The vacuum-tube radio, once an important source of news and entertainment, has become a museum piece. But it's fun to revisit those old days of radio by restoring an abandoned set.

VINTAGE RADIO

MARTY KNIGHT

IT IS SATURDAY MORNING SO YOU DEcide to go to the local flea market to search for an antique radio that you can revive. You never know what you'll find at those outdoor markets. Even if you don't find anything worth saving, at least you'll be walking around in the sunshine and mingling with the crowd.

After trudging up and down he seemingly endless rows of ables you suddenly get lucky nd chance upon a real gem. Its bsolete wooden cabinet only ints at its age, so you pull back he heavy cardboard cover at the ack and peek in to see the hape of its vacuum tubes—the est clue as to its age. Aha, ou're satisfied that you have atched onto a real "oldie but goodie."

Sure, the cloth on the line cord is torn and scruffy and the rubber insulation has turned to brittle clay. Maybe a knob is missing, and there are water stains and mold on the cabinet, but otherwise the set looks complete. After some hard bargaining you get the price down to $25—not bad for a piece of electronic history.

Once you get this "jewel in the rough" home, you begin your exploration by removing the heavy cover, knobs, and screws that hold the dusty metal chassis to the cabinet. After sliding out the chassis you say to yourself, "I'm a member of an elite group that gets a kick out of dabbling in electronic archaeology and restoring old radios to life."

Even before you remove the accumulated layers of dust and grime from the chassis, bespeaking years of neglect in an attic or basement, you examine the tubes. Their shape will give you the most reliable clues about the age of the set. Then as you happily strip away the grime, you carefully note any damaged components that should be replaced along with other components whose replacement is dictated by their age.

If you are lucky, your cleaning efforts might reveal an old paper schematic pasted to the back cover giving the names of the manufacturers of the set and the tubes. An old schematic will simplify your search for replacement parts and permit you to consult one of the many books and catalogs now available that document the history of antique radios.

However, even without a schematic, the shapes of the tubes, the parts layout on the chassis, and even the appearance of the old resistors and fixed and variable capacitors (condensers) should offer abundant clues and hint at manufacturer, circuit design, and the set's place in history—always exciting.

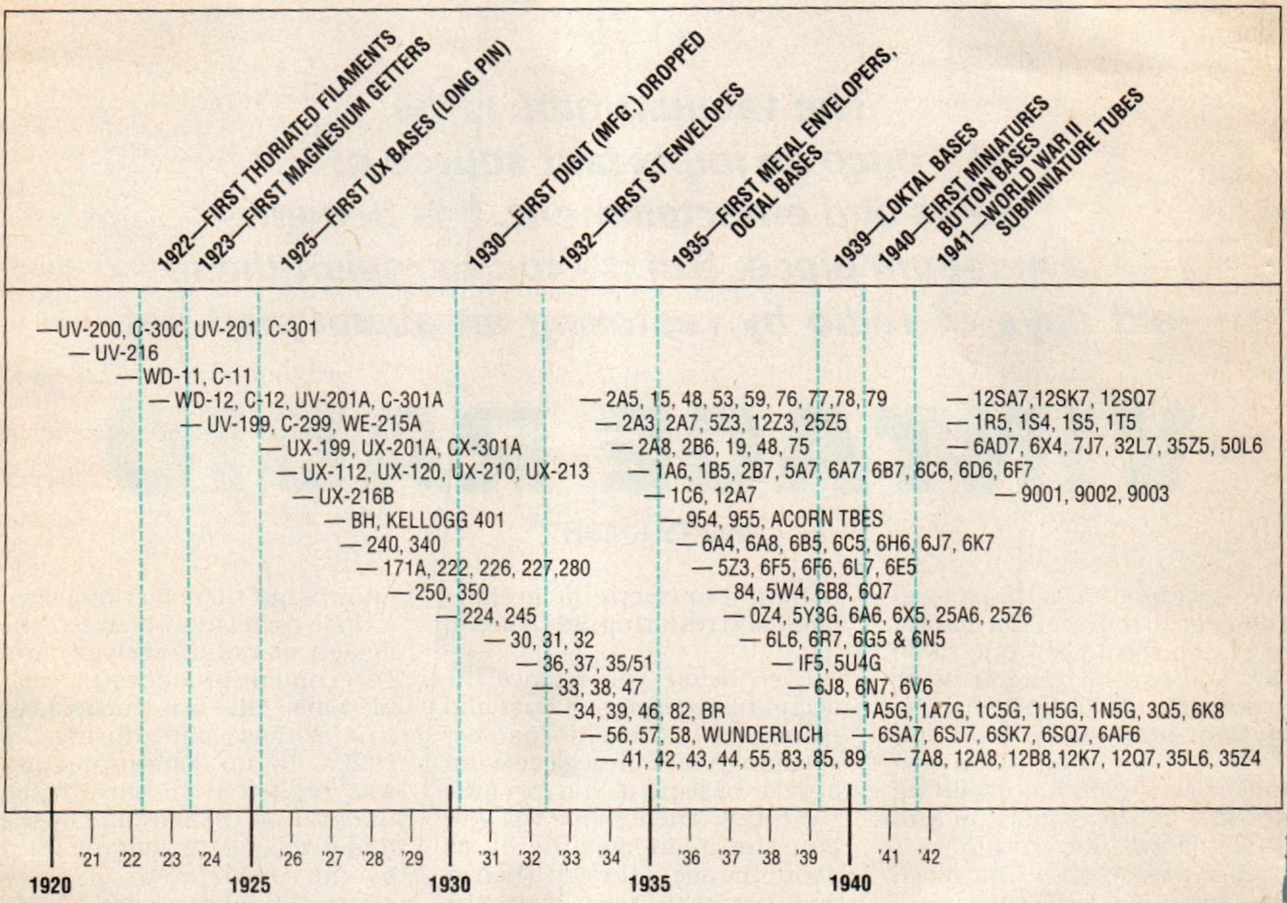
Regulation and set design

Perhaps it's not widely known, but there has long been a close correlation between the design of radio receivers and government broadcasting regulations. This was particularly true of those built during the 1920s. Radio communication was regulated in the United States from 1912 to 1927 by the Radio Act of 1912, administered by the Department of Commerce. This knowledge should come in handy if you chance upon a real "oldie."

The government didn't seem to give much thought to the future growth of radio broadcasting in the 1920s. For example, the Commerce Department licensed Westinghouse's radio station KDKA in Pittsburgh to operate at 500 kHz (in those days called kilocycles or kc). That also happened to be the maritime emergency radio band. Its hard to believe today, but this licensing policy meant that KDKA station engineers had to shut down their transmitter periodically to listen for distress calls from ships at sea!

Before 1922, radio licenses were haphazardly assigned to stations at frequencies between 500 and 1000 kHz without regard to their location or transmitting power. In fact, amateur radio operators had free access to the same frequencies. The cacophony of sound from competing radio stations reduced broadcast reception to audio babble.

TABLE 1



Vacuum Tube Development, 1921 – 1941

Early in 1922 a policy was introduced that licensed all broadcast radio stations to operate on 833 kHz. Even with reduced transmitting power, interference made listening impossible. Meanwhile, radio set ownership had increased from about 50,000 in 1921 to about 100,000 in 1922. Imagine the complaints government officials received about poor radio reception!

The first National Radio Conference sponsored by the Secretary of Commerce in the winter of 1922 resulted in the assignment of specific frequencies for both high- and low-power stations. At that time, high-power stations (from 500 to 1000 watts) were assigned to 750 kHz, and low-power stations (below 500 watts) remained on 833 kHz.

It didn't take long before that solution also proved to be inadequate. Because of their broadband reception characteristics, radios made at that time couldn't discriminate between the two frequencies. In effect, the selectivity of early radios was zero. About 1.5 million radios were made in 1924, and the market grew to 4.4 million radios per year five years later.

Although it was still difficult to tune to a program without interference, radio ownership grew to 5 million receivers by 1926. This was eight years before the Federal Communications Commission (FCC) was formed; some call this act the true birth of modern radio broadcasting.

March of technology

The first radio broadcasts could be heard with simple crystal diode detector receivers—if you were close enough to the transmitter. They could either be purchased or built by listeners as they are today. Crystal radio receivers were unstable and finicky, and they lacked a way to amplify the audio. Thes drawbacks essentially re stricted their use to a single lis tener wearing headphones.

The invention of the vacuum tube diode detector as a replace ment for the crystal detector dic little to improve radio reception Developed by British scientis J.A. Fleming, it had a filament and plate but, like the crysta diode, it was unable to amplify However, when American inventor Lee DeForest developed a tube with a third electrode called the *control grid*, the modern receiving tube arrived. Other innovations developed during that period included the tuned circuit and the grid-leak detector.

However, radio reception took another giant leap forward with the invention of the regenerative receiver by Edwin Armstrong in 1915. It includec the triode, a tuned circuit, anc grid bias. Positive feedback of fered improved sensitivity, se lectivity, and audio output power. However, its drawback was its dual-battery requirement—one to heat the filament and another for grid bias and plate voltages.

If you bought a radio in the early 1920s, you also had to buy several batteries, typically a dry Le Clanche lantern battery and a lead-acid automotive battery. Needless to say, they called for a strong shelf under the radio table and posed the ever present threat of spilled acid.

In the regenerative receiver, a small amount of amplified RF signal was fed back to the grid circuit of the triode, putting it on the verge of oscillation. This circuit design maximized signal gain and improved sensitivity, but the degree of feedback was difficult to control.

Slight changes in the ambient temperature, signal strength, battery voltage, or mechanical vibrations, for example, could cause the receiver to break into oscillation. (This was not surprising in view of the fact that an Armstrong regenerative receiver is essentially the same as an Armstrong oscillator.) If this occurred, the receiver was immediately transformed into a transmitter on the same frequency as the tuned signal. Imagine the howls that emitted from all the receivers in the neighborhood when one of them broke into oscillation!

Another frequently overlooked fact is that the regenerative receivers of the 1920s could continuously tune the maritime, limited broadcast and amateur bands that were located between 500 and 1500 kHz, all within the limits of today's 540 to 1600 kHz AM broadcast band.

Regenerative receiver popularity declined in 1923 with the introduction of the tuned-radio-frequency (TRF) radio. Better vacuum tubes, improved manufacturing techniques, and experience gained from solving earlier reception problems led to the TRF receiver.

Little more than a tuned RF amplification stage and a nonregenerative detector, these receivers eventually evolved into standard five-tube receivers that included two tuned RF stages, one detector, and two audio amplification stages. By 1926 the TRF receiver dominated the market and broadcast

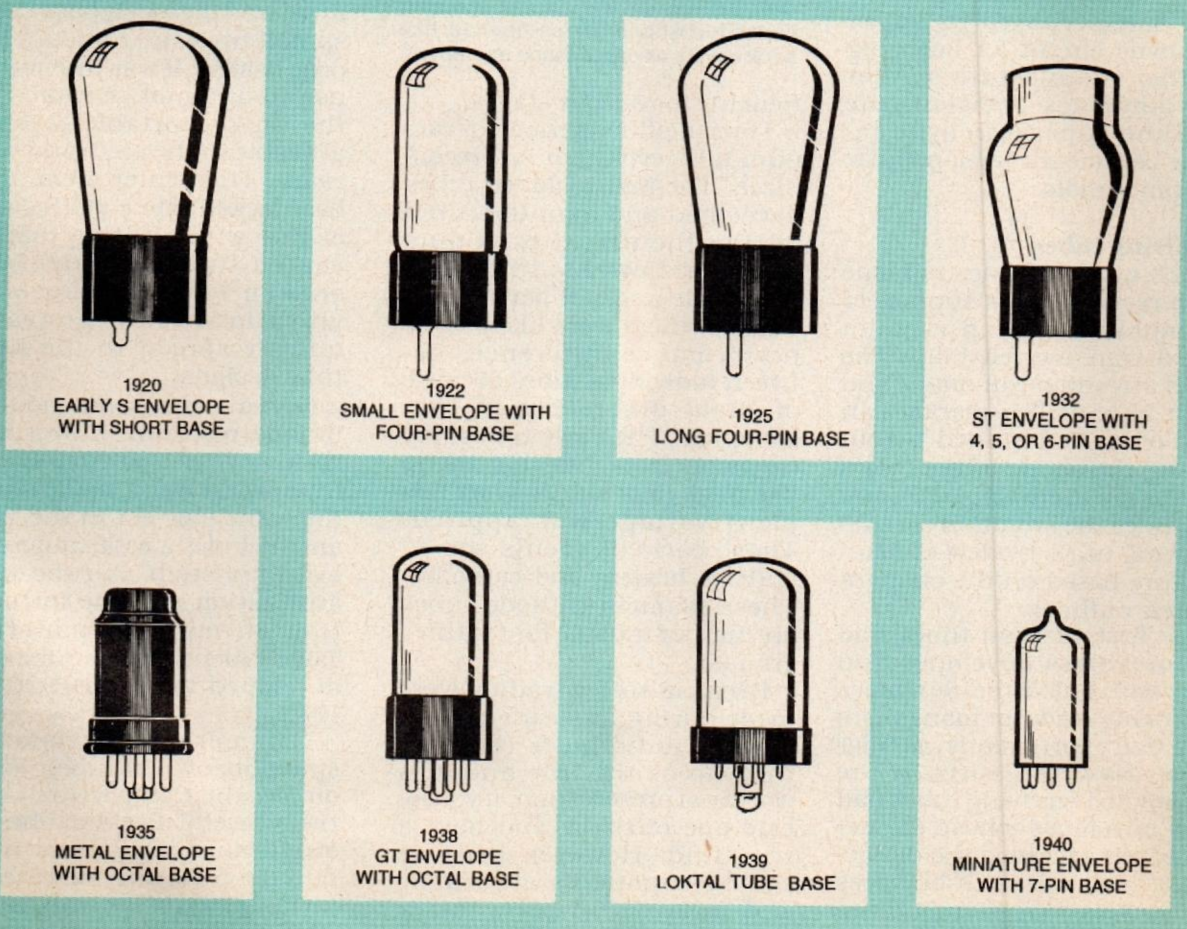


FIG. 1—THE CHANGES IN TUBE PROFILES WILL PROVIDE IMPORTANT CLUES about the age of the vintage radio you intend to restore.

stations were being licensed to operate over increments of 10 kHz. Radio was at last out of the dark ages!

But even the TRF receiver was not without its problems; strong signals were likely to cause the tuned triode RF stages to break into oscillation. The Neutrodyne receiver attempted to solve those TRF problems. It relied on a small amount of negative feedback to stabilize the tuned RF circuitry so the triodes did not oscillate.

After that development, second-generation TRF receivers took advantage of the screen-grid vacuum tube introduced in 1927. As a result, self-oscillation was eliminated and the door was opened for the first true "one-knob dialing" radios.

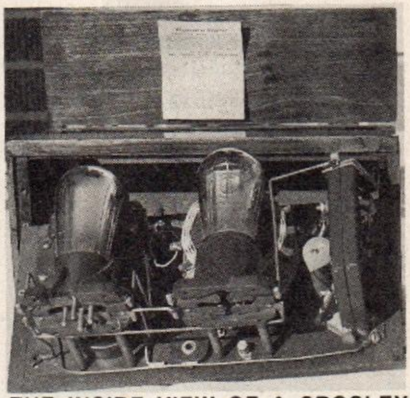
The TRF radio held the dominant share of the radio receiver market until 1932 when the Radio Corporation of America (RCA), under threat of anti-trust suits, released its superhetrodyne circuit for licensing by other manufacturers. After that landmark decision, the five-tube superhetrodyne receiver became the most popular consumer radio.

Receiving tubes

Each major advance in home radio receivers was supported by improvements in vacuum tube design and reliability. The age of any radio you might find in an attic or flea market can usually be determined by observing the shape of the tube's glass or metal envelope. Figure 1 illustrates the evolution of radio receiving tubes by date of manufacture based on the changes in their outlines.

The first vacuum tubes had bulbous glass envelopes and tubes with bulb or bottle shapes were being made for many years after that, particularly rectifier tubes. However, early in the 1920s some receiving tubes had glass envelopes whose diameters barely exceeded the diameters of their bases. Tube bases and sockets were standardized by the 1920s, but developments in base style were still taking place as late as 1939.

The first receiving tubes with metal envelopes were introduced in 1935. However, miniature glass "peanut tubes" with glass button bases (stems) and wire pins were introduced in the 1940s. Most postwar receivers had complements of these miniature tubes, but the larger tubes were in hi-fi equipment well into the 1950s, particularly for output stages.



THE INSIDE VIEW OF A CROSLEY model 51 regenerative receiver made in 1924 shows its two tubes and tuning dial. Battery-operated, it had a tuning capacitor whose plates opened like book covers as capacitance was varied.

Three distinct periods of vacuum-tube evolution are recognized. The first included tubes developed and manufactured during the period extending from World War I to 1922. Crudely made and not particularly reliable, there were likely to be performance differences between individual tubes because of slight differences in construction. The early tubes had tungsten filaments that lit up like weak pilot lamps when filament voltage was applied. Those early filaments served both as heaters and cathodes. These filament/cathode tubes are lumped into the first of three groups.

Because so few radios were made during this early period, vintage radio buffs consider them to be the true antiques worthy of preservation. If you locate one of them, you have a true find. However, because their components are fragile and replacement parts (other than those custom made by skilled artisans) are no longer available, those antiques are essentially unrepairable.

The introduction of the thoriated filament marks the start of the second period. The filaments of these tubes were coated with thorium-based chemicals capable of emitting clouds of electrons when the filament was heated to a dull, cherry-red color. However, this electron cloud was reasonably uniform within a wide range of applied filament voltage that assured generally stable circuit operation.

The third and final stage in the development of vacuum tubes began in 1927 when RCA introduced its new generation of tubes designed for AC-line operation. These tubes had separate cathodes that were heated by a separate filament. The cathode was a more efficient electron source than the coated filament. This design concept lives on in all modern cathode ray tubes.

Another interesting development was the loctal-base tube, a spinoff from the standard octal base design. It was intended for use in automotive radios and the bulky portable receivers available in the pre-World War II years. The center stem of the base locked into a mating socket hole with a spring that prevented the tube from being shaken loose by shock and vibration. This innovation quickly spread to the newer tube designs.

Nevertheless, some radio historians recognize a fourth development period that extends from World War II to the start of the transistor era in the 1960s and includes a wide range of innovations such as tube miniaturization and the introduction of improved materials. Table 1 identifies the tube types developed between 1920 and 1942.

Commercial television inspired many new tubes. For example, the Compactron—effectively several discrete tubes in a single envelope—was introduced for TV sets. However the introduction of the transistor in 1947 cut the legs out from under further receiving tube development.

Continued on page 76

VINTAGE RADIO

continued from page 66

Panel controls

As the concept of the radio receiver changed from that of a laboratory curiosity to household furnishing, the packaging of radios underwent dramatic changes. For example, tuning dials in the mid-1920s were round, fluted knobs two to four inches in diameter. Typically, they were molded from black bakelite with contrasting recessed white scale markings from 0 to 100.

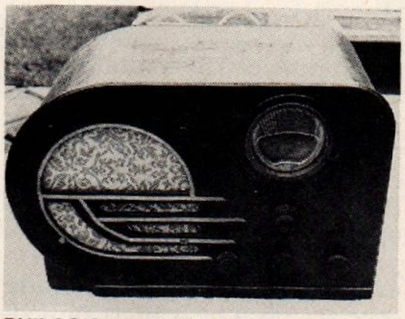
Dial calibration in units of 10 to 100 remained common as late as 1928. Toward the end of that decade, tuning dials that indicated tuning frequency were placed inside the cabinet and appeared in a small semicircular window. Numbers printed on a translucent drum were backlit by a small incandescent lamp, and an embossed escutchen plate formed the pointer. Later innovations, such as full-vision dials and the rotating pointer with fixed half-circle etched faceplate, were introduced between 1930 and 1932.

The excitement and glamor of airplanes had a major impact on the design of radio controls, particularly after Lindberg's successful solo flight to Paris in 1927. The aircraft-style round dial, mimicking an altimeter or tachometer, became quite popular. Those dials had a pointer that moved over nearly 360.° Demand for larger diameter dials grew from 1933 to 1941. The popular slide-rule dial first appeared in 1938; it has retained its popularity in transistorized radios because its pointer tracks across a long, easy-to-read faceplate.

Cabinet styles

Cabinet form is probably the most distinctive characteristic for determining the age of a radio. Unfortunately it's not practical to provide a simple identification diagram because of the many variations in style. The earliest radios were either an assembly of parts on a board or they were enclosed in boxes like laboratory instruments. Any exposed circuit became an excellent dust collector, making it almost impossible to clean without displacing or damaging some coil or capacitor.

In the early 1920s a radio receiver sold for about $40. Add to that the price of the horn-type loudspeaker, a table, batteries, and an antenna system, and the final price of the radio "system" could exceed $100.



PHILCO'S 38-10T SUPERHETERODYNE table radio could receive both broadcast and shortwave bands.

Consumer product designers soon recognized that style would sell radios. Many cabinets were oversized furniture and could easily have held as many as four radio chassis. That brings up an important point—when you get interested in vintage radios, consider where you will keep your collection before you add to it.

Most radios made in the 1940s had socketed tubes in metal chassis and were powered by the AC line. By that time effective and reliable rectifier tubes had been developed. The postwar years saw the growing popularity of radios with molded plastic cabinets in a variety of colors as well as simulated wood. Many of these radios incorporated the rounded streamlined shapes that characterized the ongoing "art-deco" style.

Getting started

The flea market is where you will probably get the best bargain—but don't forget the "buyer beware" warning. You might also try antique shops, but expect to pay more for an old radio in any established store that must pay its clerks a salary and pay overhead out of sales.

You might also search the classified pages of your local newspaper for announcements of auctions or estate sales. Also, keep your eyes open for announcements posted on trees or phone poles for garage sales or in shop windows for church benefit sales. Charity thrift stores are other possible sources.

Who knows, the exploration of your older relatives' attics might pay off. And don't forget neighborhood trash barrels on collection days. They might contain some forgotten treasures. (Naturally you'll be out walking your dog.) Your primary objective, of course, is to get a vintage radio in reasonably good condition.

If you are also a camera enthusiast, photograph your "new" old radio before, during, and after its restoration. Browsing a pictorial record of your work will give you a lot of pleasure over the years.

Be sure to record as much information as you can about the set. Look for nameplates, logos and trade names. Copy out patent numbers and their dates if you can find any. Tube location charts were often pasted on surfaces inside the cabinet. Attempt to learn as much as possible about the receiver. Marc Ellis' Antique Radio column in *Popular Electronics* is a valuable source, and there are many good books on the subject available.

Examine the catalog files in your local library. You'll be surprised about what you can find out about old radios on the shelves your local libraries. Look for advertisements of books on antique radio in this and other publications, and take advantage of fax and 800 phone numbers to obtain catalogs. You can also obtain a free copy of *Antique Radio Classified* by requesting one from A.R.C., P.O. Box 802-L11, Carlisle, MA 01741. It is a valuable resource in this field.

Restoring your set

It's important that you re-

Continued on page 86

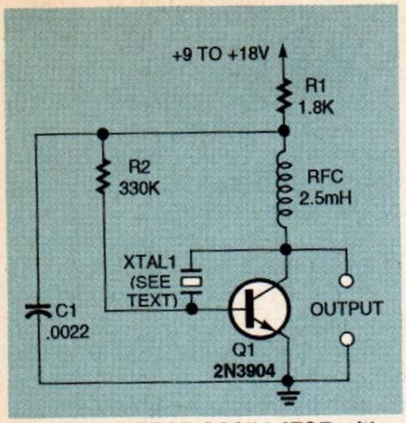


FIG. 15—A PIERCE OSCILLATOR with a parallel-mode crystal.

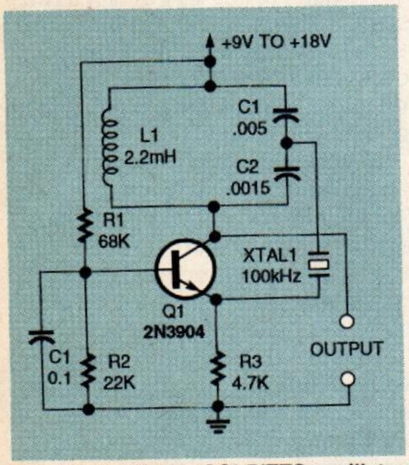


FIG. 16—A 100-kHz COLPITTS oscillator with a series-mode crystal.

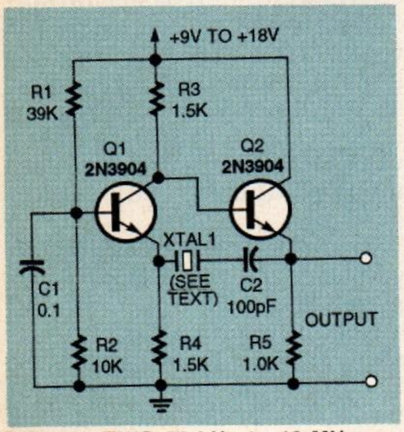


FIG. 17—THIS 50-kHz to 10-MHz oscillator will work with most series-mode crystals.

white-noise source that is in series with the base of transistor Q1. The Zener noise is amplified by the transistor to a useful level of about 1 volt peak-to-peak. Any Zener diode rated for 5.6 to 12 volts should work well in this circuit. Try different Zener diodes and compare the white-noise output.

Crystal oscillators

Crystal oscillator circuits generate accurate, stable frequencies because they include precisely cut piezoelectric quartz crystals which function as high precision electromechanical resonators or tuned circuits. The crystals in these circuits typically have Qs of about 100,000, and they can provide as much as 1000 times greater frequency stability than can conventional inductive-capacitive (LC) tank-circuit oscillators.

A piezoelectric crystal's operating frequency of a few kHz to 100 MHz is determined by its mechanical dimensions. The crystal, can be cut to provide either series or parallel resonant operation. Series-mode crystals present a low impedance at resonance, while parallel-mode crystals present a high impedance at resonance.

Figure. 15 is a practical schematic for a crystal oscillator that is designed for a parallel-mode crystal. The circuit is actually a Pierce oscillator, and it will oscillate with most 100-kHz to 5-MHz parallel-mode crystals without any circuit modification.

Figure 16 shows an alternative 100-kHz oscillator that was designed for a series-mode crystal. It is known as a Colpitts oscillator.

Its tank circuit, consisting of L1, C1, and C2, is designed to resonate at the same frequency as the crystal. However, the tank circuit component values must be changed if any other crystal frequencies are desired.

Figure 17 is the schematic for a useful two-transistor oscillator that will work with most 50 kHz to 10 MHz series-resonant crystals. In this circuit, Q1 is connected as a common base amplifier, and Q2 is an emitter follower. The output signal (from Q2's emitter) is fed back to the input (Q1's emitter) through C2 and the series-resonant crystal. This is a versatile oscillator circuit that will work even with a low-cost, marginal crystal. Because of that, the circuit can form the heart of a simple crystal tester. Ω

VINTAGE RADIO

continued from page 76

move the years of dust and grime from your new find with great care. First remove the chassis from the cabinet. Some models will have the loudspeaker mounted on the cabinet rather than the chassis: it too must be removed.

Also, many old radios have loop antennas attached to their back covers. Disconnect the leads to the antenna and set it aside. Whenever you disconnect or cut leads, note what you did and where in a notebook with comments on wire size and insulation color.

It is also a good idea to attach masking tape "flags" to the ends of any wires you cut or disconnect as well as to their termination points. Write codes or other useful data on the flags so that you can easily reconnect the wiring correctly at a later date—and avoid costly time-consuming mistakes.

Draw a parts layout diagram of the chassis showing the relative locations of the principal components, especially the tubes by type number. Remove the tubes and clean them with a damp cloth. Visit a TV/radio repair shop and ask the proprietor if you can use his vacuum tube tester. Tell him what you are doing, and you'll probably find that he will be glad to help you. Many independently run service shops stock replacement tubes.

However, if you are unable to find a local shop that handles tubes, check the classified pages of this magazine for mail-order companies that sell vacuum tubes. Some might be new unused products and others might be tubes that have been salvaged and rebuilt. Expect to find that pricing has increased markedly over their original prices, but if you only need a few, you'll find the prices to be reasonable.

Work on the chassis next. With a stiff one-inch paintbrush, remove most of the dust from the exposed surfaces. *Caution*: Do not use a vacuum cleaner—it might pull off an important part that you'll lose. Clean the surface of the chassis with a cloth dampened in water only—do not use soap or detergent! Cotton swabs such as Q-Tips are handy for cleaning in tight corners. Look under the chassis for obvious damage such as broken wires, split capacitors or broken resistors.

Replace the line cord even it appears to be in good condition. An AC cord with a hidden break in the insulation could prove to be lethal. If you are restoring a radio that was manufactured before World War II, look for a replacement cloth-covered cord. Try your local home lighting store or an electrical hardware supplier. It is important that the restored radio look authentic down to the line cord.

If practical, check the internal resistance of all paper (wax-covered) capacitors. Some vintage radio restorers replace all of those capacitors with modern film-type units with the same ratings that are approximately the same size.

Inspect all electrolytic capacitors for leakage; evidence of past leakage will show up as chalky dust or resinous seepage. Replace all electrolytic capacitors with their modern equivalents. Match the capacitance ratings as closely as you can, even if it means wiring several capacitors in parallel to obtain the right value. Also try to match the voltage ratings of the original equipment capacitors.

Now, reconnect the loudspeaker and loop antenna, and apply power to the radio with an auto transformer (commonly called a Variac). Bring the voltage up slowly while observing the filaments and plates of the rectifier tube (examples include the type 80, the 5U4, or the 35Z5).

Raise the output of the autotransformer slowly until the tube filaments glow with a dull cherry-red color. A DC voltmeter between cathode and chassis ground might indicate the presence of a DC voltage before you see the rectifier filament glow. The slow increase of voltage will reform the oxide dielectric layers in the electrolytic capacitors without damaging them. Take at least a half hour to raise the autotransformer voltage to AC line voltage.

Keep an eye on the rectifier plates that surround the tube's filaments. If they should begin to glow, turn the radio off immediately! This condition indicates a short-circuit. It will then be necessary for you to troubleshoot the radio and make all necessary repairs.

Clean the cabinet with a damp cloth that can contain mild soap, but be sure you remove all traces of soap when you have finished the cleaning. Knobs and removable plastic parts can be scrubbed with a wet toothbrush rubbed in mild soap. Rinse these parts well in warm water and let them air dry.

The cleaning of the dials and related faceplates, pointers and cords will require special care. Because of the many different forms taken by these assemblies, only general cleaning instructions can be given. Proceed cautiously with water-dampened cotton swabs or suitable soft artists' brushes.

You might want to replace the loudspeaker grille cloth of your restored radio if it is embedded with dust and grime. You might be able to obtain grill cloth with a suitable matching color and weave from your local electronics store; if not try one or more of the many mail-order electronics distributors.

The woodwork or finish on the cabinet might need repairs. Broken parts of the cabinet or seams might need to be reglued. Don't attempt this work yourself unless you have had experience in fine furniture repair. An amateurish job will detract from the restored radio's appearance and value. Unless the finish is badly scarred, confine your finishing work to a light coat of furniture wax.

If you must refinish the cabinet yourself, seek the advice of an expert in a paint or hardware store before you purchase any stains, varnishes, or lacquers. It's important to keep the cabinet's original color and tone because that's part of its history. Ω adjusts itself to give a constant and low-distortion output.

The thermal inertia of the lamp guarantees that all the AGC variations stay long-term only, instead of distorting the output waveform. This gives you elegant simplicity at its very finest.

Both RC networks must be matched very carefully, preferably better than one percent. That No. 327 bulb is a stock pilot light rated at 28 volts and 40 milliamperes.

As a second contest this month, tell me about your favorite example of elegant simplicity. Concepts similar to this superb sinewave oscillator, a P38 can opener, or a vortex cooler are what I'm after.

Coin changers

I have recently received lots of requests for low-cost sources of video-game coin mechanisms. As surplus, these are largely catch-as-catch can. But *Marlin Jones*, *American Science & Surplus*, and *Herbach & Rademan* sometimes stock them.

For larger quantities, try the ads in *RePlay*, *Playmeter*, or the *Automatic Merchandiser*. For antique versions, try the *Player Piano Company* or the ads in *Always Jukin'* magazine.

Lutech and *American Changer* are two sources for the dollar-bill changer mechanisms.

If you learn about other sources here, please let me know.

New tech lit

The Electrochemical Society is a good source for information on new battery technology, fuel cells, electroplating, corrosion, conductive polymers, and even Buckeyballs. It publishes *Interface* magazine and holds lots of trade conferences.

The third edition of the *Almanac of UFO Organizations and Publications* is offered by *Phaedra*. It's authored by David Blevins and costs $19.50. This is a combined Thomas Registry and Michelin Guide to the field. Of the 400+ resources listed, at least one of them (AI-TRAD) puts its money where its mouth is: one million dollars cash to anyone who is able to provide some *solid* evidence of either UFOs or aliens.

A fine selection of books and other resources for the handicapped is found at the *Disability Bookshop*.

Free samples of socket head caps are available from *Shear-Loc*. These caps instantly convert plain old cap screws into knurled knobs or thumbscrews, rosette grips, or tee-handles. Only a bench vise is needed to assemble the caps.

You can quickly and conveniently get copies of just about any technical standard from *Global Engineering Documents*. But note that it is often much cheaper to go directly to the standards associations themselves. We saw a full listing of these back in *Hardware Hacker, December 1991, and in my on-line and hard-copy reprints*.

Two rather strange and wondrous publications for this month are the Iron-Man Album and *Gas Engine*. They're for restorers of antique steam- and gas-powered tractors, respectively.

If you want to start up your own tech venture, be sure to get a copy of my newly revised *Incredible Secret Money Machine II*. Ω

EQUIPMENT REPORT

continued from page 18

The stainless steel blade can be used in a similar manner to remove PLCCs (plastic leaded chip carriers) and chip resistors and capacitors from circuit boards.

The *SC-7000* is available from Howard Electronic Instruments, Inc. for $395, which includes a convenient stand for benchtop use, and a cleaning pin set. An SMD removal kit, which includes a hot-air blower tip and other required materials is available for $47. Members for national, state, or local electronic association (including NESDA, ISCET, NARDA, and NESA) are eligible for a 10% discount.

Any technician who needs quality desoldering capability but who can't justify the purchase of a benchtop desoldering service center, will be well served by the DIC *SC-7000* desoldering tool. Ω