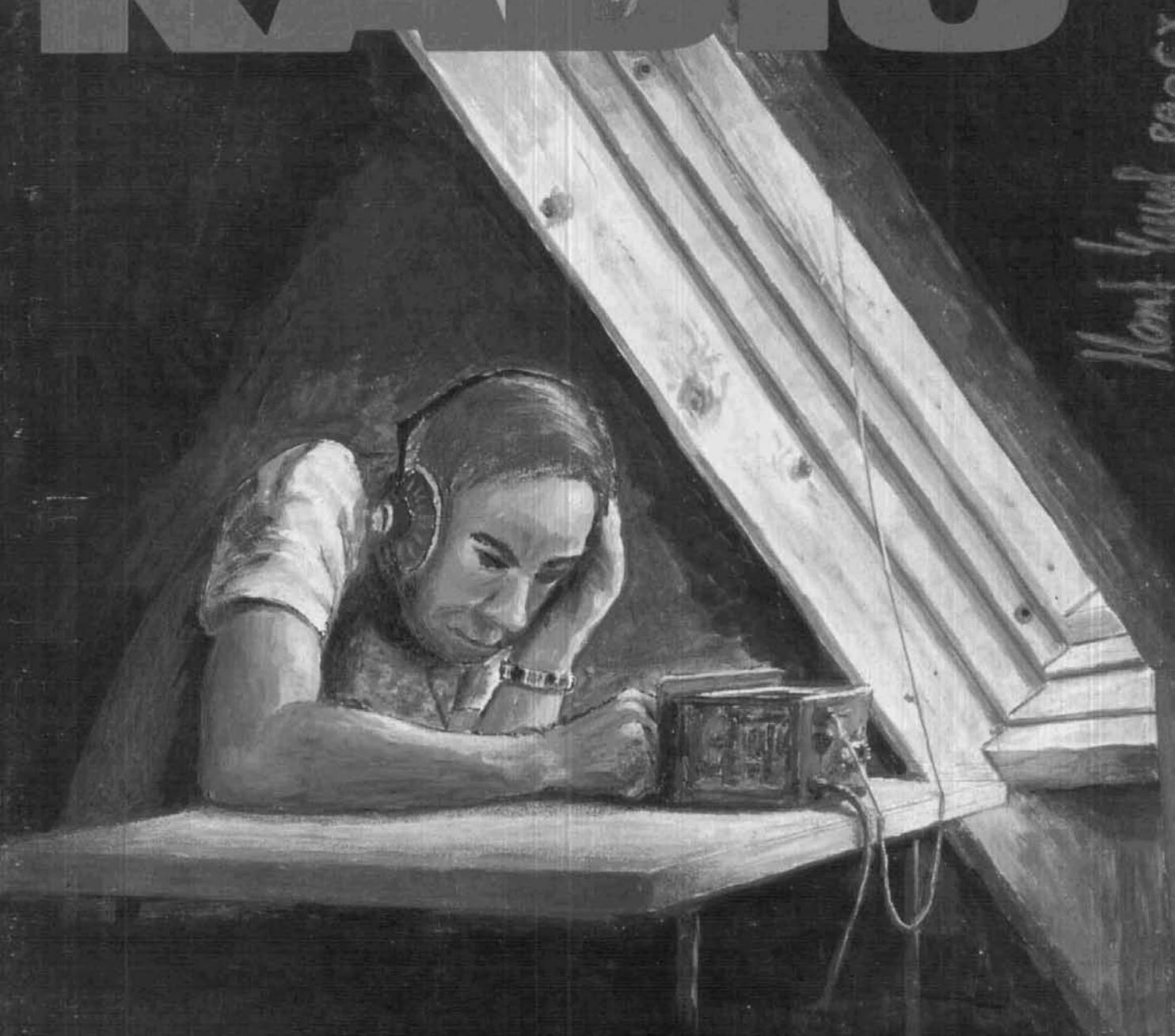


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HAM RADIO



Annual RECEIVER issue

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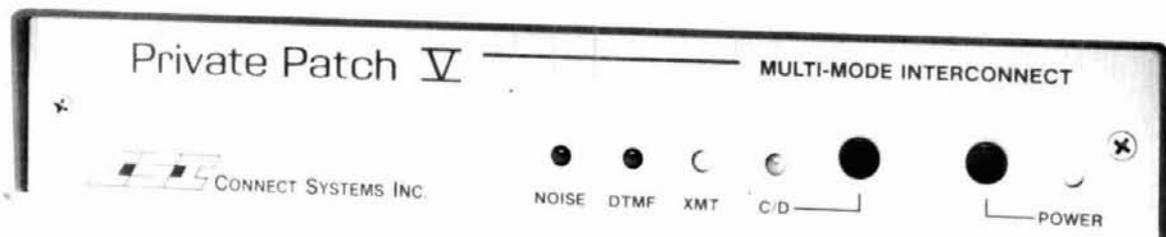


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FEATURES

10 Simple Receivers from Complex ICs

Bill Parrott, W6VEH

24 The Weekender: Improving Operation with the MFJ 989 Transmatch

L.B. Cebik, W4RNL

26 Ham Radio Techniques: The radio boys in the Pacific, or, working DX for Uncle Sam

Bill Orr, W6SAI

33 The Pepperdyne Receiver

Jim Pepper, W6QIF

60 The Weekender: A 1296-MHz Low Noise Amplifier

Norman J. Foot, WA9HUV

67 A Solid-State 75A-4 Receiver

James M. Larson, KF7M

100 Practically Speaking: An Overview of Operational Amplifiers: Part 1

Joe Carr, K4IPV

117 Elmer's Notebook: SSB Basics: Generating the Signal

Tom McMullen, W1SL



KF7M, page 67



**THE
WEEKENDER**

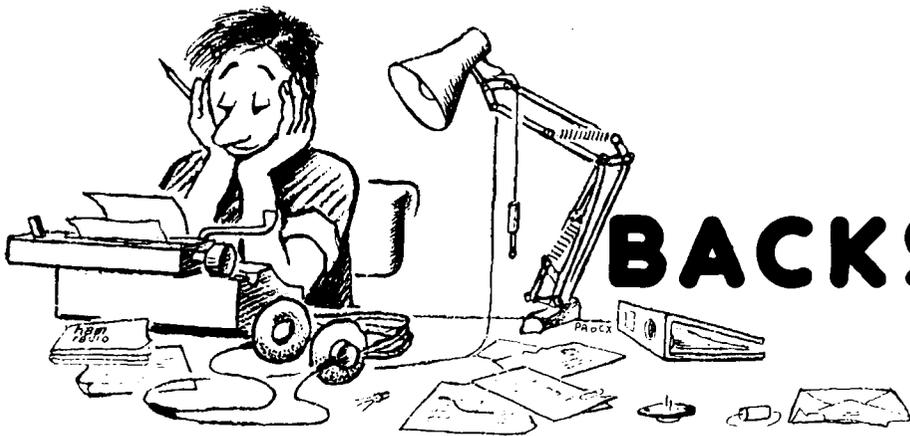
W4RNL, page 24

WA9HUV, page 60

See page 97 for the winners of
September's handheld radio
contest.

DEPARTMENTS

Backscatter	4	Flea Market	112
Comments	9	New Products	120
Ham Notebook	98	Advertiser's Index	126
Ham Mart	106	Reader Service	126
DX Forecaster	108		



BACKSCATTER

A potential danger...

Recently a great amount of attention has been given to the effects of electromagnetic radiation on the human body. Dr Samuel Milham of the Washington State Department of Social and Health Services (as well as several others*) has written a number of studies indicating that there may be a link between electromagnetic radiation and several forms of cancer. Lately Milham's studies have been picked up by the wire services and articles have appeared in newspapers nationwide. While this isn't a revelation (we all know that at certain frequencies electromagnetic energy can be harmful) it is cause for concern, because one of Milham's study groups consisted of male Radio Amateurs in the States of Washington and California.

In a paper published in the *American Journal of Epidemiology* (Vol. 127, No. 1, January, 1988), Milham observed there was an elevated rate of mortality from several different forms of cancer in male Radio Amateurs in Washington and California, during the years 1979 through 1984.

Looking at the broader field of danger from all forms of electromagnetic radiation, Milham published a paper in *Environmental Health Perspectives* (Vol. 22, pages 297-300, 1985) which included an occupational mortality analysis of 486,000 adult male death records filed in Washington State from 1952 to 1982. He looked at electrical and electronic technicians, radio and telegraph operators, radio and TV repairmen, telephone and power company linemen, power station operators, welders, aluminum reduction workers, motion picture projectionists, and electricians. He states that: "In the 1952 to 1982 data set, men whose occupations were associated with electric or magnetic fields had more deaths due to leukemia than would be expected."

Now before anyone jumps to an erroneous conclusion, let me add that at the end of the first paper, Milham states that the overall mortality for Radio Amateurs compares quite favorably with that of the rest of the population. It's also important to note that these studies are very preliminary and will require additional years of exhaustive work before any firm conclusion can be reached.

One of the biggest dangers with reports like Milham's is that the casual reader may be misled by media reports on the subject written without all the facts. Everyone knows of stories that have appeared on TV or in print, giving only partial information, which have created a great degree of unwarranted concern. Paul Brodeur's 1977 book *The Zapping of America*, while informing us of a potential danger, was written in this kind of sensational vein. Credibility is what's required — not sensationalism!

A number of hams around the world are very concerned about the bio-effects of electromagnetic radiation. In response to earlier concerns, the ARRL has formed a bio-effects committee a number of years ago. Wayne Overbeck, Ph.D., N6NB, and Stu Cowan, W2LX, are also concerned and are cooperating with a number of other concerned amateurs and organizations** in an in-depth study. While neither Overbeck or Cowan are physicians, both are experienced amateurs and want to get to the truth of the matter. Dave Rodman, M.D., KN2M, a medical doctor who is researching the bio-effects of electromagnetic radiation — specifically 60-Hz radiation.

At the ARRL National in Portland, Oregon on September 10th, 1988, Overbeck presented his preliminary findings to a packed audience of interested Amateurs. He summarized the dangers as follows: radio frequency energy, 60-hertz electromagnetic fields, and chemical agents. (See HR's December 1983 issue on the dangers of PCBs.) Overbeck did add some caveats to his research. First, it's difficult to prove cause and effect due to the myriad hazards that we face, both in the workplace and home. Secondly, with cancer, the long latent periods and subtle signs and symptoms often don't become apparent until long after exposure.

Overbeck then presented his audience with a list of common sense precautions: don't run high power into a low directional antenna or more than 25 watts on VHF/UHF mobile installations without first measuring the RF power densities;*** make sure that no one is near a ground-mounted antenna or mobile antenna when it is transmitting; and make sure that all power amplifiers are fully shielded when in use. Overbeck

(continued on page 114)

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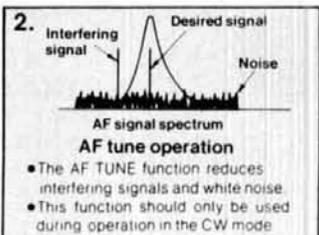
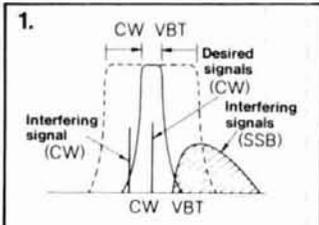
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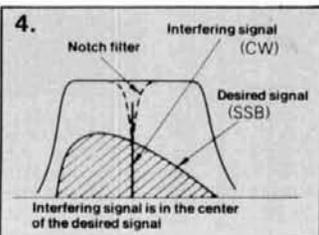
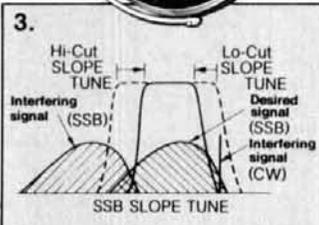
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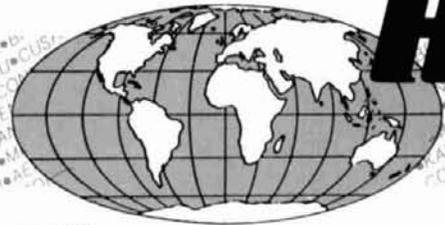
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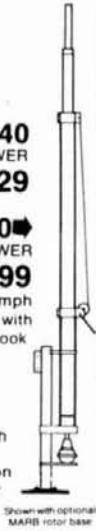
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COMMENTS

Priceless covers

Dear HR:

My wife Ginger, N5LTH, and I look forward to the *HAM RADIO* covers! PA0CX really understands the hobby and seems to always come up with a clever idea or humorous slant. He is great at using body language to tell a story. Your July "cover story" for instance is familiar to anyone who has built something from scratch—the ham is proud of his fantastic VHF circuit (his nose says so) but he's worried that people will laugh because he's used an old teapot as his resonant cavity! (crossed arms, knees together). The September cover, also cracked us up; the guy is pretending to be asleep, hoping that someone will try to make off with his treasures (note the unmistakable BC-348 and 811A) so that he can press the foot switch and zap them with the old spark coil. (See the half open eyelids and the little wires connecting all the goodies?) This is priceless. Your covers completely outclass those of any other ham magazine.

Since you are soliciting feedback on the technical and construction format — please keep up the technical emphasis. *HAM RADIO* and *QST* are the only "technical" magazines left. Please keep it up — we need you!

Don Murray, W9VE,
Dallas, Texas 75218

Congratulations!

Dear HR:

The all new *HAM RADIO* is superb. Your editorial staff has achieved a remarkably well-balanced publication—one that should appeal to just about every segment of the Amateur Radio community.

The universe of Amateur Radio presents a major challenge to those engaged in producing a technically, applications-oriented magazine. Clearly you have found the formula to yield a useful and meaningful contribution to those of us who enjoy not only operating our equipment, but also for those who still enjoy the thrill of experimentation and "rolling our own" equipment.

Your new graphics are excellent and so professionally tied in with the main theme of the story. The return of the reader service card is welcomed. It is efficient and effective...though it appears limiting the number of inquiries to 15 may dismay some of your advertisers. I usually seem to find a desire to exceed the limit.

I have every issue of *HAM RADIO* in binders, so I find your mailing wrapper a nice touch in eliminating the damage previously inflicted upon your great magazine by the postal service.

Your shorter stories are refreshing, but do run the occasional longer, in-depth story when the subject matter warrants the treatment.

In summary, the *HAM RADIO* staff deserves a round of prolonged applause for your response to your readers needs and in producing one of the finest Amateur Radio magazines available anywhere on our globe.

Kenneth M. Miller, K6IR,
President,

National Capitol DX Association,
Rockville, Maryland 20853-1128

Big is better

Dear HR:

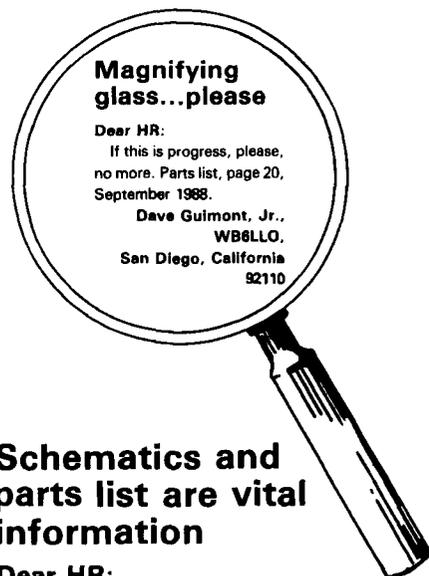
I have been a subscriber of *HAM RADIO* for many years and my sub-

scription, I believe, runs until 1991. However, the new format, in my opinion, is "lousy"!!! I would much rather have the usual "BIG" technical (articles) with depth than the smaller ones as depicted in the September, 1988 issue.

The interspersing of advertising with editorials turns what was once an excellent technical publication into a *QST* (which is okay for what it is supposed to achieve) or a *CQ*.

Perry Pollins,
Lexington, Massachusetts
02173-0362

Our advertising has always been mixed with our editorial content. Ed.



Schematics and parts list are vital information

Dear HR:

I just received my September 1988 issue of *HAM RADIO* and would like to congratulate you on the new format, with one exception. I was disappointed in the article entitled, "A Direct Synthesis VFO," by Robert J. Zavrel, W7SX. Don't get me wrong, I found the article very informative and well written. However, there were no schematics or parts lists accompanying it.

I have always enjoyed reading *HAM RADIO* for its technical content and construction articles but, I viewed this article more as an advertisement than

(continued on page 104)

SIMPLE RECEIVERS FROM COMPLEX ICs

By Bill Parrott, W6VEH, 7662 Bellaire Avenue, N. Hollywood, California 91605

As integrated circuits become more complex, ham designs can become correspondingly simpler and smaller. Multifunction ICs open the door to a whole new world of simple "weekender" receivers for Novices and old-timers alike.

Who needs a simple receiver?

Simple receivers, like the ones I'll describe, are good ones for beginners. They help bridge the "if you want to be a ham, you have to make a major investment" gap. But simple receivers shouldn't just be dismissed as Novice devices. They can be used in homebrew test equipment, time standards, net monitors, panadaptors, and other gadgets where the main shack receiver isn't appropriate.

Design goals

My projects started with a need to test some mobile antennas. I built a noise bridge, using the circuit in the

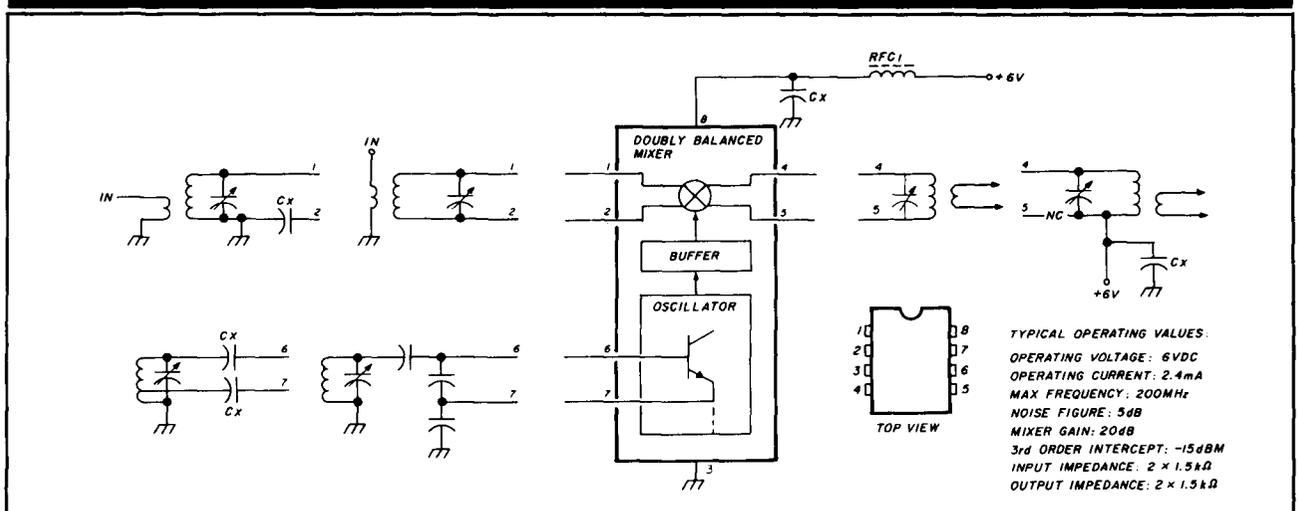
ARRL Handbook, but it needed a receiver as a noise detector. Dragging a large expensive receiver out into the driveway was clumsy, so I decided to build my own.

What I needed was a simple, low-power receiver that was quick and easy to build. I considered several of the "one-IC" receiver designs, but decided that while the chips were simple, the layout and debug problems were not. I settled on the good old direct conversion (DC) approach. Then I discovered the Signetics NE602N, one of those "magic" chips that unlocked both of the following designs.

A magic mixer

The NE602N shown in fig. 1 is a combination chip, consisting of a double-balanced mixer and an internally connected bipolar oscillator with built-in buffering. The mixer portion is similar to the MC1496G, except that the eight external resistors usually required with the MC1496G have been moved on-chip. The oscillator is also internally

FIGURE 1



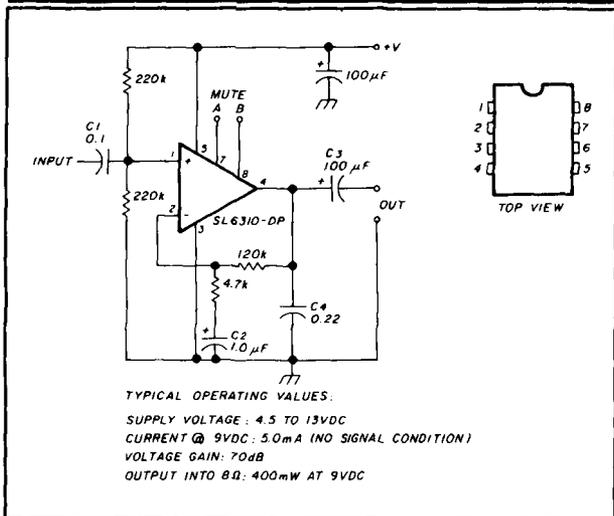
One of the possible configurations of the NE602N. Balanced circuits are preferred, but may be difficult to implement.

Cx: Blocking/bypass capacitors, 0.001 to 0.1 μ F, depending on operating frequency.

RFC 1: Ferrite beads or RFC, recommended at higher frequencies.

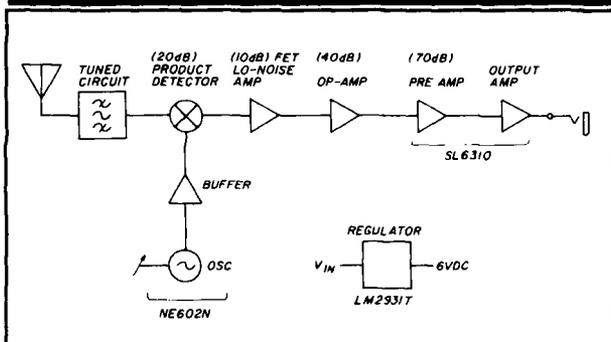
Unmarked components are tuned circuit elements.

FIGURE 2



Plessey SL6310-DP high-gain audio amplifier. All capacitor values are μF . The values shown are for "hi-fi" operation. The low frequency response can be raised by decreasing C1, C2, and C3. The high frequency response can be decreased by increasing C4. The mute pins are internally biased, and may be left open. Grounding "A" or connecting "B" to pin 5 will mute the output. The mute connections must include a 100k series resistor.

FIGURE 3



Block diagram of the 3×8 direct conversion receiver. Having more than one function per chip is advantageous.

biased, with the cathode and base connections brought out. The circuits shown in fig. 1 are examples of some of the ways to use the chip; many other versions are possible. If you compare these circuits with the usual front-end designs and then review the performance specifications, you'll see why it can be a magic chip for very simple low-power receivers!

A word of caution is in order: the internal biasing of the NE602N requires that the external circuits be isolated from ground and power, or that blocking capacitors be used. The mixer outputs are an exception; they can be connected to the positive source voltage through the output circuit.

Signetics has published only a preliminary data sheet¹, and their application note² adds very little information.

However, the information included here is really all you need. The chip is very easy to hook up and the oscillator seems to work with almost any breadboard lash-up.

A magic audio amplifier

I was encouraged by finding the NE602N and started looking for a good audio amplifier to go with it. Most DC receivers use a chain of high-gain audio stages followed by some compromise design for the output stage. After a lot of searching, I finally discovered the Plessey SL6310C, another magic chip — at least for this design.

The SL6310C (see fig. 2) can be described as a noninverting op amp, with an 8-ohm power output. In one eight-pin package I had a high-gain preamp, and more than enough audio output. The device can be muted, using pin 7 (active low) or pin 8 (active high), but these pins may be left open if you don't need the mute function. With 70 dB of gain and 400 mW of audio output, it's a great device.

A magic regulator

Because the NE602N is optimized for 6-volt operation, and since I wanted to use a 9-volt (2U6) transistor radio battery, some kind of voltage dropping and regulation was required. Zener diodes are fine for some applications, but proper operation requires that they draw heavy (10mA) current. Most of the common integrated regulators also consume a fair amount of current. My third magic chip was the National LM2931, an adjustable voltage regulator. Its quiescent current is only 400 μA , and its "headroom," or input/output differential, is only 0.6 volts! It's an "automotive" regulator and is self-protecting against shorts, overloads, reversed input voltages, and 60-volt transients. It was an ideal part for the purpose.

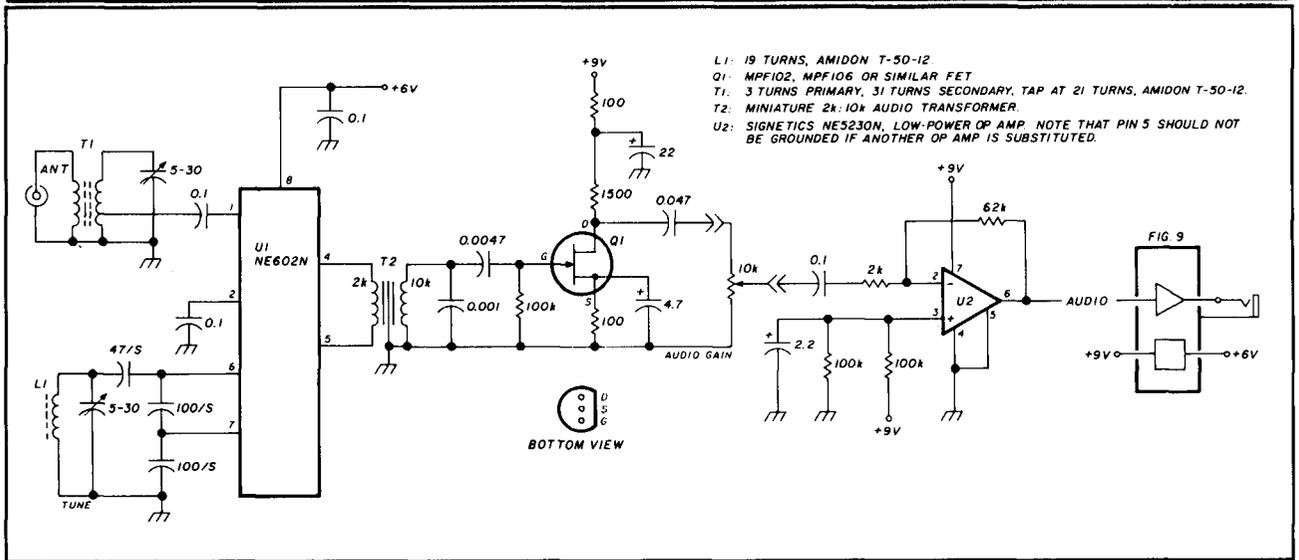
The $3 \times 8 + 2$ design

Armed with these chips, I started my noise-bridge detector design. The shortcomings of DC receivers, like microphonics and poor selectivity, are well known. However, the shortcomings had to be balanced against the advantages of small size, low current, and freedom from image problems.

Images would be a major problem with a superhet. There would be a high noise level at the image frequency, and with simple input circuits, the desired null might be masked by the image noise. Here's one of those rare occasions where a DC receiver could outperform a superhet.

I tried to keep the number of components to a minimum, but with only 20 dB of mixer gain and 70 dB of audio, the results were marginal. I added an op amp to pick up the needed gain, but I found that other authors were correct when they put a low-noise FET amplifier in front of the audio chain. Without it you have S9 + 40 op amp noise. I could have used a low-noise op amp

FIGURE 4



Schematic of the 3 × 8 direct conversion receiver. The tuned circuit values shown are for the 10-meter version, but they are easily scaled for other frequencies. Whole numbered capacitor values are pF, except for polarized capacitors which are μF. Decimal capacitors are also μF. Components marked /s (stable) are polystryene, silver mica, or NPO ceramic. The audio and regulator circuits are "recycled" from fig. 9.

instead, but the good low-noise ones draw about 14 mA. This would have exceeded my power budget.

The final DC receiver design is shown in figs. 3 and 4. The block diagram is expanded to show the many functions available from the few chips.

The front-end circuits are "no frills". The mixer shows the usual tuned circuit input, but for noise bridge use I detuned this circuit. Signals in the CB, 10 meter, and commercial ranges made the null hard to find. For noise bridge applications you can leave the capacitor out; you'll need the usual tuned circuit for other applications.

The oscillator is a simple Colpitts, which inherently provides the necessary isolation for the base and emitter input pins. For my application, bandspread tuning wasn't needed. With the components shown, the oscillator tuned from about 26 to 32 MHz. Note that this simple tuning arrangement is adequate for some test equipment, but not for communications reception. Tuning in an SSB signal on this receiver required the "freeze and hold your breath" technique. Better circuits are shown for the 5 × 8 design below, and can be substituted here.

To provide a load for the mixer output, I used one of the common 10k:2k (Radio Shack) audio transformers, with primary and secondary reversed. Terminating the secondary in a 10k resistor reflects a reasonable load back into the mixer. The transformer frame must be grounded, because its stray capacitance helps to keep RF out of the audio circuits.

The FET amplifier is straightforward; you can substitute almost any other type of low-noise FET for the one specified. The op amp circuit is also straight from the books. Note, however, that the op amp is one of the new

low-current (1 mA) types, which helps to keep the overall current drain to a minimum.

The SL6310C (See fig. 9; both designs use the same audio and regulator circuits.) provides the remaining audio gain, and also supplies the power needed to drive earphones or a speaker. Most simple receivers have weak audio outputs, but not this one. If your results duplicate mine, you'll seldom turn the audio gain all the way up!

For simplicity you would use a 6-volt battery and eliminate the voltage regulator, but the oscillator would be unregulated and the frequency would drift slowly as the battery voltage dropped. I included the regulator in my design so I could use a 9-volt transistor radio battery.

Construction

Sorry, no circuit board layout. I built the receiver on some computer prototype circuit board scraps.

You can use almost any of the usual assembly techniques. There are only a few special precautions to observe, provided you follow the usual ones like keeping the outputs well away from the inputs. One precaution concerns the audio output power circuit. Be sure to use heavy leads and run them directly back to the battery; this circuit can pull heavy current on audio peaks. Also, the 100-μF filter capacitor should be mounted very close to pin 8 because its purpose is to supply these peak currents.

The other precaution is to build the oscillator "like a battleship," since the high audio gain makes the receiver microphonic. This effect is characteristic of DC receivers in general. Careful attention to mechanical details is

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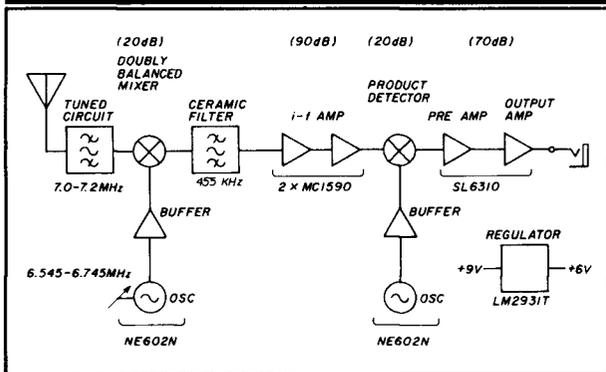
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FIGURE 5



Block diagram of the 5 × 8 40-meter superhet receiver. There are ten functional stages in five 8-pin ICs.

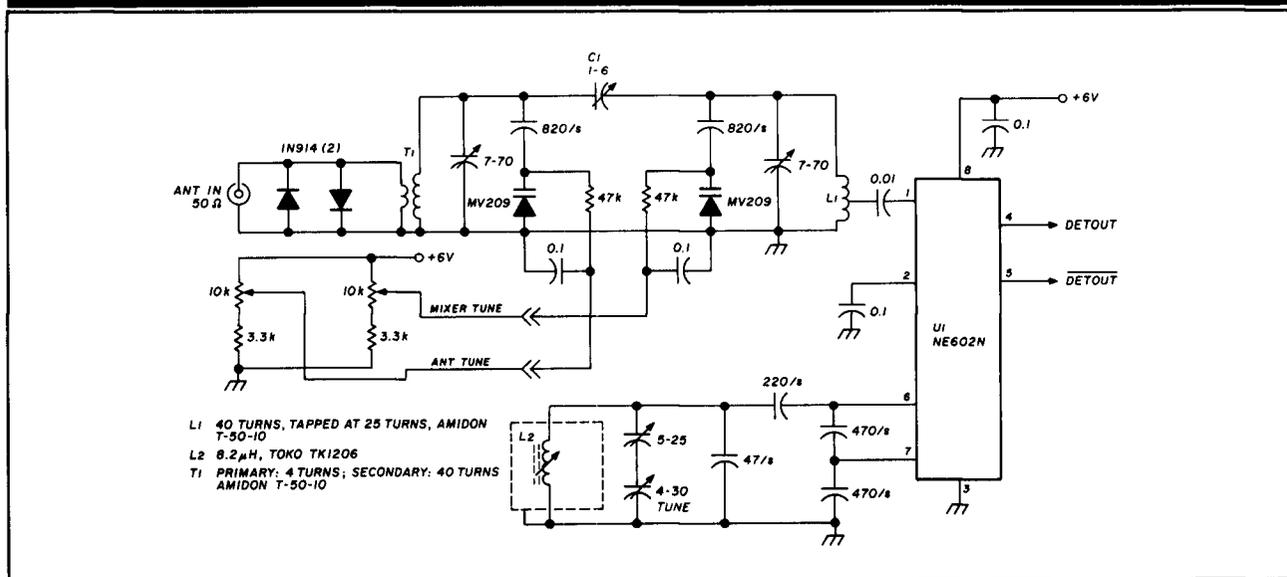
well into the VHF range, you can use this receiver anywhere between 20 kHz and 200 MHz by changing the mixer and oscillator components.

The 5 × 8 + 1 design

OK, so I got hooked. If my DC receiver was that easy to build, a simple superhet should take only a few more parts. About this time, I found a low-cost source for Toko i-f transformers and slug-tuned coils. That did it. With the above chips, and low-cost RF and i-f coils, the superhet receiver almost designed itself.

In this second design, I kept most of the previous design goals: small size, simplicity, low cost, and low current drain. I decided to switch to 9 volts of AA-size batteries, since the life of the 2U6s would be too short.

FIGURE 6



Mixer/first oscillator circuits for the 5 × 8 receiver. Decimal capacitor values of μF; whole capacitor values are in pF. Capacitors marked /s are polystyrene, silver mica, or NPO ceramic. Values are for 40 meters.

necessary to keep the receiver from living up to its name as a "boing box."

There's little to debug other than wiring errors or defective components. The only adjustment is to the local oscillator. Tweak the coil and capacitor until the proper tuning range is obtained.

Performance

I've built several DC receivers, and this design seems much less microphonic than the others — probably due to the 20-dB mixer gain. With a 5-dB noise figure and 400 mW of audio it is a "hot performer." Selectivity is typical; stability depends on the oscillator circuit and oscillator components used.

The version shown, a broad-tuning 10-meter receiver, is of limited use. However since the NE602N will work

The goals that I chose imposed some performance limitations, and I had to leave out some of the usual extras, like AGC and audio filtering. However, the basic circuits are easy to modify and the design can be expanded to meet other objectives and purposes.

The block diagram of the 5 × 8 is shown in fig. 5. An eight-pin mixer/oscillator buffer, two eight-pin i-f stages, an eight-pin product detector/L.O. buffer, and an eight-pin audio amp/output stage, plus an IC regulator make up the whole design. While the schematic looks complicated, try comparing it to other designs with the functions listed above and you'll see the difference!

If you add up the stage gains, the result seems like overkill — and it would be, except for the insertion losses in the interstage networks. I didn't include the losses in the block diagram because I couldn't measure them



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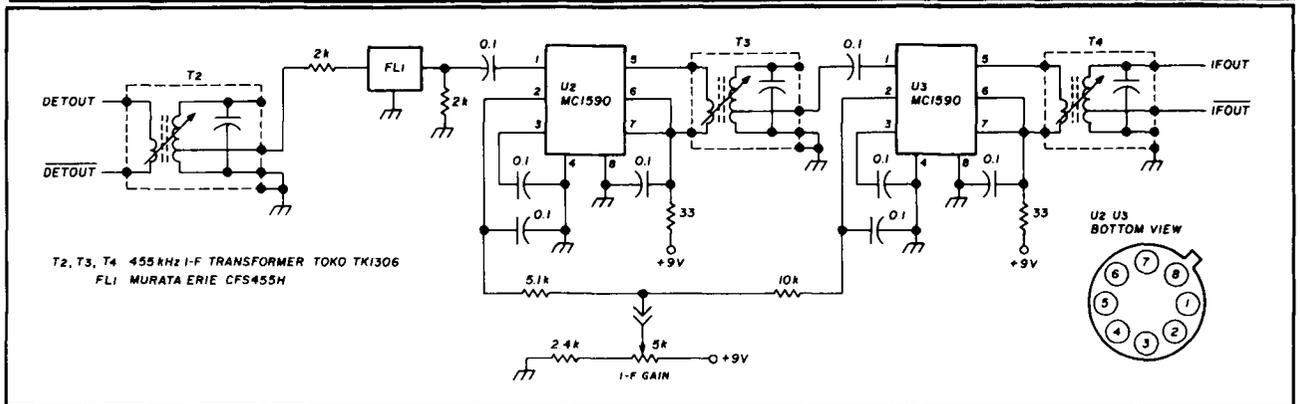
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FIGURE 7



5 × 8 i-f amplifier.

accurately. Better impedance matching would cut these losses and improve the gain, but it's an unnecessary step since there's gain to spare.

The front-end circuits

The front end (fig. 6) is an expansion of the circuit used in the 3 × 8 design. The mixer is double tuned to reduce images. Varactor tuning is an added frill that's handy but not really necessary. If you plan to use the receiver with one antenna, and on one part of the band, you can use trimmer capacitors. Peak them once and forget them. If you want optimum performance with random antennas, use either panel-mount capacitors, or varactors as I did. The controls serve a dual purpose; you can peak them for best DX reception, or use them as attenuators when the guy down the street fires up his kW rig.

The oscillator is a standard Colpitts with components added to provide the required bandwidth. The component values I used are shown in the diagram. You should expect some cut-and-try adjustments; component tolerances make the values given simply approximations.

Using a Toko slug-tuned coil for L2, instead of the usual solenoid or toroid coil, was a gamble that paid off. I was concerned with possible drift problems, but the results (at least in my case) were excellent. Having a slug-tuned coil in the oscillator makes alignment a quick, simple task. My guess is that while this little slug-tuned coil is electrically inferior to a toroid or solenoid, its thermal performance is superior due to its small size, shielding, and bonding to the circuit board.

Many authors report glowing success with their particular oscillator designs, but unless several identical units have been built with consistent results, you can suspect that the author may have been lucky. When you build a new receiver you should be prepared to swap parts and move and bond leads until you get the oscillator performance you want — even if your circuit is an "exact copy" of a published design. A good oscillator is part science, part art, and part luck.

The i-f stage design (fig. 7) is right out of the book. I could have used hotter i-f amplifiers than the MC1590, but it was the optimum choice based on a gain/ mA criterion and my design goals. Some authors use resistance-coupled designs, and rely on the filter to provide all the selectivity. I chose to use transformer coupling instead, because a resistance-coupled amplifier will amplify anything presented to it. With more than 80 dB available, any stray signal that happens to get into the amplifier chain will appear at the detector. Transformer coupling limits the passband to the signals of interest, and reduces the requirements for shielding, filtering, and decoupling.

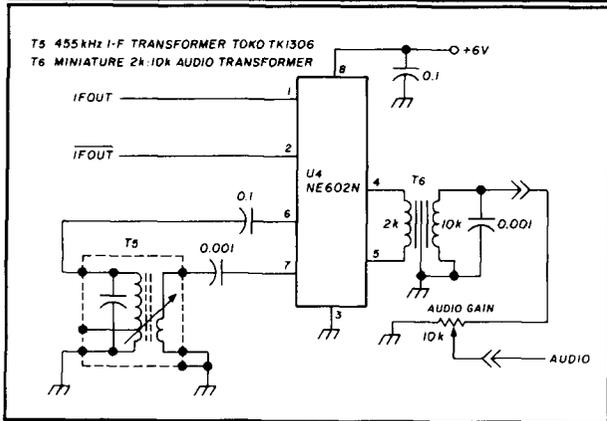
The Toko i-f transformers aren't special parts. I used them because they were inexpensive and easy to obtain. If you have a scrap transistor radio in your junk box which has 455-kHz transformers in it, use your transformers instead of the Toko ones. Because the filter sets the bandwidth, the transformer parameters are not critical.

I used a 6-kHz ceramic filter to set the receiver bandwidth. You might argue successfully that a narrower filter would be a better choice. The filter I used was more of a "procurement opportunity" than a deliberate choice, but the selection turned out to be a good one. Ideally you should use a much narrower filter, but then you'd have to switch the product-detector local-oscillator frequency and the accuracy and stability requirements would increase. The choice, and the resulting complications, depend on your needs and inclinations.

The product detector (fig. 8) also uses the NE602N; the mixer portion is a repeat of the above. For the oscillator-tuned circuit, I used one of the Toko i-f transformers in a Hartley configuration. I assumed correctly that the transformer's built-in tuning capacitor had NPO characteristics and that the frequency drift would be minimal.

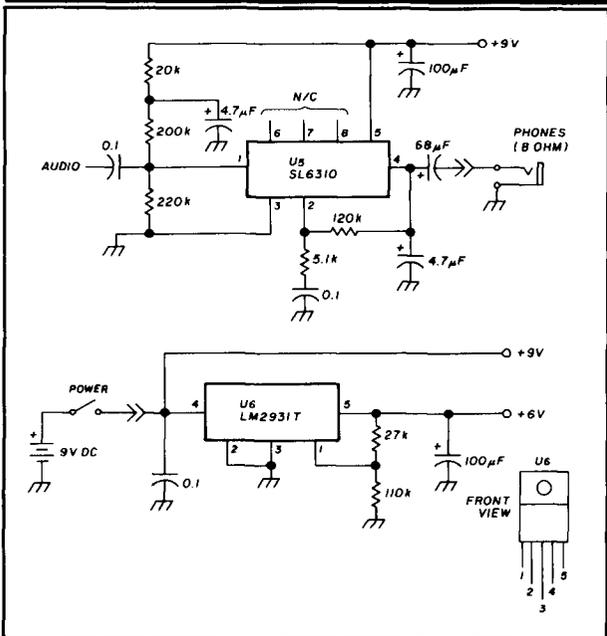
Note that the capacitor at pin 7 is 0.001 μF, while the other blocking capacitors are larger. In the whole design/debug cycle I had only one unexpected problem.

FIGURE 8



5 × 8 product detector/second oscillator. See text for comments on the capacitor at U4-7. The oscillator could be made tunable by adding a varicap diode across T5, using the circuit of fig. 4.

FIGURE 9



Audio and regulator circuits for both the 3 × 8 and 5 × 8 designs.

With a larger value capacitor, the circuit acted like a blocking oscillator and put out RF in short bursts. Reducing the capacitor to the value shown cured the problem. It's a point to consider if you use the NE602N in other designs.

The audio amplifier and regulator circuits (fig. 9) are identical to those used in the 3X8 design, and the same comments and precautions apply. When using ear-phones, be sure that you turn the audio gain down before you turn on the power!

Construction

Again, there is no circuit board artwork, because I built the receiver modular fashion. The circuits are ideal for a printed circuit layout; perhaps someone will contribute one. I would recommend building the receiver on two boards, one for the front end and one for the rest, as only the front end needs to be changed to move the receiver to different bands.

One construction problem arose when I mounted the Toko coils and the filter, because their mounting dimensions are metric. I saved a lot of time and frustration by making drill templates on small pieces of brass. The coil dimensions are shown in fig. 10. Dimensions for the filter depend on the one you choose — there is no one standard size. The effort required to make the templates is quickly repaid when you drill a circuit board.

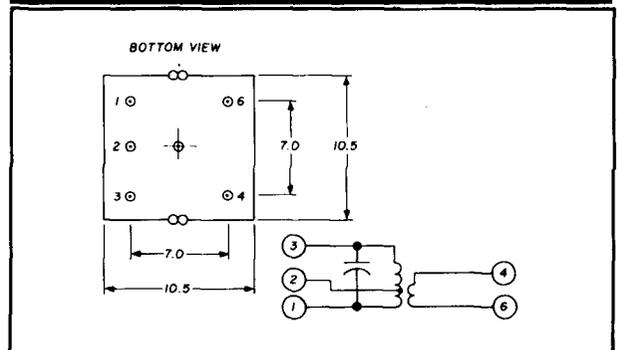
Assembly precautions

The same audio amplifier precautions mentioned above for the 3 × 8 design apply here. It's a good idea to put brass shields across the filter, the MC1590Gs, and between each mixer and its oscillator. These shields aren't shown on the schematics because I'm not certain that they are required. Shielding never hurts, and shields are easier to build in at the beginning than to add later.

If you are new at construction, I strongly recommend that you resist the temptation to crowd everything into a tiny, tightly packed assembly. If you use reasonable spacing, lots of shielding, plenty of decoupling, and keep outputs well away from inputs, your receiver should work the first time.

If you're experienced, you can make the receiver very small. The i-f transformers are available in 7-mm sizes; varactor tuning capacitors can be used; and Motorola has just announced the MC1490G, a flat-pack equivalent of the MC1590G. I suggest you build a larger version first, just to get a feel for the circuits.

FIGURE 10



Mounting dimensions for the Toko transformers. The measurements are in mm. Drill the center hole for a standard-sized screw to hold the template on your circuit board while drilling.

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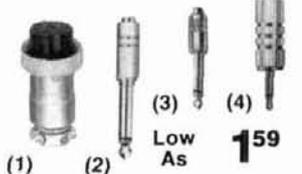
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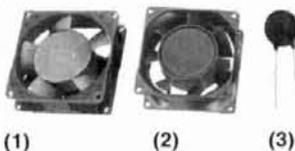
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Alignment

The first alignment step is to get the product detector and i-f strip adjusted. If you have a signal or sweep generator that covers 455 kHz, just clip it to the output of the mixer and tune up the transformers and the product detector.

If you don't have the proper equipment, you could steal a signal from the second detector of any battery-operated transistor radio. Don't interconnect the grounds; with one clip lead between radios you can get enough stray signal for a preliminary alignment.

With front-end alignment comes the familiar problem of setting the oscillator on the proper frequency (455 kHz below the input) and getting the required bandwidth. You will need a calibrated test oscillator or a general coverage receiver to do this properly. I used an old, but accurate, grid-dip meter. With the oscillator tuning capacitor set to maximum, adjust L1 for the low-frequency setting. Then with the tuning capacitor set to minimum, adjust the series capacitor for the high-frequency setting. The settings interact and several tries will be necessary. You may need to change or pad a capacitor if you can't get the desired range.

Front-end adjustment is simple. Hook an antenna to the rig, find a strong signal, set the varactor controls to middle range, and peak the input capacitors. If you want bandpass tuning, use a sweep generator to set C1 to its optimum value. A fair job can be done by setting C1 to minimum, peaking the antenna and mixer adjustments, and then increasing C1 until the output signal just starts to drop.

Once you can tune in signals, you can retouch the i-f transformers for peak performance. Use a weak signal to prevent amplifier overload. Because the filter's characteristics control the passband, you can't miss the proper adjustment points.

Performance

As I pointed out in the beginning, this was a compromise design and some tradeoffs had to be made to meet the design goals. The hardest one to accomplish was getting reasonable performance while keeping the current drain to a minimum.

On the 40-meter band, the input noise figure isn't important because external noise predominates. However, it's nice to know that the mixer does have 5-dB capability. Gain is always important, but that's not a problem here. When the controls are turned all the way up, the audio output limits on antenna noise.

The overall receiver performance is limited by the i-f bandwidth. In the weakest signal case, it is the noise riding through with the signal that limits the sensitivity. A narrower filter would improve this, but as pointed out above, you would then have second-detector oscillator problems to solve.

The receiver was designed for casual use, not for

DXCC. However, when the band is open, WAS would be easy. From my area, with a dipole antenna pointing EW and up about 15 feet, the W2s and W4s are S9 + most of the time, and the W5s and W7s are S9 + 40.

Battery drain is about 26 mA. While the design value for the power source is 9 volts, I actually use NiCd's (7.2 volts) which work equally well. One evening while trying out the breadboard version, the receiver went mushy and quit soon afterward. I checked the battery pack and found that I had been listening to the receiver until the batteries had dropped to about 3.2 volts! Goal achieved.

Stability, as I've mentioned, depends on several construction factors and adjustments. My "statistical sample of one" sat on W87PAX, the Pan-American Games station, for over two hours, copying SSB without adjustment. This was outside, with no cover on the receiver.

One unsolved problem is the feedthrough of images from strong commercial and SWBC stations that can be S9 + when the band is open. However, since I have seen the same problem in some very expensive commercial receivers, I don't feel that I'm alone. A better front end design could help cut the interference down somewhat, but it would complicate construction.

You'll find the SL6310 a real performer as an output amplifier. With a 4-inch speaker you should have arm-chair copy 10 feet away. When I use the receiver outside, my XYL keeps reminding me to "Turn that thing down before the neighbors complain!"

I've tried to provide a detailed description of the receiver performance. If you decide to build the receiver, you'll either be delighted or disappointed, depending on what you expect. If you expect this receiver to outperform its \$500 commercial counterpart, you will be disappointed. On the other hand, if you think that a receiver built from five eight-pin chips is just a toy, you could be quite surprised and pleased with the performance.

Room for improvement

Home construction projects are never really finished, but at some point you just have to draw the line. This one is no exception. Here are a few things I didn't do, that could improve the performance of the receiver:

- The filter wants to be terminated in 2,000 ohms. I didn't consider the shunt and series impedances of the source and load when I designed the circuit. The input 2k resistor could be reduced, and the output 2k resistor increased for a better match. The result would be a flatter passband.

- The antenna and mixer tuned circuits were not optimized for impedance match. I did some calculations on the computer and built the circuit accordingly. When winding these coils, you might add a few extra taps and then try to find the optimum tap combinations for best performance.

- The impedance match between the i-f transformers and the mating circuits are undoubtedly incorrect. I tried

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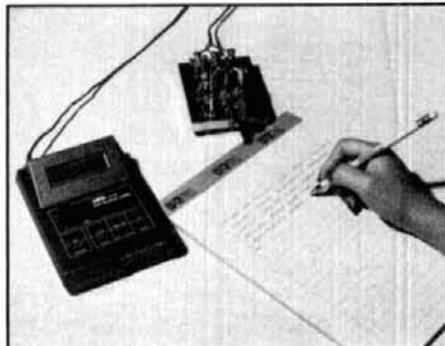
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- Keyer output** • Transistor switching,
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- Electronic keyer mode select
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- Display Indicators** • LCD 32 characters—16 per line
- Power On—Green LED
- Tuning—Red LED
- Front connections** • Paddle—Standard/Iambic
- Ordinary telegraphic key
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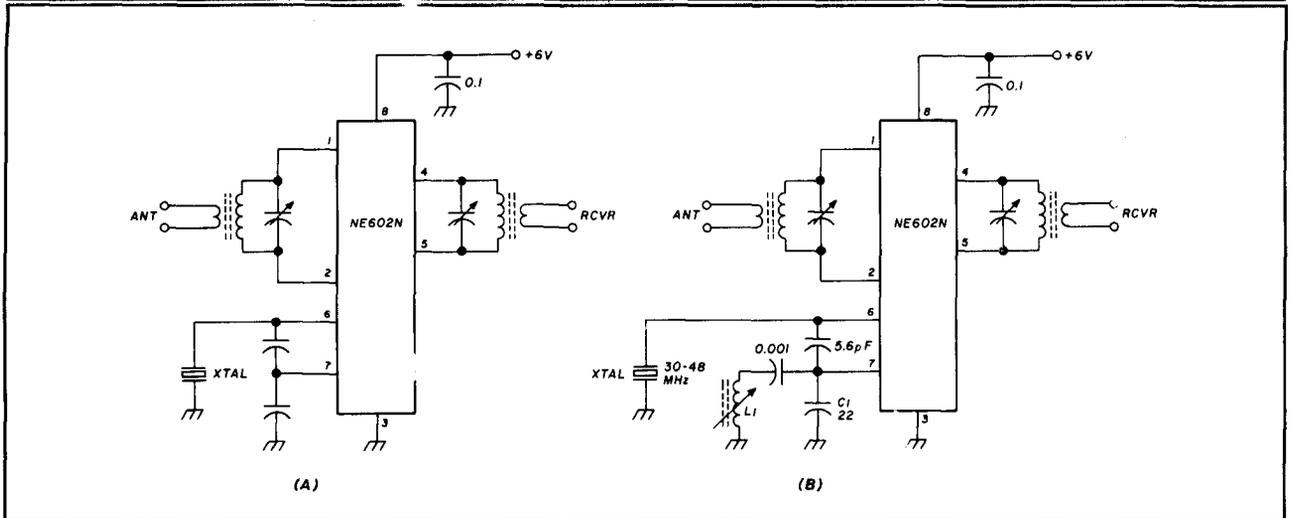
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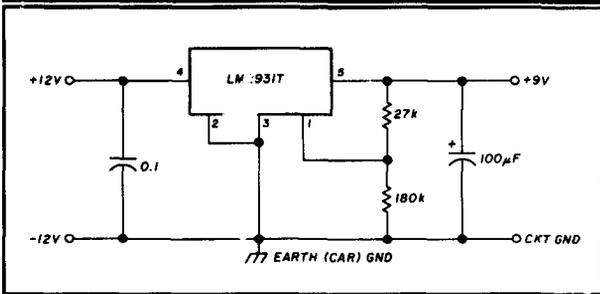
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FIGURE 11



Simple converters using the NE602N. (A) shows the circuit for fundamental crystals; (B) shows the circuit for overtone crystals. Component values for (A) depend on the frequency being converted. The (B) circuit oscillator is appropriate for 10 meters. L1 and C1 should be rough-tuned to 30 MHz, to assure operation on the proper overtone frequency.

FIGURE 12



A recommended preregulator circuit for use with automotive systems or 12-volt DC wall adapters. Note that a connection to car body or earth ground is shown to reduce stray noise and signal inputs.

to get a data sheet on the transformers, but all Toko had was one of those half-English short-form sheets, with no useful design information on it.

Additions and changes

Rather than load this discussion with detailed footnotes, I'll just point out that "Everything you ever wanted to know..." can be found in the *ARRL Handbook*, in *Solid State Design for the Radio Amateur*, and in the back issues of *HAMRADIO* magazine. You can find circuits for AGC, tuning meters, coil designs for other bands, crystal calibrators, and the other typical options.

For CW operation, the most valuable addition would be a sharp audio filter. If you plan to use an op amp active filter, and are using a battery supply, be sure to check the op amp current requirements; some op amps are real current hogs.

For maximum utility you might want to add a switch

at the i-f output and provide diode AM detection and FM detection in addition to the SSB product detector.

Those higher frequencies

Receiver performance will drop off above 10 meters, due to oscillator stability requirements and image problems. The solution is to use a front end converter. Here again the NE602N can be pressed into service. Two such converters are shown in fig. 11: one for fundamental crystal oscillators, and the other for overtone oscillators. Because there is a wide range of inexpensive microprocessor crystals available, and since the converter will draw less than 3 mA, using one of these converters makes it easy to move your receiver anywhere you want — up to the 200-MHz converter limit.

As an example, Digi-Key offers a 23.4-MHz fundamental crystal (\$1.62). Using this crystal in the fig. 11

Parts List						
Mr	Part number	6 dB B.W.	50 dB B.W.	S.B. A1	Term	Case
ME	CFW455H	6 kHz	18 kHz	35	2k	P
ME	CFW455I	4 kHz	15 kHz	35	2k	P
KY	KBF-455R-7A	7 kHz	18 kHz	37	2k	P
KY	KBF-455R-4A	4 kHz	15 kHz	40	2k	P
NTK	LF-H6	6 kHz	18 kHz	40	2k	P
NTK	LF-H4	4 kHz	15 kHz	40	2k	M
NTK	LF-C4	4 kHz	12 kHz	40	2k	M
NTK	LF-C6	6 kHz	16 kHz	45	1.5k	M
ME	CFM455H	6 kHz	15 kHz	45	2k	M
ME	CFM455I	4 kHz	10 kHz	45	2k	M
NTK	LF-E4	4 kHz	12 kHz	50	2k	M
NTK	LF-E6	6 kHz	16 kHz	55	1.5k	M
ME	CFR455H	6 kHz	15 kHz	55	2k	M
ME	CFR455I	4 kHz	10 kHz	55	2k	M
ME	CFR455J	3 kHz	9 kHz	55	2k	M
ME	CFS455J	3 kHz	9 kHz	60	2k	M
ME	CFS455H	6 kHz	15 kHz	70	2k	M
NTK	LF-D6	6 kHz	15 kHz	70	1.5k	M
ME	CFS455I	4 kHz	10 kHz	70	2k	M
NTK	LF-D4	4 kHz	10 kHz	70	2k	M
ME	CFK455H	6 kHz	15 kHz	80	2k	M
ME	CFK455I	4 kHz	10 kHz	80	2k	M

converter, with the 5 × 8 set around 5.1 MHz, will produce a 10-meter receiver. The exact frequency of the 5 × 8 will depend on the part of the 10-meter band you want to receive.

If you plan to use the receiver only with a converter, you won't need the elaborate double-tuned mixer circuits. A simple single-tuned circuit is adequate. Unfortunately, you'll probably need a double-tuned circuit at the converter's input to reduce images and strong stray signals.

Instead of adding a converter, you can use one of the circuits of **fig. 11** as the mixer/oscillator input stage for fixed-frequency operation. This can be handy for nets or for frequency-standard reception. If you use this approach for WWVH or a similar station, consider using a diode detector in place of the product detector.

Alternate power sources

In addition to operation from dry cells or NiCds, you could run these receivers from many other sources because the current drain is low and the voltage requirements aren't strict. However, there are a few things to consider. If you plan to rob power from some existing supply, be certain the supply voltage is "clean." If the supply also powers digital circuits or a microprocessor, you could have switching noise on the power supply lines. These receivers are hot; even a few microvolts of RF on the supply lines could show up in the receiver. A preregulator helps a lot (see **fig. 12**) to clean up a contaminated supply. If you still have problems, add some RF chokes and filter capacitors as required.

Parts procurement

Unless you are very lucky, you won't find the ICs that I used (see parts list) through surplus channels. They are available through the usual distributor channels, but most distributors have a \$20-\$30 minimum charge. Many ham clubs have a group purchase plan to get around this problem.

The same is true for the ceramic filters. I can't recom-

mend a reliable source, but they are common flea market items. As with crystal filters, the more elements used the better the performance and the higher the price. Because the catalogs for these parts are hard to obtain, I've listed some selected example. The parts list key follows:

ME: Murata Erie

KY: Kyocera

NTK: NTK Technical Ceramics

6 dB B.W.: Filter bandwidth at the 6 dB points

50 dB B.W.: Filter bandwidth at the 50 dB points

S.B. Attn: Stop Band Attenuation, performance of the filter outside its passband.

Term: Input and output termination impedance, ohms.

Case: P = plastic, M = metal

The filters shown are ranked in order of increasing performance. Expect to pay \$5 to \$25, depending on the characteristics. The first few on the list are not really recommended, but you can try them if you find them at the right price.

The Toko coils are available from Digi-Key³. The same company also sells inexpensive crystals.

Summing things up

I hope my work encourages you to plug in your soldering iron. These designs are simple, fun to build, and easy to modify. You can get a lot of satisfaction per hour of assembly effort.

If you have problems or questions (other than where to find the parts), drop me a line and I'll try to help. (Please include an SASE.) But if you come up with improvements, don't write me; drop a line to Marty Durham, NB1H, at *HAM RADIO*, so he can print them and we can all share your findings.

References

1. Signetics Linear Data and Applications Manual, Volume II, 1985, page 5-3.
2. Signetics Application Note AN198 (included in above Manual).
3. Digi-Key, P.O. Box 677, Thief River Falls, Minnesota 56701. Order only: 1-800-344-4539 (\$10 minimum).

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Universal Transmatch 2 KW (6:1, 9:1, or 1:1—select one)	18.50

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THE WEEKENDER

The MFJ 989 transmatch provides great versatility for the money. With 240-pF variable capacitors and a 36- μ H rotary inductor, the unit handles most loads down to 160 meters. However, you can improve its performance at 12 and 10 meters with two simple changes.

1. Remove the case top and check the rotary inductor. MFJ has used at least two different models. In my unit, the lower end (closest to front panel) of the coil was not grounded. Correcting this situation revealed another problem. The movable tap was grounded at the panel end, leaving a long path of low Q stray inductance. This reduced the available adjustable inductance at 10 meters. The fix is simple. Run a heavy ground strap from the movable tap terminal at the rear end of the inductor unit to ground. In my unit, the strap goes to a mounting lug on the chassis. The result is another half turn of available adjustable inductance, and the shape of the ground lead follows the general coil shape, yielding (I would guess) higher Q stray inductance.

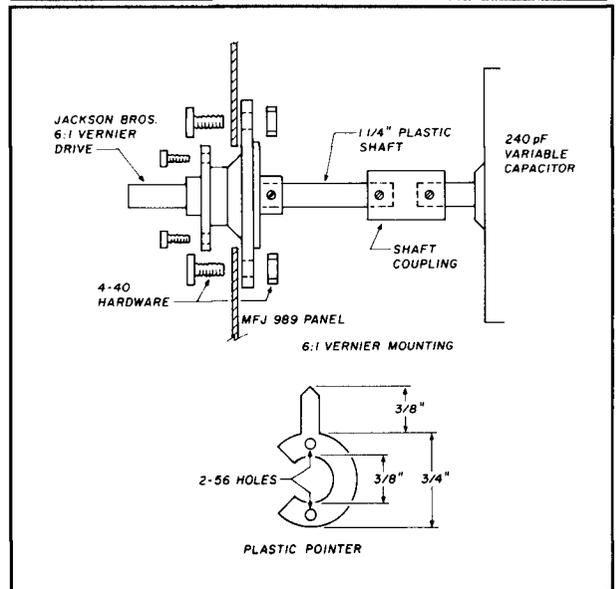
2. The variable capacitors are difficult to tune for high reactance loads. Sharp settings result in back and forth overshoot. The solution is to install a pair of Vernier drives. I used a pair of 6:1 Jackson Brothers drives. Again, installation is straightforward and requires no disassembly other than removing the capacitor knobs. The steps are as follows:

a. After removing the case top and knobs, cut the capacitor shafts to a length of 1/2". This point is just about where the plastic part of the shaft begins. Save the plastic shafts for step d. (Note: if Verniers were to be installed during initial assembly, this cutting would be unnecessary. Only the plastic shafts would need trimming.)

By **L. B. Cebik, W4RNL**, 2414 Fair Drive, Knoxville, Tennessee 37918

IMPROVING OPERATION WITH THE MFJ 989 TRANSMATCH

FIGURE 1



Sketch of vernier mounting on MFJ 989 panel.

b. With a chassis hole punch, enlarge the shaft opening in the front panel to about 7/8". Carefully align this hole so that the shaft is dead center.

c. Using the drive as a guide, drill 4-40 (1/8" diameter) holes for the mounting wings of the drive. On older model 989s with capacitor reference numbers between 1 and 6, vertical alignment avoids obscuring any number. Newer models have finer markings, and the hardware will obscure something.

d. Cut the plastic remnants of the capacitor shafts to 1-1/4", and mount to the drives. This step restores adequate insulation between the capacitors and the panel assembly. Then install the drives loosely on the front panel to check alignment.

e. If the plastic shaft aligns very well with the capacitor metal shaft, loosen the assembly and install an ordinary 3/4" long 1/4" diameter shaft coupler to join the metal and plastic shafts. Then tighten down everything and check for capacitor binding during rotation. If binding occurs, or if alignment is not very good, install a flexible shaft coupler between the capacitor and the plastic shaft. This step goes smoothly if all cut shafts have been filed smooth. Remember to vacuum the filings from the transmatch case.

f. If the drive is equipped for a secondary marker (two screws into a brass plate), cut a marker pointer from thin, stiff plastic. Plastic file folder material is ideal; it's stiff, but can be cut with shears or an Xacto® knife. Then add the original knob, align the capacitor for mark 1 or 6 (or 10 on the latest models), and reclose the case.

The result will be easier capacitor setting with no overshoot beyond minimum SWR. This speeds up resetting the transmatch when changing bands. Outside of the 4-40 mounting hardware and small pointers emerging from behind the capacitor knobs, you haven't altered the appearance of the 989 at all. The improved operation of the transmatch makes this 2-hour effort well worth the energy.

• The Jackson Brothers 6:1 Vernier dials (part no. 4511-DAF) are available through Radiokit, Pelham, New Hampshire. *Ed.*

Article B

HAM RADIO

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SSD-5*	80-40-20-15-10M space-saver dipole specify L. 42' \$105. 52' \$108 ppd	
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HAM RADIO TECHNIQUES

Bill Orr, W6SAI



The radio boys in the Pacific, or, working DX for Uncle Sam

The year was 1934. Many thoughtful Americans felt that war with Japan was inevitable, but the international political atmosphere tied their hands. Japan, in defiance of treaties, was fortifying Micronesia and busy turning the island of Truk into a large naval base. Other Japanese bases existed at Koror, Ponape, and Saipan. The military analysts in Washington thought the next thrust of Japanese military power might be in the direction of Hawaii, though a smattering of small islands lay in the path. The United States was faced with the problem of protecting and converting these islands into advance air or naval bases, without upsetting relations with Japan.

The Pan-American "smoke screen"

The proposed flights of the legendary Pan-American Airways flying boat "China Clipper" (see **Photo A**) provided a smoke screen behind which American preparations in the Pacific could take place without arousing the Japanese government. The huge flying boat with its requirements for island refueling bases was thought to be the ideal cover for preliminary investigation and eventual fortification of the islands to the west of Hawaii. The Clipper would fly on a regular commercial schedule from San Francisco to

Macao or the Philippines, stopping at various U.S.-controlled Pacific islands for refueling and to allow the passengers to rest. The uninhabited islands had to be surveyed and determination made as to which ones would be suitable as landing sites for the Clippers. A deep lagoon was needed on each island, with sufficient land area to accommodate the necessary support facilities. Survey crews were hired quickly to start the project. This is where Radio Amateurs played their fateful role.

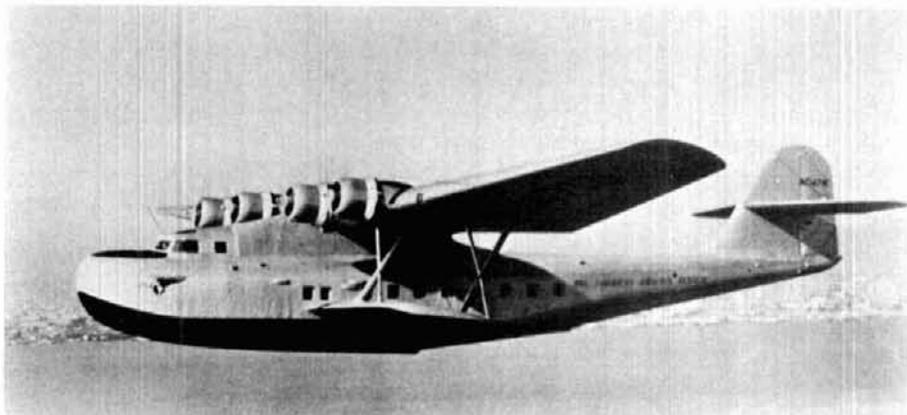
The China Clippers

The Martin M-130 flying boats were titans. Over 90-feet long and with a

130-foot wing spread, the four-engine, 26-ton giants were the first planes powerful enough to carry their equivalent weight as payload. They could fly an astounding 3,200 miles nonstop at 130 miles per hour. No other aircraft could duplicate this feat. The time was ripe for these Clippers to island-hop from the American West Coast to the Orient. Aided by covert military funds, the U.S. government set about establishing island bases to accommodate the flying boats.

Each flying boat was equipped with duplicate shortwave receivers and crystal-controlled transmitters (CW) in addition to a battery-operated emergency trans-receiver. Long-wire

PHOTO A



The Martin M-130 "China Clipper" in flight over San Francisco Bay, bound for Honolulu, Hawaii. The 26-ton flying boat carried 16 passengers and took 18 hours for the first leg of the flight to Hawaii. One-way fare to Honolulu was \$360. Round trip to China and back was \$1600.

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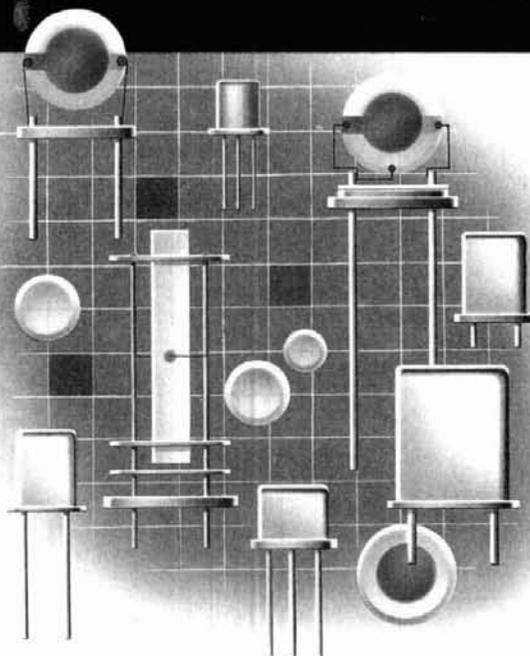
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antennas were strung between the aircraft's nose and tail. A group of frequencies in the 3-10 MHz region were allocated to the Pacific chain of bases with whom the Clippers could easily and quickly communicate. The Clippers' flights could be tracked across the Pacific by direct CW contact every half hour, as well as by direction finders placed on the islands.

Island colonization

One of the first steps to establish ownership of the islands was the Coman Oceanographic Expedition of 1935. Kenneth Lum King, K6BAZ was with this expedition. He was replacing K6GNW who had been stationed on Howland Island in connection with the tragic flight of Amelia Earhart. K6ODC was on Johnston Island, while K6INF was on Baker Island. Howland, Jarvis, and Baker Islands were being "colonized" to justify a U.S. claim on the group. The claim was supported by the fact that Americans had visited the islands between 1860 and 1880 to dig guano (fertilizer). In addition to lazing in the sun, the radio Amateurs handled commercial traffic and worked DX on 7 and 14 MHz.

Other tiny islands were also being colonized by American expeditions. They, too, had hams serving as radio operators. Kingman Reef, Canton Island, Christmas Island, and Olosenga Island (Samoa) were about to be put on the air. The islands of Hull, Swain, Atafu, and Puka Puka were also investigated as possible military sites.

Beginning in 1934, Pan-American and U.S. government crews started to work on air bases the Navy needed but couldn't get. Baker, Jarvis, and Howland Islands were claimed by the British, but in 1935 the U.S. State Department decided not to waste time discussing the matter with the British. It began to colonize the islands immediately instead. Commercial aviation supplied the "cover story".

Canton Island—American or British?

Each island base was to be self-sufficient, complete with maintenance

facility, radio and beacon stations, and a weather station. The Howland Island airstrip was built first as a navigation aid for the Earhart flight. The supply ship "Itaska" was stationed near Howland as the principal navigation system for the flight. The loss of the Earhart plane and the radio navigation problems of the "Itaska" convinced the Navy that only permanent, well-organized facilities would do. A better island was needed; that turned out to be Canton Island.

The stage was set. Americans landed on Canton Island in February 1935, only to find British settlers there. A peaceful truce came about, but in May 1939 a British cruiser blocked the American supply ship and prevented it from reaching the island. Diplomatic cables flew back and forth between Washington and London, and the cruiser eventually sailed away. Sovereignty was placed in abeyance.

While the international political game was being played between America and England, Japan watched the colonization of the islands with apprehension. These islands would be used as advance bases for the forthcoming war with Japan! The Japanese Navy began to study how to eliminate these danger spots. Perhaps the best way would be to bypass them with a direct attack on the Hawaiian Islands...

The islands are Americanized

Once the islands were declared U.S. territory, the Federal Communications Commission quickly assigned prefixes: KB6 (Guam) previously OM1 and K6 KC6 (Wake) KD6 (Midway) KE6 (Johnston) KF6 (Baker, Canton, Howland, and Phoenix Islands) KG6 (Jarvis and Palmyra) KH6 (Hawaii, previously K6).

Even so, the situation was confusing. Some of the islands were under the control of the Department of the Interior (Jarvis, Baker, and Howland), while others were supervised by the Commerce Department. Others had no direct supervision other than that

of the colonists, guided by the U.S. Navy.

During 1940-1941, while American Amateurs were banned from working foreign countries, the new Pacific islands provided a welcome source of DX. Most of the island hams worked on 7 or 14-MHz CW; a few of them were on 14-MHz phone. Some of the stations heard on the air during that period are listed in table 1.

TABLE 1

Partial list of Radio Amateur activity in the Pacific (1935-1940):

KB6-Guam
KB6RWZ
KB6CBN
KC6-Wake Island
KC6QA
K6LHA/KC6
K6TE/KC6
KD6-Midway Island
KD6FOU
KD6QHX
KE6-Johnston Island
KE6SRA
KF6-Baker, Canton, Howland, and Phoenix Islands
K6BAZ
K6JRN
K6HCO
K6ODC
K6JRN
K6JEG
KF6ROV
KF6SJJ
KF6JEG
KF6PUL
W7DBR/KF6
KG6-Jarvis and Palmyra Island
K6ODC
KG6MV
K6GNV/KG6

War!

By late 1941, the new Pacific possessions were highly visible on the Amateur bands. There was talk of other exotic islands ready to come on the air any day, but the advent of World War II quickly put the hams off the air. Most of the islands were evacuated to protect the personnel and the installations were destroyed. Only Midway and Wake Islands were

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thought to be of any use to the Navy in the long, hard days ahead.

Post-war Amateur operation

As soon as Amateurs were allowed back on the air, some of the Pacific islands became active. In particular, Canton, Wake, and Christmas Islands were represented on 20-meter phone. An interesting situation developed on Canton Island (re-christened with the new prefix KB6). British settlers arrived to strengthen the British claim on the islands. The American contingent was represented by KB6AD (Ken Neifert) and the British by VR2AZ/VR1 (Don Schroder). As far as DXCC was concerned, Canton Island counted for two countries, depending upon whom you worked!

TABLE 2

Present day listing of prefixes from the Pacific.

KH2, (KB6).....Guam
KH9, (KW6).....Wake Island
KH4, (KD6)Midway Island
KH3, (KD6)Johnston Island
KH1, (KF6).....Baker, Canton,
Howland, and Phoneix
KH5, (KG6)Jarvis and Palmyra
Island

The end of the China Clippers

The last China Clipper flight took place in April 1946. Newer, four-engine post-war transports could fly quicker, carry a heavier load, and cost less to operate than the old flying boats. Most of the island bases were no longer needed. The facility on Canton was abandoned in 1945, but partially retained as a weather station. Later, it was used as a down-range tracking station for the U.S. Air Force. By 1970 this activity ceased, but the island is still under joint U.S.-British administration.

Now most of the islands are deserted. Wind, wave, and sand have obliterated the old bases. Jet aircraft

make contrails over the islands as they fly past locations once thought vitally important in the hectic, pre-war days, but now merely relics of a forgotten period of American history.

An occasional DXpedition visits one or two of the islands. The F.C.C. has assigned new prefixes to the islands (see table 2) and hopeful Dxers still keep an ear open for radio activity from the little spots of sand that loomed so large in pre-war America planning.

The "Dead Band Contest"—"Elementary, my dear Watson"

In my July 1988 column I challenged my readers to identify a quotation from a famous work of fiction, thus proving that alert and active hams are not "couch potatoes", but are avid readers when the band is dead. The quote was: "You have been in Afghanistan, I perceive."

I was pleased and gratified at the many correct responses to this quiz and I was impressed by the depth of knowledge of the "Sacred Writings". As Bob Rosenquist, W0EHF, put it, "These were the first words spoken to John H. Watson, M.D., late of the Army Medical Department, by Sherlock Holmes in January 1881, in the laboratory at St. Bartholomew's Hospital in London."

Harry Hyder, W7IV, also illustrated his knowledge of "The Canon" and informed me he was a member of the "Sherlock Holmes Wireless Society."

Congratulations to the other readers who were kind enough to enter this contest. Within the first week of publication of the July issue of *HAM RADIO*, the following had correctly identified the quotation. The asterisk (*) after the call indicates the individual had exceptional knowledge of the famous works of Sir Arthur Conan Doyle.

George Marts, W0TDH; George Goldstone, W8AP(*); Donn Baker, WA2VOI; Bob Harmiston, WB6JOP; Dan Pierson, W6NTX(*); Fred Linn, W9NZF; Bill Calderwood, K1CT; Steve Trapp, ND4G; Russ Webster, K6WM; John Mise, AA6FK; Mike

Helm, WC5Z; Carl Scherer, VE3MDM; Ed Wetherhold, W3NQN; John Peak, KE6HS; "Doc" Roberts, K9BX; Ralph Turner, W8HXC; Bob Locker, W9KNI; Ken Morgan, KC5DW; Bob Houf, KD9UX; Steve Twiggs, KM7U; Gary Grebus, K8LT.

Another "Dead Band" Contest

Smart readers, eh? Well, try this one on for size. Identify the subject, verb, and object of this portion of the following popular song:

"Oh, say, can you see, by the dawn's early light, what so proudly we hailed at the twilight's last gleaming"

This quiz was given by Jon Carroll in his column in *The San Francisco Chronicle* of July 1, 1988.

References

1. Ronald W. Jackson, "China Clipper," Everest House, New York, 1980.
2. Kenneth Lum King, "Pounding Brass for Uncle Sam," *Radio*, November 1938, page 18-22.

Article C

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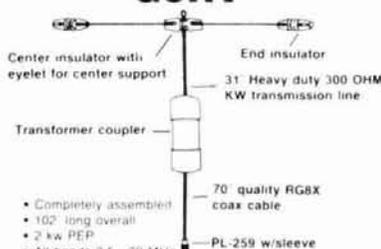
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TV-8010-3 80,40,20,15,10 44' 67.95
TV-16010-4 160,80,40,20,15,10 75' 79.95
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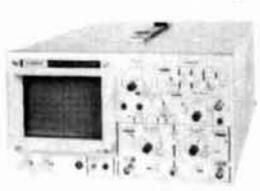
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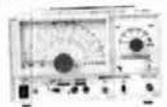
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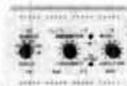
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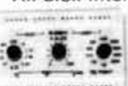
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THE PEPPERDYNE RECEIVER

Build this six-part receiver as a series of weekend projects



By Jim Pepper, W6QIF, 44 El Camino Moraga, Orinda, California 94563

There have been many articles on receiver construction. Some were good, some were beyond the capability of the average homebrewer, and some lacked sufficient information to complete the construction (e.g., pin information on special ICs and on troubleshooting). A receiver can be quite an undertaking if you're not given enough data. I've also found that it can take a substantial time investment to complete the project.

I decided to design and build a receiver that, although not in the same class as the present commercial receivers, would have some of their features and comparable performance. But most important, the builder would be able to repair it. Although this receiver is not a weekend project, it's designed to be built in sections; each takes about a weekend to build. To fulfill these

requirements, I had three goals to meet: the circuitry had to be simple, be easily serviced or modified, and use readily available parts.

Circuit description

The receiver consists of six basic sections: the mixer, the local oscillator, the i-f section, the audio board, the counter board, and the power supply.

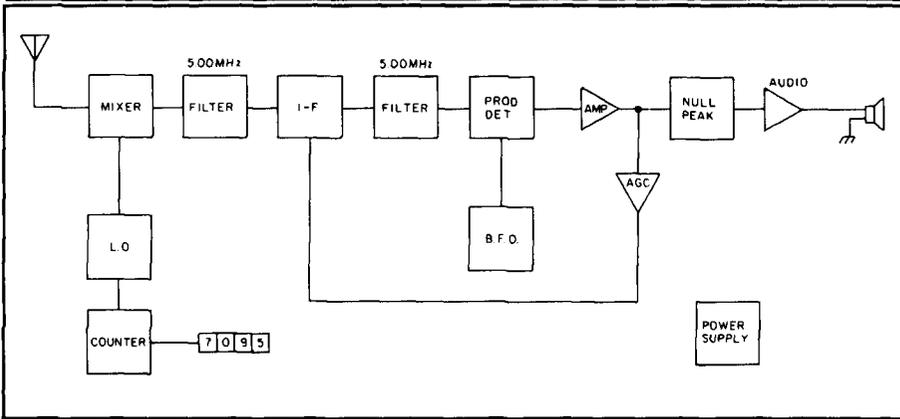
The mixer is a dual-gate MOSFET 40673 that uses a single coil to tune from 40-160 meters. A fixed capacitor is switched in parallel with the mixer-tuning capacitor to cover the 160-meter band. Using a single coil simplifies the coil-switching circuitry. The antenna is coupled to this coil through a series-tuned trap to reject 5 MHz, the frequency of the i-f. The 5-MHz trap works well as a notch filter rejecting the 5-MHz WWV broadcast; a front panel switch is

provided to shunt out the trap and allow WWV reception.

The local oscillator is a standard Colpitts circuit using a MPF102 JFET. The circuit is tuned by a varicap diode and a ten-turn potentiometer. The varicap capacitance is a nonlinear function of the applied voltage, making the frequency change per turn of the tuning pot different at one end of the dial from the other. I have compensated for this variation by using a technique known as "pot loading." A resistor is connected from the pot arm to ground and, with the right choice of resistance, the variation can be greatly reduced. (This method can also be used to give a pot an output approaching an audio taper from a linear pot.)

The local oscillator operates 5 MHz above the incoming signal and has three coils to cover the three bands. In

FIGURE 1



Complete block diagram of the receiver.

effect, there are four bands covered with the 75/80-meter band handled by one coil. The actual frequency range covered by each coil is up to you.

Using a varicap diode for a tuning device requires that the tuning voltage source output be very clean. The LM723 voltage regulator is ideal. It's also better to use a ten-turn cermet pot for this circuit, because some wire wound pots produce objectionable turn-to-turn noise when tuning. I used a 100k pot. Any value from 10k to 100k will work, but you must use a different pot-loading resistor.

The i-f amplifier stage consists of an MC1350 IC that operates at 5 MHz with a two-pole ladder-crystal network on both the input and output. I experimented first with a single two-pole network and found the skirt selectivity very poor.^{1,2,3} I then tried a three-pole network to find that crystal matching was very critical and the desired bandwidth was difficult to achieve. Finally, I decided to try the input/output configuration; it gave very good rejection and the bandwidth needed for phone operation. I chose the 5-MHz frequency because of the availability of low-cost crystals and the WWV reception capability. You can use other frequencies, but you may have to alter the network components to achieve the desired bandwidth characteristics.

The MC1350 provides about 50 dB of gain and an AGC range of 60 dB. The AGC voltage is derived from the audio

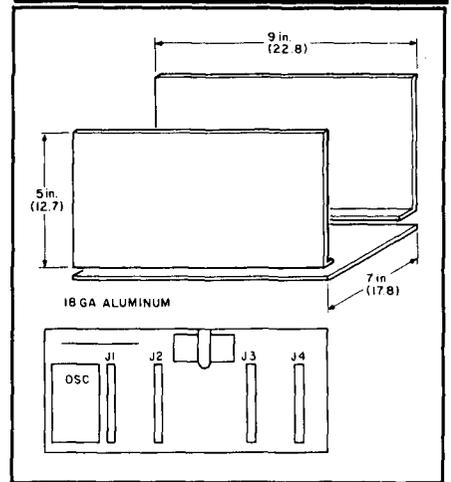
signal and there is little difference in the audio output level of signals registering from F2 to F9. I included an i-f gain control, but I don't use it very much.

The product detector in this receiver is a CA3028. I experimented with a number of different detectors and found the CA3028 to be the best from a gain standpoint. It also required the least number of parts. The BFO for the product detector is generated by a 5-MHz crystal oscillator. To keep the circuitry simple, only lower sideband reception is available. This is no real problem since 99 percent of the stations on the three bands use the lower sideband for transmission.

The audio section consists of an audio amplifier, an AGC circuit, a peak-null filter circuit⁴, and a LM380 power amplifier. The peak-null circuit can give either a sharp rejection of a given frequency, or peaking — which is very effective on CW operation. The selected frequencies are variable and controlled from the front panel. The two are independent of each other.

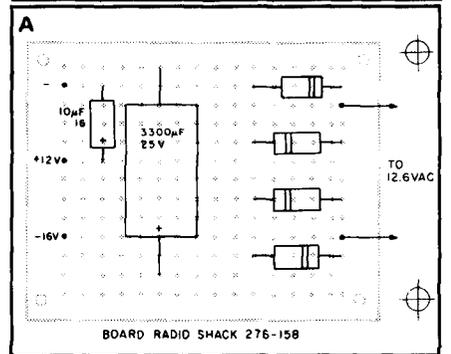
The counter circuit, with a few changes, was copied from an old issue of *Popular Electronics*⁵. The circuit consists of a timebase and a programmable counter that allows the i-f frequency to be subtracted from the local oscillator frequency, giving the frequency of the incoming signal. The circuit is designed to display to the kHz level. By adding another divide-by-10 counter, the display will read to the 100-Hz level. The two ranges are accessed by a switch on the front panel.

FIGURE 2

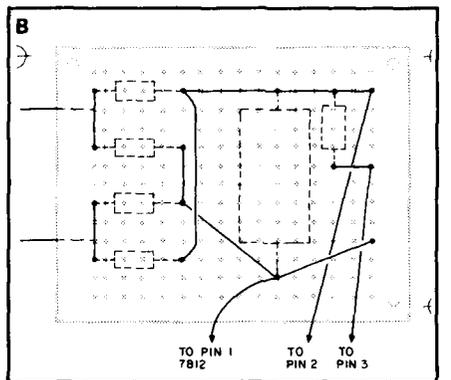


Dimensions of the receiver cabinet, and pc board placement within the cabinet.

FIGURE 3



Power supply parts placement guide.



Power supply foil-side connections.

Receiver construction

For serviceability, the receiver is broken down into six parts; four are made on plug-in boards. The fifth board, the local oscillator, is mounted on the chassis for stability and the sixth is the power

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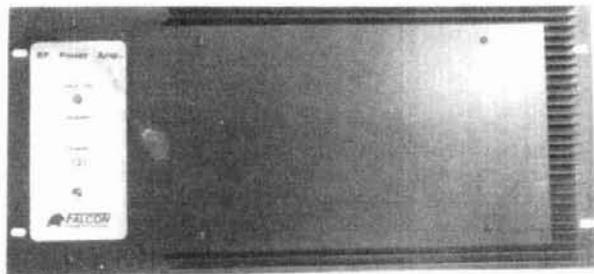
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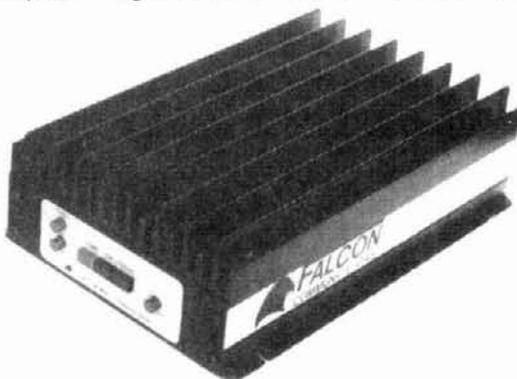
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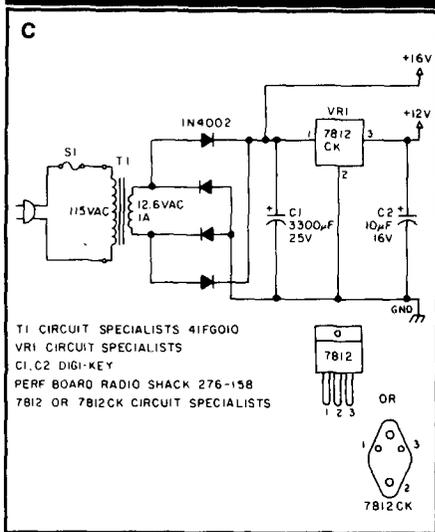
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FIGURE 3



Power supply schematic.

supply. See fig. 1, the block diagram. The parts can be purchased from the supply houses listed on the figures. (You may find many of them in your junk box.) I would advise you to send for the suppliers' catalogs before ordering; some have a minimum purchase amount.

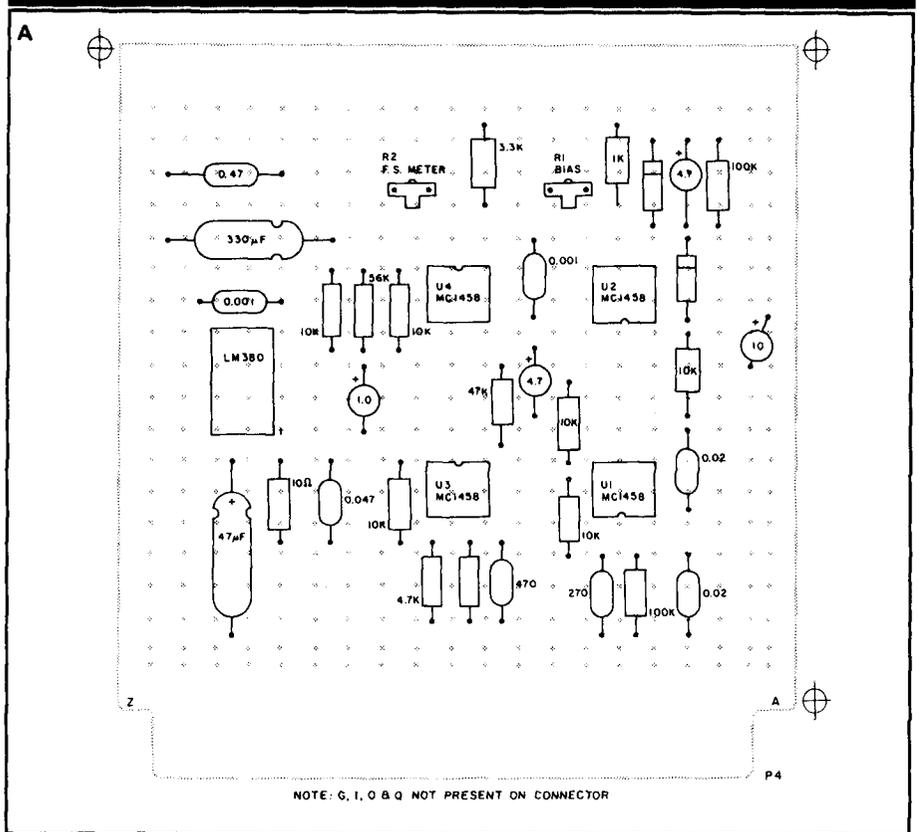
Construction hints

The tools required are those ordinarily used for homebrew work. I would suggest that your soldering iron have a small tip to be used on the pc boards. These boards, obtained from Radio Shack (no. 276-152), are similar to vector boards and come with multiple holes and pads for mounting parts.

The power supply pc board and transformer are mounted on the rear panel of the cabinet, which also acts as a heat sink for the 12-volt regulator. The plug-in board sockets (Radio Shack no. 276-1551) mount on the bottom plate with 0.5" spacers. The pc board components are mounted on push-in terminals from Circuit Specialists (no. T42). Before mounting any parts, I tinned the fingers on the board that was used for interconnects. Do this by first heating and then wiping each finger with a cloth. The tinned surfaces should be thin.

My cabinet came from Radio Shack, but it is no longer available. In order to house the pc boards, the cabinet height

FIGURE 4



Audio board parts placement guide.

must be at least 5", and to house the rest of the components, at least 7" deep by 9" wide. (See fig. 2.) Before starting on the pc boards, I suggest that you mount and wire the parts for the front and rear panels and the sockets for the boards, so each pc board can be checked for operation as it is completed. The 7812 voltage regulator is mounted directly to the rear chassis. No isolation is required.

Power supply

Build the power supply shown in fig. 3A-C first. The board is attached to the rear panel by two 0.5" spacers over the 7812 voltage regulator. When completed, the AC power can be applied and the power supply output voltages can be checked with a voltmeter for proper operation.

Audio board

Before starting on any of the following boards (figs. 4A, 4B, 4C), I would suggest that you make a copy of the assembly drawings. You can mark the

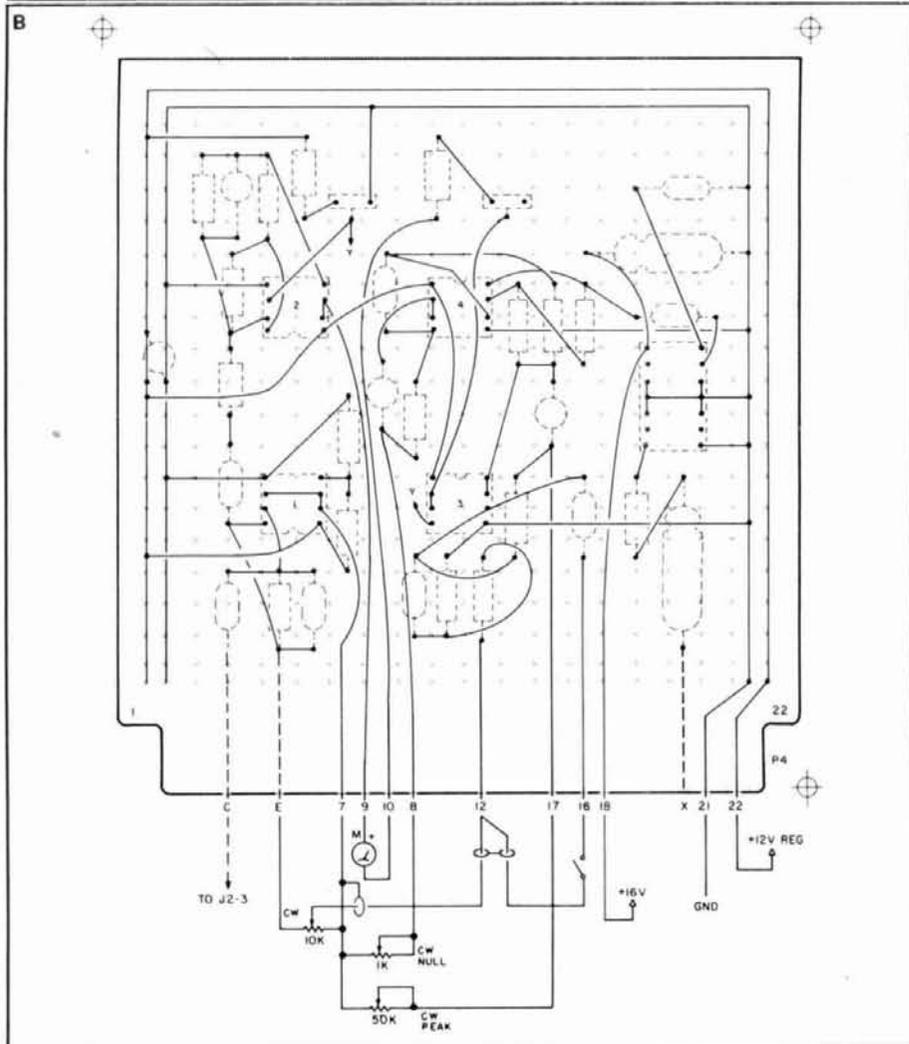
components and wires you have installed on these sheets. This makes it easier to stop your work and then pick up where you left off.

Audio board construction

The audio board consists of a pre-amplifier, an audio-derived AGC, an S-meter driver, a peak-null circuit, and an LM380 power amplifier. The LM380 and similar amplifiers are prone to oscillate under certain loads. I found that a 10-ohm resistor in series with the speaker makes the circuit stable, with little output loss. The voltage for the output is obtained from the unregulated power supply (16 volts) to allow greater output without distortion.

The audio-derived AGC controls the gain of the MC1350 i-f amplifier. An offset voltage of 5 volts is required when there is no signal and the AGC voltage moves in a positive direction for an incoming signal. This offset is generated on the audio board. The S meter is also connected to this voltage. No zero

FIGURE 4



Audio board foil-side connections.

adjustment is required with this design; however, a full scale adjustment is provided. The values shown are for an old CB S meter with a 250 μ A movement. You can use any movement up to 1 mA, but you'll have to reduce the series resistor.

Following the parts layout for the audio board (fig. 4B and C), mount the IC sockets and push-in terminals as indicated. Check the size of your components; they may be different than the type I used. This is especially true for capacitors. Mount all of the components on the push-in terminals. This makes identification of points for wiring the other side of the board easier. Save the wire clippings; they can be used for jumpers on the wire side of the board.

Next, wire all short jumpers. The same wire can be used on longer leads, if there are no crossovers. Where there are crossovers, I used wire-wrap type. Remember to mark off all work done.

Testing the audio board

Insert the required ICs into their sockets and plug the pc board into socket J4. Turn on the power and check the voltages against the schematic. Set R2 (the S-meter sensitivity pot), to maximum resistance. The peak switch (S1) should be closed, and the null pot set at the maximum clockwise position. You'll need to connect a speaker for this test. If an audio oscillator is available, connect it to pin C on the pc socket, J4. A 20 mV peak-to-peak 1-kHz signal should

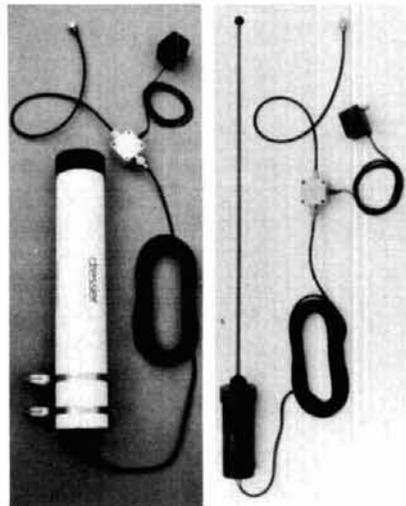
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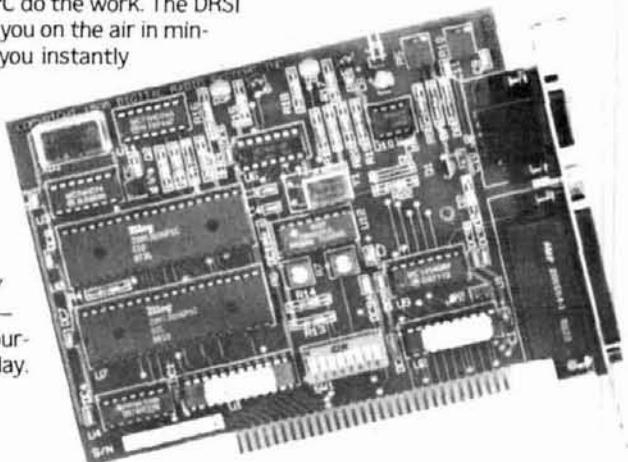
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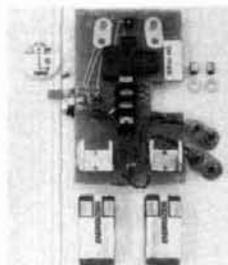
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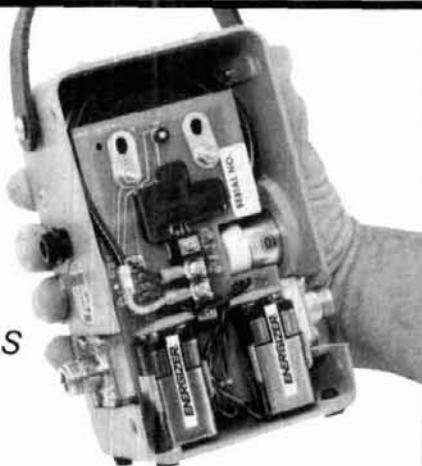
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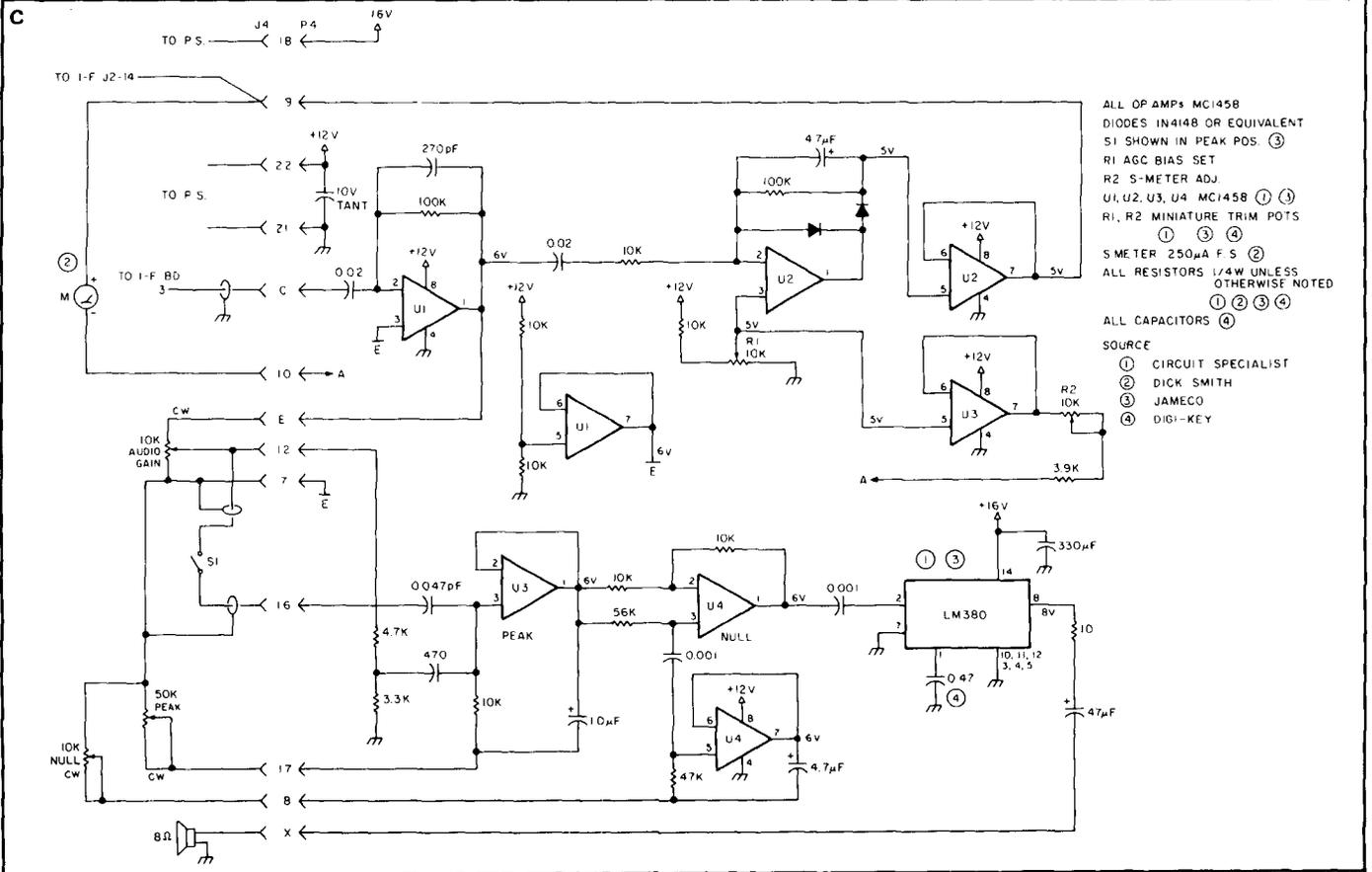
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FIGURE 4



Audio board schematic.

drive the audio to full output. The S meter should also vary as a function of the input signal. If no oscillator is available, touch your finger to pin C. You should hear a loud hum.

Building the i-f board

The i-f board construction, shown in figs. 5A-C, is similar to the audio board. The parts associated with the ladder networks should be close to the given values to obtain the proper bandwidth characteristics. The BFO for the product detector is located on the counter board because its strong field, if mounted on the i-f board, will swamp the AGC circuit.

Testing the i-f board

To check the i-f board, insert it in J2. The audio board should also be plugged in and a speaker connected. Turn on the power and check the voltages against the schematic. Reset the AGC pot

(audio board) to approximately 5 volts. Connect an antenna of approximately 25' or longer to pin V of the i-f board. You should hear WWV under nighttime conditions. An adjustment can be made to the trimmer capacitor across the output coil of the MC1350 to give maximum output.

The counter board

Construct the counter board (See fig. 6A, B, C) next; you'll use it to adjust the oscillator coils to the correct frequency.

The counter is designed as a multiplexing device — so the display must be designed for multiplexing, or for discrete displays having their common segments tied together. I used a multiplexing type and was able to cut the line to the unwanted decimals, leaving just one for the 100-Hz range. Unless you are familiar with this type of display, I recommend using discrete ones. I used

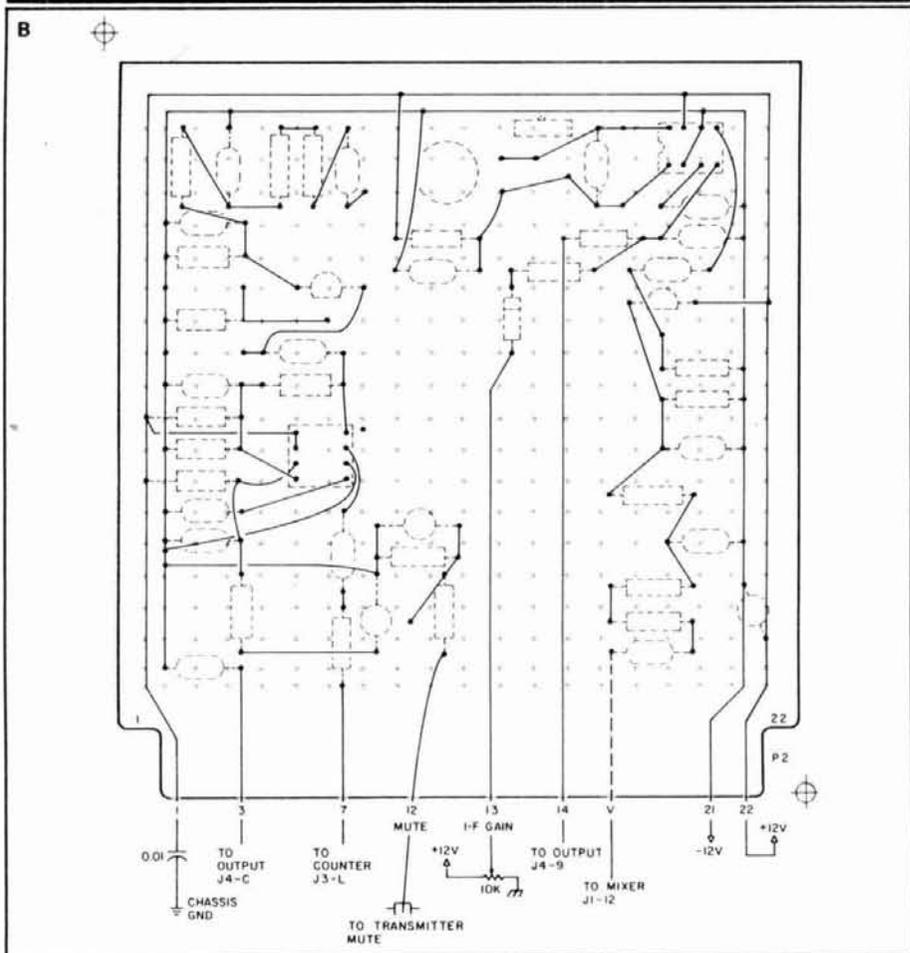
ribbon cable, with its multicolored wires, to aid in wiring the segments.

The counter programming as wired is for 5 MHz, but it can be programmed for other frequencies.⁵ The counter clock uses a 3.2678-MHz crystal. Figure 6D shows a means for shifting its frequency slightly is provided for additional calibration accuracy.

The counter board also contains the 5-MHz BFO circuit for the product detector. It too has a means to shift its frequency a bit to calibrate it with WWV.

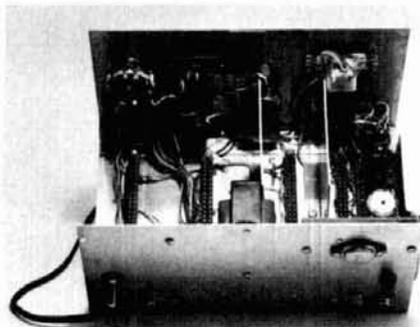
To check the counter board, do not insert any IC until you have checked the voltages present on the various IC sockets. Plug the board into socket J3. Be sure that the voltage is 5 volts to prevent any damage to the ICs — in particular the counter, which costs about \$10. Remember to turn the power off before inserting the ICs.

FIGURE 5



I-F board foil-side connections.

PHOTO A

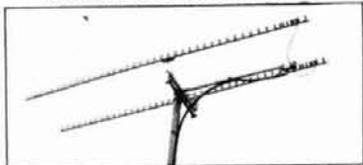


Rear view of receiver

Mixer board

The mixer board in **figs. 7A-C** is next because it has the adjustment pots for setting the oscillator frequencies. They could have been placed on the oscillator board, but my original design had the oscillator on the plug-in board. The stability of the oscillator was very poor, so I put it on a separate board attached directly to the chassis. I didn't have room for the pots, so they remained on the plug-in board. The 9-volt supply is also located on the mixer board. The mixer coil is wound on a T50-6 toroid with 80 turns of no. 30 AWG and ten turns on the primary. The number of turns on the secondary will be adjusted later to give about 10

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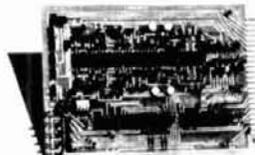
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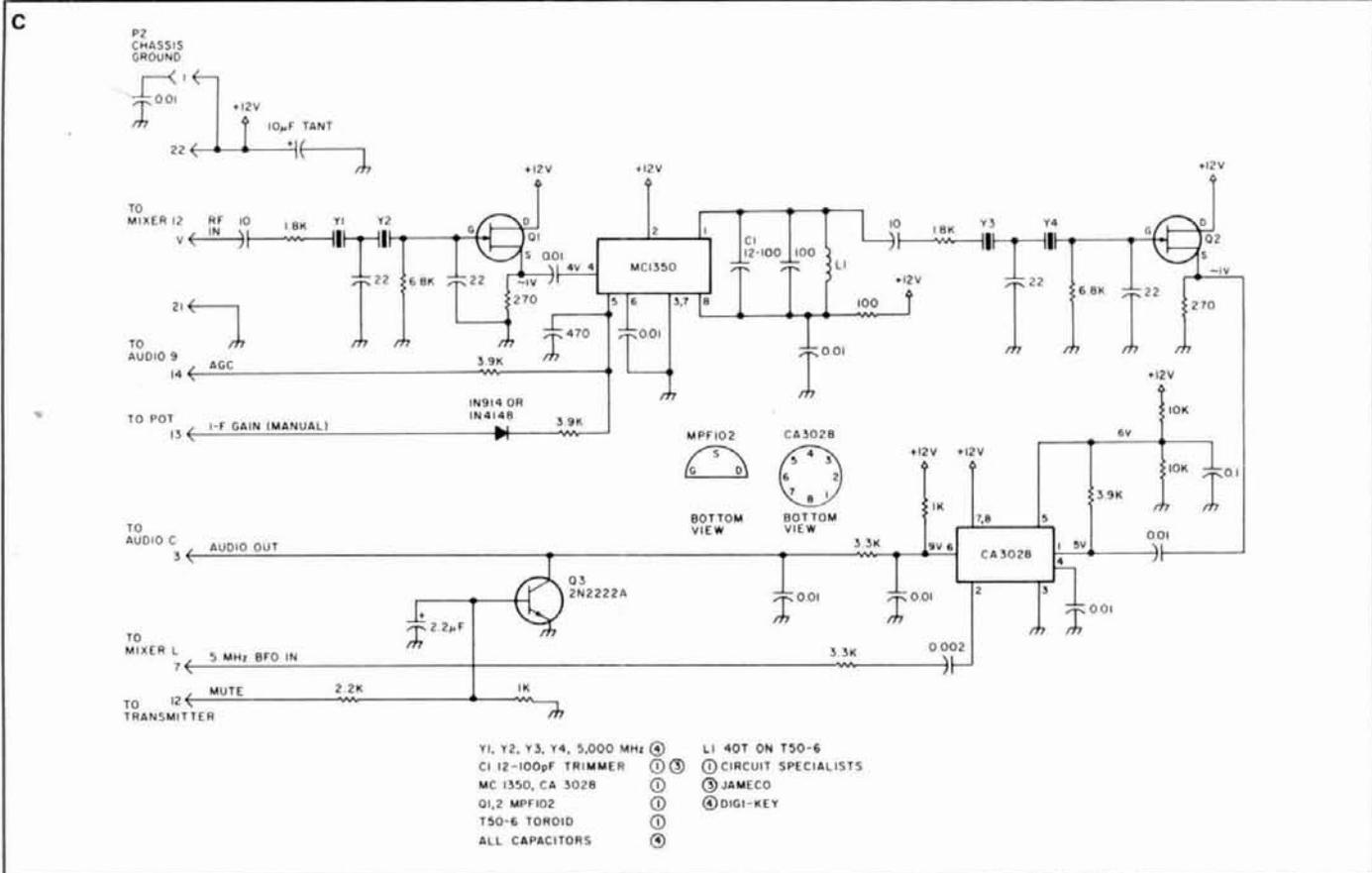
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FIGURE 5



I-F board schematic.

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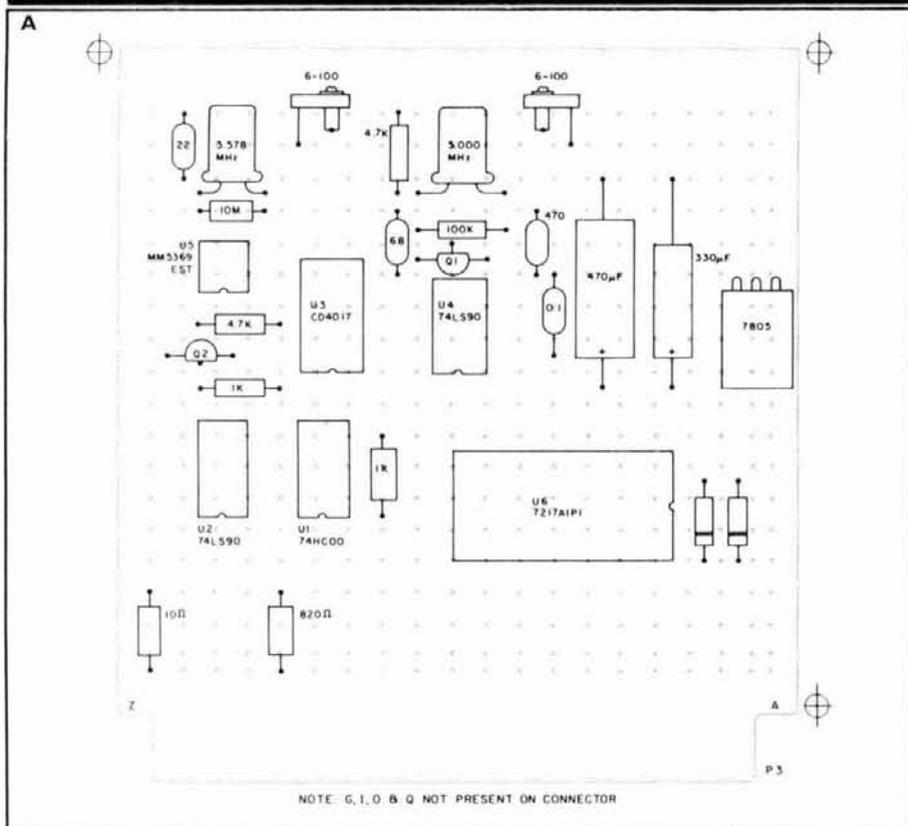
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FIGURE 6



Counter board parts placement guide.

percent of the value of the 360-pF variable for peaking the 40-meter band. Experiment to find the 160-meter switched-in capacitor. I used a 550-pF capacitor, but a lot depends on other circuit capacitances. You'll have to retune the mixer capacitor as you go across the 160 and 80/75 bands, but this greatly simplifies the circuitry.

When the board is completed, check it out by plugging it in J1. The rest of the boards should also be in. Short out the WWV trap by closing the switch across the trap coil. Connect an antenna to the input jack. With power on, you should hear WWV with the mixer-tuning capacitance set about 40 percent. (Of course this should be done during nighttime conditions when WWV comes in best.) The receiver may oscillate at this point because there are three stages tuned to the same frequency. Just detune the mixer capacitance a small amount. Some of this oscillation will be reduced

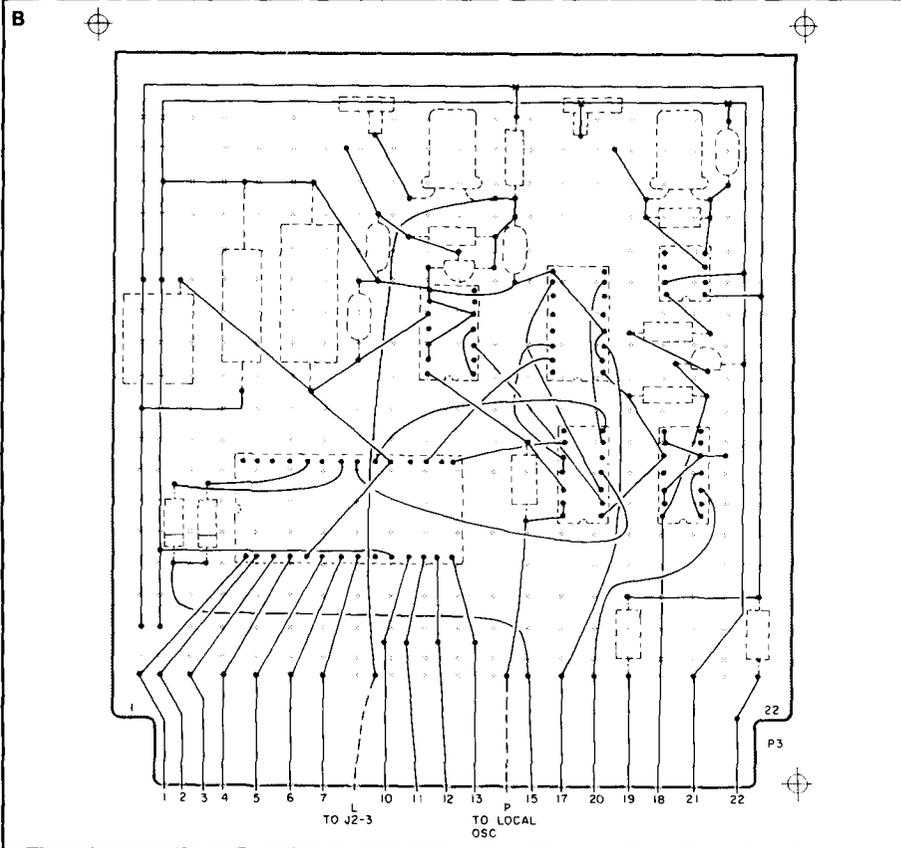
when a shield is placed between J1 and J2. A shield will also be placed between J2 and J3. Please note that there is a capacitor between pin 1 and chassis ground on both J1 and J2. I found these caps helped reduce the multiplexing noise from the counter board.

You can also check the effectiveness of the trap at this time. Open the trap switch and tune the capacitance across the coil for minimum signal. If you have successfully completed this board, the next board is the last — you're almost there!

Oscillator board

The board (see fig. 8A, B, C) consists of a conventional Colpitts oscillator and buffer with the three oscillator coils for 160, 80/75, and 40 meters tuned by a varicap and a ten-turn pot. The upper end of each band is adjusted by trimmers located on the mixer board. The lower end is done by adjusting the num-

FIGURE 6



Counter board foil-side connections.

ber of turns on the coils. It sounds like a tedious task, but you can perform it rapidly if you use a counter.

The board used for the oscillator is a Radio Shack (no. 276-148). It's mounted to the bottom plate with four stand-offs. The same type of construction is used as on the plug-in boards. Because of the limited space, the toroids are mounted vertically. I used polystyrene capacitors for temperature stability but they may be hard to find. Use, in place, any capacitor that has a low temperature coefficient.

When the board is wired and checked, mount it to the bottom plate and connect the band switch and ten-turn pot. Set the band switch to 160 meters. With all boards in and the power on, the counter should indicate a frequency somewhere between 1.5 and 2.5 MHz. Turn the tuning dial; the frequency should change. Turn the dial to give the highest reading. Adjust the trim resistor on the mixer board designated

160 M trim. Adjust it in a direction towards 2.0 MHz. Turn the dial to the other end and add or remove turns until the counter approaches 1.8 MHz. Repeat the process until adjustments give 1.795 and 2.005 MHz. Final adjustments can be made by spreading the turns. Repeat the same process for 80 and 40. The 75-meter band has two adjustments. Set the upper to 4.005 and the lower at 3.790 MHz. I have set the 80-meter band to cover 3.600 to 3.805.

Final adjustments

With the oscillator working, it's time to connect the receiver to an antenna. During the day, the best band to try is 40 meters. Set the band switch to 40 M. Be sure the mixer capacitor for 160 is out of the circuit. Adjust the mixer capacitor to about 10 percent of full scale. You should hear an increase in background noise. Signals should be audible, and the display should indicate the right frequency.

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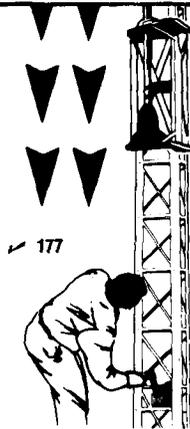
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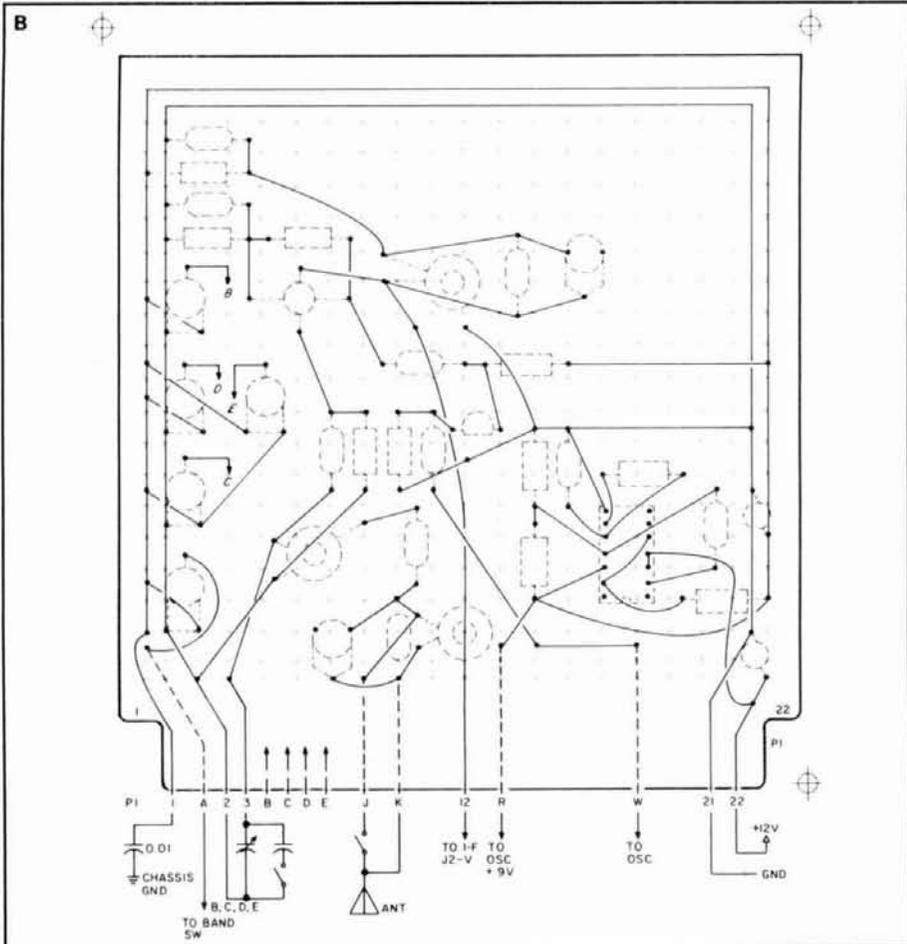
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FIGURE 7



Mixer board foil-side connections.

the unit is enclosed in a cabinet. When the shields are in place, make the following adjustments:

1. Set the AGC bias voltage.

Turn the i-f gain pot to minimum voltage. Measure the voltage on pin 5 of the MC1350. The voltage should be set to 5.0 volts using the bias adjust pot on the output board.

2. Adjust the mixer coil.

Set the receiver to the 40-meter band. With an antenna connected, adjust the turns on the mixer coil so the mixer capacitor peaks at about 10 percent of full scale. Switch to the 80-meter band and check the mixer capacitor setting. It should be about 60 percent of full scale. Repeat the operation for the 160-meter band. Clip lead a 470-pF capacitor across the mixer capacitor. Set the tuning dial to read 1.900 MHz. Vary the

mixer capacitor until a peaking in background noise is heard. If the trim capacitor is of the correct value, the mixer capacitor will be about mid-scale. It should read about 90 percent at 1.800 MHz.

3. Set the WWV trap.

If you have been doing some checks in the evening, you have undoubtedly heard WWV in the background. If you have, either the WWV switch is in the shorting position or the trap needs further adjustment. Set the band switch to 40 M and the mixer capacitor to about 30 percent scale. Adjust the trap capacitor to give minimum feedthrough. The 5,000-MHz BFO setting can be rechecked at this time. Wait until the steady tone is off, then adjust the BFO trimmer on the counter board to zero beat with WWV.

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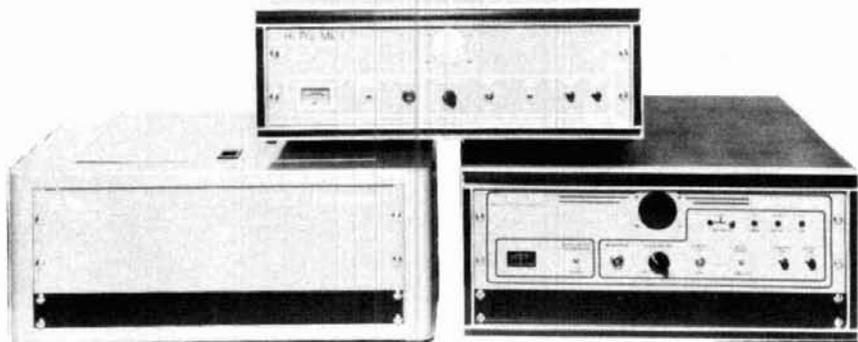
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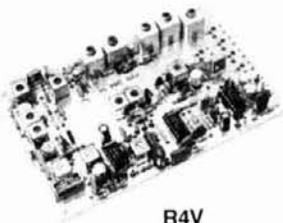
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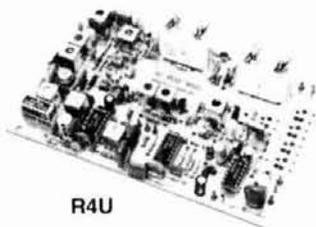


R4V

The **Hi Pro Receiver** is the heart of the Hi Pro Repeater specifically designed to commercial specifications for Repeater service, and boasts high Q multi-tuned circuits in both the rf and oscillator stages to insure low desense intermod and spurious along with choice of varying degrees of selectivity. Superior squelch action, a necessity for Repeater service, extreme sensitivity, frequency and thermal stability. This receiver not only can be used as initial receiver, but also to replace that troublesome receiver in your present repeater. Easily adapts to any system. The small size, allows for easy mounting, even where space is at a premium. The excellent front end rejection with wide dynamic range guarantees excellent desense, intermod, and spurious response rejection. Advanced squelch circuitry to produce min. squelch chopping, even with weak signals of high deviation, such as weak mobile or rapid fading signals, and also high electrical noise rejection, such as electrical storms, ignition pulses, etc.

FEATURES:

- High sensitivity
- Superior rejection
- Double-sided mil spec G-10 fiberglass boards
- Extremely stable operation
- Excellent adjacent channel rejection
- Squelch circuit designed for critical repeater use
- Small size
- Choice of passbands
- Wide selection of frequency ranges
- Separate open collector C.O.R. output
- Separate tone control squelch input
- Separate tone control output
- Discriminator meter output
- Signal level meter output
- Multi channel capability. Up to 6 channels
- Multiple Voltage Regulation
- Available with precision grade high stability crystal
- Selectable C.O.S. high or low output
- 1 year warranty



R4U

SPECIFICATIONS:

- Sensitivity:**
12 dB Sinal (EIA Method) 0.25 uv.
20 db quieting method 0.30 uv
- Selectivity:**
EIA two signal method
Standard + 15 kHz -80 dB
+ 30 kHz -130 dB
Optional Narrow + 15 kHz -100 dB
+ 30 kHz -130 dB
- Spurious Response:** -85 dB
- Intermodulation:** -70 dB
- Modulation Acceptance:** Standard + 60 kHz
Narrow + 5.0 kHz
- Squelch Sensitivity:** 0.10 to 0.20 uv
- Frequency Response:** +2 to -3 dB of 6 dB/Octave
de-emphasis from 300-3000 Hz. 1000 Hz reference
- Audio Output:** (to 8 ohm speaker) 2.0 watts max
5% distortion at 15 watts max
- Rf input impedance:** 50 ohms
- Frequency Range:**
V.H.F. 130-150 MHz, 144-175 MHz, 220-250 MHz
U.H.F. 406-450 MHz, 450-490 MHz
- Operating Voltage:** +11 to +14.5 VDC
+13.8 VDC nominal
- Current:** 90 mA nominal squelched
- Size:** 3" W x 6" L x 1" H
- Duty Cycle:** 100% at 60 C
- Operating Temp. Range:** -30 C to +60 C
- Meets or Exceeds All Published Specifications.

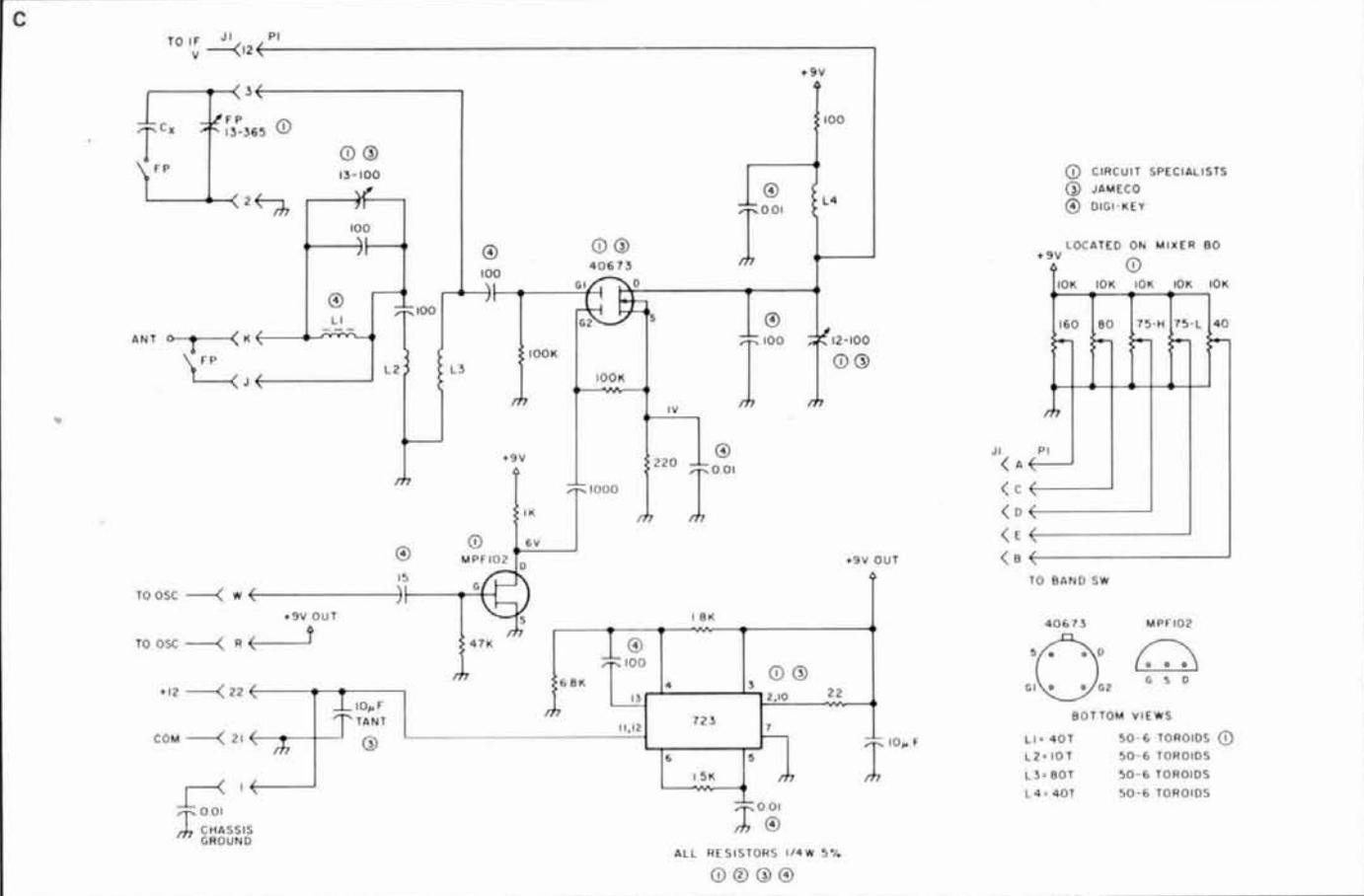


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FIGURE 7



Mixer board schematic.

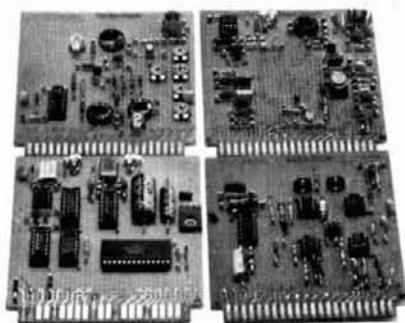
4. Mixer and i-f output capacitor adjustments.

With the receiver set on any frequency where there is noise only, adjust each of these capacitors to give maximum output.

5. Testing the peak-null circuit.

Tune in a steady carrier set to an audio tone of about 1 kHz. Switch on the peaking switch, and rotate the peaking pot until a pronounced increase in signal is present. Now rotate the null pot

PHOTO B



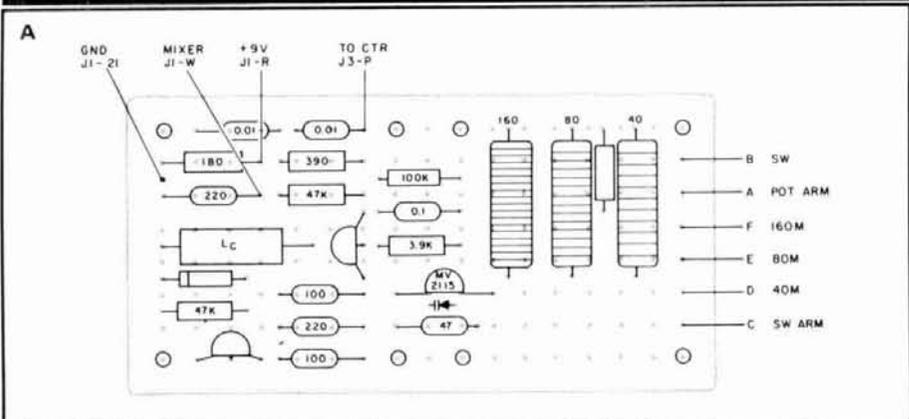
Upper left, mixer; upper right i-f; lower left, counter; and lower right, audio.

until the signal is reduced in amplitude. If these actions are noted, these circuits are operating correctly.

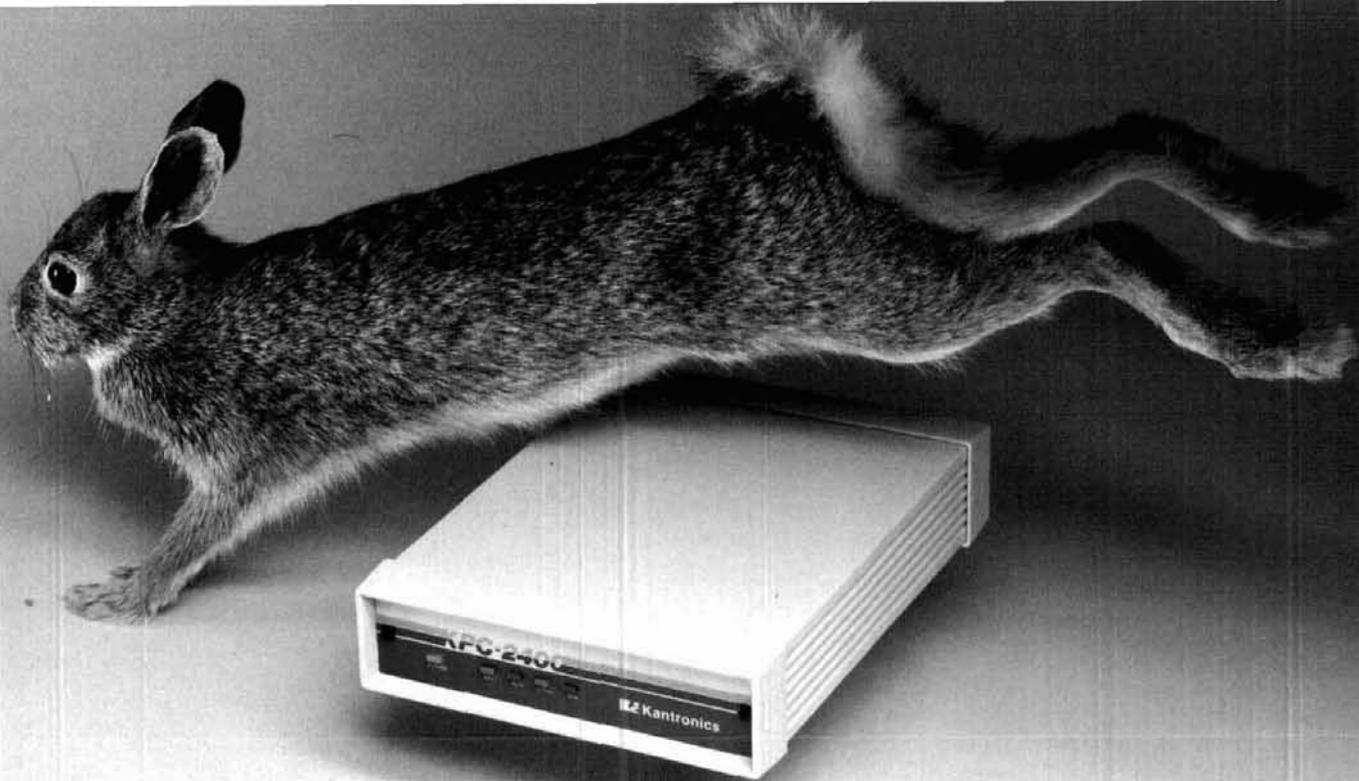
6. Final calibration.

Tune the receiver to 2.000 MHz. A weak signal will be heard that is a sub-harmonic of 5.000 MHz. Tune the

FIGURE 8



Oscillator board parts placement guide.



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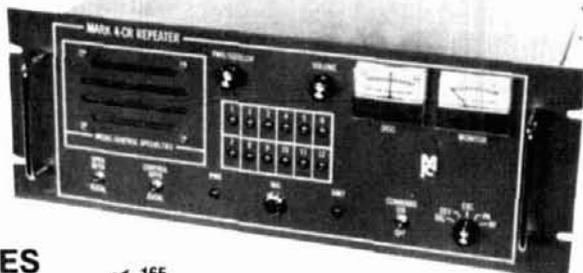
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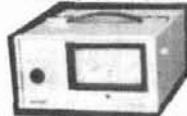
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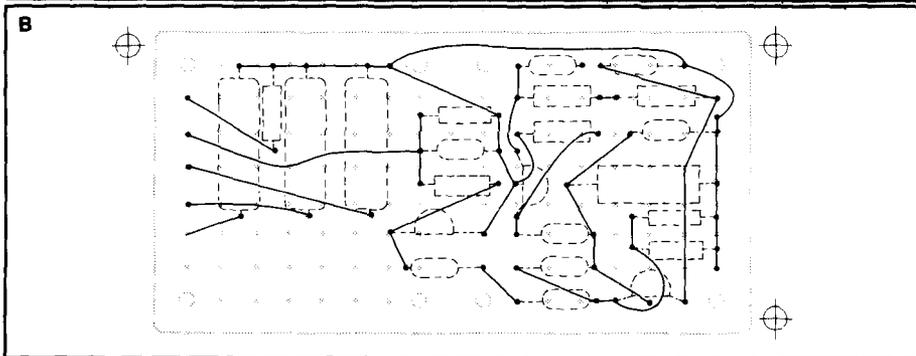
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FIGURE 8



Oscillator board foil-side connections.

problems, I'll indicate what has to be done to correct the fault. Go to it!

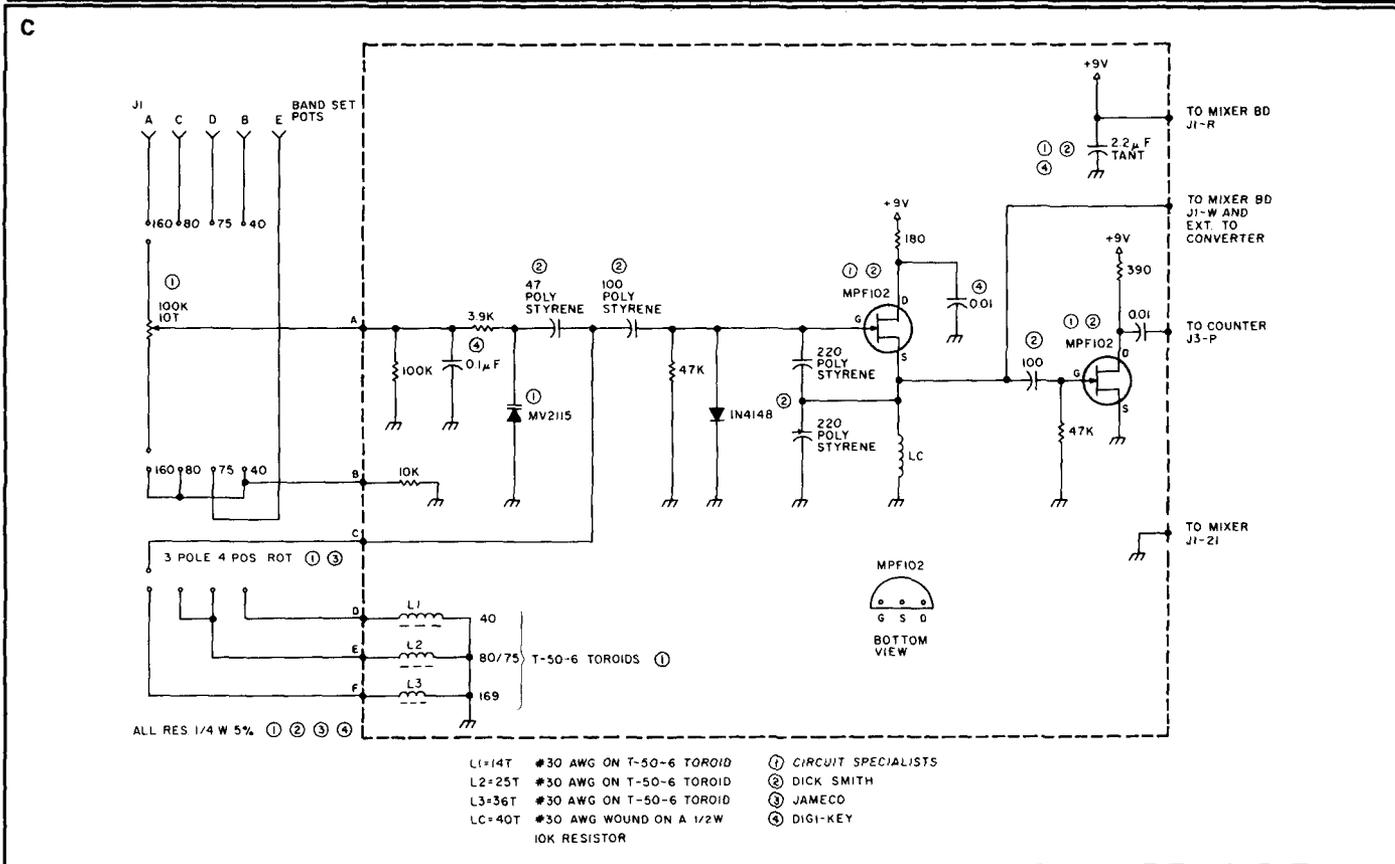
Acknowledgments

Thanks Francisco Moreno, a photo enthusiast, for taking and enlarging the photos, and to Tom Fattaruso for acting as a sounding board for some of my ideas and coming up with helpful solutions.

Note:

The photo showing the printed circuit assembly of the counter board has been changed slightly to use a different crystal frequency than the original circuit.

FIGURE 8



Oscillator board schematic.

receiver to zero beat. Then adjust the counter-oscillator trimmer so the counter reads 2.000 MHz.

Conclusion

Although this receiver is not a single weekend project, each board can be constructed in a weekend. It's a far cry from the first superhet I built before WW II using Miller coils. I've made a number

since, but this one outperforms them all. In the future, I'm going to build converters to cover the 20, 15, and a portion of the 10-meter band.

If you have any problem with any of the boards and you've followed the same pin connections that I've used, I will gladly troubleshoot your board for a small fee of \$5 per board (postage prepaid). If you've only made a small error, I'll make the correction. On major

References

1. J.A. Hardcastle, G3JIR, "Ladder Crystal Filter Design," *QST*, November 1980.
2. J.A. Hardcastle, G3JIR, "Some Experiments With High Frequency Ladder Crystal Filters," *QST*, December 1978.
3. Wes Hayward, W7ZOI, "A Unified Approach to the Design of Crystal Ladder Filters," *QST*, May 1982.
4. Jim Pepper, W6QIF, "The Magic Filter," *73*, November 1983.
5. Gary Mclellan, "Tune Your Receiver by the Numbers," *Popular Electronics*, October 1981.

Article D

HAM RADIO

THE WEEKENDER



A 1296-MHz LOW NOISE AMPLIFIER

By Norman J. Foot, WA9HUV, 293 East Madison Avenue, Elmhurst, Illinois 60126

The noise figure of an RF amplifier can be elusive, especially at VHF and above. This is true unless you are fortunate enough to have sophisticated (and very expensive) test equipment at your disposal.

Specifications

Transistors are ordinarily specified by the manufacturer in terms of their scattering S parameters. These are the electrical characteristics seen at their interfaces. Scattering parameters allow you to design an amplifier with approximately the same gain and noise figure specified by the manufacturer, as long as you follow certain rules of analysis. Unfortunately, for most of us, following these rules by longhand can be an exceedingly ambitious and time-consuming task.

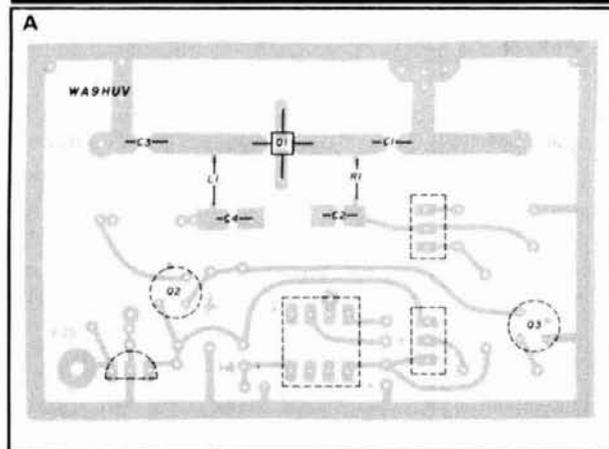
Computer needed

If you have access to a personal computer and a suitable program, you can accomplish designs quickly and with relative ease. Even so, you wouldn't expect to develop a design from scratch on a weekend.

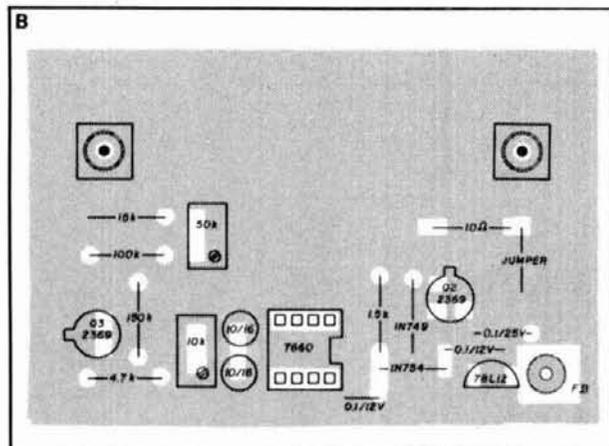
Some years ago I wrote a relatively simple computer program in BASIC for purposes of designing low noise amplifiers. With this program, using data specified by the manufacturer, I found that I could realize a design in short order.

I've built and tested a number of amplifiers with this program, employing various types of transistors — including both bipolar and GaAsFETs. My designs agreed with the manufacturer's data sheets, increasing my confidence in the program.

FIGURE 1



Trace side of PCB.



Groundplane side of PCB.

See page 97 for pc board groundplane and trace layout.

The weekender

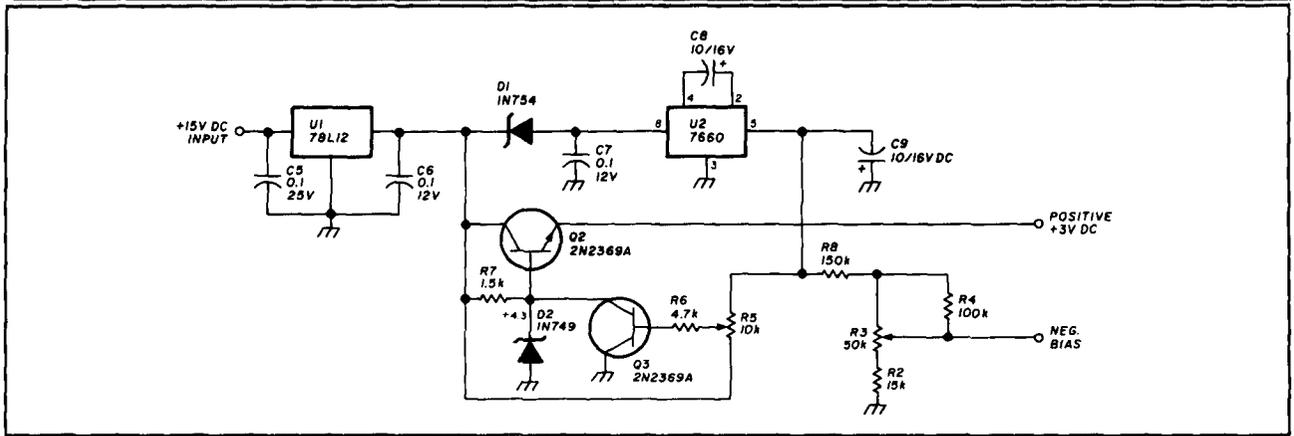
This article is about one of these designs. Centered near 1296 MHz, it employs a NEC-70083 GaAsFET. The 70083 was introduced a number of years ago and is now available at reasonable cost. It uses a 0.5 micron gate and is hermetically sealed in a stripline package.

To duplicate this amplifier, copy the microstrip layout shown in fig. 1. Notice that all traces are 50 ohms, printed on G-10 (glass-epoxy) double copper-clad pc board. No tweaking or tuning is required.

Figure 2 shows how the amplifier is powered. A +5Vdc potential is obtained by using a 78L12 regulator and a series-pass transistor driving an Intersil 7660 voltage inverter for negative gate bias. A safety circuit¹ is included; this shuts off the drain voltage in case the bias circuit fails. Figure 3 is a schematic diagram of the GaAs-FET amplifier.

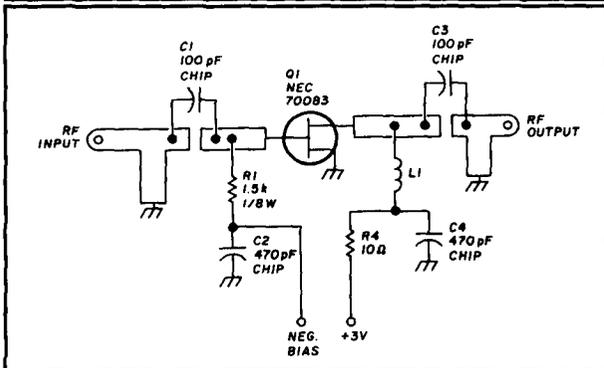
A curve of gain-vs-frequency is illustrated in fig. 4. The gain is flat within a half dB from about 1250-1320 MHz. (The improved pc board layout in fig. 1 maintains flatness over a narrower band — approximately 100 MHz.) A word of caution; the layout of fig. 1 should not be scaled to another frequency because scattering parameters are frequency sensitive.

FIGURE 2



Schematic diagram of power supply/regulator.

FIGURE 3



Schematic diagram of GaAsFET amplifier.

FIGURE 4

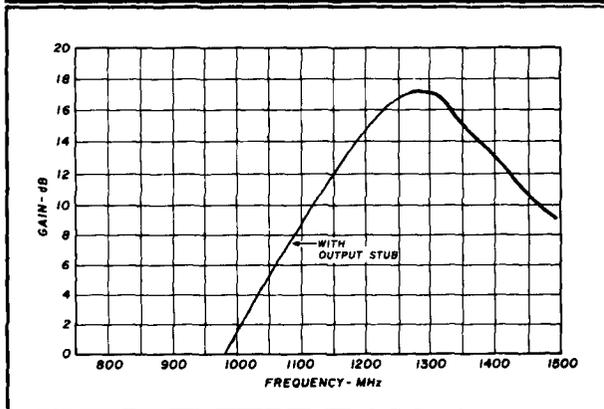


Chart showing curve of gain versus frequency.

It should be recognized that while the manufacturer specifies the optimum noise figure to be about 0.7 dB at 1296 MHz with an associated gain of 18.5 dB,² the actual noise figure will be somewhat higher and the gain lower. This is due to such factors as pc board dielectric loss, source lead inductance, or inaccuracies in microstrip dimensions. Measured gain for this particular amplifier is 17dB when $I_{ds} = 10$ mA. Differences in dielectric con-

Parts List

Capacitors

- 2 100-pF chip (Mouser—21CC610)
- 2 470-pF chip (Mouser—21CC647)
- 1 0.1- μ F disc 25 volts
- 2 0.1- μ F disc 10 volts
- 2 10- μ F electrolytic 16V

Potentiometers

- 1 10k multiturn (Mouser—ME323-4290W-10k)
- 1 50k multiturn (Mouser—ME323-4290W-50k)

Resistors

- 1 10 ohm 1/4 watt
- 1 1.5k 1/8 watt
- 1 1.5k 1/4 watt
- 1 4.7k 1/4 watt
- 1 15k 1/4 watt
- 1 100k 1/4 watt
- 1 150k 1/4 watt

Semiconductors

- 1 1N754 Zener Diode
- 1 1N749 Zener Diode
- 2 2369A Transistor
- 1 7660 IC
- 1 78L12 Regulator
- 1 NEC70083 Planar Transistor (California Eastern Labs)

Miscellaneous

- 2 SMA Connectors
- 1 8-Pin DIP Socket
- 1 PCB (FAR Circuits \$6.25)

Parts Sources

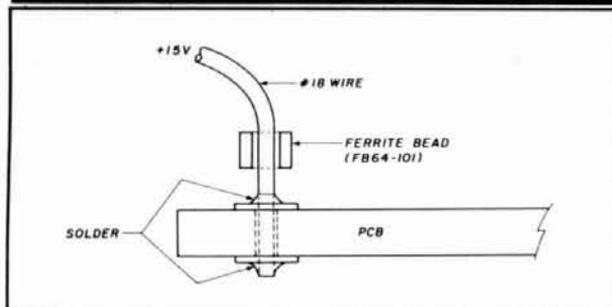
California Eastern Labs, 3260 Fay Street, Santa Clara, California 95060
 Digi-Key, 701 Brooks Avenue South, P.O. Box 677, Thief River Falls, Minnesota 56701
 FAR Circuits, 18N640 Field Court, Dundee, Illinois 60118
 Mouser Electronics, 2401 Highway 287 North, Mansfield, Texas 76063
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stant between one manufacturer's board material and another's, or between different production runs from a given manufacturer, can influence performance. A value of $\epsilon_r = 4.4$ was selected from a published table.³

Gain increases with drain current, peaking out at 19.5 dB at about 40 mA, but the manufacturer's data calls for a drain current of 10 mA for minimum noise figure.

Through-grounds are made on the pc board in fig. 1 by passing no. 26 tinned copper busbar through the ground holes and soldering on both sides. In this way, the ground on the trace side of the board is connected to the ground plane with minimum inductance. This is particularly important where the stub on the gate side of the transistor is connected via a through hole to the ground-plane side of the board, and where the transis-

FIGURE 5



Ferrite bead placement on the +15 volt Vdc line.

tor sources are similarly through-grounded (See fig. 5 for details on RFI proofing the +15 Vdc input line.

C1 and C3 are 100-pF chip capacitors; C2 and C4 are 470-pF chips. R1 is a 1.5k 1/8-watt resistor soldered directly to the traces with short leads. L1 is wound, using a 1/16" drill bit as a mandrel, with 9 turns of no. 24 enamel copper magnet wire; the turns are spaced slightly. R3 is the gate bias pot; R5 sets the drain voltage to +3 volts.

Adjustments

Before soldering the GaAsFET to the pc board, adjust the negative bias and protective circuit. Temporarily connect a 270-ohm resistor from the junction of L1 and R4 and ground to simulate transistor-drain current. Then adjust R6 until the drain voltage across the 270-ohm resistor is 3.0 Vdc. When pin 5 of the 7660 is then shorted

to ground, or if the 7660 is removed from its socket, the positive 3 Vdc ramps down to zero.

Shielding

The 1296-MHz amplifier performs noticeably better when the assembly is enclosed in a shielded box. Form brass strip 1/4" wide and 0.032" thick into a 2"x3" rectangle and solder it to the copper band around the trace side of the board. Now form a 0.015" thick piece of aluminum into a tight-fitting cover. Use a pair of 2-56 screws to hold the cover in place through tapped holes in the brass rectangle.

A final note

I make no particular claims for superior performance for the amplifier described here. It will win few contests for the lowest noise figure, but on-the-air tests make it clear that "store-bought" or homebrew converters come to life when you use it. You be the judge.

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1. Norm Foot, WA9HUV, "Safe Power for your GaAsFET Amplifier," *ham radio*, November 1982, page 20.
2. California Eastern Laboratories, Inc., NEC Data Sheet, NE700 Series, January 1983.
3. Tri T. Ha, "Solid State Microwave Amplifier Design," John Wiley & Sons, New York, 1981, page 292.

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1. George D. Vandelin, "Design of Amplifiers and Oscillators By the S-Parameter Method," John Wiley & Sons, New York, 1981.
2. T. C. Edwards, "Foundations For Microstrip Circuit Design," John Wiley & Sons, New York, 1981.

Article E

HAM RADIO

Aries-1
Amateur Radio Integrated Entry System

A
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T
W
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ID(Sta): W0ABC Name: CHAR City: DENVER State: CO
 Date: 08-10-88 Begin: 21:05 End QSO: 21:07:22 Freq: 28.485.0
 Type (mode): USB My RST: His RST: 59 Power: QSL:

Remarks: Data Base / Status Window
 Data: Status: [T/R] [CLS] Manual Mode [CLD] [Sp/F] [Qu/eX]
 Log of NV2I

W0ABC DENVER CHARLIE
 HOME BREW XMT, 3 ELEMENT TRIBANDER, LIVES NEAR UNCLE JOE

Scratch-Pad
Term Unit I/O Window

CW/RTTY/AMTOR type ahead Window

L1:ANNUAL2 RTTY 8 CU 1:AMTOR 2:PACKET 3:LINE ON 7:LINE OFF 8:Clear 9: Log 10: Optns

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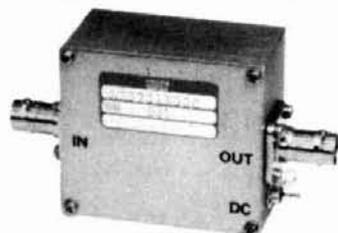
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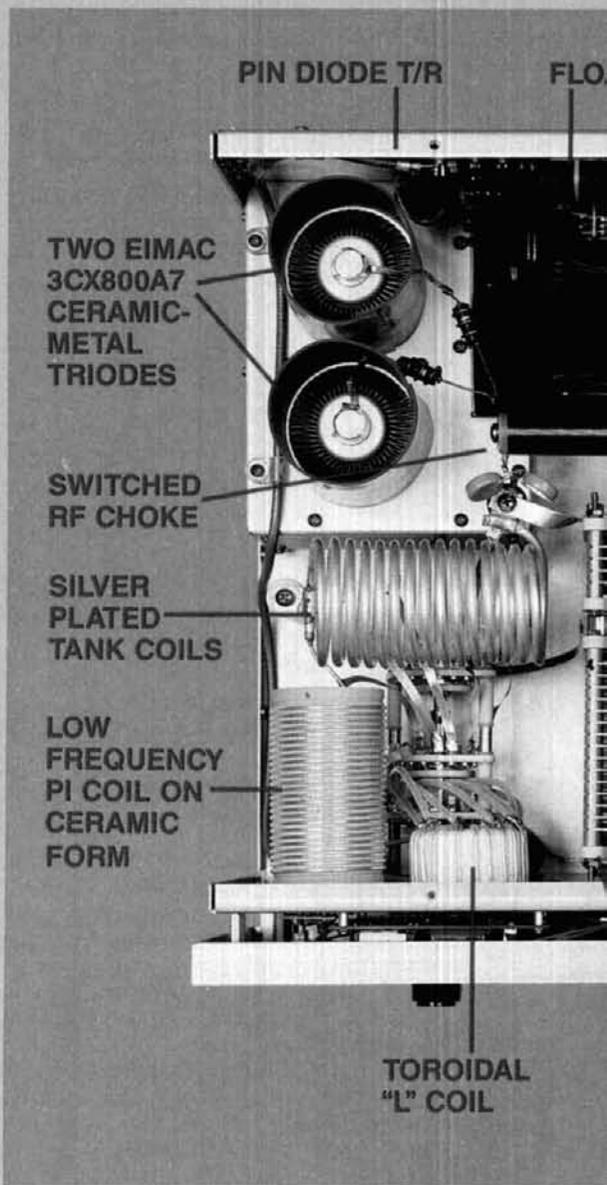
The **ALPHA 86** is adjusted *manually* by the operator (like earlier ALPHA 76/A series amplifiers) for optimum performance at any frequency between 1.8 and 22 or 30 MHz*. Smooth and easy manual tuning is provided by a combination of custom split capacitor, vernier drives, bandswitched RF choke, and level-independent LED tuning indicator. Accurate manual tuneup is easier and quicker than ever before.

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ALPHA 88 combines the full frequency coverage* amplifier circuitry of the '86 with a *microprocessor-based automatic control* system. Nominal settings for all frequency ranges are factory-loaded in memory; when drive is applied the microprocessor system samples the incoming RF, selects the proper frequency range, and trims tuning and loading for optimum performance—all within a few seconds. Tune-up is always precisely correct for your actual operating frequency and load impedance. *You always have maximum efficiency and 1.5 kW of razor sharp RF output without ever touching a knob!*

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POWER OUTPUT: 1500 watts PEP, keyed CW, or carrier (RTTY, SSTV, etc.) up to 100% duty cycle, no time limit. Optional auxiliary cooling fan recommended for operation of **ALPHA 87** at output power exceeding 1000 watts average for more than 30 minutes continuously.

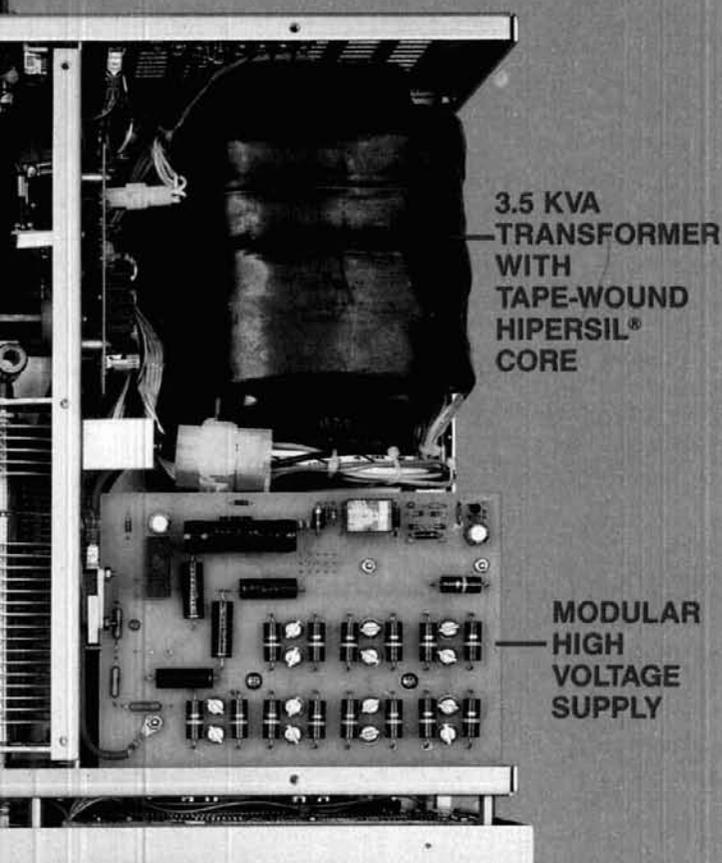
DRIVE POWER: 50 to 80 watts PEP or carrier for 1500 watts RF output.

INPUT VSWR: 1.5:1 maximum within amateur bands; 2.5:1 maximum elsewhere.

TUBE COMPLEMENT: Two EIMAC 3CX800A7 ceramic-metal, grounded grid triodes.

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SWR PROTECTION: **ALPHA 86 & 88**-Automatic tripout for VSWR > 2.5:1 @ 1500W Po. **ALPHA 87**-Automatic tripout for VSWR > 1.5:1 @ 1500W P.

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D612	\$259.95	50 Hz-1.2 GHz	0.1 PPM 20°-40°C PROPORTIONAL 10 MHz OVEN	9	15 to 50 MV	2 to 20 MV to 450 MHz	8-15 VDC 500 MA
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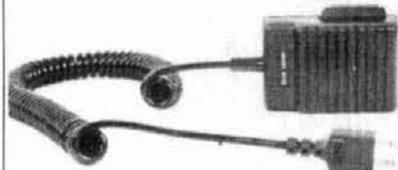
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By James M. Larson, KF7M, 2245 Ross Avenue, Idaho Falls, Idaho 83406

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I have done a solid-state conversion of the Collins 75A-4 receiver. My intention was to "get the tubes out," yet retain or improve the original operating features and performance. I wanted a receiver that looked and felt like a 75A-4, but with negligible frequency drift and improved intermodulation distortion (IMD) and overload capability. I was also looking for steeper skirts on the i-f passband and a noise limiter that was effective on the "woodpecker."

I wanted to keep all the original RF, oscillator, i-f, BFO and VFO coil structures, and their associated band-switches. The original mixing scheme would remain. An additional mechanical filter would be inserted in series with the existing i-f filters.

The end result is a receiver that, from all external appearances, is a 75A-4 (**Photo A**). But when you open the lid, you see the uncluttered view in **Photo B** — and no tubes!

The lack of background interference and hash is noticeable when you compare the new receiver with the unmodified version. The measured IMD and blocking capability are also greatly improved.

Performance characteristics

Table 1 shows performance specifications for the more important parameters of the solid-state receiver, compared to the vacuum tube original. The data is the result of comparative measurements made on a vacuum tube 75A-4 and the solid-state version.

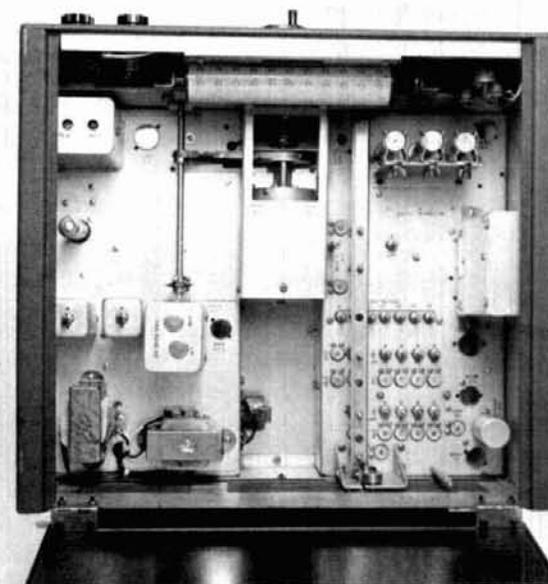
With the exception of receiver sensitivity, all other parameters of the solid-state conversion are improve-

PHOTO A



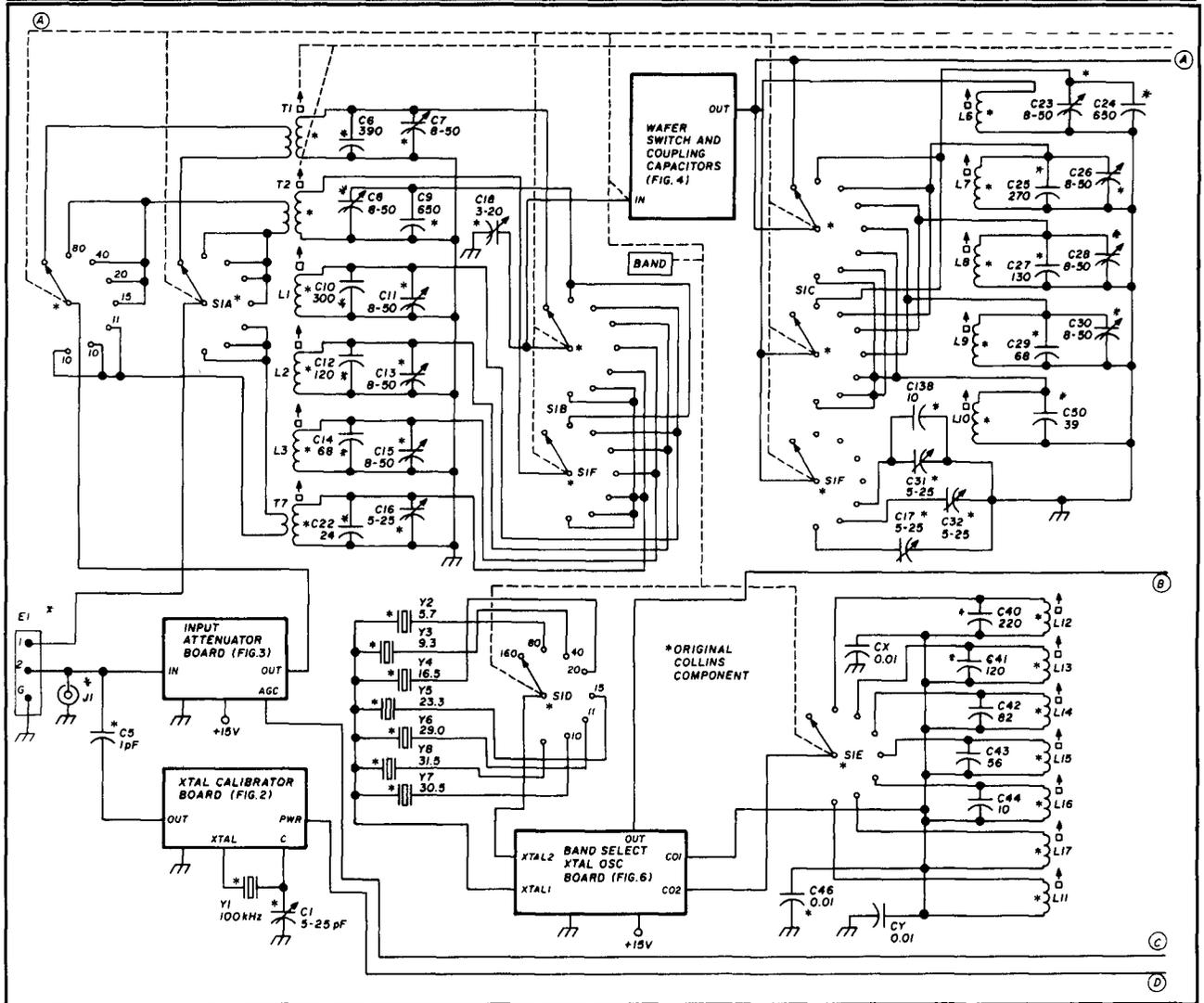
Front view of the 75A-4 receiver.

PHOTO B



Top inside view of the 75A-4 receiver.

FIGURE 1



Overall circuit diagram of the receiver.

ments over the original. The high sensitivity of the vacuum tube receiver was reduced to enhance the IMD and overload capability. The input noise of the solid-state version still remains below the typical background and galactic noise from the antenna.^{1,2}

Getting started

The first thing I did was acquire two 75A-4s. One unit was used as the comparison standard. I removed everything from the other 75A-4 except the RF coils, oscillator coils, variable i-f coils, crystal sockets, bandswitch assembly, and the sockets and switch for the mechanical filters.

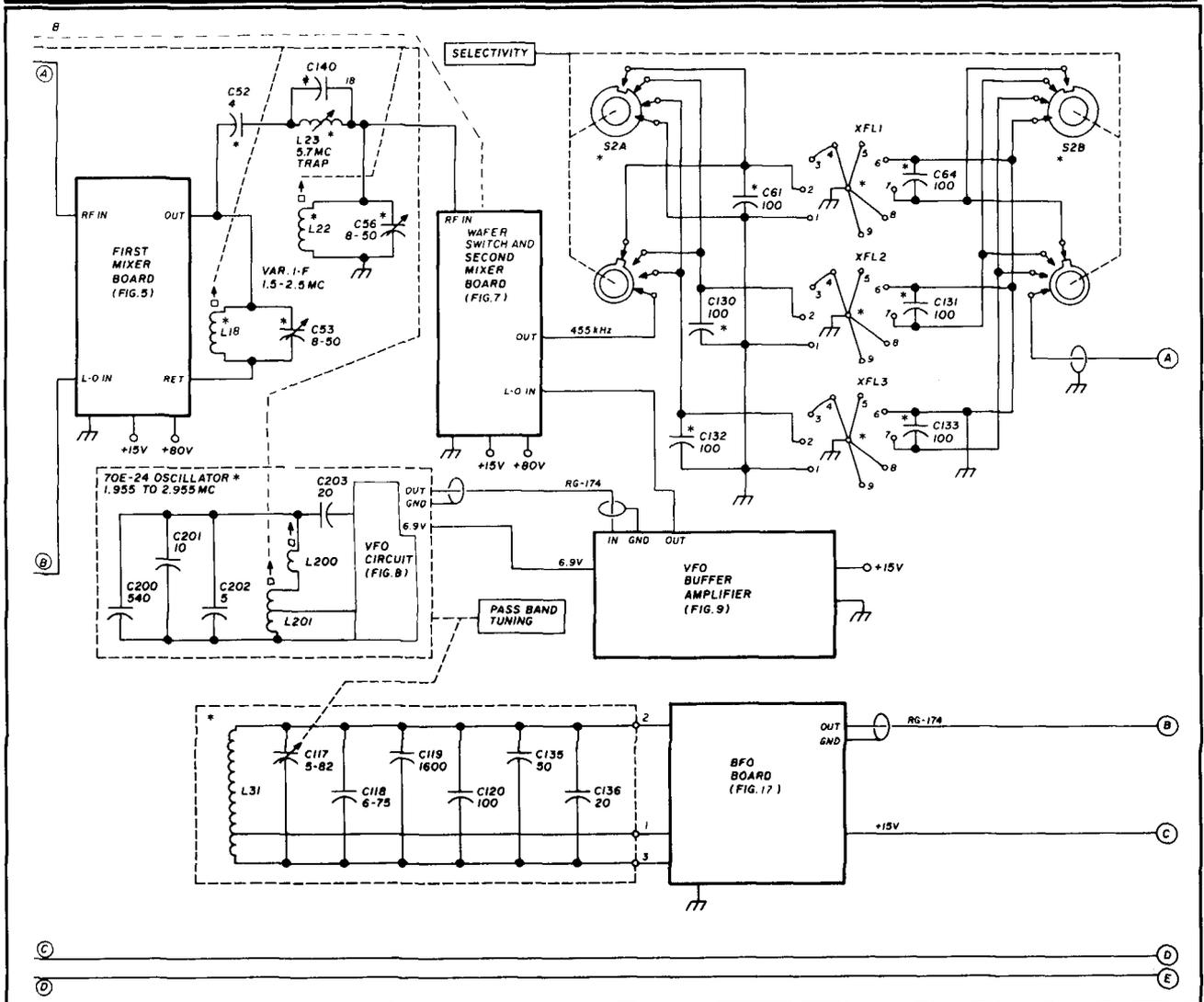
The wiring that remained included the interconnecting wires between the bandswitch, its associated coils and crystal sockets, the mechanical filter selection switch, and the interconnecting wiring to the filter

sockets. I had removed everything else, leaving an almost bare chassis.

I also stripped out the tube sockets and all wiring at the base of the tube sockets in the permeability tuned oscillator (PTO). I didn't disturb the oscillator circuit in the PTO hermetic enclosure at this time. Next I opened, cleaned, and checked the i-f cans, BFO enclosure, and the rejection filter enclosure. The megacycle dial drum, the kilocycle dial, and their pointers were cleaned and temporarily stored with the front panel. I cleaned the chassis to remove dust and stains, then remounted the i-f cans, BFO enclosure, and rejection filter enclosure.

I cut an aluminum plate to cover the portion of the chassis on the right side as viewed from the front that was riddled with holes from remnants of tube sockets, transformers, and other hardware I'd removed. The tube sockets on the left chassis, and those not easily covered

FIGURE 1



on the right, were filled with button-type hole covers. A nine-pin tube socket was mounted on the right side (see **Photo C**) for the additional 3.1-kHz mechanical filter to be added to the i-f section.

Much of the circuit was built "daub-a-gob" style on unetched copper-clad vector board. These boards are still in place, but I hope to replace them in the future.

Circuit description

The overall circuit diagram for the receiver is shown in **fig. 1A-D**. Components retained from the original receiver are also shown in **fig. 1**, accompanied by an asterisk and the component designators used by Collins on the original receiver schematic. The new solid-state circuits are shown only as circuit blocks on this diagram. The solid-state circuits comprising these blocks are described in more detail later. If you own a 75A-4, you might be interested in comparing **fig. 1** with the block diagram and schematic in your 75A-4 instruction book.

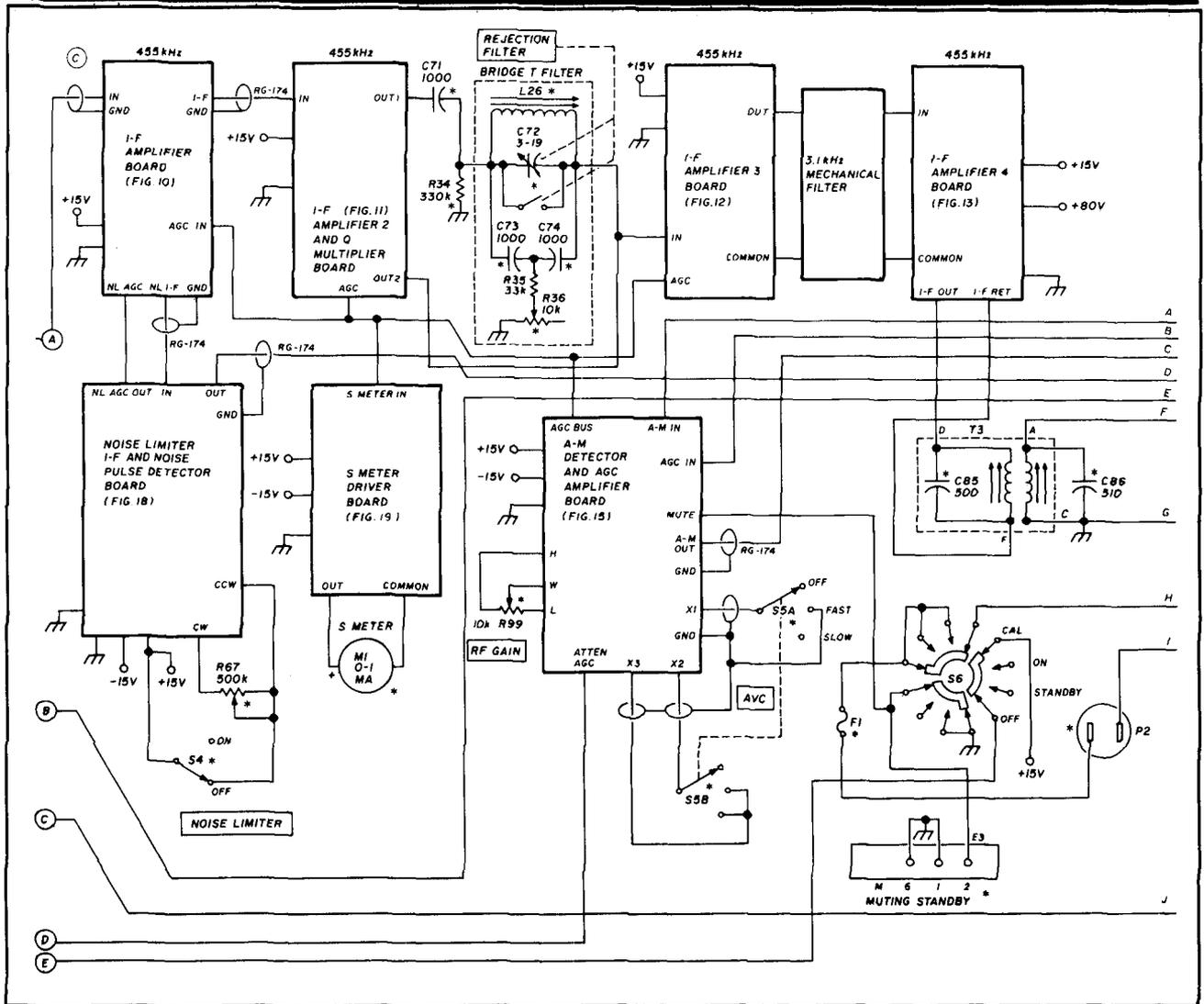
The circuit diagram shows that the new solid-state version retains the same mixing scheme and the same basic topology as the original. It differs from the original as follows:

- An AGC-controlled input attenuator has been added at the receiver input.
- There is no RF amplifier. The antenna and RF coils are now capacitively coupled, forming a double-tuned network ahead of the first mixer.
- An additional 3.1-kHz mechanical filter has been placed in the i-f amplifier to improve shape factor and i-f rejection.
- I used a gated noise limiter that has its own separate i-f amplifier for impulse noise identification.
- The S meter is driven from a special driver board.

Crystal calibrator

Figure 2 shows the schematic of the 100-kHz crystal-calibrator circuit. The active element is a CD4011 CMOS

FIGURE 1



quad nand gate. Gate U1_a, crystal Y1, resistors R1 and R3, and capacitors C1 and C3 comprise a Pierce oscillator. Gates U1_b through U1_d buffer the oscillator output and square up the oscillator signals to enhance its harmonic output. Positive 15 volts is applied to the calibrator when the front panel AC power switch, S6, is in CAL position.

Capacitor C1 and crystal Y1 are components from the original receiver. The new oscillator was built on a small piece of vector board that was mounted close to the antenna connector. This board is mounted underneath the input attenuator board and may be seen in the lower righthand corner of Photo D. The output signal from the calibrator circuit is coupled to the antenna input connector through capacitor C5, as shown in fig. 1A.

Input attenuator

The conversion transconductance first-mixer is high enough that an RF amplifier is not needed. AGC ahead

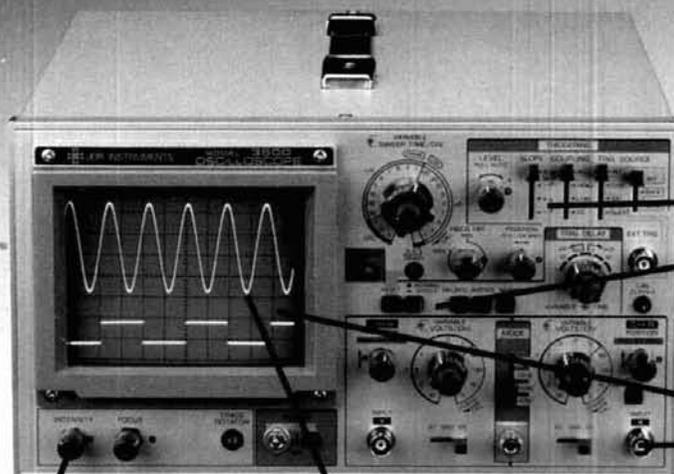
of the first mixer is provided by a voltage-controlled input attenuator in series with the antenna input and antenna coils. The input attenuator is mounted on the input attenuator board (fig. 1A). This board is shown schematically in fig. 3.

The input attenuator board consists of a Mini Circuits SAY-1 high-level, double-balanced diode mixer and transistor, Q1. The double-balanced mixer acts as an attenuator by feeding its DC-coupled i-f port with a DC voltage derived from the AGC bus. The SAY-1 has an insertion loss of about 3 dB and provides about 40 dB of attenuation with full AGC.

The SAY-1 requires about 20 mA of DC into its i-f port for minimum attenuation. This current is provided by emitter follower Q1. Resistors R1 and R2 limit the current into the i-f port to about 20 mA for an AGC input of 10 volts to the base of Q1. Capacitors C1 and C2 filter the AGC input to the SAY-1. Resistor R2 provides a 50-ohm termination to the SAY-1 i-f port.

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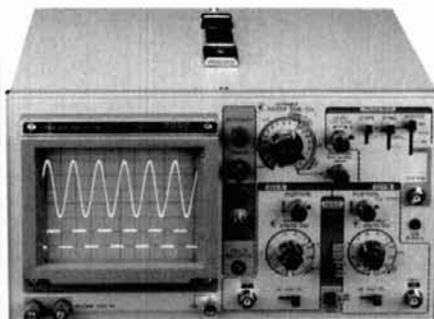
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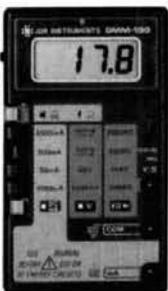
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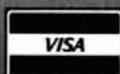


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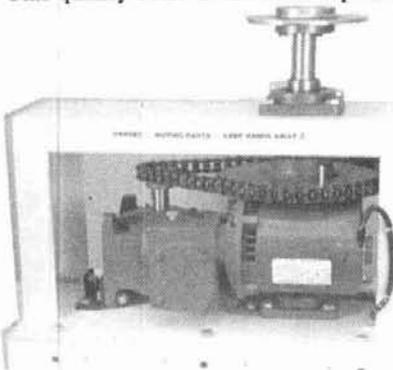
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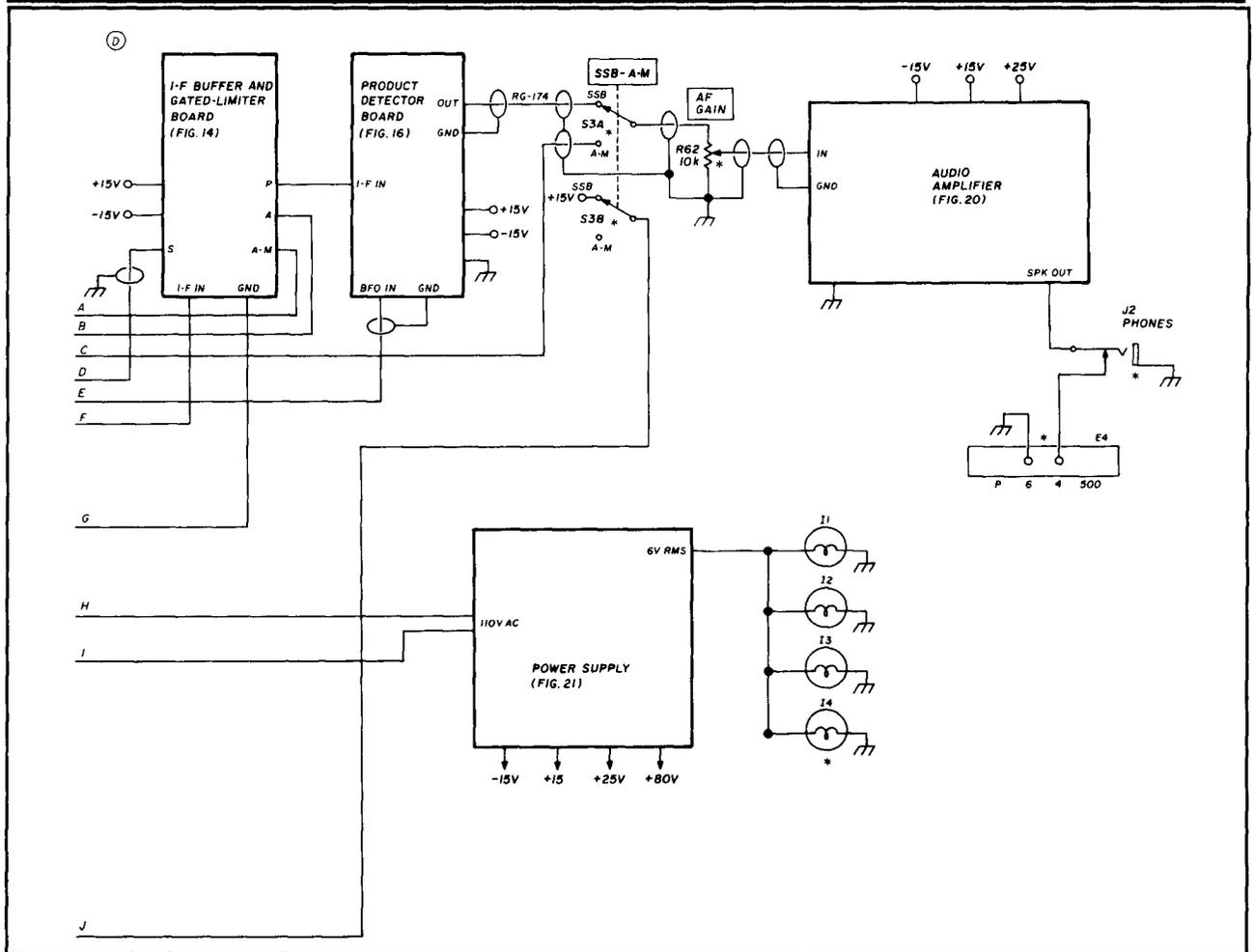
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FIGURE 1



Double-tuned input network

Originally the 75A-4 had an RF amplifier stage between the antenna and RF coils. This stage has been replaced with the passive-coupling network shown in fig. 4. The antenna coils and the first RF coils now comprise a double-tuned input network on the 10 through 80-meter bands. The purpose of switch S1-G is to change the coupling capacitance between the antenna and RF coils when different bands are selected. The S1-G switch is a Centralab YD wafer that you must add to the original bandswitch.

As shown in fig. 4, wafer switch S1-G is positioned on the existing bandswitch assembly. Its location is critical because the stray capacitance between the wafer switch and antenna coils L3, T2, and T7 is used for coupling. This capacitance is the right amount for coupling on 20 through 10 meters. Additional capacitance is added (as shown in fig. 7) for 40 and 80 meters. The input network is single tuned on 160 meters.

It's not difficult to add the wafer switch S1-G to the bandswitch assembly. Collins provides access holes on the back of the receiver that allow the bandswitch wafer-

supporting hardware to be disassembled. Part of the added wafer switch, S1-G, must be cut away for lack of room; coil T2 gets in the way. I did this with a Dremel tool.

I'd like to re-emphasize that even with the insertion loss of the attenuator and the absence of an RF amplifier, the receiver still provides an input sensitivity of approximately 0.6 μ V. This input noise level is quite acceptable because it's small when compared with the noise from a typical resonant antenna. The small loss of sensitivity, as compared with the original 75A-4, is repaid by improved IMD and overload capability.

First mixer

The output signal from the RF coils is mixed with that from the band-select crystal oscillator to derive a signal falling between 1.5 and 2.5 MHz. This is the frequency of the variable i-f of this receiver. Mixing is accomplished in the first mixer located on the first mixer board of fig. 1B. The schematic of this board is shown in fig. 5.

The mixer is a dual-gate MOSFET (Q1). Q1 is connected in cascode with Q2, which has a high collector breakdown voltage. Its collector is powered from an 80-

TABLE 1

Comparative performance specifications		
Specification	Original vacuum tube 75A-4	Solid state 75A-4
Sensitivity measured at 29.5 MHz	0.4 μV for $(s+n)/n = 10$ dB	0.6 μV for $(s+n)/n = 10$ dB
7.3 MHz	0.28 μV for $(s+n)/n = 10$ dB	0.6 μV for $(s+n)/n = 10$ dB
I-F selectivity	3.1 kHz at -6 dB	3.0 kHz at -6 dB
6 to 60 dB	5.1 kHz at -60 dB	4.1 kHz at -60 dB
3.1-kHz filter	Shape factor = 1.65	Shape factor = 1.37
I-F rejection	Greater than 80 dB	Greater than 130 dB
Image suppression	Approximately 50 dB above 21 MHz Greater than 80 dB below 14.5 MHz	Same
IMD		
Level of two-tone RF inputs at 14.02 and 14.04 MHz to produce Third order IMD product at 14.06 MHz giving $(\text{IMD product} + n)/n = 3$ dB 1-dB compression desired signal of 10 V at 14.02 MHz; undesired signal at 14.04 MHz	-67 dBm	-45 dBm
AGC	1-dB compression of the desired signal occurs for undesired signal amplitude of -47 dBm Audio rise < 3 dB for RF inputs of 5 μV to 0.2 volt	1-dB compression of the desired signal occurs for undesired signal amplitude of -20 dBm Audio rise < 3 dB for RF inputs of 3 μV to >1 volt
AGC time constants		
AGC fast	Rise time = 10 ms Release time = 0.1 sec	Rise time equivalent to 10 ms or less for 60-dB step. Release time \cong 0.2 sec
AGC slow	Rise time = 10 ms Release time = 1 sec	Rise time equivalent to 10 ms or less for 60-dB step. Release time \cong 2 sec
Audio bandwidth	-3 dB 100 Hz to 5 kHz	-3 dB 300 Hz to 3 kHz
Noise limiter	Passive diode limiter in audio circuit	Gated diode limiter in i-f circuit
Frequency stability	After 30-minute warmup, drift during any 10-minute period does not exceed 100 Hz	15 Hz in first minute following a cold start. Approximately 30 Hz per hour thereafter
For line voltage change of ± 10 percent	Does not exceed 100 Hz	Less than 1 Hz
Power input at 115 VAC	85 watts	35 watts

volt power supply. Q1 is biased to optimize conversion transconductance.

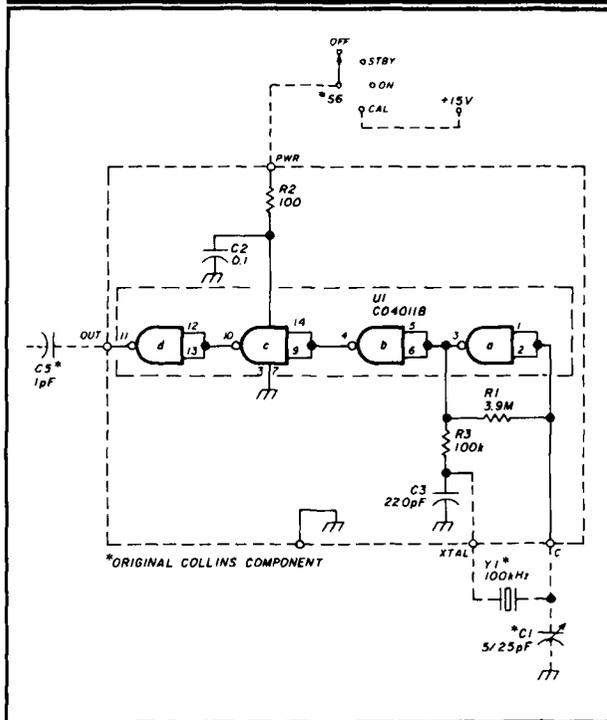
The local oscillator signal is applied to gate 2 of Q1. Slug-tuned inductor L18 is terminated on the 80-volt supply through decoupling network C3 through C5 and resistors R3 and R4. Capacitor C47, which was connected across L18 in the original vacuum tube receiver, was increased to 390 pF and connected directly to Q2's collector.

The oscillator signal at gate 2 of MOSFET Q1 is approximately 5 volts peak-to-peak on all bands. The 1-

pF capacitor, C9, connected to gate 2 of Q1 provides an isolating test point for measuring local oscillator signal amplitude with an oscilloscope and test probe. The oscillator voltage at gate 2 is the measured value read by the oscilloscope multiplied by the ratio $(C_{\text{probe}} + C9)/C9$. This test point is useful for setting local oscillator output level.

This cascode technique was so effective that I used it again in the second mixer and the last i-f stage, because these stages are also susceptible to output saturation with large amplitude signals.

FIGURE 2



100-kHz crystal calibrator schematic.

Band-select crystal oscillator

This oscillator is shown schematically in fig. 6. The topology of the solid-state oscillator is much the same as that of the vacuum tube version in the original receiver.

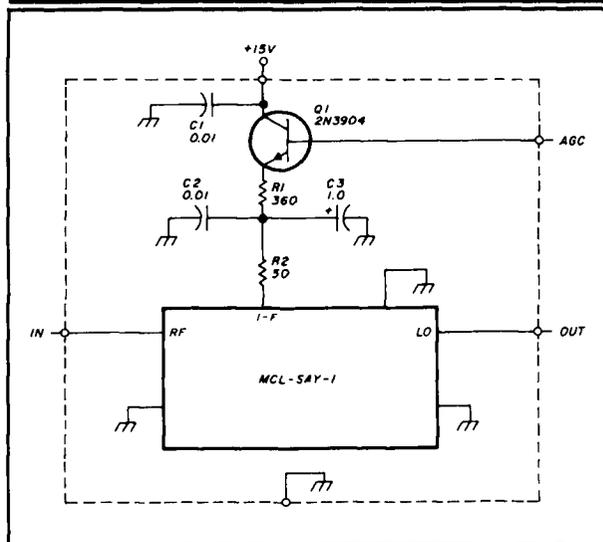
The active element in this circuit is a dual JFET, U431. In the original receiver, L11 and L17 (fig. 1A) were paralleled by 47-pF capacitors. These capacitors were removed and a single 47-pF capacitor, C1, was connected to the drain of Q1_a. (See fig. 6.) This was to eliminate a high-frequency parasitic oscillation caused by the long wire runs from the bandswitch to coils L11 through L17. This parasitic just couldn't be tamed satisfactorily in any other way. Capacitors CX and CY were added at the bottom terminals of L11 and L12, as shown in fig. 1A. This additional bypassing also helped cure the parasitic problem.

The parallel capacitance across coils L14 through L16 was reduced by approximately 47 pF so that they would resonate properly. No change was required in the capacitance paralleling L12 and L13, as these coils had sufficient adjustment range to resonate.

Second mixer

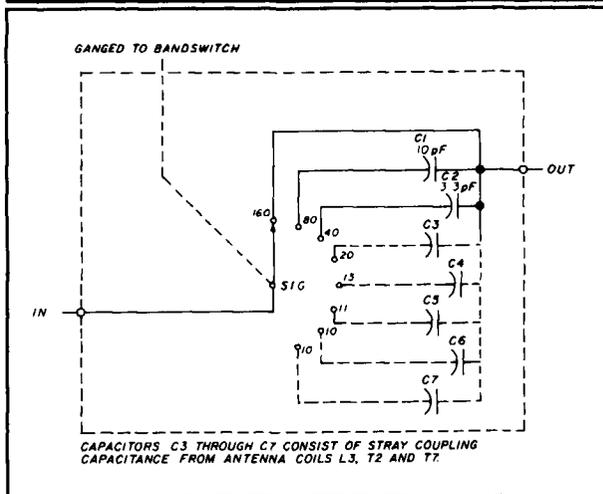
The output signal from coil L22 of the variable i-f (fig. 1B) is fed, through wafer switch S1-H. This signal is mixed in the second mixer with the VFO output to develop the 455-kHz i-f. The schematic is shown in fig. 7. The design of the second mixer is similar to the one

FIGURE 3



Input attenuator schematic.

FIGURE 4



Wafer switch and coupling capacitors between antenna and RF coils.

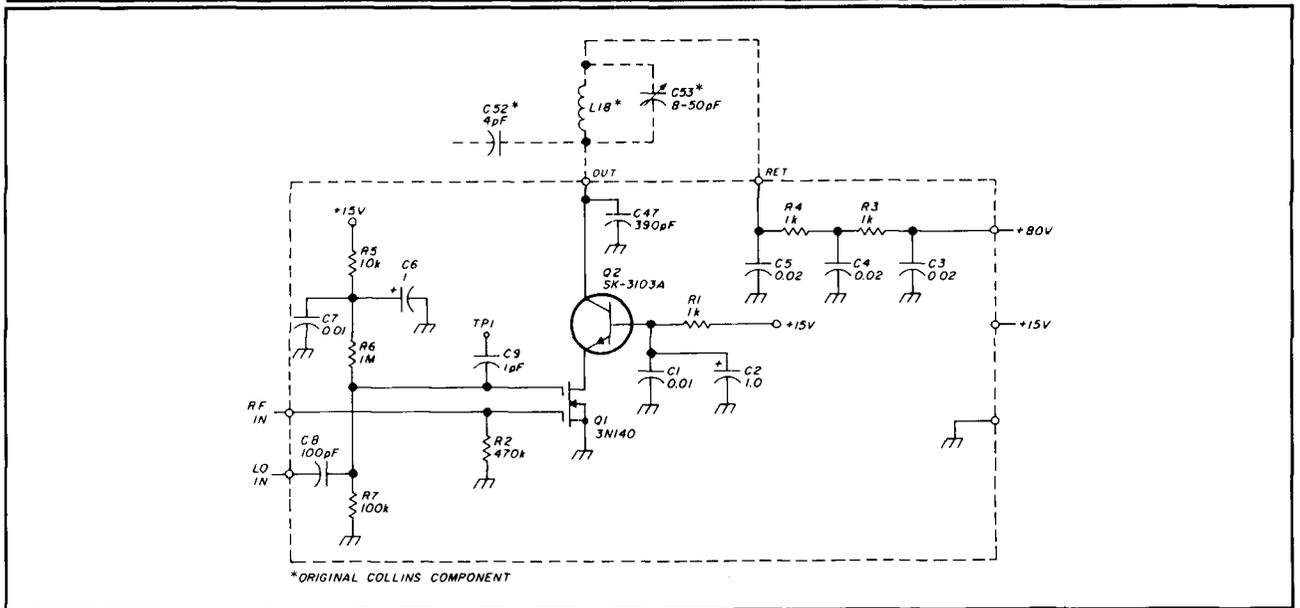
used in the first mixer. The VFO output voltage is connected to gate 2 of Q1. The voltage amplitude at gate 2 is approximately 8 volts peak-to-peak.

The S1-H switch is a Central Lab YD wafer that's added to the original band switch at the partition separating L18 and L22. S1-H is used to switch in additional attenuation when you select the 160-meter band.

Permeability tuned VFO

The permeability tuned oscillators used in Collins VFOs have always been outstanding for their smoothness, freedom from backlash, and frequency stability. The VFO shown in fig. 8 is even better because its frequency drift is almost nil. At constant temperature this

FIGURE 5



First mixer schematic.

oscillator drifts less than 5 Hz in the first minute after turn-on and about 5 Hz per hour thereafter.

Modify the VFO by first removing the tube sockets and all the circuits connected to them. A small thin piece of aluminum covers the tube-socket mounting holes. I opened the sealed portion of the VFO. It contains inductors L200 and L201, and capacitors C200 through C203 and C207. Capacitor C207 was disconnected and a new tap was made on L201 eight turns from the bottom. (C207 was originally tapped into L201 at about ten turns). I lowered the tap on L201 because that coil is now being driven from the lower impedance seen at the source of Q1. C207 was replaced by C1 and C2 which are polystyrene caps.

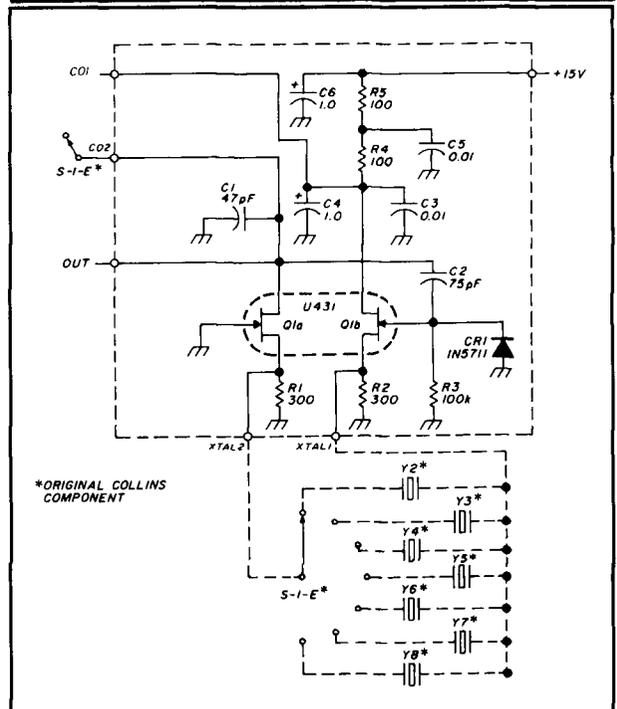
Diode CR₁, in conjunction with C203 and R1, allows the oscillator to generate negative self-bias through grid-leak action. Q2 serves as a buffer between Q1 and the outside world. Capacitor C8 at the collector of Q2 helps reduce the harmonic content at the VFO output.

VFO buffer amplifier

The output of the VFO drives the VFO buffer amplifier in **fig. 9**. This amplifier serves three purposes. It boosts the signal amplitude from the VFO to about 8 volts peak-to-peak, provides additional filtering to reduce the harmonic content of the VFO signal, and allows the resonant network in the drain of Q1 to be peaked, so that the output of the VFO circuit is flat through its tuning range.

The buffer amplifier board also provides the 6.9-volt power supply for the VFO. This supply consists of an LM329DZ precision voltage reference, (CR₁), and resistor R8.

FIGURE 6



Band select crystal oscillator schematic.

455-kHz i-f amplifier

The 455-kHz i-f section is comprised of the switch-selectable mechanical filters, i-f amplifier boards 1 through 4, bridged-T rejection network, added 3.1-kHz mechanical filter, and the i-f buffer and gated limiter board.

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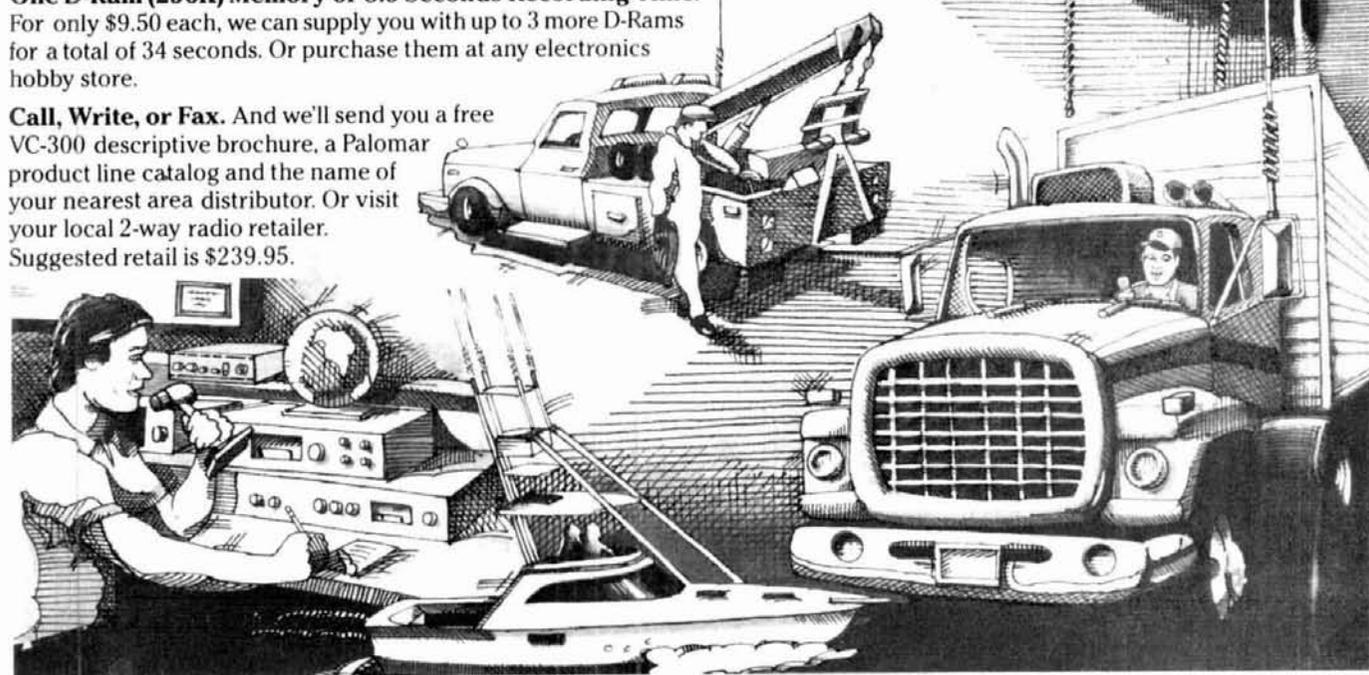
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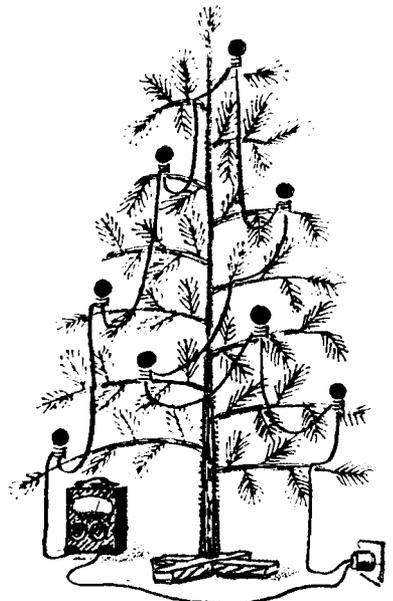
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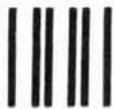
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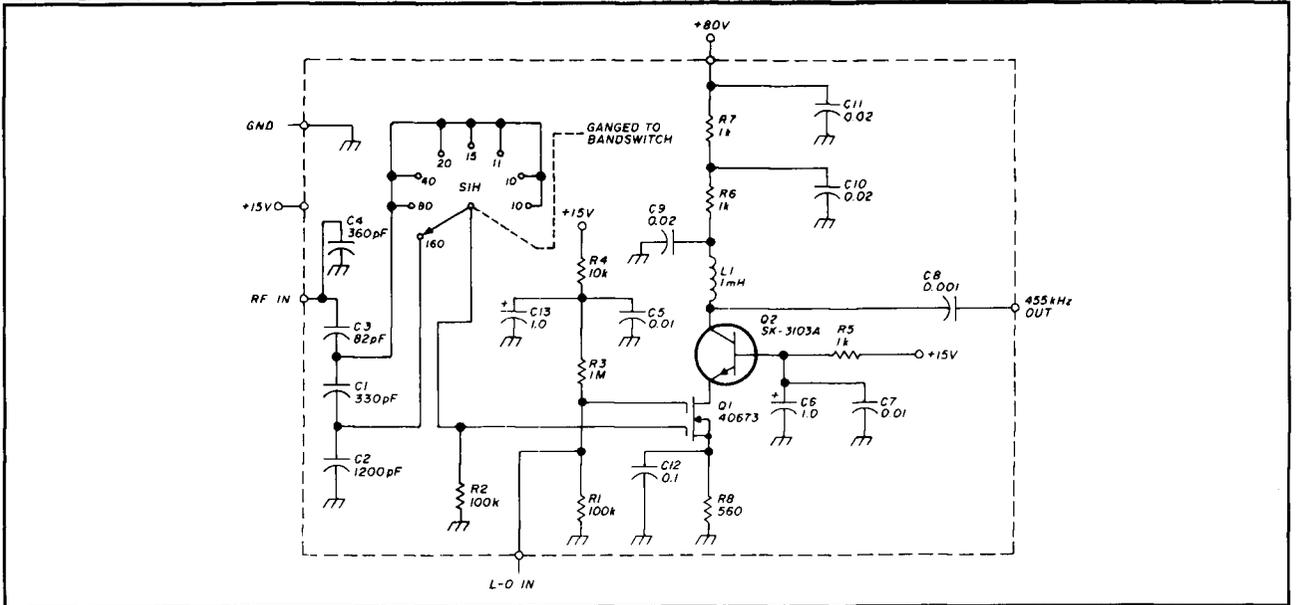
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FIGURE 7



Second mixer schematic.

The output of the second mixer is fed to the switch-selectable mechanical filters through the front panel selectivity switch, S2. The output of the selected filter drives the input of i-f amplifier board 1, shown in fig. 10.

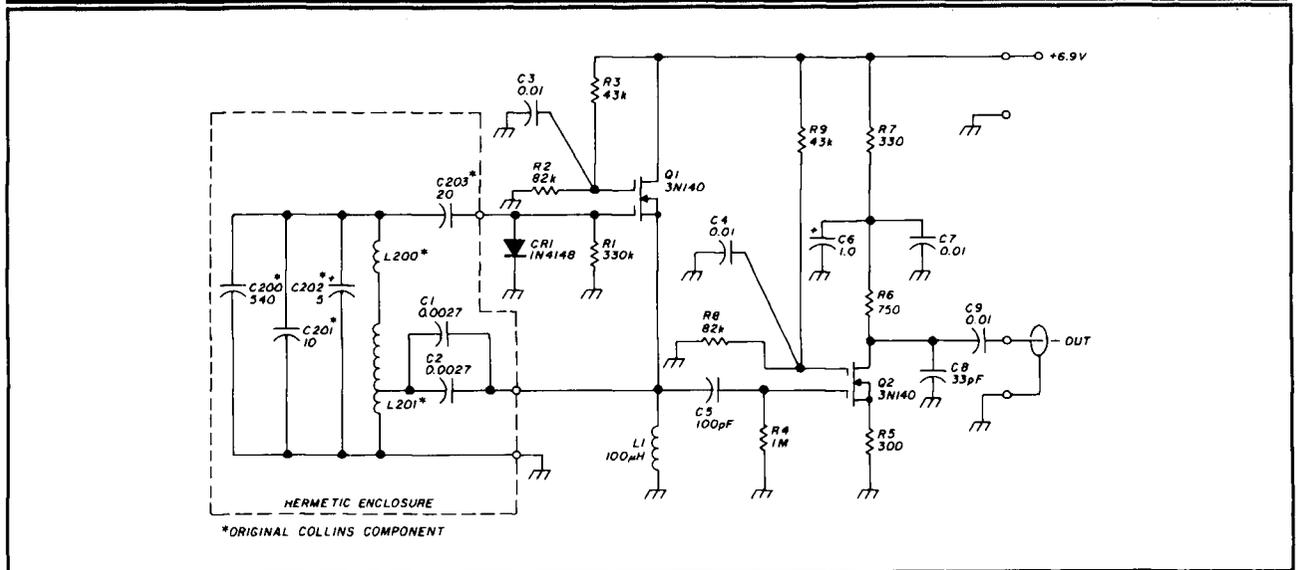
Dual-gate MOSFET Q1 on i-f amplifier board 1 is the first amplifier in the i-f chain. AGC is applied to gate 2 of this FET. Dual-gate MOSFET Q2 is the first amplifier in the noise-limiter i-f chain. The noise limiter i-f and its separate AGC bus will be described later.

The output of i-f amplifier 1 drives i-f amplifier 2 and the Q multiplier. This board is shown in fig. 11. Q1 pro-

vides additional i-f gain and AGC capability. It drives the Q multiplier rejection filter comprised of Q2 and external bridged-T network L26; capacitors C72, C73, and C74; and resistors R34, R35, and R36. The Q multiplier is an exact equivalent of the circuit in the original vacuum-tube receiver. The only difference is that Q2 is used in place of the dual triode in the original.

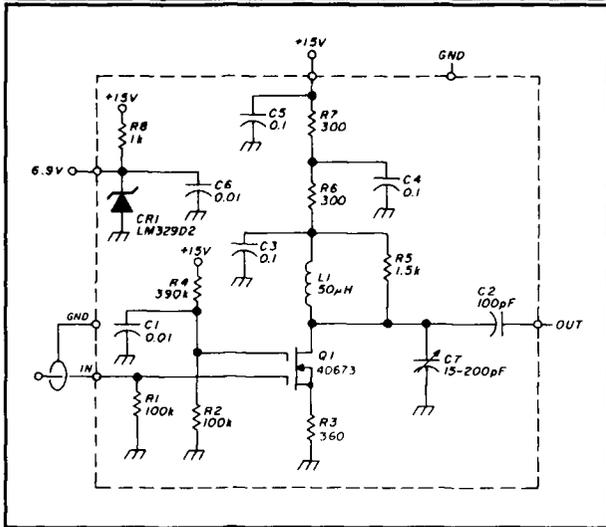
The bridged-T network drives i-f amplifier 3. This board is shown in fig. 12. Q1 provides additional gain and AGC capability. Capacitors C75 and C139 and resistor R37 terminate the bridged-T, and are identical to the

FIGURE 8



VFO schematic.

FIGURE 9

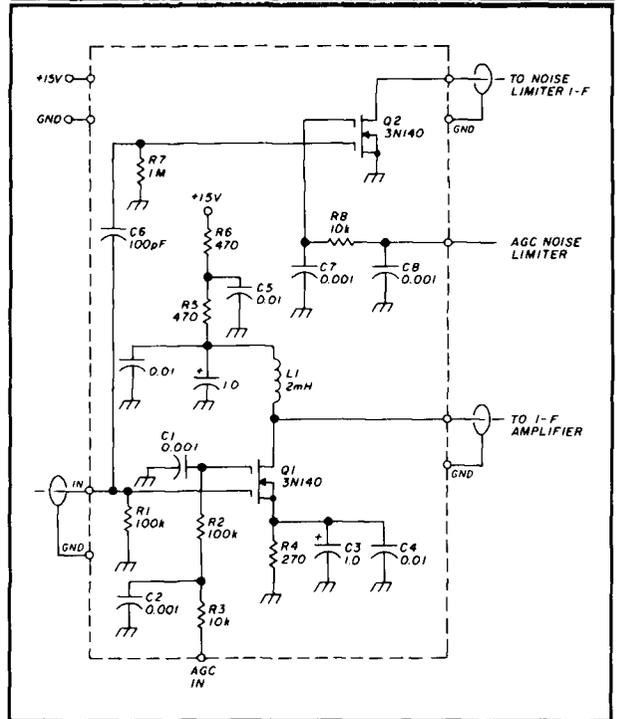


VFO buffer amplifier schematic.

components used in the original receiver. Q1 drives the added 3.1-kHz mechanical filter. The mechanical filter output drives the last i-f stage, made up of the components on i-f amplifier board 4 (see fig. 13).

Q1, on i-f amplifier board 4, is connected in cascode with Q2. The collector voltage for Q2 is derived from the 80-volt power supply. I-F transformer T3 provides coupling between Q2's collector and the i-f buffer and gated noise limiter. I used the cascode connection, with its 80-volt collector supply, for the last i-f stage. This allows for a large voltage swing.

FIGURE 10



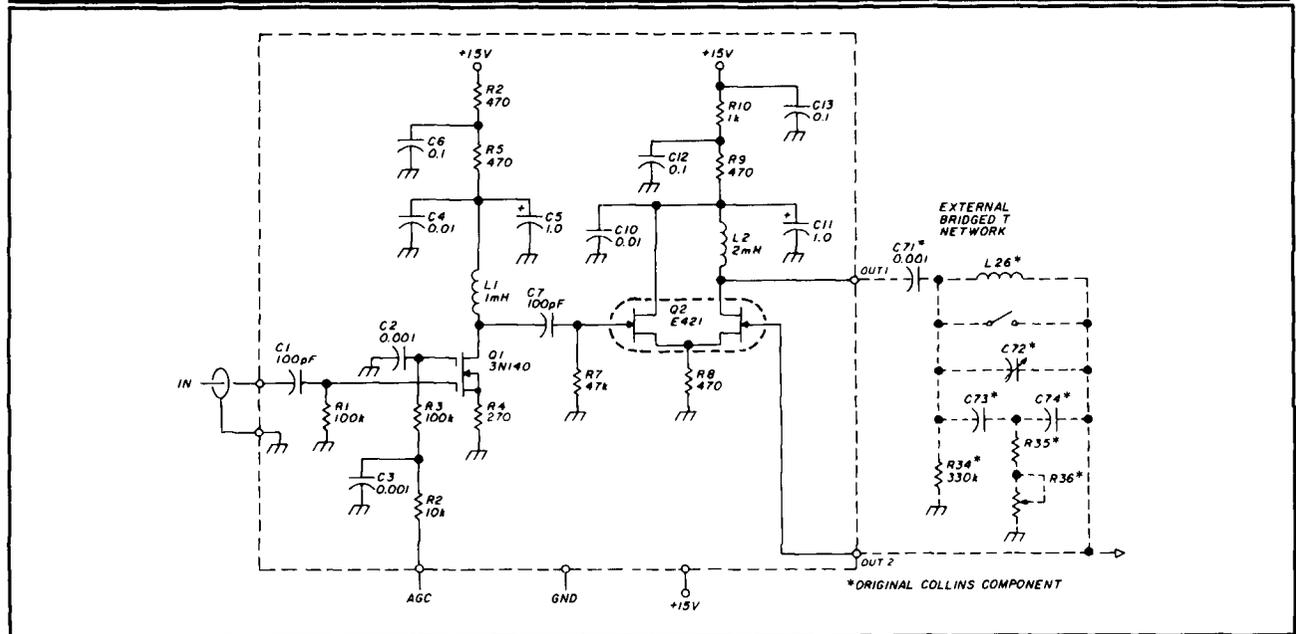
I-F amplifier 1 schematic.

I-F buffer

The last i-f stage output is derived from the secondary of i-f transformer T3, which drives the i-f buffer and gated noise limiter. This board is shown in fig. 14.

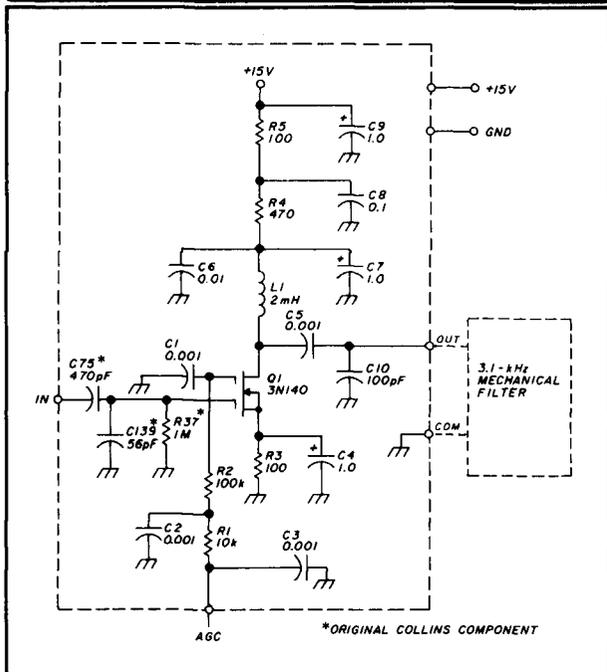
Buffer amplifier U1 on this board provides a high-

FIGURE 11



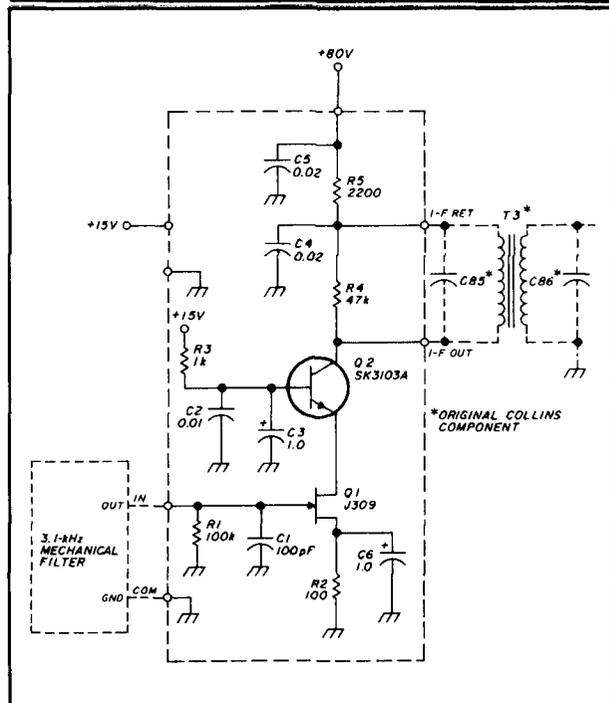
I-F amplifier 2 schematic.

FIGURE 12



I-F amplifier 3 schematic.

FIGURE 13



I-F amplifier 4 schematic.

impedance termination for the secondary of T3. In addition, it provides a low-impedance source of i-f output for the AM detector, product detector, AGC amplifier, and gated noise limiter. The product detector, AM detector, and the AGC amplifier receive their input signals through resistors R7, R6, and R5, respectively.

Gated noise limiter

The noise limiter works as follows (see fig. 14 for details): U2 and U4 are high-speed, solid-state switches. The internal switch contacts of U2a and U4 are normally closed, and the internal switch of U2b is normally open. Capacitor C1 charges to, and closely follows, the positive peaks of the i-f signal output of U1 through CR₁. Similarly, capacitor C2 charges to the negative peaks of the i-f output signal. The voltage developed across capacitors C1 and C2 also appears at the outputs of unity-gain buffers U3_a and U3_b.

U5 is a retriggerable single shot driven by the noise limiter i-f and pulse-detection circuit (described later). When a noise pulse is detected, U5 outputs a negative-going pulse which lasts for the duration of the noise pulse plus 5 milliseconds. This pulse causes the internal switch contacts of U2_a and U4 to open and the internal contacts of U2_b to close.

When the contacts of U2_a and U4 open, capacitors C1 and C2 hold the voltage to which they were charged. This voltage is the plus and minus i-f signal envelope prior to the noise pulse. When the internal contact of U2_b closes, diodes CR₃ and CR₄ are enabled and clamp the

i-f signal at the input of buffer U1 to the envelope voltage that existed just prior to the noise impulse.

The advantages of this circuit over other automatic i-f noise limiter circuits are:

- The voltage across C1 and C2 closely follows the envelope of the i-f output because R2, C1 and R3, C2 time constants are short.
- Capacitors C1 and C2 are buffered and their voltage doesn't change during the clamping interval.
- The forward voltage drops across CR₁-CR₄ cancel. As a result, the noise pulse is clamped to the exact envelope of the i-f signal just before the noise event.
- The actual interval of clamping is determined by a noise i-f amplifier having its own AGC separate from the receiver i-f section.

This circuit is extremely effective on the woodpecker, and on narrow ignition-type impulse noise. In fact, its effectiveness improves with increasing noise amplitude, because i-f AGC swamping is eliminated.

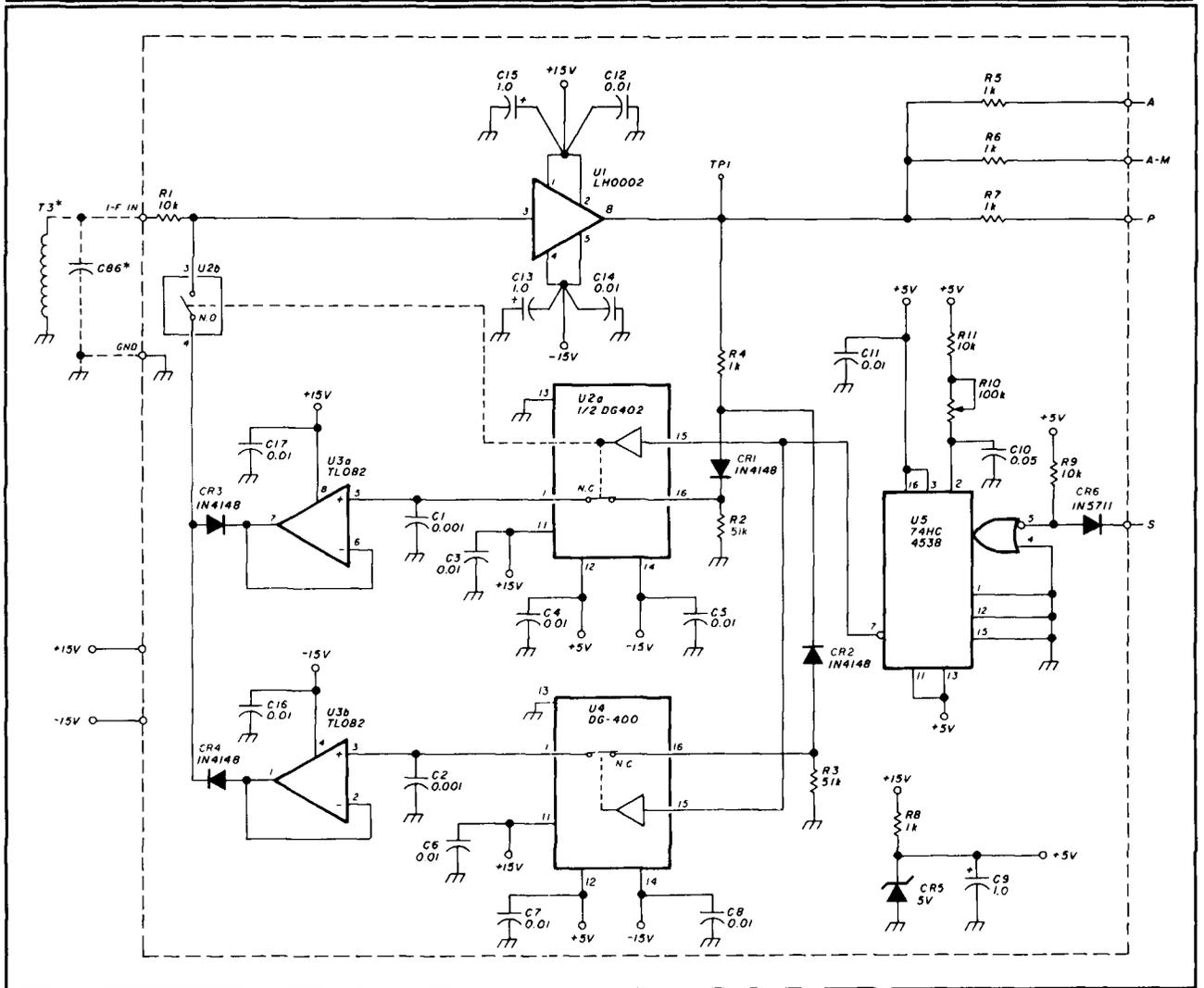
The method of generating the strobe pulses that feed U5 is very important in relation to the overall operation of the gated limiter. This will be discussed in more detail later when the noise limiter i-f circuit is described.

The 5-volt power for U5 is developed across the 5-volt zener, CR₅.

AM detector and AGC amplifier

AGC and AM detection are developed on the AM detector and AGC amplifier board (see fig. 15). AM

FIGURE 14



I-F buffer and gated noise limiter schematic.

detection is accomplished by rectifying the i-f output voltage with CR₁. The output is filtered by R2 and C2 and is buffered by op amp U1. Trimpot R3 provides an attenuation adjustment so that the AM output can be adjusted to the same amplitude as the SSB output from the product detector. The AM output from this board is routed to the front panel SSB / AM switch, S3 (fig. 1D).

The AGC voltage is developed by rectifying the i-f output voltage with CR₂. The AGC voltage developed across C7 and R8 is buffered by U2. U2, CR₃, CR₄, and resistor R9 comprise a "super diode" circuit that eliminates the forward-voltage drop of CR₃.

Similarly U3_a, in conjunction with CR₅, CR₆, and R12 eliminate the forward-voltage drop of CR₆. This circuit also buffers the output of RF-gain control R99.

The anodes of CR₃ and CR₆ are connected together when AGC switch S5 is in its fast or slow position. The two diodes form a linear "OR" gate. The voltage devel-

oped at the anodes of CR₃ and CR₆ is equal to the output voltage at the RF-gain control wiper, R99, or to the AGC voltage developed at R8, whichever is the most negative. This voltage controls the RF and i-f gain by way of the AGC bus.

If front panel AGC switch S5 is placed in its off position, the connection between the anodes of CR₃ and CR₆ is opened. In this mode the receiver gain is controlled only by the setting of the RF-gain control.

CR₆'s anode drives op amp U3_b. U3_b is a level shifter that sets the quiescent "no signal" i-f gain through trimpot R13. R13 is adjusted for an i-f output amplitude of 15 volts peak-to-peak at test point 1 on the i-f buffer and gated limiter board (see fig. 14).

U3_c drives the AGC bus. CR₇ through CR₁₁ clamp the output of U3_c so that its voltage doesn't exceed approximately 3.5 volts, or drop below approximately -2.1 volts. The mute input at the anode of CR₁₃ is normally

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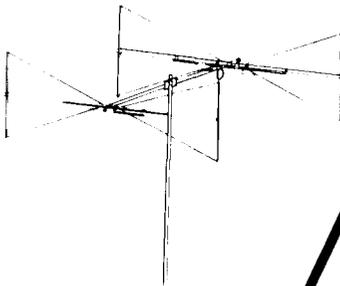
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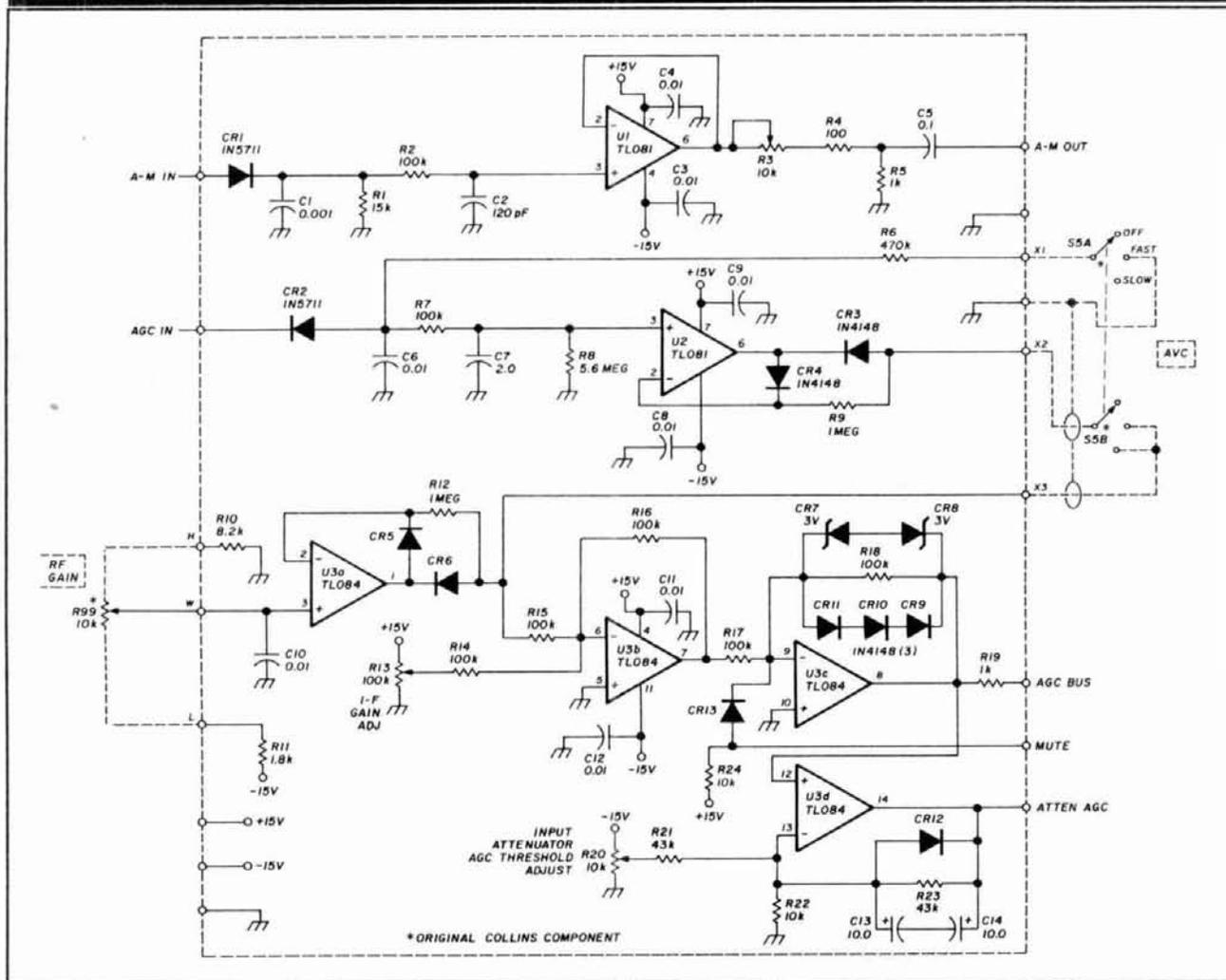
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FIGURE 15



AM detector and AGC amplifier schematic.

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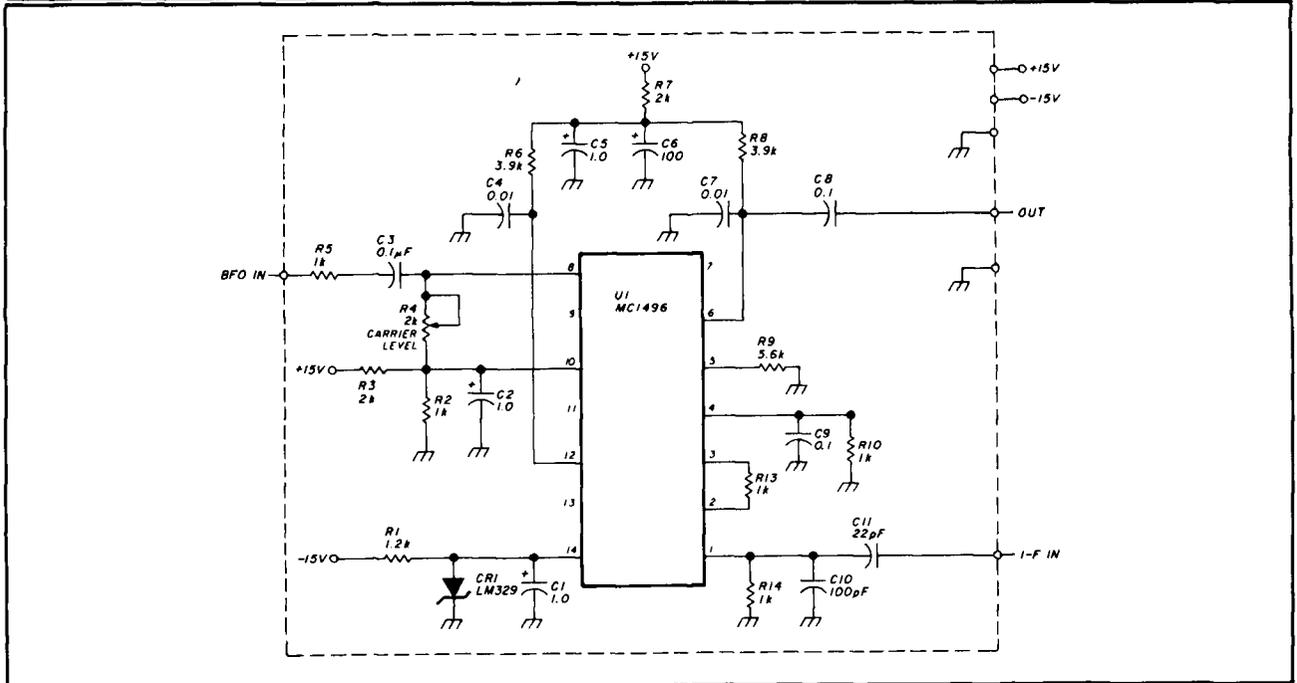
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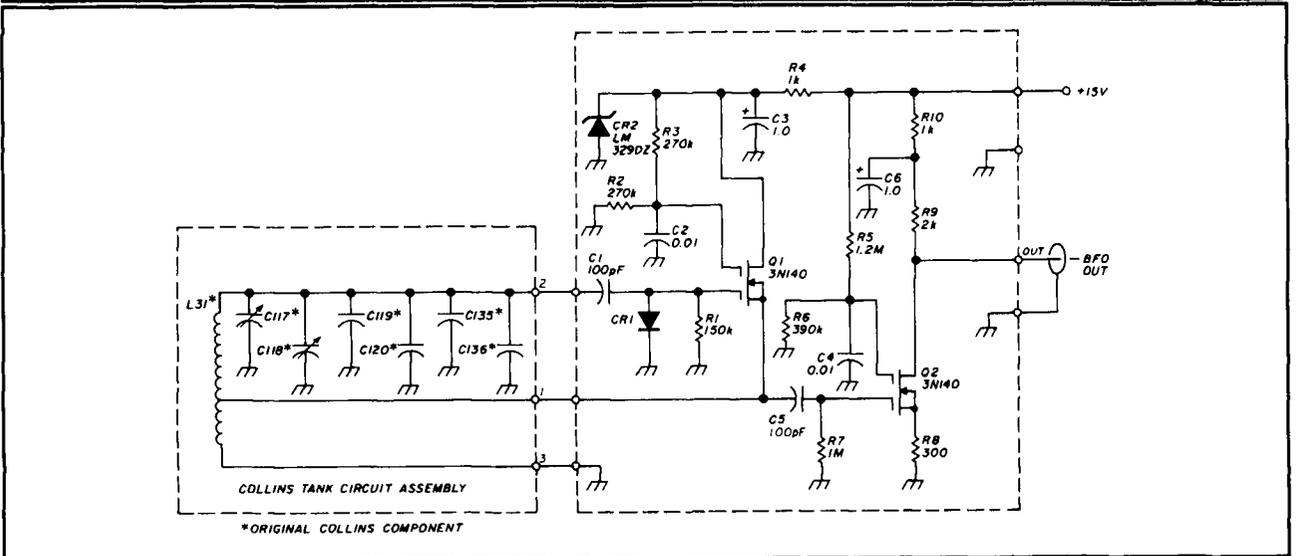



FIGURE 16



Product detector schematic.

FIGURE 17



BFO oscillator and tank circuit assembly schematic.

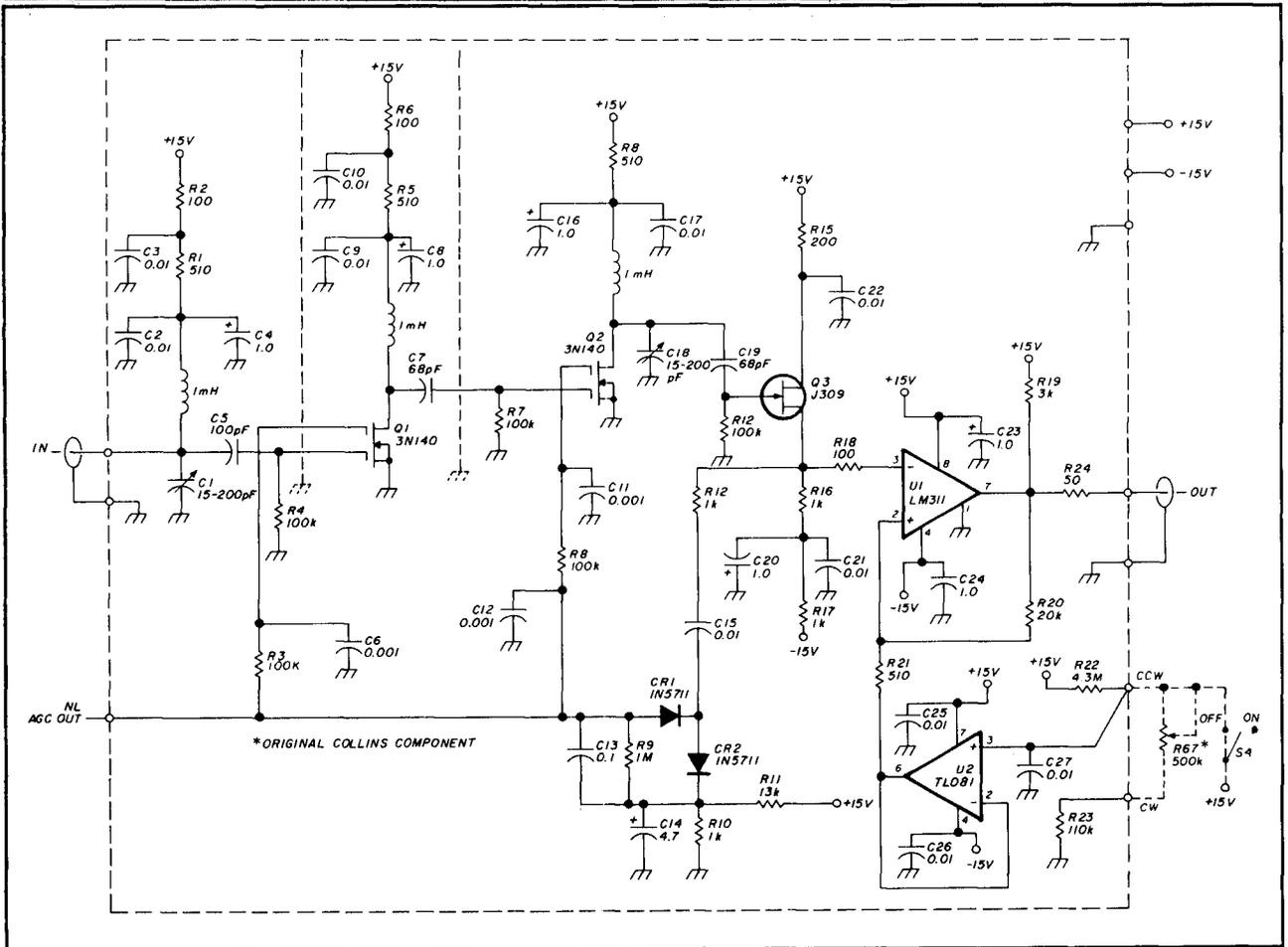
kept at ground potential so that CR₁₃ is reverse biased. When the front panel AGC power switch is in the standby position, the mute input is opened and CR₁₃ conducts. The conduction current through CR₁₃ drives the output of U_{3c} and the AGC bus to -2.1 volts; this effectively mutes the receiver.

The standby mode of the receiver may be overridden by shorting standby terminal 2 of the rear panel terminal strip E3 to ground (see fig. 1C).

The input attenuator has its own AGC voltage, which is developed at the output of U_{3d}. R₂₀ is adjusted so that the attenuator AGC voltage is approximately 5 volts when a 100-μV signal is injected at the receiver input. This voltage decreases to about 2 volts for 100 mV input to the receiver.

CR₁₂ in the feedback circuit of U_{3d} prevents the input attenuator AGC voltage from going more negative than about -0.6 volt. C₁₃ and C₁₄ slow the output response

FIGURE 18



Noise limiter i-f and noise pulse detector schematic.

of U3_d to keep the AGC bus from **motorboating** when the input attenuator is active.

Buffer amplifier U1 (fig. 14) also functions as an i-f limiter. This limiting effect is important; it prevents unpleasant noise and leading-edge signal bursts.

In the general case, the amplitude of fast-rising i-f signals and noise is limited by a fast-responding AGC. However, in this receiver design, I couldn't obtain a stable AGC loop and at the same time have an AGC attack time much faster than about 30 milliseconds. This occurs because of the delay introduced by the mechanical filters and experienced by the i-f signal as it responds to the effects of AGC.

The i-f limiting action of U1 limits the leading edge of fast-rising i-f signals and noise to an acceptable level during the time interval required for the AGC to operate. The overall effect is to make the AGC appear to have an attack time on the order of a few milliseconds.

Product detector

The product detector is shown in fig. 16. I used a Motorola MC1496 balanced modulator. This IC requires

a lot of external components, but provides linear detection and little 455-kHz output component. The CW/SSB signal is taken from terminal 6 of U1, through C8. This output signal goes to the front panel AM/SSB switch, S3, as shown in fig. 1D.

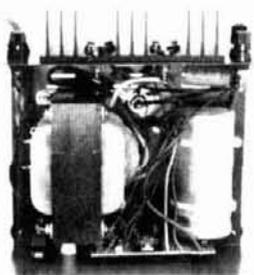
The BFO output is attenuated by carrier-level trimpot R4. This pot is adjusted for a carrier level of 300 mV rms at U1, pin 8.

BFO

The BFO is comprised of the original BFO tuned-circuit assembly and the BFO board shown in fig. 1B. The BFO board is shown schematically in fig. 17. It's nearly identical to that used in the VFO described earlier.

The BFO has its own regulator comprised of voltage reference CR₂ and resistor R4. The 15-volt power is routed to the BFO through front panel AM/SSB switch, S3.

The stability of the BFO circuit is only slightly less than that of the VFO. At constant temperature, its drift is less than 10 Hz in the first minute after turn-on, and about 10 Hz per hour thereafter.



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RS-7A	5	7	3 3/4 × 6 1/2 × 9	9
RS-7B	5	7	4 × 7 1/2 × 10 1/4	10
RS-10A	7.5	10	4 × 7 1/2 × 10 1/4	11
RS-12A	9	12	4 1/2 × 8 × 9	13
RS-12B	9	12	4 × 7 1/2 × 10 1/4	13
RS-20A	16	20	5 × 9 × 10 1/2	18
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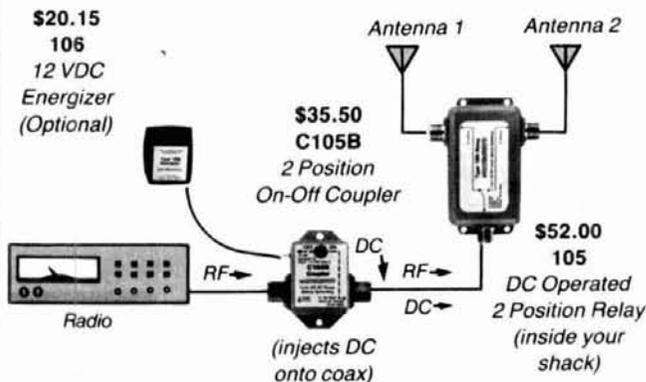
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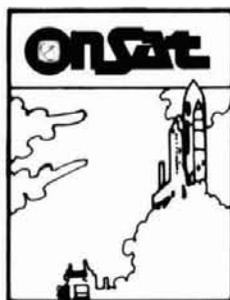
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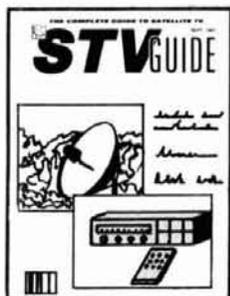
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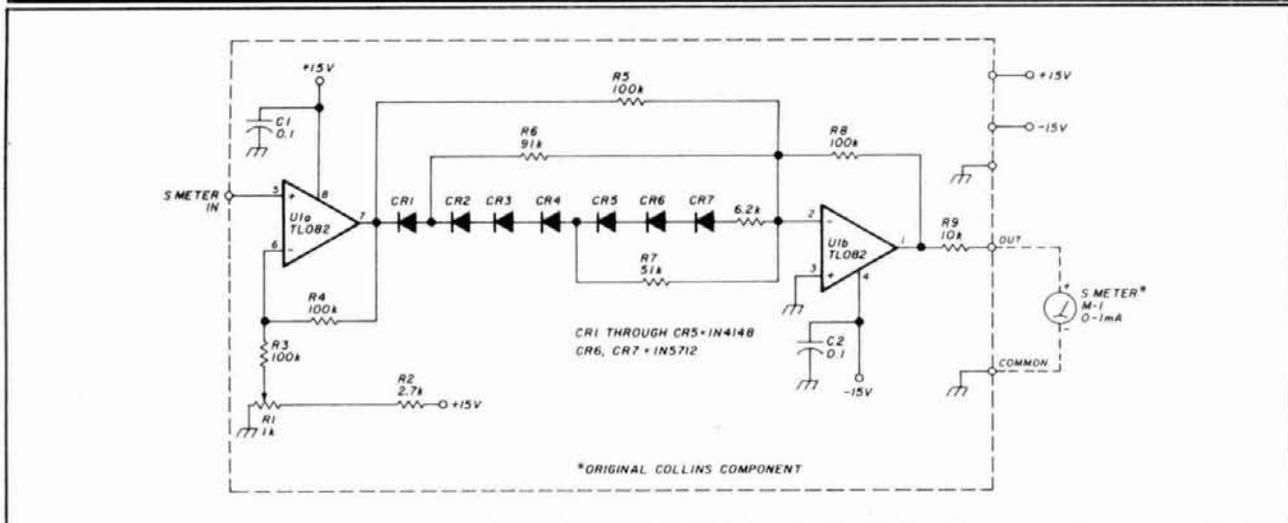
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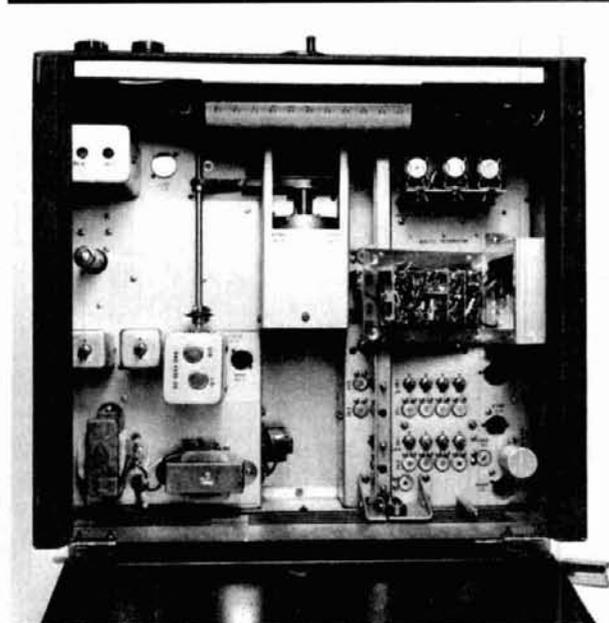


FIGURE 19



S-meter driver schematic.

PHOTO C



Top inside view showing exposed noise limiter, i-f circuit, and added 3.1-kHz mechanical filter.

Noise limiter i-f and noise pulse detector

As stated earlier, the gated noise limiter has its own separate i-f amplifier. This amplifier with the noise pulse detection circuit is enclosed in a small chassis located on the top deck of the receiver. The position of this chassis is shown in Photos A, B and C. Photo C shows the i-f chassis opened with the i-f circuitry exposed.

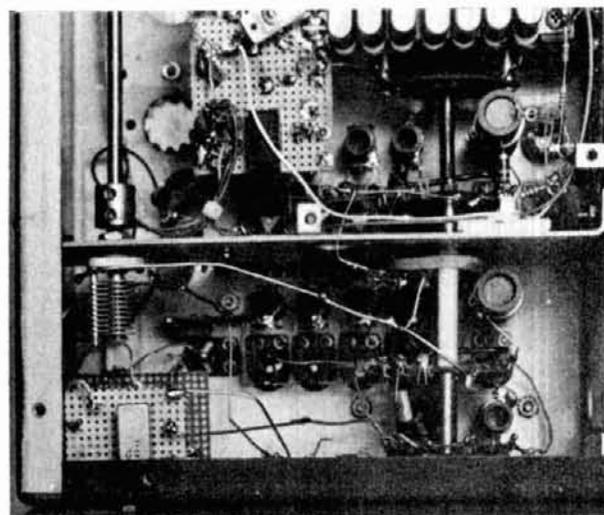
The noise limiter i-f and the pulse detection circuit are shown in fig. 18. The interconnection of this circuit with

the front panel noise limiter switch, S4; control pot R67; i-f buffer and gated-noise limiter board; and the i-f amplifier are shown in the circuit diagram of fig. 1C.

Q1 and Q2 and their associated circuits comprise the i-f amplifier. Q3 is a unity-gain buffer between the output of the last i-f stage and the AGC and pulse-detection circuit. CR₁ and CR₂ make up the AGC rectifier. AGC voltage is developed across C13 and applied to the second gate of Q1 and Q2. AGC voltage is also applied to the first stage of the noise limiter i-f, which is located on i-f amplifier board 1 (see fig. 10).

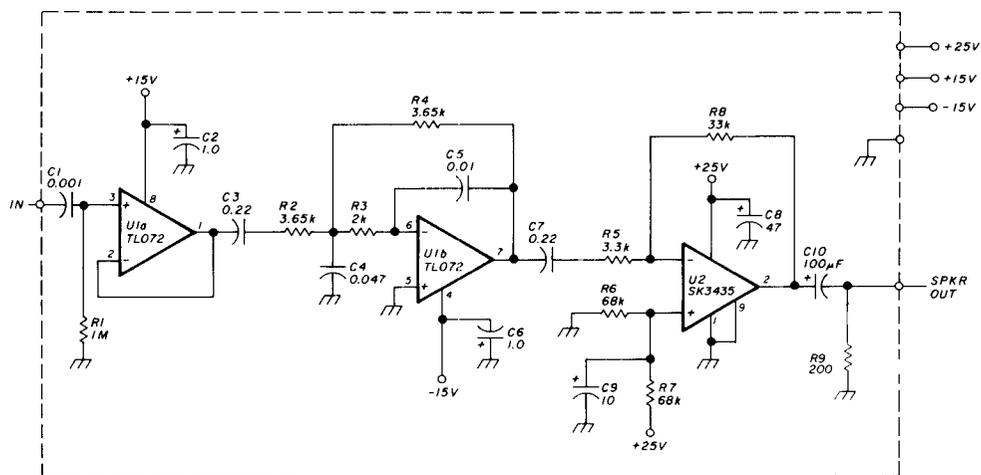
Noise pulse detection is accomplished by U1 and reference-voltage buffer U2. This circuitry functions as follows:

PHOTO D



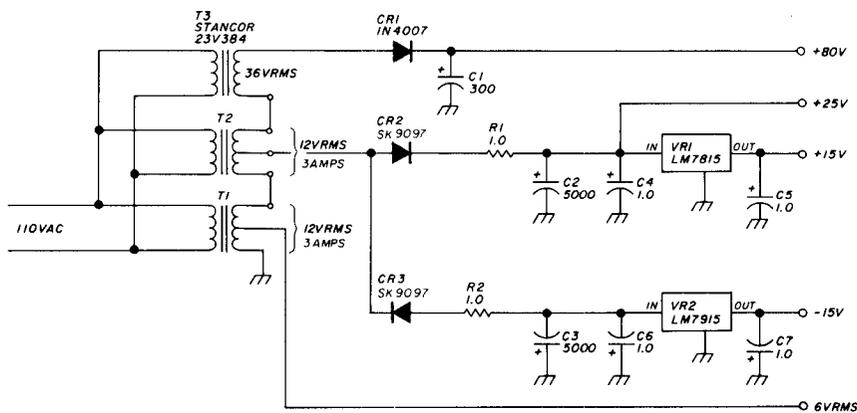
Partial bottom view showing location of switch S-1-G, input attenuator board, crystal-calibrator board, and oscillator board.

FIGURE 20



Audio amplifier schematic.

FIGURE 21



Power supply schematic.

- A variable threshold voltage is developed across front-panel **noise limiter** control R67 and is applied to the noninverting input of unity-gain buffer U2.

- Threshold voltage at the output of U2 is applied to the noninverting input of U1 through R21. R20 and R21 provide hysteresis, so that the comparator switches cleanly.

- The output of U1 goes to zero for the duration of any half cycle of the i-f signal that exceeds the threshold voltage developed at the output of U2.

The output signal from U1 is routed to U5 in the i-f buffer and gated noise limiter, (fig. 14). Because this single shot is retriggerable, it doesn't complete its time out until 5 milliseconds after the last pulse enters.

S-meter driver board

The voltage developed by the AGC bus of the solid-state receiver isn't compatible with the scale on the face

of the S meter. I didn't want to change the appearance of the receiver by making a new face. My only choice was to make some type of nonlinear circuit that would match the meter face to the solid-state receiver's AGC bus voltage. This is the circuit on the S-meter driver board in fig. 19.

U1_a of this circuit is driven from the AGC bus, as shown in fig. 1C. Trimpot R1 on the S-meter driver board adjusts the zero offset of the S meter. R1 is adjusted so that the S meter reads zero for 0.5 microvolts of RF input to the receiver. The resistor-diode network made up of CR₁ through CR₇ and resistors R5, R6, and R7 comprise what is equivalent to a nonlinear resistor having high resistance at low negative voltages, and the converse.

This circuit provides excellent S-meter calibration throughout its range. An S9 meter reading in the original receiver corresponded to a 100-mV signal. I prefer

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256 μV for an S9 reading and calibrated the meter accordingly.

Audio amplifier

The output of the product and AM detectors is routed through the front panel switch and from there through front panel **af gain** control R62 (see **fig. 1D**). The **af gain**-control output is routed to the audio-amplifier circuits shown in **fig. 20**.

The first audio stage, U1_a, is a unity-gain buffer whose output drives a unity-gain, two-pole active low-pass filter. This filter consists of U1_b and its associated components. U1_b drives an SK3435 amplifier module. Feedback resistors R5 and R8 give the amplifier a gain of 10. The module is powered from the unregulated 25-volt supply and has a power capability in excess of 5 watts. The 3-db bandwidth of the audio amplifier is 300 to 3000 Hz. The output of the audio stages feeds the speaker terminals and headphone jack as shown in **fig. 1D**.

Power supply

The power supply is shown in **fig. 21**. T1 and T2 are Radio Shack filament transformers having a 12.6-volt center-tapped secondary rated at 3A. Transformer T3 has a 36-volt secondary rated at 60 mA. The 80-volt unregulated output is obtained by connecting all of the secondaries in series. The input to the rectifiers for the ± 15 volt three-terminal regulators comes from the center tap of T2. Simple half-wave rectifier circuits are used for all the supplies. The 6-volt AC power for the panel lamps is taken from the center tap of transformer T1.

VFO alignment

I did a lot of experimenting with the permeability tuned section of the VFO while designing this oscillator. By the time I had decided on the design described above, VFO linearity wasn't what it was supposed to be.

I recalibrated the oscillator by measuring the VFO output frequency with a frequency counter, then plotted the output frequency as a function of dial setting. This plot gave a clear indication of those areas on the dial where the VFO's frequency needed to be increased or decreased.

I first adjusted the trimming stud of L200 to get the end points of the VFO dial lined up. I then opened the hermetic enclosure and adjusted the PTO tracking washers to restore the linearity between the end points. I had to repeat this process a number of times before the VFO linearity and alignment were restored.

The next time I make this modification, I won't change the location of the tap on L201 of the VFO. I suspect that the drift characteristics will be almost as good, and I'm sure a lot less effort will be necessary in the realignment of the VFO after the modifications are made.

General alignment

The balance of the alignment, with a few differences, can be done in the same order and way as that described in the 75A-4 operator's manual. The more important differences are listed as follows:

- When measuring i-f output amplitude, I made all my measurements with an oscilloscope connected through a probe to TP1 of the i-f buffer and gated limiter board, **fig. 14**.

- I adjusted the output of the band-select crystal oscillator to 5 volts peak-to-peak on all bands. This adjustment was made with the oscilloscope and probe through the 1-pF isolating test point on the band-select crystal oscillator board of **fig. 6**. The method of computing the crystal oscillator output amplitude was described in the band-select crystal oscillator section above.

Performance measurements

Comparative measurements of sensitivity, two-tone intermodulation distortion (IMD), and blocking were made using the methods and test setup described in Chapter 25 of the 1987 *ARRL Handbook*.

I used a Hewlett-Packard HP606A RF generator and a Boonton Radio Corporation 240A RF generator as the signal sources for these tests. Both of these generators have excellent precision attenuators. A Wavetek 5080.1 precision step attenuator, a Mini Circuits ZSC-2-1 hybrid combiner, and a Ballantine 323 true rms-reading voltmeter made up the balance of the test setup. A Tektronix 2235 100-MHz oscilloscope was used to verify all initial signal amplitudes before adding attenuation.

The combined drift of the BFO and VFO was measured by placing the receiver in the SSB mode and tuning in an external crystal calibrator. The audio-frequency output tone was measured for 8 hours, beginning from a cold start. The drift amounted to 13 Hz in the first minute, followed by a slow drift of about 26 Hz per hour. The slow drift stabilized after about 3 hours, giving a total drift of 91 Hz in that 3-hour period. Once stabilized, receiver drift was approximately ± 10 Hz per hour.

The major source of drift appears to be heat generated by the transformers located on the chassis near the BFO. This heat warms the chassis in the location of the BFO tuned-network assembly. A purist would probably mount these transformers on a heat sink above the chassis to improve the receiver's long-term drift. I haven't felt a need to do this because the drift that does occur seems innocuous.

Conclusion

As you might guess, this was a long-term project. I don't recommend that you take on this conversion unless you have another receiver to use in the meantime. A good oscilloscope and signal generator are essential.

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137

On the other hand, if you have the experience and equipment, you will find this a satisfying project — particularly if you have a 75A-4 that isn't being used because of circuit problems or lack of good tubes.

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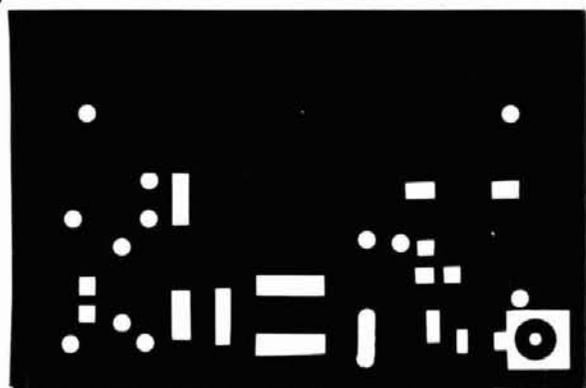
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Article F

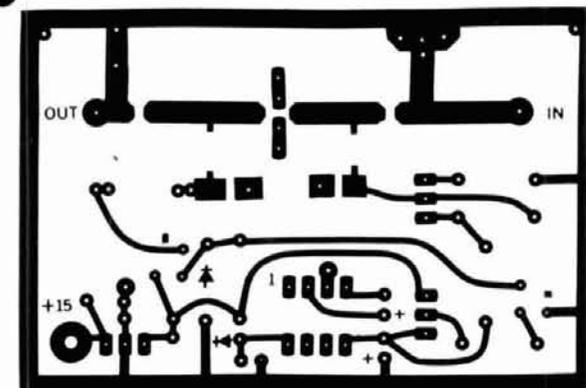
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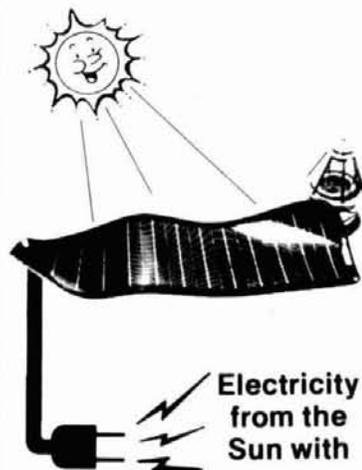
PC board layout for groundplane and trace sides, continued from page 60.

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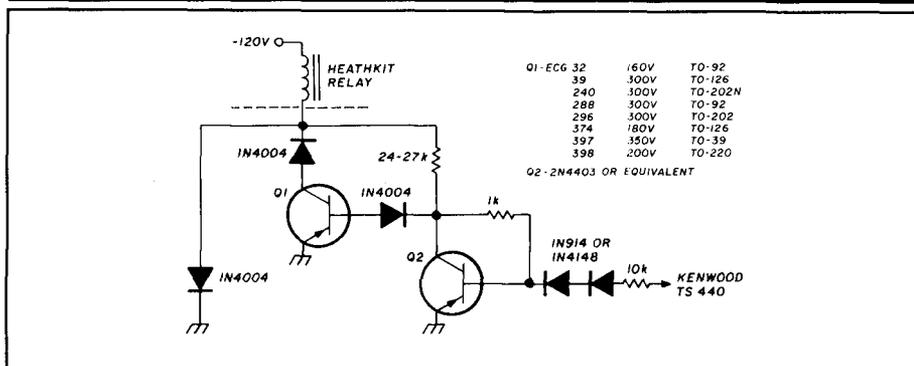
TS-440 interface for keying linears with high voltage biasing

I recently had a problem posed to me involving keying the relay of a Heathkit low-band linear from a Kenwood TS-440. The relay power in the linear is obtained from the -120 volt bias supply, and the transmit keying output from the Kenwood is +12 volts at 10 mA, maximum. The circuit below solved the problem. The key ingredient is the PNP driver transistor, which must be capable of handling at least 150 volts at about 250 mA. I've indicated several ECG types that meet the circuit requirements.

I'm sure others are running into the same or similar problem; I hope this circuit solves it!

Hugh Wells, W6WTU

FIGURE 1



Schematic of the circuit used to interface from the +12Vdc keying output of the TS440S to the -120 volt bias supply of the Heathkit amplifier.

Two simple 80-meter radiators for short and long skip

Getting the optimum performance from his equipment and antenna system is every ham's greatest desire — at least it should be! With this in mind, I want to share two simple but efficient radiators I've used during my 27 years in Amateur Radio.

The first is a high-angle radiator, the second a low-angle radiator. The first is for contests, local round tables, and other local communications. It produces a strong signal because it's really a two-element antenna. This is because the earth appears as a reflector to the antenna when the antenna is mounted at the proper height. On-

the-air comparative reports were made between the "lazy loop" mounted at approximately 25 feet and an 80-meter dipole mounted higher. Both receive and transmit reports consistently favored the loop.

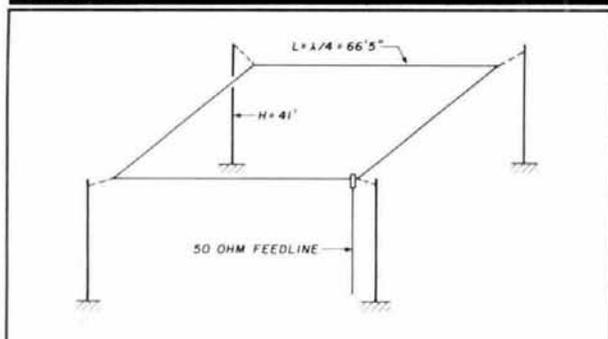
The lazy loop construction is very basic (see fig. 1). The total length of the loop is approximately one wavelength. Because the loop is actually square, each side is 66' 5" for a total wire length of 265' 8". The optimum height above ground should be in the neighborhood of 0.15 wavelength or 41'. Because of the effect of the ground on the antenna, the feed impedance is between 50 and 60 ohms. You should have no problems feeding the antenna directly with 50-ohm coax; however, you can use a balun if you wish. The loop can be

constructed from copper wire of 16 AWG and up.

The second antenna, known as the "delta loop," provides exceptional low-angle radiation, which is useful for working DX. Construction again is very straightforward; you use a suitable gauge of copper wire cut to approximately 270' in length. Provided the antenna is laid out as shown in fig. 2, the feed impedance will be close to 50 ohms, allowing a direct feed with 50-ohm coax. Some of the pluses of this antenna are:

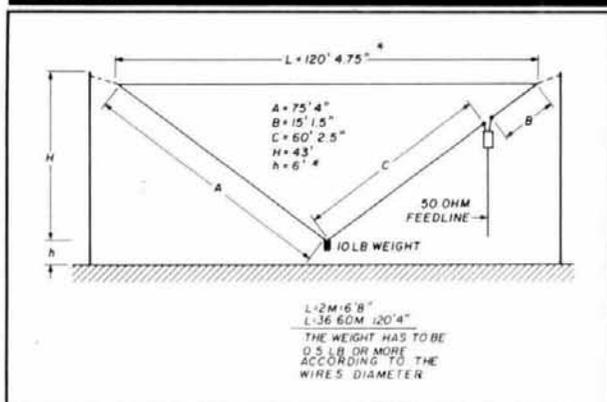
- Will fit anywhere a full-size 80 meter dipole will.
- Can be physically lower than an 80 meter dipole, and still perform as well or better.
- Can be fed directly with 50-ohm coax.

FIGURE 1



Full-wave horizontal loop with dimensions. This antenna is an excellent high-angle radiator and should be very useful for local communications.

FIGURE 2



Inverted Delta Loop for 80 meters. This antenna provides a good low angle of radiation and is excellent for Dxing.

So if you're tired of that old 80-meter dipole that just won't perform the way you want it to, here are two veteran antenna designs which will provide many hours of pleasant operating.

Sever Diaconu, YO4WU

Article G

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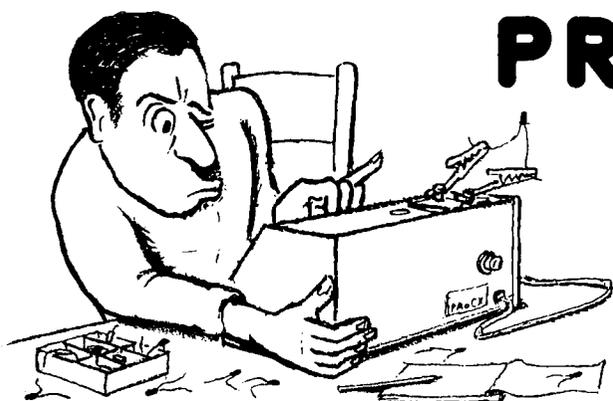
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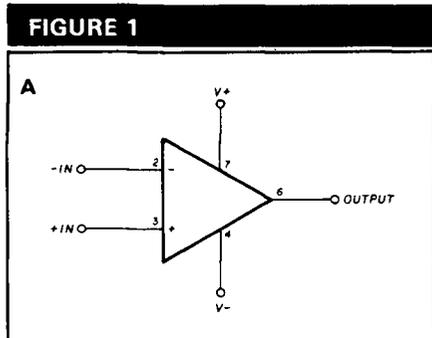
An overview of operational amplifiers: part 1

This month's topic is a discussion of the basics of operational amplifiers and other linear IC devices. Because the role of these devices is so great in radio communications equipment and circuits, it's important to understand them. Op-amps can be used for audio applications, in electronic measurement instruments, and in control circuits.

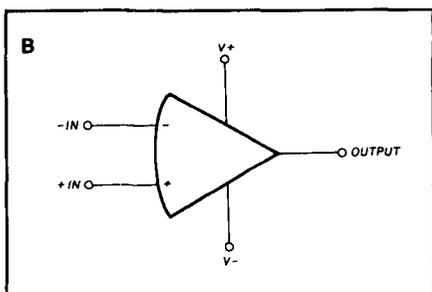
Operational amplifiers

Figure 1A shows the usual circuit symbol of the op amp. An alternate symbol is shown in fig. 1B. (Burr-Brown and some ARRL literature use the alternate symbol.) This symbol is technically the "correct" one to use. It uses a curved back to which the input leads are attached. However, the version shown in fig. 1A is used almost universally, even though it is the generic amplifier symbol, and could denote any amplifier stage — including the operational amplifier. Because it's the industry standard, I'll use the symbol in fig. 1A here.

Note the pin-outs for the amplifiers in fig. 1. The pin numbers given are for the 741 device, but have become something of an industry standard. There are two input connections, two power supply connections, and one output connection. There is no "ground" or common connection. The



Standard op-amp symbol. The pin outs are "industry standard" 741-family and fit a large number of different devices.



'Official' symbol used in some catalogs and ARRL publications.

signal common is taken from the power supply common line. More on this in a moment.

The two power supply connections are $V+$ and $V-$. The $V+$ supply is positive with respect to common; the $V-$ is negative. The range for these voltages is typically ± 4 volts to ± 18 volts, although a number of examples exist with wider (or slightly different)

voltage ranges. A GE RCA CA-3140 BiMOS device, for example, operates at potentials up to ± 22 volts for $V-$ and $V+$, while certain "low-power" or "micropower" op amps operate down to ± 1.5 volts DC.

In addition to the absolute voltage limits, there are sometimes relative limitations. For example, older 741 devices have a 30-volt limit for the voltage defined by the expression $[(V+) - (V-)]$, even though each $V-$ and $V+$ can be as high as 18 volts. As a result, if $V+$ is +18 volts, then $V-$ must be not greater than -12 volts in order that the differential not be greater than 30 volts $[(+18) - (-12) = +30$ volts].

The selection of power supply voltages might also depend on the maximum anticipated output voltage. If the amplifier is being designed for use with an analog-to-digital converter that has an input voltage range of -10 to +10 volts input, then I certainly want the output of the amplifier to be capable of achieving those values. But there is a limit on how high the output voltage can reach; that limit is a function of the power supply voltage. In general, the limitation is based on the number of PN junctions between the output terminal on the IC and each power supply terminal. Each PN junction has a 0.7-volt drop which must be accounted for. If there are four PN junctions between the output terminal and the $V+$ power supply terminal, for

example, then the maximum allowable output voltage will be $[(V+) - (4 \times 0.7)]$ volts, or 2.8 volts lower than $V+$. When I want the output terminal to swing to +10 volts, the absolute minimum $V+$ power supply voltage will be $10 + 2.8$ volts, or +12.8 volts DC. Obviously, a +12 volt DC power supply won't work in this case. In general, ordinary bipolar transistor op amps (like the 741) require a supply voltage 2 to 4.5 volts higher than the maximum required output voltage, but must also remain within the $V+$ and $V-$ constraints of the device. Some BiMOS and BiFET devices are available in which the maximum output signal voltage can be as low as 0.5 volts below the power supply potential.

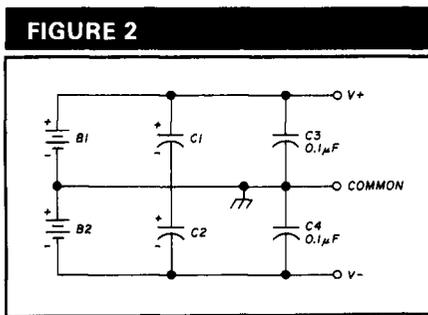
Operational amplifier inputs and outputs

The two inputs for the operational amplifier form a "differential pair" because they are 180 degrees out of phase with each other. The *inverting* input (-) produces a 180-degree phase shift between the input signal and output signal (in other words, a positive-going input signal produces a negative-going output signal, and vice versa). The *noninverting* input (+) produces a zero-degree phase shift in the output signal. Since one input produces an in-phase output and the other produces an out-of-phase output, simultaneous application of the same voltage to both inputs produces a zero net output potential. I'll use this information in a later section to form the differential amplifier. The two inputs on the op amp offer a very high impedance, which is infinite in the ideal model. On paper, they are a perfect-voltage amplifier input.

The output of the operational amplifier is also suited to a perfect-voltage amplifier circuit. The output impedance of the typical op amp is usually quite low (10-100 ohms), so it forms a nearly perfect voltage source.

Operational amplifier DC power supplies

Figure 2 shows a model of the typical operational amplifier power supply.



DC power supplies for the op amp.

Either batteries or electronic power supplies operated from the AC power lines can be used. Recall that you have two different voltages in the op amp power supply: $V+$ and $V-$. Voltage $V+$ is supplied by B1; $V-$ is supplied by B2. The common (or ground) connection is the junction between the two batteries. Normally, B1 and B2 will have the same voltage rating, but that is not a strict requirement unless other circuit considerations apply.

The capacitors shown in fig. 2 are used for decoupling, especially when multiple stages are fed from the same power supply. Capacitors C1 and C2 are normally 1-100 μF electrolytics, and are used for decoupling low-frequency signals. Capacitors C3 and C4 are used for decoupling higher frequency signals. You can't normally use the higher value C1/C2 for high-frequency signals because these are ordinarily electrolytic capacitors, which are ineffective at high frequencies. Fortunately, some new capacitors will operate to the frequencies covered by the gain-bandwidth product of most op amps.

The power supply common or "ground" connection is used as the zero-reference point for input and output signals on the operational amplifier. Whether the common is actually grounded or not depends upon circuit design considerations. In most cases it is grounded for the sake of simplicity.

In most applications, electronic power supplies used for B1 and B2 must be voltage regulated. Although there are certainly numerous applications where voltage-regulated DC power supplies are not strictly required, they are almost always good

engineering practice. Because there are low-cost three-terminal fixed-voltage regulators now on the market, it's easy to obtain regulated power supplies.

The ideal operational amplifier

Before getting further into operational amplifier circuits, let's set the stage for a simplistic circuit analysis by discussing the properties of the "ideal" op amp. This ideal device has the following:

- Infinite open-loop gain
- Zero-output impedance
- Infinite input impedance
- Zero-noise contribution
- Infinite bandwidth
- Differential inputs which "stick together."

Let's define these properties and compare them with those found in practical IC operational amplifiers.

Infinite open-loop gain. This means that the voltage gain of the ideal operational amplifier in the open-loop (i.e., no feedback) configuration is infinite. Real op amps don't even approach the ideal, but are still good enough approximations to make the device function properly. The ability of practical op amps to approach the ideal depends on having extremely high open-loop gain, otherwise the equations behave badly. In practical devices, you'll find that the open-loop voltage gain (A_{VOL}) will be 20,000 in low-cost devices, and well over 1,000,000 in premium ones.

Zero-output impedance. The operational amplifier is supposed to be a perfect-voltage amplifier, so it should offer an output impedance of zero. Real devices have output impedances of 10-100 ohms, with most being around 50.

Infinite input impedance. This parameter means that the input will neither sink nor source electrical current. Recall that input impedance is $Z = V_{in}/I_{in}$, so for input impedance to be infinite, I_{in} must be zero. In real operational amplifiers, the input current is non-zero. This is one of the primary differences between premium and low-cost devices. Low-cost amplifiers use

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bipolar transistor input stages and have input bias and leakage currents of up to 1 or 2 nA to contend with. Certain others have the input currents in the nano- to picoamp range. The RCA BiMOS op amps (1 / RCA CA-3140, etc.) use MOSFET input transistors to produce an input impedance of 10¹² ohms. For most practical purposes that impedance is "infinite."

Zero-noise contribution The noise referred to here is internal device-generated noise added to the signal. This is another difference between low-cost and premium devices. The low-cost amplifiers add considerable "hiss" noise, making them unusable on low-signal applications.

Infinite bandwidth. This parameter means that there is no limit to the operating frequency of the device, which is patently absurd in the case of real operational amplifiers. Unconditionally stable, frequency-compensated devices like the 741 may have an upper frequency limit of only a few kilohertz, while other op amps operate to several megahertz. Only a few devices are available for the high HF or low VHF frequency ranges. They are usually labeled "video quantity amplifiers," or something similar. Some devices with gain-bandwidth products that imply HF operation don't operate as op amps *per se*, but will work to some degree even though they don't operate in accordance with standard op amp rules and equations.

Differential inputs which "stick together." This property is essential to the simplified circuit analysis used. It's also used in some circuit applications, like "bridge audio." The property implies that a voltage applied to one input will also appear on the other. You must treat both inputs mathematically the same in this regard. If you apply a voltage to the noninverting input, then you must treat the inverting input as if it also sees that voltage. This statement is not merely some theoretical device used to make equations work. If you apply a real voltage to a real noninverting input, and then connect a real voltmeter to the inverting input, you will measure the same volt-

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age at that point. This point is very important, and I'll touch on it again next month when I deal with inverting and noninverting amplifiers.

Next month...

Next month I'll expand on the op amp theme and look at the three most basic circuit configurations: *inverting follower*, *unity gain noninverting follower*, and *noninverting follower with gain*. I'll derive the transfer equations, and display an interesting property of operational amplifiers — the property that makes them so easy to use.

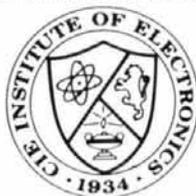
This article is based on my new book: "IC User's Casebook," (Sams No. 22488, available from the *HAM RADIO* Bookstore for \$12.95, plus \$3.50 shipping and handling. I can be reached at POB 1099, Falls Church, Virginia 22041 and would like to have your comments and suggestions for this column.

Article H

HAM RADIO

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✓ 106

(continued from page 9)

an article. The material in it was a rehash (for the most part) of an application written in *QST* (April 1984) and featured in the ARRL 1987 Handbook by a TRW engineer Fred Williams (credit was given in the bibliography). The article did go into more detail concerning phase noise and other problems associated with PLLs and how the DDS system overcame these problems. But, at least the Williams article published schematics and a parts list so "roll your own'ers" like me could play with it.

So please keep your standards high for the experimenter that your magazine addresses. Any articles that are a construction or any general theory content should have schematics and not a paragraph at the end saying, "send money." I do support an author offering to supply boards, "hard to find parts" or a complete kit for a fee, but at least require the article to supply enough information for a person to go from the article itself.

Please keep up the good work and I look forward to more informative issues.

Jeff Pierce Jr., WD4NMQ,
Kingsport, Tennessee 37663

Rave review!

Dear HR:

I will try to be succinct, but I gotta tell you.

My book shelves were getting overloaded with ham magazines so I decided to catalog those articles which were of interest to me and throw the rest away. I subscribe to two other popular ham magazines besides *HAM RADIO*.

After throwing away eighty percent of the other two as having no continuing interest, I then looked at the *HAM RADIO* file. I hadn't realized it before, but after going through all of them, I found an article of continuing interest in each one of them. Although *HAM RADIO* did not contribute to my house cleaning efforts I did end up with more room to hold future issues.

As I was writing this letter the September issue of *HAM RADIO* arrived.

All I can say is — WOW — you have outdone yourself.

As a ham who built his first radio over 60 years ago from *Popular Mechanics* magazine, first transmitter from *Radio News*, and has been licensed for fifty-five years, I have a magazine that helps me keep up-to-date on the latest technology.

Kenneth L. Freeland, W1ANF,
Raymond, New Hampshire 03077

All constructive criticism welcome

Dear HR:

I read the September, 1988 issue with trepidation. I thought of the old adage, "If it ain't broke, don't fix it," as I read the issue. I am for changes in the magazine to keep pace with the "technology and standards in the graphic arts field." I do take exception to this issue as a showcase of your efforts, however.

The new layout of articles as displayed by the easy-to-spot heavy bar denoting the figures was not used in the articles obviously set up before the (seeming last minute) decision to go with the new style. No reason came to mind to not follow through with the new style throughout the magazine.

I really applaud the inclusion of the reader service card back in the magazine, as well as the plastic bag.

I just thought I'd give you my thoughts as I finish reading the issue and they are still fresh on my mind. Keep up the good magazine! and GOOD LUCK!

Richard Herndon, K5FNI,
Austin, Texas 78757-2424

We thought we'd give you some of the new and some of the old as a comparison. Glad you like our new style! Ed.

A round of applause

Dear HR:

I wanted to express my applause to the crew for some great graphics creating a fresh, exciting new look to *HAM RADIO*! It is the best face-lift HR has had since I've seen the publication.

Ed Buffington, WB1AMU,
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- Low pass probe, audio use **16.95**
- Direct probe, general purpose use **13.95**
- Tilt bail for CT-70, 90 & 125 **3.95**
- Nicad pack for CT-70, 90 & 125 **3.95**

CT-70 7 DIGIT 525 MHz



\$139.95 WIRE INCLUDES AC ADAPTER

CT-90 9 DIGIT 600 MHz



\$169.95 WIRE INCLUDES AC ADAPTER

CT-50 8 DIGIT 600 MHz



\$189.95 WIRE INCLUDES AC ADAPTER

CT-125 9 DIGIT 1.2 GHz



\$189.95 WIRE INCLUDES AC ADAPTER

MODEL	FREQ RANGE	SENSITIVITY	ACCURACY	DIGITS	RESOLUTION	PRICE
CT-70	20 Hz-550 MHz	< 50 mV to 150 MHz < 10mV to 150 MHz < 150mV to 600 MHz	1 PPM	7	1 Hz, 10Hz, 100Hz	139.95
CT-90	10 Hz-600 MHz	< 50 mV to 150 MHz < 150mV to 600 MHz	1 PPM	9	0.1Hz, 10Hz, 100 Hz	169.95
CT-50	5 Hz-600 MHz	LESS THAN 25 mV	1 PPM	8	1Hz, 10Hz	189.95
CT-125	10 Hz-1.25 GHz	< 25mV @ 50 MHz < 15mV @ 500 MHz < 100mV @ 800 MHz	1 PPM	9	0.1Hz, 1Hz, 10Hz	189.95
CT-90 WITH DV-1 OPTION	10 Hz-600 MHz	< 10mV to 150 MHz < 150mV to 600 MHz	0.1 PPM	9	0.1Hz, 1Hz, 10Hz	229.90

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Complete kit, TD-1 **\$5.95**

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ML-1 kit **\$8.95**

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Voice activated switch kit provides switched output with current capability up to 100 mA. Can drive relays, lights, LED or even a tape recorder motor. Runs on 9VDC.

VS-1 kit **\$6.95**

VIDEO MODULATOR

Converts any TV to video monitor. Super stable, tunable over ch 4-6. Runs on 5-15V accepts std. video signal. Best unit on the market! Complete kit, VD-1

\$7.95

LED BLINKY KIT

Alternately flashes 2 jumbo LEDs. Use for name badges, buttons, warning panel lights. Runs on 3 to 15 volts.

BL-1 kit **\$2.95**

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MAD BLASTER

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MB-1 kit **\$4.95**

WHISPER LIGHT

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WL-1 kit **\$6.95**

FM WIRELESS MIKE

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FM-2 kit **\$4.95**

SIREN

Produces upward and downward wail. 5 W peak audio output, runs on 3-15 volts, uses 3-45 ohm speaker.

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DX FORECASTER

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WINTER DX SEASON

November through February is the winter DX season. Less ionization occurs because the D and E regions of the ionosphere receive less energy from the sun in the Northern Hemisphere. Attenuation results from signal energy being absorbed by ions in the D region (35-50 miles or 60-80 km above the earth) where your path crosses the D region. On any propagation path, absorption increases with the number of transits of the D region, and varies inversely with frequency. So in working DX, it pays to use the higher frequency bands to obtain more distance per hop (resulting in fewer transits) and less signal loss. But you can't always count on this; signals traveling a high-latitude path may be poor for several days at a time. This is known as the winter anomaly.

Along with lower signal attenuation, QRN decreases as fewer local thunderstorms pass through. As the large thunderstorm areas near the equator move farther south, their noise decreases by about 6-8 dB. This is particularly noticeable on the 160, 80, and 40-meter bands.

Even though ion production in the D, E, and lower F regions is less, ions are better able to diffuse and drift upward along the geomagnetic field lines into the F region. The F layer is the major factor in defining the maximum usable frequency (MUF) and the maximum on each side of the geomagnetic equator (see my October 1983 column). These maximums, which are reached most evenings at about 2200

local time, eliminate one whole earth bounce and its accompanying double-D region transits for one-long-hop propagation — real DXing.

Another advantage during the winter season is the increased stability of signal strengths resulting from the decrease in the number and intensity of geomagnetic field disturbances. This is attributable to the eccentricity of the earth's orbit. When the earth is closer to the sun, the solar flux pressure on the magnetosphere surrounding the earth tends to hold the magnetosphere steadier. So, the geomagnetic field is least disturbed during November and December, and there is less variation of the magnitude and direction of the geomagnetic field lines in a minute's time. Consequently, there are fewer periods of instability during the month, and better DXing.

Last-minute forecast

The higher frequency bands, 10-30 meters, are expected to be best during the third and fourth weeks of the month. During these days the solar flux should be highest and give good openings to the south, particularly in late evening and if a geomagnetic disturbance should occur to enhance the opening. Look for enhancement around November 5th, 15th, 22nd, and 31st. On the lower bands during these days look for lower MUFs, particularly during the night on east-west paths to Europe and Japan. These decreases may amount to 20 percent on the third night. Listen for DX openings from unusual QTHs also. Otherwise the lower bands are expected to be the best during the first and last weeks. Thanksgiving weekend (CQWW) is expected to have good openings on the higher bands and good nighttime conditions as well.

The Taurids meteor showers will occur from October 26th to November 22nd, with a maximum count of ten per hour from the 3rd through the 10th

of November. Lunar perigee is on the 20th and a full moon falls on the 23rd.

Band-by-band summary

Ten and 12 meters, the highest day-only DX bands, are nearest the MUF for Southern Hemisphere paths. They will be open most days during the 3 to 5-hour period after local noon for the solar flux available this November. These bands open on paths toward the east and close toward the west. The paths are up to 4000 km (2400 miles) in single-hop length and, on occasion, double that during evening transequatorial openings.

Fifteen meters, a day-only DX band open most of each day, has lower signal strengths and greater multipath variability than 10 and 12 meters. It will be best when the MUF is resting just above this band, until it drops below it (a transition period that occurs after sunrise and just before sunset). Transequatorial openings will occur, with distances similar to 10 and 12 meters.

Twenty, 30, and 40 meters are both daytime and nighttime DX bands. Twenty is the maximum usable band for DX in the northern directions during the day. In combination with 30 meters, it provides nighttime paths for the day-only bands. Forty meters becomes the main over-the-pole DX daytime band, with some hours covered by 30 meters. This path and east-west paths may be affected by 10-20 dB of anomalous absorption during a few days of the month.

Eighty and 160 meters, the night-only DX bands, exhibit short-skip propagation during daylight hours, then lengthen at dusk. These bands follow the darkness path, opening to the east just before local sunset, swinging more to the north-south near midnight, and ending up in the Pacific areas for a few hours before dawn. Remember the DX window of 3790 to 3800.

Article 1

GMT	WESTERN USA											
	PST	N	NE	E	SE	S	SW	W	NW	12:00	1:00	2:00
0000	4:00	20	30	20	10	12	12	10	15	12	12	10
0100	5:00	20	40	20	12	12	10	10	15	12	12	10
0200	6:00	20	40	20	12	12	10	12	15	12	12	10
0300	7:00	30	40	20	15	15	10	15	15	12	12	10
0400	8:00	30	40	20	15	15	12	20	20	12	12	10
0500	9:00	30	40	20	20	15	12	20	20	12	12	10
0600	10:00	30	40	20	20	20	15*	20	20	12	12	10
0700	11:00	30	40	20	20	20	15	20	20	12	12	10
0800	12:00	40	40*	20	20	20	15	20	20	12	12	10
0900	1:00	40	40	20	20	20	15	20	20	12	12	10
1000	2:00	40	40	20	20	20	15	20	20	12	12	10
1100	3:00	40	40	20	20	30*	20	20	30	12	12	10
1200	4:00	40	40	15	20	20	20	20	40	12	12	10
1300	5:00	40	30	12	15	20	20	20	40	12	12	10
1400	6:00	40	20	12	15	20	20	20	40	12	12	10
1500	7:00	30	20	10	12	15	20	20	40	12	12	10
1600	8:00	30	20	10	12	15	20	20	40	12	12	10
1700	9:00	30	20	10	12	15	20	20	40	12	12	10
1800	10:00	40	20	10	10	15	15	20	30	12	12	10
1900	11:00	40	30	12	10	15	15	20	20	12	12	10
2000	12:00	40	30	12	10	12	15	20	20	12	12	10
2100	1:00	40	30	15	10	12	15	20	20	12	12	10
2200	2:00	40	30	15	10	12	15	20	20	12	12	10
2300	3:00	40	30	15	10	12	15	20	20	12	12	10

GMT	MID USA											
	MST	N	NE	E	SE	S	SW	W	NW	12:00	1:00	2:00
0000	5:00	30	30	20	12	12	10	10	15	12	12	10
0100	6:00	20	40	20	12	12	10	12	15	12	12	10
0200	7:00	30	40	20	15	15	12	15	20	12	12	10
0300	8:00	30	40	20	15	15	12	15	20	12	12	10
0400	9:00	30	40	20	20	15	12	15	20	12	12	10
0500	10:00	30	40	20	20	15	12	15	20	12	12	10
0600	11:00	30	40	20	20	15	12	15	20	12	12	10
0700	12:00	40	40	20	20	20	15	20	30	12	12	10
0800	1:00	40	40	20	20	20	15	20	30	12	12	10
0900	2:00	40	40	20	20	20	15	20	40	12	12	10
1000	3:00	40	40	20	20	20	15	20	40	12	12	10
1100	4:00	40	40	15	20	30*	20	20	40	12	12	10
1200	5:00	40	20	12	15	20	20	20	40	12	12	10
1300	6:00	20	20	12	15	20	20	20	40	12	12	10
1400	7:00	30	20	12	15	20	20	20	40	12	12	10
1500	8:00	30	20	10	12	15	20	20	30	12	12	10
1600	9:00	30	20	10	12	15	20	20	30	12	12	10
1700	10:00	30	20	10	10	15	15	20	20	12	12	10
1800	11:00	30	20	10	10	15	15	20	20	12	12	10
1900	12:00	40	20	10	10	12	15	20	20	12	12	10
2000	1:00	40	30	12	10	12	15	20	20	12	12	10
2100	2:00	40	30	12	10	12	15	20	20	12	12	10
2200	3:00	40	30	15	10	12	15	20	20	12	12	10
2300	4:00	40	30	15	10	12	15	20	20	12	12	10

GMT	EASTERN USA											
	EST	N	NE	E	SE	S	SW	W	NW	12:00	1:00	2:00
0000	7:00	40	40	20	15	15	15	15	20	12	12	10
0100	8:00	30	40	20	15	15	15	15	30	12	12	10
0200	9:00	30	40	20	20	15	15	20	30	12	12	10
0300	10:00	30	40	20	20	15	15	20	30	12	12	10
0400	11:00	40	40	20	20	20	20	20	30	12	12	10
0500	12:00	40	40	20	20	20	20	20	30	12	12	10
0600	1:00	40	40	20	20	20	20	20	30	12	12	10
0700	2:00	40	40	20	20	20	20	20	40	12	12	10
0800	3:00	40	40	20	20	20	20	20	40	12	12	10
0900	4:00	40	40	15	20	20	20	20	40	12	12	10
1000	5:00	20	20	12	15	30*	20	20	40	12	12	10
1100	6:00	20	20	12	15	30*	20	20	40	12	12	10
1200	7:00	20	20	12	15	20	20	20	40	12	12	10
1300	8:00	30	20	12	12	20	20	15	20	12	12	10
1400	9:00	30	20	10	12	20	20	20	20	12	12	10
1500	10:00	30	20	10	12	15	20	20	20	12	12	10
1600	11:00	30	20	10	10	15	15	20	20	12	12	10
1700	12:00	30	20	10	10	15	15	20	20	12	12	10
1800	1:00	30	20	10	10	15	15	20	20	12	12	10
1900	2:00	30	20	12	10	12	12	15	20	12	12	10
2000	3:00	40	30	12	10	12	10	12	15	12	12	10
2100	4:00	40	30	15	10	12	10	12	15	12	12	10
2200	5:00	40	30	15	10	12	10	12	15	12	12	10
2300	6:00	40	30	15	10	12	10	12	15	12	12	10

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.
 *Look at next higher band for possible openings.

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HAMMARLUND SUPER-PRO Model SP200 with manual and spare tubes. \$75 pickup only. W. Deily, 841 Yale, DeLand, FL 32724. (904) 738-3418.

RECONDITIONED TEST EQUIPMENT \$1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

NORTH CAROLINA: November 6. The Cabarrus Amateur Radio Society's 10th annual COUNTRY HAMFEST, New National Guard Armory, Hwy 49 and Old Charlotte Road, Concord. Amateur exams. Concessions, forums. For information Concord Hamfest, 2015 Applegate Drive, Concord, NC 29025.

WISCONSIN: November 12. The Milwaukee Repeater Club's 4th annual "6.91 Friendly Fast" Sarb Hall, 51st and Oklahoma Avenue, Milwaukee, 8 AM to 1 PM. Tickets \$3. 4 tables \$4. To save \$1 SASE with payment to The Milwaukee Repeater Club, POB 2123, Milwaukee, WI 53201 before 11/5/88. Talk in on 146.91.

INDIANA: November 13. The Allen County Amateur Radio Technical Society's 16th annual Fort Wayne Hamfest, Allen County Memorial Coliseum, Coliseum Blvd, US 30, 8 AM to 4 PM. Admission \$3.50/advance; \$4.00/door. Children 11 and under free. Tables \$10 each. AC extra. Forums, non-ham activities. Talk in on 146.28/88. For reservation info AC-ARTS Hamfest, POB 10342, Fort Wayne, IN 46851. No phone reservations. For information ONLY Wayne Glasser, KA9GWE, Chairman, (219) 432-6951, 6 PM—10 PM EST.

SOUTH CAROLINA: November 19. The Sumter Amateur Radio Association's Fall Hamfest, SC National guard Armory, North Pike Road, Sumter. 8:30 AM to 4:30 PM. VE exams, indoor flea market, ATV seminar. Wheelchair access. Tickets \$4/advance, \$3/door. Talk in on 147.015. Contact SARA, POB 193, Sumter, SC 29151-0193. George Mudd, KK4OZ (803) 773-5053.

ALABAMA: November 19. The Montgomery ARC will host the 11th annual Central Alabama Hamfest. Garrett Coliseum, Montgomery. 8 AM to 3 PM. Free admission, free parking, overnight RV parking with hookup \$5/night. Flea market, dealer setup 6 AM. Tables \$7/each. Novice thru Extra license exams beginning 9 AM. For information write Montgomery Hamfest, POB 3141, Montgomery, AL 36108 or call AI, W4CNC (205) 272-9130.

OPERATING EVENTS

"Things to do . . ."

December 17-23: The Iowa Radiosport Society will be operating special event station K200RW in celebration of the Constitutional Bicentennial and the 150th anniversary of Burlington, Iowa as the first territorial capital. CW and SSB. Special QSL cards will be available for SASE, SAE and IRC sent to 923 N. 9th Street, Burlington, IA 52601.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, November 23, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee \$4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

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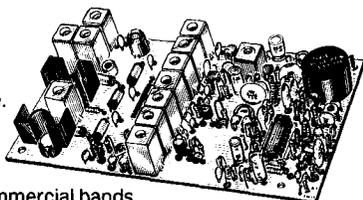
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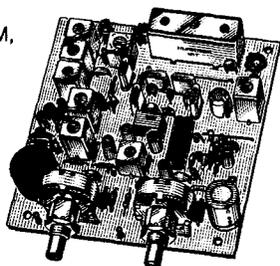
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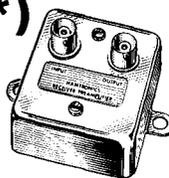
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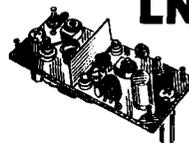
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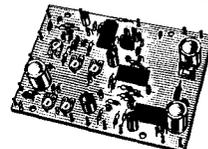
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222-224	28-30
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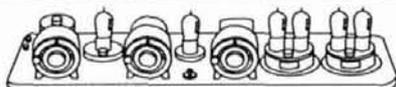
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(continued from page 4)

also urged that studies continue to be done by qualified medical researchers on the effects of all forms of electromagnetic energy on the human body, and that we quantify what power densities are involved in common Amateur activities. Only with this knowledge can we be informed as to the true nature of the danger we face and minimize their impact.

How about you; are you concerned? Are you aware of any other studies that would be of interest? This is a problem that won't go away. It's better that we be knowledgeable about the hazards than to succumb to media hysteria, ignore the situation, or take little or no action and investigate further. Drop us a line and let us know what you think.

**Craig Clark
N1ACH**

*A bibliography of what we know has been published and is available from *HAM RADIO* for a SASE and twenty-five cents postage.

**Other concerned groups, include: Electric Power Research Institute, National Career Institute, NASA, Institute of Electrical and Electronics Engineers and ARRL.

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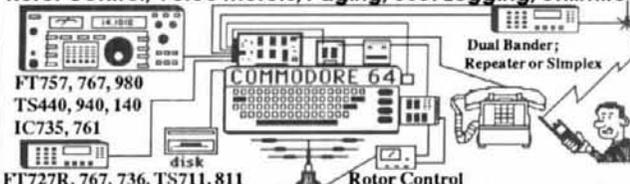
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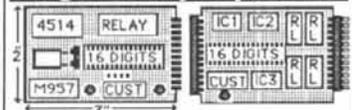
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1989 marks the 75th anniversary of the founding of the League. There's no better way of celebrating this momentous occasion, than with the new *1989 ARRL Handbook for the Radio Amateur!*

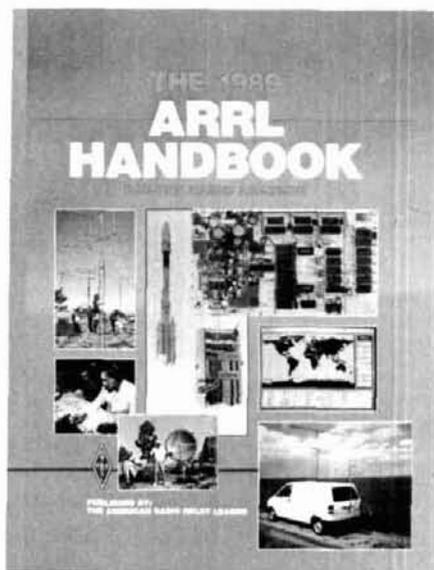
The 1200-page sixty-sixth edition contains over 2100 tables, figures and charts. The new *Handbook* is better than ever with revised information on phase noise measurement, direct frequency synthesis and spread spectrum communication techniques. The section on repeaters has been updated including a new CW identifier circuit. You'll find new spectrum analyzer and oscilloscope material, as well as several new projects in the test equipment chapter.

As always, we've added a host of new construction projects to this new edition. Just some of the new projects include: A 500-MHz frequency counter, 160 through 10 meter legal limit amplifier, simple CMOS keyer project, digital audio memory keyer and a L/Q meter for measuring coil inductance.

But that's not all. You'll find many other popular construction projects that can be built in a weekend such as power supplies and VHF/UHF preamps. For the more ambitious builder there are projects like the 1.8 MHz QSK transverter (there are VHF/UHF transverter projects too) and there are many amplifier designs to suit your needs from HF through microwaves.

The Handbook has always been famous as a reference for component data and you will find an entire chapter devoted to everything from transmitting tube and transistor specifications to aluminum tubing sizes. Satellite enthusiasts will find that the digital TR sequencer will add operating convenience to your station. Of course, you'll find the most up-to-date information on digital techniques, and the video communications chapter is packed with information not only on SSTV, ATV and FAX but Weather FAX as well. QRP enthusiasts will find the famous "Cubic incher" transmitter; not much bigger are the QRP SWR indicator and QRP Transmatch. There is also a VXO-controlled 6-watt CW transmitter for your favorite band between 80 and 15 meters. There are a number of useful station accessories that you can build like DTMF encoders and decoders, PIN-diode TR switch, digital PEP wattmeter and SWR calculator, Transmatches and dummy loads.

For \$21, *The ARRL 1989 Handbook for the Radio Amateur*, remains an exceptional value for a hardcover technical publication. The price outside the US is \$23. For postage and handling, add \$2.00 (or \$3.50 for insured mail or UPS — please specify)



Here is a description of what is covered in the Handbook:

The first 5 chapters serve as an introduction and cover: basics of Amateur Radio, electrical fundamentals, radio design technique and language, and solid state fundamentals. Vacuum tube principles as they pertain primarily to high power amplifier design are also presented in these introductory chapters. There are 12 chapters devoted primarily to these radio principles: power supplies, audio and video, digital basics, modulation and demodulation RF transmitters, receivers, transceivers, repeaters, power amplifiers, transmission lines and antenna fundamentals. Another 4 chapters cover voice, digital, image and special modulation techniques. The RF spectrum, propagation and space communications are covered in 2 chapters. The construction and maintenance section has 12 chapters of useful projects ranging from power supplies and antennas through digital equipment. You'll find up-to-date component data that the Handbook is famous for. The final 5 chapters cover how to obtain your license, station design and operation, interference, monitoring and direction finding. An abbreviations list, huge index and etching patterns make up the balance of the book.



ELMER'S NOTEBOOK

Tom McMullen, W1SL

SSB basics: generating the signal

The mode of choice for much of today's voice DX activity is single sideband, abbreviated SSB in literature, and shortened to "sideband" in the vernacular. It started out as a much larger mouthful: "single-sideband, suppressed carrier". Even the abbreviation "SSSC" didn't make it palatable to the glib of tongue, so SSB and sideband it became. It is one of the great leaps forward in radio communications and has made a great difference in our Amateur world.

Why?

The popularity of SSB, and the rapid growth of equipment that could handle this sometimes tricky mode, achieved two resounding successes almost simultaneously. First, because it eliminated the need to transmit an RF carrier, it eliminated that nerve-racking, ear-splitting beat note that is created when two carriers are within a few Hz of each other. Second, it more than tripled our band space — three or more SSB stations can now use the same space that one amplitude-modulated (AM) signal used before.

As if those two gains were not enough, it also contributed to the longevity of final amplifiers by reducing the power dissipated in just maintaining an RF carrier. In an AM signal of 100 watts, modulated 100 percent by a tone, half the power is in the RF car-

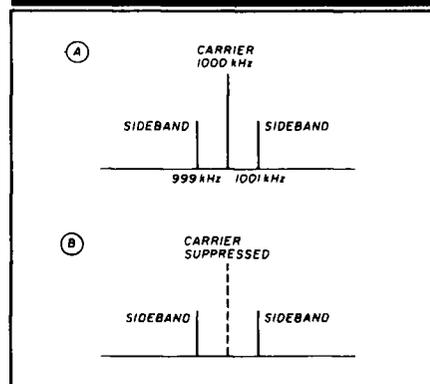
rier and the other half is shared between the two sidebands. When there is no modulation, as in pauses between words, the carrier is still there, making demands on the final amplifier. For a 100-watt carrier from a final amplifier that has perhaps 65 percent efficiency (most were much worse than that due to aging, design, or poor drive/loading), you can burn up close to 155 watts of DC just to get 100 watts of RF out, without modulation. Add modulation, and the power dissipation goes up along with it. Thus, it makes sense that if you can eliminate the steady drain of the RF carrier, your final should run cooler. By eliminating one of the sidebands, you can realize more economy in power and decrease the bandwidth required for the signal as well.

How

That sounds great, but how can you get rid of the carrier and one sideband?

To understand that, first take a look at the relationships between the carrier and the sidebands, as shown in fig. 1A. Let's assume an RF carrier at some nice round figure like 1 MHz, or 1000 kHz to make things easier to follow. To keep it easy, assume that the modulation is a sine wave at 1 kHz. This provides the classic profile of an AM signal, which has the carrier right in the middle between two sidebands. Because the frequencies both add and subtract, the product is a lower sideband at 999 kHz (1000-kHz carrier

FIGURE 1

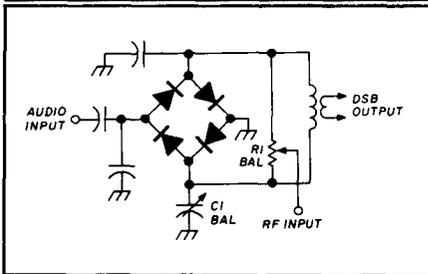


A normal AM carrier supports two sidebands, one below and one above, shown at A. Removing the carrier, as at B, leaves the sidebands, which are the elements that transmit information. After generating the sidebands, the carrier is no longer necessary for transmission.

minus the 1-kHz modulation), and an upper sideband at 1001 kHz (1000-kHz carrier plus the 1-kHz modulation).

Now, suppose you had a modulation circuit that could cause the carrier to cancel itself, leaving only the two sidebands, as in fig. 1B. Think about a basic bridge circuit for a moment — that very sensitive measuring circuit that allows only a difference between two voltages (signals) to appear at its output. Aha! The possibilities arise. Of course nobody wanted to call such a circuit a "bridge modulator," even if that's what it was — much too obvious. They're called "balanced modulators," and a sample circuit is shown in fig. 2. The carrier,

FIGURE 2



A simplified balanced modulator circuit. The RF carrier does not appear at the output, but the products of modulation — sidebands — do appear.

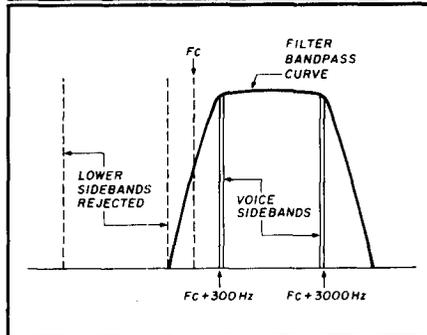
applied equally across the bridge, does not appear at the output. The modulation reacts with the carrier in the diodes (the necessary nonlinear element) and generates the sidebands. These appear at the output as upper and lower sidebands, just as in fig. 1B.

Many of the modern transmitters and transceivers used today have circuits more sophisticated than this, and some have a special integrated circuit that combines a balanced modulator and other functions on one chip. All have some means of adjusting for best carrier rejection (best bridge balance), either by varying a DC bias or by a variable capacitance to “tweak” the carrier for an exact phase shift or balance. The amount of carrier rejection can sometimes be very high in experimental circuits, but in practice it is in the range of 40-60 dB as measured at the output of the transmitter. That’s still very good. A 100-watt carrier attenuated by 40 dB is only 0.0001 watt. That will cause far less interference than the original 100-watt AM earbuster did.

One sideband goes away

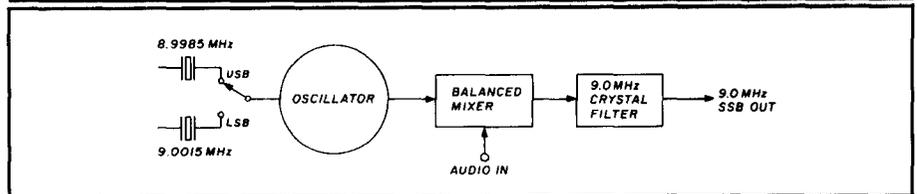
The next puzzler is how to get rid of one (and only one) sideband. There are RF and audio-phasing circuits that provide single-sideband output, but the bulk of today’s transmitters rely on selective filters to pass one sideband and reject the other. Designers can do marvelous things with crystals, ceramics, and inductors, along with impedance matching and something I’ve recently talked about called “Q”. The result is that a window can be

FIGURE 3



A crystal filter can be used to pass one sideband and reject the other. The suppressed RF carrier (F_c) is usually placed on one slope of the filter’s response curve as shown in order to pass the band of frequencies in the sideband.

FIGURE 4



A simplified diagram of a system to select between upper and lower sideband by switching oscillator crystals. The 8.9985 MHz crystal provides upper sideband; the 9.0015 MHz one is for the lower sideband.

placed right over a sideband, as shown in fig. 3. Actually, fig. 3 shows “sidebands,” because it’s hard to talk in a sine wave — voices are made up of many frequencies. This creates a range of sidebands, which must be transmitted intact if the guy at the other end is going to understand what you’re saying. Communications equipment generally limits the frequencies in voice transmissions to 300-3000 Hz, so I’ve used that range in the illustration. The resulting output is simply treated as one “sideband” — the upper one is shown in fig. 3.

But, how do you...

Select between upper and lower sidebands? It can be done by using different filters, one for the upper and one for the lower. Just switch them in and out of the circuit as needed. Fortunately, there’s an easier and less expensive way. Filters are made up of several elements and each one adds to

the cost. Crystals, on the other hand, are simpler and less expensive. Just switch the crystals in the oscillator that generates the (suppressed) carrier. If you have two crystals with frequencies spaced just right, you’ll have the upper sideband in the filter window when using one crystal, and the lower sideband in it when using the other. Neat!

Let’s look at an example from a common scheme used in several past and present transmitters. Figure 4 will give you the idea. The oscillator has a switch to select between an 8.9985-MHz crystal and a 9.0015-MHz one. As shown, the 8.9985 crystal is selected and the sidebands are at 8.9970 and 9.0000 MHz. The filter, at 9.0000 MHz,

lets the upper sideband pass. Switch to the other crystal, 9.0015 MHz, and the sidebands are at 9.0000 and 9.0030 MHz. Again, the filter lets only one sideband through, in this case the lower one which is at 9.000 MHz. (These figures assume that an audio tone at 1500 Hz is used for modulation. With voice, this system will provide “sidebands” centered at 9.000 MHz.)

From here on, it’s just a matter of amplifying the few milliwatts that come out of the filter. This must be done carefully, using linear amplifiers to prevent signal distortion, which could cause splatter and irritate fellow hams. Tubes, transistors, integrated circuits, and “amplifier blocks” can be used here to build the power up to any level needed.

Oh, yes, there’s one other thing. There is no Amateur band at 9.000 MHz, so a few conversions need to be performed to make the signal useful. Mixer circuits are used, and they can

vary from simple to complex. A balanced mixer (almost identical to the balanced modulator) is a good bet because it helps reject the local oscillator at the output, making life easier for following stages. For example, to get that 9.000-MHz sideband signal up to 28.5 MHz, you mix it with another signal at 19.5 MHz. The SSB signal is crystal controlled, so, in order to be able to move around on the band, the 19.5-MHz signal must be variable. A variable-frequency oscillator (VFO) at this frequency tends to be unstable, so the solution is to make the VFO operate at a much lower frequency, then mix it with a different crystal-controlled signal to provide stable output at 19.5 MHz (or other frequencies to use on different bands). VFOs and mixers are worthy of a greater discussion than I have space for this month, so I'll get back to them in a later issue.

Receiving SSB? That too is a subject worthy of a complete article, and I'll cover that in next month's column, along with an explanation of why SSB sounds so funny when you tune it in wrong.

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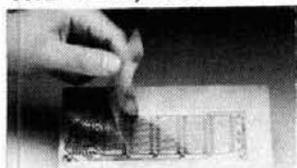
A. Microwave Associates 10 GHz Gunnplexer. Two of these transceivers can form the heart of a 10 GHz communication system for voice, mcw, video or data transmission, not to mention mountaintop DXing! MA87141-1 (pair of 10 mW transceivers) \$251.95. Higher power units (up to 200 mW) available. **B.** Microwave Associates 24 GHz Gunnplexer. Similar characteristics to 10 GHz unit. MA87820-4 (pair of 20 mW transceivers) \$739.20. **C.** This support module is designed for use with the MA87141 and MA87820 and provides all of the circuitry for a full duplex audio transceive system. The board contains a low-noise, 30-MHz fm receiver, modulators for voice and mcw operation, Gunn diode regulator and varactor supply. Meter outputs are provided for monitoring received signal levels, discriminator output and varactor tuning voltage. RXMR30VD assembled and tested \$119.95. **D.** Complete, ready to use communication system for voice or mcw operation. Ideal for repeater linking. A power supply capable of delivering 13 volts dc at 250 mA (for a 10 mW version), microphone, and headphone and/or loudspeaker are the only additional items needed for operation. The Gunnplexer can be removed for remote mounting to a tower or 2 or 4 foot parabolic antenna. TR10GA (10 GHz, 10 mW) \$399.95. Higher power units available. TR24GA (24 GHz, 20 mW) \$639.95. Also available: horn, 2 and 4 foot parabolic antennas, Gunn, varactor and detector diodes, search and lock systems, oscillator modules, waveguide, flanges, etc. Call or write for additional information. Let ARR take you higher with quality 10 and 24 GHz equipment!

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✓ 117



New mini mobile scanner from AOR

AOR, Ltd. of Tokyo, Japan has introduced a new miniature mobile scanner with frequency synthesized keyboard control. The new radio (model AR160) measures 1.5" x 4.62" x 6.5" and weighs 25 ounces. The receiver's frequency coverage is 29-52, 136-174, and 436-512 MHz.

The unit has a suggested retail price of \$189; this includes a fused dc power cable, telescopic whip antenna, mobile mounting bracket with complete hardware, plus an ac-to-dc converter for indoor use.



Twenty front keys on the top access the onboard microcomputer which controls the unit. Light emitting diodes provide bright, read-at-a-glance channel information and verify frequencies through a count-off system. A battery retains memory in the event of power loss.

For further information contact Ace Communications, Monitor Division, 10707 East 106th Street, Indianapolis, Indiana 46256.

Circle #303 on Reader Service Card.

Radio Shack offers new catalogs

Radio Shack®, a division of Tandy Corporation, highlights its line of 1989 computer products in two new catalogs; the 1989 Tandy® Computer Catalog and Express Order Software Buyer's Guide.

The 52-page Tandy Computer Catalog features the new Tandy® 5000 MC, Tandy® 4000 LX, Tandy® 3000 NL, Tandy® 1000 TL and Tandy® 1000 SL computers, plus a complete line of printers, peripherals, accessories and software.

Tandy Corporation's Express Order Software Buyer's Guide is an 84-page catalog filled with

programs for MS-DOS®, XENIX®, TRSDOS®, and Microsoft® Windows and MS® OS/2 operating systems as well as titles for Tandy's popular Color Computer family and portables.

MS-DOS software, at up to 35 percent off the manufacturer's suggested retail price, may be ordered either through Radio Shack's outlets nationwide or by calling 800-321-3133 for shipment directly to you.

The Radio Shack computer catalogs are available free of charge from Radio Shack Computer centers, Plus Computer Centers, and participating stores and dealers, or by writing Radio Shack Circulation Department, 300 One Tandy Center, Fort Worth, Texas 76102.

Circle #304 on Reader Service Card.

New Aries-1™

Aries-1™ developed by Ashton ITC, is a software program which integrates Amateur Radio equipment with an electronic Logbook (database). The program ties together multi-mode terminal units, computer capable transceivers, and a real time logging function.

In addition to controlling terminal units with simple key presses or mouse clicks (pressing the up or down arrow on the keyboard increases or decreases CW speed and RTTY baud rates) and providing for replaceable string parameters within pre-written text files (Log entries such as Name, City, Report, etc. may be automatically pulled from the on-line log and inserted into an existing text file during transmission through the Terminal Unit), Aries-1 allows for simultaneous display of the TUs input/output on the same screen with the Logbook and Transceiver status.

The electronic Logbook features data search capability and automatic entry of date and time from the computer's clock. Frequency and mode are also automatically entered into the log when using a compatible transceiver. By clicking an optional mouse on the appropriate log entry, other data such as Station ID, City, State or Country, Name, etc. may be entered into the log from data received through a terminal unit without the need to re-type the information.

Aries-1 supports a Contest Mode which has instant dupe checking (displayed dupe information includes Frequency, mode, date/time, RST and optional exchange).

Other features include: the ability to run other programs from Aries-1 while staying resident in memory; a capture buffer for selectively saving to disk input/output data from a terminal unit; searching and printing of log data by band, mode, country, etc.; updating QSO information within the log; and uploading and downloading of files through Packet, RTTY, etc.

Transceivers currently supported are Kenwood Model: TS-940S, 440S, 140S, 640S, 711A, and 811A (with appropriate Kenwood IC-10 Kit and IF-232C interface), and Icom models: IC-735, 761, 275, 375, 475, and 575 (with Icom CT-17 interface). Terminal units currently supported

include the AEA PK-232, Heathkit HK-232, and Kantronics KAM all-mode units.

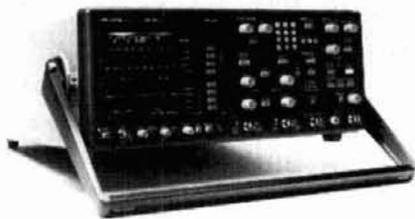
Aries-1 includes sample message files, a demo-log, and printed Users Guide. The program is available on 5-1/4 or 3-1/2-inch disks and runs on IBM PC/XT/AT, PS-2s or compatibles with at least 256K of memory. A serial port is required for connection to a compatible terminal unit or transceiver. A second serial port is necessary if you want simultaneous interface to both units. An optional mouse (Microsoft® bus version recommended) is also supported for even faster TU control and data entry. The price is \$89.95, plus shipping and handling. For more details, contact Ashton ITC, PO Box 1067, Vestal New York 13851; 607-748-9028.

Circle #305 on Reader Service Card.

New digital storage oscilloscope

The new Philips PM 3320A Digital Storage Oscilloscope from John Fluke Mfg. Co., Inc., captures single events with its 200-mhz bandwidth, real-time sampling rate of 250 MS/s and 10-bit resolution.

Two acquisition modes are available to capture signal details exceeding preset limits — Save-on-Difference and Stop-on-Difference. They compare the incoming waveform with one in memory and record the new waveform (noting the time of capture) as soon as a difference due to jitter, spikes, or amplitude variation appears between the two signals. Another function, Absolute Min/Max, creates a historical record of a large number of traces and can be used to set the Save/Stop-on-Difference parameters. Other functions include digital filtering and the display of histograms, showing the amplitude distribution of a captured signal.



The PM 3320A DSO offers an on-board Fast Fourier Transform (FFT) option with an overview of the incoming signal's frequency spectrum. Other automatic measurement functions are: RMS voltage, percentage overshoot and preshoot for step functions, and continuously variable rise and fall times — including the two pre-set options of 10 to 90 percent and 20 to 80 percent of ECL applications. It also provides

(continued on page 122)

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1 Versatility

The PK-232 should be listed in the amateur radio dictionary under the word Versatile. One data controller that can transmit and receive in six digital modes, and can be used with almost every computer or data terminal. You can even monitor Navtex, the new marine weather and navigational system. Don't forget two radio ports for both VHF and HF, and a no compromise VHF/HF/CW internal modem with an eight pole bandpass filter followed by a limiter discriminator with automatic threshold control.

The internal decoding program (SIAMtm) feature can even identify different types of signals for you, including some simple types of RTTY encryption. The only software your computer needs is a terminal program.



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2 Software Support

While you can use most modem or communications programs with the PK-232, AEA has two very special packages available exclusively for the PK-232....PC Pakratt with Fax for IBM PC and compatible computers, and Com Pakratt with Fax for the Commodore 64 and 128.

Each package includes a terminal program with split screen display, QSO buffer, disk storage of received data, and printer operation, and a second program for transmission/reception and screen display of facsimile signals. The IBM programs are on 5-1/4" disk and the Commodore programs are plug-in ROM cartridges.

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(continued from page 120)

automatic pulse width, duty cycle and phase measurements, division for ratio measurements, integration, and differentiation.

The Philips PM 3320A Digital Storage Oscilloscope suggested U.S. list price starts at \$8,990. Allow six weeks for delivery. For more information in North America, write to John Fluke Mfg. Co., Inc., P.O. Box C9090, Everett, Washington 98206.

Circle #306 on Reader Service Card.

Hands-free cellular microphone

Shure Brothers Inc. has introduced the new Shure ClearVoice™ Hands-Free System. Designed to fit on the driver's seatbelt, it provides the cellular car phone user clear voice transmission while keeping both hands on the steering wheel. The system features a highly directional, supercardioid pickup pattern that makes the microphone 60 percent less sensitive to undesirable ambient noise such as that created by a defroster fan, radio, car engine, or even surrounding traffic.

The Shure ClearVoice System can be used with most cellular car phones equipped with hands-free circuitry. Installation takes about 30 minutes and can be done by any qualified cellular installer. The suggested retail price is \$134.75.

For more information contact Shure Brothers Inc., 222 Hartrey Avenue, Evanston, Illinois 60202-3696.

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RF/microwave prototyping boards

RF Prototype Systems introduces QUICK BOARDS for rapid evaluation and verification of designs. The double-sided, FR-4 board, with plated through holes, is useful when breadboarding commonly used circuits/devices.

Three boards are offered. The LPF1 is a general filter that accommodates several filter topologies up to seven sections, including low pass, high pass, and narrow band pass. It is sized to fit standard enclosures. The GB1, a gain block layout, provides 50-ohm interconnection and dc bias for common MMIC amplifiers, like the Avantek MSA series. The TO81 is used for evaluating TO-8 voltage controlled oscillators and amplifiers and comes complete with holes for SMA connectors and power supply decoupling components.

For more information, contact RF Prototype Systems, 12730 Kestrel Street, San Diego, California 92129.

Circle #309 on Reader Service Card.

Improved electro-mechanical tool kit

Jensen has improved the popular JTK-79 Electro-Mechanical Tool Kit. Designed for the performance of a wide variety of electronic and mechanical repair tasks, the kit now contains a full 14-piece socket set, 7-piece jewelers screwdriver set, 10-piece hex key set, 4 screwdriver blades (two Phillips, two slotted), full-size handle, circuit tester, wire stripper/cutter, adjustable wrench, variety of pliers, and more.



The tools come in a compact 7 x 9 x 2" padded zipper case with Velcro snap closure to hold an optional Beckman DM 73 Meter.

The JTK-79 is priced at \$79.00. For more information and free catalog, write Jensen Tools Inc., 7815 S. 46th Street, Phoenix, Arizona 85044.

Circle #308 on Reader Service Card.

Digicom 64

Digicom 64 is a disk-based TNC emulator program for the Commodore 64 (or C128) computer. It is a public domain program written by hams in Germany that eliminates the need for a TNC and requires only an external modem for full packet radio operation.

The displayed modem circuit is based on the AM7910 chip; it supports both hf and VHF packet tones. No alignment is required. The circuit includes a "watchdog" timer as a failsafe for unattended operation and reed relay output. Power for the modem is taken directly from the C64; no external supply is necessary. The pc board is configured so that it may be plugged directly into the cassette port, or mounted remotely using a 6-conductor cable. Connectors for both configurations are included with each kit.

The complete parts kit with pc board is priced at \$49.95, plus \$2.50 shipping and handling. An assembled/tested unit is \$79.95, plus 3.50 ship-

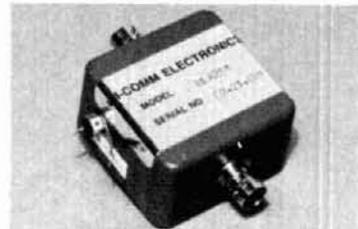
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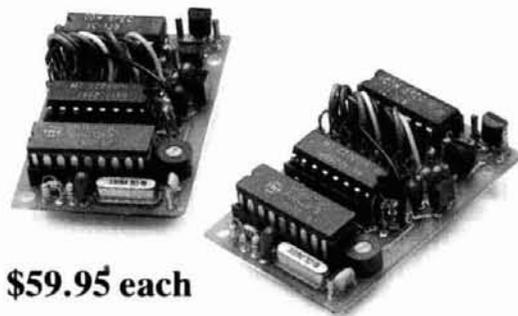
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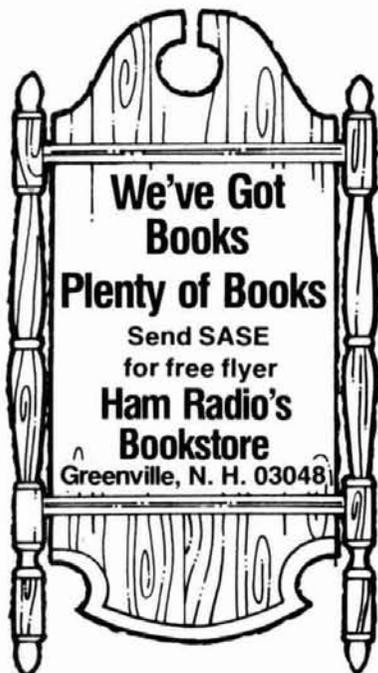
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READER SERVICE #	PAGE #	READER SERVICE #	PAGE #
176 - Ace Communications, IN	45	139 - Jun's Electronics	95
202 - Ace Communications, CA	21	168 - Kantronics	55
179 - Advanced Computer Controls	42	147 - KComm, The Ham Store	87
160 - Advanced Millwave Laboratories, Inc.	62	* Kenwood USA Corporation	2, 5, CIV
114 - Advanced Receiver Research	119	158 - Larsen Antennas	63
113 - AEA	121	126 - Madison Electronics Supply	114
133 - All Electronics Corp	102	169 - Maggiore Electronic Laboratory	53
163 - Aluma Tower Co	58	192 - Magnaphase Industries, Inc	31
181 - AMC Sales, Inc	42	177 - Glen Martin Engineering, Inc	45
194 - Amidon Associates	31	115 - The Meadowlake Corp	119
104 - AMSAT	125	161 - Michigan Radio	58
142 - Antenna's Etc	92	* Microwave Radio Corp	30
106 - Antennas West	95, 104, 125	206 - MFJ Enterprises	8
123 - Antique Radio Classified	114	165 - Micro Control Specialties	56
118 - ARRL	116	103 - Missouri Radio Center	127
159 - Ashton ITC	62	136 - Mobile Mark, Inc	99
* Associated Radio	66	135 - Monitoring Times	99
144 - Astron Corp	91	183 - Motron Electronics	43
171 - ATFAB Computers and Electronics	51	182 - NCG	43
151 - Azimuth	73	* Nema Electronics	51
* Barker & Williamson	126	148 - Nuts & Volts	87
* Barry Electronics	103	195 - Wm. M. Nye Co. Inc	27
198 - Bilal Company	23	102 - OPTOElectronics	128
189 - Bird Electronics	38	200 - Pac-Comm Packet Radio Systems, Inc	28
* Buckmaster Publishing	42	197 - P.C. Electronics	25
140 - Buckmaster Publishing	95	137 - P.C. Electronics	97
112 - Buckmaster Publishing	122	* Pauldon Associates	46
122 - Buckmaster Publishing	115	164 - President	57
* Butternut Electronics	87	178 - Radio Amateur Callbook	44
191 - C&S Sales	32	134 - Radiokit	102
* Caddell Coil Corp	23	203 - Radio Shack	19
131 - CIE	103	109 - Radiosporting	123
166 - Coaxial Dynamics, Inc	56	175 - The Radio Works	46
180 - Communication Concepts, Inc	42	129 - Ramsey Electronics, Inc	105
107 - Communications Specialists	124	124 - The RF Connection	114
208 - Connect Systems Inc	1	149 - RF Limited	79
162 - Crystek Crystals	58	117 - Rutland Arrays	119
125 - Cygnus-Ouasar Books	114	* Sherwood Engineering, Inc	104
187 - Datacom, International	40	116 - Stridsburg Engineering Co	119
155 - DigiMax Instruments Corp	66	143 - STV/OnSat	92
132 - Doppler Systems	103	146 - Synthetic Textiles, Inc	88
185 - Doug Hall Electronics	41	108 - Tel-Com	123
184 - Down East Microwave	41	* Tropical Hamboree	25
188 - DRSI	38	193 - Van Gorden Engineering	31
150 - EGE, Inc	74	145 - Vanguard Labs	88
201 - Electronic Equipment Bank	28	205 - Varian EIMAC	15
167 - Electronic Equipment Bank	56	105 - VHF Communications	125
156 - Electronic Equipment Bank	66	196 - W9INN Antennas	25
152 - Electronic Equipment Bank	72	119 - Western Electronics	115
153 - Electronic Equipment Bank	72	110 - Wi-Comm Electronics Inc	122
128 - Electronic Equipment Bank	107	173 - Yaesu USA	49
* Engineering Consulting	115	101 - Yaesu USA	CIII
157 - ETO	64, 65	199 - E.H. Yost Co	23
* EXPO '88	38		
120 - Fair Radio Sales	115		
* Falcon Communications	35		
121 - Gallatin Radio Supply	115		
190 - Giffler Shortwave	37		
170 - Gordon West Radio School	52		
174 - GTI Electronics	46		
130 - GTI Electronics	104		
172 - HAL Communications Corp	50		
138 - Hal-Tronix	97		
207 - Ham Radio Outlet	6, 7		
* Ham Radio's Bookstore	40, 110, 111, 122, 123		
* Hamtronics, NY	113		
* Hamtronics, PA	88		
* Heath Company	13		
209 - ICOM America, Inc	CII		
204 - ICOM America, Inc	16		
* International Crystal Mfg Co, Inc	28		
127 - Jan Crystals	107		
154 - JDR Instruments	71		
186 - Jensen Tools, Inc	41		
		303 - Ace Communications, Monitor Div	120
		305 - Ashton ITC	120
		306 - John Fluke Mfg Co Inc	120
		308 - Jensen Tools Inc	122
		310 - Barry Kutner, W2UP	122
		304 - Radio Shack	120
		309 - RF Prototype Systems	122
		307 - Shure Brothers Inc	122

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✓ 102



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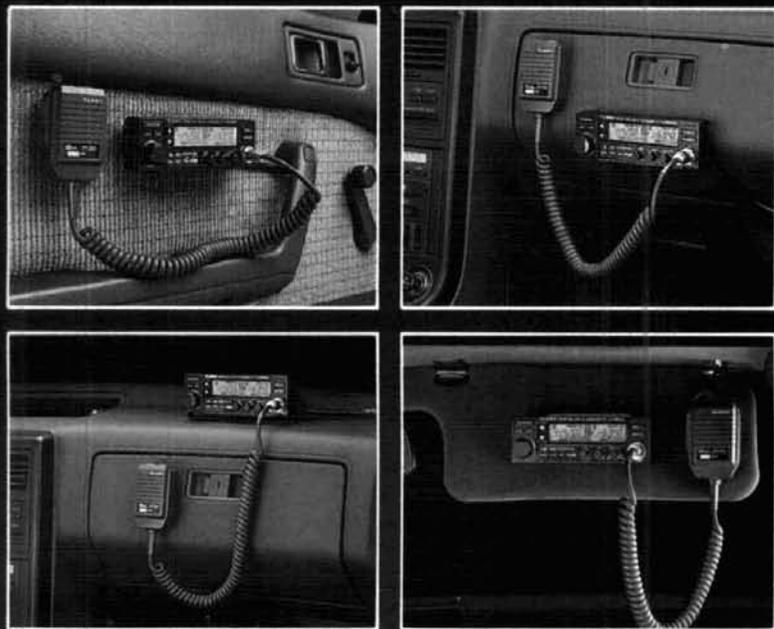


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The all-new TM-221A, TM-321A, TM-421A and TM-521A FM transceivers represent the "New Generation" in Amateur radio equipment. The superior Kenwood GaAs FET front end receiver; reliable and clean RF amplifier circuits, and new features all add up to an outstanding value for mobile FM stations! The optional RC-10 handset/control unit is an exciting new accessory that will increase your mobile operating enjoyment!

- TM-221A receives from 138-173.995 MHz. *This includes the weather channels!* Transmit range is 144-148 MHz. Modifiable for MARS and CAP operation. (MARS or CAP permit required.)

- TM-321A covers 220-224.995 MHz, TM-421A covers 438-449.995 MHz, and the TM-521A covers 1240-1300 MHz. (Specifications guaranteed for Amateur band use only.)
- Built-in front panel selection of 38 CTCSS tones. TSU-5 programmable decoder optional.
- Simplified front panel controls — makes operating a snap!
- 16 key DTMF hand mic., mic. hook, mounting bracket, and DC power cable included.
- Selectable frequency steps for quick and easy QSY.
- TM-221A provides 45 W, TM-321A 25 W, TM-421A 35 W, and TM-521A 10 W. All models have adjustable low power.
- Packet radio compatible!
- Programmable band scanning with memory scanning and memory channel lock-out.
- New amber LCD display.

- Kenwood non-volatile operating system. All functions remain intact even when lithium battery back-up fails. (Lithium cell memory back-up, est. life 5 yrs.)
- 14 full-function memory channels store frequency, repeater offset, sub-tone frequencies, and repeater reverse information. **Repeater offset on 2 m is automatically selected.** There are **two channels** for "odd split" operation.
- Super compact: approx. 1-1/2"Hx5-1/2"Wx7"D.
- Microphone test function on low power.
- High quality, top-mounted speaker.
- Rugged die-cast chassis and heat sink.



RC-10 Remote Controller

For TM-221A/321A/421A/521A. Optional telephone-style handset remote controller RC-10 is specially designed for mobile convenience and safety. All front panel controls (except DC power and RF output selection) are controllable from the RC-10. One RC-10 can be attached to **a combination of two transceivers** with the optional PG-4G cable. When two transceivers are connected to the RC-10, **cross band, full duplex repeater** operation is possible. (A control operator is needed for repeater operation.)



Optional Accessories:

- RC-10 Multi-function handset remote controller
- PG-4G Extra control cable for second transceiver
- PS-50/PS-430 DC power supplies • TSU-5 Programmable CTCSS decoder • SW-100A Compact SWR/power/volt meter (1.8-150 MHz)
- SW-100B Compact SWR/power/volt meter (140-450 MHz) • SW-200A SWR/power meter (1.8-150 MHz) • SW-200B SWR/power meter (140-450

- MHz) • SWT-1 Compact 2 m antenna tuner (200 W PEP) • SWT-2 Compact 70 cm antenna tuner (200 W PEP) • SWC-4 1200 MHz Directional coupler • SP-40 Compact mobile speaker
- SP-50B Mobile speaker • PG-2N Extra DC cable
- PG-3B DC line noise filter • MC-60A, MC-80, MC-85 Base station mics. • MC-55 (8-pin) Mobile mic. with gooseneck and time-out timer • MA-4000 2 m/70 cm dual band antenna with duplexer (mount not supplied) • MB-201 Extra mobile mount

Specifications and prices subject to change without notice or obligation. Complete service manuals are available for all Kenwood transceivers and most accessories.

KENWOOD

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