

MATELECT INDUCED SIGNAL MONITOR

Type ISM-5A



INSTRUCTION MANUAL

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MATELECT INDUCED SIGNAL MONITOR *TYPE ISM-5A/5*

Thank you for your interest in our product, we hope that it will serve your needs and prove 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-5A has established itself as the most advanced amplifier available for EBIC studies and is routinely used in many prestigious laboratories throughout the world.

Matelect produce a range of peripherals to support the ISM-5A and have also built up considerable experience of the EBIC/EBIV techniques. Please contact us should you ever require further 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-5A. Never attempt to open the instrument case as this will void our warranty. Please contact Matelect should you ever experience any difficulties.

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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 supply rating is correct for the location it will be used in. The ISM-5A can be operated on both 110 and 220V supplies by appropriate adjustment of the input voltage switch (see page 18). 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-5A is fitted with two equipment fuses for protection. These fuses are located in the IEC input socket on the rear panel of the ISM-5A. Both fuses need to be functional if the equipment is to be operated.

The instrument fuses are rated at 315 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-5A does not come into contact with fluids or corrosive gases and that it is operated within the temperature range of 0 - 40°C

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4. OVERVIEW

The ISM system has been designed to allow precise measurements to be made of induced signals created during semiconductor materials characterisation.

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 the 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 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 latterly, 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.

The ISM 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 cathode ray tube display 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-5A 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.

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 when using an appropriate detector.

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 BNC connectors. The standard configuration of these connectors can be altered to suit the individual needs of the user and it may not necessarily be the standard form as shown on page 24 of this manual.

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.

A short applications note is reproduced at the end of this manual and acts as a brief introduction to the EBIC technique. Further advice on procedures and equipment can be obtained by contacting Matelect.

This manual applies to the ISM-5A version but can also be used for the original ISM-5 unit. The 5A offers an improved frequency response, output signal matching circuitry and a more convenient head amplifier connector configuration. In all other respects the units are identical.

Within this manual, text shown in **BOLD CAPITALS** is usually used to indicate lettering that appears on the front or rear panel of the instrument.

5. GENERAL DESCRIPTION

The Matelect ISM-5A 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 ICA-1 head amplifier is used for induced current measurements (EBIC and OBIC) whilst the IVA-1 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.

Three 4½ digit LED meters are built into the control unit. These provide real time digital displays of the magnitude of the signal, applied back-off (suppression) current and the voltage bias supplied to the sample.

The electron or laser beam monitor can be switched in from the front panel of the main control unit. This action will simultaneously switch off the back-off current and the sample bias voltage.

The back-off current and sample bias voltage can be adjusted by using the **COARSE** and **FINE** controls provided for this purpose. Both sets of controls use 10 turn potentiometers. The selected current and voltage levels can be shown on the LED displays *before they are applied to the specimen* by using the in-built **TEST** facility. 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 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** switch is provided to re-arm the trigger.

Two outputs are provided on the control unit: the **RECORDER** output and the **ANALOG** 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. The signal level corresponds to that shown on the front panel **SIGNAL** LED display. The output has a full scale deflection of 1.9999V 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 **ANALOG** output is connected to the CRT 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 CRT.

The controls consist of rotary knobs and switches for the adjustment of **GAIN**, **VARIABLE** gain, **BIAS**, signal **INVERT** and **FILTERING**. The **GAIN**, **VAR.** and **INVERT** 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 level as displayed on the signal LED display or as output at the **RECORDER** socket.

Whilst the ISM-5A is a stand-alone instrument, the system can be expanded by the addition of the IU-1 computer control interface unit. This optional instrument is used to both control the front panel functions of the ISM-5A and to acquire quantitative linescan data and convert it into a form easily communicable to a host personal computer. Data transfer between the IU-1 and a PC is via the computer's RS232 serial link.

No data acquisition cards or complicated installation procedures are necessary and the complete system functions happily on all classes of PC from 8086 to 80486 based machines. Operation of the IU-1 is the subject of a separate manual, available from Matelect.

Connection of the ISM-5A to the user's microscope is very simple and straightforward. Installation is usually carried out by the user but Matelect can assist in this if required. Please see the section on Installation for further details. The ISM-5A 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). The ISM-5A is equipped with a level change facility which allows users to closely match the voltage levels of the **ANALOG** output with those acceptable to their microscopes.

A schematic of the electronics that constitute the ISM system is shown overleaf in Fig 1. The ISM-5A is supplied with three standard cables and these are also illustrated overleaf in Fig 2.

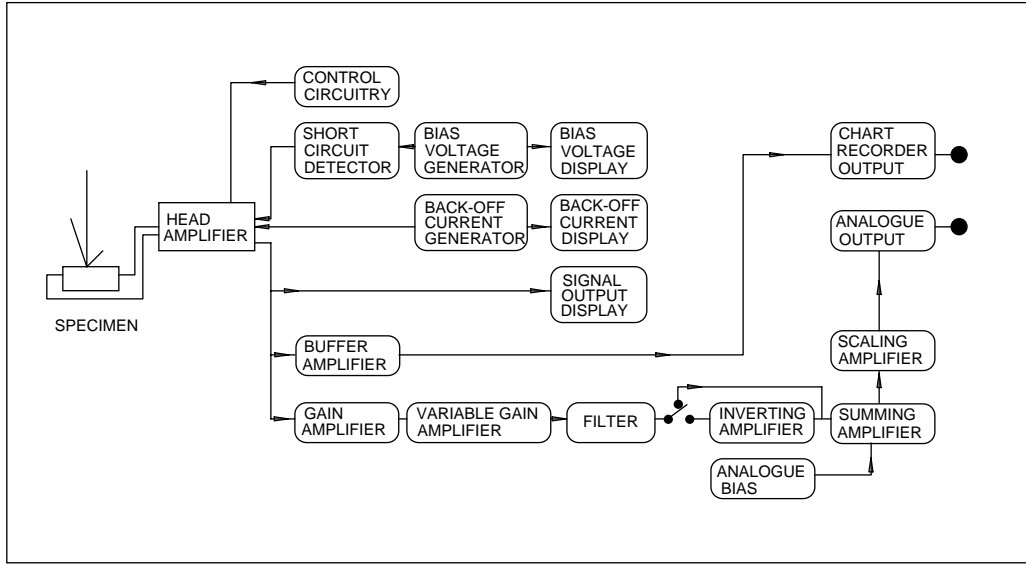


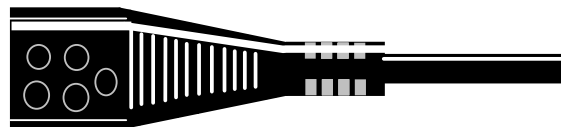
Fig.1 Schematic of the ISM-5 system



ISM head amplifier output to ISM main unit (25 way D)



ISM Analog Output (BNC) to user equipment input (BNC)



IEC mains input (ISM-5A) to local mains plug

Fig 2. Cables supplied with the ISM-5A

6. FRONT PANEL DESCRIPTION

The Front panel of the ISM-5A is shown below in Fig 3. A comprehensive description of the controls is provided in this section. For further technical information please refer to the sections entitled General Usage Advice and Specifications, Chapters 10 and 11.



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

Users should note that the ISM-5A has two functions. The first is to provide a true measurement of the induced signal. The second is to create an image of the specimen under investigation using the induced signal. The quantitative controls of the ISM-5A are thus supplemented by a series of *qualitative* image enhancing controls. For clarity, the *qualitative* controls are highlighted in grey in the following text.

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.

1. SIGNAL OUTPUT display

This represents the quantitative side of the ISM-5A. The signal display contains a 4½ digit LED numeric meter and range/unit enunciators. The meter displays the actual value of the signal being measured by the ISM-5's head amplifier.

The displayed quantity is scaled according to the range selected by the operator using the **RANGE** control (item 4).

The meter is *not* autoranging and will display a maximum of 19999 on any range with an appropriate decimal point. For example on the **20nA RANGE**, the meter will over-range above 19.999 nA. The next **RANGE (200nA)** should then be selected. Over-ranging is indicated by the continuous flashing of the meter's digits.

The rate of conversion of the meter is approximately 2.5 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 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 the **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.

2. CURRENT, BEAM, and VOLTAGE mode switch

This switch controls circuitry within the head amplifier and the motherboard of the control unit. It allows the user to select which type of induced signal is to be measured. If the ICA-1 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-1 head amplifier is employed for EBIV studies, the **VOLTAGE** or **BEAM** positions should be selected.

As a precaution, the ISM-5A control unit recognises the type of head amplifier in use and automatically disables the inappropriate options on the mode switch. Thus, when the ICA-1 is utilised, the **VOLTAGE** position is inoperative, and the unit defaults to the **CURRENT** mode.

The **BEAM** position is selected by the user when the second current measuring channel (normally used to measure beam current) needs to be monitored on the **SIGNAL OUTPUT** meter (item 1).

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.

The mode selector automatically sets the appropriate measurement unit/range enunciators within the **SIGNAL OUTPUT** meter.

3. REMOTE control switch

This toggle switch is placed in the **REMOTE** position when it is desired to operate the ISM-5A under computer control. The optional IU-1 interface unit will be required together with an appropriate software package (e.g. Matelect's ISMsoft) if computer control is to be effected.

If the IU-1 is connected, the green LED will light when the switch is in **REMOTE**. Additionally, all front panel controls will be disabled. Placing the switch in the **OFF** position, returns the unit to manual operation unless the control software has been specifically written to prevent this (see the IU-1 manual for further details on the control codes used). ISMsoft will override the action of this switch.

If the IU-1 interface unit is not connected, the switch will have no effect.

4. RANGE selector (signal)

This is adjusted by the user to the most appropriate **RANGE** for the induced measurements being made. The selector is used in conjunction with the **SIGNAL OUTPUT** display. If the display over-ranges (see item 1) the **RANGE** switch should be moved to the next highest (coarser) range.

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 error.

During an over-range condition, whilst no damage to the ISM-5A will occur, the signals available to the user at the **ANALOG** and **RECORDER** outputs will exhibit clipping (saturation).

The **RANGE** switch is marked in both ampere units (for induced current studies) and volt units (for induced voltage studies).

5. VARIABLE gain

This is the first of the controls for the **ANALOG OUTPUT** facility. These are used to apply fine variations to the quantitative signal level generated by the **RANGE** selector. The resultant signal is known as the analog output and is primarily *qualitative* in nature. The analog output is available at the rear of the ISM-5A main unit and is normally connected directly to the user's imaging display (e.g. the auxiliary input to an SEM's CRT screen).

The **VARIABLE** gain control provides a finely stepped supplementary amplification between unity and 2.5 times. It is used in conjunction with the coarser **GAIN** control (see item 12).

The **VARi**able gain control is utilised as a fine brightness adjustment for the *qualitative* image on the user's monitor. It should only be used once the **RANGE**, **GAIN** and **BIAS** (offset) settings have been correctly adjusted.

When the **VARi**able gain is greater than unity (i.e. the knob is rotated away from the extreme anticlockwise position) the **UNCAL.** LED lights to indicate that an **UNCAL**ibrated overall gain is now in operation.

6. **UNCAL.** LED

This LED lights when the **VARi**able gain control knob is rotated from its extreme anticlockwise position (see item 5).

7. **INVERT** switch

This toggle switch is used to invert the contrast level of the image as seen on the user's display monitor CRT. It is a *qualitative* signal control (see item 5) and has no effect on the quantitative measurement of the induced signal.

In the **OFF** position, the **INVERT** control does not operate.

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 item 11). The **INVERT** control will only invert that part of the analog 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 operating the **INVERT** switch. Conversely if no **BIAS** is applied (see item 11), then a complete contrast inversion will result.

8. **INVERT** LED

This lights whenever the **INVERT** function has been selected.

9 **Minus (-)** LED

This lights when a negative *qualitative* **BIAS** (offset) has been applied to the analog output signal. See item (11).

10. **Positive (+)** LED

This lights when a positive *qualitative* **BIAS** (offset) has been applied to the analog output signal. See item (11).

11. BIAS control

This control is part of the **ANALOG OUTPUT** 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 process of offset followed by a **GAIN** increase is fundamental to electronic measurement per se. DC components carry no useful information with regard to imaging. It is the small changes that are superimposed upon the DC level that are of significance. Since all instruments have a limited output voltage capability it makes sense to remove or reduce the DC component before attempting to apply amplification. A much larger degree of amplification can then be employed before the instrument's limitations are reached.

This procedure enhances the sensitivity to the small signal changes of interest.

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

Although the actual voltage level selected by the **BIAS** control knob cannot easily be determined by the user (nor is it necessary to do so as it is primarily a *qualitative* facility), LEDs (9) and (10) indicate whether the **BIAS** is positive or negative in polarity. By carefully adjusting the **BIAS** knob so that neither the red nor the green LEDs are lit, the user can set zero **BIAS**.

12. GAIN control

This rotary knob can be used to select one of 3 calibrated attenuation and one of 7 calibrated amplification factors that can be applied to the *qualitative* analog 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 *contrast* of the image as displayed upon the user's CRT monitor. Once an appropriate signal measurement **RANGE** has been selected (item 4), the **GAIN** control is used in conjunction with items (5), (7), and (11) to enhance the visual representation of the induced signal being studied.

For further details on adjustment of the analog output signal, see the section on General Usage Advice.

13. FILTER control

This rotary knob is used to select the degree of low-pass **FILTER**ing that is applied to the analog output signal.

The second order filters used, give nominal cut-off frequencies of 10, 30, 100, 200 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 **ANALOG** 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 instrument's **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.

14. BACK-OFF CURRENT display

This display is similar in operation to the **SIGNAL OUTPUT** display (see item 1). The display is used to indicate the precise quantity of back-off current that has been applied by the user (via items 15, 16, 17 and 18).

The display contains a 4½ digit LED numeric meter and range/unit enunciators. The meter displays the actual value of the back-off current applied by the ISM-5A's head amplifier. The displayed quantity is scaled according to the **RANGE** selected by the operator using the back-off **RANGE** control (item 16).

The meter is autoranging and will display a maximum of 19999 on any **RANGE** with an appropriate decimal point. The autoranging facility will always work in the user's favour by displaying the back-off current level to the highest appropriate resolution.

The available **BACK-OFF CURRENT RANGE** increments and the autoranging feature of the display 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**. In both cases it will be displayed as 90.00nA, 10nA can be similarly selected and will be displayed as 10.000 nA on both **RANGES**.

The meter will overrange if too high a back-off current is selected using items (15) and (17). Over-ranging is indicated by the continuous flashing of the meter's digits.

The measurement units appropriate to the **BACK-OFF CURRENT RANGE** selected are indicated by enunciators positioned at the right hand side of the display.

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 **ANALOG** output signal.

The **BACK-OFF CURRENT** facility is similar to the **ANALOG OUTPUT BIAS** control (item 11) in operation, in that it is used to suppress the DC component of the signal. The fundamental difference between these two controls, however, is that the back-off current is fully quantitative.

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 **1 μ A BACK-OFF CURRENT RANGE** is compatible with the **200nA SIGNAL RANGE** and a therefore good correspondence should be obtained between these two.

15. COARSE back-off current control

This knob is used in conjunction with the **BACK-OFF CURRENT RANGE** and **FINE** controls. Clockwise rotation of the knob applies a more positive back-off whereas anticlockwise rotation applies a more negative back-off.

It is advisable to place the **BACK-OFF CURRENT** facility in the **TEST** mode (see item 16) whilst making large adjustments to the back-off. This will allow the user to confirm the general level of current selected before actually applying it.

The applied back-off current is indicated on item (14).

16. ON/TEST control (BACK-OFF)

In the **ON** position, the back-off current selected by the user is applied to the signal source at the head amplifier. In the **TEST** position the back-off selected is displayed on the **BACK-OFF CURRENT** meter but is not applied to the specimen. See items (14, 15, 17 and 18) for further details.

17. FINE back-off current control

This control is similar in operation to item (17) except that it allows **FINE** adjustments to be made to the applied back-off current. It should normally be set at its mid point before adjusting the **COARSE** control so that the full range of **FINE** adjustment is available to the user.

18. RANGE control for the back-off current

This rotary switch is used in conjunction with the above **BACK-OFF CURRENT** controls to select the most appropriate **RANGE** for the back-off current. Please note that the **RANGE**s overlap so that it is possible to select the same value of back-off current on two adjacent **RANGE**s (See item 14 for further details).

Users should note that when the **SIGNAL OUTPUT RANGE** is placed in the most sensitive (**2nA**) position, the back-off current is automatically limited to the **100** and **1 μ A RANGES**.

If a back-off current has been set, it is automatically switched out when the **BEAM** mode is selected by the user (item 2). This also occurs if the ICA-1 is replaced by the IVA-1 induced voltage head amplifier.

If the **Short Circuit** detector circuitry is tripped (see item 23), the **BACK-OFF CURRENT** facility will also be switched out.

19. BIAS VOLTAGE display

The display is similar in operation to the **BACK-OFF CURRENT** display (Item 14). It is used to indicate the value of the applied bias voltage. The meter is fully autoranging and as such requires no range selector controls.

The display also contains two enunciators. A "**V**" indicates that a **BIAS VOLTAGE** facility is operable whilst a red "**SC**" indicates that the **Short Circuit** trigger has operated. (see item 23).

Users should note that the **BIAS VOLTAGE** facility is switched out automatically when the ISM-5A is in the **BEAM** mode (see Item 2). This is also the case when the IVA-1 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 Item 23).

20. BIAS VOLTAGE COARSE control

This knob is used to alter the level of the bias voltage that is applied to the specimen. The knob is used in conjunction with the **BIAS VOLTAGE FINE** control. Clockwise rotation of the knob applies a more positive bias whereas rotation anticlockwise rotation applies a more negative bias.

Bias voltage values of up to 20 volts of both polarities can be selected.

It is advisable to place the **BIAS VOLTAGE** facility in the **TEST** mode (see item 21) whilst making large adjustments to the voltage. This will allow the user to confirm the general level of bias selected before actually applying it.

The applied bias voltage is indicated on item (19).

21. ON/TEST control (BIAS VOLTAGE)

In the **ON** position, the bias voltage selected by the user is applied to the specimen through the head amplifier **BIAS** terminal.

In the **TEST** position the voltage selected is displayed on the **BIAS VOLTAGE** meter but is not applied to the specimen. See items (19, 20, 22 and 24) for further details.

Switching to the **TEST** position also has the effect of resetting the Short Circuit trigger, assuming this has tripped (see items 23 and 24).

22. FINE control (BIAS VOLTAGE)

This control is similar in operation to item (20) except that it allows **FINE** adjustments to be made to the applied bias voltage. It should normally be set at its mid point before adjusting the **COARSE** control so that the full range of **FINE** adjustment is available to the user.

23. Short Circuit trigger

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. Should the current (as measured by the head amplifier) exceed the set limit, the bias voltage and the back-off current are automatically switched off and the "SC" enunciator will light in the **BIAS VOLTAGE** display.

Once a trip condition has been reached, users should reduce either the bias voltage or the back-off current (using the appropriate **TEST** facilities to monitor the levels) and reset the trigger using the **RESET** switch (item 24). Switching the **BIAS VOLTAGE ON/TEST** switch to the **TEST** position also resets the trigger.

24. RESET trigger switch

This is a momentary action toggle switch that is used to **RESET** the Short Circuit trigger facility (see item 23).

25. POWER on indicator

This is illuminated when the instrument is connected to the mains supply and switched on by means of the switch located in the chassis plug located on the rear panel of the ISM-5A.

7. REAR PANEL DESCRIPTION

The rear panel of the ISM-5A 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.

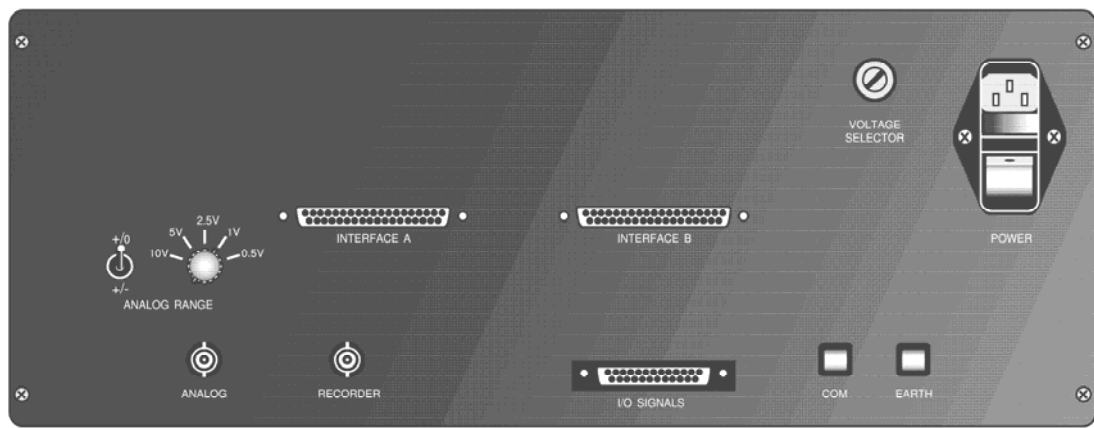


Fig. 4 The rear panel of the ISM-5A

1. Mains input socket and power switch

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-5A. If this is missing, only use an approved mains IEC connector as a replacement.

The instrument is fitted with two 315 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-5A.

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).

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.

2. VOLTAGE SELECTOR switch

PLEASE READ THE SECTION ON MAINS OPERATION at the beginning of this manual before attempting to alter the position of this switch.

The switch permits the ISM-5A to be used with either 110-120 or 220-240 mains supplies. The ISM-5A is factory adjusted to the correct mains input voltage before shipment but users may wish to alter this depending on the location of the instrument. A wide blade screwdriver should be inserted into the slot within the switch and rotated to the appropriate input voltage (as marked on the switch).

***CARE!** Disconnect the unit from the mains supply before altering the position of the switch. Operation of the ISM-5A with this switch incorrectly positioned will cause serious permanent damage to the unit.*

3. EARTH terminal

Connection to the case (chassis) is available at this terminal (also see item (4)).

4. COMmon terminal

The circuit common line is available at this terminal. Connection to this is made by depressing the sprung button and inserting a suitable length of equipment wire, then releasing the button. The circuit common of the ISM-5A is electrically isolated from the case Earth. If it is desired to connect common to Earth, a wire link can be used between the **COM**mon terminal and the **EARTH** terminal (item (3) above).

Isolation of the common is useful if external peripherals such as chart recorders are connected to the ISM-5A. If their signal common is connected to Earth, an earth loop could occur, should the ISM-5A'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.

5. I/O SIGNAL socket

This accepts the umbilical cable used to link the ICA-1 and IVA-1 head amplifiers to the ISM control unit (see Fig. 2.). This is a 25 way D type connector. Power supply lines, signal, back-off and bias voltage information, and control data is transmitted via this connector and the umbilical cable.

6. INTERFACE A socket (chassis plugs)

This socket (and item 7) is used to transmit information and control data between the ISM-5A control unit and the optional IU-1 interface unit. The sockets are of the 37 way D type.

7. INTERFACE B socket (chassis plugs)

See item (6) above.

8. 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.

9. ANALOG output

This is a BNC socket which provides a buffered output signal that represents the *qualitative* induced signal data. The **ANALOG** 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 **ANALOG OUTPUT** controls on the front panel of the ISM-5A 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 section entitled General Usage Advice.

The **ANALOG** 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).

10.& 11. ANALOG output RANGE adjustment controls

This facility has been incorporated into the ISM-5A 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.

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 above the **ANALOG** output BNC. The rotary switch (item 10) selects the peak to peak range whilst the toggle switch (item 11) sets the level shift.

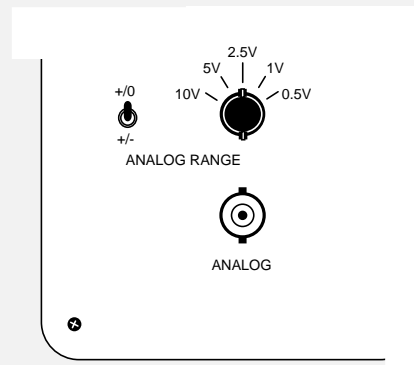


Fig 5. Rear panel location of RANGE controls

ISM units with this facility are shipped correctly set for the user's SEM. To adjust the **RANGE**, determine the acceptable input range of your microscope and select the largest analogue output range that still remains within your microscope's input range.

Exceeding your microscope's input specification will lead to a reduced range over which the ISM-5A contrast and brightness controls function (**ANALOGUE GAIN** and **BIAS**). This causes premature display saturation. *In the unlikely event of your microscope's input not being protected, exceeding the input range could also damage your microscope.*

The effect on the analog signal of the **RANGE** control is shown in the schematic below.

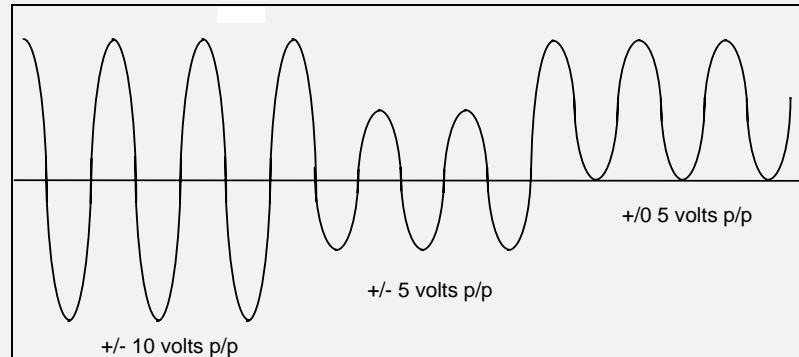


Fig. 6 Schematic of the action of the ANALOG RANGE control

Original ISM-5 units without this facility can be upgraded by specifying the Matelect OSC-2 output scalar unit. This is a compact self-powered unit that accepts the unscaled analogue output from the ISM-5 and converts it to the desired range using controls identical to those shown above. The OSC-2 is also suitable for other instruments with similar interfacing incompatibilities.

8. HEAD AMPLIFIER DESCRIPTION

The ISM-5A 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-1 head amplifier is used for induced current measurements (e.g. EBIC studies) whilst the IVA-1 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. If there is no alternative but to use cabling to connect the head amplifier terminals to the electrical feedthroughs, 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.

Schematics of the internal electronics of each head amplifier are given in the following sections.

ICA-1 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.

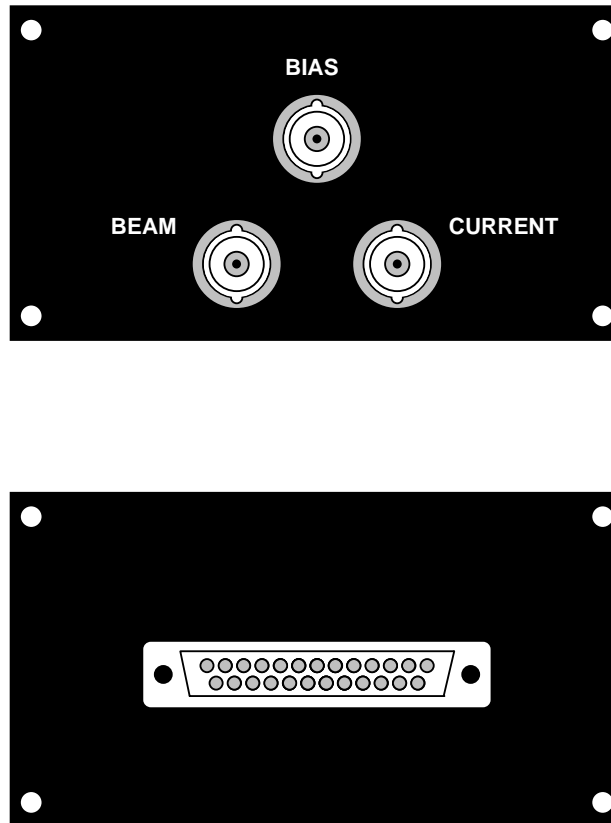


Fig 7. The front (top) and rear (bottom) panels of the ICA-1 head amplifier

1. BEAM input BNC 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-5A control unit will display and measure the signal from the beam amplifier when its front panel mode switch is placed in the **BEAM** position.

2. BIAS (Common) BNC 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-5A control unit using the **BIAS VOLTAGE** controls.

Please note that when the **BIAS VOLTAGE ON/TEST** switch (item 21, Chapter 6) is in central (off) position, the centre pin of the **BIAS** connector is tied to the circuit Common of the head amplifier via an internal relay (see Connections below).

3. CURRENT BNC 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.

4. Rear panel I/O connector

This is a 25 way "D" type chassis plug to which the control and signal umbilical cable from the ISM-5A control unit is connected. It is provided with two long location studs which mate with holes in the umbilical cable head shell. The studs are provided to assist in location, mating and retention of the plug and cable assemblies whilst also permitting separation without damage should the umbilical cable be accidentally pulled or knocked.

CONNECTIONS TO THE ICA-1.

A schematic of the internal circuitry components of the ICA-1 head amplifier and their relationship with the specimen and microscope is shown below in Fig 8.

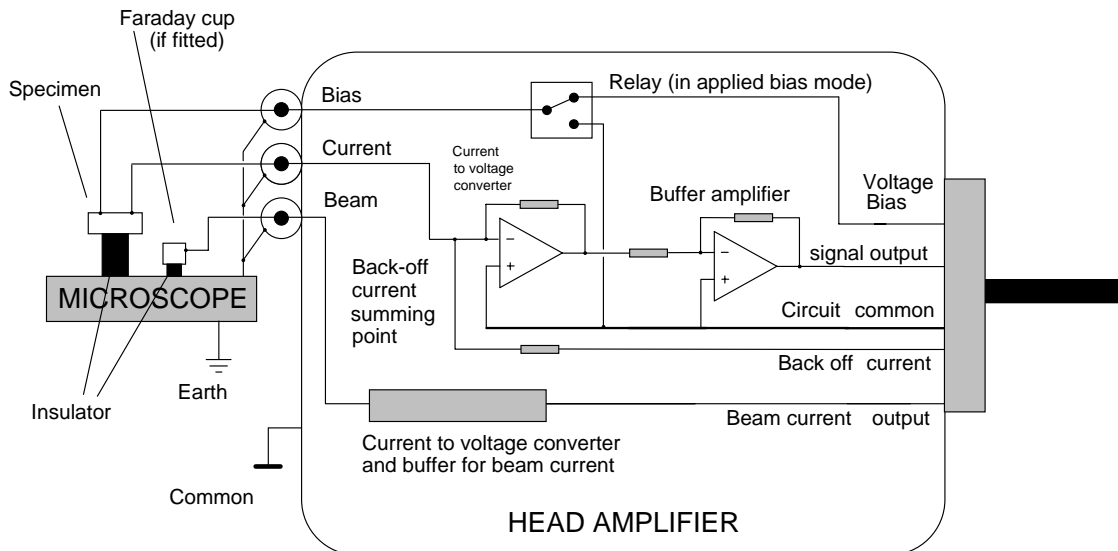


Fig 8. Schematic of the internal electronics of the ICA-1 head amplifier

The ICA-1 is connected to the ISM-5A control unit by an umbilical cable terminated in 25 way D type connectors. The cable carries power supplies to the ICA-1, 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** knob on the ISM-5A 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-5A control unit for further processing.

The specimen is directly connected to the input of the current to voltage converter via the **CURRENT** connector (see item 3). To complete an electrical circuit a second connection needs to be made to the specimen and this is done through the **BIAS** connector (item 2).

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.

Users should note that the outer portions of the head amplifier's BNC connectors are connected to circuit Common and also to the head amplifier's external case. Therefore, when the BNC outers are mated to a port plate (normally at microscope Earth) a Common to Earth link will result.

Users should ensure that at least one Common to Earth link is correctly established to prevent charge retention by the ISM-5A. Further links between microscope Earth and Common (e.g. through the Common of the **ANALOG** output) *can* cause earth loops which generate substantial noise and instability. Earth loops should be avoided at all cost.

The best location for the link between ISM-5A Common and SEM earth is at the head amplifier. For further details see section 10 on General Usage Advice - Earth Loops.

If cables are used to connect the head amplifier to the microscope, users must ensure that the cables are shielded and that circuit Common is connected to the shield and thence to the microscope earth.

Users should ensure that the inner parts of the BNC 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 (to enable bias voltages to be applied). To reduce the possibility of 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 within the chamber are rare but may 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.

IVA-1 HEAD AMPLIFIER

This is used to amplify induced voltages generated in the specimen under investigation. Fig 9. shows the unit's front and rear panels. Please also read the preceding section on the ICA-1 induced current head amplifier as this provides useful additional information.

Users should note that the **BACK-OFF CURRENT** and **BIAS VOLTAGE** facilities of the ISM-5A are automatically disabled when the IVA-1 head amplifier is in use.

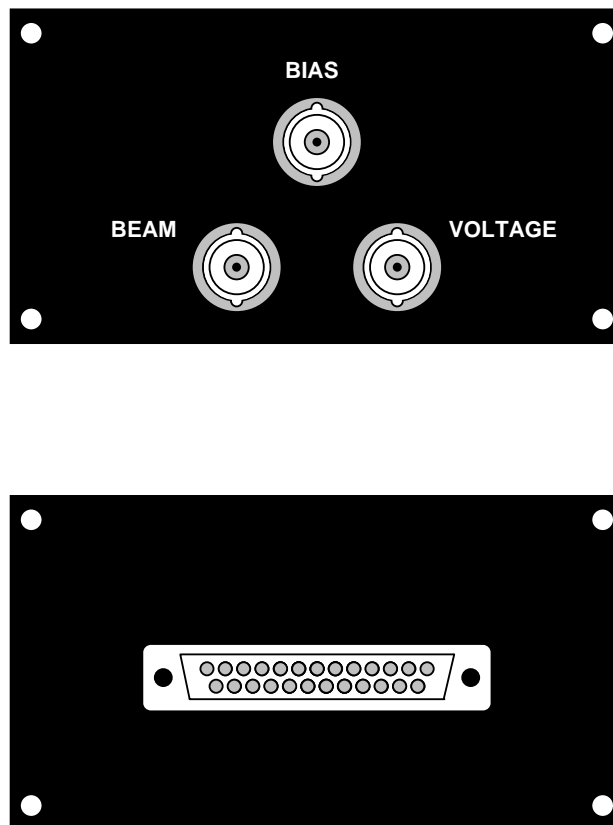


Fig 9. The front (top) and rear (bottom) panels of the IVA-1 head amplifier

1. BEAM input BNC connector

See ICA-1 section.

2. BIAS (Common) input BNC connector

The centre of this connector forms the circuit Common connection to the specimen under investigation.

3. VOLTAGE BNC connector

The centre of this connector forms the signal input to the voltage amplifier. Positive potentials with respect to those at the BIAS connector (item 2) are displayed as positive values on the ISM-5A control unit. Unlike the equivalent connector on the ICA-1, the outer portion of this BNC is *completely isolated* from the case of the head amplifier. It *must* also be electrically isolated from the user's microscope. Further details are given in the following section on Connections.

All Matelect port plates are manufactured with an isolated connector for use with the IVA-1 head amplifier. The ICA-1 head amplifier can also be connected to port plates with this feature.

4. Rear panel I/O connector

Please see similar item in the preceding section on the ICA-1 head amplifier.

CONNECTIONS TO THE IVA-1

A schematic of the internal circuitry components of the IVA-1 head amplifier and their relationship with the specimen and microscope is shown below in Fig 10.

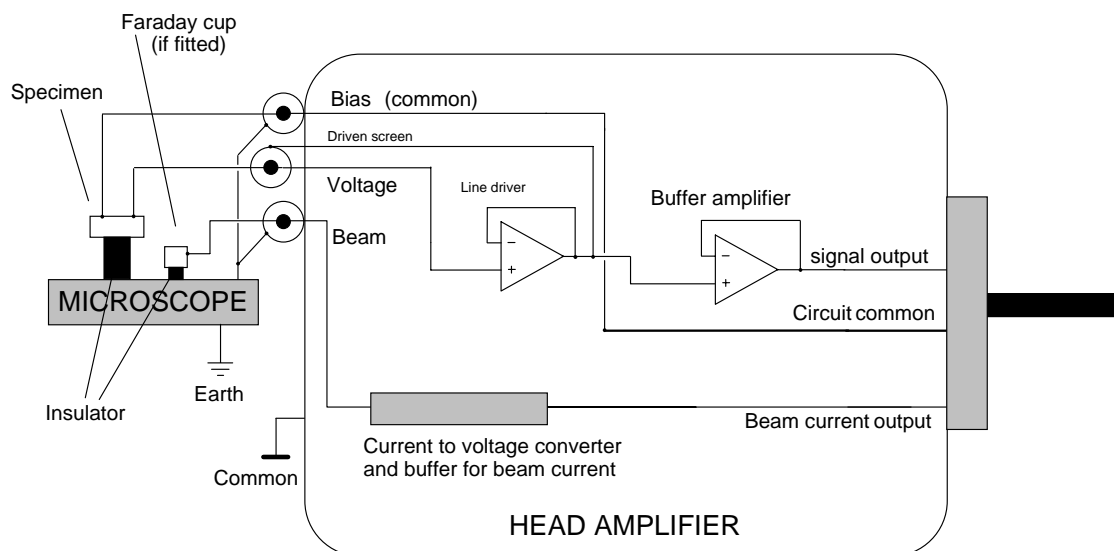


Fig 10. Schematic of the internal circuitry of the IVA-1 head amplifier

The IVA-1 is connected to the ISM-5A control unit by an umbilical cable terminated in 25 way D type connectors. The cable carries power supplies to the IVA-1, and signals representing the induced voltage, and the beam current.

The pre-amplifier consists of a first stage buffer amplifier which delivers a signal to a second stage buffer amplifier. The second stage can be switched to different amplification 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** knob on the ISM-5A control unit. The amplified signal representing the induced voltage is then supplied to the control unit for further processing.

The output of the first stage buffer is also used to raise the potential of the (isolated) outer portion of the **VOLTAGE** BNC connector. The purpose of this technique (known as a "driven screen") is to remove the influence of cable and input capacitance between the inner core and outer sheath. A few picofarads of capacitance can seriously attenuate input signals of the frequency and level encountered in induced voltage studies.

The specimen is directly connected to the **VOLTAGE** input (item 3). To complete an electrical circuit a second connection needs to be made to the specimen and this is done through the **BIAS** (Common) (item 2) connection.

Users should note that the outer portions of the head amplifier's **BIAS** and **BEAM** BNC connectors are connected to circuit Common and also to the head amplifier's external case. Therefore, when the BNC outers are mated to a port plate (normally at microscope Earth) a Common to Earth link will result.

Users should ensure that at least one Common to Earth link is correctly established to prevent charge retention by the ISM-5A. Further links between microscope Earth and Common (e.g. through the Common of the **ANALOG** output) *can* cause earth loops which generate substantial noise and instability. Earth loops should be avoided at all cost.

The best location for the link between ISM-5A Common and SEM earth is at the head amplifier. For further details see section 10 on General Usage Advice - Earth Loops.

If cables are used to connect the head amplifier to the microscope, users must ensure that the cables are shielded and that for the **BEAM** and **BIAS** connectors, the circuit Common is connected to the shield and thence to the microscope earth.

*As described in the preceding section, the outer of the **VOLTAGE** BNC must remain fully isolated.*

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

The sample should always be mounted on an isolating stand for reasons discussed in the preceding section.

Optical beam based systems should follow similar precautions.

If in doubt always isolate the specimen

Similar shielding and connection precaution as those described in the section on the ICA-1 head amplifier should be adhered to.

9. INSTALLATION

Additional information on installation is given on pages 2, 7, 19-21, and 23-30. Please read these pages before this section.

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

Installation of the ISM-5A 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-5A 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-1 or IVA-1 head amplifier to the ISM-5A main unit via the umbilical cable supplied.

It is often advantageous to power up and test the various functions of the ISM-5A 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 (see Pages 15 and 38).

Additionally, by using a low leakage diode connected across the **BIAS** and **CURRENT** inputs of the ICA-1 head amplifier, reverse leakage currents can be measured at various bias voltage levels.

INSTALLING THE HEAD AMPLIFIER

As described in Chapter (8), 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 for 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 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.

Installation on a SOM system follows similar guidelines.

The IVA-1 head amplifier **must** be mounted so that its **VOLTAGE** input connector is isolated from the casing of the user's microscope (see page 30).

The Chapter on General Usage Advice gives further details pertinent to this section (e.g. see Earth Loops).

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-5A, 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 OF THE ANALOG OUTPUT 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. 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 such 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-5A incorporates circuitry that can be used to scale the **ANALOG OUTPUT** to commonly encountered ranges. The controls that pertain to this circuitry are situated on the rear panel of the ISM-5A control unit. Please refer to page (21) for details on setting these controls.

Users should also remember that the analog output signal level is dependent upon the position of the **ANALOG OUTPUT** controls (**BIAS**, **GAIN VAR.** and **INVERT**).

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 **ANALOG OUTPUT** controls.

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

10. 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.

1. Ensure that the **BIAS VOLTAGE** and **BACK-OFF CURRENT** facility are switched out (switches in centre position). Set the **ANALOG OUTPUT GAIN** to unity (1), the **VAR.** control fully anticlockwise and the **BIAS** to zero (- and + LEDs off).
2. Connect up the sample as shown in Fig. 8.
3. Select the most sensitive head amplifier signal **RANGE**. If the **SIGNAL OUTPUT** display flashes, indicating an over-range condition, switch down to a less sensitive **RANGE**.
4. If the microscope has a waveform monitor, select this. The trace should be visible on the microscope's display. If this is not the case, change the **ANALOG GAIN** setting or use the **ANALOG BIAS** control to bring the trace into view. Adjust the **ANALOG 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 if this does not occur.
6. If all is satisfactory, position the sample as appropriate and operate the microscope.
7. The frequency response of the ISM-5A 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)** (see Chapter on Specifications for details of the frequency response.) Slow scans rates are required for effective imaging.

To improve the sharpness of the image first ensure that the **FILTER** switch is in the **OUT** position then move to a coarser **SIGNAL OUTPUT RANGE** and compensate for the reduction in signal by increasing the **ANALOG OUTPUT GAIN**. This increases the bandwidth of the system which sharpens the image or allows faster scan rates to be used.

Unfortunately this action 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 adjust the levels using the respective **TEST** modes. For delicate and valuable samples, users should ensure that they have set the **Short Circuit** detection facility to the appropriate level.

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 information on general use 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-5A, microscope electronics, and perhaps a chart recorder or data acquisition system can lead to signal instabilities.

The ISM-5A is basically a very sensitive amplifier and is therefore equally sensitive to electrical noise or "pick-up". 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-5A (and hence the sample) should be earthed to the mains Earth at only one point.

This connection should be made at the head amplifier via the outer portions of the BNC connectors. The assumption is made that the mating BNCs on the SEM are electrically connected to the metalwork of the microscope which is itself at Earth potential. If this is not the case, then a Common to Earth connection can be made on the rear panel of the ISM-5 by linking the terminals marked COM and EARTH (see Section 7).

Naturally it is important for the circuit Common of the ISM-5A 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 **ANALOG OUTPUT** BNC of the ISM-5A. This, connection however, can be the source of an Earth loop.

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-5A's Common will be earthed automatically upon connection to the **ANALOG OUTPUT** signal. If the head-amplifier, (held at ISM-5A Common), is also connected to the microscope metalwork (Earth), as recommended in Section 8, 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 **ANALOG OUTPUT**, should be broken by isolating the outer portions of the mating BNC connectors (i.e. cut the screen!)

2. 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.

3. 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).

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

5. If interference is still seen, attach a thick wire from the microscope Earth to the **COM** terminal on the rear panel of the ISM-5A control unit (this actually creates an Earth loop).

6. If the optional IU-1 interface unit is attached, check that the **COM** terminal on the unit is connected by a thick wire to the **COM** terminal on the ISM-5A.

7. Alter the position of the umbilical cable to the head amplifier and note if an improvement in noise rejection is seen.
8. Check that the screen of the umbilical cable is intact and connected at both ends to the cable head shells.
9. If all else fails contact Matelect for further advice.

Users should note that the first stage of the ICA-1 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.

CARE OF THE ISM-5A

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.

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.

CASE HISTORY: CHECKING THE ISM-5A FACILITIES

The following section details a number of problems and solutions experienced with the installation of an ISM-5A and ICA-1 (for EBIC studies) 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 **ANALOG RANGE** control should be set to give a 0-1V output range.

After selecting the correct rear panel **ANALOG RANGE**, 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 **ANALOG 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* **ANALOG OUTPUT GAIN** and perhaps readjust 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 **ANALOG 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). Switch in the **BACK OFF CURRENT TEST** position and adjust the back-off to zero.

Remember to leave the **ANALOG OUTPUT GAIN** on 1, (and the **UNCAL LED** should be off). Adjust the **ANALOG OUTPUT BIAS** control so that neither the red nor the green LED is lit.

Switch the back-off from **TEST** to **ON**. The **SIGNAL OUTPUT** meter will follow the **BACK-OFF CURRENT** meter and should thus show approx. zero. At these settings the **ANALOG** output from the rear of the ISM-5A should be giving zero if set to a +/- setting or +half the 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 **ANALOG** 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 **ANALOG** output (or fairly white), whereas -20nA will be full range in the opposite sense, and correspond to approximately 0.42V on the **ANALOG** output (or fairly black on the SEM's CRT).

Increasing the **ANALOG 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 **ANALOG 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-5A users should remember that as a finer **quantitative SIGNAL RANGE** is chosen, the bandwidth of the ISM-5A drops dramatically. Thus, it is not possible to examine a specimen under a TV mode on any **RANGE** finer than **200µA**. 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-5A 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, Matelect do the opposite. This approach may compromise imaging convenience but it does allow quantitative EBIC 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-5A 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 **ANALOG OUTPUT BIAS** control is set mid-way with both LEDs off 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 **ANALOG** output (assuming the **INVERT** is **OFF**). If no inversion occurs in the microscope, then such a voltage will result in dark contrast.

11. SPECIFICATIONS

SIGNAL OUTPUTS

(with respect to the head-amplifier output)

Induced Current (ICA1 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 (IVA1 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 (ICA1 and IVA1 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 (features autoranging)

| 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 (features autoranging)

| Range | Auto Range | Resolution |
|-------|------------|------------|
| 20 V | 0-2 V | 0.1 mV |
| | 2-20 V | 1 mV |

Short Circuit Detection Trigger Levels

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

ANALOG 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.

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 315mA fuses protect both Live and Neutral line. Fuses are located within the IEC connector.

DIMENSIONS

Head Amplifiers: 105mm x 60mm x 190mm
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

12. 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.

13. NOTES

