Hum Bug

REFERENCE MANUAL

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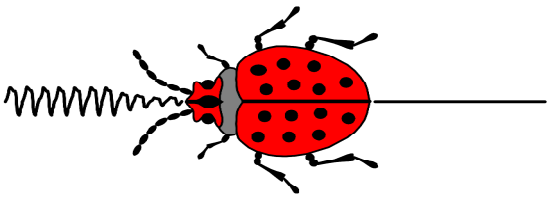

Quest Scientific

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[1] 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[2] noise and harmonics[3] without altering the frequency characteristics of the desired signal[4] 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.

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[1] The frequency depends on the AC frequency of the power mains. This frequency is 60 Hz in North America and 50 Hz in many other regions of the world.

[2] Each Hum Bug is internally configured for either a 50 or 60 Hz fundamental.

[3] Electrical interference is usually composed of a variety of frequencies which are harmonics of the 50/60 Hz fundamental. Frequencies as high as 1 kHz are not uncommon. The Hum Bug will eliminate harmonics with frequencies up to 4 kHz.

[4] For frequencies up to at least 500 kHz

THEORY OF OPERATION

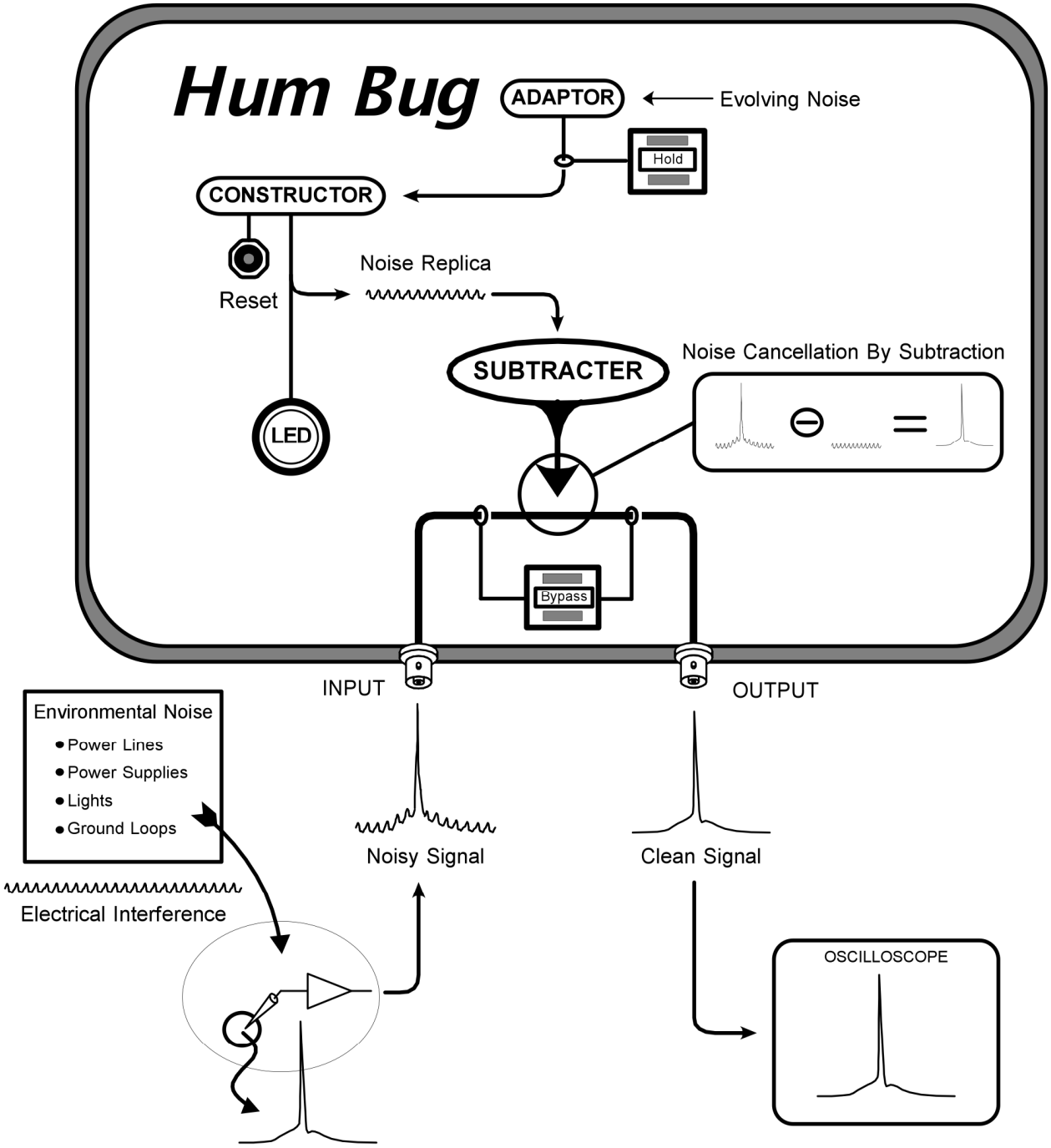
This section reviews the basic internal operations of the Hum Bug. This knowledge will help you become familiar with the front panel controls and the operating characteristics of the device.

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.

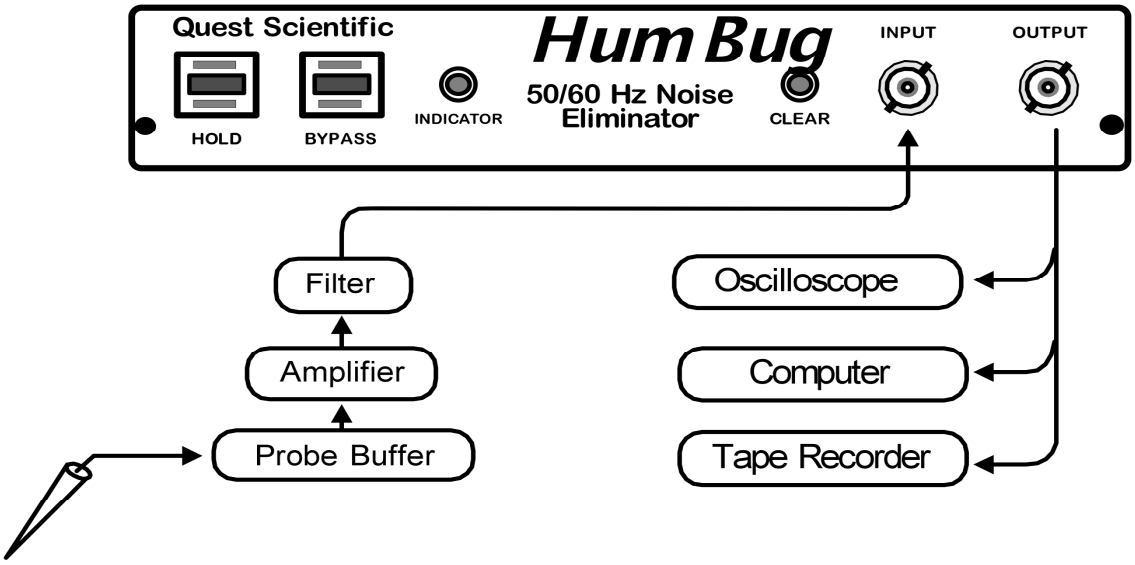
The major advantage of this method of noise elimination is the fact that the input signal is never directly filtered. In fact, the signal of interest passes through the Hum Bug without any form of waveform distortion or processing artifact. Since the Hum Bug takes several seconds to adapt to a particular 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.


Hum Bug
ADAPTOR
Evolving Noise
Hold
CONSTRUCTOR
Reset
Noise Replica
SUBTRACTER
Noise Cancellation By Subtraction
LED
Bypass
INPUT
OUTPUT
Environmental Noise
Power Lines
Power Supplies
Lights
Ground Loops
Electrical Interference
Noisy Signal
Clean Signal
OSCILLOSCOPE

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

NORMAL OPERATING MODE is active when LEDs on both panel switches are green. You can interrupt normal mode by using the *HOLD* and *BYPASS* control buttons. Illumination of the red LED on one or both of the switches indicates that the corresponding special mode is in effect.

BYPASS temporarily suspends noise cancellation. The noise replica is held internally and adaptation stops. As a result, the input signal passes directly to the output without noise elimination. When the *BYPASS* button is turned off the Hum Bug immediately resumes cancellation with the previous noise replica. The *BYPASS* key provides a convenient way to compare noise levels with cancellation on versus off.

CLEAR resets the noise replica and forces the Hum Bug to generate a new noise replica. Although rarely necessary, pressing *CLEAR* can speed up recovery following episodes of abnormal noise levels caused by ground faults, bad electrical connections, or other unexpected problems.

INPUT BNC accepts a signal from an amplifier, filter, or other signal conditioning instrument.

HOLD temporarily suspends adaptation to evolving noise. In effect, the noise replica is frozen. Noise cancellation continues but the noise replica will not respond to a change in noise characteristics on the input. *Hold* is useful when you know that a transient change in noise level is about to occur and you don't want the Hum Bug to disturb its present level of noise cancellation*.

OUTPUT BNC sends an output signal to an oscilloscope, computer, tape recorder, and/or other analysis instrument.

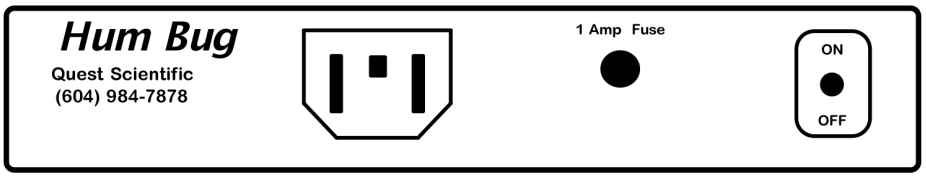
LED INDICATOR flashes red while the noise replica is growing and flashes green while the replica is shrinking. The indicator is off when adaptation approaches completion. The LED may also flash occasionally during adaptation to slowly evolving noise.

* Here is an example taken from electrophysiological research. The noise on a micropipette recording is usually stable and only changes slowly over time. However, touching a manipulator, approaching the electrode, or lifting the electrode from the experimental preparation can cause additional, but transient, noise on the recorded signal. Using *HOLD* during these manipulations will keep the Hum Bug from *chasing* the transient noise. As a result, effective cancellation of ongoing noise can resume immediately after the manipulation is complete.

BACK PANEL

POWER ADAPTER accepts a universal power cord for the outlets in your country. The voltage and AC frequency requirements are printed beside the adapter.

ON/OFF SWITCH turns the unit on and off. When the power is off, signals pass directly through the Hum Bug without modification. After the power is turned on, the Hum Bug will take about 30 seconds to initialize and begin adaptation.



FUSE HOLDER contains a 1 ampere fuse rated for 120/240 Volt operation.

GROUNDING GUIDELINES

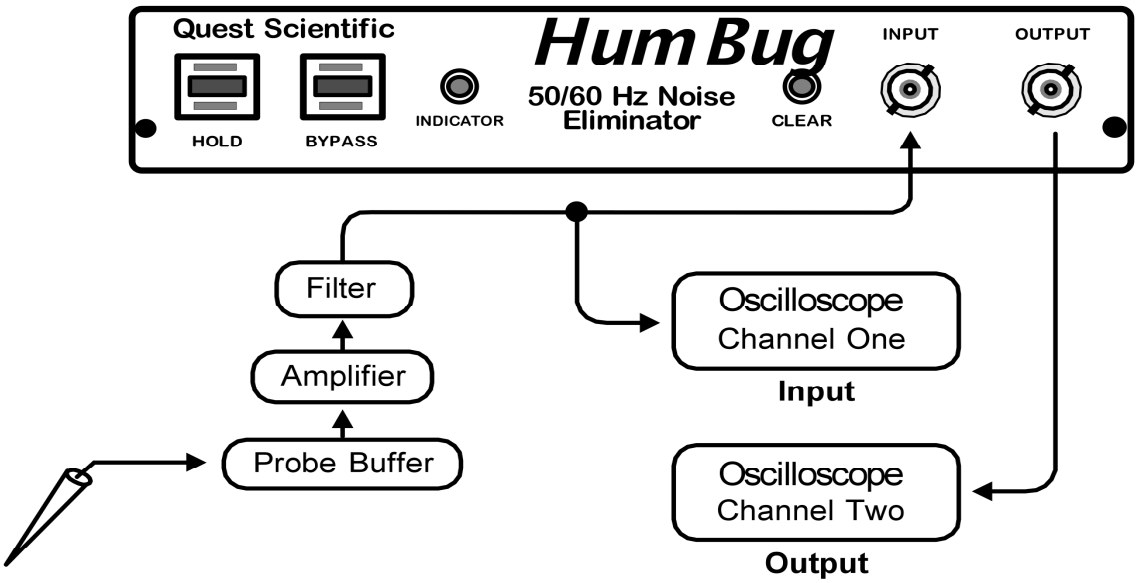
- The ground pin on the power cord is connected internally to the chassis and must be connected to your building ground for safe and normal operation of the Hum Bug.
- The grounding rings on the input and output BNCs are connected to circuit ground of the Hum Bug as well as to the cabinet and grounding pin of the power cable.
- Do not attach additional grounds to the BNCs or the chassis. These extra grounds can interfere with normal operation of the Hum Bug.

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 MΩ 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.

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.

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