S3 INLINE METER
S3 BENCTHOP AND INLINE HYBRID METER

OPERATOR’S MANUAL

January 2025 Edition

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IMPORTANT INFORMATION

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Delcom Instruments, Incorporated (Delcom) warrants this instrument to be free from defects in material and workmanship for a period of one year from the date of shipment. Delcom's obligations under this warranty are limited to replacing or repairing this instrument at its factory or facility. In the case that replacement or repair is required, the unit must be returned to Delcom, transportation charges prepaid by the customer. This warranty shall not apply to any such equipment that has been repaired or altered, except by Delcom, or that has been subject to misuse, negligence, or accident. In no case shall Delcom's liability exceed the replacement value. The aforementioned provisions do not extend the original warranty period of any product which has been either repaired or replaced by Delcom. This warranty is in lieu of all other warranties, including any implied warranty of merchantability or fitness for any particular use. Delcom shall not be liable for any indirect, special, or consequential damages.

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Information Accuracy

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The information contained in this manual is subject to change without notice.

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1: KEY CONCEPTS

Principle of Operations

The essential element of an eddy current meter is an inductor, to which an alternating current (AC) is applied. This current creates a magnetic field. When this field is introduced to a conductive material, it induces eddy currents in the material. The characteristics of the material being tested create a unique set of results that can be displayed as sheet resistance or other readings of interest to the user.

Only the magnetic field interacts with the material being evaluated. This field is relatively weak and generates no heat; therefore, it will not damage the material.

Eddy current technology has many advantages over alternative methods of measuring sheet resistance.

- Four-point probes often destroy the material they are measuring, often do not measure the bulk value of the material, cannot penetrate non-conductive coatings, and are impractical for any sort of continuous process control applications.

- Optical or other indirect methods of determining sheet resistance are often not preferred to direct measurement techniques.

Ranges

Delcom sells instruments in multiple ranges. Together these ranges span most of the values that operators seek to measure. A single sensor cannot span all ranges. Operators can purchase more than one sensor if they wish to measure across the entire spectrum of possible values.

Instruments have finite ranges because instrument sensitivity is a function of physical components. Therefore, an instrument's sensitivity is set at the factory and cannot be changed by the operator.

Delcom Range Nomenclature

If eddy current instruments followed the nomenclature of oscilloscopes, then they would be named 100k ohms/square, 10k ohms/square, etc. However, this would be misleading because no eddy current instrument can measure from zero ohms/square to 100k ohms/square with a useful number of significant digits at each decade.

In order to avoid such confusion, Delcom has chosen a somewhat arbitrary but useful naming convention. In this nomenclature, a “x1” instrument can read one ohms/square with over four significant digits. A “x10” instrument can read ten ohms/square with over four significant digits.

It is important to note that the instrument reading will have up to four and a half significant digits at the lowest decade of its range and only one digit of significance at the highest decade of its range.

Units of measurement

Units of measurement available:

- Sheet resistance in Ohms/square—see Delcom_ME1_Sheet Resistance
- Resistivity in Ohms-cm—see Delcom_ME2_Resistivity
- Thickness in microns—see Delcom_ME3_Thickness
- Sheet conductance in siemens/square or mhos/square—see Delcom_ME4_Sheet Conductance
- Emissivity—see Delcom_ME5_Emissivity

The analog circuitry of eddy current instruments actually output sheet conductance as this is directly related to the thickness – and therefore – conductivity of the material being measured.

Sheet resistance is displayed by simply taking the inverse of sheet conductance. Resistivity and thickness are only able to be displayed if the user inputs thickness and resistivity respectively.

Emissivity is displayed by multiplying sheet resistance by a customer-specified coefficient/factor.

Drift of Baseline Reading

An inductor is used to induce an eddy current in the conductive material being tested. Therefore, if the ambient temperature changes, the properties of the inductor will change. When the inductor’s properties change, the instrument reading will change. This is instrument drift due to temperature.

The instrument is temperature compensated. The instrument has temperature sensors that detect changes in temperature. Software is used to negate over 90 % of the effects of temperature drift.

Delcom uses “zero” to refer to the baseline or “no sample” instrument reading. If the operator is using ohms/square as units then the baseline is displayed as “over range” or “infinite”.

To the operator, instrument drift will affect the baseline reading of the instrument. For example, if the instrument’s maximum reading is 10,000 ohms/square, the instrument may display the following readings over the course of a few minutes: infinity, 5,000, -5,000, infinity, 5,000, etc. Such readings are normal and acceptable “dither”.

Zero and Auto Zero (Tare)

Delcom uses “zero” to refer to the baseline or “no sample” instrument reading.

From time to time, the instrument may display a reading when there is no sample in the sensor. This reading is due to temperature drift or other factors affecting the absolute reference of the instrument. In such a case, the operator will want to let the instrument know that there is no conductive material in the sensor. The operator communicates this to the instrument by pressing the **ZERO** button.

When the **ZERO** button is pressed, the instrument will tare - it records the difference between the ideal no sample state (i.e. over range) and the displayed reading. This value is saved as a permanent offset until it is reset, when the operator presses the zero button again.

The operator should zero the instrument if the instrument is displaying anything other than infinity in ohms/square or zero in mhos/square (i.e. siemens/square) when there is no sample in the instrument.

If the operator does not zero the instrument before using it, whatever the instrument has been reading will be added to the true reading of any subsequent material introduced into the sensor.

2: SETUP

This chapter covers all the information required to set up and use a Delcom resistance meter.

Components

- Sensor(s) with mounting hardware, if appropriate
- IM100 Interface Module(s) and mounting hardware, if appropriate
- Sensor-to-interface module cable(s)–the user may order vacuum-ready cables and feedthroughs
- External power supply
- Operator's manual
- USB cable to connect the IM100 Interface Module to a PC
- USB flash drive with Delcom software
- PC (optional)
- Stage (optional)

Power Requirements

Power parameters
External power supply input: 100-240V, 0.6A 50/60Hz
External power supply output: 12.0V, 1.5A 24.0W
IM100 power input: 12V DC, 2.0A 24.0W
IM110 power input: 12V DC, 2.0A 24.0W

Warnings and intended use
For indoor use only
Operating altitude: 2,000 m or less
Maximum ambient relative humidity: up to 80%
Not intended for use in wet locations
Pollution degree: PD2
External power supply shall be plugged into an outlet with a ground

Electrical protection may be impaired if equipment is not used in a manner specified by the manufacturer.

Interface options

Single-sensor systems can be operated using only the interface module, although they also have the option to use a PC interface.

- LCD on the IM100 Interface Module. (Not available if using multiple sensors simultaneously – see “Using multiple sensors” below.)
- PC running Delcom software. Connected via USB cable. See Delcom_UG8_Software.
- PLC interfacing through Modbus. Connect over a CAT5 physical layer. See Delcom_UG9_Modbus.
- Custom interface built by customer using the Delcom Python Library. See Delcom_UG12_Delcom Python Library.

Using multiple sensors

Single sensor systems can be operated using only the interface module. Single sensor systems also have the option to use a PC interface. Multiple sensor systems can only be interfaced via:

- Delcom PC application
- Via MODBUS/TCP to users PLC (for example)
- Via serial USB and Delcom’s Python library

With one sensor attached, the meter can be operated with the Zero button and the LCD display on the interface module. However, if more than one sensor is attached to the interface module, the LCD is disabled, and the user will have to operate the sensors using Delcom software. See Delcom_UG8_Software.

Computer System Requirements

To run Delcom software, a PC must have Windows XP Service Pack 3 or a newer operating system. The computer should also be equipped with a USB 2.0 or newer port.

Delcom Software

For more information on Delcom software, see Delcom_UG8_Software.

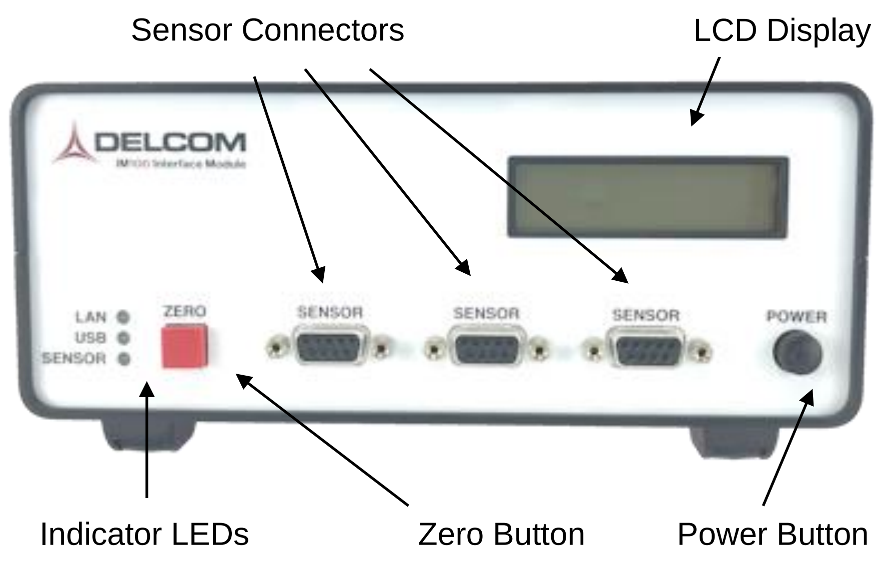
Meter setup

Follow the steps below to set up the meter.

1. Unpack all of the components.
2. Connect the sensor to the IM100 Interface Module using the provided cable. Thumbscrews should be screwed all the way in to ensure good ground connection and strain relief to the connectors.
3. Plug the Delcom external power supply into facility power source.
4. Plug the Delcom external power supply into the IM100 Interface Module

Front Panel Components

Components of the IM100 Interface Module front panel are as follows:



Indicator LEDs

On the front panel of the IM100 Interface Module are four LEDs. These LEDS are:

- Sensor: At least one sensor is communicating with the interface module
- USB: The meter is communicating with a PC via USB
- LAN: The meter is on a LAN (Local Area Network)

The power button on the front panel of the IM100 has an internal LED that will light up when power pressed into the “on” position.

Zero button

The zero button is used to “tare” the instrument. This button should be pressed if the user notices the baseline reading of the sensor has drifted noticeably.

Power button

Use this button to power on the instrument. The button is a latching switch. It includes an internal LED that will indicate when the power has been turned on.

Sensor connectors

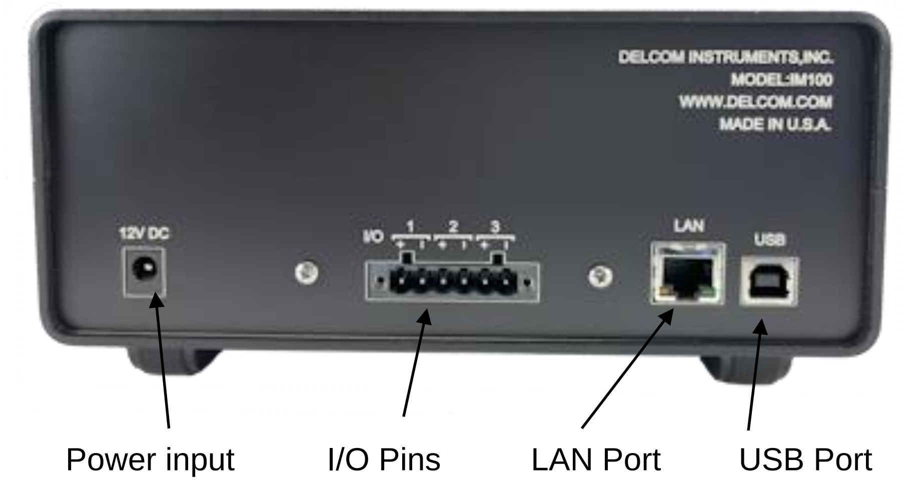
The front panel includes 3 sensor connectors. These connectors are all on the same bus. It does not matter which connector the user uses. The connectors are not associated with an assignment of sensors by the Delcom software.

LCD display

The simple 5-digit display allows the user to use the IM100 and sensor without a PC or any other external user interface. In order to change units of measurement, range, or any other setting (other than zero), the user must connect the IM100 to a PC running Delcom software and make those changes in the software. Any settings chosen in the Delcom software are remembered by the system even after the PC is disconnected. Therefore, once the user has chosen the units of measurement and range they prefer, they can disconnect the PC and need not use it again.

Rear Panel Components

Components of the IM100 Interface Module rear panel are as follows:



Power input

External power supply input: 100-240V, 0.6A 50/60Hz
External power supply output: 12.0V, 1.5A 18.0W
IM100 power input: 12V DC, 2.0A 24.0W
IM110 power input: 12V DC, 2.0A 24.0W

I/O Pins

Input/Output ports are available for control and triggering of the instrument.

LAN Port

The instrument can be fully controlled and monitored via MODBUS/TCP. See Delcom_UG9_Modbus for more information.

USB Port

The instrument can be fully controlled and monitored via the Delcom software application. See Delcom_UG8_Software.

3: SIMPLIFIED OPERATIONS

This chapter covers all the information required to use a Delcom resistance meter.

Simplified Operations with One Sensor

If more than one sensor is attached to the IM100 Interface Module, the LCD is disabled.

With one sensor attached, the instrument can be operated using only the zero button and the LCD display on the interface module.

1. Power on the meter
2. Wait for the meter to warm up.
3. With no material in or on the sensor, press the Zero button. This informs the meter that there is no material in the sensor. The meter will now set the reading to zero. All future readings will be referenced to this zero. See Delcom_KC12_Temperature Drift, Zero, and Compensation.
4. Place conductive material in/on the sensor.
5. The meter will display a reading. The default units of measurement are ohms/square. Zeros are placeholders—all other numbers are significant.

Using multiple sensors

With only one sensor attached, the meter can be operated with the Zero button and the LCD display on the interface module. However, if more than one sensor is attached to the interface module, the LCD is disabled, and the user will have to operate the sensors using Delcom software. (See Delcom_UG8_Software.)

LCD and LED feedback on power-up

When the instrument is turned on using the push button power switch on the front panel of the IM100 Interface Module, the following information will be displayed:

- For single-sensor meters, the IM100 LCD display will display its firmware version, scan for sensors, zero the sensor(s), and finally display a numerical value.
- For multisensor meters, the IM100 LCD will display its firmware version, scan for sensors, zero the sensor(s), and finally direct the operator to use a PC or Ethernet connection to read and control the meter.
- The power and sensor LEDs should be illuminated. The USB and LAN (Local Area Network) LEDs will not be illuminated.
- The user can read and control the instrument using software, Modbus, or the Web application.

Warm-up

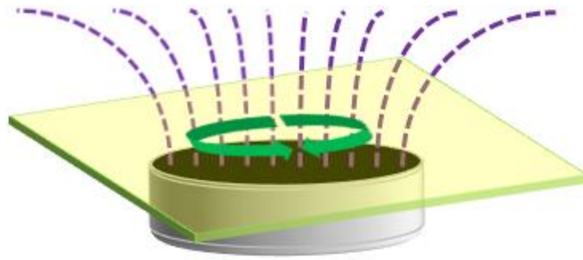
For best results, power the meter on at least three hours prior to use. The operator should feel free to leave the meter running all day or all week and turn it off only at night or on weekends.

When the meter is first turned on, the system components are at room temperature. As the components heat up to steady-state operating temperature, the meter's zero will drift. This drift is very noticeable in the first minute but almost imperceptible after a few hours.

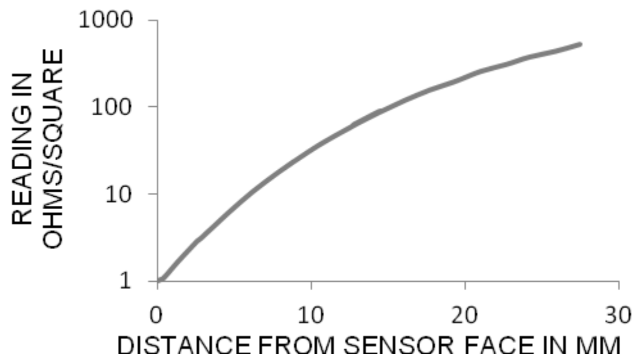
It should be noted that instrument warm-up does not mean the instrument has a required operating temperature or uses heating elements. What is meant here is that the instrument's PCBs and other components will increase in temperature due to typical electronics components such as voltage regulators.
For more information on warm-up, see Delcom_KC14_Warm-Up Time.

Lift-off

A Delcom meter uses a magnetic field to induce a circulating eddy current in the conductive layer of the material being measured. In a single-sided sensor, this field is thrown off from the face of the sensor in a fountain-like pattern. As conductive material is elevated above the face of the sensor, the field becomes less and less dense.



This causes the sensor to read the material as more and more resistive. This effect is called “lift-off.”



Instrument calibration expects sample on face of sensor

The meter is factory calibrated to expect the conductive layer to be intimate with the face of the sensor. Therefore, the user can mount the sensor into the stage from underneath the stage and lay the material to be measured conductive side down.

The user can inform Delcom prior to shipment of a specific elevation that the conductive layer of their material will be introduced into magnetic field. Alternatively, the user can calibrate the sensor themselves to any elevation using the procedure described below.

Calibration to an elevation other than intimacy

If the user has a relatively thick nonconductive substrate and does not want to lay the material conductive side down, the user can calibrate the meter to expect the conductive material at a specific height. This can be achieved by placing a sheet resistance standard of a known value on a nonconductive spacer of the appropriate thickness and then calibrating the instrument to this known value. This calibration takes less than one minute with the following process:

1. Choose the height at which all of the conductive layers will be presented into the sensor.
2. In the Delcom software, go to Calibration > Calibration.
3. Zero the meter.
4. Insert a standard of known value into the sensor at the new calibrated height.
5. Enter the value of the standard, press Set, and check the radio button next to this box to indicate that you want to use this calibration.

Now the meter is calibrated to this elevation. All subsequent readings will expect conductive layers to be presented at this elevation. To revert to the factory settings, merely uncheck the box in the Calibration window.

Significant digits

All of the digits the meter displays are significant, with the exception of zeros. This is true for the LCD display, the PC software, and values delivered via Ethernet LAN. In some cases, zeros are placeholders. For more information, see Delcom_KC6_Significant Digits.

Changing units of measurement

Units of measurement can be changed via Delcom software or by Delcom at the factory prior to shipment. If the meter is connected to a PC, and settings (such as units) are changed, then the interface module will remember these settings and adhere to them, even when disconnected from the PC. Default units are Ohms/square.

Units of measurement available:

- Sheet resistance in Ohms/square—see Delcom_ME1_Sheet Resistance
- Resistivity in Ohms-cm—see Delcom_ME2_Resistivity
- Thickness in microns—see Delcom_ME3_Thickness
- Sheet conductance in siemens/square or mhos/square—see Delcom_ME4_Sheet Conductance

- Emissivity—see Delcom_ME5_Emissivity

To change units of measurement, the user must have access to Delcom software. The software might only need to be used once, but it is necessary to set the units of measurement to be displayed:

1. Open the Delcom software.
2. Go to the main menu bar and choose Edit and then Units.
3. Select the radio button next to the units of measurement you wish to use.
4. Press the “Select Units” button and close the dialogue box.

Upon completion of these steps, all subsequent readings by the meter on any of the user interfaces will be displayed in the selected units. This includes the LCD display, regardless of whether the PC is connected to the interface module or not. The user can revert to other units of measurement at any time by editing units under the settings menu.

Display outputs

The user’s chosen interface will display any one of these outputs as readings:

- NO SENSOR. This output indicates that the sensor is not connected to the interface module. Unplug both ends of the sensor cable and plug them back in, ensuring that the thumbscrews are tightened.
- READING. When reading a material within the range of the meter, the meter will display a value. Zeros are placeholders. Default units are ohms/square.
- INFINITY. This is the normal output for a meter reading in ohms/square when there is no material in the sensor or when a material of extremely high sheet resistance is in the sensor. The meter is unable to discriminate between air/vacuum and highly resistive material that is out of the range of the sensor. Thus, the absence of material is read as over the range of the meter.
- OVERRANGE. For a meter set to mhos/square, this output means that the material is too conductive and cannot be read by the meter.
- UNDERRANGE. When reading in ohms/square, this output means the material in the sensor is of such low resistance

that it “swamps” the highly sensitive electronics of the instrument. Thus, the low resistance material is under the range of the meter.

- ALL ZEROS. When reading in mhos/square, this is the normal reading for a meter when there is no material in the sensor or when a material of extremely high sheet resistance is in the sensor. The meter is unable to discriminate between air/vacuum and material of overly high sheet resistance.
- FAULT. The meter will fault when certain types of overly conductive materials are introduced into the sensor.

Manual zero and autozero

Delcom uses the term *zero* to refer to the baseline or “no sample” meter reading. The operator should zero the meter if it is displaying anything other than “Infinity” in ohms/square or “Zero” in mhos/square when there is no material in the sensor. If the operator does not zero the meter before using it, whatever the meter has been reading will be added to the true reading of any subsequent material introduced into the sensor. See Delcom_KC12_Temperature Drift, Zero, and Compensation.

The operator should press the Zero button before making any reading. When Zero is pressed, the display will briefly flash “Zero” to inform the operator that the meter has received and executed the command.

On the IM100 Interface Module, the operator may put the meter into autozero mode by holding down the Zero button for three seconds. Exit autozero mode by holding the Zero button down for three seconds. Alternatively, the operator may select the preferred zero method by selecting the respective radio button on the main software display.

When in autozero mode, the meter will check the reading every three seconds. If the meter believes there is nothing in the sensor, it will automatically zero itself on behalf of the operator.

When in autozero mode, the meter will check the reading every three seconds. If the meter believes there is nothing in the sensor, it will automatically zero itself on behalf of the operator.

The instrument decides “that there is nothing in the sensor” by checking the sensor readings. If these readings are below the autozero threshold value, then the instrument will autozero. The user can change the autozero threshold value in the software. (See Delcom_UG8_Software.)

Autozero mode is not recommended for inline processes. One exception would be if the user is monitoring pieces of material that move through the sensor with a gap between them. With autozero set in such a case, each time a glass panel completes its transit through the sensor, the meter will rezero before the next panel enters.

4: BEST PRACTICES

This chapter covers a number of nuanced factors that when taken in aggregate can greatly improve the accuracy and reliability of readings.

Warm Up

For best results, power the instrument up at least three hours prior to using the instrument. The operator should feel free to leave the instrument running all day or all week and turn the instrument off only at night or on weekends.

Ensure Minimum Required Sample Size

Check the instrument's datasheet – or contact Delcom – to determine the minimum sample size required for sensor operation.

Ensure Sample is in Center of Sensor Head Gap

Due to the inherent field pattern within the head gap, the reading may be 5 % higher when the conductive layer is moved from the center of the gap towards one of the two poles of the sensor head. The sensor is calibrated with standards introduced into the center of the sensor head gap. Hence, for critical evaluation and comparison of a particular set of samples, register all test items such that the center of the bulk of the conductive material is located in the vertical center of the sensor head gap.

The best way to ensure your sample is in the center is to find the magnetic center. Take any conductive sample, place it in the sensor head and move it up and down until the lowest value is read. Then place every film being measured into the same location to get repeatable readings. This process is much easier with the optional stage. Turn the lever on the stage with the sample in the sensor head. Once the lowest value is read, do not adjust the stage height.

Choose the Appropriate Range

If resolution requirements allow, and the expected values reside within the high range zone, the instrument should be used in that range since less temperature sensitivity will result.

Maintain a Stable Temperature

In order to minimize the effects of temperature induced zero drift, the operator may want to use the instrument in a temperature-controlled environment.

Allow Instrument to Equilibrate to the Room's Temperature

Ensure that the instrument (especially the sensor head) is the same temperature as the room. This is to ensure minimal reading drift due to the instrument heating up or cooling down. If the sensor head has not been allowed to equilibrate to the room's temperature, it will produce reading drift at a rate of less than .25 % of max resolution per degree Celsius.

Insulate Sensor from Radiant Heat and Cold

Samples that are extremely hot or cold may radiate heat or cold which could heat or cool the sensor head. This may result in reading drift.

Prevent Deformation of Sensor Heads

Do not force a thick sample into the sensor head. This will result in an erroneous reading. Furthermore, it will damage the sensor. Delcom produces various sensor head models to accommodate most applications.

Recalibrate as Needed

Instruments are calibrated with the use of NIST (National Institute of Standards and Technology) traceable standards to an accuracy value of plus or minus 1 %. Due to shipment shock, optional high-sensitivity models may have to be recalibrated before use.

5: CALIBRATION

This chapter provides the operator with a step-by-step process to calibrate a Delcom resistance meter.

Concept of calibration

The instrument is linear, so we can describe the output of the instrument using the equation of a straight line: y=mx+b.

By zeroing the instrument, the operator has ensured that b=0. By inputting a known standard, the user has told the instrument what m should be. The instrument already has an m set by hardware. Thus, the software will calculate the difference between the m represented by the operator's standard and the factory-set analog m. This modification of the factory-set m will be represented in all future readings. At any point, the operator can revert to the factory-settings by deselecting the radio button that says **Use Digital Slope Fit**.

How to correctly insert the standard:

1. XY position: Position the standard such that the geometric center of the sample is coincident with the center of the sensor faces. The crosshair decal on the stage surface denotes the center of the sensor faces.
2. X position: The sample should be placed on the surface of the sensor. Unless Delcom (or the user) has (or wants to) calibrated the instrument to expect the standard at a different elevation. In such a case, this elevation should be achieved by placing non-conductive spacers between the sensor surface and the calibration standard.

Calibration process

The Delcom meter measures the actual sheet conductance of the material and does not derive sheet conductance from other intermediate observations. Furthermore, the instrument does not use any sort of digital piece-wise linearization software routine. For these two reasons, the meter can be calibrated with just one standard.

Steps for Calibration:
1. Have your preferred conductance/resistance standard ready.

2. Ensure there is nothing conductive in the sensor.
3. Open the Delcom software to any mode.
4. In the main menu bar, go to Calibration > Calibration and leave the window open next to the main window.
5. In the Calibration window, enter the known value of the material you are using as the calibration standard. DO NOT CLICK Set.
6. Switch to the main window and click Zero.
7. Insert the standard.
8. Switch back to the Calibration window and click Set.
9. To apply the calibration to all future readings, click the radio button that says Use Calibration.
10. To revert to the original factory calibration, simply deselect the Use Calibration radio button.

Standards and Accuracy

Delcom's non-contact instruments are calibrated with the use of NIST-traceable standards to an accuracy value of plus or minus 1 % before they are shipped from the factory. The calibration temperature is approximately 20° Celsius (68° Fahrenheit).

At first blush, accuracy may seem to be the most critical characteristic of a sheet resistance meter. For applications where accuracy is absolutely required, sheet resistance standards are available from third parties, such as VLSI Standards Incorporated (http://www.vlsistandards.com).

However, most researchers and production specialists are not concerned with how well the material there are measuring relates to an ultimately arbitrary standard. Rather, they are concerned with finding and then repeating a sheet resistance value that works for their application and/or for the eventual consumers of their product. For this reason, Delcom recommends customers follow all or some of the following steps:

- Produce or acquire material they are comfortable with that has a fairly uniform sheet resistance value, is stable (e.g. it won't oxidize), and has a low temperature coefficient of resistivity. Or, if you are producing material for a particular customer, ask them to provide material they like and what they believe the sheet resistance value of this material is.

- Measure the sheet resistance of this material using a four-point probe. Better yet, measure the material using a four-bar probe.
- Measure the exact same area on the exact same material using the Delcom resistance meter. If the values measured are within the margin of error, then passivate the standard and keep it as a means to provide assurance and confidence in your measuring processes.
- If the standard thus created differs significantly from the readings of the Delcom resistance meter, then recalibrate the resistance meter using the calibration processes to match the readings of your contact system.

Please note that if you choose to recalibrate your instrument, you are likely calibrating to a standard that has a value that is not consistent with what NIST or other institutions say the sample should measure. However, we at Delcom believe these processes are themselves arbitrary (i.e. NIST Special Publication 260-131, 2006 Ed) and the only correct process is the one the producers and consumers of the material are comfortable with.

Digital Offset

If you are taking measurements multiple times in the manufacturing process and you would like to measure the difference between two samples, use digital offset. Digital offset simply subtracts the initial reading of your material from the final reading of your material, causing the software to display the difference between the two. This difference will only be displayed on the software, not on the interface module.

NOTE: If you change the units you will need to reset the offset to what you would like it to be. Digital offset will not automatically convert between units.

NOTE: If you are going to use digital slope fit, set the digital slope fit before you set the offset.

1. Click **Calibration** from the top of the screen. From this drop-down menu select **Digital Offset**.

2. Ensure that the correct units are selected from the **Edit** drop down menu and select **Units**. Type in the desired offset value.
3. Press the **set** button.
4. Select the check box to enable Digital Offset.

6: PERFORMANCE CAVEATS

This chapter enumerates a number of factors that may complicate or render meaningless readings using Delcom resistance meters.

Ferrromagnetic Behavior in the Material

The placement of a non-conductive ferromagnetic material between the faces of the sensing head can reduce the reading value. If the instrument is zeroed, the effect can be seen as a negative conductance value. As an example, the antiquated 5.25" DSDD computer floppy disk produces a value of approximately -0.0002 mhos/square.

Dielectric Loss Tangent

A material may have a small conductance when measured at DC or low frequency; however, it can exhibit a large conductance at an RF frequency of several Megahertz. Water is an example of a material with this behavior. Pure water is relatively non-conductive at low frequencies, but at RF and microwave frequencies it is an effective power absorber. Even though this type of resistance meter operates in the low Megahertz region, certain oxides of titanium and other metals do have high dielectric losses and consequently high apparent conductance values.

Spatial Non-Uniformity of the Conductive Material

Materials that exhibit cracking, crazing, striated surfaces, non-isotropic properties, and island-like structures can cause apparent conductance variations. A DC four-contact conductance measurement responds to the unidirectional current flow over a given area of material. If the given area is composed of islands, which are isolated from each other by surface cracks, the DC conductance value can be small. However, because the confined circulating currents induced by this eddy current type monitor can reside within an island structure, the dynamic conductance can be larger than DC measured values. Similarly, a striated or non-uniform metalized film can produce reading differences of between one and two orders of magnitude.

Non-Linear Behavior

Non-linear behavior of conductance is observed in semiconductors, dielectric-metal mixtures, and loosely bound dielectric materials because they can exhibit tunneling, electron hopping, and current decrease due to large compliance voltages, heating, electromigration, and high current densities. Consequently, correlation between the RF/dynamic and the four-contact DC measurement technique depends on measurement conditions.

Skin Effects

At high frequencies, electrical currents are unable to deeply penetrate conductive materials. Consequently, the effective resistance of conductors can sometimes rise to excessive levels. However, the frequency chosen for this device is such that the skin depth properties should rarely affect accuracy.

Free Carriers in Silicon Wafers

Silicon wafers exhibit short-term reading instability. This characteristic has been noted and documented by others, including the NIST laboratory in Gaithersburg, Maryland, USA. For some values of conductance, the time period to achieve a stable reading can be one minute, for some it can be as long as six minutes. The phenomena is not understood well, and some maintain that all wafer testing and calibration should be done in a dark environment due to the release of photon stimulated carriers.

Reading Confidence

When deciding on what instrument range to purchase, potential operators should select a range that encompasses the entirety of the range of readings they expect to read for the material they are working with. Furthermore, the instrument should be selected such that the anticipated sheet resistance of the material is in the center of the range for the instrument. The closer each instrument gets to the high resistance end of its range, the lower the confidence is of the reading generated by the instrument. This characteristic of a conductance monitor is best explained by working in mhos/square. For this example, let us use an x10 instrument operating in low range (.00001 to .19999 mhos/square).

If we put a sample with a true value of .11111 mhos/square into this instrument we are likely to see the display of the instrument reading any of the following values .11110, .11111, or .11112 mhos/square. The last significant digit is always likely to move one count on either side of the true value. This equates to a confidence error of roughly 1/10000 = .01 %. This means the operator should have very good confidence in the value they are reading.

Now, let us put a sample with a true value of .00001 mhos/square into the same instrument. The last significant digit will likely move one count on either side of the true value. This will generate the following readings: .00000, .00001, or .00002 mhos/square. Each of these movements in the reading could equate to a confidence error of 1/1 = 100 %. This means that the value being read may not be very useful to the operator.

Temperature Compensation

Delcom’s line of resistance meters are susceptible to zero drift due to temperature changes. Instruments capable of measuring high sheet resistance samples are particularly prone to drift and therefore have been temperature compensated.

The instrument’s temperature compensation is calibrated before shipment for its unique physical configuration and components. Maximum drift will not exceed 1 millimhos/square per degree centigrade change per hour. Maximum ambient temperature change must not exceed 6 degrees centigrade per hour. Instruments are temperature calibrated to operate between 17 and 39 degrees centigrade with the exception of extended range and special purpose instruments.

Temperature compensation may account for some odd but useful characteristics of the instrument. For example, as the temperature rises and falls and the temperature sensors detect these fluctuations, the instrument reading may rise and fall subtly. Over time, the instrument should remain stable and fairly immune to temperature fluctuations; however, as the temperature coefficients of the sensors and the instrument sensor cannot be perfectly matched, there may be slight fluctuations in sensor readings.

7: S3 STAGE

Stage components

- A large stage surface with a cutout to accommodate the sensor
- Four screws for attaching the sensor to the stage
- Right angle D-Sub adaptor
- Four legs, which provide clearance for the sensor and the right-angle D-Sub adaptor
- Hex key wrench

Assembly instructions

1. Attach the four legs to the stage using the four included screws and hex key.
2. Attach the right-angle D-Sub connector to the sensor using the thumb screws.
3. Attach the sensor to the stage using the four screws provided. Sensor should be placed into the stage from underneath the stage such that the sensor reading surface is flush with the stage surface.
4. Tighten the screws snugly. There is no need to crank down on the screws.

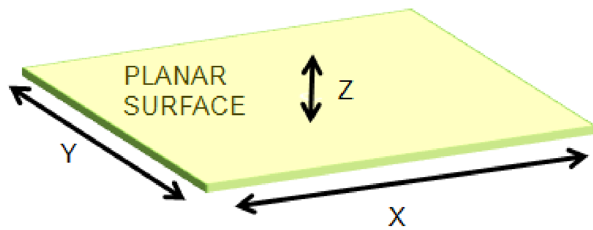
Preparation of entire instrument for use

1. Mount the sensor in the stage
2. Connect sensor, module, and PC
3. Turn on the meter
4. If using Delcom software, open Delcom software application

Purposes of the stage

The stage serves three purposes:

1. To assist the user in controlling the elevation (*z* direction) of the material relative to the sensor
2. To assist the user in keeping track of the *xy* (planar) placement of the material relative to the sensor
3. To assist the user in mapping the material in the *xy* plane



How the stage works

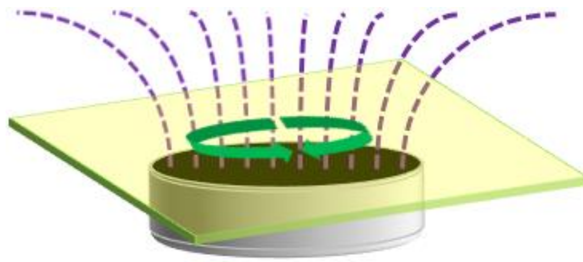
The stage consists of a stage surface on which to rest the material.

The stage surface is optimized to receive an overlay designed by the user for their purposes.

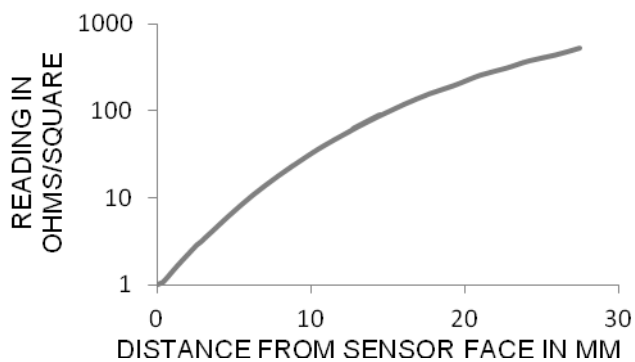
For specifications on the stage, see Delcom_DS7_S3 Stage.

Lift-off

A Delcom meter uses a magnetic field to induce a circulating eddy current in the conductive layer of the material being measured. In a single-sided sensor such as the S3, this field is thrown off from the face of the sensor in a fountain-like pattern. As conductive material is elevated above the face of the sensor, the field becomes less and less dense.



This causes the sensor to read the material as more and more resistive. This effect is called “lift-off.”



Instrument calibration expects sample on face of sensor

The meter is factory calibrated to expect the conductive layer to be intimate with the face of the sensor. Therefore, the user can mount the sensor into the stage from underneath the stage and lay the material to be measured conductive side down.

Calibration to an elevation other than intimacy

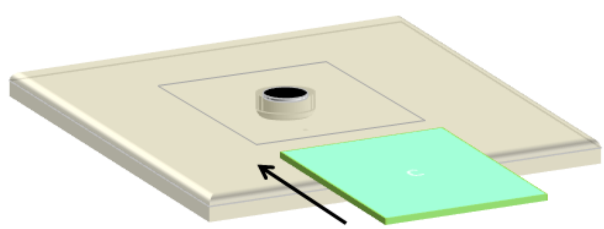
If the user has a relatively thick nonconductive substrate and does not want to lay the material conductive side down, the user can calibrate the meter to expect the conductive material at a specific height. This can be achieved by placing a sheet resistance standard of a known value on a nonconductive spacer of the appropriate thickness and then calibrating the instrument to this known value. This calibration takes less than one minute with the following process:

6. Choose the height at which all of the conductive layers will be presented into the sensor.
7. In the Delcom software, go to Calibration > Calibration.
8. Zero the meter.
9. Insert a standard of known value into the sensor at the new calibrated height.
10. Enter the value of the standard, press Set, and check the radio button next to this box to indicate that you want to use this calibration.

Now the meter is calibrated to this elevation. All subsequent readings will expect conductive layers to be presented at this elevation. To revert to the factory settings, merely uncheck the box in the Calibration window.

Controlling *XY* placement of the material

For many applications, users may wish to present material into the sensor at the same position in the *xy* plane. Users can mark the surface of the stage in any way they wish to ensure consistent placement of material.

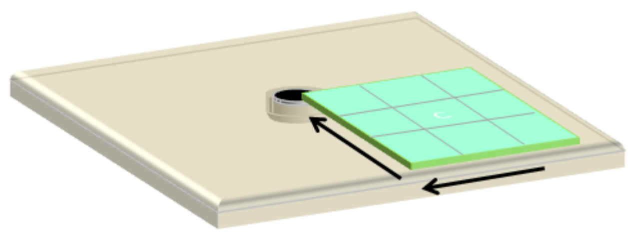


8: MAPPING

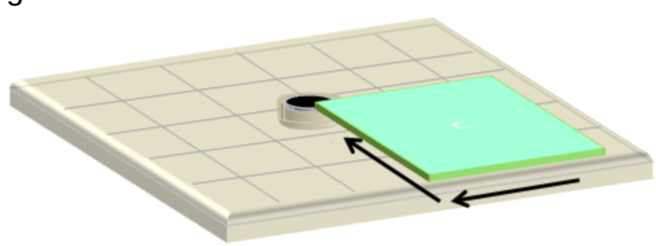
Manual mapping

Mapping of a sheet, panel, or wafer can be easily accomplished using an S3 Sensor, S3 Stage, and Delcom Software. For conception background on mapping sheet resistance of material, see Delcom_KC15_Manual Mapping.

1. How to track material location
   a. Method 1: Mark the material
      i. Use a clear plastic sheet protector of the appropriate size.
      ii. Mark a grid on the sheet. The dimensions of grid increments are at the user's discretion.
      iii. Place material to be mapped in the sheet protector.



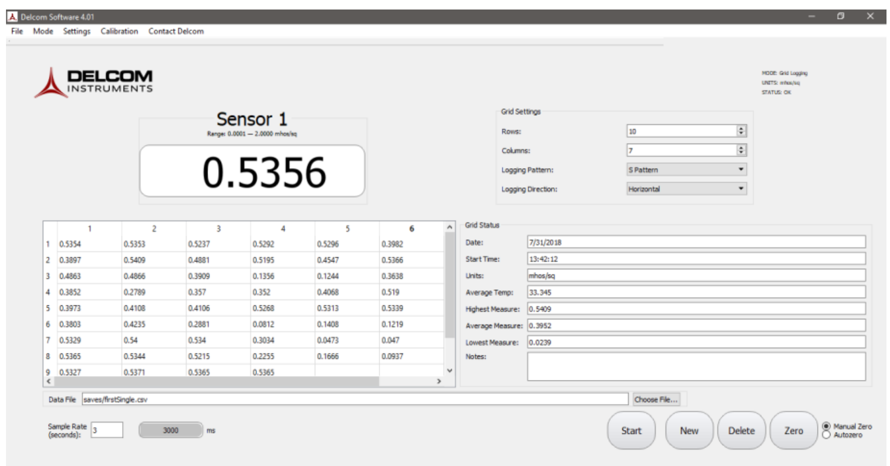
   b. Method 2: Mark the stage
      i. Mark a grid onto the stage surface.
      ii. The user is able to track increments by moving the edge of the material from one grid line to the next.



2. Set elevation (See Delcom_KC8_Lift-Off Effect for S3 Sensor)

a. If the conductive layer is to be placed intimate with the stage, then no further action concerning elevation is required.
b. If the conductive layer is to be offset from the face of the sensor and therefore subject to lift off effect, calibrate the meter to this new elevation as described above.

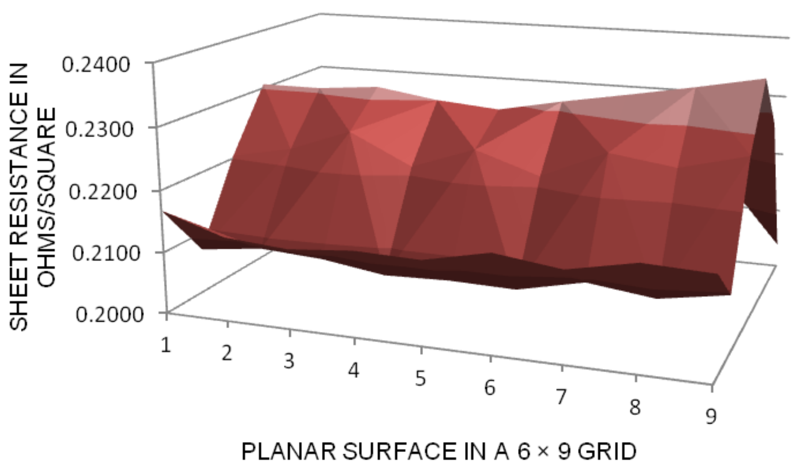
3. Set up the software
   a. Open the Delcom software, click Mode, and select Grid Logging.
   b. Choose the number of rows and columns to match those on the sheet protector and choose logging pattern and direction.
   c. Select the file path for the document save.



4. Manually map the material
   a. Zero the meter.
   b. Place the first grid increment to be mapped in the sensor spot.
   c. Log the data.
      i. If using the timed logging method, set the timer to the desired number of milliseconds, and then press Start. Increment the material one square over (or half an increment) at the completion of the countdown timer.
      ii. If using the manual logging method, press New. Increment the material one square over and press New again.

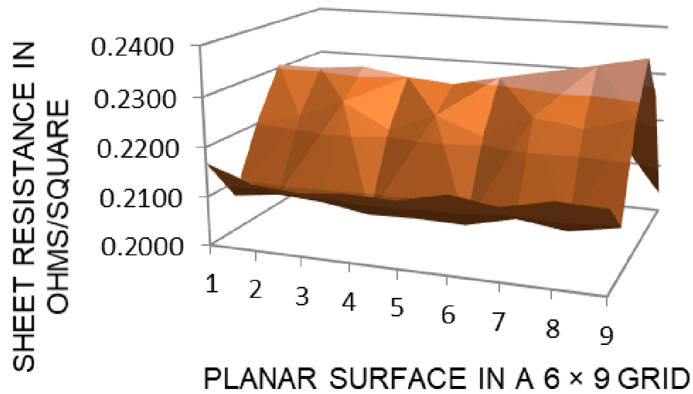
d. Upon completion, the data will already be in the destination you chose before beginning the mapping. There is no need to save when the mapping is finished—the data has been saving in real time.

5. Perform post-process analysis and display
   a. Open the file (ending in .csv) in Microsoft Excel.
   b. The user can easily create a chart to display data graphically. Select the data, then click Insert, Chart, and Surface.



Mapping without a stage

Mapping of a sheet, panel, or wafer can be easily accomplished using an S3 Sensor and Delcom software. For conception background on mapping sheet resistance of material, see Delcom_KC15_Manual Mapping. For information on how to manually map with the use of a stage, see Delcom_UG16_S3 Stage.



1. Prepare instrument
    a. Connect sensor, interface module, and PC.
    b. Turn on the meter.
2. Prepare material
    a. Use a clear plastic sheet protector of the appropriate size.
    b. Mark a grid on the sheet. The dimensions of grid increments are at the user's discretion.
    c. Place material to be mapped in the sheet protector.
3. Prepare the work surface
    a. Select a flat, nonconductive surface or table. The sensor requires about 1.5" of nonconductive material between it and any conductive layer.
    b. Test the surface for conductivity by running the sensor over the surface.
    c. Place the material (enclosed in the sheet protector) on the benchtop.
4. Set up the software
    a. Open the Delcom software, click Mode, and select Grid Logging.
    b. Choose the number of rows and columns to match those on the sheet protector and choose logging pattern and direction.
    c. Select the file path for the document save.
5. Manually map the material
    a. Zero the meter.

b. Place the sensor on the first grid increment to be mapped.
c. Log the data:
    i. If using the timed logging method, set the timer to the desired number of milliseconds, and then press Start. Increment the sensor one square (or half an increment) over at the completion of the countdown timer.
    ii. If using the manual logging method, press New. Increment the sensor one square over and press New again.
d. Upon completion, the data will already be in the destination you chose before beginning the mapping. There is no need to save when the mapping is finished—the data has been saving in real time.

6. Perform post-process analysis and display
    a. Open the file (ending in .csv) in Microsoft Excel.
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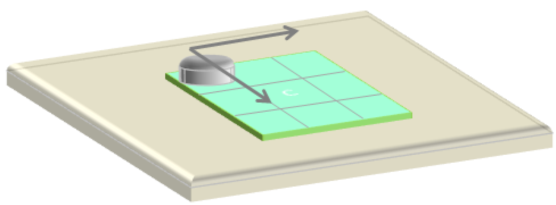


9: MEASURING SMALL SAMPLES USING SLIDES

This chapter provides the operator with dimensions and instructions for using thin slides to measure samples that are smaller than the stated required spot size.

Switching to a smaller size sensor is preferred

Delcom's smallest spot size is currently a 26mm diameter sensor. If you are using a sensor with a spot size larger than this, please request a 26 mm diameter sensor.

Introduction to concept of sample slides

For users who already have a 26mm diameter sensor but wish to measure smaller size samples, Delcom offers a unique solution.

With some effort, it is possible to use a 26 mm diameter sensor to measure pieces of material smaller than the minimum sample size. This process requires the user to arrive at standard size(s) for these extra small samples. The user then sends the dimensions of these standardized size(s) to Delcom. Delcom will then make custom slides that have indents to accept these custom sized shapes.

Delcom will then use a 3D printer to create custom material slides for the customer. If the user has access to a 3D printer of a quality machine shop, Delcom would be happy to send the user CAD drawings of recommended slide dimensions to the user.

Once the user has received/produced these custom slides, they should follow the steps below.

Step 1: Create method for inserting material

The user must make (or have Delcom fabricate) a means to introduce this smaller material into the sensor at the exact same *xy* position in the sensor gap each time.

The picture below shows 3D printed sample slides. Each of these slides is custom made to hold an exact size and shape sample.

The 3D printed slide also has indentations that are used to register the slide in the exact same position each time it is inserted.

Registration of the slide is accomplished by placing two pins in receptacles of the sensor's stage.

Step 2: Calibrate meter

First, the meter's readings must be normalized to a smaller size and shape. This can be accomplished by following these steps:

1. Create or purchase a piece of material of fairly uniform sheet resistance that is larger than the spot size of the Delcom sensor.
2. Measure the sheet conductance of this material.
3. Cut the material to the exact shape of the smaller-than-minimum sample size material that you wish to measure.
4. Insert the material into the Delcom sensor using the custom sample slide. It will read more resistive than it did when the material was larger than the minimum sample size of the sensor.
5. With the material inserted into the sensor, calibrate this smaller sample to read the same sheet resistance that the material read before being cut down. (See Delcom_UG2_Calibration.)

Step 3: Maintain exact dimensions from sample to sample

Third, all subsequent material measured must be the same shape and size as the material used to calibrate the meter to the smaller-than-minimum sample size. Note: thickness can vary.

10: MOUNTING INSTRUCTIONS

This chapter provides the operator with dimensions and instructions for mounting the S3 sensor.

Dimensions

Reach into material:	NA
Sensor gap:	NA
Overall length:	7 cm
Overall width:	5 cm
Overall height:	4 cm

Mounting location

The sensor can be mounted:

- Into a stage from the bottom
- Onto an arm or gantry which is moved via linear motion allowing for automated *xy* mapping of material
- On a fixture to hold the sensor at a fixed height above an area to be measured
- On a fixture past which material will be moving, allowing for real-time inline process control

In all cases, any conductive material should be at least 1.5 inches away from the face of the sensor.

See Delcom_KC7_Effects of Elevation in Gap and Delcom_KC9_Flutter and Bounce.

Mounting instructions

The sensor head has four mounting holes on the bottom of the sensor (i.e., the side of the sensor that faces the material to be measured). These four 6-32 tapped holes are designed to allow the sensor to be mounted into a stage. See Delcom_UG16_S3 Stage.

The sensor also has four mounting holes on the top of the sensor (i.e., the side of the sensor in which the D-Sub cable is connected). These four 4-40 tapped holes are designed to allow the sensor to be mounted onto a scanning arm or otherwise elevated above the material to be measured.

Installing the PC

If the user has requested a PC, the PC can be installed up to 15 feet away from the interface module. The interface module communicates with the PC via USB 2.0. This signal can be boosted farther than 15 feet if needed via readily available, inexpensive third-party equipment. If the operator purchased a panel PC from Delcom, mounting brackets will be included. The panel PC has its own enclosed chassis ready to be “dropped” into a control panel. Efforts should be made to ensure the panel PC has sufficient air circulation.

Mounting the interface module

If the IM100 interface module has been selected, then this component can be placed on a flat surface.

If the IM110 interface module has been selected, then the user can use the integrated flange to mount the interface module on an appropriate surface.

Cabling, vacuum, feedthroughs, and mounting brackets

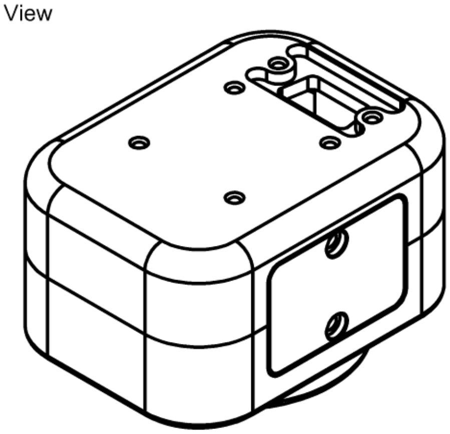
For vacuum applications, the plastic insulated Dsub cable leading from the sensor to the interface model will be replaced by: A vacuum-ready shielded cable, a feedthrough, and a plastic insulated Dsub cable.

Delcom can design and machine custom mounting brackets according to customer requirements.

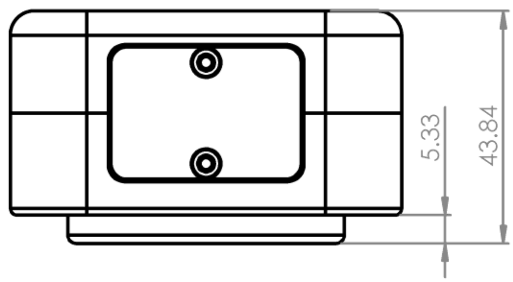
Customer may need to purchase appropriate feedthroughs. Delcom can source these if needed. Delcom recommends the Accu-Glass Products Inc. model number 9D-K40. http://accuglassproducts.com/product.php?productid=16217&cat=0&page=1.

S3 Sensor (Dimensions in mm)

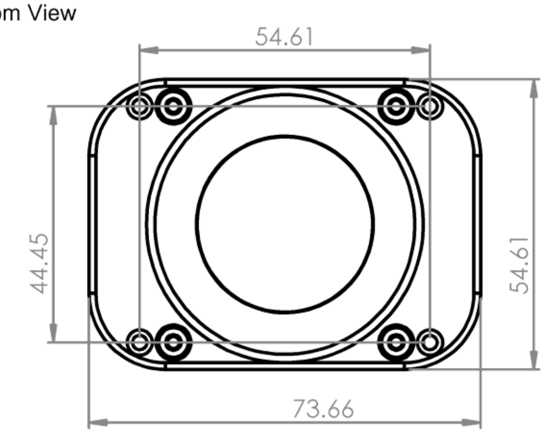
Isometric View



Side View



Bottom View



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