The Voltage Multiplier

The Voltage Multiplier (Item code: VOLT.MULT.S) is an external device which can be used to extend the voltage input/output of the Metrohm Autolab VIONIC, PGSTAT302N, PGSTAT128N, PGSTAT204, PGSTAT101, M101 and M204 (one per channel) instruments.

When used to apply potential or current to a device under test (DUT), the voltage multiplier extends the applied voltage range from ±10 V to the compliance voltage of the PGSTAT. This allows the study of the electrochemical behavior electrochemical system even if the applied voltage must be higher than ±10 V.

Table 1 shows the compliance voltages for the Autolab PGSTATs.

Table 1 - the compliance voltages for the Autolab PGSTATs

PGSTAT	Compliance Voltage
VIONIC	±50 V
PGSTAT302N	±30 V
PGSTAT128N	±12 V
PGSTAT101 / M101	±10 V
PGSTAT204 / M204	±20 V

The VOLTAGE MULTIPLIER is directly connected to the device under test (DUT).

Note

The Voltage Multiplier cannot be used in combination with an existing PGSTAT100N.

Important restrictions

1. The Voltage Multiplier reduces the **input impedance** of the differential amplifier to ~ 100 kΩ. Use the Voltage Multiplier ONLY when the total impedance of the DUT is very low with respect to the input impedance (typically, 100 Ω or less).
2. When the Voltage Multiplier is used, the **rise time** of the applied potential to the cell will increase. The magnitude of the increase depends on the cell characteristics.

1 – How Does the Voltage Multiplier work

In practice, the Voltage Multiplier works as a divider. It divides the potential measured by the differential amplifier by a factor 10. Since in potentiostatic mode this voltage is used in the feedback loop, the division forces the control amplifier to increase the output voltage to maintain the setpoint potential. Therefore, the voltage output of the potentiostat is multiplied by a factor 10, up to a maximum voltage equal to the compliance voltage of the instrument.

Figure 1 provides a schematic of the role of the voltage multiplier.

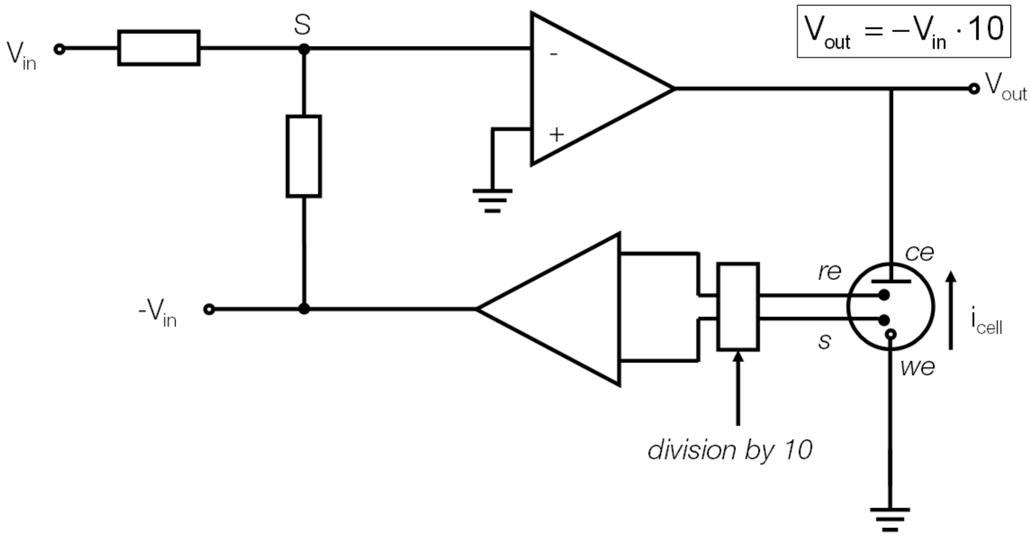

Figure 1 – Schematic overview of the voltage multiplier in the potentiostatic control loop

In galvanostatic mode, the current is controlled by the feedback loop and the potential, divided by 10, is directly measured (not controlled) by the differential amplifier. However, here the compliance voltage of the control amplifier will limit the current which can be delivered through the cell. Therefore, the voltage measured by the differential amplifier together with the voltage multiplier will be up to the compliance voltage of the instrument, like in the case of potentiostatic mode.

2 – Part list

The Voltage Multiplier kit includes the following items:

1. The Voltage Multiplier box (see Figure 2)
2. A red 30 cm long male banana-to-banana cable
3. A blue 30 cm long male banana-to-banana cable

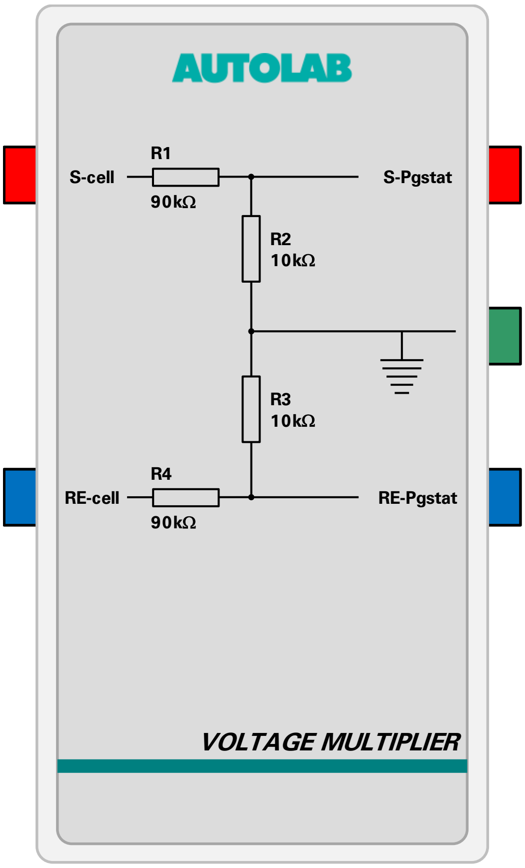

Figure 2 – The Voltage Multiplier

3 – Connections to the instrument

Connect the cell cables coming from the differential amplifier of the PGSTAT (cell cables labeled with S and RE) to the Voltage Multiplier: connect the Sense lead (S) to the S-Pgstat connector and the Reference lead (RE) to the RE-Pgstat connector on the voltage multiplier.

The Voltage Multiplier provides two connections to the DUT: one labeled as S-Cell and the other one labeled as RE-Cell.

When using a 2-electrode connection setup (e.g. connecting the PGSTAT and the Voltage Multiplier to a battery as DUT), connect the S-Cell connector to the WE banana connector of the PGSTAT and the positive pole of the DUT using the provided additional red cable. Connect the RE-Cell connector to the CE banana connector of the PGSTAT and the negative pole of the DUT using the provided additional blue cable (see Figure 3).

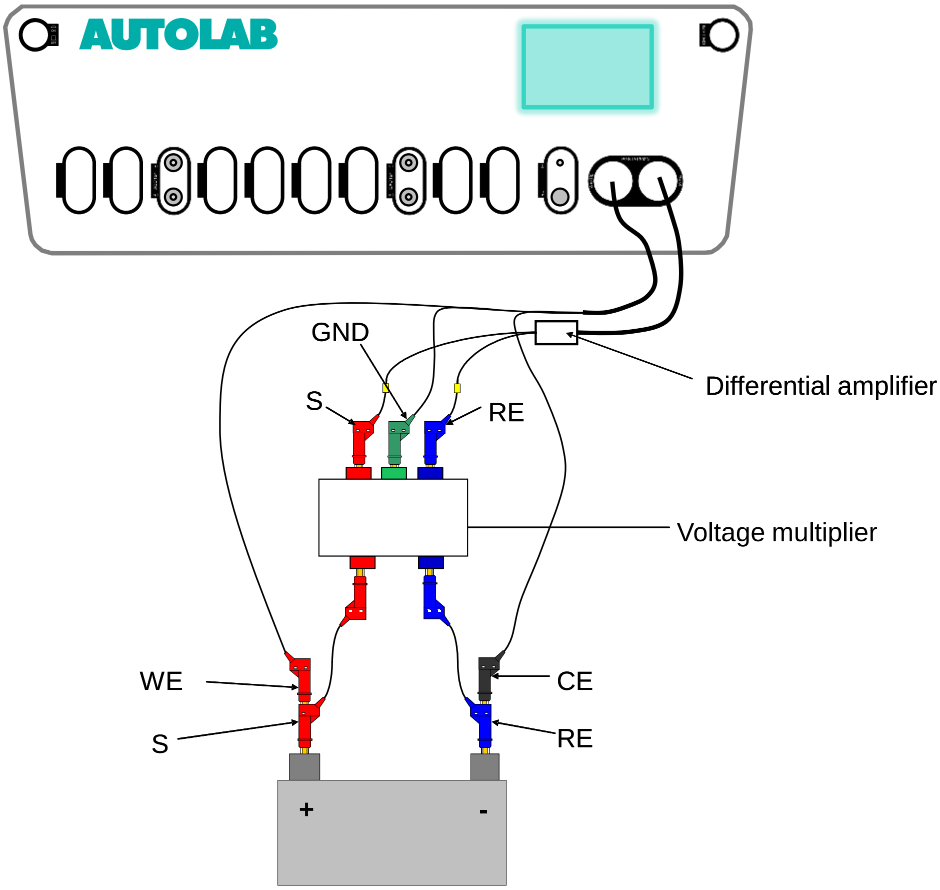

Figure 3 – Wiring diagram of the voltage multiplier between the DUT and the PGSTAT

Warning

Always connect the green EARTH ground cable from the PGSTAT to the GND connector on the voltage multiplier! The ground cable must be connected to the voltage multiplier at all times.

4 – Using the Voltage Multiplier

The Voltage Multiplier can be used in potentiostatic and in galvanostatic mode. In this manual, the tests have been performed using a PGSTAT204.

Note

The Voltage Multiplier does not affect the current range specifications of the PGSTAT.

4.1 – Potentiostatic mode

In potentiostatic mode, the potential applied without the use of the Voltage Multiplier cannot exceed ±10 V. To apply or record potentials higher than ±10 V, the Voltage Multiplier can be used.

Note

Please keep in mind that the potential measured with the Voltage Multiplier corresponds to the real potential difference divided by 10.

The Voltage Multiplier divides the potential measured by the Autolab PGSTAT by a factor of 10. The potential value introduced by the user must be divided by 10 as well.

Example 1: To apply 15 V to the Dummy Cell (e) (as DUT, see Figure 3), using the manual control in NOVA2, type 1.5 V into the Autolab display window (see Figure 4). Select the 10 µA current range (with the Dummy Cell (e), the current measured using a potential of 15 V is 15 µA). Switch the cell On. The measured current, on the dummy cell, is ~ 15 µA, i.e. ten times the value measured without the voltage multiplier.

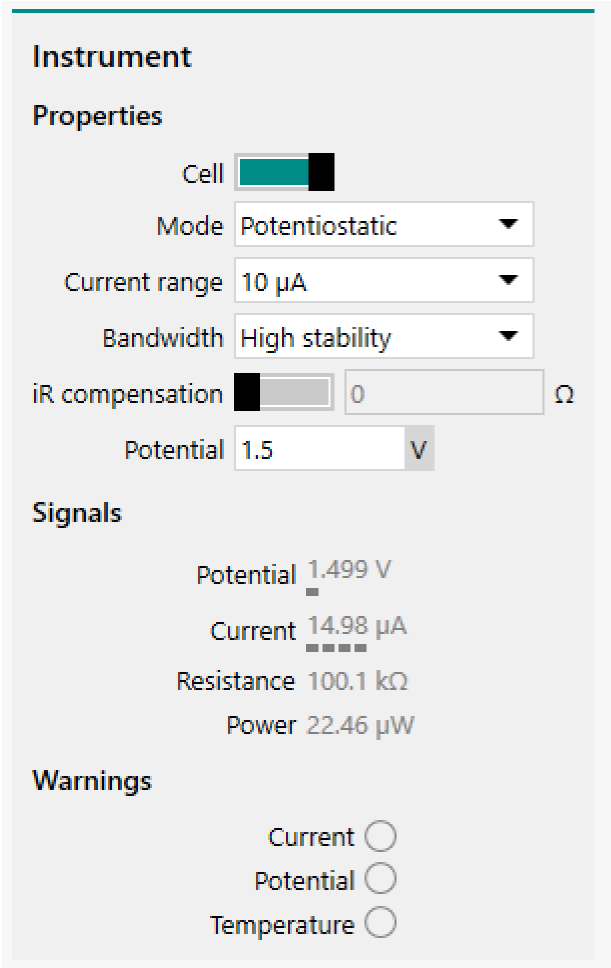

Figure 4 – Use the manual control in NOVA2 to apply 15 V to the dummy cell (e)

The same measurement example can be done by using VIONIC and the INTELLO software and connecting to the Autolab Test Cell (e) (as DUT, see Figure 3).

Example 2: Load the *Cyclic voltammetry potentiostatic* procedure in NOVA2 and start the measurement using the Dummy Cell (a) (as DUT, see Figure 3). The data presentation window will display a typical linear plot, but the slope of the plot will be ten times higher than without the Voltage Multiplier. The current values at the upper and lower vertex are 10 µA and -10 µA, respectively (see Figure 5).

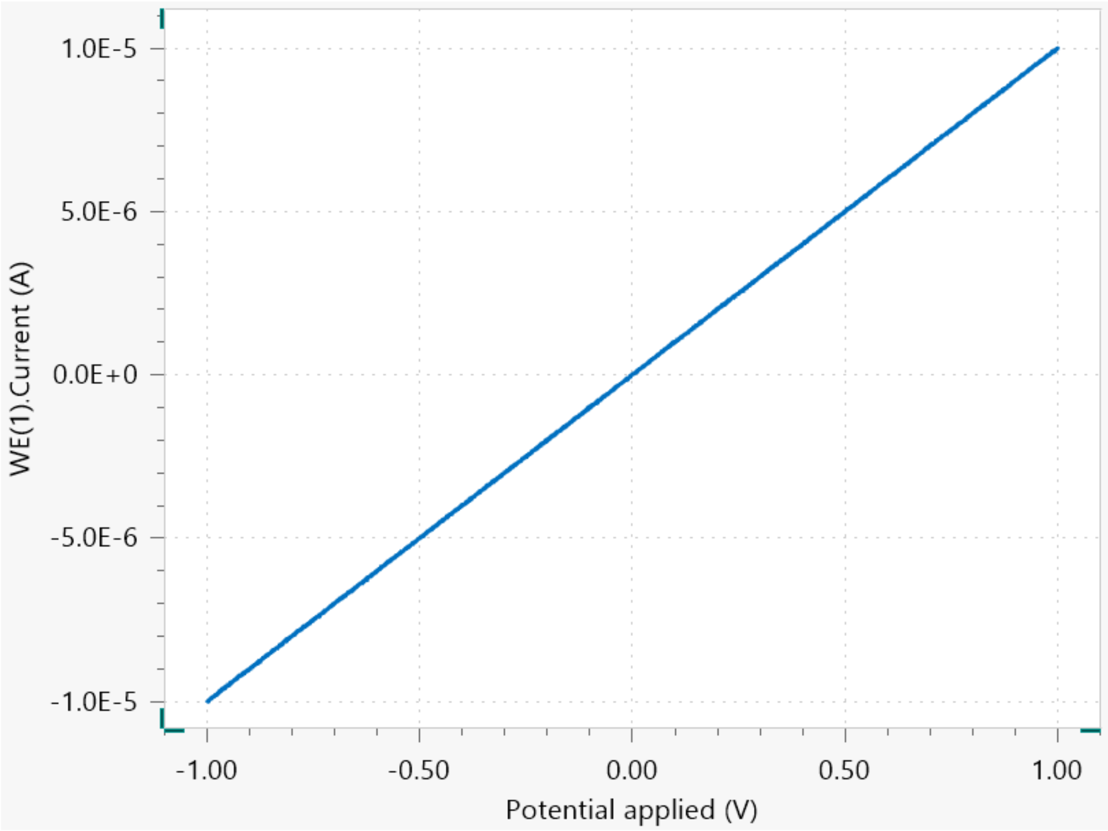

Figure 5 – The Cyclic voltammetry potentiostatic measurement in NOVA2 using the voltage multiplier

The same measurement example can be done by using VIONIC and the INTELLO software and running the CV staircase potentiostatic procedure and connecting to the Autolab Test Cell (a) (as DUT, see Figure 3).

Example 3: Load the *Cyclic voltammetry potentiostatic* procedure in NOVA2 and change the vertex potentials to + 4 V and - 4 V for the PGSTAT302N; to 1.5 V and -1.5 V for the PGSTAT 128N; to + 3 V and – 3 V for the PGSTAT204 and M204, and + 2 V and – 2 V for the PGSTAT101 and M101. Connect dummy cell (a) (as DUT, see Figure 3) and start the measurement. The data presentation window will display a linear response in a large potential range. The extremes of the scan are cut off, as the compliance voltage of the instrument is reached at ~ 20 V for the PGSTAT204. The results are shown in Figure 6.

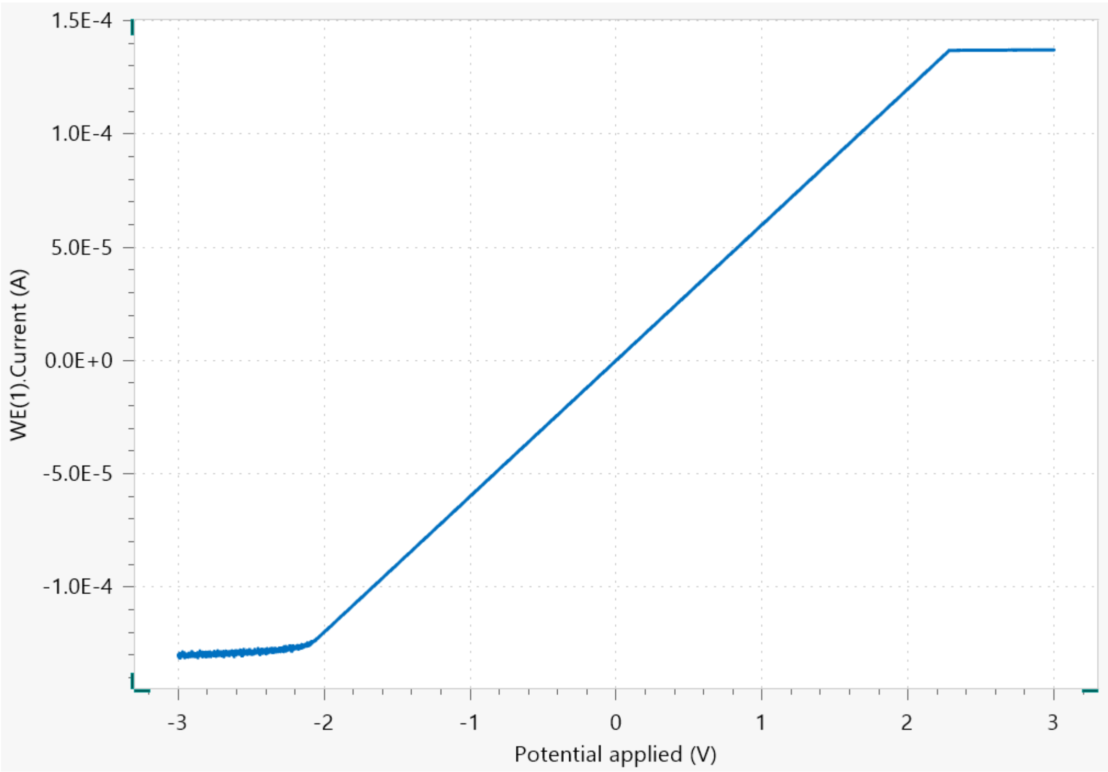

Figure 6 – The Cyclic voltammetry potentiostatic measurement in NOVA2 using the voltage multiplier showing the compliance voltage limit for the PGSTAT204

The same measurement (using the same parameters) described in Example 3 can be done by using VIONIC and the INTELLO software and running the CV staircase potentiostatic procedure and connecting to the Autolab Test Cell (a) (as DUT, see Figure 3).

Note

In NOVA2, it is possible to correct the order of magnitude of data to take the Voltage Multiplier into account after the measurement is finished (or in the procedure itself), using the Calculate signal tool. Click the CV staircase button in the data tab frame, then click the icon and then on *Calculate signal* (see Figure 7). The same can be done on the data measured with INTELLO, after transferring the data into NOVA2 by using the IN2NOVA tool in INTELLO.

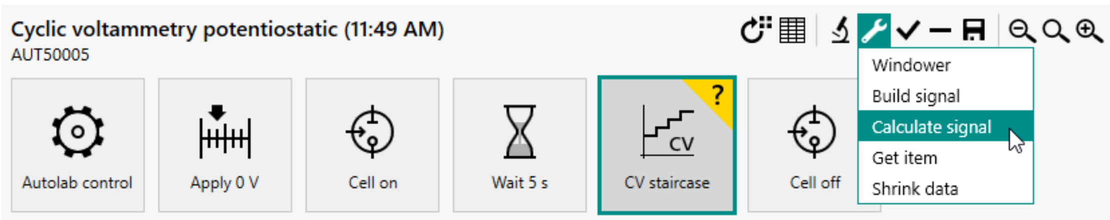

Figure 7 – Adding a Calculate signal to the measured data in NOVA2

In the *Calculate signal* window, specify the settings shown in Figure 8 to calculate a new signal called *Corrected potential*. Assign the potential signal to the Potential applied signal located below the *Link parameters* item.

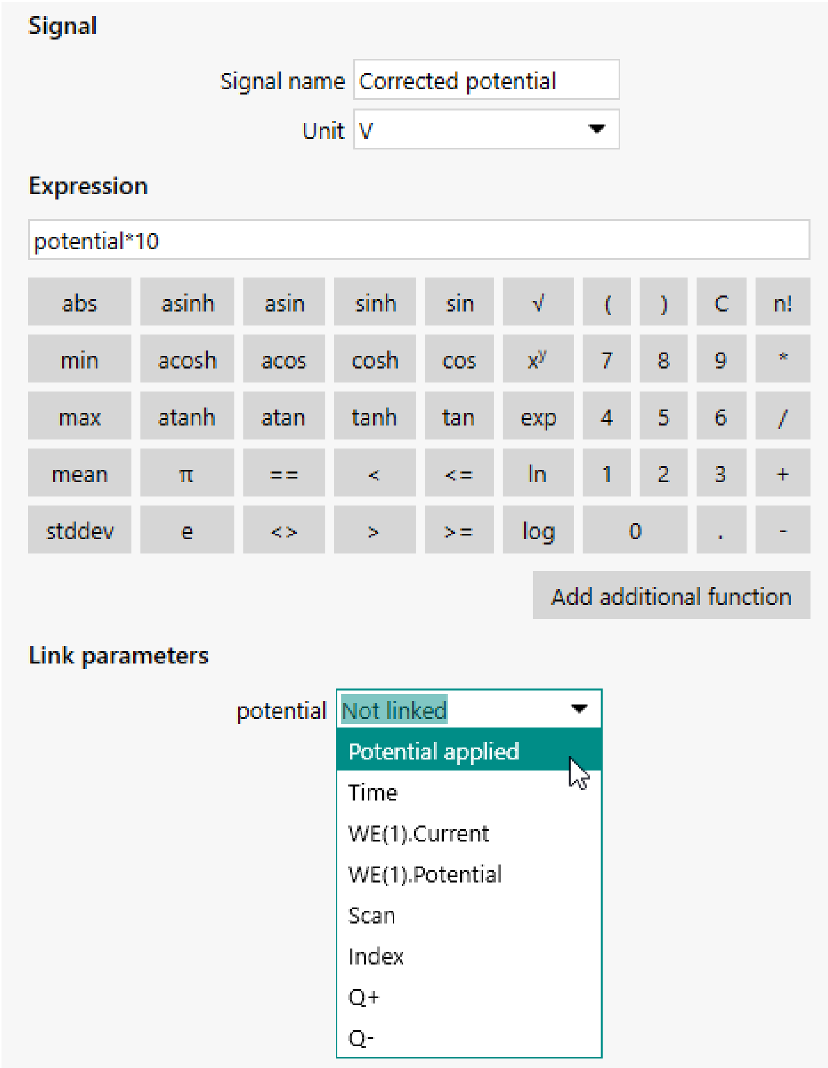

Figure 8 – Using the Calculate signal tool in NOVA2 to calculate the Corrected potential

In the *CV staircase* window, a custom plot can be created, with the X-axis setting to the new *Corrected potential* signal to display the data using the multiplied values (see Figure 9).

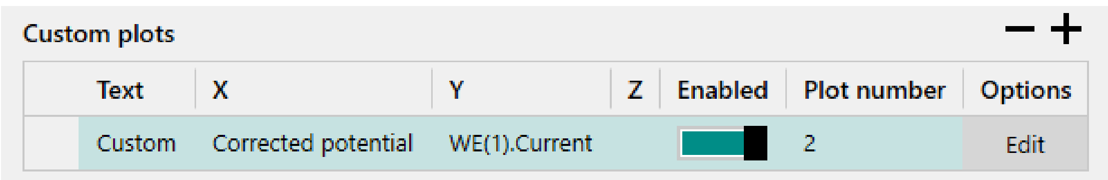

Figure 9 – The custom plot in NOVA2 with the X-axis displaying the Corrected potential

The plot will be adjusted and will display the correct potential scale (see Figure 10).

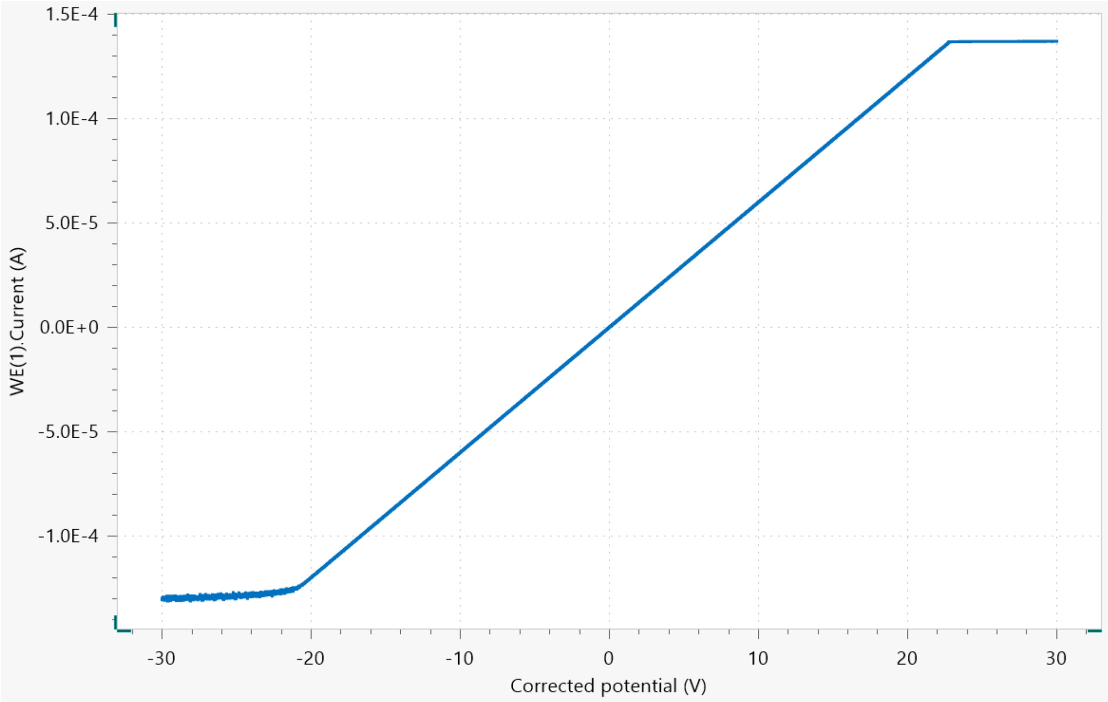

Figure 10 – i (A) vs E (V) plot with the adjusted potential scale in NOVA2

4.2 – Galvanostatic mode

In galvanostatic mode, the measured potential cannot exceed ±10 V without the Voltage Multiplier. In this case, the Voltage Multiplier acts as a voltage divider, allowing the measurement of potentials higher than ±10 V, up to the compliance voltage of the instrument.

Note

1. Please keep in mind that the measured potential displayed in the software corresponds to the real potential difference, divided by 10.
2. When VIONIC powered by INTELLO is used, the maximum measurable potential difference between the Second Sense (S2) and the Reference electrode is ±50V. For more details, please see the detailed specifications and the User manual of VIONIC.

Example 4: To apply 12 µA to the Dummy Cell (a) (used as DUT, see Figure 3), using the manual control in NOVA2, type 12 µA into the Autolab display window (see Figure 11). Select the 100 µA current range. Switch the cell on. The measured potential, on the dummy cell, is ~ 1.2 V, i.e. the real potential of 12 V, divided by 10.

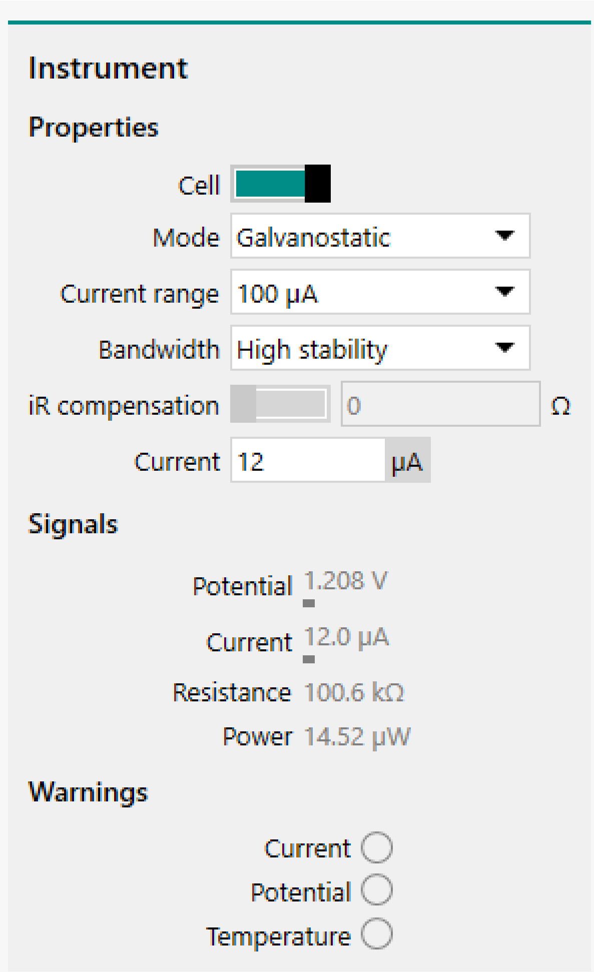

Figure 11 – Use the manual control in NOVA2 to apply 12 µA to the dummy cell (a)

The same measurement (using the same parameters) described in Example 4 can be done by using VIONIC and the INTELLO software and connecting to the Autolab Test Cell (a) (as DUT, see Figure 3).

Example 5: Load the *Cyclic voltammetry galvanostatic* procedure in NOVA2. Change the vertex currents to + 1.2 mA and -1.2 mA. Connect dummy cell (e) (as DUT, see Figure 3) and press the start button. The data presentation window will display a linear response in a large potential range (see Figure 12). The potential limits are + 1.2 V and -1.2 V, corresponding to +12 V and -12 V, respectively.

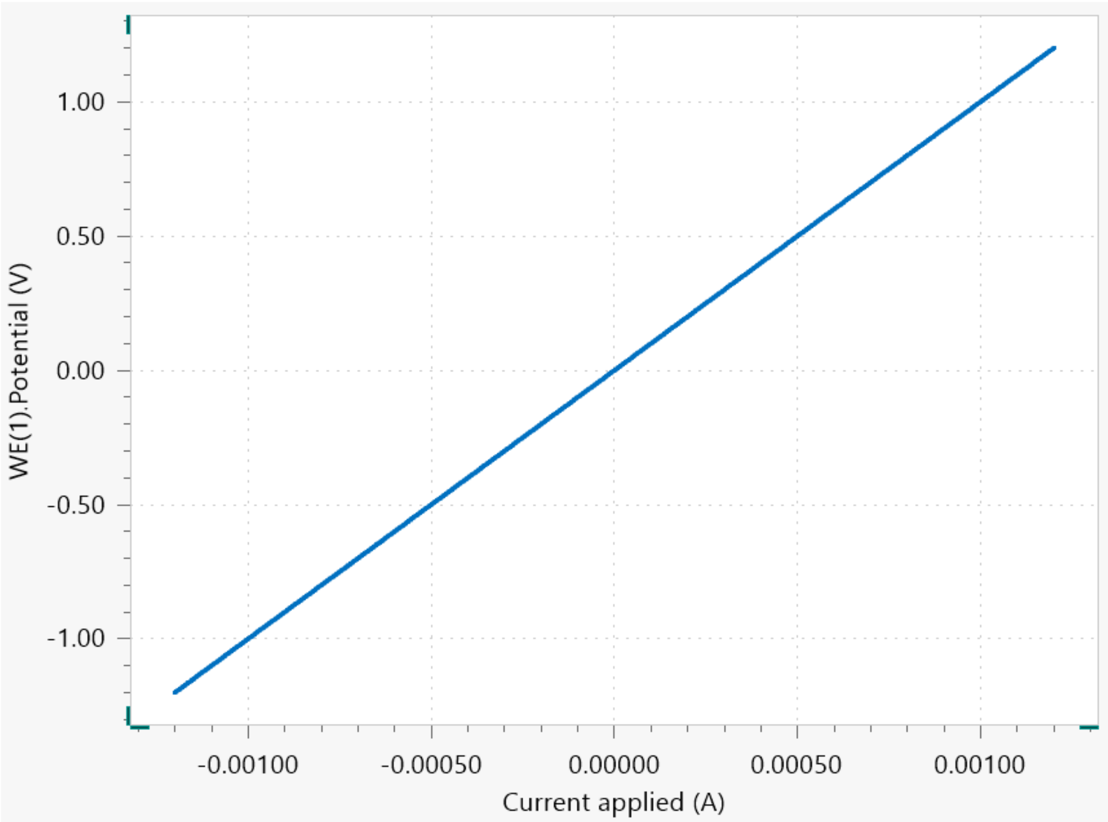

Figure 12 – The Cyclic voltammetry galvanostatic experiment in NOVA2 using the voltage multiplier

The same measurement (using the same parameters) described in Example 5 can be done by using VIONIC and the INTELLO software and connecting to the Autolab Test Cell (e) (as DUT, see Figure 3).

Note

In NOVA2, it is possible to correct the data to take the Voltage Multiplier into account after the measurement is finished (or in the procedure itself), using the Calculate signal tool (see Figure 13). The same can be done on the data measured with INTELLO, after transferring the data into NOVA2 by using the IN2NOVA tool in INTELLO.

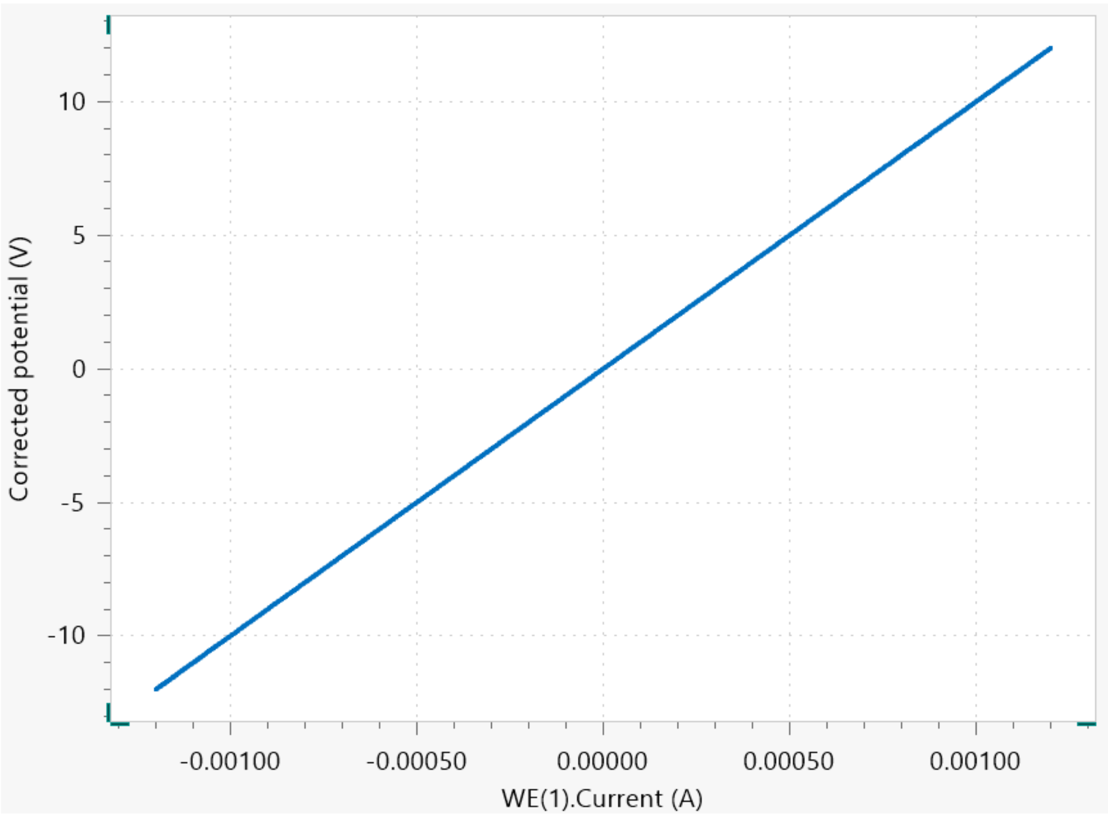

Figure 13 –Corrected (recalculated) potential scale using the Calculate signal tool in NOVA2

5 – External programming of test equipment devices

With the Autolab PGSTATs in combination with NOVA2, it is possible to program various test equipment devices, like electronic loads or boosters (other than the Autolab Booster10A and Booster20A). This is particularly useful in the case of measuring DUTs whose specs fall out of the compliance voltage and current of the Autolab PGSTATs.

In such cases, the test equipment devices are programmed by the DAC channel of the Autolab PGSTATs.

As an example, the test of a fuel cell can be taken into consideration. Here, an electronic load can be connected in series to the fuel cell and controlled in NOVA2 (through the DAC164 of the Autolab PGSTAT), to draw current and measure the potential with the PGSTAT. In this case, the control loop of the Autolab PGSTAT is used (the WE and CE leads are not used).

From the analog output of the electronic load, it is possible to measure the signal related to the current by using the ADC channels of the PGSTAT and NOVA2. Besides, the voltage multiplier is used to measure the potential drop across the entire (or part of the) stack, or across a single cell. In any case, the potential difference which can be measured together with the Voltage Multiplier can be in principle extended up to the compliance voltage of the PGSTAT. The schematics is shown in Figure 14

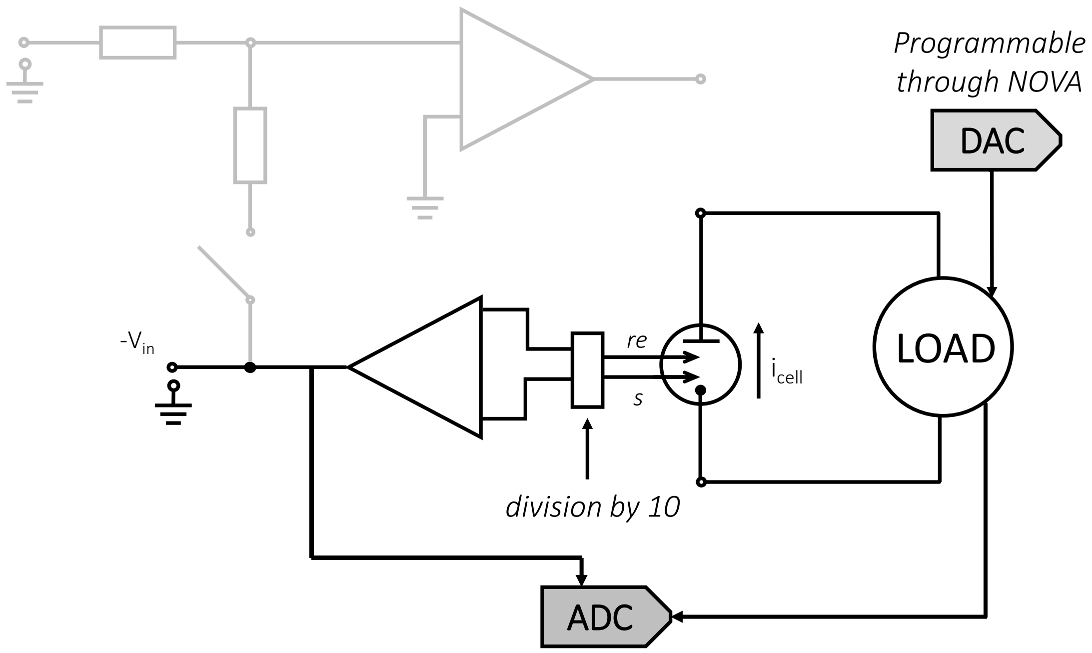

Figure 14 – Basic schematics of the connection setup including an Autolab PGSTAT (with NOVA2) and an electronic load. See text for details.

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