The Impoverished Radio EXPERIMENTER

Tricks, tips, and secrets to help the builder of simple radios and electrical gear achieve high performance at minimal cost!

4

Build a TRF Regen Receiver
One-Tube Crystal Converter
Versatile Power Supply
Slide Rule Dial! More!

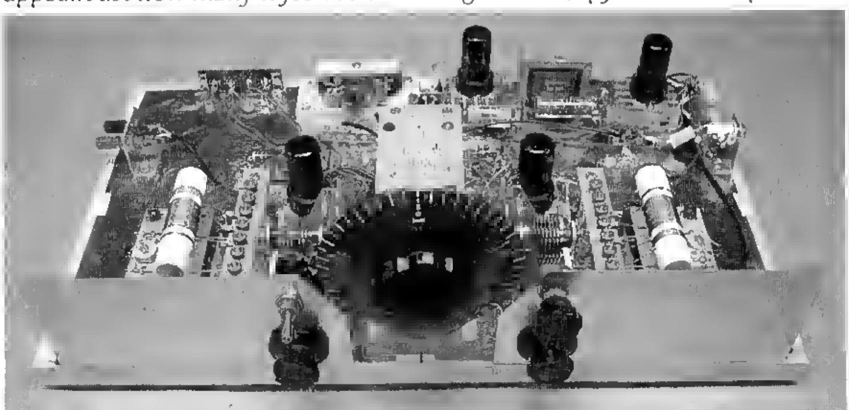
EXPERIMENTER

Building a TRF receiver, converter, power supply & more...

Building a simple radio is relatively easy. But you probably already know that. If not, then it's time to get off your posterior and build. It's slow going at first, but as you make mistakes and learn from them, you find that the building process becomes faster and easier. Before long, you'll find that simple radios have lost their appeal. Just how many crystal sets or simple regenerative receivers can you build before their novelty evaporates? If you're still building the same radio you built as a kid, or even five years ago, then it's time to break out of your rut and learn something new.

It's time to look at building better quality radios. We're talking about radios that are sensitive, selective and stable enough to use on the amateur bands, in other words, to be used for reliable two-way communication if need be. With a quality receiver it's fun to eavesdrop on shortwave communications whether it be broadcasting stations, spy stations, ships at sea, or amateur stations.

If you have a ham radio license, that is, you're a "radio amateur", then you already know what I'm talking about. If you don't have a license, you need to give it serious consideration.



This single control trf regenerative receiver offers tuned RF amplification, a regenerative detector with tickler feedback, a tuned inductive audio filter, and a power pentode to drive a loudspeaker. Its performance equals or surpasses that of any commercially built regenerative receiver. You can build one, too.

The Impoverished Radio Experimenter Volume 4

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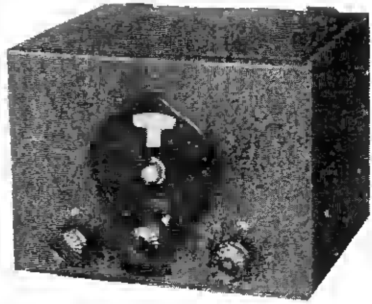
You must experience the joy and amazement that results from building a simple receiver and a transmitter and using it to talk to some other ham across the country or across the planet. If you can build a receiver, you probably have more than enough knowledge of electronics to pass the written test for a ham license, and in recent years code requirements have been reduced to five words per minutes. And five words per minutes is nothing. If you can copy any code at all, you're copying at least five words per minute. If you don't have a license, give it serious consideration because you can put on the air the simple radios we build. It's lots of fun.

For all but the earliest years, amateur radio operators have purchased commercial receivers and have built their transmitters. The reason is complexity. A "good" receiver must have many tubes, but a good transmitter need have only one tube. I think another reason is a belief in "magic". Somehow "no lowly amateur" could possibly build a receiver as good as those built by major manufacturers. Both ideas are bunk.

A decent, usable receiver need have only three tubes, and it can perform, and actually outperform comparable commercially built receivers. Enthusiasts today covet the National SW-3 or the Hallicrafters original Skyrider. I'm sure some of it is nostalgia, but I have to wonder if it isn't magical thinking again: "I could never build anything as great as the SW-3 or Skyrider." That, too, is bunk.

Lindsay Publications has reprinted the 1935 Official Shortwave Radio Manual by Gernsback & Secor. In there is a schematic and technical notes on these two receivers and many others. I'm hear to tell you, jack, that if you haven't build a regenerative receiver that operates as well as either of these two receivers (and probably better) then it's only because you haven't tried.

The National SW-3 from a late 1930's advertisement



General Coverage Coils

Catalog Number	Range	List Price Per Pair
10 or 60	9. to 15. meters	$5.00
11 or 61	13.5 to 25. meters	5.00
12 or 62	23. to 41. meters	5.00
13 or 63	40. to 70. meters	5.00
14 or 64	65. to 115. meters	5.00
15 or 65	115. to 200. meters	5.00
16 or 66	200. to 360. meters	5.50
17 or 67	350. to 550. meters	5.50

Five additional sets of coils are available to cover up to 3000 meters

Band Spread Coils

10A or 60A —	10 meter band	$5.00
11A or 61A —	20 meter band	5.00
13A or 63A —	40 meter band	5.00
14A or 64A —	80 meter band	5.00
15A or 65A —	160 meter band	5.00

The Skyrider is a four tube receiver, not counting the rectifier tube. Two remote cutoff (variable-mu) pentodes, 6D6's, serve as RF amplifier and regenerative detector, followed by a sharp cutoff pentode, 6C6, as audio amplifier driving a 42 power amplifier tube.

The SW-3 uses only three tubes. Many different tube types were used during its production life, including a pair of 24's as rf amp and detector and a 27 audio output. Other tube lineups included a pair of 36's and a 37, two 58's and a 27, or toward the end, a pair of 6J7's and a 6C5. You certainly can build a receiver that is every bit as hot a performer as the

SW-3 and more.

In this issue of the Impoverished Radio Experimenter, we start with a demonstration receiver intended to throw a number of ideas at you that you can use to build a good quality receiver. This is what hams called the TRF – that is, a regenerative receiver with a tuned radio frequency (TRF) amplifier stage. It is not to be confused with the TRF broadcast receiver which is a different beast altogether.

TRF Receivers

You can build a working receiver with a single tube. We tried that in Vol 3 with a homemade capacitor. But two tubes are usually considered the minimum: one for detection and one for audio amplification.

Adequate gain is easily attained with modern vacuum tubes. In the old days, no, not the 60's, more like the 20's, the only tubes available were triodes, and their gain was quite limited. You needed a couple of 201A's or a pair of 30's, for instance, to produce a respectable audio level in your headphones. These days, you can use a 6AU6, a high gain pentode, as the detector and a 6AV6, a very high gain triode, as an audio amp to create a receiver that will deafen you.

Just because you can create audio signals at the threshold of pain does not in any way mean you have created a quality regenerative receiver. Not at all. Despite the simplicity of these simple radios, they are notorious for receiving far more than you want. Frequently you'll not only hear the station you want but you'll also hear that spy station somewhere in Asia, the welding shop in Tupelo, and the spark plugs in that geezer's 1947 Chevy on the other side of town, not to mention broadcast stations, fourteen different amateur stations, and some jerk on a cell phone talking to his girlfriend. In other words, regenerative receivers are NOT selective. What's worse, if unwanted signals are strong enough they can destroy the bias on the detector tube and shut it down – what we call blocking.

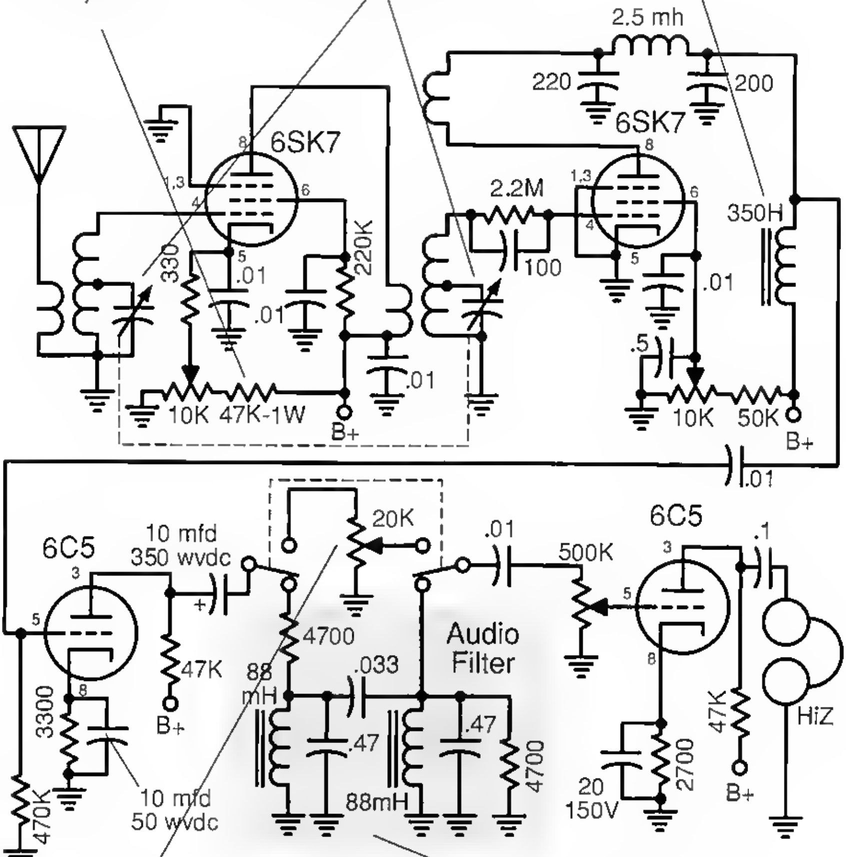
LC circuits, a coil and capacitor, resonate at one particular frequency and act as a simple filter. If we put more and better LC circuits (tank circuits as they were called) in front of our regenerative detector, we can improve selectivity. But every tank circuit eats up some of the electrical power that flows through it. And that's called insertion loss. To regain the lost energy, you'll need to pass the remaining signal through a tube for amplification.

We can immediately improve the selectivity of almost any receiver by attaching a high-Q tank circuit to the grid of a tube. The LC circuit rings like a bell at only one frequency or narrow band of frequencies. Signals coming in off the antenna literally hammer that tank circuit like a bell. It sits there and rings, but only at its natural frequency. The only voltages that can build up across a parallel tank circuit are those which have frequencies that match that of the circuit. And if those are the only voltages present in any quantity across the LC circuit, they will be the only voltages amplified in their passage through the tube. This kind of a circuit is known as a RF amplifier. Not only does it increase the strength of the signals it hears, but it also essentially deaf to all signals except those frequencies which match

Use these values. Be sure the 47K is more than 1/2 watt.

100 pfd Hammarlund capacitors used in the prototype. Your receiver may use something a bit different

Use as large a choke as you can find. A 350 henry choke is very difficult to find these days. A smaller choke will work.



TRF Regenerative Receiver with sharp audio filter

The 20K pot ensures that the signal level with or without the audio filter switched in is about the same so that you do not destroy your hearing when switching the filter in and out. A 10K or probably a 50K pot will work as well.

Two pole audio filter lifted from "Solid State Design" by Hayward & DeMaw available from the League that of the LC circuit. You get improved sensitivity *and* selectivity.

Regenerative receivers are extremely sensitive receivers. When built with modern tubes they are almost too sensitive when driven by the usual RF amplifier. Improved sensitivity is of secondary importance. What does count is the improvement in selectivity and most importantly, I think, the incredible improvement in stability. The frequency and critical regeneration adjustments needed in a regenerative detector are very easily upset by slight changes in the antenna circuit. Wind blowing a long wire around can produce noticeable effects in the pitch of received code signal. Putting an RF amplifier between the antenna and the detector creates a "firewall". Subtle changes have essentially no effect on the input circuit of the RF amplifier tube. The plate circuit of the RF tube appears to the detector like a very sensitive rock-solid antenna which never changes. And that means that detector adjustment is easier, making the receiver easier to use for communications like ham radio.

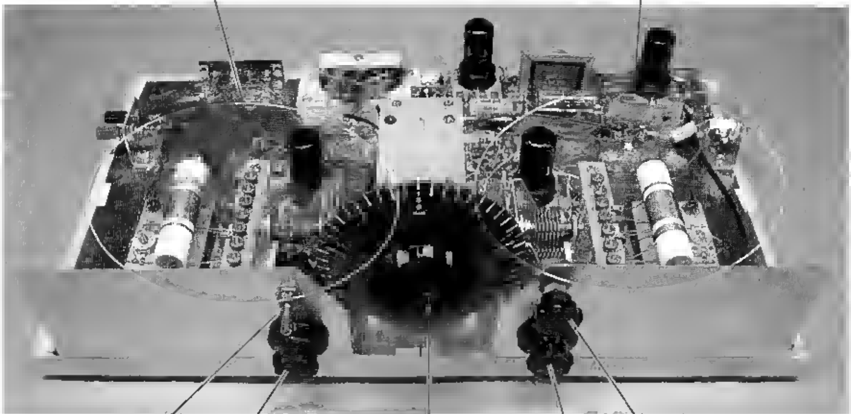
If the detector cannot "see" the antenna, but rather sees the same old RF amplifier plate day after day, that means that the main tuning circuit will have much better resetability. That means if you find that WWV comes in at 45 or very close on your tuning dial today, that it will come in at 45 tomorrow and next week as well. Without an RF amplifier merely adjusting antenna coupling to avoid a notorious dead spot could easily move WWV from 45 to 75 on the dial. You're forced to figure out the new locations of all your stations!

If you dig through old amateur radio literature, you'll find numerous receivers with an RF stage, a detector, audio stage, and sometimes a power tube to drive a speaker. The National SW-3 is an example.

Our demonstration TRF here is built around a pair of 6SK7 remote-cutoff pentodes (variable- mu) and a pair of 6C5 triodes. I like octal tubes because they are self shielding when pin one is tied to the chassis ground. You could use other pentodes such as 6D6, 6S7, and 6BA6, for example. You might want to try a 35, remote-cutoff tetrode. And sharp-cutoff pentodes will work nicely, too, such as the 6SJ7, 6C6, 6AU6, and many others.

A remote-cutoff is preferred for the RF amp because its gain changes dramatically with changes in grid bias voltage. You can see in the schematic that the cathode is connected through a 330 ohm fixed resistor to the wiper of a 10K pot. One end of the pot is supplied with 25 to 30 volts from the high voltage power supply through the 47K resistor. As the pot is rotated the DC voltage on the cathode is changed relative to ground. Since the grid is at ground, that means the DC voltage on the cathode is changed relative to the grid – and that change in bias changes the gain of the tube. In other words, the pot attached to the cathode of the remote-cutoff pentode acts as a volume control of sorts, controlling the amount of signal that hits the following detector tube.

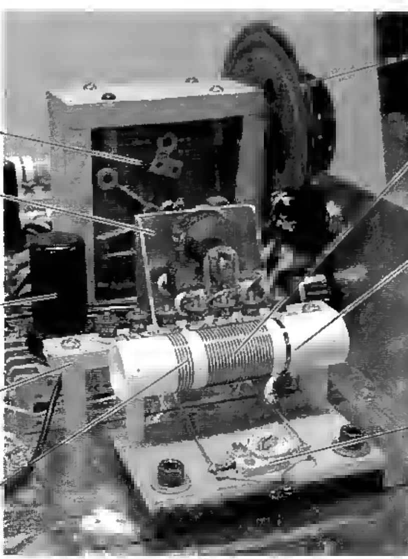
Although I used 6C5's for audio amplification, other tubes are just as good. You could use 6J5, 6C4, or even a 27 (2-1/2 volt filament). There are many other triodes. You could use a dual tube. For instance a 6U8 is a pentode and triode in one glass envelope. You could use it for the detector and first audio stage. And there are scores of unusual tubes custom



TRF Receiver

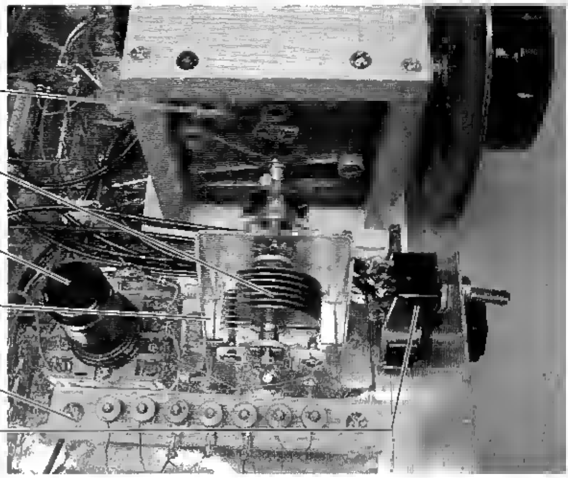
built for television sets. A scan through a tube manual from the 60's and early 70's will turn up scores of usable tubes.

But remember! If you use a glass tubes, you'll want to put a tube shield around the RF tube and the detector tube so that they don't hear anything they're not supposed to. Tube shields, especially for old tubes, can be hard to find and/or expensive. You can make your own from soda cans, aluminum foil, or even a tomato paste can (which I once put around a '24



RF Amplifier Section

RF Amplifier Section



detector tube.)

Again looking at the schematic we find a coil and capacitor (tank) circuit on the grid of the RF amplifier. And we find another such LC circuit on the grid of the detector tube. These circuits must be tuned to the same frequency at all times, in other words, they must track. If you change the frequency of one circuit by rotating the variable capacitor shaft, you must change the frequency of other as well. This can be a problem.

The classic solution is to use identical variable capacitors in both tank circuits, and to connect them to one another mechanically. Turning the shaft of one automatically turns the shaft the other. This can be accomplished by a universal joint or by searching for a hard-to-find "double-gang" capacitor of 100 to 140 pfd per section. Another solution shown here is the old National PW dial specifically designed to solve the problem.

If the capacitors are identical and ganged together, the coils to which they are connected must be identical as well: same number of turns, same spacing, same diameter, etc. This is not that difficult to accomplish if you use the same type of coil stock and the same wire. If the coils are not close wound, you can space the turns identically by winding heavy string or thread between the turns. If you happen to be lucky enough to have an engine lathe, or know someone who does, you can score grooves in the coil form with a threading tool. When you wind the coil, the wire will fall into the grooves, making it very easy to wind two identical coils.

Remember, though, you are not obligated to mechanically link the RF amp and detector tank circuits. The only absolute restriction is that they both tune to the frequency desired. You can use capacitors of different values connected to coils of different number turns, diameter and length. The only problem is that you'll need two hands to tune your radio. You'll slowly tune the detector for a signal you want, and then adjust the RF amplifier until the signal volume peaks. Making the two tank circuits track results in a receiver that is a bit more convenient to use, but it does not give overall superior reception. If you can't

Detector Stage

Bracket and 100 pfd capacitor

Detector tube

Coil terminal strip

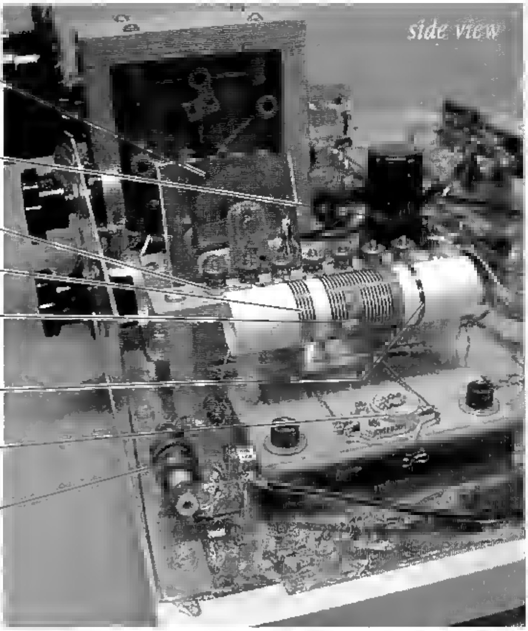
Tickler winding

Main coil winding

Winding from RF amplifier plate

"bandset" capacitors

Pi-network filter in plate circuit of detector tube



gang the capacitors, or don't care to, just bring the shafts of bothout through the front panel and put knobs on each. You'll want a vernier dial on the detector for slow-motion tuning, but no vernier is needed on the RF amp because tuning is far less critical.

The plate of the RF amplifier transfers signals through a simple winding near the tank circuit of the detector circuit. This winding is untuned, as it is in most early receivers. It would be better to tune it with another capacitor identical to the other two, so that the input tank circuit the output winding tank circuit, and the detector tank circuit would all tune to the same frequency. That could give us better selectivity and far more gain. But it could also create real problems in adjusting the detector regeneration. Besides, early tubes have grids and plates that "hear" one another all too well, when they really shouldn't, and that can allow the input tank circuit hear the output tank circuit, creating oscillation. In fact early tuned-plate-tuned-grid transmitters capitalized on this effect. Here, it would be best not to tune the plate of the RF amplifier.

The detector is a plain ol' vanilla circuit with tickler feedback. If you look at the circuit, you'll notice a problem. You have three different coils on the same plug-in form. You have two leads for the RF plate circuit, two for the tickler winding, and three for the detector grid winding, for a total of seven leads. I don't have any seven pin coil forms. Six pins are the biggest I've ever seen. The SW-3 used a custom 6-pin form with a separate lead out of the top of the coil to become the seventh lead. Usually a TRF circuit will have no tickler feedback. It's usually a Hartley whereby feedback is created

Original Dual 6C5 audio stage viewed from the rear.

Headphone jack — *First 6C5 triode* — *350 H choke* — *Second 6C5 triode* — *Two-pole audio filter on mounted on wood*

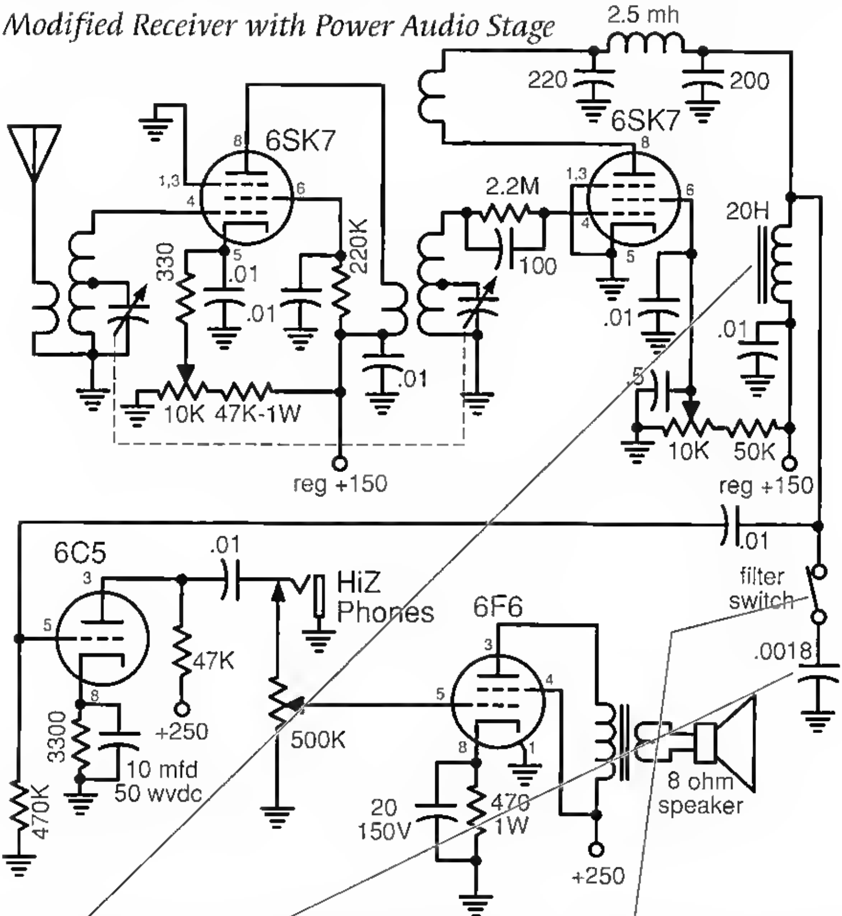
Fabricating the multi-winding coils needed by TRF receivers similar to the SW-3 is not all that difficult. But to get truly hot performance requires much more than cut-and-try methods. Anyone building advanced regenerative receivers would do well to read, study, and thoroughly understand LW Hatry's detailed classic QST article from 1934.

Tailoring Tuned R.F. Transformers for Short-Wave Receivers
A Design Method for Peak Performance
by L. W. Hatry, QST, Oct 1934, pg 14

by a tap very near the ground end of the grid winding. I don't care for Hartley detectors because with modern sensitive tubes, you may have a grid coil of 15 turns, but the feedback tap might be a 1/2 turn from the bottom. And shifting the tap up or down as much as 1/3 turn can make all the difference in whether or not the detector goes into regeneration smoothly. But it's the price you must pay if you want to build a TRF with plug-in coils.

The only unusual component used here in the detector circuit that you're not likely to find is the 350 henry choke on the detector plate. I bought this choke decades ago when they were still being made. It only passes 5 mA because the wire inside

Modified Receiver with Power Audio Stage



Choke and capacitor must resonate at about 700 cycles per second. Other combinations are possible: 15 H & .02 mfd or 8 H and .005, etc. Use your bridge to measure junk box chokes and then use the formula to calculate the amount of capacitance needed.

Switch connects the filter to the choke to turn this simple filter on and off.

Modified audio filter and amplifier viewed from the front.

In wiring up the volume control and audio filter switch, use shielded wire to avoid problems with AC hum getting into the circuits.

is so fine. It has to be! There are probably ten to fifteen thousand turns inside. At the time I write this, I know that Hammond manufactures a 150 henry 8 mA choke with a retail price of about $11. That will work just fine. But! Before you rush out and order one, read on. You may actually want a smaller choke you can tune.

In the first version of this TRF, audio that builds up across the 350 henry choke is brought through a .01 capacitor to the grid of a 6C5 triode with a resistive load on the plate. The amplified audio then passes through an audio filter fabricated from a pair of common 88 mH toroids and three capacitors. The filter allows only a narrow band of frequencies around 750 cycles to pass through to a 500K pot which acts as a volume control on the grid of the output 6C5 triode. This filter dramatically increases selectivity for the reception of code signals.

Since the filter consumes much of the audio signal (high insertion loss), you'll want to increase the volume control to compensate. When you switch the filter out of the circuit, the audio level will jump up dramatically. To compensate you must back off on the volume control. If you forget to do this (and you certainly will), you'll deafen yourself. To save your ears install a 20K pot into the switching circuit, so that it decreases the audio signal level to the same degree as the filter. This pot is adjusted so that the audio level heard in the headphones is about the same with and without the filter switched in. The audio level should stay constant for the most part, saving your hearing for another day.

So how well did this receiver work? Too well. Great gain. Great stability. At least in the 40 meter amateur band. But the audio filter was actually much too selective. So why not try what the old timers learned to do back in the 20's: resonate the detector plate choke.

The 350 henry plate choke was

Modified audio filter and amplifier viewed from the rear.

20 Henry Detector Plate Choke (part of audio filter) — *6F6 mounted in octal relay socket* — *Audio Output Transformer* — *Terminal Strip for speaker terminals*

removed and replaced with a 20 henry power supply filter choke. Referring to the section in EXPERIMENTER 3 pages 40-42, we can use the formula to calculate a capacitor to put across 20 henries so that it will resonate at 700 cycles. My calculator comes up with .0026. Digging through the junk box, I found a 1500 pfd (.0015 mfd) "postage stamp" silver mica capacitor. A quick check using the impedance bridge showed that it hadn't changed value. Feeding the numbers back into my calculator showed that 1800 pfd and 20 henries would resonate at about 840 cycles, a bit high, but okay. Putting an additional .001 capacitor in parallel with the 1800 would give .0028, resonating at 673 cycles. If you prefer a lower tone, you can adjust the resonant frequency by adding more capacitance in parallel to lower the frequency, just like you do when you wind coils for a regenerative detector.

A simple resonant plate load has far less insertion loss than the telephone toroid filter, so two 6C5's are not needed for headphone service.

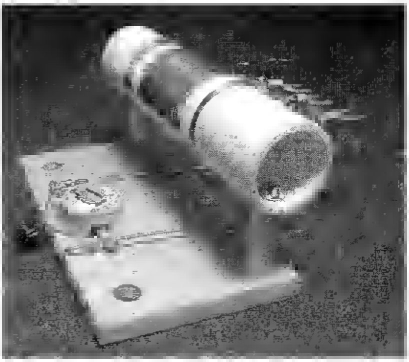
Since I have several sizeable tube power supplies (and you should, too) that deliver plenty of plate current, it was possible to replace the second 6C5 triode with a power pentode to drive a loudspeaker. Using the methods described in EXPERIMENTER 3 page 31, I looked for an output transformer in the junkbox with a high primary impedance. I didn't come anywhere close enough to what a 6F6 really needs for best performance, but the transformer I did use is more than enough. The 6F6 fills my basement lab with signals from all over the world.

The 6F6 is the classic early metal power pentode. But a 6V6 is quite usable as is a 6K6. You could probably use a 6L6 as well, but that's really a bit too big. There are many tubes. If you're using miniature tubes for your radio, you can use the 6V6 equivalent: the 6AQ5. These tubes are usually used in push-pull circuits for best efficiency, but they will work here in single-ended service quite adequately.

Just remember that four tubes driving headphones can consume 30 to 40 mA of plate current. Three tubes plus a power pentode driving a loudspeaker can consume 50 to 60 mA depending on how much power you get out of your output tube. The very simple power supply described in EXPERIMENTER 1 won't cut it. Don't even try. A more substantial power supply like those described in EXPERIMENTER 3 are needed. If you haven't built a good quality power supply, you need to. Now! Its convenience makes tube experimentation much more fun!

Coil Modules

Although I have many 4, 5 and 6 prong plug-in coil forms, I thought it would be interesting to build "plug-in" coil modules of some type. The method I used here, which under no circumstances can be said to be ideal, works very well.



This 40 meter coil is wound on 1/2" PVC which has an outer diameter of .84". The tubing was chucked in a screwcutting lathe and grooved with a threadcutting tool at a pitch of 20 grooves per inch into which 21 turns of #18 enameled wire. The bandspread tap was attached to the 5th turn from the ground end. Across the main coil is a 50 pfd fixed capacitor in parallel with a 5-20 pfd ceramic trimmer. The coil at either end consists of 5 turns. IMPORTANT! These numbers probably won't work for you exactly. You'll have to find the number turns and the tap point to get you on the band you want. You'll have to adjust tickler turns to get smooth regeneration.

What I do is wind a test coil for the detector stage to determine the number of turns and the coil dimensions. Your grid-dip meter and the formulas will help greatly in this task. Once you have a coil that works, you build two coils with these specifications as identically as you can. You probably don't have a lathe to cut grooves, but you can use twine and heavy string to space the windings evenly like radio builders did in the old days.

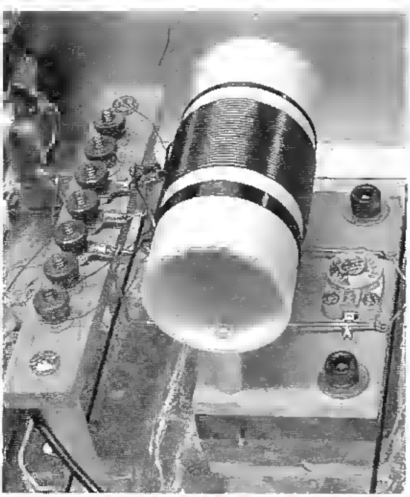
(left) Hardware store spade connectors for 18-22 gauge wire and #6 screws were soldered to the heavy wire leads to make their connection to the terminal strip easier.

Each 2" x 3-1/2" base was cut from 3/8" thick phenolic that I picked up at a flea market for 50¢ a sheet. I wanted phenolic because it was nonmetallic yet could be easily drilled and tapped to accept 1/4-20 cap screws which serve as poor man's thumbscrews.

Coils are wound on PVC tubing and mounted to 3/4" nylon standoffs with brass machine screws. These standoffs, in turn, are fastened to 2" x 3-1/2" pieces of 1/4" plywood with flat head machine screws that have been drilled to match the holes in the phenolic base plate. On this plywood plate can be mounted the necessary padding capacitors that the bandspread formula (EXPERIMENTER 2 pg 39) tells you are necessary.

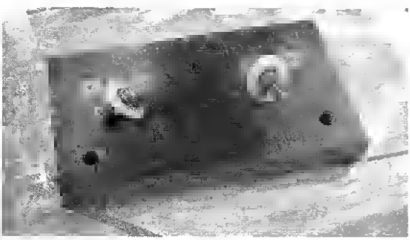
With physically large coils, you'll create physically large fields, so keep metals as far away from the windings as possible. And use nonferrous screws and the like if at all possible. Be sure to make the coil pairs as much a like as possible so that they will track properly in your receiver.

(below) Coils to tune 3-3.3 were wound on 1-1/2" diameter PVC tubing. The main tuning coil is wound with 26 turns of #16 enamel wire, tapped at 13 turns. The pad around the main coil is fabricated from a 75 pfd silver mica capacitor in parallel with a 5-20 ceramic trimmer. The tickler coil consists of 20 turns of #28 and then input coil is about 8 turns of #28.



The 3-3.3 mHz frequency was chosen so that a converter (details to follow) could be fabricated around an 18 mHz computer crystal allowing amateur radio signals in the 15 meter band (21 mHz) to be received.

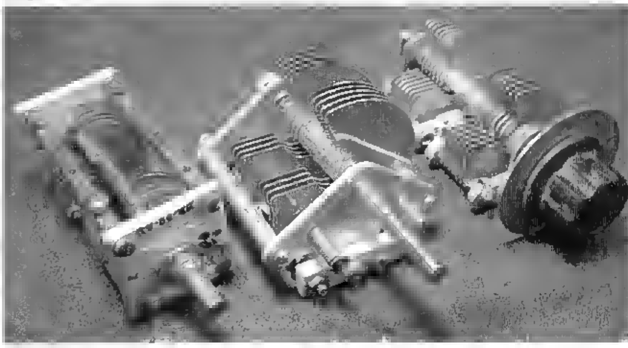
The terminal strip is merely a strip of oak (acrylic plastic would work quite well) held above the breadboard by plastic tube standoffs. A 9/64" hole is drilled every half inch to accept 3/4" brass 6-32 machine screws. Over the brass screws is slipped a soldering lug and the screw is inserted into the hole from below. Then a washer and nut are tightened down. Finally a common 6-32 thumbnut is added to make attachment of the coil leads easier.



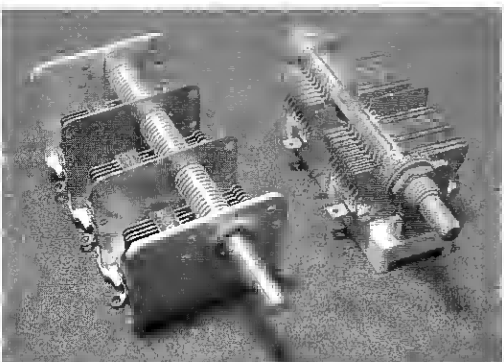
(left) Each coil base is cut from 3/8" thick scrap phenolic drilled to accept two wood screws that attach it to the breadboard, and drilled and tapped to accept the two cap screws shown which serve as thumbscrews. No doubt, you could use plywood replacing the capscrews with woodscrews or long hexhead sheet metal screws.

Multi-Section Capacitors

If you choose to build a deluxe "single control" TRF regenerative receiver, you'll need two capacitors of identical value mechanically linked to one another. Such capacitors were produced commercially at one time and can still be found.



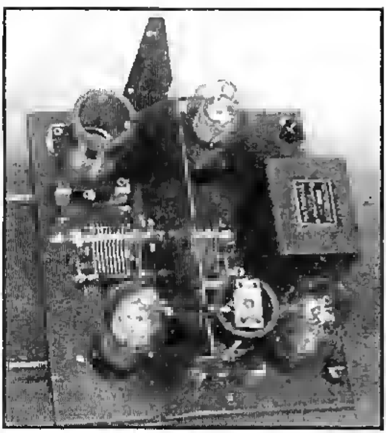
Here, we see common "hamfest" finds ranging in price from 50¢ to $3.00. It may be necessary to put a shield between the sections so that they are less likely to "hear" one another.



Multi-section broadcast capacitors are quite common, but each section is usually 365 pfd or more in value. That's far too much for the usual shortwave receiver. You would have to pull plates out to reduce the capacitance of each section. (left) a three section 23 pfd capacitor manufactured for an early FM receiver. (right) a dual 140 pfd Hammarlund capacitor on a heavy porcelain base.

(right) You can make your own multi-section capacitor if you can find two identical capacitors. Hammarlund 100 and 140 pfd dual bearing capacitors are still quite plentiful. With some searching it's not impossible to locate two identical units and couple them with a universal joint (foreground.) The bearings must be free and turn smoothly or the torque needed to turn two such capacitors simultaneously might make your friction dial drive slip. The advantage to "rolling" your own is that you can couple the two sections with a long section of 1/4" shaft keeping the two sections and their circuits widely separated if you choose.

(right) One of these capacitors is probably the most desirable. These are National capacitors with insulated shaft between sections and 270° of rotation, and were used in the SW-3 and FB-7 receivers. Believe it or not, both of these units turned up in a cardboard box that I bought for a dollar at a fleamarket. With enough searching you could probably find one, but not for a dollar.



A GOOD EXAMPLE OF HOW NOT TO SHIELD

A study of shielding in the development of the receiver described brought out some surprising points. The example illustrated looks good but isn't, as explained in the text. This arrangement is the same one shown at A in Fig. 1.

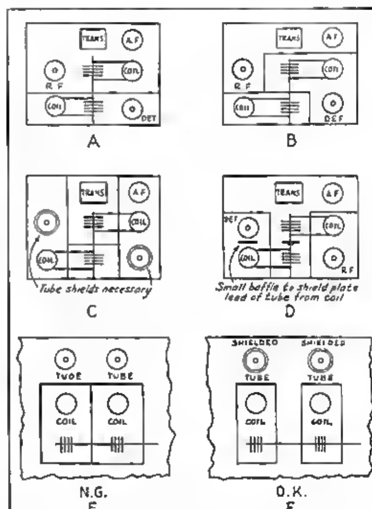


FIG. 1—SHIELDING ARRANGEMENTS, GOOD AND BAD

That shown at D is used in the receiver described.

In my opinion, anyone who wants to build a TRF regenerative receiver should read and study the article written by James Millen W1AXL published in the September 1931 issue of QST describing the development of the SW-3. An archive of these back issues is available on CD-ROM from the League.

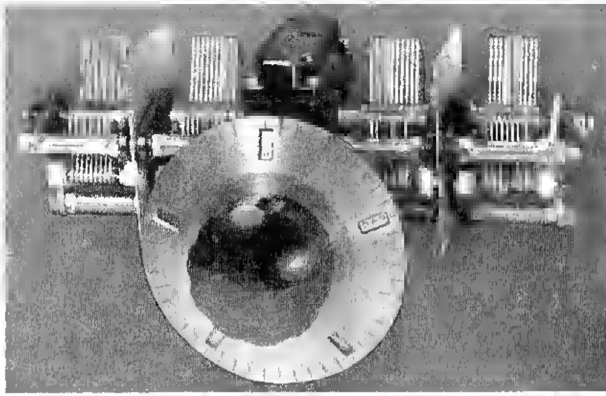
(above left) View of a chassis design that did not provide enough shielding. A shielding plate can be seen installed between capacitor sections. (above right) various shielding arrangements tried, rejected, and the one used.

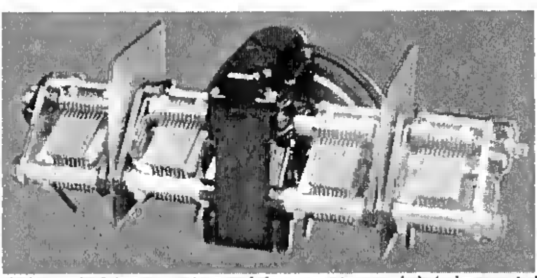
Remember that the SW-3 was developed around screen grid tubes (tetrodes) which were much more susceptible to oscillation than later pentodes. For these early glass tubes, the shielding described was, no doubt, necessary. With better tubes, though, and proper tube shields, you can get away with less stringent shielding configurations.

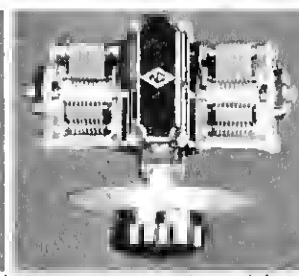
National's PW-3 Dial Drive

In the 1930's another National receiver developed by James Millen and his crew was the HRO. Its PW dial drive mechanism was an amazing piece of engineering. The PW unit I acquired wasn't cheap and was missing the capacitors. But after careful restoration, it became apparent how fine a dial drive it was, and still is.

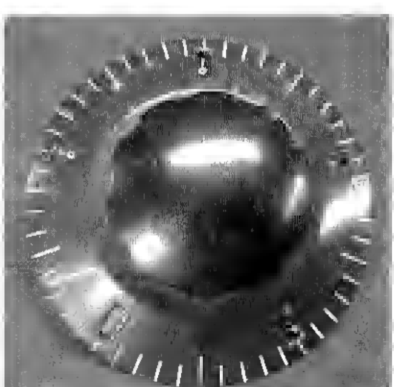
(right) the PW-4 consisted of a front dial mechanism, a spring-loaded worm gear reduction housed in the black back behind the dial, and four capacitor sections securely anchored to the die-cast box to create a self-supporting structure.





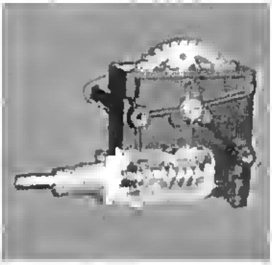


(above left) rear view of four unit model (above right) PW-2, two unit model

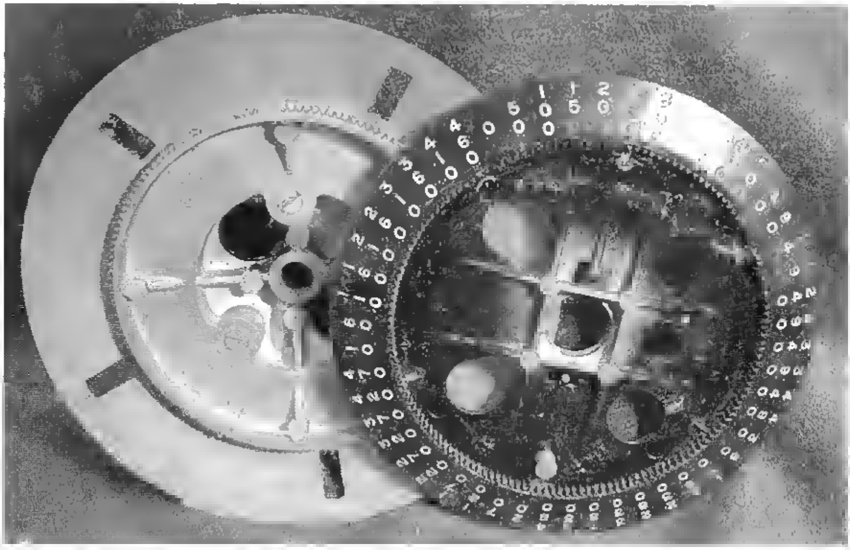


If you have never used one of these dials, you've missed something. They're magic. The window at the top shows a number. (left) we see the number 10 at the top. As you rotate the dial clockwise, that window obviously rotates around and comes back up to the top again, but this time the number in the dial will be 60. Another rotation, and the very same window will show 110! So ten full revolutions will rotate the capacitors 180° spread over 0-500 dial graduations. Note the large the space between adjacent lines. That space is 1/500 of the full rotation. It's quite easy to estimate to a quarter of that space. This is a dial that could really provide precision bandspread!

A pair of large diameter gears are sandwiched together inside the die-cast gear box and are held together with springs. The tension thus applied ensures that the teeth engaged in the worm gear below fit perfectly thereby eliminating all backlash.

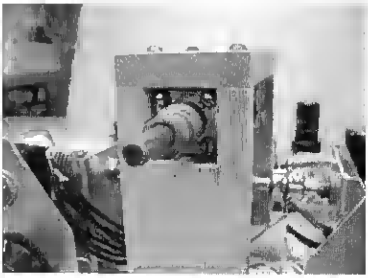


The unit I acquired was still loaded with the original 70 year old grease which had hardened into something resembling concrete. By slowly and carefully dismantling the unit, taking notes as I went along, I managed to reduce the mechanism to basic parts. These were completely cleaned with lacquer thinner, reassembled, and packed with a good quality lithium bearing grease. Having done this, the 20 to 1 reduction unit operated as smoothly as the day it was made.

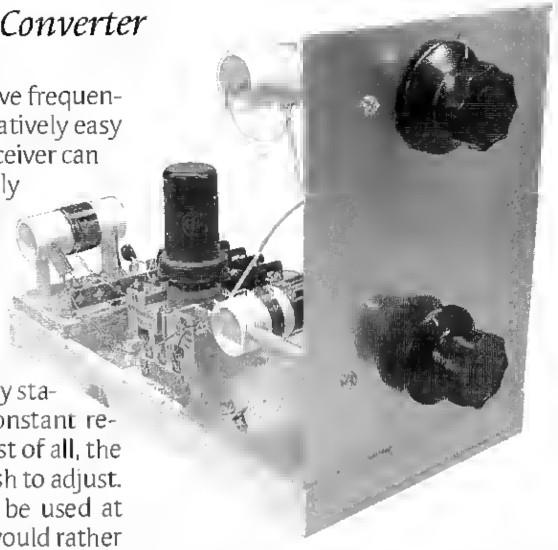


(above) the ingenious dial revels its secrets when dismantled. The dial face on the left has a gear ring of slightly smaller diameter than the internal gear ring on the number plate to the right. The teeth can mesh at only one point. Notice that the shaft bore of the left plate is smaller than the bore of the right plate. When assembled, these bores do not sit on the same axis, but offset to force the gear rings to mesh and provide the proper numbers in the windows.

(right) For my receiver, I built a wood carrier to turn the gear box upside down to allow the mounting of outboard capacitors on the breadboard. I had to pull the four screws from the plate shown, turn the plate upside down and reassemble to get the dial numbers to appear properly. Notice that the smaller shaft is not concentric with larger shaft on which the number plate rides.



Crystal Controlled Converter



Receivers for shortwave frequencies below 10 mHz are relatively easy to build. A regenerative receiver can be built that is reasonably stable and, therefore, easy to tune and adjust. But if you want to use a simple receiver at higher frequencies, you will probably be disappointed. Sensitivity drops off. Frequency stability is poor requiring constant retuning. And probably worst of all, the regeneration can be devilish to adjust.

Simple receivers can be used at higher frequencies, but I would rather not do so. I would much rather build my simple receiver for frequencies just above the AM broadcast band, and bring the higher shortwave bands to my receiver with a converter. We covered this idea in EXPERIMENTER 2 with the 6K8 and 6SA7 converter tubes.

To review, these converter tubes have more grids and plates than you can shake a stick at. Some of the electrodes are connected up to create an oscillator that generates a high frequency signal that is mixed with a signal that moves from the antenna to one of the other electrodes in the tube. Out of the plate comes the original signals, plus two new signals: the sum and the difference. A tuned circuit on the plate responds only to the difference signal which we feed to our simple receiver.

The converters in VOLUME 2 were simple LC oscillators. As such, their oscillator frequency would change as the coil and capacitor changed temperature. That meant that the signal fed to the receiver would drift, perhaps upward for a while and then downward. But the simple receiver drifted in frequency, too – perhaps not quite as badly because it operated at a much lower frequency, but drift it did. With two sources of instability in the receiver system, tuning a narrow signal, like code, for instance, meant constant retuning. Keeping a signal tuned in could be difficult.

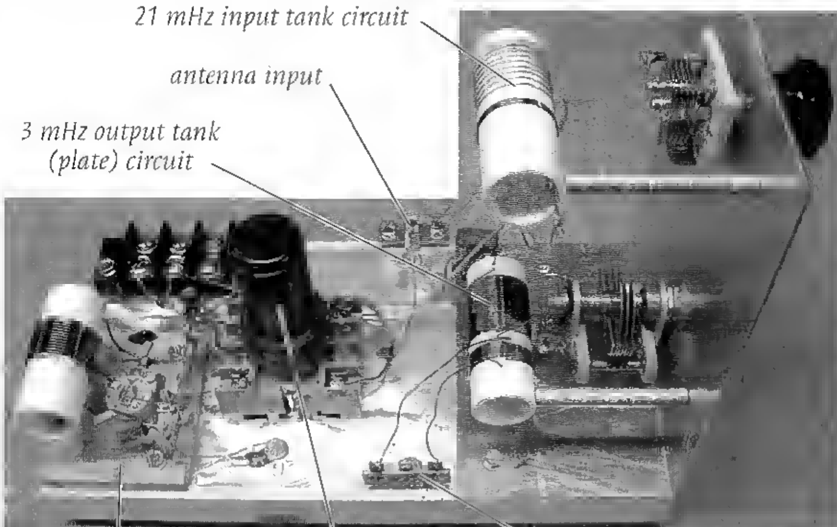
The solution is to lock the frequency of the converter tube oscillator with a quartz crystal. Tiny slabs of quartz vibrate at unimaginable frequencies and convert some of their mechanical energy into electrical energy. Since the frequency of vibration is determined by the dimensions of the quartz crystal, the crystal operates at essentially only one frequency and does not drift. While an LC circuit in our radios might have a Q of 150 if we're lucky, crystals frequently exhibit Q's in the neighborhood of 200,000 on up! That dramatically higher Q means dramatically higher frequency stability. A converter with a crystal controlled oscillator is about as close to drift-free as you'll get.

If you look back through radio literature, you'll find that crystals were first used in the early 1920's. Amateurs used them to control their transmitter frequency. Later in the 1930's, crystals were used as filter elements in superheterodynes.

Seldom do you see in any early literature crystal controlled converters. Why? Probably because of cost. Crystals were just plain expensive. The public didn't want the added expense in their broadcast receivers, especially during the Great Depression, and really didn't need it. And the amateur radio operators who worked the shortwave bands put their money into transmitting crystals and got along as best they could with their high frequency receivers.

Things have changed. If you need a crystal for a particular frequency, you'll probably have to have it custom ground at a reasonable cost of $20 to $30. But you can buy mass-produced crystals of somewhat lower quality targeted for use in computer clock circuits for less than a dollar! If you have access to old computer circuit boards, you may find a crystal that meets your needs at exactly the right price: free.

Let's suppose we want to tune the 30 meter amateur band from



This converter is build on yet another pine breadboard covered with kitchen aluminum foil to act as a ground plane. An inexpensive plastic relay socket accepts the pentagrid converter tube with the oscillator circuit at the rear being mounted so that leads to the appropriate tube elements are kept short. Single 2" long aluminum standoffs are more than strong enough to hold the coils very rigidly. No slow-motion dial drives are needed since tuning here is not as critical as that of the receiver. The large black barrier terminal strip allows convenient power connections.

10.100 to 10.150. We look through a list of computer crystals available and find that an 8 mHz crystal costs only $.79. We'll feed 10.1 into the grid of our converter tube, mix it with 8 mHz, and get the difference frequency of 2.1 out. If we wind coils for our regenerative receiver so that it will tune from 2.1 to 2.15, we'll have a rock solid, sensitive receiver for the 30 meter band.

If you want to reduce the number of windings in your broadcast band crystal set so that it tunes from 1.5 to 2.0 mHz, you could probably listen to foreign broadcast stations occupying frequencies just below 10 mHz using a converter and an 8 mHz crystal.

Here, for demonstration purposes, I decided to put the TRF receiver on the 15 meter amateur band: 21.0 to 21.45 mHz. Since an 18 mHz computer crystal is available, I merely had to wind coils to make the TRF receiver tune 3.0 - 3.45 mHz.

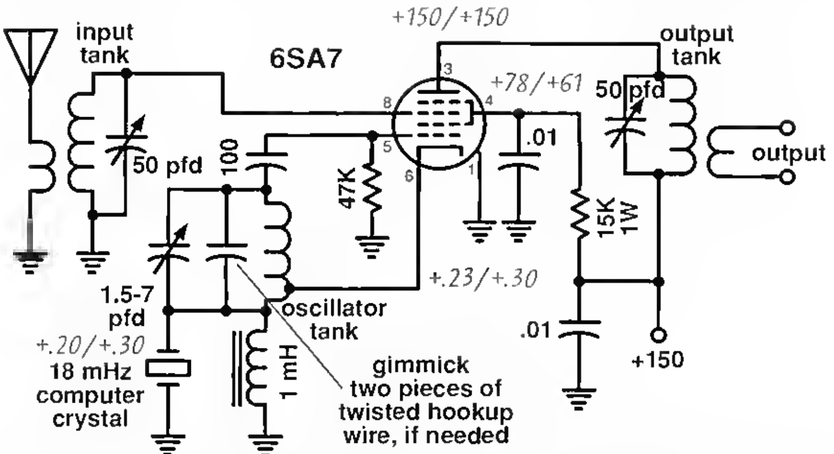
Three coils must be wound. The input coil must resonate at the target frequency: from 18 to 23 mHz, for instance. The oscillator coil must resonate from about 16 to 20 mHz, with the crystal frequency 18 mHz being somewhere near the center. And the output tank circuit on the plate of the converter tube must resonate at the difference frequency of about 2.5 to 4 mHz. Adding a little extra range into the tank circuits allows you to compensate for unexpected circuit capacitances and the like.

I used a 6SA7, a great metal converter tube. Its miniature equivalent is the 6BE6. Millions of these tubes were produced for use in cheap AM broadcast radios, and millions of them are still floating around. You should be able to pick up used ones for pennies, and new ones for a couple of dollars.

The circuit is a standard one. Part of the tube acts as an oscillator, and part of the tube is the mixer. The most difficult part in building the converter is winding the coils so that they resonate at the proper frequencies. With a grid-dip oscillator (Experimenter 2) you should be able to get them working quickly. Winding the oscillator coil may take some experimentation because the variable capacitor may be small and the circuit capacitance may be high. The formulas won't be accurate because you don't know what capacitance the circuit is contributing. But bringing the grid dip meter near the coil after installation in the circuit will tell you if it is in the proper range.

The converter was connected to a power supply and to an antenna. A wire from the output tank circuit was connected to the antenna input of the TRF receiver. When the power was applied, I heard exactly nothing from the receiver. In the beginning none of the tank circuits is going to be on the correct frequency. So each must be adjusted. I started by tuning the output tank circuit, and at one point the noise level came up a bit. Then I adjusted the antenna tank until it came up a bit more. Then back to the output tank. Then tuning the TRF I heard a faint signal. The back to the converter to retune. Once the radio signal was heard in the receiver, I adjusted the oscillator tank, the signal level became very strong very quickly. It was obvious that resonating the oscillator tank circuit was increasing the oscillator level which, in turn, increased "conversion" gain. The converter tube was not only mixing but amplifying the incoming signal as well. The correct dial positions were marked on the face plate of the con-

Crystal controlled down-converter. *Voltages shown: first number is voltage when oscillator is not functioning; second voltage is with oscillation*



Input tank circuit resonates at 21 mHz and feeds signal to mixer grid of 6SA7. The crystal and cathode tank circuit resonate at 18 mHz. The output tank circuit on the plate resonates at 3 mHz – the difference between 21 and 18.

verter as a reminder to make adjustments in the future faster.

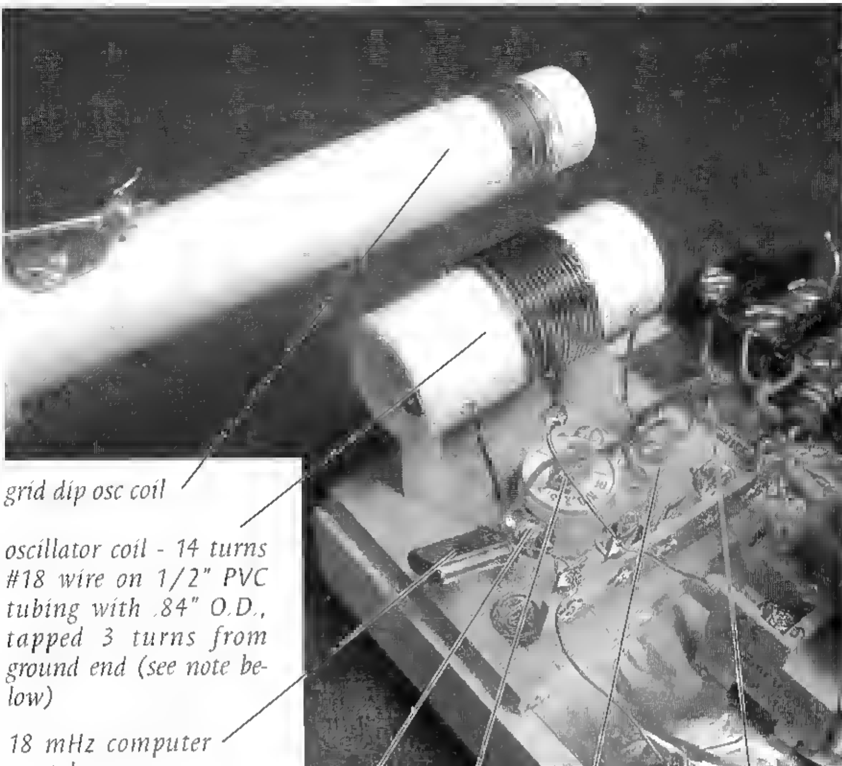
You may find that increasing or decreasing the capacitance of the oscillator trimmer increases the signal strength right up to the point where you cannot increase or decrease the capacitance anymore. You have "run out of trimmer." In this case, you'll want to remove a turn from the coil if you're using minimum capacitance. If the capacitor is at its maximum setting, you may want to add a small silver mica capacitor, say 10 pfd, across the trimmer. Or you could replace the trimmer with a larger value. Maximum signal strength occurs when the oscillator tank is at resonance.

Performance is quite remarkable. The 15 meter band is usually "open" during daylight hours, but becomes next to useless after dark. One Sunday noon, rotating the main tuning dial of the receiver pulled in signals from one end of the band to another. An amateur CW contest must have been in progress. There were more signals that I could keep track of. In the sideband portion of the band, one California amateur was conversing with a ham in England and other DX stations. Signals were strong, plentiful, easy to tune in, and easy to keep in tune.

You can build a modular receiver. Start with a one tube regenerative detector mounted on a much-larger-than-needed breadboard. After you get it working, add a triode amplifier. You may want to add a volume control, and you may want to add a capacitor across the detector plate choke to provide some audio filtration. Maybe a speaker tube can be added if your power supply is powerful enough.

Then you can add an RF ampli-

(continued page 24)



Converter Oscillator

The oscillator in this converter works very nicely providing a strong stable signal that provides noticeable conversion gain. But the coil could use some experimenting. This tank circuit would not oscillate if much padding capacitance was added.

Even off resonance the oscillator worked very nicely but the converter circuit did not provide much gain. As the trimmer was adjusted closer to resonance, the signals coming from the receiver got very much louder. Gain increased. But adding more capacitance killed the oscillator. As shown, I ended up with a hookup wire "gimmick" capacitor of 2-3 pfd to get 18 mHz and maximum conversion gain.

If I were to wind another coil, I would use perhaps 12 turns of No. 18 wire closewound instead of 14 turns. And I would probably still put the feedback tap for this Hartley oscillator at three turns above ground but four might be better. Then I would add a silver-mica capacitor so that varying the trimmer would put 18 mHz at about midpoint. It's important to use your grid-dip meter with the tank circuit connected into the circuit so that disturbances caused by tube and circuit capacitance are taken into account.

fier. The RF amplifier tuning capacitor does not have to be attached mechanically to the tuning capacitor. You'll have to use one hand to tune the amp and the other hand to tune the detector. That was considered an inconvenience and led to the mechanical "ganging" of the capacitors.

Then you can add a crystal controlled converter for your favorite band, choosing a computer crystal frequency that when subtracted from the frequency you want, will yield something between 2 and 3.5 mHz. For instance, a 12 mHz crystal and a 2 mHz receiver will receive 14 mHz, the 20 meter band.

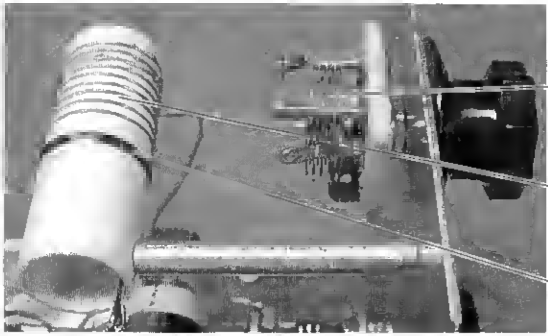
You can build each stage on a separate breadboard if you wish, but be resigned to wire up all the numerous connections between each circuit board. What you will have built is a regenerative superhet.

In this demonstration system, we've converted 21 mHz with an 18 mHz crystal to an intermediate frequency (IF) of 3 mHz. We've then amplified and detected the 3 mHz signal with our receiver. Our superhet has a variable frequency IF amplifier, generally referred to as a tunable IF. Most superhets use doubly tuned IF transformers or other filters that are designed for one frequency and are, therefore, not variable. Our scheme here is a true superhet, nonetheless, and is not unlike the system used in Collins Radio's famous 75A series receivers.

If you set out to build a receiver like this, it would be smart to change the order of stages. Instead of putting the RF amplifier between the converter and the detector, move it out front between the antenna and the converter. Let the amplifier select and amplify the signal and then convert it before sending it to the regenerative detector. You'll get better performance, but it means winding another coil for each band. Every design has its necessary trade-offs.

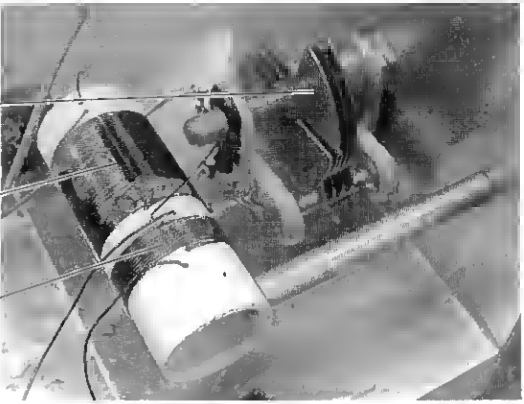
The demonstration receiver and converter as shown is a hot performer that can be built piecemeal. Breadboard it. Get it working. And then rebuild it, putting it inside of a nice wooden cabinet, or even behind a standard relay-rack panel. You'll have something to be proud of.

Input Tank Circuit

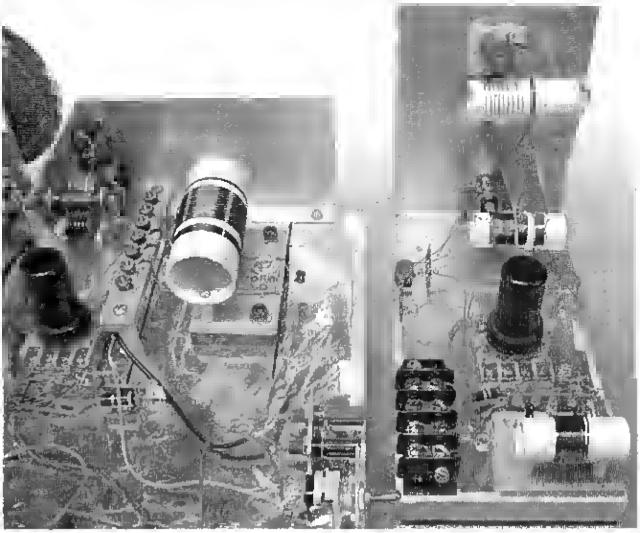


The coil form is 1/2 inch PVC tubing with an outer diameter of .84 inches. The antenna winding consists of 4 turns of #26 enameled wire. Other gauges will do. The main resonant coil consists of 10 turns of #22 tinned bus wire spaced 1" from end to end. Spaced windings with bus wire are handy for experimenting with bandspread taps and the like.

Output Tank Circuit



(above) the main resonant winding consists of 46 turns of #22 enamel wire on a 1/2" PVC (outer diameter of .84"). This gives a winding of about 74 µH which when resonated with about 38 pfd resonates at the desired 3 mHz. Using the formula from Vol 2 pg 23 and assuming the variable capacitor provides 8 to 50 pfd over its full range, we can calculate that we can tune from 2.6 mHz to 6.5 mHz. In reality the frequency range will be somewhat lower due to stray circuit capacitance and the effect of the tube. The output winding is about ten turns.

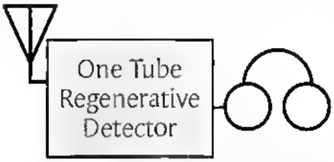


(right) Here, I've placed the converter near the RF amplifier end of the TRF receiver and have installed the 3 mHz coils in the receiver. The next step (not shown) was to connect the two with alligator-clip jumpers and create a rats-nest of wires. Power is "stolen" from the receiver, and the 3 mHz output coil is connected to the antenna input. It's important to not forget to clip front panels together to form one continuous ground between the two units.

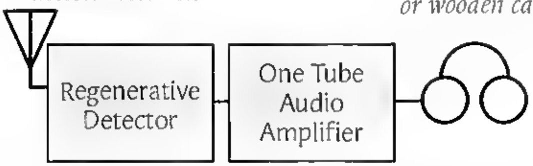
If you decide to build a converter on a chassis mounted in a shielded box, you'll probably want to route RF through coaxial cables possibly with BNC connectors. It will certainly look nicer than the breadboard hookup seen here, but it probably won't work any better. Building quality radios doesn't have to be difficult. The old guys back in the 20's often built remarkably good receivers that looked like they had been created with baling wire!

Building a Hot Performing Receiver Step by Step

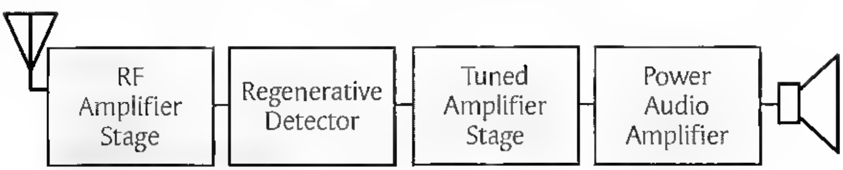
A complex receiver can be built up stage by stage, each being built on its own breadboard. Each stage can be built, tested, adjusted and perfected before building another stage. Once a successful working receiver is developed, the components can be mounted on a metal chassis if desired, and placed inside a metal or wooden cabinet.



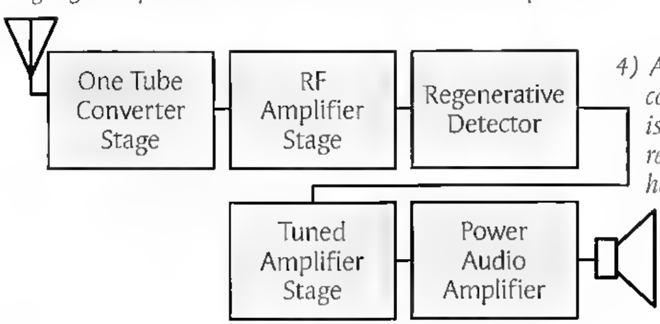
1) A one-tube pentode regenerative detector receiver.



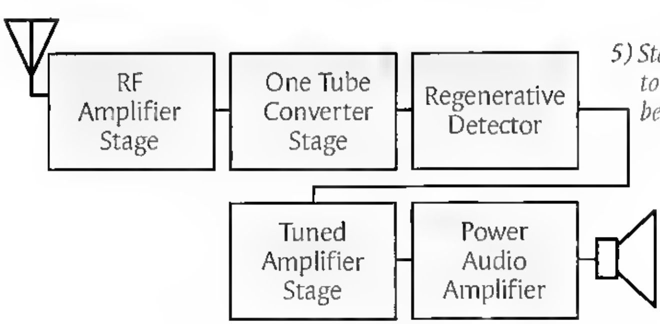
2) A triode audio amplifier is added. Once working, the choke in the regenerative detector can be tuned for better selectivity.



3) A tuned RF amplifier is added. Capacitors do not have to be mechanically ganged. A power audio tube is added to drive a speaker.

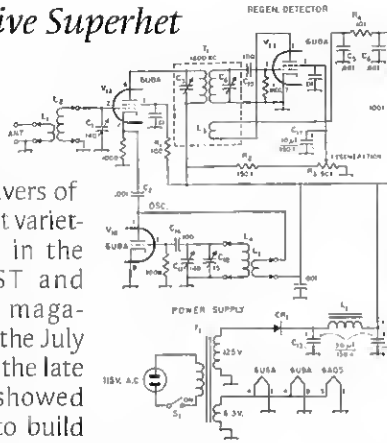


4) A one-tube crystal controlled converter is added to create a regenerative super-heterodyne receiver.



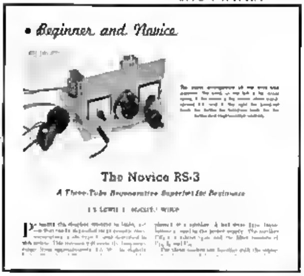
5) Stages are rearranged to provide slightly better performance.

Regenerative Superhet



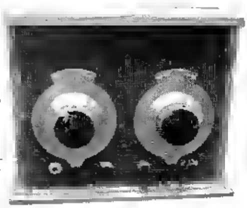
There have been many regenerative superhet receivers of many different varieties described in the pages of QST and other radio magazines. One, in the July 1963 issue, by the late Lew McCoy showed novices how to build a three tube receiver they could use on the air. Shown here is my adaptation of the circuit.

Back issues of QST are available on CD-ROM from the ARRL.

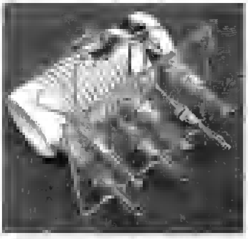


Another classic is the two tube model using a 6K8 converter and 6C8 double triode appearing in the Feb 1941 issue of QST, and reprinted in ARRL Handbooks as late as the 1946 edition.

The JONES 1936 RADIO HB (and later years) also detailed a number of designs. Check out the "Super Gainer".



Bandset and bandspread capacitors each have their own National Model N Velvet Vernier dial drive. No doubt, this machine will soon be scrapped, components being recycled into a new receiver.



(right) Coils are mounted on acrylic plastic sheet and are soldered to banana plugs on 3/4" centers. Binding posts on the chassis serve as a socket.

McCoy specified a modified 1600 kc IF transformer that is no longer available. A homebrew transformer was wound with two toroids mounted in a PC board box linked by weak capacitive coupling.

Performance is fairly good for CW. Like all regeneratives AM reception is poor. Heat buildup causes a lot of drift. Although McCoy claimed the receiver could be used in 21 mHz amateur band, I have to wonder. The converter + TRF just described would work far better.

Experimenter's Power Supply

Unlike transistors and integrated circuits, tubes demand a lot of power. With a transistor circuit all you need is a lantern battery. But when it comes to tubes, batteries won't cut it. You'd go broke trying to stock enough batteries (if you could buy them) to keep your experiments operating. That's why in the late 20's people demanded battery eliminators that could change house current into the voltages and currents needed by their radios.

If you're serious about experimenting with tubes, you need a convenient power supply, one that provides filament voltages, high voltage, and regulated medium high voltages. Shown here is a power supply, just built, which evolved from a multitude of other power supplies.

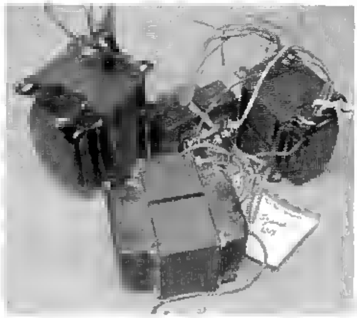
Inside one housing are really two power supplies. One provides direct current at voltages up to 300 volts. The other provides 6.3 volts AC for filaments, 150 volts regulated, and between 300 and 350 volts unregulated for other purposes, if needed. With such a supply you can power experimental breadboard hookups using tubes manufactured as far back as the early 1930's. You'll have regulated plate voltages to prevent your regenerative receiver from jumping in frequency every time the furnace or air-conditioner kicks on. And you'll have enough current at high voltage to supply a power tube capable of driving a loudspeaker to respectable volume.

The "iron" used in this power supply is old secondhand stuff. I was lucky to buy a couple of identical power transformers for $2 each at a flea market – a common price. I've more than once come across someone with transformers and chokes spread out on a blanket with a sign: "Free! Help Yourself!" The greatest cost in collecting iron is the hernia you acquire carrying 40 pounds of transformer back to the car.

I've seen dealers on the internet offer used transformers and chokes. And they're still available new. New prices are high by comparison to flea market prices, but are really quite fair when you consider the amount of work and materials that go into building a transformer or choke. If you plan to continue experimenting with tubes and haven't stocked your junk box

I always pick up chokes when I come across them. Here are flea market items that you can find, too. Sometimes you'll have to buy some piece of filthy tube gear that no one wants for $3 just to get at the choke. Most Bozo's at flea markets see only the obvious. When you and I see an old piece of tube gear, we see components that are impossible to buy, and can be used in the radios we'll build. Even if one of these chokes were burned out, the core could be rewound with 10,000 turns of wire, if you have the patience, to get a very high inductance choke for the plate of your regenerative detector.

At flea markets I'm always a sucker for iron. The largest of these four transformers is probably capable of handling 300 to 400 watts of power. But that rating includes both filament and B+ windings. Purchased new, assuming you can find them, these transformers could cost as much $100 these days. Yet these used versions which all tested good, cost no more than a couple of dollars each tops. If they don't deliver exactly what you need, you can always take them apart and rewind them to get exactly what you want. Articles on transformer winding are easy to find, and deliver excellent how-to.



with iron, it's time to begin looking.

Another place to find power supplies is to buy a boat anchor. These heavy old vacuum tube monsters are obsolete pieces of junk of little historical value that few people want. Inside them you'll find the transformer, choke, and other components you need. You merely "transplant" the components to a new chassis (EXPERIMENT 3 pg 46.) For instance, I bought a 40 pound Beckman vacuum tube frequency counter with manual for $1. It is loaded with tubes, and its power supply is high quality. The problem is that I can't bring myself to cannibalize it because, in essence, the counter is an early vacuum tube computer. It might have historical value. So for now it sits. But comparable junk awaits your scavenging nose.

You must know the transformer color code. It will tell you that the filthy transformer in that box under the card table at the flea market is a power transformer. Black leads are primary. Green leads are 6.3 volt filament leads. If yellow leads are present, they power the 5 volt rectifier filament – something we won't be needing. And you should find two red leads for high voltage with another red lead with yellow stripes for the center tap. There may be other leads, but the leads noted here are the essential ones. You won't know exactly what you're getting, but if the transformer is a dollar or two, you stand to gain more than you will lose.

You need a variable autotransformer, that is, General Radio's famous Variac. These days they are manufactured by many companies and are readily available, but can be quite expensive – $60 for a 3 amp model. Flea market "sharps" will tell you that you should be able to acquire a Variac in good condition for about $2 per amp. So instead of paying $65 for a new Variac, with diligence, you should be able to ferret out a 5 amp model for no more than $10. And you need one because it allows you to create about any plate voltage you need.

RADIO HANDBOOK or RADIO AMATEUR'S HANDBOOK from the late 30's, 40's or 50's will show you the necessary details for building tube power supplies. The most common system, and one used here, is the capacitor input filter system.

Tube rectifiers can be used, and probably should be if you're remounting a power supply from an old piece of gear. But if you're designing your own supply, use silicon diodes, or rectifiers, instead of the old 5Y3, 5Z4 or

These two identical power transformers have a 280-0-280 high voltage secondary and a 6.3 volt winding. It's hard to say exactly how much current they can deliver, but a good fistful of iron should be able to transform at least 100 watts of power. And an educated guess would say the winding was designed to deliver 250 volts at 80 to 100 mA and 6.3 volts at 3 amps. The transformer has no 5 volt winding, so it was probably designed with solid state rectifiers in mind.

Keep in mind that you do not need identical transformers. I used them because I had them, and they were of a convenient size. In most cases, you'll use whatever transformers you happen to have or can find.

Old radio catalogs like Newark and Allied make great references for checking out unknown components. If you have a transformer of a given weight or size and know the voltages of the windings, you can find a similar transformer listed in the catalog, and be fairly sure the current ratings listed are close to your unknown.

5U4 rectifier tubes. For pennies you can get diodes capable of handling as much as one amp, more than most tubes, with Peak Inverse Voltage (PIV) ratings as high as 1000 volts. I bought a strip of a hundred 1N4007 rectifiers for just a few dollars with exactly those specs: 1 amp at 1000 volts max.

I used the center tap and a pair of rectifiers to create a full wave rec-

As one intrepid experimenter keeps telling me, "You can never have too many Variacs!" I think you can never have too many power supplies. His rule-of-thumb is that a flea market Variac in good working condition should cost no more than $2 per amp. The black top left Variac is a genuine General Radio 5 amp model from the late 30's. At the lower left is a Powerstat 300 watt model, while at the lower right is a 10 amp version. The large black Variac mounted on the oak base is very handy for testing transformers, controlling resistance heaters such as soldering irons, and for general experimentation.

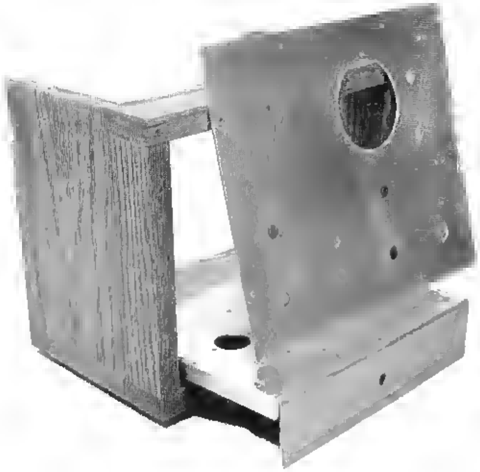
tifier. A 560 volt winding with center tap is actually a pair of 280 volt windings joined together at the center tap which is grounded. You'll get something close to 280 volts out of the rectifiers. There is essentially no voltage drop across the silicon rectifiers. Tube rectifiers, on the other hand, could have 60, 70, even 80 volts drop through them. Transformers designed to be used with tube rectifiers often have windings that produce significantly higher voltages that when added to the tube rectifier voltage drop gave about what was needed. In other words, if you wanted 250 volts out of the rectifier tube, and the tube usually had about a 60 volt drop, the transformer secondary would be wound to deliver about 250+60 or 310 volts. What this means, then, is that if you use a transformer designed for tube rectifiers with silicon rectifiers, you'll end up with more voltage than you really need and probably want. A Variac on the primary of the transformer can be set to deliver 96 volts instead of the usual 120 volts. That's about 80% of normal. The voltage coming out of the 310 volt winding will be about 80% low, or 248 volts – just what we want. The Variac is a highly efficient way of adjusting the voltage.

Another important point to remember is that voltage is also lost in the secondary windings and choke windings due to resistance. A secondary winding sitting on the workbench may show 310 volts on the secondary when there is nothing hooked to it, in other words, with no load. As soon as you pull 60 mA out of the power supply, however, the 200 ohms of resistance in the secondary winding will create a .06 x 200Ω = 12 volt drop. Ohms law is always at work in the choke winding as well. If it has a 200 ohm resistance, another 12 volts will be lost.

What this all means is that you may have a power supply that delivers 275 volts with no radio connected to it. Put your two tube regenerative on it, and the voltage may be pulled down to 250. Put a four tube receiver on the same power supply, and the voltage may slip to 230 volts. The higher the current drawn, the lower the voltage goes. Here, again, giving the Variac a partial turn can bring the voltage back up to the desired level to compensate for the additional current drawn.

When studying power supply diagrams in old radio books, remember that back then high value, high voltage capacitors were very expensive. Back in the 30's for instance, 8 mfd at 400 volts, was about the largest value you could buy with taking out a second mortgage. To compensate for what was missing in microfarads, a large choke was placed in series with the high voltage line. In a sense, the capacitors shorted circuited the nasty, unwanted AC ripple on the high voltage line to ground, while the choke in series was a bottle neck that the ripple could not easily get through. The choke and capacitors work together as a team to eliminate any ripple that comes from the rectifiers.

These days for $3 to $4 you can get a 100 mfd at 450 volts. Because you have a capacitor that is larger than any 1930's radio builder could ever hope to buy, you don't need to use as large a choke as they did in the old days. For instance, a power supply from 1940 might have a pair of 8 mfd capacitors on either side of a 20 henry choke. As a rule of thumb I multiply the henries times the microfarads. If I use different size components I



An oak case built for another power supply project will hold this new, improved power supply. The chassis was cut and bent from .050" aluminum sheet obtained from the local sheet metal shop for $3.50 per pound. The face plate is cut from .063" thickness. The mounting hole for the meter was cut with a metal blade in an electric jig saw (scroll saw.) A simple sheet metal brake and a good pair of tin snips will allow you to make custom chassis and cabinets for a fraction of the cost of ready-made equivalents.

make sure that their values multiply out to at least the same value. For instance, 8 mfd X 20 H equals 160. If I use 100 mfd and 2 H, the product comes to 200 which is higher than the 160. In other words, because we can get much high value capacitors today, we don't need to use as large a choke to get adequate filtering. In fact, a low value resistor with an adequate power rating can be used in place of the choke. Since I pick up chokes whenever I can and have many on hand, I always use them in my supplies.

If you're planning to build a power supply to power a transmitter, consider using choke input filtration. It means using two chokes in the filter section, but you get far better voltage regulation. That means the changes in output voltage as the transmitter draws more or less current are much smaller. Details on choke input supplies are explained in scores of old radio books.

I usually use a conventional capacitive input filter – two capacitors on either side of a choke. On the input side I use a smaller capacitor, perhaps a 22 or 47 mfd of the highest voltage I can easily get, usually about 500, while on the other side of the choke, I almost use a 100 mfd with a 450 voltage rating.

Unlike the choke input filter, the capacitor input filter will take 250 volts out of the rectifiers and bump it up to over 300 volts. Although this may seem like magic, it is not. The 250 volts is RMS voltage (root mean square). This is pulsating DC varying from zero to over 350 volts, but having an "average" voltage of 250. The capacitive filter will attempt to charge the capacitors up to the 350 peak voltage until you pull current out of the supply. This confusing concept is beyond this little booklet, and I urge you to study the differences between AC and DC voltages and root mean square measurements. Many electronics text and handbooks will explain this more thoroughly than I have room for here.

The only difficult part of building a power supply is calculating the bleeder resistor(s) and the dropping resistor for the voltage regulator tube. Here, again, check amateur radio handbooks for details on power supply construction.

NEVER omit bleeder resistors.

When you shut off the power supply, they discharge the capacitors completely so that you can't get accidentally shocked. And they add some voltage regulation by always having at least a small load on the filter circuit.

In the Variac adjustable power supply shown here, maximum voltage was expected to be 300. A small bleeder current of 5 mA (.005 amp) was desired. Actually, 10 mA might be a bit better choice for better regulation. To find the size of the bleeder resistor, you use Ohm's law: 300 V ÷ .005 A = 60,000 ohms. And since a bleeder is no run-of-the-mill resistor, you must calculate wattage. That's easy, too. Square the current and multiply by the resistance: .005 x .005 x 60,000 = 1.5 watts. This means the resistor will generate 1.5 watts of heat, and you should use something much bigger than 1.5 to limit the heat build up. I would use 3 watts minimum.

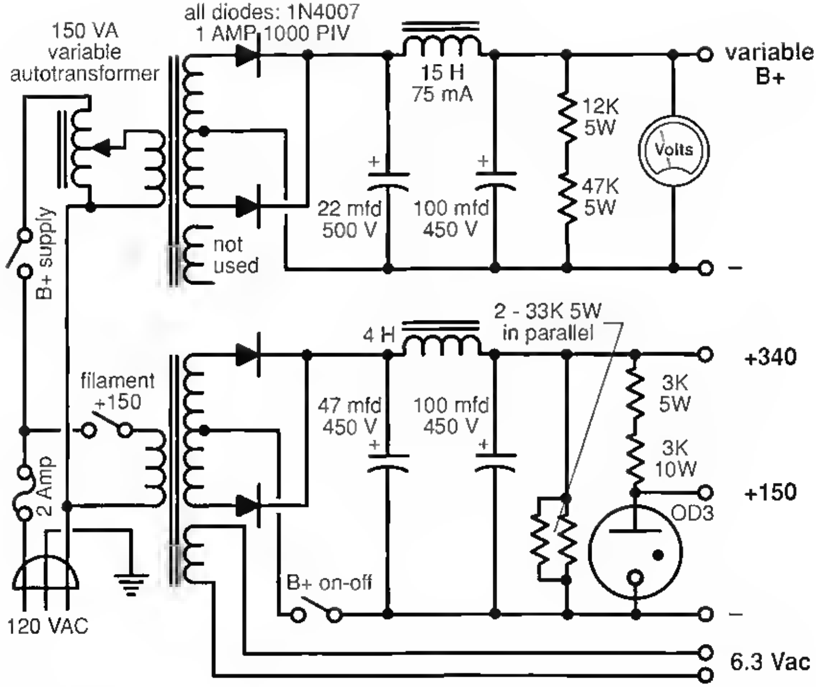
Digging through my junk box did not turn up a 60,000 ohm 3-watt resistor. They just don't grow on trees. And I wasn't about to order one. But I did find a 12K 5-watt and a 47K 5-watt. After measuring their resistance with a volt-ohmmeter to be sure they weren't burned out, I wired them in series to get a 59K resistor. That's a bit smaller than 60K, so it will draw slightly more current. The two 5 watt resistors in series don't really give you 10 watts of safety. How much heat will the 12K resistor generate? First figure how much current flows through 59K at 300 volts: 300 ÷ 59,000 = .0051, or 5.1 mA. Use this to calculate watts in the 12K resistor: .0051 x .0051 x 12,000 = .31 watts. So 5 watts is an overkill. And how about the 47K resistor: .0051 x .0051 x 47,000 = 1.22 watts, and here, 5 watts is a good safety margin.

Use Ohm's law and wattage formulas to calculate resistors for the bleeders and for all the other resistors in your radio. The math is simple. And the calculation is very simple with even the cheapest calculators. Knowing these simple electrical laws pays enormous dividends.

In the filament/150 volt supply we have an output voltage of about 340 volts. Here I decided to pull 20 mA (.020 amps) of bleeder current, since very little B+ current would be taken from this supply. Resistance is calculated: 340 V ÷ .020 A = 17,000 ohms. Wattage becomes: .02 x .02 x 17,000 = 6.8 watts. Digging through the junk box turned up a pair of identical 33K 5 watt resistors. Putting them in parallel creates a resistor of half that value: 16.5 K. Since half the current flows through each resistor, the heat buildup is shared equally by the resistors. And therefore, each 5 watt resistor will dissipate about 3.4 watts of heat. Now, that's not as much of a wattage safety margin as I would like, but it is enough. The resistors will get hot, but won't burn out. When mounting them, give them plenty of room to "breathe".

The 150 volt regulator tube is an interesting problem. You can use an 0A2 which can handle 30 mA of maximum current, or an OD3, like the one used here, to handle 40 mA max. To prevent excessive current flow in the regulator tube, you must use a dropping resistor. Sizing it becomes the problem.

If the main B+ runs at 340 volts, and if the plate of the tube is fixed at 150 (that's why we call it a 150 volt regulator) then the resistor will have 340 – 150 = 190 volts across it. All you have to do is calculate the resistance using the maximum current the tube can handle, 40 mA (.04 amp) in this



Two power supplies are mounted inside of one case. The output voltage of the upper circuit is controlled by a Variac which varies the input voltage to the transformer primary. The lower circuit is a more or less standard power supply circuit providing filament voltage, unregulated B+ as well as much as 27 mA of regulated current at 150 volts.

Switches allow the filament voltage to remain on, while high voltages can be switched off. This is very useful when experimenting. The tubes stay warm but the high voltages can be removed from the circuits while adjustments and modifications are made.

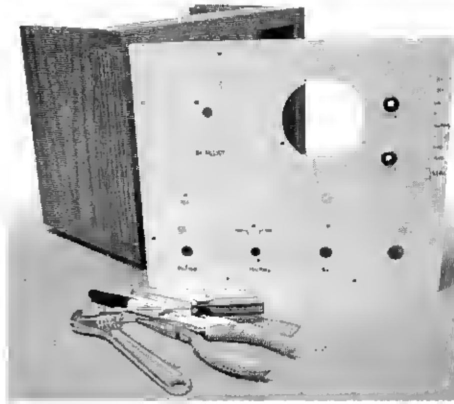
case. Resistance: 190 ÷ .04 = 4750 ohms. Any resistance less than this will cause more than 40 mA to flow through the tube and damage it. So we must use something a bit larger if anything.

What wattage? Worst case: 4750 ohms at 40 mA. Wattage: .04 x .04 x 4750 = 7.6 watts. So we'll need something larger than 4750 ohms with at least 10 watts of power handling capacity. A journey through the filthy dirty junk box turned up a 3000 ohm 5 watt resistor, and 3000 ohm 10 watt resistor. Putting them in series gives us a 6000 ohm resistor with a dissipation of something between 10 and 15 watts.

So what will happen? Well, 190 volts across 6000 ohms: 190 ÷ 6000 = .032 or 32 mA. That's not too bad. Wattage: .032 x .032 x 6000 = 6 watts, and that's within our 10 watt limit.

We'll have 32 mA flowing through the tube when no current is being drawn by the outside world. If

The front panel has been painted with Rustoleum spray paint in a muted cream color so that it doesn't clash with the walnut stain of the case. Grommets have been installed, and legends written on the paint with a fine point "Sharpie". You may want to use decals. Whatever you do, be sure to label the panel. It's all too easy to forget the function of each control.

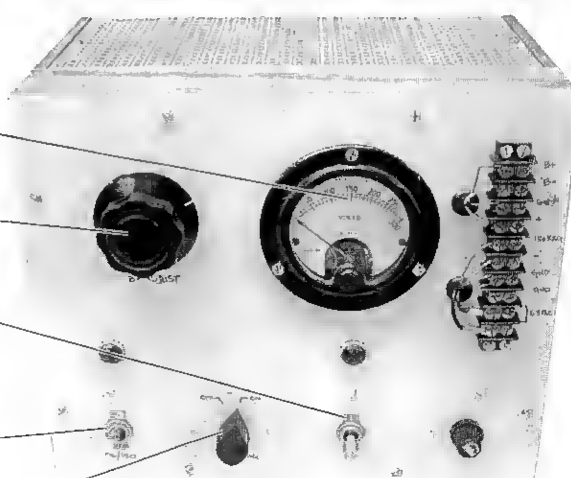


we hook the plate of our regenerative detector which draws 5 mA up to the regulator output, we'll have 5 mA flowing out of the power supply and only 32 minus 5, or 27 mA, now flowing in the tube. If several tubes draw, say, 20 mA, the regulator tube will conduct 32 (no load) less 20, or 12 mA.

Through the dropping resistor will be a constant 32 mA. Some of the current leaves the regulator circuit to power a tube, and whatever is left flows through the regulator tube. Maximum current, then, flows through the tube when no current is being drawn by the outside world (your radio). As the outside world pulls more and more current out of the regulator circuit, less and less current remains to flow through the regulator tube. But! If we want the regulator tube to function properly it will need at least 5 mA flowing through it at all times. That means that most regulated current at +150 volts that can be drawn is the original 32 mA less the 5 mA, or 27 mA.

Recommendation: always put a regulator circuit in your power sup-

Adjustable Power Supply



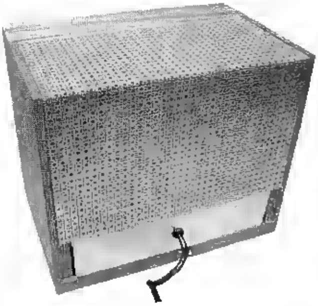
0-300 volt DC meter

B+ adjust (Variac)

adjustable B+ switch

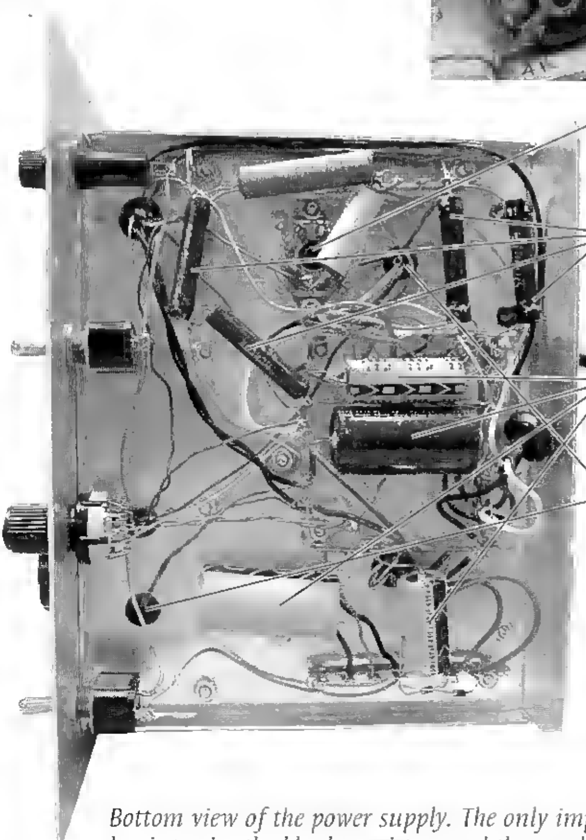
Filaments/150 power

150 B+ switch



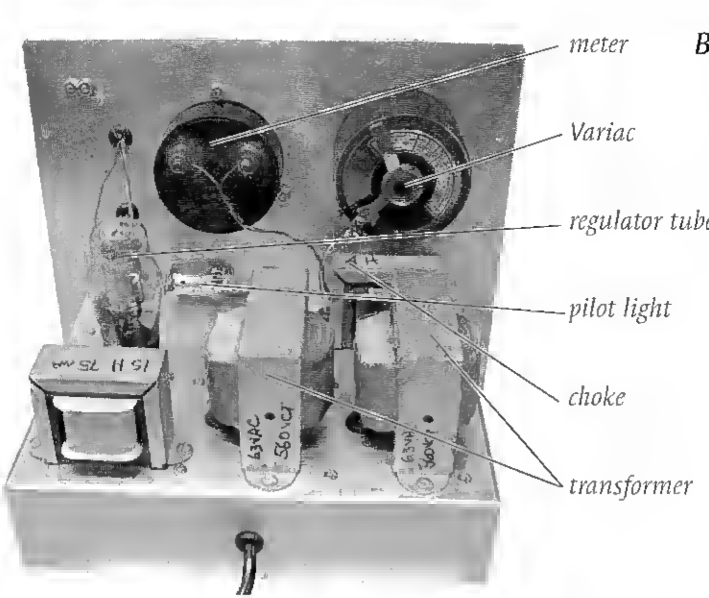
The rear of the power supply is covered with aluminum "cane" metal obtainable in hardware stores. The grounded cover is necessary to prevent anything from falling inside the supply and accidentally shorting out components. Because a vacuum tube rectifier was originally used, screening was needed to allow heat to escape. Regulator tubes have no filament and generate practically no heat. The power supply described here generates very little heat, so the screening may not be necessary.

A shallow groove, or rabbet, was cut into the edge of the case with a carefully set table saw blade. It provides just the right depth to accommodate the cane metal cover.



Power Supply Wiring

Bottom view of the power supply. The only important point to remember is to give the bleeder resistors and the regulator plate resistor plenty of room. They'll get very warm, and you don't want them damaging other components or wiring.



ply that can provide at least 10 to 15 mA at 150 volts. Use that current on the plate and screen of your regenerative detector, or the local oscillator of your superheterodyne. Without regulation, slight variations in the voltage supplied to your home can produce noticeable changes in signal pitch in your earphones. Regulation can mean the difference between a great receiver and one that can barely hold onto a signal. Use the unregulated B+ on your other tubes. They are far less sensitive to changes in plate voltage.

You're not obligated to use 150 volt regulator tubes. There are others for 90, and 105. And you can mix and match to create other voltages. Here again, check the handbooks for details.

And think safety. It's no fun getting shocked. And although we deal with low voltages, it is nevertheless capable of killing you under special circumstances. Always fuse your supply so that if you drop a screwdriver into your radio and short out the high voltage, the fuse goes rather than everything else. Use a three wire cord to ground the chassis and all panels. I do this a routinely. Bleeders, grounds and fuses. Oh, my! Use them.

$I = \frac{V}{R}$	*current in amps equals volts divided by ohms* *-or- current in milliamps equals volts divided by kohms*
$V = I \times R$	*volts equals amps times ohms* *-or- volts equals milliamps times kohms*
$R = \frac{V}{I}$	*ohms equals volts divided by amps* *-or- kohms equals volts divided by milliamps*
$W = I^2 \times R = \frac{V^2}{R}$	*power: watts equals amps times amps times ohms* *-or- volts time volts divided by ohms*

More often than not you will find a large transformer weighing ten to twenty pounds that does not provide the voltages you need. You can do what so many impoverished ham radio operators did for so many years: change the windings. Probably the two best articles I'm aware of are...

Tailor-Made Volts
An Almost-No-Cost Power Transformer
by Lewis G. McCoy, W1ICP, QST, Feb 1964 pg 36

Rewinding Old Transformers
by Lyall Sherred, CQ, Mar 1966, pg 63

Another pair of articles more concerned with higher voltages and higher currents for transmitter power supplies are...

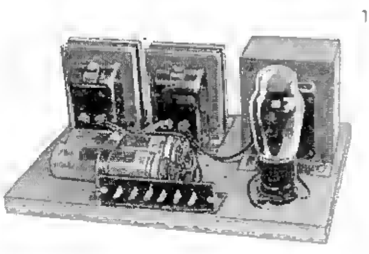
A Cool Kilowatt Plate Transformer
by Robert B. Coats, W9ESD, QST, Sept 1959 pg 24

More on Homemade Transformer Design
General Procedure for Constructing High Voltage Units
by T J Maresca, W2VLA, QST, Nov 1960, pg 30

And the very best book I've ever come across revealing the practical details of winding and rewinding transformers of all types is no longer being printed. You may be able to find a used copy somewhere...

Practical Transformer Design Handbook
by Eric Lowdon, Howard W. Sams & Co, 1980

In addition, you'll find rewinding information in pre-1940 radio handbooks published by the ARRL, RADIO MAGAZINE, and others.



Power supply for c-w operation. Low capacity filter condensers are used.

From Jones 1936 Radio Handbook. I would never build an open power supply like this. It would be too easy to get a nasty shock.

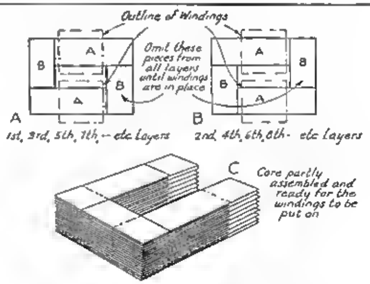


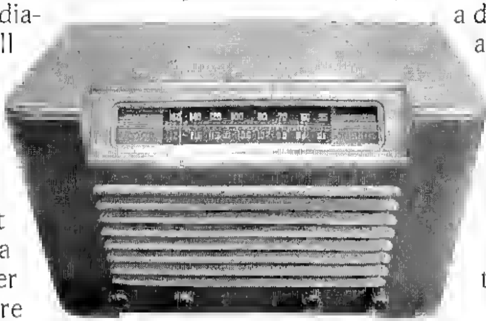
FIG. 1013 — HOW TO PUT A TRANSFORMER CORE TOGETHER

From 1934 Radio Amateur's Handbook. Rewinding transformers was necessary during the Great Depression. reprinted in THOSE GREAT OLD HANDBOOK RECEIVERS (Lindsay Publications Inc)

Slide-Rule Slow Motion Dial Drive

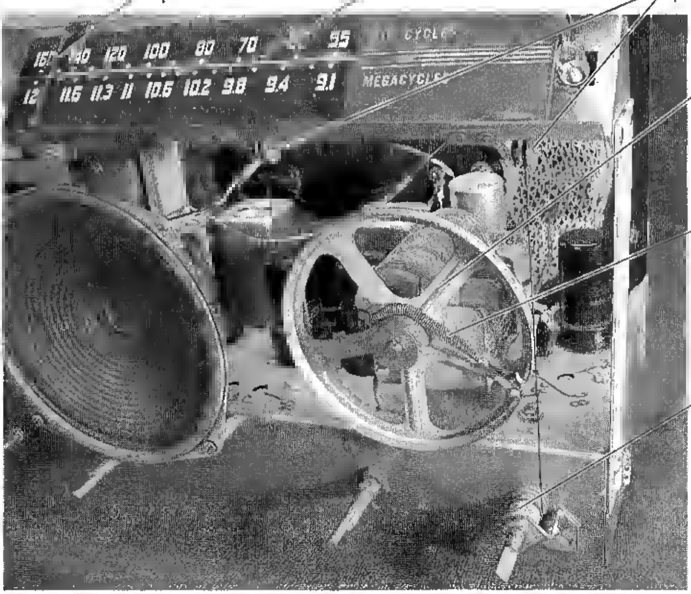
As I've said before, you'll find numerous old books with many different circuit diagrams for all types of receivers. There is no shortage of electronic ideas. But converting a circuit diagram into a working receiver is usually more about mechanics than electronics. So much of what is presented in this Experimenter series is about the mechanical aspects of radio building. Other books can explain the electronic theory better than we can, but they ignore the hardware issues that you and I must face.

Although it may appear that locating tubes, sockets, transformers, variable capacitors and all the rest is a difficult task, it really is not. What IS difficult is finding some of the mechanical parts: connectors, universal joints, and especially slow-motion dial drives.



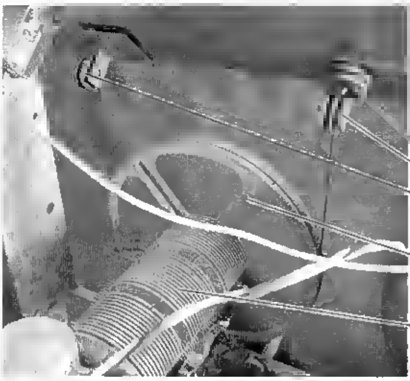
This 1940's vintage shortwave/AM broadcast receiver is equipped with a common slide rule scale dial drive mechanism.

Many inexpensive consumer AM tube radios used a slide-rule dial that coupled a large, expanded frequency scale with a slow-motion tuning mechanism. The whole thing was done with cord and pulleys, and it worked beautifully despite its simplicity and low cost. Here are the concepts and ideas behind building such a dial.



The main tuning capacitor (I still call them condensers) has a large grooved pulley mounted on its shaft. In the groove lies a cord attached to one end of a spring which maintains tension on the cord. One portion of the cord is wrapped several times around the small diameter shaft of the main tuning knob. A pointer is connected to the cord and changes position as the cord moves.

(continued page 44)



(left) Main tuning capacitor showing the backside of the main pulley. The small pulleys here are fabricated from wood, while the large capacitor pulley is stamped from metal. Despite the simple and inexpensive design, this drive works very well.

pulleys

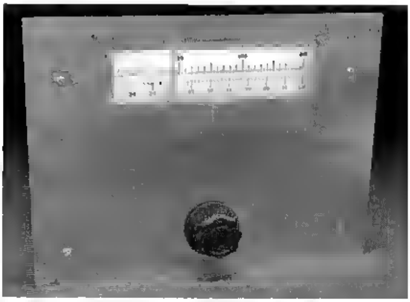
main capacitor pulley

3-gang tuning capacitor

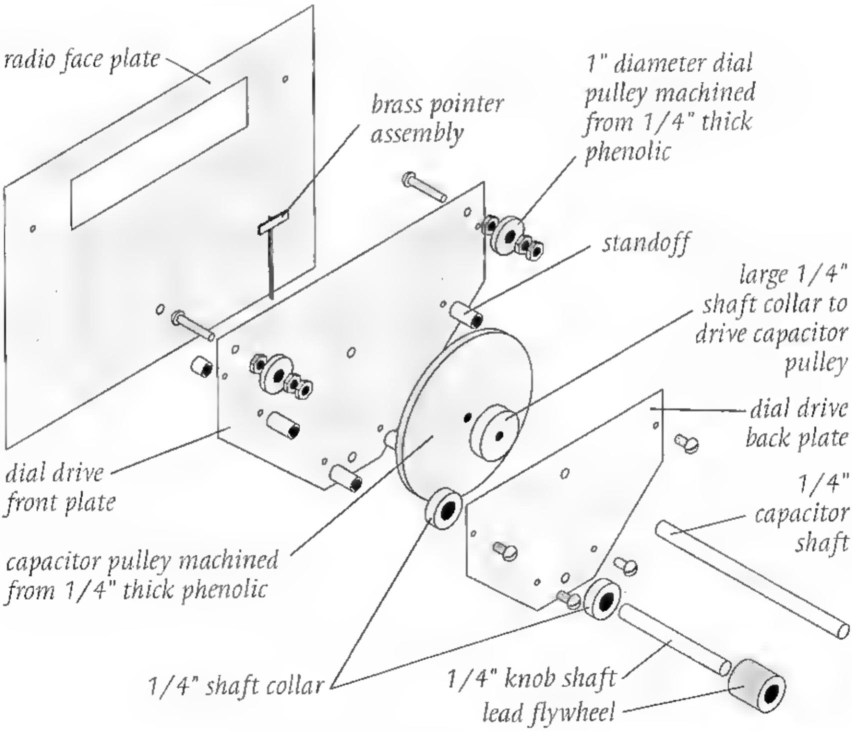
(above) Back side of the slide rule scale.

pointer

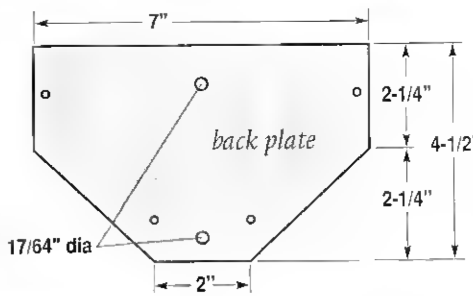
(above) Two flea market capacitors with pulleys still attached. Most such pulleys are pressed onto the knurled capacitor shaft and cannot easily be removed to be used on other capacitors. Occasionally, a pulley with set screw for a standard 1/4" shaft will appear. Don't hesitate to buy to it. The capacitor to the left is a dual section AM broadcast unit, while to the right is an FM capacitor with probably 5.5-23 pfd per section.

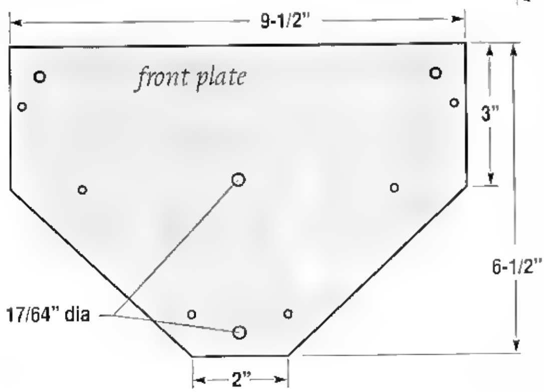


(above) We can build our own version of the cord dial drive. The length of the slide rule scale is equal to half the circumference of the large capacitor pulley, and the overall tuning "gear" reduction is the ratio between the knob shaft diameter and the capacitor pulley. With care, great reductions are possible. Generic numeric scales can be used, or custom scales of professional appearance can be created with computer software.



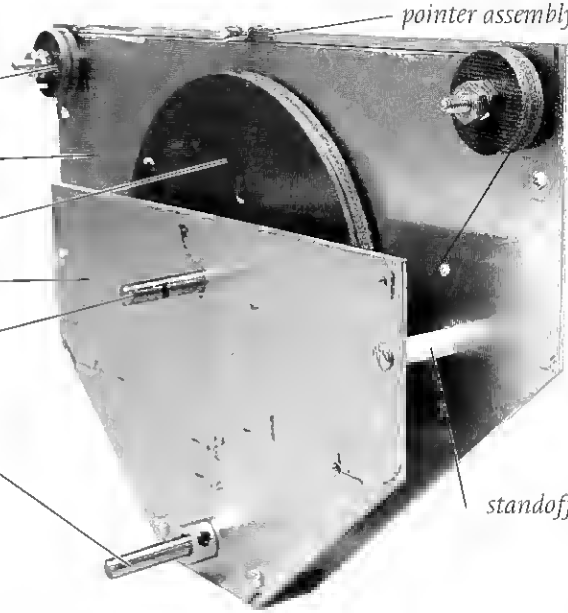
This first generation dial drive consists of a sandwich of two aluminum plates between which the various shafts and pulleys are mounted. Although the assembly is quite bulky, it is relatively easy to work on and can be moved from one radio to another when desired.

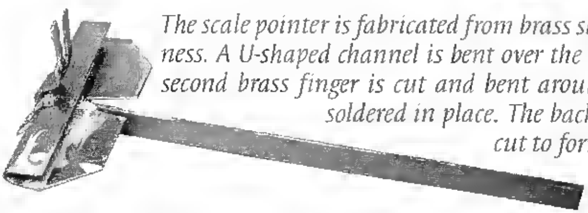




The pulleys, special shaft collar, and lead flywheel were machined on a metal lathe, simply because it was available. If you don't have a lathe, you'll have to substitute some imagination and scavenging to acquire the parts. Since this is such a simple device, not having a lathe, wood or metal, is not an insurmountable obstacle.

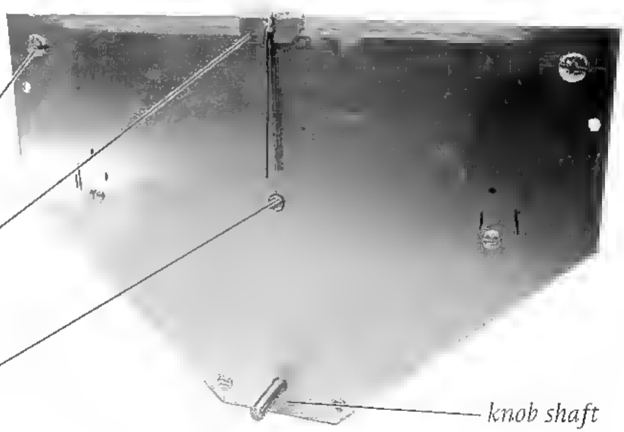
Dial drive assembly from the rear.

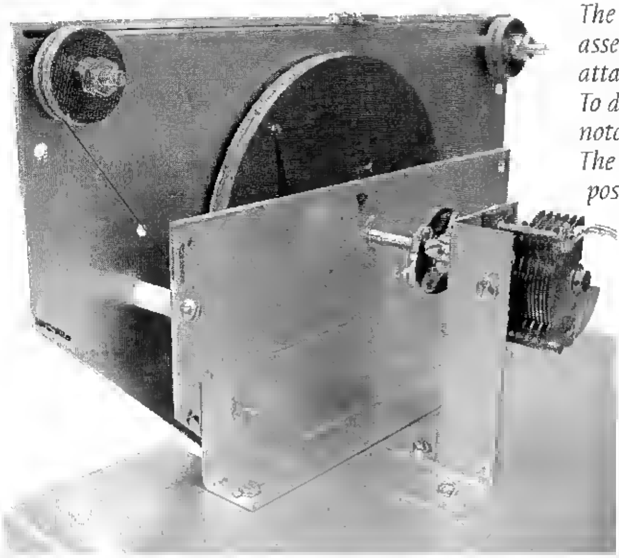




The scale pointer is fabricated from brass sheet about .016" in thickness. A U-shaped channel is bent over the edge of the front plate. A second brass finger is cut and bent around the channel and soft soldered in place. The backside end of the finger is cut to form a "Y" to accept the dial cord. You may find it quite difficult to cut a thin brass strip with snips and keep it flat and straight. It will want to curl. This flat strip was cut with a shear. You may want to consider using a stiff wire as the indicating finger instead. With proper crimping and a liberal application of grease, you should find the pointer assembly slides easily across the top edge of the front plate.

Front of slide rule dial assembly





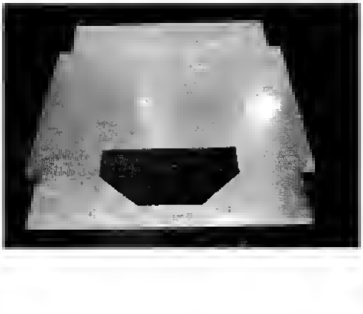
The complete dial drive assembly must be attached to the chassis. To do this, a special notched chassis is cut. The assembly is fixed in position with a wide L-bracket or section of aluminum angle.

A custom bracket will have to be fabricated to hold the capacitor of your choice which will be turned by the main shaft through a universal joint.

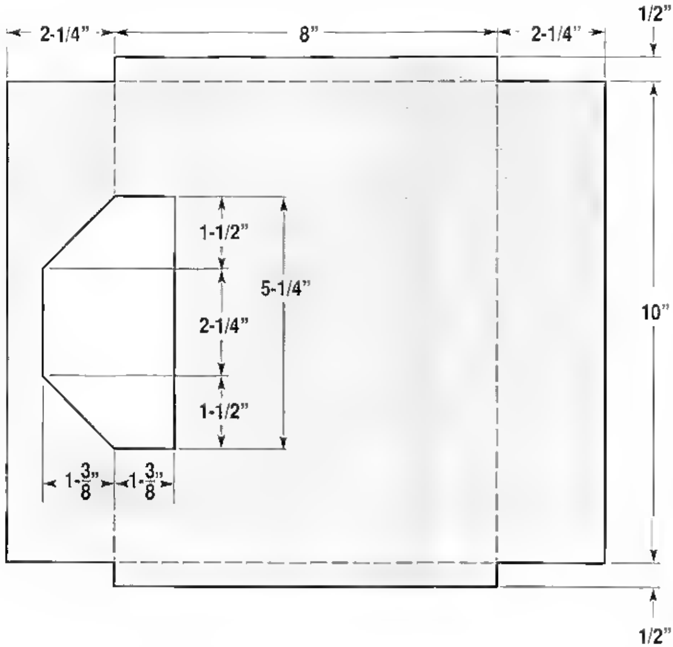
Front side of the slide rule dial assembly mounted to the notched chassis.

Standoff between front plate and radio face plate attaches here

Radio face plate is attached here with a machine screw. No standoff is used. These points of attachment together with the L-bracket on the back side create a very solid assembly.



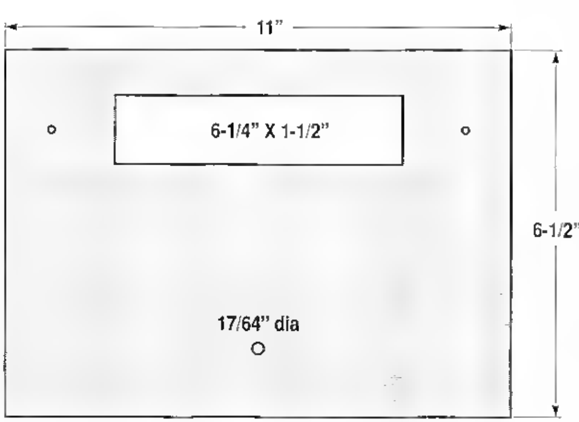
(left) The cut chassis plate before bending in the sheet metal brake. You can buy a more expensive (but fairly priced) chassis from dealers, or you can buy aluminum scrap from a sheet metal shop and create custom chassis with a simple finger brake, tin snips, a nibbler, and even a scroll saw. The result is something that meets your needs exactly at very low cost.



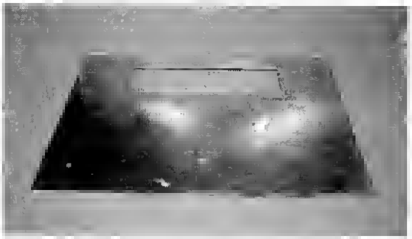
(left) Chassis plate layout. Your layout will probably be different. This provides an 8x10 chassis surface which is a bit small. You might want to make something much bigger, say a chassis to fit a 19" relay rack. It might be wise to create a "test" chassis out of cardboard to test your design.

If the tuning capacitor is driven by a 4" diameter pulley, and the knob shaft is 1/4" in diameter, the gear reduction is 4 ÷ 1/4, or 16. That's 16 to 1 reduction. In other words, it would take sixteen turns of the knob to rotate the tuning capacitor pulley just one turn. Since most capacitors rotate only 180°, or half a turn, we could tune our capacitor from one end of the band to the other with eight turns. Making the capacitor pulley larger and/or the knob shaft smaller increases the ratio even more. For instance, a 5" diameter pulley and 1/8" shaft, gives a 40 to 1 ratio.

A pointer connected to the cord slides along a scale to indicate the fre-



(left) The main radio face plate is cut from .063" aluminum plate scrap bought at the local sheet metal shop. The window was cut by drilling a 1/4" hole in each corner, and using a metal cutting blade in a scroll saw. Careful filing quickly brought the sawn edges to the layout lines scribed in the aluminum, creating a professional appearance.



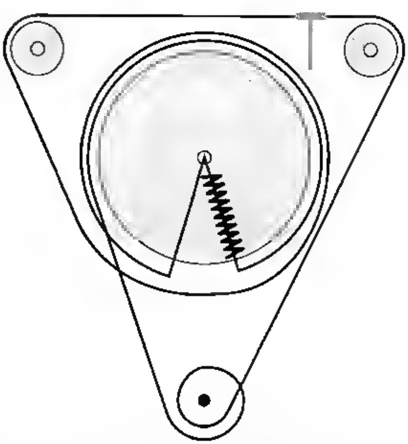
(left) The main radio after cutting, drilling and sawing the window. Behind the window is mounted a section of 1/8" acrylic plastic available in hardware stores as replacement for glass windows. Since the cut edges of the plastic window won't show, you can cut them just about any way you like.

quency being tuned. The length of the scale is half the circumference of the capacitor pulley. A four inch diameter pulley will have a circumference equal to four times pi (3.142): 4 x 3.142 = 12.6 inches. Since the capacitor only moves through a half rotation, our scale can only be half the circumference, or 6.3 inches in length. A five inch diameter pulley would give 5 x 3.142, or 15.7 inches, or a scale length of 15.7 ÷ 2, or 7.8 inches.

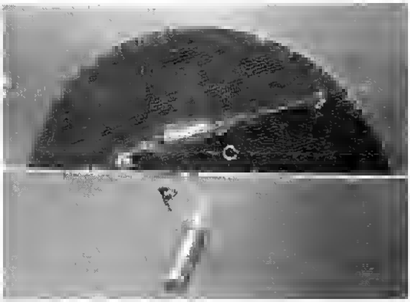
The slide-rule dial drive you see here consists of two aluminum plates separated by small threaded tubes, or standoffs. Holes in each of the plates form primitive bearing surfaces. A large pulley turned from a piece of phenolic (Bakelite™) is mounted on the capacitor shaft. The 1/4" knob shaft is turned down slightly to accept the cord and give a slightly higher reduction ratio. A lead flywheel weight on the knob shaft adds smoothness to the tuning. A simple brass pointer assembly slides across the top of the front plate. The slide rule dial assembly mounts behind the main radio face plate which has a window cut in it to reveal a scale attached to the dial front plate.

The whole assembly is large and admittedly cumbersome, but it works very well. It is very smooth, does not slip, tunes very slowly, and it provides a six inch easy-to-read scale.

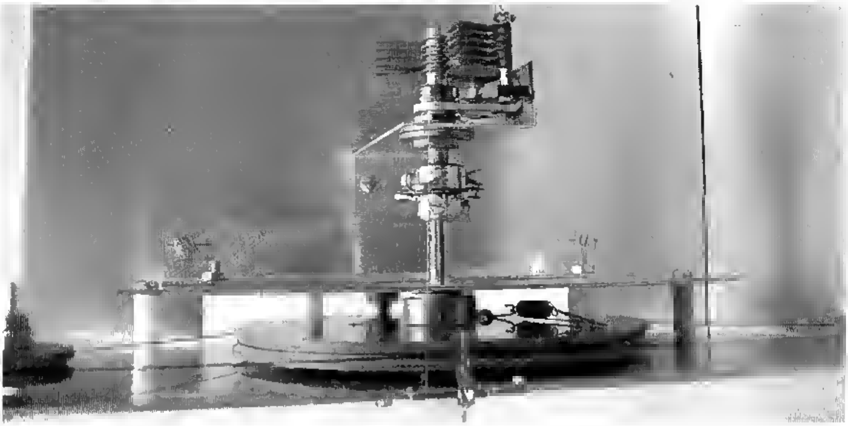
A few dimensions are provided here to give you an idea of scale. The exact dimensions you use will depend on the materials you have on hand or can acquire. If you don't have facilities to turn a pulley on a wood or metal lathe, you may be able to acquire a multi-gang tuning capacitor from an old radio that still has a pulley attached. They are still quite common. It may be that you'll have use it in some custom configuration of your own design. And that's the way it should be. Use your imagination. De-



There are many different ways to wind the cord. You'll want to wrap numerous turns about the knob shaft to get enough friction to prevent slipping. You'll need a turn or two in either direction on the main capacitor pulley to allow free rotation. Although genuine dial cord is available from radio restoration parts houses, I used heavy thread used for sewing carpets. It's available locally, inexpensive, and works very well.



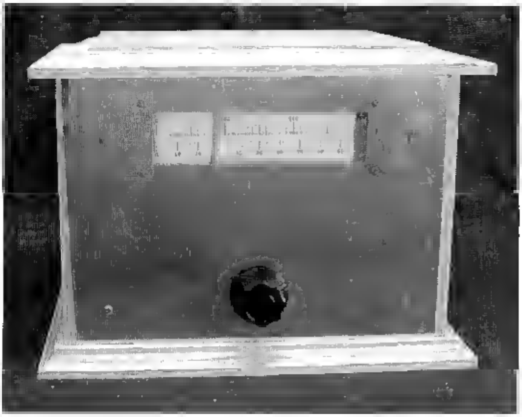
(left) The main capacitor pulley is drilled from the edge at a very steep angle to the side of the pulley so that the dial cord can be attached to the spring. Here, both ends of the dial cord are fixed to the end of a junk-box spring. The other end of the spring is held in place by a machine screw. This view is from the back of the assembly.



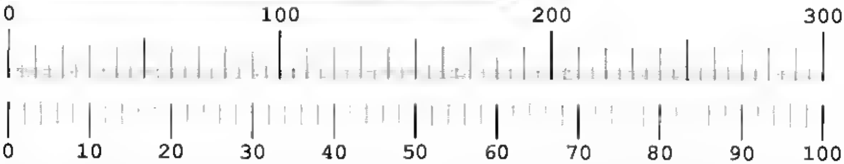
(above) Top view of the assembly mounted on the notched chassis.

(left) View from the bottom showing the knob shaft projecting through the front plate. Threaded nylon standoffs commonly available from parts suppliers can be seen.

The lead flywheel was cast by melting lead shot used by skeet shooters to reload shotgun shells. The molten metal was poured into the bottom of a tomato paste can. Once frozen, a pair pliers was used to tear the can away from the cast lead cylinder. It was chucked up in the lathe, center drilled, and turned on a mandrel. A hole was drilled and tapped to accept a very coarse thread set screw. Pouring and machining lead is an easy way to get lead poisoning. Use plenty of ventilation when melting, and a mask when machining.



(left) Here the slide rule dial assembly mounted on the notched chassis with the main face plate is surrounded by newly cut wooden panels that will form a case that resembles something from a bygone era. This case will be stained and varnished, and the face plate probably painted satin black. Additional knobs will control the internal workings of the radio to be built around the dial assembly.



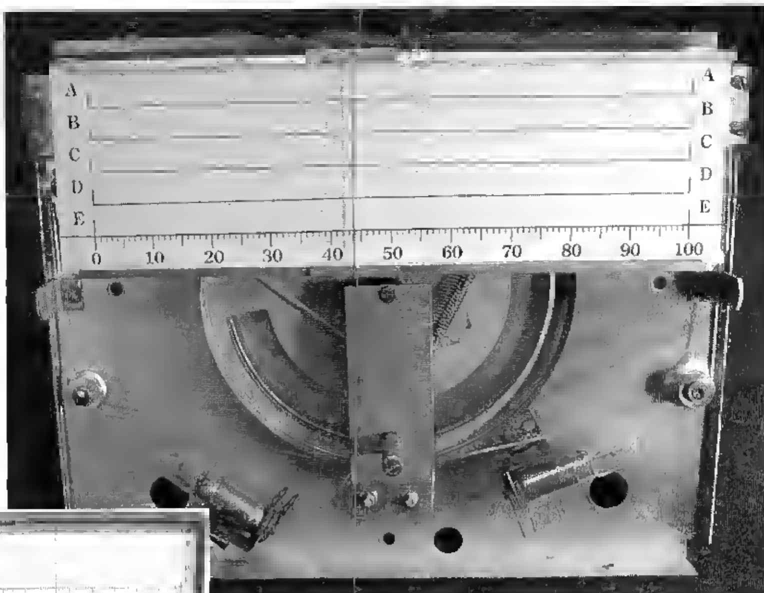
(above) Taped to the front plate behind the plastic window is a scale created with software and printed on a laser printer. Simplicity is better. The hallmark of a beginner is the use of bright colors, PT Barnum lettering, and ridiculous patterns. Don't do it, keep it simple, or you'll end up with something almost as disgusting as the cover of this booklet! Keep it simple.

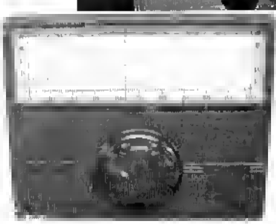
sign your own machine. What you see here is literally my first attempt at building such a unit. With the lessons I've learned, I could probably come up with something simpler and smaller if I had to. You can do it to.

If you're not quite sure that all the parts will fit together properly consider building a "prototype" from heavy cardboard, or 1/8" Masonite, or something easy to experiment with. Work out the placement of parts, dimensions, and relationships between components. Once you're confident that the design has a real chance of working, then you can cut the main aluminum plates, or have them cut. Or maybe you'll just build your unit out of tempered Masonite. Think creatively.

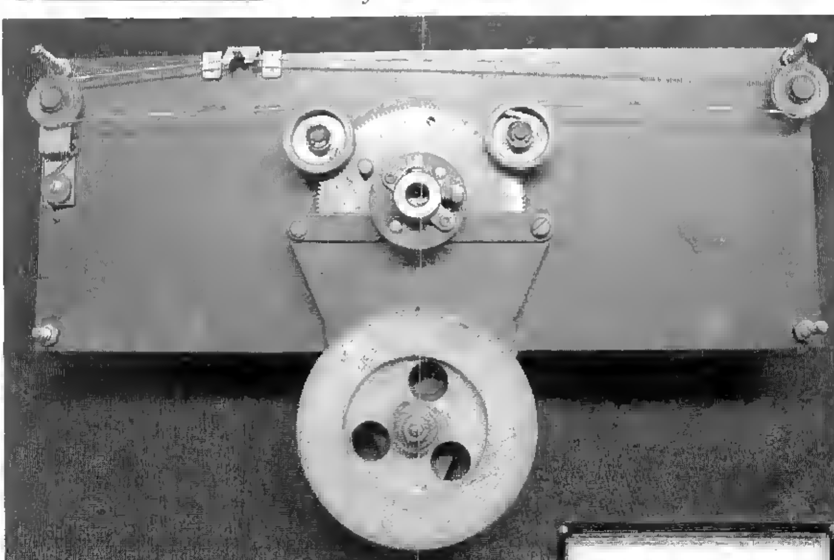
You may want to find a junk receiver and cannibalize it, using the essential components in a new receiver of your own design. That's probably the easiest way. But building your own from scratch isn't that difficult either.

When you mount your slide-rule dial radio inside of a custom wooden case that looks like it's right out of the 1920's and tell people you use it to talk to people on the other side of the world (assuming you have a ham radio license), they'll be amazed (or they'll have you put away.) Whether anyone appreciates what you do or not is really not important. What counts is having fun building your own equipment. And building this slide-rule dial is fun. In the end you'll have an exceptionally useful mechanism that will make operating your radio even more fun.



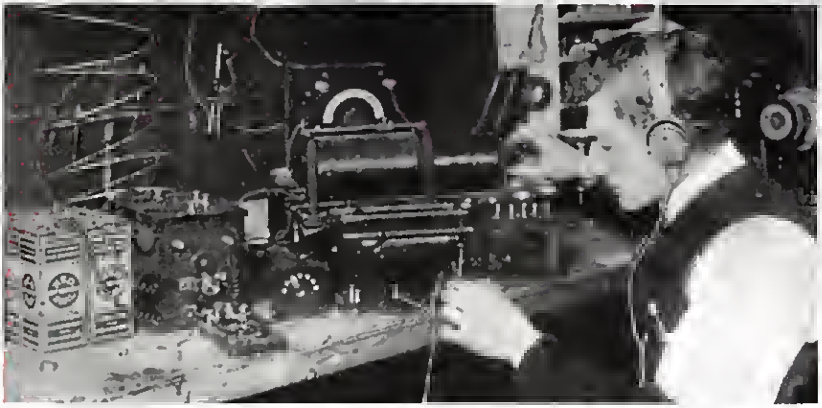


(above) This classic Millen dial drive is hard to find, but not impossible. I've seen several appear on internet auction sites. The homemade version just described is actually much smoother than this commercial drive.



The Eddystone (British) dial drive is among the best ever produced. It uses gearing to produce a very long scale, high reduction ratio, and massive flywheel creates very smooth, steady tuning. Difficult to find.

YOU can build old-time radios!



Vacuum tubes are to the electronics industry what steam locomotives are to the railroading industry: hot, inefficient maintenance headaches. But like a steam locomotive, a tube has a simple fascinating charm that no high-tech chip can match.

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