A QRP SSB/CW Transceiver for 14 MHz

Part 1: Exotic circuitry and hard-to-find components aren't necessary if you want to build excellent performance into a home-brew SSB/CW transceiver: Careful design is the key.

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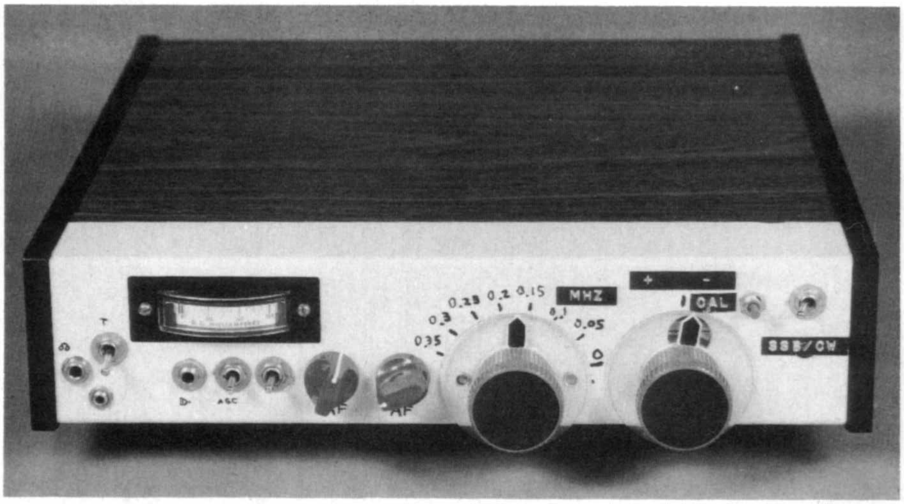

It's hard to justify the construction of a complete SSB/CW transceiver in this "modern" era of readily available commercial equipment. The popular, multiband MF/HF transceivers offer excellent performance, often at a reasonable cost. Still, I feel a twinge of guilt when I use them. They offer nothing of the feeling of exploration that I've grown to expect from Amateur Radio.

The rig described here is not a copy of the usual "appliance." I've used the project as a vehicle to investigate alternative circuits and a block diagram that departs from the traditional. The circuit is simple and modular, with flexibility that allows for later changes.

I present this rig in order to encourage other home-brew enthusiasts to give QRP SSB a try. I'll not dwell on the standard circuits that are already covered in *Solid-State Design* or in *The ARRL Handbook.*[1,2] Rather, I'll emphasize only those circuits that depart from the traditional. This is intended to be an idea article rather than a construction piece. There are no circuit boards or patterns available for this rig. All construction was done using "ugly" methods.[3]

System Architecture

The filter method was chosen for this transceiver. While that is generally considered to be "the only choice," phasing methods should not be overlooked for an experimental transceiver.[4] The block diagram is shown in Fig 1.

The traditional filter transceiver shares one or more crystal filters between the receive and transmit modes. I wanted to avoid the compromises and complexities of filter switching, so I decided to use separate filters for each function. The transmit and receive modules can then be used for completely independent operation. This might be especially interesting for use with, for example, a VHF/UHF station for OSCAR communications.

Commercial crystal filters from my junk box were used in this project. They are all 9-MHz circuits that are, fortunately, well matched to each other. A 5-MHz local oscillator drives both the receiver and transmitter mixers. Budget-minded builders may elect to built their own filters.[5,6]

The Receiver

The receiver is very much like the Progressive Receiver that's been in *The ARRL Handbook* for several years.[7] The front end and VFO are presented in Fig 2. I initially used a VFO variable capacitor with a vernier drive mechanism. Problems occurred with the mounting, however. The VFO was rebuilt without a vernier. Instead, two capacitors were used. One (C1, **BANDSET**) tunes the entire band, while the other (C2) is a bandspread control with a total range of only 25 kHz. This scheme seems to be practical for a simple transceiver.

The receiver begins with a doubly tuned preselector and a diode-ring mixer (U1, a Mini-Circuits SBL-1). This is followed by a bipolar transistor (Q3, an NEC99532) in a negative-feedback IF amplifier. A ferrite transformer (T4) matches the IF amplifier to the receiver crystal filter (FL1) as shown in Fig 3. The filter I used is similar to the KVG XF-9B. The less-expensive KVG XF-9A was tried in this application and was found wanting for stop-band attenuation.

The crystal filter drives an MC1350P IF amplifier (U2) and a diode-ring product detector (U3, an SBL-1). I would discourage a builder from departing from a diode-ring detector. An NE602 detector was tried, but suffered from severe in-band intermodulation distortion.

The BFO signal is low-pass filtered before driving the detector. A reduced-voltage sample of the BFO energy is routed to the transmit balanced modulator (to be described in Part 2 of this article). Care was taken to extract the sample from a point away from the detector. (The diode-ring detector clips the BFO waveform; clipped carrier-oscillator drive for the balanced modulator is undesirable.)

The audio amplifier (Q6-Q8 and U4) is standard. However, the audio-derived AGC system departs from the usual. U5A (one section of an LM324) amplifies the audio to a level suitable for

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[1] Notes appear on page 20.

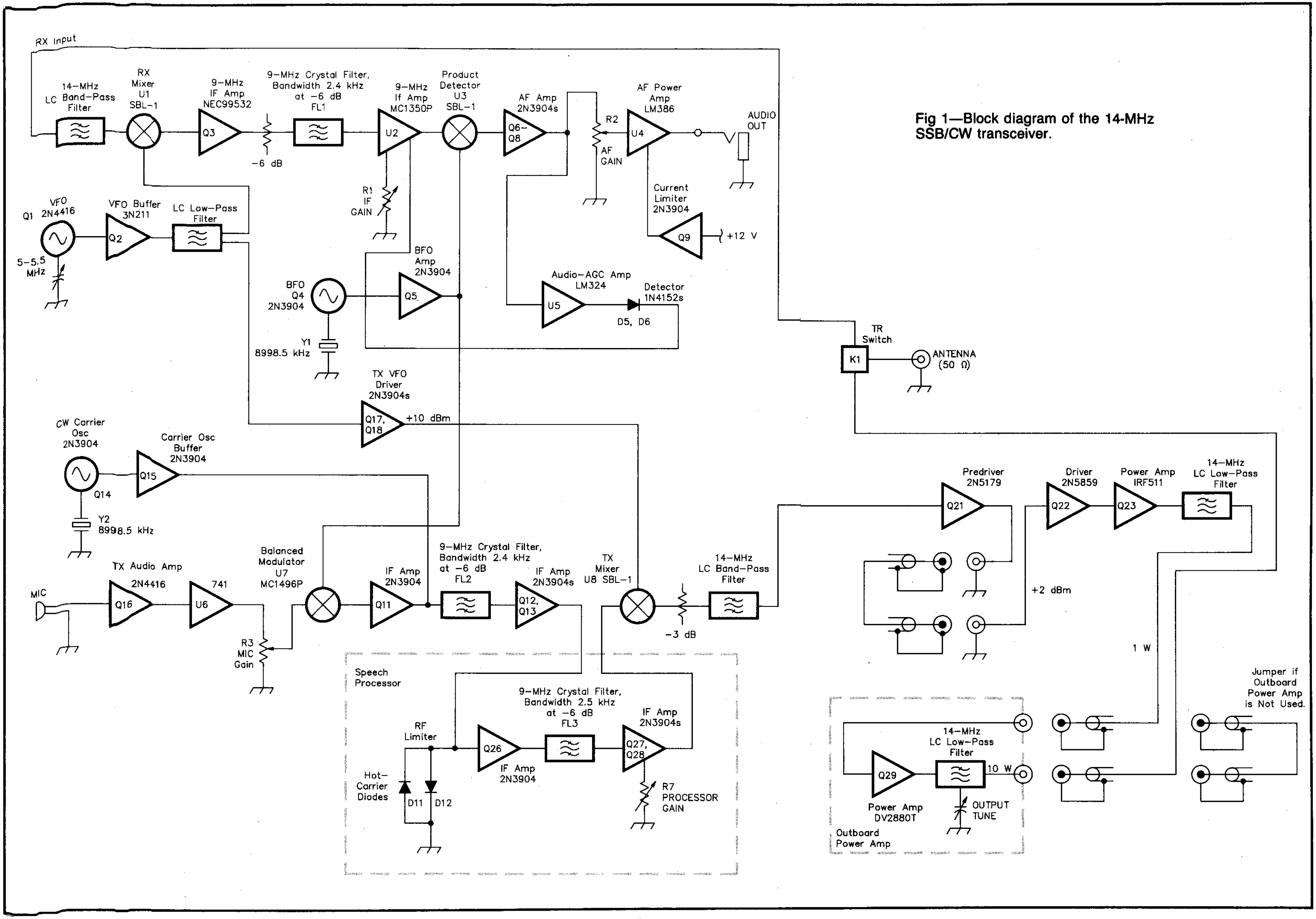

Fig 1—Block diagram of the 14-MHz SSB/CW transceiver.

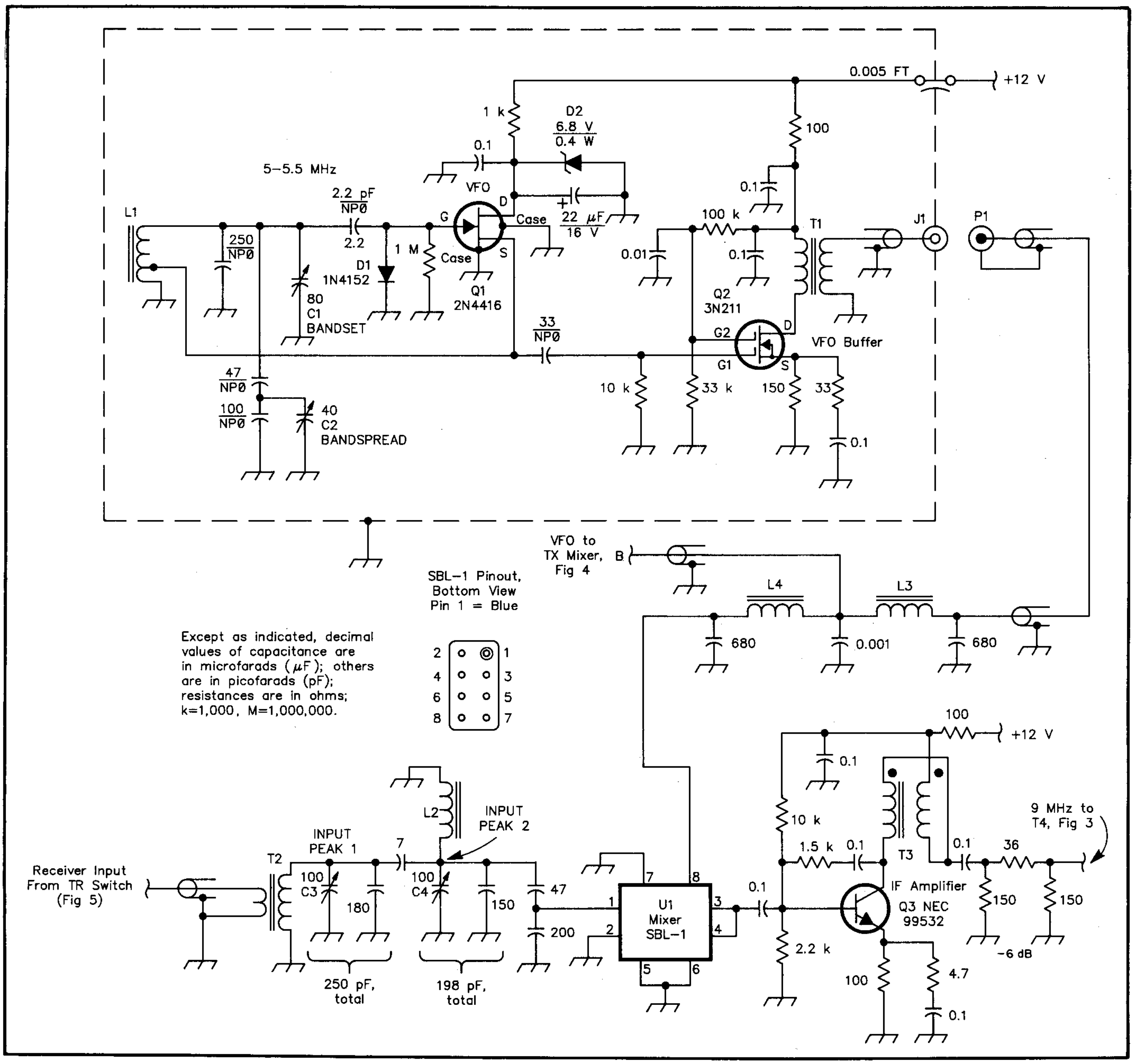

Fig 2—Schematic of the transceiver front end and VFO. Resistors are ¼ W, carbon film; unless otherwise indicated, capacitors are monolithic or disc ceramic. The VFO circuitry is built into a die-cast aluminum box.

C1, C2—Panel-mountable, air-dielectric variable with ¼-inch-diam shaft.

C3, C4—100-pF ceramic- or mica-dielectric trimmer.

J1—Coaxial jack. (The prototype transceiver uses a panel-mount SMB jack here, but a BNC or phono jack is suitable.)

L1—23 turns of no. 22 enam wire on a T-68-6 toroidal, powdered-iron core, with a feedback tap 5 turns from the grounded end of the winding.

L2—11 turns of no. 24 enam wire on a T-44-6 toroidal, powdered-iron core.

L3, L4—25 turns of no. 24 enam wire on a T-37-6 toroidal, powdered-iron core.

T1—Broadband transformer: Primary, 16 turns of no. 26 enam wire on an FT-37-43 toroidal, ferrite core; secondary, 4 turns of no. 26 enam wire wound over the primary.

T2—Narrow-band transformer: Tuned winding, 11 turns of no. 24 enam wire on a T-44-6 toroidal, powdered-iron core; input link, 2 turns of no. 24 enam wire over the tuned winding's grounded end.

T3—Broadband transformer: 10 bifilar turns of no. 28 enam wire on an FT-37-43 toroidal, ferrite core. Observe phasing.

detection by D5. U5D functions as a unity gain inverter to drive a second diode (D6), providing full-wave detection. Each diode operates as a peak detector, providing one sample of the audio level per cycle. Full-wave operation doubles the sampling rate to better approach the Nyquist criterion. The practical result is a simple circuit with better dynamic performance than other audio-derived ones I've tried.

Notes

[1] W. Hayward and D. DeMaw, *Solid-State Design for the Radio Amateur* (Newington: ARRL, 1986).

[2] K. Kleinschmidt, ed, *The 1990 ARRL Handbook,* (Newington: ARRL, 1989).

[3] R. and W. Hayward, "The Ugly Weekender," *QST,* Aug 1981, pp 18-21.

[4] G. Breed, "A New Breed of Receiver," *QST,* Jan 1988, pp 16-23.

[5] W. Hayward, "Designing and Building Simple Crystal Filters," *QST,* Jul 1987, pp 24-29.

[6] W. Hayward, "A Unified Approach to the Design of Crystal Ladder Filters," *QST,* May 1982, pp 21-27; also see Feedback, *QST,* Jul 1987, p 41.

[7] W. Hayward and J. Lawson, "A Progressive Communications Receiver," *QST,* Nov 1981. Also see Feedback, *QST,* Jan 1982, p 47; Apr 1982, p 54; and Oct 1982, p 41. This receiver also appears in the 1982 through 1990 editions of *The ARRL Handbook.*

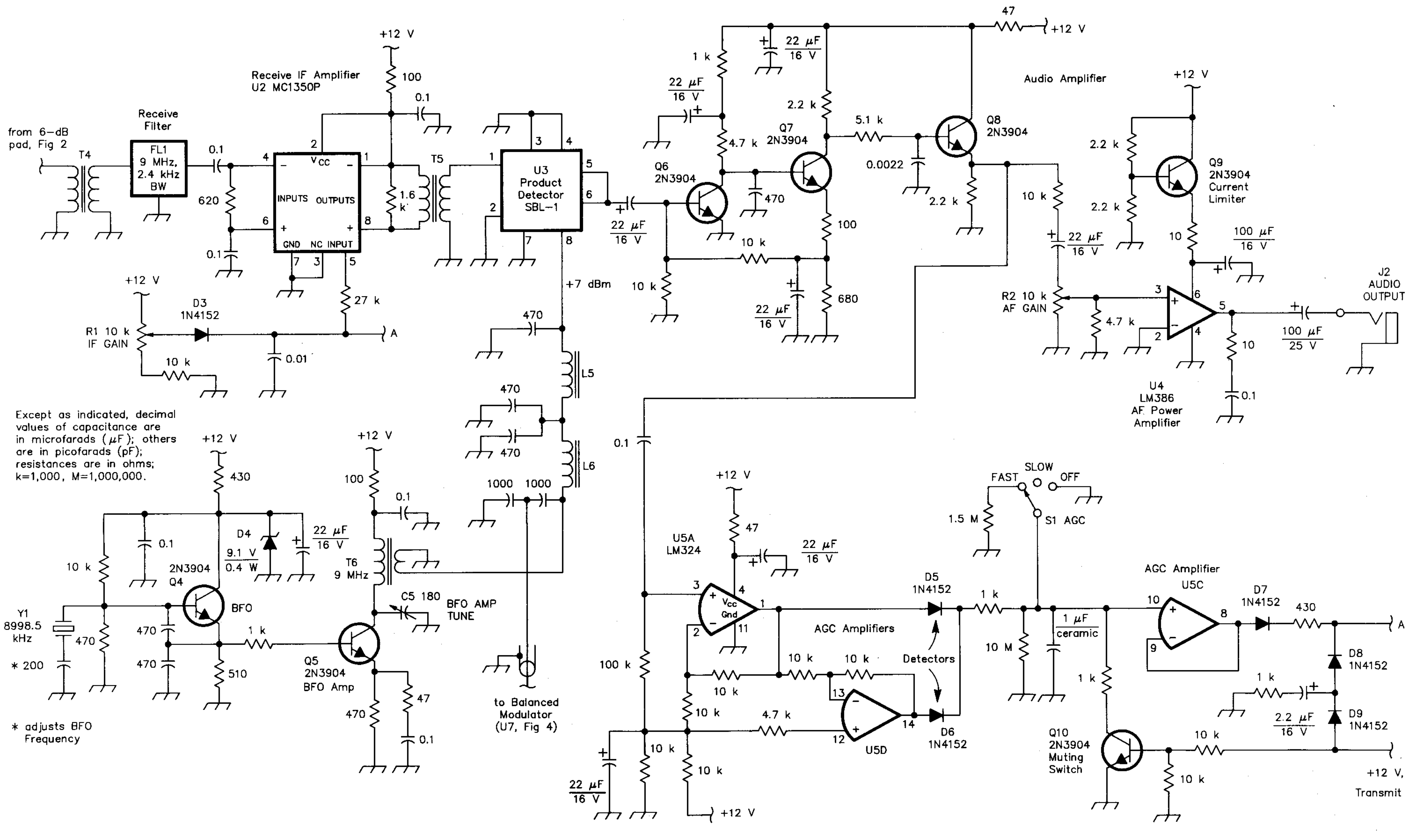

Fig 3—The transceiver receive filter, IF amplifier and detector circuitry. Resistors are ¼ W, carbon film; unless otherwise indicated, capacitors are monolithic or disc ceramic.

FL1—9-MHz crystal filter, 2.4 kHz wide at −6 dB (KVG XF-9B).

L5, L6—22 turns of no. 26 enam wire on a T-37-6 toroidal, powdered-iron core.

T4—Broadband transformer: Primary, 5 turns of no. 26 enam wire wound over the secondary winding; secondary, 16 turns of no. 26 enam wire on an FT-37-43 toroidal, ferrite core.

T5—Broadband transformer: Primary, 20 turns of no. 26 enam wire on an FT-37-43 toroidal, ferrite core; secondary, 3 turns over the primary.

T6—Narrow-band transformer: Primary, 26 turns of no. 24 enam wire on a T-50-2 toroidal, powdered-iron core.

Y1—8998.5-kHz crystal (KVG XF-901 suitable).

A QRP SSB/CW Transceiver for 14 MHz

Part 2[†]: This month, W7ZOI rounds out his description of a 1- or 10-W SSB/CW rig with details on its transmitter, TR switching and optional speech processor.

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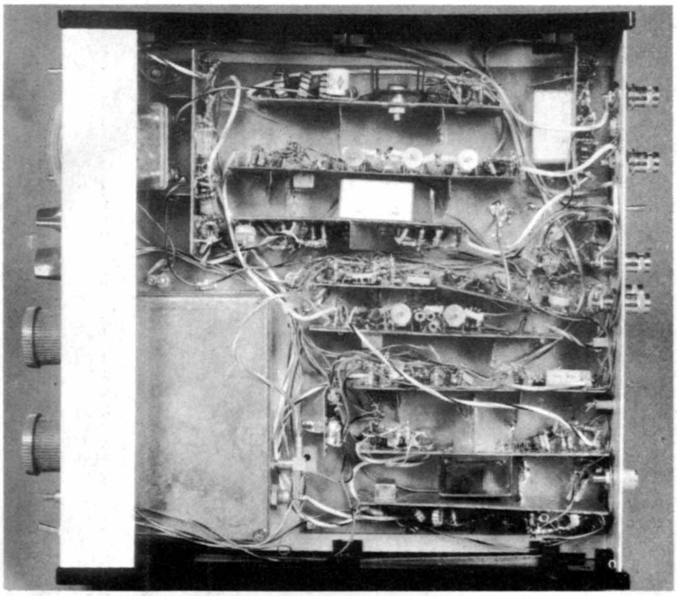


Most of the transceiver's components are contained in ugly-constructed modules, with the exception of the VFO (lower left) and panel-mounted controls and jacks.

SSB generation occurs in the circuit shown in Fig 4. A microphone amplifier (Q16-U6) supplies audio to an MC1496 balanced modulator (U7). One-microfarad capacitors (C6-C8) are used at the output of the audio amplifier and at several positions in the balanced modulator. (Originally, 10- or 22-µF units were used, but these caused the system to respond slowly during TR transitions.)

The modulator output is applied to Q11, a 2N3904 IF amplifier. This stage terminates the transmitter crystal filter and provides a convenient place for CW carrier injection. Another IF amplifier (Q12-Q13) follows the crystal filter. The **TX GAIN** control, R5, is set for an output of −10 dBm from Q13. This level is applied to the transmit mixer, or to the speech processor described later.

Fig 5 shows more of the transmitter. SSB energy at −10 dBm drives the transmit mixer, U8, another diode ring mixer. The 5-MHz VFO signal is amplified to +10 dBm for the mixer by Q17 and Q18. A 3-dB pad terminates the mixer, with the signal continuing to a three-pole, LC, band-pass filter. The first stage in the output-amplifier chain is Q21, a 2N5179 feedback amplifier with an output of +2 dBm. This signal is looped through a coaxial-cable jumper on the transceiver rear panel for use with VHF transverters.

The driver, Q22, a 2N5859, is capable of about +20 dBm output. Transceiver output is obtained from Q23, an IRF511 HEXFET® PA operating at the 1-watt-output level. This power level is a little low for use on the air with dipoles, but is too high for many transverter applications.

Louder-Signal Options

Two additional circuits, shown in Fig 6, round out the SSB system. The first, at Fig 6A, is an IF speech processor. The cable between T8 and transmit mixer U8 is broken and applied to the processor. The processor is driven with a −10 dBm signal. This signal is clipped with parallel, reverse-connected, hot-carrier diodes (D11 and D12). The intermodulation products generated by the clipping are rejected by an additional crystal filter (FL3). The signal is then amplified back to the original −10 dBm level by Q27 and Q28. This circuit generates about 10 dB of clipping. Reports and measurements made on the clipped signal indicate good quality, a potential problem area with many speech processing systems.

Fig 6B shows a 10-watt-output FET power amplifier. The FET that I used (an M/A-COM DV2880T) is no longer available, but is similar to the Motorola MRF138. Alternatively, one could obtain several watts of output from another IRF511.[8] The TR switching in the transceiver is set up for an outboard PA.

Summary

This was a very enjoyable project, and one that I would recommend for other experimenters. The 20-meter phone band, however, can be a little intimidating for the QRP enthusiast.

A rig like this can probably be built and adjusted by those with only modest test equipment. A 15-MHz oscilloscope served as my test-equipment workhorse during construction of this project. A home-brew spectrum analyzer also served as a very useful tool, but is not required. Fig 7 shows the transceiver's CW output spectrum. The 270-Ω resistor and 0.56 µF capacitor associated with the base of Q20, Fig 6, provide CW rise and fall times of 1 and 1.5 ms, respectively. Careful measurement of signal levels during construction helps to keep the system spectrally clean.

Acknowledgments

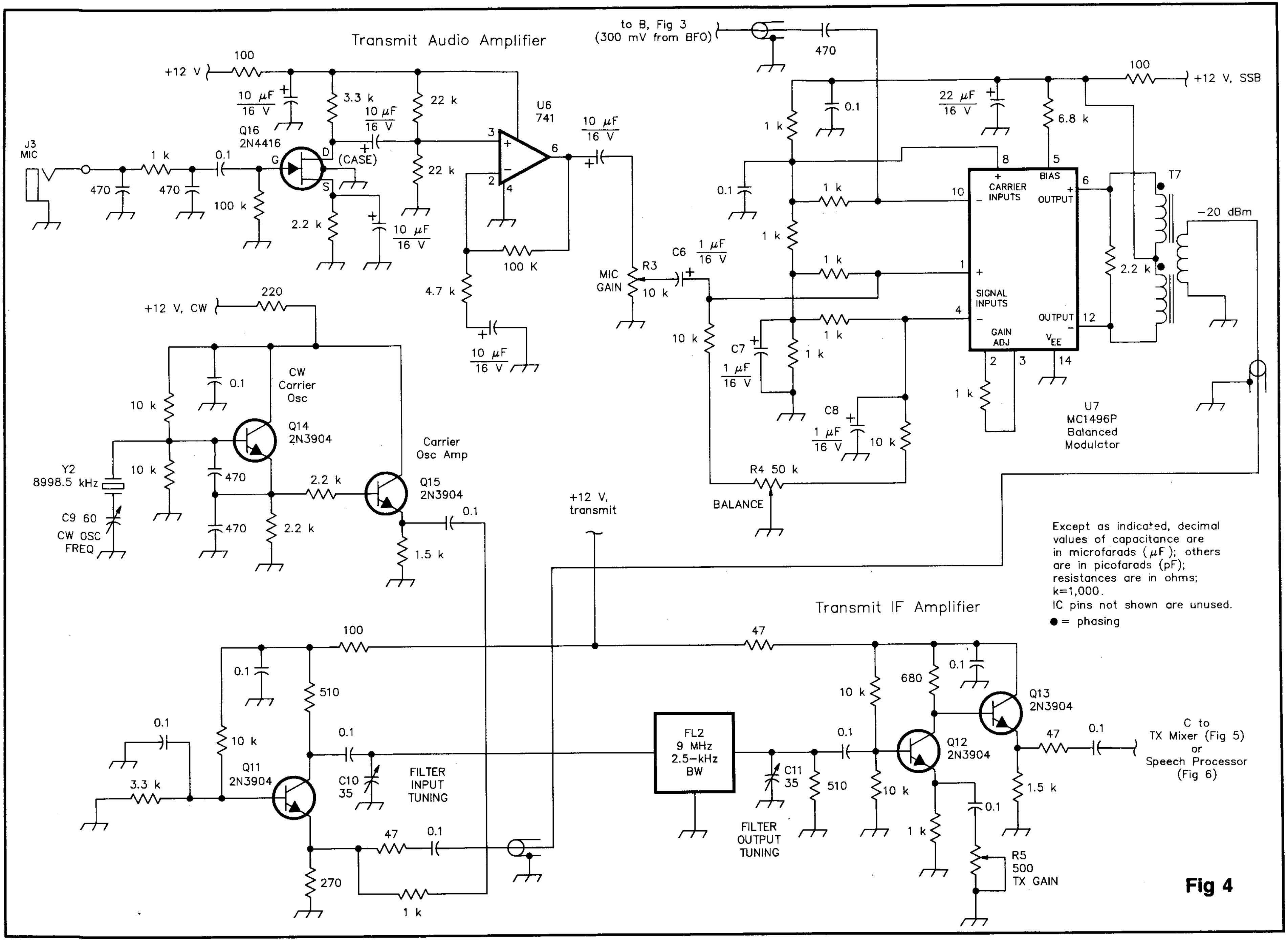
The author gratefully acknowledges the photographic assistance of Dee Lynch, KA7NPN, and technical discussions with Jeff Damm, WA7MLH.

Fig 4—The transceiver SSB generator. Resistors are ¼ W, carbon film; unless otherwise indicated, capacitors are monolithic or disc ceramic.
C9—60-pF, ceramic-dielectric trimmer.
C10, C11—35-pF, ceramic-dielectric trimmer.
FL2—9-MHz transmit filter, 2.5 kHz wide at −6 dB (KVG XF-9A).
T7—Broadband transformer: Primary, 10 bifilar turns of no. 28 enam wire on FT-37-43 toroidal, ferrite core; secondary, 3 turns of no. 28 enam wire over the primary. Observe phasing.
Y2—8998.5-kHz crystal (KVG XF-901 suitable).

Fig 5—The transmit mixer, driver, final amplifier and associated circuits. Unless otherwise indicated, resistors are ¼ W, carbon film, and capacitors are monolithic or disc ceramic.
C12-C14—60-pF mica- or ceramic-dielectric trimmer.
D13—1-A, 600-PIV diode.
K1—12-V dc relay.
L7-L9—20 turns of no. 24 enam wire on a T-44-6 toroidal, powdered-iron core.
L10—15-µH choke.
L11-L13—14 turns of no. 24 enam wire on a T-50-6 toroidal, powdered-iron core.
T8—Broadband transformer: Primary, 15 turns of no. 28 enam wire on an FT-37-43 ferrite, toroidal core; secondary, 4 turns of no. 28 enam wire over the primary.
T9, T10—Broadband transformer: 10 bifilar turns of no. 28 enam wire on an FT-37-43 ferrite, toroidal core. Observe phasing.

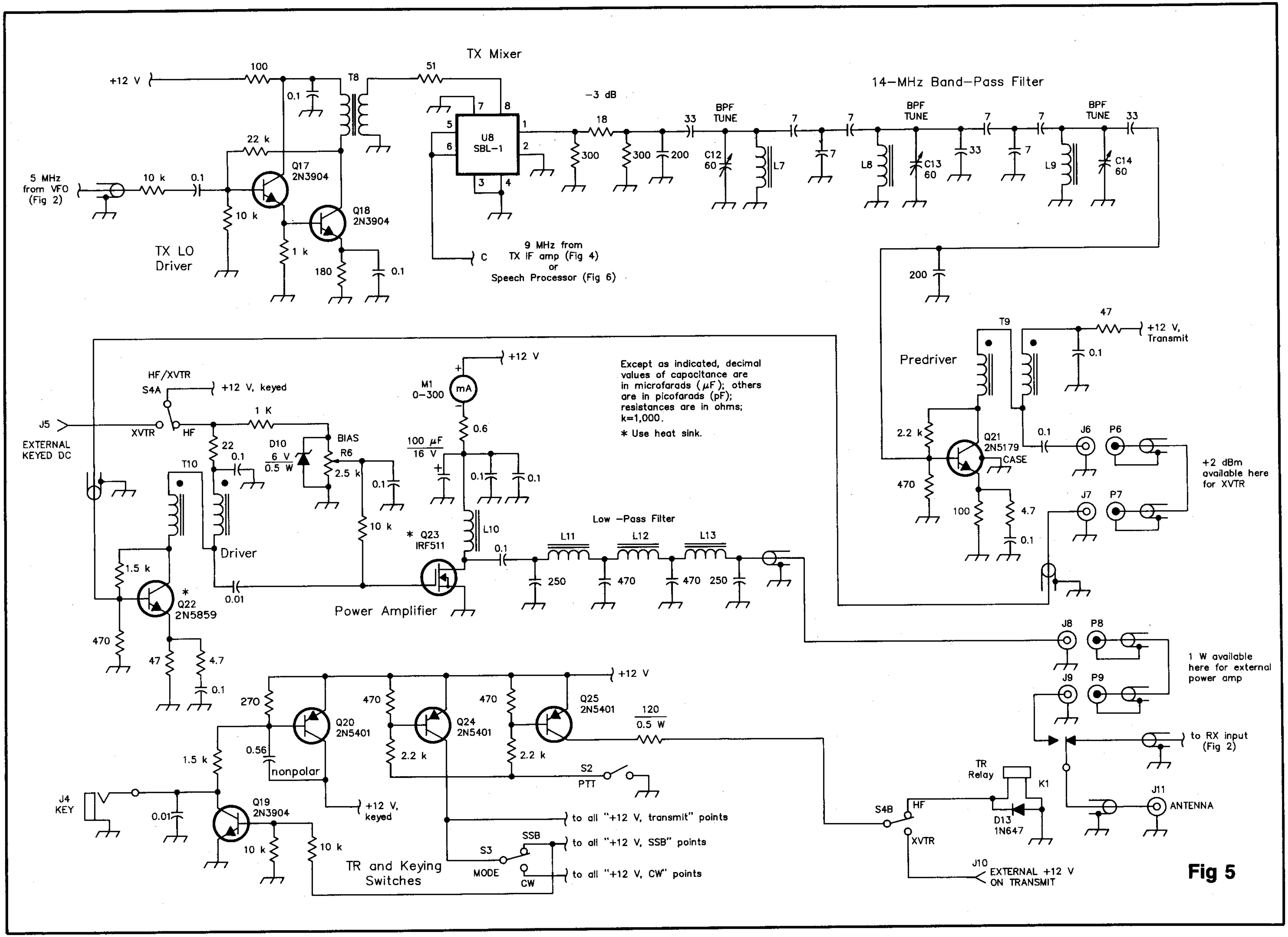
[†] Part 1 of this article appeared in *QST*, December 1989, pp 18-21.

[8] W. Hayward and J. Damm, "Stable HEXFET® RF Power Amplifiers," Technical Correspondence, *QST*, Nov 1989, pp 38-39.



Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k=1,000.
IC pins not shown are unused.
● = phasing

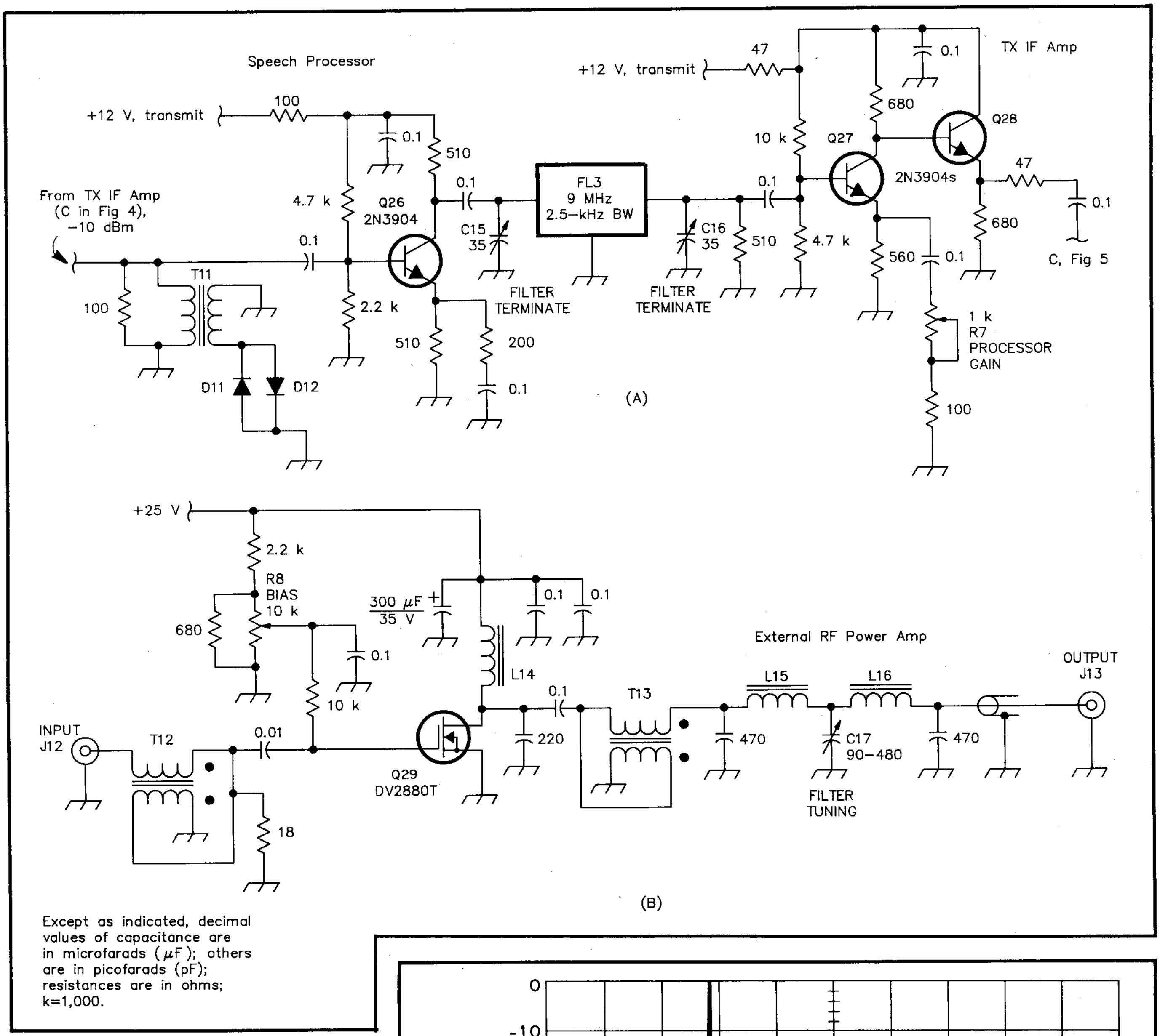
Fig 4



Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k=1,000.

* Use heat sink.

Fig 5



Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k=1,000.

Fig 6—The optional speech processor (A) and outboard power amplifier (B) circuits. Unless otherwise indicated, resistors are ¼ W, carbon film, and capacitors are monolithic or disc ceramic.

C15, C16—35-pF, ceramic-dielectric trimmer.

C17—90- to 480-pF, mica-dielectric trimmer.

D11, D12—Hot-carrier diode, HP-5082-2672 suitable.

FL3—9-MHz transmit filter, 2.5 kHz wide at −6 dB (KVG XF-9A).

L14—50 turns of no. 26 enam wire on a T-68-2 toroidal, powdered-iron core.

L15, L16—19 turns of no. 20 enam wire on a T-50-6 toroidal, powdered-iron core.

T11—Broadband transformer: Primary, 3 turns of no. 28 enam wire over secondary; secondary, 16 turns of no. 28 enam wire on an FT-37-43 toroidal, ferrite core.

T12—Broadband transformer: 7 bifilar turns of no. 22 enam wire on an FT-50-43 toroidal, ferrite core. Observe phasing.

T13—Broadband transformer: 11 bifilar turns of no. 18 enam wire on an FT-82-61, toroidal, ferrite core. Observe phasing.

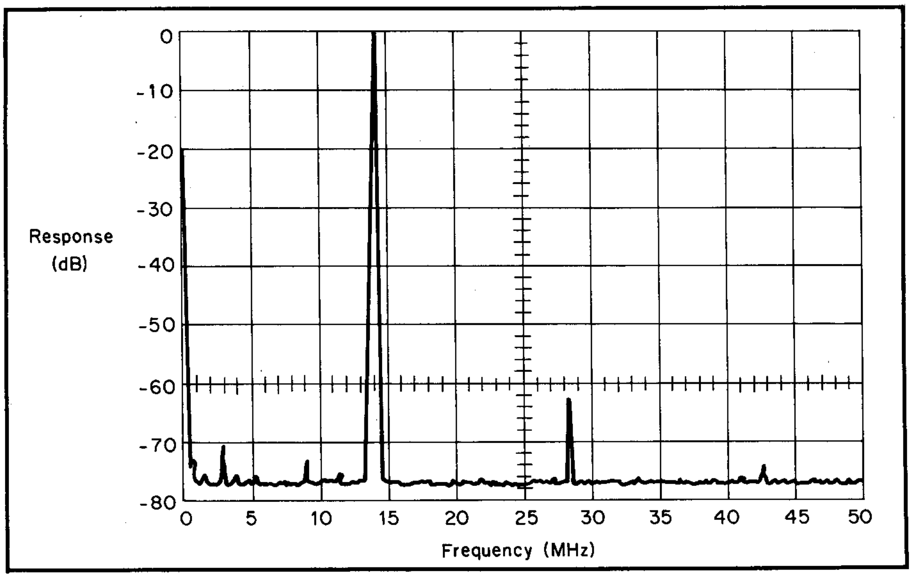


Fig 7—The transceiver's output spectrum contains a second-harmonic component 63 dB below its 1-W CW output. The major nonharmonic spurious response is a 2:1 spur near 1.5 MHz ([2 × VFO] − IF); this component is −70 dBc. The spike at far left is the spectrum analyzer's "zero-spur." An external 20-dB pad in the coaxial line provided extra protection for the analyzer, a Tektronix 2756P. The spectrum-analyzer measurements were provided by Stan Griffiths, W7NI. The transceiver complies with current FCC specifications for spectral purity.