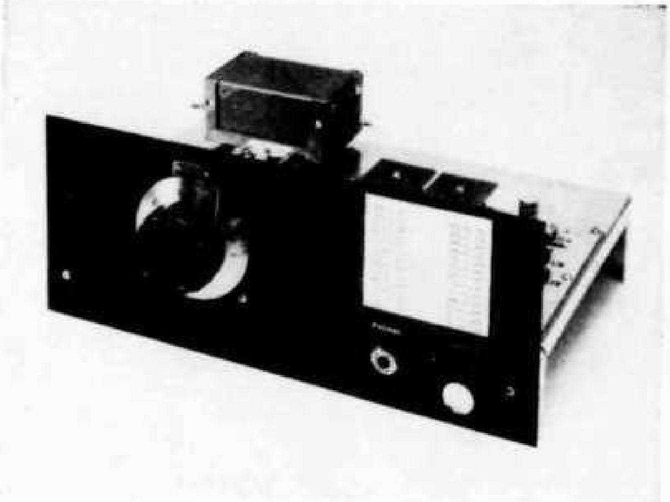
The D.C. 80-10 Receiver

BY DOUG DEMAW,* W1CER



Front view of the direct conversion receiver. The panel is finished in machine gray spray paint. The two controls are main tuning and audio gain.

THE D.C. 80-10 should appeal to those amateurs who are interested in building practical solid-state equipment. This receiver operates from 12 volts d.c. and draws only 40 ma. These modest power requirements suggest that it could be operated for long periods from a flashlight-cell battery pack, an important consideration during portable and emergency operations.

A 0.3-μv. c.w. signal can be detected easily on all of the ham bands covered by the receiver. Ample audio output is available to drive high-impedance phones to a comfortable listening level, on weak signals. Since there is no warm-up drift after approximately 10 seconds, good stability can be expected. A 2.5-kHz. toroidal audio filter provides suitable selectivity for copying a.m. and s.s.b. signals, even when the bands are crowded. Though the receiver operates nicely on c.w., additional audio selectivity could be added "outboard" by those who desire a narrower passband.

By using the direct-conversion approach in this design[1] complexity is greatly minimized. A product detector is used as the first stage of the receiver for 80-meter reception, and serves as the input stage of a tunable-i.f. receiver when the plug-in converters of Fig. 2 are used for receiving the four higher bands. The detector is used in combination with a b.f.o. which tunes the same range covered by the detector — 3.5 to 4 MHz. Audio output from the detector is passed through the 2.5-kHz. toroidal filter, then is amplified to headphone level by a single audio stage. Performance is comparable to that of a superhet except that single-signal reception (in which the audio image is eliminated) is not possible, nor is there any automatic gain control. Because of the simplicity of the circuit, and because there are only two operating controls, beginners should have no problems in building and using this receiver. The b.f.o. is always in operation, but a.m. signals (if they are stable) can be copied as easily as they are on a standard s.s.b. receiver.

A quick price analysis showed that the main section of the receiver costs approximately $26, minus the circuit board, if all components are purchased brand new. The converters cost approximately $12 each, less circuit board, when new parts are purchased. Naturally, the workshop "goodie" trove should provide many of the parts required, thus greatly reducing the total cost.

Circuit Information

Though the circuit of Fig. 1 may appear somewhat involved, it isn't. There are only three stages in the main receiver section — an integrated-circuit detector, U_1, a JFET b.f.o., and a bipolar-transistor audio amplifier. The input tuned circuit, consisting of L_2 with C_1, C_2 and C_{3A}, covers the range 3.5 to 4 MHz. Light coupling is used between the tuned circuit and the detector input to minimize spurious responses from strong out-of-band signals, especially those of commercial broadcast stations. (Heavier coupling caused cross modulation to occur when the receiver was used in the vicinity of some local broadcast transmitters.)

The b.f.o. operates over the same range as the detector, and the two stages are gang-tuned by means of C_3. The b.f.o. signal from Q_2 beats

Here is a direct-conversion receiver that is easy to build, uses semiconductors throughout, and provides ham-band-only reception from 3.5 to 29.5 MHz. with excellent stability and sensitivity. Circuit-board construction assures neatness and helps to minimize mechanical and electrical instability.

* Assistant Technical Editor, *QST*.

[1] Hayward and Bingham, "Direct Conversion — A Neglected Technique," *QST*, November 1968.

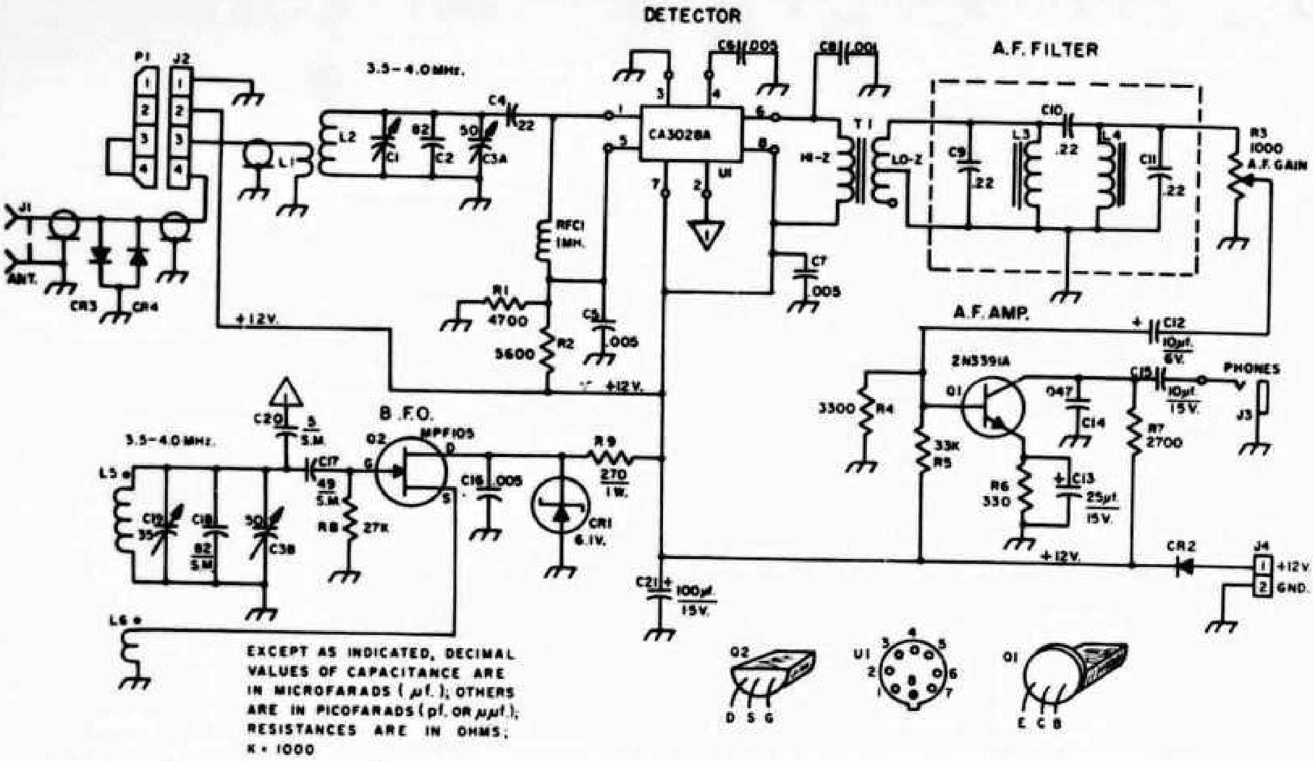


Fig. 1—Schematic diagram of the main portion of the D.C. 80-10. Capacitors with polarity marking are electrolytic. Other fixed capacitors are disk ceramic unless marked S.M. (silver mica). C_9, C_{10}, and C_{11} are dipped polyester types. Fixed resistors are ½-watt composition unless noted otherwise. Component numbers not listed below are for identification purposes on the circuit board.

C_1—3-30-pf. compression trimmer.

C_3—Split-stator variable, 50 pf. per section (see text).

C_9-C_{11}, inc.—Dipped polyester, 100 volts (Cornell-Dubilier type DMF suitable).

C_{19}—7-35-pf. ceramic trimmer (Centralab type 827-D or similar).

CR_1—Zener, 6.2 volts, 1-watt (Motorola HEP 103).

CR_2—Silicon top-hat rectifier, 50 p.r.v., 100 ma. or higher (Motorola HEP-161 suitable).

CR_3, CR_4—Small-signal silicon switching diode (1N465A or similar).

J_1—SO-239-type chassis connector; phono jack also suitable.

J_2—4-pin tube socket.

J_3—Single-circuit phone jack.

J_4—Male two-terminal chassis connector (Switchcraft 5501MP or similar).

L_1—6 turns No. 24 enam. wound over L_2 to occupy ⅓ of core.

L_2, L_5—36-inch length of No. 24 enam. on Amidon* T-68-2 toroid core; 45 turns total.

L_3, L_4—88-mh. toroid (see *QST* Ham Ads for suppliers).

L_6—14 turns No. 24 enam. wound over L_5 to occupy entire circumference of core. *Observe polarity.*

P_1—Base from discarded 4-pin tube, or jumper made from two banana plugs.

Q_1—Low-noise a.f. preamplifier transistor, n-p-n silicon, high beta rating.

Q_2—N-channel JFET, 30-MHz. rating or greater (Motorola MPF105 or HEP 801).

R_3—1000-ohm linear-taper carbon control.

RFC_1—1-mh. r.f. choke (Millen J300-1000 or similar).

T_1—10,000-ohm primary to 1000-ohm secondary driver (Lafayette Radio 99T6124; use ½ of secondary).

U_1—RCA CA3028A integrated circuit.

* Amidon Associates, 12033 Otsego St., North Hollywood, Calif. 91607

Converter Coil—Capacitor Table

Band (MHz.)	*Osc. (MHz.)*	L_7 *(Turns)*	L_8 *(μh.)*	*Miller No.*	C_{22} *(pf.)*	L_{10} *(μh.)*	*Miller No.*	C_{28} *(pf.)*	C_{29} *(pf.)*
7-7.5	11.0	7	9.4-18.7	42A155CBI	33	1.7-2.7	4503	220	150
14-14.5	10.5	3	3.6-8.5	42A686CBI	25	1.7-2.7	4503	220	150
21-21.5	17.5	3	2.12-4.10	42A336CBI	15	1.7-2.7	4503	100	100
28.5-29	25	3	1.3-2.7	42A226CBI	15	0.44-0.76	4501	100	100

Capacitors C_{28} and C_{29} should be silver mica for best stability. Miller parts can be ordered from J. W. Miller Co., 5917 South Main St., Los Angeles, California 90003, or from authorized J. W. Miller distributors. L_7 is close-wound over ground end of L_8 using No. 24 enam. wire.

against the incoming signal to furnish a beat note for c.w. reception and to provide a carrier for copying s.s.b. signals. Zener-diode voltage regulation is used in the drain supply to Q_2, to enhance the stability of the receiver.

Audio output from the detector is passed through a 2.5-kHz. bandpass filter which uses two telephone-type surplus 88-mh. toroids.[2] Output from the filter is routed to the gain control, R_3, which terminates the filter in its characteristic impedance. A bipolar transistor, Q_1, amplifies the audio signal to headphone level. The a.f. amplifier is designed for use with high-impedance phones, 1000 ohms or greater. A polarity-guarding diode, CR_2, prevents damage to the circuit components in the event the power supply is connected for the wrong polarity. It will conduct when positive voltage is applied to its anode, but is nonconducting with negative voltage.

For 80-meter operation a jumper plug, P_1, is inserted into J_2, the converter socket. P_1 completes the antenna circuit by shorting terminals 3 and 4 of J_2, and the receiver operates straight through. Plug-in converters are attached to the receiver at J_2 for 40-, 20-, 15-, and 10-meter operation. This results in a double-conversion arrangement, the main portion of the receiver being a tunable i.f. system. Diodes CR_3 and CR_4 conduct at approximately 0.6 volt to offer burn-out protection to U_1 during 80-meter reception. When operating the four higher bands the diodes protect the mixer FET in the converter being used. This precaution is necessary when the receiver is to be used near or in combination with a transmitter.

The circuit for the converters is shown in Fig. 2. Each consists of an FET mixer, Q_3, and a fixed-tuned FET oscillator, Q_4. A crystal-controlled oscillator was considered, but in the interests of economy a self-excited oscillator was used. It is very stable and is easy to adjust. Though Zener-diode regulation is not used on the drain-supply line to the converter, it could be added if desired. This would entail the addition of a 100-ohm 1-watt resistor and a 9.1-volt Zener diode. The Zener diode and dropping resistor would be connected to the circuit in a like manner to that used at Q_2 in the main receiver. The two components could be connected to the converter socket, J_2, under the main chassis, at pin 2.

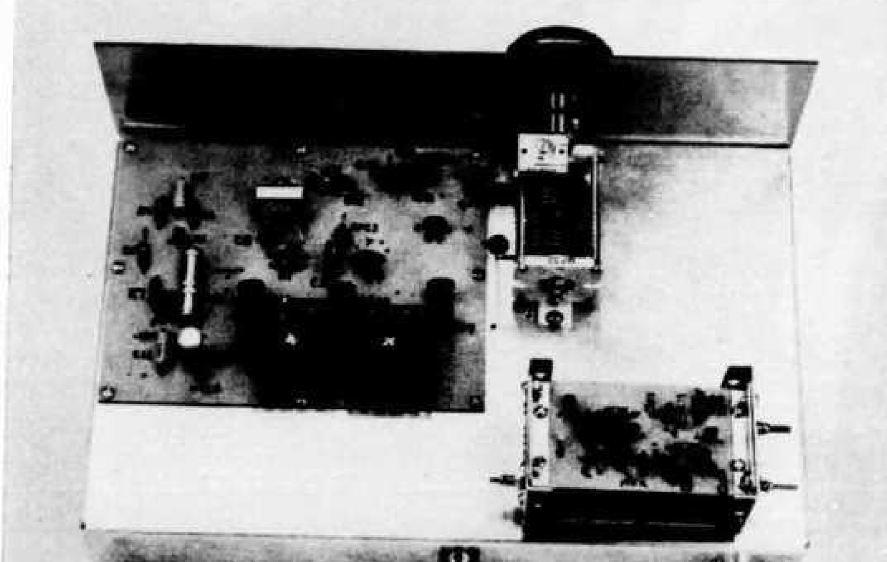
Construction Notes

A hand-made aluminum chassis and panel are used as a foundation for the receiver. Since the chassis is 2 inches high, 11 inches wide, and 7 inches deep, a Bud AC-407 can be substituted. The panel is 11 inches long and 4½ inches high. The chassis is larger than necessary, but the unused areas provide space for additional circuits that may eventually be added, such as an audio amplifier board for speaker operation. If the builder wishes to make the receiver smaller in size, it should be a simple matter to rearrange the components accordingly.

Though etched-circuit construction[3] is shown here, there is no reason why point-to-point wiring cannot be used. (Examples of both wiring methods are shown in Fig. 3. The circuits are the same, one converter being built for 40 meters and the other for operation in the 20-meter band.) The integrated circuit, U_1, is mounted on the foil side of the circuit board by means of a 10-pin integrated-circuit socket (Motorola HEP 451).

[2] Uncased 88-mh. telephone-type toroids are usually listed in *QST* Ham-Ads. Many surplus houses handle them too.

[3] Ready-made circuit boards for this receiver can be obtained from Stafford Electronics, 427 S. Benbow Rd., Greensboro, N. C. Also, Foto-Etch Co., 1760 Santa Maria Drive, Concord, Calif. 94520. Scale templates are available from ARRL for 25 cents.



Looking at the top of the chassis, the plug-in converter (its cover removed) is installed at one corner of the chassis. The main circuit board is located near the front panel and is mounted over a chassis cutout. Unused space remains for the addition of circuit refinements later on.

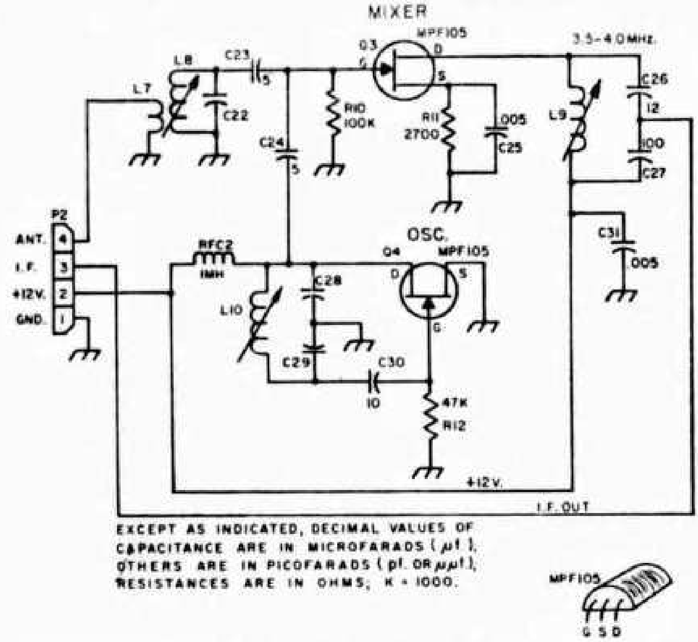
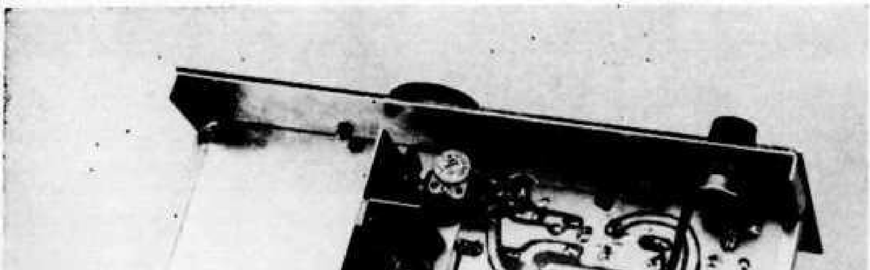


Fig. 2—Schematic diagram of the plug-in converters. These units can be used with any communications receiver that covers the 80-meter band. Capacitors are disk ceramic unless marked S.M. (silver mica). Numbered components not listed below are for circuit-board layout identification.

C_{22}, C_{28}, C_{29}—See coil table.
L_7, L_8, L_{10}—See coil table.
L_9—120 to 190-μh. variable inductor (J. W. Miller 4512).
P_2—4-prong plug mounted on converter box (Amphenol 86-CP4 or equiv.).
Q_3, Q_4—N-channel JFET, 30-MHz. rating or higher. (Motorola MPF105 or HEP-801.)
RFC_2—1-mh. choke (Millen J-300-1000 or equiv.).

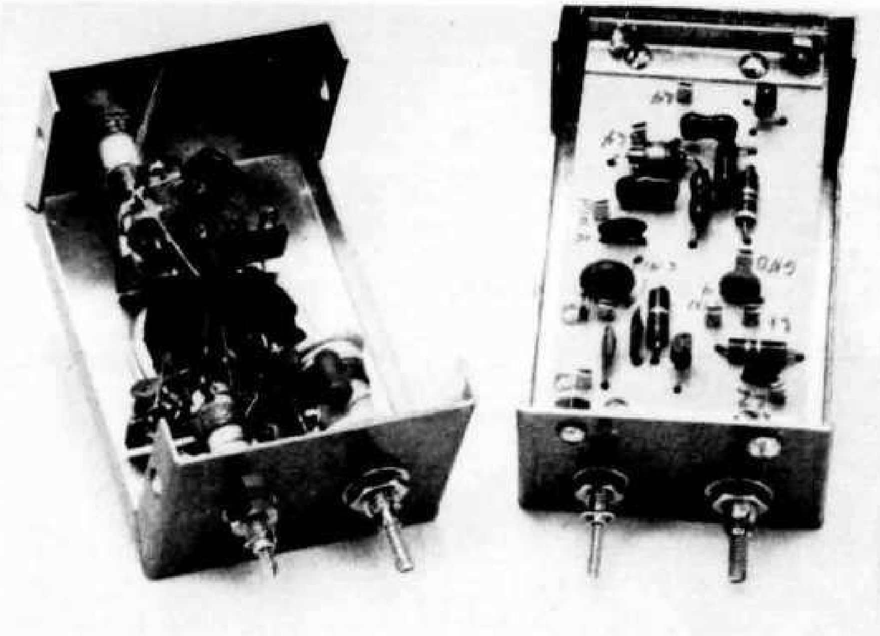
The pins of the socket are bent out at right angles from the base, then are soldered to the foil elements of the board. The IC can be soldered directly to the board if desired, but the use of a socket is recommended to prevent damage from heating during installation.

Toroidal inductors L_3 and L_4 are attached to the main circuit board by means of 6-32 × 1-inch machine screws and hex nuts. A small square of insulating board is used on each toroid as a retainer. Spaghetti tubing is slipped over each mounting screw so that the screw threads cannot damage the coil windings. Similarly, the r.f. toroids, L_2 and L_5, are mounted on an under-chassis aluminum bracket, but each coil has two squares (top and bottom) of insulating board



Looking into the bottom half of the chassis, the integrated circuit, U_1, is at the center of the main circuit board. An aluminum bracket and divider holds toroidal coils L_2 and L_5. The coil leads connect to terminal strips which are mounted in front of the bracket. Twisted-pair hookup wire connects the antenna lug on the converter socket to input link L_1. Diode CR_2 is mounted on a terminal strip near the 12-volt input jack (J_1) near the rear apron of the chassis (center). Diodes CR_3 and CR_4 should be mounted directly at J_1 (not shown here).

Fig. 3—Photo of two of the plug-in converters showing how point-to-point wiring compares to etched-circuit construction. The converters are built in 3¼ × 1⅝ × 2⅛-inch Miniboxes. The three slug-tuned coils mount on the ends of the boxes. In the circuit-board version, the coils are below the board.



to hold it in place. The bracket (see photo) is made of aluminum sheet, 3 inches wide and 1¾ inches high. A 1-inch wide aluminum divider helps isolate the oscillator coil, L_5, from the detector coil, L_2. Though the toroidal inductors are self-shielding, the divider was added to help reduce capacitive coupling.

A transistor socket is used for Q_2; it was installed to permit various types of FETs to be tried in the circuit. Q_1 is soldered directly to the circuit board, but a socket can be put there if the builder wishes to use one.

Trimmer C_1 is mounted on the frame of C_{3A} between the rotor lug and the stator rod. Though an E. F. Johnson 167-52 is used for C_3 in this model almost any miniature 50-pf. split-stator capacitor can be used. A less expensive and more compact tuning capacitor would be the Hammarlund HFD-50, or the James Millen 21050RM. The primary requirement, as in any good receiver, is that the shaft of the capacitor turn freely and smoothly, and that the rotor bearings make positive contact with their connecting lugs.

In this model an imported tuning dial provides the vernier action for the tuning capacitor. Though low in cost, the dial mechanism works well. Some backlash was noted initially, so the unit was taken apart and inspected, and it turned out that the simple remedy was to flow solder over both sides of each of the three brass pivots on which the dial-drive wheels are mounted. Each has a peened roller shaft for its bearing, and some slack was noted at each point. The addition of the solder secured the three bearings, thus correcting the backlash. A 100-watt iron will be needed. Some other dials of the same manufacture were tried and showed no backlash. If you get a good one, fine. If not, the cure is a simple one. A good substitute dial drive would be one of the precision verniers taken from a war-surplus TU-6B-series tuning unit — available from many surplus houses for a nominal price.[4]

There is room under the chassis to mount eight size-C flashlight cells by means of an aluminum bracket. Series connected, the batteries will provide the required 12 volts d.c. for the receiver. If this is done, an on-off switch can be added to the gain control, R_3.

Preliminary Testing

It is always wise to inspect any etched-circuit board used in a new project before applying operating voltages. Make certain that there are no cold-solder joints. Inspect the board for unwanted solder bridges between the various copper elements. The next check can be made by connecting an ohmmeter between the *circuit* side of CR_2 and chassis ground. With a v.t.v.m. the d.c. resistance in this model is 170 ohms. With the test prods reversed a reading of 80 ohms was noted. The ohmmeter tests should be made with one of the converters plugged in, and with all semiconductors in their sockets. Any significant departure from these readings will indicate a bad component or a wiring error.

Connect +12 volts to J_4 after inserting jumper plug P_1 into J_2. Tune in the signal from Q_2 on the 80-meter band of a ham receiver. (It may be necessary to connect a short wire to the antenna post of the monitor receiver, placing its free end near Q_2 in order to pick up the signal.) Adjust C_{19} so that the signal is heard at 3.5 MHz. when C_3 is fully meshed. With the plates of C_3 fully unmeshed the signal from Q_2 should be heard at 4 MHz. Actually, there should be some overlap at each end of the band, providing a tuning range of approximately 3495 kHz. to 4005 kHz. If

[4] Available from Fair Radio Sales, Lima, Ohio. Catalog gives complete listing of available tuning units.

Q_2 does not oscillate, check to make sure that L_5 and L_4 are phased correctly as shown by the two black dots in Fig. 1. Both windings must be put on the core the same way; that is, both can be wound either clockwise or counter-clockwise, but not in opposite sense to one another.

After aligning the b.f.o., connect an antenna to J_1 and tune in a signal near the center of the 80-meter band. Adjust C_1 for peak signal strength. This will permit the detector and b.f.o. tuned circuits to track across the entire tuning range. Since there is no a.g.c. circuit in this receiver strong signals will overdrive the audio amplifier, Q_1, if the gain control, R_1, is set too high. Backing it off slightly will correct the problem, should it occur.

A plug-in converter can now be substituted for P_1 at J_2. Its oscillator signal can be monitored on a general-coverage receiver during alignment. When this is done L_{10}, Fig. 2, is adjusted until the required oscillator frequency is heard (see coil table). With an antenna connected at J_1, tune in a signal near the center of the band covered by the converter. Adjust the slugs in L_8 and L_9 for maximum signal response. The receiver should now be ready to use.

On 40 meters the band will tune "backwards," i.e., 7000 kHz. will tune in at 4 MHz. on the main dial, and 7500 kHz. will fall at 3.5 MHz. The other bands will tune conventionally, their low ends falling at 3.5 MHz. A calibration chart can be made up to show where the 10-kHz. points of each band fall on the tuning dial. A dial chart for the 80-meter band is pasted on the panel of this receiver, and calibration for the other four bands is carried out by means of mental gymnastics. *Note:* Other 500-kHz. segments of the 10-meter band can be turned by setting L_{10} for the proper frequency. Use the same 10-meter constants given in the coil table.

Performance

The operator of this direct-conversion receiver will be hard pressed to tell this equipment from a conventional superhet as he scans the bands. With only two controls to operate there is little to confuse a beginner. Sideband signals are tuned in the same way as with an s.s.b. receiver. The sideband being transmitted — upper or lower — will determine at which side of the signal the main dial must be set. A little practice will make this a simple procedure. A.m. signals must be tuned in at exact zero beat as is customary on an s.s.b. receiver. C.w. signals can be tuned in on either side of zero beat. The operator can select whichever side that has the least QRM on it.

Sensitivity is about the same on 80 meters as it is on the four higher bands. Stability is comparable to that of most top-quality communications receivers. Hand-capacitance effects are minimal, eliminating the need for a shield around the main tuning capacitor.

Radiation from the 3.5 MHz. oscillator is low because of the low power level at which Q_2 operates — 6.1 volts at 4 ma. U_1 offers additional isolation between the antenna and Q_2. The oscillator signal should be heard only in the immediate neighborhood of the operator's home. Enclosing the receiver in a metal cabinet should further reduce radiation.

The total current drawn by the receiver, converter installed, is only 40 ma. This means that many hours of operation can be expected from a flashlight battery pack connected to give 12 volts. Penlight cells are not recommended because of their low capacity. This receiver is suitable for any class of ham station, and should not be overlooked as part of a homemade portable or emergency station, especially if battery operation is a prime consideration. QST

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