



# SHEET RESISTANCE MONITOR

## MANUAL



Protected by US Patent Nos. 6645301, 6734434 and 6849854.  
Other patents Pending

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Current version of this manual can be found at

<https://telemark.com/sheet-resistance-monitor/>

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# 1

## SYSTEM OVERVIEW

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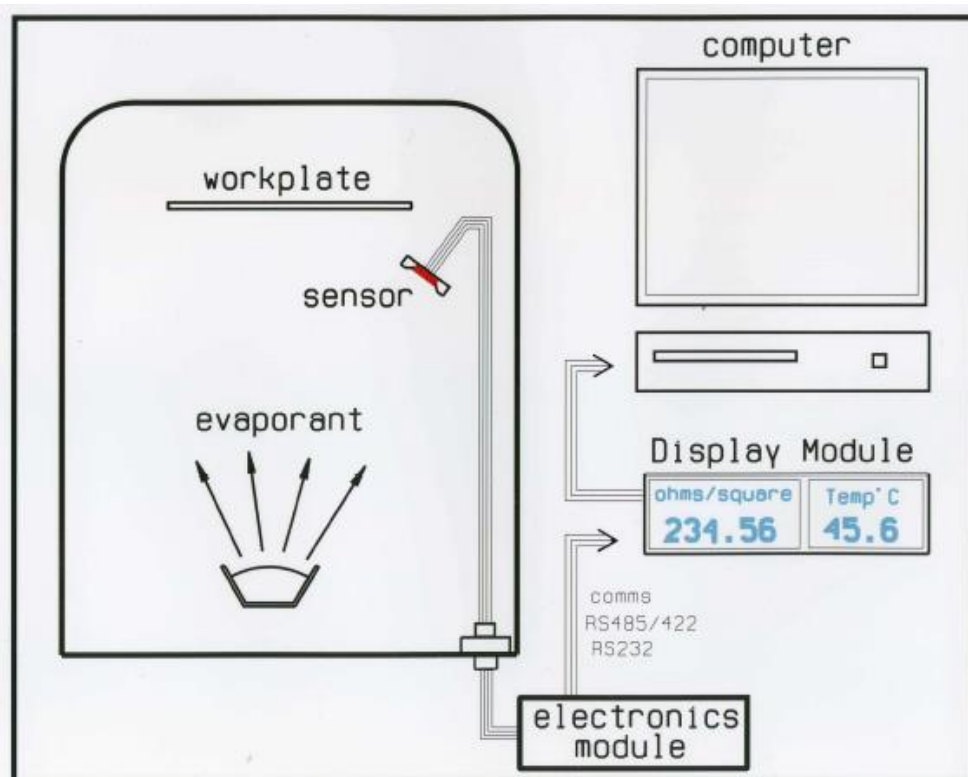


The Sheet Resistance Monitor Model SRM-150 has been developed to provide information on the electrical properties of electrically conducting films. The SRM-150 has been designed to accurately measure the sheet resistance of electrically conducting thin films in real time.

In particular, the device will monitor the sheet resistance of films produced by thermal evaporation processes, for example, metal films evaporated by thermal and electron beam evaporators. It is not recommended the device be used to monitor the sheet resistance of films produced by plasma processes, e.g. DC or RF magnetron or ion beams (IAD, IBAD, DIBS, etc). The measurement process will be considerably disrupted by bombardment from electrically charged particles, e.g. ions or electrons

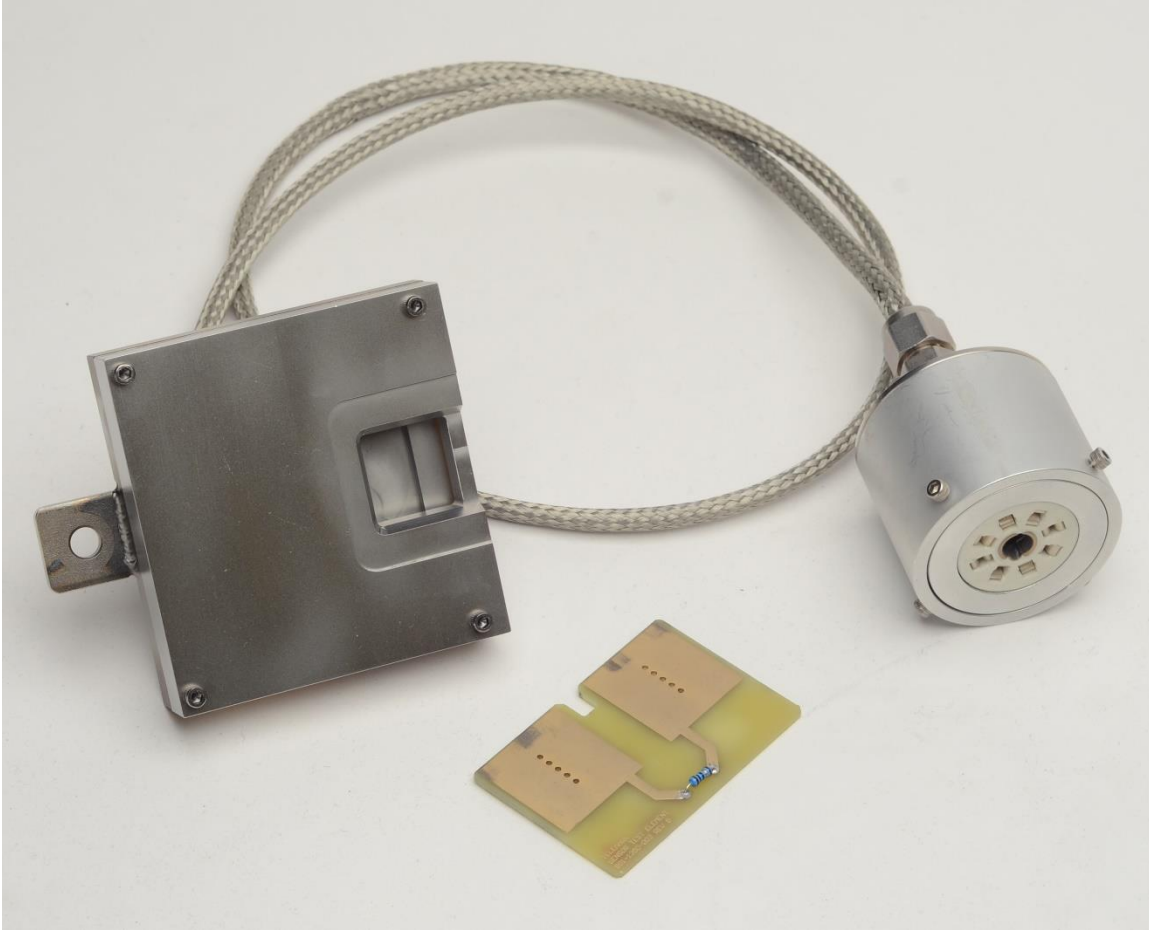
The device uses a sensor head mounted *in-situ* within the deposition chamber and strategically located to sample the vapor stream. The device uses the 4-wire probe technique to accurately determine the sheet resistance of the depositing film material. The depositing film is deposited across two gold coated copper contacts separated by a dielectric substrate. The electronics module provides an electrical current flow through the depositing film and the resistance to electrical flow produces a voltage which is then used to calculate the sheet resistance.

The signal produced by the electronics module can be ported to other display modules such as computers.



## The Sensor Head

The sensor head contains a receptacle that accepts an uncoated sensor element. The sensor element is a single use component that is pushed into location. A rectangular shaped window in one face of the sensor head is located to allow evaporant to pass through and coat a specified area of the sensor element.



The sensor head also contains special gold coated BeCu fingers that make positive contact to the sensor element. The four sets of fingers provide the electrical contacts for the four-wire probe.

Also included in the sensor head is a K-type thermocouple used to monitor the temperature of the process. The sensor head is rated to operate at temperatures up to 200 C however, the standard sensor elements are only rated not to exceed 150 C.

# 2

## INSTALLATION

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The complete Sheet Resistance Monitor package includes the following items:

- Sensor Head
- Amplifier Module
- Blister-pack containing 25 sensor elements
- One test sensor element fitted with a 10 ohm resistor
- Power cable (IEC connector)
- Multi-pin electrical feedthrough
- Information CD
- 24 VDC power pack

The electrical connector should be installed in the base plate feedthrough port at a location as close as practical to the location of the sensor head. The sensor head should be located within the vapor stream of the evaporant and at a location that ensures a true sample of the depositing material.

The Sensor Head is hard wired to the vacuum-side multi-pin ceramic connector.

The air-side connector is attached to the electronics module by a short cable. The electronics module should be located in a safe position and secured in place. The 24 VDC power pack can be plugged into the module and powered from a suitable power source of between 100 – 250 VAC 50/60 Hz.

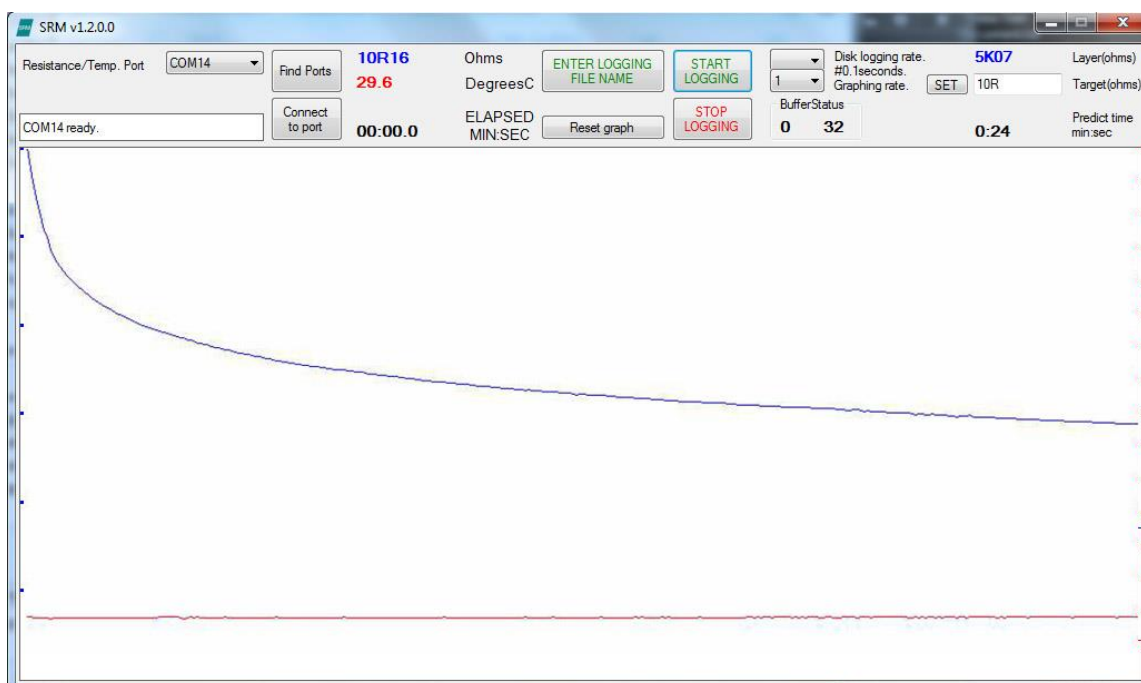
## Mounting the Sensor Head

A small mounting bracket is provided on the rear of the Sensor Head to which a bracket may be attached. The bracket would be made by the installer to suit the particular requirements of the installation. Once the sensor head is installed, the wiring should be routed to the multipin feedthrough. The socket is then installed to the vacuum side of the electrical feedthrough. Do not apply any force to the wires. The cable assembly should be wrapped with aluminum foil for protection against being coated

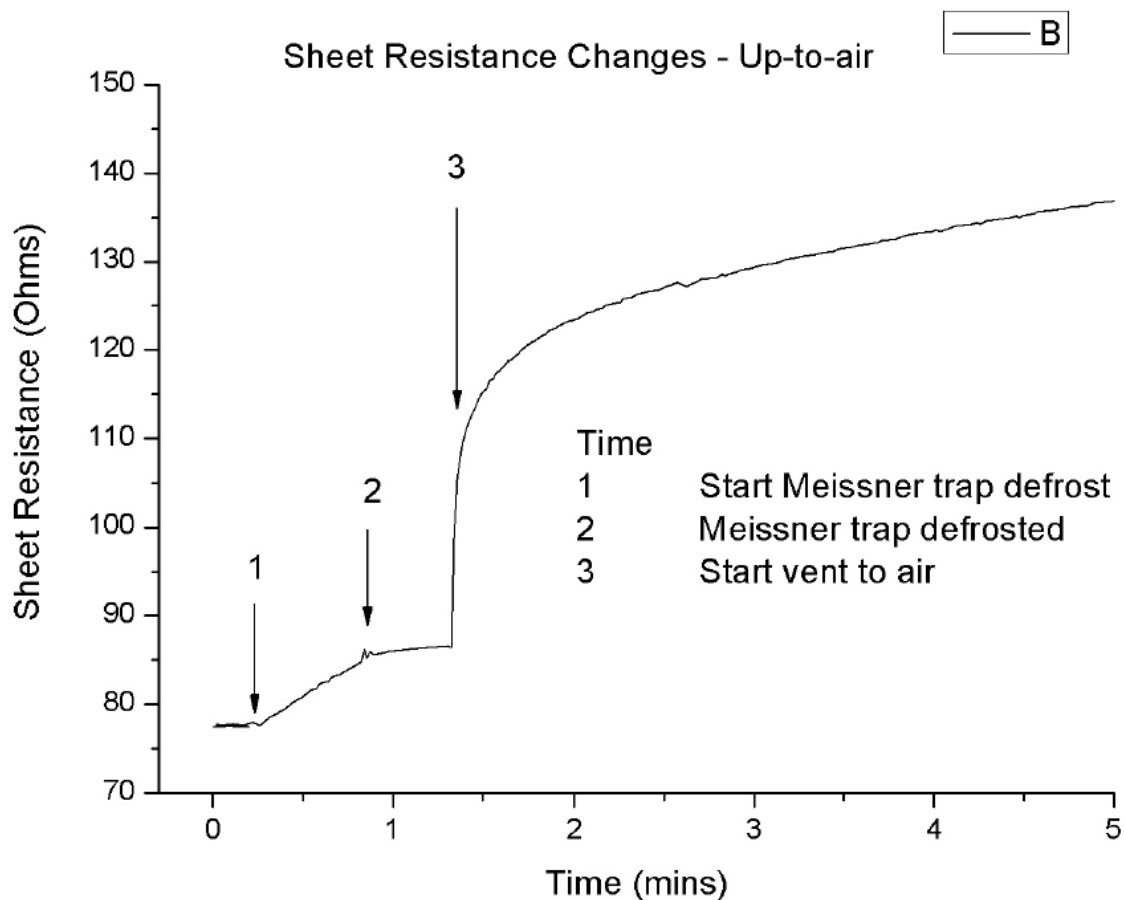
## Applications of the Sheet Resistance Monitor

### Computer Program

Figure below shows the image of the SRM application offered with the package. In the image shown, the resistance data is displayed as the blue trace. The red data stream is the temperature of the sensor head.

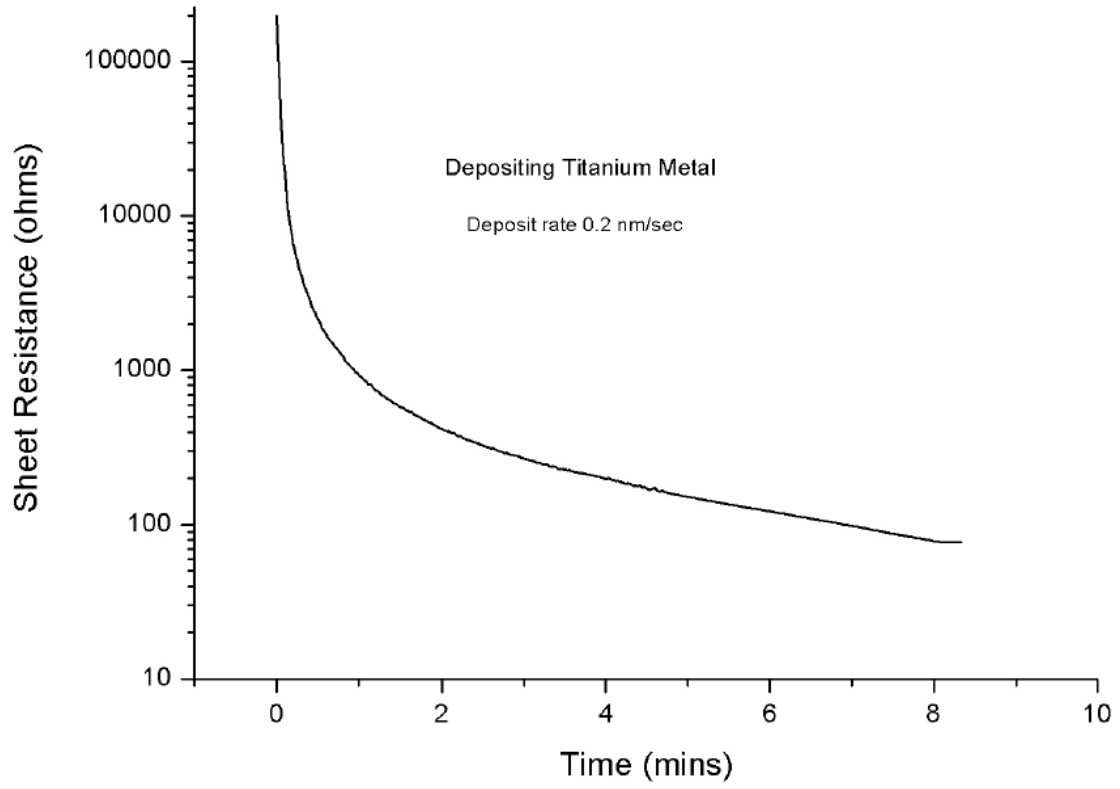


The data from the deposition can be logged and plotted out in a suitable graphics package. Data is collected in .csv format. Figure above shows typical data for a metal film deposition.



The figure above shows data collected during the venting procedure following deposition. Useful information can be collected showing changes that may occur both during and following the deposition process.





# 3

## MAINTENANCE

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Apart from occasional cleaning, there should be no normal requirement for further maintenance of the Sensor Head.

### CAUTION

If the SRM-150 is not in use although retained in the vacuum chamber during deposition of any films (dielectric or metal), the SRM-150 Sensor Head should be fully protected by wrapping in aluminum foil. Do not allow any stray film material to deposit into the sensor head. If any material, either metals or dielectric, is allowed to deposit on the electrical contacts within the sensor head, the sensor head will be permanently damaged

If the SRM-150 is not required for any period of time, it is recommended to remove the sensor head from the chamber.

# 4

## CONNECTION TO COMPUTER

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The electronics module DE9M connector has pins assigned to provide external 24VDC power from external equipment, in this case do not connect the supplied 24 VDC power pack into the DC power connector. A cable will be necessary to connect the electronics module to the monitoring computer.

### CAUTION

Label each end of the cable, e.g. SRM-150, the other PC or computer. This will avoid connecting the wrong ends to the wrong equipment.

## DE9 connector pin assignments

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- Pin 1. +24V DC POWER | Also connected to the
- Pin 2. +24V DC POWER | centre pin of 2.1mm DC connector.
- Pin 3. Not connected
- Pin 4. 0V DC POWER | Also connected to the
- Pin 5. 0V DC POWER | outer barrel of 2.1mm DC connector.
- Pin 6. RS485/RS422 TX+
- Pin 7. RS485/RS422 TX-
- Pin 8. Ground reference for TX pins
- Pin 9. RS232 TX

The 24V DC POWER is allowed a tolerance of  $\pm 10\%$  and is reverse voltage protected by a SB360 schottky diode. This assumes the power source is short circuit protected. The transmit ground reference pin 8 is fully isolated from the 24V DC power. All pins are isolated from the chassis frame/earth which connects to the vacuum chamber wall via the connecting cable shield.

Example cable to connect SRM-150 to PC running the supplied Visual Basic programs.

DE9F (SRM-150)	DE9F (RS232 COM port)
Pin 9. TX -----	Pin 2. RX
Pin 8. Ground reference -----	Pin 5. Ground.

## Transmit serial protocol

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- 9600 baud
- No parity
- 8 data bits
- 1 stop bit

The transmit sequence is:

Carriage return (0x0d) followed by Line feed (0x0a). This is the header.

Followed by eight ASCII hex digits - most significant sent first. This is a 32bit signed integer representing resistance directly in milliohms. A value of 0x7FFFFFFF represents an unknown resistance greater than 204K4 ohms.

Followed by an ASCII comma (0x2c).

Followed by three ASCII hex digits - most significant sent first. This is the least significant 12bits of a 16bit signed integer representing temperature times 10 which has a range from 0.0 to +400.0 degrees Celsius.

If the SRM box has PIC software v1.3 then:

Followed by an ASCII comma (0x2c).

Followed by a single ASCII hex digit in the range 0x0...0x3. This is the test current generator select gain. 0==20mA, 1==2mA, 2=200uA, 3==20uA.

The above transmit sequence is repeated every 100mS (0.1 seconds).

The supplied CD has a Visual Basic application that can be installed that receives the transmit protocol from the electronics module and displays the data graphically and also allows logging to disk. Run the "setup.exe" program found in the "publish" sub-folder of the d:\SRM program folder.

These programs require that the Microsoft .NET runtime system be installed.

The Visual Basic application is supplied as a complete source code project – as is. All care and attention to detail has been taken but not all user requirements can be met in a general program, this is why it is provided as a complete source project so the user may make modifications to suit specific requirements. Any bug reports or comments should be directed to the Telemark factory.

# 5

## VISUAL BASIC SOFTWARE

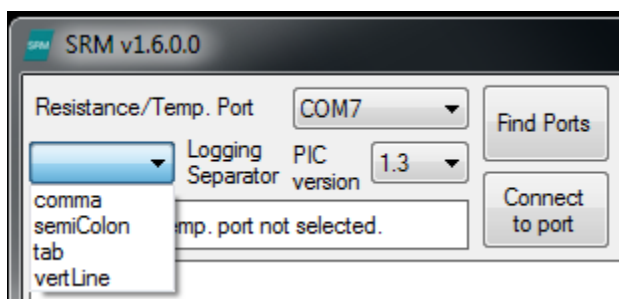
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At the very end of file "frmUI.vb" a subroutine named "TargetReached()" is called at the logging/update rate when the measured resistance  $\leq$  target resistance. Insert your own code to interface with any external equipment. There is a subroutine named "TargetReachedReset()" that is called when the "START LOGGING" button is pressed, this would be used to reset any external equipment to a known condition before material deposition is started.

When this program is closed (X) information is saved in My.Settings that become the default conditions when next executed, e.g. communication port names, target resistance value, display/logging rate etc. The Windows registry is not used.

This program requires a display resolution of 1024 x 600 pixels.

## SRM v1.6



Button Find Ports will collate a list of available PC COM ports. Select from the combo box marked Resistance/Temp. Port, the port that is connected to the sheet resistance monitor box. The selection will be saved when the application is closed and will be loaded as the default when next executed.

The combo box marked PIC version determines which communications protocol is used. V1.2 is the original protocol, V1.3 has the test current select {0...3} appended to the transmitted data.

The combo box marked Logging Separator selects which ASCII character is used to separate field data to the logging disk file.

Button Connect to port will attempt to open the port and establish communications with the sheet resistance monitor box. Port status will be displayed in the text window under the combo box.

When the application is executed, ports will automatically be found and the default connection will be attempted.

If the port is via a USB connection and the USB cable is inadvertently unplugged, the port will need to be re-found by pressing the Find Ports button and then re-connected by pressing the Connect to port button.

<b>19K8</b>	Ohms
<b>20uA</b>	Test Current
<b>27.2</b>	DegreesC
<b>00:00.0</b>	ELAPSED MIN:SEC

The received resistance value is displayed in **BLUE**. If the SRM box is not connected and/or the serial port to the box is not open “NoRECEIVE” is displayed. The value of the resistance is displayed in modified engineering notation where the decimal point is replaced with a letter (K, R) that indicates the exponent multiplier, i.e.  $K=10^3=1000$ ,  $R=10^0=1$ . The resistance has unit’s ohms. The general form is: number followed by the Multiplier Letter followed by the remainder, the remainder is the resistance value in ohms MODULO multiplier. Examples: 750ohms  $\equiv$  750R, 7500ohms  $\equiv$  7K5, 0.25ohms  $\equiv$  0R25. If the remainder is zero it is not shown. The SRM uses a 10 bit ADC; therefore any remainder can only have a maximum of three digits.

The absolute maximum resistance that can be measured is 204400 ohms (204K4); any value higher is reported as unknown.

The received test current value is displayed in BLACK. If the SRM box is not connected and/or the serial port to the box is not open “NoRECEIVE” is displayed. There are four test currents: 20uA, 200uA, 2mA and 20mA. If PIC version 1.2 is selected “UNKNOWN” is displayed.

The received temperature value is displayed in **RED**. If the SRM box is not connected and/or the serial port to the box is not open “NoRECEIVE” is displayed. The temperature has unit’s degrees Celsius and is displayed in floating point decimal form. Be aware that the cold junction compensation measurement technique assumes an ambient of +25°C; any difference will be reflected in the displayed temperature.

The elapsed time is reset to zero and advances after the START LOGGING button is pressed and is displayed as MINUTES:SECONDS. The display halts at 90 minutes.





The SRM box transmits values every 100mS (0.1 seconds). The combo boxes marked #0.1 seconds have four selections {1, 2, 5, 10}; these determine the rate (in multiples of 100mS) at which disk logging or graph updating is to occur. The selections will be saved when the application is closed and will be loaded as the defaults when next executed.

The number at the right hand side of the group box marked BufferStatus indicates the SRM receive buffer length, this is a first-in-first-out buffer that operates at the SRM transmit rate of 0.1 seconds. This allows for 3.2 seconds of data capture before over/under run occurs. The number at the left hand side of the group box indicates the current buffer in-out difference; this should be zero, maybe going to one when the disk is first accessed when logging. Higher values indicate a slow computer, usually in the graphics/screen department. As the number of entries to graph increases it takes more time to plot all the entries. When the left hand value becomes greater than half the right hand value the graphing rate will be reduced to the next graphing rate in the selection list. The current graphing rate selection or the disk logging rate is not changed/affected.

The button marked Reset graph will reset the graph insert index so a new graph can be entered/plotted. NotaBene: If you require a graph display but are not logging this button must be pressed to start the graph.

The button marked ENTER LOGGING FILE NAME displays a file selection dialog box - select or enter a file name that will be used to save the data to, “.csv” is the default extension. You will be notified if the file already exists so you can change your selection if necessary. When the file name has been accepted it will be displayed on the title bar at the top of the screen to the right of the program version number.

The button marked START LOGGING will start logging data to the file name currently displayed on the title bar – if no file name is displayed you will be prompted to enter/select one. Any existing file on the disk with the currently displayed title bar name will be over-written, rename it before pressing the button if you want to keep the data file. The button then changes color to **firebrick** and shows “**HALT LOGGING**”. Pressing the button again will halt logging data to disk,

the graphing and display of data is not affected; the color changes to **green** and shows “**CONTINUE LOGGING**”. Further pressing of the button will toggle between the halt and continue states. Finally the graphing of data is enabled. New file names are disallowed from being entered after starting – the “enter logging file name” button is greyed out.

The button marked **STOP LOGGING** closes the disk file, stops graphing data and stops updating the elapsed time.

The PIC v1.2 Comma Separated Variable disk file has the following structure per line: **TIME STAMP, RESISTANCE, TEMPERATURE**

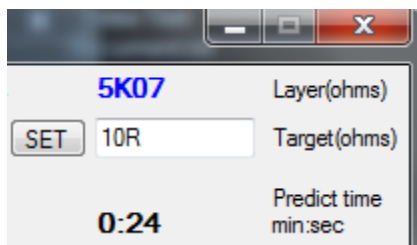
TIME STAMP is a floating point decimal value - unit's seconds.

RESISTANCE is a floating point decimal value - unit's ohms.

TEMPERATURE is a floating point decimal value - unit's degrees Celsius.

If the PIC version is 1.3 there is appended a comma then one of the following: {20uA,200uA,2mA,20mA}

Floating point decimal values are written to disk as ASCII strings.



The TextBox marked “Target(ohms)” allows entry of a target resistance value ranging from 1Ω to 200000Ω with a resolution of 1Ω. This value is saved when the application is closed and will be loaded as the default when next executed. After entering the target resistance (Enter/Return is not required), press button **SET** to initialise the target resistance for comparison; if the value entered is valid the display will change to the modified engineering notation where the decimal point is replaced with a letter (K, R) that indicates the exponent multiplier, i.e. K=10<sup>3</sup>=1000, R=10<sup>0</sup>=1; invalid entries display the previous valid resistance. When the received resistance ≤ target resistance the text color of the label “**Target(ohms)**” changes to red and subroutine “TargetReached()” is called to

execute any user code. The label text colour only returns to the system color when the resistance becomes unknown.

The label marked Layer(ohms) indicates a resistance value displayed in **BLUE** that has been calculated due to material being deposited since the last layer resistance. “**UNKNOWN**” is displayed if the received resistance or previous received resistance is unknown. The layer resistance may take several receive update periods in order to establish a viable value, especially if the current resistance is low and/or material is being deposited slowly therefore thinly. The value of the layer resistance is displayed in modified engineering notation where the decimal point is replaced with a letter (M, K, R) that indicates the exponent multiplier, i.e.  $M=10^6=1000000$ ,  $K=10^3=1000$ ,  $R=10^0=1$ . The resistance has unit's ohms. The general form is: number followed by the Multiplier Letter followed by the remainder, the remainder is the resistance value in ohms MODULO multiplier. Examples: 750ohms  $\equiv$  750R, 7500ohms  $\equiv$  7K5, 0.25ohms  $\equiv$  0R25, 39205000ohms  $\equiv$  39M205. If the remainder is zero it is not shown. The remainder is displayed with a maximum of three digits.

The layer resistance is used to calculate a prediction time stamp that corresponds to **when** the target resistance will be attained and is displayed as MINUTES:SECONDS. Any prediction greater than 9999 minutes is not displayed, the previous time remains. “**UNKNOWN**” is displayed if the received resistance or previous received resistance is unknown; it requires two known resistance values to determine a layer resistance.

## DATA GRAPHING WINDOW

The bottom of the graph window represents zero; the top is full scale:

200K $\Omega$  for resistance

400°C for temperature

At the far left side are resistance decade markers, marked in **BLUE**; from top to bottom they indicate values of 200K $\Omega$ , 20K $\Omega$ , 2K $\Omega$ , 200 $\Omega$ , 20 $\Omega$ , 2 $\Omega$  and 0.2 $\Omega$ .

At the far right side of the graph window are temperature markers, marked in **RED**; these indicate linear steps of 25 degrees Celsius.

Each update period (determined by the display/graphing rate) the two data values are inserted into a buffer that can hold a maximum of 3600 entries, one entry holds both data values. The insertion index position is reset to zero when button Reset graph is pressed or a new log is started. At the one second rate this allows for 60 minutes of data capture and 6 minutes at the 0.1 second rate; when the buffer is full new data replaces the last entry. This should be able to display the complete deposition from start to finish.

The graph window can display 1000 entries in total. If there are more than 1000 entries in the buffer, the 1000 display entries are distributed linearly over the total number of buffer entries. Until the number of entries in the buffer reaches 1000 the graph window is divided up by the actual number of entries; i.e. as the number of entries increase, the line segment displayed for each entry gets shorter until the line segment is only one pixel, this correspond to 1000 display entries.

# 6

## WARRANTY CONDITIONS

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### Limited Warranty

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Telemark products are warranted to be free of defects in materials and/or workmanship for a period of 12 months after shipment from the Telemark factory. This warranty is valid only for normal use, where regular maintenance has been performed. This warranty shall not apply if the product has been repaired or alterations made by anyone other than authorized Telemark service representatives, or if a malfunction or damage occurs through abuse, misuse, negligence, shipping damage, or other accident. No charge will be made for repairs covered by this warranty at a Telemark service facility. Telemark reserves the right to determine if the malfunction was caused by defective materials or workmanship. The customer will be responsible for freight charges to Telemark's service facility.

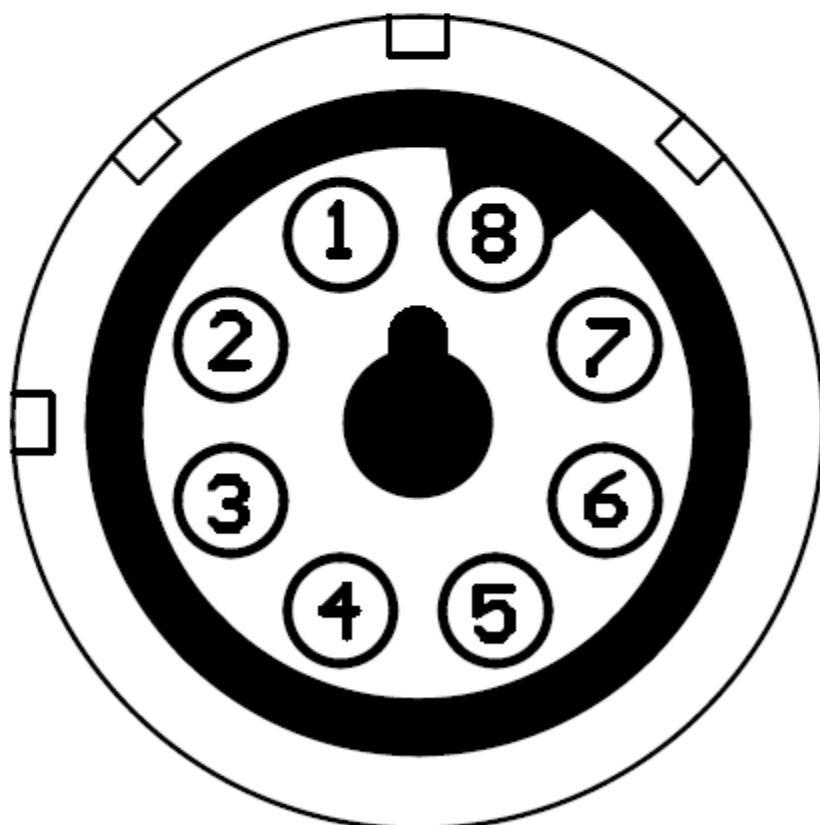
# 7

## APPENDIX

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	To Sheet Resistance Monitor DE9F		To PC RS232 port DE9F																																																													
	<table border="1"> <thead> <tr> <th>Pin #</th> <th>Signal</th> <th>Colour</th> </tr> </thead> <tbody> <tr><td>1</td><td>+24V DC POWER</td><td></td></tr> <tr><td>2</td><td>+24V DC POWER</td><td></td></tr> <tr><td>3</td><td>not connected</td><td></td></tr> <tr><td>4</td><td>0V POWER</td><td></td></tr> <tr><td>5</td><td>0V POWER</td><td></td></tr> <tr><td>6</td><td>RS485/RS422 TX+</td><td></td></tr> <tr><td>7</td><td>RS485/RS422 TX-</td><td></td></tr> <tr><td>8</td><td>0V reference for TX pins</td><td>Black</td></tr> <tr><td>9</td><td>RS232 TX</td><td>White</td></tr> </tbody> </table>	Pin #	Signal	Colour	1	+24V DC POWER		2	+24V DC POWER		3	not connected		4	0V POWER		5	0V POWER		6	RS485/RS422 TX+		7	RS485/RS422 TX-		8	0V reference for TX pins	Black	9	RS232 TX	White		<table border="1"> <thead> <tr> <th>Pin #</th> <th>Signal</th> <th>Colour</th> </tr> </thead> <tbody> <tr><td>1</td><td></td><td></td></tr> <tr><td>2</td><td>RX</td><td>White</td></tr> <tr><td>3</td><td></td><td></td></tr> <tr><td>4</td><td></td><td></td></tr> <tr><td>5</td><td>Ground</td><td>Black</td></tr> <tr><td>6</td><td></td><td></td></tr> <tr><td>7</td><td></td><td></td></tr> <tr><td>8</td><td></td><td></td></tr> <tr><td>9</td><td></td><td></td></tr> </tbody> </table>	Pin #	Signal	Colour	1			2	RX	White	3			4			5	Ground	Black	6			7			8			9			
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	<p>Interconnect cable is 22-24 AWG two core twisted. E.g. AlfaWire part number 1172C</p>																																																															

THERMOCOUPLE MUST BE ISOLATED FROM EARTH INSIDE SRM HEAD.

PIN 1	T+ (CHROMEL)
PIN 2	T- (ALUMEL)
PIN 3	V+ } SENSE
PIN 4	
PIN 5	I+ } DRIVE
PIN 6	
PIN 7	not used
PIN 8	EARTH/FRAME



PINS UP VIEW  
VACUUM SIDE.