Refining the SB-104

Want to improve the performance of your favorite rig? Perhaps these ideas are just what you've been looking for.

By David Palmer,* W6PHF

Introduction of the Heath SB-104 hf transceiver in 1976 provided a product of solid-state engineering at a price attractive to many hams. Completely solid state (except for the digital frequency counter displays), it made efficient portable and mobile operation possible. However, after a few hours of use in the real world of weak signals and crowded bands, and the occasional "rock crushing" signal from the kilowatt down the block, a few deficiencies became apparent. Cross-modulation, intermodulation and desensing (blocking) of the receiver in the presence of strong signals are particularly annoying with the original receiver front-end board. Although the 40673 dual-gate MOSFET mixer used in the '104 is better in many respects than the vacuum tube pentagrid mixer, a major weakness exhibited is that of relatively poor dynamic range.

In 1977,[1] Heath released a series of modifications that included a new receiver front-end board, thus creating the "A" model. Discrete component doubly balanced mixers (DBMs) replaced the two 40673 mixers, and redesigned, prealigned bandpass filters for each band resulted in improved performance.

But, for those like me, whose primary interest is chasing cw DX, the new receiver front-end board was a disappointment since the noise floor had not been lowered and additional spurs were evident. Masking of weak cw signals occurred when the 400-Hz crystal filter and an active audio filter were used. An examination of the receiver suggested poor gain distribution, and modifications to several of the circuit boards ensued. What follows is a description of the steps I took in an effort to improve the performance of my SB-104. Physical placement of the required components is left to the discretion of the owner/modifier.

Receiver Front-End Board Modifications

An article by Cheadle[2] suggested that the poor balance of the discrete DBMs is the source of the intermodulation and cross-modulation problems, and part of the blocking problem. Apparently, precise DBM balance using discrete components is difficult to achieve. This results in the creation of in-band mixing products from the combined presence of strong signals and the LO emission which, in the SB-104A, exceeds 20 microvolts on 20 meters. Consequently, I installed two Mini-Circuits[3] SRA-1 DBM modules on the circuit board with suitable terminations for the ports.[4]

Refer to Fig. 1. The first mixer i-f port is terminated with a 24-MHz diplexer, and the hf injection level is increased to approximately +7 dBm by changing C441 (a 33-pF mica capacitor on board D) to a 56-pF unit.[5] Installation of another SRA-1 DBM at the second mixer requires the addition of a 10-MHz diplexer that is constructed from 5%-tolerance silver-mica capacitors and an rf choke. Somewhat improved performance can be realized by replacing the rf choke with a toroidal inductor. A VFO buffer/amplifier is built on the circuit board to increase the injection level to +10 dBm and to reduce the mixer insertion loss. An L network is used to maintain a 50-ohm impedance match with the DBM LO port.

Better receiver performance resulted from the installation of the two DBMs, but the noise floor was still too high. Increasing the i-f gain after the second mixer is accomplished by installing a CA3028A cascode amplifier mounted in an eight-pin TO-5 IC socket in the area near the 8-MHz bandpass filter. The RF GAIN control (R15A) is replaced with a dual, concentric-shaft 10-kΩ linear taper potentiometer. The front section is used to ad-

---

[1] Notes appear on page 26.

*638 Benvenue Ave., Los Altos, CA 94022

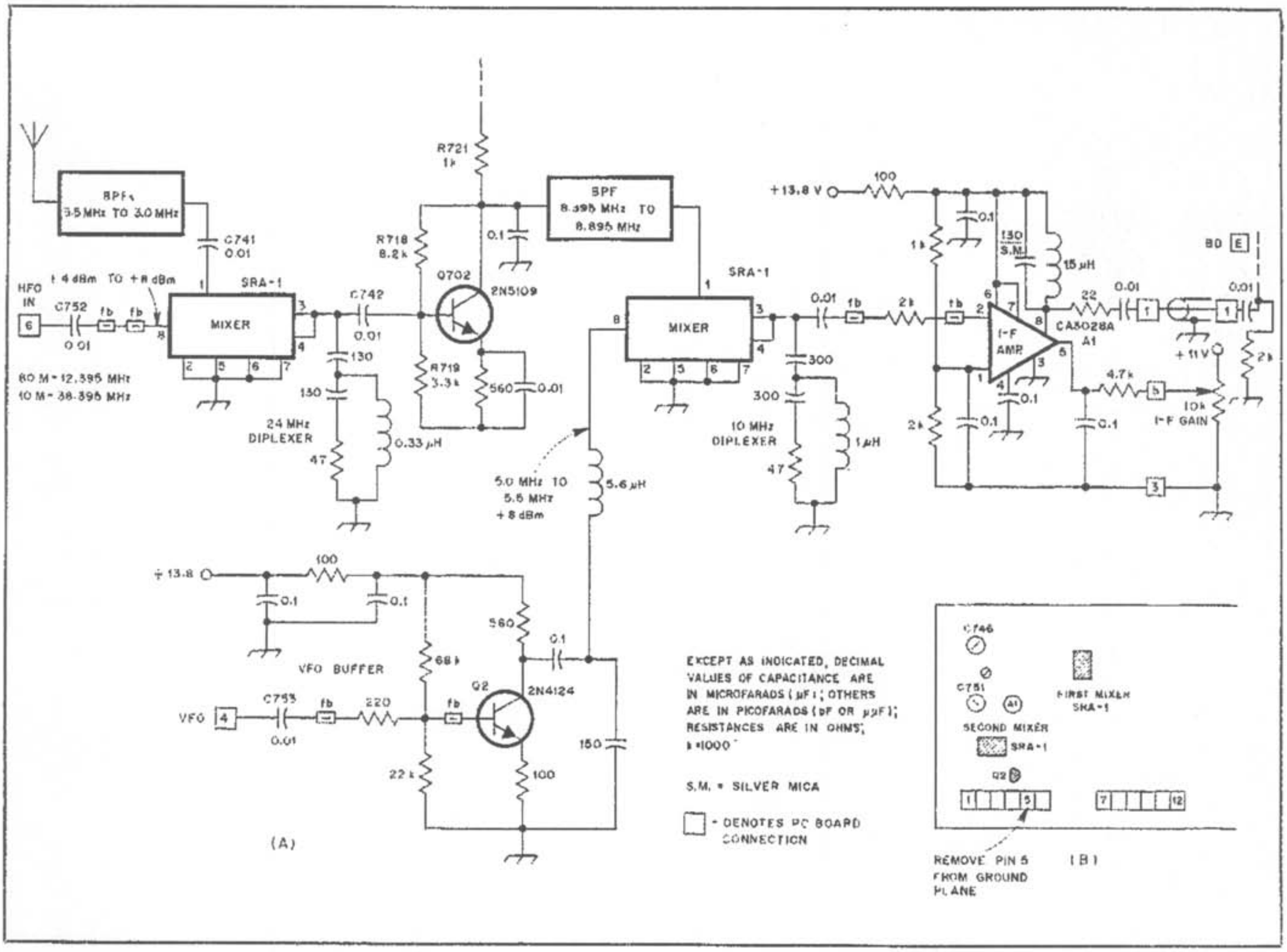


Fig. 1 — Schematic diagram of changes made to the SB-104 receiver front-end board (G). Pin 5 is removed from ground and used as a terminal for the I-F GAIN control. Heath component identification has been retained. All resistors are 1/4-watt, 5% types; capacitors are 50-V units.

just the i-f amplifier gain (board F) and the rear section is wired to board G terminal 5, which is first disconnected from the ground plane. The increased i-f gain markedly lowers the noise floor; this is particularly noticeable when using the 400-Hz cw filter.

Carrier Generator/Crystal-Filter Board Changes

The series noise blanker system used by Heath considerably degrades receiver performance. Therefore, Q601 was replaced by a 40673 MOSFET. This permits the attachment of a shunt type of noise blanker to gate 2 of the device (see Fig. 2).

In the cw mode, a "beep" was heard in the speaker during the transition from transmit to receive. This is caused by a long time constant on the V_{cc} bus of Q611, the CW GENERATOR. Changing C635 from a 22-µF capacitor to a 0.1-µF unit solves the problem by permitting the CW GENERATOR to turn off during the transmit/receive changeover interval.

Difficulty in achieving a good carrier null in the balanced modulator was caused by poor carrier-frequency bypassing at the

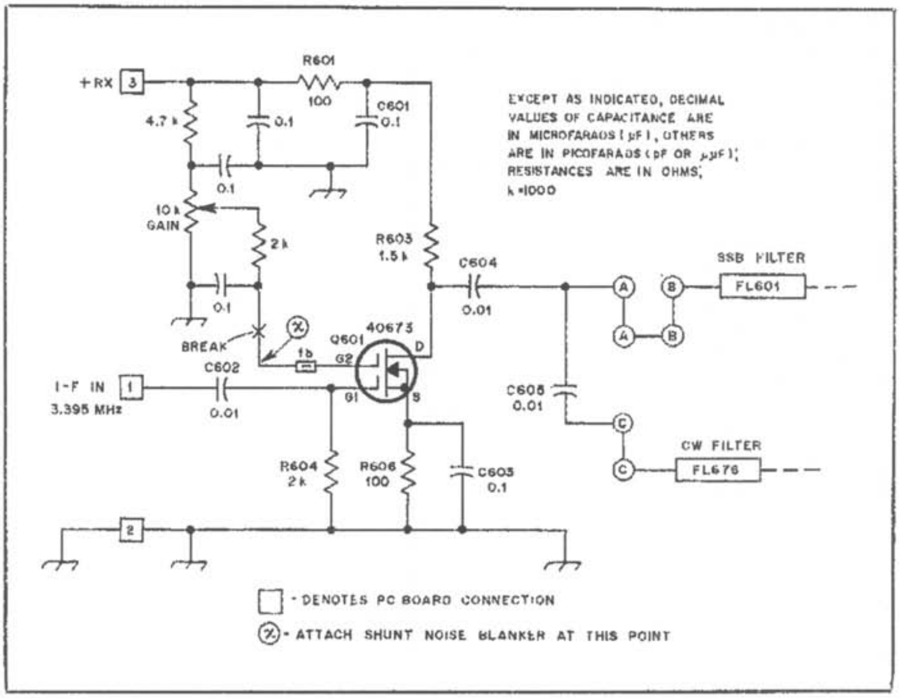
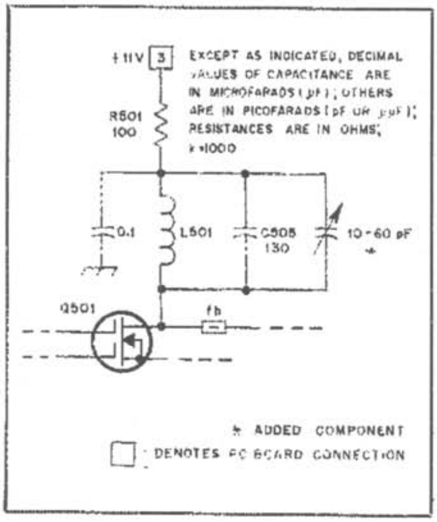


Fig. 2 — Carrier generator/crystal filter board (E) changes. A shunt type noise blanker may be attached at point X. The bipolar transistor (Q601) has been replaced by a dual-gate MOSFET.

modulation input port. Replacement of C646 (a 4.7-µF tantalum capacitor) with a 0.1-µF ceramic capacitor and series-connected 47-ohm resistor produces better suppression.

Receiver I-F/Audio Board

The first modification to be made (see Fig. 3) provides additional receiver gain by tuning L501 with a 10- to 60-pF trimmer capacitor. A gain improvement of approximately one S unit should be noted.



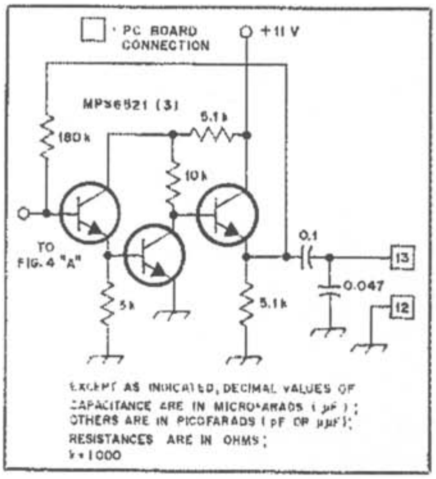
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k=1000

* ADDED COMPONENT

☐ DENOTES PC BOARD CONNECTION

Fig. 3 — A trimmer capacitor is used to tune L501 on board F to obtain additional receiver gain.

During cw operation an annoying wide-band audio hiss was noted in the receiver. It was discovered that the IC502 low-pass filter section turnover frequency was approximately 15 kHz rather than the 1.5 kHz it should be to match the ssb crystal-filter passband. After some discussion with Bob Warmke (W6CYX), the entire active filter was redesigned and the IC502 high-pass filter section was converted to another low-pass filter. Both filters were modified as shown in Fig. 4 to low-pass filters with 2-kHz turnover frequencies.



☐ · PC BOARD CONNECTION

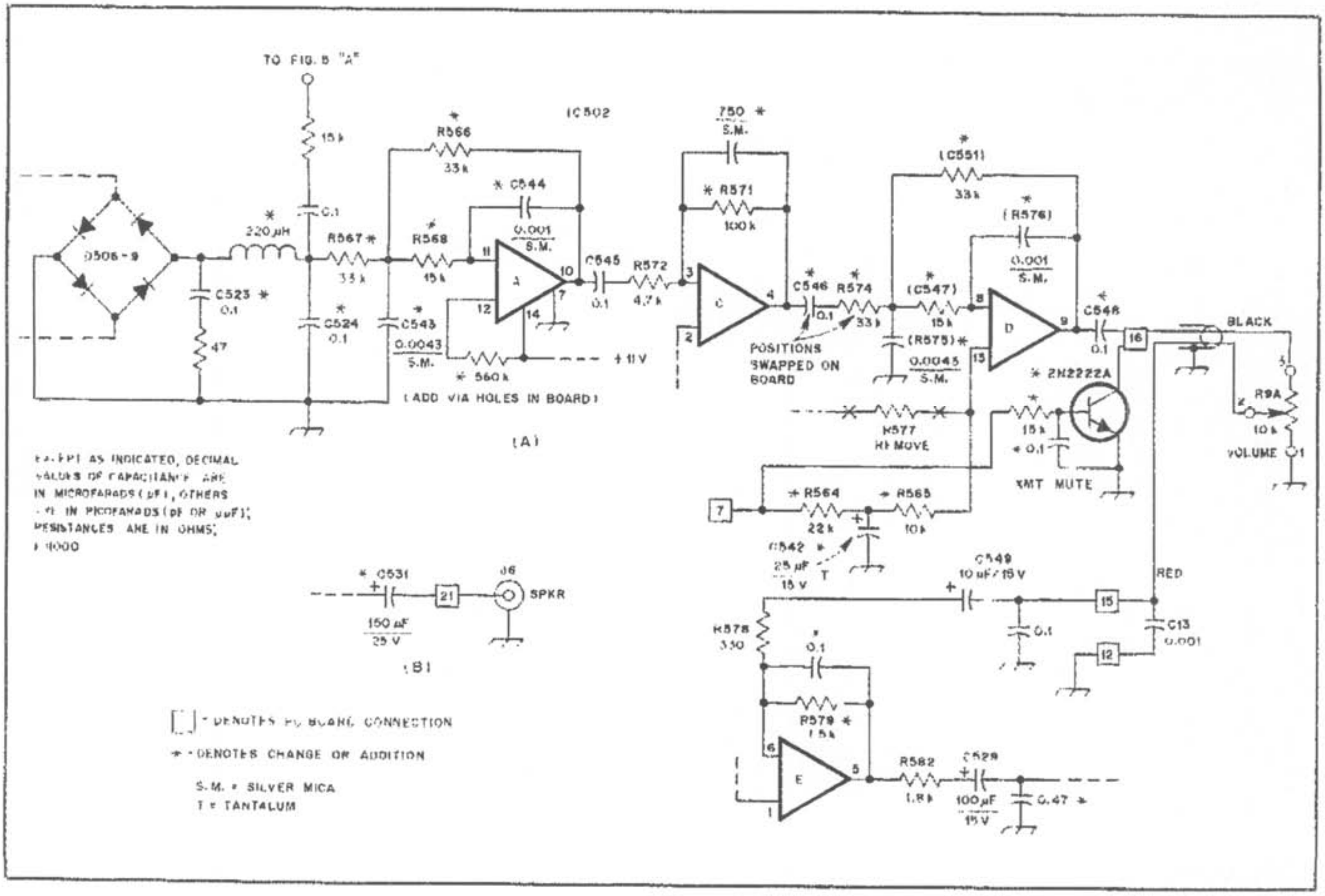
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k=1000

Fig. 5 — Schematic diagram of the audio preamplifier added to board F. Resistors are 1/4-watt, 5% types; capacitors are 50-V units. Pads for mounting Q1 through Q3 may be cut into the existing ground plane.

Attempts to properly decouple the AF board inputs to eliminate af feedthrough during transmit proved ineffective because of a ground loop. Therefore, a transistor switch was built between board terminals 12 and 16, with the transistor base connected through an RC filter to the +XMT bus. In the transmit mode, the base is pulled high and the transistor saturates, effectively shorting the filter output.

While using the HP-1144 power supply, an annoying 60-Hz hum was noticed. The hum pickup was traced to the two shielded wires that connect from terminals 15 and 16 on board F to the AF GAIN control. These two wires are in the same harness as the 117-V ac wiring to power switch S3F. Using a separate twisted pair of shielded wires, connected from the AF GAIN control to the appropriate terminals on board F, eliminated the hum.

A preamplifier to drive a cw active audio filter was constructed on the board



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF), OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k=1000

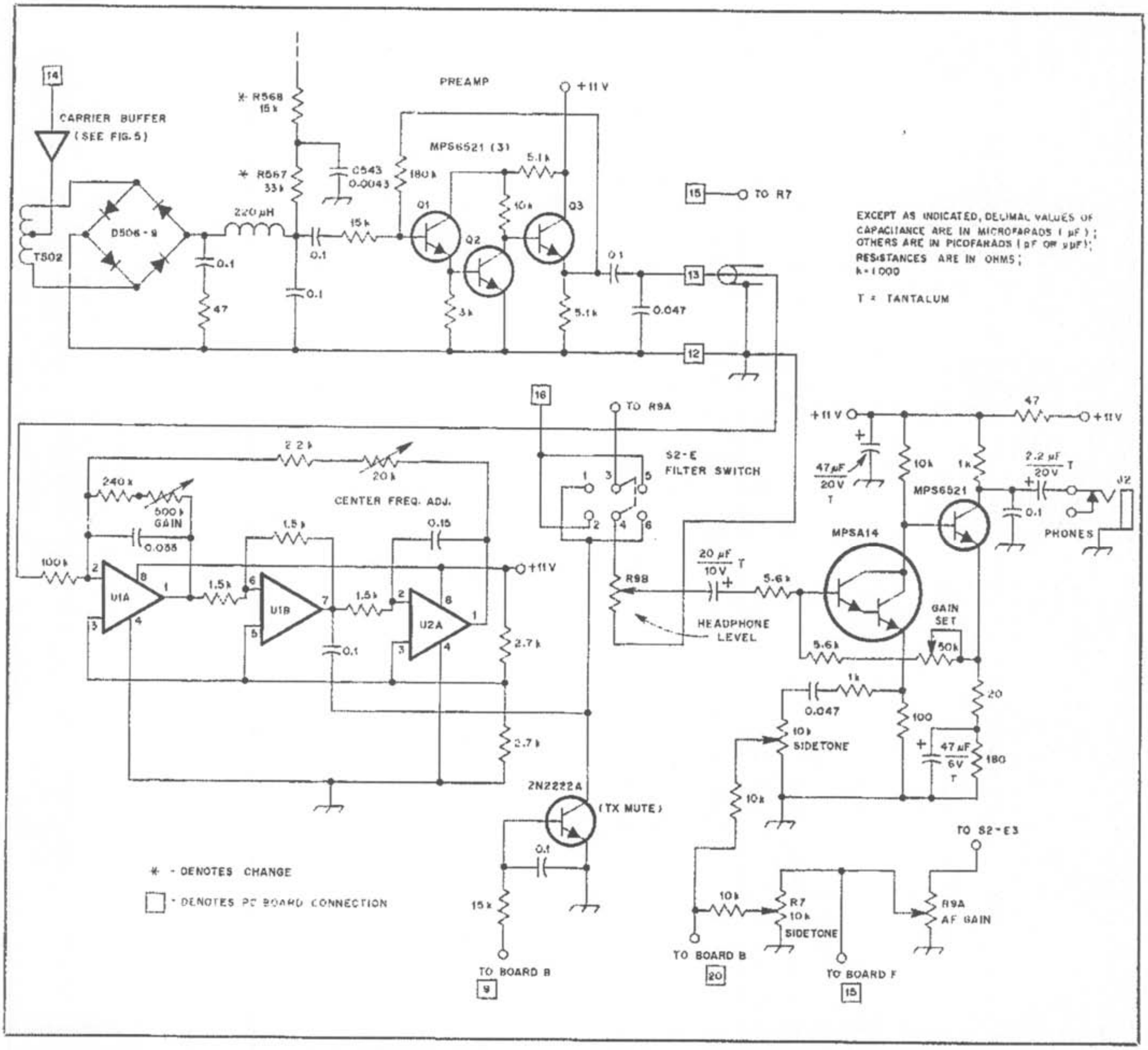
☐ - DENOTES PC BOARD CONNECTION

* - DENOTES CHANGE OR ADDITION

S.M. = SILVER MICA

T = TANTALUM

Fig. 4 — Other changes made to the receiver I-f/audio board (F) are shown here.



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k = 1000

T = TANTALUM

* - DENOTES CHANGE

□ - DENOTES PC BOARD CONNECTION

Fig. 6 — An adjustable active cw band-pass filter and headphone amplifier are assembled on a piece of perf board and interconnections made as described in the text. R9 is replaced with a dual potentiometer.

in the area between the i-f strip and the audio amplifier. Terminal 13 is removed from ground and a shielded cable is connected to the filter board. This is shown in Fig. 5.

Active CW Filter and Headphone Amplifier

Having used an HRO-60 with a sharp crystal filter, it soon became apparent that the SB-104A cw filter was not adequately separating weak cw signals from the noise. A biquad active audio filter[4] (Fig. 6) was assembled on a piece of perf board along with a low-noise, low-distortion headphone amplifier. One advantage of the filter is that both the frequency and bandwidth can be adjusted to suit the operator's preference. Wideband noise generated by the high-gain i-f amplifier is also eliminated, considerably improving the overall cw noise figure.

Because of a personal preference, the headphone amplifier was wired directly to the PHONES jack, and the af power amplifier was wired to the rear panel SPKR jack. S2E was then rewired to connect the cw or the ssb audio filter to the headphone amplifier or speaker power amplifier. The AF GAIN control (R9) was replaced with a dual, concentric-shaft 10-kΩ audio-taper potentiometer to permit independent control of the headphone and speaker audio levels.

Carrier Buffer Amplifier and Product Detector

Distorted audio, particularly noticeable on weak signals, was caused by insufficient carrier level being fed to the product detector. A scope at the LO port of T502 (see Fig. 7) revealed a 150-mV peak-to-peak sine wave indicative of inadequate drive. A buffer amplifier consisting of a transistor and an LC matching network was constructed on the circuit board using point-to-point wiring. The transistor is mounted in a 3-pin socket and the other components are wired to it. The trace from terminal 14 (CARRIER INPUT) is severed at the terminal and then connected to the board ground plane. A short length of RG-174/U is then connected to the terminal, the shields are grounded and the center conductor is soldered to the 0.01-μF ceramic capacitor in series with a 1.5-kΩ resistor at the base of the tran-

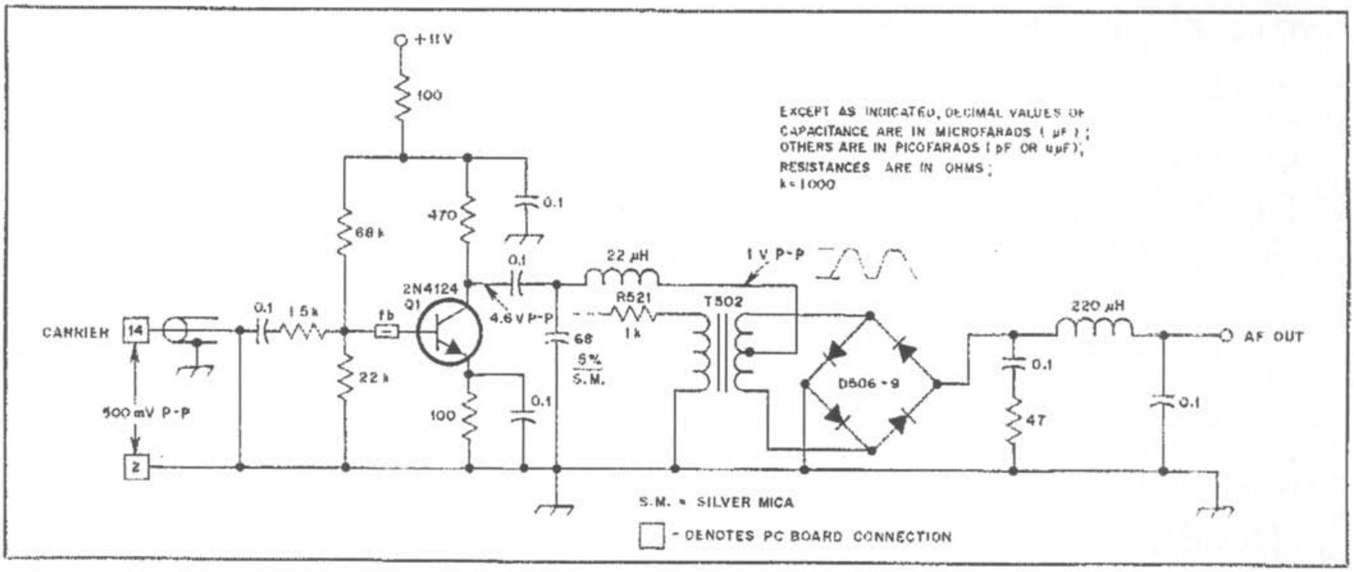


Fig. 7 — Point-to-point wiring is used to construct a buffer amplifier on board F. C522 (between T502 secondary center tap and terminal 14) must be removed.

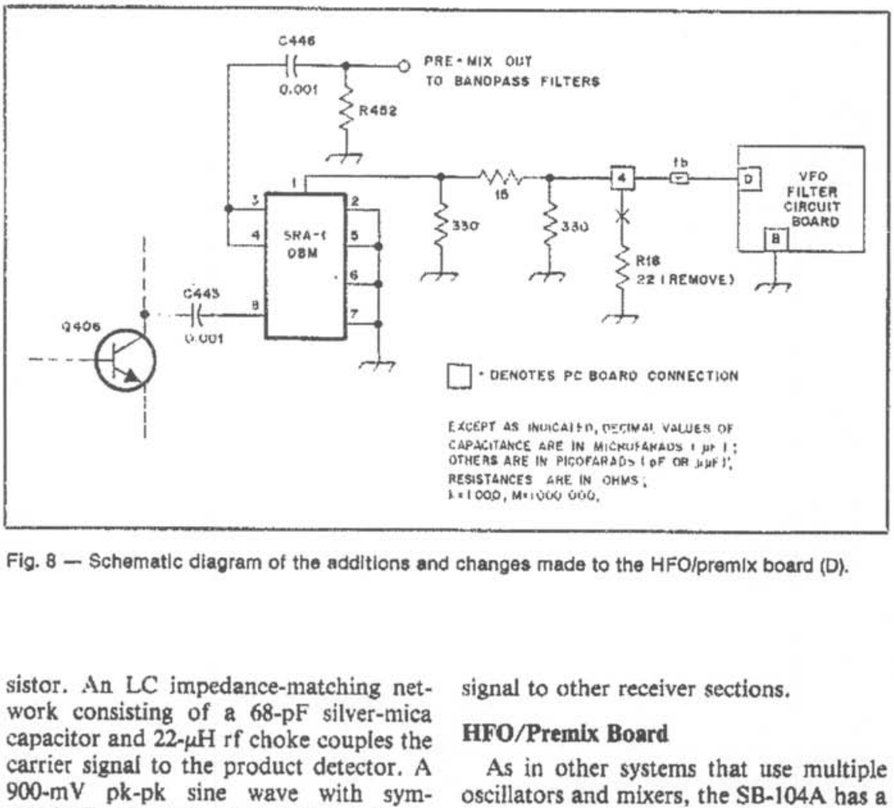


Fig. 8 — Schematic diagram of the additions and changes made to the HFO/premix board (D).

sistor. An LC impedance-matching network consisting of a 68-pF silver-mica capacitor and 22-µH rf choke couples the carrier signal to the product detector. A 900-mV pk-pk sine wave with symmetrically clipped peaks observed at the LO port indicated the correct drive level had been obtained.

Proper diode ring termination is accomplished by installing a series RC network comprised of a 0.1-µF capacitor and a 47-ohm resistor. A low-pass filter made from a 220-µH rf choke and 0.1-µF capacitor prevents the carrier signal from entering the audio circuits. The resulting recovered audio is best described as crisp and clean with negligible intermodulation distortion. As a final step, remove C519 (0.01 µF) to prevent leakage of the carrier signal to other receiver sections.

HFO/Premix Board

As in other systems that use multiple oscillators and mixers, the SB-104A has a few in-band mixing products — "birdies" — that pass through the chain and can create problems. Spurious emissions can occur in the transmitter output where band-pass filters cannot attenuate them, and receiver spurs will often interfere with the reception of a desired signal. Several spurs were traced to the pre-mixer on board D. Refer to Fig. 8. Installing a 2-dB H pad at the LO port to terminate both the DBM and the VFO filter properly did reduce the amplitude of the spurs, but did not eliminate them. The original DBM was removed and an SRA-1 DBM mounted directly on the board. If your SB-104 has been modified to the "A" version by the installation of a new VFO filter board (part no. 85-1930-1), remove the 22-Ω resistor wired between the edge connector terminal 4 and chassis ground.

Transmitter I-F Board

Transmitter output measurements revealed several in-band spurs generated by the mixer on board C. After removal of the original mixer components, an SRA-1 DBM was installed (as shown in Fig. 9) directly on the circuit board. Some modifications were made to the circuit to accommodate the new mixer. The Q301 emitter-bias network was removed from ground and wired between the emitter pad and terminal 1 of the DBM module. C314 was changed from 0.01 µF to 0.1 µF because of the low impedance of the rf port.

To terminate the LO port properly, a 2-dB H pad was constructed from R326 (changed to 430 ohms), R325 (unchanged), and another 430-ohm resistor, soldered between terminals 7 and 8 of the DBM module. An undesired low power output condition can often be solved by increasing the i-f signal level at IC301 pin 4 by reducing the resistance of R318 from 1.8 kΩ to 470 ohms.

I-F Buffer Amplifier

The omission of a wideband, low level i-f output from the SB-104A precludes the use of a Heath Scanalyzer or other i-f spectrum display. A buffer amplifier (Fig. 10) consisting of a CA3028A cascode amplifier, a toroidal transformer (T1) and a few other components was built on a piece of perf board and mounted on the underside of the chassis between circuit board sockets F and G. A 3/4 ×

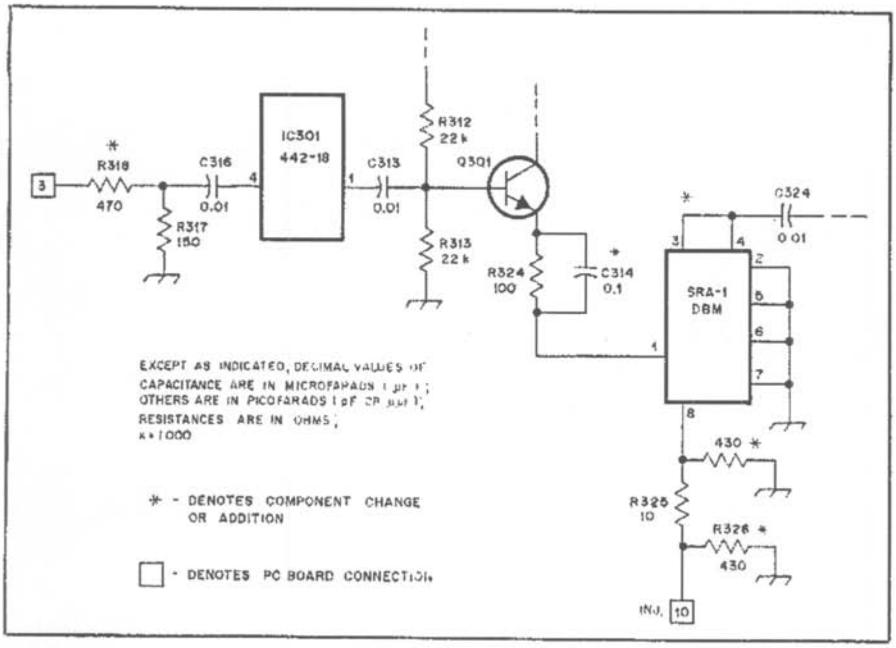


Fig. 9 — A modular DBM replaces the discrete component mixer on the transmitter i-f board (C), and some existing component values are altered.

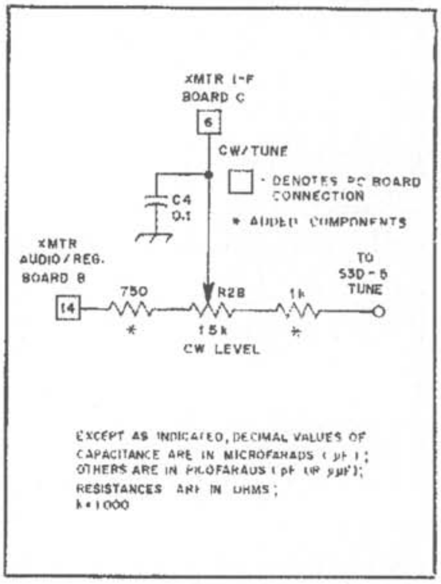


Fig. 12 — Independent adjustment of the MIC GAIN and CW LEVEL controls requires R2 be replaced by a control with concentric shafts. R2A (MIC GAIN) is not shown. Added resistors are 1/4-watt, 5% carbon types.

2-1/2-inch (mm = in. × 25.4) board will easily accommodate all components and allow space at one end of the board for the installation of a 6-32 spade lug for mounting purposes. Connect the output of the buffer amplifier to terminal 1 of board G and solder the coaxial cable removed from terminal 11 of board G to the low-impedance secondary winding of T1.

ALC Relay Switching

During operation, I noticed that a pulse was being placed on the alc bus when the transmitter was keyed. The transient was generated by the opening of the bus by the T-R relay. Moving the switching function from the relay to the unused half of the HI-LO power switch, S3E, as shown in Fig. 11, solves the problem.

Cw Level/Mic Gain

Independent control of the CW LEVEL and MIC GAIN functions was desired. So, R24A was replaced by a 100-kΩ/1-kΩ dual, concentric-shaft potentiometer. To obtain better control of the CW LEVEL, the range of the control was reduced as shown in Fig. 12.

VOX Instability

Rf feedback on the +11-V bus of circuit board B can result in the VOX circuit malfunctioning when using an amplifier.[7] A 0.1-µF ceramic capacitor connected between pins 7 and 14 of IC201 eliminates the feedback.

Another source of erratic VOX operation can be cured by substituting a

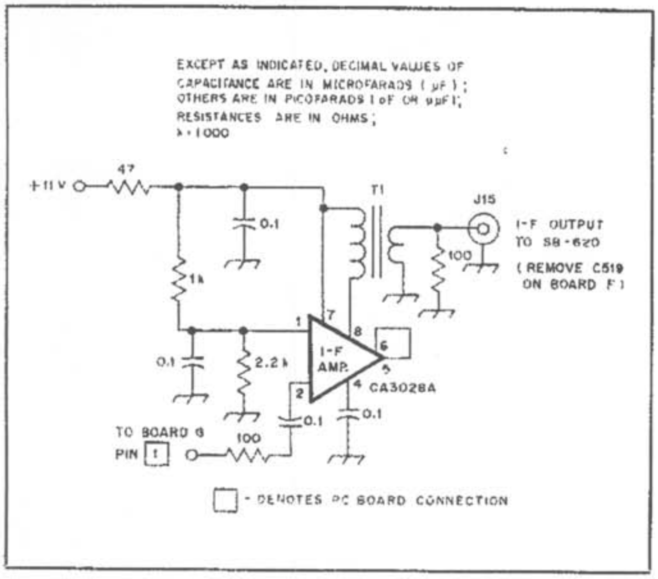


Fig. 10 — Schematic diagram of the i-f buffer amplifier added to the SB-104 to permit use of an i-f spectrum display. All resistors are 1/4-watt, 5% types; capacitors are 50-V units. T1 consists of 20 primary turns and 4 secondary turns wound on a T50-2 core.

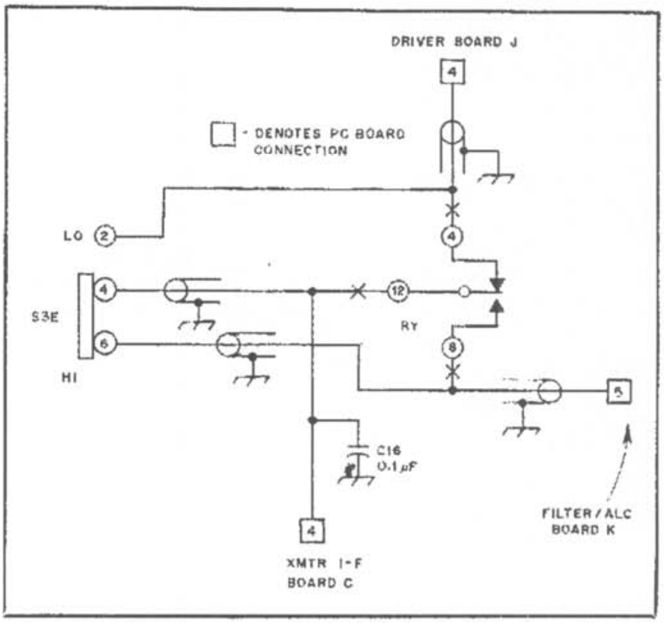


Fig. 11 — Alc/output board (K) changes. Heath component identification is used in the schematic diagram.

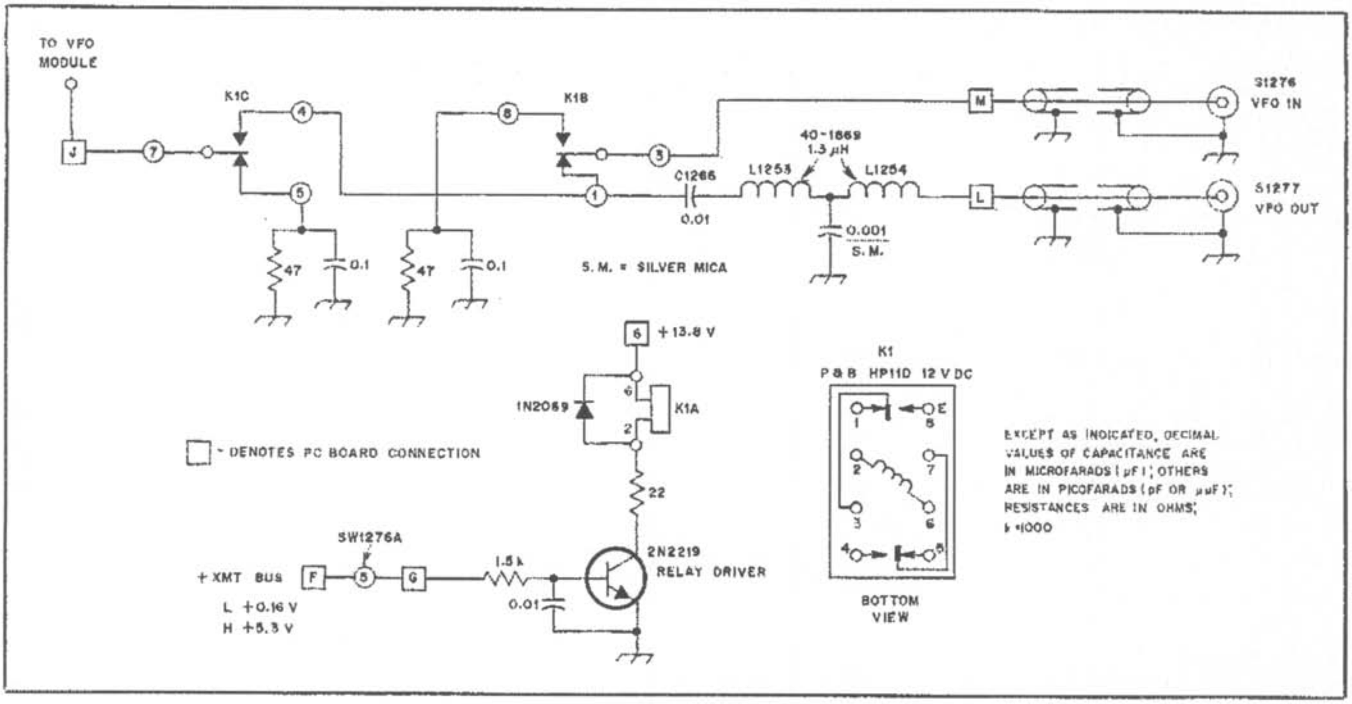


Fig. 13 — A relay replaces the transistor switches used in the SB-644 remote VFO. Resistors are 1/4-watt, 5% carbon composition types; capacitors are 50-V units.

Darlington pair for Q203 on board B. Relay driver Q207 can fail because of high voltage transients should D204 fail. A 0.1-μF capacitor between the collector of Q207 and the board ground plane will dampen any such transients.

Diode Substitution

Replacement of the four discrete DBMs will free 16 FH-1100 hot-carrier diodes (part no. 56-87). Twelve of these should be used to replace the band-pass filter switching diodes (part no. 56-24). A noticeable improvement in receiver sensitivity and noise figure will result, as the hot-carrier diode has significantly less internal capacitance and a much lower conduction voltage. After substituting the diodes, realign the receiver front-end filters using a sweep generator or a noise source.

SB-644 VFO Modifications

Conversion of the SB-104 to the "A" version creates a switching interface problem when using the SB-644 remote VFO. The SB-644/A assembly manual (part no. 595-2055-02) suggests a simple way of solving several quirks in the original unit. The necessary components to make the conversion, including a new circuit board and the toroidal inductors for the low-pass filter, were purchased from Heath and installed.

A significant reduction of VFO harmonics and a considerable improvement in VFO isolation can be achieved by replacing the transistor switches with a Potter and Brumfield HP11D dpdt 12-V dc relay. See Fig. 13. As the fixed-frequency feature of the transceiver was not used, the relay was mounted directly on the circuit board in the space intended for the crystal-oscillator circuit.

HP-1144 Overvoltage Crowbar

One unfortunate experience of a few SB-104 owners involves a collector-to-emitter short in one of the power supply series pass devices, which places approximately 22 volts on the 13.8-V bus. Component destruction is immediate and expensive, and repair is difficult.

In 1977, Heath offered a crowbar field-retrofit kit (part no. 830-33) that will protect the transceiver should an over-voltage condition occur. This modification should definitely be made, as it will eliminate a possible source of grief. If rf hash is created by the power supply, a 0.02 μF/100-V ceramic capacitor should be wired in parallel with each bridge-rectifier diode to act as a transient bypass.

Addendum

When instability is encountered in the high-gain rf and af amplifier stages used in the transceiver, it can often be traced to inadequate shielding and bypassing. Several rf and i-f circuits in the SB-104 were found to be at the threshold of oscillation during the transition from receive to transmit. Usually the problem can be solved by improving the circuit decoupling from the V_{cc} bus. A number of 0.1-μF and 0.001-μF/50-V ceramic capacitors were eventually installed in several circuits.

Every circuit board terminal with a dc function was bypassed with a 0.1-μF ceramic capacitor where it entered the board. Some of the 0.01-μF capacitors in the original circuit were replaced with 0.1-μF units. Distribution points for the +5-, 11- and 13.8-V dc sources were bypassed with a parallel capacitor combination consisting of a 15-μF/20-V tantalum and 0.1-μF and 0.001-μF ceramic units. The alc bus and all unshielded rf and af signal wires were replaced with lengths of RG-174/U coaxial cable, with the shield grounded only at one end.

I hope the preceding modifications will be of help to other SB-104 owners. The resulting improved performance should increase your operating enjoyment considerably. Please include an s.a.s.e. with any correspondence. QST

Notes

[1] Heath Co., SB-104A modification kit (part no. SBM-104-2).

[2] D. Cheadle, "Selecting Mixers for Best Intermod Performance," *Microwaves*, November and December 1973.

[3] Mini-Circuits, 2625 East 14th St., Brooklyn, NY 11255.

[4] W. Hayward and D. DeMaw, *Solid State Design for the Radio Amateur* (Newington: ARRL, 1977).

[5] R. Jefferis, WB6OQP; private communication.

[6] J. Rohler, "Biquad Bandpass Filter for CW Use," *Ham Radio*, June 1979, p. 70.

[7] See note 4.

Bibliography

DeMaw D. and G. Collins, "Modern Receiver Mixers for High Dynamic Range." *QST*, January 1981, p. 19.

Tashner, R. "Improved Receiver Performance for the Heathkit SB-104A." *Ham Radio*, April 1981, p. 78.

Woodward, G., ed. *The Radio Amateur's Handbook*. Fifty-ninth edition. Newington: ARRL, 1982.