Using Squidstats for Stack Measurements on Fuel Cells or Batteries

This application note describes the differences between using a serial connection versus a parallel connection when studying fuel cell or battery stacks

For applications where a series of individual fuel cells or batteries are connected in a stack, a user might be interested in finding out what is happening in each cell in the stack during operation, or the entire stack itself. Any electrochemical devices such as fuel cells, batteries or supercapacitors, can be combined in a multi-cell configuration to provide higher energy and power than they could if each cell were used individually. A user can connect multiple Squidstat channels to various parts of the stack to investigate portions of the entire system. There are two basic ways to accomplish this, either using a *Serial Connection* scheme or a *Parallel Connection* scheme.

Serial Connection

In a serial connection, the negative terminal of an electrode pair is connected to the positive terminal of an adjacent electrode pair. The total voltage is the sum of voltages of each cell pair within the series. But, the current flowing through each cell in the series has the same magnitude and direction. Because of this, the cells connected in series should only be run in a galvanostatic mode. Galvanostatic mode means that current is the variable being controlled by the potentiostat.

A recommended configuration is shown below to test electrochemical devices in series with any of our Squidstat potentiostats. In this configuration, the entire stack of cells is controlled by Squidstat channel 1 in galvanostatic mode. Squidstat channels 2 and 3 should be run only in an open circuit mode.

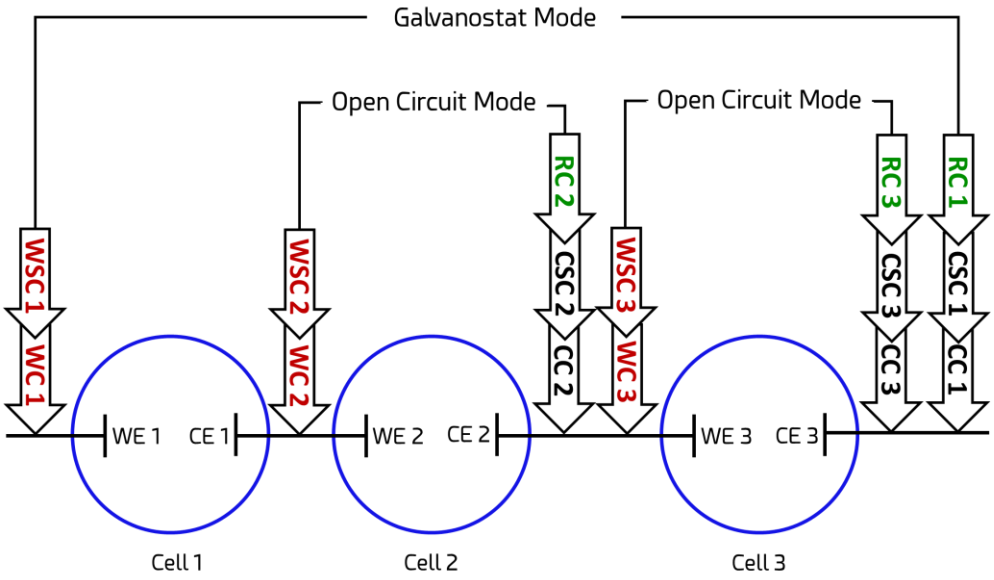

Figure 1. *Schematic for connecting multiple channels to cells in series. In the above example, channel 1 is controlling the whole stack with a galvanostatic or current-controlled experiments. Channels 2 and 3 are running open circuit potential experiments. In this way, voltage drop across each cell can be measured. (WE: working electrode, CE: counter electrode, RE: reference electrode, WSC: working electrode sense clip, WC: working electrode clip, RC: reference electrode clip, CSC: counter electrode sense clip, and CC: counter electrode clip)*

In serial connections, users must be careful that the total voltage of the combined stack of cells does not exceed the voltage limit of the Squidstat running the experiment. The maximum controlled voltage limit of all Squidstat potentiostats currently available is ±10 V. Users in need of a higher voltage range can consider the ±55 V range of the Zahner P600 workstation. This workstation is available for purchase through Admiral Instruments.

At a glance, it might seem like channels 2 and 3 can also be run in galvanostatic mode by setting the same current across the cell 2 and 3. This would be erroneous because the CCs can be at different potentials and will interfere with the feedback control of each channel. Therefore, only one of the potentiostat, Squidstat 1, can be controlling the current.

Parallel Connection

In a parallel connection, terminals of all cells with the same sign are connected to each other. The voltage across each cell is the same, and equal to the total voltage of the stack. But, the total current is the sum of all the currents from each cell. In such a configuration, a user might be interested in finding out the current flowing through each cell. At a glance, it might look like this can be achieved by setting the same potential across each cell and then measuring the current. However, this would be wrong because the current flowing in one cell will affect the current flowing in another cell. This interferes with the feedback control of each potentiostat channel. Therefore, it is not possible to run cells connected in parallel with multiple channels even in potentiostatic mode without interference.

A recommended configuration is shown below to test multiple cells connected in parallel with a single potentiostat channel controlling the whole configuration. In this set-up, the channel can be run both in potentiostatic or galvanostatic modes. A user must be careful not to exceed the total current limit of the Squidstat they are using. Users in need of a higher current range can consider the Zennium workstations with PP-series boosters up to 40 A and EL-series electronic loads (up to 600 A) which are available for purchase through Admiral Instruments.

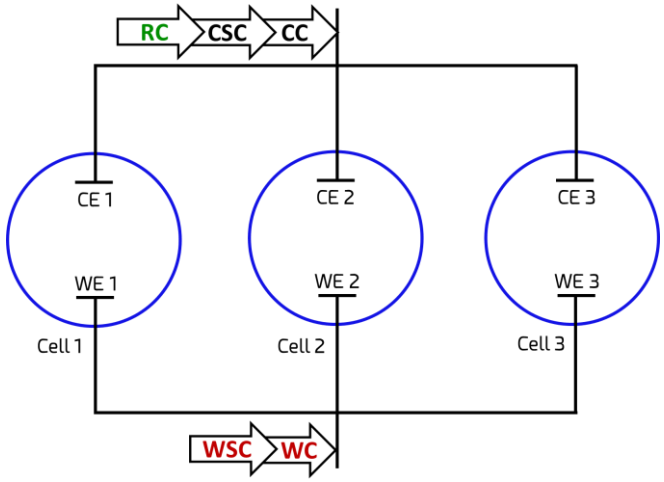

Figure 2. *Schematic for connecting multiple channels to cells in parallel. It is not possible to find current flowing through each cell by running them in potentiostatic mode because current from one cell will try to flow through the other cell. (WE: working electrode, CE: counter electrode, RE: reference electrode, WSC: working electrode sense clip, WC: working electrode clip, RC: reference electrode clip, CSC: counter electrode sense clip, and CC: counter electrode clip)*