MA-812

Microprobe Data Acquisition System

Scan Amplifier and Scan System

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Preface

This manual contains details on the MA-812 Microprobe data acquisition system.

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Table of Contents

1. INTRODUCTION ..................................................................................................3
2. SCAN AMPLIFIER ...............................................................................................3
3. CABLES ................................................................................................................6
4. INTERCONNECTION OF THE HARDWARE .................................................7
5. SCAN COIL UNIT ...............................................................................................8
6. SIMULATION OF THE SCANNING SIZES IN VARIOUS MICRO-PROBE SYSTEMS. .................................................................10
7. DEADTIME OPTIONS .....................................................................................11
1. Introduction

The MA-812 system comprises a scan amplifier and associated scanning coils designed to be driven from the MicroDas II unit. The system is designed with the following properties:

- To work with ion beams up to a magnetic rigidity of 12 u.MeV/°2.
- The scan coils to be positioned immediately upstream of the probe forming lens system and to provide scan sizes up to 3x3 mm² in the case of the Russian antisymmetric quadruplet probe forming lens system.
- The scan coils be positioned immediately upstream of lens 3 and provide scan sizes up to 250x3000 μm² in the case of the quintuplet probe forming lens system.

2. Scan Amplifier

The scan amplifier supplied with the standard MicroDas unit is a dual channel transconductance amplifier designed to drive magnetic scan coils. The transconductance amplifier maintains a constant current independent of the impedance of the scanning coils. The standard transconductance amplifier supplied with the MicroDAS system is a Murray type 534.

**Warning:** Never power on the transconductance amplifier without a load! As this is a transconductance amplifier, operation without a load will cause the output voltage to swing to the maximum. This will destroy the output transistors after a short time. Connecting a load to a powered, unloaded unit, will result in a hazardous spark.

The Murray 534 output transistors are type 2SJ56.

**Note:** Abnormal operating conditions may result in an overload protection fuse blowing. This will be noticed by the scan reducing to half wave. The fuses are located inside the top cover.

The system is theoretically capable of driving high frequency scans, up to around 10kHz. However, use of magnetic scanning in the typical configuration, requires the scan frequency to be limited to 20Hz. The reason for this is the induction of eddy currents in the walls of the beam tube within the scan coils. These eddy currents cause the magnetic field to lag behind the current in the scan coils. Unless the scan frequency is sufficiently low to minimise this problem, the images produced will display severe ghosting. This issue is discussed further in section 3 below.
The MicroDas system described in this manual employs magnetic scanning. The analogue signals from the MicroDas unit could also be used to drive high voltage scan amplifiers connected to electrostatic scanning plates. In this case the limitation of the scan frequency imposed by the eddy current, discussed above, would be removed. Experience has shown that owing to the high voltages required on the scan plates, this is a less desirable arrangement compared to magnetic scanning.

**Parameters of Murray Modified MA534 Dual Transconductance Amplifier**

The twin amplifier is housed in a two rack unit (19 inch) chassis and may be free standing or rack mounted. The design is based on the Murray Amplifier hybrid thick film integrated circuit and uses power MOSFETs as output devices. Toroid transformers are used for the power supply and the 100V line output. The electronics consist of two identical amplifier boards (CD84) which plug into a connecting motherboard (CD85) by type D Euro connectors. This CD85 board also contains the power supply fuses and the low voltage DC supply. It also mounts the controls and indicator light emitting diodes. The amplifiers are short-circuit protected and unconditionally stable.

**Input:**

| Type                  | Fully balanced, transformerless |

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Impedance: 20 K ohm bridging (return loss > 34db)

Amplitude: Maximum signal level at minimum gain > 10 V rms, 20 dBV

Common Mode Rejection: > 70 dB from 20 Hz to 20 KHz Maximum common mode signal 25 V rms

Output:

Type: Unbalanced direct or isolated 100V transformer, selectable by switch

Impedence: Direct output: 1.0 KHz < 0.2 ohm
20.0 KHz < 0.25 ohm

Power Rating:
- 4.0 ohm - 150 W
- 8.0 ohm - 100 W
- 20.0 ohm - 70 W

Gain: Approximately 25 dB

Control:
- Local: By front panel potentiometer (if installed)
- Remote: DC by external 10K ohm linear potentiometer

Attenuation:
- Local: > 90 dB from 20 Hz to 20 KHz
- Remote: 100 dB at 20KHz; 80 dB at 20 KHz

Adjustment: Maximum gain of the VCA unit is unity, hence the maximum gain of the amplifier is set by the front panel potentiometer if installed.

Frequency Response:
- Direct output +/- 1 dB, 20 Hz to 20 KHz
- with local gain +/- 3 dB, 14 Hz to 58 KHz

Transformer coupled output:
- +/- 3 dB, 14 Hz to 17 KHz
- Below 20 Hz and above 30 KHz, rolloff approaches second order

Noise:
- 15 KHz bandwidth, input terminated in 600 ohm (rms noise voltage)
- Gain set to maximum
  - VCA out - 0.1 mV
  - VCA in - 0.3 mV
- Gain set to -10 dB
  - VCA out - 0.05 mV
  - VCA in - 0.2 mV
- Gain set to minimum
  - VCA out - < 0.05 mV
  - VCA in - < 0.05 mV

Signal to 15 KHz BW noise ratio:
- VCA out - > 100 dB
- VCA in - > 95 dB


Power Supply: 240 V 50 Hz +/- 10%, or 115 V if in North America
3. Cables

Digital cables

Microdas to ADC 36-way centronics
(4 required)

Microdas to Lab-PC+ card
50-way ribbon
(1 required)

Scan signal cables

Microdas to transconductance
scan amplifier (2 required)

Transconductance scan amplifier to
scan coils (2 required)
4. Interconnection of the hardware

To install the hardware of the MicroDas system, follow the layout in the diagram and proceed as described here. It is recommended that the control computer, the MicroDas unit and the Murray Amplifier all be installed in close proximity to each other and preferably in the same instrument rack to avoid problems with earth loops and signal degradation from long cables.

However it is possible to replace the short Lab-PC+ 50-way ribbon cable with a shielded cable up to 10 m long provided there is sufficiently low electromagnetic interference in the local environment.

1. Select appropriate Base Address, IRQ and DMA jumpers on the LAB-PC+ card to avoid conflicts with other cards in the computer.

2. With all components powered off, install the Lab-PC+ card securely into a spare slot on the motherboard. Observe normal precautions against static electricity when handling the Lab-PC+ card and the other components of the computer.

3. Connect the Lab-PC+ card to the MicroDas unit using the Lab-PC+ 50-way ribbon cable [a].

4. Connect one or more ADC units to the MicroDas unit using the 36-way cables fitted with the centronics connectors [b].

5. Connect the scan x and y output signals from the MicroDas unit to the input of the Murray amplifier [c].

6. Connect the x and y output of the Murray amplifier to the scan coils [d].

7. This completes the interconnection process.

**Warning**: Never power on the transconductance amplifier without a load! As this is a transconductance amplifier, operation without a load will cause the output voltage to swing to the maximum. This will destroy the output transistors after a short time. Connecting a load to a powered, unloaded unit, will result in a hazardous spark.

Interconnection diagram
5. Scan Coil Unit

The scan coil unit is designed to provide scan amplitudes up to 3 mm (or larger in some circumstances) in size when used with 3 MeV protons and positioned upstream of a nuclear microprobe probe forming lens system with a demagnification of 25.

The unit is constructed with two pairs of ferrite cored 256 turn coils. Taps are provided at 16, 128 and 256 turns. This allows the scan amplitude to be quickly changed by a precise ratios of 1/16, 1/2 and 1 by simply changing the taps. Additional taps are provided internally at smaller divisions if required. The coils generate a 300 Gauss field at the centre of the beam tube for the 256 turn tap and a current of 1 Amp.

**Warning:** Ensure the scan amplifier is switched off before changing taps on the scan coils.

The scan coil unit must be mounted on the beam line with correct orientation as marked on the body of the unit. Observe the “top” and “beam direction” labels. The distance from the scan coil unit to the lens system is not critical, as the scan amplitude is a weak function of this distance.

The scan coil unit can also be mounted between the probe forming lens system and the specimen if desired.

If the unit is mounted upstream of a probe forming lens system that incorporates one or more crossovers, then it will be necessary to reverse the connections for the direction(s) that incorporate the crossover to ensure the scan direction is correct.

The unit is designed to produce a deflection to the right for a positive x current and a deflection up for a positive y current when looking downstream. Images produced from the MicroDas data acquisition system will therefore directly correspond to the view of a front viewing optical microscope.

**Note:** The x-coils are located internally within the unit downstream of the y-coils. Therefore the scan produced by the unit will not be precisely square when equal currents are used in both coils. It is recommended that the scan be calibrated before use.
Scanning coil unit showing the three available taps for the x- and y-coils.
6. Simulation of the scanning sizes in various micro-probe systems.

In order to map the regions of the interest in the samples, the focussed ion beam is scanned using a set of magnetic scanning coils. These scanning coils are driven by high current amplifiers circuits (Murry amplifier unit). The Murry amplifier is controlled through MICRODAS unit, which is the heart of the data acquisition unit.

Using the ray tracing program PRAM, it is possible to simulate the maximum scanning distances in X and Y directions for different probe forming lens systems, optimising positions of the scanning coils. One such simulation is shown in the figure below for the MP2 microprobe system in the Microanalytical Research Centre at the University of Melbourne.

In order to calibrate the theoretical simulations, it is necessary to know the magnetic fields in the scanning coils as a function of the scan amplifier gains from the MICRODAS unit. These fields are shown in the next figure. The fields were obtained using the largest number of turns of the scanning coils.

*PRAM simulations for the maximum scanning distances in X, Y directions. Here we have shown the maximum distance in X-direction per 100 Gauss magnetic field for 2 MeV He\(^+\) ion beam with MP2 system.*
In Table 1, the maximum scanning distances in X and Y directions for different microprobe systems are shown.

<table>
<thead>
<tr>
<th>PRAM simulations</th>
<th>Ion beam</th>
<th>Scanning size in X direction per 100 gauss magnetic field (in μm)</th>
<th>Scanning size in Y direction per 100 gauss magnetic field (in μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP2</td>
<td>1 MeV H</td>
<td>2060</td>
<td>2040</td>
</tr>
<tr>
<td>Russian quadruplet</td>
<td>3 MeV H</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>2 MeV He⁺</td>
<td>730</td>
<td>720</td>
</tr>
<tr>
<td>MARC/CSIRO quintuplet</td>
<td>3 MeV H</td>
<td>1200</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>2 MeV He⁺</td>
<td>740</td>
<td>110</td>
</tr>
<tr>
<td>MP3-short</td>
<td>3 MeV H</td>
<td>260</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>2 MeV He⁺</td>
<td>160</td>
<td>1200</td>
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<tr>
<td>Experimental values</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MP2</td>
<td>3 MeV H</td>
<td>1200</td>
<td>~1200</td>
</tr>
<tr>
<td></td>
<td>2 MeV He⁺</td>
<td>670</td>
<td>~670</td>
</tr>
</tbody>
</table>

7. Deadtime Options

This section provides a very brief introduction to this topic. For a full discussion see the “Guide to extended features” manual of the MpSys4 data acquisition and analysis system.

Deadtime correction for a nuclear microprobe system is a complicated problem that has few simple solutions. The scan area may cover several hot spots in the specimen that produce a high count-rate in different detectors. Consequently, the system deadtime is different for each pixel in the image and different for each detector.

In most cases a few simple precautions can minimise the problems caused by deadtime. For example, when using PIXE signals, it is desirable to fit the x-ray detector with appropriate
filters to eliminate signals from major elements in the specimen. This is particularly true if the specimen contains regions with large variations in the concentration of the major elements. This will ensure that all regions of the specimen provide counts at about the same rate. In this case, little deadtime correction is necessary.

Nevertheless, some specimens will require more accurate solutions.

**Full deadtime correction for one detector:**

The MicroDas unit will provide fully deadtime corrected images automatically, provided only one station is enabled and the scan software, “Mpscan” is operating in “ADC” mode. Mpscan is described below. In this case, deadtime correction is accomplished by internally gating the scan off when the ADC is busy. Therefore the beam dwells for longer in real time on hot spots on the specimen to ensure they receive the same amount of live time as the rest of the scan area.

This technique allows deadtime corrected images to be produced from more than one detector by performing scans serially with each detector in turn. No special data processing is necessary. Experience has shown that the simplicity of this mode of operation is a significant advantage over other methods.

**Full deadtime correction for two or more detectors:**

Simultaneous, fully deadtime corrected images from two or more detectors can only be accomplished if a “deadtime map” is collected online. This map can then be used to divide out the variations in livetime in images produced by individual detectors. The deadtime map can also be used to make appropriate corrections to spectra extracted from regions of interest within the scan.

The deadtime maps provide the system livetime at each pixel for each detector. In order to produce these deadtime maps, it is necessary to employ an additional counter card in the control computer, some additional cables from busy outputs on the detector amplifier units and a fan-out box on the deadtime correction socket on the MicroDas unit. In addition, full deadtime correction options in the MpSys data acquisition software must be installed. These options add a very significant level of complexity. They are available as an optional add-on to the MicroDas system.

Full documentation for the add-on unit is available as a supplement to this manual.

End of Manual