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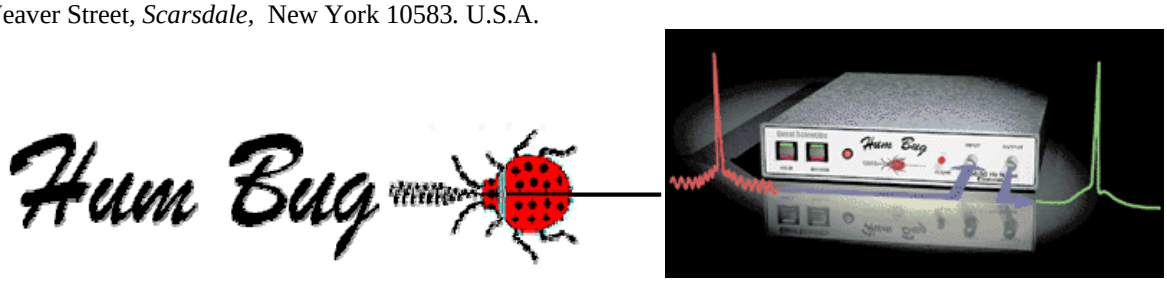


50/60 Hz Noise Eliminator

ELIMINATE 50/60 Hz NOISE AND HARMONICS WITHOUT FILTERING!

A New Solution

Quest is proud to introduce the Hum Bug -- a new approach to Noise Control. This is a powerful new technology for cancelling electrical interference in real-time, avoiding all of the traditional problems associated with notch filters. The Hum Bug constructs a replica of noise present on the input signal and continuously subtracts this replica from the signal as it passes through the instrument. It performs this function in the presence of biological activity even when noise characteristics evolve over time.

Advantages

The Hum Bug is not a filter. It does not create phase delays, amplitude errors, DC shifts or waveform distortion. Simply connect it betweenyour preamplifier and any analysis equiment and it will automatically eliminate 50/60 Hz noise and harmonics with frequencies up to several kHz. Noise is eliminated without altering the signal of interest even when frequencies within the signal overlap with noise components. No settings or adjustments are required.

Eliminates Electrical Interference

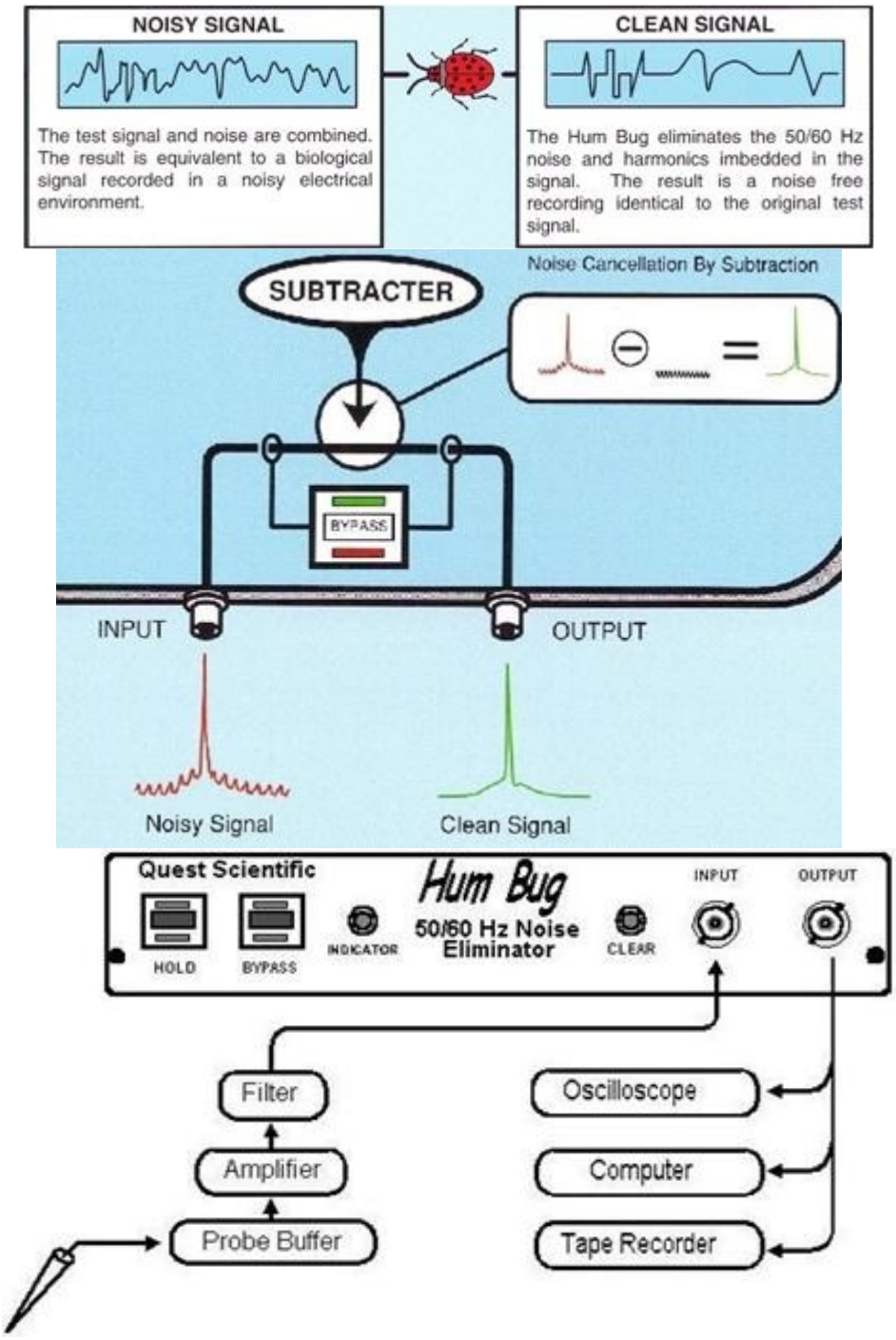
- Simple 50/60 Hz Sine Waves
- Mixtures of 50/60 Hz Harmonics
- Noise Spikes from Dimmers
- Complex Noise from Flourescent Lamps

No Waveform Distortion

- No Frequency Loss
- No DC Voltage Shift
- No Signal Attenuation
- No Phase Error

35 Weaver Street, *Scarsdale*, New York 10583. U.S.A.

HumBug Noise Eliminator



一款非常好用的电噪音消除装置，能很好地搭配膜片钳等电生理记录设备使用

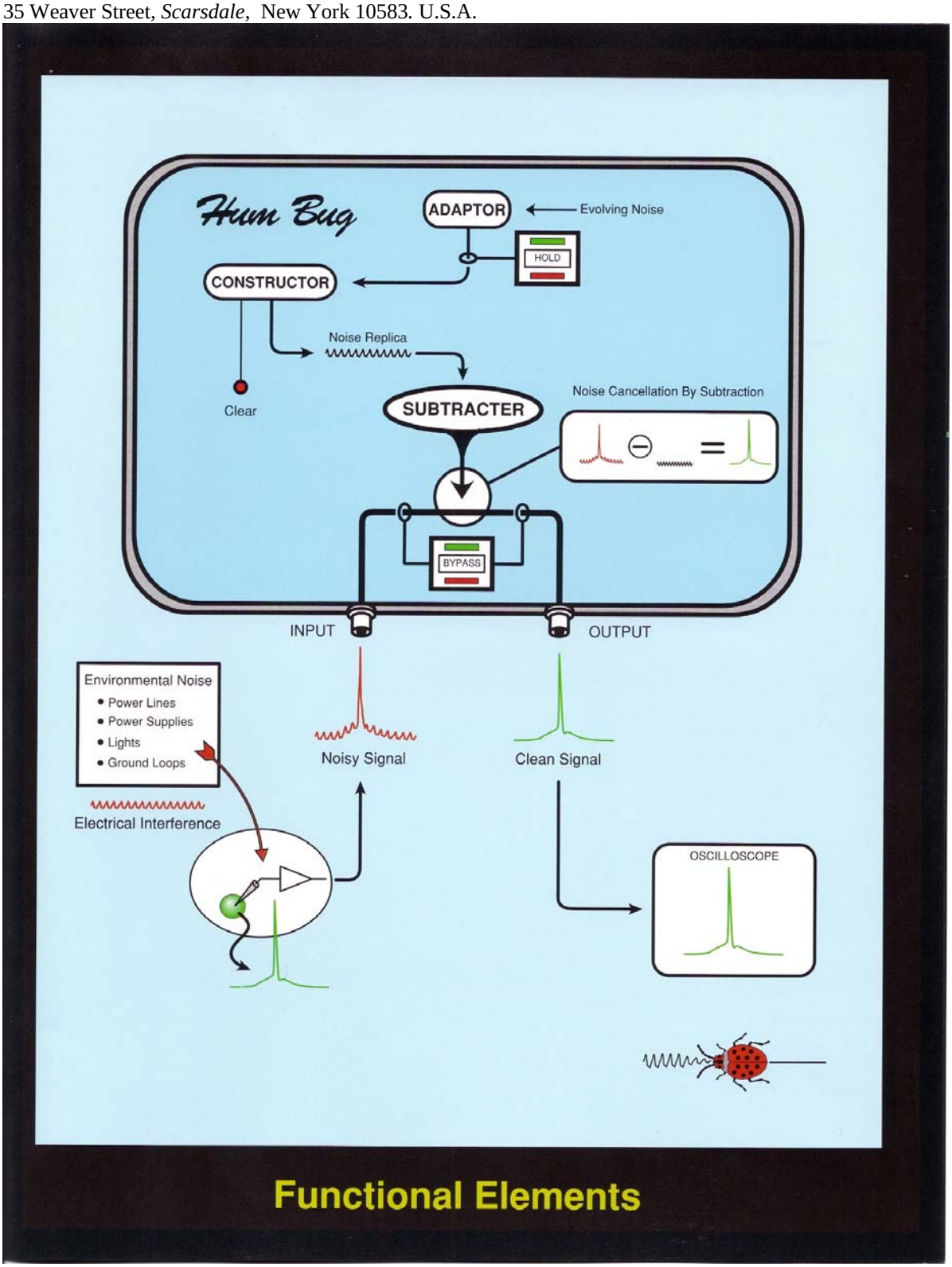
Hum Bug 采用能够根据环境电噪音实时产生反相的电噪音，从而抵消环境噪音对输入信号的干扰，整个除噪过程无需滤波。

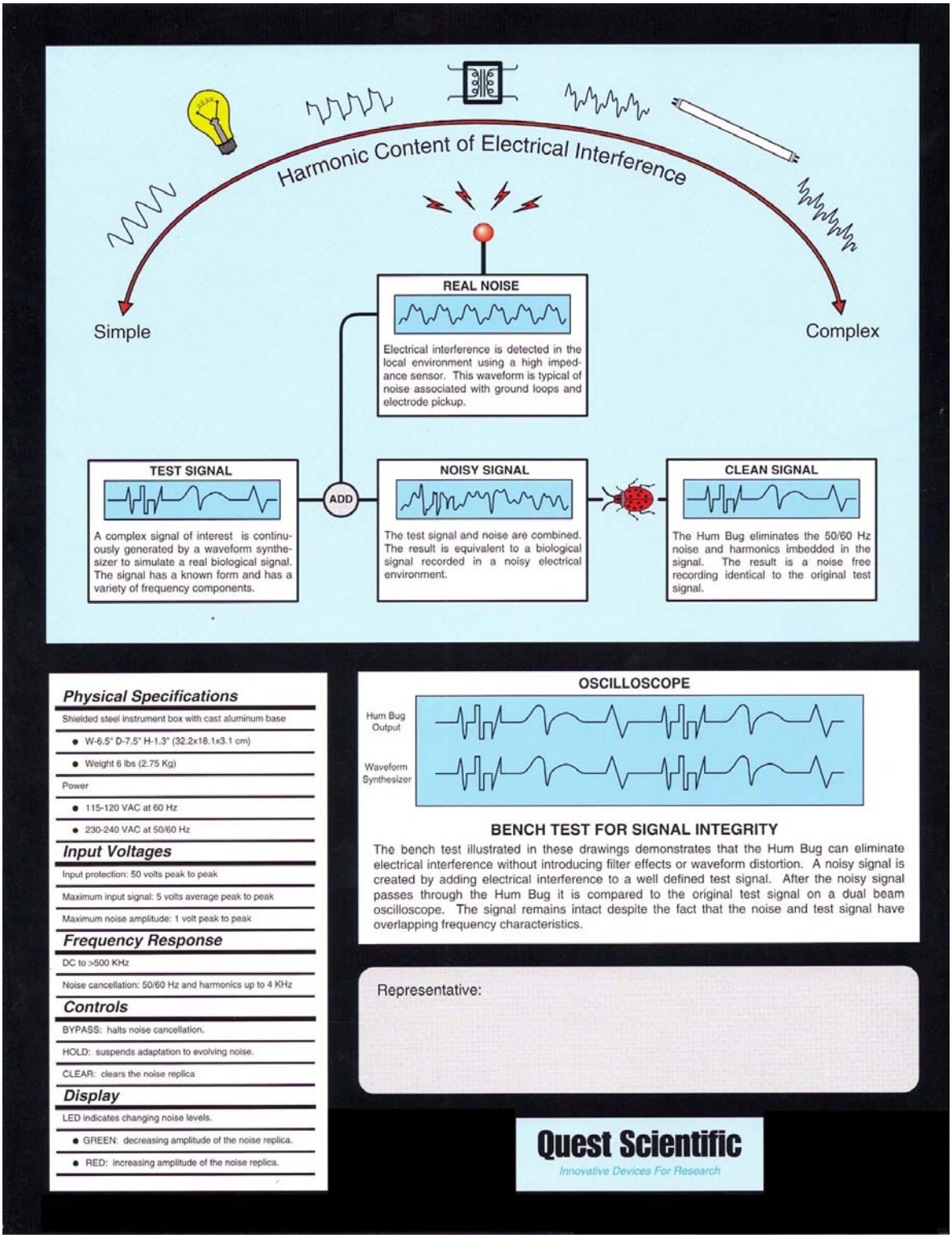
可以消除各种电噪音：

*** 简单的 50/60Hz 正弦波形噪音**
*** 50/60Hz 谐波混合噪音**
*** 调光器 Spike 噪音**
*** 荧光灯产生的复杂电噪音**

不会对信号的波形产生任何影响：

*** 没有频率损失**
*** 没有直流电压漂移**
*** 没有信号衰减**
*** 没有相位错误**


Hum Bug
ADAPTOR
Evolving Noise
HOLD
CONSTRUCTOR
Noise Replica
Clear
SUBTRACTER
Noise Cancellation By Subtraction
BYPASS
INPUT
OUTPUT
Environmental Noise
• Power Lines
• Power Supplies
• Lights
• Ground Loops
Electrical Interference
Noisy Signal
Clean Signal
OSCILLOSCOPE
Functional Elements


Harmonic Content of Electrical Interference
Simple
Complex
REAL NOISE
Electrical interference is detected in the local environment using a high impedance sensor. This waveform is typical of noise associated with ground loops and electrode pickup.
TEST SIGNAL
A complex signal of interest is continuously generated by a waveform synthesizer to simulate a real biological signal. The signal has a known form and has a variety of frequency components.
ADD
NOISY SIGNAL
The test signal and noise are combined. The result is equivalent to a biological signal recorded in a noisy electrical environment.
CLEAN SIGNAL
The Hum Bug eliminates the 50/60 Hz noise and harmonics imbedded in the signal. The result is a noise free recording identical to the original test signal.
Physical Specifications
Shielded steel instrument box with cast aluminum base
W-6.5" D-7.5" H-1.3" (32.2x18.1x3.1 cm)
Weight 6 lbs (2.75 Kg)
Power
115-120 VAC at 60 Hz
230-240 VAC at 50/60 Hz
Input Voltages
Input protection: 50 volts peak to peak
Maximum input signal: 5 volts average peak to peak
Maximum noise amplitude: 1 volt peak to peak
Frequency Response
DC to >500 KHz
Noise cancellation: 50/60 Hz and harmonics up to 4 KHz
Controls
BYPASS: halts noise cancellation.
HOLD: suspends adaptation to evolving noise.
CLEAR: clears the noise replica
Display
LED indicates changing noise levels.
GREEN: decreasing amplitude of the noise replica.
RED: increasing amplitude of the noise replica.
OSCILLOSCOPE
Hum Bug Output
Waveform Synthesizer
BENCH TEST FOR SIGNAL INTEGRITY
The bench test illustrated in these drawings demonstrates that the Hum Bug can eliminate electrical interference without introducing filter effects or waveform distortion. A noisy signal is created by adding electrical interference to a well defined test signal. After the noisy signal passes through the Hum Bug it is compared to the original test signal on a dual beam oscilloscope. The signal remains intact despite the fact that the noise and test signal have overlapping frequency characteristics.
Representative:
Quest Scientific
Innovative Devices For Research

美国健康医疗仪器国际公司
American Health & Medical Supply International Corp.
35 Weaver Street, *Scarsdale*, New York 10583. U.S.A.

PERFORMANCE AND SIMPLICITY

PROBLEM: Signals recorded using biological sensors and other high impedance devices are often contaminated with 50/60* Hz noise and harmonics originating from power supplies, power mains and lights. The presence of noise corrupts the information content of these signals and can degrade the quality of subsequent data analysis. This electrical interference is notoriously difficult to remove without altering the original signal imbedded within the noise.

In theory, proper attention to grounding and appropriate shielding can eliminate electrical interference. In practice, noise remains a frequent and distressing problem in the daily operation of many laboratories. Even with diligent attention to details, noise may come and go for no apparent reason and may appear during critical phases of data collection. The effort required to maintain noise at an acceptable level is both time consuming and frustrating. The Hum Bug solves these problems.

TRADITIONAL APPROACH: Faraday cages decrease the magnitude of environmental noise sources but this protection is often incomplete and working within a cage can be cumbersome. Notch or comb filters are occasionally used to suppress 50/60 Hz noise and harmonics but these filters will distort the input waveform if frequency components of the signal overlap with the filtered frequencies.

NEW SOLUTION: Quest Scientific has developed a powerful new technique to eliminate 50/60 Hz noise and harmonics from analogue signals without filtering. The Hum Bug constructs a noise replica in real time and continuously subtracts this replica from the input signal. It performs this function in the presence of biological activity even when noise characteristics evolve over time.

ADVANTAGES: The Hum Bug is not a filter. It does not create phase delays, amplitude errors, DC shifts or waveform distortion. It effectively eliminates 50/60 Hz noise and harmonics without altering the frequency characteristics of the input signal even when these frequencies overlap with noise components.

SIMPLICITY: The Hum Bug is a real-time device. Simply connect it between your preamplifier and any analysis or recording equipment (oscilloscope etc.). It will automatically eliminate electrical interference while it lets the signal of interest pass through unchanged. No settings or adjustments are required. The front panel switches are only used if you wish to bypass cancellation (BYPASS), stop the adaptation process (HOLD), or clear the noise replica (CLEAR).

TECHNICAL OVERVIEW

THEORY OF OPERATION: Principle operations of the Hum Bug are illustrated on the right. All functions occur in parallel as the signal passes in a direct analogue path between the input and output. The key innovation developed by Quest Scientific is the ability to effectively isolate noise from an input signal even when noise characteristics are evolving and the frequency components of the noise and input signal overlap.

FREQUENCY RESPONSE: Biological signals pass through the Hum Bug unchanged for frequency components in the range of DC to greater than 500 KHz.

COMPLEX NOISE: Electrical interference often generates a mixture of harmonics at multiples of 50/60 Hz (e.g. 120 Hz, 180 Hz, 240 Hz). The Hum Bug eliminates all harmonics with frequencies up to several KHz. Therefore, even the complex spikes generated by dimmers and fluorescent lamps are eliminated.

APPLICATIONS: The Hum Bug can eliminate 50/60 Hz noise from virtually any analogue signal. It is equally effective at removing noise associated with inadequate grounding, ground loops, and electrical pick up. Common applications include noise elimination from signals recorded using microelectrodes, skin electrodes (EKG, EMG, EEG), high gain amplifiers, magnetic sensors and audio equipment.

*60 Hz in North America, 50 Hz in Europe and many countries outside of North America.

TRADITIONAL CONCERNS:

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Shielded steel instrument box with cast aluminum base
• W-6.5“ D-7.5" H-1.3" (32,2 x 18.1 x 3.1 cm)
• Weight 6 lbs (2.75 Kg)
Input Voltages
• Input protection: 50 volts peak to peak
• Maximum input signal: 5 volts average peak to peak
• Maximum noise amplitude: 1 volt peak to peak
• Power Supply: 120V and 240V available
Frequency Response
• Noise cancellation: 50/60 Hz and harmonics up to 4 kHz
Controls
• BYPASS: halts noise cancellation
• HOLD: suspends adaptation to evolving noise
• CLEAR: clears the noise replica
Display
• LED indicates changing noise levels
• GREEN: decreasing amplitude of the noise replica
• RED: increasing amplitude of the noise replica

Introducing an exciting new productivity tool from Quest Scientific. The 'HumBug' Line Noise Eliminator removes line frequency noise from electrophysiological signals, without filtering. It removes noise from a wide range of signal levels, continuously, and without intervention. That adds up to more time getting results, and less time solving continuously evolving noise problems.

The HumBug was developed in the laboratories of Tom Richardson MD., PhD, as a way to remove residual line noise picked up by glass electrodes in brain slice preparations. Quest scientific now offers the same technology in a precision laboratory instrument.

ELIMINATES ELECTRICAL INTERFERENCE
• Simple 50/60 Hz Sine Waves

• Mixtures of 50/60 Hz Harmonics
• Noise Spikes From Dimmers
• Complex Noise From Fluorescent Lamps

NO WAVEFORM DISTORTION
• No Frequency Loss
• No DC Voltage shift
• No Signal Attenuation
• No Phase Error

Although the HumBug uses a powerful signal processor, your signal is never digitized. Your signal will not suffer frequency loss, phase error, DC shift, or digitization. The HumBug continuously constructs a replica of evolving noise present on the input signal and subtracts this replica from the signal, leaving the physiological signal intact. It performs this function in the presence of biological activity even when noise characteristics evolve over time.

The HumBug is not a filter, and does not create phase delays, amplitude errors, DC shifts or waveform distortion. Simply connect it between your preamplifier and any analysis equipment and it will automatically eliminate 50/60 Hz. noise and harmonics with frequencies up to several KHz. Noise is eliminated without altering the signal of interest even when frequencies within the signal overlap with noise components. No settings or adjustments are required.

The HumBug is effective at removing noise associated with inadequate grounding, ground loops, and electrical pick up. Common applications include noise elimination from signals using microelectrodes, skin electrodes (EKG, EMG, EEG), high gain amplifiers, magnetic sensors and audio equipment.

HUM BUG
REFERENCE MANUAL

CONTENTS

INTRODUCTION

This manual describes the operation, connections and normal use of the Hum Bug in the neurosciences and related fields of research. The original Hum Bug was developed in the electrophysiology laboratory of Dr. Tom Richardson in response to problems with electrical interference during intracellular studies. In theory, proper attention to grounding and appropriate shielding can eliminate 50/60 Hz noise induced by electrical wiring, power supplies, and lights. In practice, this noise remains a frequent and distressing problem in the daily operation of many electrophysiology laboratories. Even with diligent attention to detail, noise may come and go for no apparent reason and may appear during critical phases of data collection. The effort required to maintain noise at an acceptable level is time consuming and frustrating.

Notch or Comb filters are sometimes used to attenuate 50/60 Hz noise and related harmonics. Unfortunately, the composition of many biological signals includes these frequencies.

As a result, critical components of the signal are filtered along with the noise. This distortion and loss of information is usually unacceptable for scientific investigation.

The Hum Bug is a simple and hassle free solution to these problems. It will eliminate electrical interference from physiological recordings without altering your signal of interest.

Simply insert it into the signal path of your recording system and it will automatically eliminate noise without any need for adjustment.

The Hum Bug is not a filter. It is a new class of instrument capable of eliminating electrical interference from analogue signals without creating phase shifts, frequency loss, amplitude errors, DC shifts, time delays, or digital distortion. It effectively eliminates 50/60 Hz noise and harmonics without altering the frequency characteristics of the desired signal even when frequencies within the signal overlap with noise components. It uses an advanced signal processing circuit to continuously construct a replica of noise present on the input and to subtract this replica from the original signal. The end result is a clean signal which is free from distortion. It performs this function in the presence of biological activity even when the shape, amplitude, and harmonic content of the noise evolves over time.

The Hum Bug can eliminate 50/60 Hz noise from virtually any analogue signal. It is equally effective at removing noise associated with inadequate grounding, ground loops, and electrical pickup. Common applications include noise elimination from signals recorded using microelectrodes, skin electrodes (EKG, EMG, EEG), high gain amplifiers, magnetic sensors, and audio equipment.

THEORY OF OPERATION

This section reviews the basic internal operations of the Hum Bug. This knowledge will help you become familiar with the front panel controls and the operating characteristics of the device.

A noisy analogue waveform is the summation of two separate components. One component is the biological signal of interest and the other is noise of various forms. These forms of noise include: A) random fluctuations generated by the sensor, amplifier and background biological activity, and B) electrical interference generated by electrical wiring and instruments in the vicinity of an experimental setup. The Hum Bug is designed to cancel electrical interference. It constructs a replica of noise imbedded within the input signal and subtracts this replica from the noisy signal as it passes through the device. The end result is an output which consists of the input minus its noise content. Therefore, the output contains only the original signal of interest.

The figure on the facing page illustrates the internal operations of the Hum Bug. Three processes occur in parallel. These include: 1) adaptation to evolving noise levels on the input signal (ADAPTOR), 2) construction of a noise replica (CONSTRUCTOR), and 3) subtraction of the replica from the input signal (SUBTRACTER). The continuous operation of these processes results in effective noise cancellation even when the amplitude, frequency content, and phase characteristics of the noise are changing. The time constant for adaptation is 5 to 10 seconds under ideal conditions but is slower when low amplitude noise is dominated by ongoing physiological activity and/or noise harmonics are greater than 1 kHz. Therefore, the noise replica may lag behind if the noise characteristics suddenly change. Under these conditions, some noise will transiently appear on the output while the Hum Bug adapts to the new characteristics.

The major advantage of this method of noise elimination is the fact that the input signal is never directly filtered. In fact, the signal of interest passes through the Hum Bug without any form of waveform distortion or processing artifact. Since the Hum Bug takes several seconds to adapt to a particular pattern of electrical interference, physiological activity passes through the device with little or no effect on the noise replica. Even if the noise replica does get disturbed, the cancellation procedure will not distort the signal of interest. The only result will be a failure to completely cancel the electrical interference.

The controls on the front panel allow you to interrupt the normal operation of the Hum Bug. When the Hold Key is activated the ADAPTOR halts and the CONSTRUCTOR does not

update the noise replica. Noise cancellation continues but the Hum Bug will not adapt if the input noise changes. Activation of the Bypass Key halts the SUBTRACTER. Noise is not
eliminated and the input signal simply passes directly from the input to the output. Depressing the Clear Button resets the noise replica to a flat line. The LED Indicator flashes when
the noise replica is changing. It flashes red when the replica is growing and green when it is shrinking. When the LED is not flashing the noise replica is stable or undergoing small
adjustments.

INSTALLATION

The Hum Bug can be immediately put to use by inserting it into your recording system as illustrated in the diagram below. Input and output connectors are located on the front panel
and the power switch is on the back of the unit. Insert the Hum Bug at any point in the chain of instruments after the signal from your electrode or sensor is buffered and before
the signal is connected to your oscilloscope, computer, and/or tape recorder. The ideal location is after the signal is fully amplified and any filtering is complete. This location will
maximize the amplitude of signals passing through the Hum Bug and will ensure that any electrical interference accumulated along the signal path will be eliminated.

Turn on the Hum Bug and confirm that the green LED on the Bypass Switch is illuminated. If not, press the Bypass Switch to toggle the indicator from red to green. Now ensure that
the indicator on the Hold Switch is also green. The Hum Bug is now in normal operating mode.
During your initial evaluation of the Hum Bug it is a good idea to turn off any computer monitors in the vicinity of your recording setup. This will eliminate possible confusion between
50/60 Hz noise and any additional interference associated with your monitors. See the section on monitor noise for more details.
After an initial warm up period of approximately thirty seconds the Hum Bug will be fully operational. It will then start adapting to whatever level of electrical interference happens to
be present in the input signal. As adaptation proceeds, noise in the output signal will gradually decrease to minimal levels. During this period the LED Indicator on the front panel will
flash red to indicate that the noise replica is growing. As noise cancellation approaches completion the rate of flashing will slow down and stop.
If the characteristics of noise in the input signal are not constant you may notice that the LED Indicator occasionally flashes. This indicates that the noise replica is either growing
(red) or shrinking (green) as the Hum Bug adapts to these changing conditions. On other occasions the LED may remain solid green. This indicates that little or no electrical
interference is present in the input signal. The LED will also alert you if the noise amplitude grows beyond the 1 volt upper limit for cancellation. Under these conditions the LED will
continue to flash red indefinitely and some noise will remain in the output signal.

CONTROLS

All operations of the Hum Bug are automatic and no adjustments or settings are required. However, on occasion you may wish to observe your signal without noise cancellation. If
so, depress the Bypass Switch to toggle from normal to bypass mode. The red LED on the switch should illuminate. When bypass is in effect, noise cancellation is temporarily
suspended and the input signal is passed directly to the output. Toggling bypass mode on and off is a good way to quickly determine how much noise the Hum Bug is eliminating.
On other occasions you may want the Hum Bug to continue noise cancellation at the present level without adapting to new or changing levels of noise. If so, depress the Hold
Switch to toggle from normal to hold mode. When the red LED on this switch is illuminated the Hum Bug continues to cancel noise but ignores any changes in the noise
characteristics. This switch is useful if you know that something you are about to do will cause a transient change in noise characteristics (e.g. touching a micromanipulator) and
you don't want to disturb the present level of noise cancellation.
The Clear Button is the only other control function on the front panel. Pushing it will clear the noise replica and force the Hum Bug to generate a new noise replica from scratch. In
effect, this causes the Hum Bug to immediately forget the noise waveform. This function is seldom necessary since the Hum Bug automatically adapts to changing noise conditions.

INPUT SIGNAL

The Hum Bug will operate on analogue signals originating from virtually any laboratory equipment including amplifiers, filters, and other signal conditioning instruments. It
automatically adjusts to signals over a wide range of amplitudes and has no special requirements for impedance matching. Even so, following the guidelines given below will help
optimize operation of the Hum Bug.

Signal Levels: Ideally, the relevant events present in the input signal (population spikes, single units, channel activity, etc.) should have

an amplitude greater than 100 mV at the
input to the Hum Bug, although amplitudes as low as 25 mV are acceptable. In many electrophysiological applications the amplitude of signals arising from the initial instrument
connected to a sensor or electrode may fall below this limit. Although the Hum Bug will eliminate noise from these small signals, adaptation will proceed more slowly. In extreme
cases the amplitude of physiological events may approach the noise floor of the Hum Bug. Therefore you should insert the Hum Bug into the signal path after the signal is fully
amplified.
It is also important to confirm that the amplitude of the input signal is not too large. Although signals as large as 50 volts will pass through the Hum Bug, the procedure used to adapt
to changing noise levels only operates while the signal is below 5 volts peak-to-peak. Although occasional excursions beyond this limit are acceptable, adaptation rates will be
optimal if the average level of the input signal remains within the 5 volt limit.

Noise Levels: The previous discussion views the input signal with respect to events of interest. The Hum Bug actually focuses on the noise imbedded in the signal. Therefore the
amplitude of noise in the input signal also has important implications. These are outlined below.
The Hum Bug will cancel 50/60 Hz noise with amplitudes up to 1 volt peak-to-peak. If the amplitude of noise in the input signal is greater than this limit, then some noise will remain in
the output signal. Under these conditions the LED Indicator will continue to flash red indefinitely as the Hum Bug attempts, unsuccessfully, to increase the amplitude of its noise
replica above the 1 volt limit.
The lower limit for noise cancellation is less well defined. The Hum Bug will effectively eliminate noise with amplitudes as small as a few mV. However, the adaptation rate to
evolving noise is slightly reduced when the noise amplitude is less than 15 mV and the rate is further reduced when the amplitude falls below 5 mV.

Frequency Response: Physiological activity with frequencies in the range of DC to greater than 500 kHz passes through the Hum Bug unchanged while 50/60 Hz noise and all
harmonics up to 4 kHz are eliminated.
NOISE GENERATED BY COMPUTER MONITORS
Monitors can generate two forms of electrical interference. One is generated by the power supply and related circuitry. The frequency of this interference is the same as the
power mains so it will be eliminated by the Hum Bug. The second form of interference, referred to as refresh noise, is generated each time a monitor refreshes the image displayed
on its screen. The frequency of this interference will depend on the video mode assigned to the monitor. In most cases it will differ from the power mains and will not be
recognized as noise by the Hum Bug. Fortunately, following the guidelines outlined below will help eliminate this form of electrical interference.

Monitor Placement: The electric field generated by a monitor during screen refresh emanates directly from the screen and quickly dissipates with distance. Therefore, the easiest
way to minimize refresh noise is to move all monitors as far away as possible and to make sure that their screens don't face your experimental setup. However, keep in mind that a
person standing or sitting in front of a monitor can distort the electric field emanating from its screen. As a result, even a monitor which is facing away from an experimental setup
may generate varying levels of noise when someone is working nearby. The only way to be sure that a given monitor is in a safe location is through careful evaluation under
actual working conditions.

Screen Grounding: If it is not practical to move your monitor to a safe location you can eliminate refresh noise by shielding the screen. This is done by placing a grounded cover
over the glass of the display. These shields are constructed from a piece of anti-glare glass with an electrically conductive coating. A wire is provided to connect the conductive
coating to ground. These screens are very effective protection against refresh noise and are relatively inexpensive (<$100). Most computer and office supply outlets keep them in
stock.
SOURCES OF COMPLEX NOISE
Fluorescent lamps, dimmers and related noise sources can induce very narrow spikes of interference which repeat at some multiple of 60 Hz (or 50 Hz). Under worse case
conditions the frequency components within these spikes can approach the upper limit of your signal conditioning filters.
The Hum Bug will eliminate spikes with frequency components up to 4 kHz. If you routinely set the upper limit of your signal conditioning filters to a value greater than this limit, you
may occasionally find that high frequency noise components are not fully eliminated. If so, try adjusting your signal conditioning filter to a lower setting. This will remove some of the
highest frequency harmonics so that the remaining noise can be eliminated by the Hum Bug. Whether this trade off between noise elimination and frequency response is

acceptable will depend on your application. Feel free to consult Quest Scientific for more information.

ADAPTATION RATE

The Hum Bug adapts to changing noise characteristics in the input signal. Under normal conditions these characteristics evolve slowly and the Hum Bug is able to maintain effective
noise elimination. However, noise will appear in the output signal following a sudden change in noise characteristics. This output noise will then decay with a time constant related
to the adaptation rate of the Hum Bug. Under ideal conditions this time constant is in the order of 5 to 10 seconds. In practice, the exact time constant is difficult to predict because it
depends on the change in noise amplitude, the harmonic content of the noise, and the magnitude of the noise relative to ongoing physiological activity. The Hum Bug adapts rapidly
when the input signal is dominated by noise and proceeds more slowly when low amplitude noise is imbedded within continuous physiological activity. Adaptation is also slower
for harmonics with frequencies greater than 1 kHz.

FRONT PANEL*

BACK PANEL

TROUBLE SHOOTING

The Hum Bug is very reliable and should give you years of trouble free service. However, on occasion you may encounter a problem. In some cases the problem may be based on
a simple misunderstanding about the operation of the device and in others, the Hum Bug may need repair. The following procedures will help you solve any problems as quickly as
possible.

Initial Evaluation: A good way to start trouble shooting is to systematically evaluate the operation of your Hum Bug under test conditions. The following procedures are designed to
exercise all of its important functions. Compare the operation of your unit to the expected behavior described for each procedure.

Step One: Set up your equipment in a manner similar to the illustration shown below. The objective is to simultaneously view the input and output of the Hum Bug on different
channels of an oscilloscope while recording a noisy signal. This description assumes that you are recording neuronal activity using a micropipette, but a similar procedure could be
used for other forms of recording. If it is not convenient to use an actual biological preparation to generate a noisy recording you may wish to use a model cell connected to an
intracellular probe (50 M resistor in parallel with a 500 pF capacitor or similar values). Short current pulses can be used to make model electrophysiological events.

Step Two: Make sure that the signal and noise conform to the frequency and amplitude ranges outlined in connections and setup.

Step Three: Observe the operation of the Hum Bug in BYPASS mode. In this mode the input and output of the Hum Bug should be identical. Here are some explicit steps to help you
with the procedure.

" Make sure that you are recording a noisy signal.
" Turn on the Hum Bug.
" Press the BYPASS key. The red LED should be on. Note that the HOLD function will also become active.
" Using your oscilloscope, confirm that the input and output of the Hum Bug are identical. If not, check the calibration on the oscilloscope. If you are not sure that the calibration is
correct you can use a single channel on the oscilloscope to alternately observe the input and output.
" Initiate normal operation by pushing the BYPASS key again. Make sure that HOLD is also disengaged. Both the BYPASS and HOLD switches should have their green LEDs
illuminated.
" Watch any 50/60 Hz noise present on the input signal gradually disappear from the output signal. The LED Indicator will flash red as the noise replica grows to the required size.
When adaptation is complete the Indicator should be off.
" Toggle BYPASS mode on (red LED) and off (green LED) to observe the signal with and without noise cancellation.
" Compare the input and output signals. You should find that the primary signal of interest is not modified by the Hum Bug.

Step Four: Observe the Hum Bug adapt to changing noise conditions. One easy way to change the level of noise is to place your hand near the recording electrode. Alternatively,

turn on a light or a nearby instrument known to cause noise in your recordings.
" Cause a change in the noise level and/or wave-form and then observe the Hum Bug adapt to the change. Rapid changes require time for full cancellation whereas the output will
remain relatively free from noise when noise on the input is slowly evolving.
" Activate the HOLD function (red LED) and then cause a change in the input noise. The level of noise cancellation present before HOLD was activated should continue but the Hum
Bug should not adapt to the change in noise level.
" Return to normal operating mode by turning off the HOLD function and observe the Hum Bug catch up to the new noise level on the input.

Step Five: Observe what happens when you press the CLEAR button. Before you carry out the following steps confirm that the Hum Bug has completely canceled any noise on
the input signal.
" Press CLEAR. The internal noise replica will be cleared and all input noise should appear on the output. The LED Indicator should turn green.
" After a brief pause, the Hum Bug will begin to adapt to the noise on the input and the noise on the output should gradually decrease to minimal levels. During this phase the LED
Indicator should flash red.
" The LED Indicator should turn off when cancellation is nearly complete and should remain off unless the noise on the input changes. If the indicator continues to flash red, check
that the amplitude of the input noise is not greater than 1 volt peak-to-peak (the upper limit for noise). If it remains green then the noise level at the input may be negligible.

Specific Failure Modes: The following sections focus on different types of abnormal Hum Bug behavior. The tasks outlined in each section are designed to help you identify the
specific cause of abnormal behavior in your Hum Bug.

A. The Hum Bug fails to operate.
1. No LEDs are illuminated on the panel switches and the indicator does not illuminate when you push clear.
" Check that the power switch is on.
" Check that the power cable on the back panel is pushed fully into its socket.
" Confirm that the voltage printed beside the connector agrees with the power in your outlets.
" Check the fuse on the back panel and replace it if necessary. The fuse rating is printed beside the holder. If replacement fuses fail repeatedly, contact Quest Scientific.
" Confirm that your wall outlet is functional. An easy way to quickly check that power is available is to use the same outlet to power another instrument.
" Try a different universal power cord (borrow one from another instrument).
2. A switch on the front panel fails to operate or is unreliable.
" An LED may be burned out. If so, the instrument will operate correctly even though the LED fails to illuminate.
" Perhaps the switch is faulty. Push the switch firmly and slowly and then let it go. Try several times.

B. The Hum Bug is operating but noise cancellation is inadequate or abnormal.
1. The LEDs on both switches are green and clear causes the indicator LED to turn green. However, noise remains on the output signal of the Hum Bug.
" Confirm that your Hum Bug is configured for the appropriate AC line frequency for your country. The frequency is recorded next to the connector.
" Perhaps the noise present in your recordings is not electrical interference from the power mains or the power supplies in your equipment. Computers, terminals, video displays,
and some oscilloscopes can generate interference which looks like 50/60 Hz noise but has a different frequency. A standard Hum Bug will not cancel these forms of interference.
Look at the noise with your oscilloscope set to line triggering. If the noise is rolling across the screen, or it's frequency is varying, the noise is not emanating from the power mains
or related sources. Try to determine the source of the noise by systematically turning off the power on each instrument in the vicinity of your setup. If you find the cause, move it
away or shield it with metal foil connected to ground. If you continue to have problems with non-50/60 Hz electrical interference, contact Quest Scientific for further advice.
" Perhaps the peak-to-peak level of noise is too large for the Hum Bug to completely cancel. If so, the indicator will continue to flash red. Connect the input signal of the Hum Bug to
an oscilloscope and determine the noise amplitude. The Hum Bug cannot cancel noise greater than 1 Volt peak-to-peak. If your noise levels are higher than this limit you may have
to reduce the gain in your preamplifier.
" Perhaps the amplitude of the noise you are attempting to cancel is too small for the Hum Bug to detect. If so, the indicator will remain green. The Hum Bug is most efficient when
noise levels are greater than 15 mV peak-to-peak (after preamplification). Adaptation to signals below 1 mV may be very slow. You

can solve this problem by increasing the gain
of your amplification system.
" Perhaps the noise on the input is rapidly changing or jumping to new levels. Under these conditions the ADAPTOR may lag behind and noise will transiently appear on the output.
This pattern of noise usually suggests that the grounding system in the experimental setup may be a problem. Contact Quest Scientific for advice.
2. The 50/60 Hz noise on the output of the Hum Bug increases to very high levels even when little or no noise is present on the input.
" Check that the input and output are not reversed. If the signal passes through the Hum Bug in the wrong direction the noise replica will grow without constraint.
" There may be a grounding problem between the Hum Bug and other equipment in your setup. Refer to section D1.
C. The output of the Hum Bug has too much baseline noise (random, wide-band noise).
1. Are you attempting to use the Hum Bug on very low level signals (less than 1 mV)? If so, circuit noise from the Hum Bug may be detected on the output.
" Compare the input and output on two channels of your oscilloscope. The baseline noise should look identical on both signals for levels down to 1 mV. Below this level additional
circuit induced noise may appear on the output. If the baseline noise on your input signal is below 1 mV and the additional noise introduced on the output is a problem in your
application, it may be necessary to increase the gain of your amplifier.
2. The baseline noise on the output of the Hum Bug is greater than on the input, even when its amplitude is greater than 1 mV.
" Directly ground the input connector of the Hum Bug and observe both the input and output at the same time. Is the baseline noise on the output more than a few mV even when
the input is grounded? If so, there may be a problem with grounding. Refer to section D1.
3. The baseline noise is only a few mV when the input is grounded but much larger than expected when an input signal is connected to the Hum Bug.
" Perhaps the grounding of the Hum Bug and associated equipment is the problem. See section D1.
" Are you connecting the Hum Bug to an unusual piece of equipment? If so, check the output impedance of the device. Although the Hum Bug will adapt to a wide range of input
characteristics, a signal source with a very high impedance could present a problem. This problem can be solved by passing the signal through a suitable impedance-matching
amplifier (buffer) before it enters the Hum Bug.
D. The Hum Bug adds 50/60 Hz noise to the output.
1. Incorrect grounding is the most likely cause of this problem.
" Confirm that the grounding prong on the power cable is connected to the building ground at your preferred grounding point. Avoid using more than 1 service outlet for your setup.
A good way to bring all of the instrument grounds in your system to one point is to use a power bar. The ground on the power bar becomes the final common ground connected to
the wall outlet. However, poor ground connections are a frequent problem with inexpensive power distribution bars.
" Make sure that the signal ground on your probe preamplifier is not attached to the Hum Bug other than through the BNC cable connecting the two instruments. This helps prevent
ground loops.
" Remove any additional grounding wires connected to the chassis of the Hum Bug. These additional ground wires will make inappropriate connections between grounds in your
setup and the grounds in the power mains.
" Check your cables to make sure that the braided shield is connected to the ground ring of the BNC connector on both ends.
If you have tried the suggestions outlined above and still have problems or questions please contact Quest Scientific.

SPECIFICATIONS
Physical

Standard steel instrument box with cast aluminum base.
" W-6.5" D-7.5" H-1.3" (32.2X18.1X3.1 cm).
" Weight - 2.8 lb. (1.3 kg).
Power
" 115-120 VAC at 60 Hz.
" 230-240 VAC at 50/60 Hz.

Input Voltages

Input protection: 50 volts peak-to-peak.
Maximum input signal recognized by the adaptor: 5 volts peak-to-peak.
Maximum noise amplitude for complete cancellation: 1 volt peak-to-peak.

Frequency Response

Input to output: DC to greater than 500 kHz.
Hz and harmonics cancellation: 50/60 Hz to 4 kHz.

35 Weaver Street, *Scarsdale*, New York 10583. U.S.A.

Controls

BYPASS: halts noise cancellation by routing input directly to output.
HOLD: suspends adaptation to evolving noise characteristics.
CLEAR: clears the noise replica.

Display

LED indicates changing noise levels.
" GREEN: decreasing amplitude of the noise replica.
" RED: increasing amplitude of the noise replica.

Quest Scientific HumBug

Many HumBugs have been sold by Digitimer in the last 5 years, the list below includes a handful of papers by a few users of this unique device.

Keiko Ikeda, Tatsushi Onaka, Makoto Yamakado, Junichi Nakai, Tomo-o Ishikawa, Makoto M. Taketo, and Kiyoshi Kawakami **Degeneration of the Amygdala/Piriform Cortex and Enhanced Fear/Anxiety Behaviors in Sodium Pump α2 Subunit (*Atp1a2*)-Deficient Mice.** J. Neurosci., Jun 2003; 23: 4667 - 4676.

Oliver Behrend, Antje Brand, Christoph Kapfer, and Benedikt Grothe **Auditory Response Properties in the Superior Paraolivary Nucleus of the Gerbil**. J Neurophysiol, Jun 2002; 87: 2915 - 2928.

Sophia Kröther, Joachim Mogdans, and Horst Bleckmann **Brainstem lateral line responses to sinusoidal wave stimuli in still and running water** J. Exp. Biol., May 2002; 205: 1471 - 1484.

M.P. Burnham, R. Bychkov, M. Félétou, G.R. Richards, P.M. Vanhoutte, A.H. Weston, and G. Edwards **Characterization of an apamin-sensitive small-conductance Ca^{2+}-activated K^+ channel in porcine coronary artery endothelium: relevance to EDHF**. Br. J. Pharmacol., Mar 2002; 135: 1133 - 1143.

R. James Storer, Simon Akerman, and Peter J. Goadsby **GABA receptors modulate trigeminovascular nociceptive neurotransmission in the trigeminocervical complex**. Br. J. Pharmacol., Oct 2001; 134: 896 - 904.

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Marcello G. P. Rosa, Rowan Tweedale, and Guy N. Elston **Visual Responses of Neurons in the Middle Temporal Area of New World Monkeys after Lesions of Striate Cortex**. J. Neurosci., Jul 2000; 20: 5552 - 5563.

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Thomas A. Macek, Hervé Schaffhauser, and P. Jeffrey Conn **Protein Kinase C and A_3 Adenosine Receptor Activation Inhibit Presynaptic Metabotropic Glutamate Receptor (mGluR) Function and Uncouple mGluRs from GTP-Binding Proteins.** J. Neurosci., Aug 1998; 18: 6138 - 6146.