POCKET LOCK-IN™ AMPLIFIER
Instruction Manual
MODEL VK-90

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1. CHARACTERISTICS

1.1 INTRODUCTION

Congratulations on your purchase of the Pocket Lock-in Pocket Lock-in™ Amplifier. With its compact size, low weight and low power requirement this instrument is designed to fit easily within the mechanical constraints of your experiment, apparatus or portable battery powered equipment.

1.2 SPECIFICATIONS

1.2.1 Signal Input Characteristics

Configuration: Single-ended, voltage or current input. Internal jumper selected.

Input Impedance: depends upon jumper setting

1MΩ, voltage

50Ω, current

Input Sensitivity: Two position switch selected

1mV—100mV

1nA—100nA

High Pass Cutoff: 0.1Hz

Low-pass Cutoff: 100kHz

Input Noise: <20nV/√Hz

1.2.2 Reference Input Characteristics

Input Impedance: 27KΩ

Input Wave Shape: Sinusoidal or square (50% duty cycle)

Input Level: 200mV peak to 5V peak

Phase Control: Automatic vector tracking maintains positive polarity output voltage.

Frequency Range: Three position switch selected

20Hz—200Hz

200Hz—2kHz

2kHz—20kHz

1.2.3 Signal Output Characteristics

Output Level: ±1V full scale

Output Impedance: 56Ω

Output Expand: Three position switch selected

x1

x10

x100

1.2.4 Time Constant

Time Constant: 100ms (220ms rise time, 1.59Hz cutoff)

Slope: 12dB per octave

Accuracy: ±10%

1.2.5 General Environmental Constraints

Operating Conditions:

Ambient Temperature Range: 10°C to 40°C

Relative Humidity: 5% to 85%, non-condensing

Storage Conditions:

Ambient Temperature Range: 0°C to 70°C

Relative Humidity: 5% to 85%, non-condensing

1.3 CONNECTORS AND CONTROLS

1.3.1 Panel Connectors

The connector types are shown surrounded by [ ].

SIGNAL INPUT [BNC]

The AC signal to be measured is applied to this input.

OUTPUT [BNC]

A DC voltage proportional to the magnitude of the signal applied to the Signal Input BNC is available at this output.

REFERENCE INPUT [BNC]

Frequency and phase reference is derived from the sinusoidal or square wave signal applied to this input.

POWER [4-Wire modular jack, AMP 520249-2]

Accepts +12V, −12V and power supply return (ground).

1.3.2 Panel controls

SENSITIVITY [two position slide switch]

This switch selects the full-scale input sensitivity.

OUTPUT EXPAND [three position slide switch]

This switch selects the amount of gain that is applied to the low-pass filtered mixer output.

REFERENCE RANGE [three position slide switch]

This switch selects the lock-in frequency range or the spot operating frequency, if so equipped.

1.4 POWER SUPPLY REQUIREMENTS

The Pocket Lock-in receives its power from an outboard regulated DC power source. Its nominal power requirements are:

+12V at 60mA

−12V at 60mA

The Pocket Lock-in will meet specifications over the power supply range of 11 to 13 volts when tracking supplies are used.

The power input jack accepts a standard 4-Wire Modular Handset Plug type: AMP 5-641334-3.

1.5 WEIGHT

1.0 lb.

1.6 SIZE

2.9"W x 1.3"H x 7.0"D

1.7 SAFETY INSTRUCTIONS

Newly received equipment should be inspected for shipping damage. If any is noted, immediately notify

ElectroSolutions and file a claim with the carrier. The shipping container should be saved for possible inspection by the carrier.

WARNING! The protective grounding could be rendered ineffective if the equipment is damaged during shipment. Damaged apparatus should not be operated until its safety has been verified by qualified service personnel. If the equipment is damaged, it should be tagged to indicate to potential users that it may be unsafe and that it should not be operated.

The Pocket Lock-in is inherently safe from the view point of electrical shock hazard. There are no voltages in the device greater than 12V with respect to ground when operated from batteries or the optional power supply. Earth grounding is achieved through the host system as provided by the user of this device. The integrity of ground must be maintained at all times to protect operating personnel from danger.

WARNING! Any interruption of the ground distribution inside or outside the apparatus may make the equipment dangerous. Intentional interruption is prohibited.

Whenever it is likely that the protection provided by the connection to earth ground has been impaired, the system should be made inoperable and it must be secured against any unintended operation. The grounding protection is likely to be impaired if, for example, the equipment:

(1) shows visible damage,

(2) fails to perform its intended functions, or fails to allow associated devices to properly perform their intended functions,

(3) has been subjected to prolonged storage under unfavorable conditions,

(4) has been subjected to severe transport stresses.

Such apparatus should not be used until its safety has been verified by qualified personnel.

2. INSTALLATION AND OPERATING INSTRUCTIONS

Caution! Read this section of the manual carefully before attempting to operate the Pocket Lock-in. Operation of the device without consideration to proper usage may cause problems and/or damage.

2.1 INSTALLATION

In a typical experiment, you need to be concerned with connecting the signal of interest to the Signal Input BNC, applying a synchronous reference to the Reference Input and applying power. You will want to monitor the Pocket Lock-in Output with a dc voltmeter, chart recorder or possibly a PC-based signal acquisition card.

2.1.1 Cabling

50Ω coaxial cables are recommended for all input and output connections. Keep all cables as short as possible. When possible, arrange to place the lock-in near the signal source and let the Output, Reference and Power cables make up the difference in length.

2.1.2 Power cable color code

The Pocket Lock-in is supplied with a three feet long power cable. A modular plug is attached to one end. The plug fits into the power receptacle of the lock-in. The other end of the cable is unterminated. You may wish install a connector of your choosing onto unterminated end or wire it directly to a power supply. One spare modular plug is included.

Observe power polarity and wire color code when connecting the Pocket Lock-in to external power supplies.

POWER SUPPLY	COLOR CODE
GROUND	BLACK
+12V	RED
N.C.	GREEN
-12V	YELLOW

2.1.3 Optional power supply

An optional ±12VDC, 500mA power supply module is available from ElectroSolutions at additional cost. The Model PS-1 Power Supply wall plug-in type power converter derives its power from 120VAC, 60Hz power mains.

2.1.4 Power cable length

For long cable runs power should be provided over 20-22 gauge, four conductor cable. The standard power cable can be spliced onto the larger gauge cable at the point of use.

In electrically noisy environments, four conductor shielded cable is recommended. A series of experiments may be necessary to determine the most effective way to connect the cable shield. Refer to "Grounding and Shielding Techniques in Instrumentation, 2nd Ed.," by Ralph Morrison, 1977, John Wiley & Sons., Inc.

WARNING! Any interruption of the ground distribution inside or outside the apparatus may make the equipment dangerous.

Modifications to chassis ground returns and cable shields must only be carried out by personnel experienced and aware of the hazards involved. The following information may be helpful to such personnel in their grounding and shielding efforts. The extruded case makes a single-point connection to the power supply return (power ground) through the rear panel by virtue of the four mounting screws and a hardwired connection between the panel and the PCB ground plane.

2.2 OPERATING INSTRUCTIONS

The Pocket Lock-in is designed for plug-and-play use. Nevertheless, basic characteristics should be reviewed before operating the unit.

2.2.1 Signal Input

The Pocket Lock-in can accept a number of input signal types. The two types of signals commonly encountered originate from voltage sources, characterized by a low output impedance, and current sources having high source impedance. Many photodetectors fall into the current source category. However, opto-electronics manufacturers now provide sensors with amplified and buffered voltage outputs. The input circuitry can be configured with three on-board jumpers to provide high or low input impedance.

As shipped from the factory, the input circuitry is configured for high input impedance. If the signal of interest originates from a low impedance source, then the standard configuration should suffice.

The input can also be configured to provide a low impedance. Choose this configuration when working with high impedance current output devices such as photodiodes or photomultiplier tubes; or if the sensor is specified to drive low impedance loads.

In the high impedance configuration a 1.1MΩ resistor establishes the input resistance. This resistor provides the DC load needed by some signal sources. The input signal is ac-coupled to a non-inverting voltage follower buffer amplifier. The input resistor combines with the impedance of the capacitively coupled buffer input resistor to yield a nominal 1MΩ input impedance.

The high impedance input configuration can sustain up to ±50V DC biases. This limit is imposed by the coupling capacitor voltage rating.

The input buffer is unprotected from voltage transients caused by capacitive discharges or electronic “thumps”. Such conditions might arise from connecting a biased photodiode or powered photomultiplier tube to the signal input, or by power supply transients that occur during turn-on or turn-off. Any incoming transients should be externally limited to ±12V peak.

The input buffer can be configured as a current sensitive amplifier by changing the circuit topology via an on-board jumper matrix. In this configuration the signal is dc-coupled at the input stage—but ac-coupled at later amplifier stages—and loaded by 51Ω. Alternatively, this configuration can be considered as a high gain inverting amplifier with low input impedance.

The maximum safe input current for the low impedance input is 1mA, or less. This limit is imposed by the current handling capability of the integrated circuit amplifier.

The fact that the input buffer configurations have different polarities is unimportant to the operation of the Pocket Lock-in. It will automatically adjust itself to present a positive polarity output.

See Appendix A for detailed instructions on how to reconfigure the input buffer and input impedance.

2.2.2 Output

The output of the Pocket Lock-in is a DC voltage proportional to the magnitude of the signal applied to the Signal Input BNC. The nominal full-scale output is ±1 volts. Once phase locked, for any input signal phase, the output voltage has a positive polarity.

The output voltage can exceed ±5V during input overload situations, but will not go beyond the ±6 volts power supply limit of the output amplifier.

There is a 56Ω resistor in series with the output amplifier. The voltage divider effect caused by low value resistive loads must be taken into account when measuring a signal.

The minimum recommended load is 1kΩ.

Avoid large value capacitive loads. The output amplifier can become unstable and oscillate.

2.2.3 Reference Input

Frequency and phase reference is derived from the sinusoidal or square wave signal applied to this input. The reference frequency must fall within the selected range or the lock-in will be unable to achieve phase lock. Without phase lock, the output voltage will be meaningless.

Pulse type signals having duty cycles other than 50% do not work well with the internal lock-in phase shift circuits. At best, the lock-in would be able to phase lock onto signals whose phase is within a few degrees of one of the internal discrete quadrature points; i.e., 0, 90, 180, 270.

A 1MΩ resistor establishes the input resistance. This resistor provides the DC load needed by some signal sources. Further, the input signal is ac-coupled to a inverting buffer amplifier. Its input resistor combines with the impedance of the capacitively coupled buffer input resistor to yield a nominal 27KΩ input impedance.

Reference signals must be between 200mV peak to 5V peak. The reference input circuitry will sustain up to ±50VDC biases. Like the signal input, the reference input is unprotected against high voltage transients and should be protected similarly.

2.2.4 Input Sensitivity switch

A sinusoidal signal having an rms level equal to the switch setting will result in full-scale output voltage. 1mV or 100mV full scale input sensitivity is selected with the two-position front panel slide switch.

2.2.5 Output Expand switch

The demodulated signal output of the mixer may be amplified up to an additional 100 times. This gain is applied to the post-mixer low-pass filter.

The Output Expand function is provided to allow the user to make tradeoffs between input dynamic reserve and output stability or to increase the resolution of the output measuring device.

2.2.6 Reference Range or Spot Frequency switch

The Pocket Lock-in will operate over four decades of frequency range. To optimize the performance of the lock-in, the range has been partitioned into three single decade wide sub-ranges covering 20Hz to 20kHz. A sub-range is selected with the Reference Range switch.

If the reference frequency is on the dividing line between two reference ranges, then choose the lower frequency range. This puts the operating frequency on the high side of a lower range and results in faster signal acquisition.

There is some overlap in the reference ranges. This makes it possible to operate the lock-in at frequencies higher than that indicated by a particular range. Doing so may result in unspecified performance. Always choose a range to bracket the reference frequency.

If you are using a Pocket Lock-in optimized for single, or Spot Frequency, use, then each position corresponds to the exact center frequency. The amount of off-center-frequency lock range is limited and unspecified.

2.2.7 Power Input

The Pocket Lock-in has internal voltage regulators to provide conditioned voltages to the critical signal processing circuitry contained within. Less sensitive circuits receive power directly from the power input connector. The voltage at the input connector is low-pass filtered before being applied to those circuits. Nevertheless, low noise—low ripple—power supplies should be provided. General purpose laboratory bench power supplies are adequate.

Power supply voltages should be maintained between 11 to 13 volts for specified operation. For battery powered applications the supplies should track each other.

Under no circumstances should the power supplies be allowed to exceed 16 volts or damage may occur to the unit.

2.3 STORAGE

When storing the Pocket Lock-in for an indefinite length of time choose an area that provides a cool, dry environment.

2.4 INITIAL CHECKS

After installing the Pocket Lock-in you may wish to make some simple checks to verify that it is working properly. The following procedure allows such checks to easily be performed.

To make these checks you will need a sine wave oscillator capable of generating a variable amplitude sine wave at frequencies of 100Hz, 1kHz and 10kHz. Amplitudes of 10mV and 100mV are sufficient. The generator will provide the input and reference signals to the Pocket Lock-in. You may require attenuators if the generator cannot provide independent signal and reference output wave forms. You will also need a dc voltmeter to measure the lock-in output, a number of BNC cables and interconnection “Ts.” The procedure follows.

2.4.1 Set the generator to produce a 100mV rms sine wave at 100Hz.

2.4.2 Connect the output of the signal generator to the Pocket Lock-in Signal Input and Reference Input by using a “T” to split the signal into two paths.

2.4.3 Connect a dc voltmeter to the Output BNC of the Pocket Lock-in.

2.4.4 Set the Pocket Lock-in controls as follows:
Sensitivity: 100mV
Reference Range: 20 to 200Hz
Output Expand: x1

2.4.5 Apply power to the Pocket Lock-in.

2.4.6 Observe the dc voltmeter settling to a reading of +1 volts DC, nominally.

2.4.7 Reduce the signal level to 10mV rms while maintaining 100mV rms to the Reference input. Insert an attenuator in the signal path, if required. Observe the new voltmeter reading. The reading should be +100mV DC, nominally.

2.4.8 Set the Pocket Lock-in Output Expand to x10 and observe the voltmeter reading. The meter should read +1 volt, nominally.

2.4.9 Repeat the procedure with 1kHz and 10kHz reference frequencies.

This completes the initial checks. If the described results have been obtained, then you can be reasonably sure that the Pocket Lock-in is working properly.

3. TEST AND CALIBRATION PROCEDURE

There are no internal user serviceable calibrations or adjustments.

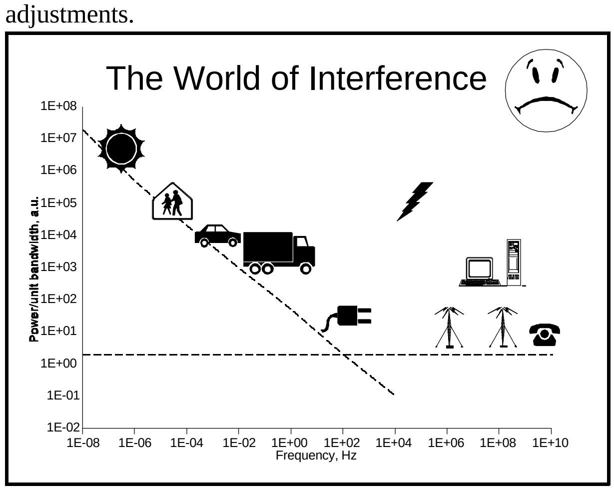

Figure 1 Manmade and natural noise sources interfere with precision measurements.

4. LOCK-IN AMPLIFIER BASICS

Manmade and naturally occurring noise sources barrage experiments and interfere with precision low-level signal measurements.

Figure 1 illustrates some of the most frustrating sources. Starting with high frequency end mobile and portable cellular telephones dominate. Next are AM and FM radio broadcasts and the spurious high frequency radiations of tabletop and portable computers. The power line—and its harmonics—dominates at low frequencies and often is the toughest noise source to overcome. Below 1Hz the vibrations caused by the movement of machinery and automobile and human foot traffic become prevalent—earthquakes, too. Earth's axial rotation causes the sun to interject daily temperature fluctuations into our surroundings—and our yearly trip around the solar system adds yet a longer term variation. It's a noisy world—and getting noisier.

In your work you may be faced with making precise low-level measurements. Yet getting clean signals from sensors can be against the odds. After all. . .

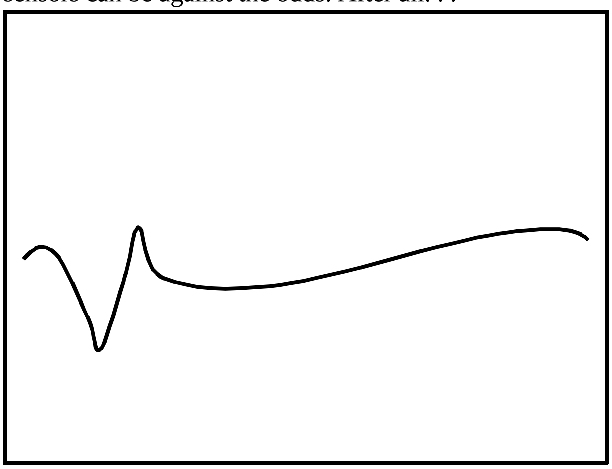

Figure 2

But you know what?

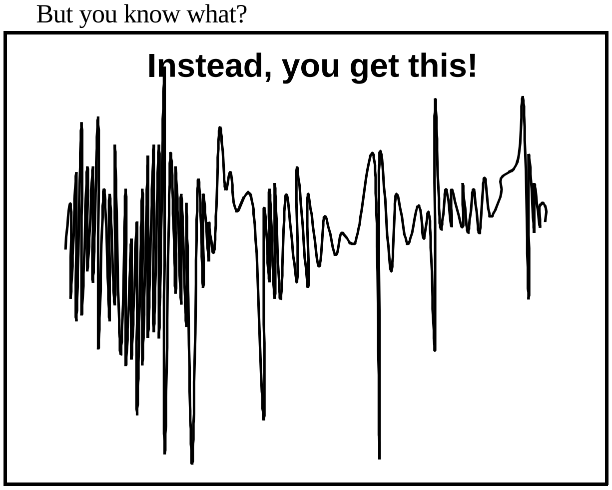

Figure 3

In the unhappy world of interference, much of the noise occurs at frequencies that are higher than the signal of interest. The normal reaction to a noisy signal is to try to clean it up a bit before measuring it. So a low-pass filter may be employed to eliminate the offending high frequency interference.

After adjusting the cutoff frequency of the filter the acquired signal begins to approximate the expected wave shape. While much of the noise has been filtered out, the signal to noise ratio still leaves a lot to be desired. The uncertainty in the result is too high.

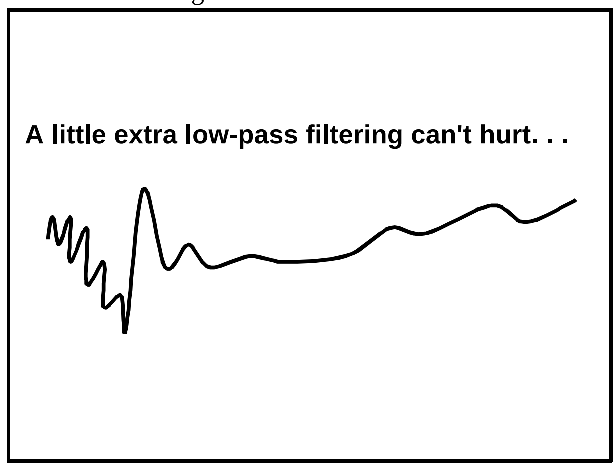

Figure 4

Driven by a need to improve the situation further and somewhat by curiosity; if a little low-pass filtering works so well, then wouldn't a little more be beneficial?

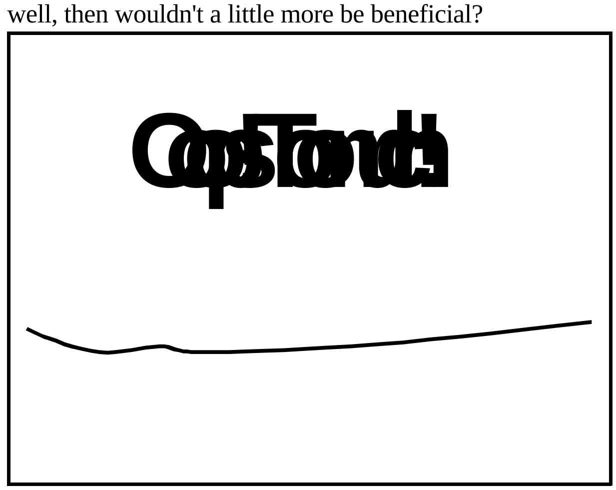

Figure 5

Well, the worn out moral of the story is painfully clear. Besides, even if the high frequency noise were effectively reduced, what about the very low frequency components like thermal drift and 1/f that interfere with DC performance?

After pondering the nature of the world of interference, a solution does present itself. If the signal of interest could just be moved away from the noisy regions and then band-pass filtered, rather than simply low-pass filtered near zero frequency and left at that, then signal quality could be restored and acquired with ease.

Shifting the signal of interest away from zero frequency and band-pass filtering is the underlying concept of lock-in amplifier techniques. More specifically, the phase sensitive technique. You may be asking yourself at this point, "I thought the Pocket Lock-in was phase *insensitive*. So why are we discussing phase sensitive methods of signal acquisition?" The Pocket Lock-in incorporates phase sensitive techniques, but by design has been rendered phase insensitive. This will be explained later.

There are fours steps needed to exploit the advantages of phase sensitive detection.

4.1 Modulate or chop the signal of interest to raise it from near zero frequency, or dc, to a noise-free frequency region.

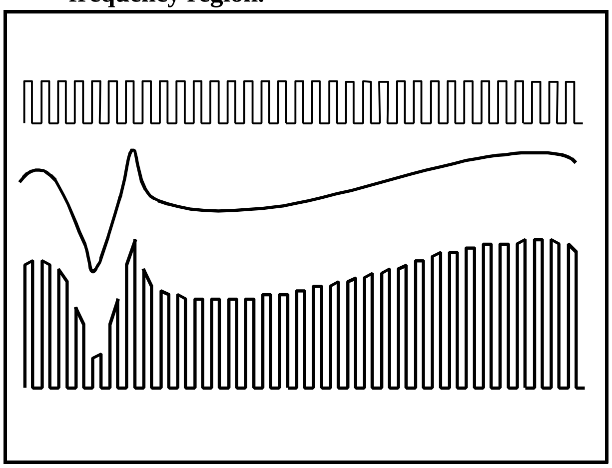

Figure 6 Modulated excitation evokes a modulated output response.

In many experiments, a sample is stimulated or probed by optical or electrical means. The characteristics of the sample change or become apparent under the influence of the excitation. Figure 6, upper, shows a modulated source. The middle curve represents the time response of the sample over the measurement interval. The lower curve shows sample response multiplied by the modulated source. In this case the modulation is 0% to 100%.

Within the experiment, sensor and sensor electronics noise sources add their influence to the chopped signal.

Many noise sources encountered in experiments have 1/f noise characteristics. Figure 1 shows an example of a 1/f curve that eventually intercepts the noise floor at around 100Hz. The intercept point of the two curves is called the "knee." Common sensors have higher knees than that. Choosing a convenient modulation frequency higher than the knee usually suffices.

The modulation frequency is the lock-in reference frequency in most cases. There are times, however, when it is desirable for the lock-in to lock onto two, three, four, or more times the reference frequency. The Pocket Lock-in is incapable of locking onto higher multiples of the reference frequency.

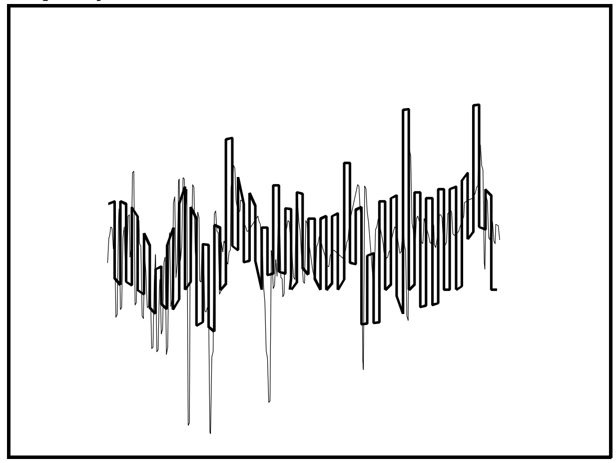

Figure 7 Post-sensor noise to the modulated signal.

Generally, a 400Hz to 1kHz reference frequency is sufficiently high to get above the 1/f noise.

The reference frequency must be within the lock-in signal amplifier bandwidth. That is because the reference frequency carries the signal information. To preserve signal information, the modulation frequency must be higher than the maximum frequency of the measured process. The Pocket Lock-in signal amplifier cutoff frequency is near 100kHz—well above its maximum operating frequency of 20kHz.

It is important to always modulate ahead, or upstream so to speak, of the introduction point of the interfering noise sources. Otherwise, the up front noise sources can become modulated along with the signal. Once that happens, the signal cannot be extracted from the up front noise and all the benefits of phase sensitive detection diminish.

4.2 Amplify the signal at the reference frequency.

Because of the synchronous nature of the lock-in process, amplifying at the reference frequency is a natural consequence of using the Pocket Lock-in.

A basic lock-in amplifier comprises an ac-coupled amplifier to boost the signal of interest, a detector or mixer to demodulate the incoming signal and extract the signal information, and a low-pass filter and dc amplifier to smooth the output of the mixer and amplify the resulting DC voltage.

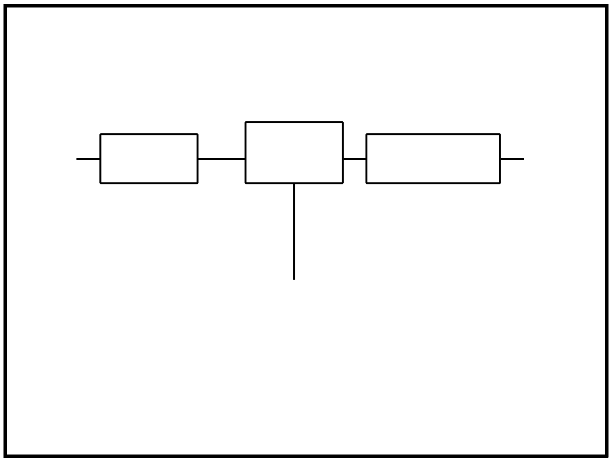

Figure 8 Basic lock-in block diagram.

Some extremely noisy applications benefit from the introduction of a band-pass filter tuned to the reference frequency to further bandwidth limit the noise going into the lock-in. Such a filter may be externally applied between the signal source and the Signal Input of the Pocket Lock-in. The signal amplifier chain within the Pocket Lock-in can be modified to yield a band pass filter response. Contact the factory for more information.

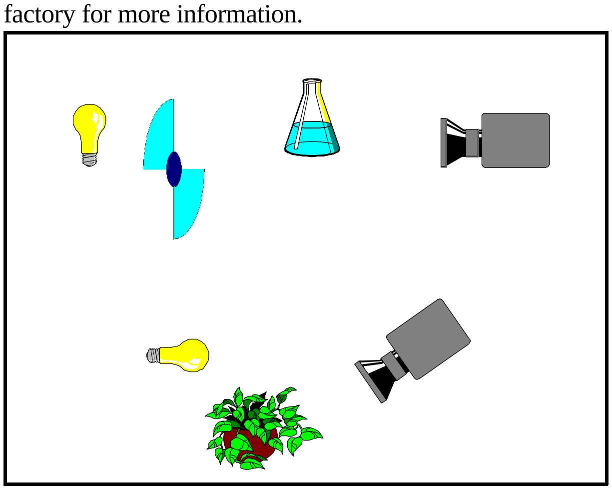

Figure 9 Always modulate ahead of the noise entry points.

4.3 Use phase sensitive detection to the signal.

This section discusses phase sensitivity and then leads into how the Pocket Lock-in is phase insensitive.

Because the received signal is amplitude modulated, the carrier must be stripped away to leave only the signal of interest.

Figure 10 provides an example of mixer operation. For clarity the reference is shown as a square wave; the signal a sine wave. Generally, the reference is phase and frequency stabile, the signal to be demodulated is at the reference frequency and its phase relative to the reference is unknown.

The mixer effectively allows the incoming signal phase to be compared against a standard—the lock-in reference signal. Were the amplitude of the signal constant and known, then the average mixer output voltage would be indicative of phase. Like wise, were the phase constant and known, then the mixer output would provide signal amplitude information.

With zero phase difference between the reference and signal, the mixer presents a familiar full wave rectified output wave form. So does a signal 180° out of phase with the reference—but with opposite polarity. Notice, also, that the mixer output fundamental frequency is twice the reference frequency.

At 0° and 180°, the average mixer output voltage is always maximum and proportional to signal magnitude. Were the phase difference always maintained at 0° or 180°, then the mixer output voltage could be relied upon to represent the signal magnitude.

For sinusoidal signals occurring at 0° and 180°, the mixer output voltage can be expressed as:

—

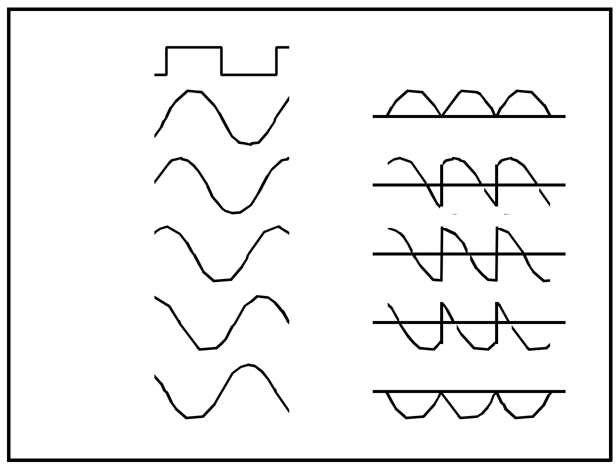

Figure 10 A mixer can be phase or amplitude sensitive.

As the signal phase rotates from 0° through 180°, the mixer output voltage changes from maximum positive through zero to maximum negative. Zero output voltage occurs at 90° and 270°, or what is termed quadrature. At quadrature, the mixer DC component is phase sensitive, magnitude insensitive and varies as cos(Θ). This characteristic is key to the phase insensitivity of the Pocket Lock-in and will be explored in the block diagram discussion.

One final point. So far the discussion has only considered clean sinusoid. What about noisy signals? Noisy signals are nonsynchronous with the reference frequency and only cause AC fluctuations in the mixer output. They cannot not produce a dc output like the synchronous signal does.

4.4 Apply low-pass filtering to remove the carrier frequency—which is twice the reference frequency—from the mixer output and to narrow the response bandwidth.

The low-pass filter averages all components of the mixer output having frequencies beyond the filter cutoff—the frequency at which the gain of the filter falls to 70.7% of, or to −3dB from, its maximum value.

In noise reduction applications, the equivalent noise bandwidth of the filter may be more meaningful. The noise bandwidth is not the same as the −3dB bandwidth, or cutoff frequency. The noise bandwidth is always greater than the cutoff frequency.

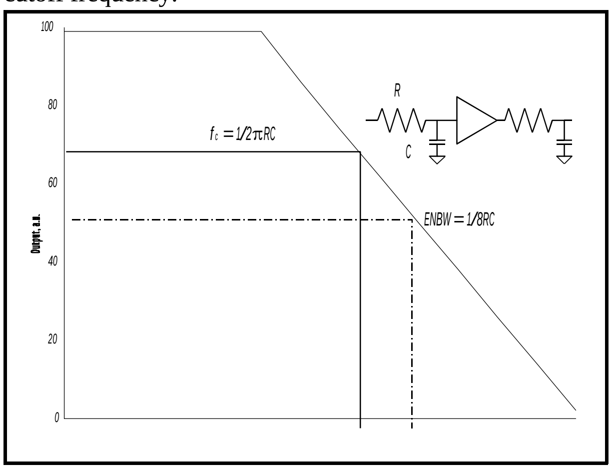

Figure 11 A second order low-pass filter.

Loosely speaking, the −3dB bandwidth is the frequency span between the half power points of the filter frequency response. While noise bandwidth is a theoretical, rectangular frequency response having a maximum gain equal to the filter frequency response and produces the same rms output noise as the actual filter. Refer to “Low Noise Electronic System Design,” by Motchenbacher and Connelly, 1993, John Wiley & Sons for a detailed explanation.

Figure 12 shows a model of the two pole filter used within the Pocket Lock-in. For the sake of discussion the model is of two cascaded single pole RC filters separated by a buffer amplifier. The filter is characterized by −12dB/octave filter gain roll off rate.

So what does this all mean? For the moment consider the lock-in as a frequency selective filter-amplifier whose performance is specified by its Q—the center frequency divided by the 3dB bandwidth. For example, let's say the reference frequency is 400Hz and the post mixer low-pass filter bandwidth is 1.59Hz. The yields a lock-in amplifier Q of approximately 250. That is very impressive considering how difficult it is to coax Qs greater than 100 out analog band-pass filter designs.

The phase insensitivity of the Pocket Lock-in comes from the fact that it has two mixers in the signal channel. One is used to detect the in-phase component of the input signal. The other detects the quadrature component and provides phase information.

Refer to the Pocket Lock-in block diagram of Figure 12. The phase circuits lock onto the applied reference frequency and synchronously drive the in-phase and quadrature channel mixers. The phase difference between the mixer drives is 90°. The signal to be measured is applied to both mixers.

The output of the quadrature mixer is integrated, amplified and fed back as an error signal to the phase control circuits. The phase circuits adjust the common mixer drive phase, ϕ, until the quadrature error signal has been reduced to zero. Remember from the mixer discussion and Figure 10 that signals at quadrature relative to the reference have an average value of zero. Therefore, once the phase has been adjusted so the quadrature signal is zero, and because of the 90° phase difference between the in-phase and quadrature channel, then the in-phase channel has produce a magnitude output.

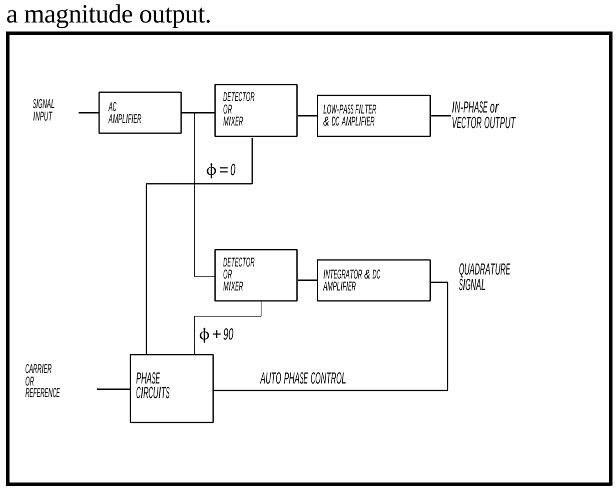

Figure 12 The Pocket Lock-in block diagram.

When the signal goes out of phase with the reference the quadrature channel output level moves away from zero. The phase circuits sense the non-zero value and finely adjust the overall mixer phase to restore zero.

The error signal merely indicates whether the signal phase leads or lags the reference. There is a finite limit to the value of the error signal. Once that limit is reached the phase circuits step the overall phase by 90° in the direction indicated by the error signal. The error signal then adjusts the quadrature channel to zero in the new quadrant.

5. HINTS AND TECHNIQUES

Take a few moments to acquaint yourself with the operation and signal response of the Pocket Lock-in before applying it to your signal recovery problems. At first, use clean signals from a common generator. Vary the amplitude and phase to learn how the Pocket Lock-in responds under various conditions. After you feel confident with its operation, then apply it to your experiment.

As you first begin using the Pocket Lock-in, you may experience problems. We summarized the most frequently asked questions and provided tips and techniques to help you make your measurement.

5.1 The output seems stuck at zero volts.

When the unit is first activated it may take a minute or so for the Pocket Lock-in to acquire the signal, adjust to the proper quadrant and present an output. At most, the lock-in will have to cross three quadrants to reach the correct one. Once locked, a single quadrant change typically does the trick.

The time taken to detect the need for a quadrant change and then make the change depends upon the frequency of operation. A single quadrant change will require about 20 seconds for frequencies at the low end of a reference frequency range. At the high end, 2 seconds. During that time the output may be in transition and invalid.

Assume the 20Hz-200Hz range is selected. The reference frequency is 200Hz—at the top of the range. A quadrant change will take two seconds. That same 200Hz reference at the bottom of the 200Hz-2KHz range would result in a 20 second long quadrant change. Within a range, the time is proportional to reference frequency.

Check that the reference signal is present and that the range selection switch is set for the proper range.

Try increasing the output expand. If that doesn't work, then return it to its original position and increase the input sensitivity. Then try increasing the output expand once more.

Be sure the input is configured correctly for the signal type of interest.

5.2 The measured signal abruptly changed phase by 180°, the lock-in output polarity changed as expected. It has been minutes and the lock-in has yet to adjust to the new phase situation.

Luckily, sudden polarity inversions in real life measurements are rare occurrences. However, in exploratory operations with the Pocket Lock-in, some users invert the input signal polarity because it is a natural and easy thing to do with most signal generators. Unfortunately, that is the toughest phase situation for the Pocket Lock-in to figure out. Here's why. The Pocket Lock-in integrates the quadrature component and adjusts its internal phase relative to the signal so that the integral is zero. Changing the signal phase by exactly 180° results in the same zero integral value. The Pocket Lock-in cannot immediately detect that the phase has inverted. The quickest way to recover from this condition is to slightly offset the frequency of operation, restore the original signal phase or cycle power to the unit.

The perceptive reader will immediately recognize and suggest that the output polarity can be monitored and used as a factor in phase control. This is true, however, because of time and phase delays in the output relative to the internal workings of the lock-in, such a feedback control loop could only be conditionally stable—an unacceptable arrangement for a general purpose instrument.

5.3 The output periodically changes from a negative level to zero to positive to zero and back to negative again.

The Pocket Lock-in is trying to acquire the signal by switching quadrants. The dwell time in each quadrant is determined by the reference frequency and its relation to the reference frequency range. See 5.1, above. For low level signals it may take several complete rotations through the quadrants to acquire phase lock. Once locked, minor phase changes will be tracked satisfactorily.

To insure phase lock upon start up, the input signal should be no less than 1% of the full scale sensitivity—that is 10μV for the 1mV Sensitivity setting and 1mV for the 100mV.

5.4 The output voltage is stuck around ±6 volts.

Either the input signal is too large for the input sensitivity selected or the output expand is set too high. Decrease either or both until the signal drops into range. If that doesn't do it, then reduce the signal amplitude, itself. Then wait for the Pocket Lock-in to recover and acquire the signal.

While the full scale output of the Pocket Lock-in is ±1 volt, there is an additional 4 volts of output dynamic range. Therefore, outputs of up to ±5 volts may be reliably measured. Six volts is the absolute maximum sustainable by the output amplifier.

Be sure the input is configured correctly.

5.5 The Pocket Lock-in signal input is connected to an experiment. The reference is applied, but the signal has not yet been enabled. The lock-in output is showing a large offset. The offset bounces around.

Decrease the input sensitivity—double check the output expand setting. If the offset disappears, then noise was overloading the Pocket Lock-in.

While much attention is usually given to setting the input sensitivity range correctly for the input signal, the effect of noise can sometimes be overlooked. After all, a lock-in is supposed to recover signals obscured by noise. Such thinking can lead to sloppy signal preparation and conditioning.

The Pocket Lock-in mixer can accommodate signals up to 4 times full scale input before nonlinearities occur. The onset of those nonlinearities is called the input overload level. Any input signal equal to, or greater than, the input overload level will cause unreliable results.

The Pocket Lock-in works best when the noise to signal ratio is 10:1, or less. By the way, routine experiments have 5:1, or so, noise to signal ratios.

As a starting point, arrange for the signal to be about 10% of the input sensitivity and set the output expand to x10. Lock-in manufacturers define this arrangement of settings as high dynamic reserve operation because it provides enough room between the anticipated noise level—of say, 5 to 10 times signal—and the input overload level of 4 times full scale. Then use the output expand to keep the output signal within the output dynamic range.

6. LIMITED WARRANTY

This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

ElectroSolutions Incorporated warrants each instrument of its own manufacture to be free of defects in material and workmanship. Obligations under this Warranty shall be limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned, shipment prepaid, to ElectroSolutions Incorporated, for that purpose within ninety (90) days of delivery to the original purchaser, provided prior authorization for such return has been given by an authorized representative of ElectroSolutions Incorporated.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control. This Warranty shall not apply to any instrument or component not manufactured by ElectroSolutions Incorporated. When products manufactured by others are included in ElectroSolutions Incorporated equipment, the original manufacturer's warranty, if any, is extended to ElectroSolutions Incorporated customers.

ElectroSolutions Incorporated reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

There are no warranties which extend beyond the description on the face hereof. This warranty is in lieu of, and excludes any and all other warranties or representations, expressed, implied or statutory, including merchantability and fitness, as well as any and all other obligations or liabilities of ElectroSolutions Incorporated, including, but not limited to, special or consequential damages. No person, firm or corporation is authorized to assume for ElectroSolutions Incorporated any additional obligation or liability not expressly provided for herein except in writing duly executed by an officer of ElectroSolutions Incorporated.

7. SHOULD YOUR EQUIPMENT REQUIRE SERVICE

Contact ElectroSolutions, Inc (Phone: 908/788-8445; FAX 908/788-7521) to discuss the problem. If it is necessary to send the equipment back to ElectroSolutions, we need the following information:

(1) Model and serial number.

(2) Your name, the instrument user.

(3) Your address.

(4) Address to which the instrument should be returned.

(5) Your telephone number and extension.

(6) Symptoms (in detail including control settings).

(7) Your purchase order number for repair charges.

(8) Shipping instructions (if you wish to authorize shipment by any other method than normal surface transportation.

(9) Ship the equipment being returned to:

ElectroSolutions, Inc.
160 Voorhees Corner Road
Flemington, NJ 08822

Visit www.electrosolutions-usa.com for the lates FAQs on this and our other products.

APPENDIX A

CONFIGURING THE INPUT BUFFER

Because of the wide range of input signal sources, the Pocket Lock-in input circuitry has been designed to accommodate a number of useful amplifier topologies. While not meant to substitute for outboard preamplifier modules, these configurations are useful, nonetheless, when something is needed on a temporary or short notice basis.

Figure A-1 shows how a current sensitive, or transimpedance, and standard input amplifier configurations can be created by simply repositioning the jumpers on the header matrix.

To configure the third, non-inverting gain, configuration requires the addition of a wire jumper. For that you will need a low wattage soldering iron, small gauge electronic grade solder, and a short length of small gauge solid insulated wire.

Before opening the unit, remove all signal sources and cables from the Pocket Lock-in. Remove the power cable from the unit. Locate the front panel. The Signal Input protrudes through the front panel.

To gain access to the printed circuit board, remove the four long screws holding the front panel in place. Set aside the screws and front panel.

ALERT! The printed circuit board (PCB) is permanently attached to the extruded case by a short grounding wire. Therefore, the PCB cannot be entirely extended out of the case. Do not try to force the board out of the case or the protective ground wire may break. **WARNING!** A broken ground wire may make the equipment dangerous to use.

While looking at the label on the top of the case, hold the unit with its rear panel closest to you. This puts the Signal Input furthest away. Carefully slide the printed circuit board (PCB) part way—about 2 inches—out of the case.

You should now see the component side of the PCB. Locate the Signal Input BNC. Look the right of the Signal Input BNC and locate the jumper matrix pad.

Refer to Figure A-1 for the circuit you wish to configure and make the required jumper changes. To avoid confusion it is best to remove all the existing jumpers before installing the new ones. **WARNING! Incorrect jumper settings or solder bridges, i.e. unwanted shorts, may cause damage to the Pocket Lock-in or to equipment connected to the Signal Input. Such damage is not covered by the Warranty.**

After making the appropriate jumper and/or wiring change reassemble the unit by carefully sliding the PCB back into the extruded housing. Reattach the front panel with the four panel mounting screws. Carefully engage the screw threads with the extrusion. Do not over tighten. Cross threading and stripping of threads can occur very easily.

Once the unit is completely assembled, reconnect all cables and apply power. You may want to test the new configuration by following the steps outlined in Initial Checks. Note, however, that the procedure is written for high impedance operation. You will have to make the proper signal substitution to match the configuration you selected.

APPENDIX B

MODIFYING THE POST MIXER CUTOFF FREQUENCY

A second order, -12dB per octave, low-pass filter has been implemented within the Pocket Lock-in for the purpose of smoothing the full wave rectified output of the mixer. The filter, a common single operational amplifier circuit known as a Sallen-Key second order filter was chosen because it is convenient to use and can easily be changed to a Bessel, Butterworth or Chebyshev response by simply adjusting resistor and capacitor values. The Pocket Lock-in uses a Butterworth response filter.

There many design methods for calculating the appropriate circuit values. For more information refer to "Rapid Practical Designs of Active Filters," by Johnson and Hilburn, 1975, John Wiley & Sons, and Chapter 10 of "Handbook of Operational Amplifier Circuit Design," by Stout and Kaufman, 1976, McGraw-Hill, Inc. These applications oriented books provide shortcut methods to filter design and, for the most part, avoid filter theory.

Page B-2 presents a method for computing the second order low-pass filter cutoff frequency. In this method the resistor values equal each other and the capacitors have a 2:1 ratio in value.

For applications incorporating the Pocket Lock-in within a feedback control loop, a single pole, or -6dB per octave, low-pass filter is recommended to give the best overall loop stability. The circuit and design procedure is shown on page B-3.

APPENDIX C
SCHEMATICS