The modern age has provided radio amateurs with lots of fancy gear. Today, virtually all radios are of the multistage superheterodyne type with digital memories and multistage filtering. Unfortunately, this advance in technology has come to us at a very high price. Today, most people are so intimidated by the complexity of modern receivers that they would never even consider building their own equipment from scratch.

Back in the 1920s and '30s, most radio amateurs (even non-hams) built homebrew receivers. The novelty of radio, not to mention the pride hobbyists felt in constructing their own equipment, strongly affected the culture of that time. In addition to having fun and saving money, the knowledge gained from homebrewing also greatly improved builders' technical skills. However, as the great depression came to a close, low-cost commercial receivers became available, and people were no longer required to build their own equipment—so many did not. Naturally, commercial firms chose to market varieties like the superhetero-

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**Figure 1.** Various types of transmitted waveforms: (A) damped wave (spark) transmission, (B) amplitude modulated (AM) transmission, (C) continuous wave (CW) transmission.
Figure 2. Block diagrams of some common receiver types: (A) crystal receiver, (B) regenerative receiver, (C) tuned radio frequency receiver, (D) direct conversion receiver, (E) superheterodyne receiver.

dyne, which are the easiest to use, but the most difficult to homebrew.

For several decades, we have been living in the "dark ages" of receiver homebrewing. As interest in home construction faded from popular culture, much of the early homebrew circuit technology was also forgotten. This is most unfortunate because many of these early circuits were, and still are, ideal for home construction. Recently, however, a small renais-
sance has occurred with the rediscovery of the simple heterodyne receiver. Today it's called the direct conversion receiver.

Another important receiver technology in common use during the 1920s and '30s was the regenerative circuit. This used positive feedback, called "regeneration," to dramatically increase both the sensitivity and selectivity of simple receivers—typically by a thousand times or more. This article provides a comprehensive look into regeneration, reviews its history, and shows how to build high performance regenerative receivers using modern components.

**Types of radio signals**

**Figure 1** shows some of the different types of radio signals that are (or were) used on the shortwave bands. In **Figure 1A**, you see the so-called "damped" waves produced by the spark-gap transmitters used in the early days of radio. When diode detected and low-pass filtered, they provide a crude audio output. This is one of the main reasons why "spark" signals were used: the damped wave provided an easy way to modulate the RF carrier, so a simple crystal diode could detect the signal.

**Figure 1B** shows an amplitude modulated (AM) signal and its diode detected and filtered output. Like the early spark transmissions, this type of waveform can be detected using a simple diode.

**Figure 1C** shows a continuous wave, or CW, signal. Here, simple diode detection and filtering produces only a DC voltage. Reception of an audio output from CW requires some type of heterodyne circuit where one frequency, from a local oscillator inside the receiver, is mixed with the incoming signal, to produce sum and difference frequencies.* If the local oscillator's frequency is set just slightly above, or below, the incoming signal's frequency, an audio output frequency is produced. Single sideband signals are AM waveforms without a carrier wave.

*Note that, strictly speaking, a diode detector isn't just a simple rectifier. Being a nonlinear device, it also operates as a "mixer," producing both sum and difference output frequencies. If used with a local oscillator, it too can produce an audio frequency output for receiving CW.
and, like CW, also require some type of heterodyne to provide an audio output.

An overview of some common types of receivers

Figure 2 shows the block diagrams of several types of receivers. It's interesting to note that, except for the crystal receiver, basically all of the fundamental circuits used in the reception of radio frequency signals were developed between 1914 and the mid-1930s by Edwin Howard Armstrong.\(^1\)\(^2\)

Crystal receivers

As illustrated in Figure 2A, the simple crystal receiver requires only an LC tuned circuit, a diode detector, a low-pass filter, and headphones. The low-pass filter was usually just a single capacitor connected across the headphones. In the early days of radio, crystal detectors were made using an amazing number of different materials including galena, germanium, and zinc oxide. Another type of simple diode detector classified as a "coherer" actually used iron filings inside a sealed chamber. The filings would move in the presence of (strong) radio frequency signals; the detector was shaken periodically to rescramble the filings.\(^A\)

Electrolytic detectors, a close cousin of the electrolytic rectifier, were also used. Early amateurs used some clever schemes to get the most out of their homemade detectors. Tricks included the addition of a battery and rheostat to forward bias the detector, so it operated at the most sensitive point in its curve.\(^B\) Although they didn't need any active components, all of these passive detectors suffered from poor sensitivity (by modern standards) and required very long outside antennas. Also, there was no buffering between the tuned circuit and the headphones, which meant that the already poor selectivity was further degraded by the loading of the headphones. Finally, they could only detect AM or "spark" signals.

The regenerative receiver

As Figure 2B shows, the regenerative receiver heterodynes a local oscillator signal with the incoming RF to produce an audio frequency output. But the regenerative circuit does double duty, also serving as a very high gain amplifier. The regenerative circuit oscillates, heterodynes, and amplifies simultaneously—all within a single stage.

Because of its use of positive feedback, or "regeneration," a regenerative receiver also has very high selectivity, or "Q." A regenerative detector typically provides an audio output...
CIRCUIT

Secondary
Ticker much too large

Good Arrangement
Ticker has small tuning effect

Bad Arrangements
Ticker has large tuning effect

Ordinary Tickler—Series Feed
Feed back controlled by moving the tickler

Circuit

-fixed tickler

Secondary Coil
Plate Coil

PanCake Type

Secondary

Small space
Plate Coil L3

Tube Type

Ordinary Arrangements
Feed back condenser has some tuning effect

Weagant-Reinartz Arrangement
Fixed tickler, shunt feed. Feed back controlled by variable feed back condenser

Normal Throttling Condenser System

Throttling Condenser System Suggested by IARL

Fixed tickler, series feed. Feed back controlled by variable feed back condenser. Coil arrangement same as Weagant-Reinartz.

Figure 6. Regeneration control methods and "tricks" used by "old-timers" of the 1920s. (Courtesy of the ARRL.) (A) Ordinary tickler-series feed, (B) throttling condenser systems, (C) the Weagant-Reinartz arrangement.
Simple capacitive coupling to detector. Loading adjustment is a tradeoff between best selectivity (very little capacitance) and best sensitivity (max capacitance). Hand capacitance greatly detunes circuit when loading control is adjusted.

Better Connection. Tap on coil allows signal to be injected at a lower impedance point. Selectivity vs sensitivity tradeoff still serious but reduced. Hand capacitance effects also reduced.

Much better connection. Now signal is inductively coupled to the detector. There is now very little loading and much more signal is transferred to the detector.

Best connection. Combination of inductive and capacitive coupling allows operator to adjust coupling for optimum performance.
Regenerative detectors are much easier to homebrew than other receiver types. Receiver negatives include detection regenerative feedback (RF coupling), and local-regenerative feedback. The transformer provides some audio gain but is bulky, expensive & hard to find. Detector voltage regulation is good.

Transformer coupling using an audio Interstage transformer. The transformer provides some audio gain but is bulky, expensive & hard to find. Detector voltage regulation is good.

Inductive coupling using the primary of a tube-type audio output transformer. Again, the transformer is bulky, expensive and may be hard to find. Detector voltage regulation is still good.

Resistive coupling off the JFET drain. Resistive coupling is cheap & easy. But both the output level and the detector voltage regulation have been reduced.

Resistive coupling off the JFET source. Only a coupling capacitor is needed. The audio output level is high and the detector voltage regulation is good.
Figure 9. An amateur "breadboard" receiver of the 1920s and its parts list. (Courtesy of the ARRL.)

Tuned Radio Frequency receivers

A common circuit in early commercial receivers, the tuned radio frequency (TRF) receiver (Figure 2C), provided one or more tuned RF gain stages ahead of a diode or low-gain detector and audio amplifying stages after it. Unfortunately, many cascaded tuned RF stages were required to provide even modest selectivity, because even a tuned circuit using an air core coil with a Q of 100 would still have a bandwidth of 100 kHz at 10 MHz. In addi-
tion, the basic TRF design could only receive AM signals. However, TRF designs that used a regenerative detector had greatly improved performance and CW signals could now be copied.

Heterodyne or “direct conversion” receivers

As illustrated by Figure 2D, the heterodyne or “direct conversion” (DC) receiver is similar to the regenerative receiver. It, too, mixes a local oscillator signal with the incoming RF to produce sum and difference frequencies. When the local oscillator is operating just above or below the received frequency, an audio output will result from the reception of CW or SSB signals. If the local oscillator is set to “zero beat” the carrier, makeshift AM reception is also provided. The key difference between the regenerative and DC receivers is that, with regeneration, both the circuit’s gain and selectivity are amplified a thousand times or more during the heterodyne process.

Major problems inherent to direct conversion receivers include oscillator leakage out the antenna and a very low-level audio output from the detector, requiring very high audio gain to recover the signal. This makes the DC receiver prone to microphonics. Modern DC homebrewers have come up with some clever designs that overcome these difficulties and provide excellent performance; but, typically, the receiver’s parts count is very high. Designs I’ve seen have required several transistors or other active devices, many toroids, lots of crystals, and large numbers of other components. I believe these complexities have “scared off” many would-be homebrewers.

The superheterodyne receiver

The superheterodyne receiver (Figure 2E) mixes the RF signal and that of a local oscillator to produce an intermediate frequency RF signal. The local oscillator tracks the received frequency to ensure that the difference (or the sum) between the two frequencies is always equal to the IF frequency. Most of the amplification is provided at a single, fixed IF frequency using a high gain, high Q, single frequency amplifier (with one or more stages). The superhet, therefore, changes the signal frequency to fit its IF amplifier, rather than trying to create RF amplifiers that can work directly over the entire frequency range of the receiver.

Oscillator leakage is minimized in a superhet because the local oscillator doesn’t operate at the received frequency and is therefore greatly attenuated by the receiver’s input circuitry. On the negative side, superheterodyne receivers are quite difficult to homebrew unless the range of received frequencies is very small. The reasons for this are: (1) as the receiver is tuned, the local oscillator must closely track mixer tuning over the entire frequency range and (2), very good preselection is needed to prevent the mixer’s image from passing through to the IF amplifier. Images occur because the local oscillator can heterodyne with frequencies both above and below that of the IF. Historically, the best superhets have used high Q multistaged preselectors with the RF and mixer stages tracking each other precisely over frequency using multiganged tuning capacitors (each carefully “tweaked”). Unless it’s built from a kit, the need for very close tracking and effective image rejection has made the superheterodyne impractical for all but the most skilled (or persistent) homebrewers. Having built two working superhets “from scratch,” I can personally attest to these difficulties.

The actual mechanism of regeneration

Figure 3 illustrates the basic regenerative circuit. If the output of a radio frequency amplifier is fed back to its input—in phase so the signals add—the input signal will be reamplified over and over, providing a thousand times (or more) increase in gain over a conventional RF amplifying stage. Although the power gain of an active device such as a tube or transistor is fixed, the voltage gain in a regenerative circuit (ideally) approaches infinity as it comes into oscillation. The practical result is that a regenerative detector using a single transistor or JFET can convert microvolt-level RF input signals to hundred-millivolt-level audio output signals.

The actual mechanism of regeneration is complex. It introduces negative resistance into a circuit in such a way that its net positive resistance is reduced. Since the circuit’s selectivity or “Q” is equal to its net reactance divided by its net resistance, the circuit’s selectivity is also greatly increased when regeneration is introduced. When the regeneration level is below self-oscillation, the circuit’s negative resistance (produced by regeneration) is less than its fixed positive resistance. When adjusted to this level, regeneration provides a stable increase in both gain and selectivity.

When more regeneration is applied, the circuit’s negative and positive resistances are almost equal. This is a very critical state, just at the threshold of oscillation. The exact “balancing” point where the net circuit resistance is zero is impossible to maintain, as even the smallest random noise source, given time, will
build up to a self-sustained free oscillation.

As regeneration is increased further, the circuit exhibits a net negative resistance and oscillates. As regeneration is increased beyond oscillation, curious secondary oscillations of a lower frequency are introduced that tend to turn off or “quench” the main oscillation under certain conditions of input signal level and degrees of regeneration. Because of the quenching action, RF input signals are amplified tremendously, with circuit gains approaching one million in a single stage. Discovered by Armstrong, the phenomena is called “Super Regeneration” and its discovery led to the development of the first practical VHF receivers (For more information, see “Super Regeneration: The Lost Technology,” Communications Quarterly, Fall 1994).

In actual use, a regenerative detector performs quite differently depending on whether it’s operated above or below the oscillation threshold. For the best sensitivity and selectivi-
ty when receiving AM signals, the detector is adjusted just to the threshold of oscillation. Receiver performance can be quite good, but it does require frequent readjustment of the regeneration control and a certain amount of operator skill.

When receiving CW or SSB, the detector is set to oscillate and then detune from the center of the carrier to produce an audio heterodyne or beat note. So-called oscillating or "auto dyne" (self-force) detectors are far more sensitive than any other type. And the "grid leak" biasing normally used in the regenerative detector tends to maintain a constant oscillation amplitude over wide frequency ranges and, therefore, doesn't require frequent readjustment. Furthermore, because the detector is operating beyond the threshold of oscillation, it's less susceptible to static interference than other types.

Key design rules for regenerative detectors

Regenerative detector circuits. Figure 5 shows some of the many possible regenerative detector circuits, all of which are based on standard oscillator circuits. As with an oscillator, a critical design issue is frequency stability over changes in power supply and temperature.

Regeneration control methods. Unlike oscillators, regenerative receivers need a practical method for controlling the amount of regeneration. The "old-timers" of the 1920s used many "tricks" with one common goal: to allow the smooth and gradual adjustment of regeneration up to and beyond the threshold of oscillation, without causing the circuit to detune.

Figures 6A through 6C from the 1927 Radio Amateur's Handbook\(^3\) show some of these tricks. They included winding the tickler coil at the ground end of the main tuning coil; using the smallest possible tickler; winding the tickler on a separate, smaller diameter coil form attached to the bottom of the main form; and using heavier gauge wire for ticklers used in CW receivers than those for AM. One of their most important discoveries was the "throttle condenser" regeneration control method.

"Rotating tickler" control. Figure 6A depicts the rotating tickler method. This technique was commonly used in the 1920s for
broadcast receivers—often using a commercial unit called a “variometer,” which consisted of a smaller inner coil rotating inside a larger outer coil. Aside from their cost and complexity, rotating ticklers detuned the signal as regeneration was increased and the detector approached oscillation.

“Throttle capacitor” and resistive regeneration controls. Figures 6B and 6C illustrate the “throttle capacitor” method of regeneration control. The throttle capacitor method provides for the smoothest adjustment up to and beyond the threshold of oscillation. Widely used by amateurs in the 1920s, the throttle capacitor method was phased out during the 1930s, and replaced with various resistive control techniques. This was probably due to the fact that higher gain screen grid tubes had replaced the early triode designs and because the simple expedient of using a potentiometer to vary the screen voltage of the detector was cheap and easy to do.

Unfortunately, performance suffered. Resistive controls are noisy and lack the smoothness of a capacitive control. More importantly, the use of a throttle capacitor permits the detector voltage to be regulated—a very desirable feature. A regulated supply allows a much closer adjustment to the oscillation threshold when receiving AM signals and when oscillating, the frequency stability of the detector is also greatly improved. With resistive controls, detector voltage varies widely and there always seems to be some degree of overshoot. The combination of a “throttle” capacitor and a regulated power supply provides the highest sensitivity, selectivity, and stability for a given detector.

JFETs, bipolar transistors, or tubes? JFETs are ideal for use as regenerative detectors. Although they provide much less gain than comparable bipolar devices, their “soft” turn-on characteristics permit much better regeneration control. They are most effective when used with some combination of source and “grid leak” bias. The “grid leak bias” (Figure 3) is a parallel RC network in series with the gate that provides an automatic increase in negative bias with increasing RF amplitude. This tends to maintain a near constant output amplitude from the detector when
it's in an oscillating condition, greatly improving CW and SSB performance. For most JFETs, a 1-meg resistor and 100-pF capacitor are about optimum for the network.

Pentode vacuum tubes have operating characteristics very similar to JFETs, except their output impedance's are much higher and their supply voltages are much greater. Input impedances' are similar, however. Old-timers claimed that tube circuits with very large values of grid leak resistor (2 to 10 megohms) provided the best CW performance.

Bipolar transistors have high transconductance that provides very high gain within the regenerative loop. The signal input to the detector must necessarily be kept low to avoid overloading. The use of large amounts of negative bias is very helpful in making the regeneration level in these circuits easier to control. Bipolar detectors provide a high audio output level but, in the oscillating condition, the circuits I've built never seem to work as well as any of my JFET designs.

Detector loading issues. Detector loading is one of the most important issues and tradeoffs involved in the design of regenerative detectors. The ideal state is a condition where the maximum possible input signal can be applied to the detector while not loading it at all.

**Figure 7** shows several methods of coupling the RF input signal to the detector.

**Tickler turns.** Always use the minimum number of turns on the tickler that will permit oscillation throughout the receiver's entire frequency range. This is best determined by trial and error. A good "cookbook" method is to use approximately 1/3 the turns on the tickler as are used on the main tuning coil, test the circuit, and then reduce the turns to the minimum needed.

**Detector gain.** In 1933, Robinson¹ wrote a classic article in which he detailed a series of experiments investigating how component changes within the feedback loop affect detector gain and selectivity. He recommended using pentode tubes instead of triodes and told readers to first optimize their detectors for best sensitivity in the nonregenerative state before connecting the regenerative loop. Although the use of a high-gain device within the regenerative loop does provide a higher audio output signal,
the benefits of high gain are misleading. As with any receiver, overall gain is far less important than the signal-to-noise ratio of the first stage. Higher gains within the regenerative loop also contribute to its instability.

Pulling. "Pulling" is an effect that causes two oscillators to become synchronized if they are operating close to the same frequency. In a regenerative receiver, this causes the detector to lock onto the centers of strong RF signals. This can make it difficult to receive strong SSB or CW signals, because the detector needs to oscillate at a frequency just above or below the carrier to produce the necessary heterodyne. Pulling can also cause problems when the detector is receiving AM signals and not oscillating. When many stations are close together, the receiver will tend to jump around, locking onto whichever station is stronger. Pulling can be prevented by simply adding an RF gain control or input attenuator to the receiver.

Receiver power supply. Hum modulation can arise from excessive power supply ripple or from having any power transformers or AC line voltage anywhere on the receiver. Your best bet is to power the receiver with batteries or use a well-filtered power supply that’s physically isolated from the receiver chassis by several feet.

RF stages. Use an untuned RF stage preceding the detector. In a regenerative receiver, only a small amount of RF gain is needed; detector isolation is a much more important issue. The use of an untuned stage greatly eases construction, as a tuned RF stage will usually oscillate unless its coil and that of the detector are both shielded. Shielding should be avoided because it increases the dielectric losses that can ruin the receiver’s selectivity. A tuned stage can also cause tracking problems. For a single ham band, an RF stage tuned to the center of the band will normally suffice; however for general coverage use, the LC circuit of the RF stage also needs to closely track the detector circuit over frequency.

Extracting the audio output from the detector. Figure 8 shows several methods of extracting the audio output from a JFET detector; Figure 8D is the preferred connection.

Practical regenerative receiver circuits

Classic regenerative receivers of the 1920s. Figure 9 shows an amateur “breadboard” shortwave receiver from the 1920s, including its parts list and 1927 prices! Figure 10 shows some commercial plug-in coils available in the 1920s and a block diagram of another receiver from the same period. Note their use of variable input coupling, throttle capacitor regeneration con-
trols, vernier dials, and detector shock mounting. Also note that they simply connected their high-impedance headphones in series with the plate of the audio tube, which was common practice in those days. Because they used their receivers in the oscillating condition (for receiving CW), and they had sensitive, very narrow bandwidth headphones, both the sensitivity and selectivity of these early receivers was probably pretty good. Those interested in building regenerative receivers using vacuum tubes should refer to David Newkirk’s article in QST.5

**An ultra low-cost shortwave receiver for the beginner.** Figure 11 answers the challenge: “How many parts do you really need to build a useful shortwave receiver?” The entire circuit uses less than $10 worth of parts (not counting speaker or headphones) and operates from almost any battery. Battery current is only 6 mA for the entire receiver. This is an excellent project for a boy (or girl) scout’s merit badge, or as a gift for a young child. Regenerative detector Q1 amplifies microvolt level input signals up to hundreds of millivolts to drive an LM386 audio op amp. Regeneration is simply (and a bit crudely) adjusted by potentiometer R3. R1 and C3 provide “grid leak” bias for the JFET while R4 adds source bias. Some circuit layouts may require a few pF between the drain of Q1 and ground to permit the circuit to oscillate. For best results, use a 50 foot long wire antenna with this receiver.

**A bipolar regenerative shortwave receiver.** Figure 12 shows the circuit for a very sensitive shortwave receiver using 10-cent bipolar transistors. With bipolar transistors and an RF stage, this receiver is sensitive enough to be used with just a short whip antenna. Transistor Q1 is used as an untuned RF amplifier with LI/C1 forming a high-pass filter to block interference from any nearby AM broadcast stations. Q2 is a high-gain regenerative RF amplifier connected in a Hartley oscillator configuration. Potentiometer R6 allows smooth regeneration by increasing the negative bias on Q2, and the amount of positive feedback simultaneously. Diodes D2-D4 provide simple voltage regulation. The output from the regenerative stage drives diode detector D1, which connects directly to a two-stage audio amplifier. An op amp or LM386 circuit could be substituted for the audio stage to reduce the parts count. To further limit the parts count, cost, and (performance) omit the RF stage and increase C3 to approximately 5 pF. Then connect an external antenna directly to C3.

**A high-performance JFET shortwave receiver**

Figure 13 shows a highly sensitive and selective shortwave receiver appropriate for either general coverage or ham band reception. It features an RF stage with a built-in input attenuator, a high-performance JFET regenerative detector, selectable audio filtering, and a high-gain low-noise audio output stage. The overall performance of this circuit equals or exceeds that of many superheterodyne designs, yet it has a very low parts count and draws less than 12 mA from its two 9-volt batteries. JFET Q1 operates as a grounded gate RF stage to improve sensitivity and isolate the detector from the antenna. Capacitor C1 is a variable input attenuator that’s very useful for eliminating “pulling” effects or for increasing the receiver’s selectivity when receiving strong signals.
diode D1 regulates the drain voltage of the detector, so it's very stable in the oscillating mode. Commercial plug-in coil forms (see list of parts suppliers) are used to allow multiband operating (bandswitching would be difficult with 3 windings). When winding the coils, the same winding on each coil should occupy approximately the same space (expand or compress turns as necessary) and the spacing between windings should also be the same. This helps to reduce the distributed capacitance. The frequency range of this or any of the receivers in this article may be extended up or down by simply winding additional plug-in coils.

The audio output is extracted from the JFET source and low pass filtered by the switched audio filter. Audio feeds from the volume control R5 to an Analog Devices' AD745 op amp. This JFET op amp provides high gain and very low noise, high quality audio. The op amp output drives series connected common not used) Sony “Walkman” type stereo headphones.

The optional buffer amplifier of Figure 14 can be added to drive an external low-cost frequency counter. A pick-up loop located close to the detector coil extracts some of the signal from the detector when it's oscillating or close to oscillation. A bipolar transistor amplifies the loop signal and isolates the load presented by the BNC from the detector coil. The BNC cable connects directly to a low-cost commercial frequency counter.

To obtain the best frequency stability from this receiver on CW and SSB, adjust the regeneration control so the detector is operated well beyond the oscillation threshold. For single sideband, use the input attenuator to reduce the signal strength enough to avoid “pulling.” For AM reception, use two hands—one for tuning, and the other for regeneration—and use the input attenuator to help separate stations on a crowded band.

Construction guidelines

Use a wooden chassis. The original concept of a breadboard was just that: a hard wooden cutting board. There are some very good reasons for using this type of chassis. First, the detector coil must be kept as far away as possible from any metal object. A metal chassis, shield cans, metal sides and back panels all absorb energy from the circuit and add to the dielectric losses, which directly affect the overall circuit “Q” and the receiver selectivity. The optimum setup for a homebrew receiver is to use a wooden base, sides, and back, and a grounded metal front panel. A wooden front panel can also be used if the metal bodies of the controls are grounded and a small, grounded, sheet metal plate is used between the fine tun-
ing control and the back of the front panel (to reduce hand capacitance effects).

As shown, fine tuning can be incorporated into these receivers by adding a small variable capacitor in parallel with the main tuning capacitor. For general coverage receivers, use a vernier dial on the main tuning capacitor; for ham receivers, put the vernier on the fine tuning control for maximum band spread on the amateur bands.

Build the electronics on a small fiber glass board and screw that down to the wooden base board. I prefer poplar for the receiver base because it's commonly available and fairly hard. Oak looks better, but is more difficult to cut and drill. Softwoods like pine are okay, but dent easily.

Before winding a coil, I recommended that you test the coil form in a microwave oven for a minute or so. If it heats up, the dielectric absorption is too high. When winding coils, first drill two small holes in the coil form at the beginning of each winding. Next, feed the wire through the first hole, then out again through the second. If you're using insulated hook-up wire, simply tie a knot at the point in the wire where it enters the form—this will keep the wire from loosening up later on. Then wind the coil tightly onto the form. When the winding is finished, drill two more holes at the end of the form, to hold the winding in place, and feed the wire through. Be sure to sandpaper the ends of copper enameled wire before soldering connections. When the coils are finished (and working correctly) use Q dope to cement the windings firmly to the form.

New plug-in coil forms are available from Antique Electronics Supply (see list of parts suppliers). Old vacuum tubes can be "cannibalized" and their bases attached to thin-walled PVC drain pipe, plastic pill bottles, or plastic film cans. With plug-in coils, run the wires from each winding inside the coil form and solder them to one of the pins, making sure all the coils are wired exactly the same. The completed coil form then plugs into a companion tube socket attached to the receiver's base. Be sure to locate the coil at least 1 inch away from any metal object.

Component layout for these high-frequency RF circuit designs is very important. All ground leads should be kept as short as possible. Try to keep the audio wiring physically separated from the RF wiring. The volume controls should be connected using shielded wire. Also, connect a separate wire between the ground side of the control and chassis ground to avoid control loops through the shield. The ICs should have their power supply bypass capacitors located right at the chip using short leads to the ground. Most of the circuits for this article were built using Vector type 4112-4 plug board, a predrilled universal breadboard with a ground plane on one side. Standard low-cost fiber glass board can also be used if a copper-clad board is located below it on spacers and all grounds are made to the copper board.

Testing

Always wire receiver circuits backwards; i.e., first the audio stage, then the detector, then the RF stage. As each stage is completed, test it before going on to the next.

To test any of these receivers, first connect the batteries, plug in a set of headphones, and turn the volume control up half way. Test the audio stage with an audio oscillator or just place your finger on the top of the control and listen for a buzz in the headphones. Test the detector by first seeing if it oscillates. Starting from minimum, slowly adjust the regeneration control until the detector produces a "live sound" (a large increase in the background noise). If the detector refuses to oscillate, carefully check the wiring and, if it seems okay, try swapping the wires to the tickler winding. Once the detector is oscillating, temporarily connect an antenna in series with a 5 to 20 pf capacitor to the top of the main tuning coil. Tune in a strong station, adjusting the regeneration level and volume for best reception. When the receiver is completely wired, test the RF stage by connecting the antenna to the receiver's input and tune in the same station. Reception should be at least as good as without the RF stage.

Future developments

Since regenerative receiver circuit development basically ended many years ago—before homebrewers had low-cost semiconductors, op amps, or zener regulators at their disposal—it should now be possible to design some new features into this traditional circuit. These could include some type of regenerative AGC circuit for AM signal reception—using an op amp and rectifier, etc., to maintain a constant level of regeneration as the receiver is tuned. Crystal oscillator circuits could also be made regenerative to produce a very high gain, high "Q", low drift, single frequency amplifier (for IF stages, etc.). Applying regeneration in a limited controlled way into several RF stages simultaneously (to raise their gain and "Q") is also a possibility. I would very much like to correspond with others interested in exploring this very fascinating technology.

Parts suppliers

Parts suppliers for the receivers described in
newfoundland...narrow leads in notre dame bay will close on wednesday and ice pressure will develop late wednesday. moderate to strong ice pressure is expected from cape freels to fogo island.
cma in noy.
larme bay and 400pm the norther.
biferno a on thursday.
and friday, the ice edge will retreat westward during the period.
very close pack geyw7he and thin first year ice in most of bona vista bay throughout the period. we vilc5move into conception.
t.
irony bay on wednesday thursday and friday and very close pack.
ice will be found in most of the bays on friday. more ice will move to south of cape race and some will be found in the vicinity of placencia.
and fort pierre et iceloon by theedac.
ulthe period. ice will move into the tongue of water to.
eh lnm.

labrador...ice will pack against the coast during the period. moderate ice pressure expected.

end/dd

figure 15. sample r tty and fax printouts. (courtesy john hartman, nmihl.)

this article may be purchased from the following sources:

- tuning capacitors, tubes, tube sockets, transformers, knobs, potentiometers, wire, resistors, fixed capacitors, and other miscellaneous components: (new) antique electronics supply, 6221 s. maple avenue, tempe, arizona 85283. phone: 602-820-5411. (surplus) fair radio sales co., p.o. box 1105, 1016 e. eureka street, lima, ohio 45802. phone: 419-223-2196.

- plug-in coil forms: antique electronics supply.

- rf chokes and coils: antique electronics supply (above); digi-key corp., 701 brooks avenue, south, p.o. box 677, thief river falls, minnesota 56701-0677. phone: 800-344-4539.

- vernier dials: fair radio sales co. (above); ocean state electronics, p.o. box 1458, 6 industrial drive, westerly, rhode island 02891. phone: 401-596-3080.

- knobs, headphone jacks, 2n2222 transistors, national semiconductor lm386 ic's, miscellaneous items: radio shack.

- the analog devices ad745 op amps and the motorola j310 and 2n4416 jfets: newark electronics.

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3. r. radio amateur's handbook, 1927 edition. american radio relay league, 225 main street, newington, connecticut 06111.
4. h.a. robinson, w3lw, "regenerative detectors: what we get from them—how to get more," qst, february 1933, pages 20-30.

editor's notes
a. the operation of the center detector is more mechanical than elec-
ic, and is not a true rectifying detector. The presence of strong RF currents
would cause the fine metal filings to "clutter," or bond together, thus reducing
the electrical resistance path to the recording instrument. In operation, the
coherer more or less acted as a one-shot detector device. (Cobalt is usually
down sensitive relays which are in turn operated crude mechanical recording
device.) A secondary function of the relay arm employed a mechanical "bell-
type" clapper arm, which upon detection of a signal, tapped the coherer, reset-
ting the filings in preparation for the next "signal."

The first coherer was demonstrated by Patissou Edward Botsman in the
1890s, it used iron filings packed loosely in a glass tube capped with two elec-
trodes. By 1895 Marconi had discovered that using a mixture of nickel and sil-
vet filings greatly improved the coherer's sensitivity.

B. Many substances were tried as detectors, the most popular was lead ore,
or galena crystal, a natural substance. Despite the sensitivity advantages offered
by galena and other point contact mineral detectors, they all suffered from sen-
sitivity to burn out from strong RF fields and induced currents from nearby
lightning strikes. Elaborate protection schemes were used to isolate the detec-
tors when the spark gap transmitters were fired up. They were also finicky to
adjust, and were easily jolted out of alignment. Several fixed Carboniram devices
in my collection still function to this day.

To counteract these problems, a detector was developed using
Carboniram—which is man made and produced as high temperature electric
furnaces. The Carboniram detector used a relatively high pressure contact
system, and was immune to damage from strong RF fields and unaffected by
vibration. Unlike any other detector, the Carboniram detector often used a
small variable bias voltage source to improve its performance. The
Carboniram detector was also better suited for use in high impedance circuits.
C. Early superhet were as complicated to tune as their TRF cousins. As an
example, RCA's Radiola 26, an early "portable" superhet made in 1925,
employed separate tuning dials for oscillator and RF stages.
D. To reduce cost, and eliminate expensive variable capacitors whenever
possible, Variometers were often used as main tuning elements. A vari-
ometer's winding was done as two sections, the first on a fixed cylindrical form,
the second winding was wound on a rotatable coil form inside of the first. A
shaft tuning arrangement allowed the inside coil to be rotated nearly 180
degrees, for series adding or opposing tuning resulting a wide range of inductive
-tuning.

Although similar in design to the Variometer, the Variocoupler employed
two discrete windings. Variocouplers were used to control antenna coupling,
oscillator feedback, regeneration and interstage coupling.

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Appendix A: Armstrong's 1914 Circuit

In 1914, while conducting experiments in his home workshop, Edwin Howard Armstrong
discovered regeneration, which is certainly one of the most significant discoveries in the history
of radio. While others before him may have inadvertently caused circuits to oscillate,
Armstrong was the first person to clearly understand what was happening and to develop practical circuits using this principle. In his classic 1915 paper, Armstrong\(^1\) introduced this new technology to the world.

Armstrong’s original circuit for the regenerative detector is shown in Figure 4. In this 1915 circuit, a vacuum tube is the amplifying device. The tube is drawn horizontally with the filament on the left, the grid in the center, and the “wing” (today called the plate) at the right.

Small changes in grid voltage would cause large current variations in the plate or “wing” providing gain. A coupling unit supplied positive feedback via the interaction of two coils—L2, a coil in series with the main tuning coil and a feedback or “tickler” coil, L3. Armstrong varied the amount of feedback by manually adjusting the spacing of the two coils; the two windings were brought into close proximity with each other, the mutual coupling between the coils providing the feedback path. Two batteries operated the circuit: an “A” battery (usually a 6-volt car battery) to power the filaments and a 22.5 or 45 volt “B” battery to supply the voltage to the “wing” (plate) circuit.

Appendix B: Independent Evaluation of the High Performance JFET Receiver of Figure 14 by Amateur Extra Class Licensee John Hartman, N8\(\lambda\)1H.

My Evaluation of Charles Kitchin’s Receiver.

Those who think that the days are gone when you could build your own simple communications receiver that rivals professional amateur gear in basic performance, should consider this rig. I had the opportunity to evaluate it one night and was impressed by its sensitivity, selectivity, excellent audio, very low noise, and surprisingly good stability.

I connected the receiver to my all-band Windom antenna and tuned up on the 80 and 40-meter amateur bands. The antenna loading control proved handy in preventing overload and blocking due to the better than 1 microvolt sensitivity of this receiver and its lack of AGC. CW was very easy to copy on the novice and extra bands. However, with the audio bandwidth switch in the “full” position, more than one station was heard, due to the 15 kHz or so bandpass of this receiver. Using the audio filters, I was able to attenuate the higher frequen-cy CW tones. This, combined with no noticeable drift, allowed me to easily copy CW.

Tuning up to the voice part of the amateur bands, I was surprised to be able to easily tune in SSB. The audio quality was better than any Japanese transceivers I’ve heard. I could detect no background hiss, and again, no drift.

Being a serious shortwave listener, I then tuned in HCJB, Equator. I was treated to what I can only say was AM high fidelity (be sure to use a high-quality headset for this rig). The audio was very good. I could even hear the announcer’s breathing!

Now for the acid test. I connected my MFJ 1278 multi-mode TNC to the receiver’s audio output jack. I then tuned to the 4 and 8 MHz marine bands. Not only was I able to copy almost perfect RTTY, I was also able to print several weather FAX maps. Again, no drift and no frequency tweaking was necessary on these RTTY and FAX printouts (see examples, Figure 15). Coast station CW decoding was a problem due to the 200-Hz input filter on the MFJ and the relatively coarse fine tuning control on the receiver.

So, what are the other negatives, besides the coarse fine tuning control? Well, this is a regenerative receiver, so you will have to learn to fiddle with regen, antenna coupling, and volume for best results. But, it’s like driving a car with a standard shift. Once you get used to it, it can be fun! Like most hackers turned amateurs, Kitchin’s workmanship left a little to be desired. He used loose, multi-stranded wire for point-to-point wiring in the RF stage, so there were some microphonics. However, Kitchin’s use of a pick-up loop, buffer amplifier, and frequency counter for a direct frequency readout solves the classic regen “where am I on the band?” problem. I did find some frequency readout error, but this could have been my tuning.

All in all, this is a very good performing receiver that’s definitely worth the effort to construct—and, for a fraction of the cost of anything you could buy (minus the $100 frequency meter). This would make a nice project for a son or daughter to build, as well as the serious SWLer. In the words of Winston Churchill, if he had been a hacker: “never in the course of human endeavor has so much performance come from so few components.”

John Hartman