



Application Note 1084-402

AC Transport “constant current” vs. “low impedance” modes

The AC Transport option offers the user the ability to put the current source in a low output impedance mode. This mode is useful when investigating materials with highly nonlinear I-V characteristics (e.g., tunnel junctions). This mode is described briefly in Sec. 3.2.1 of the AC Transport user’s manual, but will be expanded upon in more detail in this application note. Please read this note as well as Chapter 3 of the AC Transport manual before performing measurements in low impedance mode.

NOTE: “low impedance” mode refers to the output impedance of the current excitation source, and is obtained by un-checking the “constant current mode” box that appears in the I-V, resistivity, and Hall coefficient measurement dialogs. In contrast, the “low resistance mode” check box in resistivity dialog and the “small coefficients mode” check box in Hall coefficient dialog refer to the resistance of the sample and are not relevant to this discussion.

In constant current mode, the drive circuit of the ACT is a good approximation of an ideal current source, providing the requested excitation up to the 20 volt compliance of the source. In low impedance mode (equivalent circuit shown in lower half of Fig. 1), the drive circuit can be represented by a voltage source behind the source resistance R_{source} (lead resistance is also represented here, and will be discussed below).

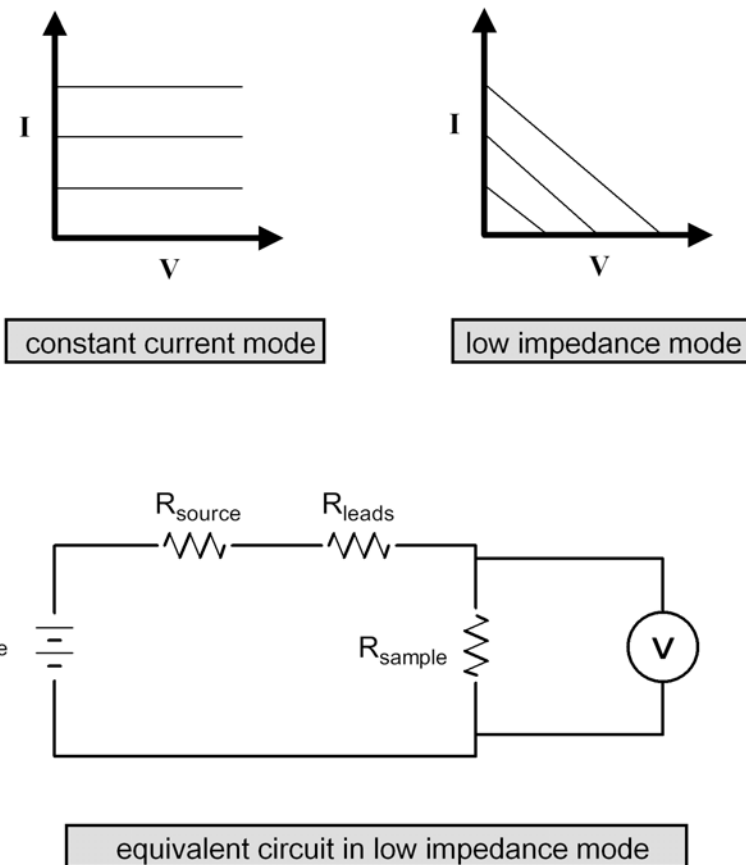


Figure 1. ACT current source load lines in constant current and low impedance modes

The load lines in the graphs in Fig. 1 show the supplied current as a function of voltage for three different requested values of excitation current. In the case of low impedance mode, the family of lines is given for one particular current range. If the current range is changed, the slope of these lines will be different, as shown in Fig. 2. For ease in viewing in Fig. 2, only 4 representative currents were chosen on each range: 40, 60, 80 and 100 % of full range. Also, this is done only for the highest three current ranges of 20 mA, 200 mA, and 2 A. The dashed line shows the I-V curve for a 100 Ohm resistor. For example, in the 200 mA range and with a requested current of 80 mA (40% of full range), the source will supply only about 40 mA (see intersection of dashed line and lowest blue line in Fig. 2). The maximum input for the AC Transport voltmeter is 5 volts, so the grey region of the graph is not accessible for measurements.

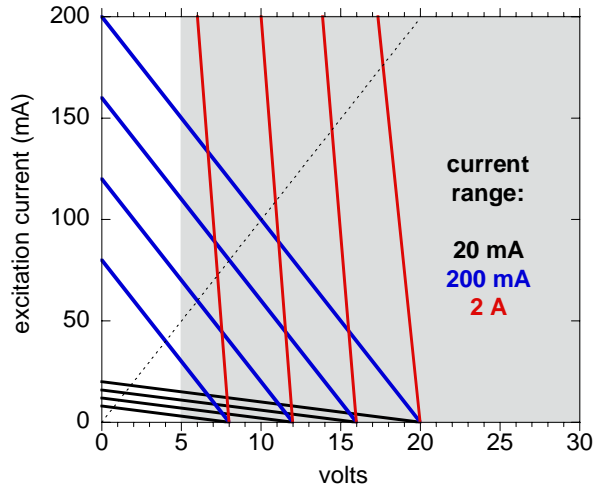


Figure 2. ACT drive circuit load lines in low impedance mode and using various current ranges.

In low impedance mode, the maximum value of V_{source} is 20 volts. Thus, R_{source} takes different values depending on the current range, and varies from 10 Ohms to 100 kOhms. See Table 3-1 in the AC Transport user manual, which is also duplicated at the end of this application note.

IMPORTANT: the AC Transport software reports only the *requested* current in the measurement data file, not the actual current. So, when using low impedance mode one must deduce the real current from the reported voltage and the current range as follows:

$$I = \frac{\frac{(20\text{ V}) \cdot I_0}{I_{FULL}} - V_{meas}}{R_{source} + R_{leads}}$$

where:

- I real current
- I_0 requested current (“Excitation (mA)” in measurement .DAT file)
- I_{FULL} maximum current on this range, determined in I-V measurements by the value of the current limit chosen by the user
- V_{meas} measured voltage across sample (“Volts ch1” or “Volts ch2” in .DAT file)
- R_{leads} resistance of current leads, as shown in Fig. 1

The resistance of the current leads R_{leads} (including the ACT cable and the sample chamber wiring) is typically about 1.5 Ohm and is therefore only a significant part of the denominator in the above equation when R_{source} is small, i.e., when using the 200 mA range ($R_{source} = 100$ Ohm) and the 2 A range ($R_{source} = 10$ Ohm). Note that contact resistance at junctions to the sample or puck can increase the value of R_{leads} .

Thus, when using low impedance mode in I-V, resistivity, or Hall effect measurements one must apply the above correction to the current. In the case of Hall effect measurements this is complicated by the fact that V_{meas} is the transverse voltage instead of the longitudinal voltage drop along the sample, so the longitudinal voltage needs to be determined in a separate

measurement in order to make the correction to the current. This can be done, for example, by measuring Hall effect on Ch1 and standard resistivity on Ch2.

As an example, Fig. 3 shows I-V curves for a Zener diode on the 20 mA current range ($I_{FULL} = 20 \text{ mA}$; $R_{source} = 1 \text{ k}\Omega$) using both constant current and low impedance modes. The upper graph is the full I-V scan up to 20 mA, showing that applying the correction to the excitation current in low impedance mode (black dots) makes the data match with that taken in constant current mode ('+' symbols). If the excitation current is not corrected when measuring in low impedance mode, we see a significant artifact in the I-V curve (line). The lower graph in Fig. 3 shows a close-up at low currents and demonstrates the advantage of using the low impedance mode: the tilted load lines allow us to resolve the features in the curve even when the slope dI/dV is very small.

Table 3-1. Model 7100 Drive Source Impedance in Low-Impedance Mode

OUTPUT RANGE	NOMINAL DRIVE SOURCE IMPEDANCE
200 μA	100 $\text{k}\Omega$
2 mA	10 $\text{k}\Omega$
20 mA	1 $\text{k}\Omega$
200 mA	100 Ω
2 A	10 Ω

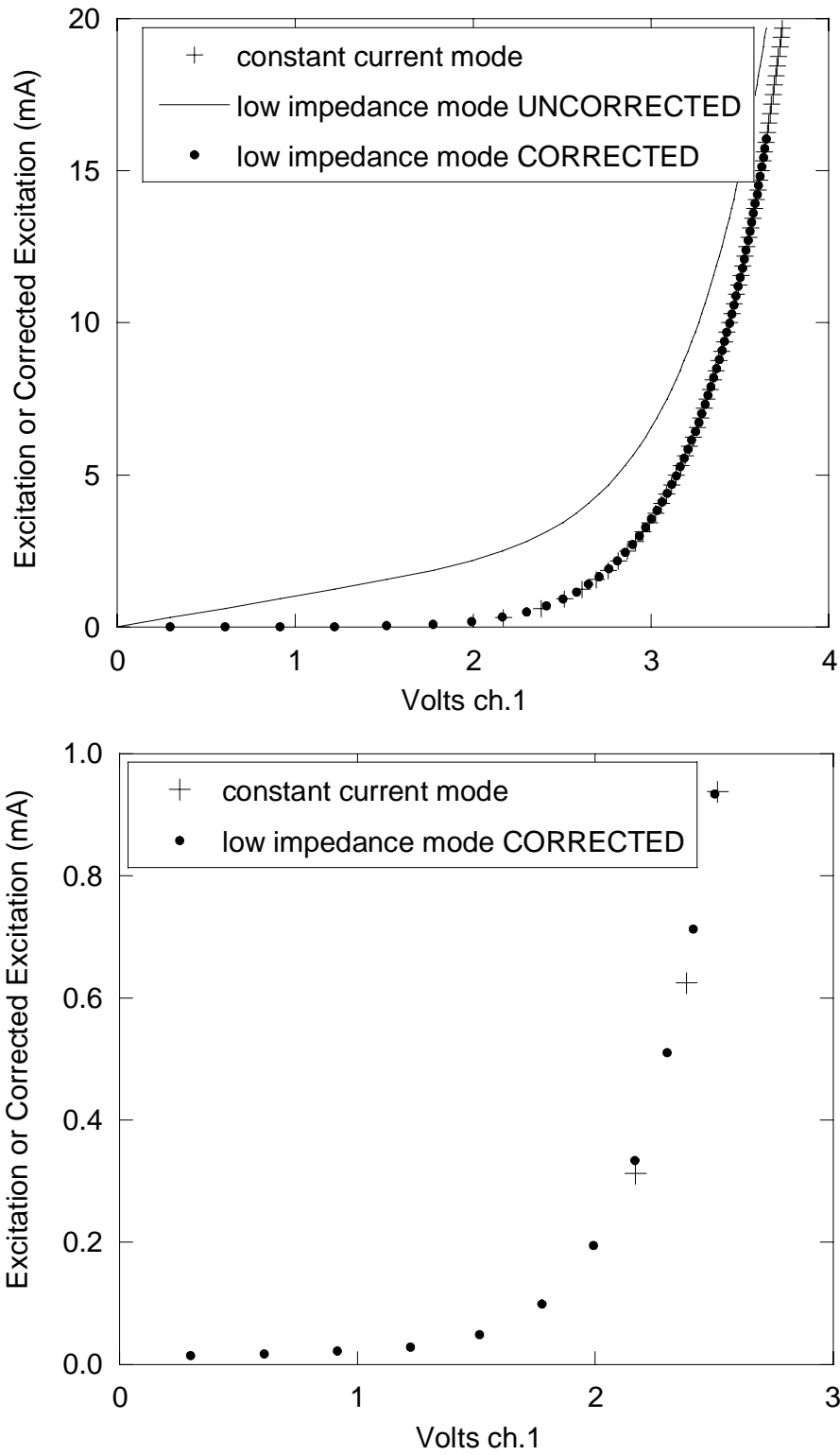


Figure 3. I-V curve of Zener diode using both constant current and low impedance modes