SIGNAL RECOVERY

Multiplexed Measurements using the 7225, 7265 and 7280 DSP Lock-in Amplifiers

APPLICATION NOTE

AN 1004

Introduction

There are many experiments in which the researcher would like to be able to use lock-in amplifier detection techniques to measure more than one signal. This application note describes the options available to the users of ***SIGNAL RECOVERY*** products, from the simplest case of two signals through to an example of a system requiring ten measurement channels.

Simultaneous Measurements

When two or more signals are to be measured simultaneously then in general the same number of lock-in amplifiers are required. This may be achieved either through the use of multiple instruments, or, if all signals are at the same reference frequency, using a multi-channel instrument.

However, if there are only two signals that are at different frequencies and of comparable magnitude then the ***SIGNAL RECOVERY*** models 7265 or 7280 lock-in amplifiers may well be suitable. This is because these instruments include both Dual Harmonic and Dual Reference modes of operation, allowing independent measurement of each signal. Further information about an experiment that takes advantage of this capability to use just one instrument where previously two would have been required is given in Application Note AN1000.

Sequential Measurements

In many cases is not necessary to measure the required signals simultaneously. An example of this is in the study of photosynthesis in leaf tissue, where several detectors are monitoring the absorption of light at different points on the leaf during an experiment lasting one day. All that is required is that each detector be connected in turn to the lock-in amplifier's input, the output be allowed to settle and the value recorded. Clearly this could be done manually but this is often inconvenient and is prone to error. The solution is to automate the system and use some form of input multiplexer to connect the required detector to the instrument's input.

If there are just two such signals and they are single-ended voltages then the ***SIGNAL RECOVERY*** model 7265 or7280 lock-in amplifiers can perform the required switching without the need for any further equipment. One signal is connected to the **A** and the second to the **B** channel inputs and the selection of which one is used can then be made via the front-panel, but more usefully in a computerized system, by computer command. Figure 1 shows how this can be done with the model 7265. The only correction which might need to be applied is to allow for the signal inversion of the **B** input channel.

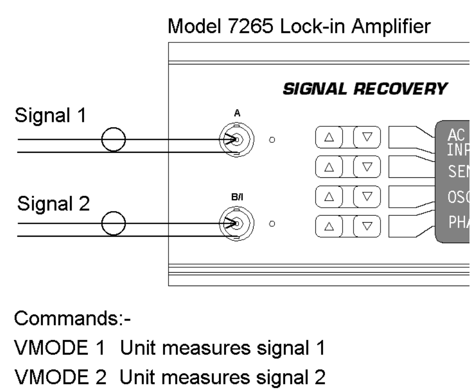

Figure 1, Two-Channel Input Multiplexing with the model 7265

When three or more signals need to be measured then an external multiplexer is required. Such devices are available from a number of sources, but the rest of this application note describes a ten-channel system built using a standard model 7265 lock-in and two model 7200 ten-channel multiplexers. These were designed and manufactured as special items by ***SIGNAL RECOVERY*** for this particular experiment.

10-Channel System for Measuring Critical Current Density in Superconductors

In the manufacture of superconductive probes from coated wafers the measurement of the critical temperature T_c and the critical current density J_c above which superconductivity ceases is important for the following processing stages. T_c can be determined by making contact with the wafer at its periphery, but the traditional measurement method for J_c implies forming a narrow bridge structure on the wafer. The technique is well established but for testing larger areas or higher quantities a non-destructive approach is preferable.

Claasen[1] et al (1991) proposed such a technique which generates an eddy current in the sample by inductive coupling and uses a pick-up coil to measure the resulting field. When the sample current density is below the critical level the system remains linear and the signal at the pick-up coil is at the same frequency as that applied, but as soon as the critical level is reached the resulting non-linearity causes a signal at the third harmonic to be generated. By detecting when a signal at this frequency occurs as the applied signal is increased it is possible to determine J_c

The ten-channel system, built by Zaitsev[2] et al (1999), uses this same technique but extended to ten measurement channels to measure the characteristic properties of YBCO films, intended for use as passive microwave devices for which a critical current density of 3 MA/cm^2 is required.

The experimental system is shown diagrammatically in Figure 2.

The 7265 is operated in internal reference mode at a frequency of 1.1 kHz, but set to the 3*f* detection mode so that it will measure signals at 3.3 kHz. The oscillator output signal, **OSC OUT**, is taken to an audio power amplifier which is operated at low output power to minimize distortion, and its output is fed to the **Common** input of the first of two ten-way multiplexers. The multiplexer connects the amplified oscillator signal to the driving side of one of the ten measurement coils, of which only two are shown in the diagram for the sake of simplicity.

Each coil consist of two concentric windings of 50 µm diameter wire, the inner one of 1100 turns being used as the driving element and the other one of 170 turns for the pick-up. The power amplifier is adjusted so that the driving current lies in the range 1 to 120 mA.

The overall diameter of each coil is about 6 mm and ten of them are distributed evenly over the surface of the 3" diameter wafer. The wafer and the coils are of course mounted in a liquid nitrogen dewar that is also not shown on the diagram.

Each pick-up coil is connected to the corresponding input of the second ten-channel multiplexer, which in turn connects one input to its **Common** connector. This is then connected to the **A** input connector to the lock-

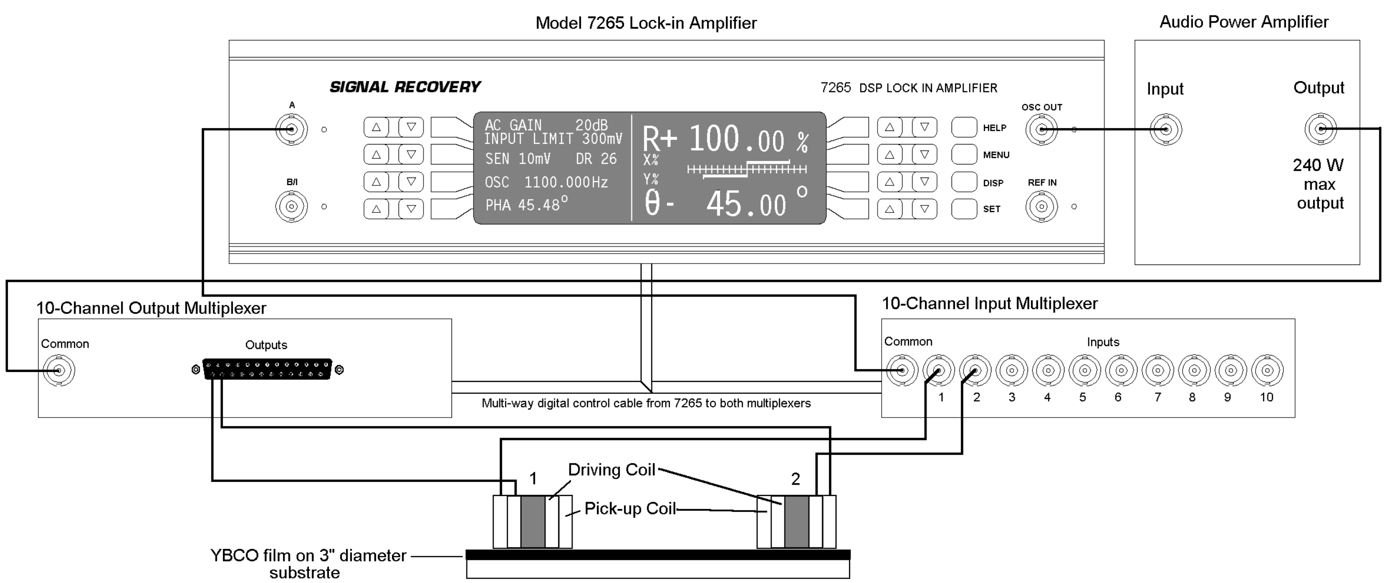

Figure 2, Ten-Channel System for Determining Critical Current Density in Superconductors

in amplifier. With the given driving current the typical signals at this point lie in the range of 1 to 50 µV.

The two multiplexers are controlled via the 8-bit digital output port of the lock-in amplifier, so that under computer control the system can connect the amplified oscillator signal to one of the driving coils and the corresponding pick-up coil back to the lock-in amplifier. The lock-in is operated in the 3*f* detection mode, in which it detects signals at the third harmonic of its reference frequency, or in other words at 3.3 kHz. Hence by increasing the oscillator output signal amplitude and monitoring the 3*f* amplitude the critical current density can be determined.

The system is calibrated by comparison with measurements taken on test samples using the traditional method.

Results

Figure 3 shows the plot of the output of one pick-up coil as the excitation current is increased, for the case of a wafer substrate only and one coated with a YBCO film. It can be seen that for the former sample the 3*f* detected signal is close to zero throughout. When, however, the superconducting film is present the 3*f* signal rises strongly at excitation currents greater than about 70 mA, which point corresponds to the critical current density for the sample.

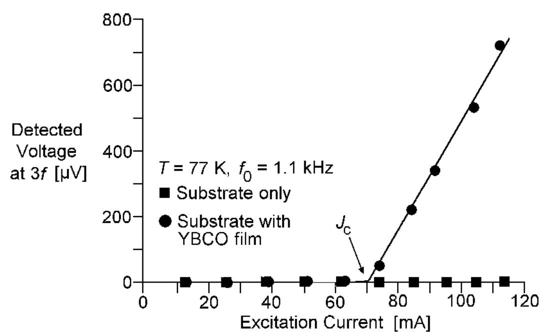

Figure 3, 3*f* Signal as a Function of Excitation Current for Superconducting Sample on Substrate and Substrate only conditions

Advantages of 10-Channel System

The major advantage offered by the use of the multiplexers is the speed with which the experiment can be performed. Setting up a single coil on the sample and cooling it down to 77K can take 10 to 15 minutes, so measuring ten points required several hours of time simply to allow the sample to heat up to room temperature, reposition the coil and cool it down again for each measurement. Using the multiplexed method, all ten coils are set up at the same time, which adds only a few minutes to the process, and then all ten measurements are made without needing to remove the sample from the dewar. This has the added advantage of reducing the risk of damage to the superconducting material that can be caused by water condensation during sample cooling and heating process.

Conclusions

In cases where several signals need to be measured using a lock-in amplifier the user is often not restricted to the obvious, but costly, solution of using multiple instruments in parallel. In some cases the use of the special detection modes offered only by the ***SIGNAL RECOVERY*** models 7265 and 7280 lock-in amplifiers may provide a solution, and in others the use of multiplexing techniques will give a cost-effective system.

Acknowledgement

SIGNAL RECOVERY acknowledges the assistance given by Dr Zaitsev of Forschungszentrum Karlsruhe, INFP, 76021 Karlsruhe, Germany, in the preparation of this note.

References

1 Claasen J H, Reeves M E and Soulen R J, Jr. 1991, Rev.Sci.Instr. 62, 996
2 AG Zaitsev, R Schneider, J Geerk et al., European Conf. on Appl. Superconductivity, 1999 Sitges (Spain)

Further Information

This application note is an introduction to the concept of input signal multiplexing. Additional information may be found in the following and other ***SIGNAL RECOVERY*** publications, which may be obtained from your local ***SIGNAL RECOVERY*** office or representative or by download from **www.signalrecovery.com**

TN 1000 What is a Lock-in Amplifier?
TN 1001 Specifying a Lock-in Amplifier
TN 1002 The Analog Lock-in Amplifier
TN 1003 The Digital Lock-in Amplifier
TN 1004 How to Use Noise Figure Contours
TN 1005 What is a Boxcar Averager?
TN 1006 Boxcar Averager Specification Comparison
TN 1007 The Incredible Story of Dr D.P. Freeze

AN 1000 Dual-Channel Absorption Measurement with Source Intensity Compensation
AN 1001 Input Offset Reduction using the Model 7265/7225 Synchronous Oscillator/Demodulator Monitor Output
AN 1002 Using the Model 7225 and 7265 Lock-in Amplifiers with software written for the SR830
AN 1003 Low Level Optical Detection using Lock-in Amplifier Techniques
AN 1005 Dual Beam Ratiometric Measurements using the Model 198A Mixed Beam Light Chopper

SIGNAL RECOVERY

SIGNAL RECOVERY is part of AMETEK Advanced Measurement Technology, Inc

801 SOUTH ILLINOIS AVENUE
OAK RIDGE
TN 37831-2011
USA
Phone: +1 865 482 4411
Fax: +1 865 483 0396

SPECTRUM HOUSE
1 MILLARS BUSINESS CENTRE, FISHPONDS CLOSE
WOKINGHAM, BERKS RG41 2TZ
UNITED KINGDOM
Phone: +44 (0)118 936 1210
Fax: +44 (0)118 936 1211

E-mail: info@signalrecovery.com **Web Site: www.signalrecovery.com**