



Application Note 1076-304

## Performing Van Der Pauw Resistivity Measurements

In typical resistivity measurements, 4 electrical leads are attached to a rectangular sample along a straight line (Fig. 1). A current is fed from contact A to contact B, and the voltage is measured across contacts C and D, which must be far away from the current contacts in order for the lines of current flow to be uniform and parallel between C and D. The resistivity of the sample can be derived from the voltage drop across contacts C and D, the applied current, and the geometry of the sample.

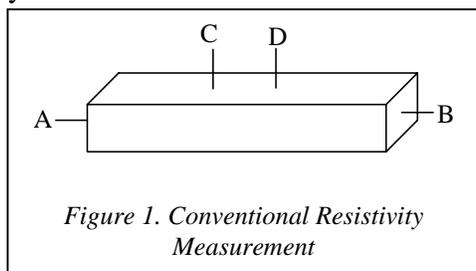


Figure 1. Conventional Resistivity Measurement

Frequently the sample does not have a geometry that is favorable for the above style of measurement, leading to an unknown current distribution. Also, it is often difficult to determine accurately the geometry of the sample, limiting the accuracy of the calculated resistivity. In such a case, one often uses the technique of van der Pauw to determine the resistivity of the sample.<sup>1</sup> A common geometry for such a measurement has 4 electrical

contacts at the four corners of a roughly square sample (Fig. 2). However, the van der Pauw technique is applicable for an arbitrary shaped sample as long as the thickness of the sample is known and is uniform, the contact areas are small, and the contacts are all on the perimeter of the sample. In this case, van der Pauw showed that

$\exp(-\pi R_{AB,CD}d/\rho) + \exp(-\pi R_{BC,DA}d/\rho) = 1$  where  $d$  is the thickness of the sample,  $\rho$  is the resistivity,  $R_{AB,CD}$  is the resistance determined by dividing the

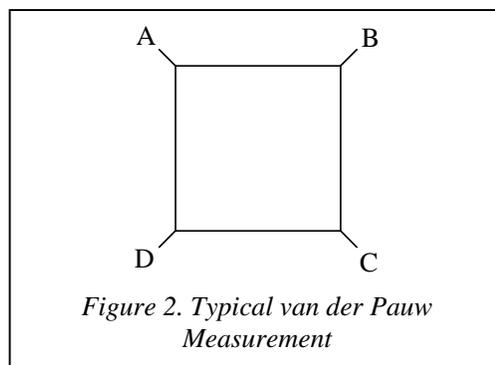


Figure 2. Typical van der Pauw Measurement

potential difference  $V_D - V_C$  by the current going from A to B, and  $R_{BC,DA}$  is defined similarly.

After measurement of the thickness of the sample and the two resistance values, the resistivity is determined simply by inverting van der Pauw's relation.

The Quantum Design PPMS with either the Resistivity Option (model P400) or the AC Transport Option (model P600) is a well-suited instrument for van der Pauw resistivity measurements because it integrates precise temperature and magnetic field control with sensitive multi-channel resistivity measurements.<sup>2</sup> In order to set up the PPMS for a van der Pauw

<sup>1</sup> L. J. van der Pauw, Philips Res. Repts. **13**, p. 1 (1958).

measurement, the user must simply perform a bit of wiring so that the two resistance measurements necessary for the van der Pauw technique can be made using two channels of the resistivity bridge or the AC Transport lock-in.

The Resistivity Option is a bridge optimized for samples whose resistance is in the range of  $\sim\Omega$  to  $\sim M\Omega$ , and uses a chopped dc current source. In contrast, the AC Transport is optimized for samples from  $n\Omega$  to  $k\Omega$  and uses a DSP-generated sinusoidal current excitation and a phase-sensitive voltage detection.

When measuring with the Resistivity Option, the user can use either of two pucks for the measurement. One option is a standard puck (part # 4084-100), which is identified by a flat, gold-plated top surface. The other option is a resistivity puck (part # 4084-109), which has a circuit board with solder pads for three 4-wire resistance measurements and the words “RESISTIVITY OPTION” printed on it. The connections to be made by the user are described in Tables 1 and 2. In these tables, A, B, C, and D are consecutive contacts around the perimeter of the sample, as shown in Fig. 2. The wiring is such that resistivity channel one reports  $R_{AB,CD}$  and channel two reports  $R_{BC,DA}$ .

*Table 1: Connections for resistivity (or ACT) puck*

Solder pad on circuit board	Connection to be made by user
Ch 1 I+	Sample A
Ch 1 I-	Sample B
Ch 1 V-	Sample C
Ch 1 V+ ( $V_{a+}$ )	Sample D
Ch 2 I+	Ch 1 I- solder pad
Ch 2 I-	Ch 1 V- solder pad
Ch 2 V-	Ch 1 V+ ( $V_{a+}$ ) pad
Ch 2 V+ ( $V_{a+}$ )	Ch 1 I+ solder pad

<sup>2</sup> On some older systems, the user bridge board may have all of the I- leads tied to ground. These bridge boards are not suitable for van der Pauw measurements because of the interconnections made between bridge channels for this measurement. To check your bridge board, first turn off the power to the Model 6000 and then remove its cover. Then locate the user bridge board, which is in the back right of the Model 6000 when facing the 6000 from the front. On the left side of the bridge board, locate the part number, which is printed after the letters “PCA.” If the part number is 3076-050, the bridge board is suitable for van der Pauw measurements. If the part number is 3076-012, locate the board revision which is printed after the letters “REV.” If this revision is D0 or later, the board is suitable for van der Pauw measurements. If the part number is 3076-012 and the revision number is before D0, the board is not suitable for van der Pauw measurements. Contact Quantum Design to obtain a replacement (phone 1-800-289-6996 or email [service@qdusa.com](mailto:service@qdusa.com).)

<sup>3</sup> For the numbering of the solder pads on the sample puck bottom, see page 2-2 of the “Resistivity Option User’s Manual” or page A-12 of the “PPMS Hardware Manual.”

*Table 2: Connections for standard puck<sup>3</sup>*

Solder pad on puck bottom	Connection to be made by user
3	Sample A
4	Sample B
6	Sample C
5	Sample D
7	Solder pad 4
8	Solder pad 6
10	Solder pad 5
9	Solder pad 3

After wiring the sample and installing the puck in the PPMS, the user can activate the Resistivity Option or AC Transport Option in the MultiVu software and measure the resistance on channels one and two. In the Resistivity Option, when setting up the data file for this measurement, the user should be sure to select units of Ohms to insure that the resistance, rather than the resistivity or conductivity, is reported. In the case of AC Transport, enter lead separation = 1 cm and cross-section = 1 cm<sup>2</sup> so that the reported resistivity (in  $\Omega$ -cm) is the same as the resistance (in  $\Omega$ ). Once the data are collected, inversion of the van der Pauw relation yields the material resistivity.