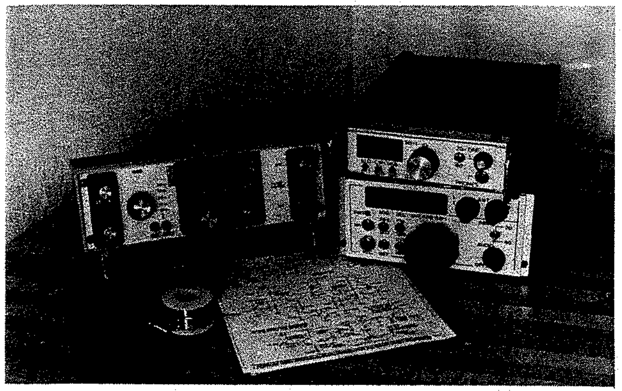


Three different versions of the receiver, two of which have been expanded into transceivers. The one on the left is the original which was built in modules. It uses a cabinet available from Radio Shack, and a homemade front panel. On the top right is the basic receiver described in this article. It uses an inverted chassis with cover plate. Wooden rails have been added to both sides and an aluminum trim strip adds a finishing touch to the front panel. A bar graph display has been used here instead of an S-meter. It is mounted just above the digital readout. On the bottom right is a unit built by Bob Kirby, WA3DYF. His version includes an antenna tuner, so that a random length wire can be used as an antenna.

modular two-band receiver

State-of-the-art circuitry with digital frequency readout

I have often been impressed by the many excellent articles which have been published about my favorite subject — communications receivers. A problem I have found with most of the articles, however, is that duplicating some of the circuits is often difficult. Some receivers use surplus or discontinued parts, or parts not readily available. In some cases extremely expensive, custom-made components are used.

There is no reason why a top-quality, high-performance receiver should cost a small fortune to build — or require a bench full of sophisticated test equipment to adjust. You *can* build a receiver for less money than you would have to spend to purchase one of similar performance.

This article describes my answer to these problems. Here is a reliable, high-performance Amateur communications receiver that will perform as well as some of the best receivers available to Amateurs today. The basic two-band design can be expanded to cover the other bands, and, with the addition of two boards, can operate as a transceiver on CW and SSB.

the evolution of the design

The typical receiver should be able to handle strong signals (both on and off frequency), such as

By Jim Forkin, WA3TFS, 3210 Shadyway Drive, Pittsburgh, Pennsylvania 15227

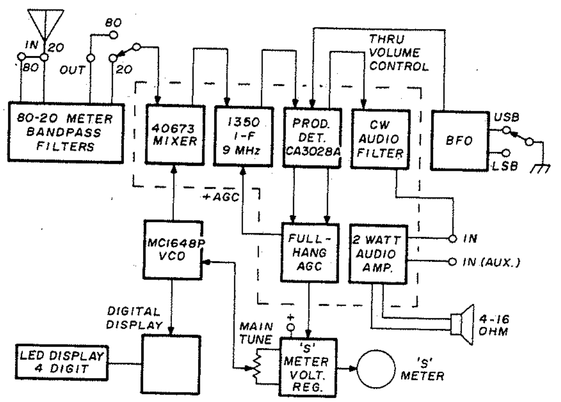


fig. 1. Block diagram of the SSB/CW receiver.

those typically found under Field Day type operation. Many otherwise excellent receivers sold to Amateurs are terrible at this. Manufacturers, in an attempt to improve poor dynamic range, add an attenuator to the front end of their receiver. This does not really cure the problem, but substitutes one problem for another. Yes, the receiver no longer overloads on strong signals, but now the operator can hear only the strongest signals. It should not be necessary to use an attenuator or to run an rf-gain control at less than maximum sensitivity under any type of operation encountered on the Amateur bands today.

Most interference heard on the lower Amateur bands is generated in the receiver. Poor dynamic range, as well as excessive gain in the front end, are usually to blame. Selectivity in the front end and i-f are also factors which are not given proper consideration in many designs.

A typical receiver should have excellent calibration. Digital readout is by far the best way to achieve this. Also, a digital-readout system eliminates the need for a mechanical dial drive, which can be extremely difficult to construct in the typical home workshop.

The receiver must have selectivity suitable for both SSB and CW reception. In this design, a KVG XF9B eight-pole crystal filter has been used. This filter is readily available, reasonably priced, and has excellent skirt selectivity, (see **table 1**). An audio filter with a bandwidth of less than 200 Hz can be switched in before the audio amplifier to help slice through the thickest QRM.

Any modern rig should, ideally, be able to operate on 12 volts dc. This not only simplifies portable operation, but during an emergency, this feature may save the day. Even during the worst disaster, a truck, auto, or motorcycle battery can provide enough power to get the communications started. The receiver draws only about 100 mA at normal volume level.

With emergency and portable operation in mind, small size and minimum weight are nice features to consider. One weight- and time-saving method involves eliminating the mechanical dial drive, readout, and tuning capacitor. I used a Jackson Brothers 6:1 reduction drive, which turns a ten-turn potentiometer, giving sixty turns to cover a 500-kHz band. The regulated voltage from this control is used to tune the VFO. Since the varactor diodes in the VFO require only a dc voltage, the packaging of the various boards needs not be influenced by any mechanical considerations. This packaging flexibility opens up a few new possibilities.

If mobile operation is contemplated, a remote-mount type of packaging could be used. The main receiver board, along with the VFO and BFO, could be in one box. The digital readout, tuning control, volume control, and S-meter, in a small box mounted under the dash, would complete the receiver. This idea is especially attractive for use in the small cars which are becoming so popular.

Finally, and of major importance, any circuit used in a receiver should be entirely reliable. By this I mean that only readily available, well-proven, solid-state devices should be used in circuits which are easy to duplicate without problems of instability. No changes or critical adjustments should be required to get the receiver working the first time.

In this design, I have relied heavily on the use of integrated circuits. This cuts size, complexity, and cost. The design has shown itself to be reliable and trouble-free. I know of no better way to put two pounds of circuitry into a one pound box.

the design

The two-band receiver consists of six printed circuit boards (see block diagram in **fig. 1**). The main receiver board contains the mixer, i-f filter and amplifier, product detector, AGC circuitry, active audio filter, and audio power amplifier. Other boards include the VFO, BFO, the voltage regulator and S-meter board, and the digital-readout board. Both of the bandpass filters are on one board.

table 1. Specifications for the KVG XF-9B filter.

application		SSB/RX
number of filter crystals		8
bandwidth (6 dB down)		2.4 kHz
passband ripple		<2 dB
insertion loss		<3.5 dB
input-output	R_t	500 ohms
termination	C_t	30 pF
shape factor		(6:60 dB) 1.8
		(6:80 dB) 2.2
stop band attenuation		>100 dB

bandpass filters

Each band has its own double-tuned bandpass filter (**fig. 2**). This filter design has good rejection of unwanted signals both above and below the band of interest.[2] The two coils for each band are wound on ferrite cores and tuned with ceramic or mica trimmer capacitors.[3] (See **table 2**.) Once initially adjusted at the center of each band, the filters require no other tuning or adjustments.

One drawback of this type of front-end filter is the fact that the antenna must present a 50-ohm load.

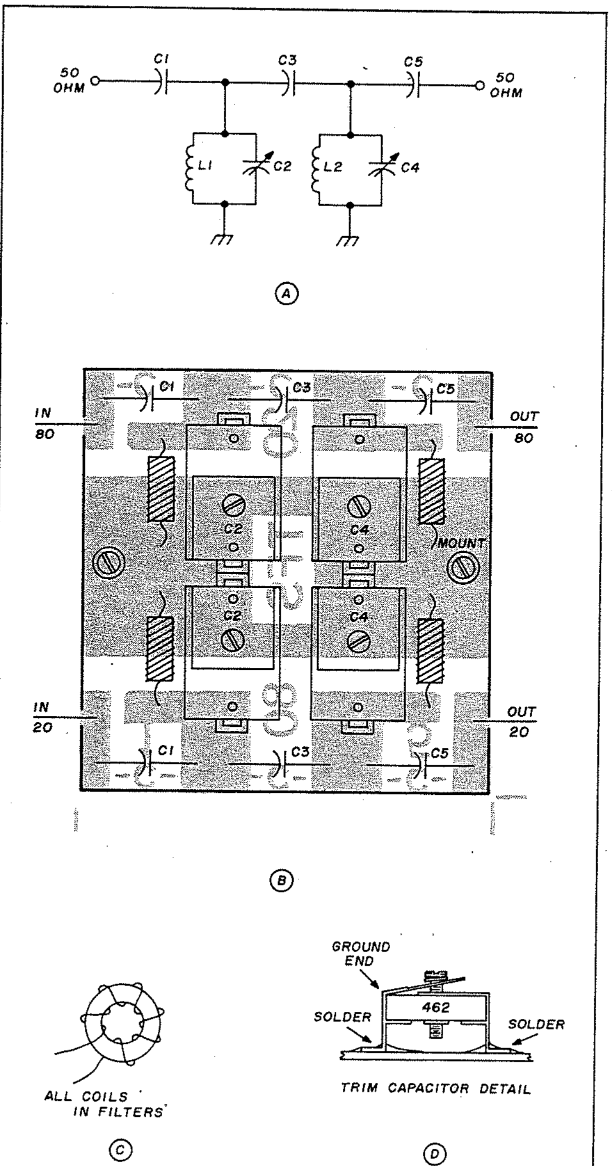


fig. 2. Schematic diagram (A) of the bandpass filters, and parts location (B). All coils are wound on a toroidal core as shown by (C); see table 2 for values. The tabs on trimmer capacitors are bent outward and soldered to the circuit board as in (D). All parts are on foil side of board.

Two more versions of the receiver, both of which have been expanded in function. The one on top has been designed for mobile use. It is built in a compact package measuring only 4 × 7 × 11 inches. The cabinet is formed by using two chassis fastened together with a top and bottom cover. A separate front panel hides the seam where the two chassis join together. The bottom unit is the dual-diversity unit mentioned in the article. Note the two dot displays to the left of the digital readout. These give a direct comparison of signal strength on each channel.

Severe mismatch at the antenna will detune the filter and cause a loss in sensitivity. It is not possible to just hang a wire on the antenna input and obtain good results. With a matched antenna, the filters are excellent.

table 2. Component values for the bandpass filters. C1, C3, and C5 are silver-mica capacitors. Coils are wound with No. 28 enamel wire.

	C1-C5	C3	C2-C4	L1-L2
80 meters	100 pF	12 pF	ARCO 464	35 turns on T37-2 core (red)
20 meters	15 pF	2 pF	ARCO 462	27 turns on T37-6 core (yellow)

the mixer

Initial experiments with the mixer stage involved double-balanced diode mixers, but these were rejected in favor of a dual-gate mosfet stage, as shown in the receiver-board schematic (**fig. 3**).

In theory, the diode double-balanced mixer is, perhaps, the ultimate design. However, in practice, the maximum capabilities of this device are rarely achieved in a home-built receiver.

The diode mixer, in order to work properly, must be terminated at all frequencies present — not just the i-f. This requires a circuit called a diplexer. This circuit can be very difficult to get working properly with simple test equipment. This type of mixer exhibits a loss and also requires a high-level local-oscillator signal. This not only consumes extra power, but makes interstage coupling of the local oscillator signal a problem.

A dual-gate mosfet mixer, on the other hand, is not in the least bit temperamental, and good performance can be obtained without any adjustments. The drain is terminated in the eight-pole crystal filter. Impedance matching is handled by a 510-ohm resistor in the drain circuit of the mixer, which approximates the 500-ohm input impedance of the KVG filter.

the intermediate frequency amplifier

The local-oscillator signal and the desired incoming signal are mixed (heterodyned) to produce an output signal at the i-f center frequency of 9.0 MHz. This signal is then passed through the eight-pole crystal filter with a −6 dB bandwidth of 2.4 kHz. The outstanding skirt selectivity of this filter (1.8 shape factor) rejects off-frequency signals very well. It is this selectivity which allows you to separate the closely spaced signals which are common on the Amateur bands.

The signals at the output of the crystal filter must be amplified, of course, and this is handled by an integrated circuit which provides about 50 dB of gain and a bit more than 60 dB AGC control.

Although this eight-pin chip appears quite simple, the MC 1350 is really quite sophisticated.[1] It is also inexpensive. The gain of this stage is controlled by applying a voltage of 5 volts or greater to pin 5. An increase in voltage on this pin causes a decrease in gain in the chip.

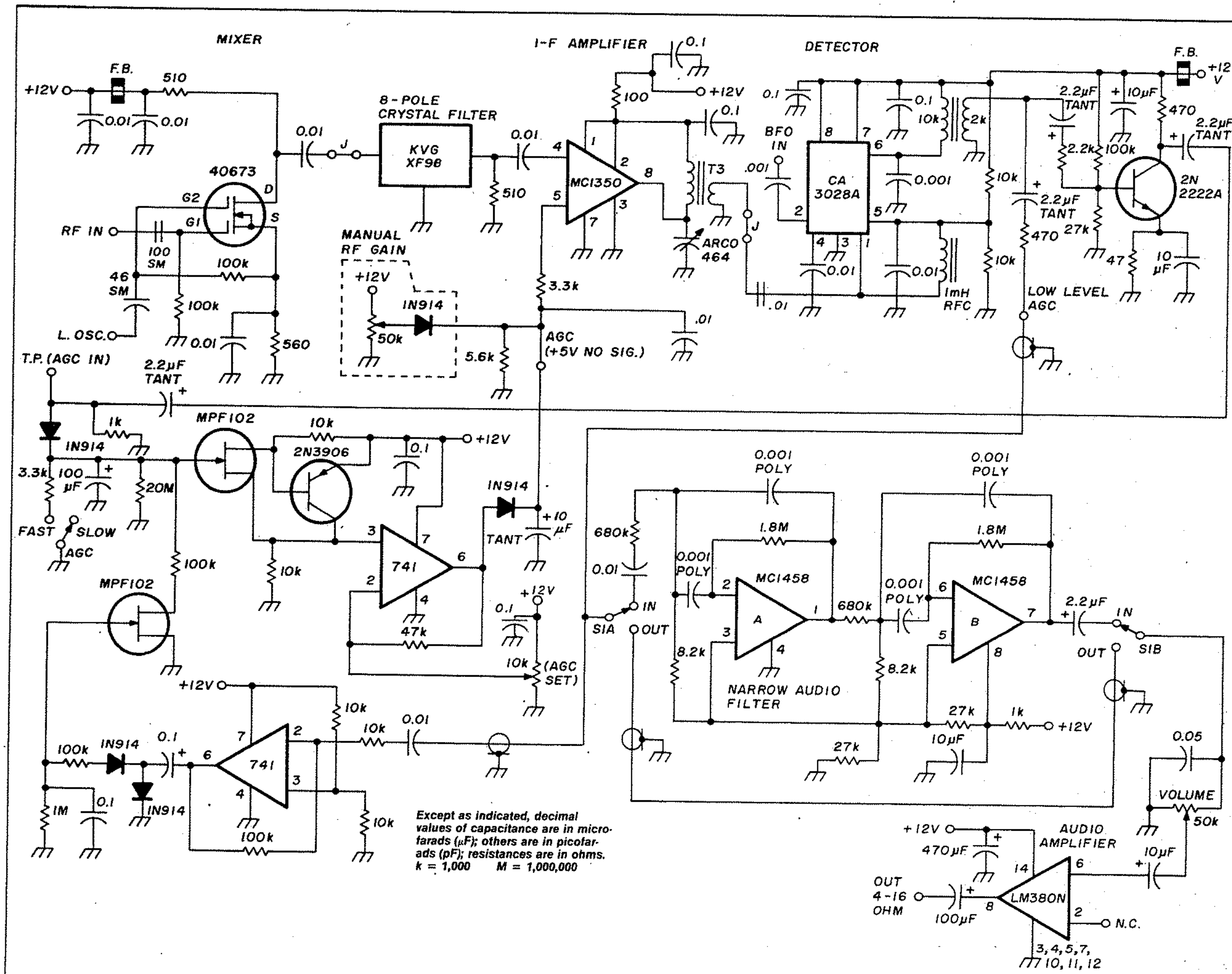


fig. 3. Schematic diagram of the receiver board of the modular receiver. S1 A and B is a miniature dpdt toggle switch. Capacitors in audio filter must be polystyrene or mica. Capacitors marked + can be either tantalum or other electrolytic. T3 primary is twenty-five turns No. 28 enameled wire on T37-6 core; secondary is five turns No. 28 wound over primary.

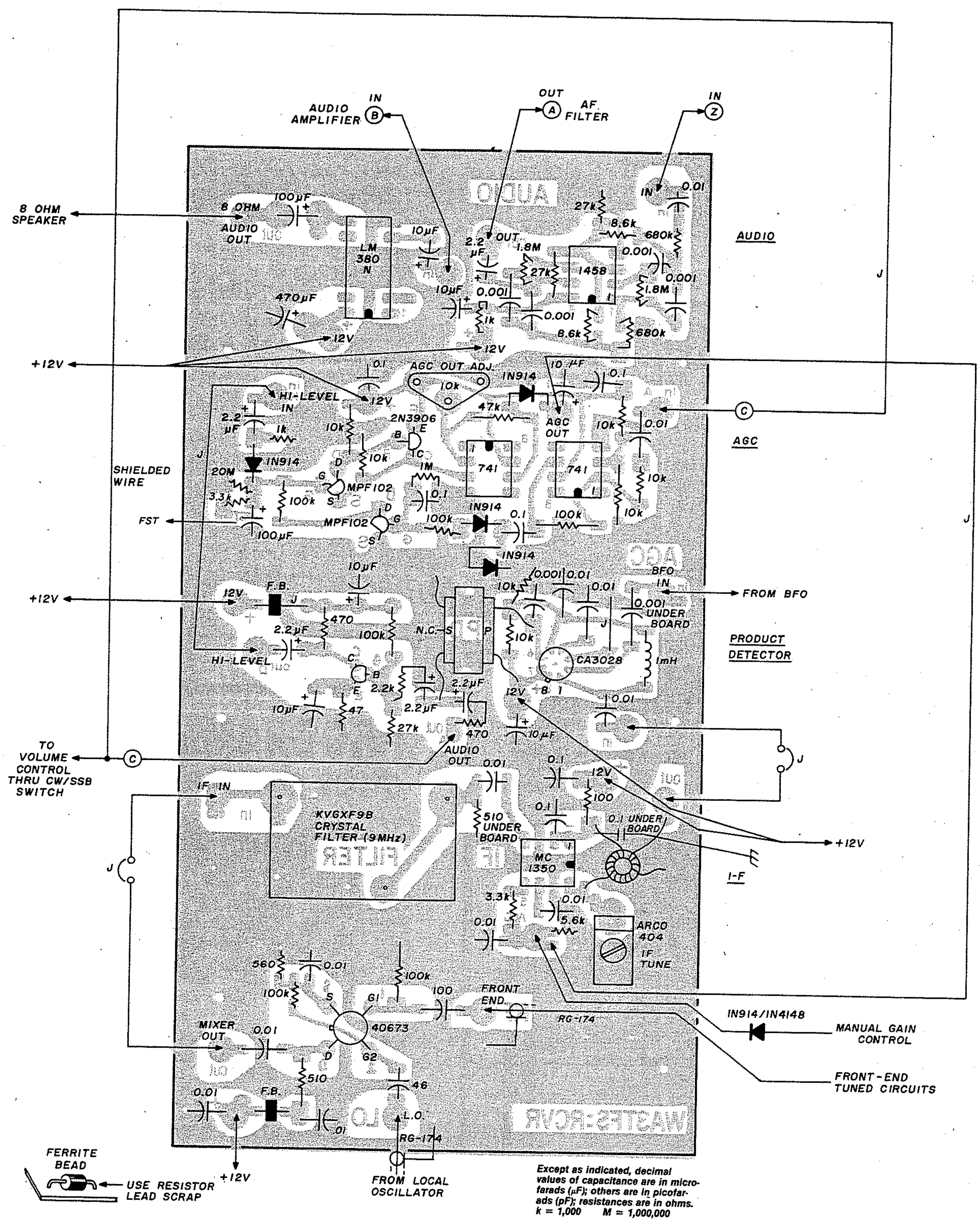


fig. 4. Component placement guide for the receiver board, viewed from the component side of the board with the printed circuit board in the background.

The printed circuit board (**fig. 4**) is designed so that the entire i-f amplifier stage, along with the crystal filter, can be diode or relay switched whenever this receiver is modified for use as a transceiver.

Although it was not included in the original design, a two-pole crystal filter was added at the output of the i-f amplifier. This was not necessary to realize excellent performance in the receiver, but it does produce a quieter receiver by eliminating most of the noise generated in the i-f amplifier. The use of the filter is especially noticed and appreciated when copying extremely weak signals near the noise floor of the receiver.

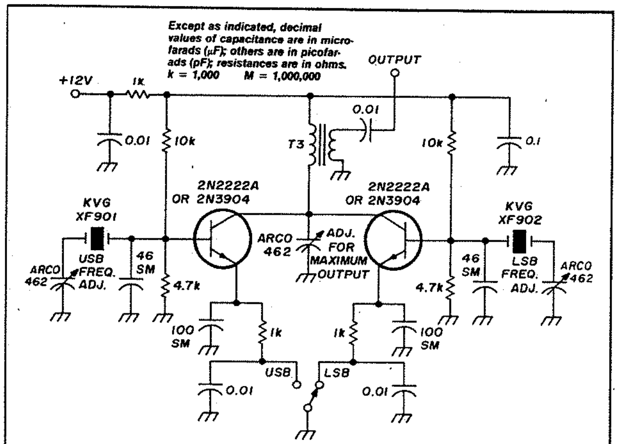


fig. 5. Schematic diagram of the BFO for the receiver. T3 primary is forty-five turns No. 28 enameled wire on T50-2 core; secondary is three turns No. 28 over primary.

The low cost involved by adding the two-pole filter is justified by the increased performance. The filter can be added without modification to the printed circuit board.

the product detector

I have experimented extensively over the past several years with direct conversion receivers (synchrodyne) and have found that the RCA CA3028-A integrated circuit works very well as a product detector. I have, therefore, used this device in this receiver. It exhibits good gain, low noise, excellent stability, low distortion, and a reasonable level of recovered audio. BFO level requirements are reasonable and non-critical. This chip also handles strong signals very well and this ability simplifies the design of the AGC system.

the audio stages

Detected signals from the product detector are coupled through an audio interstage transformer to the following stages. If more selectivity is desired for the reception of CW signals, the audio is routed through an audio filter.

Operational amplifiers have made filtering for selectivity at audio frequencies a practical method to use in the design of a new receiver or to improve an older receiver. This receiver uses a design based on an MC1458 dual-operational-amplifier integrated circuit. No critical parts are required, as experiments have shown that excellent performance can be obtained using typical 5 percent resistors and polystyrene capacitors. When it comes right down to it, it is

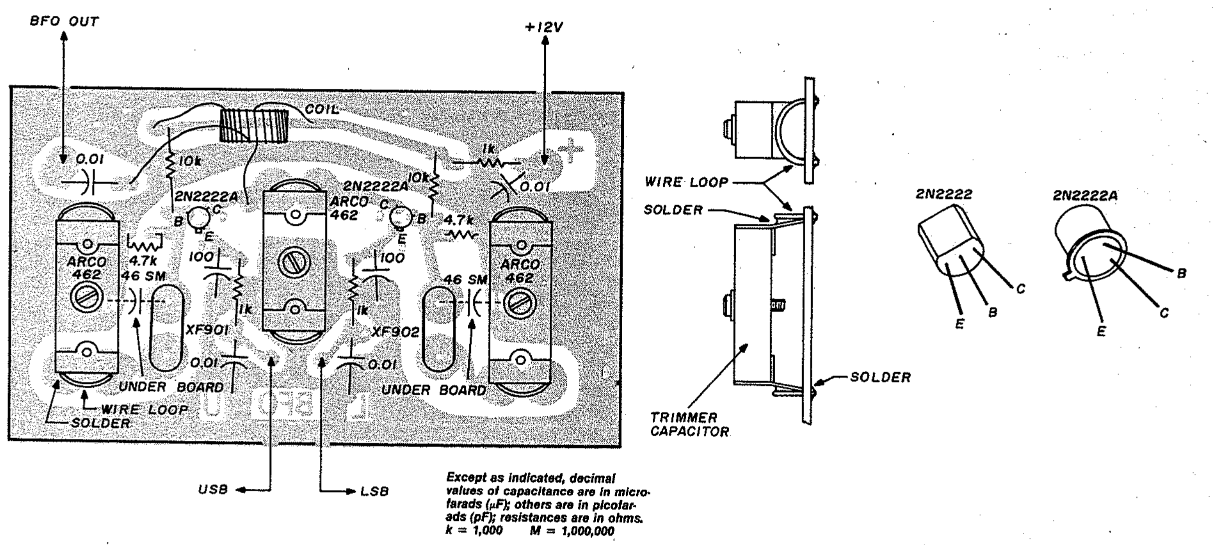
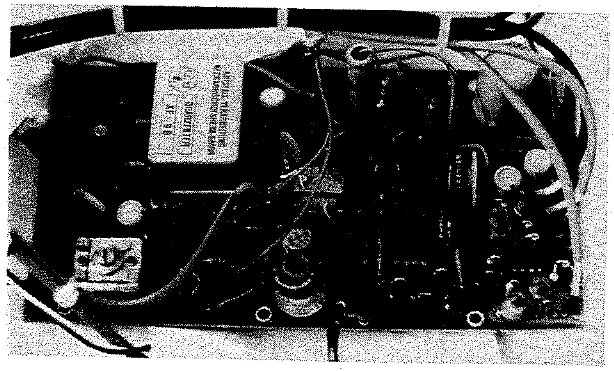
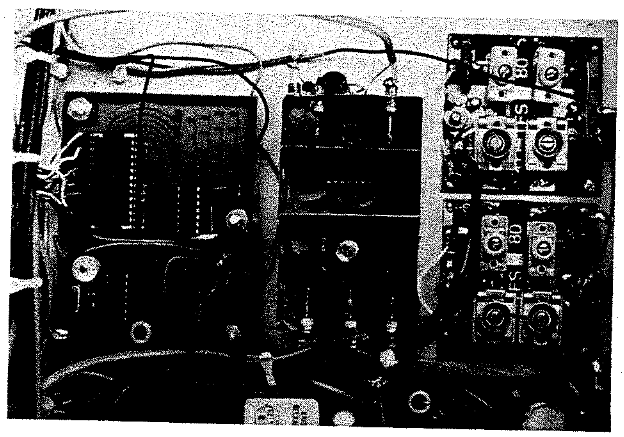


fig. 6. Component placement guide for the BFO board, shown from the component side with the printed circuit board in the background.



The main receiver board. Note the shielded wiring used on all audio and rf connections. From left to right are the mixer, crystal filter, i-f amplifier, product detector, AGC circuit, audio filter, and audio amplifier.



Three of the assembled boards. From left to right they are the digital readout board, the VFO, and the bandpass-filter board for 80 and 20 meters. A shielded control line goes to the VFO.

not important whether the center frequency is at 1.0 kHz or 1.1 kHz, or that the bandwidth at −6 dB is 200 Hz or 210 Hz. The design specifications call for a bandwidth of about 200 Hz at −6 dB, and a center frequency of 1.0 kHz. This is wide enough to eliminate any ringing tendency, yet narrow enough to cut through some of the worst interference.

One of my most basic concepts of receiver design is that simple is usually best. This idea is carried to the extreme when you consider the audio output stage. Only three parts are needed. The LM380-N integrated circuit will provide about 2 watts output in this configuration. It has low distortion, good gain, and is even thermally protected so you don't have to be concerned if the speaker becomes disconnected. I have used this receiver mobile and have found the audio output to be more than adequate when connected to an external speaker of good quality. The output stage will drive any load between 3 and 16 ohms. Don't ruin the excellent audio quality of this receiver by using an inferior speaker. Any of the many CB-type mobile speakers should be a good choice.

Incidentally, the audio chip has two input pins. One is used here, the other left floating. If the receiver is used as part of a transceiver, the other pin can be connected to the sidetone oscillator.

the AGC system

After weeks of experimenting with both audio- and rf-derived AGC systems, it became apparent that an audio-derived, full-hang AGC system worked best under signal conditions ranging from casual rag-chews to weak-signal CW work, DX pileups, and Field Day QRM.

Perhaps you have used a receiver and noticed that the S-meter (actually an indicator of AGC action in the receiver) would deflect up scale on signals not even detected in the audio output. This is typical of receivers using rf derived or i-f derived AGC systems that do not have sufficient selectivity ahead of the detectors for the AGC.

Because of this problem, the desired signal completely disappears or appears to become very weak because of the AGC action. Obviously, this is not an ideal situation. The receiver sensitivity should be totally controlled by the signal you wish to detect, not by QRM.

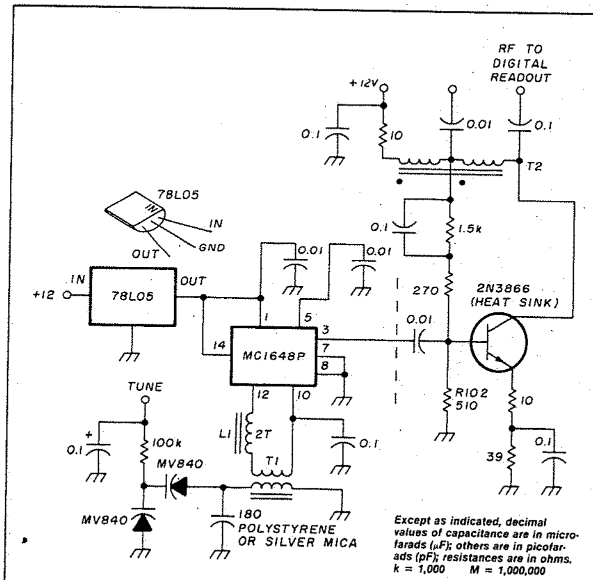


fig. 7. Schematic diagram of the VFO (local oscillator). T1 primary is thirty-five turns No. 28 enameled wire on T37-6 core; secondary is eight turns No. 28 over primary. T2 is ten turns No. 28 enameled wire wound bifilar on FT37-43 core. L1 is two turns No. 28 enameled wire on ferrite bead.

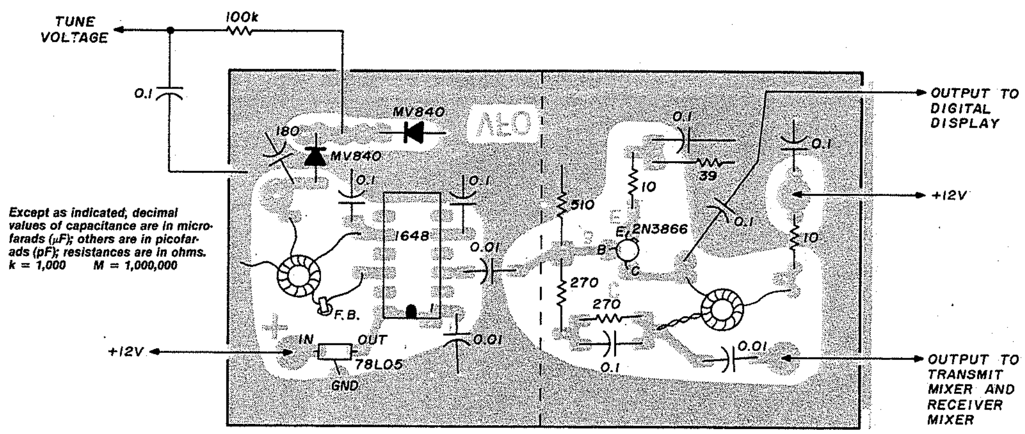


fig. 8. Parts placement guide for the VFO board with the printed circuit board in the background.

In practice, this is nearly impossible to do. But, through the use of selective filters and an audio-derived AGC system (as used in this receiver), this ideal comes closer to reality than you find in many commercial receivers.

A signal, first of all, must be detected and be present in the product-detector output to produce any AGC action. The strength of this signal determines how much AGC voltage will be applied to the i-f amplifier stage. When the need for a control voltage no longer exists, an FET switch is turned on, thereby shunting this voltage to ground, which brings the receiver back to maximum gain within a period of time determined by the time constants. The type or strength of the signals received does not affect this hold-in time. This type of circuit is discussed in greater detail in an ARRL publication.[1]

Two AGC time constants are available. The slower one is excellent for general SSB and CW use and the faster one allows good copy under adverse conditions.

the BFO

The beat-frequency oscillator is crystal controlled for stability. The circuit consists of two oscillators which share a common output tuned circuit (see **figs. 5** and **6**). The upper and lower sideband crystals are selected by grounding the appropriate control line. This board, like all the others, can be placed anywhere in the cabinet. Since only dc is being switched, it is not necessary to keep the control wires very short.

Each crystal has a trimmer capacitor so it can be set exactly on frequency. Another trimmer capacitor peaks the output tuned circuit at 9.0 MHz.

the VFO

Readers who are familiar with synthesized 2-meter equipment will probably recognize the MC1648 integrated circuit used in the VFO (**figs. 7** and **8**). It has become fairly common in VHF equipment but has not been used before, as far as I know, in a high-frequency receiver. It operates very well in this configuration.

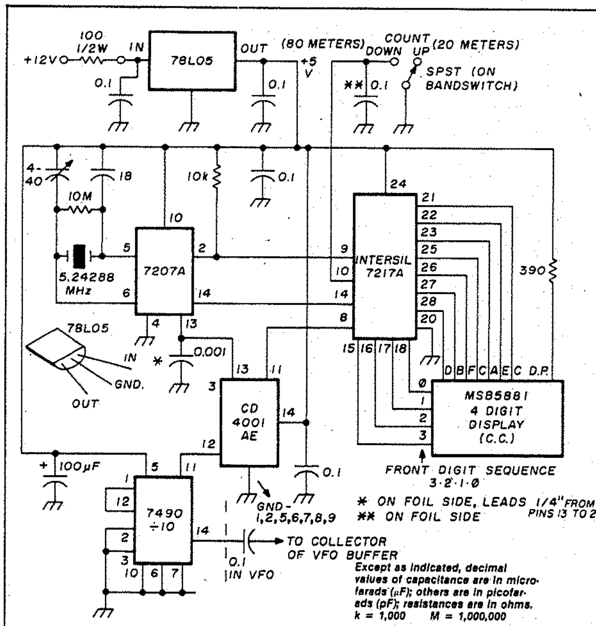


fig. 9. Schematic diagram of the digital frequency readout for the receiver.

One problem which may occur when using this integrated circuit is that it can oscillate above 250 MHz. The high-frequency oscillation is prevented by link coupling the tuned circuit to the IC through an rf choke. This low value inductance, as well as short lead length, proper pc board layout, and proper bypassing, prevents instability.

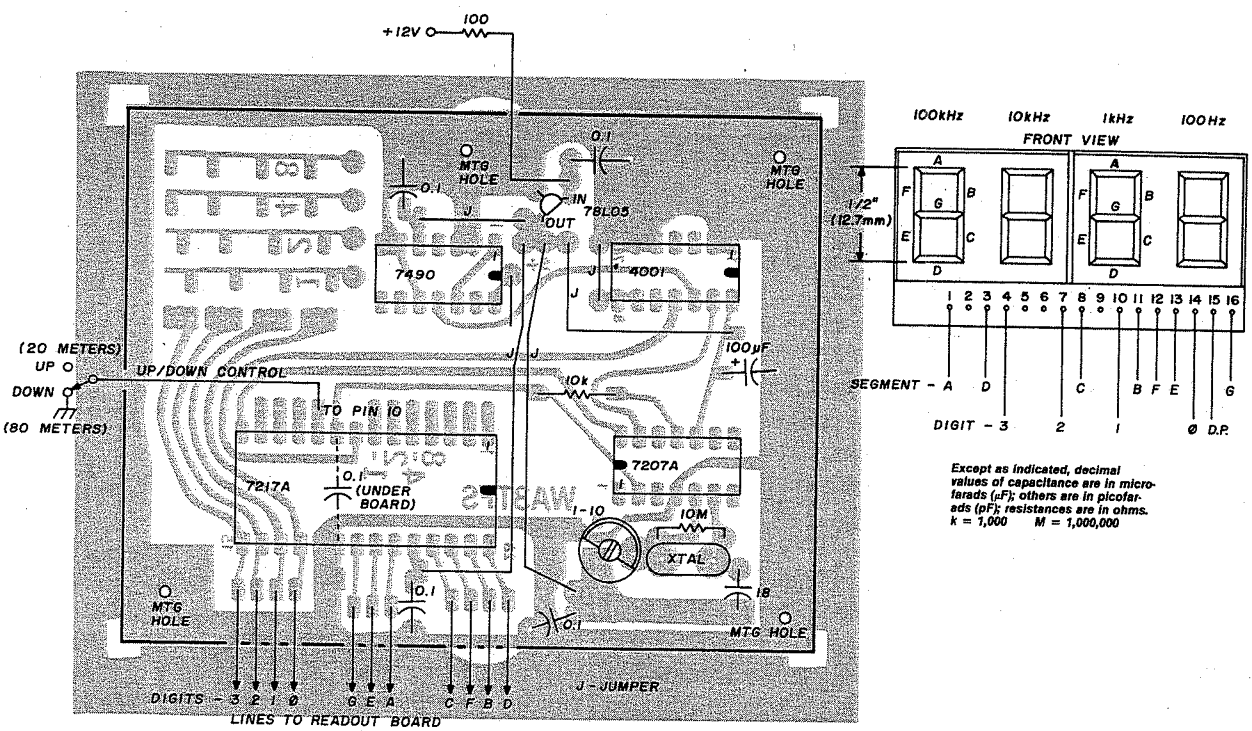


fig. 10. Parts placement of the frequency readout board with a printed circuit board in the background. The display is NSB5881 by National Semiconductor. To calibrate the readout, check against a freqency counter or calibrated receiver and adjust the 1-10 pF trim capacitor until readout is correct. Note that the first figure (MHz) of the VFO frequency (or the received frequency) is not displayed. Example: 5243.6 kHz (VFO) will be displayed as 243.6. Similarly, 14243.6 kHz will be displayed as 243.6 on the readout.

Two varactor diodes are biased by a regulated dc voltage which is controlled by a panel-mounted ten-turn potentiometer. A Jackson Brothers 6:1 vernier drive gives good bandspread.

VFO output is amplified and buffered by a Class-A 2N3866 stage. Output from the buffer is applied to the mixer stage in the receiver. Output to the digital readout is taken via a capacitor from the collector of this stage. This eliminates the need to add pulse shaping in the digital counter.

The regulated voltage, which is used to tune the VFO, is derived from a 6-volt, three-terminal integrated-circuit regulator which is mounted on the S-meter/voltage-regulator board.

Temperature compensation was found to be unnecessary for base-station applications. After a short warm-up period the drift is low enough to allow me to copy the ARRL RTTY bulletins without retuning. If you wish to use your receiver under adverse conditions, such as might be encountered during mobile operation, it may be necessary to add some sort of temperature compensation. Several schemes have been published and just about any of them will work. One simple method I suggest is to wire a 120-pF N750 ceramic capacitor in series with a low-value piston trimmer (approximately 2-5 pF) across the two varactor diodes. The trimmer should be adjusted to mid-range with a cold receiver. Hook a frequency counter to the VFO output and turn on the receiver. Plot the drift over about an hour's time. If drift is excessive, adjust the trimmer slightly, allow the receiver to cool and try the test again. This takes quite a bit of time, but once the magic combination is found, no further adjustment is needed.

digital readout

From the initial planning stages of this receiver, I decided to use a digital frequency display, but did not want the high current consumption, heat, or complexity of the usual designs. An Intersil LSI counter chip, along with three other integrated circuits, provides a four-digit readout with an accuracy of ±100 Hz (**fig. 9**) with a components layout and printed circuit board shown in **fig. 10**.

The counter counts the VFO output and displays the last four digits. This corresponds to the frequency of the received signal. For example, a received frequency of 14,230.6 kHz is displayed as 230.6. On 80 meters, the counter counts down so that a received frequency of 3,976.8 kHz is displayed as 976.8.

Current consumption with this design is very low, and no noise from the counter can be heard in the audio output. The time base for the counter is a 5.24288 MHz crystal.

S-meter/voltage regulator

A meter amplifier designed to drive a low-current meter is included on this board (see **figs. 11** and **12**). The meters are readily available as CB surplus. Their current ranges are between 50 and 250 μA, and their cost is very low. A trim pot is used to set the meter to zero under no-signal conditions. Sensitivity of the amplifier is adjusted by changing the input resistor.

The board also holds a 6-volt, three-terminal integrated circuit and trim pots to set the upper and lower tuning range of the VFO. The trim pots should be set to allow a tuning range of about 4990 kHz to 5510 kHz. This range could be extended slightly to allow tuning in MARS or CAP frequencies.

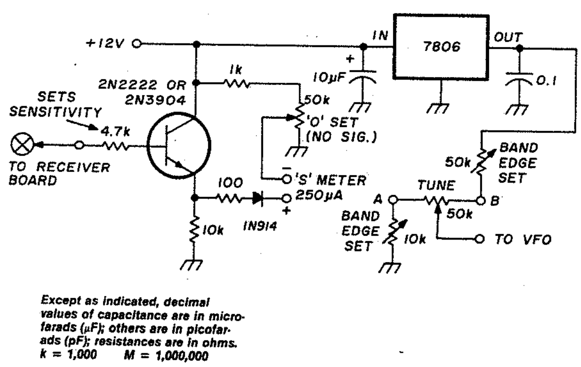


fig. 11. Schematic diagram of the voltage-regulator/S-meter board.

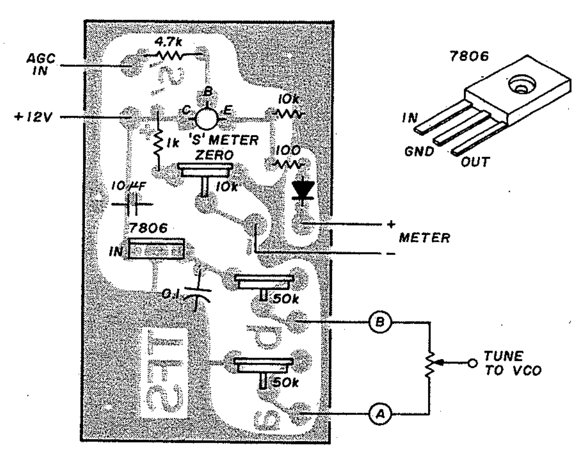


fig. 12. Parts placement guide for the voltage-regulator/S-meter board, component-side view with a printed circuit board in the background.

tuneup

Tuneup is a breeze!

1. Set BFO to frequency on either upper or lower sideband.

2. Peak i-f amplifier for maximum signal strength.

3. Peak bandpass filters for maximum at the center of each band.

4. Set AGC level at +5 volts with no signal on the input.

5. Set the timebase for the display on the digital display board so that the displayed frequency is accurate.

6. Set trimpots on the VR/S-meter board for the proper tuning range.

7. Set the zero adjust for the meter with no signal input.

8. Repeat as needed.

This receiver has been compared with some of the best available to Amateurs; in all cases it's held its own. The receiver sounds much quieter than any of the other receivers. Signals seem to pop out of the background. There is no roar of noise in the speaker when no signal is being received.

Single-tone dynamic range tests at 14.2 MHz work out to about 124 dB (**table 3**). This is with a signal

table 3. Specifications for the two-band receiver.

tuning range	3.5 to 4.0 MHz 14.0 to 14.5 MHz
VFO frequency	5.0 to 5.5 MHz (remotely tuned via dc)
i-f	9.0 MHz center frequency
BFO	USB: 8998.5 MHz LSB: 9001.5 MHz
digital readout time base	5.24288 MHz crystal
tuning resolution	± 100 Hz
voltage requirements	+ 12 Vdc; on-board regulation supplied as needed
current requirements	approximately 100 mA at medium volume setting
selectivity	SSB: 2.4 kHz (6 dB down) 1.8 shape factor (6.60 dB) 2.2 shape factor (6.80 dB) CW: peak type audio filtering; approximately 1-kHz center frequency with 6-dB bandwidth of 200 Hz
blocking	Better than 120 dB. (20-kHz spacing, 1-μV received signal strength at 14.2 MHz)

spacing of 20 kHz. A CW signal of 0.2 μV is very easily copied.

At the time of this writing, the receiver which I have described has been duplicated several times with consistent results. The receiver design has since been expanded to include two other boards which give it transceive capability on SSB and CW. This combination has been used to work forty-six states and several countries. Output power is four watts.

I have also designed a heterodyne-oscillator board that allows the receiver to be used on 160 through 10 meters.

packaging

The photographs show a few ideas for packaging your receiver. One uses a cabinet available from Radio Shack and other similar stores. Other versions are built into aluminum chassis which are used as cabinets. Surplus cabinets salvaged from old test equipment can be found for a minimal price. One of the receivers shown makes use of two standard Bud chassis (AC402 — 7 × 5 × 2 inches) assembled top-to-top with a front panel.

A very economic approach is to strip out an old low-cost receiver or transmitter. This will provide you with not only the chassis and cabinet, but also all the hardware you may need. Because of the design of the receiver, you need not worry about the mechanical arrangement of the various controls, as everything is switched with voltages. An old CB transceiver is another possibility. A new paint job and some rub-on letters will give a modern appearance. The only limit to the project is your imagination.

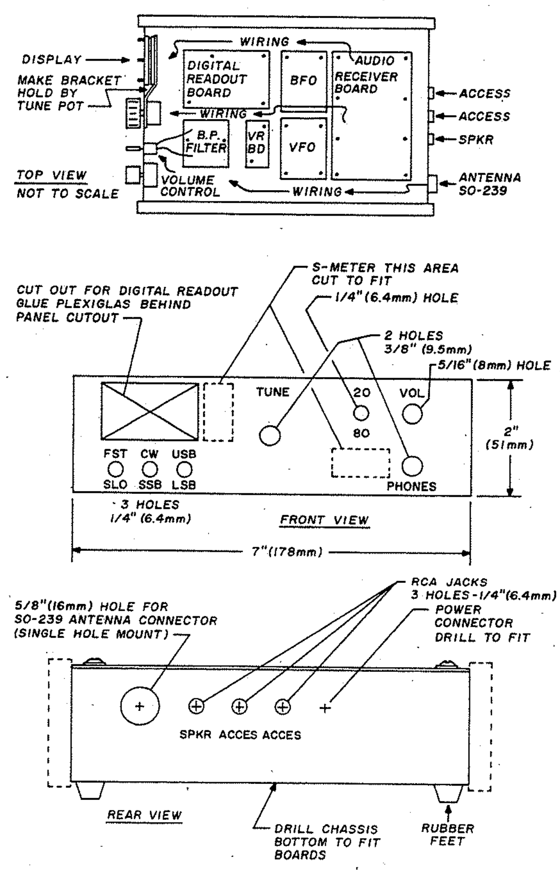


fig. 13. Suggested packaging for the two-band receiver. The enclosure is a standard 2 × 7 × 11 inch aluminum chassis (Bud AC402) with cover plate. Wood rails are added to the side and stained. The cabinet and panel can be painted to choice. Miniature toggle switches are used, and the volume control is a miniature type with on/off switch.

conclusion

Experiments have been performed using this design in a dual-diversity configuration, with excellent results. Basically, the design consists of one VFO board, one BFO, a digital frequency readout, two receiver boards, one audio stage, and a logic board to complete the hook-up.

This entire project has been approached from the viewpoint of an Amateur Radio operator, rather than as an engineer. It is relatively inexpensive and provides maximum performance at minimum cost, compared to receivers of similar performance. The design is easy to build, adjust, and package. None of the circuits are unstable, nor do they require any tinkering to achieve best performance. Best of all, the very nature of the design project promotes experimenting in the fascinating field of communication receivers.

As I have done with several of my projects, I have assembled several kits of parts for this two-band receiver. The kit includes all six pc boards and all parts needed to assemble them. A four-digit, ½-inch display and a Jackson Brothers vernier drive are also included. Documentation includes schematics, parts lists and layouts, block diagrams, and instructions. Drilling templates are provided for the version using a 2 × 7 × 11 inch (5 × 17.8 × 27.9 cm) chassis as a cabinet, **fig. 13**. The builder must supply the hardware, wiring, and cabinet. The cost of the kit is $320 here in the United States. Please send an SASE to the author with any inquiry.

references

1. Wes Hayward and Doug DeMaw, *Solid State Design for Radio Amateurs*; ARRL Inc., Newington, Connecticut 06111, pages 89, 92-94, 111-114, 117-119.
2. Doug DeMaw, *ARRL Electronics Data Book*, ARRL Inc., Newington, Connecticut 06111, page 55.
3. *Toroid Core Data Sheets*, Amidon Associates, 12033 Otsego Street, No. Hollywood, California 91607.

ham radio

extending the modular 2-band receiver

Add two boards — and build yourself an HF transceiver for SSB and CW

In the July, 1983, issue of *ham radio* I presented a design for a practical, easy-to-use HF receiver with digital readout.[1] The simple addition of a converter to the front end extends the receiver's frequency coverage to VHF; the addition of just two more boards turns the unit into an SSB/CW transceiver as well, see **fig. 1**.

design concept

Simply stated, an SSB transmitter amplifies voice, mixes it with a carrier frequency in such a way as to balance out the carrier, removes one sideband, and mixes the result up or down in frequency to the desired output frequency.

In this design, see **fig. 2**, the audio from the microphone is amplified by a two-stage speech amplifier and applied to a simple two-diode balanced modulator that removes the carrier, providing a signal that contains two sidebands and a suppressed carrier. The carrier source is the BFO. By selecting either USB or LSB, the operating mode for the transmit signal is also selected. To remove one of the sidebands, the signal is passed through the same crystal filter used for receive. Just as the unwanted sideband is removed on receive, the output from the crystal filter contains only one sideband. Because this sideband signal, however, is too low in level to allow the transmitting mixer to function properly, an IF amplifier must be used to increase the signal to an effective level. The output of this stage is injected into the MC1496 double-balanced mixer IC, where it again mixes with the VFO to produce outputs at 14 and 4 MHz ($9 + 5 = 14$ and $9 - 5 = 4$). The same filters as those used for receive are used here to remove the undesired output. The 20-meter filter removes the 80-meter signal and vice-versa.

The SSB signal present at the output of the bandpass filter is clean but at a very low level. A two-stage broadband amplifier has been designed for an output of about 10 watts (see **fig. 3**). The driver transistor is a 2N3866 which in turn drives a 2N5590 operating in class AB. The output at this power level is "clean" (low spurious/harmonic content) and requires no additional filtering. However, if you wish to drive a much higher output broadband amplifier, I would recommend adding low-pass filters for each band. Several articles on this subject have been published in this and other magazines.

operation

The same mixing scheme used for SSB transmission can be used to generate CW. A twin-T oscillator serves the dual purpose of generating both a sine wave tone, used for monitoring, and the CW signal. When a clean tone of a single frequency is applied to an SSB transmitter, a single output frequency, separated from the removed carrier frequency by the frequency of the applied tone, is produced from the transmitter. For example, if a 1 kHz tone is injected into the SSB transmitter, a CW output offset by 1 kHz is generated. Conversely, if tuning in another station produces a 1 kHz CW tone on receive, your transmitter will be on the exact transmitting frequency of the other station when you answer. (A similar method was used to produce CW in the old Heathkit SB/HW series of transceivers.)

To send CW it's necessary to activate the transmitter by either manually switching to transmit or, more easily, using the included 555 timer circuit. This keeps the transmitter on between the dots and dashes. The twin-T oscillator and the timer circuit are keyed at the same time; only the 555 timer is keyed in SSB. This timer stage switches all stages into transmit for a period determined by the adjustable time constants. In addition, the AGC for the IF amplifier must be disabled while in the transmit mode by grounding the AGC control pin 5 on the MC1350, through a 4.7 kilohm resistor.

By James J. Forkin, WA3TFS, 3210 Shadyway Drive, Pittsburgh, Pennsylvania 15227

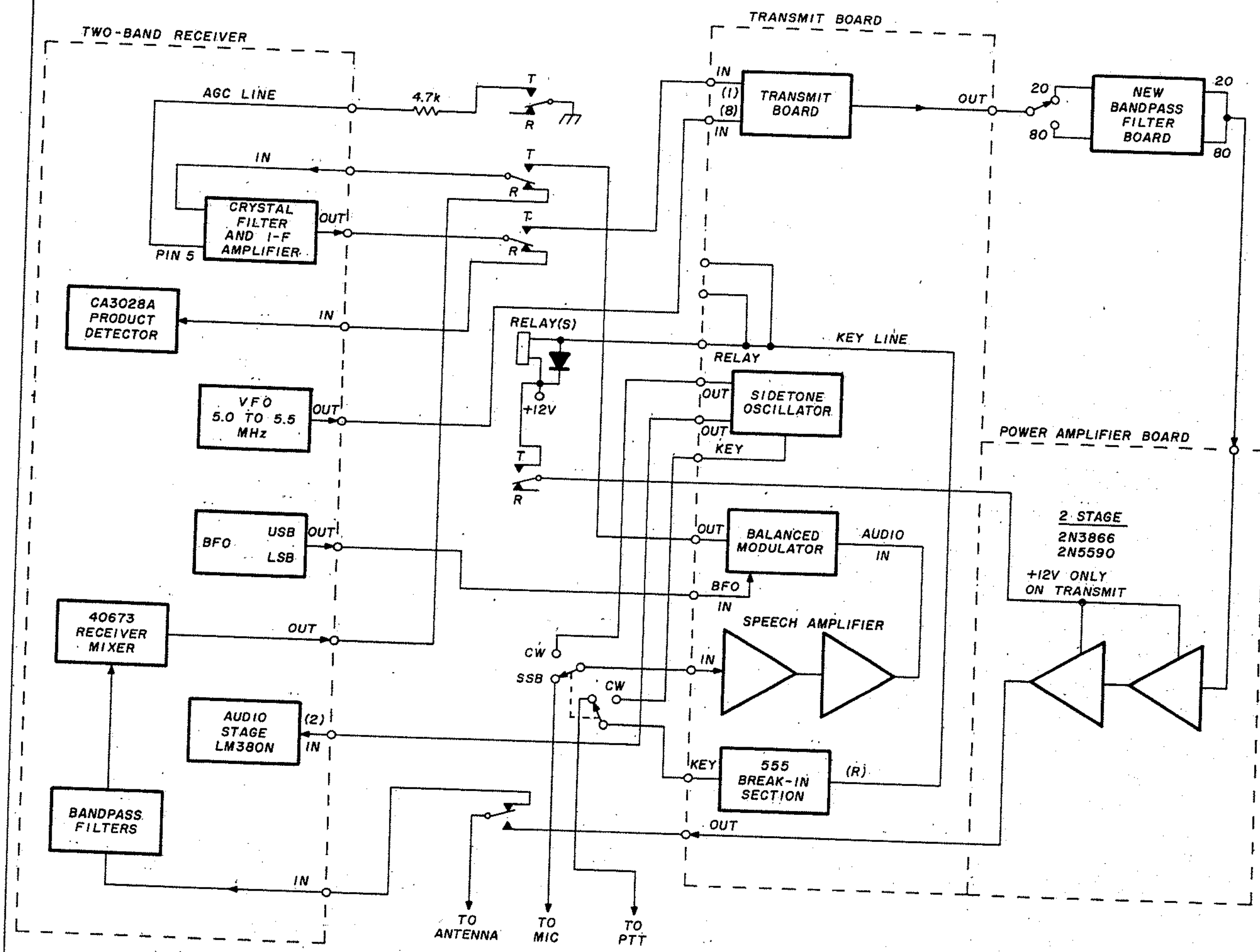


fig. 1. The interconnection diagram. Circuits within the dotted lines are on either the receive board on the left or the transmit board on the right. If more than one relay is used, wire the coil in parallel with the one shown. Use a protection diode as shown on each. Use shielded wiring on all audio circuits and 50-ohm coax on the transmit/receive relay wiring. The new bandpass filter board is identical to the board described in the July, 1983, *ham radio* receiver article.

construction

The transmit modification is accomplished through the addition of two PC boards. One consists of the two-stage amplifier described above. (Component layout and printed circuit board artwork are detailed in **figs. 4**, and **5**, respectively.) The other board, however, is the actual transmit conversion. Shown on the board, (component layout and printed circuit board artwork are detailed in **figs. 6** and **7**), from left to right, is the 1 kHz sidetone oscillator coupled through a panel switch to the speech amplifier stage in the CW mode. Next is the 555 timer stage, which holds the rig in transmit for a period of time adjusted by the trimmer pot. To the right of the timer is the transistor, used to switch the relays used in the various stages of the receiver. Next in line is the two-stage speech amplifier; note that the two stages are coupled by a jumper wire to simplify the addition of audio companders, processors, or other components later. The balanced modulator is next. Be careful to wind the toroid core exactly as shown, keeping all leads as short as possible. It is this stage that determines the ultimate level/amount of carrier suppression the transceiver will offer. The double-balanced mixer completes the board.

switching

It is important to switch the crystal filter and IF amplifier stage when going from receive to transmit. A single-pole, double-throw miniature relay mounted close to the input and output of this stage does this. Use shielded wire to and from the transmit board. (RG-174 miniature coax works well.) The front end filters must also be modified by adding two relays or alternatively, replaced with new filters exactly like those used for receive for the transmitter, thus eliminating the need for relay switching here. The only

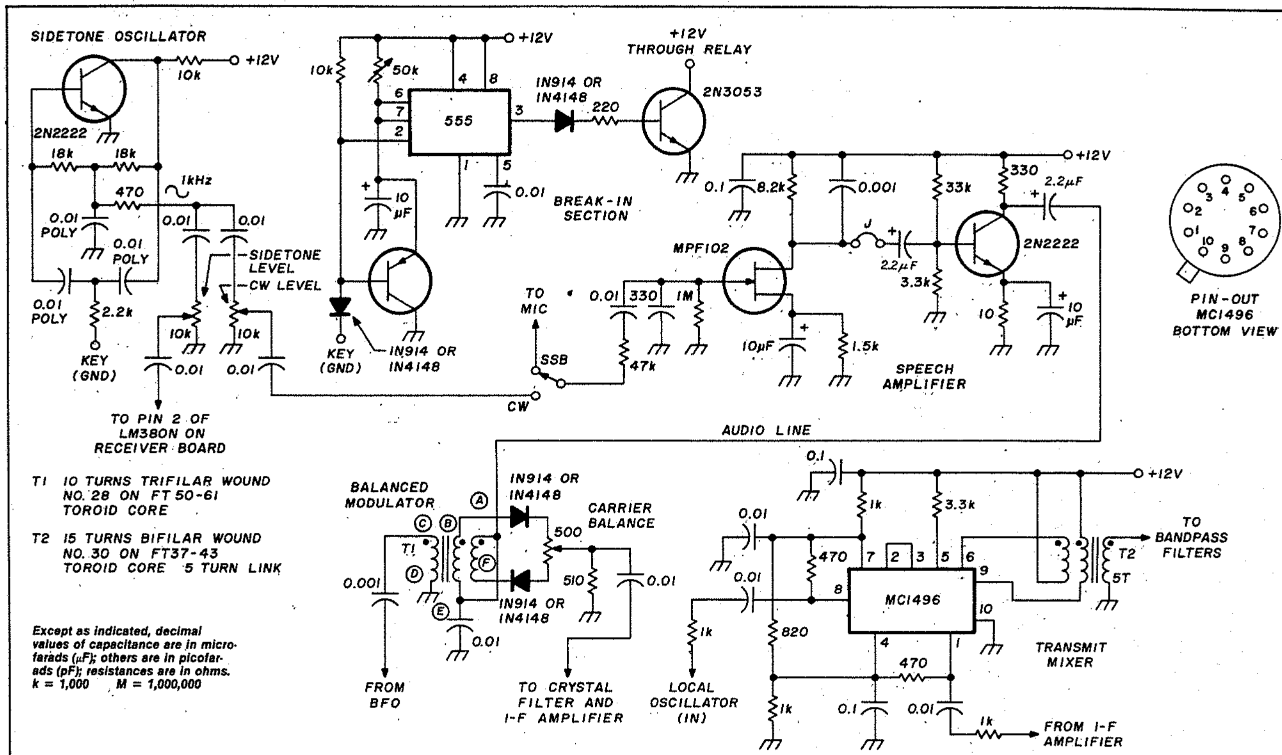


fig. 2. The schematic diagram of the transmitter board.

disadvantage to the latter approach is the need to allow for weight and additional space; despite these disadvantages, replacing the filters rather than adding relays does simplify the modification. Use coax for the filters — keep the RF where it belongs! And don't forget that to pull the AGC voltage below 5 volts for maximum gain, you'll have to use another relay or add an extra set of contacts to one of the other relays to ground pin 5 of the IF amplifier through a 4.7 kilohm resistor. Should you choose to use diode switching instead of relays, you may wish to consult several articles that have been published on the subject for help with the design.

For simplicity's sake, you may decide, as I did, to use relays. Several types of 5- and 12-volt DC relays are available on the surplus market. Use 12-volt relays if you can find them at a reasonable price, or wire three 5-volt relays in series; they'll key reliably on 12 volts. Mount your relays to the board with double-sided foam tape or glue. Place a diode across each relay coil to prevent voltage spikes.

initial adjustments

After completing the modification, make sure that the receiver still works. Realign it and check the BFO frequencies. When you're convinced that the receiver is working as well as it did before the modification, connect a dummy load to the antenna terminal and key the transmitter in the CW position. Check that all

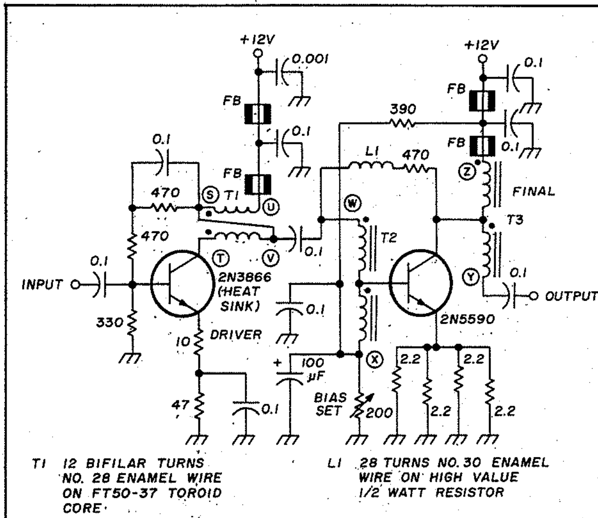


fig. 3. The schematic diagram for the final amplifier board. The driver section is similar to the VFO buffer in the receiver and the final stage is patterned after the original design.

relays switch as they should and adjust the 555 for a hold-in time of about 1 second. Check that the AGC voltage at pin 5 of the MC1350 is in fact dropping below 5 volts on transmit. Put the rig into SSB and

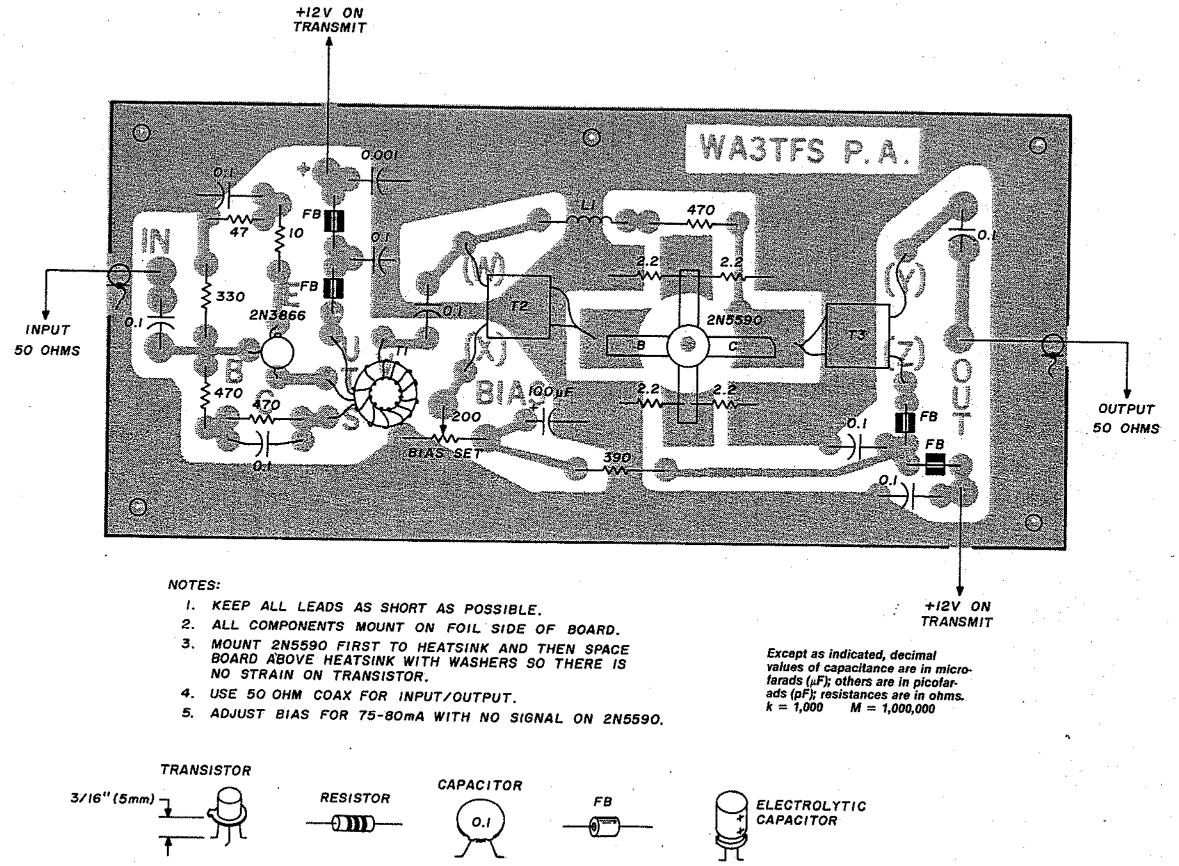


fig. 4. The parts layout for the RF amplifier board. Positive 12 volts is applied only on transmit. Set bias adjustment for an idle current in the final stage of 75 to 80 mA with no drive applied to the board.

adjust the output stage for a resting current of 80 mA. With the rig in SSB there will be no drive to the final stage. Put the switch back in CW. When keying, adjust the trim pot in the oscillator stage for sidetone level. Increase the drive level with the other trim pot until no increases in output level from the transmitter are noted. Back off the adjustment slightly. CW tune-up is completed.

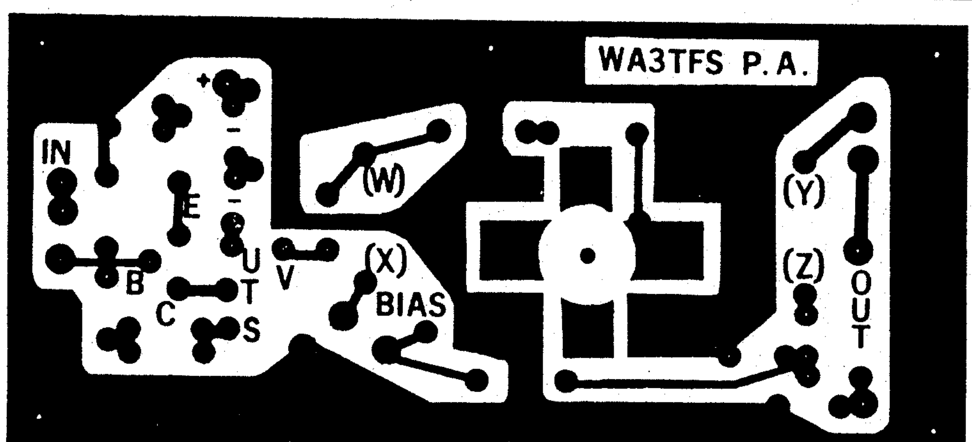


fig. 5. The foil side layout for the RF amplifier board. All parts on this board are mounted on the foil side.

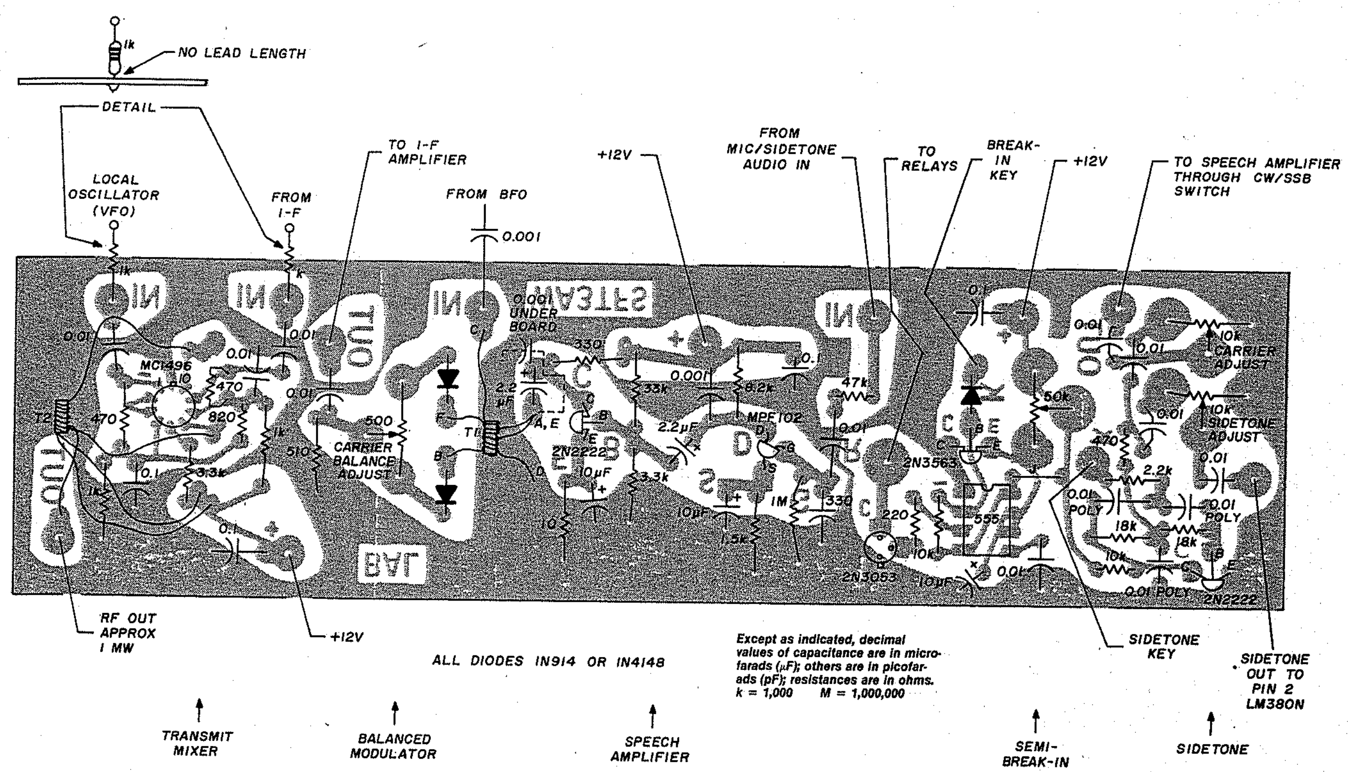


fig. 6. The parts layout for the transmit board. (Note: On this board components are *not* mounted on the foil side.) Use shielded wire for all audio connections, and 50-ohm coax for all RF wiring.

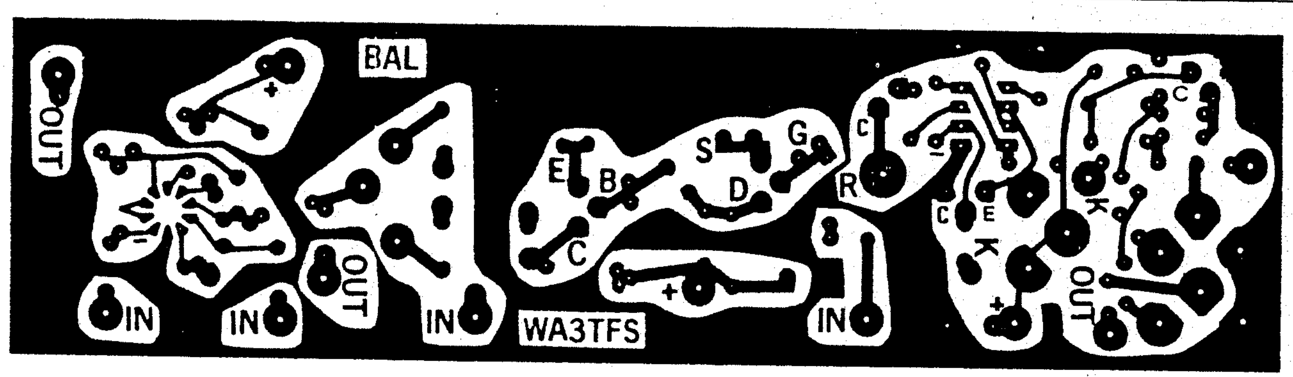


fig. 7. The foil side layout for the transmitter board.

Next attach a microphone to the input. (A CB replacement microphone will be sufficient.) If the CW/SSB switch has been wired correctly, the microphone will be connected to the input of the speech amplifier and the twin-T oscillator will be disconnected. When you press the PTT and whistle into the microphone, the RF output should increase. The level should be about the same as when transmitting CW, but may vary because of different output levels of various microphone elements.

Disconnect the microphone and while still in SSB, key the transmitter with a jumper wire. While checking the output with a meter, or better still, an oscilloscope, adjust the trim pot in the balanced mixer for minimum output and, consequently, maximum carrier suppression. If you can't see any change in the meter reading as you make this adjustment, you'll know you've either wound the coil in the balanced modulator incorrectly or caused some stage to oscillate because of poor wiring layout or failure to ground something. Check your construction step by step. You should see a definite null in output power. If everything appears to be in order, go back and readjust everything until no further change occurs. Your new transceiver is now ready to be connected to the antenna.

conclusion

This complete transceiver will operate reliably and efficiently as long as care is taken to attach a matched 50-ohm load. The output stage will not self-destruct if you have high SWR or forget to attach the antenna, but output power will be low. The rig should run about 8 to 10 watts out into a matched antenna. I have worked all states on 20-meter sideband and find I require no more power from the home station.

A kit is available from the author to make the modification described in this article. For details, please send an SASE to me at the address shown at the beginning of this article.

ham radio