A Zero Bouncing Circuit for Battery Short-Circuit Model Development

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ABSTRACT

The apparatus employed for short circuit testing is expensive and the nature of testing is sensitive due to the possibility of explosion. This poster discusses the results of pulse discharge testing conducted on Lithium-ion 21700 batteries, in order to estimate the battery's behavior during a short circuit using safe levels of current. The terminal voltage across the battery is measured for the entire duration of a short discharge pulse. The parameters for the equivalent battery circuits, 1RC and 2RC, are extracted using nonlinear least square curve fitting method. These tests are repeated for three different values of load, three different temperature values and ten state of charge values.
These equivalent circuits, namely 1RC and 2RC, of varied complexities translate a battery's behavior into different number of passive components, 4 and 6 respectively.
The apparatus used for testing eliminates any mechanical and moving parts so as to limit bouncing during high current switching. Power MOSFET due to its high current carrying ability, low switch-on resistance and smooth switching is used. The setup uses LabVIEW for creating an automated testing environment and Compact Rio (CRio) for its very high sampling rate required for studying battery parameters in the beginning of the short circuit.

INTRODUCTION

Lithium-ion 21700 is a relatively less researched and studied lithium-ion battery as compared to 18650. They are bigger than 18650 and offer higher capacity. There are many battery tests that are widely used to study battery properties like capacity tests, pulse discharge tests, spectroscopy and pulse discharge test. The poster will go over results of a Pulse Discharge Testing (PDT) conducted on a 21700 battery for short circuit current prediction purposes. This is to cut down on the costs of equipment, make testing safer and omit bouncing in the testing due to moving mechanical switching parts.

Pulse Discharge Testing

Pulse discharge test, as the name suggests, is nothing but discharging the battery in short pulses and can be used to obtain internal battery resistances; such as ohmic resistance, Ro, which comprises all electronic resistances of the cell and is typically responsible for the steep voltage drop instantaneous of applying the current pulse, charge transfer resistance, R1, which is attributed to the charge transfer reaction at the electrode/electrolyte interface and typically occurs within the first few seconds of applying the current pulse and polarization resistance, R2, which accounts for ionic diffusion in the solid phase and is usually considered to be the rate determining step for Li-ion cells and internal capacitances.

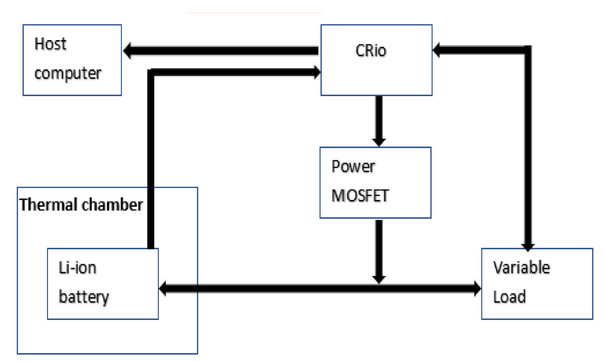

Fig 1. LabVIEW and CRio based Experimental Set-up

Zero Bouncing

The combination of the power MOSFET and CRio ensures zero bouncing upon switching as well as a very high sampling rate which is crucial to short circuit model development. This test uses 500µs as the sampling time. Fig 2. shows the 10s discharge period and zooms in to show a smooth beginning upon switching the MOSFET on.

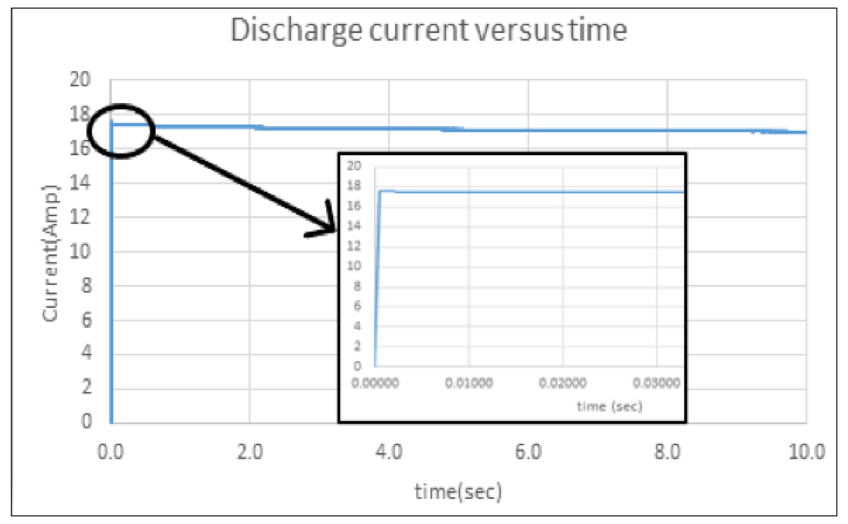

Fig 2. Zero bouncing during current switching

1RC versus 2RC

The instantaneous change in battery terminal voltage, immediately after the discharge pulse is applied is used to calculate Ro. Equation 1 and 2 are used to calculate the remaining circuit parameters for both circuits.

$$V(t) = Voc + IRo + IR1\left(1 - e^{-\frac{t}{R1C1}}\right) \quad (1)$$

$$V(t) = Voc + IRo + IR1\left(1 - e^{-\frac{t}{R1C1}}\right) + IR2\left(1 - e^{-\frac{t}{R2C2}}\right) \quad (2)$$

While 1RC circuit has lesser number of unknowns and is simple in complexity, it does not emulate the behavior of the battery as closely as the 2 RC circuit. This is confirmed using the curve fitting in MATLAB using nonlinear least squares algorithm. The residuals for the 1RC circuit are higher than those for 2RC circuit.

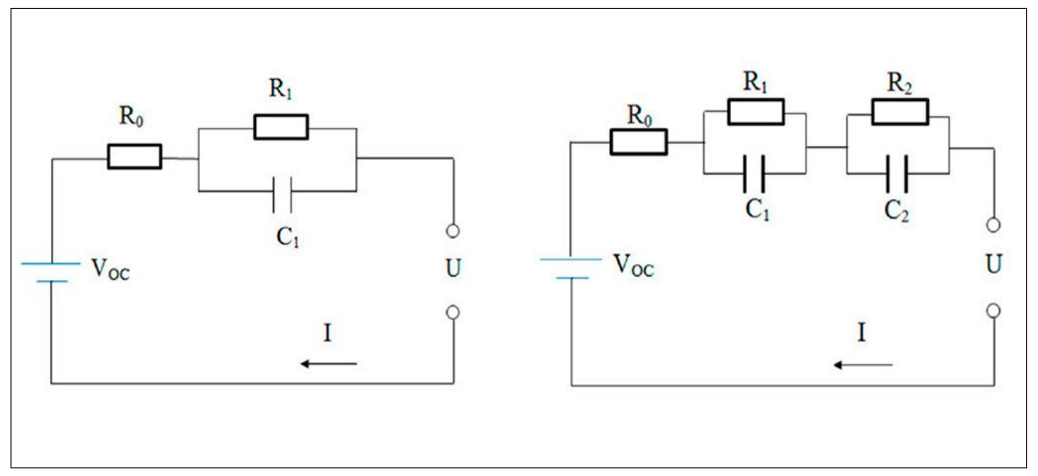

Fig 3. 1RC and 2RC battery equivalent circuits

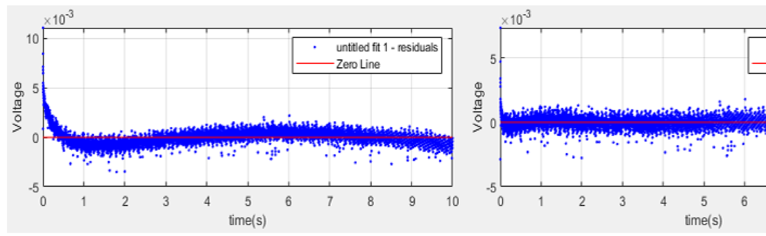

Fig 4. Residuals for 1RC versus 2RC circuits

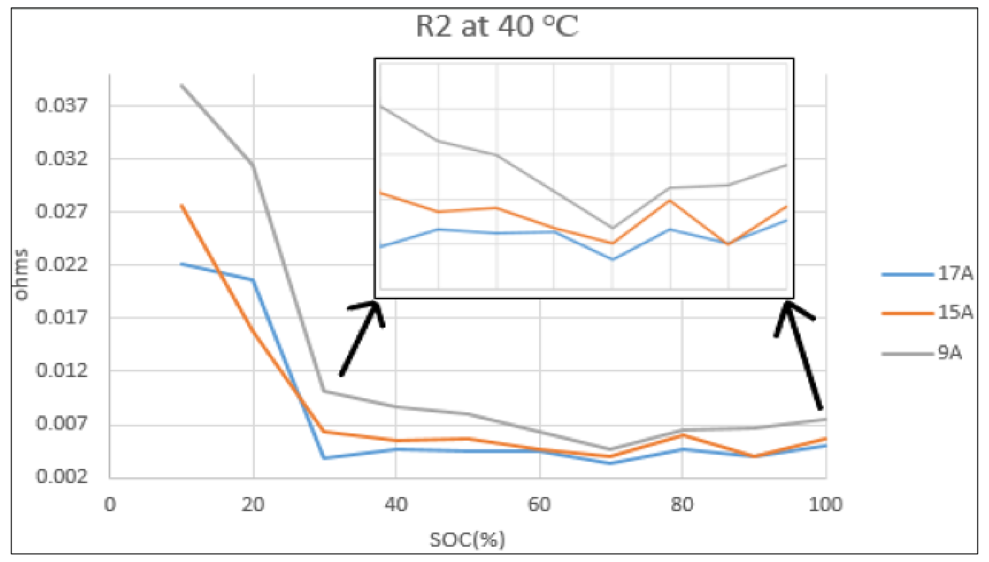

Fig 5. R1 versus SOC for 17A ,15A and 9A

The fig 4. shows that for 2RC circuit the residual is more concentrated around the x-axis, whereas for 1RC circuits it deviated from the x-axis more as the number of circuit parameters are not enough to mimic the electrochemical behavior of the battery.

Preliminary results, as can be seen in fig 5, show that the internal battery parameters change with the increasing discharge current. For instance, for R1, the higher the current, the lower the value of R1.

CONCLUSION AND DISCUSSION

Hence, instead of conducting battery tests at short circuit current levels and bouncing contacts during switching, this poster proposes conducting battery testing within safe current levels provided by the specification sheets and power MOSFETS. The parameter values extracted from the terminal voltage are checked for trends with the changing current values. The power MOSFET not only enables the switching to be fast but also smooth with no spikes observed in recorded voltage and current after switching. This mechanical bouncing corrupts results even after using sophisticated testing equipment. The other important point that we would like to find out is whether we can perform the test at lower current level to derive the short circuit current model of the battery.
In FY 21 it was seen that these tests can be used to design a model for short circuit current prediction.
Another observation made is that for early external short circuit current prediction, the ohmic resistance, Ro can be used as it can be measured in as short as 500µs.
In FY 22, a short circuit current prediction model will be implemented.

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