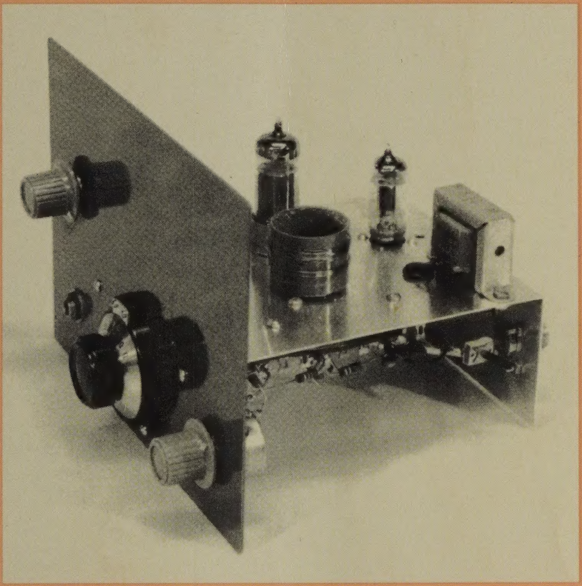
How to Build Your First



Vacuum Tube REGENERATIVE RECEIVER

by T. J. Lindsay

A "Bonehead to Genius in One Step" Book

How to Build Your First

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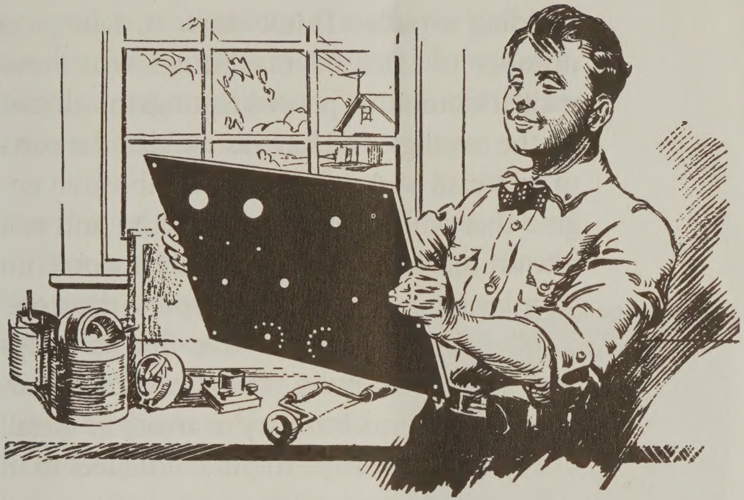
Contents

Notice of Disclaimer

The author of this book is not a professional engineer nor has he had formal training in the design or operation of regenerative receivers. The author is an amateur but has been successful in building and operating the device discussed herein.

The methods that he describes are presented merely as guidelines for others in developing such receivers. These devices can be dangerous, possibly even lethal, and dangers have been pointed out wherever possible. Since the author is not a professional in this field, there are probably other dangers involved in construction and operation as well.

Both the author and Lindsay Publications Inc hereby disclaim any liability for injury to persons or property that may result while using this book. Neither intends by this publication to explain all dangers known or unknown that may exist in the building and operation of the project described.



1 Introduction

(above) an illustration from a manufacturer of phenolic panels... "lifted" from an early QST Magazine

So you want to build a vacuum tube regenerative receiver? Great! I've built many of them. I'll show you how it's done.

Regenerative receivers can be at times ornery devils to adjust and hold on frequency. But when you see how these little "peanut-whistle" sets built from a handful of components pull in the signals, you'll know in minute how addictive building them can be.

Tubes? Who in their right mind would build anything from tubes these days? The answer is simple. We're not in our right minds. Solid state is better. No question about it. If you're interested in building a high performance machine using easily obtained components, use transistors and integrated circuits. Just put this book down and walk away.

Tubes? Yes! Why? Because we're not just

building a radio. Think about it. I know a number of talented machinists who have melted aluminum, poured castings, machined up the castings, and have assembled the parts to create an unusual internal combustion engine that will sit on your table top and run like the dickens. What good is it? It won't run your lawn mower. It can't get you to the store. In other words, it has no use. But it's sculpture. Kinetic sculpture. These men call themselves machinists but they're artists in metal. They mold and shape it, put a little fuel in it, and watch it come to life.

A cabinet maker loves to take a tree and convert it into a beautiful piece of furniture. It's sculpture. A baking fanatic will go to great lengths to decorate a cake just so. Will it taste any better? No. It's just cake. But it's a cake sculpture. So it is here.

We're going to build a radio from big, old, clunky components that, for the most part, haven't been used in years. It takes time and effort to acquire them. But when we do, and we assemble them into our electronic sculpture, our creation, like a homemade engine, comes to life and delivers radio signals from all over the planet. It's magic!

Our goal here is not to build the ultimate regenerative receiver. That will need to be covered in another book, or a whole series of books. What we want to do is to build that first regenerative tube receiver, get it working on a lower frequency band, with smooth regeneration, and plenty of audio so that you can listen to foreign broadcasts, ships at sea, amateur radio operators, "secret" communications and a lot more.

You'll need other books...

I'm not going to go into a lot of theory. You can pick up much simple radio theory from early RADIO AMATEUR HANDBOOKS published by the American Radio Relay League, especially those before 1940. Another essential book is the SECRETS OF REGENERATIVE RECEIVERS by C. F. Rockey. "Rock" started building receivers in 1934, and he will sit you down on his knee and teach you all the things you need to know. Check with Lindsay Publications to see exactly what kind of regenerative books are available.

Don't make fun of regenerative receivers. You'll hurt my feelings...

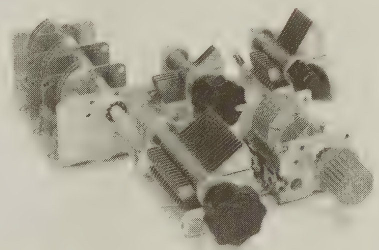
What I intend to show you is the practical stuff. What kind of coil and capacitor can we use? What tube? What choke? How do you adjust the regeneration? And how do you do it all on the cheap. Always on the cheap. But we want it to be impressive, too. Once you've built one, you'll realize that it's not that hard to do. But when you show your unusual shortwave receiver to your knucklehead neighbor, he'll think you're an absolute genius. And we're certainly not going to tell him any differently.

I'll try to give you an idea of how and where you can improvise. I certainly don't expect – don't want – you to exactly duplicate the little receiver I have here. I built it based on what was available in my basement-size junkbox. Don't be afraid to substitute. Between this book and Rock's book you should have plenty of information to get you going.

2 Salvage

Finding Components

The first step in building a receiver is accumulating the components. You can't just run down the local radio store like you could in the old days, so I'm told, to buy the parts you need. These days you have to search for them. That may seem hopeless, but it is anything but. There is so much vacuum tube gear floating around out there that no one wants, that just a few dollars will land you more parts than you're likely to use.



One day's haul at a hamfest. A triple gang 26pfd, a Hammarlund 50, 100 & 140 pfd, and a broadcast unit...

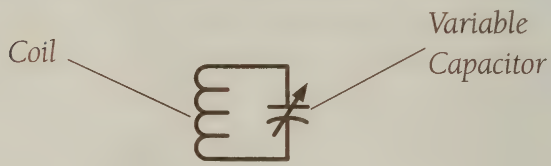
Probably the best place to look is at hamfest/computer show. Most are held during the warm summer months early on a Sunday morning. And they're numerous. You'll find them all over the country. Between May and September there are at least a dozen such flea markets within a two hour drive of my home. If you want to drive three hours, there are many more. And as you may already know, the largest is held in Dayton, Ohio in mid-May every year. It's something to see.

Get out of bed, stash a sandwich and a cold drink in the cooler, and head off to the flea market. You'll be amazed by how little money it takes to fill the trunk with "junk". 'Course you may have some explaining to do to the wife.

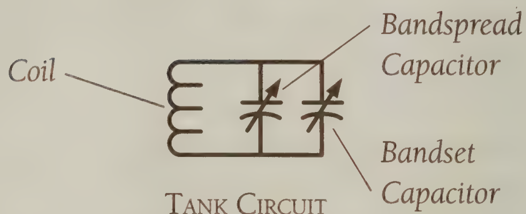
Let's look at the most essential components you will need to search for.

The Tank Circuit is the Heart...

Don't ask me why it's called a tank circuit. The old timers who named the familiar LC circuit are all gone. Whatever you choose to

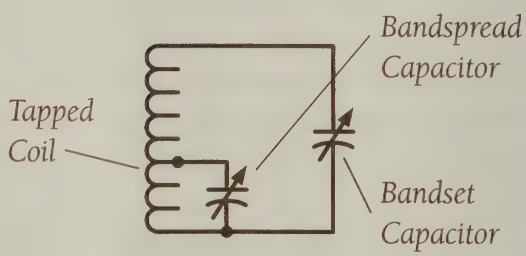


TANK CIRCUIT



TANK CIRCUIT WITH TWO CAPACITORS

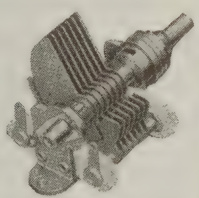
The bandset capacitor is a larger coarse tuner, while the bandspread is a smaller "fine" tuner.



TANK CIRCUIT WITH TAPPED COIL

call it the coil and capacitor combination is the core of our receiver. Most often used is a variable capacitor with a maximum capacity in the range of 50 to 140 pfd. You could get by with a 365 pfd capacitor which is the standard for the AM broadcast band. But for shortwave, it's really far too much. I recommend 50 to 100 pfd for a smooth tuning receiver. The 365's are still being made and can be purchased from parts dealers. You can reduce their maximum capacitance by carefully removing plates. If you remove half of the plates of a 365, you'll end up with roughly an 8 to 180 pfd capacitor. Rockey shows you this trick in his book.

A double bearing capacitor is desirable for maximum mechanical stability but is not es-



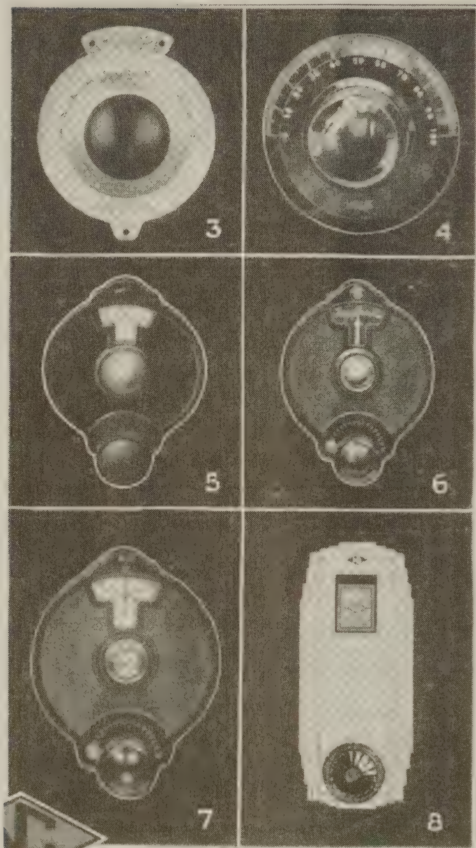
"MC" MIDGET CONDENSERS

Ideal variable for ultra-short wave and short wave tuning, laboratories, etc. Isolantite insulation. All contacts riveted or soldered. Vibration proof. New improved Hammarlund split type rear bearing, and noiseless wiping contact. Cadmium plated soldered brass plates. Shaft—¼".

CODE	CAPACITY	LIST
MC-20-S	20 mmf.	$1.40
MC-35-S	35 mmf.	1.50
MC-50-S	50 mmf.	1.60
MC-50-M	50 mmf.	1.60
MC-75-S	80 mmf.	2.00
MC-75-M	80 mmf.	2.00
MC-100-S	100 mmf.	2.25
MC-100-M	100 mmf.	2.25
MC-140-S	140 mmf.	2.50
MC-140-M	140 mmf.	2.50
MC-200-M	200 mmf.	2.75
MC-250-M	260 mmf.	3.00
MC-325-M	320 mmf.	3.50

"M"—Midline Plates "S"—Straight Line Cap. Plates

Advertising for Hammurland variable capacitors. From the 1939 RADIO AMATEUR'S HANDBOOK



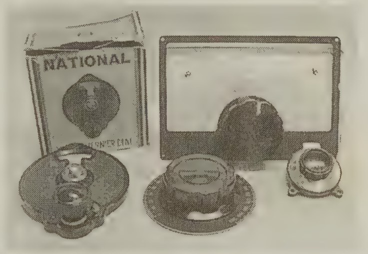
Ads for National Dial Drives – from the 1936 RADIO AMATEUR'S HANDBOOK

sential. ...at least, not for our first set. Surprisingly beautifully built capacitors like Hammarland, Cardwell, or EF Johnson can easily be found. I could buy a dozen capacitors at every hamfest I attend for anywhere from one dollar to three dollars each.

We Need A Dial Drive, Too!

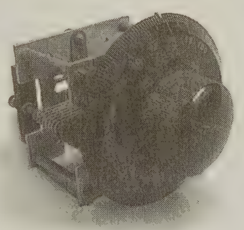
An absolute must is a slow-motion, or vernier dial drive. You must be able to rotate the shaft of the variable capacitor very slowly in order to pick out the stations you want. Trying to tune a regenerative receiver, or any shortwave receiver for that matter, without some type of reduction drive is an exercise in frustration.

You can get brand new imported vernier drives with numerical scales for ten to fifteen dollars. But you can also pick up classic dial drives like the National Velvet Vernier, in both stainless steel and bakelite. They're not common, but they are available. This summer I picked up another, a rare pre-WWII version with nickel plating, for $10 at flea market catering to antique radio collectors. Another came attached to WWII frequency meter for $7. One bakelite model was mounted on a 250 pfd antique capacitor, and I got the whole thing for $4! I don't even remember where I picked up the others.



Four different dial drives: a rare 20:1 National from the 1920's; an ACN at the rear; a General Radio dial to the front; and a currently available imported vernier...

The National ACN dial uses the same planetary drive as the Velvet Vernier, but instead of a vernier numerical dial, it offers a plastic pointer on a semi-circular paper scale on which you can mark frequencies. These are not all that common either. But luckily one summer I managed to find three, one for $10, and another on a generator that looked like it had been stored in a leaky barn for 50 years for only $5. These are fantastic dials for old time radios – especially if you want to build something that looks like it came out of Dr. Frankenstein's lab.



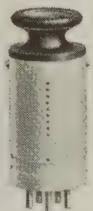
A hard-to-find bakelite National "Velvet Vernier" and capacitor. Only $4 at a hamfest recently! You can find similar bargains...

Look through ads in old radio magazines (1950 and before) or old Radio Amateur Handbooks to get an idea of what was being manufactured. Great old dial drives can still be found if you go looking for them. Finding them is half the fun. And for gawd's sake don't think that you'll never find any. You will. They're there. The sad truth is, that ham radio operators don't build gear anymore. They go out and buy fancy solid state gear. That means that the crazies like you and me can walk in and scoop up all these parts that no one else wants. And for that very reason, the prices we pay are next to nothing. Commercial dealers must charge much more.

Find Plug-In Coil Forms...

Once we have our variable capacitor and a dial drive with at least a 5 to 1 gear ratio for slow motion tuning, we need to hook the capacitor up to a coil to form a resonant circuit. This is the very heart of our receiver. You can wind a coil on a toilet paper tube if you want, but I don't. I almost always wind the coil on some type of plug-in form. That way, I can wind coils with various number of turns to pull in a variety of shortwave bands. Check the old construction articles. You'll see what I mean.

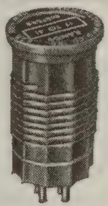
For twenty-five years I've accumulated old plug in coil forms, the Hammarlund being the classic. I've got them in four, five and six prong varieties. They're getting less plentiful now, but they're out there. You only need a few. Standard price these days seems to be about $3 a coil form, although this summer alone I saw one gentleman asking $10 for a box of eight. That was a steal. I would have picked it up, but I have all the coil forms I'm likely to need.



"CF" ISOLANTITE COIL FORMS

Popular coil forms so many fans are using today. Black enameled wooden knob. Removable paper indicating disc protected by celluloid. Surface "non-skid." Plenty of holes—eliminates drilling. Slotted bottom for primary or tickler. Four, five, and six prong types. 1½" diameter. 2½" long exclusive of knobs and prongs.

CODE	LIST
CF-4 (four prongs)	$1.25
CF-5 (five prongs)	1.25
CF-6 (six prongs)	1.25



"XP-53" COIL FORMS AND KITS

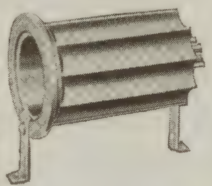
Outstanding forms using new low loss insulation material—XP-53. Natural coloring eliminating losses. Groove-ribbed for air spaced windings. Flange grips, meter indexes. Moulded threaded shelf in form. 1½" diameter and 2⅞" long exclusive of prongs. Kits with wound coils for MC-140-M condenser also available.

CODE	LIST
SWF-4 (four prongs, coil form only)	$ .35
SWF-5 (five prongs, coil form only)	.35
SWF-6 (six prongs, coil form only)	.40
No. 40 coil (wound coil, 4 prongs, 10-20 meters)	1.00
No. 41 coil (wound coil, 4 prongs, 17-41 meters)	1.00
No. 42 coil (wound coil, 4 prongs, 33-75 meters)	1.00
No. 43 coil (wound coil, 4 prongs, 66-150 meters)	.75
No. 44 coil (wound coil, 4 prongs, 135-270 meters)	.75
BCC-4 (wound coil, 4 prongs, 250-560 meters)	1.25
No. 60 coil (wound coil, 6 prongs, 10-20 meters)	1.25
No. 61 coil (wound coil, 6 prongs, 17-41 meters)	1.25
No. 62 coil (wound coil, 6 prongs, 33-75 meters)	1.25
No. 63 coil (wound coil, 6 prongs, 66-150 meter)	1.00
No. 64 coil (wound coil, 6 prongs, 135-270 meters)	1.00
BCC-6 (wound coil, 6 prongs, 250-560 meters)	1.50
SWK-4 (kit—4, four-prong coils, 17-270 meters)	3.00
SWK-6 (kit—4, six-prong coils, 17-270 meters)	3.75

"TCF" COIL FORM

A transmitting coil form of XP-53 dielectric is also available. This may be permanently mounted on special brackets supplied, or in plug-in coil fashion. 2¼" diameter. 3⅞" long exclusive of prongs.

CODE	LIST
TCF-4 (4 prongs)	$.70
TCF-5 (5 prongs)	.70

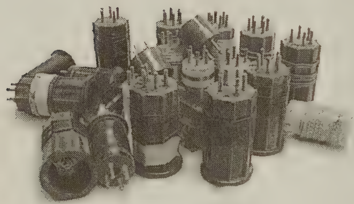


Hammarlund coil forms ads from the 1939 RADIO AMATEUR'S HANDBOOK

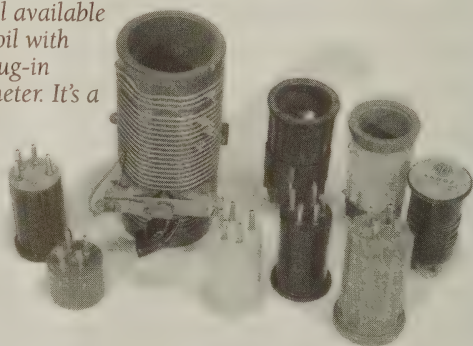
You should have been there to get them for your radio.

These coils are 1 1/2" in diameter and five inches high. The five prong varieties are most common, and useful enough for us. But if you see them at a reasonable price, pick them up. They're not made anymore. At least not these mica-filled phenolic varieties.

For our little set in this book, I've used a base from an early four-prong tube. I don't advocate breaking up four-prong tubes for their bases. In the old days you could do that. The tubes were plentiful. These days, they're collectibles. In Russia and China, four prong tubes are still being built. The tube bases I used here as coil forms were obtained from Antique Electronic Supply in Arizona. They appear to brand new, I would guess having been stripped from new broken or defective four prong tubes. Maybe they're coming directly from tube manufacturers in Russia. I don't know. But I don't care. All I want to do is wind a coil to resonate with my tuning capacitor.



I highly recommend you check out the section on coil forms in Rockey's book on regenerative receivers. He will show you how he wound his coils in detail. Great secrets!



A few plug in coils are still available if you search. The large coil with the knob is not really a plug-in form, but rather a variometer. It's a rotary variable inductor used to control feedback in early radio sets. At the lower left is a brand new four-prong tube socket that is used in building the set described in this book.

Here are the specifications on a few of the plug coils in my junk box:

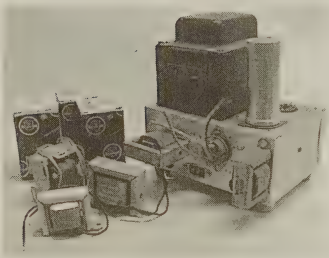
Manufacturer	Dia	Height	Pins	mHz
Insuline Corp of America (ICA)	1 5/8″	2 3/4″	5	1.4
ICA	1 1/4″	2 1/8″	5	1.4
Hammarlund	1 1/2″	2 1/2″	4,5,6	1.4
James Millen	1″	1 1/2″	5	4.2
? clear plastic	1 1/4″	2″	5	2
4 prong tube base	1 3/16″	1″	4	4.5

The low frequency shown in the rightmost column is the lowest frequency at which the coil will resonate when connected to a variable capacitor set at its full capacity of 100 pfd. These are rough calculations based on the assumption that coils have been closewound at 32 turns per inch with plenty of room left on the form to wind a tickler coil. You can significantly lower the resonate frequency by using finer wire so that more turns will fit on the coil and/or by winding multiple layers.

There you have the most crucial parts of the radio: the coil form, the variable capacitor, and the slow-motion dial drive.

Look for a Choke...

Another major component you may have to search for is a choke with an inductance of at least several henries. The purpose of this iron and copper beast is to get direct current to the plate of the detector without letting the audio frequencies generated by the detection process get back into the power supply sys-



To the left are three brand new chokes used in power supplies obtained at flea markets for as little as $2 each. The monster to the right sports a huge power transformer and two filter chokes on the side. It was given away at a recent flea market. I guess it was too heavy to lug back home...

tem where they are lost. I use power supply chokes. In the radio we're about to build, I've used a 4 h choke although bigger is better. It's physically small because it has been wound with fine wire which can conduct only a few millamperes of current before overheating. You could use a 4 h choke rated at half an ampere if you wanted, but it might weigh ten pounds! I've picked up brand new chokes in their original boxes for three or four dollars each. One pour soul at one flea market was so desperate to get rid of a boat-anchor sized power supply he gave it away! To me! On there is a nasty looking choke I haven't even measured. But I'll bet it would work in a regen receiver.

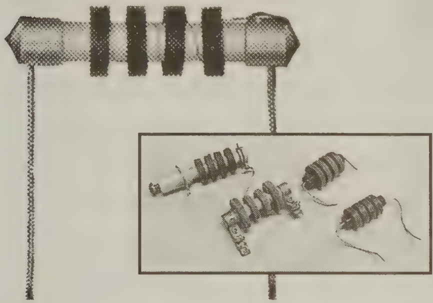
We'll need a large audio choke from 1 to a 100 henries, and an RF choke of about 2.5 mH

You can use interstage or output transformers from old tube radios or amplifiers. They often have several henries of inductance in one of the windings. You can use the primary (or secondary) and leave the other winding unconnected.

Using a restored General Radio 650 im-

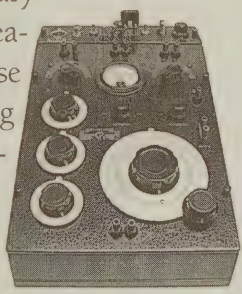
NATIONAL R. F. CHOKES

R-100. Isolantite mounting, continuous universal winding in four sections. For pigtail connections or standard resistor mountings. Inductance 2½ m.h.; distributed capacity, 1 mmf.; D.C. resistance 50 ohms; Current rating, 125 M.A. For low powered transmitters and high frequency receivers. **List Price, $.60**



At least one of the RF chokes shown here is needed in a regen receiver. They're used in many circuits, so if you see a bargain, grab several. They sell for more than $3 new from dealers. But I've purchased them in like-new condition at four for a dollar...

pedance bridge, I measured some inductors in my junk box. One output transformer measured 2 henries across the primary (red and blue leads). Another transformer measured 3.8h across the black leads, but only 13.8mh across the green-white leads. The primary of a 117 volt to 24 volt transformer measured 1.2h. I suppose you could even use those small box transformers that plug directly in the wall and charge the batteries in your electric screwdriver or handheld vacuum cleaner. One such transformer rated at 6 watts measured 2.85h, and another rated at 9 watts measured 1.88h.



The classic General Radio 650 impedance bridge. A beautiful ol' beast. Very useful.

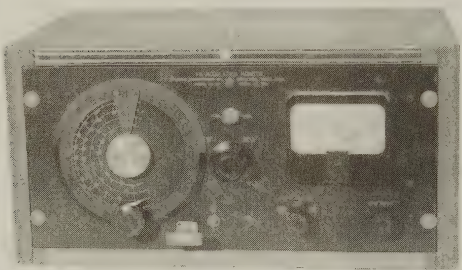
You cannot really judge an inductor's size by measuring the dc resistance of the windings. It IS somewhat of measure, but not very good. For instance, a Stancor C-1515 filter choke has an inductance of 20.0 henries and

Heathkit RLC Bridge. Useful for measuring unknown capacitors, resistors, and inductors. Still available at hamfests for $10-$20. A must-have for builders and salvagers...

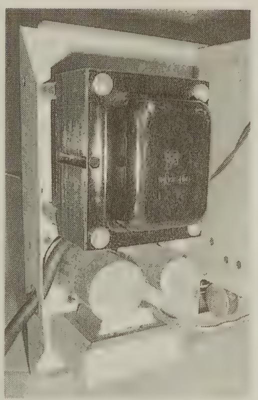
a dc resistance of 900 ohms and can handle 15 ma of current. A Stancor C-1355 is only 8 henries and 290 ohms and can handle 75 ma of current. To be sure you need to measure them with an impedance bridge, also called an RLC bridge. You'll find these bridges at flea markets, too. You might find a old Heathkit in excellent working order for $15. Or you might find the professional General Radio 650 in rough condition for $30. You can build one easily enough, but that's the subject of another book.

A Power Supply Must Be Found...

Another major component is a power supply. Actually, it's a whole piece of gear in itself. At first glance, it might look like a major obstacle. But really, with all the tube gear out there practically being given away, power supplies are easy to find. I bought a deviation meter on a standard 19" rack panel in a case for $5.00. It was loaded with tubes, a great



Five dollars bought this back-breaking deviation meter loaded with tubes, power supply, 100 μa meter, dial drive, and rack panel case. Junk to most people. Gold to me and you...



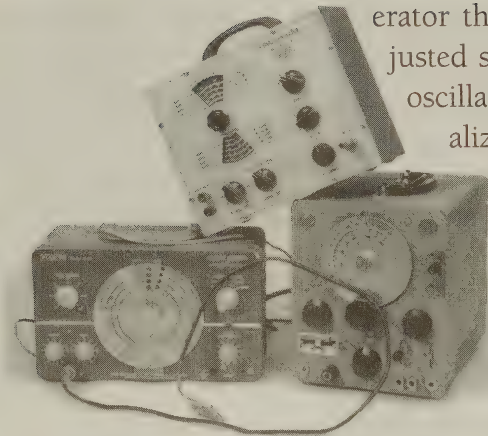
The power supply in a four tube lab-quality audio oscillator purchased for $5. This is industrial quality throughout. Most of the parts needed for a regen receiver are in this case...

vernier dial drive, an excellent 100-0-100 μa meter and best of all, a hefty power supply to drive the whole unit. (I really just bought it for the case and the dial drive!) Another industrial grade audio oscillator in a heavy steel case has an equally solid power supply. Even inexpensive test gear like VTVM's and rf generators have power supplies that can be cannabalized.

That's where you start. Get some type of coil form, preferably plug-in variety, a good variable capacitor and a slow-motion dial to drive it, and a solid power supply. It sounds formidable. Actually, you can round up almost everything you need in two hours at a Sunday flea market. And you'll spend more on gasoline than you will for the gear!

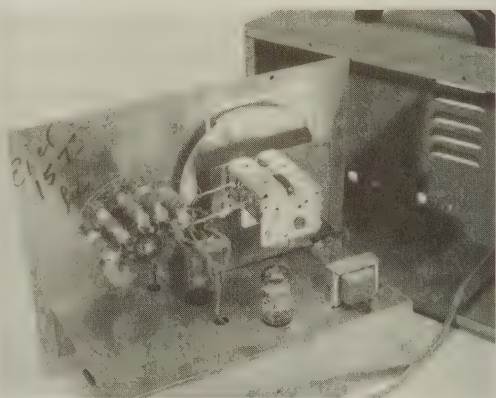
Buy Signal Generators!

Great sources of radio gear are old tube RF generators. I have EICO, Heathkit, PACO and others. No one wants them. They sell for $5 to $10, and they provide almost everything you need to build a radio: coils, capacitor, drive, power supply, tubes, sockets, and miscellaneous parts. If you visualize a regenerative receiver as actually being just an rf gen-



erator that is carefully adjusted so as to just barely oscillate, you quickly realize that an rf generator has 80% of the parts you'll need. Buy several. The one that works best can be used as a signal source to test and adjust your receiver, and the poorer units can be cannabilized and/or modified.

You may have to add a triode like a 6C5 or 6C4 to boost the audio, or maybe a double triode like the 12AT7, or the 12AX7 (if you're really hard of hearing). With luck you can mount them right on the same chassis. You won't have to perform much sheet metal work at all!



Interior of a typical inexpensive signal generator. You'll find tubes, power supply, variable capacitor, slow-motion dial drive, coil forms, switches, and most of the components needed for a receiver...

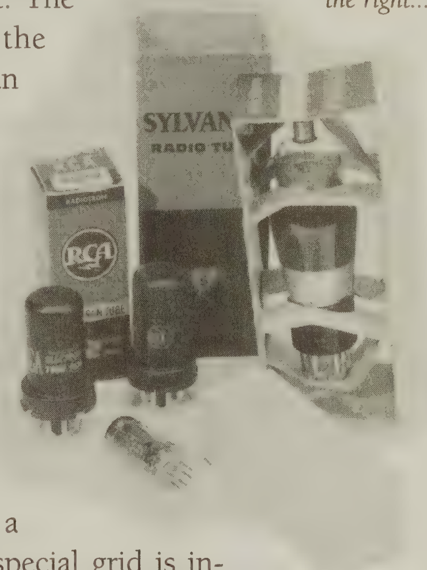
Tubes Are Still Plentiful...

Next on our list of components to acquire is tubes. What shall we use?

Most of tubes manufactured were triodes and pentodes. In a sense, a pentode can be thought of as two triodes piggy-backed. If you look at an electron-coupled oscillator you'll see the cathode, the control grid and the screen grid acting as a triode to create an alternating current. The additional grid and the plate almost act like an additional triode to amplify the generated signal. If you hit the plate of a triode with a heavy load for instance, the control grid will "feel" it because the plate and control grid are connected by inter-electrode capacitance. In a pentode, however, a special grid is inserted to remove this linking capacitance. If you load down the plate of a pentode, the control grid will hardly feel a thing. This is the reason why triodes when used as RF amplifiers have a nasty tendency to oscillate, whereas, pentodes are far less likely to do so.

Triodes, especially high gain triodes, make dandy regenerative detectors. Feedback is usually applied through a tickler winding just as

Brand new tubes – metal octals to the left, a 7 pin miniature in front, and a 6 prong 6C6 pentode to the right...



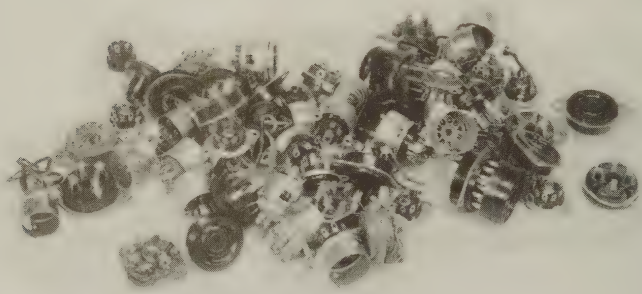
These tubes are still available brand new from Antique Electronics Supply and other dealers!

we will do here, but control of the feedback is best achieved by a "throttling" capacitor. It's an excellent regeneration control method, but it requires a quality variable capacitor in addition to the main tuning capacitor.

For our radio here I've chosen a pentode because by controlling the voltage to the screen grid we can control of the overall gain of the tube and therefore the regeneration. Voltage control is easily achieved by using a potentiometer, or "pot" rather than a variable capacitor. Pots are still being manufactured by the millions and can be purchased brand new for about a dollar and half. The same cannot be said of a Hammarlund 140 pf variable!

But which pentode? Just about any really. A classic miniature pentode is the 6AU6. You'll find them just about everywhere. You should have no trouble any finding them. But they're not the only pentodes that will work.

At this point you need a tube manual.



Consider picking up used sockets. A single new octal socket can cost you $3-4 new from a dealer. All of these salvaged sockets were purchased for $3!

Some of the best ever published where put out by RCA. I have several. The 1959 edition has been reprinted and is especially good because it covers both the “new” miniature tubes as well as the early octal and four prongers.

Every Radio Amateur Handbook published in the early 1960's or earlier provided a great tube reference complete with basing diagrams at the end of the book near the index. I've photocopied the pages of several editions and keep them in a three ring binder for reference.

So where does that leave us? Well, we could use miniature types like the 6AU6, 6BA6, or 6BZ6. Or we could use large metal or glass tubes with octal pin basing like the 6SK7, 6J7, 6S7, or 6K7. We could go back even further and use a 6C6 or 6D6. I've even used 2.5 volt filament tubes like the screen-grid '24 (a tetrode) and '27 (a triode). Even these old tubes are still available brand new as new-old-stock (NOS).

You'll see most pentodes listed as sharp cutoff pentodes. Remote cutoff pentodes (once called variable-mu or super-control) change their gain as the grid bias is varied. These tubes are valuable for use in circuits where we want to change the gain of an amplifier stage with an electrical signal. A sharp cutoff pentode offers more-or-less constant gain despite changes in control grid bias. Sharp cutoff pentodes are more common, and I've used them with great success in traditional grid-leak circuits.

Avoid the "Heavy Weights"...

There are other octal pentodes like the 6L6 or 6V6 which are power pentodes designed more for high power audio amplifiers than anything else. They will work as regenerative detectors. In fact radio amateurs used them regularly to create oscillators and transmitters. The only problem is that they are built for much higher power levels than we need and therefore draw far more heater and plate power than other tubes.

The same story applies to more modern power pentodes like the miniature 6CL6. Another is the octal based 6DQ5 designed for television horizontal output use with its 24 watt plate dissipation and 2.5 amp filament current. Much too high!

wired for 12 volts

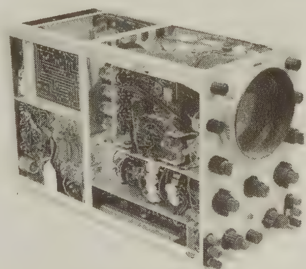
Perhaps I should explain that the first number of a modern tube number denotes the filament voltage. A 6AU6 has a 6.3 volt filament. A 12AV6 is a high gain triode with a filament voltage of 12.6 volts which is electrically identical to a 6AV6 with its 6.3 volt filament. Most power supplies provide 6.3 volts. Before this numbering system was introduced in the early 1930's, you could buy 2.5 volt filament tubes with numbers like UY-224 and UY-227, which became known as '24 and '27.

filament wired for six volts

Don't overlook multi-purpose tubes. You'll find inside of a 9 pin miniature glass envelope a pentode and a triode waiting to be used.

That's two tubes in one package. Television manufacturers loved them since they were an easy way to reduce complexity and power requirements which translated into lower costs. At one flea market recently I found a pair of 1960's vintage Hewlett-Packard oscilloscopes that had long since stopped working. I told the owner I was only interested in them for parts. He said "Give me a dollar a piece". For two bucks and an aching back I lugged them to the trunk of my car. When I pulled them from their cases back home, I found them to be loaded with multi-purpose tubes, as well as, most of the other components I would need to build a dozen regenerative receivers!

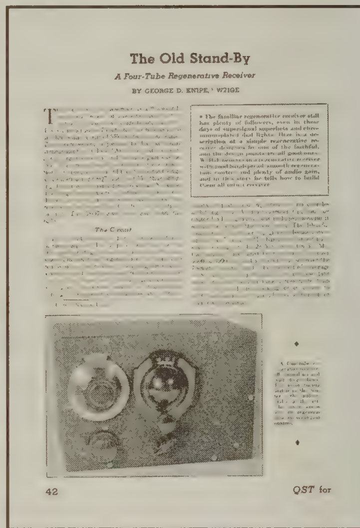
Some of the numbers I found where 6U8, 6AW8, 6AX8, 6AZ8, 6EA8, and others. All were pentode-triode combinations. Many articles from the early 1960's Amateur Handbooks show receivers and converters fabricated from 6U8's. I decided to save the 6U8's for other projects, and therefore pulled a 6AW8 for use as my regenerative receiver.



A one-dollar oscilloscope loaded with valuable parts...

The RCA '59 tube manual lists the 9-pin minature tube as a high-mu triode and sharp-cutoff pentode. The pentode section does not have as high a gain as a 6AU6, and triode offered a mu of 70 which is high but not as high as the 6AV6 which has a mu of 100. If you've

February 1947 QST Magazine *shows our hero frantically trying to get his transmitter repaired in time for the beginning of the big DX contest. A classic "Gil" cover...*


The Old Stand-By

A Four-Tube Regenerative Receiver

BY GEORGE D. KNIPE, W7IGE

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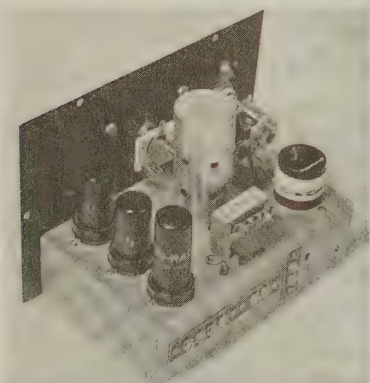


Even as late as 1947 amateurs like George Snipe, W7IGE, were still building low cost receivers like "The Old Stand-By", a regenerative detector followed by three audio stages driving a speaker. Superhets were the norm by '47, but the price-performance trade off of a regen still couldn't be beat...

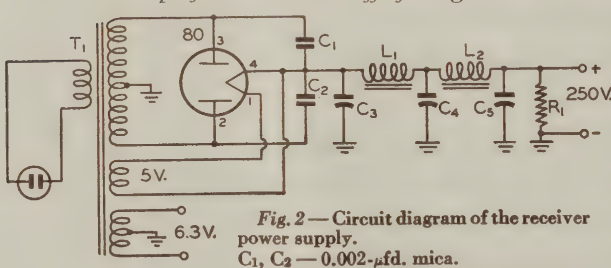


***Fig. 2* — Circuit diagram of the receiver power supply.**
C_1, C_2 — 0.002-μfd. mica.
C_3, C_4, C_5 — 8-μfd. 450-volt electrolytic.
R_1 — 50,000 ohms, 5-watt wirewound.
L_1, L_2 — 10-henry 50-ma. choke.
T_1 — Power transformer, 240–0–240 volts, 50 ma.; 5 v.; 6.3 v.

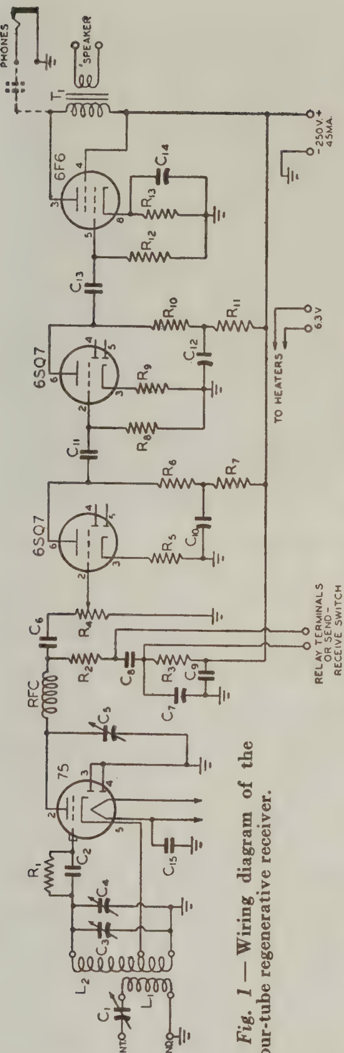
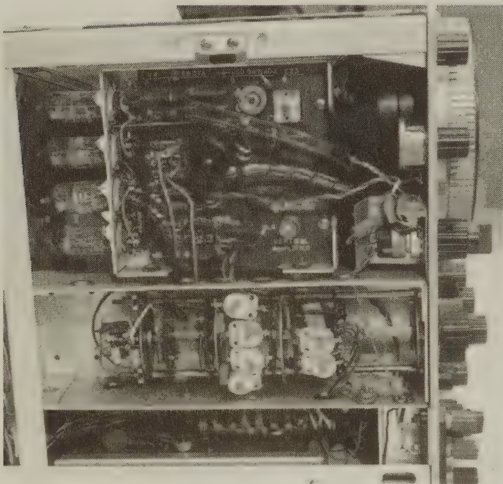


Fig. 1 — **Wiring diagram of the four-tube regenerative receiver.**

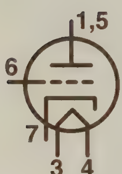
C_1 — 70-μμfd. adjustable mica (Hammarlund MICS-70).
C_2 — 100-μμfd. mica.
C_3, C_5 — 140-μμfd. variable (Hammarlund MC-140-M).
C_4 — 10-μμfd. variable (Cardwell ZR-10AS).
C_6, C_8, C_9, C_{11}, C_{13} — 0.01-μfd. paper or mica, 400 volts.
C_7 — 8-μfd. electrolytic, 250 volts.
C_{10} — 2-μfd. electrolytic, 250 volts.
C_{12} — 4-μfd. electrolytic, 250 volts.
C_{14} — 10-μfd. electrolytic, 50 volts.
C_{15} — 0.005-μfd. mica.
R_1 — 4.7 megohms, ½ watt.
R_2 — 0.2 megohm.
R_3, R_{10} — 47,000 ohms.
R_4 — 0.5-megohm potentiometer (Mallory Type N).
R_5, R_9 — 1000 ohms.
R_6 — 40,000 ohms, wirewound (Mallory 1 HJ).
R_7 — 4700 ohms.
R_{11} — 47,000 ohms.
R_8, R_{12} — 0.56 megohm.
R_{13} — 390 ohms, 2 watts.
Resistors are 1-watt composition unless otherwise mentioned.
L_1 — 80 m: 9 turns. 40 m: 4 turns. 20–10 m: 2 turns.
L_2 — 80 m: 39 turns tapped at 1¾ turns. 40 m: 11½ turns tapped at 1 turn.
20–10 m: 4 turns tapped at ¾ turn.
L_1 and L_2 wound with No. 22 d.c.c. wire, close-wound on 1⅜-inch diameter form (tube base).
RFC — 2½-mh. r.f. choke (National R-100).
T_1 — Output transformer, 6F6 to speaker.

Here we have a classic Hartley oscillator (feedback through the cathode circuit) with regeneration controlled by a throttling capacitor, C_5. The old six-prong 75 is essentially identical to the octal 6SQ7 which is identical to the 9-pin 6AV6. The 6F6 could probably be replaced by a miniature 6CL6 or something similar if loudspeaker operation is needed.



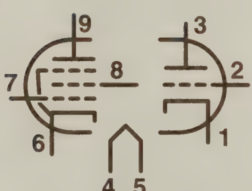
Interior of a one dollar oscilloscope revealing a treasure trove of parts for the experimenter and builder...

seen the 1934 SHORTWAVE MANUAL reprinted by Lindsay Publications, you will have no doubt seen the tiny two-tube receiver built by Hijame Suzuki of Tokyo as reported in the Novice column written by the late Walt Burdine. Suzuki used a 6AU6 detector followed by a 6AV6 audio amplifier to achieve satisfactory volume. Using a 6AW8 here, however, is going to leave us short on volume. There won't just won't be enough gain. We'll need another stage. To get the needed gain, I resorted to the 6C4.

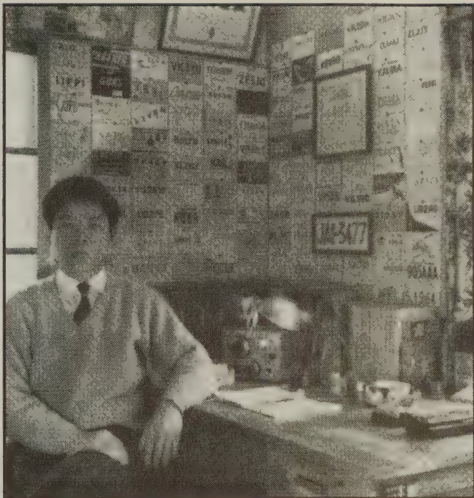


6C4

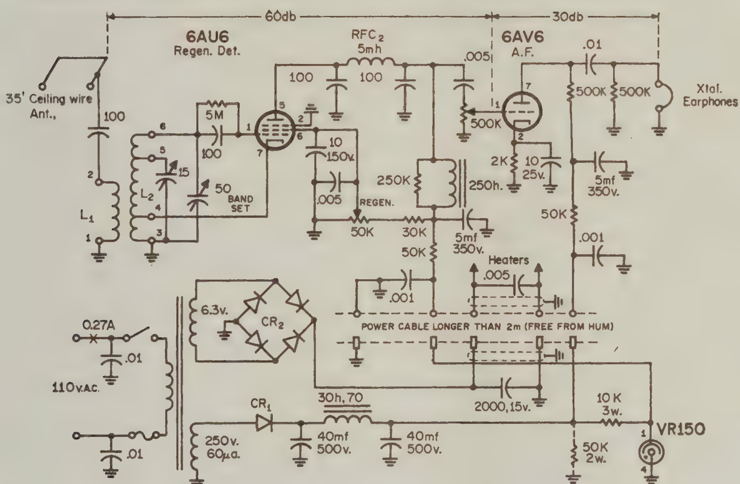
The receiver we'll build here is a 6AW8 followed by a 6C4. This is actually a pentode-triode-triode. You could easily use a metal 6J7 pentode followed by two 6C5 triode metal tubes. Of course, you might want to apply the lessons learned here directly to the Suzuki receiver and build his 6AU6 & 6AV6 design. Another option is a pentode such as the 6AU6 followed by a 12AT7 double triode which has a filament which can be wired for 6 volt operation. If you're hard of



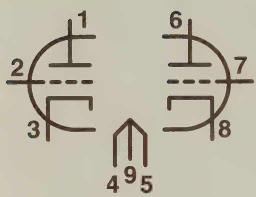
6AW8
6AU8
& others



Hijame Suzuki and his "peanut whistle" set as reported in the late Walt Burdine's "Novice" column in the Feb 1966 issue of CQ MAGAZINE. *See Lindsay Publication's* 1934 OFFICIAL SHORTWAVE RADIO MANUAL *where you'll find the entire article reprinted with the kind permission of* CQ MAGAZINE.



hearing you could use a 6BA6 followed by a high gain 12AX7 double triode. The combinations are endless. In your travels look for a pentode and a couple of triodes. Whether or not they're combined in the same glass envelope or separate envelopes is not important. Generally what I do is buy a piece of junk for a dollar or two and see what it presents. At one flea market recently I passed up two tube oscilloscopes which had an enormous price tag of "free!" on them. The owner had no trouble getting rid of them. And I'll guarantee you, all the tubes you would need (and power supply, too) were inside waiting to be used.



12AU7
12AT7
12AX7

3 - Circuit Details

There are a number of excellent regenerative circuits from which to choose. Our next step is to pick one.

Remember that our receiver is an oscillator carefully adjusted so that it just barely oscillates. The audio that is extracted is fed to an audio amplifier stage or stages. Most of the regenerative circuits I've seen in recent literature are based on the Hartley oscillator. A lead from the cathode of the pentode detector tube is connected to a tap near the bottom of the tuning coil. In a sense the cathode, the control grid, and the screen grid form a triode, the gain of which is controlled by varying the voltage on the screen grid. The plate and its special suppressor grid can be thought of as another triode stacked on the lower triode, the two giving tremendous gain. Through this "second triode" the audio signal is brought out.

The Hartley has the advantage that feedback is introduced through a tap rather than through an entire separate winding. That means instead of needing a plug-in coil form with four pins, we only need one with three. The fourth pin can be used to feed a winding through which the antenna signal can be brought in. A Hartley oscillator needs one less pin on the coil form.

Tickler Coils Very Popular

The other popular method uses a tickler

Figure 2 from an article entitled "How Our Tube Circuits Work" by Robert S. Kruse, Technical Editor as it appeared in the December 1926 QST.

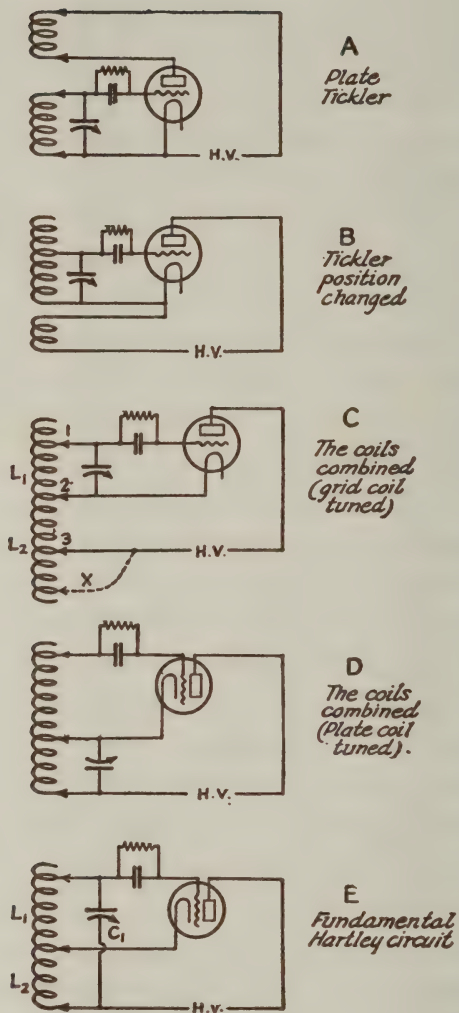


FIG. 2 – DEVELOPING THE HARTLEY CIRCUIT FROM THE PLATE-TICKLER-CIRCUIT

coil to feed some of the plate voltage back to the grid. Two coils require four pins on the coil form. Regeneration can be controlled by varying the screen voltage or by using a variable "throttling" capacitor to change the amount of radio frequency energy being radiated by the tickler. Again, see Rockey's book for details.

I've built both types of sets, and have gotten great results with both. The Hartley may make better use of the coil form, but it can be difficult to adjust feedback properly. The tuning coils have to be wound with space between the windings so that you can get in and solder a tap where you want it. Sure, you could bring taps out as you wind the coil, but you never quite know for sure where to taps need to be placed for optimum performance. Only after experimentation will you know. And frequently taps on a Hartley coil are only a half or three-quarter turn from the ground end! Feedback can be that touchy.

The tickler feedback coil on the other hand is easier to create. I usually wind the main tuning coil and get it working properly. Then I wind the tickler coil and adjust it. It's quite easy to remove a turn from the tickler until the feedback control provides smooth operation. In adjusting the feedback you can always adjust the number of turns. If removal of a turn results in too great a change, the tickler must be wound farther from the tuning coil to reduce rf linkage. That can make adjustment easier. In terms of adjusting the feedback of the coil, I like tickler coils. I think they're easier to work with.

Hartley detectors sometime have a problem with hum since the cathode is grounded for direct current (the biasing current), but is "above" ground as far as radio frequency current is concerned. That means that the audio signal is susceptible to 60 ac hum being picked up from the filament circuit. This can usually be eliminated by grounding one of the filament leads of each tube, and bypassing the other through a .01 mfd capacitor to ground.

So which do you want to build? The choice is yours. If you want to try the Hartley, I suggest the Hijame Suzuki or "Old Standby" circuits we just examined. You can go back to attempt to locate the original articles. A complete reprint of the Suzuki article can be found in Lindsay's reprint of the OFFICIAL 1934 SHORT-WAVE MANUAL. But you should be able to build either using the circuit diagram and hints and tips in Rockey's regenerative receiver book, and Lindsay's OLD TIME RECEIVERS reprint of early ARRL HANDBOOK recommendations.

Because we've already supplied two Hartley diagrams, I'm going to build a plate tickler receiver here. We'll use a four-prong tube base as our plug in coil form. Two pins will connect to the tuning coil, and other two to the tickler. A coil form with two more pins would be nice so we could add a antenna coupling coil and have a tap on the tuning coil for bandspread. As is, we'll limit this design to lower frequencies where bandspread taps are less important, and we'll use capacitive antenna coupling.

We'll take the 6AW8 pentode-triode tube

we found and couple it with a 6C4 triode and see what we get. Actually, we could use just the 6AW8, but the audio volume isn't going to be very great. It will certainly be greater than a crystal set, but more audio amplification will certainly add to the enjoyment.

Let's take a look at the circuit on page 39.

The antenna coupling capacitor needs to be small – less than 50 pfd. In this little set I use a compression trimmer set to a very low capacitance. This component will adjust how tightly your antenna is coupled to your set. Light, loose coupling will generally produce better results. If your antenna is too tightly coupled to your set, it becomes part of the tuning circuit and can create real problems. The specific coil and capacitor cannot be specified. You'll have to use the capacitor you can find and wind a coil to match. The basic, classic coil winding formulas in Rockey's book and all ARRL HANDBOOKS will help you come close.

Next, the signal selected by the coil and capacitor is fed to the control grid of the tube through a capacitor. Here we've specified 100 pfd, a commonly used value. It doesn't have to be exactly 100 pfd. If you don't have one, try a 47pfd or even a 200. If you have two 200 pfd's put them in series to get a 100. If you have a 47pfd and a 33pfd put them in parallel, and you'll have 80pfd. That will work just fine. I use silver dipped mica capacitors in this part of the circuit.

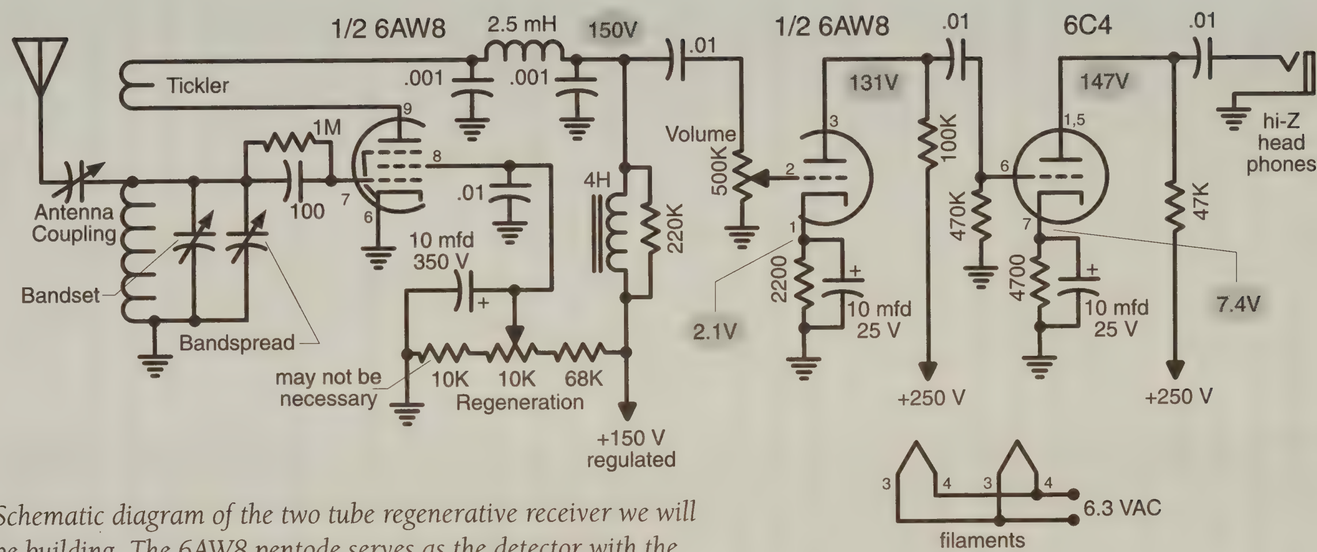
You need to be familiar with components

and Ohm's law. Let's say you need a 2 watt 250 ohm resistor but don't have one. You can take a pair of 470 ohm 1 watt resistors, wire them in parallel, and end up with a 235 ohm 2 watt resistor which in most cases is close enough. Knowing how to "make up" a resistor from values that you have lying around is one of the secrets of being able to build equipment from components at hand. The know-how is very basic electric circuit theory – something you must know. You'll find this basic theory in the ARRL HANDBOOK – all editions.

In the July 1924 QST magazine, Allen Bradley Co advertised this grid-leak made up of a fixed capacitor and variable resistor. I just found one at a hamfest for 50¢. You never quite know what valuable components you'll find.

The Grid Leak

The one megohm resistor is standard, too. This is the grid leak resistor that puts bias on the grid to allow detection. Rockey will tell you how it works in detail. The old timers have said that two or five megohm resistors are better because they give a detector more sensitivity. Tests don't show that at all. One megohm is all you need, but two or five will do, too. I wouldn't use anything much less. If you can't find a one meg



Schematic diagram of the two tube regenerative receiver we will be building. The 6AW8 pentode serves as the detector with the triode functioning as audio preamplifier. The 6C4 provides more gain to the headphones. Almost any tubes could be used with proper circuit adaptions. Tubes manufactured before 1935 could present a few problems since they usually did not provide as much gain as late octal and miniature tubes.

just hook up a couple of 470K, which are very common, in series. You'll have 940K plus or minus. Good enough.

Next, look at the screen grid circuit. Right at the tube base we must attach a .01 bypass capacitor to a nearby ground lug. This is to remove radio frequency current that might be on the line that brings dc into the tube. I use disc ceramic capacitors. Caution... Disc ceramics are common in modern transistor gear and offered in modern catalogs. Most of them are good for no more than 50 volts. On the screen grid you can probably get away with a low voltage capacitor. But in other parts of the circuits you can easily have 250 volts or more. And these higher voltages will destroy the capacitor. The .01 mfd value is usually used for bypass. If you can't find any in the gear you're junking, you can use .02, .05 or even .1 mfd capacitors, if you want. Go higher in value, rather than lower if .01's aren't available. I bought 100 .01 mfd 500 volt disc ceramics inexpensively after I decided I would build a lot of tube gear. You might want to do the same.

The Regeneration Control

The regeneration control is a pot sandwiched between two fixed resistors which channel 150 volt regulated dc to ground. What is happening here is that the string of resistors is acting as a resistive voltage divider. That is, the 150 volts is spread out along the resistors. If you move the wiper on the regeneration pot closer to the 150 side you'll get more voltage. Move the wiper closer to the ground side, and you'll get less voltage.

The resistors have to be chosen in order to get the voltage you need on the screen grid. I have found about all that is needed is 20 to 30 volts. A 10K pot is really the best value for this area of the circuit. A smaller value pot, say 5K, will not give you enough variation in voltage. It just won't be responsive. On the other hand a 50K pot is often too much. It *will* work. The Hijame Suzuki receiver uses one successfully, but a 10K pot with a properly wound tickler coil will allow you to gently ease into regeneration, making tuning much easier.

The 10K resistor on the ground side of the pot may not be needed depending on what you find works with your particular tube. If we use the three resistors shown, we find that the total resistance from the 150 side to ground is 88K ohms. At the ground side of the pot we'll have 10/88 X 150 volts or 17 volts. At the high side of the pot we'll have the 10K fixed resistor and the 10K of the pot for a total of twenty thousand ohms. The voltage at the high side of the pot will be 34 volts (20/88 X 150 volts). Turning the regeneration control from minimum to maximum will supply us with from 17 to 34 volts. In reality, the voltage will be lower than this because the screen is drawing current through the 68K resistor in addition the currrent already flowing to ground. That will create a bigger voltage drop. So depending on the tube being used you might actually wind up with more like a 14 to 28 volt spread. We'll talk more about these resistors later when we adjust our set.

Filters Route DC, AF and RF in Different Directions

Current flows out of the plate of the detector tube, through the tickler coil, and then into a pi network. It's called a pi network because it looks like the Greek letter pi. Here we have a .001 capacitor on each end of a 2.5mh choke. The capacitors values you use should be close. The .001 capacitor looks almost like a short to rf current that is on the tickler coil. This is important. We need to develop rf voltage across the tickler, and the only way that can happen is if the "top" end (at least in our diagram) is solidly anchored to ground. The .001 has no effect on the direct current flowing to the plate, but is a short to ground for rf. But remember! There are three signals flowing in this single wire: dc, rf, and audio. This pi network is a filter that has no effect on the dc, stops the rf, but allows the audio to flow through. If you use a capacitor that is larger than .001, you'll start shunting part the audio signal to ground. So stick with .001 mfd here.

Any rf that remains is blocked by the 2.5 mh choke. It looks like an open circuit to the rf but has no effect on dc. The audio passes through it easily, too. Like the capacitor, larger values will hurt the audio, smaller values will let rf leak out, creating regeneration problems, instability, and who knows what else. Although a 2.5mh is specified, you can probably get by with a choke from one to five millihenries.

On the back side of the choke is another capacitor to take any rf sneaking through to ground to keep it out of the audio section.

At this point the circuit branches into two different directions. In one direction we find a hefty 4 henry choke shunted by a 220K resistor. This choke serves a purpose similar to that of the 2.5mh choke that we just talked about. This choke is kind of a fence, too. It keeps the audio from leaking out into the power supply. Because audio frequencies are much lower, we need a much large inductance to resist the flow of audio frequencies. At 1,000 cycles a 4 henry choke will provide 25,000 ohms of reactance to audio – that is, no significant resistance to the dc flowing through it, but 25,000 ohms of impedance to the audio. A one henry choke will offer only a quarter of this amount, about 6,000 ohms. A four henry choke works well, as does the primary winding of an output transformer, but bigger is better. I have on hand a 350 henry monster that I bought "back in the old days" specifically for this circuit. Some of the old regens like the National SW-3 used a coupler which had a 700 henry choke. You don't need anything that large really. Larger values should, in theory, produce somewhat larger audio signals for the audio stage. But a

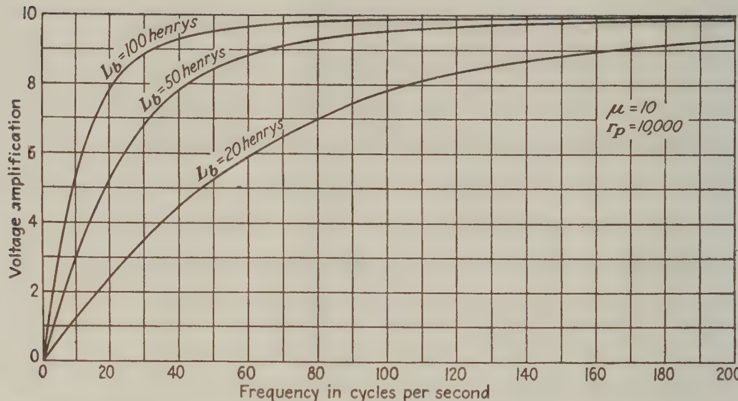


FIG. 104.—Variation of voltage amplification at low frequencies for various values of inductance in the plate circuit.

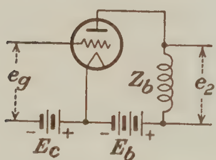


FIG. 103.—Amplifier with an inductive load.

In his 1936 engineering text, PRINCIPLES OF RADIO ENGINEERING, *R. S. Glasgow, demonstrated with a very simple graph (figure 104) how a choke coupled audio amplifier (figure 103) could deliver all the amplification that a tube could possibly deliver. The graph shows a sample tube with a* μ *(amplification factor) of 10 and a plate resistance of 10,000 ohms and three chokes: 20, 50 and 100 henries. The 20 henry choke could deliver an amplification of more than 9 for frequencies above 160 cycles, whereas, the 100 henry choke could extract almost 10 above 90 cycles or so. This shows that 20 henries is a good value to shoot for in a regenerative radio, but more is better.*

4, 8, or 12 henry choke from a power supply will work just fine.

The 220K resistor suppresses oscillations that can occur under certain conditions. Rockey explains how it works in detail.

The 500K pot on the grid of the first audio triode should be easy to find. I wouldn't substitute here. You might be able to get away with 200K, and maybe a 1 meg, but 500K pots were the most common volume control pots in old radios. It provides not only volume, but is a necessary component in the bias circuit for the tube.

The second branch from the 2.5mh rf choke takes the audio through a .01 mfd capacitor to the audio stage. Vacuum tubes, like field effect transistors, have enormously high input impedances. They present very little load to the circuit. For that reason a .01 mfd is more than large enough to get the audio into the grid of the audio tube. If we were feeding audio to the base of a bipolar transistor, we would need a capacitor in the 10 to 100 mfd range because of the low input impedance. I used a .01 because I have many on hand at all times. You can use something larger if you want: .02 or .05 or even .1. They will work. Just make sure they can handle the plate voltage.

The Audio Amplifier Section

Bias for the grid is actually provided by the resistor in the cathode lead of the tube. Current flowing through the tube will create a voltage drop across the resistor. This actually "raises" the cathode above ground in terms of direct current. The grid then is connected to ground through the 500K grid resistor. This resistor is large enough to prevent the audio

Resistance-Coupled Amplifiers

(See page 338 for explanation of column headings)

E_{bb}	R_p	R_g	R_{g2}	R_k	C_{g2}	C_k	C	E_o	V.G.
90	0.047	0.047	–	2200	–	2.5	0.063	14	9
		0.1	–	2800	–	2.0	0.033	18	10
		0.22	–	3200	–	1.7	0.015	20	10
	0.1	0.1	–	4100	–	1.4	0.032	13	10
		0.22	–	5400	–	1.0	0.013	20	11
		0.47	–	6400	–	0.9	0.007	24	11
	0.22	0.22	–	8500	–	0.67	0.015	18	11
		0.47	–	12000	–	0.5	0.0065	23	11
		1.0	–	14000	–	0.43	0.0035	27	11
180	0.047	0.047	–	2000	–	2.9	0.062	32	10
		0.1	–	2500	–	2.2	0.033	42	10
		0.22	–	3000	–	1.9	0.016	47	11
	0.1	0.1	–	3800	–	1.5	0.033	36	11
		0.22	–	5100	–	1.1	0.015	47	11
		0.47	–	6200	–	0.9	0.007	55	12
	0.22	0.22	–	8000	–	0.73	0.015	41	12
		0.47	–	11000	–	0.5	0.007	54	12
		1.0	–	13000	–	0.4	0.0035	69	12
300	0.047	0.047	–	1800	–	3.0	0.063	58	10
		0.1	–	2400	–	2.4	0.033	74	11
		0.22	–	2900	–	2.0	0.016	85	11
	0.1	0.1	–	3600	–	1.6	0.033	65	12
		0.22	–	5000	–	1.2	0.015	85	12
		0.47	–	6200	–	0.95	0.007	96	12
	0.22	0.22	–	7800	–	0.73	0.015	74	12
		0.47	–	11000	–	0.5	0.007	95	12
		1.0	–	13000	–	0.43	0.0035	106	12

7

6BF6
6R7
6SR7
12BF6
12SR7

See Circuit Diagram 1

E_{bb}	R_p	R_g	R_{g2}	R_k	C_{g2}	C_k	C	E_o	V.G.
90	0.047	0.047	–	1600	–	3.2	0.061	9	10■
		0.1	–	1800	–	2.5	0.033	11	11★
		0.22	–	2000	–	2.0	0.015	14	11
	0.1	0.1	–	3000	–	1.6	0.032	10	11★
		0.22	–	3800	–	1.1	0.015	15	11
		0.47	–	4500	–	1.0	0.007	18	11
	0.22	0.22	–	6800	–	0.7	0.015	14	11
		0.47	–	9500	–	0.5	0.0065	20	11
		1.0	–	11500	–	0.43	0.0035	24	11
180	0.047	0.047	–	920	–	3.9	0.062	20	11
		0.1	–	1200	–	2.9	0.037	26	12
		0.22	–	1400	–	2.5	0.016	29	12
	0.1	0.1	–	2000	–	1.9	0.032	24	12
		0.22	–	2800	–	1.4	0.016	33	12
		0.47	–	3600	–	1.1	0.007	40	12
	0.22	0.22	–	5300	–	0.8	0.015	31	12
		0.47	–	8300	–	0.56	0.007	44	12
		1.0	–	10000	–	0.48	0.0035	54	12
300	0.047	0.047	–	870	–	4.1	0.065	38	12
		0.1	–	1200	–	3.0	0.034	52	12
		0.22	–	1500	–	2.4	0.016	68	12
	0.1	0.1	–	1900	–	1.9	0.032	44	12
		0.22	–	3000	–	1.3	0.016	68	12
		0.47	–	4000	–	1.1	0.007	80	12
	0.22	0.22	–	5300	–	0.9	0.015	57	12
		0.47	–	8800	–	0.52	0.007	82	12
		1.0	–	11000	–	0.46	0.0035	92	12

8

6C4
7AU7•
12AU7•
12AU7-A•

See Circuit Diagram 1

■ At 3 volts (rms) output. ★ At 4 volts (rms) output. ● One triode unit.

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A sample amplifier tube design table from the 1959 RCA RECEIVING TUBE MANUAL RC-19 *which has been reprinted by Antique Electronic Supply.*

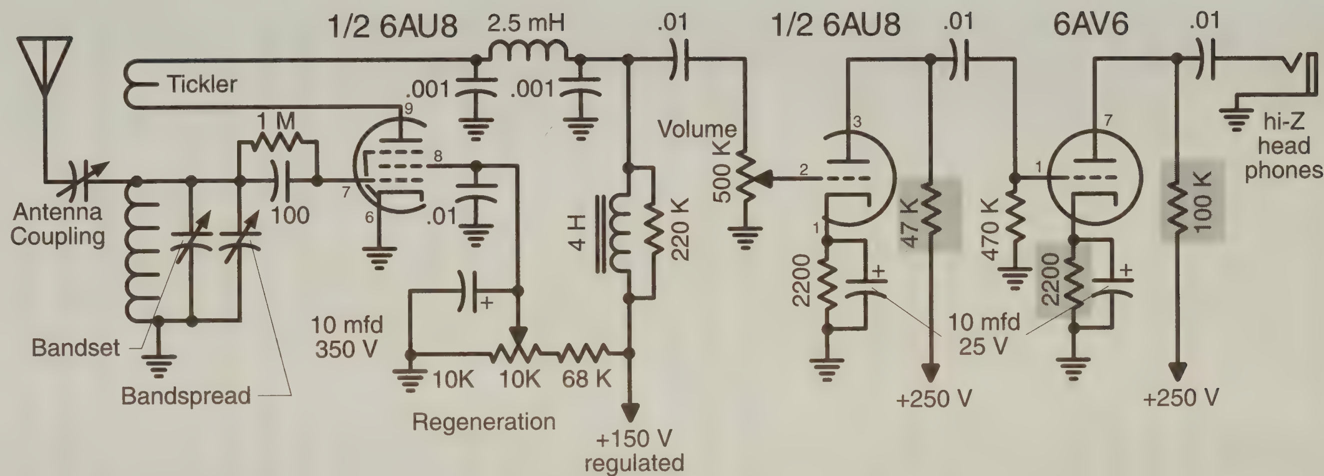
signal from flowing to ground, but still appears as a short to direct current. This curious action is due to the fact that the grid conducts ac but no appreciable dc. The cathode resistor as well as the grid and plate resistor can be calculated, but it's much easier just to check the tables in the tube manual. There you'll find sets of values for a wide variety of tubes operating at a variety of plate voltages. If you put a voltmeter across the cathode resistor, you'll actually be measuring the grid bias. If the tube manual says that six volts is desirable, and you only have three across the cathode resistor, then you need to double the size of the cathode resistor. These are experiments I think you need to make with your receiver. Not only will you be learning about building a receiver, you'll be gathering basic information on tubes and their characteristics. All these miscellaneous things you learn will become incredibly valuable tools the first time you want to build something and need to design it yourself. Don't be afraid to change the bias resistors on a tube to see what happens. Tubes are very hardy. Just be careful you don't shock yourself or blow up your power supply with a dead short.

Around the cathode resistor is an electrolytic audio bypass capacitor. Remember that in the audio tubes we have both dc and audio ac flowing. The cathode resistor is very good for the direct current health of our tube. The problem is that the resistor eats up some of the audio voltage gain created by the tube. We could get more gain if we could connect the cathode directly to ground. And that's what we do. The 10 mfd capacitor is a dead short to ground as far as the audio signal is concerned, but an open circuit for dc. Both ac and dc needs are met.

Next, we feed the audio signal coming off the plate of the first triode into the grid of the 6C4. This is a repeat of the first triode stage. Here, instead of a variable 500K volume control, we just use a 470K fixed resistor for bias. The only other changes are in the values of the cathode and plate resistors. These must be matched to tube being used. But here again, all the design has been done. We merely have to look up the values in the back of the tube manual.

Dealers still offer 2,000 ohm phones brand new.

Finally, coming off the plate of the second triode we channel the audio through another .01 mfd capacitor, a very handy component, and feed it to our high impedance headphones. They must be high impedance. Modern low-impedance phones designed for use with portable tape and CD players won't cut it. They'll load the tube circuit far too much. A pair 2,000 ohm headphones are very much worth pursuing if you're going to build radios. You could work around the problem by installing a standard output transformer, say 2,000 to 8 ohm, in the plate circuit of the tube. Then you could hook a pair of modern earphones into the 8 ohm secondary winding. Output transform-



A variation of our basic circuit using a 6AU8 pentode/triode and a 6AV6. Changes in circuit values are flagged with a gray box. The 6AV6 provides much higher voltage amplification than a 6C4, and therefore will provide more volume in your earphones.

ers, though, are not something I have a lot of. If you have to buy them new, they're not especially expensive. But remember, one of our goals is to experiment on the cheap.

I always use a standard 1/4" phone plug jack in my sets. If you're using modern low impedance earphones, you'll need a miniature socket. In the old days, earphones had metal tips that were connect to binding posts or Fahnestock clips. On a metal chassis here you could get by with banana plug binding posts. The socket you use depends of course on the connections on your headset.

Which One Will You Build?

That's what we're going to build in this book. If you'd rather build the "Old Standby" by George Snipe or the Suzuki receiver you can make similar adjustments and substitutions in component values.

In the "Old Standby" for instance, a 5 megohm grid leak is specified. A one megohm will work just as well. The grid bias resistors are .56 megohm. I'm not sure I've ever seen one! Just use a 470K. That's all you need. I would use something close to the cathode and plate resistors specified for the 6SQ7. After all you want them to amplify with minimum distortion. The 75 detector tube that Snipes uses would be a prime candidate for my 350h choke since this is a low plate current tube. But the ironic thing is that when the plate current drops to below a couple of milliamps where an incredibly huge choke can be used, you don't really need the choke at all! You can get by very well with resistive coupling as shown. When the plate current gets to 5 to 10 milliamps, you need the choke in order to get DC into the detector tube with minimum voltage loss. If I were to build the "Old Standby" I would eliminate the 6F6 stage altogether and hook my headphones to the .01 mfd capacitor C13. The 6F6 tube is not easy to find, not cheap new, and is not needed with 'phones since it's a power pentode like the 6V6 and the 6L6.

The Hijame Suzuki receiver is quite interesting because it uses slightly different component values than are usually found in American radio amateur literature. The pi network in the plate circuit, for instance, uses lower value capacitors and a high value rf choke, that we'll use here. He also uses a 250 henry choke for coupling. I'm not sure I've ever seen one of these. I wonder if his use of direct current on the tube filaments is necessary. Any problems I've had with hum have been quite adequately eliminated with grounding and a liberal use of bypass capacitors. He also uses a 50K pot with a 30k fixed resistor in the regeneration circuit. That's a lot more than I like to use. The 10K pot I use spreads the regeneration out. I can't help but think that regeneration here might be very touchy. But it might be necessary because his feedback taps on the tuning coil are at fractions of a turn above ground. Very touchy! The Suzuki receiver obviously performs very well after it has been tuned and optimized.

4 Starting to Build

The first step in building our little set is to create a chassis. We want to keep it reasonably small so that we don't have to cut and bend large sheets of metal. But we can't miniaturize too much, or we'll have a difficult time wiring the circuits.

I take the major components – coil form, variable capacitor, tubes and choke – and lay them out on a sheet of paper. Then I draw a rectangle around them only as large as needed to accommodate the parts. In doing so it's important to get the coil close to the capacitor and pentode detector tube so that leads can be as short as possible. It's also important to keep the coil away from the metallic front panel in order to avoid a reduction in the Q of the coil. The old rule of thumb, and it seems to be a good one, says to keep the coil at least half a coil diameter away from the nearest shielding, in this case, our front panel. Similarly, keep the coil away from the choke.

Since our little radio is physically small, only about 5"x 6", a simple U-shaped chassis of light weight aluminum attached to a simple 6"x 8" front panel is more than adequate. If your choke is heavy and/or your tubes large, octal tubes for instance, you'll need a larger chassis, and you'll want to reinforce the edges of the chassis to increase rigidity. This can be done by making additional bends with a sheet metal brake, or you can use machine screws to attach a strip of small aluminum angle sold in most hardware stores. A heavy choke should be placed very close to the rear of the chassis where it is most rigid.

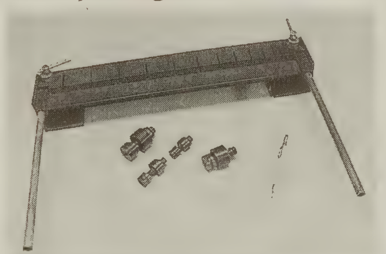
For the set shown here, I used a .040" aluminum cookie sheet. This particular alloy was not very malleable. It wasn't hard to bend, but it wouldn't take much bending before fatigue cracks appear. These simple cookie sheets are hard to find in my area anymore. Cookie sheets around here are now of fancy double wall construction that can't be used.

Tin Shop Aluminum is My Favorite

My favorite source of aluminum is the "tin shop". I doubt if they've ever seen tin, but that's what they're called. They do custom sheet metal work for contractors and industry. I generally walk in with a micrometer and tell them I'd like to buy some small pieces of aluminum sheet, just scrap. This is very malleable aluminum, easy to bend and easy to cut. The thinnest material, .040", is a bit too light for larger tube chassis's, but makes great boxes, small chassis's, and compartment shields, brackets, etc. The next size up, .050" is my favorite. It's sufficiently rigid for most construction, but not so thick as to make it difficult to work. The .063" is great for heavy front panels and other applications. That's as thick as I go, however. Anything more substantial gets tough to cut and bend.

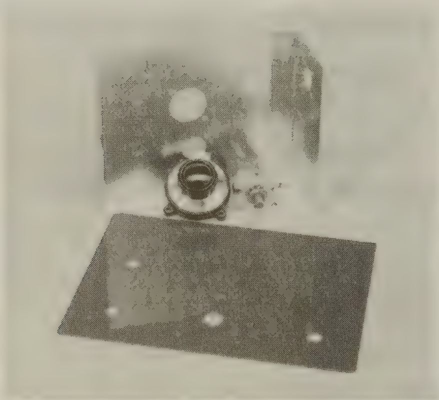
I draw out the chassis on paper, calculate the overall lengths, and double check everything. Then I lay it out on the aluminum panel with a carpenter's and a machinist's square. I use a carbide tip scriber to scribe a light line right on the aluminum. A nail will work almost as well.

Next, I take a pair of heavy tinsnips and cut out the panel staying at least an 1/8" outside the lines. As you cut, the aluminum sheet will pucker a little. The first cut is usually the worst. The second cut, right on the scribed line, usually produces less distortion in the metal. The cut can then be dressed with a fine tooth metal file and emery paper. If the distortion is more than I like, I straighten it using a rubber mallet and a flat block of steel as an anvil. Careful tapping will usually straighten it out. Don't use a steel hammer. It will damage the metal and create more distortion than you are trying to cure.



Sheet metal brake, Greenlee chassis punches, and a scriber – valuable tools for the vacuum tube radio builder.

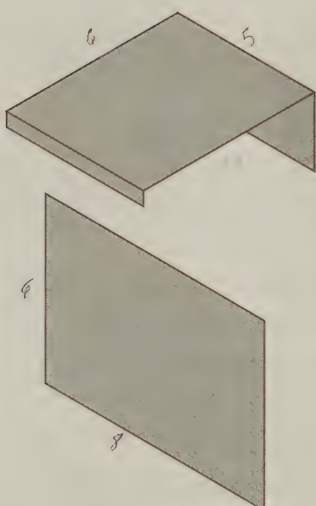
Another effective method of cutting aluminum used in the "old" days (believe it or not, the 1950's) is achieved by not just scribing the metal, but by scoring it as deeply as possible. Two pieces of wood or angle iron are then carefully and tightly clamped at the score. By bending the free aluminum back and forth carefully, the scored line will eventually break. The somewhat ragged edge is easily cleaned up with a file. This is



After cutting, bending, drilling, and painting, the panels for our radio look like this. This part of construction is more metal sculpture than it is electronics.

particularly effective with thicker aluminum sheets.

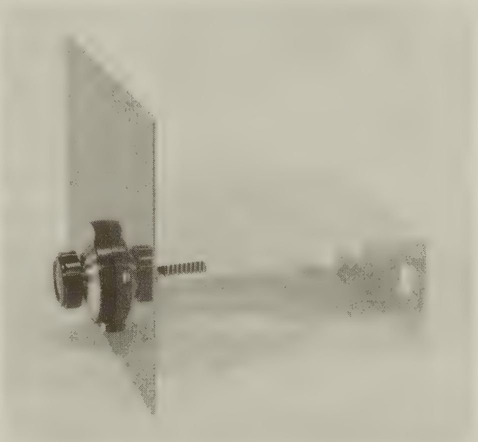
If you're going to build tube radios regularly, I highly recommend your buying or building a small sheet metal brake. My finger brake is decades old, handles 18" wide sheets, and is one my most valuable tools. They're not easy to find, and not necessarily cheap anymore. Simple brakes are not difficult to make, and plans are available. Consider Dave Gingery's plans (Lindsay Publications) as a starting point.



Simple aluminum panels with simple bends are all that we need.

With a simple chassis like ours and .040" aluminum you can make the two necessary bends by clamping the sheet metal between two lengths of angle iron held in a metal vise. The sheet metal is bent slowly and carefully over the angles. The final, necessary tight bend can be made by carefully hammering with a rubber mallet or by using a steel hammer and a block of wood. This all sounds very primitive, but these techniques have been used for decades, as far back as the 20's and 30's when metal chassis's were replacing breadboard layouts.

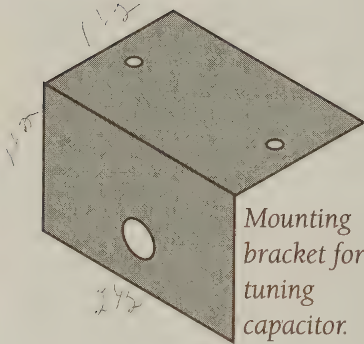
The next step in fabricating our radio is the positioning of the tuning capacitor. This is where a little ingenuity will be needed. You'll have to invent a mount designed around the physical attributes of your capacitor and dial drive. Plentiful Hammarlund 100 and 140 pfd capacitors most often have two mounting feet on their bottom and a threaded flange around their shaft. If possible, use all the mounting methods available so as to make the capacitor to chassis attachment as rigid as possible. If the capacitor mount is flimsy and moves, it will seriously affect your ability to tune and hold a station.



The front panel has been bolted to the chassis, and the capacitor and dial drive have been installed.

Bracket Holds Tuning Capacitor

The little 100 pfd capacitor used here had only a threaded flange mount. It was necessary to bend an L-bracket from a strip of 3" x



Mounting bracket for tuning capacitor.

2 1/2" aluminum. A 3/8" hole was drilled in one face of the bracket to mount the capacitor, and two 9/64" holes in the other face to allow mounting to the underside of the chassis with 6-32 machine screws.

The chassis is attached to the front plate of the radio with 4-40 or 6-32 machine screws. Slip the capacitor through the 3/8" hole of the L-bracket, and screw on the larger washer and nut. Next, slide the L-bracket/capacitor assembly along the underside of the chassis until the shaft touches the front panel about where you want the vernier dial drive to be. Take a fine point "Sharpie" marker and draw around the shaft. When you pull the capacitor away, you'll discover a crude circle. This is the point at which either the capacitor shaft will protrude forward from the front panel, or the dial drive flange will protrude backward into the underside of the chassis.

You can turn sheet aluminum into attractive radios using surprisingly simple tools.

Here I used a modern imported vernier dial drive. This type of drive mounts flush against the front panel with its set screw collar protruding into the innards of the radio on the underside of the chassis. Using the circle drawn with the marker, I center punch and then drill a hole large enough to accommodate the flange, usually about 1/2" diameter. Then I place the dial drive in position and grab the capacitor-bracket assembly and mate them to see if they come together properly. The trick is to get everything to mount rigidly and tightly, but at the same time have everything aligned properly so that the dial drive and capacitor turn smoothly without binding. With careful work and frequent checks for fit, this is surprisingly easy to accomplish (even for a klutz like me). There is usually enough play in the machine screw holes to allow more than enough adjustment for alignment.

After you are sure that the main dial drive hole is properly drilled, you can hold the drive in position while you use the marker to draw points for the mounting screws. It's a simple matter to center punch and drill these holes as well.

Make Notes on the Panel With Markers

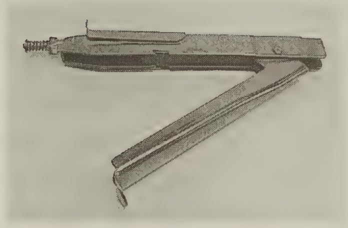
I like the "Sharpie" brand of markers, both standard and fine tip varieties, because they are lacquer based markers. Unlike dye based markers, they draw smoothly and easily on aluminum sheet. By the time I'm done drilling and fabricating a chassis, it is covered with lines, notes, dimensions and circles, all in marker. Just before mounting the components, I can easily remove the markings with a tissue dampened with lacquer thinner.

You can see from the drawings and photographs the particular layout of my little set. Your layout, of course, will depend on the physical dimensions of your components. My advice to you is not to worry too much about appearance in the beginning. If you're new to building, you'll make plenty of mistakes. No sooner will you get the radio working, than you'll have an idea you'll want to try. You'll want to try a different choke. Or wire in a different detector tube. If you're a real experimenter like me, you'll make so many changes, the chassis will start to look like Swiss cheese. Get the first set working nicely. Make the second set work *and* look nice as well.

A big problem for all tube builders is cutting the large holes needed for tube sockets. If you plan to build many radios, get some standard Greenlee chassis punches. Purchased new, they're expensive. You might find some used at a flea market. Or you might be able to borrow some. Common sizes are 5/8" for 7-pin miniature tubes, 3/4" for 9-pin, and 1 1/8" for 8-pin octal as well as for 4, 5 and 6 prong sockets. To use them, you simply drill a 1/4" or 3/8" pilot hole, bolt the two halves of the punch together with the sheet metal sandwiched between, and tighten the halves together with a wrench until the punch cuts completely through. The resulting hole is perfectly circular and perfectly dimensioned.

Get a Nibbler

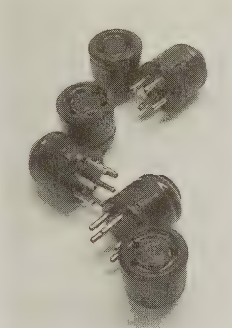
If you're starting out, you can get by without chassis punches. What you need is a nibbling tool which sells for a fraction of the cost of a single punch. You drill a 3/8" or 1/2" pilot hole in the center of circle you've drawn with marker. Then you carefully nibble away the metal right up to the line. You can smooth and finish the hole with a semicircular or rat tail file. This process is time consuming, but with care you can cut large holes not only for tube sockets but for transformers, meters and just about any component you're likely to encounter.



I wouldn't be caught without my nibbler. It can cut large and/or irregular holes. Cutting large holes is slow going and uses a lot of muscle, but a nibbler provides great performance at low cost.

You may want to try hole saws mounted in a drill press. I've never had much success with a flycutter. Chassis punches and a nibbler are my tools of choice.

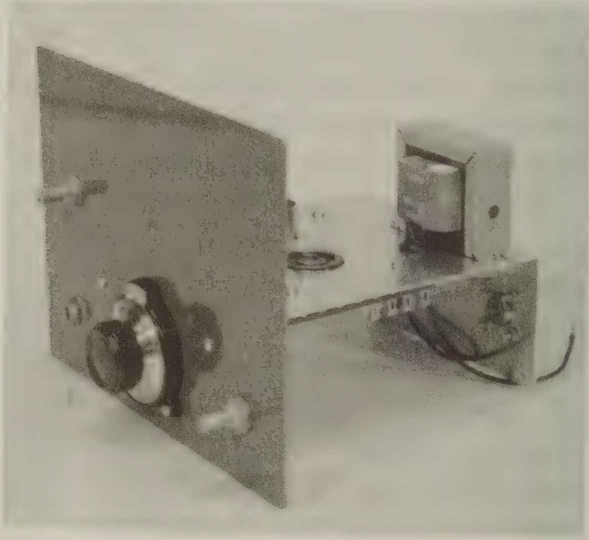
One problem with our radio here is the use of an octal tube socket for power connection. Since the tube socket is female, that means there must be a male plug attached to the power supply. That's dangerous because that means there can be hundreds of volts of B+ on exposed pins. The smart way is to mount a male plug on the chassis with the female socket attached to the cord going to the power supply. Components for this purpose were made, but are not



Male-female pairs of 4, 5 and 6 prong power cord connectors. Not easy to find, but worth looking for.

easy to find today. If you use my method here, be very careful. It's a potential hazard.

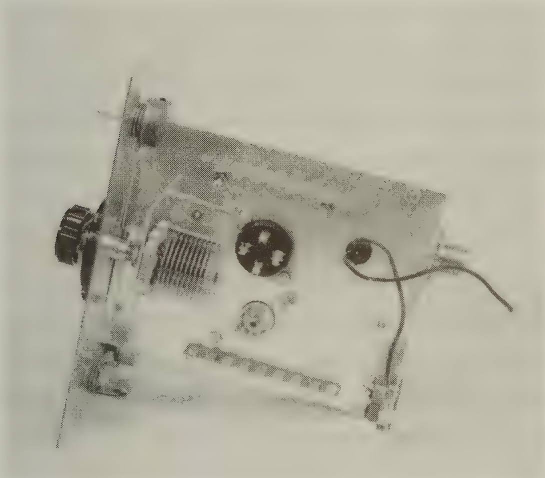
From the photos you'll see that components are mounted with 4-40 and 6-32 machine screws. I generally get these in 1/4", 3/8" and 1/2" lengths from radio parts catalogs. They're inexpensive. The smallest machine screws you'll find in a hardware store are 6-32 and at least 1 1/2" long. That's much too big for most of our needs. And they cost about five times as much as they should.



Chassis with major components mounted. Ready for wiring.

Plan to Make Changes

Many builders recommend laying out the chassis on a flat sheet of metal, cutting all holes and then bending it up. I wish I could plan that far ahead. It seems no matter how carefully I plan, something doesn't work out quite right. I always expect to have to make changes while I'm building. In industry, the design of a new product usually requires the construction of several prototypes to work out these bugs. Once a prototype version has been perfected, the drill-and-then-bend method can be achieved. We don't have that luxury.



Underside of our radio. Ready for wiring.

It's always smart to allow yourself extra room to accommodate changes (and design accidents) that are sure to occur. In fact, the little set here is, for the most part, a test set. It's not something to put on the shelf and admire. It's starting point for experiments – a demonstration radio.

I never paint the chassis. You want soldering lugs to press into bare metal to form tight grounds. Paint could prevent that.

Painting the Panel

The front panel is another matter. I usually paint the front panel with Rustoleum brand spray paint. It certainly is not the only paint available. But I have gotten consistently good results, and it seems to be available almost everywhere. There many other excellent brands. Krylon is a good one for instance. In fact Krylon offers a black crinkle finish that was so popular in the 40's and 50's. You might consider it.

Sometimes the front panel is cut from salvaged aluminum and may have deep scratches or gouges. What you need to do is lightly sand the surface to roughen it, to remove ragged edges, and to smooth over scratches and gouges. Next, degrease the panel with tissues and lacquer thinner. Don't touch the surface with your fingers. Keep it clean.

Give it a coat of primer which usually dries in an hour or less. Then use "wet-or-dry" sandpaper, and sand the panel under a stream of water. The water acts a lubricant to reduce scratching. I sand until metal starts to show through. The paint that is left behind lies in the lowest parts of the metal panel. That way the gouges and deep scratches are filled, at least partially, with paint. If the gouges still show, give the panel another coat of primer, and sand again, perhaps not as much as before. I find that two coats of primer will hide almost any scratch or gouge.

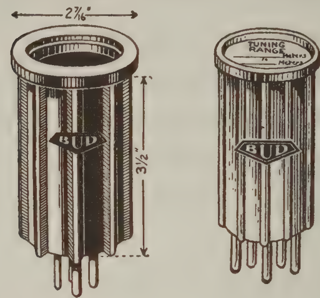
I Bake the Enamel

Finally, give the panel a finish coat of spray paint. What I like about Rustoleum is that I can lay the panel on a block of wood usually outdoors and spray a reasonably thick coat of paint without sags or runs. I let it dry for fifteen minutes or so, and then I put it in my electric kitchen oven at the lowest possible heat for about an hour. After that I jack the heat up to about 250°F and bake it for about twenty minutes more.

This baking gives off fumes that your wife or girlfriend might complain about. And I would not recommend using a gas oven. The fumes might cause an explosion. I've never done it, but a heat lamp might achieve the same effect. If you can't or don't want to bake, just let the panel dry overnight. Baking gives a tough durable finish on a panel that can be assembled in a matter of a couple of hours. Remember, these are my experiences with an electric oven and Rustoleum spray paint. Other combinations might be dangerous or deadly, or at the very least produce less desirable results. As you experiment, be careful.

Bakelite

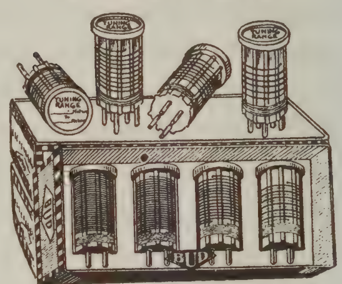
PLUG-IN COIL FORMS



Three sizes, 1¼, 1½ and 2¼ inch Dia. Made in 4, 5 and 6 prong units to fit standard tube sockets. Ideal form for receiver or Xmitter Inductances.

In the 1930's Bud Radio Inc of Cleveland offered coil forms in a variety of sizes for receivers and transmitters, as well as pre-wound sets of coils for both.

LO-COIL KITS



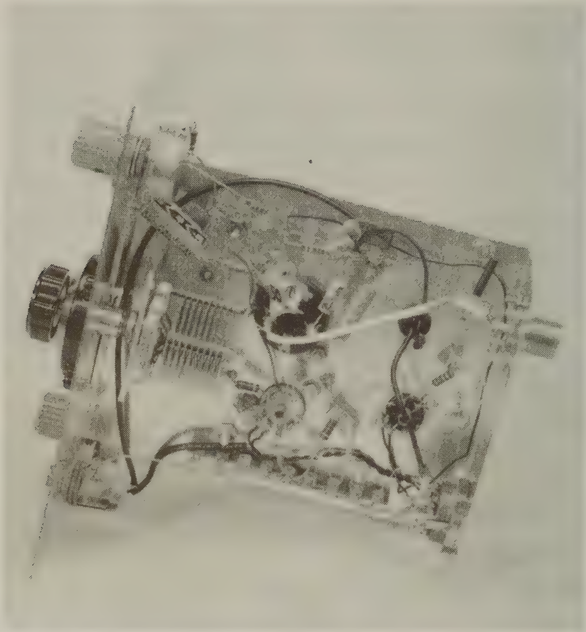
Wound coils in 4, 5 and 6 prong units for S. W. Receivers and Transmitters.

5 Wiring

Components must be soldered together to build a functioning radio. Phenolic solder terminal strips are, for me, essential. They can still be purchased new or can be stripped from old tube equipment. Being made of tinned steel and phenolic plastic, the strips can withstand a lot of heat and abuse before they disintegrate. At hamfests you'll often find them at giveaway prices.

I usually end up mounting more terminal strips than I need. Often half the lugs on the strips go unused, but that's the way I like it. I never quite know what components I'm going to have to use to get the best performance from the radio. If I have to add components, extra lugs can be handy. Sometimes, I want to try a component with a different value and size. Extra lugs allow experimentation and modification. My advice is to install more than you think you'll need.

I may carefully plan the layout of the major components such as sockets, transformers, chokes, and variable capacitors, but I install terminal strips on the fly. The same screw that holds a tube socket to the chassis can anchor a terminal strip. It's also a simple matter to drill a 9/64" hole with an electric drill to accommodate a 6-32 machine screw. You can quickly and easily install terminal strips where ever needed.



Liberal use of terminal strips and grounding lugs will make assembly and modification easier. Leads to and from the volume control are RG173 miniature coaxial cable. The shielding it provides helps prevent ac hum from getting into the audio signal.

Install Solderling Lugs, Too

Soldering lugs are also very useful, and like terminal strips are available new or can be salvaged. Slip them under mounting screws to provide convenient grounds for your circuit. You can't very well solder a bypass capacitor to the aluminum chassis, but you can easily solder to the ground lug.

Use rosin core solder made for electronics. You can use the 63-37 solder which melts at a lower temperature than 60-40. I use both.

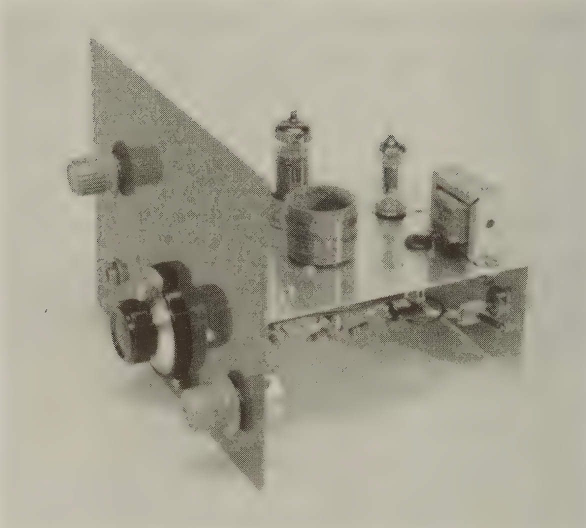
I usually use the higher temp stuff on tube gear, especially salvaged gear where decades-old solder remains on the lugs. The 63-37 variety is a modern composition used mainly on PC boads. And I find that 60-40 provides a bit more mechanical strength. Whatever you do, don't use acid core plumbing solder.

You may find that old components don't solder well. Some old unused carbon resistors I have are made with tinned steel leads. Before installing them, I brighten them with a little emery paper, stick them into some solder paste, and apply a thin coat of solder to "tin" them. That way I know when I solder that resistor to the lug of a tube socket that the solder will flow and a good solid connection will be made. Soldering paste helps wet the metal making the solder flow more easily.

I use run-of-the-mill plastic coated 22 gauge hookup wire for most of my wiring. But I have saved lengths of cloth insulation wire from old tube equipment for incorporation into the radios that I want to look old. I have found that new cloth covered wire is not readily available.

Start by Wiring Filaments

I start by wiring up all the filaments. In doing so, the filament leads end up next to the chassis. The natural capacitance between the leads and the chassis will help suck unwanted rf out of the filament leads. That can help improve stability in a regen receiver. All



The wired receiver ready to powered up, tested and adjusted.

the remaining wiring and components wind up above the filament leads.

There isn't too much to say about wiring. If you've never done anything but wire up printed circuit boards, then examine a piece of tube gear, and see how it was done.

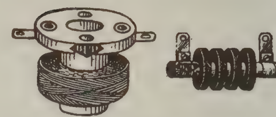
Like PC boards, watch for blobs of solder creating shorts. And watch to see that high voltage leads are not dangerously exposed (unless you really do like getting shocked).

After you think you've completed wiring your machine, go back and trace every wire to be sure you have it right. I almost guarantee you that you'll find a mistake and/or omission.

And before you turn the radio on for the first time, check the wiring again. I know from experience that even with a couple of checks of wiring, I miss something about half the time. You don't want to burn up some component and have to waste days or weeks, and money, to find a replacement.

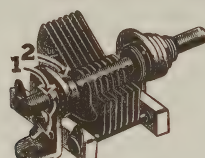
Bud Radio Inc of Cleveland manufactured many components of value to builders of radios and transmitters in the 1930's. In later years the name "Bud" came to be associated with steel cabinetry and relay racks. Many early Bud components can still be found at hamfests today.

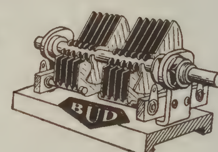
R. F. CHOKES



In several styles and types and numerous values for any purpose.

MIDGET CONDENSERS





For S. W. Receivers and Xmitters. Numerous capacities in single and dual units with single or multiple spacing.

TANK FORMS

Made of ISOTEX in three sizes for 20, 40, 80 and 160 meter bands.

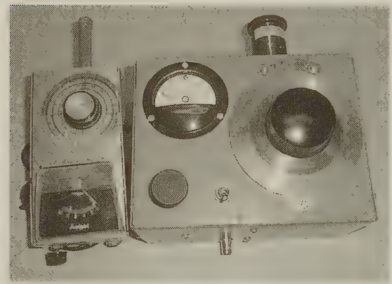
6 Adjustment

A regenerative receiver needs to be carefully adjusted if it is to be a hot performer. The regeneration control has to be tested, the main tuning coil wound, and then a tickler wound and adjusted. In the beginning, these were confusing procedures for me. But no more. Here's how I do it.

The first thing you must do before putting power to your radio is to double check all the wiring. You don't want to send B+ into a dead short. And you don't want B+ getting into the anode of the regulator tube or you could pop it. Make sure you have wired the set properly.

The place to start is with the audio section. Unsolder the B+ supplies to all tube sections except the last section. If you slip on your high impedance earphones and touch the grid of the tube, being careful not to touch the B+!!, you'll hear your old friend, 60 cycle hum. If you don't, you had better check the voltages. Make sure that you have at least 100 volts on the plate. If it's lower than that, you must have weak B+ or your plate resistor is too large. Check the cathode voltage. It should be anywhere from 1 to 6 volts. That's your grid bias. Check the tube manual to see what is recommended. If a grid bias of 4 volts is recommended and you only have 2 volts, your cathode resistor is half of what it should be or your plate resistor may be too large reducing the amount of current that can flow through the tube.

With the last stage working you can connect the next audio stage. Here, you repeat the process. Most tubes used in audio sections like 6C4, 6C5, 12AT7, 12AU7, 12AX7, 6AV6 and others have cookbook bias arrangements. You can swipe the values for the bias resistors from another circuit using the same tube. Or you can choose values from the cookbook biasing section at the rear of the RCA tube manuals. I've never really had much trouble with the audio section of a regen receiver, and when I did, it was usually some really dumb wiring mistake that I have overlooked.



Grid dip meters can measure the resonant frequency of the coil-capacitor tuning circuit without actually connecting to it. On the left is an old Knightkit model still available at hamfests. To the right is a much more sensitive and stable homebrew model. These meters can also be used to measure small capacitances and inductances.

The Coils are the Heart of the Receiver

The most challenging part of getting a regen receiver to work well is in winding the coils. I start by 1) winding the main tuning coil, 2) making adjustments to the regeneration voltage circuit, and 3) winding and adjusting the tickler coil.

After I choose the desired frequencies and know the maximum capacitance of the tuning capacitor, I calculate the inductance needed using standard formulas. Then I use that inductance to calculate the number of turns I need for the coil form I have on hand. Rockey's book (and most handbooks) provide these basic formulas. The calculated number of turns is never exactly right, but the results are remarkably close – close enough that it is worth doing the calculations.

You can use a pocket calculator to find the necessary inductance, but what makes this design task not only easy, but enjoyable, is the use of a computer spread sheet. If you can use basic algebra, you can build a spread sheet. You supply the knowns and it will instantly calculate the unknows. In a matter of minutes you can walk through a number of "what if" scenarios and find one that works for you.

Once you know what inductance you're aiming for, you can use the solenoid coil formula to figure the number of turns based on the diameter of the coil form you're using and the size of the wire you have.

In running all of these calculations it is important to realize that a coil is not a pure inductance. It has capacitance between adjacent windings as well. That means if your formula tells you that you need 25 turns for use with 50 pfd to hit the frequency you want, you will actually need fewer turns. The wiring connecting the components together, itself, can contribute several picofarads or more. And the capacitance of the coil will add more.

To compensate for this stray capacitance, you'll need fewer turns, say 22. Since stray capacitance will vary with every radio, cut-and-try is the only method that will work for sure. You can come amazing close at lower frequencies, but here, too, adjustments will be needed. And remember the antenna can change the resonant frequency of the receiver especially if the coupling is very tight.

Frequently I tell my spread sheet that I have a fixed capacitor in parallel with my tuning capacitor. For instance, if I have a 8-100 pfd variable, I tell the spread sheet that it is in parallel with a 50 pfd fixed capacitor. That gives, as far as the calculations are concerned, a true variable capacitance of 58 to 150. After I run through the calculations, I wind the coil exactly as calculated. When I wire up the set I put a 50 pfd trimmer in parallel with the tuning capacitor. I then adjust the trimmer so that the tuning capacitor hits the band I intended. If the wiring contributes 5 pfd and the coil provides 3 pfd, the trimmer will be set at 8 pfd less than the 50 max, in other words, 42 pfd. The trimmer provides a "fudge factor" that allows me to put the radio on frequency. Obviously if I'm using plug-coils, the trimmer has to be mounted on the coil somehow, since each band will have its own unique setting.

Coils on Old Tube Bases

For this set I've used bases from 4-prong tubes. I don't believe in cannabalizing old tubes for their bases. New bases are inexpensive and easy to get from Antique Electronic Supply, so I don't feel too badly if something goes terribly wrong and I have to pitch the whole assembly and start over.

I start by deciding which pin is to get which wire from each winding. Then I drill a 1/16" hole through the base wall. You may want to use Rockey's method of cutting a slit down the side of the tube base. Then using the traditional method of clamping one end of the wire in vise, I wind the coil carefully and tightly. Once the wires are soldered into the pins, I lay a thick coat of clear finger nail polish over the coil. It takes only minutes to dry, and is a valuable addition to the completed coil. The polish is valuable while adjusting because you can unwind or cut a couple of turns off a winding to increase the resonant frequency without having all the remaining turns in the coil unravel. Much the same thing can be accomplished with masking tape, but nail polish will be added sooner or later, so why not sooner?

I usually check the frequency of the tank circuit by using an rf signal generator. For years I used my old vacuum tube KnightKit grid dip meter, not only to check the resonant frequency of the coil-capacitor circuit, but to generate a radio signal that I could listen to while checking the regeneration control. If you don't have a signal generator of any kind, you can find your way around by noting the number of turns on the coil and the size of the capacitor, and by noting where certain bands of stations fall. For instance, you'll find the 80 meter amateur band, then a group of shortwave broadcast stations, the 5 mhz WWV station, perhaps ship traffic and then the 40 meter amateur band. After a while, you almost know what you're hearing without needing a signal generator.

I wind only the tuning coil, and solder it into the tube base pins. Then I insert it into the radio. Since there is no tickler yet, I temporarily solder a wire across the socket pins to which the future tickler will be connected. In the finished radio, the B+ flows through the tickler to the detector plate. Here, we have no tickler, so we have to short the pins out to provide a path for the B+.

Determine the Region of Maximum Detector Sensitivity

Next, we check the screen voltage to see when maximum amplification occurs. Without a tickler winding the tube will not regenerate, but it will receive some strong signals because it is operating as a grid leak detector. As you bring the regeneration control up, the voltage on the center pin of the pot should rise from zero to thirty or forty volts. I have found that at zero, you'll hear nothing. Starting about ten volts you'll start to hear signals, usually foreign shortwave broadcast stations. As you continue to advance the regeneration, control the volume increases steadily until it has reached almost its maximum. Advancing the regeneration pot further adds little additional volume. You need to modify the regeneration circuit if necessary so that this area of steadily increasing gain occurs from about 9 o'clock and 3 o'clock on the control. Below 9 o'clock you should hear little or nothing. Above 3 o'clock you should notice very little increase.

If the sensitive region lies between 7 and 10 o'clock, for instance, you need to increase the resistance of the pot, or you need to decrease the resistance between the pot and the 150 volts. But this can be tricky. You cannot reduce fixed resistance very much without running the risk of having too much current flow through the pot. The result can be a pot that smokes and burns out, or the current load can exceed what the power supply is capable of delivering. If this is the case, the regulated 150 volts can fall to 125 or 100. Usually a 10K pot and about 68K above it to the 150 regulated supply will give you the results you need.

If the sensitive region falls at the high of the control movement, say between 2 and 5 o'clock, you can move it back by reducing the size of the pot, or by increasing the size of the fixed resistor between it and 150 volt supply.

This area of maximum change in gain is where you want your finished receiver to begin to regenerate. I try to wind the tickler coil so that regeneration begins at 12 o'clock and changes smoothly and continuously all the way to the righthand extreme of rotation. Done right, the regeneration will smoothly come up from near silence to a slight hiss to noticeable increase in background noise. If there are signals, advancing the control will change the pitch of the signal but not wildly.

This method of checking the point of sensitivity was reported by H A Robinson, W3LW, in his February 1933 article in QST MAGAZINE entitled *Regenerative Detectors. What We Get from Them – How to Get More* (chapter 10). Many of the tests and recommendations he made are must reading for the regen fanatic. I have found that some tubes reach a point of maximum sensitivity which then falls off if voltage is increased. Trying to get regeneration to occur at the point of maximum tube sensitivity increases Q and overall gain.

Now that you know where maximum sensitivity occurs with your particular detector tube and the regeneration control, you can wind the tickler. Sometimes I use a marker to put a dot on the front panel to remind me where the tube reaches its maximum gain. Wind the tickler with a couple of turns more than you think you'll need. It's always easier to remove unneeded turns than it is to add additional turns.

Adjust the Tickler

If you find that your receiver begins to regenerate at 9 o'clock, you need to remove a turn from the tickler. With fewer tickler turns, you will need more control. If your tickler only a has a couple of turns, you can decrease the inductance of the coil by spreading the turns somewhat. If that doesn't work you may have to drill a hole half around the coil form in order to create just half of a turn. Decreasing the number of tickler turns means that you'll need an increase in regeneration control to get the radio to regenerate. Usually I wind more than enough turns for a tickler, coat them with nail polish, and then remove one turn at a time until they being to regenerate at about 12 o'clock when the tuning capacitor is set with its plates half meshed.

Although I almost always wind too many tickler turns and therefore have to remove them, it is possible to have too few turns. When this happens, regeneration will begin at 3 o'clock or not at all, even with the regeneration control to the max. You'll need to add a turn, or rewind the coil entirely. But before you do, check to see that you have the tickler wired correctly. If you get the tickler leads reversed, no amount voltage on the screen grid of the detector is going to make it oscillate.

The feedback required changes with frequency. At lower frequency, you usually need less regeneration, or feedback. At higher frequencies where gain falls off naturally, more feedback will be needed. That means you'll need more turns and/or more control. If you've wound a coil that covers a wide range of frequencies, getting the regeneration at 12 o'clock with the tuning capacitor set in the middle of the band is very important.

A well adjusted coil will regenerate smoothly at both ends of its frequency band. The regeneration should be smooth and easily controlled. You should be able to walk right up to an amateur single sideband signal and adjust the tuning to clear it almost completely. The last remnants of "Donald Duck" can be eliminated by adjusting the regeneration control. If the tickler is not properly wound, this last step will be very tricky or impossible. A well designed and built regenerative receiver will tune sideband signals without difficulty.

7 Design Modifications

This little set was built to test its suitability as a a tunable IF receiver. In other words, this radio was intended to take the output of a downconverter, amplify and detect it. Regenerative receivers are tricky dogs at high frequencies. Their stability and sensitivity start to drop off making them devilish to operate. Rather than take the regenerative receiver to high frequencies, I decided to bring the high frequency down to the regenerative receiver. That way I could optimize the regen to receive just one small band of frequencies, and let the converter do the hard work.

A test converter was built using octal tubes. The tuned rf amplifier fed its signal to a pentagrid converter. There it met the signal generated by the crystal controlled local oscillator. By using inexpensive computer crystals costing less than $2 each, I could hit a received14 mhz signal with a crystal controlled 12 mhz signal to get a 2 mhz result that could be fed to the regenerative receiver. Rather than tune the high frequency, the converter changed the 14.0 to 14.3 mhz amateur band into 2.0 to 2.3 mhz. At this lower frequency it is quite easy to extract high performance from a regenerative receiver.

I will admit that this complexity defeats our goal of simplicity. Actually what we've built is a superheterodyne receiver with a regenerative IF (intermediate frequency) amplifier/de-

A low cost down converter. The left-most section is the local oscillator. The variable capacitor in the background is not used since the section has become controlled by a 12 mhz crystal. Output from the oscillator feeds the center mixer stage where it mixes with either 14mhz or 10mhz signals from the rf amp at the right to produce a 2 mhz signal that a regenerative receiver can easily tune.

tector section.

Because the converter will provide some of the overall gain, I decided to use the 6AW8 (pentode & high gain triode) from the junk oscilloscope, and follow it with a 6C4 (low gain triode). As we discussed before, the pentode section of the 6AW8 is used as the detector, and triode section provides some audio gain. The 6C4 which is more suitable for power gain than voltage gain is used to boost the signal to a comfortable listening volume. Used without a converter, however, and the gain is adequate, although more would be desirable.

Using the 6AW8, I found that the pentode gain changed rapidly with a change of about 15-25 volts on the screen grid. With an appropriate coil and two additional capacitors across the tuning variable capacitor, I found that I could easily tune from 1.8 to 2.3 mhz.

Converter Covers Two Amateur Bands

It is possible to use a converter with a 12 mhz crystal to tune, not one, but two amateur radio bands. A 14 mhz signal mixed with 12 mhz gives 26 and 2 as an output. The same 12 mhz when mixed with 10 mhz gives 22 and 2. We can choose which band is selected by tuning the rf amp and detector tank circuits to the appropriate band.

By simply and quickly retuning the converter, I could tune either the sum or difference of the incoming signal and the 12 mhz local oscillator. The overall combination allowed me to tune from 9.7 to 10.2 mhz, which provides some shortwave broadcasts, WWV, and the 30 meter amateur band. I could also tune from 13.8 to 14.3 which gave me the 20 meter amateur band. The combination of converter/regenerative gave me a receiver that was sensitive and rock stable. It was surprisingly easy to tune 20 meter SSB signals.

After the test was complete and I knew building a more permanent receiver was practical, I decided to modify this little receiver for "stand alone" use. To do this I found a new 6AU8 among my parts. This pentode - medium mu triode combination uses exactly the same pin arrangement as the 6AW8. Only the bias resistors on the triode section would need to be changed.

Making this change, however, told me that the seven pin miniature 6C4 with its 18 or so voltage gain would provide far too little. In its place I decided to use a 6AV6, a triode - double diode, that was routinely used as a detector audio amp in receivers. Properly biased, the 6AV6 can give a voltage gain of 50 or more. The 6C4 and 6AV6 have different pin-out basing arrangements, but rewiring would be necessary anyway because a 6C4 must biased to draw far more plate current than the 6AV6. New plate and cathode resistors must be used. So installing the 6AV6 was no real problem. Rewiring only took a few minutes.

Once the modifications were made, I found that the pentode detector gain changed most rapidly in the 15-30 volt range. The same regeneration control circuit could be used. Another 4 prong tube socket was drilled and a 27 turn close wound tuning coil was wound with #26 wire. That turned out to be too much. The highest frequency tunable was in the low 3 mhz range. By removing about five turns, and by using a 50 pfd adjustable padding capacitor across the tuning capacitor, I could get the receiver to tune from about 3.5 mhz to 5.5 mhz. That got me the 80 meter amateur signals and WWV at 5 mhz if the very strong foreign shortwave broadcasters nearby didn't overload the receiver. And the gain provided

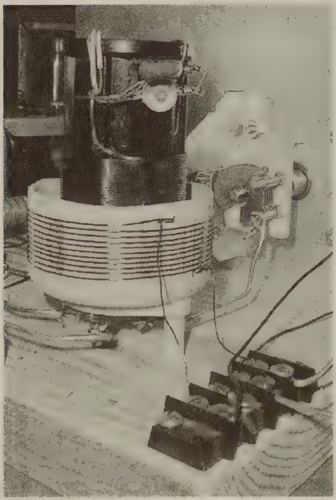
A stable, calibrated 2 mhz receiver for use with the downconverter. A passive audio filter built from telephone toroids provides extra selectivity for CW. Three different padding capacitors can be switched across the tuning capacitor to spread the 1.85mHz to 2.4 mHz into three bands. Controls at the bottom from left to right: passive audio filter switch, audio gain, antenna coupling capacitor, bandswitch, and regeneration. This receiver grew out of the lessons learned from building the receiver described in this book.

by the two triodes produced all the volume I needed in my high impedance earphones.

Although that's as far as I took the receiver, that is by no means the end of the possibilities. I think the next logical improvement would be the change over to five prong coil forms. You could then wind a coil to fall into a desired band, and use the new, fifth pin to connect the variable tuning capacitor to a tap way down on the coil. That would give you better bandspread, and to my way of thinking would almost be an absolute necessity in using the receiver on higher frequencies.

Experiment with Antenna Coupling

Changing the antenna coupling can often improve a receiver. You can use a third coil to provide inductive coupling either by going to six prong coil forms (which are difficult to find at best) or by building an outboard coupling

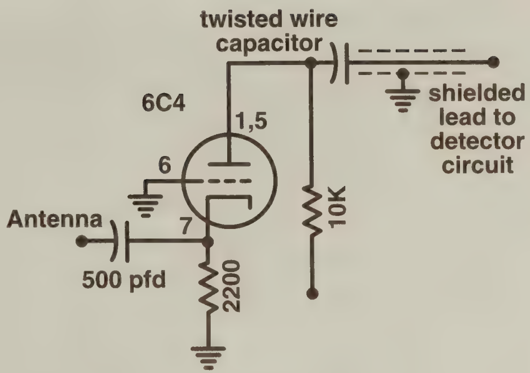


Here, on another experimental set, we see an antenna coupling coil wound around the cap taken from a bottle of laundry fabric softener. The antenna coil is permanently fixed while the five prong tuning coil can be removed.

coil. I did this by winding about four turns on the base of a plastic bottle. The bottle was attached to the chassis so that it surrounded the plug-in coil form. The coils could be replaced, but the antenna winding stayed in placed. It worked very well.

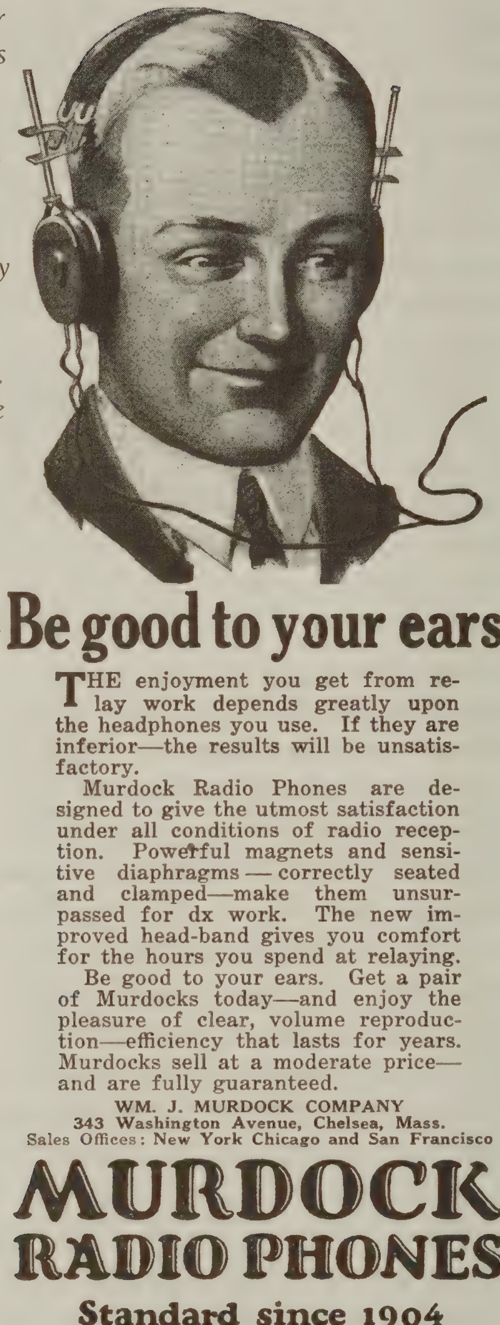
Another highly recommended alteration you can try if you care to increase the complexity is to add an rf amplifier stage between the antenna and detector. It doesn't have to be complex. It doesn't even have to be tuned. I put our old friend the 6C4 in a grounded grid arrangement with two resistors and a capacitor. The improvement in performance was impressive. The rf amp isn't there necessarily to provide much gain, and in fact, my circuit didn't even provide an improvement in selectivity. The rf amp isolates the detector from the antenna circuit. And since the detector needs precision adjustment to get maximum performance, the rf amplifier makes our job easier by removing outside disturbing influences.

If you've studied the Hijame Suzuki receiver, you know it is a 6AU6 pentode detector followed by a 6AV6 audio amplifier. It's quite effective. Another very effective arrangement is the 6AV6 used as the detector. With its very high gain and low plate current, you can resistively couple the detector circuit thereby eliminating the need for a coupling transformer or choke. But you will have to find another variable capacitor to act as a throttling capacitor to control the regeneration. A 12AT7 dual triode provides two stages of audio amplification and gives more than enough volume.



A very simple, grounded grid triode rf amplifier. Added to a simple regenerative receiver, it reduced noise, increased stability and sensitivity. A twisted wire capacitor consists of two short lengths of insulated wire tightly wrapped around one another but not electrically connected.

What I'm trying to prove to you here is that you can build regenerative tube receivers for almost nothing. A regenerative receiver is an electronics project that let's you tune in on the world. It's a sculpture composed of big old obsolete components. It's history. And it's something for almost nothing. I hope I've given you enough ideas to get you going. The only way to learn to actually build a set.



An advertisement for Murdock headphones from the July 1924 issue of QST Magazine. *I just picked up a pair in rough condition at a flea market for $10. They worked but not as well as my WWII Signal Corps phones. My theory is that the difference in performance was due to weak permanent magnets in the Murdock phones, in other words, old age.*

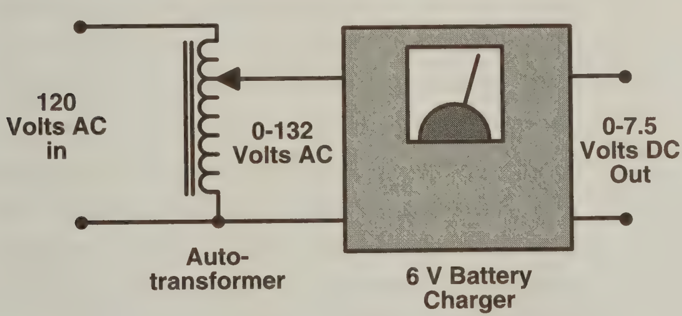
8 Power Supply

To use your new receiver, you will have to build a power supply. For me it is probably the only part of the whole project that I find less than exciting.

You could avoid building a power supply by using batteries. But they are expensive. And if you're planning to build more receivers, and I'm sure you will once you get started, the process of building a transformer power supply is worth the effort.

You can power the filaments of your receiver with a six volt storage battery or a battery charger if you have some way to reduce the voltage. This can be done by wiring a rheostat in series with the filaments or by adjusting the 120 volt input voltage to the battery charger with an autotransformer or Variac.

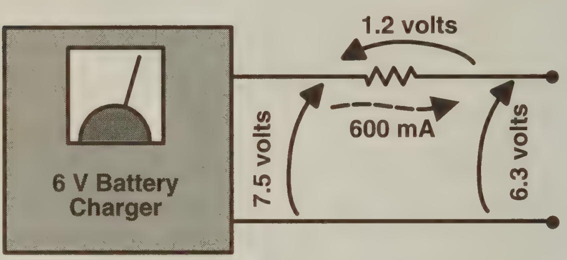
If a lead acid cell delivers 2.2 volts, then three cells provide 6.6 volts. The tubes are



The output voltage of an analog battery charger can be varied by using an autoformer (Variac™) to control input voltage. Don't try this on a switching power supply, however.

rated at 6.3 volts at .3 amps. The old rule of thumb about keeping filament voltages within five percent means that 6.6 volts is about the maximum you want to supply. So you could light the filaments with a six volt storage battery.

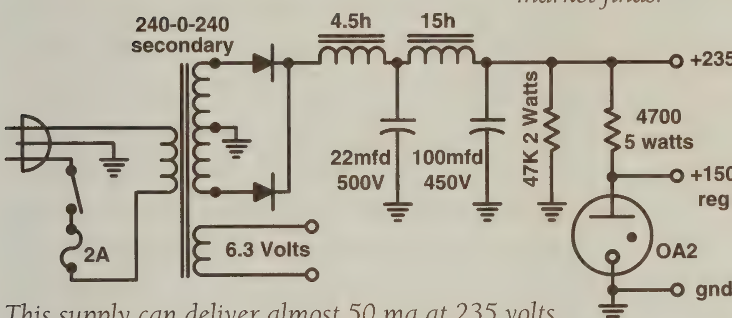
Let's suppose you have a battery charger that delivers 7.5 volts when charging a 6 volt battery. You need a reduction of 1.2 volts to get to 6.3. If you have two tubes each drawing .3 amps, you'll have a total draw of .6 amps.



A rheostat or fixed power resistor in the output side of the battery charger can be used to reduce voltage.

Ohms law says the resistance you will need is equal to the voltage divided by the current, or, 1.2 / .6, which comes to 2 ohms. Next, figure the heat that will be generated by multiplying the current times the current times the resistance, or .6 x .6 x 2, giving .72 watts. Your two ohm resistor needs to be greater than .72 watts in size, at least the next size higher, 1 watt. So to drop the 7.5 to 6.3 volts requires a 2 ohm 1 watt resistor. You could put three quarter-watt 6 ohm resistors in parallel to get 2 ohms at 3/4 watt, or two half watt four ohm resistors in parallel to get the 2 ohm 1 watt rating. Of course, a five or ten watt 10 ohm

A dual choke filtered power supply. The 4.5h choke reduces the output voltage from over 300 to 235 and gives better load regulation. Most of the parts used here are flea market finds.



This supply can deliver almost 50 ma at 235 volts and 20 ma at 150 volts regulated.

rheostat would fill the bill. You might find one at a hamfest among antique radio parts.

Alkaline flashlight batteries, D size, will provide about 100 ma of current for extended periods of time, and up to 400 ma for much shorter periods. You may have to wire cells in series to provide the voltage your filaments need. Modern alkaline D cells have impressive discharge rates and may serve your needs handsomely. Rechargeable NiCads which have a voltage of 1.2 per cell may also power filaments for you.

For high voltage, you might be able to get away with alkaline 9 volt transistor batteries connected in series. Fifteen such batteries would deliver about 135 volts at 8 to 10 ma. Here, battery power is not out of the question. But, first you had better calculate what the batch of fifteen batteries is going to cost. My recommendation is to build a power supply.

It's not that hard really. The best how-to info I've found on tube power supplies is located in the RADIO AMATEUR'S HANDBOOK, almost any edition, but especially those before 1975. You'll find complete design tables, formulas, charts, hints and tips and sample designs. Even the latest handbook has information on analog power supplies, but understandably, it's geared to solid state equipment which needs low voltages at high current. Our high impedance tubes need high voltage at low current.

You'll need a power transformer and a choke along with filter capacitors. The capacitors, I think, might be better if purchased new. They're inexpensive, and deliver much more capacitance in a smaller package at higher voltages than old, used capacitors. New transformers and chokes are available, but are quite expensive. At a hamfest, you can find almost any choke or transformer available at from one to three dollars. You'll find that used transformers come with no specs. But you don't really need them since the wires emerging are color coded. Hook 110 volts up to the primary winding (black wires) and measure the

B+ winding (red wires). You'll know what the output voltage is. You won't know the current rating however. For receivers, that's no big deal. Just about any transformer bigger than your fist will easily power a three tube receiver.

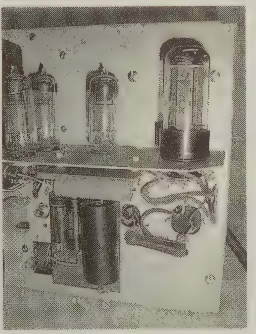
By far, I think, the smartest thing to do is go to a hamfest with the intent to buy some large piece of tube gear having a low price tag and to extract the power supply from it.

I just bought a signal generator which works beautifully at a flea market for $5. The late 1930's machine has about seven tubes in it. The power supply will power any radio I need.

Vacuum tube volt meters are routinely available for less that $10, often less than $5. They will have a small power supply capable of powering a couple of small tubes with about 150 volts of B+. Just trace the power supply circuit, and draw it out on paper. Don't be surprised if it uses a voltage doubler in the B+ side (again, documented in the ARRL Radio Amateur's Handbook).

I routinely bend up an aluminum chassis and mount the power supply components taken from some old gear. It's quick and dirty and cheap.

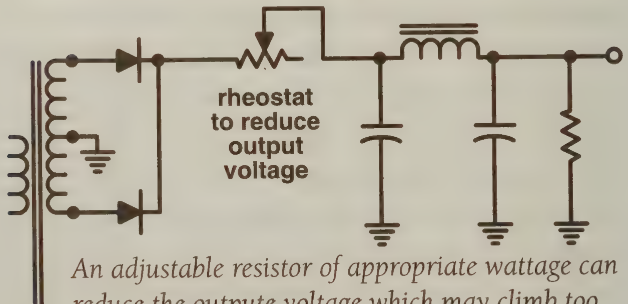
The power supply from this $5 hamfest audio generator will power a small radio easily. (above) The black power transformer is mounted above the two cylindrical electrolytic capacitors. Below it is the filter choke. (below) On the reverse side, we find the rectifier tube and the bleeder resistor wired to the terminals of the filter capacitors.



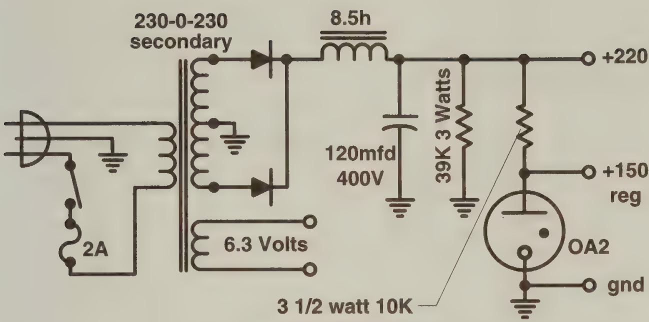
The only problem with doing this is that you don't know what the final output voltage is going to be. The internal resistance of the transformer and filter choke will drop the voltage from some high no-load value to its final full-load value. The output voltage drops in proportion to the number of milliamps you draw from the supply.

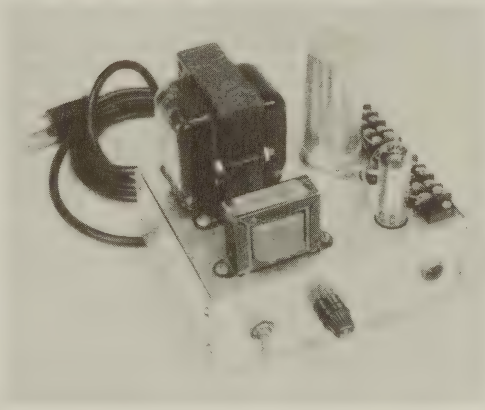
If you have a power supply designed to deliver 250 volts at 100 ma to a dozen tubes, and you intend to use it to power a two tube receiver that only needs 10 ma, the voltage will probably be over 300 volts. Remember that the missing 90 ma draw in the original piece of equipment served to pull the voltage down to the needed 250 volts.

To control the voltage you can install a power resistor between the transformer and the choke with a movable tap, which at this time costs about $5 new, or a install a rheostat. Let's suppose with no load on the power supply you measure 350 volts at the output. And let's suppose you want 250 volts maximum when you're drawing 10 ma. That's a



An adjustable resistor of appropriate wattage can reduce the outpute voltage which may climb too high when current draw is low.





A very simple yet effective homebrew receiver power supply with a regulated 150 output. This low cost supply will provide about 25 ma at 220 volts and 12 ma at 150 volts regulated. The filament winding will deliver 2.5 amps of 6.3 vac.

hundred volt drop. Ohms law says you need 100 volts / 10 ma or 10,000 ohms. What wattage? Ten milliamps is .01 amps. So wattage equals .01 x .01 x 10,000, or 1 watt. That's not very much. But we still need to do some thinking here.

If our power supply kicks out 350 volts with no load and 250 volts with a 100 ma (.1 amp) draw, we know that the internal resistance of the original power supply must be: 100 volts / .1 amp, or 1000 ohms.

Let's suppose we're drawing 40 milliamps.

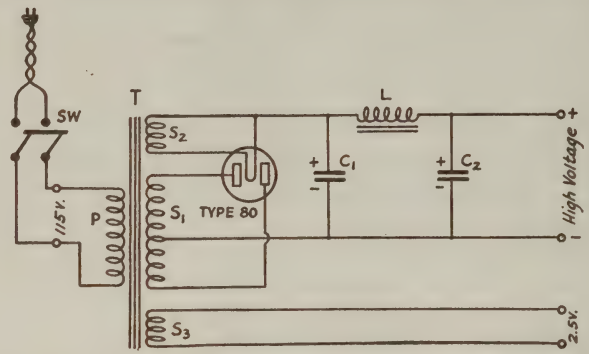


FIG. 1511 — WIRING DIAGRAM OF THE POWER SUPPLY SHOWN IN FIG. 1510

T* — *Power transformer; high-voltage winding, S_1, 350 volts each side of center tap; rectifier filament winding, S_2, 5 volts; transmitting-tube filament winding, S_3, 2.5 volts. Transformers of this type are sold for broadcast-receiver purposes.

L* — *Filter choke, commercial inductance rating 20 to 30 henrys, current-carrying capacity 100 ma.

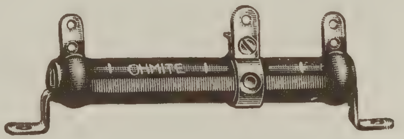
C_1, C_2* — *8-μfd. electrolytic filter condensers rated at 500 volts peak.

A simple power supply circuit from the 1936 Radio Amateur's Handbook. *Today we would put a fuse in the primary side of the transformer and use a three-wire cord for safety. The 80 rectifier would be replaced with two inexpensive silicon rectifiers such as 1N4007. A choke of 4 henries would work if modern 100 mfd 400wvdc capacitors were used instead of the 8 mfd units shown. The basic circuit hasn't changed but modern components have made it easier and cheaper to build.*

What will the output voltage be now? We calculate 350 volts – (1000 ohms X .04 amp), or 310 volts. We need to drop the voltage another 60 volts from 310 to 250. How big does our resistor need to be now? Same Ohm's law formulas apply. We need 60 volts / .04 amps, or 1500 ohms. Wattage? – .04 x .04 x 1500, or 2.4 watts.

If you run through a few more "what if's", you can decide what kind of a resistor to use. In this example, I would probaby use a 5 or 10 watt rheostat possibly with fixed power resistors so that the total resistance comes to 10,000 ohms. At maximum resistance the rheostat will cut the voltage to a minimum. As you draw more current from the supply, you can decrease the rheostat setting to bring the voltage up.

An Ohmite brand power resistor as advertised in QST in the 1920's. They still look the same today. Something this size could handle 25 watts or more.



The same type of a power resistor with an adjustable tap.

If this sounds too hairy for you, you need to get very familiar with Ohm's law. It's probably the single most used formula in radio design. That and the wattage formula. The formulas are simple, and a pocket calculator will do all the hard work. If you have a computer with a spread sheet program, it becomes even easier.

A pair of Ohmite wire wound rheostats.

Right now, I'm rebuilding a big power supply from the $5 deviation meter. I bought it for the case, but got the dial, a beautiful meter, this huge power supply, and all kinds of vintage components. I guarantee you that I won't be buying any batteries any time soon.

Be sure that you install a bleeder resistor in your power supply. This is a small perma

Two power supply circuits described in the 1936 ARRL Handbook. Because capacitors of high voltage and high capacitance were not available, designers used multiple chokes to smooth the rectified AC into DC. Today we would probably use a single choke. Resistive voltage dividers provide various circuit voltages. The 2.5 volt filament windings were intended for use with such tubes as the '27 , '24, 58, 56 and others.

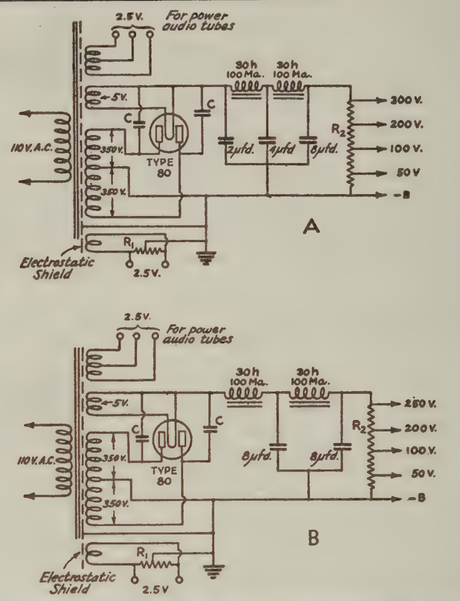


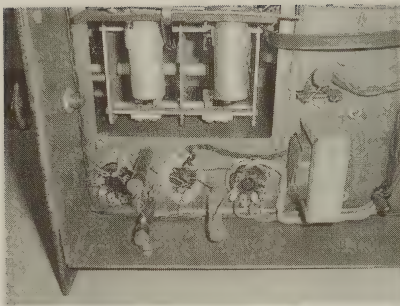
FIG. 1515 — WIRING DIAGRAMS FOR RECEIVER POWER SUPPLIES

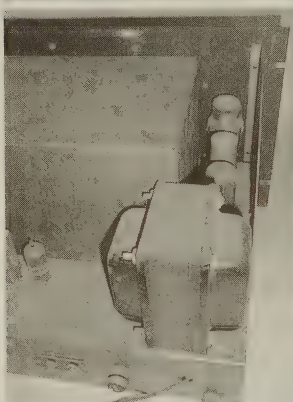
Condenser C should be a mica condenser of about .002 μfd. capacity. Its size is not critical and it will be required only if tunable hums are present, as explained in the text. Resistor R_1 is 20 ohms total, tapped at the center. R_2 is the voltage divider for obtaining different voltages from the power supply. If the receiver itself is equipped with a divider (the preferable method) R_2 will be a simple bleeder of about 15,000 ohms. Otherwise it may be any of the regular voltage dividers sold commercially for this use, or may be a 15,000 ohm resistor tapped at every 3000 ohms. The resistance needed between taps will depend upon the currents to be drawn at each of the taps. It is not usually necessary to have the voltages nearer rated values than within 20%, with modern receiving tubes.

nent load attached to your power supply output. For instance, you may have a supply that is capable of supply 100 ma. The bleeder might easily consume 20 ma. Why waste the power and turn it to heat? Safety. When you shut off the power supply, the bleeder will "bleed" off the voltage remaining on the filter capacitors. Without a bleeder, the capacitors could stay charged at 250 volts for hours, and probably days. You could come back to the lab a week later, pick up the power supply, and get the XXXX kicked out of you. It's no fun. And it's downright dangerous. There is no need for it. I always put bleeders in my supplies.

One other topic is important to receivers: regulation. It's no fun being in the shower when someone somewhere else in the house flushes the toilet, and you get doused with cold water. The same thing can happen electrically. You could be copying a faint station on your tiny radio when someone kicks on the electric range in the kitchen or an electric clothes dryer next door. The voltage in the house can drop half a volt. The output of your power supply could drop twice that, or one volt, since we use a step-up transformer in the power supply. One volt doesn't sound like much, but slight fluctuations of power being fed to a regenerative detector adjusted to the very threshold of oscillation can produce noticeable effects. You could easily lose the station. Sure, you can retune and readjust. But, no doubt, about the time you do that someone will shut off the range or dryer, and you'll have to find the station all over again. It's easier just to regulate the power supply voltage so as to remove the effects of line voltage fluctuation.

You can provide regulation with a gas regulator tube. I usually use a 150 volt tube, like an OD3, VR150, or OA2. These tubes are unusual in that they conduct current, usually 5





This huge power supply from a $5 hamfest deviation meter will power the largest receiver you and I will ever build. (left) We see the hefty power transformer and behind it the capacitors and rectifier tube. (above) We see the underside of the chassis where we find the filter choke and bleeder resistors. This equipment is out there waiting to be purchased and recycled by a rare group of people who appreciate and want to understand old tube gear.

to 30 ma, with a fixed 150 volt drop across them. Another way to say it, is that from the cathode to anode of the tube, you'll measure 150 volts whether the tube is conducting 8 ma or 28 ma.

Designing a regulator circuit is relatively simple. You put a resistor in series with the tube to ground. You take power from the anode of the tube out to your radio.

Let's suppose your supply provides 250 volts. That means you have to lose 100 volts through the resistor so that 150 volts appears across the regulator tube. How big a resistor should we use? Most regulators will not pass more than 30ma, or .03 A. So we calculate 100 volts / .03 A, or 3333 ohms. A standard value would be 3900 ohms. What wattage? Again, .03 x .03 x 3900, or 3 watts. It would be smart to use 5 watts or greater.

When we are not drawing power from the regulator tube, the current through the tube will be 100 volts / 3900 ohms, or about 26 ma. Since the tube needs a minimum of 5 ma to function properly, we can draw 21 ma out to our receiver. In effect we divert the current from the tube to our radio.

Often I'll put the full unregulated 250 volts on the audio amplifier stages, and use the 150 regulated volts for the regenerative detector. A two, or even three, tube regenerative receiver should draw less than 21 ma. So the whole receiver could be regulated. In practice, though, you can get more voltage gain if you put higher voltages on the audio stages, and on these stages small changes in plate voltage produce no noticeable effects.

Complete details on designing regulator circuits can be found in earlier editions of the RADIO AMATEUR HANDBOOK. They are easy to design and install, low cost, and add significantly to the enjoyment of a simple radio. And if you are intending to get maximum performance from a "peanut whistle" set, a regulator tube is essential.

Yes, building power supplies is boring, I think. But putting the time into a good supply that can power any tube gear connected to it is an investment. You know in advance that just about any receiver you build will be adequately powered. You can concentrate on the receiver design and construction because the problem of power has already been solved.

Appendix

OHM'S LAW

When a continuous current is flowing thru a given conductor, whose temperature is maintained constant, the ratio of the potential difference or voltage existing between the conductor terminals and the current carried by the conductor is a constant, no matter what the value of the current may be. The mathematical formulas for Ohm's Law may be expressed in the following forms:

reprinted from the 1937 Sylvania Tube Manual

$$R = \frac{E}{I} \qquad I = \frac{E}{R} \qquad E = IR$$

Where

R =resistance expressed in ohms
I = current expressed in amperes
E = potential difference or voltage in volts

A practical **example** is given to illustrate the use of Ohm's Law: If the screen current for a certain tube is 2 milliamperes (0.002 ampere) what value of resistance should be used to reduce the screen voltage to 90 volts from a supply voltage of 250 volts?

SOLUTION: The required voltage drop across the resistor would be 250 - 90 or 160 volts.

$$\text{Therefore} \quad R = \frac{E}{I} = \frac{160 \text{ volts}}{0.002 \text{ ampere}} = 80{,}000 \text{ ohms}$$

POWER

The few formulas presented in the next couple of pages are all the math you'll need to build almost any radio...

Power is the time rate of doing work. Since energy is the ability to do work, power may also be defined as the time rate of expending energy. From the fundamental definitions of power, electromotive force and current it is easy to show that power may be computed from the following expression: $P = EI$

If E is expressed in volts and I in amperes then the power P will be given in watts. Using values for E or for I from Ohm's Law, the above expression becomes either:

$$P = I^2R \quad \text{or} \quad P = \frac{E^2}{R}$$

If the first equation for power is used, the wattage rating of the resistor used for reducing the screen voltage may be computed.

$$P = EI = 160 \text{ volts} \times 0.002 \text{ ampere} = 0.32 \text{ watt}$$

A 0.5 watt resistor should be employed.

RESISTORS CONNECTED IN SERIES AND IN PARALLEL

When two or more resistors are connected in series, so that the same current flows through each resistor, the total effective resistance (R_t) of the network will be the sum of the separate resistances. Thus:

$$R_t = R_1 + R_2 + R_3 + \ldots$$

If a number of resistors are connected in parallel so that the voltage drop is the same across each resistor, then the current in each resistor will be inversely proportional to the resistances. The total effective resistance (Rt) of the network, will be given by:

$$1/R_t = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$$

For the case of two resistors in parallel:

$$R_t = \frac{R_1 \ R_2}{R_1 + R_2}$$

CALCULATION OF CONDENSERS IN SERIES AND IN PARALLEL

When a number of condensers are connected in series, the total effective capacity (Ct) is computed from the relation: $$1/C_t = 1/C_1 + 1/C_2 + 1/C_3 + \ldots$$

For the case of two condensers connected in series this expression reduces to the form: $$C_t = \frac{C_1 \ C_2}{C_1 + C_2}$$

The total capacity (C_t) of any number of condensers connected in parallel is the sum of the separate capacities:

$$C_t = C_1 + C_2 + C_3 + \ldots$$

CALCULATION OF PROPER RESISTOR FOR SELF BIASING

From Ohm's Law

$$R = \frac{\text{Grid Bias in Volts X 1000}}{\text{Total Cathode Current in Ma. X Number of Tubes Involved}}$$

For triodes the total cathode current is equal to the plate current. For tetrodes and pentodes the total cathode current is the sum of the plate and screen currents.

For pentagrid converters the plate, screen and oscillator anode currents must be added to obtain the total cathode current.

EXAMPLE: What biasing resistor is required for two Type 42 tubes operated in push-pull with 250 volts applied to the plates?

The following data are taken from the characteristics shown for Type 42:

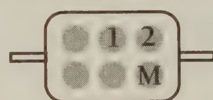
Grid Bias = 16.5 Volts
Plate Current =34.0 Ma.
Screen Current = 7.5 Ma.
Total Cathode Current =41.5 Ma.

$$\text{Hence:}\quad R = \frac{16.5 \text{ X } 1000}{41.5 \text{ X } 2} = \frac{16500}{83} = 198 \text{ ohms}$$

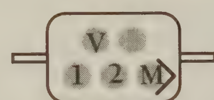
When over-biased operation is employed the recommended bias resistor values will be specified under Ratings or Circuit Application notes for the tube type involved. A complete Bias Resistor Chart will be found in this Appendix.

radial lead ceramic capacitor

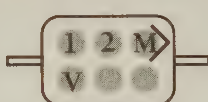
bypass/coupling ceramic capacitor



Molded Mica Capacitor (after '48)

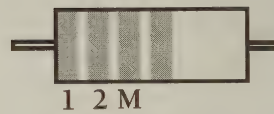


Molded Mica Capacitor - 5 Dot



Molded Mica Capacitor - 5 Dot

Tubular Molded Paper Capacitor



axial lead resistor

1 = *1st significant digit*
2 = *2nd significant digit*
M = *multiplier*
V = *voltage in 100's of volts*

Standard Color Code

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Example: yellow-violet-orange is a resistance of 4,7 plus three zeros or 47,000 ohms.

RESONANT FREQUENCY OF COIL & CAPACITOR

f = frequency in kiloHertz
L = inductance in µh
C = capacitance in pfd (mmfd)

$$f\ (\text{kHz}) = \frac{10^6}{2\pi\sqrt{LC}}$$

INDUCTANCE OF SINGLE LAYER COIL (SOLENOID)

L = inductance in µh
a = coil radius in inches
b = coil length in inches
n = number of turns

$$L(\mu h) = \frac{a^2 n^2}{9a + 10b}$$

10 Robinson Article

Below are reprinted the essential conclusions reached by H. A. Robinson, W3LW, in his article *Regenerative Detectors: What We Get from Them – How to Get More* which appeared in QST Magazine in February 1933.

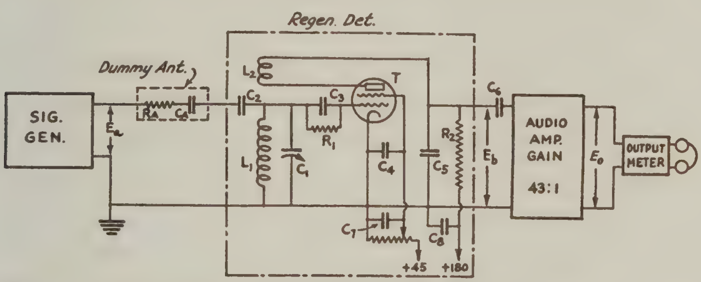


FIG. 1 — CIRCUIT USED FOR THE EXPERIMENTAL INVESTIGATION

C_A — 100 μμfd.
C_1 — 10 to 125 μμfd.
C_2 — 7 μμfd.
C_3 — 100 μμfd.
C_4 — .001 μfd.
C_5 — 150 μμfd.
C_6 — .006 μfd.
C_7 — 0.5 μfd.
C_8 — 0.5 μfd.
R_A — 100 ohms.
R_1 — 100,000 ohms to 5 megohms.
R_2 — 100,000 ohms.
T — Type '36 tube.
L_1 and L_2 — See Table II.

...The optimum screen-grid voltage for the Type '36 tube as a non-regenerative grid leak detector, for the plate load resistance and supply voltage employed in these tests, was approximately 30 volts at low signal levels. The data of Table I show that by adjusting the tickler coupling so that the point of critical regeneration occurs at this optimum screen voltage, maximum amplification was obtained as a regenerative detector. The value of the grid leak seemed to be of minor importance and values from one to five megohms showed little difference. Increasing the signal level on the detector (here measured in turns of the output level E_o) results in a decided decrease in regenerative

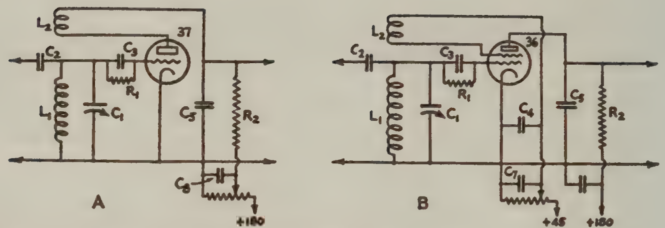


FIG. 2—THE TYPICAL REGENERATIVE DETECTOR CIRCUITS STUDIED

The circuit constants correspond with those of Fig. 1.

gain. The regenerative amplification was greatest for the lower-loss tuned circuits and increased with the L-C ratio. The screen-grid tickler arrangement of Fig. 2B resulted in practically the same regenerative amplification at critical regeneration as the more usual plate-tickler circuits. The triode Type '37 tube as the regenerative detector (in circuit Fig. 2A) gave only slightly over one-third the gain of the screen-grid tubes.

Considered from the standpoint of the reception of c.w. signals (oscillating detector), the regenerative amplification is also a maximum at the point of critical regeneration and hence is limited by any instability of circuit elements or supply voltage fluctuation which will not permit operation very near this point. A fairly high value of grid leak (3 to 5 megohms) decreases the amplitude of the self-sustained oscillations and results in a detector action over a restricted region of the tube characteristics. Hence the conditions for maximum detector gain for an oscillating detector approach those for a non-oscillating regenerative detector. The data of Table I confirm this, the detector gain for c.w. reception increasing as the point of critical regeneration is shifted to the opti-

mum value by adjusting the tickler coupling. The effect of the tuned circuit impedance and other factors seem to be much less pronounced than in the case of the non-oscillating detector. The screen-grid tickler circuit of Fig. 2B again shows the same amplification as the plate tickler arrangement.

SUMMARY

Tuned circuit L-C ratios and losses are of minor importance in regard to selectivity in a regenerative circuit.

Lower loss tuned circuits and higher L-C ratios result in increased regenerative amplification.

Regenerative amplification and selectivity decrease very greatly for slight departures from point of critical regeneration.

Regenerative detector amplifications as high as 7000 for 30% modulated reception and 15,000 for c.w. reception are obtained at critical regeneration and optimum adjustment.

Critical adjustment and improved stability of circuit and voltages are of major importance.

Optimum regenerative detector voltages and circuit constants are practically the same as for maximum non-regenerative detector gain at the same signal output level.

11 Armstrong Patent

United States Patent Office

EDWIN H ARMSTRONG, OF YONKERS, NEW YORK

Wireless Receiving System

Specifications of Letters Patent

1,113,149 Patented Oct. 6, 1914

Application filed October 29, 1913.

Serial No. 797,947

To all whom it may concern:

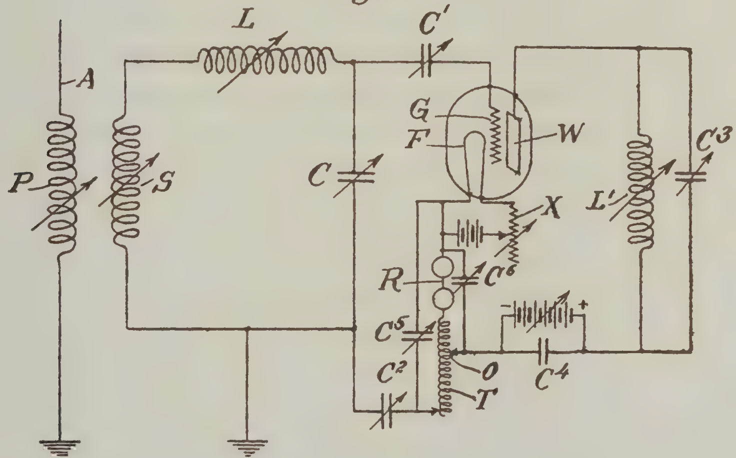
Be it known that I, EDWIN H. ARMSTRONG a citizen of the United States, residing at 1032 Warburton avenue, Yonkers, county of Westchester, State of New York, have invented certain new and useful improvements in Wireless Receiving Systems; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This is a transcription of the original patent issued to Edwind Armstrong in 1914 for his regenerative receiver

The present invention relates to improvements in the arrangement and connections of electrical apparatus at the receiving station of a wireless system, and particularly a system of this kind in which a so-called "audion" is used as the Hertzian wave detector; the object being to amplify the effect of the received waves upon the current in the telephone or other receiving circuit, to increase the loudness and definition of the sounds in the telephone or other receiver, whereby more reliable communication may be established, or a greater distance of transmission becomes possible. To this end I have modified and improved upon the arrangement of the receiving circuits in a manner which will appear fully from the following description taken in connection with the accompanying drawings. As a preliminary, it is to be noted that my improved arrangement corresponds with the ordinary arrangement of circuits in connection with an audion detector to the extent that it comprises two interlinked circuits; a tuned receiving circuit in which the audion grid is included, and which will be hereinafter referred to as the "tuned grid circuit", and a circuit including a battery or other source of direct current and the "wing" of the audion, and which will be hereinafter referred to as the "wing circuit". As is usual, the two circuits are interlinked by connecting the hot filament of the audion to the point of junction of the tuned grid circuit and the wing circuit. I depart, however, from the customary arrangement of these circuits in a manner which may, for convenience of description, be classified by analysis under three heads; firstly, the provision of means, or the arrangement of the apparatus, to impart resonance to the wing circuit so that it capable of sustaining oscillations corresponding to the oscillations in the tuned grid circuit; secondly, the provision of means supplementing the electrostatic coupling of the audion to facilitate the transfer of energy from the wing circuit to the grid circuit, thereby reinforcing the high frequency oscillations in the grid circuit, and thirdly, the introduction into the wing circuit of an inductance through which the direct current of the wing circuit flows, and which is so related to the grid circuit that the maintaining electromotive-force across the terminals of the inductance due to reduction of the direct current is effective in the tuned grid circuit to increase the grid charge and consequently to further reduce the current in the wing circuit and in the telephones. By a further extension of this idea, the effect of the maintaining electromotive-force upon the grid current may be augmented by the use of a transformer in a manner which will be understood from the following description.

Figure 1 illustrates the arrangement and connection of apparatus with which I have thus far obtained the best results and which embodies in combination the several features of improvement which I have invented or discovered. Fig. 2 represents a like arrangement with the exception that there is no transformer for augmenting the effect of the maintaining electromotive-force, and several condensers, which may advantageously be employed but which are not essential, are eliminated. Fig. 3 illustrates an arrangement in which the advantages of my invention are only partially present, the inductance which produces the maintaining electromotive-force effective on the tuned grid circuit being eliminated. Fig. 4 illustrates an arrangement in which inductance, in this case the inductance of the telephones, is employed for producing the maintaining electromotive force effective on the tuned grid circuit, but the wing circuit is not resonant. Fig. 5 illustrates an arrangement in which an inductance replaces the telephones in that portion of the connections which is common to the two circuits and the telephones are put in the wing circuit, and Fig. 6 illustrates an arrangement in which a double winding transformer is used, the primary being located in the wing circuit.

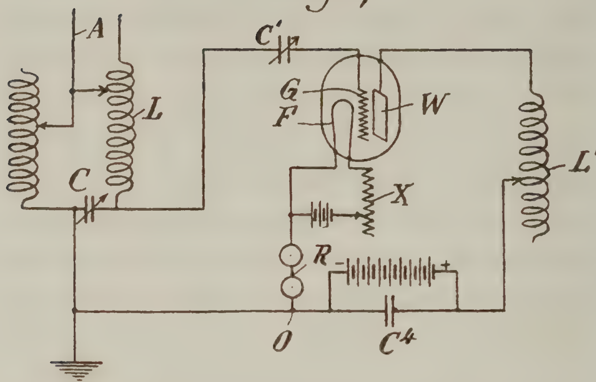
Fig. 1,



Referring particularly to Fig. 1, A represents the ordinary grounded aerial connected to the primary P of an oscillation transformer, the secondary S of which is connected as usual in the tuned grid circuit, this circuit also including the inductance L and preferably a shunted capacity C as is usual. Between the inductance L and the audion grid G is located a condenser C' adapted to receive and hold the charge which accumulates on the grid as a result of the received oscillations. The grid lies within the audion in the path of current in the wing circuit and the grid circuit is connected to the wing circuit at the junction point O, so that the two circuits are interlinked from the grid to that point. Between the junction point O and the filament of the audion I insert the telephone receivers R and the primary of the auto-transformer T. From junction point O the tuned grid circuit is completed through the secondary of the auto-transformer and condenser C2 back to the secondary S; and the condenser C5 is connected as shown in shunt to the telephones and the secondary of the auto-transformer. The wing circuit may be traced from the positive terminal of the battery through the inductance L' to the wing W and through the connections which are common to the two circuits, including the current path through the audion to the filament F, the telephone receivers R, and the primary of the auto-transformer and back to the negative terminal of the battery. The inductance L' is preferably shunted by a condenser C3 and a condenser C4 is placed across the battery terminals to afford a path of low impedance for the high frequency oscillation. The telephones R and the auto-transformer T are shunted by a condenser C5 which affords a path for the high frequency oscillations in the grid circuit; and the telephones R and the primary of the auto-transformer are shunted by a capacity C6, which affords a path for the high frequency oscillations in the wing circuit, and I find that the audion is made more stable and shows less tendency to become a high frequency generator and to set up oscillations in the interlinked circuits, if the tuned grid circuit is grounded as indicated. Each of the pieces of apparatus crossed with an arrow on the drawing is continuously variable, that is, may be varied by infinitesimal increments, and the condenser C4 is preferably made adjustable by steps. I find that with such an arrangement of apparatus, and by properly adjusting the reactances, signals which are scarcely audible with the ordinary audion connection can be amplified to a point where they are too strong for, and "paralyze" the most stable audions that I have been able to obtain. The present understanding and modes of explanation of the phenomena which present themselves in such an arrangement is such that any theory of operation which may be advanced in regard to them is merely an attempt to explain the results attained in language which will be understandable to those skilled in the art; and it is with this idea in mind that the following description is written.

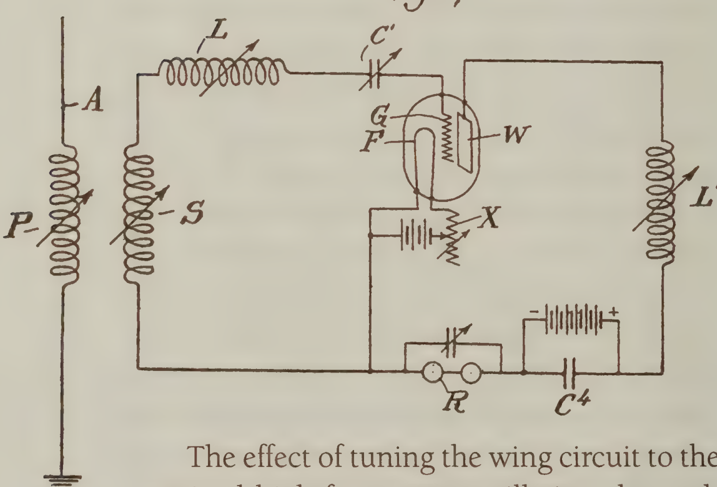
Upon reference to Fig. 2 of the drawings, which is an attempt to simplify the illustra-

Fig.2,



tion of the essential elements of my invention, it will be observed that the auto-transformer T, and the condensers C2, C3 C5, and C6, are omitted. In this case, the capacity of the telephone cords is sufficient to by-pass the high frequency oscillations.

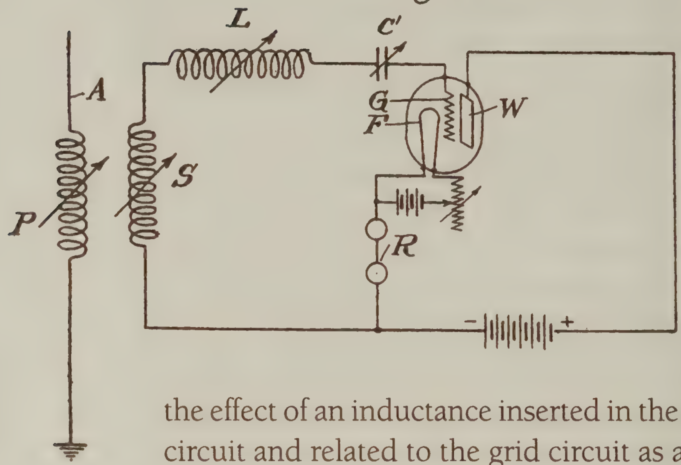
Fig.3,



The effect of tuning the wing circuit to the received high frequency oscillations by such an arrangement of apparatus as is illustrated in Fig. 3, may be explained as follows: In the ordinary audion connection, the wing W will be constantly maintained at the same potential with respect to the filament F and will constitute a surface of positive potential within the audion and having a constant tendency to absorb electrons. When the wing circuit is made resonant in accordance with my invention, the initial received oscillations in the grid circuit set up corresponding oscillations in the wing circuit so that a negative charge on the grid is accompanied by an increase of the potential of the wing, and a positive charge on the grid is accompanied by a decrease of the potential of the wing. The absorption of electrons by the grid and the building up of the charge in the condenser C' occurs only when the potential of the grid is positive with respect to the potential of the filament, and during these periods the potential of the wing with respect to the filament is reduced, thereby reducing its absorption of electrons and increasing the absorption of electrons by the grid. The charge thus built up in the condenser C' by absorption at the grid is entrapped and is an effective counter-electromotive-force in the wing circuit to reduce the current in the telephones. It is understood that on each successive wave train this effect is repeated, it being probable, according to my observations, that the full condenser charge is not built up by the first wave of a train but is gradually built up during the first portion of the wave train; and because of the high resistance of the discharge path of the condenser C' this charge outlasts the duration of the wave train.

Referring now to Fig. 4, we may examine

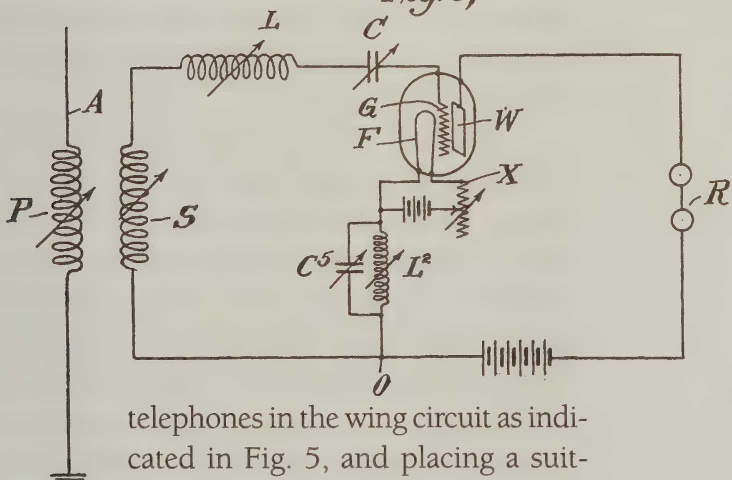
Fig. 4,



the effect of an inductance inserted in the wing circuit and related to the grid circuit as above defined. The reduction of current through the telephones, due to the received oscillations, produces a maintaining electromotive-force across the terminals of the telephones R which is in the same direction as the battery electromotive-force, and, because of the fact that the telephones are in that portion of the connections which is common to the two circuits, this maintaining electromotive-force is effective upon the tuned grid circuit to charge the condenser C' in the same sense that the flow of electrons from the filament to the grid would charge the condenser. I have found as a practical matter that the arrangement of apparatus shown in Fig. 4 is effective to materially increase the loudness of the signals but obviously better effects are obtained by combining the arrangements of Fig. 3 and 4 to make up the arrangement of Fig. 2. In this figure an auto-transformer L is used instead of the two-coil transformer P.S., and in Figs. 2 and 4, the capacity of the telephone cords affords a path of low impedance for the passage of the high frequency oscillations about the inductance of the telephones. It will be observed, that this capacity of the telephone cords in Figs. 2 and 4. and likewise the capacity C5 in Fig. 5 and the distributed capacity of the transformers in Figs. 1 and 6, is in each case common to the grid circuit and the wing circuit and constitutes an electrostatic coupling facilitating the transfer of energy from the wing circuit to the grid circuit and increasing the effect upon the grid of high frequency pulsations in the wing circuit. This effect occurs whether the wing circuit is tuned or not, but obviously the transfer of energy is increased by tuning the two circuits alike. I have discovered, however, that the beneficial effect may be still further increased by the interposition of a transformer in such a way as to increase the effect of the maintaining electromotive-force due to the reduction of current through the telephone receivers, and such a transformer is shown at T in Fig. 1. With the foregoing discussion in mind the effect of this transformer will at once be apparent. The inductance of the primary of the transformer is of course added to and increases the effect of the inductance of the telephones, but beyond this the maintaining electromotive-force across the primary is transformed into a higher electromotive-force in the tuned grid circuit. I have found that a ratio of transformation of 2 to 1 is sufficient in most cases when the inductance of the primary is equal to the inductance of the telephones, since a greater ratio causes the audion to become a high frequency generator setting up disturbing oscillations in the grid and wing circuits. The condenser C5 by-passes the high frequency oscillations in the grid circuit about the telephones and the auto-transformer T, and the condenser C6 by-passes the oscillations in the wing circuit about the telephones and the primary of the auto-transformer. The capacity of the telephone cords may, however, be relied upon to by-pass the oscillations about the telephones and condensers C5 and C6 utilized for bypassing the oscillations about the transformer only. The manner in which the different reactances will be adjusted so as to tune the two circuits to one another will be at once understood by those skilled in the art, and it will also be understood that the adjustable resistance X may be varied to get the proper temperature of the filament. Furthermore, it will be understood from what has been said that the ratio of transformation of the transformer should be adjusted to get the maximum signals without causing the audion to generate oscillations. The condenser C5 has the additional effect, as I have found, to steady the audion and enable it to withstand greater variations of potential of the grid G and wing W without becoming a generator of disturbing oscillations in the grid and wing circuits. Particularly when working with long waves it is advisable to use this condenser in every case. I also find that the introduction of a condenser C2 in the place indicated in Fig. 1, that is, between the auto-transformer and the secondary S, has the effect to prevent buzzing or humming in the telephones.

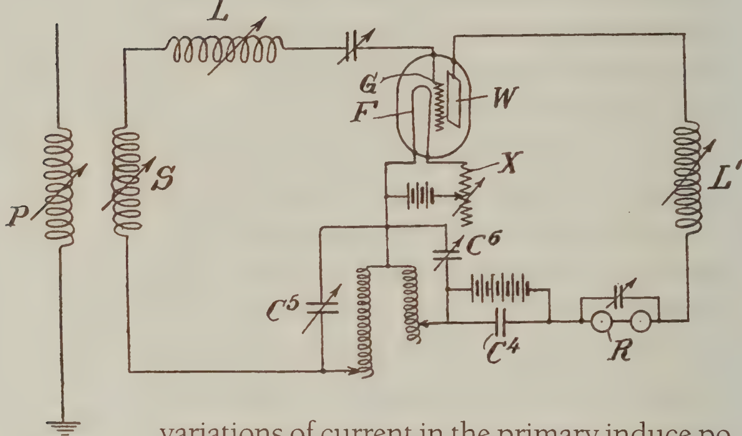
From what has been said, it will be understood that the inductance of the telephones may be utilized as the generator of the maintaining electromotive-force by inserting the telephones in the connections common to the two circuits, as shown in Figs. 1, 2 and 4; but a like result will be obtained by locating the

Fig. 5,



telephones in the wing circuit as indicated in Fig. 5, and placing a suitable inductance as L2 in that portion of the connections which is common to the two circuits. Indeed I find that the beneficial effect of an inductance so located can be obtained, as would be expected, by utilizing the primary of the transformer alone, as indicated in Fig. 6. In this case a two coil transformer is shown in place of an auto-transformer and the

Fig. 6



variations of current in the primary induce potential variations in the secondary which may be given any value by properly selecting the ratio of transformation.

Inasmuch as the purpose of the transformer is to magnify the effect of the maintaining electromotive-force in the inductance, it will be obvious that by increasing this inductance, the transformer may be rendered unnecessary, and some simplification of the whole arrangement may be attained by using telephone receivers of extremely high inductance and locating them in the position shown in Fig. 2, without any transformer.

The purpose of the condenser C3 in Fig. 1 is to enable the wing circuit to be made resonant with the grid circuit when long waves are to be received. The capacity of the audion and the distributed capacity of the inductance L' are such that up to 2000 meters wave length resonance can be obtained in the wing circuit with reasonable values of inductance. For waves longer that 2000 meters resonance can be obtained in the wing circuit without the parallel condenser, but only by unduly increasing L'.

For the purpose of completing the disclosure of my invention, and to facilitate its practical application by those skilled in the art, I give below the values of the constants which I have found to work well for a wave length of 1800 meters, using an antenna having a capacity of .0012 microfarads and a standard McCandless audion. The inductance of the primary P was 760 microhenries and the combined inductance of the secondary S and the coil L was 3660 microhenries. The capacity of C was about .00025 microfarads, the capacity of C2, .01 microfarads, the of C4, 2 microfarads. The values of C' and L' are largely dependent upon one another and upon the amplitude of the received oscillations as well as the characteristics of the audion. These are the two elements which are chiefly relied upon by the operator to bring the system into condition to give the best results in receiving the signals from any particular station. The value of L' will be in the neighborhood of 10,000 microhenries, and of C' between .00003 and

.0001 microfarads. If the inductance L' is not used, the value of C' can be much larger. I have usually employed about .003 microfarads as a matter of convenience; but there does not seem to be any particular advantage in increasing the capacity of C' beyond .0005 microfarads. The batteries, and the resistance X are as used in the standard audion set. The way to tune this set is to cut out L', set C' at .00005 microfarads, and the adjust P, S, L and C as in the ordinary audion set until signals are strongest. The inductance L' is then gradually cut in and the strength of the signals will increase many times until a point is reached where the signals lose distinctness and there is a loud hiss in the telephones. This indicates that the audion is generating high frequency oscillations in the grid and wing circuits, and the inductance L' should be set at a point just below that at which this occurs. If there is no hiss as L' is increased, and the signals pass through a maximum of strength and begin to fall off, then L' should be set at the point of maximum strength of signals and C' should be increased to a point just below that at which the hiss appears. Under these circumstances, the increase of C' will be accompanied by an increase of the strength of the signals, the maximum strength being obtained in each case just below that point at which the audio begins to act as a generator of high frequency oscillations.

I find that the capacity required to by-pass the oscillations about the inductance which is common to the two circuits, and about the transformer, if the transformer is used, is relatively small; and when the telephone receivers are used as the inductance at this point, the capacity of the telephone cords is sufficient. With greater wave lengths, however, when it becomes necessary to increase the tuning inductances L and L', the audion begins to be unstable, and I find that its stability can be restored by the use of a considerably larger capacity C5. For example, with wave lengths of 4000 to 7500 meters I use a capacity C5 of from .001 to .003 microfarads.

Having thus described my invention, what I claim is...

At this point appear eighteen formal claims to meet the legal requirements of the patent. Signed: Edwin H. Armstrong. Witnesses: William H. Davis and John C. Pennie

Build a vacuum tube regenerative receiver!

Why? Because they are incredibly simple sculptures of metal, plastic and glass that come to life and perform far better than most people would ever expect. Besides, almost anything built from vacuum tubes these days looks like science fiction. Your bonehead neighbor who can't tell a memory chip from a cow chip will think you're a certified mad scientist. He'll think you're an absolute genius. (I know from experience.) And we certainly won't tell him any differently will we?

Tube regen receivers are easy-to-build and very low-cost. The hardest part is just getting off your butt, building the first one and getting it adjusted. Even before you've finished it, you'll already have big ideas and even bigger plans for the next receiver and the one after that.

Here, you'll learn the practical aspects of finding old components and adapting them to your goal of building a little radio. You'll learn how to make it happen. The set described inside is not the ultimate receiver. Rather it is a real, working receiver that was built from salvaged material on hand. It is not about hopes and dreams. It is about building a working radio, about getting results.

Build your first regenerative receiver. We'll coach you through it. Careful, though! Your knucklehead neighbors and inlaws might really think you're a mad scientist and try to have you put away! I guarantee you that you will be the talk of the neighborhood just like the first regenerative receiver builders were more than seventy years ago!

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