CHARLES D. RAKES

Receiver and Detector Circuits

Building and experimenting with receiver and detector circuits can be as much fun and as educational today as it was for the electronic pioneer of yesteryear. I firmly believe that the majority of electrical engineers and technicians in the first three-quarters of this century got their start in electronics by building either a crystal set or a tube or transistor broadcast receiver. At least the majority that I've talked to over the years have indicated that fact to me. We learn the best by doing—which is as true today as it was at anytime in our history.

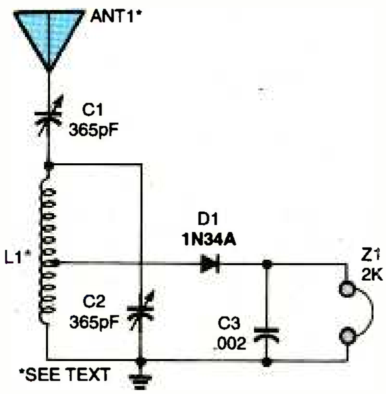

Fig. 1. This simple but functional crystal receiver—comprised of a germanium diode (D1), a hand-wound inductor (L1), and three capacitors (C1–C3)—can tune AM broadcast-band stations transmitting on a frequency ranging between 550 and 1600 kHz.

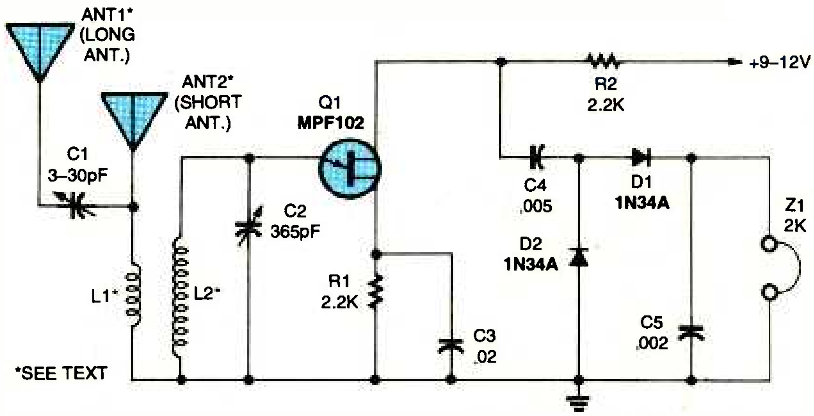

Fig. 2. Unlike the previous circuit, which includes no amplification and uses a single-diode detector—this simple receiver contains a single-stage, tuned-input RF amplifier and a dual diode detector.

PARTS LIST FOR THE CRYSTAL RECEIVER (FIG. 1)

ANT1—Antenna wire (see text)
C1, C2—365-pF tuning capacitor (see text)
C3—0.002-µF, ceramic-disc capacitor
D1—1N34A general-purpose, germanium, switching diode
L1—See text
Z1—2000-ohm impedance headphones
Printed-circuit or perfboard materials, power source, wire solder, hardware, *etc.*

If you've never built a receiver circuit from scratch and are not sure if your efforts would prove fruitful, then wait no longer because one of our receiver circuits could be your first step to a successful hobby or career. Even if you are an old hand, give one of these circuits a try and see how it compares to receivers of the past.

The first receiver circuit built by so many folks in the early days of radio was the elegant and simple crystal set. The crystal detector is an amplitude-modulated (AM) radio in its simplest form. AM is the only form of modulation that the crystal detector can unravel. CW, FM, single-side-band signals, and all other methods of modulation that are not amplitude in form cannot be received on a crystal radio. That was a problem in the early days of amateur radio because CW was the mode most often used. Only clicks could be heard when CW was received on a crystal radio.

Then along came a true genius, Edwin H. Armstrong, with his famous regenerative detector, which solved the problem. The regenerative detector is truly a multifaceted radio detector—bar none! In its simplest form, the regenerative receiver can unravel many forms of RF modulation, including AM, CW, FM, and single-side-band without requiring special circuitry for each mode. Not bad for a 1914 design—long before the general public knew what a vacuum tube was and how it would change their lives.

PARTS LIST FOR THE SINGLE-STAGE JFET RECEIVER (FIG. 2)

CAPACITORS
C1—3-30-pF trimmer or similar size variable
C2—365-pF tuning
C3—0.02-µF, ceramic-disc
C4—0.005-µF, ceramic-disc
C5—0.002-µF, ceramic-disc

ADDITIONAL PARTS AND MATERIALS
ANT1—Antenna wire (see text)
D1, D2—1N34A general-purpose, germanium, switching diode
L1, L2—See text
Q1—MPF102 JFET
R1, R2—2200-ohm, ¼-watt, 5% resistor
Z1—2000-ohm impedance headphones
Printed-circuit or perfboard materials, power source, wire solder, hardware, *etc.*

First things first, the elegant crystal set.

Crystal Receiver

Our very first receiver entry this month is a simple, but functional, crystal set that can tune American and other AM broadcast-band stations transmitting on a frequency ranging between 550 and 1600 kHz. A schematic diagram of the circuit is shown in Fig. 1. The receiver's tuning range can be modified by changing the values of L1 and C2. Higher component values allow the receiver to tune the lower frequencies, while lower values allow the receiver to tune the higher frequencies.

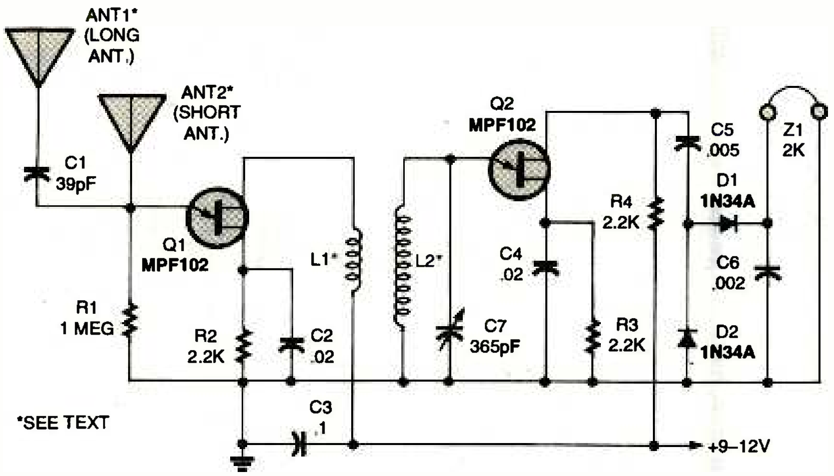

Fig. 4. This receiver circuit, an "evolved" version of our last circuit receiver, uses a pair of JFETs. One JFET (Q1) serves as a broadband RF-booster amplifier, while the other is configured as a tuned RF amplifier.

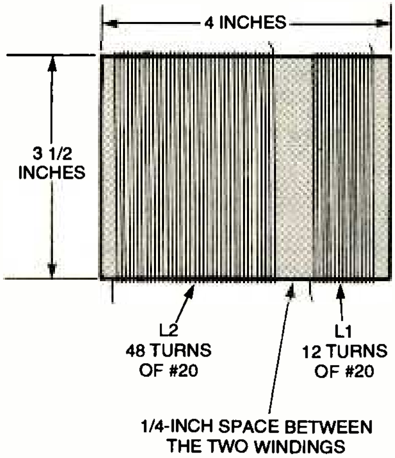

Fig. 3. Details for fabricating the homebrewed coils (L1 and L2)—which are comprised of a total of approximately 60 feet of #20 enameled wire wound on a 4-inch length of 3½-inch diameter PVC pipe—used in the Fig. 2 circuit is shown here.

If all of the signals present at an antenna were visible, it would no doubt look like the aftermath of an explosion at a spaghetti factory. That's because along with the desired signal you'd find an untold number of other RF signals covering the entire RF spectrum all jumbled together at the same antenna—all of them, of course, vying for a chance to meet your receiver's detector circuit.

The circuit's only frequency-selective elements are L1 and C2, which allow the receiver to select the desired station and to reject all other signals. Of course, in the real world things don't exactly happen that way. Strong out-of-band signals can override weaker signals—crowding out the desired frequency altogether. In addition, stations transmitting on adjacent frequencies, if strong enough, can crowd in and appear at the detector's output. The higher the Q factor or "Q" of the tuned circuit, the better the receiver's selectivity. In spite of all of the negative factors, a single tuned LC circuit can still offer ample selectivity in most simple receiver applications. So let's get back to our crystal set and see how it performs in the real world.

A good antenna and ground are a must for any crystal set to perform at its best. But if you live in an area where it's impossible to put up a long-wire antenna or drive a ground rod, it's still possible to receive a few local stations. Just about any length of wire over 20 feet strung around the room can be used for an antenna; the ground for the set can be another similar length of wire strung around another part of the room (to act as a counterpoise) and connected to the receiver's ground input. In any case, since the receiver circuit contains no amplification, the circuit's audio level depends on the strength of the RF signal and the length of antenna used.

Inductor L1 is comprised of about 75 turns of number 22 enamel-covered copper wire wound on a 2-inch diameter plastic form. A length of PVC pipe, a pill bottle, or any similar material can be used as the coil form. The detector tap is made at the 30th turn up from the bottom of the coil.

The two 365-pF tuning capacitors can be salvaged from old AM radios or purchased new. Very nice new 365-pF tuning capacitors are available from the Xtal Set Society, Box 3026, St. Louis, MO. 63130, or go to their Web site at *www.midnightscience.com* and look over the number of interesting crystal-set components. The detector diode, a 1N34A germanium unit, is available from RadioShack and most electronic mail-order houses. The circuit layout isn't critical, so just about any construction scheme—printed circuit, perfboard, experimenter's board, *etc.*—can be used as the component substrate.

PARTS LIST FOR THE TWO-STAGE JFET RECEIVER (FIG. 4)

CAPACITORS

C1—39-pF, ceramic-disc
C2, C4—0.02-µF, ceramic-disc
C3—0.1-µF, ceramic-disc
C5—0.005-µF, ceramic-disc
C6—0.002-µF, ceramic-disc
C7—365-pF tuning

ADDITIONAL PARTS AND MATERIALS

ANT1, ANT2—Antenna wire (see text)
D1, D2—1N34A general-purpose, germanium, switching diode
L1, L2—See text
Q1, Q2—MPF102 JFET
R1—1-megohm, ¼-watt, 5% resistor
R2–R4—2200-ohm, ¼-watt, 5% resistor
Z1—2000-ohm headphones
Printed-circuit or perfboard materials, power source, wire, solder, hardware, *etc.*

Single-Stage JFET Receiver

Our next receiver, see Fig. 2, uses a single-stage, tuned-input, RF amplifier with a dual-diode detector In that circuit, an MPF102 JFET is used to amplify the incoming RF signal. The output of the amplifier is fed to a two-diode detector circuit that rectifies the amplified RF, sending a demodulated audio signal to the headphones. The Single-

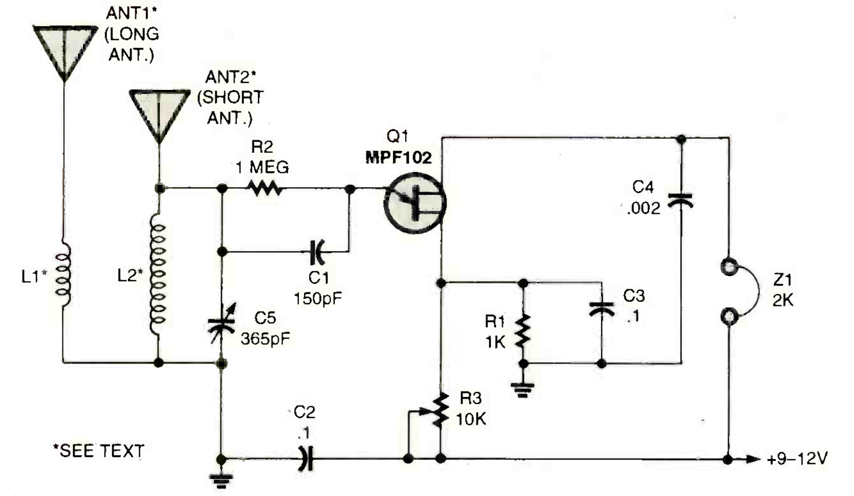

Fig. 5. This solid-state equivalent of a receiver (grid-leak detector) of a bygone era replaces the vacuum tube with a JFET (which operates somewhat like a triode vacuum tube in detecting RF signals).

PARTS LIST FOR THE GRID-LEAK DETECTOR EQUIVALENT (FIG. 5)

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—1000-ohm
R2—1-megohm
R3—10,000-ohm potentiometer

CAPACITORS
C1—150-pF, ceramic-disc
C2, C3—0.1-µF, 50-WVDC,
C4—0.002-µF, 50-WVDC
C5—365-pF tuning

ADDITIONAL PARTS AND MATERIALS
ANT1—Antenna wire (see text)
L1, L2—See text
Q1—MPF102 JFET
Z1—2000-ohm headphones
Printed-circuit or perfboard materials, power source, wire solder, hardware, *etc.*

Stage JFET Receiver is a good performer that is well suited to receiving local stations using a short antenna and a short counterpoise for the ground.

The inductors in that circuit, L1 and L2, are a pair of homebrewed coils that were fabricated by hand-winding approximately 60 feet of #20 enameled-covered copper wire on a 4-inch length of 3½-inch diameter PVC pipe. Additional details for fabricating the coils are given in Fig. 3. Now would be a good time to wind the two coils, since the very same coils are used in most of the remaining receiver circuits. If the suggested wire size isn't readily available, try using the next closest size and adjusting the number of turns in the coil to obtain the desired tuning range. If the low-frequency end of the band can not be tuned, add a few turns to L2, and if the high-frequency end of the band won't tune, remove a few turns from L2. The best way to start out is to wind extra turns on L2 and remove turns if necessary to obtain the desired tuning range.

Two-Stage JFET Receiver

Our next entry, see Fig. 4, adds a broadband RF-booster amplifier to the receiver to increase sensitivity for use in a weak-signal area. Transistor Q1, an MPF102 JFET, amplifies all of the incoming RF signals and sends the output to the tuned RF amplifier (built around Q2) through L1 and L2. Inductor L2 along with C7 is used to select the desired frequency. The amplified-output signal of Q2 is converted to audio by a dual-diode-detector circuit, comprised of D1 and D2.

Inductors L1 and L2 are homebrewed coils fabricated as outlined in Fig. 3. The Fig. 4 circuit has more gain than the single-stage one, so it is important to keep all interconnecting leads between components as short as possible to prevent parasitic oscillatons.

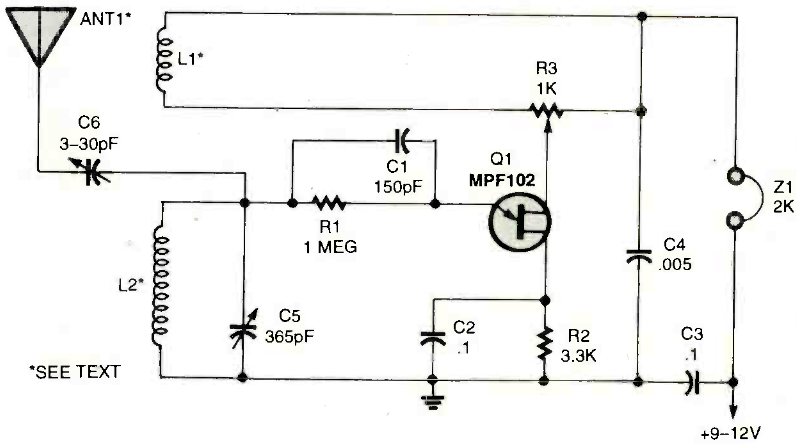

Fig. 6. The regenerative receiver, popularized during the radio era of yesteryear, replaces the vacuum tube used in the original design with an MPF102 JFET.

PARTS LIST FOR THE SOLID-STATE REGENERATIVE RECEIVER (FIG. 6)

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—1-megohm
R2—3300-ohm
R3—1000-ohm potentiometer

CAPACITORS
C1—150-pF, ceramic-disc
C2, C3—0.1-µF,ceramic-disc
C4—0.005-µF, ceramic-disc
C5—365-pF tuning
C6—3–30-pF trimmer

ADDITIONAL PARTS AND MATERIALS
L1, L2—See text
Q1—MPF102 JFET
Z1—2000-ohm impedance headphones
ANT1—Antenna wire (see text)
Printed-circuit or perfboard materials, power source, wire solder, hardware, *etc.*

Grid-Leak Detector Equivalent

Our next circuit, see Fig. 5, is very similar to a popular old vacuum-tube circuit, the grid-leak detector. Here we've replaced the tube with the modern JFET, which operates somewhat like a triode vacuum tube in detecting RF signals. The major difference between the vacuum-tube receiver and the solid-state version is in the operating power. The tube's filament, even on a battery-type tube, alone consumes several times the power the JFET receiver uses.

The desired incoming signal is selected via an LC network, comprised of L2 and C5, and fed to the JFET's gate where it is detected and amplified, after which the signal is sent on to the phones. The JFET operates best as a detector when the gate bias is set near its cut-off value. Since JFET characteristics vary from device to device, the tuning range of R3 allows the bias to be set to its optimum value for RF detection.

Solid-State Regenerative Receiver

Our next circuit is a solid-state version of Mr. Armstrong's famous regenerative receiver. Figure 6 is typical of the type of circuit that was made famous in the vacuum-tube era. Here we've replaced the vacuum tube with an MPF102 JFET. With R3 set to the end of its rotation at the junction of C4, the receiver circuit operates like a grid-leak detector, without any influence from L1. But as R3 is turned toward the opposite end, RF energy begins to feed back into L2. That in-phase signal raises the "Q" of the L2/C5 tuned circuit and the RF voltage across it. If too much energy is returned to the input, the circuit goes into sustained oscillation and no longer behaves like a detector. Having R3 connected across the feedback winding gives the circuit excellent stability and very little frequency shift when regeneration adjustments are made. The circuit's transition to and from regeneration is very smooth.

Often in the tube-equivalent circuit the potentiometer is connected in a rheostat configuration across the feedback coil (tickler for the old timers), which changed the loading on the main tuned circuit each time the regeneration control was adjusted. That would cause a frequency shift in the tuned circuit each time the regeneration control was turned. P

Q & A

(continued from page 14)

Writing to Q&A

As always, we welcome your questions. The most interesting ones are answered in print. Please be sure to:

(1) include plenty of background information (we ll shorten your letter for publication);

(2) give your full name and address on your letter (not just the envelope);

(3) type your letter if possible, or write very neatly; and

(4) if you are asking about a circuit, include a complete diagram.

Questions can be sent to Q&A, **Poptronics** Magazine, 500 Bi-County Blvd., Farmingdale, NY 11735, or e-mailed to q&a @gernsback.com, but please do not expect an immediate reply (because of our backlog) and please don t send graphics files larger than 100K. Due to the volume of mail, we regret that we cannot give personal replies. P

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On the Internet: See our Web site at *www.gernsback.com* for information and files relating to our magazines (**Electronics Now** and **Popular Electronics**) and links to other useful sites.

To discuss electronics with your fellow enthusiasts, visit the newsgroups sci. electronics.repair, sci.electronics.components, sci.electronics.design, and rec.radio. amateur.homebrew. "For sale" messages are permitted only in rec.radio.swap and misc.industry.electronics.marketplace.

Many electronic component manufacturers have Web pages; see the directory at http://www.hitex.com/chipdir/, or try addresses such as http://www.ti.com and http://www. motorola.com (substituting any company's name or abbreviation as appropriate). Many IC data sheets can be viewed online. www.questlink.com features IC data sheets and gives you the ability to buy many of the ICs in small quantities using a credit card. You can also get detailed IC information from www.icmaster.com, which is now free of charge although it formerly required a subscription. Extensive information about how to repair consumer electronic devices and computers can be found at *www.repairfaq.org*

Books: Several good introductory electronics books are available at RadioShack, including one on building power supplies.

An excellent general electronics textbook is *The Art of Electronics*, by Paul Horowitz and Winfield Hill, available from the publisher (Cambridge University Press, 1-800-872-7423) or on special order through any bookstore. Its 1125 pages are full of information on how to build working circuits, with a minimum of mathematics.

Also indispensable is *The ARRL Handbook for Radio Amateurs*, comprising over 1000 pages of theory, radio circuits, and ready-to-build projects, available from the American Radio Relay League, Newington, CT 06111, and from ham-radio equipment dealers.

Copies of past articles: Copies of past articles in **Electronics Now** and **Popular Electronics** (post 1995 only) are available from our Claggk, Inc., Reprint Department, P.O Box 4099, Farmingdale, NY 11735; Tel: 516-293-3751.

Electronics Now and many other magazines are indexed in the *Reader's Guide to Periodical Literature*, available at your public library. Copies of articles in other magazines can be obtained through your public library's interlibrary loan service; expect to pay about 30 cents a page.

Service manuals: Manuals for radios, TVs, VCRs, audio equipment, and some computers are available from Howard W. Sams & Co., Indianapolis, IN 46214 (1-800-428-7267). The free Sams catalog also lists addresses of manufacturers and parts dealers. Even if an item isn't listed in the catalog, it pays to call Sams; they may have a schematic on file which they can copy for you.

Manuals for older test equipment and ham radio gear are available from Hi Manuals, PO Box 802, Council Bluffs, IA 51502, and Manuals Plus, PO Box 549, Tooele, UT 84074.

Replacement semiconductors: Replacement transistors, ICs, and other semiconductors, marketed by Philips ECG, NTE, and Thomson (SK), are available through most parts dealers (including RadioShack on special order). The ECG, NTE, and SK lines contain a few hundred parts that substitute for many thousands of others; a directory (supplied as a large book and on diskette) tells you which one to use. NTE numbers usually match ECG; SK numbers are different.

Remember that the "2S" in a Japanese type number is usually omitted; a transistor marked D945 is actually a 2SD945.

Hamfests (swap meets) and local organizations: These can be located by writing to the American Radio Relay League, Newington, CT 06111; (http://www.arrl.org). A hamfest is an excellent place to pick up used test equipment, older parts, and other items at bargain prices, as well as to meet your fellow electronics enthusiasts—both amateur and professional.