SIGNAL RECOVERY

Digital Noise at Lock-in Amplifier Input Connectors

TECHNICAL NOTE
TN 1008

Overview

Since their invention in the early 1960's, lock-in amplifiers have been used whenever the need arises to measure the amplitude and/or phase of a signal of known frequency in the presence of noise. Unlike other AC measuring instruments they have the ability to give accurate results even when the noise is much larger than the signal - in favorable conditions even up to a million times larger.

Early instruments used analog technology, with manual controls and switches, and with output readings being taken from large panel meters. Later, microprocessors were added to give more user-friendly operation, digital output displays, and to support computer control. More recently still the analog phase sensitive detectors forming the heart of the instrument have been replaced by DSP (digital signal processing) designs, further improving performance.

But the addition of this digital technology has had one unfortunate side effect, which is that the instrument itself can act as a source of digital clock and switching noise that is typically coupled back into the experiment via the signal input or internal oscillator output connectors. This noise is of course rejected by the lock-in and generally does not impair its performance, but the power it dissipates in the sample or device under test can cause serious problems. This is particularly the case in low temperature physics and semiconductor research.

The ***SIGNAL RECOVERY*** model 7124 precision lock-in amplifier has been designed to be particularly suited to such work. It uses a unique analog fiber optic link to interconnect a remote connection unit (RCU), to which the experiment is connected, with the main instrument console. In normal operation there are no digital clock signals within the RCU, and so it can emit no switching noise. This architecture gives an instrument with all the advantages of the latest DSP technology for signal detection, and a powerful processor for easy user operation, as well as the low noise performance that until now has only been available in instruments of all-analog design.

This technical note describes measurements of the noise emitted by the signal input connectors on a number of lock-in amplifiers to demonstrate the superior performance of the Model 7124. The following instruments are considered:

Model Number	Supplier	Design
SR830	Stanford Research Systems	DSP
7265	***SIGNAL RECOVERY***	DSP
124A	Princeton Applied Research, the brand name used historically for ***SIGNAL RECOVERY*** products. The product was discontinued in 1994 but is still widely cited in the technical literature	Analog
7124	***SIGNAL RECOVERY***	DSP with separate all-analog front-end connection unit connected to main console via analog fiber links

The Model 7265 and the SR830 are general purpose DSP lock-in amplifiers, and were chosen for these tests in order to illustrate the performance of the Model 7124 compared with the most commercially popular instruments. The Model 124A is a sought after, but now obsolete all-analog instrument, which has attained legendary status in low temperature physics research because of the complete absence of digital switching noise at its input connectors.

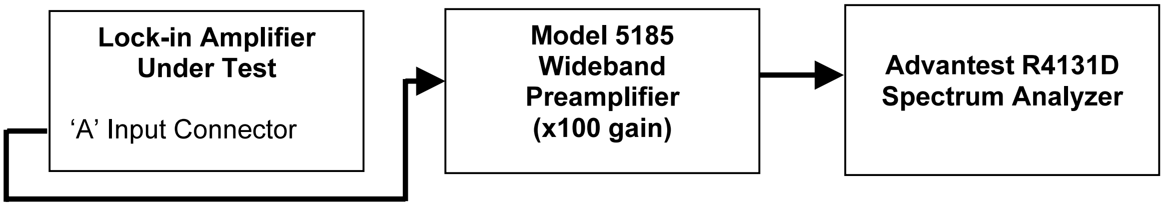

Figure 1, Spectral Measurement Test Setup

Spectral Measurements

In the first set of tests the input connector on each instrument was connected to a general-purpose spectrum analyzer via a low noise wideband preamplifier, in order to improve the overall sensitivity of the measurement. The preamplifier was set to ×100 gain with an input impedance of 50 Ω, and had a bandwidth of greater than 200 MHz. The test setup is shown in figure 1.

It might be expected that if the lock-in amplifier were turned off then there would be no measurable signal on the spectrum analyzer. However, the presence of interconnecting cables and ground connections to the line power source mean that this is not the case, so two sets of measurements were therefore taken. In the first, the instrument was connected to the line power supply but turned off, giving a "background" measurement, and in the second it was turned on. The intention was to identify the additional energy generated by the instrument when it is turned on and which is therefore properly attributed to its operation. In many real experiments researchers use a Faraday cage and extensive RF filtering on the line power supply to significantly reduce the background level.

Figure 2 shows the background spectrum for the Stanford Research Systems model SR830 when it is turned off, and figure 3 the same measurement when it is turned on. The significant increase in energy above 40 MHz that is output from the input connector is very apparent.

Figures 4 and 5 show the results for the same measurement using the ***SIGNAL RECOVERY*** model 7265. The two spectra are similar for frequencies up to 100 MHz, but there is some additional energy in the region above this when the instrument is operating, although very much less than in the case of the SR830.

The benchmark against which the model 7124 will be compared is, though, the model 124A. Figures 6 and 7 show the results for this unit. There is some increase in signal in the 40 MHz to 80 MHz region, which given that this unit has no digital clock signals cannot be caused by these breaking into the signal channel. Rather, it is most likely to be due to changes in the impedance of the input circuits between their powered and unpowered states. Most noticeably, though, in the region above 80 MHz there is no significant difference in the spectra, and there is less energy than in the case of the Stanford Research Systems model SR830 or ***SIGNAL RECOVERY*** model 7265.

Figures 8 and 9 show the results for the ***SIGNAL RECOVERY*** model 7124. In this case there is no additional noise when the unit is turned on, and indeed the rejection of background interference in frequencies up to 40 MHz actually improves, again

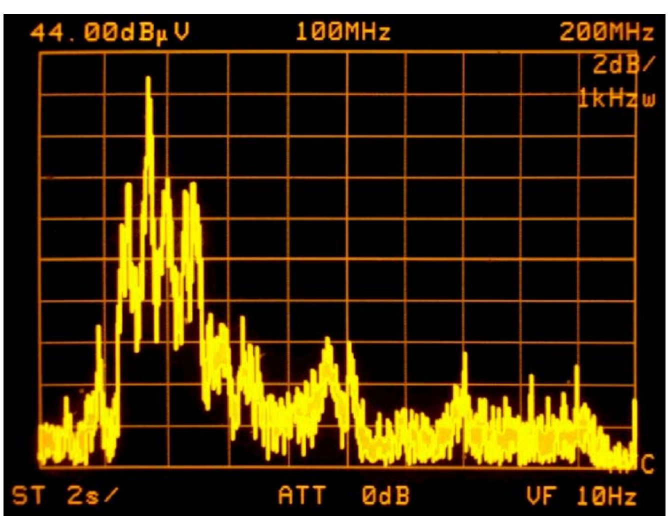

Figure 2, Background Spectrum when turned Off - Model SR830

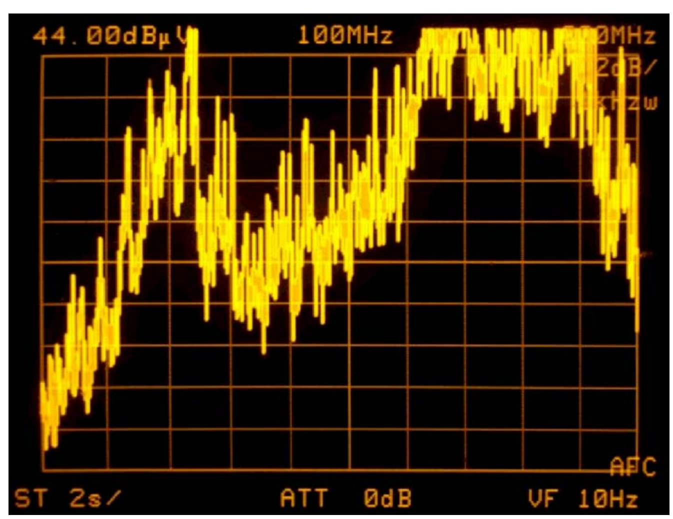

Figure 3, Spectrum when turned On - Model SR830

most probably due to changes in the impedance of the input circuits between their powered and unpowered states.

In conclusion, the spectral power tests clearly indicate that of the three instruments in current production, the model 7124 has the lowest emission of interfering signals from its input connectors, and furthermore, its performance matches or even exceeds that of the now-obsolete model 124A.

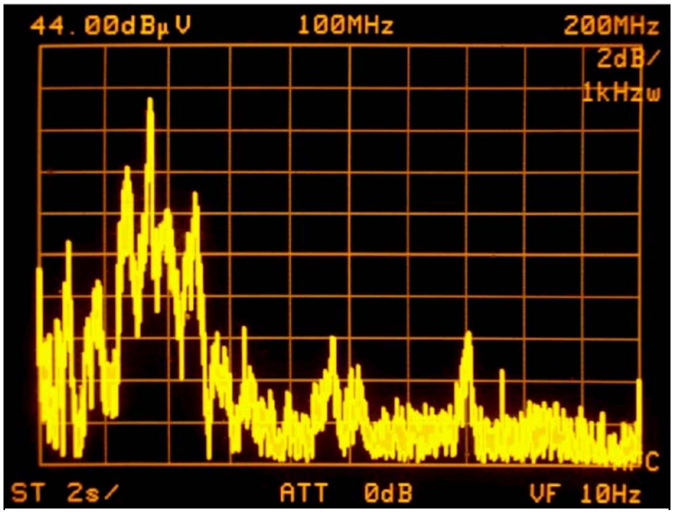

Figure 4, Background Spectrum when turned Off - Model 7265

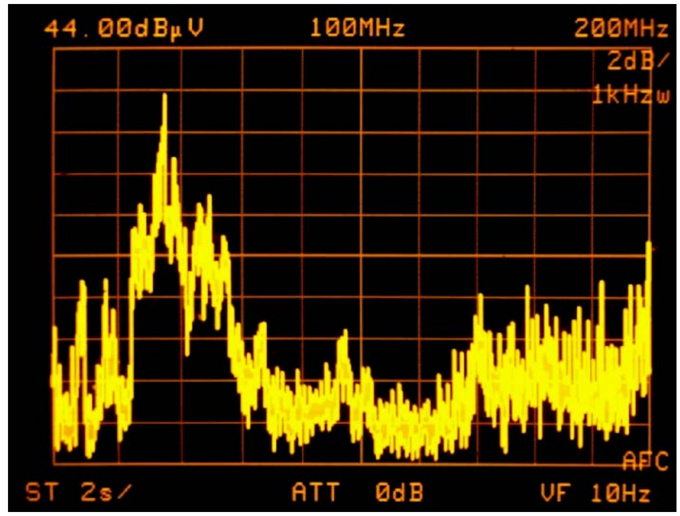

Figure 5, Spectrum when turned On - Model 7265

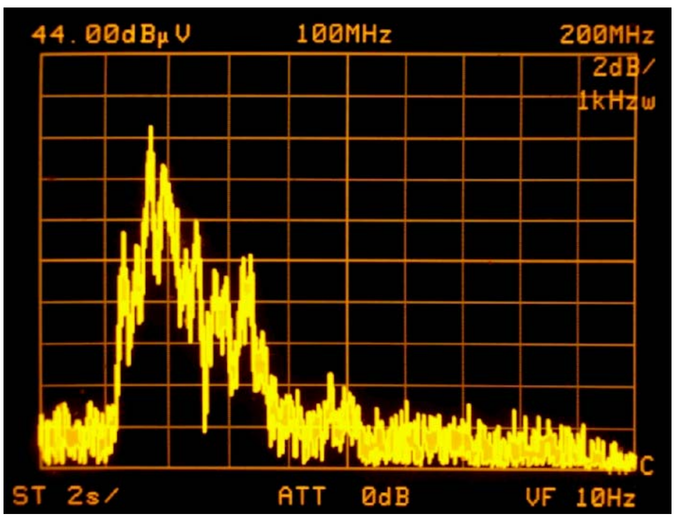

Figure 6, Background Spectrum when turned Off - Model 124A

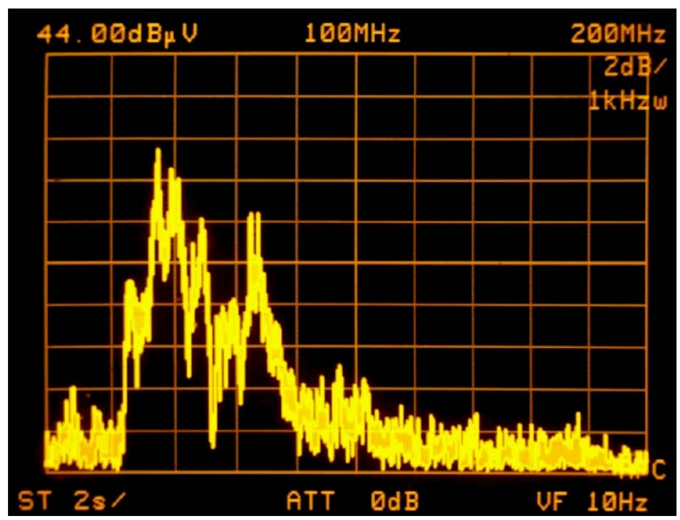

Figure 7, Spectrum when turned On - Model 124A

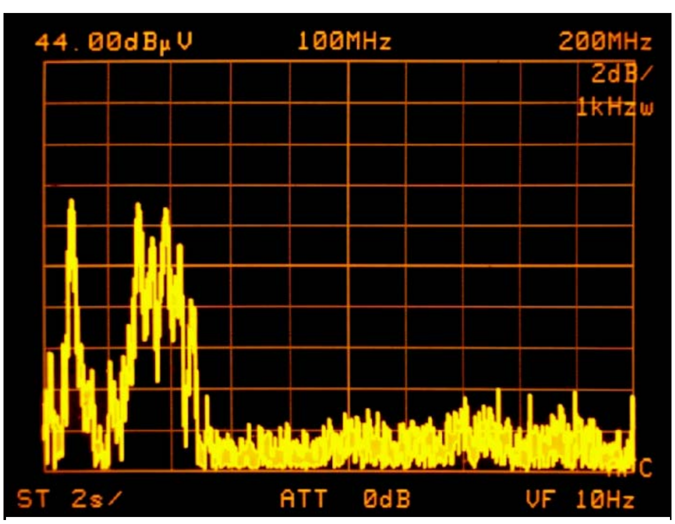

Figure 8, Background Spectrum when turned Off - Model 7124

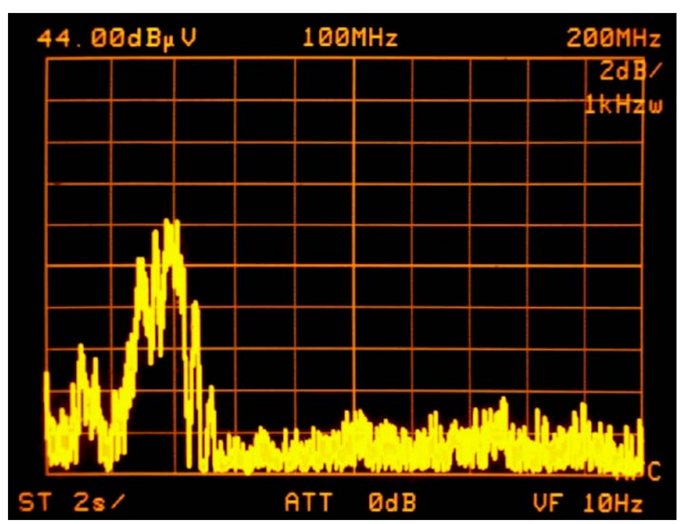

Figure 9, Spectrum when turned On - Model 7124

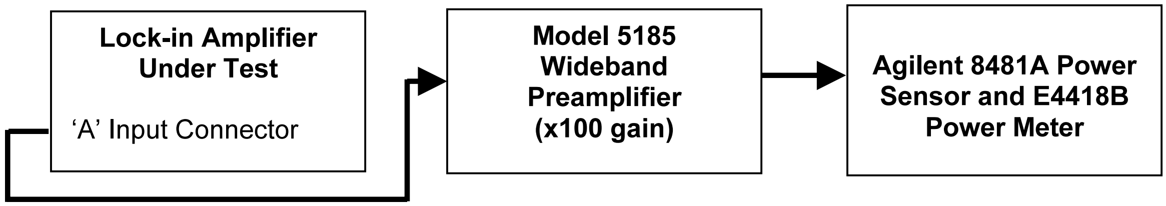

Figure 10, Power Measurement Test Setup

Power Measurements

The actual spectral density of the power emitted from the input connectors does not normally matter. What is of most interest is the total power, since it is this that causes sample heating and affects experimental results.

A second set of tests was therefore performed. The input connector on each instrument was connected to an Agilent power meter via a low noise wideband preamplifier, again in order to improve the overall sensitivity of the measurement. The preamplifier was set to ×100 gain with an input impedance of 50 Ω, and had a bandwidth of greater than 200 MHz. The test setup is shown in figure 10.

The results of these measurements are given below in Figure 11. In this chart, power expressed in dBm is the power expressed in decibels with respect to a power of 1 mW; hence the lower the figure, the lower the power.

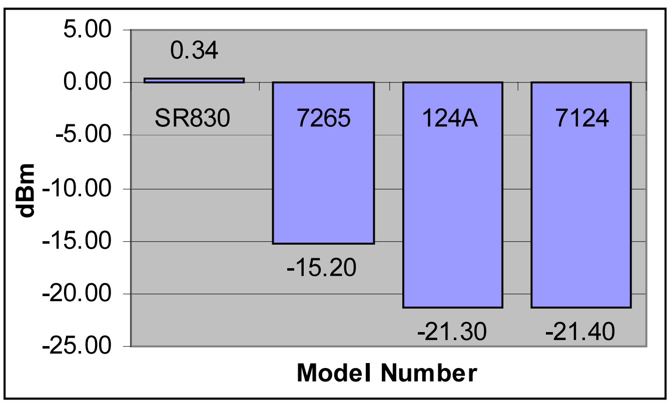

Figure 11, Power Measurement Results

It can clearly be seen from these results that the noise emitted from the input of the model 7124 is more than 21 dBm (125 times) lower than that from the SR830, and 6 dBm (4 times) lower than that from the model 7265. It also matches the performance of the model 124A.

Conclusions

Digital switching noise emitted from the input connectors of a lock-in amplifier can cause problems where the power it dissipates affects the experiment. Of the currently commercially available instruments, the ***SIGNAL RECOVERY*** model 7124 offers the best performance in this respect, and matches that delivered by the now-obsolete model 124A. It is therefore the optimum choice of instrument for any research where this key specification is critical.

Equipment Tested

The results reported herein were measured using the following instruments: Model SRS830 S/N 21378, Model 7265 S/N 08028799, Model 124A S/N 98103, and Model 7124 S/N 08199246.

Further Information

The following Technical Notes give further information about the selection and operation of lock-in amplifiers. They may be downloaded from our website at **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 1007 The Incredible Story of Dr D.P. Freeze

Company Names

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