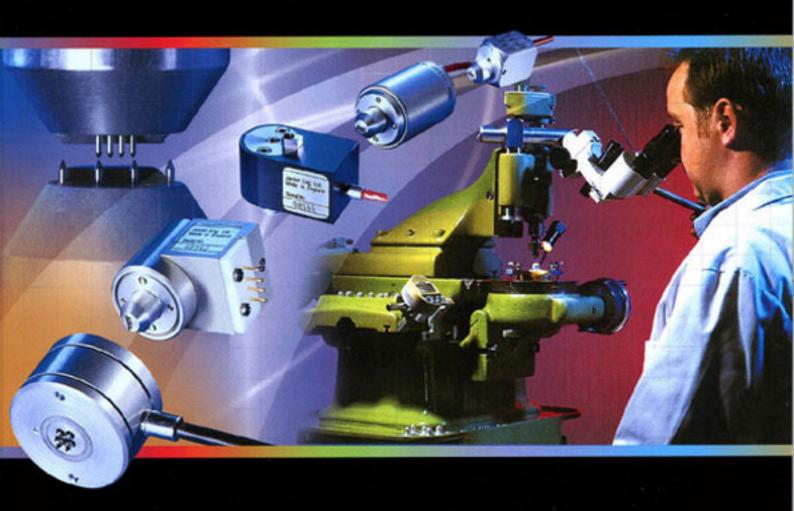# JANDEL

RM3-AR
INSTRUCTIONS

RM3-AR Test Unit Instructions

The RM3-AR is a combined constant current source and digital voltmeter. It has been designed for use in making resistivity measurements in combination with four point probe equipment. The unit supplies a constant current and displays either the resultant voltage or the sheet resistance of the sample in ohms/square, depending which function has been chosen.
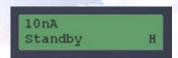
Unpacking

When you unpack the RM3-AR you should find:

1) A Jandel RM3-AR Test Unit
2) A power lead
3) A 100 ohm test resistor
4) A green case key which can be used to open the RM3-AR cabinet (not recommended)
5) A copy of the RM3-AR software for computer control and exporting of results
6) A USB lead

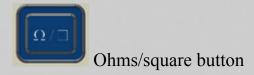Getting to know the RM3-AR

On the RM3-AR you will find the display:

```
10nA
Standby        H
```

and there are also a number of buttons, the names used throughout this manual are listed here:

Numeric Keypad   Current level buttons

Ω/□ Ohms/square button

To the right of these there are four more buttons:

FWD Forward button

STBY/AUTO Standby / Auto button

REV Reverse button

ZERO Zero button

There are four 'preset buttons' marked A-D.

A **B** **C** **D**

Four buttons remain as follows:

Hi High button

Low Low button

STORE Store button

TEST Test Button

Operation of the RM3-AR

<u>Selecting a current</u>
The keypad is used to input the desired current level. It is used in combination with the current level buttons.

The current level buttons are nA (nanoamps), uA (microamps) and mA (milliamps). Values between 10nA and 99.999mA can be entered, and the accuracy of the current delivered does not depend on the number of decimal

places inputted, i.e. 10nA (pressing 1, 0, nA) is equivalent in accuracy to 10.00nA (pressing 1, 0, ., 0, 0, nA)

Storing Currents using the Preset Buttons
Commonly used currents can be stored in positions A to D. When the required current has been dialled in, pressing and holding one of the buttons will store the current in that location. Successful storing is demonstrated by a prolonged beep. Retrieving the currents is simply done by pressing the relevant letter.

Displaying ohms/square or mV values
Pressing the ohms/square button toggles the display between giving measurement results in mV or results in ohms/square.

Starting or stopping current flow through the sample
Pressing the forward button will pass the selected current through the probe head in a forward direction, and should yield a positive voltage reading

Pressing the standby button when current is flowing in the forward or reverse direction will put the unit in standby so that no current is flowing. Pressing the standby button while the unit is already in standby will begin the autorange feature which is discussed later in this manual.

Pressing the reverse button will pass the selected current through the probe head in a reverse direction, and should yield a negative voltage reading of equal or similar magnitude to the forward reading

High Resolution
The High button puts the unit in high resolution mode and is the most desirable setting for high accuracy measurements. In high resolution voltages from 0mV to 150mV can be measured.

Low Resolution
The Low button puts the unit in low resolution mode. Low resolution can be used where less accuracy and higher speed are required, or where highly insulating samples are being measured which yield a voltage higher than 150mV, but below 1.2V which is the unit's measurement limit.

Storing Readings

Pressing the store button stores the displayed voltage value to on board non volatile memory. If the display is showing an ohms/square reading the equivalent voltage reading is stored. The measurements stored on the unit can be deleted by pressing and holding the Store button until the display shows "Erasing Memory…". Stored measurements can be retrieved from the unit with the RM3-AR software. It is possible to store a maximum of 50 readings.

System Test

The RM3 is supplied with a 100 ohm test resistor. When this resistor is plugged into the rear of the unit and the Test button is pressed the RM3-AR will perform a self test against an internal reference (this is quite a lengthy process taking a few minutes).

Getting Started – First use of the RM3-AR

When using small currents or measuring small voltages we recommend a 15 minute warm up period for the unit. For currents above 1uA a 5-10 minute period is recommended. For the largest currents / voltages no warm up period is required.

Switch the unit on. The RM3-AR will self calibrate and then zero before putting itself in Standby. The unit is now ready to use with the default resolution 'High'.

Plug in the 100 ohm test resistor so that the unit will believe it is measuring a sample.

Set a current of 1mA (press '1' and 'mA').

Press 'FWD'. The unit is now passing a current through the resistor and measuring the voltage. As V=IR you can expect a reading of 100mV. The unit's accuracy is quoted at 0.3% so the reading should be between 99.70mV and 100.30mV. In practice, particularly above 1mV and when warmed up the accuracy is better than 0.3% so it would not be unusual to find that you are within 0.1% of the expected value.

Press 'REV'. The HM20 is now passing current in the reverse direction. Again you should receive a reading of 100mV, but this time with a minus figure.

The voltages made may be slightly offset. In this case press the Zero button to remove the offset. ***The zero button is most effective when pressed while a current is being passed.***

Press the 'Ω / □' button. For thin samples the most commonly used measurement is sheet resistance. This is measured in ohms per square. As the size of the square is not relevant to the measurement there are no units such as 'square centimetre' or 'square metre'. The formula for sheet resistance is quite complicated but can be resolved to 4.5324 x V/I. When using a 100 ohm resistor you can expect the reading to be approximately 453.24 ohms/square.

Press the 'Ω / □' button again and the unit will once again show the reading in mV. Note that the ohms/square value is absolute and therefore does not have a positive or negative sign.

The range of measurement in high resolution is 0-150mV. In Low resolution it is 0-1250mV. Where practicable the high resolution should be used and a mV reading of 10-100mV is ideal.

With the unit back in Standby remove the resistor. Attempt to make a reading by pressing the 'FWD' key. This will cause an error and the message "Contact Limit" will be displayed. By removing the resistor the RM3-AR can't drive the current – you can therefore equate this to a four point probe being on a sample but the RM3-AR having a problem driving the current. This could be because the sample is too insulating, because the current needles are not in proper contact with the sample, or simply that a lead is disconnected! Using a lower current will sometimes prevent a 'Contact Limit' error – this could be a situation where the sample has become damaged due to excessive current, or where the contact resistance of the material is high.

Autorange
Queries for poor results are often raised where the cause is simply that an inappropriate current has been selected. The Autorange facility is not designed for use before every measurement, but can be used to select an appropriate current range for the samples being measured.

When making measurements and the RM3-AR is in standby, pressing the Standby button will initiate the Autorange feature. It will begin at 10nA and increase the current by a factor of 10 until a suitable level of voltage measurement is made. At this time it will stop and display the voltage. It is not necessary to use only the current given for the measurements, but it indicates the level around which optimum results can be achieved.

Example:
Plug in the 100 ohm test resistor and while the unit is in standby press the Standby / Auto button. The unit will begin to autorange and should stop at 100uA current (yielding 10mV reading).

Where a sample has very high or very low resistivity you may observe the following:

Low resistivity – the current will autorange up to its maximum current and stop (99.99mA). This does not mean that the reading obtained is invalid, simply that the measured voltage is below what we consider to be ideal. Where the maximum current is required and the reading is below 10mV it is more likely that the unit will need to be zeroed (while the probe is in contact with the measured material and the current is flowing) in order to get good forward and reverse readings.

High Resistivity – samples with very high resistivity can sometimes take some time to reach the optimum voltage level. If a contact limit is obtained when the unit has reached only the 10nA or 100nA level try setting 10nA and observing what happens. It may be that the sample can still be measured but it is necessary to note that:

1) The voltage may take a period of a few seconds, up to a couple of minutes, to reach the voltage to be measured. In this case the 'peak' voltage should be noted.
2) The unit may need to be set to Low sensitivity. This is the case if the RM3-AR displays 'Out of Range' rather than 'Contact Limit'. If the measurement still cannot be made but 'Out of Range' is displayed it is possible to measure the voltage using an external voltmeter plugged into the rear of the RM3-AR (this is where the voltage exceeds 1.2V).

Error Messages

During attempting a reading several error messages are possible instead of a reading.

"Out of Range" indicates that the reading exceeds the maximum input of the in-built DVM. Reduce the current or the sensitivity of the internal DVM, or use an external DVM.

"Contact Limit" indicates that the automatic compliance voltage has been reached due to contact resistance or too much current, try reducing the current

"Illegal Current" indicates that the set current is outside the normal 10nA to 99.999mA range. Set a new current.

"Calibration Error" indicates an error in the factory calibration

Calibration / Self Calibration

The overall calibration of the current source is carried by potentiometer adjustment. The internal DVM has no calibration potentiometers; its calibration is carried out in the factory. This can be recalibrated if required. If the calibration factor is outside certain limits or has become corrupted 'Calibration Error' is displayed.

A separate internal DVM calibration occurs at power up. It recalibrates against an internal reference at power up and when changing from Low to High sensitivity, or vice versa. Zeroing also occurs at this time.

Compliance Voltage

The compliance voltage is automatic, and is used to limit the power dissipated in the sample under test. For currents under 1mA the voltage applied is the maximum 40mV. For currents of 1mA and above the voltage applied to the source is limited to an absolute maximum of 25V. Above 10mA the voltage is limited so as no more than 0.5W could possibly be dissipated in the sample, so at 50mA the compliance voltage is limited to 10V, and at 99.999mA it is limited to 5V. Extra caution is required on the use of currents over 10mA to avoid damaging the samples.

Useful Equations

Sheet resistance = 4.5324 × V/I   (units ohms/square)

Bulk Resistivity for a wafer = sheet resistance × wafer thickness **in cm** (units ohm.cm)

Bulk Resistivity = 2 × π × s × V/I where s is the probe spacing **in cm** (units ohm.cm

Siemens are the SI unit of electric conductance and represent the reciprocal of electrical resistance.

Correction Factors
Probing close to the edge of a sample or on unusual / intermediate shapes and sizes of sample can mean that correction factors are required.
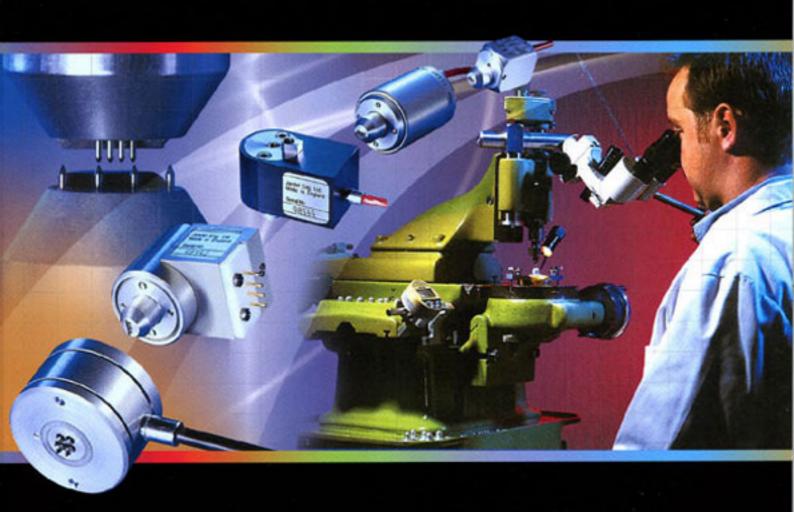
A broad range of correction factors have been determined by Haldor Topsoe.

At http://www.jandel.co.uk/topsoe.html you can find all of the pages from the 1966 (revised 1968) Haldor Topsoe book, "Geometric Factors in Four Point Resistivity Measurement", with each page available as an individual PDF file.

Software
The next section of the manual deals with the use of the software supplied with the RM3-AR.

JANDEL

RM3-AR SOFTWARE INSTRUCTIONS

Accuracy & Precision

RM3-AR Test Unit Software Instructions

(for installation instructions please see the software set up leaflet)

When the software is opened it gives a graphical representation of the unit itself. Anything displayed on the unit's LCD screen is displayed in the green area of the software.

FIGURE 1

Note that the LED's are also represented. In figure 1 the unit is in 'standby' and so the LED next to the standby button is illuminated.

The RM3-AR can be controlled via the software by clicking on the display buttons as if pressing the unit's buttons. Please refer to the RM3-AR instruction manual for how to use the unit.

Accuracy & Precision

Stored Readings

Stored readings are shown in the bottom left corner of the software display with the most recently taken reading at the top. The number of readings stored is shown by the number to the left of the top reading shown. When more than four readings are stored it is possible to scroll through the readings using the scroll buttons to the right of the 'stored readings' area.

Deleting Readings

If a reading has been taken which the user no longer requires it is possible to delete it from the list. Scroll through the readings so that the reading to be deleted is on display and click on the reading to highlight it. If you now 'right click' the reading will be erased.

It is not possible to recover deleted readings.

Pop-up menu.

Right clicking on the software screen will give a pop-up menu as shown in Figure 2.

Connect
Save Readings
Erase Memory
Download
About...
RM3-AR State
Quit

FIGURE 2

There are a number of options and these can be used as follows:

Connect – if the computer and RM3-AR have ceased communicating after a period of inactivity then clicking this will reconnect them

Save Readings – if you want to save the readings that are showing in the 'Stored Readings' area of the software, clicking this will give you the save options (see 'Exporting Measurements' below).

Erase Memory – if the RM3-AR has readings stored in its memory then this will erase those readings. Erased readings cannot be recovered

Download – this will download any readings which have been stored to the internal memory of the RM3-AR. While downloading readings you will see an information window showing progress (Figure 3). This only takes a few seconds and it is necessary to wait until the process is complete, at which time there is an option to clear the stored results from the RM3-AR memory.
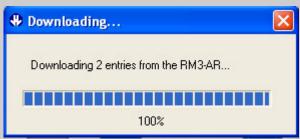

FIGURE 3

About – this gives software version and copywrite information

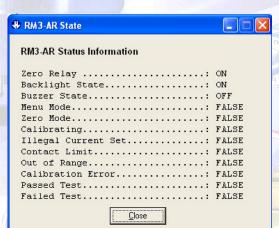**RM3-AR State** – this gives the pop-up shown in Figure 4

FIGURE 4

This represents the state of the RM3-AR in its basic form and can be used for diagnostics in case of suspected errors.

Quit – this will safely quit the RM3-AR software program

Exporting Measurements

By right clicking and selecting 'Save Readings' you can export readings to a spreadsheet in one of several formats.
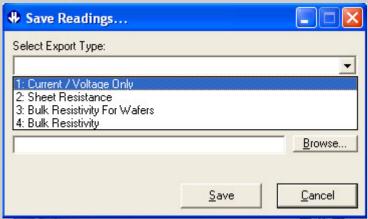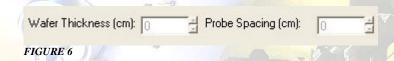

FIGURE 5

In the 'Save Readings' window, clicking on the down arrow by 'Select Export Type' will give you 4 saving options (Figure 5). These can be used as follows:

Current / Voltage only – outputs the current setting and voltage measurement only for each stored reading

Sheet resistance – this outputs the current setting and voltage measurement, along with the calculated sheet resistance

(The next two options require user input for the calculation)

FIGURE 6

Bulk Resistivity for Wafers – this can be used where the bulk resistivity of a thin material is required. It outputs the current setting and voltage measurement, along with the calculated Bulk Resistivity. For this type of measurement it is necessary to input the sample thickness in *centimetres* (on the left in Figure 6) I.e. for a typical wafer thickness of 600 microns, the thickness is 0.06cm.

Bulk Resistivity – this can be used where the bulk resistivity of a large piece of material is required (typically samples > 5x probe spacing). It outputs the current setting and voltage measurement, along with the calculated Bulk Resistivity. For this type of measurement it is necessary to input the probe spacing in *centimetres* (on the right in Figure 6) I.e. for a typical probes spacing of 1.00mm, the spacing is 0.1cm.

When you have chosen your output and, if necessary, inputted the required information, click 'browse' to select an output file name and location on your computer. The program will output the results in a CSV format (comma separated variable) which can be displayed on the vast majority of spread sheet programs.

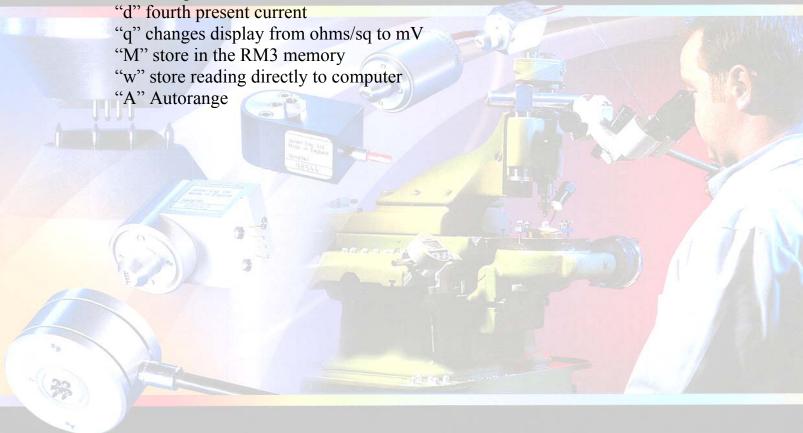|	A	B	C	D	E	F	G
1	Entry	Current Range		Reading		Sheet Resistance	
2	1	5	mA	68.05	mV	61.68596	
3	2	5	mA	-67.469	mV	-61.1593	
4	3	5	mA	69.773	mV	63.24783	
5	4	5	mA	-70.576	mV	-63.9757	
6	5	5	mA	69.386	mV	62.89702	
7	6	5	mA	-69.917	mV	-63.3784	
8	7	5	mA	69.68	mV	63.16353	
9	8	5	mA	-70.446	mV	-63.8579	
10	9	5	mA	69.731	mV	63.20976	
11	10	5	mA	-70.016	mV	-63.4681	

FIGURE 7

Firgure 7 shows a typical spreadsheet output, in this instance showing the calculated sheet resistance. Note that the units and the values have been placed in separate columns so that if required it is possible to write algorithms to manipulate the numerical values.

<u>Keyboard operation</u>

With the software running, or through interface software such as HyperTerminal, it is possible to control the RM3 using the computer keyboard. The remote control commands simply mimic the operation of the keypad.

Accuracy & Precision

The keyboard controls (case sensitive) are:

"1" to "9" and "." to set the current. Terminate in "m", "u", or "n"

"m" for mA

"u" for uA

"n" for nA

"e" will erase the current setting. If entering a current sending.

"f" sets the forward current

"r" sets the reverse current

"s" puts the RM3 in standy mode

"z" zeros the reading

"h" sets high resistivity mode (either 2 or more decimal places max +/- 130mV)

"l" low sensitivity (1 decimal place max +/- 1250mv)

"a" first preset current

"b" second present current

"c" third preset current

"d" fourth present current

"q" changes display from ohms/sq to mV

"M" store in the RM3 memory

"w" store reading directly to computer

"A" Autorange

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USA Representative:

USA

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