

The Neophyte Receiver

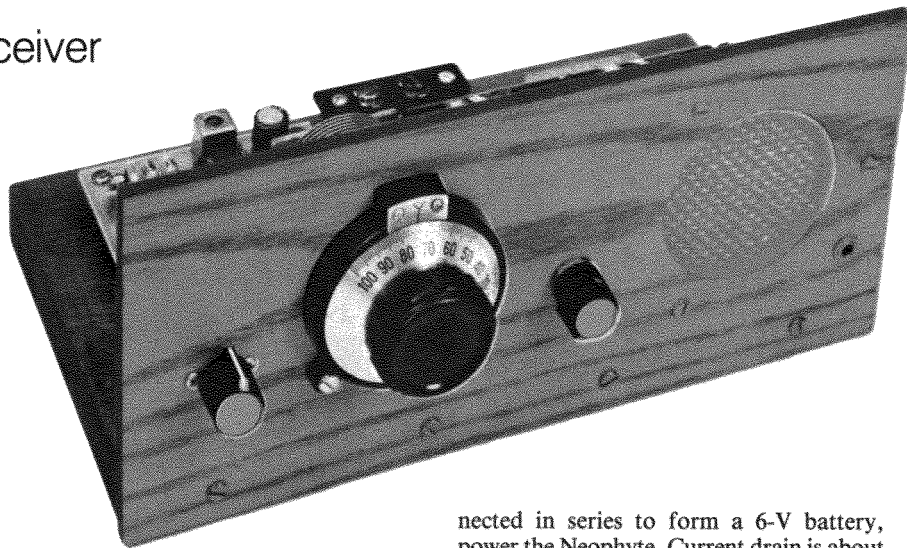
QST February 1988, pp. 14-18

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The Neophyte Receiver

Looking for a simple receiver to tune the 80- or 40-meter ham bands? Build the Neophyte!

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It doesn't take long for prospective hams to discover that there's much more excitement in hearing real signals than listening to "canned" code from a tape or computer program. After all, getting on the air and working with *real* radio is the object of getting an Amateur Radio license! Here is a simple 80- or 40-meter receiver that can bridge the gap between a code-practice machine and your first transceiver by giving you on-the-air listening experience. Dubbed the Neophyte, it's been designed with the needs of the neophyte (beginner) in mind, but will find favor with long-time hams as well.

The Neophyte uses two ICs to receive CW, SSB and AM signals in the 3.5-4.0 or 7.0-7.3 MHz ham bands. It's battery-powered, and most of its circuitry fits on a circuit board just 1-7/8 × 2-5/8 inches in size. The Neophyte's frequency stability allows copy of SSB and CW signals for hours without retuning, and it's sensitive enough to detect signals of less than 0.5 microvolt at its antenna terminals.

How the Receiver Hears

The Neophyte is a *direct-conversion* (D-C) receiver. A D-C receiver converts radio signals directly to audio by mixing the incoming signal with a local oscillator (LO) operating very close in frequency to the incoming signal. The mixing process has this effect: Whenever the LO is tuned so that the frequency difference between it and an incoming radio signal is in the audio range—a few hundred to a few thousand hertz for usable CW, SSB and AM reception—the frequency difference appears at the mixer output as an audio signal. Example: For an incoming Novice CW signal operating at 3737.0 kHz, setting the Neophyte's LO to 3737.6 kHz (a difference of 0.6 kHz, or 600 Hz) will allow you to hear that CW signal as dots and dashes at a 600-Hz pitch. (You could also set the Neophyte's LO to 3736.4 kHz,

600 Hz *below* 3737.0 kHz, to receive the same signal at a 600-Hz pitch.) AM and SSB signals are received by tuning the Neophyte's LO to zero beat—zero frequency difference—with the incoming carrier (or suppressed carrier, in the case of SSB signals). The Neophyte converts the modulation on these signals to audio.

The Neophyte does its D-C job with just two active devices, both of which are ICs. The receiver's *front end*—the RF-handling circuitry from the antenna to the mixer, inclusive—consists of a Signetics NE602N mixer/oscillator IC. The NE602's 8-pin mini-DIP (*miniature dual inline package*) contains bipolar-transistor LO and doubly balanced mixer stages, and a voltage-regulator circuit. The mixer circuitry provides 20 dB of *conversion gain*. This means that the power of an incoming signal is amplified 100 times as the signal is converted to audio by the NE602's mixer and LO.

The other active device in the Neophyte is a National Semiconductor LM386N-1 audio amplifier IC, also contained in an 8-pin mini-DIP. This IC provides 46 dB (power gain, 40,000) of audio amplification to drive headphones or (in a quiet room) a 2¼-inch speaker. Four "C" cells, con-

nected in series to form a 6-V battery, power the Neophyte. Current drain is about 10 mA at low audio-output levels.

Fig 1 shows the schematic diagram of the Neophyte. If you'd like to learn the function of each component in the schematic, see the sidebar, "Signal Flow in the Neophyte." You needn't wade through signal flow, however, if you just want to do what we're going to do next: *build* the Neophyte.

Building The Neophyte

Fig 2 shows a rear view of the Neophyte. Most of the receiver's components are contained on the circuit board. Fig 3 shows the etching pattern for the board; parts placement is shown in Fig 4A. The Neophyte's "cabinet" consists of a 4½- × 8¼-inch piece of ¼-inch-thick pine (base) and a 4- × 8½-inch piece of ¼-inch-thick particle board, plywood or similar material (front panel). The base can be stained or painted as desired; alternatively, a metal or plastic cabinet can be used to house the Neophyte, if desired.

Components

Although no exotic electronic parts are required, many of the Neophyte's parts are not available at the corner Radio Shack® store. T1 and T2 are 10.7-MHz IF transformers with a 7:1 turns ratio; they have green-colored cores. Other transformers (with different turns ratios) were tried, but receiver performance suffered. Capacitors C7-C11 should be NP0, polystyrene or silver mica units for good frequency stability. At this point, you should decide what band you'd like your Neophyte to cover. The values of C7-C11 depend on the band you choose (see Table 1). For details on the differences between the 80- and 40-meter versions, study the sidebar, "Building the Neophyte for 40 Meters." In the rest of this discussion, I'll concentrate on the construction, testing and adjustment

Table 1
Neophyte Capacitor Values for 80 and 40 Meters

Band	C1	C7,C8	C9	C10	C11
80 m	330	1000	470	270	120
40 m	not used	330	120	68	150

All capacitances are in pF (1000 pF = 0.001 μF). C1 is disc ceramic; C7-C11 are NP0, polystyrene or silver mica units.

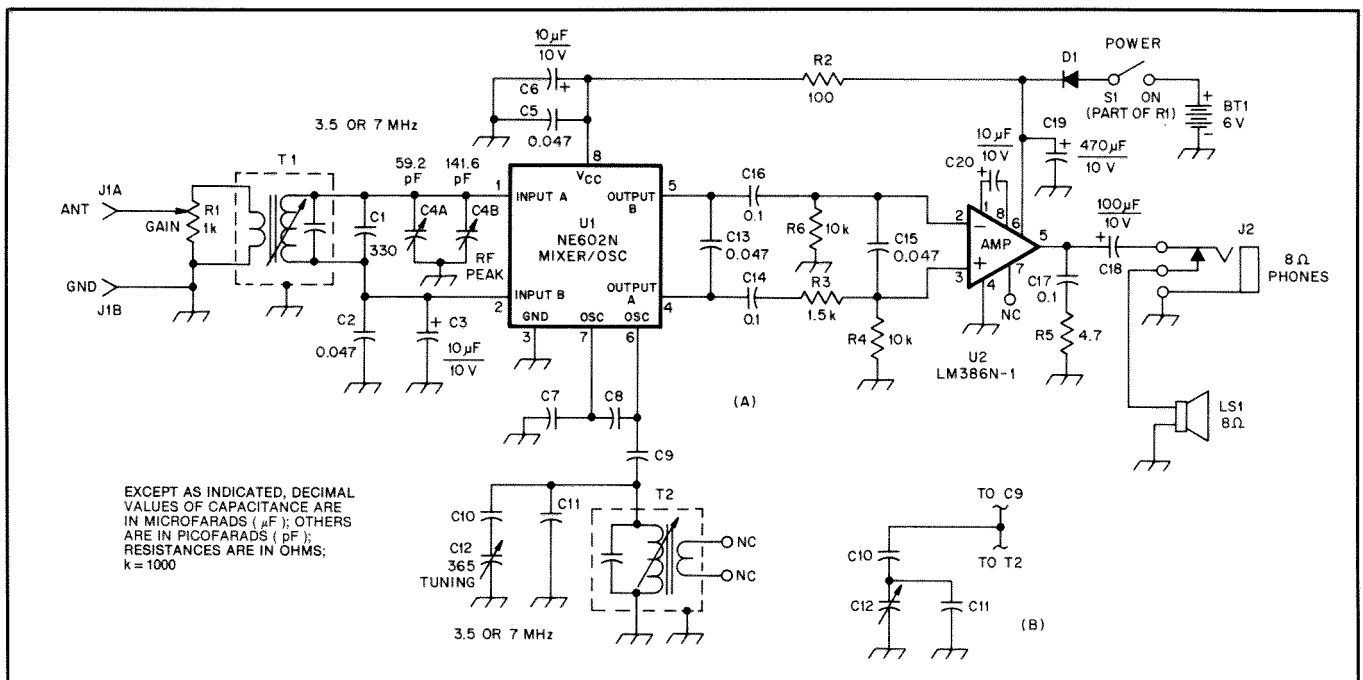


Fig 1—Schematic of the Neophyte receiver. Ceramic capacitors shown below, but not listed in Table 1, may be monolithic or disc units; fixed resistors are 1/4-W, carbon film. Component designators shown in the schematic, but not listed below, identify parts for placement on the PC board (see Fig 4). For 40-meter operation, the oscillator circuit is modified slightly, as shown at B. See text and the sidebar, "Building the Neophyte for 40 Meters." Parts kits are available from Penntek Electronics; see Note 2.

- BT1—6 V battery (four "C" cells connected in series).
- C1—Ceramic. This capacitor is not used, or is changed in value, for 40-meter operation—see "Building the Neophyte for 40 Meters."
- C2, C5, C13, C15—0.047- μF polyester film or ceramic. (0.01 μF also suitable for C2 and C5).
- C3, C6, C20—10- μF aluminum electrolytic, 10 to 25 V.
- C4—Two-section, polyethylene-dielectric variable; sections 59.2 and 141.6 pF (Mouser 24TR222 or equiv). See text.
- C7-11—See Table 1.

- C12—365-pF, air-dielectric variable (Mouser 524-A1-227, Circuit Specialists A1-227 or equiv). See text.
- C14, C16, C17—0.1- μF polyester film or ceramic.
- C18—100- μF aluminum electrolytic, 10-25 V.
- C19—470- μF aluminum electrolytic, 10-25 V.
- D1—1-A, 50-PIV silicon diode (1N4001 suitable).
- J1—Two-position terminal strip (Mouser 534-4188, Radio Shack 274-663 or equiv).

- J2—Closed-circuit phone jack, 1/8-inch.
- LS1—8- Ω speaker, diam 2 1/4 inches (Mouser 25SP024 or equiv).
- R1—1-k Ω audio-taper potentiometer with SPST switch (Mouser 31VM301 or equiv).
- S1—SPST switch mounted on R1.
- T1, T2—10.7-MHz IF transformer, 7:1 turns ratio, green core (Mouser 421F123 or equiv). See text.
- U1—Signetics NE602N mixer/oscillator IC (Arrow Electronics 9778CA2).
- U2—National Semiconductor LM386N-1 audio-amplifier IC.

Signal Flow in the Neophyte

RF energy from the antenna is fed through GAIN control R1 to the untuned, low-impedance primary winding of T1. This control actually is an RF attenuator. It can be adjusted to prevent very strong signals from overloading U1 when band conditions are especially good, or when strong local signals are present. T1's primary couples incoming signals to the tuned circuit consisting of the T1 secondary, padding capacitor C1, and RF PEAK capacitor C4. This tuned circuit provides *preselection*—it emphasizes signals at its resonant frequency and tends to reject others. The preselected RF is injected into pin 1 of the mixer/oscillator IC, U1.

The oscillator section of U1 serves as the receiver LO. Capacitors C7-C12 and the tuned winding of T2 make up the LO tuned circuit. (T2 is used as a tuned circuit in this application and not as a transformer; its untuned winding is not used.) Because the frequency stability of the oscillator determines the stability of the receiver, temperature-stable capacitors (NP0, polystyrene or silver mica types) are used to minimize drift. Energy is applied to U1 at pin 8. Capacitors C5 and C6 *bypass* U1's supply pin for ac: Their purpose is to bring the supply pin to ground potential for RF and AF signals while blocking dc. R2 helps these capacitors do their bypassing job by resisting the flow of RF and AF signals on the power-supply line. C2 and C3 are bypass capacitors, also.

Within the mixer section of U1, the LO and preselected RF signals are mixed to provide balanced audio output. The audio appears at pins 4 and 5 of U1. This signal is fed through a simple low-pass filter (C13, C15 and R3) to the inputs (pins 2 and 3) of U2, the audio power amplifier. The low-pass filter tends to pass lower audio frequencies while rejecting higher ones, hence its name. C14 and C16 are blocking capacitors: They block the flow of dc while allowing ac—in this case, audio—to pass.

R4 and R6 set the bias on the input transistors of U2. C20 sets U2's gain to 46 dB. C17 and R5 suppress unwanted HF oscillation in U2. C18 is the output blocking capacitor: Like C14 and C16, it blocks dc while allowing audio signals to pass—in this case, to headphones or speaker. C19 bypasses U2's dc-supply pin for audio. (Because C5, C6, C19 and R2 also work to reduce unwanted audio coupling between U1 and U2 along the dc supply line, they serve as *decoupling* components in the dc line. Decoupling aids stability in high-gain circuits.)

Energy for the Neophyte is provided by four "C" cells connected in series (6 V). S1 is the receiver POWER switch. Diode D1 allows current to pass in only one direction between the battery holder and the receiver circuitry, preventing damage to the receiver components should the batteries be placed in the holder backwards.

About the NE602 Mixer/Oscillator IC

The Signetics NE602 (SA602 for operation over a wider temperature range) is an IC of interest to builders and designers of low-power communications gear, particularly where low power consumption (as during battery operation) is important. Fig A shows its equivalent circuit. The '602 contains doubly balanced mixer, oscillator and voltage regulator elements. Its oscillator circuitry can operate up to 200 MHz in LC and crystal-controlled (fundamental and overtone) configurations. The '602's mixer typically can handle signals up to 500 MHz. Typical dc current drain is 2.4 mA; minimum supply voltage is 4.5, maximum 8.0.

The NE602's mixer is known as a *Gilbert cell* multiplier. (If you've ever built a circuit using a Motorola MC1496 or one of its equivalents, you've used a mixer based on the Gilbert cell.) The Gilbert cell consists of balanced switching circuitry driven by a differential amplifier; in the NE602, the amplifier inputs serve as the mixer RF inputs.

The NE602's mixer inputs (RF) and outputs (IF) can be single- or double-ended (balanced) according to design requirements. The resistance of these ports is 1.5 k Ω ; the mixer input capacitance is approximately 3 pF up to 50 MHz. The mixer noise figure is typically 5.0 dB at 45 MHz; typical conversion gain is 18 dB at this frequency. The typical two-tone, third-order intercept point of the '602 (measured at 45 MHz with 60-kHz spacing), is -15 dBm.

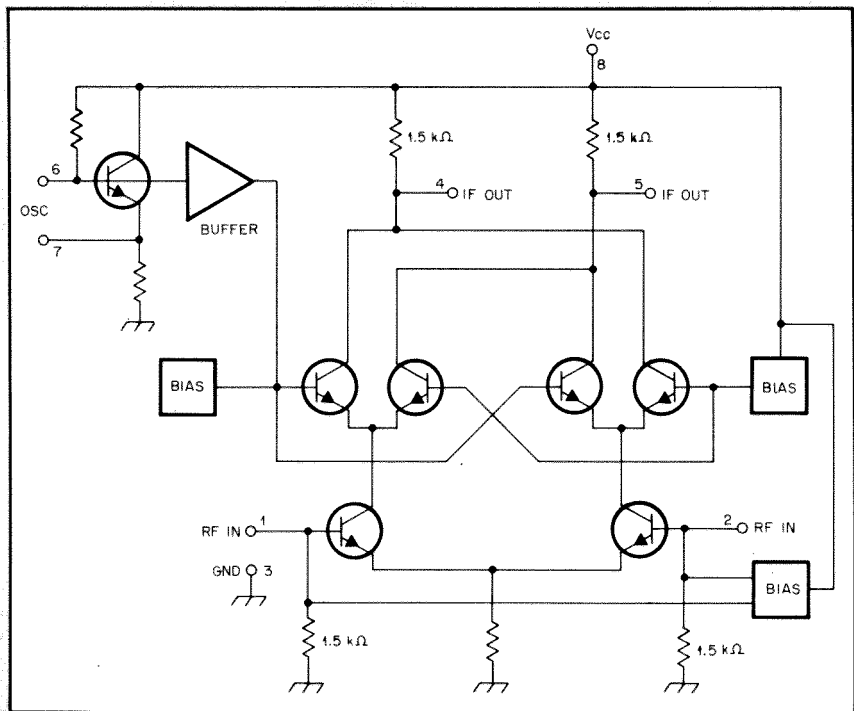


Fig A—The equivalent circuit of the NE602 doubly balanced mixer/oscillator IC.

The Neophyte uses the NE602's on-board oscillator circuitry to achieve good frequency stability at 3.5 and 7 MHz. If the '602's oscillator is unsuitable for a particular application, however, an external LO can be applied to pin 6 of the chip via a dc blocking capacitor. At least 200 mV (P-P) of external-LO drive is required

for proper operation of the mixer.—Ed.

This material is based on information in Signetics Corporation's SA/NE602 Product Specification, and in Robert J. Zavrel, "Tomorrow's Receivers: What Will the Next Twenty Years Bring?," *Ham Radio*, Nov 1987, pp 8-9, 11-13 and 15.

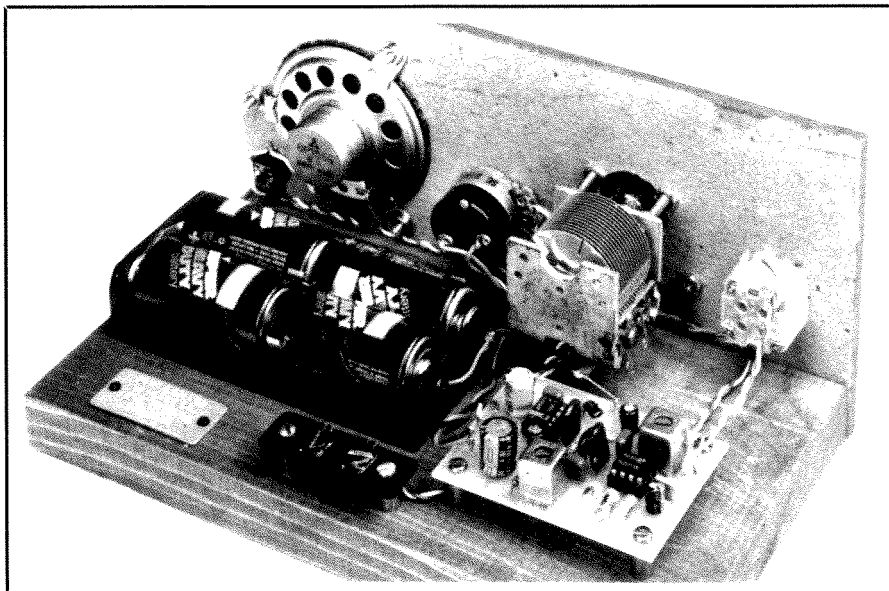


Fig 2—The Neophyte's cabinet, battery and front-panel controls dwarf its circuit board (right foreground). From left to right, the front-panel components are J2, LS1, R1, C12 and C4. The tuning capacitor mounts to the front panel by means of flat-head, 1-inch, no. 6-32 screws, and no. 6-32 nuts. The screws serve both as fasteners and mounting standoffs for the tuning capacitor (see Fig 5). The antenna terminals have been colored with felt-tip markers to indicate their function: black for the ground connection, green for the antenna.

of the 80-meter Neophyte.

The TUNING capacitor, C12, is a 365-pF, air-dielectric unit. One section of a two-section capacitor can be used at C12, but you may have some difficulty mounting such a capacitor to the front panel with the technique we'll cover shortly in "Construction." Local hamfests offer an excellent opportunity to find a tuning capacitor, as well as a reduction drive to turn it. These reduction drives are generally found in two diameters, 1½ and 2 inches. You can use either size.¹

RF PEAK capacitor C4 is a two-section, plastic-dielectric variable. Similar capacitors are commonly used in small, portable radios. The unit specified for C4 in the parts list (see the Fig 1 caption) provides a maximum capacitance of about 200 pF with both sections connected in parallel. Off the shelf, its shaft is only about ¼ inch long—too short to be useful for our purposes. The shaft can be extended by bolting a ¼-inch-diameter round standoff, ½ inch long, to the existing C4 shaft. Use a *metric* (2.5-mm-diameter) screw to match the threads in C4's shaft; the force necessary to turn a non-

¹Notes appear on page 18.

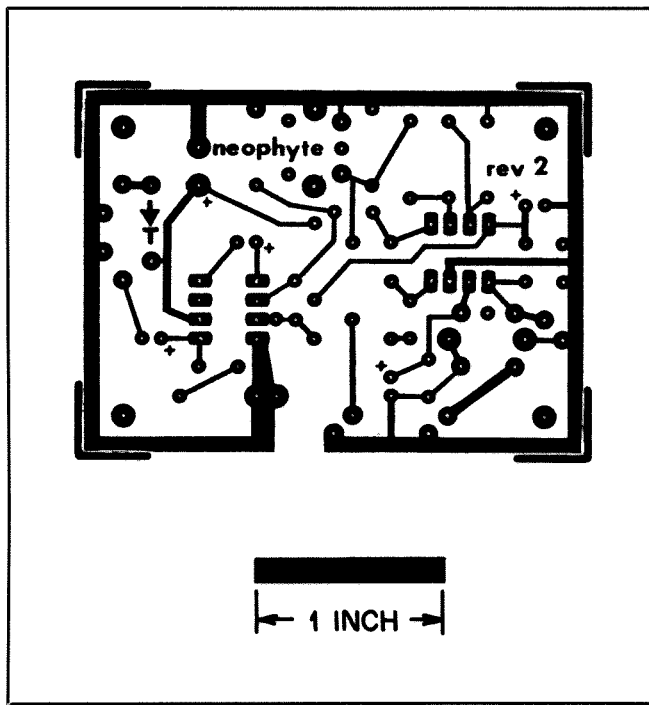


Fig 3—Circuit-board etching pattern for the Neophyte. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper foil.

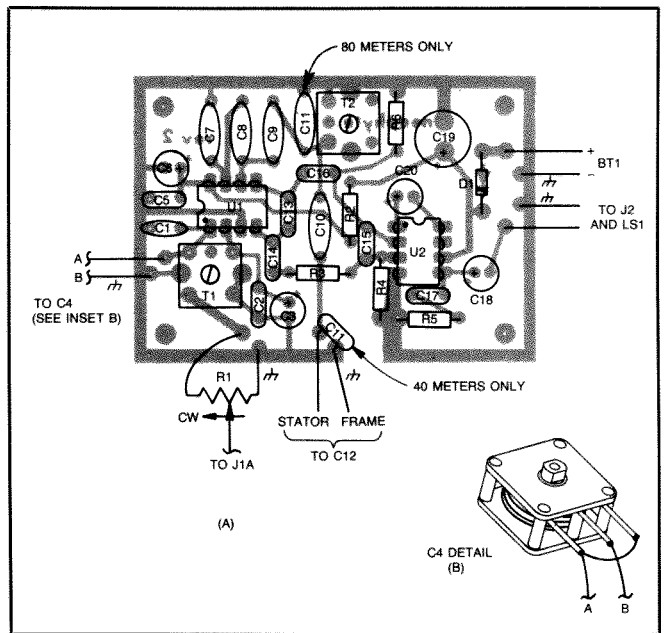


Fig 4—Parts-placement guide for the Neophyte (A) and detail of connections to C4 (B). Parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. The placement of C11 depends on whether 80- or 40-meter coverage is desired; see text and "Building the Neophyte for 40 Meters."

metric screw into C4 can destroy the capacitor. (By the way, don't be tempted to use one of these inexpensive plastic capacitors for C12, the TUNING capacitor. You would be disappointed with the tuning drift that occurs as the capacitor's dielectric sheets settle each time you tune the receiver.)

In general, it's best not to attempt parts substitutions. By using the specified parts, you stand the best chance of being rewarded with a receiver that works correctly the first time it's turned on. Etched and drilled PC boards, and complete parts kits, are available from Penntek Electronics.² The Appendix shows the addresses of parts distributors if you'd rather order direct from them. Note, however, that some of these

firms may have minimum order requirements or small-order service charges.

Construction

Building the cabinet and mounting controls and mechanical components is the greater part of constructing the Neophyte, so do this job first! Mounting the TUNING capacitor and reduction drive to the panel is the most time-consuming part of construction. The panel hole for the reduction-drive bushing must be large enough to allow rotation of the bushing and its set screw, but small enough to leave enough material to pass and hold the flat head screws used to mount the TUNING capacitor (see Fig 5). The best way to mark these holes is to make

a drilling template by pushing a piece of paper down over the capacitor shaft. The shaft punches through the paper, marking the position of the hole for the reduction-drive bushing. Next, hold the paper against the capacitor frame and use a pencil point to punch holes in the paper corresponding to the mounting-screw holes in the capacitor frame. Instant drilling template! The bushing hole shown in Fig 5, 7/8 inch in diameter, leaves just enough panel material to hold the countersunk holes for the three no. 6-32 capacitor mounting screws. The best technique is to enlarge the bushing hole *last*, widening it only enough to pass the

Building the Neophyte for 40 Meters

The Neophyte receiver can be built for 7.0-7.3 MHz coverage as follows: Omit C1. C7 through C11 take the 40-meter values shown in Table 1. C11 is mounted in parallel with C12 instead of across T2 (see Fig 1B); this is easily done by mounting C11 across the PC-board connections to C12. Before mounting T2 to the circuit board, remove the small, tubular capacitor in the base of the transformer. Do this carefully with a small razor knife.

Forty-meter alignment is similar to that for the 80-meter Neophyte. Adjust T2 for an oscillator tuning range of 7.0-7.3 MHz, with some overtravel at both ends of the range. With the TUNING control set to the center of the band, set the RF PEAK knob to one o'clock. Adjust T1 for maximum signal strength. This completes alignment of the 40-meter Neophyte.

Because of decreased LO-mixer isolation in the NE602 at 7 MHz, adjustment of the RF PEAK control "pulls" the LO slightly in the 40-meter Neophyte. (Pulling is perceptible as a shift of received-signal pitch as RF PEAK is varied.) This isn't much of a problem, because the RF PEAK control needs little adjustment from one end of the 40-meter band to the other. In fact, you can eliminate the RF PEAK control in the 40-meter Neophyte if you do most of your listening in one part of the band. To do this, omit C4, install a 150-pF capacitor at C1 and adjust T1 for maximum signal strength at your favorite spot in the band.

The Neophyte in ARRL Lab Tests

ARRL Lab testing of one sample of the 80-meter Neophyte netted these results: minimum discernible signal (MDS), -118 dBm (decibels relative to a milliwatt) at 3520 kHz and -113 dBm at 3747 kHz; two-tone, third-order dynamic range with 100-kHz tone spacing, 73.5 dB; selectivity, 1 kHz at -3 dB and 7.5 kHz at -20 dB. Blocking dynamic range was not measured. No microphonics were noted.

The frequency coverage of the sample receiver was 3473-4027 kHz. The poorer of the two MDS figures above (-113 dBm) confirms that the Neophyte is capable of detecting signals down to 0.5 microvolts across 50 ohms, as specified by WA3RNC. At 3520 kHz, sensitivity improved to just under 0.3 microvolt.—Ed.

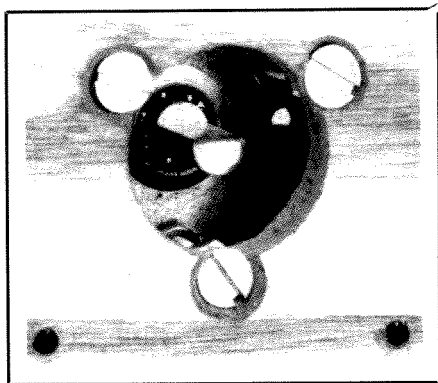


Fig 5—Detail of the mounting holes for the TUNING capacitor, C12. The holes are countersunk to keep the screw heads flush with the panel surface, allowing the reduction drive to be mounted flat to the panel. See text.

reduction-drive bushing and its set screw—after the capacitor mounting screw holes have been drilled.

Mounting the Neophyte's TUNING capacitor to the front panel as just described provides good mechanical stability. If you use a capacitor other than the one shown in the parts list for C12, carefully study your mounting options. Make sure that the mounting screws don't penetrate too far into the capacitor and damage the plates. Whatever you use for C12, mount it to the panel rather than the base, if possible.

The specified speaker requires a 2-inch hole (or a field of ¼-inch holes 2 inches in diameter). A small piece of wire screen or grille cloth between panel and speaker can be used to protect the speaker cone. (This is especially important if you mount the speaker behind a single large hole.) The speaker is attached to the panel with clips designed for this purpose (Mouser Electronics 48SC004); hot-melt glue or epoxy cement can be used instead. A 3.5-mm or 1/8-inch headphone jack is used to allow connection of inexpensive transistor radio earphones; if you prefer, you can use a

Microphonics, Hum, LO Radiation: Low to Absent in the Neophyte

Although the Neophyte is simple, it does not exhibit the drawbacks sometimes associated with D-C receivers. Microphonics—unwanted noises that occur with vibration when electronic parts unexpectedly act like microphones—simply do not exist with this receiver, and I have not heard any hum, even when using an external power supply. LO radiation—sometimes a problem in simple receivers using LOs at any frequency—isn't a problem with the Neophyte: The measured LO level at the receiver antenna terminals is only 80 microvolts.

¼-inch jack here.

The antenna connectors (J1A and J1B in Fig 1) are part of a two-position terminal strip; this is mounted to the receiver base by means of standoffs and screws. Radio Shack push-button speaker terminals would be a good substitute here. The battery holder is a 4-“C”-cell holder from Mouser or Radio Shack.

Solder the components to the circuit board, being careful to observe capacitor polarity and IC orientation. (I recommend that you use IC sockets instead of soldering the ICs directly to the board.) After you've soldered the components to the board, cut off excess wire. Check carefully for solder bridges between circuit-board traces, proper electrolytic capacitor polarity, and correct orientation of D1, U1 and U2. If all looks well, wire the board into the rest of the receiver. As shown in Fig 2, use twisted-pair wiring for connections to C4, J1, J2 and R1. The capacitor specified for C4 has three terminals. Fig 4B shows how to wire these for connection to the circuit board.

When you've completed all connections, mount the board to the cabinet base by means of screws and spacers. Next, we'll align and test the Neophyte.

Checkout and Alignment

Before applying power to the receiver, recheck your wiring once again. Install four “C” cells in the Neophyte's battery holder. (Note: You can use a regulated dc supply in place of the batteries if you wish, but *do not apply more than 8 V to the receiver*, or you'll damage the ICs.) Install a milliammeter or digital multimeter (DMM) in series with the batteries, and turn on the receiver. If the meter indicates less than 15 mA, all's well so far.

Adjust the TUNING capacitor almost to minimum capacitance (plates just short of fully unmeshed). Connect a signal generator to the antenna terminals and inject a 500- μ V, 4-MHz signal into the Neophyte.³ Turn the Neophyte's GAIN control to maximum (fully clockwise if you've wired it correctly) and adjust oscillator coil T2 until you hear the test signal.

Position the RF PEAK knob on C4's shaft so that maximum capacitance (knob fully counterclockwise) is at nine o'clock and minimum capacitance is at three o'clock. Set the RF PEAK capacitor nearly to minimum capacitance (almost fully clockwise; near two o'clock) and adjust T1 for maximum signal strength. Verify that the receiver tunes 3.5-4.0 MHz with a slight overtravel at both ends of the range. Also check that the RF PEAK control tunes through resonance at both ends of the band.

Disconnect the signal generator from the Neophyte and connect a good antenna, such as a dipole, to the receiver. As you tune the Neophyte across the band, adjust the RF PEAK control for best signal strength. (Don't expect outstanding performance with a clip-lead antenna!) If you don't have a dipole, use a long random-wire antenna. (Use of a random-wire antenna also requires a ground connec-

tion.) Set the GAIN control no higher than necessary for solid reception; this reduces the likelihood of detector overload. This practice also lengthens battery life because U2 draws more energy from the battery as the receiver output increases. Battery life, longest when headphones are used in place of the speaker, can exceed 300 hours when fresh alkaline cells are used!

Summary

I welcome your comments and questions on the Neophyte—please include an SASE if you expect a reply. Several Neophytes have been built using different construction techniques. All perform flawlessly. The Neophyte usually can hear any signal audible on a typical ham transceiver. Its selectivity is adequate for band scans and casual listening, and it's an excellent project for schools, ham-radio classes, beginners and old-timers. In short, the Neophyte is fun!

APPENDIX

Parts for the Neophyte are available from a combination of these sources, and from Penntek Electronics (see Note 2):

Arrow Electronics 25 Hub Dr Melville, NY 11747 tel 800-932-7769	Mouser Electronics 2401 Hwy 287 N Mansfield, TX 76063 tel 817-483-4422
Circuit Specialists PO Box 3047 Scottsdale, AZ 85257 tel 602-966-0764	Radiokit PO Box 973 Pelham, NH 03048 tel 603-635-2235
Mouser Electronics 11433 Woodside Ave Santee, CA 92071 tel 619-449-2222	

Notes

¹Mouser Electronics carries 1½- and 2-inch reduction drives as part nos. 45KN100 and 556-S50, respectively. Radiokit carries a 2-inch drive as part no. S-50. See the Appendix for the addresses of these firms.

²Circuit boards and parts kits for the Neophyte receiver are available from Penntek Electronics, 14 Peace Dr, Lewistown, PA 17044, tel 717-248-2507. Prices are as follows: (1) An etched and drilled PC board, \$4.50; (2) all PC-board-mounted components, and an etched and drilled PC board, \$17.50; (3) a complete Neophyte kit, including drilled wooden panel, wooden base, all hardware and parts, \$45; (4) builders who wish to supply their own parts for the Neophyte, but who have trouble finding a small-quantity source for the Signetics NE602N IC, can purchase the NE602N from Penntek Electronics for \$3.25 postpaid. Add \$3.50 for shipping and handling to all orders for options 1, 2 and 3. Pennsylvania residents, add sales tax to all orders. When ordering options 2 and 3, be sure to specify 80- or 40-meter operation. The ARRL and QST in no way warrant this offer.

³If you don't have access to a signal generator, you may be able to generate a test signal by feeding a 4-MHz transmitter signal into a dummy load. Connect a short length of wire to the Neophyte's antenna terminal (J1A) and bring the wire near the dummy load. Vary the spacing between the wire and the load—or reduce the transmitter output—until the transmitter signal is just strong enough to use.—Ed.