

# *A High-Performance Homebrew Transceiver: Part 2*

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*Let's begin our look inside this transceiver with the IF board. It contains the IF amplifier, AGC, noise-blanker and RF speech clipper circuits.*

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By Mark Mandelkern, K5AM

**P**art 1 gave a general description of the K5AM homebrew transceiver, built for serious DX work and contest operating.<sup>1</sup> This article gives complete circuit details for the IF board. While obtaining gain at 9 MHz is routine, care is taken to ensure optimal AGC performance, non-crunch noise blanking and QRM-piercing transmit audio.

The IF board in any radio is perhaps its most crucial component. While the other parts of the radio are certainly important, converting to the IF—and later to audio—are essentially trans-

lation functions. The IF board must provide most of the gain; it must control this gain automatically and smoothly, provide all of the selectivity, blank out noise and also process the transmitted signals.

## **IF-Board Features**

The IF board is shown in Fig 1. Relay-switching of the SSB and CW filters avoids diode-generated distortion. This also reduces “blow-by,” resulting in high ultimate attenuation. Sharp filters are used near the IF amplifier’s output, as well as at the input. This improves the signal-to-noise ratio.

Other features include:

- A high-performance, no-pop, no-click, hang-AGC circuit<sup>2</sup>
- A non-crunching noise blanker<sup>3</sup>

- A sensitive integrating squelch circuit (see Reference 2)
- RF speech clipping for transmitted SSB with a punch
- Special operating features (discussed in Part 1)

## **The Circuit**

A general description of the IF board has been given in Part 1. The IF board consists of the IF amplifier, noise blanker and AGC section. The block diagram in Fig 2 shows the arrangement of the three sections as well as the individual stages of the IF amplifier. An explanation of the terminal designations is given in Table 1. The attenuator pads at the input and output of each crystal filter provide proper out-of-band terminations,

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<sup>1</sup>Notes appear on page 8.

reduce distortion and improve the skirt and ultimate selectivity. The 9-dB pad before the second SSB filter compensates for the additional loss of the CW filter, and assures proper performance of the RF speech clipper (see below). Fig 3 shows the IF-amplifier schematic diagram. The various control lines are provided by the logic board.

#### RF Speech Clipper

A general description of the RF speech clipper, including microphone calibration and operating instructions, was given in Part 1. The clipper has three sections. The DSB amplifier, Q8, controls the amount of RF clipping by adjusting the input level to the IF amplifier, using the **CLIPPING** control on the front panel. When receiving, or when transmitting in the carrier modes (CW, AM, FM), the DSB amplifier (Q8), the clipping meter amplifier (Q9) and the SSB output buffer (Q10) are disabled by control line  $\beta$ SSB. The clipper proper consists of the two diodes in the drain circuit of Q4. The third section of the RF speech-clipping system provides metering on the front panel. It consists of amplifier Q9 and two op amps; see Figs 2 and 5. Clipping-meter amplifier Q9 parallels Q4, with a detector at the output rather than clipping diodes. This detector provides an output that tracks the amount of conduction in the clipping diodes. The detector output is amplified by a peak-indicating circuit, shown in Fig 5, and displayed on meter M1. The peak-indicating circuit gives the operator true indications of RF speech clipping level.

One special element in the clipper circuit is crucial for proper performance. Credit for it is due to Robert Sherwood, NC0B, and it was communicated to me by Paul Kollar, W8CX5. This crucial element is the isolation between the clipping diodes and the following SSB filter. Rob conducted extensive tests on the CX7 clipping circuit—which had no isolation. He found that the clipping circuit caused distortion because it was an inadequate termination for the filter. The necessary isolation may be provided by either a pad or a buffer stage. In this circuit, an additional 9-dB pad is added ahead of the SSB filter. The pad also conveniently compensates for the extra loss of the CW filter. The resultant 12 dB of attenuation provides a stable load for clipping stage Q4 as well as proper termination for the filter.

#### Noise Blanker

The noise blanker has been described in Reference 3. When not in use, the noise blanker is switched completely out of the signal path by relay K1, at the input to the IF amplifier. This avoids any possible signal degradation by the blanker gate diodes. The noise-channel gain is set by the front-panel **BLANKER** control through control line  $\delta$ N and the op-amp circuit shown in Fig 5.

A tap on the noise amplifier provides a signal to feed an external monitor scope via the **SCOPE** (output) jack on the rear panel. A scope is very useful for locating nearby power-line noise. Attempts to locate such noise by watching the S-meter indication while rotating the antenna are doomed; the meter only shows the aggregate noise peak. A scope, on the other hand, can be used to determine the direction of the individual noise sources, since each noise source tends to have a distinctive oscillograph signature.

This precise information can then be relayed to the local power company.

#### An AGC Update

More experience on the 160-meter band with extremely weak DX signals under high-atmospheric-noise conditions has led to a further AGC improvement. Under such conditions, it is best to use zero hang time, in the **FAST** mode. The modification is simple. Look at Fig 8 in Reference 2, disconnect the Fast Adjust trimmer from terminal F of the **AGC HANG TIME** switch; then connect terminal F to the collector of the discharge transistor, Q304.

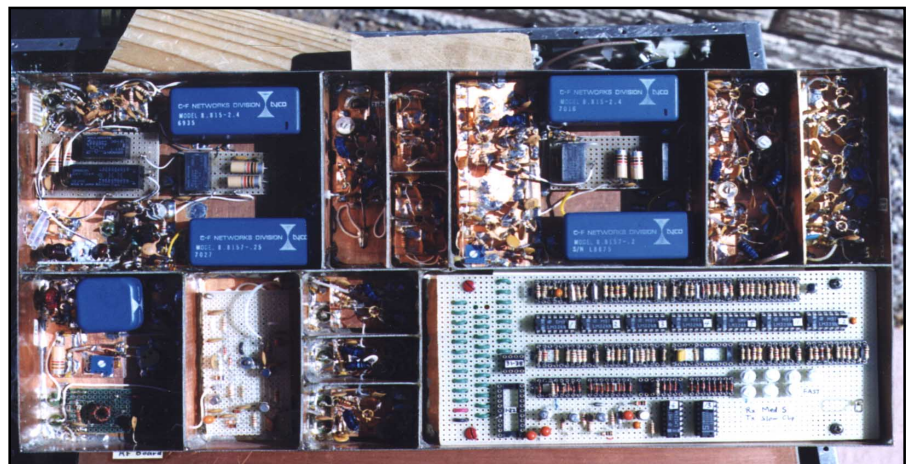
#### Construction

The general method of construction was described in Part 1, where the need for careful shielding and lead filtering was emphasized. Each power and control lead to the IF board passes through a  $\pi$ -section filter (two 10-nF bypass capacitors and a 1-mH choke) and a 1-nF feed-through capacitor.

**Table 1**

Terminals on the diagrams are labeled according to the function of the signal or control line. The characteristic of each line is indicated by an initial Greek letter, according to the following scheme:

$\alpha$	alpha	Line keyed to ground, such as PTT and Keyline
$\beta$	beta	Control line that switches nominally from +15 to -15 V
$\delta$	delta	dc control line
$\iota$	iota	Local oscillator injection voltage for a mixer
$\rho$	rho	Rheostat or potentiometer control line
$\sigma$	sigma	Signal
$\mu$	mu	Control line that switches nominally from 0 to -15 V
$\phi$	phi	RF voltage obtained from an oscillator



**Fig 1**—Top view of the IF board in the K5AM homebrew transceiver. Several shielding-compartment covers have been removed for this photo. The IF amplifier is at the top, with signals traveling left to right. The noise blanker and AGC sections are below, on the left and right, respectively. (Photo by Lisa Mandelkern.)

In passing signals to and from the board, it is important to avoid any signal leakage. Teflon-insulated miniature coax, type RG-178B, facilitates good connections because it allows safe use of a soldering iron. Simply drill a hole (# 51 bit) through the circuit board, remove the cable's outer jacket and solder the braid to both sides of the board.

The board's bottom surface is shown in Fig 6. Each IF stage is built dead-bug style on a sub-board mounted inside its separate compartment. Power and control leads connect to the feed-through capacitors on the floor of the main board. Coax cables run through the floor and up to the sub-boards. The AGC sub-board is constructed using wire-wrap methods on perf-board.

### Alignment

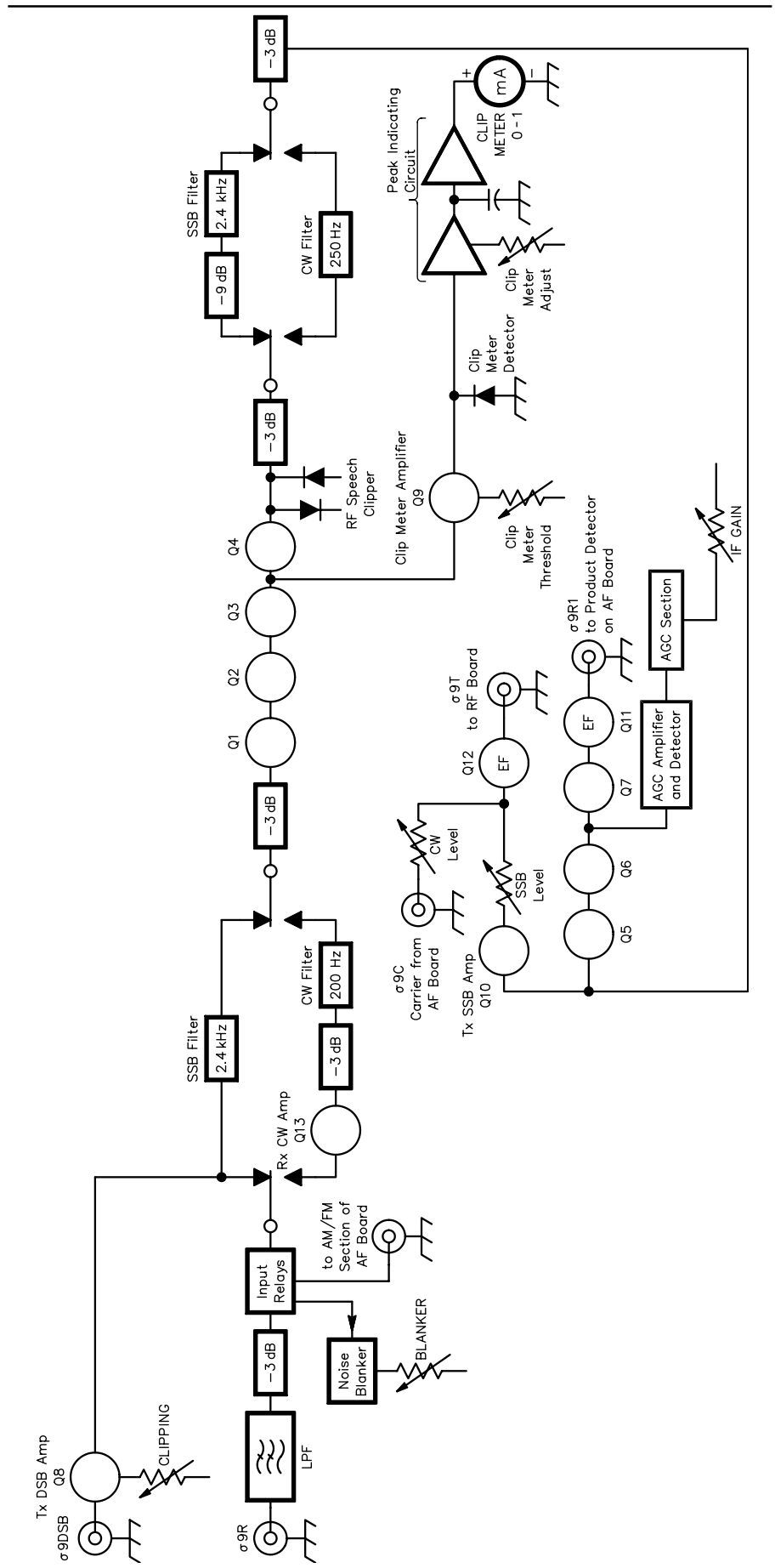
The IF amplifier operates at a gain of 90 dB overall, between terminals  $\sigma 9R$  and  $\sigma 9R1$ . First, the no-signal AGC line level is set to 2.0 V by the Rx Gain Adjust trimmer in the AGC section (see Fig 7 in Reference 2).

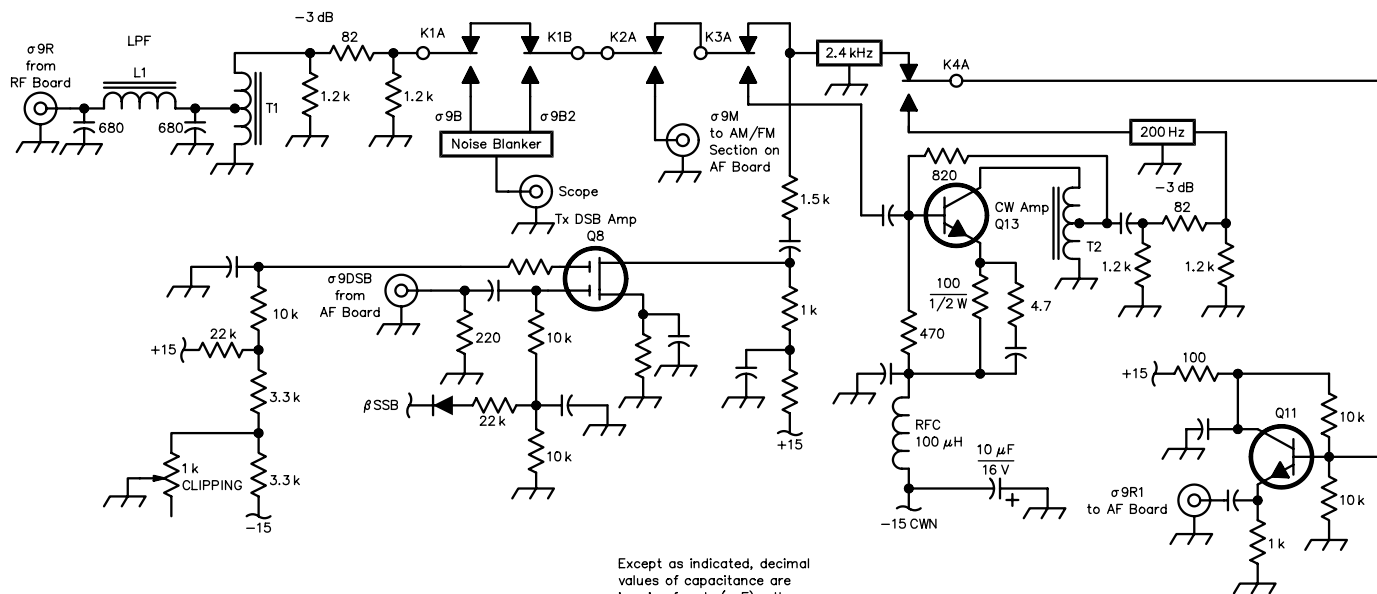
Then, with the AGC off, and an input at  $\sigma 9R$  of -100 dBm, adjust the IF Gain Adjust trimmer at Q7 for an output at  $\sigma 9R1$  of 200 mV (P-P, -10 dBm).

The output level of the IF amplifier with the AGC on is set by the AGC Adjust trimmer (see Fig 6 in Reference 2). With a -70 dBm signal at terminal  $\sigma 9R$ , adjust the trimmer for 200 mV (P-P) output at terminal  $\sigma 9R1$ .

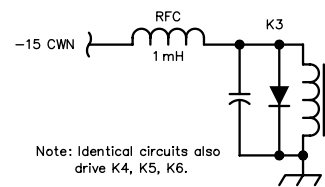
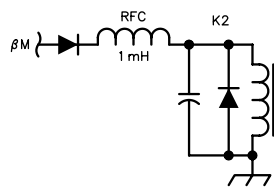
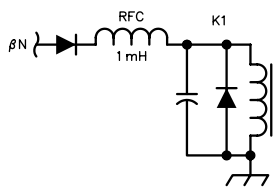
The S-Meter Adjust trimmpot, shown in Fig 9 of Reference 2, sets the full-scale S-Meter reading at 100 dB above the AGC threshold. The S-Meter threshold is the same as the AGC threshold. The S-Meter is calibrated directly, from 0 to 100 dB above the

**Fig 2—IF board block diagram.** This shows the individual stages of the 9 MHz IF amplifier. The AGC section has been described in Reference 2, and the noise blanker in Reference 3. Potentiometers labeled in all capital letters are front panel controls; others are circuit-board trimmers for internal adjustment. The transistors shown are all small-signal, dual-gate, VHF-type MOSFETs, except Q13, a strong bipolar, and the small bipolar emitter followers labeled "EF." The gain of the Q13 stage compensates for the additional loss of the CW filter. The triangles indicate op amps. When receiving, the input is at terminal  $\sigma 9R$ ; the output is at terminal  $\sigma 9R1$ . For transmitting SSB, the input is at terminal  $\sigma 9DSB$ . For transmitting in the carrier modes (CW, AM, FM), the input is at terminal  $\sigma 9C$ . Terminal  $\sigma 9T$  is the transmitting output.





Except as indicated, decimal values of capacitance are in microfarads ( $\mu\text{F}$ ); others are in picofarads ( $\text{pF}$ ); resistances are in ohms; k=1,000.



Note: Identical circuits also drive K4, K5, K6.

**Fig 3—IF amplifier schematic diagram.** Each resistor is a  $1/4$ -W carbon-film type. The diodes are all small-signal silicon types, such as 1N4148. The unlabeled coupling and bypass capacitors are all 10-nF disc ceramic types. Also, each control and power terminal has a bypass capacitor that is not shown. The trimmer capacitors are 5 to 18-pF miniature ceramic types. The crystal filters, salvaged from an irreparable CX7, have an impedance of 220  $\Omega$ ; the attenuators and transformers are designed accordingly. Potentiometers labeled in all capital letters are front-panel controls; others are circuit-board trimmers for internal adjustments. Certain other simplifications have been incorporated in this schematic to save space and improve clarity. In the MOSFET stages, the gate-2 isolation resistors, source resistors and drain-circuit decoupling resistors are all unlabeled; each is 100  $\Omega$ . Note that there is no bypass capacitor directly at gate 2; the resistor serves as a parasitic suppressor, which is more effective than a ferrite bead. As a further simplification, circuit elements for stages Q2 through Q7 that are identical to those of the preceding stage are omitted. An obvious exception: The drain circuit of Q5 is the same as that of Q1. Not shown on this diagram is the additional filtering at each terminal; it is described in the text under “Construction.” The noise blanker was described in Reference 3; some additional details are given in Fig 4. The AGC section was described in Reference 2; the AGC amplifier and detector circuits, located in the IF-amplifier section, are shown in Fig 6 of Reference 2. The clipping-level circuit requires only a single lead to the front panel, and provides a range of  $-0.6$  to  $+2.0$  V for gate 2 of Q8; this allows a 25-dB gain variation. The tuned circuits at the inputs to stages Q1 and Q5 provide a voltage gain. On the other hand, the inductors in all the drain circuits are untuned, and function simply as chokes. The R/T line disables Q5 through Q7 during transmission; it switches from 0 to  $-15$  V. The squelch circuit (part of the AGC section) disables Q7 by control line  $\beta\text{SQ}$ . The 1- $\mu\text{F}$  capacitor in this muting circuit is a monolithic ceramic type.

**K1**—Low-loss, high-isolation RF DIP relay; DPDT, 12-V dc. Omron #G5Y-254P-DC12; Digi-Key #Z704 (Digi-Key Corp, tel 800-344-4539, 218-681-6674, fax 218-681-3380; [www.digikey.com](http://www.digikey.com)).

**K2-K6**—Low-loss, high-isolation RF DIP relay; SPDT, 12-V dc. Omron #G5Y-1-DC12; Digi-Key #Z724.

**L1**—0.7  $\mu\text{H}$ , 15 turns #26 enameled wire on a T-37-6 powdered-iron toroidal core.

**L2-L8**—14  $\mu\text{H}$ , 16 turns #26 enameled wire on an FT-37-61 ferrite toroidal core. L2 and L6 are tapped 4 turns from the cold end.

**Q1-Q10**—Small-signal VHF-type dual-gate MOSFET. Type 3N140 is used here, but any similar type may be substituted.

Type NTE 221 is available from Hosfelt Electronics Inc, tel 800-524-6464, 740-264-6464, fax 800-524-5414, fax 740-264-5414.

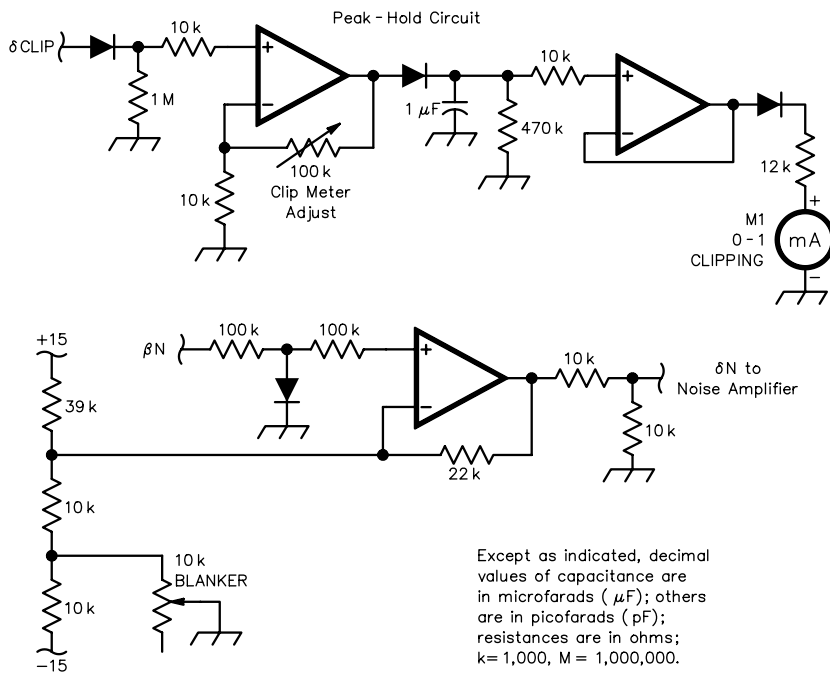
**Q11-Q12**—2N2222A.

**Q13**—2N5109.

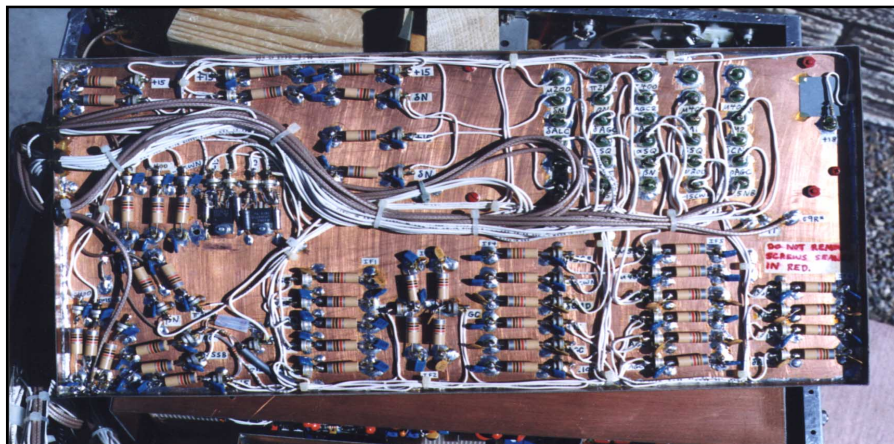
**T1-T3**—8 bifilar turns #26 enameled wire on an FT-37-61 ferrite toroidal core.







**Fig 5—Control-section schematic diagram.** Each op amp is one section of an LM324N, powered from the  $\pm 15\text{-V}$  rails. The  $1\text{-}\mu\text{F}$  capacitor in the peak-hold circuit is a monolithic ceramic type. The blanker gain circuit, requiring only a single lead to the front panel, provides a range of  $-3$  to  $+2$  V for the gate-2 leads of the noise-amplifier MOSFETs. The circuit also disables the noise amplifier when not in use, by means of control line  $\beta\text{N}$ . For general notes on the schematic, refer to the caption for Fig 3. This control section occupies a portion of the AGC sub-board.



**Fig 6—Bottom view of the IF board.** Effective filters are installed at each terminal, and coax cables are soldered directly to the double-sided circuit board (see text). To minimize connector troubles, the board is hard-wired to the radio; a 12 inch long bundle of wires and cables allows the board to be easily lifted and serviced. The IF amplifier has unusually high gain, and operates at an unusually low signal input level. This is done as a gain-distribution method to achieve high dynamic range. The stages ahead of the sharp SSB and CW crystal filters can operate at relatively low gain and are not easily overloaded. The stages after the filters are shielded from signals outside the filter passband. The high gain of the IF amplifier makes it vulnerable to stability problems. The low signal input level makes it vulnerable to entrance of BFO energy. These vulnerabilities create the necessity for exceptional filtering and shielding of the IF strip and account for the large number of RF chokes, bypass capacitors and feed-through capacitors on the bottom of this board. The careful filtering and shielding also contributes to the effective ultimate attenuation of the filters. (Photo by Lisa Mandelkern.)

AGC threshold. The AGC threshold at terminal  $\sigma 9\text{R}$  is  $-100$  dBm. The threshold is  $-110$  dBm at the  $40\text{-MHz}$  input on the RF board, and nominally  $-130$  dBm at the antenna. The MDS (bandwidth =  $2$  kHz) at terminal  $\sigma 9\text{R}$  is  $-116$  dBm. The MDS at  $40$  MHz is  $-126$  dBm, and nominally  $-138$  dBm at the antenna.

Setting the Clip-Meter Threshold trimmer requires a means of precisely determining the point at which clipping begins. This is done with a dual-trace scope by monitoring the IF amplifier signal level at the input to Q4, and at the transmit-output terminal,  $\sigma 9\text{T}$ . With the front-panel CLIPPING control set to minimum, the two-tone audio test oscillator and MIKE controls are set to obtain  $1$  dB of compression at the output; the Clip Meter Threshold trimmer is then adjusted for a  $10\%$  meter indication. The CLIPPING control is now advanced to obtain a  $20\text{-dB}$  increase at the input to Q4, and the Clip Meter Adjust trimmer in the control section, Fig 5, is adjusted for a full-scale indication. Finally, a meter calibration chart is made, so the operator may select a desired degree of RF compression. For normal use,  $3$  dB is adequate and pleasant sounding. For extreme conditions,  $10$  dB may be used effectively.

When transmitting, the DSB input level at terminal  $\sigma 9\text{DSB}$  is nominally  $200$  mV P-P; the carrier input level at terminal  $\sigma 9\text{C}$  is  $500$  mV P-P. The SSB Level and CW Level trimmers are adjusted to obtain  $200$  mV P-P output at terminal  $\sigma 9\text{T}$ . The AGC sub-board reduces the gate-2 voltage of the MOSFETs to about  $1.2$  V during each transmission; this can be varied as required by a trimmer in the AGC section (see Fig 7 in Reference 2).

## Summary

This article gives a complete description of the  $9\text{-MHz}$  IF board in a high-performance homebrew transceiver. The board is designed for optimal performance; it includes sharp filters for SSB and CW, a high-performance hang-AGC circuit, a non-crunching noise blanker and a powerfully effective RF speech clipper.

## References

1. M. Mandelkern, K5AM, "A High-Performance Homebrew Transceiver: Part 1," *QEX*, March/April 1999, pp 16-24.
2. M. Mandelkern, K5AM, "A High-Performance AGC System for Home-Brew Transceivers," *QEX*, Oct 1995, pp 12-22.
3. M. Mandelkern, K5AM, "Evasive Noise Blanking," *QEX*, Aug 1993, pp 3-6. □