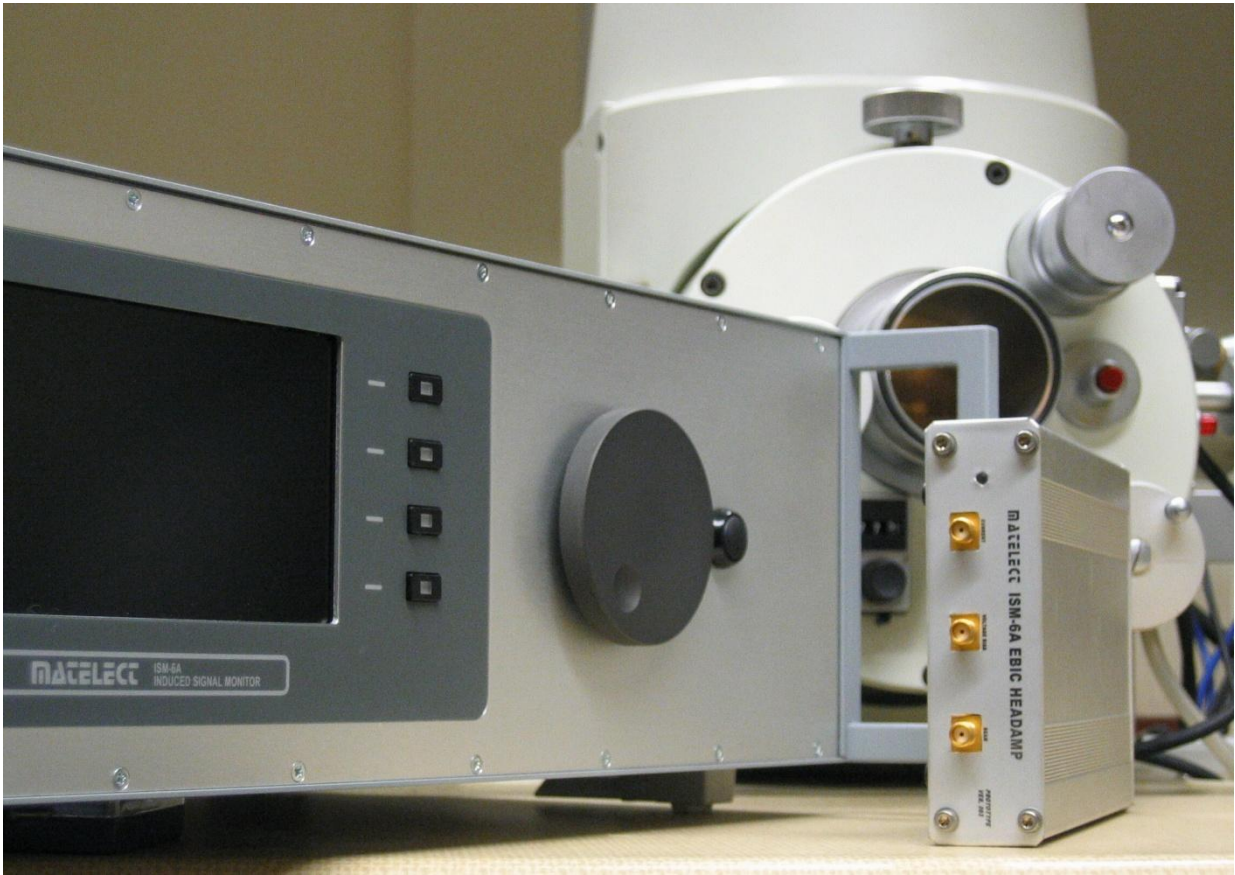


MATELECT INDUCED SIGNAL MONITOR

TYPE ISM-6



INSTRUCTION MANUAL

Issue 1.1

MATELECT INDUCED SIGNAL MONITOR

TYPE ISM-6A

Thank you for your interest in our product, we hope that it will serve your needs and proves a reliable tool.

This product has been designed to the highest standard in both electronic and mechanical design, with careful attention to stability, reliability and electrical safety.

The ISM-6A is the latest in a line of induced signal monitors produced by Matelect Ltd since the early 1980s. These instruments are designed to make measurements of beam-induced currents and voltages, principally when examining semiconductor materials within an electron microscope. The ISM-6A builds on two decades of success enjoyed by the ISM-5A, an instrument which established a large and loyal following among university and industry based researchers, and which became regarded as the instrument of choice for measurements made when undertaking studies involving techniques such as EBIC, EBIV, OBIC, & CL.

The ISM-6A updates the ISM-5A and brings it firmly into the digital age, with usage enhancements and greater connectivity, however it utilizes much of the original analogue circuit techniques and therefore continues to provide low noise quantitative as well as qualitative induced signal measurement performance, but with significant improvements in certain areas (particularly with a view to bandwidth) thanks to use of modern devices and higher quality componentry.

In common with the original ISM instruments, Matelect produce a range of peripherals to support the ISM-6A, including Labview based software for linescan acquisition, a port plate service for connection to end-user microscopes, and specimen mounting stages. With over 30 years of experience in EBIC/EBIV techniques, we are able to provide advice and technical support, standard equipment, and even bespoke measurement/software solutions for more demanding users. Please contact us should you ever require information or assistance.

IMPORTANT

Please read these instructions carefully before you use the instrument. Please pay particular attention to the section that follows on mains operation. For your reference please also read our terms and conditions of sale printed at the rear of this manual. Please note that there are no user serviceable parts within the ISM-6A. Never attempt to open the instrument case as this will void our warranty.

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2. MAINS OPERATION

This section applies to all mains operated instruments
PLEASE READ BEFORE OPERATION

Before use, please make sure that the instrument's mains supply rating is correct for the location and country it will be used in. The ISM-6A can be operated on both 110 and 220V supplies by appropriate adjustment of the input voltage switch (see pages 23-24). Before shipment, your instrument will have been set for the commonly used voltage in your locality.

The instrument must be connected to the mains supply using an IEC mains lead terminated with the appropriate local mains plug. The unit is supplied with a suitable lead for this purpose.

The instrument is housed in a metal case for strength and electromagnetic screening purposes and therefore PLEASE ENSURE that the instrument is earthed to the mains earth via the IEC connector.

In addition to the fuse that may be present in the mains plug (e.g. UK versions), the ISM-6A is fitted with two equipment fuses for protection. These fuses are located in the IEC input socket on the rear panel of the ISM-6A. Both fuses need to be functional if the equipment is to be operated.

The instrument fuses are rated at 1000 milliampere and are of the 20mm "anti surge" type. Never replace these with fuses of a different type or rating as the instrument can be seriously damaged.

Ensure that the ISM-6A does not come into contact with fluids or corrosive gases and that it is operated within the temperature range of 0-40 degrees C.

3. QUICK REFERENCE

This section applies to all mains operated instruments
PLEASE READ Chapter 2 before reading this!

Here it is assumed that the ISM-6A is to be used for EBIC measurements. The ISM-6A comes into two parts – a main unit and a head amplifier. The latter is connected to the former by an umbilical cable, and is usually sited close to the display console of the user's SEM. To reduce noise, the head amplifier is usually directly mounted onto a side portplate on the SEM specimen chamber. Three vacuum tight electrical feedthroughs are required (Matelect can supply port plates with suitable connectors) but for basic EBIC work, this can be reduced to two and a temporary connection can be achieved with any existing feedthroughs, by using short cables. A special specimen mount is not usually required, but can make EBIC work less fiddly and users should consider either purchasing a mount or designing their own. More information is given in Chapters 9, 10 & 11.

Operation of the ISM-6A divides into two distinct modes – qualitative (i.e. imaging) operation and quantitative (measuring actual numerical quantities) operation. The unit is capable of doing both simultaneously (and without the imaging side affecting the measurement side). It is therefore important to understand which instrumental controls are dedicated to imaging, and which are important for measurement (see Chapter 6). The ISM-6A is unique in this respect and has been designed at the outset from the viewpoint of an end user who wishes to both use their instrument to obtain images of EBIC activity, optimised for contrast and brightness, whilst also retaining the possibility of simultaneously measuring the actual magnitudes of the induced current so that properties such as carrier diffusion lengths can be obtained.

The ISM-6A is normally manually controlled, however all front panel functionality can be accessed, parameters set, and values measured, from a Windows based virtual instrument software package which can be supplied with the unit. An industry standard RS232 serial communications connection is employed (USB and Ethernet interfaces are also available). This digital communications link enables a stream of real-time EBIC data to be recorded and stored for later retrieval. This is especially useful if end-users wish to record the change in induced signal generated as a beam traverses a feature on the specimen. This could be as simple as measuring the EBIC response as the electron beam scans across a PN junction. When an induced signal is likely to change spatially, then recording such a "linescan" is the only way of obtaining meaningful quantitative data, and reading an average induced signal on the front panel of the unit will largely be pointless.

More information on the operation of the ISM-6A is given in Chapters 7 to 11. The quantitative controls centre on the setting and/or measurement of three related parameters – induced signal magnitude, current suppression (back-off current), and applied bias voltage. Parameter adjustment is performed using a simple and intuitive graphical menu system, in tandem with a single large adjustment knob. This combination retains the traditional feel of analogue instruments with the digital power and connectivity of modern digital systems.

4. CONTENTS

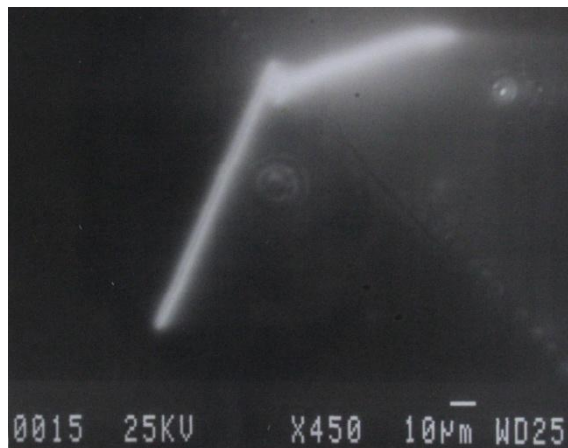
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5. OVERVIEW

Microscopy was significantly altered by the advent of the electron microscope and latterly by the arrival of scanning techniques that rely upon a laser or electron beam as a route to specimen imaging. These concentrated sources of energy are directed onto the specimen and scanned in a raster over a defined imaging area.

The specimen interacts with an incident beam in a number of ways. Each category of interaction can be used to generate an image of the specimen that depends on the level of the interaction at each point on the raster. Thus, when an electron beam hits a material, other electrons are emitted from the surface regions of the specimen. These can be detected by an appropriate detector and used to create a "secondary electron image". This image gives a good representation of surface topography of the specimen. Many more interactions can occur, however, and these can be used to provide further information about the sample, (e.g. the emission of X rays can be used to determine chemical composition). In semiconductor studies it is the electron-hole pairs, generated (induced) by the scanning beam, that can be measured and used to create an image. Such images are a representation of the ability of the electron-hole pairs to recombine and, therefore, not contribute to the measured signal level. This ability is largely governed by the electronic materials properties of the specimen.

Qualitative images generated from induced currents (and alternatively, induced voltages), together with the *quantitative* measurement of these, can thus convey significant information about the structure and perfection of a specimen with respect to its electronic properties. Below is a typical image of an electrically active fault in a semiconductor, obtained under EBIC conditions.



The ISM system has been designed to allow precise measurements to be made of induced signals created during semiconductor materials characterisation. It is also designed to assist end-users to create images of induced signal activity, which can be finely adjusted for contrast and brightness without affecting the qualitative measurement of the signal magnitudes.

This “dual-use” functionality enables end-users to obtain both an optimised image of electrical activity as well as measure the magnitude of the effects present and thus later (using theory established in the literature) generate data on particular materials properties and physical constants.

The ISM system is mainly used for electron beam induced current studies (EBIC) although it is able to perform induced voltage (EBIV) work and various forms of cathodoluminescence measurements by using an appropriate detector.

The system is utilised in conjunction with the user's scanning electron or scanning optical microscope. Precise measurements of induced current and induced voltage are possible depending on the system configuration. In addition, the amplified induced signal can be fed back into the SEM's or SOM's display circuitry (a cathode ray tube display in older instruments, or a PC based LCD in modern systems) so as to create an image of the specimen using that particular quantity.

Induced currents can be suppressed by an internal facility on the ISM-6A so that small signal variations can be detected on a much larger DC level. The unit also provides a variable in-built voltage supply which permits the biasing of specimens under test. Biasing a semiconductor in this way can often generate large current flows, and change the induced signal response. Such currents have to be internally “suppressed” by the ISM-6A before the more subtle variations in induced signal response can be detected. Similarly many semiconductors are sensitive to light and heat, and charge carriers are generated simply as a consequence of the exposure of the specimen to these external influences. Measuring small changes in a specimen's response (for example as generated by electrically active defects present within it) which have been swamped by large intrinsically generated currents thus requires a unit with a significant current suppression capability.

The ISM system comprises a main control unit and a head amplifier. The latter is attached to the user's microscope and performs pre-amplification of the induced signal. The head amplifier is connected to the microscope via three triaxial LEMO connectors, arranged in with triangular symmetry. This configuration can be altered to suit the individual needs of the user and it may not necessarily be the standard form as shown on page 28 of this manual.



The ISM-6A as supplied, with associated ICA-2 head amplifier

The main control unit contains all the functionality required to optimise images and measure induced signal magnitudes. This functionality is accessed through a backlit LCD graphics display. An intuitive menu system and set of push buttons (located either side of the display) allow navigation of the unit's facilities.

A large single dial is used to provide a manual "feel" to the adjustment of parameters such as suppression current and back-off voltage, and allows end-users to concentrate on optimising the clarity of the image so produced without watching the front panel of the instrument.

Computer control of the ISM-6A is possible using the inbuilt PC interfaces – serial, and Ethernet based. Matelect produce software for this purpose but can also supply the protocol used or a Labview based VI for end-users who wish to write their own code. The software allows setting of all the parameters normally set through the front panel controls but in addition, permits the logging of linescans – induced signal data which has been obtained as a time varying signal.

The linescan facility is normally employed when induced signals are created by a scanning action, (e.g. in a SEM, as the electron beam traverses a specimen), to record the data in a spatial sense, and thus characterise the change in signal across a microstructural feature (such as grain boundaries and PN junctions). Linescan data are often more useful than "spot" magnitudes of induced signals, especially when determining materials parameters and physical constants by established practices.

To successfully record a linescan, the ISM-6A needs to know the start and finish of the scanning process being undertaken by the end-user's beam based equipment. For example, in EBIC work within an SEM, the linescan start point normally corresponds to the start of the beam scan across a specimen. Of course, the beam will make many such scans in order to create a single "frame" – i.e. the image of the specimen, and therefore it is normal to place the SEM in a linescan mode, whereupon it will make a single scan of the specimen along a pre-determined line (usually the centre line of the image plane).

The ISM-6A begins linescan acquisition when it receives a trigger signal from the end-user's scanning equipment – usually locating a suitable output from the equipment is a simple case of referring to the instruction manual or the manufacturer. Matelect can help in this respect, and the internal trigger circuitry of the ISM-6A can detect and deal with most raster waveforms emanating from end-user equipment. Once a trigger event has been registered by the ISM-6A/software, data acquisition commences and ends after a precise period of time. This corresponds to the duration of the linescan, and the software permits end-users to input bespoke durations (again, obtainable from the scanning equipment's specification).

The end-user is referred to the vast collection of published literature which can be accessed in order to ascertain the best use of the ISM-6A's linescan facility. Further information and applications advice can be obtained directly from Matelect.

To create an image of induced signal activity in a specimen, the ISM-6A provides a buffered output of the signal magnitude that it is measuring. This is normally fed into an auxiliary signal input channel on the end-user's scanning equipment. Older SEMs would normally have an analogue input channel available for this purpose, whilst modern SEMs simply have an extra A-D channel on their digital interfaces or PC controller cards. Acceptable input voltage ranges on these devices are as diverse as the devices and manufacturers themselves, but it is important to match the input range to the output of the ISM-6A.

As an example, if a large discrepancy exists between what the SEM is expecting to represent a high signal (i.e. high brightness) and what the ISM-6A outputs, then at worst, the image brightness and contrast controls on the ISM-6A will not give users the range of adjustment that they need in order to optimise the image, but at worst, possible damage could occur to the input of their SEM (and/or the ISM), if it has not been adequately protected from an overload condition.

In recognition of the fact that one manufacturer may expect bright-white to correspond to an output signal of 2 volts, whilst another might require 5 or 10V, the ISM-6A incorporates circuitry which permits the end-user to scale the output range of the ISM-6A to match the input range of the end-user's equipment. This is a once-only, set and forget adjustment, provided that the ISM-6A is not transferred between SEMs, although of course, should the latter occur, the end-user simply has to again adjust the output range of the ISM-6A to suit. This adjustment is simply effected by controls placed on the rear panel of the ISM-6A.

The ISM system has been successfully employed by many research institutes, universities and industrial users, world-wide. It is regarded as the best instrument of its kind, with features specified by experimentalists prominent in the field of beam induced signal measurement. Further advice on procedures, peripheral equipment, and getting the best out of the ISM system can be obtained by contacting Matelect.

This manual applies to the ISM-6A BETA, which is a semi-production digital instrument which builds on the successes of the ISM5 – an industry standard induced signal monitor with a long history of use by researchers in academia and industry involved in EBIC, OBIC and CL studies. In this manual, text in **BOLD CAPITALS** is usually used to indicate lettering that appears on the front or rear panel of the instrument.

6. GENERAL DESCRIPTION

The Matelect ISM-6A has been designed to detect and process induced current and voltage signals which are produced in semiconductor materials and devices during observation in a scanning electron or laser microscope. The instrument consists of a head amplifier which is attached to the microscope and a control unit to which the head amplifier is connected by a multi-core cable.

There are two types of head amplifier: The ICA2 head amplifier (supplied as standard) is used for induced current measurements (EBIC and OBIC) whilst the IVA2 unit is used for induced voltage measurement. Both head amplifiers contain a second amplifier channel which can be used to monitor the electron or laser beam when it is connected to a Faraday cup or calibrated photodetector, as appropriate. Obtaining a value for the magnitude of the excitation beam is important to maintain a base-line correction and normalisation if trying to make precise quantitative measurements. For imaging purposes it is much less important.

The front panel display of the ISM-6A control unit provides real time digital displays of the magnitude of the signal, applied back-off (suppression) current and the voltage bias supplied to the sample, as well as a virtual environment for setting all instrumental parameters and controlling the imaging functions of the system. The quantitative measurement side of the ISM-6A operates very much like a non-autoranging multimeter, with separate controls for the signal measurement range, which the user can select via the graphics screen.

When a voltage head amplifier is connected into the ISM system, both the back-off and the bias voltage generators are automatically disabled.

Short Circuit TRIGger detection is provided on the sample bias voltage line. Trigger levels can be set from the front panel of the ISM control unit. When a short circuit is detected (i.e. when the current in the bias voltage line exceeds the preset limit), the bias voltage is automatically removed and a warning sign displayed on the control unit. A reset command is registered when the **S C TRIG**ger function is re-accessed, but the bias voltage must be reduced if the short circuit is not to occur a second time.

Two outputs are provided on the rear of the control unit: the **RECORDER** output and the **ANALOGUE** output. The former provides a buffered output of the signal as measured by the head amplifier, suitable for direct input into a chart recorder or data acquisition system, including A-D cards in a PC. The output signal level corresponds to that shown on the front panel main **SIGNAL** display. The output has a full scale deflection of 2.0000V on any range. Thus a display of 199.99 on the 200nA range corresponds to 1.9999V on the **RECORDER** output. This output represents the true quantitative value of the induced signal.

The **ANALOGUE** output is connected to the CRT/LCD display of the user's scanning electron (or optical) microscope to produce an image of the induced signal.

The magnitude of the output is determined not only by the true quantitative value of the induced signal but also by the settings of a number of supplementary controls. These controls are used to enhance the brightness and contrast of the image on the microscope's display. Additionally the rear panel signal scaler facility also affects the ultimate voltage swing of the analogue output.

The front panel functions that affect the analogue output are located at the centre of the graphics display and allow for adjustments of **GAIN**, **VARIABLE** gain, **BIAS**, signal invert functionality (via negative gain) and **FILTERING**. The **GAIN**, **VAR.** and negative gain controls alter the *contrast* of the image, whilst the **BIAS** control changes the *brightness* level. It is important to note that these controls do not alter the *quantitative* signal as displayed on the front panel graphics display, nor as output at the rear panel **RECORDER** socket.

Whilst the ISM-6A is a stand-alone instrument, the system can be expanded by the addition of Matelect software to allow computer control of the unit. This optional PC based package is used to both control the front panel functions of the ISM-6A and to acquire quantitative linescan data and convert it into a form easily utilizable by commercial spreadsheet packages. Communications and data transfer between the ISM-6A and a PC is via the computer's RS232 serial link (or USB), or alternatively via the included Ethernet facility.

No data acquisition cards or complicated installation procedures are necessary, although to action the linescan facility, when using, say, an SEM as the scanning device, a connection needs to be made between the ISM-6A and a suitable waveform output from the SEM to allow the former to be triggered by the latter when a scan commences. The software functions happily on PCs running the Microsoft XP or Vista OS. Operation of the software is the subject of a separate manual.

Linescan data is useful when quantitative measurement are required across a feature on a specimen – for example, a transverse section through a PN junction in a semiconductor, and where the signal reading is likely to alter in the temporal sense – hence making a single average reading (as provided by the **SIGNAL** readout on the front panel graphics display), insufficient and unrepresentative. Linescans can also be recorded from the **RECORDER** socket of the ISM-6A. This would usually be done by feeding the signal into an external A-D system and it is therefore possible for end-users to use this output as part of their own linescan acquisition system.

Connection of the ISM-6A to the end-user's microscope, for purposes of imaging, is very simple and straightforward. Installation is usually carried out by the end-user but Matelect can assist in this if required. Please see the chapter on Installation for further details. The ISM-6A can be connected to most types of scanning microscope providing the latter is equipped with an appropriate auxiliary input facility. Such inputs are commonly used for the connection of supplementary detectors (e.g. absorbed electron detectors in SEMs).

As mentioned previously, the ISM-6A is equipped with a signal scaler/level change facility which allows users to closely match the voltage levels of the **ANALOGUE** output with those acceptable to their microscopes.

This needs to be adjusted by the end-user and then left alone, so long as the ISM-6A is not transferred to a different imaging instrument, at which point the adjustment may need to be altered. Instructions for matching up the signal scaler are given later in Chapter 8.

A schematic of the electronics that constitute the ISM-6A is shown below in Fig 1.

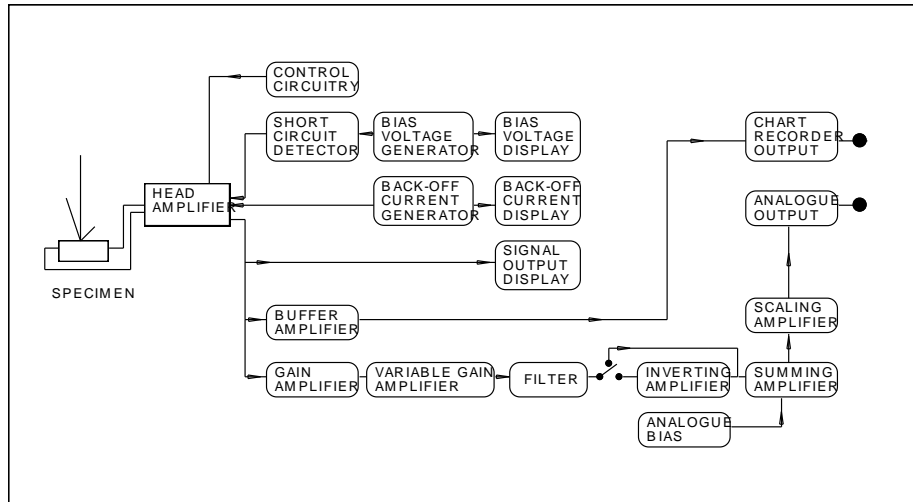


Fig.1 Schematic of the ISM-6A system

The ISM-6A is supplied with four standard cables and these are illustrated in Fig 2.

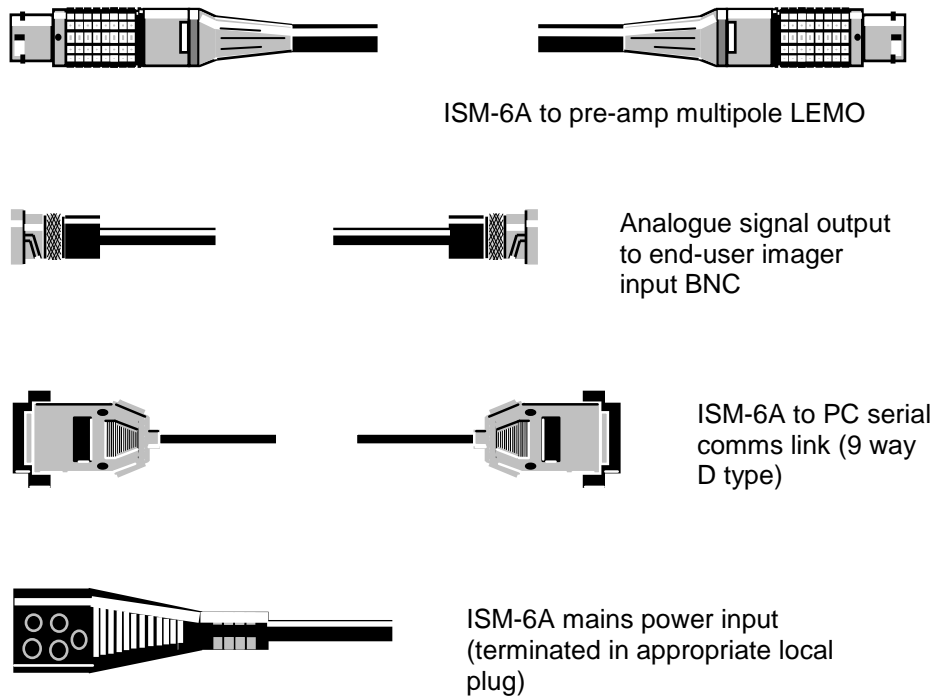


Fig 2. Cables supplied with the ISM-6A

7. FRONT PANEL DESCRIPTION

The Front panel of the ISM-6A is shown below in Fig 3. The controls are fully described in this section. For further technical information please refer to Chapter 11 on General Usage Advice.

ISM-6 Front panel functionality

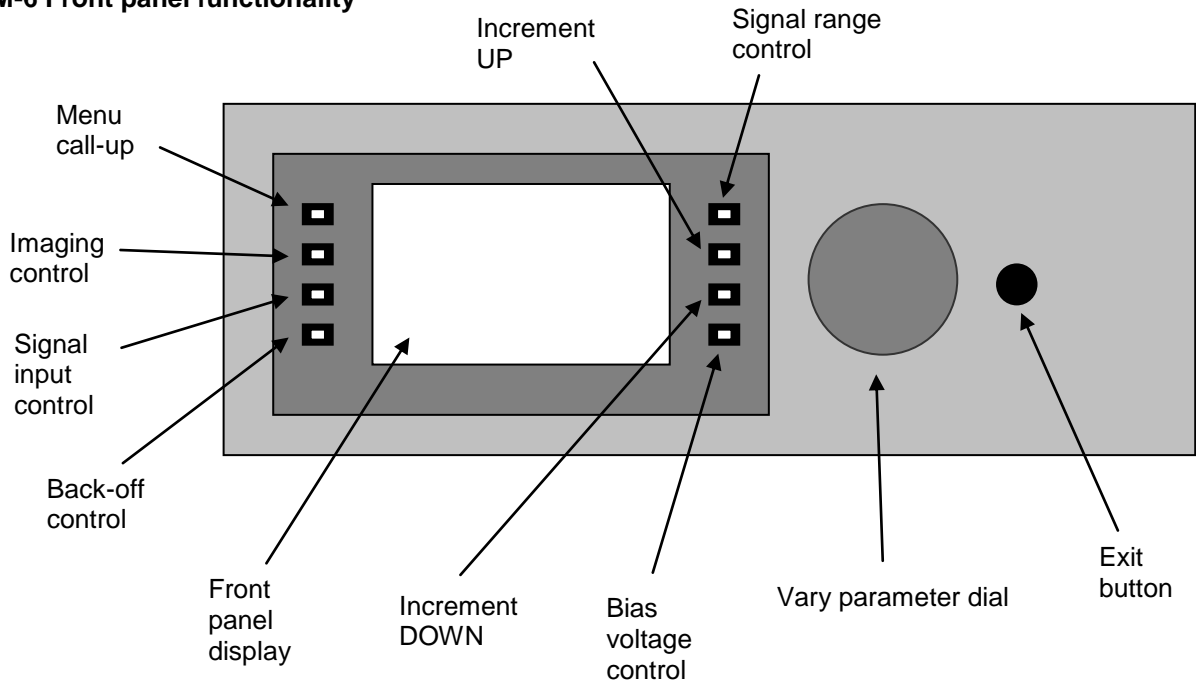


Fig. 3. The front panel of the ISM-5A

Basic Design

Users should recall that the ISM-6A has two main functions, and the controls on the instrument naturally divide into those that serve one or other of these. The first function is to provide a true measurement of an induced signal. The second is to create an image of the specimen under investigation *using* the induced signal.

The quantitative controls of the ISM-6A are thus supplemented by a series of *qualitative* image enhancing controls.

It is important to note that whereas the settings of the quantitative controls influence the *qualitative* image, the *qualitative* controls have **no** effect on the magnitude of the quantitative signal.

Front panel graphics display

The front panel display of the ISM-6A is the main man-machine-interface through which users select and set parameters, observe the status of the instrument, and read measured data values. Both the qualitative and quantitative functionality of the instrument are accessed through this display.

The display screen is divided into zones, each of which deal with the three main parametric sections of the ISM-6A – display of the qualitative induced signal, setting and display of the back-off current, setting and display of the bias voltage. Additionally there are zones which relate to the setting of the imaging controls and with other functions that require manual adjustment and/or pre-setting.

Accessing the zones of the display, in order to set the appropriate parameters, is achieved by using the set of 8 pushbuttons alongside the display.

The functions of each of these and the zones is described in turn below.

Control buttons (Cb1-8) aside graphics display

Control button 1 – MENU selector – this brings up a menu that allows users to adjust parameters such as the preferred PC communications method, and the contrast of the front panel LCD graphics display.

Control button 2 – Imaging control selector – activates options which alter the magnitude of the analogue (i.e. imaging) output, namely the brightness and contrast (gain and bias), and the image noise filtering level.

Control button 3 – Signal INPUT control – activates a sub-menu to allow selection of the input channel on the head amplifier. The EBIC head amp. contains 2 separate channels, one to measure a beam current, and the other, the specimen current.

Control button 4 – BACK-OFF selector – this highlights the back-off current zone, and in conjunction with button 6 and 7 and the Vary Parameter Dial, permits the setting of a current to suppress the input signal.

Control button 5 – SIGNAL range control – this highlights the signal zone on the front panel, and together with button 6 and 7, allows alteration of the measurement range (e.g. from nA to mA when in induced current mode).

Control button 6 – UP button – this is only activated as a consequence of selecting buttons 1,2,3,4,5, and 8, and is used as a cursor control to move highlighted text boxes up by one increment, each time the button is pressed.

Control button 7 – DOWN button – this is only activated as a consequence of selecting buttons 1,2,3,4,5, and 8, and is used as a cursor control to move highlighted text boxes down by one increment, each time the button is pressed.

Control button 8 – BIAS selector – this highlights the bias voltage zone, and in conjunction with button 6 and 7 and the Vary Parameter Dial, permits the setting of an output voltage which can be used to bias the specimen under test.

Ancillary front panel hardware controls

Vary parameter dial (VPD) – this is used to provide precise adjustment of the back-off current within the selected range, the bias voltage (again within a selected range), and importantly, the image brightness and contrast, plus other variable functions (e.g. LCD contrast), depending on which operational zone is highlighted.

The VPD provides for both coarse and fine adjustments of parameters being set, by using an algorithm that detects how far and fast the VPD is being rotated – hence gradually raising the rate at which the parameter is being adjusted to provide a coarse control, then dropping it down to fine increments, when the rate of adjustment begins to drop as users get closer to their desired set-point.

Exit/Back button (E/B)– must be pressed once to deselect operation of activated control buttons and zones, and to confirm the set-level of parameters such as the applied back-off and voltage bias.

SIGNAL zone on graphics panel

This represents the quantitative side of the ISM-6A. The meter in this zone displays the actual value of the signal being measured by the ISM-6A head amplifier. The displayed quantity is scaled according to the range selected by the operator using the range control (see below). The signal zone can be accessed using control button 3 (Cb3) for purposes of altering the measurement range to achieve optimum sensitivity of measurement.

The meter is *not* autoranging and will display a maximum of 20000 on any range with an appropriate decimal point. For example on the **20nA** range, the meter will over-range above 20.000 nA. The next range (**200nA**) should then be selected (via Cb5 to enable, and Cb6 and Cb7 to increment, or decrement).

Currently over-ranging is not indicated by any means and therefore end-users should be cautious about relying upon signal values close to the 20000 digit limit. An induced signal measured over an extended area or line on a specimen (for example an EBIC signal across a semiconductor PN junction observed in an SEM) can vary through several orders of magnitude. Thus, whilst users should always select the most sensitive (finest) range to monitor their signals, they should also be wary of generating a *transient* over-range situation.

During an over-range condition, whilst no damage to the ISM-6A will occur, the signals available to the user at the **ANALOGUE** and **RECORDER** outputs will exhibit clipping (saturation).

The rate of conversion of the meter is approximately 5 times per second. The meter therefore responds to the average of the signal that is being measured. Users wishing to record the instantaneous value of the signal at the frequency response of the instrument can do so by using the **RECORDER** output socket located on the rear panel (see following chapter).

The measurement unit (amps or volts, nano, micro etc) appropriate to the signal range selected, and the head amplifier fitted, is displayed at the right hand side of the **SIGNAL** output meter.

Users should note that the displayed value of the **SIGNAL** output is the arithmetic summation of the specimen signal and the value of any **BACK-OFF CURRENT** applied. If a **BIAS VOLTAGE** is also applied to the specimen, the reading on the **SIGNAL** output display will also be expected to change.

MENU zone on graphics panel

Normally inactive to adjustment, unless selected via Cb1. This contains options for adjusting the display contrast and brightness, and the activation of either serial or Ethernet communications ports. When selected, Cb6 and Cb7 also become active, allowing the selection and setting (via the E/B button) of the parameters.

Fine control of display contrast and brightness is achieved via the VPD.

Signal INPUT zone on graphics panel

Normally inactive to adjustment, unless selected via Cb2, but will reveal the status of the mode currently selected. This contains options for setting the input signal channel on the pre-amplifier. For the ICA-2, two channels are selectable, one to measure the **BEAM** current (this could be connected to an internal Faraday cup within the end-user's SEM), and the other would be allocated to the actual specimen **CURRENT**. The beam channel would be used to acquire magnitude data for normalisation/calibration of the specimen current. When selected Cb6 and Cb7 switch between the menu options, and E/B confirms the selection.

If the ICA2 induced current head amplifier is being utilised (e.g. if EBIC or CL measurements are being performed) the mode switch must be in either the **CURRENT** or **BEAM** position. Conversely if the IVA-2 head amplifier is employed for EBIV studies, the **VOLTAGE** or **BEAM** positions should be selected, when present. As a precaution, the ISM-6A control unit recognises the type of head amplifier in use and automatically disables the inappropriate options on the menu. Thus, when the ICA-2 is utilised, the **VOLTAGE** position is inoperative, and the unit defaults to the **CURRENT** mode.

The reading in the **SIGNAL** output zone (and emanating from the rear panel **RECORDER** output) corresponds to the source selected in the **INPUT** zone. The **INPUT** zone setting automatically confers the appropriate measurement unit enunciators (volts, amps) shown in the **SIGNAL** output zone.

When either the **BEAM** or **VOLTAGE** modes are selected, the instrument's ability to supply a back-off current or bias voltage will be disabled.

BACK-OFF CURRENT zone on graphics panel

Normally inactive to adjustment, unless selected via Cb4, but will reveal the status and precise value of any back-off (suppression) current applied by the end-user. This zone contains a 10000 digit meter and range/unit enunciators. The meter displays the actual value of the **BACK-OFF CURRENT** applied by the ISM-6A head amplifier. When selected, Cb6 and Cb7 also become active, allowing the selection and setting (via the E/B button) of the parameters. The displayed back-off quantity is formatted according to the range selected by the operator using the back-off range control (Cb6 and Cb7 to increment or decrement ranges). The measurement units appropriate to the range selected are indicated by enunciators positioned to the right hand side of the meter display.

To set a value of the **BACK-OFF CURRENT**, an appropriate range for the magnitude applicable should be first selected (using Cb6 and Cb7), then the VPD can be employed to dial up the precise back-off value. Note that the VPD provides for both fine and coarse setting of the back-off value, using its distance sensing algorithm. The set value of the back-off is applied to the specimen input as soon as it is dialled up, but when the E/B button is subsequently pressed, the set-back-off menu returns to its inactive state.

The available **BACK-OFF CURRENT** range increments make it possible to obtain the same level of back-off current on two separate back-off ranges. For example, 90nA can be set on both the 100nA and 1uA ranges. End-users should select the appropriate range for their desired back-off, such that widest use of the range is made. When the back-off current is set via the PC communications link, and Matelect software, the ISM-6A is placed in the best range automatically.

User's should note that the **BACK-OFF CURRENT** facility is fully quantitative and that it acts directly upon the input signal from the specimen. Consequently application of a back-off current would be expected to alter the quantity displayed on the **SIGNAL** output meter. In this respect, the back-off current will also alter the **RECORDER** output signal and the **ANALOGUE** output signal.

When considering the effect on the brightness of an image, the **BACK-OFF CURRENT** facility acts in a similar manner to the **ANALOGUE OUTPUT BIAS** control (see later) in operation, in that it is used to suppress the DC component of an EBIC signal. The fundamental difference between these two controls, however, is that the **BACK-OFF CURRENT** is fully quantitative, and acts directly upon the current emerging from the specimen, whilst the analogue bias control acts on the processed EBIC signal (i.e. after any back-off is applied), and has no effect on the quantitative value of the signal – only upon the signal sent to a user's SEM to create an image. There would be nothing, for example, to stop both types of suppression to be applied in sequence, to maximise image clarity.

When no specimen is connected to the ISM system and a back-off current is applied, the **BACK-OFF CURRENT** meter and the **SIGNAL** output meter should read approximately the same value of current.

Please note that the instrument is calibrated to indicate a reasonable one-to-one correspondence between the two displays only on certain range combinations. For example, the 200nA back-off range is compatible with the 200nA signal range and therefore good correspondence should be obtained between these two.

Users should also note that when the **SIGNAL** range is placed in the most sensitive position, the back-off current should ideally be set to the 100 & 1 μ A ranges to avoid large back-off values being set and thereby swamping the specimen signal.

If a back-off current has been set, it is automatically switched out when the **BEAM** mode is selected by the user. This also occurs if the ICA-2 is replaced by the IVA-2 induced voltage head amplifier.

ANALOGUE OUTPUT zone on graphics panel

Normally inactive to adjustment, unless selected via Cb2, but will reveal the status, and value, of any of the major parameters in this zone.

This **ANALOGUE OUTPUT** facility is used to apply fine variations to the *quantitative* signal level generated by the circuitry relating to the **SIGNAL** zone. The resultant is known as the **ANALOGUE OUTPUT** and is primarily *qualitative* in nature. This output is available at the rear of the ISM-6A's control unit and is normally connected directly to the user's imaging display (e.g. the auxiliary input to an SEM's CRT/LCD screen or image acquisition system). No numerical value, as such, of the output is given on the front panel graphics display.

Adjustments made in this zone **do not** affect in any way the value of the true signal (in the **SIGNAL** zone), nor of the **RECORDER** output, however it is important to note that changes made in the **SIGNAL** zone and in the **BACK-OFF CURRENT** zone will affect the **ANALOGUE OUTPUT**

The controls in this zone divide into:

- i) **GAIN** (adjusted in large steps, & then subsequently in a continuously variable sense (**VAR**). Equates to an image contrast control.
- ii) **BIAS** (an infinitely variable level shift), which works like an image brightness control, raising or lowering it as desired.
- iii) **FILTER** (adjustable in steps), which acts to remove noise from the signal which would otherwise create "snow" on the image.

Once an appropriate signal measurement range has been selected (in **SIGNAL** zone), the **GAIN** control is used in conjunction with the **VARIABLE** gain, **FILTER** and **BIAS** controls to optimise the visual appearance of the induced signal image. The controls are described below but further details on adjustment of the analogue (imaging), see the chapter on General Usage Advice.

GAIN (level amplification) – image contrast control

Press Cb2 to access menu, **GAIN** should then be highlighted (Cb6/Cb7 can be used to highlight option if not already), & use VPD to adjust **GAIN** in increments. Gain changes are instantly applied to the image output, but a final press of the E/B button saves the settings and exits the menu. This sequence can be used to select one of 3 calibrated attenuation and one of 7 calibrated amplification factors that can be applied to the *qualitative* analogue output signal.

The **GAINS** available are 0.1, 0.2, 0.5, unity, 2, 5, 10, 20 , 50 and 100 times.

The **GAIN** facility effectively controls the difference between the bright and dark features on an image – i.e. the *contrast* of the image - as displayed upon the user's display monitor. Negative gains are also provided, which permits the image contrast to be reversed (see below).

VARiable gain control

Press Cb2 to access menu, Cb6 to highlight **VAR** option, & VPD to adjust **GAIN** in “infinitely” fine increments. This facility provides a variation of a few percent of the existing applied **GAIN** value. It is used in conjunction with the coarser **GAIN** control as a fine brightness adjustment for the *qualitative* image on the user's monitor. It should only be used once all other parameters (e.g. signal range (**SIGNAL** zone), **GAIN**, and **BIAS** (see below)) settings have been correctly adjusted, else its effect will be minor.

When the **VARiable** gain is greater than unity, the overall gain is now unknown and is therefore “uncalibrated”. An indication that the output is now in this mode occurs in the zone on the graphics screen. This might be important to know if the end-user was externally recording the magnitude of the **ANALOGUE OUT**put signal, for some reason, although if this was desired, then the **RECORDER** output should be utilized instead, as this remains unaffected by the setting in this zone.

When a new coarse increment **GAIN** is subsequently set, the **VARiable** gain setting defaults to unity so that the absolute position of the VPD is irrelevant, and it can continue to offer maximum variation.

Negative GAIN control – image invert

Negative gains can be set in the **GAIN** menu, as well as positive ones. This permits the image contrast to be reversed - i.e. what would have appeared a white feature on a black background, is now a black feature on a white background. This can be thought of as an image “invert” feature.

Care should be exercised in using this control as it will not always appear to reverse the contrast levels of the image (i.e. substitute black for white and vice-versa). This is because the invert function works in conjunction with the **BIAS** (offset) control (see below).

The invert function will only invert that part of the analogue output signal that is superimposed upon the **BIAS** level. Thus if a substantial **BIAS** level has been selected and only a *small* induced signal is present, no inversion of the contrast will be observed on accessing the invert facility. Conversely if no **BIAS** is applied, then a complete contrast inversion will result.

BIAS (level offset) - image brightness control

Press Cb2 to access menu, Cb6/Cb7 can be used to highlight **BIAS** option (if not already), & the VPD used to adjust **BIAS** in increments. The **BIAS** is applied in real-time to the imaging output of the ISM-6A. A single press of the E/B button exits this menu, but retains the user settings.

This control is part of the **ANALOGUE OUT**put facility and is used to apply a *qualitative* offset to the measured signal. It is analogous to a zero shift or offset control on a chart recorder, in that its purpose is to remove the DC component of a signal so that further analogue **GAIN** can be applied. The higher **GAINS**, which are then achievable, deliver more image detail.

The process of offset followed by a **GAIN** increase is fundamental to electronic measurement per se. The DC component of a signal carries no useful information with regard to creating an image. It is the small changes that are superimposed upon the DC level that are of significance. Given that all instruments have a limited output voltage capability, it makes sense to remove or reduce the DC component before attempting to apply any amplification. A much larger degree of amplification can then be employed before the instrument's limitations are reached. This procedure thus enhances the sensitivity to the small signal changes of interest.

In effect, the **BIAS** control acts to vary the *brightness* of the image that is displayed upon the user's display monitor, unlike the **GAIN** and **VARIABLE** gain controls, which alter the *contrast*.

Although the actual voltage level selected by the **BIAS** control cannot easily be determined by the user (nor is it necessary to do so as it is primarily a *qualitative* facility), symbols on the graphics display in the relevant zone indicate whether the **BIAS** is positive or negative in polarity, and approximate magnitude. By carefully adjusting the **BIAS** level so that neither symbol type is lit, the user can set zero **BIAS**.

FILTER – Image noise control

Press Cb2 to access menu, Cb6/Cb7 can be used to highlight **FILTER** option (if not already), & the VPD used to adjust filtering in increments. Filtering is applied in real-time to the imaging output of the ISM-6A. A single press of the E/B button exits this menu, but retains the user settings.

This control is used to select the degree of low-pass **FILTER**ing that is applied to the **ANALOGUE OUT**put signal. The second order filters used, give nominal cut-off frequencies of 10, 30, 100, 300 and 1000 Hz, 3, 10 and 30 kHz.

In the **OUT** position all the filters are by-passed and only the raw, unfiltered signal is fed to the rear **ANALOGUE** output BNC. The **FILTER** control is normally used to remove extraneous noise that is superimposed upon the induced signal. The control does not affect the quantity displayed on the **SIGNAL** output meter, nor the signal measurable at the ISM-6A rear panel **RECORDER** output.

Users should always commence imaging with the filter in the **OUT** position. This will prevent any important features from being missed through the over-application of filtering.

BIAS VOLTAGE zone on graphics panel

Normally inactive to adjustment, unless selected via Cb8, but will reveal the status and value of any voltage bias applied to the specimen under test, and the status of the **Short Circuit TRIGGER** safety feature.

Biassing the specimen is a way of altering its conductivity and hence any response that is induced within it by the action of an excitation beam. Often defects will be easy to spot in images created under biased conditions, compared to non-biased cases. Reverse biasing a pn junction for example, is very likely to reveal a different image contrast than forward biasing.

The short circuit safety feature is used to trip out the voltage bias when a specified level of specimen current has been reached. This is done in order to avoid any damage to the specimen, should a large current flow as a result of an applied but inappropriate voltage bias.

The controls in this zone divide into:

- i) **BIAS Voltage** display and adjustment
- ii) **Short Circuit TRIGGER** set level, and status

BIAS VOLTAGE

Press Cb8 to access menu, Cb6/Cb7 can be used to highlight **BIAS Voltage** option (if not already), & the VPD used to adjust the level in “infinite” steps either in the forward or reverse direction, and up to the maximum permitted by the instrument (see below). A single press of the E/B button exits this menu, but retains the user settings. Note that the VPD provides for both fine and coarse setting of the voltage value, using its distance sensing algorithm. The set value of the voltage is applied to the specimen as soon as it is dialled up. Clockwise rotation of the VPD applies a more positive bias whereas rotation anticlockwise reduces the bias and ultimately applies a negative one.

Users should note that the **BIAS VOLTAGE** facility is switched out automatically when the ISM-6A is in **BEAM** mode (see earlier). This is also the case when the IVA-2 induced voltage head amplifier is fitted or when a short circuit is detected as a result of applying a bias voltage to the specimen (see below).

Short Circuit Trigger

Press Cb8 to access menu, Cb6/Cb7 can be used to highlight **Short Circuit TRIGger** option (if not already), & the VPD used to adjust the applicable trigger level in fixed steps. A single press of the E/B button exits this menu, but retains the user settings.

This control is used to limit the current drawn by the user's specimen when a bias voltage is applied. The trigger can be adjusted to one of 5 preset current levels (0.1, 0.5, 1, 5, and 10 mA). Should the current (as measured by the head amplifier) exceed the set limit, the voltage bias is automatically switched off, and the voltage reading will fall to zero – this acts as an indication that the safety trigger has tripped.

Once a trip condition has been reached, users should reduce the bias voltage first (to avoid it happening again) and reset the trigger by simply highlighting the trigger level setting and changing up or down to a different level. This will clear the it trigger condition. Users can then return to the original trigger level if desired, or stay at the new level.

BIAS VOLTAGE – caution!!!

The ISM-6A has been designed to provide up to 120 volts of forward or reverse bias, so that, for example, high power electronic devices and materials can be tested at levels close to their operating conditions. This voltage is potentially dangerous to operators and the output at the ICA-2 preamplifier should therefore be treated with caution. As a precaution, the Short Circuit TRIGger is always in operation and therefore the maximum current available at 120V, is 10mA. The 120V facility is enabled only upon customer request (usually at the time of ordering) but as standard, it is firmware limited to 25V.

8. REAR PANEL DESCRIPTION

The rear panel of the ISM-6A is shown below in Fig 4. The controls are fully described in this section. For further technical information please refer to the sections entitled General Usage Advice and Specifications.

ISM-6 Rear panel functionality

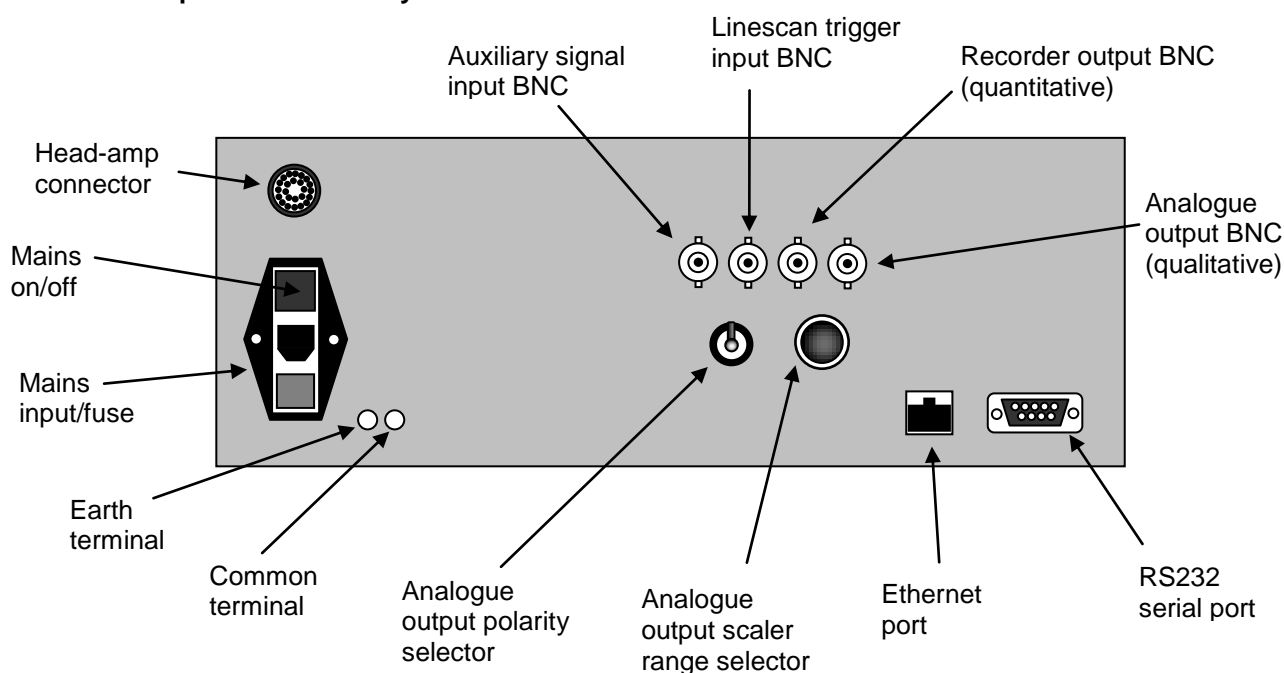


Fig. 4 The rear panel of the ISM-6A

Mains input socket, power switch and voltage selector

PLEASE READ THE SECTION ON MAINS OPERATION before attempting connection to this socket.

The socket is of the standard IEC mains input type with integral line filter, mains switch and mains fuse. A suitable lead, terminated with a local mains plug, will have been supplied with the ISM-6A. If this is missing, only use an approved mains IEC connector as a replacement.

The instrument is fitted with two 1000 milliampere anti-surge 20mm fuses. If any of these fail, then the equipment should be disconnected from the mains supply, and the fuses replaced with ones of the **same** rating and type. DO NOT use a fuse of a higher rating as permanent damage may result to the ISM-6A.

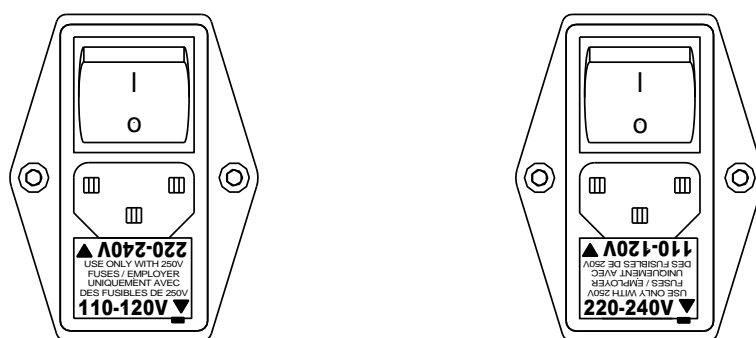
The fuses are accessible via a sliding carrier tray. This can be levered out using the blade of a slotted screwdriver placed in the recess within the carrier.

If the local mains plug also incorporates a fuse (e.g. UK versions) then this should be of a similar rating to the fuses within the IEC socket (1 Ampere recommended).

CARE! Always ensure that the mains input lead has an Earth connection and that this is in good order. This is necessary both for safety purposes and in order to obtain sensible results.

The ISM-6A can be operated off either 100-110 volt AC or 220-240 volt AC supplies. It is NOT auto-sensing, therefore it MUST be pre-set for the appropriate range before it is powered up. Usually units are shipped set to the appropriate voltage range, however the end-user can easily change this by accessing and rotating the fuse tray below the IEC mains input socket. – a screwdriver is used to lever open the tray. Its orientation with respect to the white marker, below the tray, indicates the main voltage range chosen (see Fig 5 below).

CARE! Disconnect the unit from the mains supply before altering the mains input range. Operation of the ISM-6A with this switch incorrectly positioned will cause serious permanent damage to the unit, and may injure the operator.



Unit set for 110-120V

Unit set for 220-240V

Fig. 5. Rear panel IEC mains socket formats

EARTH terminal

Connection to the case (chassis) is available at this terminal. The connector accepts a standard 4mm “banana” type plug.

COMMON terminal

The circuit common line is available at this terminal. Connection to this can be made as per above, using banana plugs. The circuit common of the ISM-6A is electrically isolated from the case Earth. If it is desired to connect common to Earth, a wire link can be used between the **COMMON** terminal and the **EARTH** terminal.

Isolation of the instrument's common is useful if external peripherals such as chart recorders and data acquisition systems are connected to the ISM-6A. If their signal common is connected to Earth, an earth loop could occur, should the ISM-6A's common also be connected to Earth. Such loops are sources of signal instability and should therefore be avoided.

Please see the section on General Usage Advice for further details on avoiding earth loops.

HEAD AMPLIFIER connection socket

This accepts the umbilical cable used to link the ICA-2 and IVA-2 head amplifiers to the ISM control unit (see Fig. 2.). This is a multipole LEMO type socket. Power supply lines, signal, back-off and bias voltage information, and control data is transmitted via this connector and the associated umbilical cable.

RECORDER output

The output voltage at this connector lies between -1.9999 volts and +1.9999 volts and therefore exactly represents the displayed value on the **SIGNAL OUTPUT** display (see preceding chapter). For example, 1.5nA on the 2nA range will be displayed on the **SIGNAL OUTPUT** display as 1.5000nA and will generate a **RECORDER** output voltage of 1.5000 volts. Similarly 0.15nA will be displayed as .1500nA and generate a 0.1500V output.

Please note that the maximum voltage output will be the same irrespective of the **SIGNAL OUTPUT** range selected by the user and represents the full scale deflection possible on that particular range. Thus 199.99nA on the 200nA range will generate a 1.9999V **RECORDER** output and a signal of 19.999 μ A on the 200 μ A range will also generate 1.9999V.

ANALOGUE output

This is a BNC socket which provides a buffered output signal that represents the *qualitative* induced signal data. The **ANALOGUE** output supplies the signal that is used to create the image of the specimen under investigation.

The signal level is determined by the settings of the **ANALOGUE OUTPUT** controls on the front panel of the ISM-6A control unit. These alter the image brightness, contrast and filtering. Please see the preceding section for a full description of these controls. Further information is given in the chapter entitled General Usage Advice.

The **ANALOGUE** output should be connected (using the BNC cable supplied) to an appropriate auxiliary input of the user's microscope. (see chapters on Installation and General Usage Advice).

ANALOGUE output scaler controls

This facility has been incorporated into the ISM-6A to enable users to scale the unit's analogue output to a voltage range that is compatible with their microscope. The 10 output combinations provided cater for almost all SEMs thus removing the need for the unit to be factory fitted for only one type of microscope. Both the span (range) of the output and the level can be altered enabling connections to systems that work on dual polarity or from zero upwards. The following output ranges are possible:

plus/minus peak to peak of 0.5, 1, 2.5, 5 or 10 Volts
plus/zero peak to peak of 0.5, 1, 2.5, 5, or 10 Volts.

The controls are situated below the **ANALOGUE** output BNC. A rotary switch selects the peak to peak range whilst the toggle switch sets the level shift.

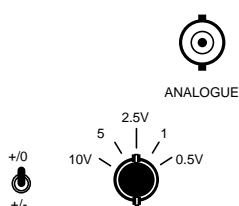


Fig 5. Rear panel location of RANGE controls

ISM-6A units with this facility are normally shipped correctly set for the user's SEM, if known. To adjust the settings, users should determine the acceptable input range of their microscope and select the largest analogue output range that still remains within the microscope's input range.

Exceeding a microscope's input specification will lead to a reduced range over which the ISM-6A contrast and brightness controls function (the analogue **GAIN** and **BIAS** controls). This will cause premature display saturation.

Caution!!! - in the unlikely event of a microscope's input not being protected, exceeding its acceptable input range could also damage the microscope!

The effect on the **ANALOGUE** signal of these controls is shown in below.

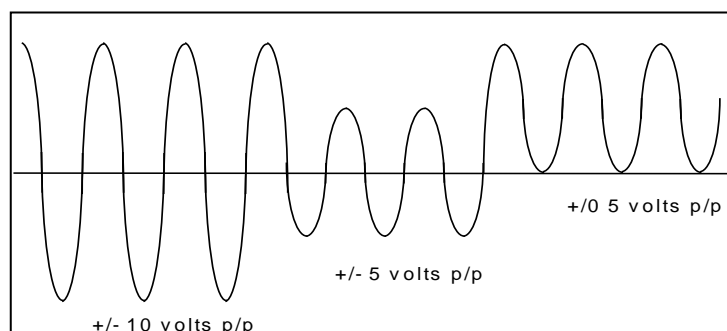


Fig. 6 Schematic of the action of the ANALOG range controls

9. HEAD AMPLIFIER DESCRIPTION

The ISM-6A control unit is connected via an umbilical cable to one of two different head amplifier units which are in turn connected to the specimen under investigation.

The ICA-2 head amplifier is used for induced current measurements (e.g. EBIC studies) whilst the IVA-2 is used for induced voltage studies. Both head amplifiers contain separate circuitry for the measurement of beam current (necessary for true quantitative experimentation).

When measuring minute signals it is necessary to use a head amplifier in order to reduce the influence of extraneous noise. Often the electrical noise present in a testing environment is greater in magnitude than the signals of interest. The head amplifier is effectively a first stage or pre-amplifier that increases the true signal level so that the noise present will form a smaller percentage of the overall measured signal. For this method to work, the pre-amplifier must process the signal **before** noise is superimposed upon it (otherwise the noise will be amplified as well!) In practice this means locating the pre-amplifier as close to the specimen as possible.

The head amplifier is usually mounted directly on a custom port plate attached to the user's microscope. For the case of an SEM, the port plates contain the required electrical feedthroughs to the inner vacuum chamber of the microscope (use LEMO part number HGP1S650CTLP - bulkhead vacuum tight fitting). The connectors on the front panel of the head amplifiers are of the non-locking LEMO triaxial type. The outer conductor is connected to the case (instrumental Earth) of the pre-amplifier. The centre pin carries the signal, whilst the intermediate shield carries the return line (corresponding to circuit Common).

If there is no alternative but to use cables to connect the head amplifier terminals to electrical feedthroughs in end-user equipment, then these should be well screened and as short as possible.

Custom port plates can be supplied by Matelect for any microscope or configuration. Users wishing to fabricate their own port plate are advised to contact Matelect for design recommendations.

It is important for end-users to understand how the head-amplifiers function, as a sound knowledge of their operation will enable the best possible specimen set-up to be designed. For example, in some cases specimens should be electrically isolated from the earth of the end-user's microscope, whereas in others, it is an unnecessary complication. Schematics of the internal electronics of the ICA-2 head amplifier is given in the section below, and advice on connecting specimens is given in the chapter on General Usage Advice.

ICA-2 HEAD AMPLIFIER

This is used to amplify induced currents generated in the specimen under investigation. Fig 7. shows the unit's front and rear panels.

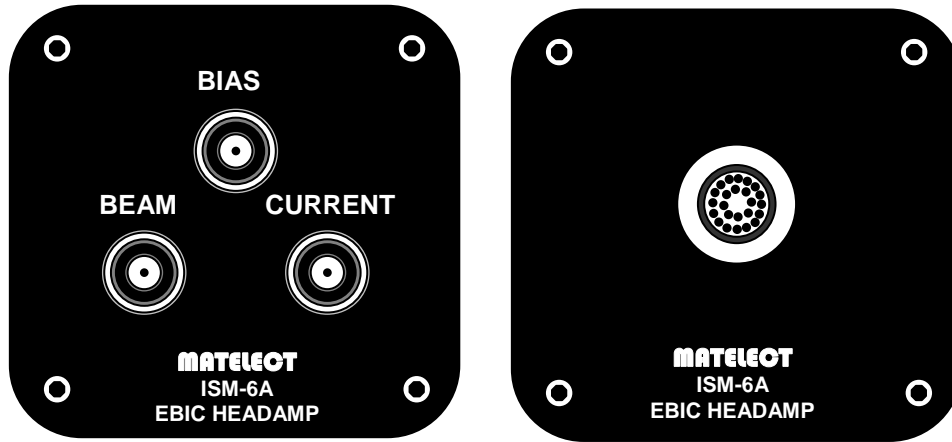


Fig 7. The front (top) and rear (bottom) panels of the ICA-2 head amplifier

BEAM input LEMO connector

For accurate quantitative studies it may be necessary to measure the excitation current of the scanning electron beam used in an SEM or the flux of the scanning laser beam in a SOM. The centre pin of this connector serves the auxiliary current amplifier that is provided for beam measurement.

The ISM-6A control unit will display and measure the signal from the separate, but in-built, beam amplifier when the **BEAM** mode has been selected via the front panel graphics screen.

BIAS (Common) LEMO connector

The centre pin of this connector delivers the bias voltage, selected by the user, to specimen. The actual level of the bias voltage is set from the front panel of the ISM-6A control unit using the **BIAS VOLTAGE** controls.

*Please note that when the **BIAS VOLTAGE** is not activated, the centre pin of the **BIAS** connector is normally tied to the circuit Common of the head amplifier via an internal relay (see Connections below), BUT for the ISM-6A BETA, this relay is **not** currently activated. Thus end-users who intend to bias their specimens can use the **BIAS** terminal as their return (Common) connection, **but** users who simply want to monitor induced currents under non-biased conditions, **need** to make their return connection through the inner shield of the triaxial connector on the **CURRENT** input.*

CURRENT LEMO connector

The centre pin of this connector forms the input to the induced signal amplifier. All input currents that constitute a flow of electrons *into* this connector are deemed *negative* in nature, whereas a flow of electrons out of this connector is regarded, and displayed, as a positive current.

Rear panel I/O connector

This is a locking multipole LEMO type chassis plug to which the control and signal umbilical cable from the ISM-6A control unit is connected. It is provided with a single location slot which mates with a ridge in the umbilical cable head shell. The ridge is provided to assist in location, mating and retention of the plug and cable assemblies. To separate mated connectors, the outer knurled ring on the LEMO plug is first grasped and pulled back, and the locking action is then released.

CONNECTIONS TO THE ICA-2

A schematic of the internal circuitry components of the ICA-2 head amplifier and their relationship with the specimen and microscope is shown below in Fig 8.

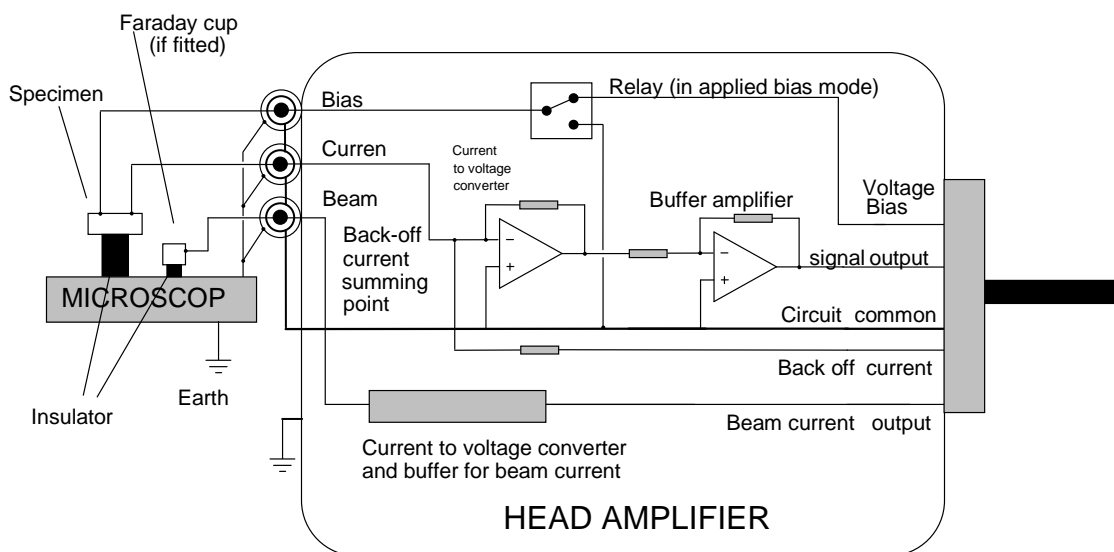


Fig 8. Schematic of the internal electronics of the ICA-2 head amplifier

The pre-amplifier umbilical cable carries power supplies to the ICA-2, and signals representing the specimen bias voltage and applied back-off current. The cable also carries the pre-amplifier output to the control unit. The pre-amplifier consists of a current to voltage converter circuit which can be switched to different sensitivities via a bank of relays (not shown).

The umbilical cable carries the required signals to these relays as determined by the settings of the **SIGNAL** range setting on the ISM-6A control unit.

A similar arrangement is used for the **BACK-OFF CURRENT** facility. Summation of the signal input current and the back-off current takes place in the head amplifier. A second amplifier buffers the output voltage of the converter and sends this to the ISM-6A control unit for further processing.

The specimen is directly connected to the input of the current to voltage converter via the **CURRENT** connector. To complete an electrical circuit a second connection needs to be made to the specimen and this is done through the **BIAS** connector.

Normally, when no bias voltage has been selected by the user, the centre pin of the **BIAS** connector is directly connected to the Common line of the ISM circuitry via a relay within the head amplifier. When the **BIAS VOLTAGE** facility is operated, the set voltage is switched through to the specimen by the same relay. In the ISM-6A BETA however, the relay connection to the Common line is not enabled, hence connections to the specimen are different depending on whether a voltage bias is intended to be applied or not. If no biasing is done, then the return connection needs to be made to the inner screen of the triaxial **CURRENT** connector.

Users should note that the outer portions of the head amplifier's LEMO connectors are connected to the head amplifier's external case, and thus to the case/instrument Earth of the ISM system. Therefore, when the LEMO outers are mated to a port plate (normally at microscope Earth) an earth loop will result.

Users should ensure that at least one circuit Common to Earth link is correctly established to prevent charge retention by the ISM-6A. Further links between microscope Earth and Common (e.g. through the Common of the **ANALOGUE** output) *can* cause earth loops which could well generate substantial noise and instability. Earth loops should be avoided at all costs. The best location for the link between ISM-6A Common and an SEM earth is at the specimen/head amplifier end. For further details see Chapter 11 on General Usage Advice.

If cables are used to connect the head amplifier to the microscope, rather than a Matelect port-plate, users must ensure that the cables are of the shielded type and that circuit Common is connected to the outer shield (if coax is used) or to the inner shield (if triax is used). If the user's cable mates with a coaxial bulkhead connector, then the outer portion of this could well be electrically connected to the microscope earth – hence a common-earth link is made by default – so users should be wary of making any further link.

Users should ensure that the inner parts of the LEMO connectors are thoroughly clean as even a small amount of grease, dirt or moisture can cause leakage of the minute currents which they are trying to measure.

In an SEM, the sample should always be mounted on an isolating stand within the microscope chamber because of the risk of induced signals being leaked to Earth. To reduce any leakage currents, PTFE isolation should be used.

If the **BIAS VOLTAGE** facility is to be used, the specimen **must always** be isolated from the microscope Earth. If this is not done, the bias voltage will be effectively shorted to Earth and serious damage could occur to the ISM system. If voltage biasing is not used then it is feasible to use an earthed sample holder with a single connection to the head amplifier **CURRENT** connector. For safety reasons, this is not recommended.

If in doubt always isolate the specimen

Optical beam based systems should follow similar precautions.

Shielding of the specimen connection wires *within* the microscope chamber in an SEM is not a critical requirement. The metal chamber (at Earth potential) acts as a Faraday cage which effectively eliminates extraneous noise sources. Sources of noise (electrical rather than thermal) within the chamber are rare but if they exist would necessitate the use of shielded cable to the specimen. Otherwise the use of low leakage PTFE covered wire is recommended for internal connection to the specimen or holder.

Shielding in optical beam based systems may be required if an earthed metallic chamber for the specimen is not a feature of the equipment.

10. INSTALLATION

It is assumed that the user has read and become familiar with preceding chapters.

Additional information on installation is given elsewhere in this manual and it is best therefore to read the whole document before commencing with any procedures. Installation of the ISM-6A should pose no major problems or difficulties and is easily performed by the end user. Those who experience difficulties should contact Matelect for detailed advice and assistance.

AFTER UNPACKING

After checking the equipment for obvious signs of transit damage, users should ensure that the ISM-6A control unit is correctly adjusted for their local mains supply.

Please read the chapter on Mains Operation before attempting to power up the equipment.

Once these checks have been performed the system can be assembled. This simply consists of attaching the ICA-2 or IVA-2 head amplifier to the ISM-6A main unit via the umbilical cable supplied.

It is often advantageous to power up and test the various functions of the ISM-6A before attempting to connect it to a microscope's auxiliary input or to a specimen. All of the major quantitative functions can be checked by this route. For example, with no specimen, various values of back-off current can be selected, applied and the **SIGNAL OUTPUT** meter checked for correspondence.

Additionally, by using a low leakage diode connected across the **BIAS** and **CURRENT** inputs of the ICA-2 head amplifier, reverse leakage currents can be measured at various bias voltage levels.

INSTALLING THE HEAD AMPLIFIER

As described in Chapter 9, for the case of SEMs, provision needs to be made for the direct mounting of the head amplifier to the microscope chamber. This minimises noise pick-up by eliminating the need for cables. This is usually accomplished by the use of a dedicated port plate. The triangular arrangement of the head amplifier connectors allows the whole enclosure to be self supporting on the port plate although a support bracket is recommended.

Custom port plates for SEMs can be supplied by Matelect. Alternatively we can provide design advice, engineering drawings and suitable vacuum tight triaxial feedthroughs for those users wishing to fabricate their own.

The use of cables as links between the head amplifier and specimen chamber is not recommended. In certain cases, say where space is restricted, cables may be the only viable method of connection and users should ensure that they are kept as short as possible, shielded cables are used and care is taken to ensure earth loops are not inadvertently set up (see Chapters 9 and 10).

The optional IVA-2 head amplifier **must** be mounted so that its **VOLTAGE** input connector is isolated from the casing of the user's microscope.

Installation on a SOM system follows similar guidelines.

The Chapter on General Usage Advice gives further details pertinent to this section.

CONNECTION OF THE SAMPLE

Sample connection methods vary from user to user and specimen to specimen. There are no firm rules for this subject and the user is advised to investigate the methods described within the published literature for further details.

In most cases it is advisable for a user to fabricate or purchase a specimen holder that both isolates the specimen from the body of the microscope and supports the electrical leads to the specimen. In the vacuum chamber of an SEM, the leads travel from the electrical feedthroughs to the sample holder. Much finer wires can be used to provide the electrical connection from the specimen holder to the surface of the specimen itself.

Two connections are required to the specimen, one to the **CURRENT** (or **VOLTAGE**) input of the head amplifier, the other to the **BIAS** (Common) input.

If it desired to utilise the **BEAM** current measurement facility of the ISM-6A, then a further connection needs to be made to a suitably isolated metal area or purpose built Faraday cup.

Further advice on this subject can be obtained from Matelect.

CONNECTION TO THE USER'S DISPLAY MONITOR

This forms the only other external connection required by the ISM system. The user should locate a suitable input on the microscope, to which the **ANALOGUE** output of the ISM-6A should be connected. Using the **RECORDER** output instead is **not** recommended for imaging purposes, as the image controls (i.e. contrast, brightness and noise reduction) of the ISM-6A do not operate on this quantitative output.

Most commercial microscopes accept external analogue signals thereby allowing the creation of an image from signals generated by third party peripherals or detectors.

Such inputs are usually labelled as AUXILIARY or AUX. If no suitable input is present, then users are advised to contact the microscope manufacturer and Matelect for advice and assistance.

Auxiliary inputs will accept signal levels over only a limited range of values. For example JEOL SEMs accept signal levels between the limits of +10 volts and -10 volts. Ranges as diverse as zero to +1.2 volts have been encountered in some microscopes. It is usual for the most positive voltage to correspond to maximum brightness on the display monitor, whilst the most negative corresponds to maximum darkness.

The ISM-6A incorporates circuitry that can be used to scale the **ANALOGUE** output to commonly encountered ranges. The controls that pertain to this circuitry are situated on the rear panel of the ISM-6A main control unit. Please refer to page 8 for details on setting these controls.

Users should also remember that the analogue signal level is dependent upon the position of the front panel based **ANALOGUE OUT**put controls (**BIAS, GAIN, VAR.** and invert facility).

Most SEMs have a waveform monitor mode (labelled WFM, GRAPH or similar). This allows the input signal level to be displayed as a line on the display. It is useful to use this mode to check the setting of the scaling circuitry and to gain familiarity with the **ANALOGUE OUT**put controls.

Please see the following Chapter entitled General Usage Advice for further details.

11. GENERAL USAGE ADVICE

This chapter contains additional information on the use of the ISM system, likely problems and their solutions. It should be read in conjunction with the rest of this instruction manual. It is assumed that the user has read and become familiar with the preceding sections.

INDUCED CURRENT STUDIES IN AN SEM: BASIC PRACTICE

Once the system has been correctly installed according to the earlier sections, the user can begin imaging real specimens. The following procedures form a good basis for everyday studies, for both quantitative measurements and for the more common case of qualitative imaging.

1. Ensure that the **BIAS VOLTAGE** and **BACK-OFF CURRENT** facility are switched out, or set to their zero levels. Set the **ANALOGUE OUTPUT GAIN** to unity (1), the **VAR.** control and the **BIAS** should be left at their default “out” positions.
2. Connect up the sample as shown in Fig. 8.
3. Select the most sensitive head amplifier **SIGNAL** range. If the **SIGNAL** output display reaches 20000 digits, then it is likely that the signal is over-range, thus the range should be gradually reduced until the signal is below the maximum 20000 digits applicable at each range setting.

Alternatively, users can begin with the coarsest range and work their way up. The obvious idea in both cases is to ensure that the range is appropriate for the signal so that maximum sensitivity is obtained – so a 10nA signal would be best measured on the 20nA range, rather than the 2mA range (but users should consider issues of bandwidth for imaging purposes – see below).

4. If the microscope has a waveform monitor, select this. A trace corresponding to the variation in the rear panel **ANALOGUE** output of the ISM-6A should be visible on the microscope's display. If this is not the case, change the **ANALOGUE OUTPUT GAIN** setting or use the **ANALOGUE OUTPUT BIAS** control (both accessed via the front panel menus) to bring the trace into view. Adjust the **ANALOGUE OUTPUT BIAS** so the trace is placed in the centre of the graph (i.e. neutral contrast).
5. With the specimen still outside the microscope chamber, shine a light onto its surface or cover the specimen to exclude light. Performing this with a semiconductor specimen correctly connected to the system will result in a significant change in the signal level and hence in the position of the trace on the microscope's waveform monitor. Check the connections to the specimen if this does not occur.

6. If all is satisfactory, position the sample as appropriate in the microscope and operate as normal.

7. The frequency response (bandwidth) of the ISM-6A circuitry limits the use of the instrument for imaging at TV scan rates. In practice such rates are only compatible with the coarsest signal range (**2mA**). For information on this, please see Chapter 12 on Specifications, which gives details of the frequency responses with respect to the measurement ranges. Thus slow scan rates are required for effective imaging on the finest ranges of the instrument.

To improve the sharpness of the image first ensure that the **FILTER** facility is in the **OUT** position then move to a coarser **SIGNAL** output range and compensate for the reduction in signal by increasing the **ANALOGUE OUTPUT GAIN**.

This increases the bandwidth of the system which sharpens the image or allows faster scan rates to be used. Unfortunately it also increases the level of noise on the signal. Frequency response and noise sensitivity are thus mutually opposed.

8. The **FILTER** facility can be used to reduce noise on the image at the expense of bandwidth. However, when performing very slow scans such as those encountered in image acquisition systems or photographic camera attachments, the **FILTER** can be used to clean up the image without fear of losing detail.

9. Before attempting to use the **BIAS VOLTAGE** or **BACK-OFF CURRENT** facilities, users should check and optimise the settings under un-biased and un-suppressed conditions. For delicate and valuable samples, users should ensure that they have set the short circuit detection facility to an appropriate level.

The **BACK-OFF CURRENT** facility forms a powerful way of enhancing image detail, and it can be used to optimise images without over-working the image brightness and contrast controls. If a large standing DC exists (as will normally be the case), then this should be backed-off so as to reduce the overall signal magnitude. This will then enable the user to select a finer measurement range, thus magnifying any small changes in the induced signal. This is a basic tenet of good measurement practice – suppress any DC offsets, then amplify to see the small changes. Amplification of a signal which contains a large offset will rapidly saturate the measuring instrument.

Backing off a standing or average current is not always feasible however – for example if wild fluctuations in the signal are already present. Also, using suppression to make use of a finer measurement range is not a good idea if the bandwidth of the range is too small for adequate imaging, and fine features and contrast simply “smear” as a result.

The above points form only a brief outline of the procedures recommended. Users should regard them as general guidelines. Advice and assistance on specific problems and applications is available from Matelect and users should not hesitate to contact our head office at the address given at the front of this manual. Further general information can be found later in this chapter under the Case History section.

EARTH LOOPS AND OTHER PROBLEMS

Of all the problems encountered in electronic measurement instrumentation, noise or interference due to earth loops is perhaps the most insidious, difficult to trace and difficult to cure. The problem is compounded when two or more instruments are connected together. It is therefore not surprising that the combination of the ISM-6A, microscope electronics, and perhaps a chart recorder, computer, or data acquisition system can lead to signal instabilities.

The ISM-6A is basically a very sensitive amplifier and is therefore as equally sensitive to electrical noise or "pick-up", as it is to "real" signals. Earth loops can accentuate the effect of noise, especially that due to mains frequency pick-up (e.g. 50 or 60 Hz). If such noise is detected on the signal, e.g. if regularly spaced lines are seen on an image or oscillations on a waveform monitor then:

1. Check for earth loops.

The ISM-6A's circuit Common line should ideally be earthed to the mains Earth at only one point (or left floating, although charge retention can sometimes occur). Additionally, the supplementary Earth shield of the ISM-6A should always be connected to the Earth of the end-user's microscope, to reduce electrical interference and maintain safety.

The Earth connection is normally made at the head amplifier via the outer portions of the LEMO connectors. The assumption is that the outer shields of the mating triaxial LEMOs on a microscope port-plate are electrically connected to the metalwork of the microscope which is itself at Earth potential. However, if a non-triaxial, non-isolated feedthrough is being used by the end-user then, additionally, a connection between the microscope Earth and the ISM-6A signal Common may be inadvertently made.

Naturally it is important for the circuit Common of the ISM-6A to be connected to the circuit Common of the microscope - otherwise the two instruments will be unaware of each others reference levels. This link is normally (automatically) made via the external portion of the **ANALOGUE** output BNC of the ISM-6A (this being isolated, hence at Common potential, not case Earth).

If the microscope's Common is also its Earth (this is easily determined by checking for electrical continuity between the microscope metalwork and the BNC outers) then the ISM-6A's Common will be **earthed automatically** upon connection to the **ANALOGUE** output signal. If the head-amplifier Common is also connected to the microscope metalwork (Earth), as described above, two Common to Earth links will have been established, an Earth loop will have been created, and signal interference may result.

The solution is simple: One of the loops, preferably that made via the **ANALOGUE** output should be broken by isolating the outer portions of the mating BNC connectors (i.e. cut the screen!)

2. Check cables and wiring

Check that there are no long lengths of wire or cabling leading from the inside of the microscope chamber to the outside. Such wires can act as aerials, picking up mains noise from the environment and transferring it into the microscope chamber and thence to the specimen.

Reduce the length of any cabling used between the head amplifier and the microscope chamber (ideally mount the head amplifier on the chamber - see the Chapter on Installation).

Ideally the specimen should be electrically isolated from the microscope by using an insulating stand/specimen holder.

If interference is still seen, attach a thick wire from the microscope Earth to the **COMMON** terminal on the rear panel of the ISM-6A control unit (this actually creates an Earth loop).

Alter the position of the umbilical cable to the head amplifier and note if an improvement in noise rejection is seen.

Check that the screen of the umbilical cable is intact and connected at both ends to the cable head shells.

Terminate the shield of the BNC lead connecting the image output of the ISM-6A to the auxiliary imaging input of the SEM (as described in previous section). Terminate it at the SEM end – but obviously before it contacts the SEM.

If all else fails contact Matelect for further advice.

3. Check for oscillations

Users should note that the first stage of the ICA-2 head amplifier can oscillate if the capacitance of the specimen is greater than about 300 picoFarads. If this is suspected, altering the **SIGNAL** output range will change the frequency response of the amplification circuitry and the oscillations should disappear. Oscillations are normally simple to distinguish from “noise” as the latter is random and the former tends to generate regular patterns on any images that are observed.

CARE OF THE ISM-6A

Please note that there are no user serviceable parts within the ISM system. Opening the units should not be attempted and will invalidate our Warranty. More seriously, tampering with the internal circuitry of the equipment can alter its calibration and hence render the equipment's readings suspect or at worst, useless. High voltages are also present in the instrumentation. Remember mains voltages can easily kill.

If a fault is suspected in the equipment, please contact Matelect for further advice. Our address is at the front of this manual.

Users should not allow the instrument cases to come into contact with any solvents or liquids such as acetone, methanol or water. Adequate ventilation for the instrument must be provided to prevent the build up of heat which could eventually lead to the failure of the internal electronics.

Do not expose the equipment to sources of heat such as space heaters, other equipment, bright lights or ventilation fans. Ideally, use the ISM-6A in a reasonably constant thermal environment. This will help to minimise stress on its internal circuitry and drift on its measurements and on its output signals.

Keep the equipment clean and dust free. Use only a soft cloth for cleaning. The cloth may be lightly dampened with water or mild detergent to remove more stubborn soiling and stains.

CASE HISTORY: CHECKING THE ISM FACILITIES

The following section details a number of problems and solutions experienced with the installation of an ISM system (actually an ISM-5A and ICA-1, but modified for an ISM-6A) on a Cambridge Instruments (now Leica Cambridge) S250 Mk11 scanning electron microscope. Further advice and information can be obtained from Matelect.

The S250 Mk11 accepts a 0-1V analogue voltage input into its display monitor. White is represented by 1V and black by 0V. Both INPUT 1 and SCA accept the same voltage levels. Both inputs are therefore suitable, although SCA (specimen current amplifier) at least sounds relevant! In this case the rear panel mounted **ANALOGUE** range and offset controls should be set to give a 0-1V output range.

After selecting the correct rear panel output format, attaching a specimen and activating the microscope, the user should begin by following the simple procedure given earlier in this chapter.

If a sensible signal is indicated on the **SIGNAL** output meter but no image contrast is observed, it is possible that incorrect settings on both the **ANALOGUE OUTPUT GAIN** and **BIAS** controls have been made. As described previously, these control the contrast and brightness respectively of the analogue signal (without altering the quantitative value as displayed on the **SIGNAL** output meter) that is available to the SEM. If the **BIAS** is set too high or the signal is strong, then saturation can occur (either complete darkness or complete whiteness - so no contrast).

The solution is to alter the **BIAS** level or, if no change is experienced, reduce the *qualitative* **ANALOGUE OUTPUT GAIN** and re-adjust the **BIAS** for optimum viewing.

It may also be advisable to reduce the quantitative gain by altering the **SIGNAL** output range setting. This alters the gain in steps of 10, so it is a lot coarser than the **ANALOGUE OUTPUT GAIN** control, thus users should expect a big change when switching ranges. More information on these controls is given in Chapter 6.

If no success results, then it is wise to check the operation of the instrument, and the effect it has on the SEM display, by artificially simulating a specimen using the in-built **BACK-OFF CURRENT** facility. Users should do this as follows.

Disconnect any specimen first. Select any **SIGNAL** output range - e.g. **20nA** for the signal and an appropriate **BACK-OFF CURRENT** range (**100nA** in this case). Do not apply any back-off yet.

Leave the **ANALOGUE OUTPUT GAIN** at unity, and the **ANALOGUE OUTPUT BIAS** facility out (i.e. at zero level).

Select the **BACK-OFF CURRENT** menu and dial up a current. The **SIGNAL** output meter will follow the **BACK-OFF CURRENT** meter and should thus show approx. similar quantities.

At these settings the **ANALOGUE** output from the rear of the ISM-6A should be giving zero, when the back-off is adjusted to zero, if the rear controls are set to a **+/-** setting or **+half** the desired output range on a **0/+** setting. Thus for the S250 Mk11, the **0/+ 1Volt** output range would apply, and 0.5 volts should be measurable at the **ANALOGUE** output BNC. This can be checked with a voltmeter. If this is not the case, suspect a fault in the unit.

If 0.5V does register, then when fed into the SEM, this should create a uniform brightness mid way between all white (i.e. +1V) and all black (i.e. 0V).

The SEM's waveform monitor can be used to visualise this and the trace should lie mid way between the 0 and 1 volt limits. By altering the back-off current applied, the screen brightness should change or the waveform trace should move to a new position. On the settings suggested, 20nA back-off will correspond to full range and approximately 0.58V on the **ANALOGUE** output (or fairly white), whereas -20nA will be full range in the opposite sense, and correspond to approximately 0.42V on the **ANALOGUE** output (or fairly black on the SEM's CRT).

Increasing the **ANALOGUE OUTPUT GAIN** control to the **X2** position should raise the voltage limits to 0.65 and 0.35V respectively. A **GAIN** of **10** will cause signal saturation at the full scale deflections (remember, no signal higher than +1V or lower than zero is allowed at the settings chosen for the S250).

If this test is successful then the user can rest assured that all is OK. It is then a question of gaining familiarity with the operation of the **ANALOGUE OUTPUT GAIN** and **BIAS** controls. As indicated above, these can have a dramatic effect on the waveform's position on the CRT and hence on the appearance of the image.

When using the ISM-6A, users should remember that as a finer *quantitative* **SIGNAL** range is chosen, the bandwidth of the ISM-6A drops dramatically. Thus, it is not really possible to examine a specimen under a TV mode on any range finer than **200 μA** . A slow scan mode should be used instead. The **2nA** range is the extreme example of this. On that range, only a very slow scan will permit imaging. The **2nA** range is normally reserved for careful work using an image acquisition and processing system. Very slow scans are possible with such systems.

The reason for this bandwidth dependency is simply technology. The ISM-6A employs amplifier chips that have minute input bias currents and offsets. These are costly state of the art electrometer chips. They are not designed for bandwidth, but for accuracy. The two criteria are unfortunately mutually opposed. Most commercial current amplifiers sacrifice accuracy for bandwidth. The Matelect ISM-6A does the opposite. This approach may compromise imaging convenience but it does allow quantitative work to be performed.

SIGNAL CONVENTIONS AND EXPECTED CONTRAST

When imaging specimens or recording quantitative readings, it is important to be aware of the direction of current flow (or potential polarity) and the effect that this has on image contrast.

In the case of induced current studies, the best way of determining this is to image the metal contact on the specimen that carries current to the **CURRENT** input of the head amplifier. A high magnification must be used to ensure that only metal is bombarded by the beam. The contact will thus act as a Faraday cup. The current measured by the ISM-6A will essentially then be the beam current. This is a flow of electrons *into* the head amp and thus constitutes a *negative* conventional current. The **SIGNAL** output meter should register a negative current (with no back-off or voltage bias applied).

A negative current will create a dark image (assuming the **ANALOGUE OUTPUT BIAS** control is at zero and the **GAIN** is set so that signal clipping is not occurring). For the case of the Cambridge S250 mentioned earlier, (set to a 0-1V analogue output range), a voltage *below* 0.5V should therefore be measurable at the BNC of the **ANALOGUE** output. If no inversion occurs in the microscope, then such a voltage will result in dark contrast.

12. SPECIFICATIONS

Note: these values should be considered preliminary.

SIGNAL OUTPUTS

(with respect to the head-amplifier output)

Induced Current (ICA-2 head amplifier)

Range	F.S.D.	Resolution	Accuracy	Bandwidth (kHz)	Noise (r.m.s.) (pA)
1	2 nA	0.1 pA	1 pA	3	2.5
2	20 nA	1 pA	10 pA	6	2
3	200 nA	10 pA	100 pA	24	2
4	2 μ A	100 pA	1 nA	70	1
5	20 μ A	1 nA	10 nA	100	1
6	200 μ A	10 nA	100 nA	150	1
7	2 mA	100 nA	1 μ A	230	1

The capacitance between input and ground is 100pF. Higher capacitance values reduce the bandwidth and increase the noise.

Induced Voltage (IVA-2 head amplifier)

Range	F.S.D.	Resolution	Accuracy
1	2 mV	100 nV	1 μ V
2	20 mV	1 μ V	10 μ V
3	200 mV	10 μ V	100 μ V
4	2 V	100 μ V	1 mV

Bandwidth performance for the IVA1 head amplifier depends on the impedance of the sample.

Beam Monitor Current (ICA-2 and IVA-2 head amplifiers)

Range	F.S.D.	Resolution	Accuracy	Bandwidth
1	2 nA	0.1 pA	1 pA	200 Hz
2	20 nA	1 pA	10 pA	6 kHz
3	200 nA	10 pA	100 pA	24 kHz
4	2 μ A	100 pA	1 nA	70 kHz
5	20 μ A	1 nA	10 nA	100 kHz
6	200 μ A	10 nA	100 nA	150 kHz
7	2 mA	100 nA	1 μ A	230 kHz

Back Off Current

Range	Resolution
0-2 nA	0.1 pA
2-20 nA	1 pA
20-200 nA	10 pA
0-200 nA	10 pA
0.2-2 μ A	100 pA
2-10 μ A	1 nA
0-20 μ A	1 nA
20-200 μ A	10 nA
0.2-1 mA	100 nA
0-2 mA	100 nA
2-20 mA	1 μ A

Arranged in seven distinct switched positions

Bias Voltage (continuously variable)

Range	Value	Resolution
normal	0 to +/-20 V	1 mV
extended	0 to +/-120 V	1 mV

Short Circuit Detection Trigger Levels

Range	Accuracy
0.1 mA	5%
0.5 mA	5%
1 mA	5%
10 mA	5%

ANALOGUE OUTPUTS

Gain: x0.1, x0.2, x0.5, x1, x2, x5, x10, x20, x50, x100

Variable Gain: x1 to x2.5 in 15 steps (uncalibrated). The bandwidth is typically 70 kHz with **Gain** and **Variable Gain** at x1.

Filter: Low pass cut off: (nominally) 10Hz, 30Hz, 100Hz, 300Hz, 1kHz, 3kHz, 10kHz, 30kHz.

RECORDER OUTPUT

Unity gain buffered output for use with chart recorders/data acquisition systems.

ADDITIONAL FEATURES

Invert signal amplitude
DC bias control

POWER

220-240V and 110-120 AC mains, 50 or 60Hz line frequency
Input via earthed and fused IEC connector
Input voltage range must be preselected by user

LINE FUSES

Two 20mm anti-surge 1000mA fuses protect both Live and Neutral line.
Fuses are located within the IEC connector.

DIMENSIONS

Head Amplifiers: 120mm x 860mm x 80mm
Control Unit: 471mm x 191mm x 262mm

MECHANICAL

Cast aluminium frame with pressed aluminium alloy panels finished in standard RAL epoxy powder coat colours.

OPERATING TEMPERATURE RANGE

0-40 Degrees Celsius for electronics.

MASS 12kg

SEALING To IP20

STANDARD Constructed in accordance with CEI/IEC 1010-1 1990

13. Warranty, and service information

The following text is an extract from our standard conditions of sale. It covers the terms of warranty and liability only. Please refer to the full text, supplied upon delivery of the goods or contact Matelect Limited.

Extract 6. WARRANTY

Items sold by the company are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the company agrees to correct, whether by repair or, at its election, by replacement, any defect of materials or workmanship which develops within twelve months after delivery of the instrument to its original purchaser by the company or by any authorised representative provided that investigation and factory inspection by the company discloses that such defect developed under normal and proper use (unless covered by a separate agreement or guarantee written by the company).

The exceptions and conditions mentioned above are the following.

- a). The company makes no warranty concerning components and accessories not manufactured by it. however, in the event of the failure of such components or accessory, the company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.
- b). The company shall be released from all obligations under its warranty in the event of repairs or modifications being made by persons other than its own or authorised service personnel unless such repairs by others are made with the written consent of the company or unless such repairs are minor or merely the installation of a new Matelect component.
- c). The warranty is only valid providing that the terms of payment in clause 4 are strictly adhered to.
- d). No product may be returned except with the company's permission in writing. After receiving factory authorisation, goods requiring repair or replacement should be sent prepaid to the factory in the original container properly packed accompanied by a Return Goods Authorisation, purchase order or letter stating as completely as possible the defects and the condition under which it occurred.

Extract 8. CONDITIONS PARAMOUNT

The company expressly disclaims any liability of whatsoever nature and in any circumstances whatsoever, to its customers, dealers or agents, except as stated in the forgoing terms and conditions.

Extract 9. These terms and conditions of sale may be amended or altered at any time the company feel it necessary to do so.

REPAIR AND RECALIBRATION:

Matelect Limited can repair and/or recalibrate instruments manufactured by it, after the warranty period has expired. If this service is required then please contact Matelect and we will be pleased to provide a quotation for the work necessary.

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