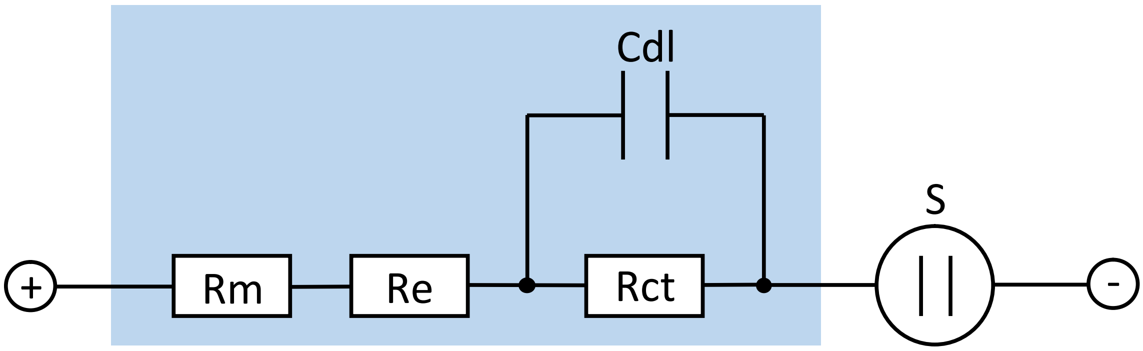
What resistance does the TMC-2001RTS actually measure?

This article is a short and simple presentation of battery testing with our TMC-2001RTS.
When it comes to testing batteries, the main thing is to look for accelerated aging to check the "state of health" (SOH) and thus the performance of a battery. The "Check" is unfortunately not as trivial, as it is normally represented. A good analogy is our body. In a test of its performance, it makes little sense only to look for deposits in the arteries (comparable to corrosion in the battery blocks). Rather, it is also necessary to check whether there is sufficient oxygen in the blood and that this is also transported and made available as required. This analogy corresponds to the so-called charge-transfer resistor Rct. It describes the resistance of the current flow at the electrode / electrolyte interface. Rct is highly dependent on the nature and structure of the active plate material and is thus an important indicator of the health of the battery.
A common replacement circuit diagram for a battery is the so-called Randles model (blue-background). It is shown here in simplified form and shows the schematic arrangement of the components:



The voltage source S symbolizes the actual charge storage, Cdl a capacitor, which is formed by the ion distribution on the surface of the plates. Rm is the metallic resistance (poles, pole bridges, grids, ...), Re is the resistance of the electrolyte.
Today's test equipment apply an alternating current on the battery. The resistance is calculated from the resulting voltage response. The frequency of the alternating current used is device-dependent. The frequency-dependent resistance, the impedance, is thus measured with a test device. In the case of higher-quality systems, the resistors are determined phase-synchronously in the time or frequency domain, and in the case of simpler systems with an analog RMS measurement. Unfortunately, the price of the test systems does not always correspond to the quality of the methods used.
Based on this model and the applied alternating current, three groups of measuring instruments can be categorized:

1) "**Ultrasound examination of the arteries**". At very high frequencies (eg 1000 Hz), the real part of the impedance is measured. All electrochemical reactions are short-circuited by Cdl. Thus, the internal resistance is the sum of Rm + Re. This internal resistance mainly reflects the state of the metallic parts and connections and the conductivity of the electrolyte. **The nature of the active material and the charge transport are not of interest**. This measurement is suitable for batteries which are designed for very high pulsed currents. This method is unsuitable for testing batteries which have to supply a direct current for a longer period (the typical backup job).

2) "**We check the pulse**". As the frequency of the applied alternating current increases, the resistance of Cdl decreases. The current distribution over Rct and Cdl is frequency depending (eg 10-60Hz). In this case, the impedance of a complex circuit formed by Rm, Re, Rct and Cdl is measured. All components have an influence on the measured value. **Significant changes are, however, only detected very late (see the following table), since only very strong changes in the comparison of the measured values become visible**.

3) "**ECG**". In the case of direct current (0 Hz), Cdl blocks and the current is flowing through the series resistance of Rm + Re + Rct, the DC resistance. This direct current resistance is important for batteries which have to supply a direct current over a long time. **The voltage losses are not just related to the metallic components.**

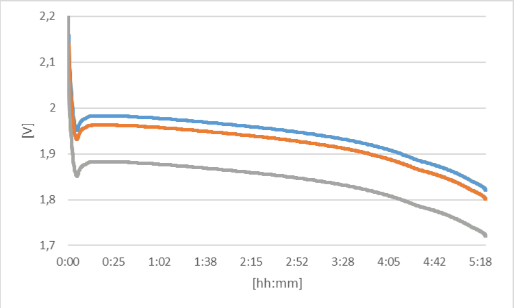
Many manufacturers of test devices decide either for the 1000Hz or the 20-60Hz variant. The TMC-2001RTS works with two frequencies. At about 1000Hz, to determine the internal resistance and with nearly constant current, to detect Rct and thus the DC resistance.
The following table shows the significant differences in the measurement results (typical 100Ah cell):

Test object (100Ah, Cdl=1,5F)		**Third party tester with**		**TMC-2001RTS**	
Ri	Rct	25Hz	1000Hz	Ri	Rct
1mΩ	1mΩ	1,96 mΩ [0%]	1,02 mΩ [0%]	1,02 mΩ [0%]	0,98 mΩ [0%]
1,5mΩ	1mΩ	2,46 mΩ [25,4%]	1,51 mΩ [49%]	1,51 mΩ [49%]	0,98 mΩ [0,2%]
1mΩ	1,5mΩ	2,38 mΩ [21,4%]	1,01 mΩ [0%]	1,01 mΩ [0%]	1,48 mΩ [50,9%]

The first line shows the values for a healthy 100 Ah battery. In the following, Ri and afterwards Rct are increased by 50%. **The TMC-2001RTS identifies the outliers Ri with 49% and Rct with 50.9%. Such significant changes are difficult to detect with 25Hz devices. 1000Hz systems fully ignore Rct**.

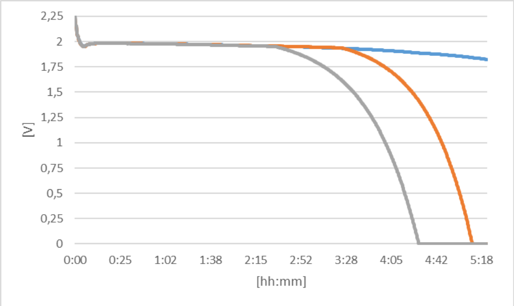
In the following, a typical discharge curve of a constant-current discharge (a 5-hour capacity test) illustrates the influence of ohmic and chemical factors on the performance of a battery:

Effect of ohmic losses:



The metallic losses follow Ohm's law. The voltage drop is proportional to the discharge current and visible from the start of the discharge. The blue curve corresponds to the mean value of all blocks, the orange and gray curves have increased internal resistances (Rm increased) and are thus shifted parallel in their voltage position.

Effect of electrochemical factors:



The electrochemical factors are difficult to predict. While a discharge is in progress, defective blocks may break earlier. At the beginning of a discharge, these cells are not visible. **It can be seen from the curve that short-term load tests (5-30min) are not very useful in this case**.

On the background of these discharge curves, it is again shown why electrochemical components are an integral part of testing. The TMC-2001RTS determines the internal resistance and the DC resistance. The value of Rct is dynamic. It decreases at discharge and increases with charge, so to speak, the readiness either to absorb or to deliver charge. Uneven distributions of Rct in charge condition can identify possible insufficient charged blocks. Rct is strongly increased in such a case, a sign that the charge of a block take place with increased losses, or is simple limited.

The argument that the internal resistance is correlated with capacity is often called. Unfortunately, this internal resistance increases significantly only after a discharge depth of approximately 50%. The increase is due to the consumption of sulfuric acid in the electrolyte during discharge and the concomitant reduction in conductivity. Thus, if possible, a density test of the electrolyte (in case of vented batteries) should always be carried out. This indicator has a better correlation to the charge / discharge state. For this reason, the TMC-2001RTS is also directly equipped with an IrDA interface for the connection of a density sensor.
VRLA batteries show a better relation between the internal resistance and the aging of a battery caused by the gradual dry out (no refilling possible). In all discussions about the various resistances, it should be remembered that all these methods represent an additional tool for the identification of defective blocks. Only a complete capacity test up to the discharge voltage also relates to the charge accumulator S and enables an accurate determination of the SOH.
In practice, it has been shown that resistance changes can be 30% of the average value for defective blocks. Anticipated aging by giving absolute reference values is not useful (you always deal with pre-aged values). If you have any further questions, please contact us.