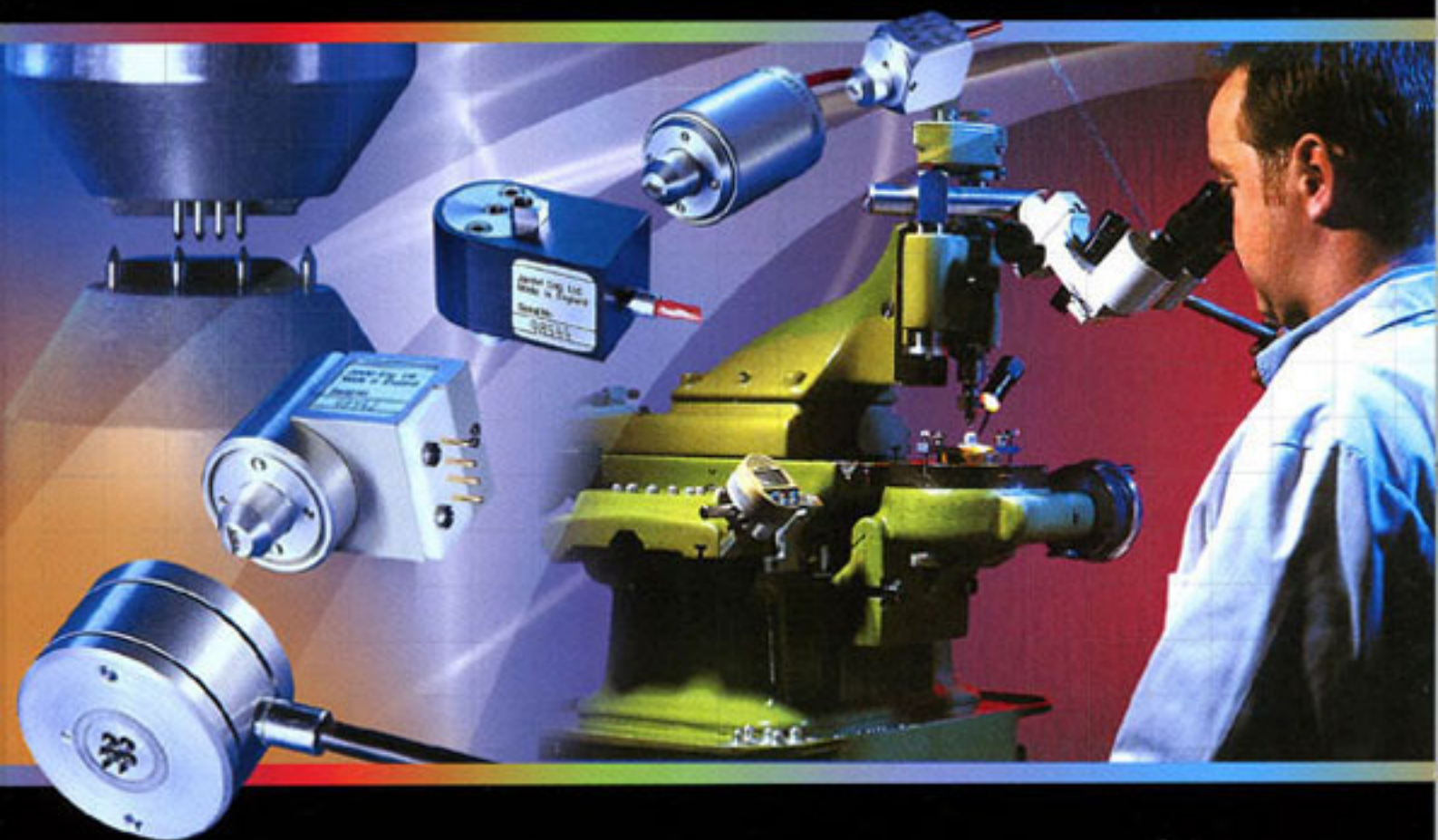




RM3000

INSTRUCTIONS



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RM3000 Test Unit Instructions

The RM3000 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 can display the resultant voltage, sheet resistance or volume resistivity depending which function has been chosen. For calculation of volume resistivity it is possible to input wafer thickness or probe spacing as required.

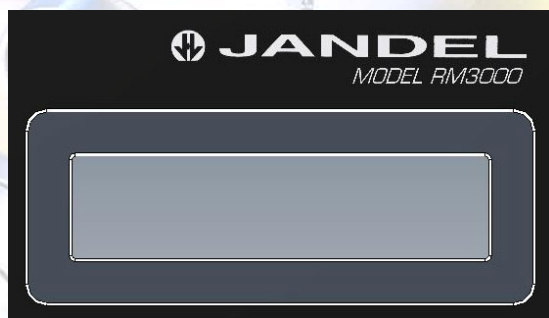
Unpacking

When you unpack the RM3000 you should find:

- 1) A Jandel RM3000 Test Unit
- 2) A power lead
- 3) A 100 ohm test resistor
- 4) A green case key which can be used to open the RM3000 cabinet (not recommended)
- 5) A copy of the RM3000 software for computer control and exporting of results
- 6) A USB lead

Getting to know the RM3000

On the RM3000 you will find the display area:



This is where the current being used is displayed, the direction of the current and the output in mV, ohms/square and ohm.cm.

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

To the left on the front of the unit you will find:



Numeric Keypad



Current level buttons



Ohm button

To the right of these there are four more buttons:



button

Forward button



Standby / Auto



Reverse button



Zero button

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



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Four buttons remain as follows:



High button



Low button



Store button






Mode / Test Button

Operation of the RM3000

Selecting a current

The keypad is used to input the desired current. It is used in combination with the current level buttons.

The current level buttons are  (nanoamps),  (microamps) and  (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 the unit beeping. Retrieving the currents is done by simply pressing the relevant letter.

Displaying ohms/square , ohm.cm or mV values

Pressing the ohms button toggles the display between giving measurement results in mV and one of ohms/square, ohm.cm (wafers) or ohm.cm (volume). The default setting toggles between mV and ohms/square. Pressing and holding the ohms button until a beep is heard will change this to toggle between mV and ohm.cm (volume resistivity). Pressing and holding again until a beep is heard will change it to toggle between mV and ohm.cm (for wafers). To get the correct results for wafers or volume

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resistivity information on probe spacing or wafer thickness may be required from the user which is discussed later in the manual. If the unit is switched off then next time it is switched on it will be on the default setting of toggling between mV and ohms/square.

When using FWD and REV the voltage is indicated as either positive or negative on the screen. For ohms/square and ohm.cm values the display will show either 'F' for forward current or 'R' for reverse current.

If the setting is ohm.cm for wafers a 'W' will also appear when displaying ohm.cm values to indicate that this is the measurement mode

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 or ohm.cm reading the equivalent voltage reading is stored. The measurements stored

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on the unit can be deleted by pressing and holding the Store button until the display shows that the readings are being deleted. Stored measurements can be retrieved from the unit with the RM3000 software. Readings are time-stamped using an on-board clock.

System Test

The RM3000 is supplied with a 100 ohm test resistor. When this resistor is plugged into the rear of the unit and the Mode/Test button is pressed the RM3000 will perform a self test against an internal reference (this process takes several minutes).

Mode

The mode button allows user adjustable settings to be changed. Pressing and holding the Mode/Test button enters the adjustment menu where the following items can be changed:

1. V Correction. This multiplies the measured voltage by the correction factor entered here, for instance if readings need to be corrected for sample size. The correction can be entered by using the keypad and the stored by pressing 'Store'. Displayed voltages will be shown having been multiplied by the correction factor, and if this is the case an asterisk (*) will be shown on the display to indicate that the voltage has been adjusted. The correction can be removed by setting the correction to 1.00, by setting the unit to its default settings or by switching the unit off and on.
2. Wafer thickness. Here the thickness of wafers being measured can be entered (in cm). This enables the unit to display the value of such items in ohm.cm. The default setting is 650 microns (0.065cm). This setting is held in non-volatile memory and so will not change when the unit is switched off. It can be returned to the default value manually or by resetting the RM3000 to its default settings.
3. Probe spacing. The probe spacing (in cm) can be entered here. This enables the unit to display the volume resistivity of bulk samples in ohm.cm. The default setting is 0.1000 (1mm spacing). This setting is held in non-volatile memory and so will not change when the unit is switched off. It can be returned to the default value manually or by resetting the RM3000 to its default settings.

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4. Time. Here the correct time can be entered for time stamping readings taken by the RM3000. The time is set by entering the correct time using the keypad by entering hours, minutes and seconds separated by a period in the format HH.MM.SS and then pressing 'store'.

5. Date. Here the correct date can be entered for date stamping readings taken by the RM3000. The date is set by entering the correct date using the keypad by entering the day, month and year separated by a period in the format DD.MM.YYYY (if the unit is in UK format) or MM.DD.YYYY (if the unit is in US format).

6. Date format. Here the user can press '1' for UK date format (DD.MM.YYYY) or '2' for US date format (MM.DD.YYYY).

7. Set defaults. This is to reset the unit to its default modes. To reset it is necessary to type in the code '222' and press store – this is to prevent someone accidentally resetting the unit.

Default modes are as follows:

V Correction: 1.00 (resets to this when unit is switched off)

Wafer thickness: 0.0650cm (non-volatile)

Probe spacing: 0.100cm (non-volatile)

Set time: current set time (non-volatile)

Set date: current set date (non-volatile)

Date format: UK (non-volatile)

Getting Started – First use of the RM3000

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

Switch the unit on. The RM3000 will self calibrate and then zero before putting itself in Standby. The unit is now ready to use with the default resolution 'High'.

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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 RM3000 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 / \square ' 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 $4.5324 \times V/I$. When using a 100 ohm resistor you can expect the reading to be approximately 453.24 ohms/square.

Press the ' Ω / \square ' 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, but 'F' or 'R' will be shown on the display to indicate in which direction the current is flowing.

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 RM3000 can't drive the current – you can therefore equate this to a four

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point probe being on a sample but the RM3000 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 RM3000 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

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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 RM3000 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 RM3000 (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.

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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 = $4.5324 \times V/I$ (units ohms/square)

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

Bulk Resistivity = $2 \times \pi \times s \times V/I$ 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.

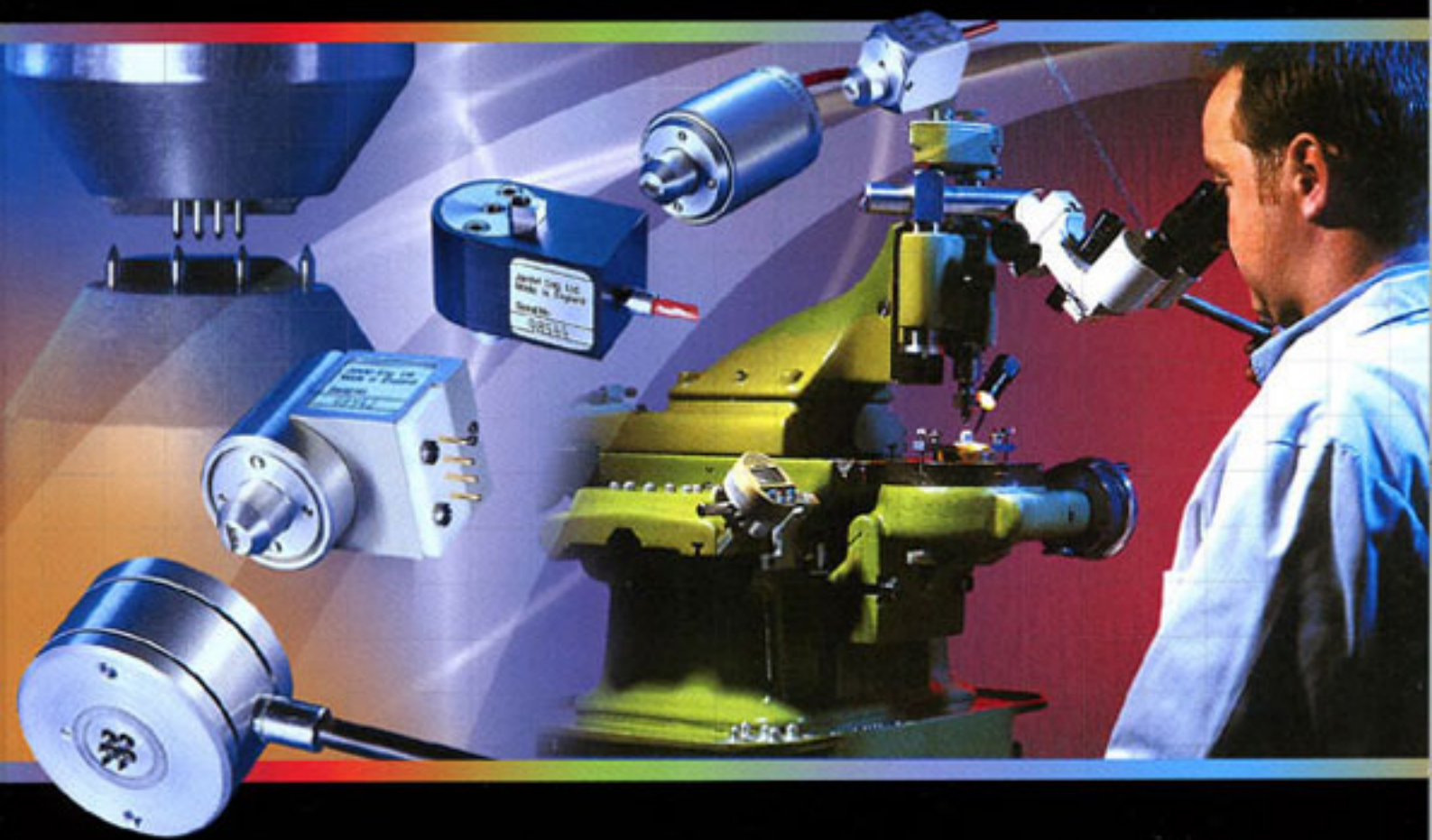
Software

The next section of the manual deals with the use of the software supplied with the RM3000.

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RM3-AR SOFTWARE INSTRUCTIONS



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RM3000 Test Unit Software Instructions

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 RM3000 can be controlled via the software by clicking on the display buttons as if pressing the unit's buttons. Please refer to the RM3000 instruction manual for how to use the unit.

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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
- Clear List
- Erase Memory
- Download
- RM3000 State
- Enter Menu (MODE Button)
- Settings
- About...
- Quit

FIGURE 2

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

Connect – if the computer and RM3000 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).

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Clear List – this will clear the list of readings (if any) which are stored in the bottom left corner of the software window

Erase Memory – if the RM3000 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 RM3000. 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 RM3000 memory.

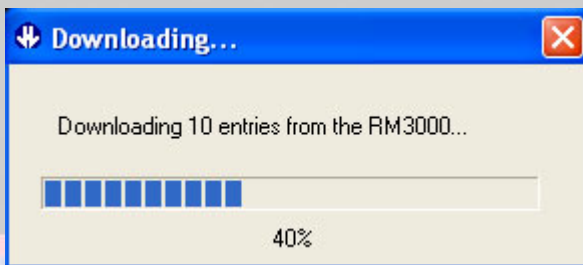


FIGURE 3

About – this gives software version and copywrite information

RM3000 State – this gives the pop-up shown in Figure 4

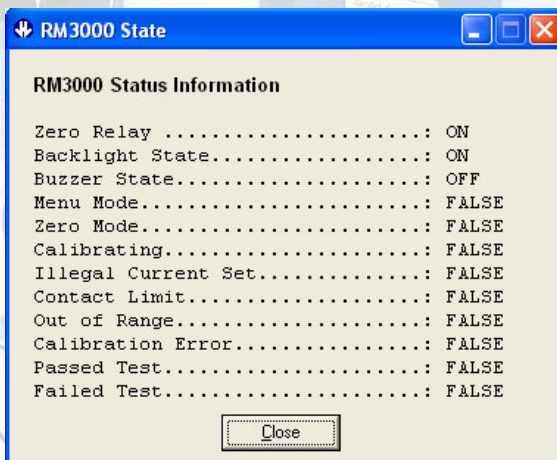


FIGURE 4

This represents the state of the RM3000 in its basic form and can be used for diagnostics in case of suspected errors.

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Settings – this enters the menu for selecting auto-detect or manual port select for the RM3000, and to give the location of the default spreadsheet program

Enter Menu (MODE button) – this enters the menu as if pressing and holding the 'MODE' button on the RM3000 to adjust probe spacing, time, date etc.

Quit – this will safely quit the RM3000 software program

Exporting Measurements

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

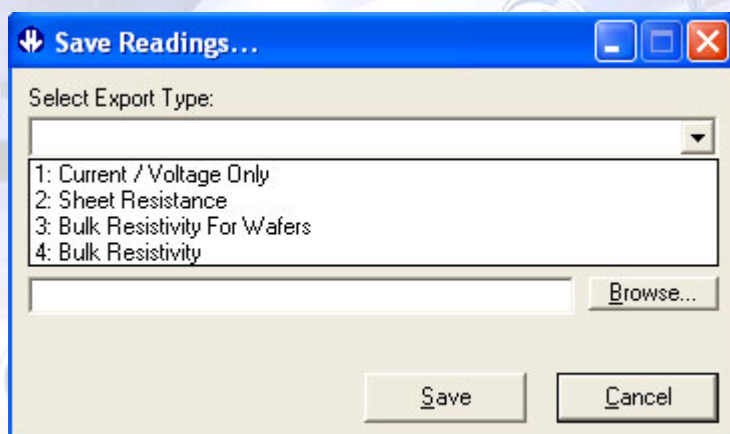


FIGURE 5

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

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

Wafer Thickness (cm): Probe Spacing (cm):

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	H
1	Entry	Current Range	Reading			Sheet Res	Time	Date
2	1	1 mA	100.116 mV			453.7658	10:03:49	05/03/2011
3	2	1 mA	100.116 mV			453.7658	10:03:52	05/03/2011
4	3	1 mA	100.119 mV			453.7794	10:03:54	05/03/2011
5	4	1 mA	100.12 mV			453.7839	10:03:56	05/03/2011
6	5	1 mA	100.12 mV			453.7839	10:03:58	05/03/2011
7	6	1 mA	100.117 mV			453.7703	10:04:00	05/03/2011
8	7	1 mA	100.115 mV			453.7612	10:04:03	05/03/2011
9	8	1 mA	100.116 mV			453.7658	10:04:05	05/03/2011
10	9	1 mA	100.116 mV			453.7658	10:04:08	05/03/2011
11	10	1 mA	100.113 mV			453.7522	10:04:10	05/03/2011

FIGURE 7



Figure 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.

Keyboard operation

With the software running, or through interface software such as HyperTerminal, it is possible to control the RM3000 using the computer keyboard. The remote control commands simply mimic the operation of the keypad.

The keyboard controls 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 RM3000 in standby mode
- "z" zeros the reading
- "h" sets high resistivity mode (either 2 or more decimal places max +/- 150mV)
- "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

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