Model 7210
Multichannel DSP Lock-in Amplifier

FEATURES

- Up to 32 DSP dual phase lock-in amplifier channels operating in parallel
- Common reference frequency
- Independent per-channel control of sensitivity, reference phase and time constant
- Units may be interconnected to increase available channels
- Voltage or Current mode signal channel inputs
- Complete with software

APPLICATIONS

- Spectroscopy
- Magnetic measurements
- Superconductivity tests
- Impedance measurements
- Pump-probe experiments

DESCRIPTION

The SIGNAL RECOVERY Model 7210 represents a significant advance in the application of DSP technology in the design of a lock-in amplifier. Until now, instruments have been restricted to a single signal channel, allowing only one, or at most two, signals to be measured at any one time. The model 7210, with its use of the latest technology, allows up to 32 signals to be measured simultaneously. What is more, units can be linked together to give more detection channels. For example, four units give 128 channels, while sixteen would give 512 channels.

The instrument can effectively operate as 32 parallel dual-phase lock-in amplifiers, running at the same external reference frequency, measuring 32 signals and generating 32 pairs of X and Y outputs. It can also operate in a tandem mode (see page 37) in which it generates a second reference signal which is an integer division of the external reference. This second reference is applied to the external experiment in such a way as to amplitude modulate the signal at the first reference frequency.

The amplitude modulation is detected by the first set of demodulators, which run at the external frequency, and then further demodulated by a second set of demodulators running at the generated reference frequency, to give a second set of X and Y outputs per channel. This detection method would previously have required two lock-in amplifiers connected in series, so in this mode the 32-channels of the 7210 are equivalent to 64 dual phase lock-in amplifiers. To date, no other lock-in amplifier matches this capability.

SPECIFICATIONS

General
Dual-phase 32-channel DSP lock-in amplifier operating over a reference frequency range of 20 Hz to 50.5 kHz. External Reference mode only. Independent control of sensitivity, AC Gain, reference phase and time constant on each channel.

Tandem and 2F detection modes. User-upgradeable firmware.

Measurement Modes
Single-frequency 32 channel dual-phase lock-in amplifier, running with an external reference frequency in the range 20 Hz to 50.5 kHz. Outputs in this mode are X1 and Y1 (in-phase and quadrature components) for each channel.

Tandem-operation 32 channel dual-phase lock-in amplifier, running with a first, external reference frequency (the carrier frequency) in the range 20 Hz to 50.5 kHz and generating the second reference frequency by integer division of the first. The range of the second frequency is 0.001 Hz to 100 Hz. Outputs in this mode are X1 and Y1 of the carrier frequency and X2 and Y2 of the amplitude modulation of the carrier frequency by the second reference frequency.

Signal Channel
The signal input specifications depend on the type of signal board fitted, of which three are available:

<table>
<thead>
<tr>
<th>7210/99 Signal Board - Voltage Mode Inputs</th>
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</thead>
<tbody>
<tr>
<td>Voltage Mode Inputs</td>
</tr>
<tr>
<td>Mode</td>
</tr>
<tr>
<td>Connector</td>
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Lock-in Amplifiers

<table>
<thead>
<tr>
<th>Specification</th>
<th>Specification</th>
<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Impedance Shell to Ground</td>
<td>Full-scale sensitivity</td>
<td>Sample Rate</td>
</tr>
<tr>
<td>1 kΩ or 0 Ω - set by</td>
<td>100 pA to 1 µA rms in a</td>
<td>208 kHz ≤ f &lt; 1 kHz</td>
</tr>
<tr>
<td>internal pin jumpers</td>
<td>1-3-10 sequence (9 settings)</td>
<td></td>
</tr>
<tr>
<td>Input Impedance</td>
<td>Frequency Range, f1</td>
<td>Internal Oscillator - reserved</td>
</tr>
<tr>
<td>10 MΩ</td>
<td>20 Hz to 50.5 kHz</td>
<td>for future expansion</td>
</tr>
<tr>
<td>Input Voltage Noise</td>
<td>Lock Acquisition Time</td>
<td>Reference Output - lights</td>
</tr>
<tr>
<td>&lt; 10 nV/√Hz at 1 kHz</td>
<td>20 Hz to 5.5 kHz</td>
<td>when no suitable reference is</td>
</tr>
<tr>
<td>Max Safe Input</td>
<td>Reference (Tandem frequency)</td>
<td>applied and the unit switched</td>
</tr>
<tr>
<td>± 12.0 V</td>
<td>f1/n, where n, an integer, is</td>
<td>on.</td>
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<td></td>
<td>calculated by the instrument</td>
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<td></td>
<td>to give a frequency as close</td>
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<td>as possible to a user-specified</td>
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<td></td>
<td>value in the range 0.001 Hz</td>
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<tr>
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<td>to 100 Hz</td>
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<tr>
<td></td>
<td>Amplitude</td>
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<td></td>
<td>Impedance</td>
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<td>Type</td>
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<td>Sampling Rate</td>
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<td>208 kHz ≤ f &lt; 1 kHz</td>
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<td></td>
<td>to external reference (f1)</td>
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<tr>
<td></td>
<td>frequency operation</td>
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<tr>
<td></td>
<td>only, 2f ≤ 50 kHz</td>
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<tr>
<td></td>
<td>Frequency, f2</td>
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<tr>
<td></td>
<td>Type</td>
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<tr>
<td></td>
<td>Synchronous digital</td>
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<td></td>
<td>FIR filters</td>
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<td></td>
<td>Harmonic Rejection</td>
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<td></td>
<td>&gt; 90 dB</td>
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<td></td>
<td>Dynamic Reserve</td>
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<td></td>
<td>&gt; 80 dB</td>
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<td></td>
<td>Tandem-Frequency Operation</td>
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<td></td>
<td>Applying to f1 outputs:</td>
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<tr>
<td></td>
<td>Time Constants</td>
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<td></td>
<td>4 ms to 1 ks in 1-3-10</td>
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<td></td>
<td>sequence (12 steps)</td>
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<td></td>
<td>Slope</td>
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<td>12 dB/octave</td>
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<td>Synchronous digital</td>
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<td>Dynamic Reserve</td>
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<td>&gt; 80 dB</td>
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<td>Tandem-Frequency Operation</td>
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<td></td>
<td>Applying to f2 outputs:</td>
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<td></td>
<td>Time Constants</td>
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<td></td>
<td>30 ms to 1 ks in 1-3-10</td>
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<td>sequence (11 steps)</td>
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<td>Slope</td>
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<td>12 dB/octave</td>
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<td>Synchronous digital</td>
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<td>FIR filters</td>
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<td>Data Outputs</td>
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<td>The outputs available from</td>
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<td></td>
<td>the instrument are:</td>
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<td>Single Reference Mode:</td>
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<td></td>
<td>X1 &amp; Y1</td>
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<td></td>
<td>Tandem Mode</td>
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<tr>
<td></td>
<td>X1, Y1, X2 and Y2</td>
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2710/98 Signal Board - Wide Bandwidth

Current Mode Inputs

Current Input

Mode: Virtual Ground, floating
Connector: BNC
Impedance Shell to Ground: 1 kΩ or 0 Ω - set by internal pin jumpers
Input Impedance: ≤ 1 kΩ at 1 kHz to virtual ground
Input Current Noise: < 150 fA/√Hz at 1 kHz
Max Safe Input: ± 12.0 V

Frequency Response over which following four specifications apply: 20 Hz to 5 kHz
Gain Accuracy Overall: ± 0.5%
Gain Match between Channels: ± 1.0%
Phase Accuracy Overall: ± 2°
Phase Match between Channels: ± 1°

Full-scale sensitivity: 100 pA to 1 µA rms in a 1-3-10 sequence (9 settings)

Demodulator

Main ADC’s, each channel
Type: 12 bit
Sampling Rate: 208 kHz ≤ f < 1 kHz
Harmonic Detection: f and 2f (in single-frequency operation only, 2f ≤ 50 kHz)

Reference Output (Tandem frequency)
Frequency, f2
f1/n, where n, an integer, is calculated by the instrument to give a frequency as close as possible to a user-specified value in the range 0.001 Hz to 100 Hz

Resolution
1 Hz

Reference Output (Virtual ground)
Resolution
0.001 Hz

Tandem Reference Frequency Meter
Resolution
0.001 Hz

2710/97 Signal Board - Low Noise Current Mode Inputs

Current Input

Mode: Virtual Ground, floating
Connector: BNC
Impedance Shell to Ground: 1 kΩ or 0 Ω - set by internal pin jumpers
Input Impedance: ≤ 1 kΩ at 1 kHz to virtual ground
Input Current Noise: < 50 fA/√Hz at 1 kHz
Max Safe Input: ± 12.0 V

Frequency Response over which following four specifications apply: 20 Hz to 5 kHz
Gain Accuracy Overall: ± 0.5%
Gain Match between Channels: ± 1.0%
Phase Accuracy Overall: ± 2°
Phase Match between Channels: ± 1°

Full-scale sensitivity: 10 pA to 100 nA rms in a 1-3-10 sequence (9 settings)

Reference Channel

External Reference Input
Impedance: 1 MΩ/35 pF
Level: 250 mV to 2.5 V rms
Connector: BNC

Orthogonality
90° ± 0.001°

Frequency Range, f1
20 Hz to 50.5 kHz

Lock Acquisition Time
2 seconds max

Reference Phase Shifter (each channel)
Set Resolution
10 m°

Gain Match between Channels
± 1°

Phase Accuracy Overall
± 2°

Gain Accuracy Overall
± 0.5%

Gain Match between Channels
± 1.0%

Frequency Response over which following four specifications apply: 20 Hz to 51 kHz
Gain Accuracy Overall: ± 0.5%
Gain Match between Channels: ± 1.0%
Phase Accuracy Overall: ± 2°
Phase Match between Channels: ± 1°

Full-scale sensitivity: 100 µV to 1 V rms in a 1-3-10 sequence (9 settings)

Reference Output (Virtual ground)
Resolution
0.001 Hz

Reference Output (Tandem frequency)
Frequency, f2
f1/n, where n, an integer, is calculated by the instrument to give a frequency as close as possible to a user-specified value in the range 0.001 Hz to 100 Hz

Resolution
1 Hz

Reference Output (Virtual ground)
Resolution
0.001 Hz

Tandem Reference Frequency Meter
Resolution
0.001 Hz

External Reference Frequency Meter
Frequency
f1/n, where n, an integer, is calculated by the instrument to give a frequency as close as possible to a user-specified value in the range 0.001 Hz to 100 Hz

Amplitude
> 3 V pk-pk square-wave

Impedance
< 200 Ω

Connector: BNC

Harmonic Detection
1 and 2f (in single-frequency operation only, 2f ≤ 50 kHz)

Reference Unlock - lights when no suitable reference is applied

Master/Slave - when lit indicates that the instrument is set to function as a "master" and that its synchronizing signal connectors are configured as outputs

Power On - a single LED which is lit when line power is applied and the unit switched on.

Communications Activity - indicates when command is being received and response is waiting to be read or being transmitted.

Signal Channel Overload - a single LED warning of input or output overload in any one of the 32 channels. It is possible to identify via a computer status command which channel(s) is affected and the type of overload condition

General

Computer Interfaces
Type: GPIB (IEEE-488) and RS232

Connectors: Standard GPIB
Centronics connector, 9-pin female RS232

Comms Settings
Set by rear-panel DIP switches

Command Set
ASCII commands for all instrument controls and data readout.

Binary dump commands for data readout

Power Requirements
Voltage
100/120/220/240 V

Ac

Frequency
50 - 60 Hz

Power
200 VA max

Dimensions
Width
446 mm

Height
3U (133.5 mm)

Depth
435 mm

Weight
12.5 kg
Single and Tandem Reference modes explained

Single Reference Mode
This is the conventional mode of operation common to all lock-in amplifiers. The instrument measures the amplitude of the components of the signal at its inputs that are in-phase and in quadrature (i.e. 90° out of phase) with an internally-generated sinusoidal demodulator signal. This demodulator signal is in turn phase locked to the applied external reference signal.

These two components are conventionally known as the X and Y channel outputs. All signal channels are measured with respect to the same external reference signal, so with a 32 channel instrument there are 64 output values.

Tandem Reference Mode
If an amplitude-modulated sinusoidal carrier signal is applied to a conventional lock-in amplifier operated at the carrier frequency and with its reference phase adjusted to yield zero Y channel output, then the X output signal will be the modulating signal. This only applies if the output time constant is sufficiently short to allow the modulation to pass.

If this X output signal is applied to a second lock-in amplifier, but this time running at the modulating frequency, then the second lock-in can directly measure the amplitude of the modulation.

Historically, this type of experiment would have required two instruments, with a physical cable coupling the X output of one to the input of the second. However, the 7210 includes this capability as a standard feature.

In order to allow the second lock-in amplifier’s demodulator to run synchronously with the first, it is desirable for its reference frequency to be the result of an integer division of the first reference frequency. This condition is best satisfied by ensuring that the second reference frequency be internally generated by the instrument and made available via a connector so that it can be used as the source of modulation for the signal.

Consequently the 7210 is fitted with two reference connectors; REF 1 IN is used to apply the external reference frequency at which the first demodulation stage operates, and the second, REF 2 OUT, outputs a TTL reference waveform at the frequency of the second stage. The user can specify the divisor used to generate the second reference from the first.

It will be appreciated that in tandem mode there are four outputs per signal channel, an X and Y pair from the first stage and an X and Y pair from the second. To avoid confusion, the outputs from the first stage, even when the unit is operating in single reference mode, are referred to as X1 and Y1 and those from the second as X2 and Y2.

It can also be seen that in Tandem mode an instrument with 32 channels generates 128 output values.

Ordering Information
In view of the specialized nature of this product, the model 7210 is currently available to special order only, with instruments being individually configured to meet customer requirements.

The basic model 7210 will support up to eight signal boards, each with four signal channels. Three types of board are available:

- 7210/99 Signal Board - Voltage Mode Inputs (20 Hz - 51 kHz)
- 7210/98 Signal Board - Wide Bandwidth Current Mode Inputs (20 Hz - 51kHz)
- 7210/97 Signal Board - Low Noise Current Mode Inputs (20 Hz - 5 kHz)

For example, a 32 channel unit with voltage mode inputs would require one model 7210 and eight model 7210/99 boards.

When multiple instruments are ordered together, 1 meter long interconnecting GPIB and reference link cables are supplied. Each instrument is of course supplied complete with a comprehensive instruction manual containing full programming information.

Software
A free LabVIEW driver that allows full instrument control is available for this instrument, which can be used as issued to control up to four instruments or incorporated into user programs. A fully compiled version of this program, MULTILOCK, is also available which also allows data to be saved directly to disk for later analysis using third-party software.