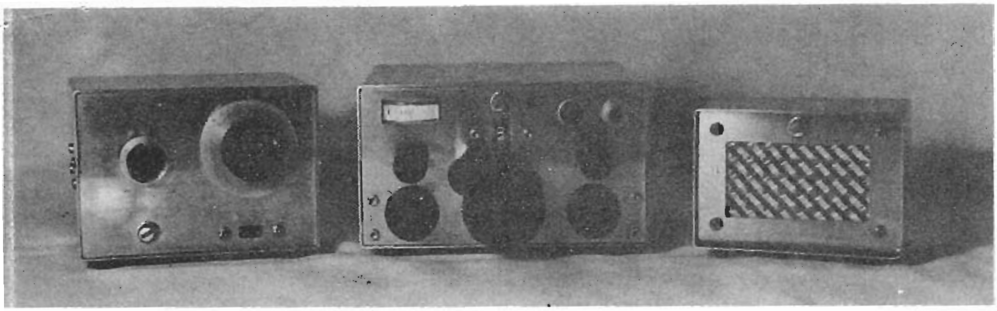


A General Coverage Solid State Communications Receiver With Direct Digital Frequency Read-Out

BY JACK PEROLO,* PY2PE1C

DIFFERENT considerations on the pros and cons of general coverage communications receivers have already been brought forth in previous *CQ* articles;[1,2] As time goes by, and after using almost exclusively monoband receivers during the last five years of operation, I believe that, by current technological standards, there is no way to beat the performance of a monoband set.

In recent years, in different areas, this concept has become more popular than it used to be: monoband transceivers command a reasonable share of the market and, with the introduction of high frequency crystal filters of bandpass characteristics competitive with those of mechanical filters, the popularity of two-band sets has also increased. The two-banders are designed around a single v.f.o., by beating its signal above or below the input signal, and by choosing a suitable intermediate frequency complete with crystal filter. The idea is evidently a close relative of a monobander, and some of the monobander's inherent advantages are retained in sets of this type.

Along this philosophy, and thinking for a minute of the v.f.o. as being a permeability tuned affair, it would be feasible to build a single conversion multiband receiver preserving some of the basic advantages of a monobander with digital frequency readout. Figure 1 outlines the principle behind this idea: by installing the tuning slugs of the v.f.o. coils on opposite sides of a holding plate, when the plate is moved (by means of the tuning knob of the receiver), one slug is moving into one of the coils whereas the other is moving out at the same rate; by properly selecting the filter frequency, the same design v.f.o. coil can be used to cover two bands, and the direction of reading of the dial counter is not changed.

Another possibility would be to alternate the use of ferrous and non-ferrous slugs to achieve electrically what has just been outlined mechanically.

The principles above are definitely applicable, but the actual construction of a receiver built around such a v.f.o. would be a

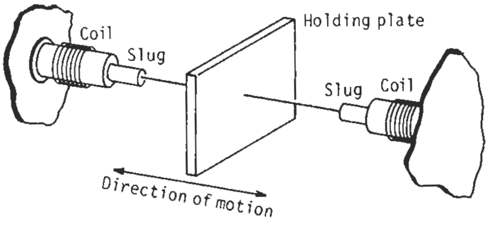


Fig. 1—Principle suggested for a bidirectional v.f.o.

*P.O. Box 2390, S. Paulo, Brazil

1 Perolo, J., "A Transistorized Communications Receiver with Digital Frequency Read-Out," *CQ*, July/Aug. 1970, p. 14.

2 Perolo, J., "A Universal Solid State Preselector/Converter for the SW Bands," *CQ*, June 1971, p. 49

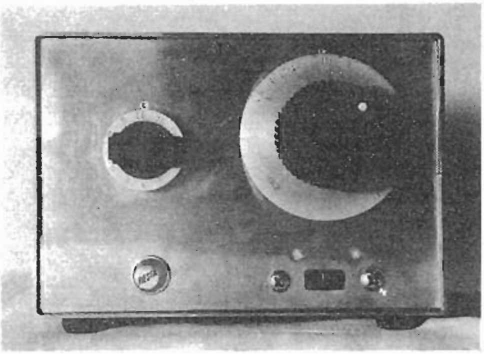


Fig. 2—The h.f. converter has three front panel controls: Bandswitch (left, marked in mHz); R.F. Tuning (large knob with H and L skirt markings corresponding to Hi and Lo ranges); and Hi and Lo Range switch (slide switch selects r.f. coils for Hi—5-18 mHz or Lo—2.5-6.0 mHz ranges). Emblems on this and other units are fabricated from stainless steel and finished in black and red.

formidable undertaking for different reasons. Even though it might not be readily evident, in order to maintain the mechanical counter direct frequency read-out capability throughout the bands, the various v.f.o. coils must cover a full megacycle. Add to this that the v.f.o.'s must be linear and that the dial counter is a unidirectional device (*i.e.*, the counter can only display, say, a frequency increase by being tuned clockwise). Mechanically, a frame that could move five or 10 slugs at the same time without detectable backlash and with acceptable resettability is quite a project by itself, and it is definitely beyond reach for the most constructors.

A multiband set designed along these lines, therefore, only solves mixing and conversion problems at the expense of mechanical complexity; one can expect a superb freedom from spurious, assuming a careful preliminary analysis of the various mixing combinations has been worked out. Articles on this matter have already been published by *CQ*, [3,4] bringing in considerable readers' feedback, showing the interest that presently exists on this matter.

I must admit, however, that *CQ* Managing Editor Alan Dorhoffer has a point in insisting that I design and build a more conventional continuous coverage set, and within the reach of the construction capability of most amateurs. To this, I should add that the bulk of *CQ* readers are hams, whose mode of operation is characterized by the possibility of a slight frequency change, while still carrying out a satisfactory QSO; such frequency changes are quite common during a contact in order to avoid a heterodyne, side splash from a nearby operator and other reasons, including to avoid spurious that may be internally generated by the equipment in use.

On the other end, my interest is nowadays primarily directed toward the shortwave broadcast bands, where the situation is altogether different: most stations (not all, though) use high stability crystal oscillators to generate and control their carrier frequency. If a certain station happens to broadcast right on the frequency of the listener's receiver spurious, this situation will add an otherwise avoidable difficulty to pick up readable signals from that particular station.

Essentially because of Alan's suggestion, a reasonably conventional multi-band solid state communications receiver with digital frequency read-out has been designed and built, being described herewith. Figures 2

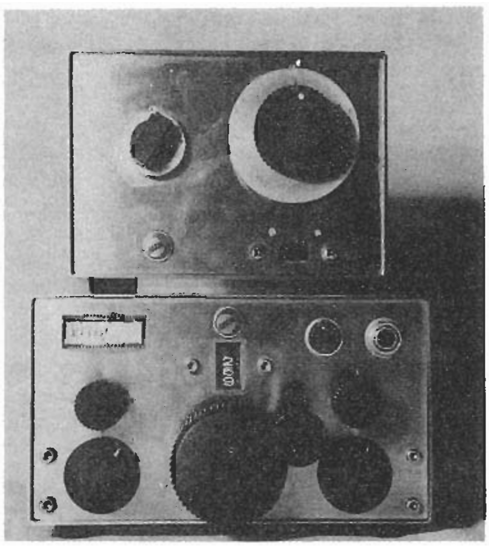


Fig. 3—The l.f. receiver shown with its h.f. converter. At the top left of the receiver is the edge reading S-meter (Japanese import), with the R.F. Gain and Preselector controls below. The crank-type tuning knob and mechanical counter are at the center, while at the right are the On/Off switch and phone jack (top), A.F. Gain, and Frequency (calibration reset) controls.

[3] Lee, J.G., "Mixer Spurious Frequency Analysis," *CQ*, Sept. 1965, p. 42

[4] Perolo, J., "An Analytical Approach to Mixer Spurious Evaluations," *CQ*, Aug. 1971, p. 24

and 3, and the picture at the beginning of this article give an idea of what this set looks like.

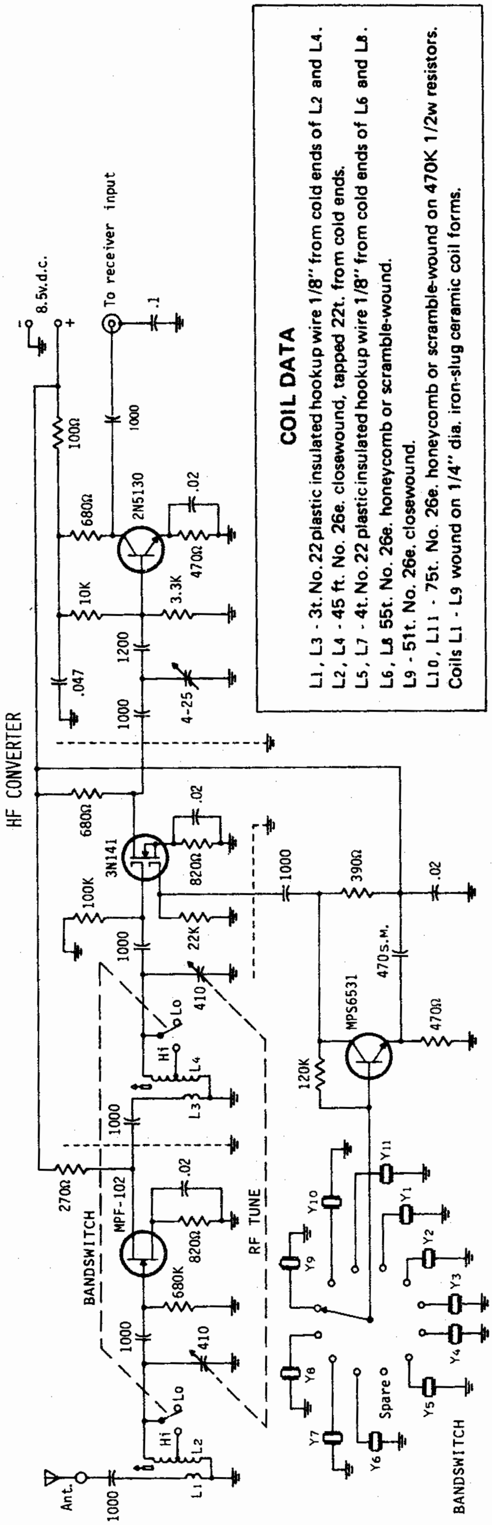
Construction Considerations

Rather than enclosing the whole works in the same cabinet, it was decided to build separately the first conversion unit as an independent h.f. crystal converter, feeding a low frequency monoband receiver hooked after it. By so doing, with a chance for a "break" between the converter and the receiver construction, the whole project does not expose the builder to a loss of interest throughout the assembly period, as happens at times when the undertaking is too lengthy.

As an added bonus, the crystal converter can be used separately with sets other than the one it was designed for, thus adding flexibility or resale value to it. With this purpose in mind, as a close look at the schematics of fig. 4 will reveal, the converter output is aperiodic, as to allow feeding receivers tuned anywhere up to 30 mHz; along the same line, the converter outlet allows direct connection without any modification to either positive or negative ground receivers. This is an advantage for those who, like me, got started early with transistors and have positive ground equipment at hand.

The converter (See figs. 2, 3, 5, 6, 7), as originally built, covers the 2.5-18.0 mHz range; no layout changes would be required to cover the 80 thru 15 m. bands for ham operation, only different coil windings. If 10 m. or, for that matter, 160 m. were to be added, then a different layout would become mandatory, as a different bandswitching system should be used. Since both the converter and the receiver are reasonably small, it would be wise to plan in detail in advance the component layout, so as to assure no trouble will develop at time of assembly.

The receiver v.f.o. (See figs. 8, 9, 10) linearly covers the 2,955-3,955 kHz range, and here goes another word of warning to prospective builders. To achieve frequency linearity with accuracy of half a kHz or less over this range, freedom from backlash and spurious response, signal stability and flat response requires some previous experience in the area and I would not recommend undertaking duplication of this receiver unless there is somebody around who can



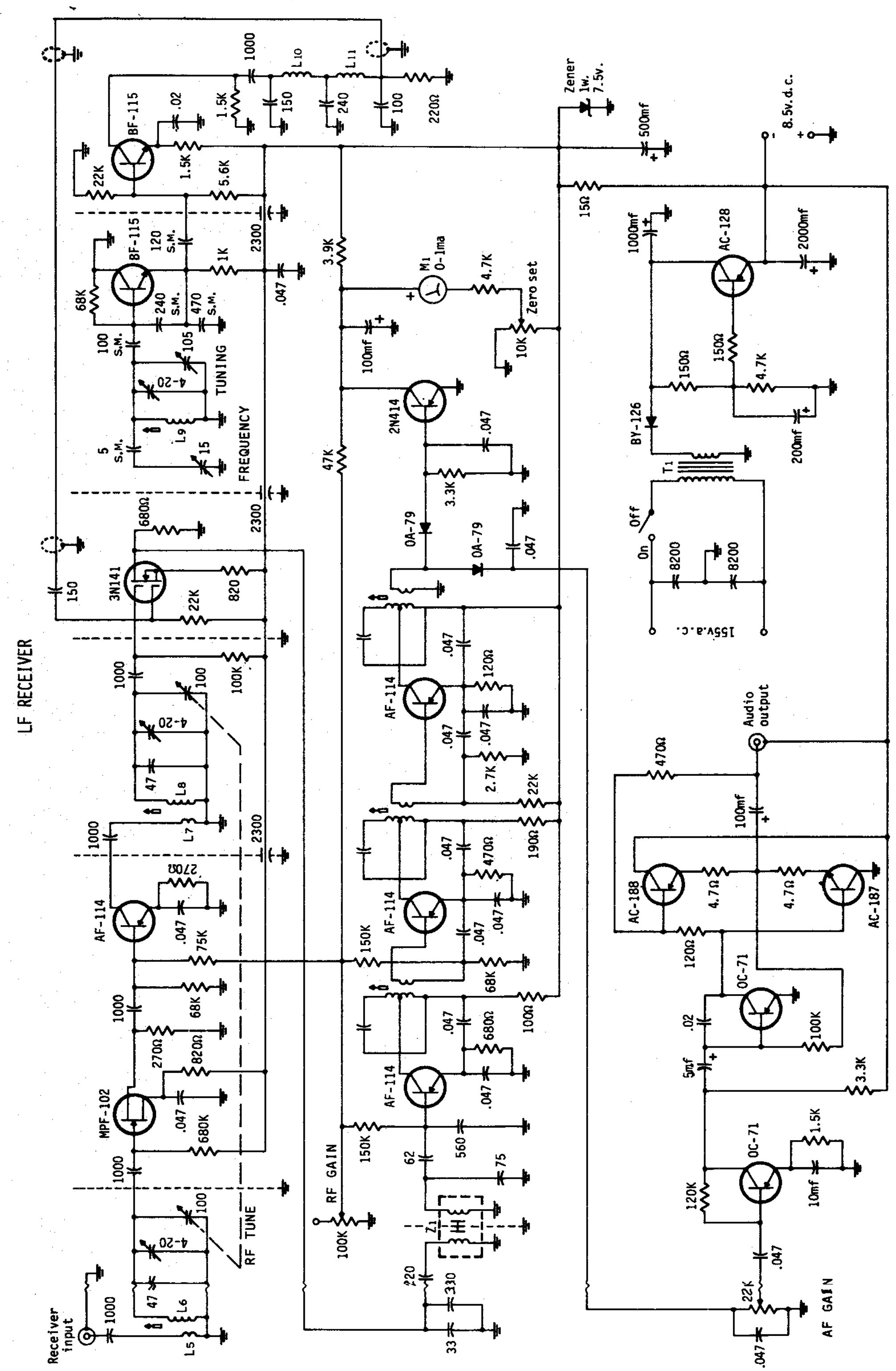


Fig. 4—Schematic of h.f. converter (page 30) and l.f. receiver (above).

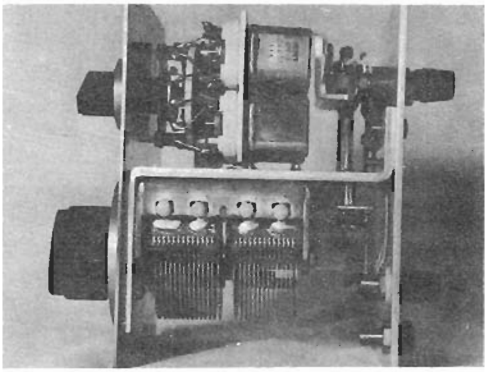


Fig. 5—Top view of the converter with the cabinet removed. The crystal bank is supported on the bandswitch, with the i.f. amplifier visible to the rear of the crystals. To the rear of the 2-gang R.F. Tuning capacitor is the r.f. amplifier stage. Jacks at the rear panel bring power from the l.f. receiver.

offer help, if needed. Breadboarding the circuit externally to get it operating temporarily prior to proceeding to the actual assembly is always quite helpful. Using a larger layout would also minimize trouble in some areas. At any rate, I'll be most happy to offer support by mail, as in previous cases; no SASE is needed.

With electronic counters becoming cheaper and with light emitting diodes replacing the heat generating display tubes, some may wonder why I still stick to mechanical counters on my receivers. The basic advantage of an electronic counter evidently being that the v.f.o. linearization is no longer needed, as an electronic counter responds directly to an electric signal whereas a mechanical counter relys on physical position principles to operate. Trouble is, an electronic counter would be at least as large as the receiver itself, and anywhere between perhaps 20 and 100 times more expensive than a mechanical counter. The addition of an electronic counter would further reduce the number of those willing to give a try at the project. Finally, an electronic counter could always be added externally with the advantage that it could be used for other purposes and for future projects, rather than remaining a built-in feature of this particular project.

If, for any reason, the transistors used will be different from those specified, it will become mandatory to adapt the corresponding bias network to make it operate with the new active device. This is especially true for the crystal oscillator, as explained below.

Construction Details

The cabinets and front panels are built out of 16 gauge AISI 304 stainless steel. Even though stainless steel is difficult to work and even special tools suffer from it because of its mechanical characteristics, there are advantages: the finishing is superb, and the equipment never loses its "brand-new" appearance. Scratches with nails or dusting simply do not exist. The extra time needed to build the cabinets out of stainless steel is, at least in my case, more than compensated by the fact that they don't need to be painted, which is a time consuming operation.

The back panel is 3/32" aluminum, whereas the chassis is made from 1/8" aluminum sheet. All bending is done on a 16 ton press, although obviously a more than adequate job could be done with more modest equipment.

The size of the converter is about 5" w. × 3.5" h. × 4" d. while that of the receiver with the built in power supply, is approx. 6.25" w. × 3.5" h. × 7" d. The loudspeaker is an oval affair 3" × 4", housed in a cabinet measuring 4.25" w. × 3" h. × 3.25" d.; the speaker was added more as a matter if esthetics rather than of opertion, as all serious listening is done here with headphones.

All front and back panel lettering (fig. 2 3, 10,) is mechanically engraved using 1/16" high steel stamps, heavy duty type to survive stainless steel markings. The con-

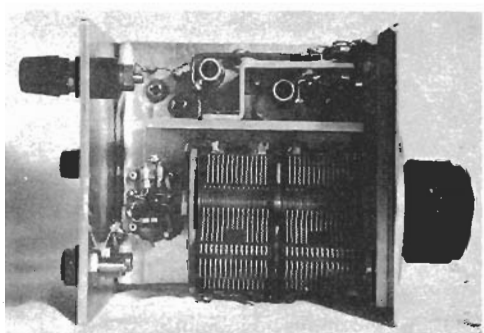


Fig. 6—Right side view of the converter, bottom up. The r.f. and mixer coils are at the top with the 1/16" aluminum plate providing shielding between the slide switch sides. Antenna input is at top left, while the power input is at bottom left.

verter knob skirts (fig. 2) are made out of ⅛" aluminum, mechanically engraved and then fastened with 2-56 screws to the knobs themselves. Obviously, in the case of the preselector dial skirt, engraving is only possible after the converter is functioning properly and calibrated, as to ensure accurate correspondence of the dial markings to the received frequency.

All shieldings are made out of 1/16" aluminum. Components are first class; the v.f.o. worm gear (figs. 8, 9) is of the "spring loaded" variety, mounted on four ball bearings. Manufactured by Bendix, this is available in the New York area as a surplus unit.

The counter is a Veeder Root affair, with three vertical digits; even though this receiver is tiltable, a vertical counter eliminates parallax problems. A three-digit unit was preferred since, because of the extended coverage of the receiver, only the hundreds, tens and units of kHz are read on the counter; the tens and units of megacycles are read on the converter bandswitch.

The tuning rate is 25 kHz/revolution, which is reasonably comfortable. A crank tuning knob is recommended to allow for fast band excursions. The v.f.o. variable capacitor (figs. 8, 10) is a low torque unit with ball bearings at both ends, coupled with a flexible joint to the worm gear. The S-meter is a Japanese import, held in place by a rear bracket to avoid showing its fastening screws on the front panel.

With reference to the converter, the crystals are HC6U type, with 11 sockets installed on the bandswitch that supports an

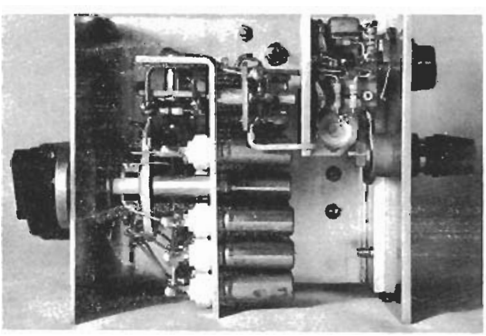


Fig. 7—Left side view of the converter, bottom up. The L-shaped aluminum bracket fastened to the bandswitch holds the 11 crystal sockets. The oscillator sub-assembly is above the bandswitch (inside the L bracket), while the mixer sub-assembly is to the right of the bracket, above the crystals. The buffer stage is at top right, feeding the RCA jack at its right.

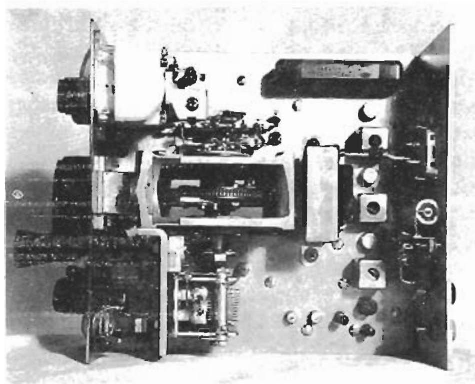


Fig. 8—Top view of the receiver with the cabinet removed. At center the worm gear unit supports a sub-chassis with the v.f.o. capacitor fastened to it. The counter is between the worm gear and the front panel. Right above the worm gear is the RF_2 and RF_3 circuitry. The i.f. strip runs from top to bottom at the right, along the back panel; the Collins mechanical filter is at the top of the IF strip, while at the bottom are the four audio transistors and the a.v.c. amplifier stage. The power transformer is to the immediate right of the worm gear.

L shaped bracket with the whole sub-assembly.

The r.f. two-gang capacitor is a 2 × 410 pf affair with built-in 6:1 vernier. Output from the receiver to the converter goes via coaxial cable, and RCA jacks and plugs.

In both the receiver and the converter, the cabinet is built in two halves kept in place by ⅛" × ¾" brass spacers (not shown in the pictures), fastened by 4-40 plated binder head screws.

Circuit Considerations

The block diagram of this receiver is shown in figs. 11 and 12.

Notice the concepts used for the front end: since miniaturization of the unit was a point of primary interest, the same set of coils is used for both the Lo and Hi positions. By shorting part of the coil winding out, the higher part of the band is covered. These coils must be definitely breadboarded using components locally available to make sure that the slugs show good performance on both bands or else a deterioration of sensitivity will occur.

Both RF_1 and MIX_1 are FET's because their inherent advantages in these applications.

The crystal oscillator circuit is critical, as no tuning coils were used on it. Because of its wide frequency excursion capability (2-20 mHz), this circuit requires careful adjustment to make sure that it oscillates throughout the band, delivering a reasonably flat signal response. A frequency counter comes extremely handy at this point. The output buffer helps matching the mixer output impedance to the receiver input impedance; depending on the coaxial cable length and the output frequency (when the converter operates, for example, with a receiver different from that described), proper matching makes quite some difference. A trimmer is provided for this purpose. Provisions are also made to pull an a.v.c. signal from the receiver to RF_1, if so preferred.

Looking at the receiver block diagram (fig. 12), RF_2 and MIX_2 are also FET stages. The double gate FET's show a particularly good performance in the mixer stage. A low-pass filter between the v.f.o. and MIX_2 is a five pole affair designed to attenuate signal above 4.0 mHz.

The v.f.o. is a key piece in any communications gear. Its design was derived from prior receivers; the frequency of operation was chosen, among other considerations, by the capacitance of the variable capacitor available (105 pf), that is later further reduced when, in order to linearize the v.f.o., the capacitor plates are filed down, losing about 20-30% of its initial capacitance.

The mechanical filter has a nominal bandpass (at 6 db down) of 2.1 kHz. The 3 i.f. stages that follow are rather conventional, using germanium transistors. There is no doubt that more modern transistors, primarily silicone, are available today, but there are different reasons for this selection. At 455 kHz, frequency cut-off has not been a problem for many years, and leakage current is not overly critical; on the other hand, this circuit has been used so extensively by the author that not only its performance is well known in advance, but also an extremely high gain is assured, without loss of stability.

The audio stages end up with a complementary pair wired to avoid transformers of any sort. Delivering about 0.8 watts, the audio level is much in excess of the need for headphones comfortable listening. The power supply is electronically regulated providing, through external connections with banana plugs, the d.c. power necessary to run the converter or any other ancillary gear.

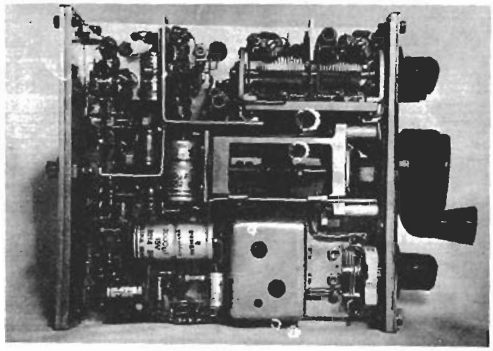


Fig. 9—Bottom view of the receiver. At the center is the main tuning gear with the bevel gear that actuates the counter on the same shaft. On top of it is a two gang variable capacitor for RF_2 and MIX_2 peak tuning. Notice shielding between stages and also between input and output of the mechanical filter, at top left. The power supply is to the left of the worm gear, the two large electrolytic capacitors being part of it. The v.f.o. can hides the v.f.o. circuit and also shields the Frequency control (bottom right) from the rest of the receiver.

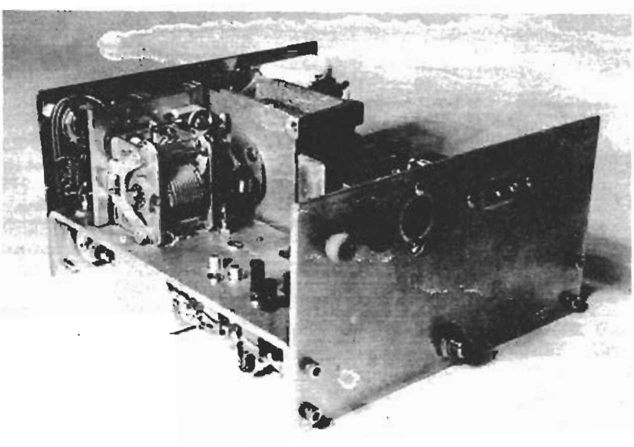


Fig. 10—Three-quarter view of the I.f. receiver, from the right rear side. The v.f.o. variable capacitor is shown fastened to its 1/8" aluminum sheet bracket; behind the bracket is the v.f.o. buffer circuitry. The v.f.o. coil is to the right of the tuning capacitor. On the rear panel are the d.c. power outlet jacks (top left), the 11-pin socket to power the converter, and the 115 v.a.c. connector. Signal from the converter is fed to the receiver via the RCA jack at the bottom center.

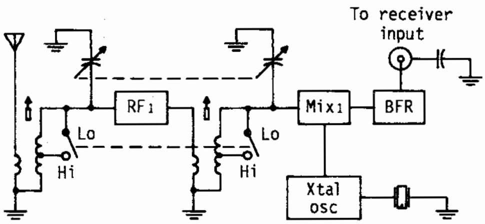


Fig. 11—Block diagram of the crystal converter.

Frequency	*S-meter reading*
Fundamental	9 + 10
2nd harm.	4
3rd harm.	2
4th harm.	0.5
5th harm.	unreadable

Table I—Five Pole V.F.O. Low-Pass Filter Attenuation.

Circuit Details

Because of the extremely high gain of this receiver, proper shielding and by-passing techniques should be used throughout to achieve stable operation. All tuned circuits are shielded from the circuitry of the corresponding active devices. Heavy filtering is used on all power lines; feed-thru capacitors in the whole front end ensure no stray coupling or ground loops take place through the power supply.

The whole v.f.o. circuit and coil are shielded; the v.f.o. capacitor is not shielded because it must be well accessible in order to allow for comfortable filing of its plates during the linearization procedure. It must be noted, though that during linearization (*i.e.*, filing) of the v.f.o. capacitor a small temporary shield must be taped or fastened to the top of the v.f.o. variable capacitor to simulate the effect of the metallic cabinet of the receiver. Failure to do so will result in losing the whole linearization job of the receiver, as the metallic cabinet (when put in place) will throw off the linearity of the v.f.o.

Another area where stray capacitances may affect performance is in the v.f.o. five pole filter. It would be convenient to check (using, for instance, another receiver) the signal strength of the v.f.o. signal on its fundamental frequency and the next five or six harmonics. The readings of Table I were obtained with the prototype, using a converter ahead of a Collins 75A-4 receiver, to check for relative harmonic strength.

What is extremely important to recall on a v.f.o. linear over one mHz is that the simple change of a wiring harness may throw out the calibration by some kHz at the band edge. Therefore, when starting the linearization of the v.f.o. capacitor, all screws, nuts, wires, components, etc. must be securely tightened in place and no circuit changes should be made during or after linearization. The easiest way to achieve perfect linearity is to file down the capacitor to within 1 kHz or so of the nominal frequency; from then on, the fine part of the linearization should be done by slightly bending and properly adjusting the side plates of the capacitor rotor. This procedure has the advantage of being a reversible one, whereas filing is not.

To avoid problems either during filing or in mobile operation, I use a lockwasher on all screws and a small drop of transparent paint. This procedure would probably not be applicable to highly experimental units, as it makes it somewhat difficult to remove screws and components that had already been set in place.

Even though the number of amplifying stages may look excessive, some design requirements are in effect keeping the gain down from what it would be possible to

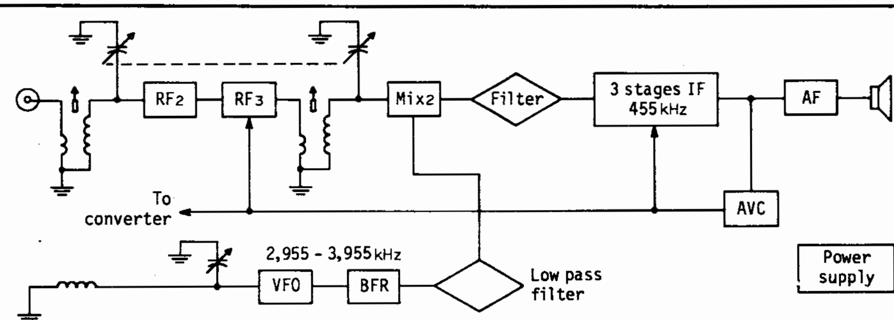


Fig. 12—Block diagram of the 2.5-3.5 mHz receiver.

achieve and what this receiver would still handle from a stability standpoint. For example, all r.f. stages have coils with loose coupling between primary and secondary winding to increase r.f. selectivity and minimize overloading effects; both the first and second mixer are operated at low gain, to avoid internal spurious generation. Consequently, a high number of stages is used in order to obtain satisfactory overall performance.

Ham Band Operation

If this receiver were to be duplicated to cover the ham bands, 80 thru 10 m., the v.f.o. should operate at a frequency approximately one mHz higher. By so doing, the 80 m. band reception would become a single conversion affair, with the converter acting as an r.f. preselector; the converter bandswitch would insert no crystal into the crystal oscillator circuit for this band, thus leaving the oscillator itself inactive. The frequency stability of the set would not suffer from this modification for ham operation, even for s.s.b. The difference in v.f.o. stability between 3 and 4 mHz is negligible. Most commercial sets use v.f.o.'s in this frequency range or even higher with satisfactory results. Consequently, the receiver input should tune 3.5-4.5 mHz or thereabout. As far as the converter is concerned, no circuit changes would be required, except that the coils should have an extra tap to allow coverage of the 10 m. band; a triple position slide switch would then be required. On this matter it is worth noting that a slide switch was initially selected because of its small size, but it is imperative to shield its sections effectively to avoid feedback; such shield is shown in fig. 6.

What might encourage the duplication of this receiver for ham band operation, however, is the fact that direct frequency readout is probably not as necessary as for operation on the SW bands. If one is willing to have direct read-out on some ham bands (say 3.5-4.0 mHz), and willing to add to the dial reading a fixed number on certain other bands (say, 500 kHz), it would then be possible to reduce the v.f.o. coverage from one mHz to 500 kHz. Among the advantages that this option offers, are that linearity is much easier to achieve over 500 kHz than over one mHz, making the v.f.o. easier to linearize. Another advantage is that using the same worm gear to control the v.f.o., but changing the bevel gears that move the counter, one can tune instead of 25 kHz/rev. as mentioned, 10 or 20 kHz/rev., making s.s.b. tuning more comfortable. The price for this, I repeat, is that on some bands one should mentally add 500 kHz to the dial reading. Since direct frequency read-out is an extremely convenient feature, I would never consider missing it, at least for my type of operation.

Conclusions

To sum up a generalized appreciation of this project, I would classify as favorable characteristics the compact size, dial accuracy and frequency read-out, stability, selectivity (this goes to Collins' credit, though, not mine . . . .), low power drain, sensitivity and a reasonably flat frequency response over the bands. Also the MTBF (Mean Time Before Failure—a measure of reliability) is way up when compared to tube sets, and about 2.5 times better than the HRO-500.

Some aspects that are not so favorable are that, at least in the US, for $220 one can buy a used set in reasonably good condition, with more diversified features and a higher resale value. If space is not a premium item, by increasing the size, especially of the converter, the whole circuitry can be made more siphisticated and show a better performance. Using a standard wafer bandswitch with different coils for each band and also tuning the crystal oscillator output to MIX_1 will definitely improve the performance of the set. This will lead to a converter about the same size of the receiver itself.

I will not comment on spurious response, because it is all Alan's fault: I did my best to stay away from them, but those that are there (as they *are* on *any* commercial multiband set) should be charged to Alan's account. After this, I guess, I will be left alone to continue my crusade for those superbly spurious free and outstanding flat response receivers that are the monobanders.

Acknowledgement

Good ole Maiso, PY2GP has been so generous, helpful and patient over the years that I could never close down without mentioning his continued support to these projects. Tommy, PY2DFR gets the credit for the pictures. All the errors left I claim as my own. ■