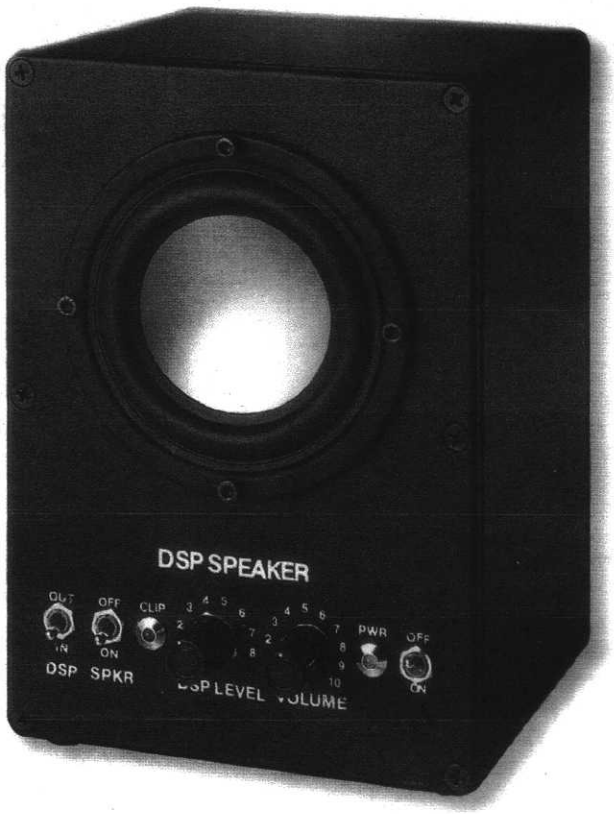
Build Your Own DSP Speaker

Build this noise reducing system to help you pull in the weak ones.

Allen Baker, KG4JJH



Adaptive filters using digital signal processing (DSP) can be very effective in improving the receive quality of Amateur Radio communications. DSP analyzes the signal and differentiates between the noise and the desired signal. Unwanted noise and interference are then attenuated to leave only the signal of interest. The signal is constantly monitored and the DSP automatically adapts to any changes in the signal conditions.

BHI Ltd has a line of DSP products aimed at the Amateur Radio community.[1] A popular radio modification is to add the NEDSP1061-KBD module inside the radio.[2] It adds a microprocessor and LED to the basic module with a pushbutton that steps through four levels of noise reduction.

This project allows us to take advantage of noise reduction on multiple radios while using the basic NEDSP1061-PCB module. This implementation provides eight levels of noise reduction. Audio from the radio is fed to a level attenuator, clipping indicator, DSP module and a power amplifier that can drive a speaker or headphones.

Circuit Description

Figure 1 is the schematic of the unit, along with its parts list. Toggle switch S3 powers the unit and turns on the yellow PWR LED. Speaker and headphone levels are controlled by VOLUME potentiometer R17. The DSP LEVEL is selected by rotary switch S1. Toggle switches S2 and S4 switch the DSP in and out and turn the speaker on and off, respectively. The rear panel (see Figure 2) contains INPUT jack J1, PHONES jack J2, and 12 V dc POWER jack J3. Board mounted jumper JP1 allows the use of stereo headphones by connecting the output to both channels. Ferrite beads are used on all signals entering and exiting the circuit to reduce RFI.

M1, NEDSP1061-PCB

This tiny noise reduction module measures 1.45 × 1.06 inches and has 10 input/output pins. It has an internal voltage regulator, allowing it to operate over a 5-15 V dc range. The eight available DSP levels correspond to 9-35 dB of white noise or hiss reduction and 4-65 dB of tone or heterodyne reduction. Pins 1-3 have internal pull-up resistors to 3.3 V dc and determine the DSP level as indicated in Table 1.

Table 1
NEDSP1061-PCB DSP Level Setting

DSP Level	*Tone Reduction (dB)*	*White Noise Reduction (dB)*	*Pin 3-N2 (V dc)*	*Pin 2-N1 (V dc)*	*Pin 1-N0 (V dc)*	*BCD Value*
1	4	9	0	0	0	0
2	5	11	0	0	3.3	1
3	6	13	0	3.3	0	2
4	8	15	0	3.3	3.3	3
5	16	17	3.3	0	0	4
6	21	20	3.3	0	3.3	5
7	25	24	3.3	3.3	0	6
8	65	35	3.3	3.3	3.3	7

The N0, N1 and N2 voltage levels correspond to BCD numbers 0-7 and would preferably be set with an eight position BCD complement switch. Panel mounted BCD switches are not readily available, however, so the DSP level is set with an SP8T rotary switch and diodes D1-D12. Resistors R6 and R7 form a 10 dB attenuation pad to reduce speaker level to line level.

The noise cancellation can be turned off by grounding pin eight. However, this method results in a loss of high frequencies, so toggle switch S4 switches between the input and the module output.

U1, TL062 Dual Op Amp

The M1 module requires input levels greater than 50 mV_{RMS}, with a nominal level of 300 mV_{RMS}. The maximum input level is not specified but appears to be around 350 mV_{RMS}. The module includes a surface mounted LED to indicate clipping levels, but the LED is very small and not amenable to panel mounting. Therefore, a simple CLIP indictor has been added.

U1 forms a window comparator to detect

[1]Notes appear on page 34.

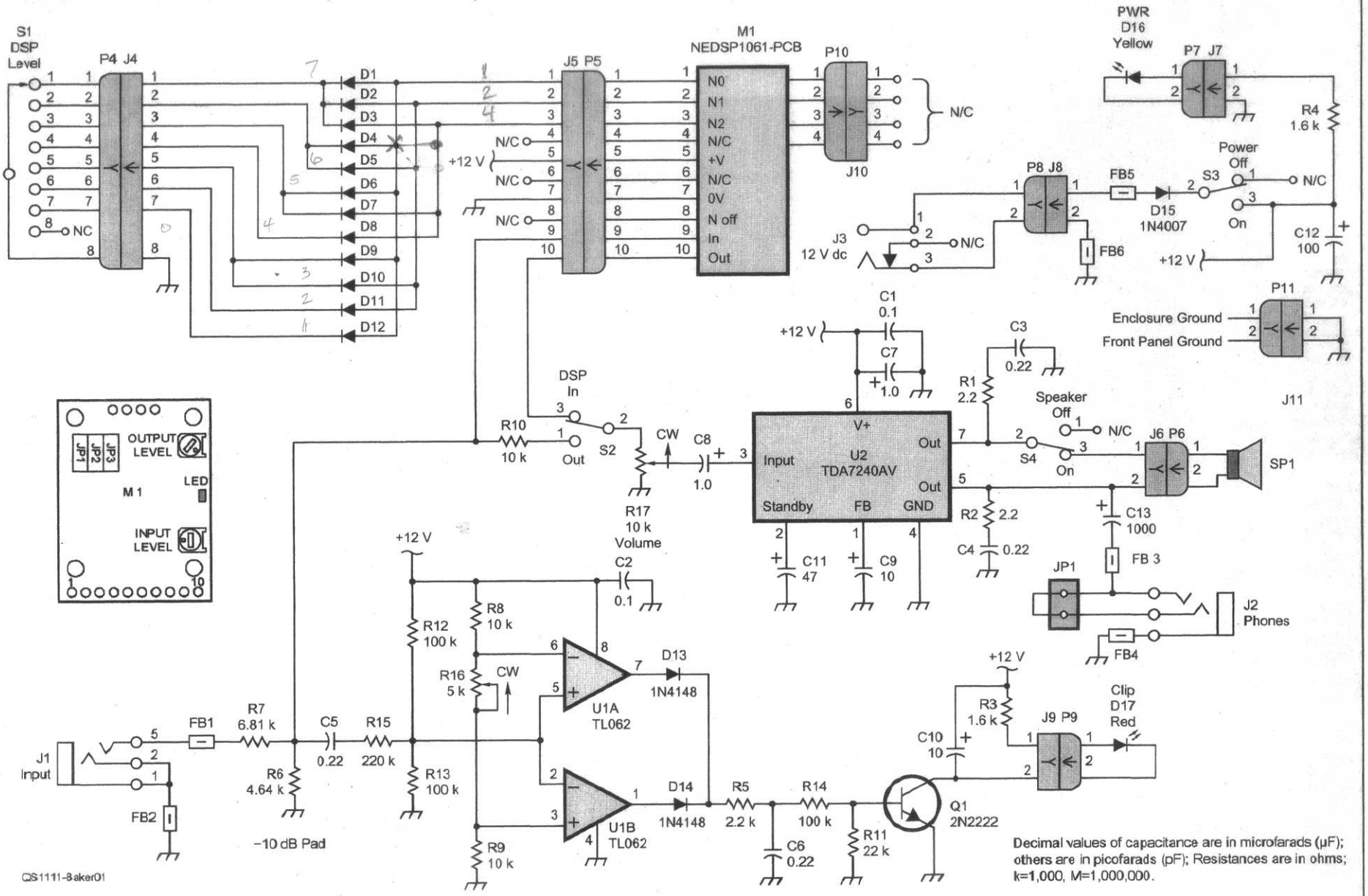


Figure 1 — Schematic diagram and parts list of the DSP speaker. Digi-Key parts are available from www.digikey.com, McMaster-Carr parts from www.mcmaster.com, Mouser parts from www.mouser.com, Parts Express parts from www.parts-express.com and Pololu parts from www.pololu.com. The inset shows the adjustments on the DSP module.

C1-C2 — Capacitor, ceramic, 0.1 µF, 50 V (Mouser 581-SR215C104KARTR2).
C3-C6 — Capacitor, ceramic, 0.22 µF, 50 V (Mouser 581-SR215E224MAR).
C7-C8 — Capacitor, electrolytic, 1 µF, 25 V (Mouser 140-XRL25V1.0-RC).
C9-C10 — Capacitor, electrolytic, 10 µF, 25 V (Mouser 140-XRL25V10-RC).
C11 — Capacitor, electrolytic, 47 µF, 25 V (Mouser 140-XRL25V47-RC).
C12 — Capacitor, electrolytic, 100 µF, 25 V (Mouser 140-XRL25V100-RC).
C13 — Capacitor, electrolytic, 1000 µF, 25 V (Mouser 140-XRL25V1000-RC).
D1-D14 — Diode, 1N4148 (Mouser 512-1N4148TA).
D15 — Diode, 1N4007 (Mouser 583-1N4007-B).
D16 —LED, Panel Mount, Yellow (Mouser 696-LXR3612SYD-150).
D17 —LED, Panel Mount, Red (Mouser 696-LXR3612SID-150).
FB1-FB6 — Ferrite bead, mix 43, 1.3 mm ID × 3.3 mm long (Mouser 623-2643000101).
HS1 — Heat sink, TO-220, 4.4°C/W (Digi-Key HS410-ND).
J1-J2 — Jack, 3.5 mm, stereo (Mouser 806-STX-3100-3C).
J3 — Jack, dc power, panel mount, 2.5 × 5.5 mm (Mouser 163-MJ22-EX).
J4 — Header, male, 1 × 8, 0.1 inch pitch (Included with P5).
J5 — Header, female, 1 × 10, 0.1 inch pitch (2 pack) (Pololu 1020).
J6-J9, J11 — Header, male, 1 × 2, 0.1 inch pitch (Pololu Included with P5).
J10 — Header, female, 1 × 5, 0.1 inch pitch (Pololu 1015).
JP1 — Shorting block, 1 × 2, 0.1 inch pitch (5 pack) (Pololu 970).
M1 — Module, noise reduction (BHI bhi-ltd NEDSP1061-PCB).
P4 — Crimp connector housing, 1 × 8, 0.1 inch pitch, 10 pack (Pololu 1907).
P5 — Header, male, 1 × 10, 0.1 inch pitch, 1 × 40 (Pololu 965).
P6-P9, P11 — Crimp connector housing, 1 × 2, 0.1 inch pitch, 25 pack (Pololu 1901).
P10 — Header, male, 1 × 4, 0.1 inch pitch (Pololu, included with P5).
Q1 — Transistor, NPN, 2N2222 (Mouser 863-P2N2222AG).
R1-R2 — Resistor, carbon film, ¼ W, 5%, 2.2 Ω (Mouser 291-2.2-RC).
R3-R4 — Resistor, carbon film, ¼ W, 5%, 1.6 kΩ (Mouser 291-1.6K-RC).
R5 — Resistor, metal film, ¼ W, 1%, 2.2 kΩ (Mouser 271-2.2K-RC).
R6 — Resistor, metal film, ¼ W, 1%, 4.64 kΩ (Mouser 271-4.64K-RC).
R7 — Resistor, metal film, ¼ W, 1%, 6.81 kΩ (Mouser 271-6.81K-RC).
R8-R10 — Resistor, metal film, ¼ W, 1%, 10 kΩ (Mouser 271-10K-RC).
R11 — Resistor, metal film, ¼ W, 1%, 22 kΩ (Mouser 271-22K-RC).
R12-R14 — Resistor, metal film, ¼ W, 1%, 100 kΩ (Mouser 271-100K-RC).
R15 — Resistor, metal film, ¼ W, 1%, 220 kΩ (Mouser 271-220K-RC).
R16 — Potentiometer, trimmer, 5 kΩ (Mouser 652-3362R-1-502LF).
R17 — Potentiometer, 7 mm, 10 kΩ, audio taper (Mouser 311-701AF-10K).
S1 — Switch, rotary, 1P8T (Mouser 611-A10815RNZQ).
S2-S4 — Switch, toggle, SPDT, threaded (Mouser 612-100A-T2B1M7Q).
SP1 — Speaker, 3 inch, HiVi B3N (Parts Express 297-428).
U1 — IC, dual opamp, TL062 (Mouser 511-TL062CN).
U2 — IC, power amplifier, TDA7240AV (Digi-Key 497-2168-5-ND).
Speaker grill, fan guard (McMaster-Carr 19155K95).
Enclosure, gasketed black textured aluminum, 6.73 × 4.76 × 3.98 inch (Digi-Key HM1217-ND).
Knob, ½ inch diameter, ¼ inch shaft (Mouser 450-2034-GRX).
IC socket, 8P DIP (Mouser 571-1-390261-2).
Acoustic foam, ½ inch thick (Parts Express 260-520).

ENCL HM 1550 WFBK

M1 = ~~R85~~ → R 99,95

Figure 2 — View of rear panel of DSP speaker. As shown, there are INPUT, OUTPUT and POWER jacks.

the positive and negative peaks of the audio input. The op amp outputs are mixed by diodes D13 and D14, smoothed by C6, R5 and R14, and feed the LED driver Q1 with a positive pulse. C10 adds a small output delay in order to allow detection of very short peaks.[3]

U2, Audio Amplifier, TDA7240AV

If supplied with 12 V dc, this amplifier will deliver approximately 8 W_{RMS} into an 8Ω load at 0.5% THD. This is more than enough power to cleanly drive most speakers. U2 has one input and a differential output, so neither side of the bridged speaker output is grounded. The headphone output utilizes one side of the amplifier output referenced to ground. Do not omit coupling capacitor C8 as the amplifier will not work without it.

SP1, Speaker, HiVi B3N

This full range shielded speaker has a frequency response of 80-8,000 Hz and a fairly smooth response curve. The speaker was selected to cover the voice frequency spectrum without adding too much bass. Although the speaker sensitivity level (SPL) is low at 81 dB, the U2 amplifier has enough reserve power to overcome this deficiency. A speaker grill is recommended for those who are concerned about the unprotected speaker cone getting damaged. Commercially available grills are either too large for the enclosure or have mounting holes that interfere with the speaker frame. A substitute speaker grill can be fashioned from a fan guard mounted on ¼ inch standoffs in front of the speaker.

Construction

The prototype was built using perf-board construction and point to point wiring. Figure 3 shows the top of the board indicating layout approach, while Figure 4 shows the wiring side. Detailed fabrication plans and layout drawings are on the QST-in-Depth website.[4]

Keep inputs away from outputs and be sure to ground the enclosure. For non-metallic enclosures, shielded cable is recommended on all audio lines. To prevent unwanted rattles, put a small dab of silicon sealant on the ferrite beads.

Headers of 5 and 10 pins are soldered to the M1 module, which is then plugged into board mounted sockets. The 5 pin header/socket helps to mechanically secure the module to the board and has no pin connections. For ease of assembly, components mounted off of the board are connected via male headers and female header plugs. The LED rear mounting nut can be threaded over the 2 pin header connector. First, knock the edges off of the connector with a small file and then cut threads by screwing the nut over the connector.

Sealed speaker enclosures should be airtight to prevent unwanted leaks that could unload the speaker. For this reason, the front and rear panel controls and jacks are threaded and sealed with a nut. There is still some air leakage but it is not objectionable in this frequency limited application.

The enclosure features a front panel gasket that reduces air leakage and prevents rattles. The enclosure walls are lined with ½ inch adhesive backed acoustic foam to absorb internal standing waves and prevent reflections to the speaker cone. Keep the foam away from the heat sink to prevent it from melting. Before mounting the speaker, install the supplied adhesive-backed gasket material around the speaker cutout and install the speaker from the outside of the enclosure using 6-32 × ½ inch screws.

If the front and rear panel components are mounted on the perf-board according to the drawing, then the drilling template can

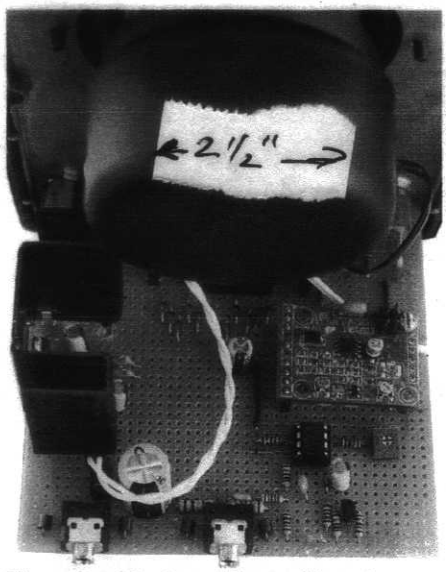


Figure 3 — The top of the perf board indicating component layout.

be used to mark the holes. Print the full-size drilling template on the QST-in-Depth website and then measure the panel and mark horizontal and vertical centerlines. Align the template with the panel centerlines and fasten it to the panel using a glue stick or rubber cement. Next, center-punch and drill all holes. The 2⅞ inch diameter speaker cutout was made with a metal hole saw. Alternatively, small holes can be drilled around the circumference of the hole to remove the bulk of the material and then the edge filed smooth.

Labeling can be added using dry transfer letters or a labeling machine. I used white dry transfer lettering (Woodland Scenics Railroad Gothic DT507) from the railroad section of my local hobby shop. A method of applying dry transfer letters is to print the lettering template full size on clear film. Secure the panel to a table top and then center and tape the clear film over the panel. Place the dry transfer sheet under the clear film, line up the appropriate letter, and then burnish. Follow up with a couple of coats of clear matte lacquer to protect the lettering. Be sure to try the lacquer on a test piece first to ensure compatibility.

Setup

Connect 12 V dc from the radio power supply to a 2.5 × 5.5 mm plug (center positive) to power the unit. The DSP speaker can draw over 1 A at high volumes, so make sure the power supply is adequate. Connect the speaker/headphone output from the radio to the INPUT jack using a shielded cable with a 3.5 mm mono phone plug on one end and a suitable plug on the radio end. The Yaesu FT-817/857 radios have a slide switch that switches the audio output to speaker or headphone levels but there is little difference observed between the two settings.

The M1 module has onboard input and output trimpots for setting sensitivity levels. Set these input and output trimpots to midpoint. The trimpots don't have stops so there will be a dead band area over which the sound disappears. Referring to the inset in Figure 1, the trimpot settings are indicated by a small circle in front of the screwdriver slot and are shown at midpoint. The DSP level is set by rotary switch S1, so remove the shorting blocks on headers JP1, JP2 and JP3.

The clip detector is adjusted with the DSP speaker connected to the radio. Tune in a strong station and adjust the radio VOLUME until you see the M1 OVERLOAD LED light on the peaks. Adjust trimpot R16 until the CLIP LED turns on, mimicking the M1 LED.

Operation

Operation couldn't be simpler. First, set your radio receiver for full bandwidth and disable any built-in noise reduction. Start with low DSP levels and increase the level as band conditions warrant. At the higher DSP levels the audio is somewhat watery sounding but still readable. The DSP is compatible with all modes of operation but is most remarkable on SSB. Heterodynes, static, hiss, buzzing and other noises can be attenuated to a remarkable degree. The audio files on the QST-in-Depth website were made with a DSP setting of 5.

As with all DSP processors, there is a time delay associated with the reduction of noise. The time required to analyze the signal and respond appears to be less than a second for the BHI DSP unit and is the same for all levels of DSP.

Yaesu FT-817/857 radios will begin to light the CLIP LED with the volume control at the 12 o'clock position. For other radios, increase the radio volume until the CLIP LED lights and then back off slightly. The DSP Speaker volume is set to the 9 or 10 o'clock position for normal listening. I find that the extra audio power comes in handy if I am some distance from the radio, for example manually turning a beam while listening for peak reception. I am looking forward to the next VHF contest to put the DSP speaker to good use. Six meter band noise at our contest location gets old after only a few hours of operation.

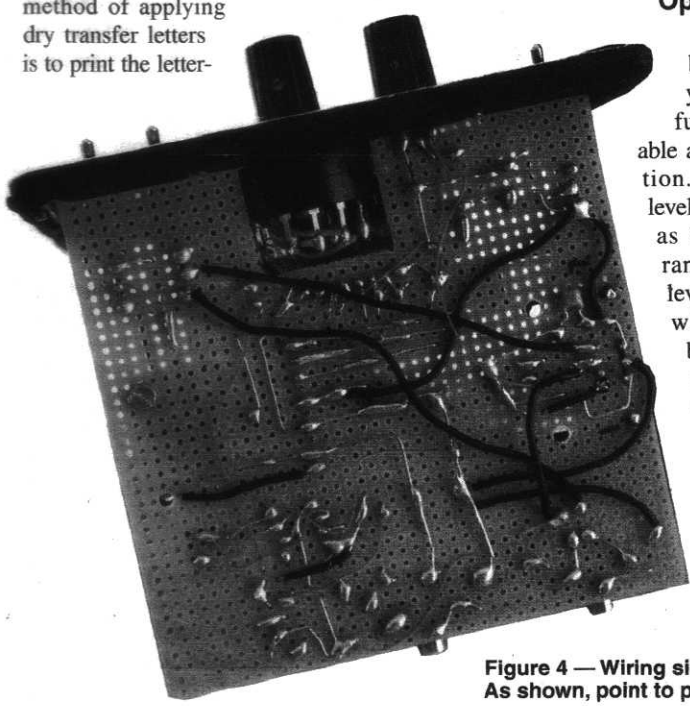


Figure 4 — Wiring side of perf board. As shown, point to point wiring is used.

Conclusion

The DSP Speaker is a versatile tool that will clean up received audio and significantly improve intelligibility for radios not so equipped. The aluminum enclosure has a small footprint (6¾ × 4¾ × 4 inches HWD) and can be used with any radio with a speaker or headphone output. A highly effective noise reduction module teamed up with a hefty power amplifier and quality speaker form an impressive audio system for your radio. The result is less listener fatigue. So clean up the noise pollution and get more enjoyment out of your radio!

Notes

[1]BHI Ltd, PO Box 318, Burgess Hill, West Sussex, RH15 9NR, UK, **www.bhi-ltd.com**.

[2]BHI DSP Noise Reduction Module for Yaesu FT-817, Chris Lorek, G4HCL, **www.wimo.de/download/bhi_rdcom_nedsp1061_review-dec03.pdf**.

[3]Audio clipping indicator, **www.redcircuits.com/Page132.htm**.

[4]**www.arrl.org/qst-in-depth**

ARRL member and General class licensee Allen Baker, KG4JJH, received his license in 2000, after a lifelong dream of becoming a ham. He holds a BS in Industrial Engineering from Tennessee Tech and works as an Instrumentation and Controls Engineer for the company that operates the US Department of Energy weapons plant in Oak Ridge, Tennessee. Allen is active on SSB and the digital modes, enjoys the challenge of working QRP and loves to experiment with antennas and radio gear. He can be reached at 211 Brochardt Blvd, Knoxville, TN 37934 or at **kg4jjh@arrl.net.**

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