Application Note

Connection of the 1888 Megohmmeter/High Resistance Meter to the 1888-11 Resistivity Test Cell

The 1888-11 Resistivity Test Cell when used in combination with the 1888 Megohmmeter/High Resistance Meter provides a simple and easy to use system for the measurement of volume and surface resistivity.

The 1888 Megohmmeter can directly display volume resistivity and surface resistivity so that no calculations are required.

The 1888-11 contains all the required adapters and cables to directly connect to the 1888 Megohmmeter/High Resistance Meter.

The items included with the 1888-11 are the following:

1. 1888-11 Test Cell
2. BNC to Triaxial Adapter (goes to Detector)
3. BNC-M to Binding Post Adapter (goes to HV Out)

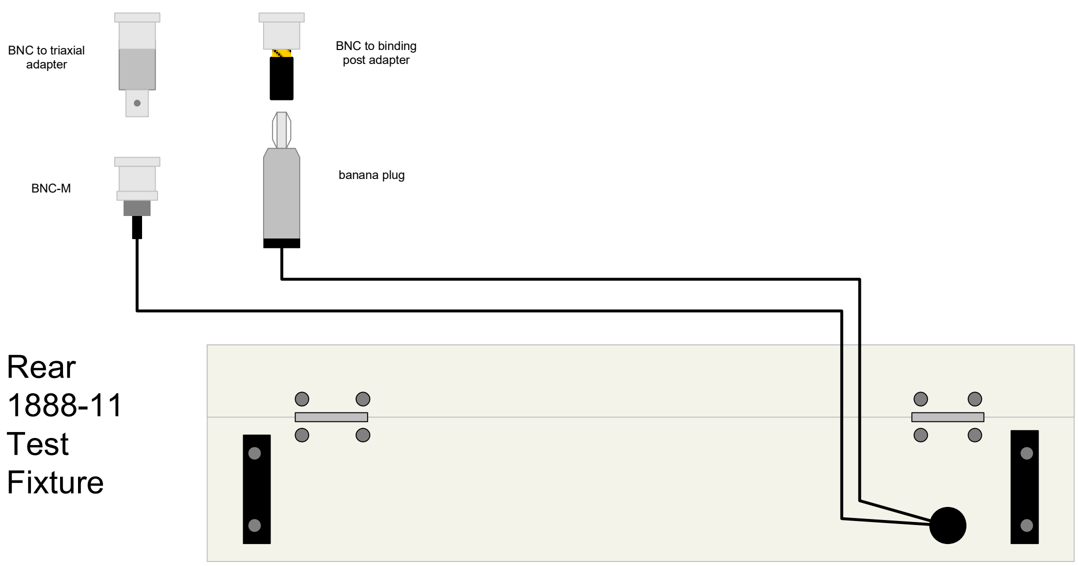

Figure 1: Rear View of 1888-11 Test Cell

The Resistivity Cell Fixture has a known geometry and using the formulas given in ASTM D257 we can use unique formulas to convert measured resistance into Surface Resistivity and Volume Resistivity. Measuring resistance through the fixture is theoretically the same concept as measuring without the fixture.

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Application Note

Volume Resistance is the **Resistance** through the chosen material whereas Surface Resistance is the **Resistance** on the surface of the chosen material. The 1888-11 Resistivity Fixture will allow stable and accurate measurement despite external radiation/ leakages.

How to Connect the Fixture

Make connections carefully as illustrated in Figure 2. It is important to follow these directions exactly to avoid improper measuring techniques and damage to the test fixture. Proper knowledge of material and fixture allows the DUT to be measured accurately while considering correct polarity.

To connect the 1888-11 fixture to an 1888 Megohmmeter:

1. First remove any DUT/Cables from the 1888 instrument.
2. Carefully insert the 1888-11 BNC Male into the BNC to triaxial adapter.
3. Insert the triaxial adapter into the **DETECTOR** on the 1888 instrument.
4. Insert the 1888-11 banana plug into the BNC to binding post adapter
5. Insert the BNC adapter into the **HV OUT** on the 1888 instrument**.**

Figure 2 illustrates the connection of the 1888-11 Test Cell to an 1888 Megohmmeter.

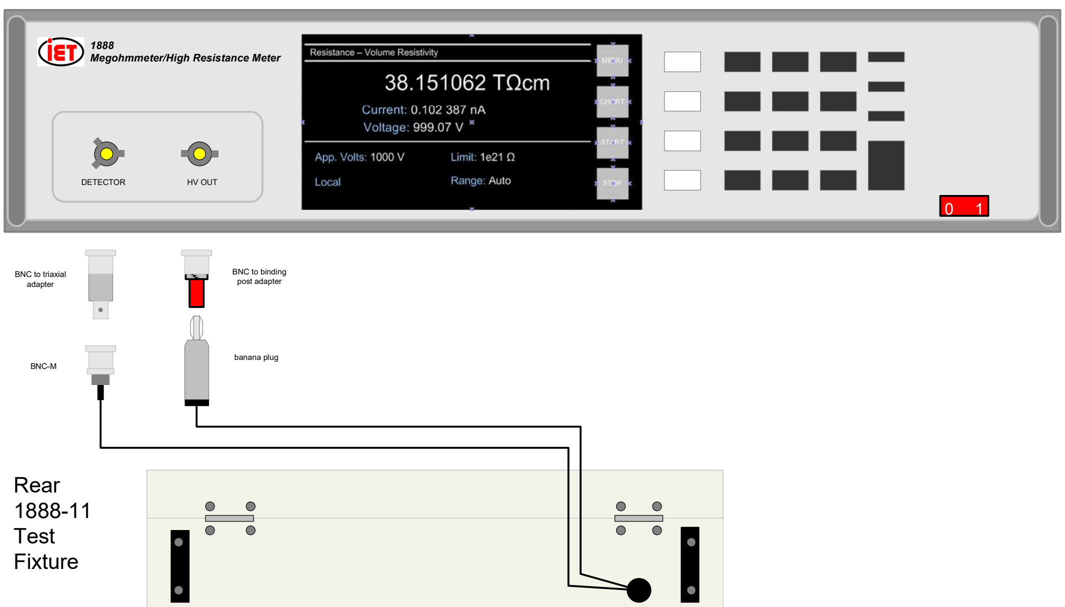

Figure 2: Connection of an 1888-11 Test Cell to an 1888 Megohmmeter

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Application Note

Performing a Zero

A zero should be performed each time the voltage is changed or during initial setup, to minimize errors in the measurement due to leakage in the 1888-11 Fixture and cables.

Make sure the 1888-11 is connected to the 1888, as shown in Figure 2.

Open the fixture and set the switch to either Rv or Rs, depending on which measurement is to be performed.

Using the 1888, go to MENU >> UTILITIES and select Zero. A Full Zero is recommended to zero Ranges 4, 5, 6, and 7. The Full Zero takes longer compared to Quick Zero, which only zeros Ranges 6 and 7. When prompted, press the Start button and verify that the zero process completes without any errors.

This completes the zeroing process.

Theory of Operation

> WARNING
> *Do not open the fixture while voltage is present at its output. Any material that holds charge may be hazardous until completely discharged.*

There are two methods of reading resistance yet each is used very differently. The first and most commonly used method for reading high resistance (megohm range) is the constant voltage method. In this method, voltage is applied in series with the resistor (or this case an insulator) and a current meter.

This will allow a known high voltage to pass through the resistor while the current meter detects the amount of current that passes through the insulator. Using Ohm's Law for resistance R= V/I the resistance of the insulation can be calculated and displayed.

The second method commonly used is a conductivity test. The conductivity test applies a known measured current through the resistor and measures the voltage drop across the resistance. This method has been used at a high resistance $<10^{10}$.

The measurement accuracy of both methods is affected by the surrounding electromagnetic environment (radiation). When measuring high resistance charging of the insulation is required to offset radiation effects. This occurs naturally when an object with a high concentration of electrons is moved near an object with no or a small number of electrons (or vise versa). Any slight electron change can result in noisy readings or wrong readings. One method to avoid noise is to use a Guard or Shield.

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Surface Resistivity

Surface Resistance is defined as the electrical resistance between two points or electrodes on one side of a material. This resistance is calculated using Ohm's law.

Rs = V/Is where:
Rs = Surface Resistance
Is = Surface Current
V = Applied Voltage

Surface Resistivity is defined as the electrical resistance between two points or electrodes on one side of a material with respect to the area of a "flat" annulus. The megohmmeter measures the current that travels on the surface of the material with respect to a distance and displays the resistance.

The easiest way is finding the area of two different circles and subtracting them. The space between two concentric objects is known as the annulus. The Surface Resistivity is calculated using the formula where ρs = Rs x L x W for a quadrilateral or in the case of the IET 1888-11 Resistivity Test Cell, an annulus.

ρs = (Rs x A) (Ω/sq.), where $A = \pi (a^2 - b^2)$ and a > b.
a = 3.5 cm radii for the outer electrode
b = 2.5 cm radii for the inner electrode

Substituting values into the equation based upon the diameters of the electrodes of the 1888-11 cell, gives a surface resistivity constant value of 18.84955 (1/sq). Therefore, if the measuring device reads 2.20 MΩ for the Rs value, multiply that value by 18.84955 (1/sq.).

ρs = Rs x A = 2.20 MΩ x 18.84955 1/sq. = 41.46901 MΩ/sq.

According to the ASTM D257 – 99 (2005) Standard, the formula for Surface Resistivity of a circular electrode is:

ρs = Rs x P/g (Ω/sq) where: $P = \pi (D_o)$
$D_o = (D1+D2)/2$
D1= diameter of inner electrode (cm)
D2= diameter of outer electrode (cm)
g = is the distance between them (cm)
ρs = Surface Resistivity in (Ω or Ω/sq.)

> Note: g can be factored out only if the thickness of the sample is much smaller than g.
> i.e.: t<<g ~ <8mm. 8mm is the max thickness of the 1888 Resistivity Test Cell.

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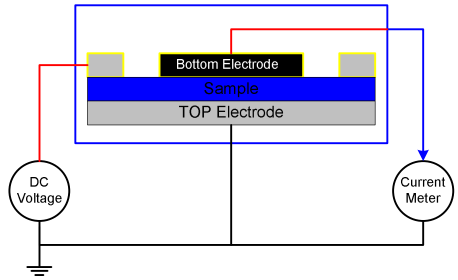

Figure 3: Surface Resistance

The 1888 Megohmmeter/High Resistance Meter Simplifies Calculations

The 1888 Megohmmeter/High Resistance Meter simplifies the calculations by allowing the operator to enter the surface resistivity cell constant into the menu and selecting Surface Resistivity as the display type.

The 1888-11 Volume/Surface Resistivity Cell comes with a label showing the surface resistivity cell constant which is 18.85 (1/sq.). The Cell Constants can be entered into the Cell Constants menu as shown in Figure 4.

The 1888 Megohmmeter has the default cell constants already preprogrammed for the 1888-11 Resistivity Cell. If another cell is used these constants can easily be changed to accommodate the new cell.

In the 1888 Menu>>I/O Settings the Display Type can be changed to Surface Resistivity. When Surface Resistivity is selected the calculations will be performed using the surface resistivity cell constant and the Surface Resistivity displayed as shown in Figure 5.

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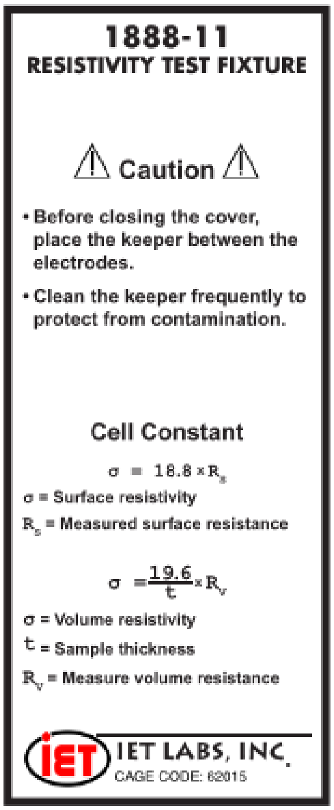

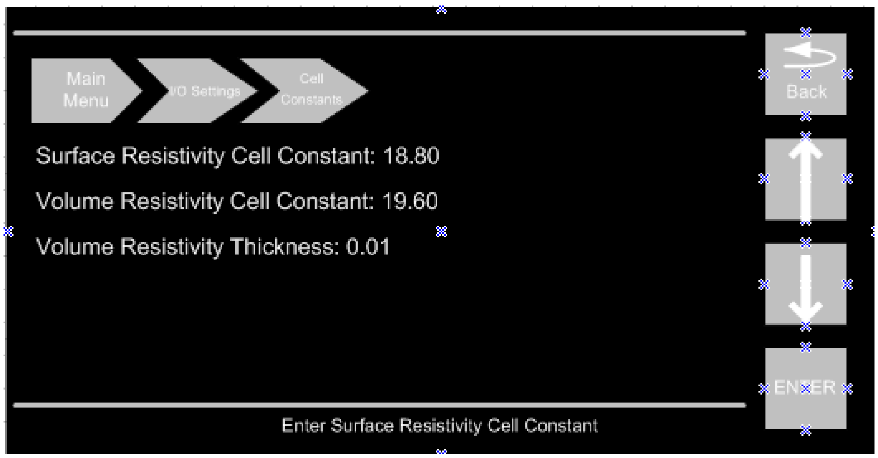

Figure 4: Surface Resistivity Cell Constants

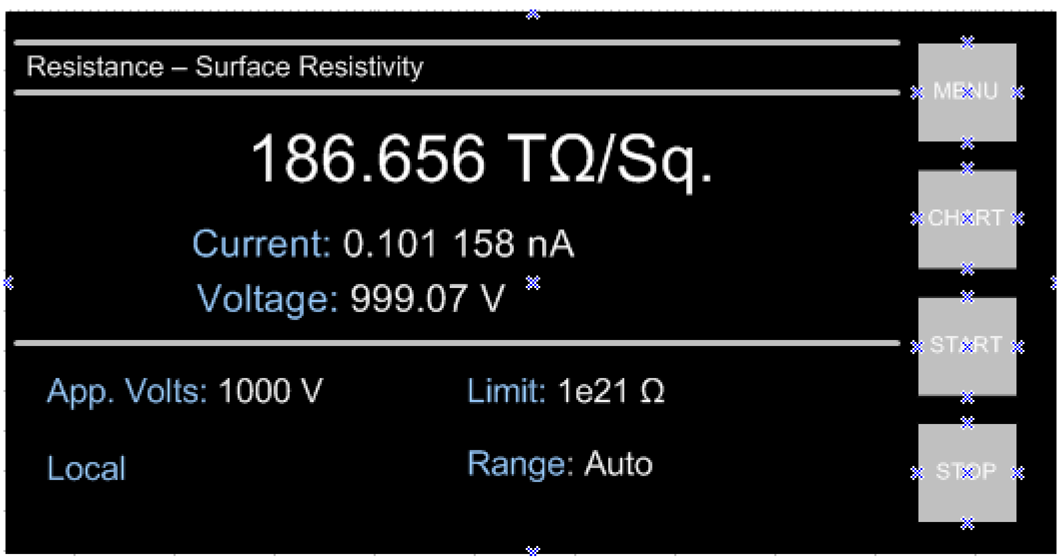

Figure 5: Surface Resistivity Display

Application Note

Volume Resistivity

Volume Resistance is defined as the electrical resistance between opposite faces of an insulating material. This resistance is calculated using the simplified version of Ohm's law.

Rv = V/Iv where:
- Rv = Volume Resistance
- Iv = Volume Current
- V = Applied Voltage

Volume Resistivity is defined as the electrical resistance through a specific volume on one side of a material to the opposite side. The measured resistance is multiplied by the cross sectional area (A) of the electrodes and divided by the thickness (t) of the material. This volume resistivity is calculated using the formula $\rho = [Rv \times L \times W]/t$ for a quadrilateral electrode or in the case of the IET Labs 1888 Resistivity Cell.

$\rho = [Rv \times A]/t\ (\Omega\cdot cm)$ where: $A = \pi (b^2)$ or $\pi (D1^2)/4$
- b = 2.5 cm radii for the inner electrode
- D1 = 5 cm diameter of inner electrode
- t = thickness of sample; needs to be << 8mm
- ρ = volume resistivity in (Ω * cm)

Substituting values into the equation for the diameters of the electrodes of the 1888-11 cell, gives a volume resistivity constant value of 19.634554 cm^2.

Therefore, if the measuring device reads 20.20 MΩ for the Rv value and the sample has a thickness of 3.3mm (0.33cm), then the volume resistivity is calculated as shown below.

$\rho = [Rv \times A]/t = [20.20\ M\Omega \times 19.634554\ cm^2]/.33cm = 1.201872\ G\Omega\cdot cm$

According to the ASTM D257 – 99 (2005) standard, the formula for Volume Resistivity of a circular electrode is:

$\rho = [Rv \times A]/t\ (\Omega\text{-}cm)$ where: $A = [\pi (D1+g)^2]/4\ (cm^2)$
- D1= diameter of inner electrode (cm)
- D2= diameter of outer electrode (cm)
- g = is the distance between inner & outer electrode (cm)

> Note: g can be factored out only if the thickness of the sample is much smaller than g.
> i.e.: t<<g ~ <8mm. 8mm is the maximum thickness of the 1888-11 Resistivity Cell.

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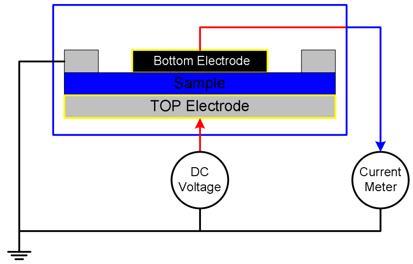

Figure 6: Volume Resistance

The 1888 Megohmmeter/High Resistance Meter Simplifies Calculations

The 1888 Megohmmeter/High Resistance Meter simplifies the calculations by allowing the operator to enter the volume resistivity cell constant and the thickness of the material into the menu and selecting Volume Resistivity as the display type.

The 1888-11 Volume/Surface Resistivity Cell comes with a label showing the volume resistivity cell constant which is 19.634554 cm^2. The cell constants and thickness of the material in cm, can be entered into the cell constants menu as shown in Figure 4.

The 1888 Megohmmeter has the default cell constants already preprogrammed for the 1888-11 Resistivity Cell. If another cell is used these constants can easily be changed to accommodate the new cell.

In the 1888 Menu>>I/O Settings the Display Type can be changed to Volume Resistivity. When Volume Resistivity is selected the calculations will be performed and the Volume Resistivity displayed as shown in Figure 7.

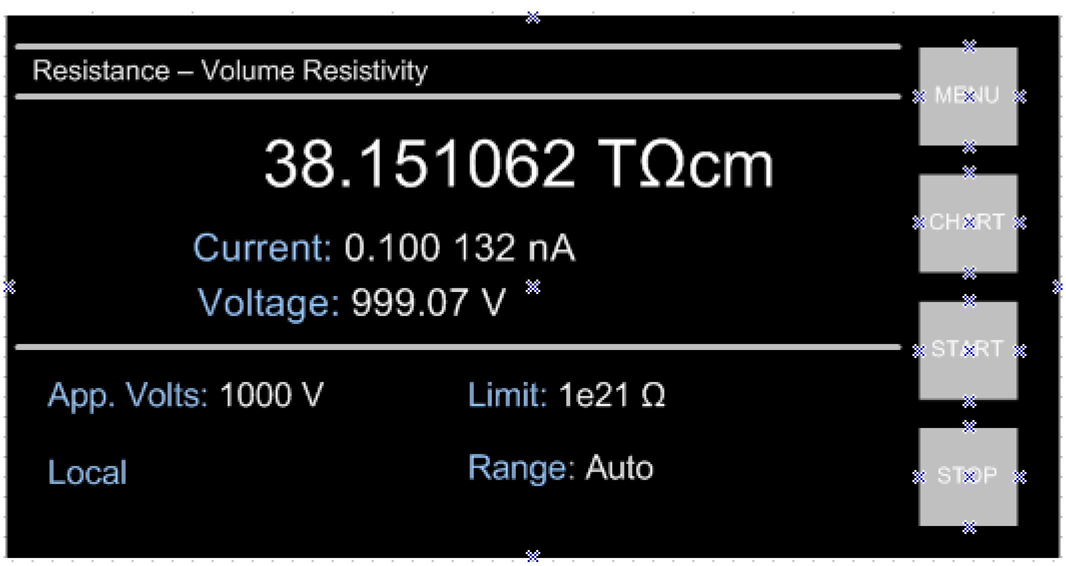

Figure 7: Volume Resistivity Display

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Application Note

Cleaning the Resistivity Test Fixture

Before touching any of the electrodes disconnect all wires from the measuring device. Clean the remote test fixture only if the previously tested material left some type of remnant or residue on any of the electrodes. Do not remove the rubber conductor unless it comes out by itself where it would then need to be cleaned and replaced as is.

For removal of dirt and wax use warm clean water first with a lint free cloth, if residue is still visible use mild detergent diluted in water to wipe down residue. If all else fails use isopropyl alcohol on a Q-tip to soften and remove dirt from selected areas on the electrodes. Do not douse the electrodes with isopropyl alcohol – use only a small amount on a Q-tip. Dry thoroughly with a lint free cloth before using.

Figure 5: 1888 Megohmmeter and 1888-11 Test Cell

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