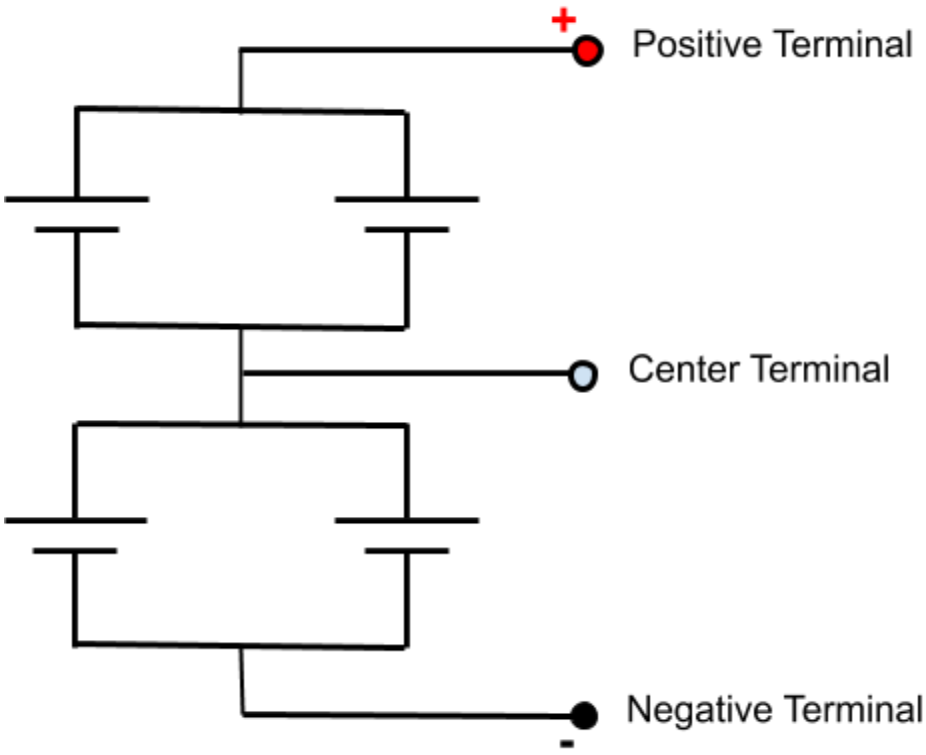
Testing Procedure for the 2012 Nissan Battery

Nissan Leaf Battery Data

- Minimum capacity in Ah: 66Ah
- Nominal voltage: 7.5V
- Minimum voltage: 5V
- Maximum voltage: 8.3V
- Maximum discharge current: 130A
- Normal discharging current: _____ (20A (1/3C))
- Maximum charge current: 130A
- Normal charging current: _____ (20A (1/3 C))
- Charge termination current: _____ (2A)
- Operating temperature range: -25~60 °C
- Battery packing configuration:



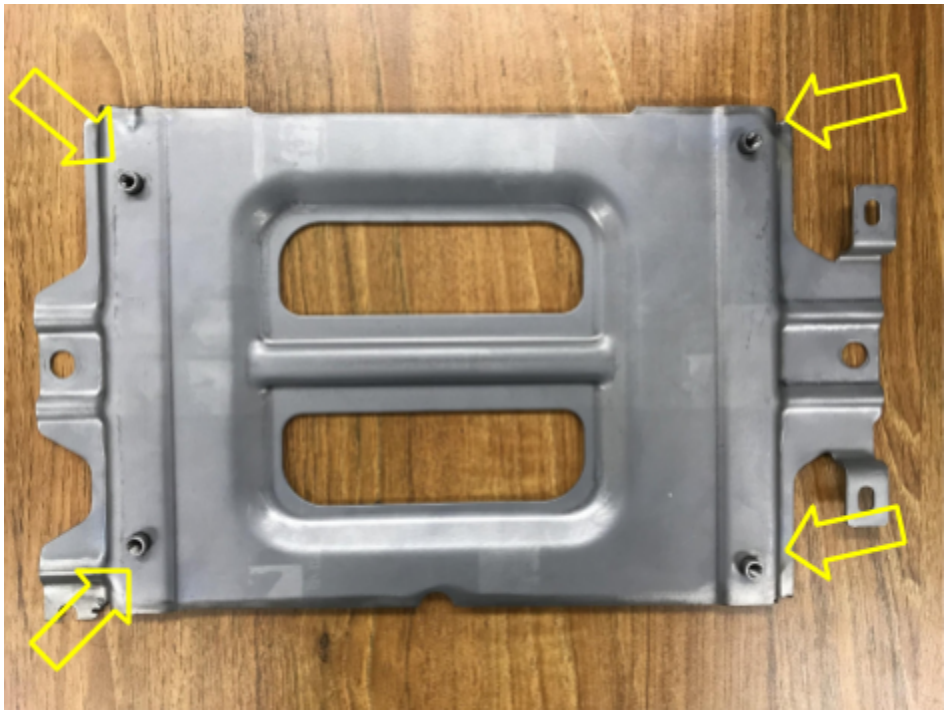
Preliminary Calculations

Max Capacity = 60 Ah

10% of the max capacity = 60Ah*0.1 = 6Ah (amount decreasing each discharge)

Putting Battery into the Compressing Case

1. Take the base seen in the photo below and place with the cylinders facing up



2. Place one battery on top of the base so the cylinders on the base go into the holes on the battery (make sure the battery number written on the side of the battery is face up)
3. Place the two metal strips with holes on top of the battery as seen in the picture below (be sure to line up the holes with the holes in the battery)

4. Place the second battery on top and line up the holes again
5. Place the metal sheet on top of the second battery as seen in the picture below (make sure to line up the holes)

6. Take the long screws seen in the picture below, place them in each of the four holes, and tighten until the batteries are secure

7. After steps 1-6 are finished, the battery is ready for testing

Constant Charge Procedure

1. Put the batteries into the compressing case (see above for instructions)
2. Connect the battery in the test chamber
    a. Make sure the positive and negative terminals from the battery test system aren't touching and don't ever touch
    b. First connect the positive terminal of the battery to the positive terminal of the Battery Test System and then the negative terminal to the negative terminal
    c. Ensure the battery is completely on the plastic mat
3. Turn on Battery Test System
    a. Turn the system on from the bottom up - Power Module 2, Power Module 1, Operation turned to Ready, On/Standby
    b. Wait until the Battery Test System displays the "NH Research DC PM 1" screen. This screen shows the voltage, current, power, and energy of the battery currently connected in the chamber
    c. Open PowerPanel on the testing computer
    d. Ensure the voltage of the battery in the testing system is the same as the voltage recorded with the multimeter (If not, reconnect the battery until the proper voltage appears)
4. Charge the battery
    a. On the test computer NH Research DC PM 1 screen click the "More…" button and then the "Set Safety Limits" button
    b. Check that the battery voltage is within the global safety limits range and that the discharge safety limits and charge safety limits are set correctly for the battery being tested
    c. Click the "More…" button and then the "Set Battery Detect Voltage" button
    d. Set the voltage to 4V
    e. Click the "On/Off" button (there will be a loud click)
    f. Press the "Settings" Button and move the slide to charge
    g. Set the values to the ones shown below and press "ok"
        i. Max Voltage: 8.3V
        ii. Max Current: _____ (20A)
        iii. Max Power: _____ (0.166 kW)

h. Record the start time
i. Wait until the voltage of the battery is 8.3V and the current decreases to _____ (2A)
j. Rest the battery

5. Turn off the Battery Test System
    a. Once the test is complete press the “More…” button on the computer and select the red “Exit/Shutdown” button, click either “Logout” or “Shutdown,” and wait until it closes
    b. Then do the same thing on the Battery Test System screen
    c. Once the screen on the Battery Test System is black turn off the system in the opposite order as it was turned on - On/Standby, Operation - Ready, Power module 2, Power Module 1

Constant Discharge Procedure

1. Check that the battery being tested is fully charged using a multimeter (8.3 V)
2. Put the batteries into the compressing case (see above for instructions)
3. Ensure the Battery Test System and thermal chamber are turned off completely
4. Connect the battery in the test chamber
    a. Make sure the positive and negative terminals from the battery test system aren't touching and don't ever touch
    b. First connect the positive terminal of the battery to the positive terminal of the Battery Test System and then the negative terminal to the negative terminal
    c. Ensure the battery is completely on the plastic mat
5. Turn on Battery Test System
    a. Turn the system on from the bottom up - Power Module 2, Power Module 1, Operation turned to Ready, On/Standby
    b. Wait until the Battery Test System displays the "NH Research DC PM 1" screen. This screen shows the voltage, current, power, and energy of the battery connected in the chamber
    c. Open PowerPanel on the testing computer
    d. Ensure the voltage of the battery in the testing system is the same as the voltage recorded with the multimeter (If not, reconnect the battery until the proper voltage appears)
6. Run the Test
    a. Record the date, test type, initial open circuit voltage in V, and initial Ah
    b. On the test computer NH Research DC PM 1 screen click the "More…" button and then the "Set Safety Limits" button
    c. Make sure the battery voltage is within the global safety limits range and that the discharge safety limits and charge safety limits are set correctly for the battery being tested
    d. Click the "More…" button and then the "Set Battery Detect Voltage" button
    e. Set the voltage to 4V
    f. Click the "On/Off" button (there will be a loud click)
    g. Press the "Settings" Button and move the slide to the discharge section
    h. Set the values to the ones shown below and press "ok"

i. Max Voltage: 5V
ii. Max Current: _____ (20A)
iii. Max Power: _____ (0.1 kW)

i. Record the start time
j. Wait until the Active Mode Ampere-Hours in the Energy section of the screen reaches 6.6Ah and then press the “On/Off” button again (there will be another loud click)
k. Record the end time
l. Rest the battery
m. Record the Final OCV in V and the final Ah
n. Perform the test at the following SOC percentages by repeating the steps above: 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%

7. Turn off the Battery Test System
    a. Once the test is complete press the “More…” button on the computer and select the red “Exit/Shutdown” button, click either “Logout” or “Shutdown,” and wait until it closes
    b. Then do the same thing on the Battery Test System screen
    c. Once the screen on the Battery Test System turns black turn off the system in the opposite order as it was turned on - On/Standby, Operation - Ready, Power module 2, Power Module 1

Electrochemical Impedance Spectroscopy (EIS) Test Procedure

When performing this test make sure the following do not occur

- The positive Battery Test System terminal, negative Battery Test System terminal, impedance analyzer CE connector, and impedance analyzer WE connector never touch each other
- When opening the testing chamber doors make sure the disconnecting and connecting of the battery terminals is done quickly to not change the temperature in the testing chamber

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Impedance Analyzer Experiment Setup

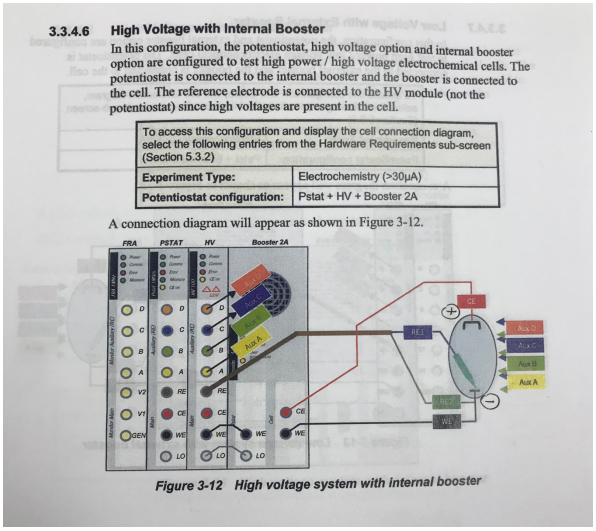
1. Open the Modulab program on the computer
    a. To start an experiment, a new project needs to be created
    b. Create a new project by clicking “File” on the marked menu bar and then “New Project”
    c. Input a name and some comments for the project that can be used later to identify the work
    d. Press the “Create Project” Button
2. Preparing Modulab for the experiment
    a. Click on the “Setup” button under Experiment 1
    b. Under the “Hardware Requirements” dropdown make the following changes
        i. Experiment Type: Electrochemistry (>30μA)
        ii. Potentiostat Configuration: Pstat+HV+Booster 2A
        iii. Leave all other sections as default
    c. Ensure the panel on the right shows the proper connection diagram displayed above
    d. Click the “1: Step” button that appears directly below the “Setup” button
    e. Under the “Impedance Current Control” dropdown, select the “Galvanostatic Impedance” button
    f. Under the “Impedance Setup” dropdown make the following changes
        i. Technique: Frequency Sweep
        ii. Amplitude (rms): _____ ($\sqrt{2}$ A rms or smaller)
        iii. Start Frequency: 1 mHz
        iv. End Frequency:1 kHz

Thermal Chamber Experiment Setup

1. Changing the temperature in the thermal chamber
    a. Turn on the thermal chamber and set it to the desired test temperature (See the Lab Procedure Manual for instructions)
    b. Wait until the process value display reaches the desired temperature
    c. Wait 4 hours for the battery to reach and stabilize near the desired temperature

Starting the EIS Test

1. Put the batteries into the compressing case (see above for instructions)
2. Measure the voltage of the battery using a multimeter and record it in the spreadsheet
3. Connect the battery to the impedance analyzer
    a. Make sure the battery is disconnected from the Battery Testing System
    b. Connect the CE Wire (red end) to the positive terminal and then connect the WE wire (blue and green end) to the negative terminal
4. Turn on the impedance analyzer



3.3.4.6 **High Voltage with Internal Booster**

In this configuration, the potentiostat, high voltage option and internal booster option are configured to test high power / high voltage electrochemical cells. The potentiostat is connected to the internal booster and the booster is connected to the cell. The reference electrode is connected to the HV module (not the potentiostat) since high voltages are present in the cell.

To access this configuration and display the cell connection diagram, select the following entries from the Hardware Requirements sub-screen (Section 5.3.2)	
Experiment Type:	Electrochemistry (>30µA)
Potentiostat configuration:	Pstat + HV + Booster 2A

A connection diagram will appear as shown in Figure 3-12.

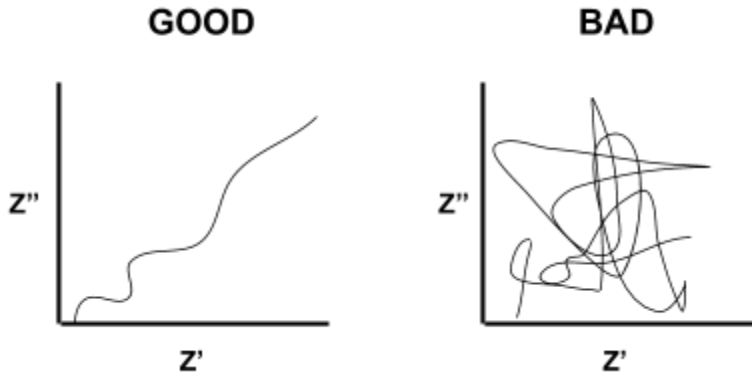
Figure 3-12 High voltage system with internal booster

    a. Ensure the analyzer has the set up of the picture shown below
    b. Ensure a battery is not connected to the impedance analyzer
    c. Flip the single power switch on the back of the device
    d. Wait for the impedance analyzer to complete its startup sequence - All “Power” lights and the right two “Comms” lights will be green and steady
5. Open the Nissan Leaf Battery Project

6. Start the Experiment
    a. Click “Experiment” under the Project tab
    b. Click the “OC Measure” button to the left of the run button to measure the open circuit voltage of the battery in the testing chamber (the measured voltage will be displayed at the bottom of the screen under “Measurements”)
    c. Make sure the voltage measured is the same as the initial voltage measured at the beginning of the test
    d. Click the “Experiment 1” button in the left panel and then the “run” button in the right panel to start the experiment
    e. When the experiment is running, the “CE on” button on the Solartron analytical machine will be yellow
    f. To ensure the experiment is running properly change the “Graph 1” under the “Axes” tab to “I vs. Time” (a sine wave will appear showing the changing current over time)
    g. When “idle” is shown under “Step” at the bottom of the screen, the experiment is complete
    h. If for any reason the test needs to be stopped during the experiment click the “Stop All” button in the toolbar
7. Once the test is completed
    a. Disconnect the impedance analyzer from the battery terminals and connect the battery to the Battery Testing System
    b. Be sure to not touch any terminals together and to complete this task quickly to not change the temperature in the testing chamber
8. Perform the test at the following SOC percentages by repeating steps 4-6 above: 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%
9. Turn off the impedance analyzer
    a. Make sure the analyzer is not being used in any experiment
    b. Turn off the power switch on the back of the device

Nissan Leaf Battery Testing Shortened Procedure

1. Put the batteries into the compressing case (see above for instructions)
2. Connect the battery to the Battery Test System in the thermal chamber
3. Turn on the battery test system
4. Open PowerPanel on the testing computer
5. Fully charge the battery
    a. Max Voltage: 8.3V
    b. Max Current: _____ (20A)
    c. Max Power: _____ (0.166kW)
6. Rest the battery
7. Record the OCV
8. Disconnect the battery from the testing chamber and connect it to the impedance analyzer
9. Turn on the impedance analyzer
10. Open ModuLab ECS on the testing computer and go to setup under the project labeled "Nissan Li-ion Battery"
11. Measure the OCV of the battery with Modulab and make sure it is the same as the voltage recorded in step 6 (checks to see if the battery is connected properly)
12. Click "Run" to start the EIS test
13. The software will show a graph under "Graph Setup"
14. Select the "I vs Time" graph and a sinusoidal wave starting with the negative cycle should appear
15. The test will end on its own and when it is finished "idle" will appear under "Step" at the bottom of the screen
16. Once the test is done, check the "Complex (Z)" graph to verify whether the testing done was successful



17. Disconnect the battery from the impedance analyzer, turn off the impedance analyzer, and connect the battery to the Battery Test System
18. Discharge the battery until the Active Mode Ampere-Hours in the Energy section of the screen reaches 6.6Ah (10% of the total capacity)
    a. Max Voltage: 5V
    b. Max Current: _____ (20A)
    c. Max Power: _____ (0.1kW)
19. Rest the battery
20. Record the OCV for the battery after the resting time
21. Repeat steps 6-18 to complete the test for the SOCs of 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%
22. Once the tests are complete for the battery turn off the Impedance analyzer and Battery Test System