

BATTERY SIMULATION WITH THE DC POWER SUPPLIES R&S®NGM200 AND R&S®NGU201

Products:

- ▶ R&S®NGM201
- ▶ R&S®NGM202
- ▶ R&S®NGU201
- ▶ R&S®NGM-K106
- ▶ R&S®NGU-K106

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1 Overview

This application note is about creating your own battery model for the R&S®NGM200 and R&S®NGU201, beyond the standard models provided within the battery simulation option NGM-K106 and NGU-K106. The main purpose is to gradually discharge a battery or a rechargeable battery using the internal QuickArb function. The discharge of the battery can then be recorded using the fast data logging functionality FastLog. The recorded data are stored in a .CSV file. This file can then be adapted to be used as a battery model in the battery simulation mode of the R&S®NGM200/NGU201. For this purpose, Rohde & Schwarz provides a tool for developers to make their work easier. This tool calculates all the data required for a battery model. The following chapters describe the procedure from building an arb file up to working with the tool.

2 Battery characteristics

The simplest way is to consider a battery that powers an electronic circuit as a basic ideal voltage source.

Batteries are quite dynamic energy sources and the voltage of a battery is hardly constant - it varies depending on the state of charge, load, temperature, the age of the battery and much more. Think of a car battery on a cold winter's day, which may have difficulty starting the car, while on a warm summer day this would normally not be a problem.

The reason for this is that the battery itself performs through chemical reactions that are influenced by several factors. The geometry of the cell, the surface of the electrodes, the temperature of the reactants, the diffusion rate within the electrolyte and many more, all affect the reaction speed of the battery. Hardly any value remains constant in the battery while the battery is discharging or the outside temperature changes. Due to this dynamic behavior, the simulation of a battery requires a good model.

With the R&S®NGM200/NGU201, developers can simulate the behavior of a battery under different conditions and requirements. As a result, early in the R&D cycle, essentially a real battery can be used.

The selection of batteries or rechargeable batteries during the development of various battery-powered products is often a challenge. However, with the essential requirements, the characteristics of available batteries can be compared or selected with the battery requirements. Only seldom does a battery system fulfill all requirements. Consequently, the selection process usually involves compromises between the different battery properties. The R&S®NGM200/NGU201 can make it easier for the developer of a battery-powered product to select the right battery.

However, the first step is to understand all the important parameters and to apply them to the respective product requirements and applications. Some of these parameters are described below. Section 4 "Testing the Battery Model" explains how to simulate or replicate these parameters with the R&S®NGM200/NGU201.

2.1 Open Circuit Voltage

The cell voltage varies with the selected chemical composition. Depending on the application, choosing the right battery with the right cell voltage can affect the efficiency and complexity of the power electronics circuits in the device. Batteries are marked with a nominal voltage - however, the open circuit voltage of a fully charged battery can be 5 to 7% higher.

2.2 State of charge

The State of Charge (SoC) is defined as the level of charge of a battery relatively to its capacity in percent. If the battery is fully charged, the SoC is 100%.

2.3 Temperature

The charging and discharging temperature of the energy storage cells is very important as DUTs are often used in harsh conditions. At high temperatures, for example, the self-discharge rate increases significantly. At low temperatures the internal resistance increases. Zinc-carbon and alkaline batteries are not normally used for operation below 0°C. Lithium cells can operate down to -40°C, but with significantly reduced performance.

2.4 Internal resistance (ESR)

During the discharge cycle, the internal resistance remains comparatively constant, and the internal resistance rises sharply towards the end of the discharge. As a result, the internal resistance strongly contributes to the heating during charging or discharging and thus converts power loss. The R&S®NGM200/NGU201 can fully simulate the variable internal resistance, depending on the state of charge. The following figure 1 illustrates an example of a battery. If the SoC drops, the open circuit voltage also decreases, but the internal resistance increases.

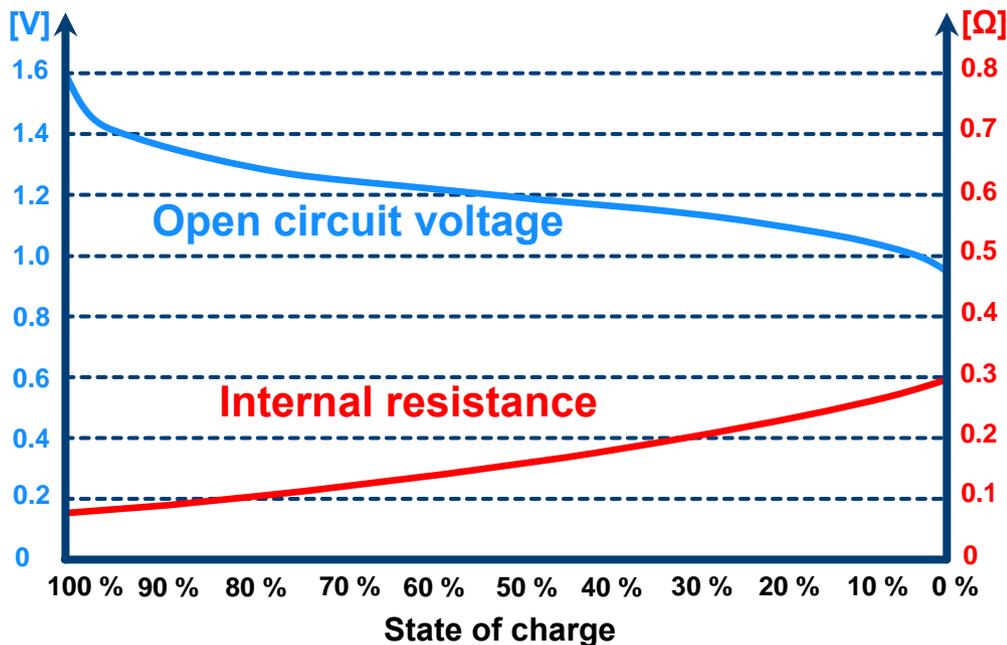


Figure 1: Example of the increasing internal resistance over the state of charge

2.5 Durability

The durability of a battery is the period of operation between the time of delivery and the time at which the battery falls below predefined values due to aging. However, the durability of a battery depends on several factors such as battery type, state of charge of the battery, ambient temperature, number of cycles and the depth of discharge. The self-discharge rate increases with the temperature. Most manufacturers' specifications are given at room temperature, so developers are advised to check the battery's properties. The service life of a battery can then also be calculated for the specific environmental effects or simulated and tested with a battery simulation.

3 Battery Model

This chapter is about creating your own battery model. Thereby it is described step by step how to proceed. Rohde & Schwarz also provides a tool that supports the developer in creating the model. To simulate or build a battery model, the NGM-K106 and the NGU-K106 option is required. You can find the ordering information in chapter 6.

3.1 Battery Model Editor

To define a specific battery model, the battery data can be entered conveniently using the built-in battery model editor. The battery model editor allows you to create and edit battery models with custom behavior. In the editor, the open circuit voltage (Voc) and the internal resistance (ESR) can be defined for different states of charge (SoC) of the battery [1] [2]. Data sets for the frequently used battery types, like Lead, Li-Ion, NiCd and NiMH are already available as preconfigured data sets. These can be easily modified and thus adapted to the requirements of a specific application. Additional battery data sets can be loaded from a USB stick and stored on the hard disk of the R&S®NGM200/NGU201 power supply unit. The following steps describe the procedure for loading a data set for battery simulation to the NGM200/NGU201.

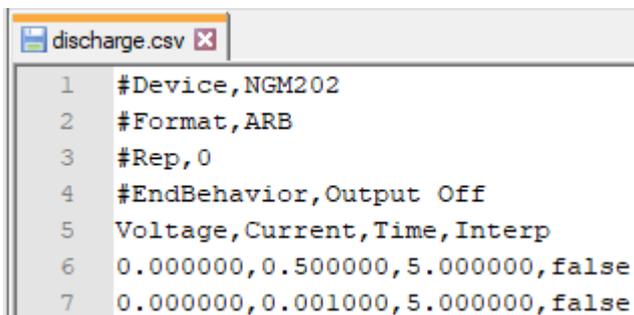
The Battery model editor can be accessed from the device menu. After activating the editing mode, you can select whether you want to create a new battery model or load a saved file. The R&S®NGM200/NGU201 loads the selected battery model file into the battery model editor.

3.2 Building a battery model

For the battery model, three steps are necessary to create this. First, a battery must be discharged. Then this data needs to be logged. After that, the tool that calculates the battery model is used.

3.2.1 Building the Arbitrary File

In order to get from your battery to your battery model you have to perform a discharge test. A battery must be discharged in stages to be able to determine the internal resistance and the varying open-circuit voltage versus the state of charge. To achieve highest accuracy, the built-in QuickArb functionality can be used to generate the required discharge load profile with the internal timer. After opening the Arb Editor on the device, it can be adjusted with the following cycle. A 10 second cycle with 0.5 A discharge current for five seconds followed by 1 mA discharge current for 5 seconds. This ensures that the open circuit voltage can be determined during the discharge. The following figure shows the arbitrary-file used for the characterization of a Li-Ion battery which was used for illustration in this application note:



```
1 #Device,NGM202
2 #Format,ARB
3 #Rep,0
4 #EndBehavior,Output Off
5 Voltage,Current,Time,Interp
6 0.000000,0.500000,5.000000,false
7 0.000000,0.001000,5.000000,false
```

Figure 2: Battery discharge Arb-File

The discharge current should be modified according to the own use case. Note that the average discharge current over the cycle is only half the value entered.

Open the channel menu and select the channel connected to the battery. Now the arbitrary function configuration must be selected and the following window appears:



Figure 3: Arbitrary Settings

To load the generated file to the R&S®NGM200/NGU201, the file must be saved to a USB memory stick. The USB memory stick can then be plugged into the USB port of the NGM/NGU. Now the file can be selected via "Load from file". As soon as the button "Enabled" is pressed, the function is activated on the respective channel and the arbitrary symbol appears on the screen.

Once you have made the settings, you can save them and connect the selected cell to the channel of your choice. Using a four-wire remote sensing setup will increase the accuracy of your results.

3.2.2 Preconditioning

To run the Battery Modeling Tool, a few steps have to be done. A Python environment needs to be installed. The open-source software Spyder IDE¹ from Anaconda is recommended. Here you do not have to make any settings and the following steps do not need to be followed.

If you only have a Python IDLE the following steps have to be followed. To run the tool properly, the following libraries have to be installed:

- ▶ matplotlib
- ▶ scipy
- ▶ python-csv

To install the libraries, the following command must be entered at the command prompt (cmd) for each library.

- ▶ C:\User\> py -m pip install yourlibrary

Once all libraries are installed, you can proceed with the next step.

¹ <https://www.spyder-ide.org/>

3.2.3 Recording the data

After the arb file is created and setup, the discharge is recorded with the integrated logging function.

Activate data logging and select an interval (reciprocal of sample/s). The data can be stored internally or on a USB memory. Initiate the desired channel to start discharging the battery. An automatic current range should be used for the measurement.

To prevent an error message from occurring, the log file should contain enough data. As a guideline, about 15k lines have to be used. Depending on the model this value can deviate.

In order to employ the log-file-data as battery model, some computing effort is required. Rohde & Schwarz provides a python-tool² that calculates the state of charge (SoC), the internal resistance and the voltage parameters from the discharge log file and generates a .CSV file with the corresponding battery model. The following steps describe how to use this tool.

First, save the tool as well as the log-file data on your computer. After the preconditioning has been made, the Python tool can be started. An Explorer window opens, in which the relevant .log-file needs to be selected. Another Explorer window opens, where the file location of your CSV-file can be selected. It is recommended to save the file directly on a USB stick, in order to be able to load the file onto the power supply subsequently. Now the program starts and a plot is displayed, which shows the battery specific data in diagrams. The following figure shows the plot of a sample file.

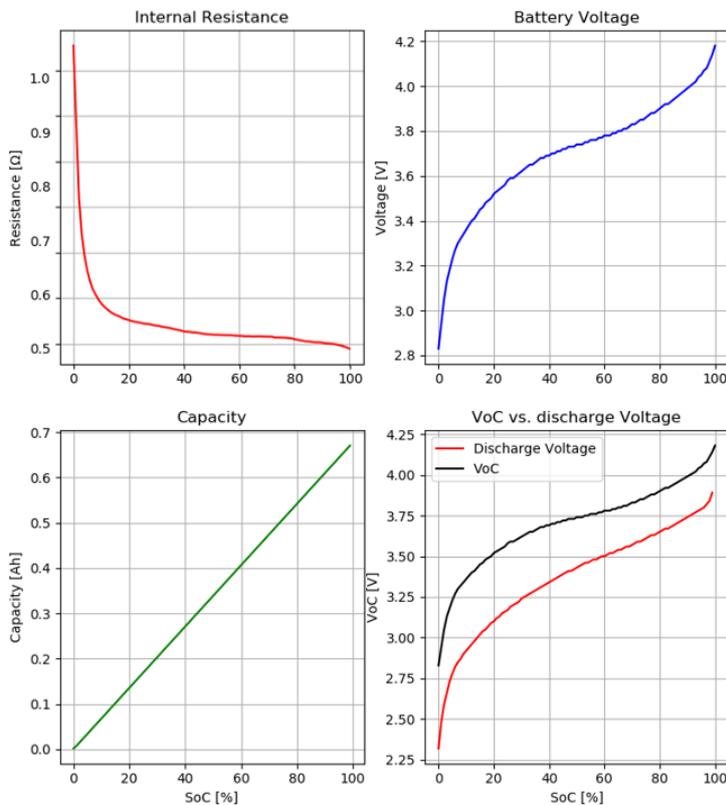


Figure 5: Plot Battery modelling Tool

² Python 3.7 environment needed

Finally, you get a .CSV file, which contains the values of the internal resistance, the state of charge and the battery voltage.

4 Testing the battery model

After you have measured and recorded the real data of your battery, you can open it in the battery simulation of the R&S®NGM200/NGU201. With the integrated USB interface, the stored data can be easily loaded from an USB storage. In the dialog window you can activate the Editor mode. Now you can select the battery model file on your USB storage. The R&S®NGM200/NGU201 loads the selected file into the battery simulation. The loaded parameters from the file are reproduced by the battery simulation. Now you can set the SoC, with which you want to start the simulation and the capacity of your battery.



Figure 7: Simulation of the Battery Model

5 Conclusion

Batteries are dynamic energy sources whose behavior in many cases deviates from an ideal voltage source. A model with a dynamic internal resistance, which changes depending on the state of charge, is used by R&S®NGM200/NGU201 to simulate batteries. By using a load step method, it is possible to derive the parameters required to create a battery model file for the R&S®NGM200/NGU201. With a little effort in Excel any battery model can be simulated. While the battery model itself is simplified and understanding is necessary to ensure proper use, the resulting effect is that we are able to emulate e.g. a Ni-MH cell very accurately. It requires relatively little effort to build the battery model. Thus, the developer is relieved of some work.

6 Ordering Information

Designation	Type	Order No.
Single-Channel Power Supply	R&S®NGM201	3638.4472.02
Dual-Channel Power Supply	R&S®NGM202	3638.4472.03
Battery simulation	R&S®NGM-K106	3636.6626.02
Two-Quadrant Source Measure Unit	R&S®NGU201	3639.3763.02
Battery simulation	R&S®NGU-K106	3663.0625.02

7 Bibliography

- [1] R&S®, "R&S®NGL200/NGM200 Power Supply Series User Manual," Rohde & Schwarz, 2021.
- [2] R&S®, "R&S®NGU Source Measure Units User Manual," Rohde & Schwarz, 2021.

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