A Simple Electronic Stethoscope

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Introduction

An electronic stethoscope is a handy tool to have around. You can use it for all the usual purposes, with two important bonuses. With the electronic version, you can add gain -- which will let you hear sounds normally not audible through an acoustic 'scope; and in addition, the analog output signal can be recorded for making a permanent record of what you were hearing.

The unit described here is the author's first attempt at building such a device. As such, it is a prototype and might not be well suited for mass-production in its current form. In particular, the acoustic design of the microphone pickup needs more attention to improve its performance and reduce its susceptibility to ambient noise.

Circuitry

Figure 1 shows the electronic circuitry within the stethoscope. It only has one active part, U_1, a high-performance operational amplifier. It isn't very complicated at all!

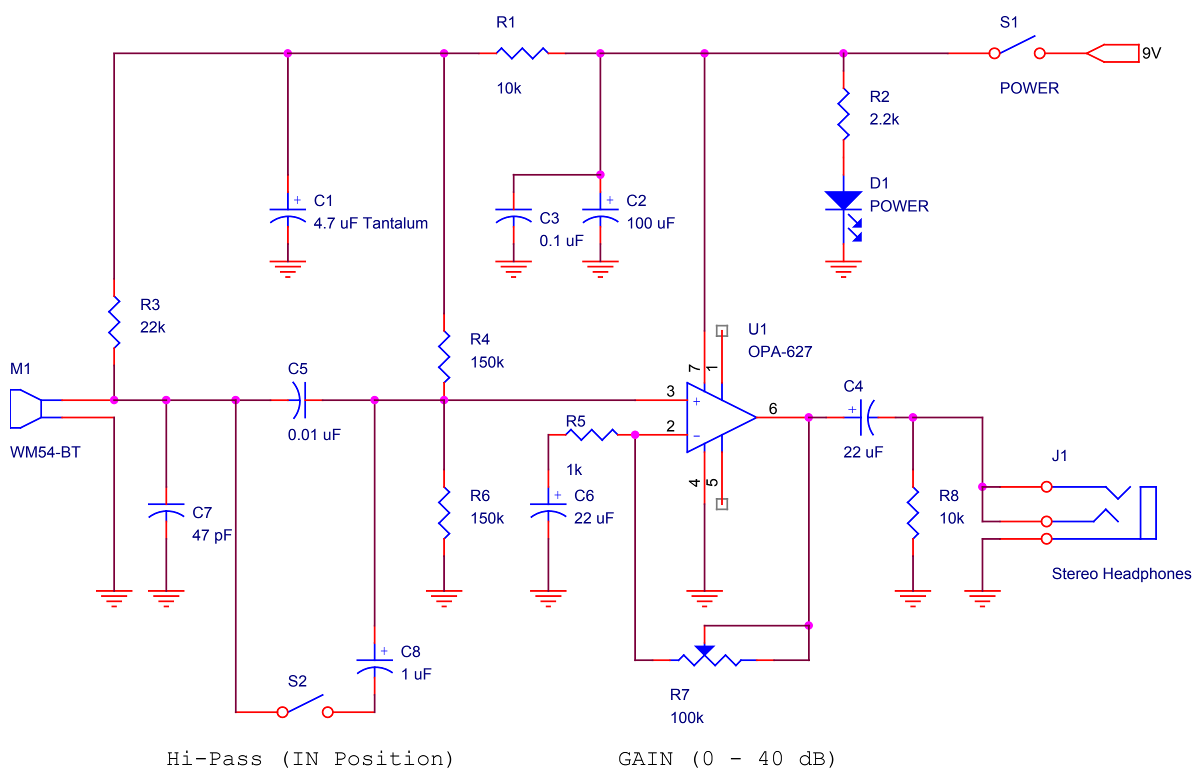

Figure 1: Electronic stethoscope circuitry

The circuit in Figure 1 uses a Panasonic WM54-BT electret condenser microphone element as the pickup. The dc bias for the microphone is provided through R_3. The microphone dc supply is filtered by R_1 and C_1 to eliminate any noise that might get passed into the sensitive microphone circuit through the power supply rail.

The microphone is coupled to U_1, the amplifier, through C_5 and C_8. The combination of C_5 and the Thevenin resistance of R_4, R_6 form a high-pass filter with a corner frequency of 212 Hz -- this filter eliminates most of the heavy low-frequency (bass) energy that would normally be objectionable and distracting when the pickup is in direct contact with a vibrating object (like a chest wall). The "flat" response of the amplifier can be selected by closing S_2, which adds C_8 in parallel with C_5, reducing the corner frequency to 2 Hz.

The Burr-Brown OPA-627 op-amp is configured as a non-inverting amplifier. The amplifier is biased to Vcc/2 for single-supply operation by R_4 and R_6. The voltage gain is controlled by R_7 (the variable resistor) and R_5; C_6 is a dc block required since Vcc/2 appears on pin 2 of U_1. The low-frequency pole introduced by C_6 is at 7 Hz, well below the lowest frequency the amplifier will normally be expected to pass. The output of U_1 can directly drive stereo headphones (which usually have an input impedance of more than 100 ohms, even though they're typically used with 8 ohm systems). The output can also drive the line input of an audio recorder by using an appropriate adapter cable. R_8 is present to ensure that C_4 never becomes reverse polarized in the event that the circuit is connected to an audio recorder input stage lacking a bleeder resistor. R_8 also prevents thumps in the headphones when they're plugged in with the power turned on.

Mechanical Construction

Figure 2 shows the completed stethoscope. The electronics are a bit bulky! The size could be reduced considerably by using miniature controls and connectors, which were not available when the prototype was constructed. The use of a smaller power source (such as a common 12 volt garage-door opener battery) would further reduce the real estate requirements.

Figure 2: Completed electronic stethoscope

The internal layout of the unit is shown in Figure 3. The drawbacks of using standard-sized components are very evident. The 9V battery takes up a considerable amount of the enclosure volume. The active electronics (visible at bottom, back) were built using "ugly construction" on a 3 cm^2 copper plate. The copper plate forms an effective ground plane, improving the noise immunity of the circuitry.

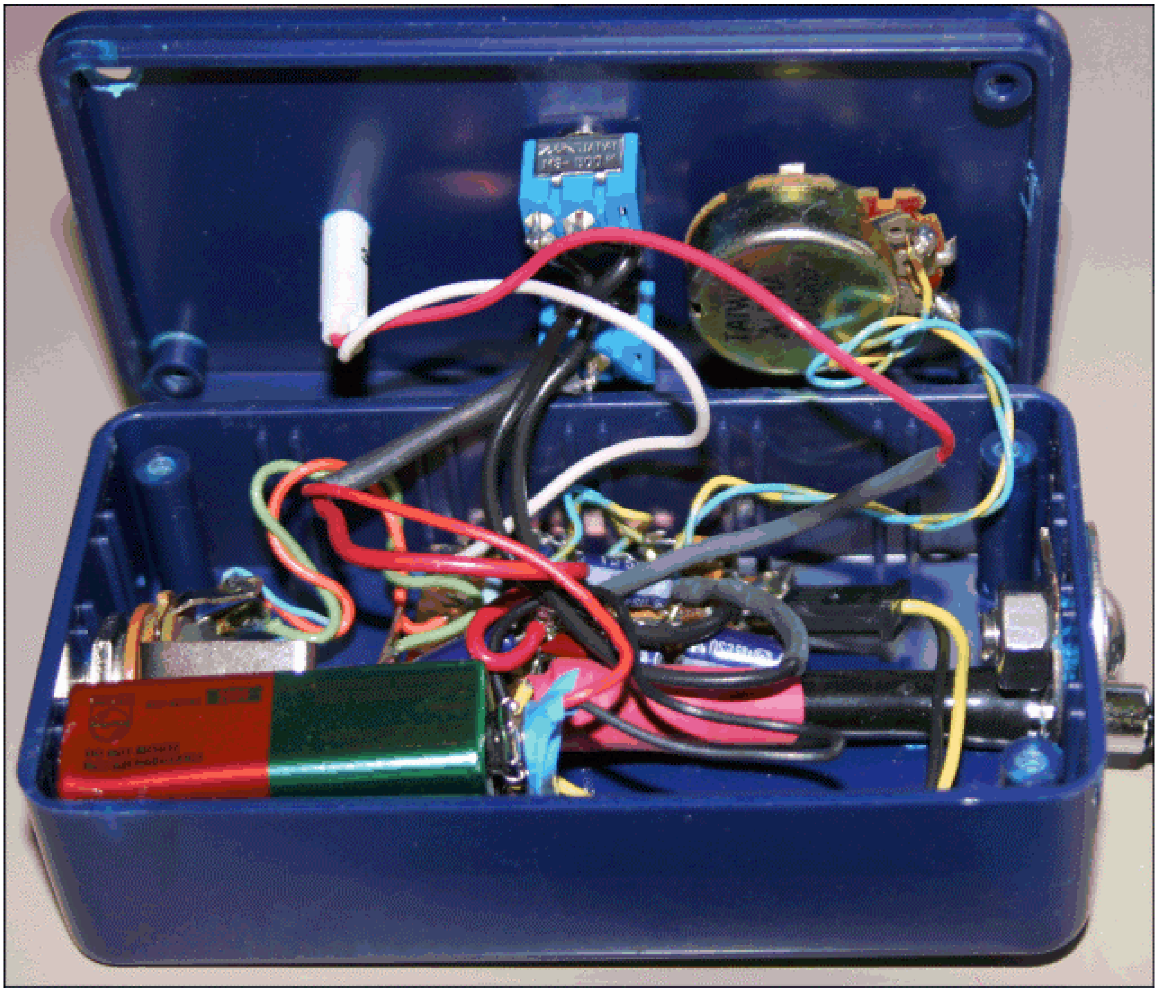

Figure 3: Internal view of the electronic stethoscope circuitry

The microphone is visible in the bottom middle of the enclosure. It's connected to the amplifier via the black and yellow wires and a two-pin connector. The connector allows easy substitution of the microphone pickup for later experimentation and optimization.

The microphone is acoustically coupled to the pickup head through the black tubing. A short length of shrink wrap (red) mechanically couples the microphone and tubing. If you look just to the left of the black and yellow signal wires, you'll see the vent hole punched in the tubing.

This vent hole is absolutely necessary for correct operation; without it, the sound will be excessively bassy and mushy because the microphone diaphragm will be dc coupled (acoustically) to the stethoscope diaphragm.

A better picture of the microphone assembly is shown in Figure 4. The microphone element is visible as a slight bulge at the left of the red shrink wrap covering. The vent hole is made adjacent to the hose barb on the stethoscope pickup head. This hole should be between 0.8 and 1.6 mm in diameter (try smaller first -- if there's too much "boom" in the response, very gradually widen the hole.)

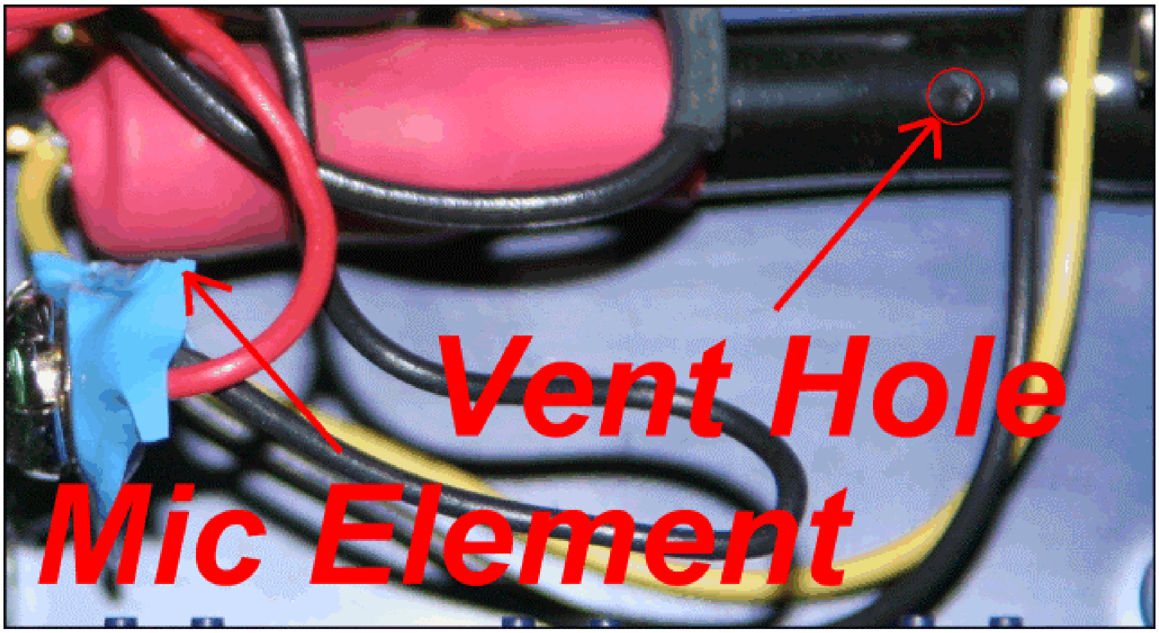

Figure 4: Detail of microphone assembly

Figure 5 shows how the stethoscope head is attached. Two stainless steel fender washers were used to cinch down the head to the body of the instrument. A small indentation was ground off the edge of both washers to accommodate the hose connector of the pickup head. Not visible in Figure 5 is the *internal* washer, made in the exact same fashion. The two washers form a "sandwich" around the plastic wall of the enclosure, strengthening and stabilizing this interface.

It's not clear that having such tight mechanical coupling between the pickup head and instrument box is a good idea, acoustically. This will be the subject of a later investigation.

The author feels that a solid metal enclosure would go a long way towards reducing pickup of unwanted ambient noise. The prototype is packed with acoustic foam (not shown in the photos) to reduce the noise problem, but this is only a temporary solution.

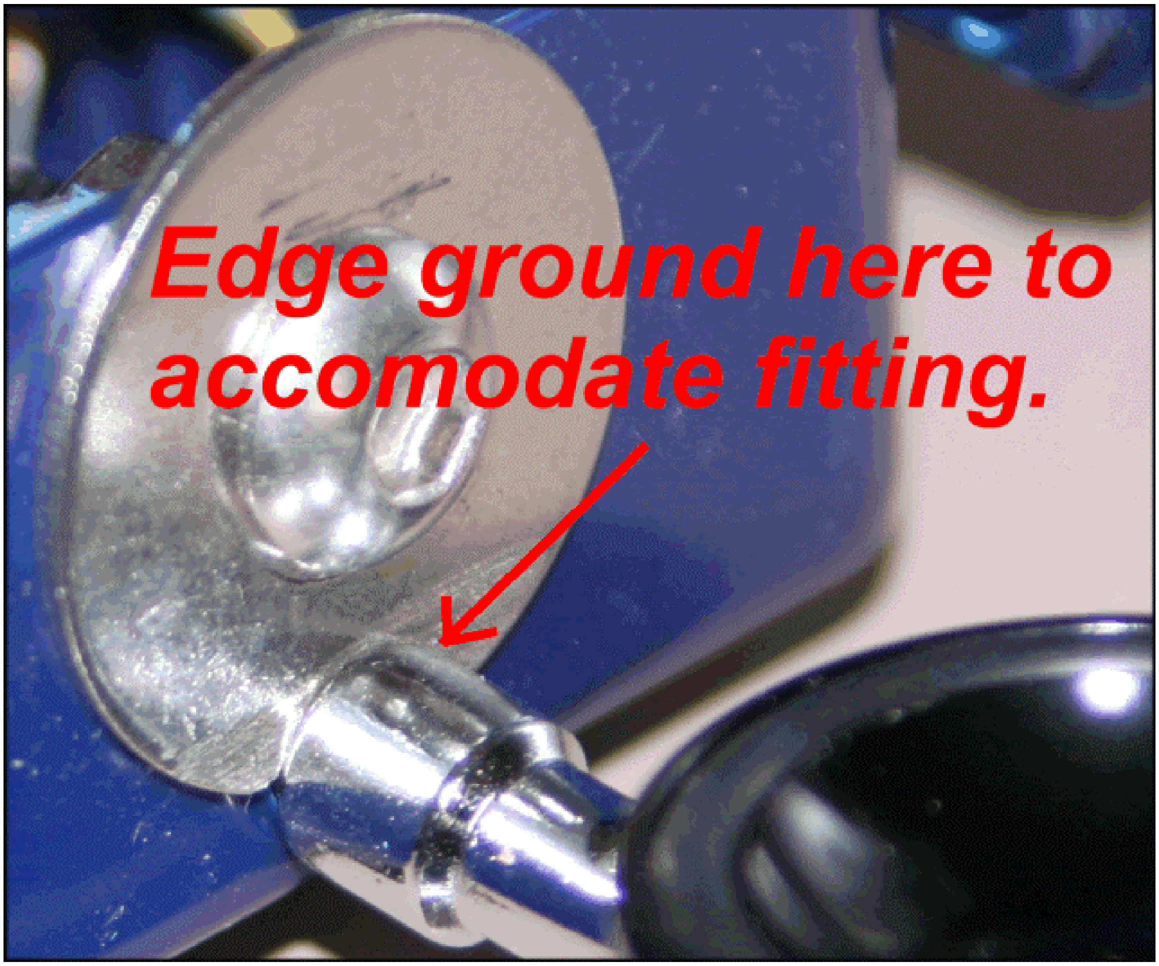

Figure 5: Attachment of pickup head to body of instrument

Construction and Checkout

Build and test the amplifier unit first. Its construction is not critical. The usual analog precautions apply -- keep the outputs away from the inputs, place filter capacitors immediately adjacent to ICs, and keep component leads as short as possible. Metal-film resistors are recommended for R_4, R_6, R_3, and R_5. Construction on a copper ground plane is not required, though it will improve the noise immunity of the unit.

To test the amplifier, apply a 10 mV p-p, 1 kHz input signal, and set the high-pass filter to OFF. With the GAIN control fully counterclockwise, you should observe close to 10 mV p-p at the output. Increase the GAIN to maximum; the output should now be close to 1 V p-p. Turn on the high-pass filter -- there should be no visible change in the 1 kHz output. Finally, reduce the frequency to 100 Hz. The output should now be less than 0.5 V p-p, since the high-pass is reducing the amplitude below its cutoff frequency of 212 Hz.

Operation

To operate the unit, plug in a set of headphones into the output jack, turn the gain control to minimum, and apply power. It's recommended that you use headphones that cover the ears for two reasons. First, this reduces distracting noise for the listener. Second, this greatly reduces the possibility of acoustic feedback between the headphones and the pickup (this unit has a great deal of gain).

Always start with the gain control at minimum. This unit can produce painful levels of volume at the headphones, so be careful. Keep the pickup head away from the headphones at all times!

For listening to heart sounds, you'll probably want the high-pass filter in the ON position. Otherwise, the low bass sounds may tend to obscure the more subtle sound components. Conversely, you may want the high-pass filter in the OFF position if you're using the unit for peripheral blood pressure measurements. Use the position that works best for you.

The unit draws very little current (less than 10 mA) from the battery, so a 9V alkaline battery should last for a very long time (probably about 40 hours of continuous operation). If you want to almost double the battery life, just leave out D_1 and R_2!

Conclusion

It's not hard to build a electronic stethoscope. The unit described here can be constructed for well under $25.00; it's simple in design, mechanically rugged, and reliable. It will be a tool you'll find useful for years to come.