The Impoverished Radio EXPERIMENTER

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

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Vacuum Tube Substitutions
Inexpensive Tube Power Supply
Grid-Leak Detectors
Regenerative Receiver & more!

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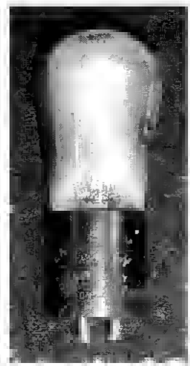
EXPERIMENTER

Substituting Rare Vacuum Tubes with Modern Varieties

Original books and reprints loaded with radio circuits dating back to the earliest days of radio are readily available. Many people dream of building one or more of these simple early circuits, but they're often discouraged if the circuit calls for a vacuum tube that is not easily found. If it *is* available, it could be very expensive. But circuits designed around rare, old tubes can be built nonetheless by substituting later, more common, and certainly cheaper tubes.

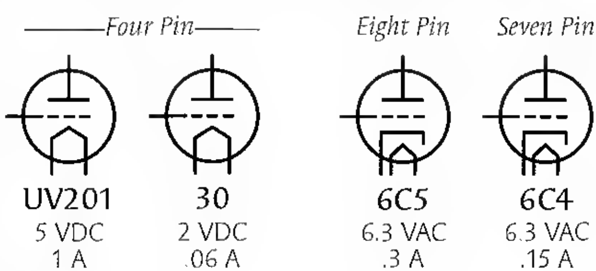
The earliest mass produced tubes had a filament, a grid, and a plate inside of a rounded glass envelope (globe shape) with a four pin (or prong) base and a small pin on the side for locking the tube into a bayonet socket.

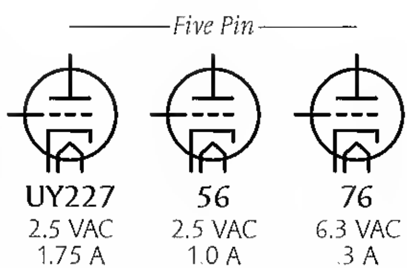
The classic tube was the 201 with a five volt filament drawing one amp for a total of five watts (five volts times one amp equals five watts) of filament power. That's a lot. Especially when you consider that the plate current drawn was usually a milliamp or two (1/1000 ampere). Heating the filament boiled off electrons that were attracted to the plate. Because early filaments were inefficient emitters of electrons, they needed a lot of power.



201A

Filaments were later coated with oxides to improve their emission of electrons and to reduce the amount of filament power needed. These improvements allowed an improved version of the 201, called the 201A, to be manufactured. It still needed five volts, but drew only one-quarter amp





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which was quite an improvement. For example, an early six-tube radio with 201's consumed six amps at five volts. You'd have to pull the six volt battery out of your car to power it. If you replaced the tubes with the new version 201A's, you needed only 6 times 1/4 amp or 1-1/2 amperes of current at 5 volts – meaning your filament battery would last much longer.

By today's standards the 201A was a poor performer with a voltage amplification factor (µ or mu) of only 8. But at the time it was the only widely available tube, and it fueled the technological revolution called radio. It is usually this tube that you find in the early circuit diagrams – diagrams that often specify no tube type at all.

Other available lower power receiving tubes of the early 1920's include the 199, 200, 202, WD11, WD12, VT1 and a few others.

All of these tubes are difficult to find. Some are almost impossible to locate. And if you're just experimenting, I think you're foolish to use them. Leave them to restorers of old radios, or at least wait until you have lots of experience in radio building before you risk damaging or destroying a early rare tube. Here, I'll give you ideas on how to use later tube types that are far more plentiful.

A couple of books that will help you understand the evolution of vacuum tubes are SAGA OF THE VACUUM TUBE by Gerald Tyne and 70 YEARS OF RADIO TUBES AND VALVES by John Stokes. Tyne's book explores tubes of the world up through 1929, whereas Stokes's book covers tubes from their beginnings until the end of their production in the late 1900's. Tubes are actively collected by historians of technology. In a few specialized periodicals such as the OLD TIMER'S BULLETIN published by American Wireless Association, you'll often find articles revealing historical details and discoveries. The early history of these "bottles" with its technological innovation and incredible patent battles makes for interesting reading.

By the late 20's, radio was a booming business, and sets of amazing variety appeared in American homes. The first radios were battery powered, but consumers didn't seem to mind too much, probably because it was a small price to pay to join in the excitement of radio in the roaring 20's. After the novelty wore off, however, and radio was considered almost a household necessity, it became obvious that radios would have to be powered by house current to eliminate the constant need to replace batteries.

UY-227

Early tubes needed direct current for their filaments to provide a steady stream of electrons. Alternating current on the filament would produce a varying stream of electrons that resulted in hum being heard in the audio output. If radios were to be powered by 110 volt AC house current and were to be inexpensive, it was obvious tube filaments would have to change.

First, filaments were coated with oxides and fed 1.5 volts AC from the power supply transformer. This was done in the 226 triode, for instance. Older power audio tubes could tolerate AC on their filaments even though they were designed for DC because the hum introduced made up only a very small part of the signal being amplified.

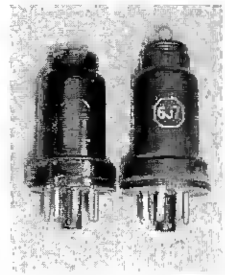
In 1927 the UY-227 was introduced. A filament powered by 2.5 volts AC heated an oxide coated, electrically insulated cylinder called a cathode. When the cathode came up to temperature, it provided a steady stream of electrons despite the fact that the filament was AC powered. This was the first in a new family of tubes, and to my way of thinking, was the first modern tube.

76

About 1930 a series of tubes was marketed with low power DC filaments – 2 volts at 60 milliamps – for battery powered receivers used in areas of the country where homes hadn't yet been electrified. The '30 was a triode that could almost directly replace the 201A (now called the '01A) because of near-identical specifications. The '30 and other members of the 2 volt family were popular with portable radio builders.

In the early 30's an improved version of the '27 was developed – the 56. Shortly thereafter the 76 appeared as a direct replacement for the 56, the only change being that the filament now needed 6.3 volts rather than 2.5 volts. The new, higher filament voltage meant that the tube could be AC powered from a power supply, or could be fired up by an automobile battery whose voltage was a convenient 6.3 volts. Separate families of battery and AC tubes were no longer necessary.

In 1935 came the next family of tubes, those whose envelopes were made of metal rather than glass and which had an eight-pin, keyed base (octal). The new 6C5 triode offered 2.5 times the voltage gain of the old '01A, and it was just the first of many high performance tubes in the family.



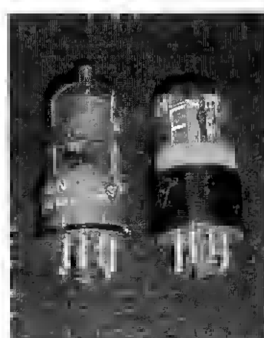
Metal octal tubes with 6 volt filaments

Despite the remarkable advances being made in the vacuum tube performance at the time, the octal 1H4G was introduced as a replacement for the '30 which had replaced the '01A. In other words, although there were better tubes available, apparently designers and builders still found a place for a tube with simple '01A specs.

Before long, tube manufacturers decided to shift back to glass envelopes, probably to save money. The majority of tube types available in metal shells were also made available in glass envelopes.

In the 1940's came the miniature tubes with 7 and 9 pins molded right into the glass envelope rather than being part of a separate base. In this family was the 6C4 triode, a 7 pin miniature.

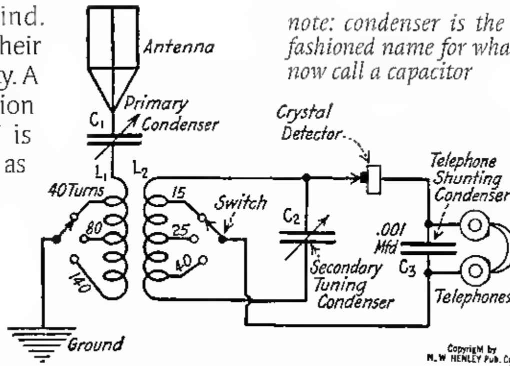
The 201A, the '30, and the



Octal base tubes designed for battery operated filaments

UY-227 are hard to find. They're out there, but their prices reflect their scarcity. A '27, a more modern version of the original UY-227 is relatively common as far as early tubes are concerned. So if you really want to use an early tube, my advice is to start with a used '27.

note: condenser is the old-fashioned name for what we now call a capacitor



Circuit 76. Method of Obtaining Greater Selectivity.

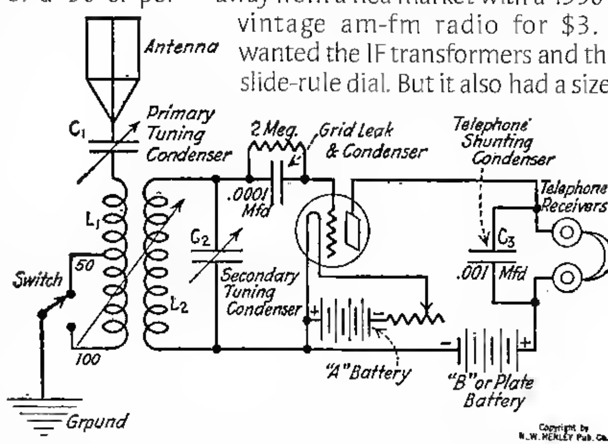
My attitude is that if you're going to experiment, then acquire the necessary tools that will make your tinkering enjoyable. Put your limited funds into tools that will allow you for years to come to turn scavenged materials into a variety of useful machines. You'll absolutely have to have a voltmeter. You'll find a variety of accurate volt-ohm-millameters at your hardware store at very reasonable prices. And you'll need some hand tools. But I think one tool you absolutely must have is a power supply – if nothing else – a small, simple one. Plans for just such a supply can be found in the pages that follow.

If you insist on using batteries, you'll need a 1H4G or a '30 or perhaps a 19 dual triode. Your choice will be limited to tubes primarily designed for batteries.

If you build a power supply with a 6.3 volt AC filament supply, you open up the world of tubes that manufactured from 1935 until transistors took over completely in the 70's. There are still hundreds of millions of six volt tubes out there, mostly used, but with plenty of life left in them waiting for you to put them back into service.

One of my favorites is the 6C5 and its cousin, the 6J5 triode. These tubes are still available brand new, in their original box, for just a few dollars. And you'll find them for 50¢ each or less at flea markets. In 1998 I passed up a big coffee can at one hamfest filled with probably thirty tubes with an asking price of $10. That's 33¢ each. They are still quite common as I write this in the year 2000.

A couple of weeks ago I came away from a flea market with a 1950's vintage am-fm radio for $3. I wanted the IF transformers and the slide-rule dial. But it also had a size-



Circuit 92. Double Circuit Vacuum Tube Receiver.

able power supply that could be pirated. In addition there was a 6SN7, almost like having two 6C5's inside a single shell, and a 6V6 power pentode waiting to be put back into service, along with other tubes. And this find is by no means unusual. Remember, solid state is superior. No debate. No argument. But most people don't appreciate older technology because they know nothing about it. So tube gear is generally unwanted and cheap. Grab it, experiment, and learn. Put your money into good tools, and recycle "junk".

So you have a 6C5 or even a 2.5 volt '27. How are you going to use it in an old circuit? It's really simple.

In the old circuits, the filament provided electrons for the circuit as well as the heat needed to generate the electron flow. The filament was part of a battery circuit that powered it, and one side (or the middle) of this power circuit was connected to the main radio circuit, usually to the common ground.

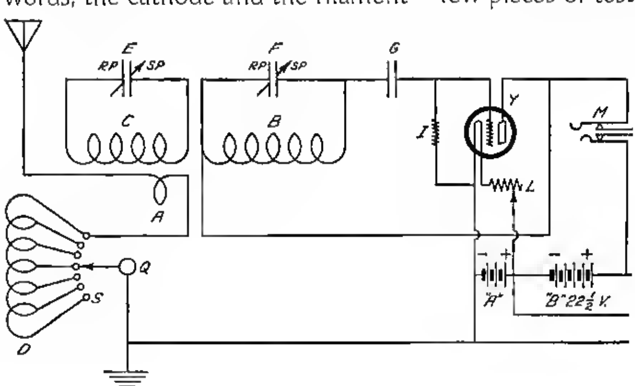
With an indirectly heated cathode-type tube, the cathode is connected to the main circuit often the ground, and the filament is connected in parallel to other tube heaters which are supplied by a 6.3 volt winding on the power transformer. In other words, the cathode and the filament really have separate jobs to do. In early tubes both tasks were performed by the filament.

Putting Newer Tubes Into Older Circuits

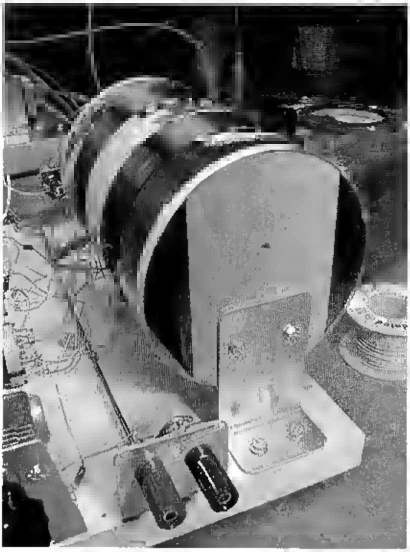
To demonstrate the idea and test modern tubes in early circuits, I decided to build a crystal set much like that of Circuit 76 from Henley's 222 Radio Circuit Diagrams from 1923. Then I could replace the semiconductor (a modern crystal) detector with a triode grid-leak detector like that of Circuit 92. And this arrangement would be similar to the circuit found on page 46 of How to Build Your Radio Receiver by Banning & Cockaday from 1924.

To build it like the old timers did, you would use an oatmeal box on which to wind the main tuning coil. But I don't eat oatmeal. Porridge ain't my thing! I'm more of a cornbread-and-a-beer-for-breakfast kind of a guy. So I used a Quaker™ cylindrical corn meal box which turned out to be 4" diameter. I close-wound 50 turns of #24 enamel wire with taps at 30, 35, 40 and 45 turns. The full 50 turns measured about 370 µh on a laboratory impedance bridge.

I assume you don't have a bridge, but you should. They are one of the few pieces of test gear I wouldn't be



Circuit found on page 46 of How to Build Your Radio Receiver *by Banning & Cockaday from 1924*



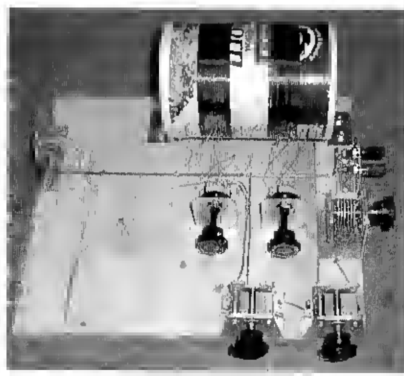
Detail showing the brackets used to mount the coil to the breadboard.

without. Perhaps, in another edition of EXPERIMENTER, I can show you how to build a very precise bridge that will allow you to measure resistance, capacitance and inductance to a high degree of precision and accuracy.

If 50 turns yields 370 µh, then what inductance would 30 turns yield, assuming ideal conditions? It's a simple calculation. Inductance varies as the square of the turns. If you double the number of turns, the inductance increases by a factor of not two, but four. Triple the turns and inductance increases by a factor of nine. Since we're looking for a fraction of the total, divide 30 by 50 to get .6, or 60%. Square it on your high-tech (thank gawd for transistors) pocket calculator to get .36 or 36%. Multiply 370 by .36 to get 133 µh.

Our lowest tap should provide about 133 µh of inductance. Now, of course, it won't be exactly that because of variations in magnetic coupling and capacitance between wires. But 133 is a good guess. Since we need about 200 µh to match up with our 365 pfd variable capacitor, one of the taps between our extremes of 133 µh and 370 µh should give us something close.

After winding the coils and coating them with clear finger nail polish at various points, I popped the ends out of the carton and glued in a couple of 1/2" thick pieces of wood whose ends had been cut in an arc to match the curvature of the cardboard cylinder. To these wooden supports I attached small aluminum brackets with steel screws. No doubt the metal changed the inductance of the coil. Steel will increase inductance slightly while aluminum will decrease it, but the coil was far away that effect was probably not great. If you're trying to



Breadboard crystal set. Dual 50 turn coils wound on Quaker™ Corn Meal Box (4" diameter) are mounted to the rear right. Immediately in front are two single-pole five position rotary switches mounted on brackets to which the coil taps are connected. To the right are binding posts and a 50 pfd variable capacitor for future experiments. At the front are two 365 pfd variable capacitors on aluminum brackets. At rear left is a 1/4" phone jack mounted on an aluminum bracket. From this bracket to the binding posts at the right runs a rigid bus bar ground.

A portion of a page reproduced from the 1929 catalog of W C Braun Company.

Braun offered sets, kits, parts and supplies to radio builders as well as tools, parts and appliances to automobile enthusiasts and homeowners.

The tubes sockets seen here are not easy to find, but it is not impossible for you to build your own. In fact, radio builders can build with only moderate effort almost any parts they need except the vacuum tubes. But a few hardy enthusiasts have set up glass shops with vacuum pumps and have even made their own tubes. I remember vaguely an illustrated article in CQ Magazine *(I believe) about an Englishman who, in the late 1950's or early 1960's, was fabricating and using his own high power transmitting vacuum tubes. It's difficult, but possible.*

Pilot Shock-Proof Socket

Cushioned on four specially tempered phosphor-bronze springs which act as shock absorbers. Eliminates vibrations. For standard UX and UY tubes. Shpg. wt., 4 oz.

3N3516 List, Ea., 50c Net

3N3516—List, each, 50c. **25c**

Pilot Insulated Socket

Insulated Socket for use on metal panel. Wiring can be done either above or below panel. Solder direct to terminals. Strong springs, short leads.

3N3517—4-prong. List, 35c. Net.......... **15c**

3N3518—5 prong. List, 40c. Net.......... **15c**

Pilot Subpanel Socket

Genuine Bakelite for use on bakelite or rubber subpanel. Drill holes and connect wires from underside of panel. Very neat connections. Will take UX, UY and UY tubes. Self-locating prong guide.

3N3519—4-prong. List, 20c. Net.............. 10c

3N3520—5-prong. List, 25c. Net.............. 15c

New Eby Socket

A very satisfactory socket for new AC sets. Has guide for the tube prongs—a simple twist of the tube in the grooved top of the socket and the prongs locate themselves. New and improved contact springs—a perfect wiping contact the full length of the tube prong. Springs will not loose tension. Easy to mount—either above or below wood, Bakelite or metal. Even though the socket is mounted on top of the panel, drilling six holes makes subpanel wiring possible. Shipping weight, 4 oz.

3N5730—UX Type 4-Prong. List, 40c. Net........................ **24c**

3N5731—UY Type 5-Prong. List, 50c. Net........................ **29c**

Molded Tube Holders

3N2074 201A Base, 22c

3N3041 UV199 Base 23c

3N3042—C11 Base 30c

3N3043—UX Base (no barrel) 18c

Fine quality. Strong and durable. Reinforced slot and screw holes. Binding post connections plainly marked make connections easy. Positive contact springs of phosphor bronze. Shpg. wt., 4 oz.

Frost Socket

Made of moulded genuine bakelite in polished maroon finish. Neat, compact design for panel or base mounting.

With Lugs and Lock Nuts on Top

3N703—4-prong tubes.

With Screws Projecting Through Bottom of Socket or Sub-base Wiring

3N704—4-prong. Shpg. wt., 4 oz. List, either type, 40c. Net.... **24c**

BUFFALO BAKELITE SOCKET

4 or 5 Prongs

Moulded of genuine bakelite. Very durable and strong. New style side swiping contacts, phosphor bronze, heavily tinned, insure positive connections with the tube prongs, thus eliminating the possibility of tube noises from poor contacts. Equipped with lugs for convenient and neat soldering connections. Takes all of the new UX type and all of the old UY type bases with the exception of the UY 199 type tube. Shpg. wt., 4 oz.

3N3226—UX for 4 prongs. Each............ **13c**

3N3227—UY for 5 prongs. Each **22c**

De Jur Shock Proof Socket

The last word in socket construction, this unit not only combines good appearance with high electrical efficiency, but is also in itself a safeguard against shocks and vibrations, which may otherwise be communicated to the delicate elements of the audion. Its use in the detector stage, or in the last R. F. stage in receivers bordering on regeneration, will eliminate to a large degree the howling caused by sound vibrations from the speaker jarring the elements of the tube. Made of genuine Molded Bakelite.

3N3228—UX 4-prong. List, 50c. Net.......... **27c**

3N3229—UY 5-prong. List, 75c. Net.......... **42c**

BENJAMIN Cle-Ra-Tune

For 4 or 5 Prongs Shock Absorbing Non-Microphonic

Have longer life and protect tubes from those sudden impacts which destroy heater, grid and plates. Positive side wiping connections. All moulded bakelite.

With Mounting Base

3N4153 — Benj. No. 9030 for UY 5-prong tubes. List, $1.00. Net.......... **59c**

With Mounting Base

3N4154 — Benj. No. 9040 for UX 4-prong tubes. List, 75c. Net........ **44c**

For Direct Panel Mounting

For attachment to either ¼ or $\frac{3}{16}$ inch panels where it is desired to have socket wiring connections below the subpanel.

3N4155—Benj. No. 9037 for UY 5-prong tubes. List, 75c. Net.................. **44c**

3N4156—Benj. No. 9044 for UX 4-prong tubes. List, 50c. Net................ **29c**

Manufacturers Sub-Panel Type

List 25c Net **12c**

You will agree this is one of the easiest sockets to mount as well as one of the most efficient on the market today. Above the panel is a black bakelite prong guide and below a piece of composition fibre to which are attached contacts.

Contacts are lead covered and have heavy spring clips to insure positive contact.

3N5732—UX Type for 4-Prong Tubes.

3N5733—UY Type for 5-Prong Tubes.

Alden Special

A neat, easily mounted socket for surface or subpanel mounting. One screw holds it in place. Single piece shell. Spring and soldering lug in one piece. Low Loss. Yellow groove aids in locating prong holes.

3N2073—List, 25c. Net........................ **15c**

Sub-Panel Socket

Genuine Bakelite socket for above subpanel use. Four small holes through which wire connections are made and one centre hole to tighten socket in place are all that is necessary to mount. Takes all UX type prong tubes.

3N4025—4-prong. Each...................... **10c**

3N4026—5-prong. Each...................... **15c**

Air-Gap Universal Sockets

3N4091—List Price, 50c. Net 29c

Air gap in sockets prevents socket capacity. Clean side swipe springs assure perfect contact. Make any circuit more stable and sharpens the tuning. Shpg. wt., 4 oz.

Socket Spring Contacts

Under panel type. Phosphor bronze contact springs. Rivet to sheet bakelite. Double contact. Side wiping type. Shpg. wt., 2 oz.

3N4214—For UX prongs. Per dozen (3 sets) 24c

100 lots...............$1.50

wind coils with the highest possible Q, try to keep all metal away from the coil. If you're new to radio building, the technology of creating high-Q coils is a science and art in itself.

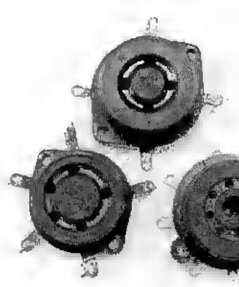
Early breadboard-mount tube sockets

To switch the circuit into the various coil taps I used modern low-cost British rotary switches available from Mouser and probably other suppliers as well. These particular switches have one wiper and 12 contacts. A convenient ring allows you to stop the movement at any point so that you can quickly change the switch into the 2, 3, 5, 8 or whatever position switch you happen to need. Here, of course, I set the ring at five to pull off four taps plus the end connection of the coil. Simple "L" brackets cut with common tin-snips from sheet aluminum and bent in a vise allowed me to mount the switches in front of the coil on a 3/4" thick piece of glued up pine board left-over from another project, but originally purchased from a home improvement store.

A pair 365 pfd capacitors and a 50 pfd unit where mounted again using simple custom brackets from scrap aluminum. They're quick and easy to make. You measure up the capacitor with a precise rule, layout the bracket with a scribe or awl on thin aluminum sheet (baker's cookie sheets were my favorite at one time), center punch the holes, and drill them. Finally you cut the bracket out with a pair of tin snips and make the bends in a vise. A file or coarse emery paper will remove rough edges, and the bracket is ready to use.

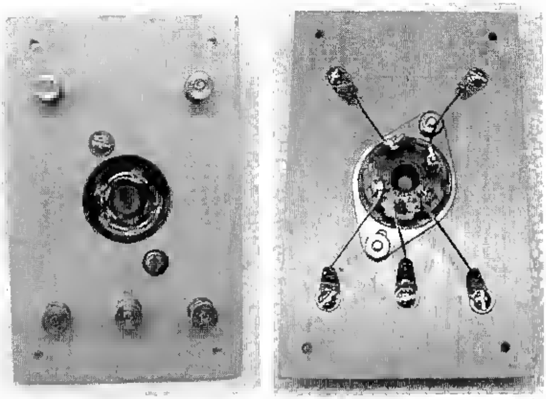
The 365's were wired to the switches in accordance with the circuits from the book. The 50pfd was mounted "just in case" I wanted to experiment with coupling between coils or the antenna or anything else. In this circuit it's unused. A couple of binding posts for antenna and ground and a 1/4" phone jack for the headphone were mounted.

The only thing left was to find a detector. I have some cat-whisker galena detectors, but I decided to use a Schottky-barrier diode, a 1N5711. I've never confirmed it, but it's supposed to even more sensitive than a germanium 1N34. It worked quite well. Two powerful local stations were easily heard and several others much fainter were heard in the background. Now I had what I wanted: a test platform to test grid-leak detectors. I had something I knew worked, and something against which I could compare the performance of a vacuum tube.



Early breadboard-mount tube sockets.

In the old days, late 20's and early 30's, you could buy five pin sockets with binding posts designed to be mounted on a breadboard. They're certainly not manufactured any more, and used ones are not



A five prong test socket was fabricated from a rectangle of 1/4" softwood. The chassis-mount socket was mounted through a hole cut with a standard 1 1/4" spade bit. Five 6-32 machine screws with brass binding post nuts (available at most hardware stores) provide easy connections to the rest of the circuit. This platform is mounted to the breadboard with 1" standoff tubes cut from 1/4" steel brakeline tubing.

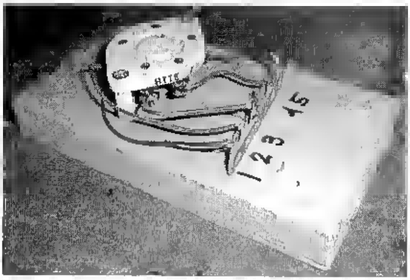
easy to find. So instead, I cut a piece 2-1/2 x 5" rectangle of 1/4" thick softwood. With a 1-1/4" spade bit I easily cut a hole in which I could mount a "modern" 5-pin porcelain tube socket originally designed to mounted to the underside of a metal chassis. In a series of 9/64" holes I mounted #6-32 x 1" machine screws with the threaded ends sticking up. I found knurled brass binding post nuts at the hardware store and screwed them onto the studs to create binding posts. Common 6-32 nuts, steel or brass, would work as well. After soldering a wire from each socket terminal to each binding post screw on the underside, the whole assembly was mounted to the radio baseboard using homemade 1" standoffs cut from a piece of steel brakeline tubing, again another hardware store item, and #8 x 1-1/2" wood screws. The result is a convenient test socket for early 5-pin tubes.

The first tube tried was an early globe '27. I used a variac-driven 2.5 volt filament transformer to heat the tube. The variac allowed me to put precisely 2.5 volts AC as measured with a meter on the filament. Too much voltage which is quite possible can pop the filament. Too little voltage can reduce the ability of the cathode to emit electrons in the future.

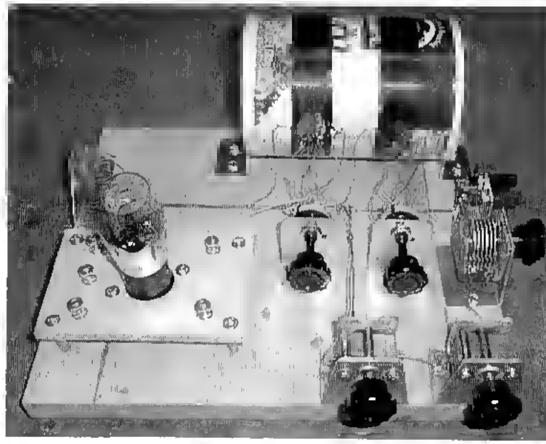
I used a more-or-less standard grid-leak pair of 2.2 megohm and 100 pfd, although for the broadcast band frequencies we are listening to, a 250 pfd is a more traditional value. In a grid-leak receiver, the adjustment of the grid-leak resistance can have a material effect on performance.

When I applied just 25 volts to the plate, I found that the 27 would draw about 1-1/2 milliamps (mA)

UY-227 being tested as a grid-leak detector



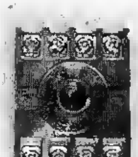
Five prong sockets can be directly mounted to a breadboard using standoffs and wood screws. Wires soldered on the socket pins are brought out to a terminal strip. 'Taint pretty, but it works very well. Porcelain five prong sockets were (and still are) used for power transmitting tubes, and are, therefore, still relatively common.



A 76 triode about to be wired up and tested as a grid-leak detector

through the headphones. And it was immediately apparent that the band was alive with stations that were barely audible with the crystal detector. Boosting the plate voltage to 47 created a plate current of 3.4 mA with only a slight boost in volume. The grid-leak pair would probably need to be optimized in order to get maximum output from the tube. Many early radio engineers studied detector circuits in detail, and their findings are quite interesting if you want to jump into the theory.

Before removing the 5-pin test base, I plugged in a 76 triode and found that 48 volts would draw about 2-3/4 mA of current.



Brand new, low cost plastic octal relay socket.

And it sounded very much like the '27.

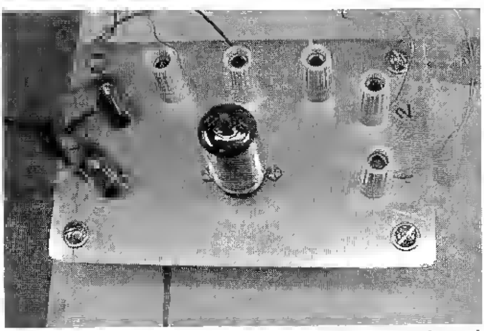
Next, I wanted to test several octal base tubes. Finding a base for this tube is easy: just order a $2 octal relay socket from a parts supplier. Each plastic socket is designed to be breadboard mounted and is equipped with eight screw terminals to make connections for the experimenter fast and easy. A 6C5 and a 6J5 metal triode

A 6C5 octal metal vacuum tube under test in a plastic relay socket.

were tried and were found to work quite nicely at low voltages. Results can be found in the table that follows.

Next, an aluminum plate was drilled to mount a 7-pin miniature socket and seven standard plastic binding posts in much the same way that the 5-pin wooden base was fabricated. It was mounted on the breadboard, and a 6C4 power triode, a 6AV6 hi-gain triode, and even a 6AU6 pentode were tried as grid-leak detectors.

If you study the circuit diagrams showing the evolution of the grid-leak detector from an early triode to a more modern triode, the differences between old and new should be apparent. As stated briefly above, the old 201A, 199 triodes and others had no cathode. To substitute in a more modern triode merely connect the indirectly heated cathode to the circuit and remove the filament battery circuitry. Bring the AC filament leads out to a separate power supply. Again, in the old tubes the filament did double duty: as a heat source and as an emitter of electrons. In modern tubes the job is divided into two: cathode as emitter, AC powered filament as heater. Just connect the cathode into the critical radio circuitry. The AC is almost a separate, lazy little electrical circuit on its own. Study the diagram. You'll see. The only unusual change is the necessity of connecting one of the filament leads to the ground of the main circuit through a .01 mfd capacitor to eliminate hum that can get into the cathode from the filament. I usually use a simple, cheap disc ceramic bypass capacitor to do the job.

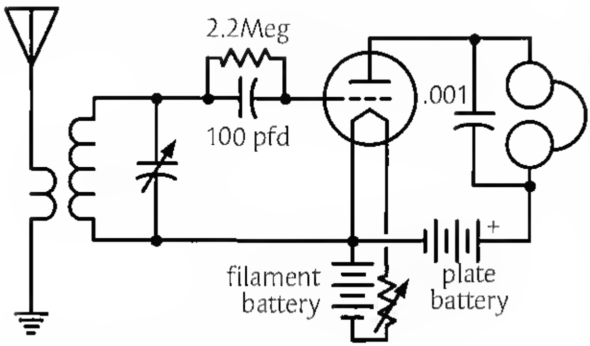


6C4 7-pin miniature triode under test in a breadboard socket similar to the 5 prong socket build earlier. Here, aluminum plate holds a standard 7 pin socket. Because the aluminum is conductive, plastic binding posts which are insulated from the plate by design were used.

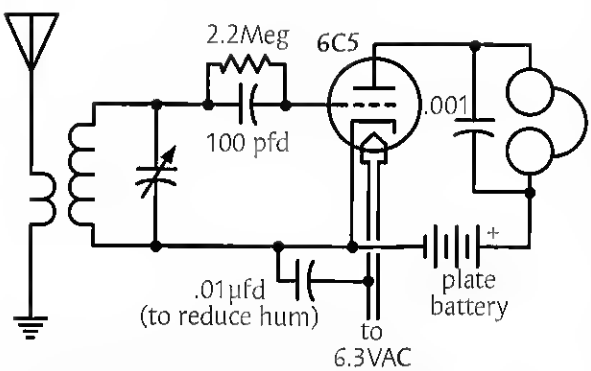
If you look at the results of the tests I ran with the tubes I happened to have on hand, you'll see that the '27 is a great substitute for a 201, and I'm sure a 56 would work very well, too. But these tubes have 2.5 volt filaments drawing heavy current. They're relatively common as old tubes go, but finding a 2.5 volt transformer may take some scrounging. Old 2.5 and 5.0 volt center-tapped transformers can be found floating around hamfests now and then. You can buy expensive new replacements, but I'm not sure they are worth it, at least not for the beginning experimenter.

What appeals to me, as I said

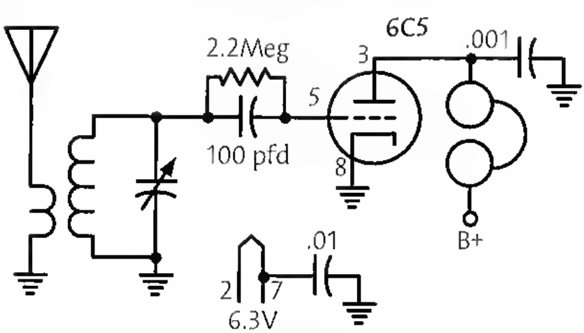
Evolution of the grid-leak detector from an early triode to a modern triode.



Original circuit with very early tubes.



Same circuit using an octal tube with the diagram drawn in the same old-fashioned way.



Same circuit as above, but drawn in a more modern fashion.

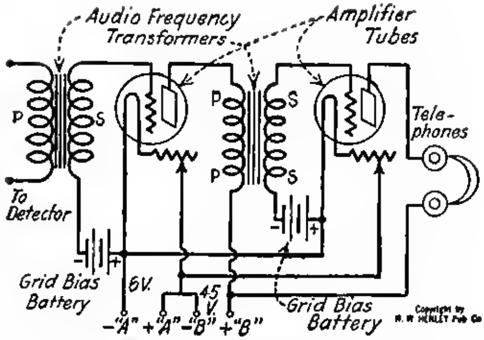
before, is the 6C5, or its improved version, the 6J5. These tubes use 6.3 volts on the filament, and they detect and amplify beautifully in a grid-leak circuit at 45 volts and even less. That means you could solder together in series five 9-volt transistor batteries to get a 45 volt battery that would easily power a single tube circuit.

A grid-leak circuit is a zero bias circuit in which the tube is always conducting to a small degree when no signal is present. When the signal comes along, it actually shuts off some of the current flow. The subtle change in audio grid voltage that is developed across the grid-leak capacitor and resistor pair and is amplified. This kind of a detector is great for very weak signals, but it can't handle large signals because they'll shut the tube off completely. It is essential that low plate voltages be used, so that, technically speaking, the signal detection occurs in the non-linear region of the characteristic curve, in other words, resulting in square-law detection. If this

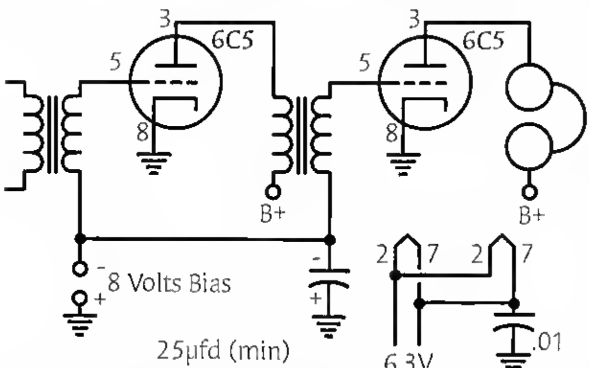
Results of Triode Grid-Leak Detector Tests

tube type	plate volts	plate current (milliamps)	observations
'27	25	1.4	clearly superior to a crystal detector (as expected) – surprising performance considering the low voltages and currents needed
	48	3.4	
76	25	1.1	comparable to the '27
	48	2.7	
6C5	25	.9	perhaps not as good the '27 probably because it was never intended for such use, but still good – nasty hum until bypass capacitor attached to a filament lead
	48	2.4	
6J5	26	.7	comparable to the 6C5, but far less of a problem with hum
	48	2.3	
6C4	48	2.7	works fairly well, but this is a power triode never intended for low voltage work. plate current approaching the maximum that 2000Ω headphones can handle
	80	5.8	
6AV6	85	.5	extremely high gain triode, not really designed for grid-leak work - lots of hum – better volume at higher voltage – but not a good choice for grid-leak applications
	144	1.5	
6J7	80	5.2	metal octal pentode – worked very nicely as grid-leak detector - would probably work even better with a high impedance load
6AU6	49	1.5	modern workhorse, high-gain miniature pentode – good audio volume output
	81	4.2	

By the time pentodes were in production and widely available, grid-leak detection had effectively been abandoned in favor of plate detection and linear diode detection. Our pentode tests here are for curiosity's sake only. We probably would have gotten much better pentode performance if we had loaded the plate with a very large audio choke (reactor) of 300 to 1000 H, as was done in the SW-3 with a S-101 coupler. Headphones offer insufficient load to a pentode plate.



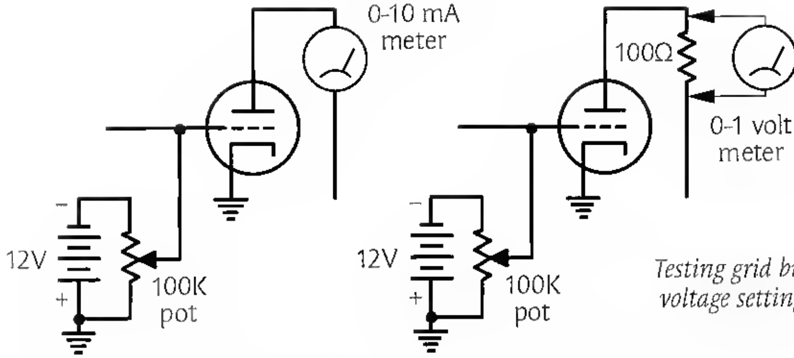
Circuit 143. Two Stage Audio Frequency Amplifier.



statement sounds like a foreign language to you, then you'll have to explore the amazing world of grid leak detectors and learn it's specialized jargon. You can use it to impress your brain-dead friends, the senile old ladies down the street, and maybe even the wino's sleeping under the bridge!

For larger signals and for amplification of audio with minimum distortion, you'll need to add negative bias voltage to the grid with a separate battery. For example, circuit no. 143 in Henley's 222 Radio Circuit Diagrams shows a simple audio amplifier using old triodes. Two grid bias batteries are shown. Also shown is the circuit redrawn with modern tubes. The cathodes of the 6C5's are grounded. The tube manuals recommend -8 volts on the grids for audio amplification. To achieve this, just put a battery of about 8 volts, perhaps five 1.5 volt penlight cells in series for a total of 7.5 volts, with the negative lead connected to the transformer secondaries and the positive side to ground. Polarity is very important here. The current drawn will be very small so the smallest batteries (like AAA) are good enough. A 9 volt transistor battery would probably work quite well, too. The only real modification from old circuit to new is to add an electrolytic capacitor as shown. I'd use 25 mfd or more. The purpose is to ensure that the maximum audio voltage is developed in the transformer secondary. A battery is supposed to look like a dead short to alternating current, but that may not happen, especially if the battery gets old and run down. The capacitor ensures that the lower end of each transformer secondary is at ground potential. In other words, it will ensure that you get maximum amplification from your circuit. The capacitor can be one scavenged from transistorized equipment. Just make sure that its working voltage is at least a little bit higher than the bias battery. If you put 7.5 volts bias in, the capacitor should have a working voltage of 12, 15 or more volts. Try something. It's not at all critical. You've got nothing to lose, and lots to gain.

If you don't know what to make the grid bias voltage, you can always run a test. You can put a milli-amme-



Testing grid bias voltage settings

ter in the plate circuit, or put a 100 ohm resistor in series with it and measure the voltage drop across the resistor with an electronic voltmeter. One milliamp of plate current will create one-tenth volt across 100 ohms (Ohms law, again). Or, in other words, if you take the voltage reading and multiply it by ten, you'll have the plate current in milliamps.

Heat up the tube and feed it plate voltage but no signal. Without any bias voltage on the grid, you should see a sizeable current flow. In fact this may be the maximum plate current flow possible in this circuit with this particular plate voltage.

Let's suppose you're using a '27 and without bias voltage you measure .9 volt across the 100 ohm resistor. That means you have 9 milliamps flowing. If you apply a negative voltage to the grid, you'll actually shut off some of that current flow. You can put a variable resistor across a 12 volt battery so that you can adjust the voltage being applied from 0 to minus 12. Just about any potentiometer from 20K to 100K will do. You can adjust the grid bias voltage until you see your meter read .45 volts. You now have 4.5 milliamps flowing in the tube without any signal. When signal is applied to the grid, the plate current will increase and decrease either side of the 4.5 milliamps. In other words the plate current can vary from 0 milliamps to 9 milliamps, a swing of ±4.5 milliamps either side of the 4.5 milliamps without signal. This is the maximum signal the tube can handle. If you know you'll be supplying a weak signal and that the current flow will vary only ±1 milliamp, then you can set the bias without signal at, say, 2 milliamps. Then the plate current swing will vary from 1 and 3 milliamps. By biasing the tube to a lower plate current by applying a higher negative grid voltage, you're shutting the tube off to a greater degree and thereby conserving your plate battery.

What you're doing in essence with this simple test is creating those fancy graphs and curves you see scattered throughout tube manuals. It's those curves that tell you how the tube behaves and how to control it. Learn what those curves mean. It's not all that difficult, and it's is a valuable tool when experimenting with tubes.

In practice you may want to be able to adjust the bias voltage and listen to changes that occur in the headphones. But a tube manual or your own experiments will indicate a good place to start.

The most important point to remember in experimenting is to provide your tube with the proper filament voltage so that you don't blow it up. Other than that, there is little damage you can do. You can't hurt the tube with the voltages that you're likely to supply. And any other component in your circuit that could be damaged is easy and inexpensive to replace. And above all, remember that if you make a mistake and something doesn't work, view it as an opportunity to learn something. The great old radio builders were never afraid to try something new.

'24A Tetrodes with original globe envelope (left) and the newer shouldered ST envelope (right)

nerable.

Physics tells us that anytime you have two conductors with a difference in voltage between them, you'll have an electric charge stored on them. This is how we define capacitance. The triode grid can hear the plate because the pair is, in fact, two different conductors at different voltages.

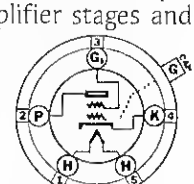
The capacitance between the control grid and the plate is a nuisance in a radio frequency circuit when the plate circuit is tuned to the same frequency as the grid circuit. Even if the coils and capacitors on the grid and plate are solidly shielded so they can't "hear" one another directly, they will still be able to "hear" one another through the capacitance that exists between the plate and grid.

Screen-Grid and Pentode Tubes

A triode is somewhat like a public address system. We all know what happens when the PA microphone "hears" the speakers too well. The system howls, squeals, breaks into oscillation. To prevent this unwanted condition which renders the PA system useless, some minor sound proofing between speakers and microphone is needed to reduce or eliminate the feedback.

If you imagine the grid of a triode to be a microphone and the plate to be the speakers, you can imagine what happens if the grid can "hear" the plate too well. You will get unwanted oscillations and howling. This frequently happens when a triode is used as an RF amplifier, either as the first tube in a receiver or as an amplifier in a superhet if amplifier chain. It can happen in more complicated tubes, but triodes are especially vul-

An early (and still effective) solution to the problem was take a small amount of the signal off the plate circuit, flip it, and put it back into the grid circuit. This reverse small current could be adjusted to cancel out the effects of the grid-plate capacitance. This cancelling out was called neutralization, and was extensively used in transmitters to prevent unwanted oscillation. Doc Haseltine went so far as to patent his receiver with multiple neutralized RF amplifier stages and call it the Neutrodyne. (This may not be the precise story. But it's something close.)



pin diagram for '24A tetrode

The real breakthrough came when, in the late

1920's, another grid was inserted between plate and grid. This "screen" grid was held at a fixed DC voltage, and provided the "sound proofing" needed to prevent the grid from "hearing" the plate. Grid to plate capacitance was reduced dramatically. For instance, in the '27 triode the grid-plate capacitance is about 3.3 pfd. But in the '24A screen-grid tube (an approximation would be to think of the 24 as a 27 with a screen grid) the grid-plate capacitance is only .007 pfd, which for the usual shortwave frequencies is essentially zero.

The tetrode – meaning four elements: cathode, grid, screen grid, plate – became an immediate hit with designers who had to build oscillation-proof RF amplifiers and intermediate-frequency (IF) amplifiers (which are lower-frequency RF amplifiers). The grid could no longer hear the plate at all!

Introducing a second grid also changed the characteristics noticeably. The transconductance (ratio of plate current to input grid voltage) of a '24 is about the same as a '27, but the plate resistance (the ratio of change of plate voltage to change of plate current) was more than fifty times higher. This meant that the '24 could provide more than 50 times as much voltage gain: just 9 for a '27, but about 525 for the '24.

But a big problem popped up. If the plate voltage was kept significantly higher than the control screen grid voltage, the tube could amplify beautifully. But should the voltage difference fall, and even worse the plate have less voltage the screen grid, weird things could and would happen. It was called negative resistance. And it could turn a beautiful signal into trash.

So solve this problem, a third grid was introduced between the screen grid and plate, and was called the suppressor grid. When the suppressor was grounded, and most are connected to the cathode inside the tube, the weird negative resistance effects disappeared. And suddenly the new five element tube – the pentode – could amplify with high gain, low distortion, and best of all, the grid couldn't hear the plate.

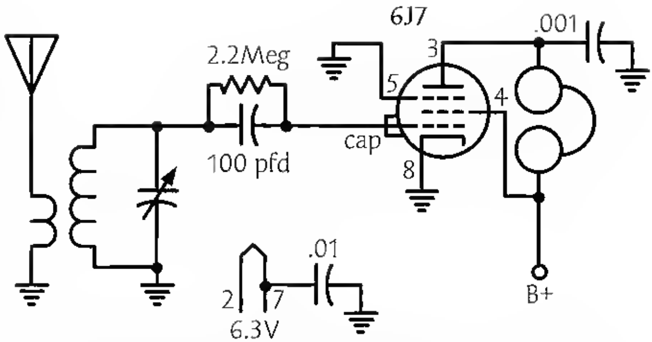
A 6-prong 6.3 VAC 6D6 Variable-mu Pentode

The early tetrodes were the 222 screen grid with a 3.3 volt DC filament followed shortly by the '24 (224, 324, etc) with its 2.5 volt AC filament. You'll find many early regenerative circuits in QST issues from the late twenties using a 222 as an RF amplifier in front of a 222 or 201A triode regenerative detector followed by a 201A audio amp stage. With the introduction of the '24 in 1929, circuits started using 24's in the front end and detector stages followed by a '27 in the audio stage.

The next tetrode introduced used a grid with special uneven spacing of the grid wires which made it possible to change the gain of the tube by adjusting the grid bias. This was called super-control, and the 34 (2 volt DC filament) and the 35 (2.5 volt AC filament) are examples. Such tubes were a dream for designers of RF amplifiers because they wouldn't oscillate, and the gain of the stage could be changed by varying the bias voltage applied to the grid.

As you dig through old circuits you'll most likely stumble across 222's, 24's, 32's, 35's, and 36's. For these tubes, there are no real later replacements. After these tetrodes were introduced development for receiver applications essentially stopped. Who needed it when you had the superior pentode?

If you want to build an early tetrode circuit, you'll find that these tubes are still available, often brand-new in their original boxes. Only the 2.5 vac filament variety, the 35, seems to be hard to find. The 36 with its 6.3 vac filament would probably be the tube of choice if you absolutely need a tetrode for use in a circuit like the dynatron oscillator (a strange oscillator based on the apparent negative resistance of a tetrode – something for you to research in old books).



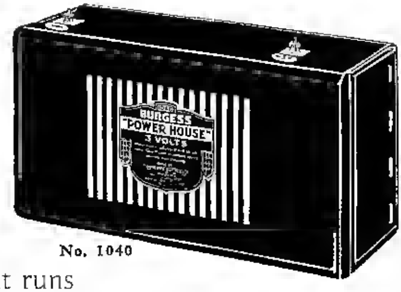
circuit used to test 6J7 pentode as grid-leak detector – good performance despite the fact that the plate load is insufficient

But if obtaining a tetrode seems like more trouble than it's worth, then you should consider the pentode. The pentode and tetrode are used in a similar manner. Because of its freedom from the negative resistance characteristic the pentode delivers better performance. Signal is put into the control grid, that is, the grid nearest the cathode. The screen grid is usually held at a fixed voltage almost equal to that of the plate. Usually a bypass capacitor from the screen grid lug on the tube socket runs directly to ground to remove any signal.

In an unusual application you may find that the screen grid may be used to mix in another signal. For instance, the control grid may get a signal from an antenna, and the screen grid gets a signal from a local oscillator. The two are mixed inside the tube to create two new frequencies, one of which becomes the intermediate frequency in a superhet receiver. You may see such circuits in early 1930's circuits where tetrodes were used as less-than-perfect mixers in superhets.

In experimenting with tetrodes or pentodes, remember that you must supply the signal to the signal grid, and that the screen grid must have a voltage on it almost as high as the plate voltage. If you reverse the roles of the grids, or fail to put any high voltage on the screen grid, the tube won't amplify. In fact, you can effectively control the tube gain by changing the voltage on the screen grid, and you'll see this very often as a way of controlling regeneration in later regenerative receivers. With voltage as high as the plate, you'll get maximum amplification. As you take the suppressor grid voltage down to 30 volts with 150 volts still on the plate, you'll find the gain drops off to almost nothing.

If you keep these basic principles in mind, you should be able to swap vacuum tubes with little trouble. You must alway remember to supply the proper filament voltages or you'll destroy the tube. Other changes in bias voltages and gain can be readily seen in tube charts and manuals. For instance, you'll see that the '24 uses high screen voltages and that the screen draws somewhat higher screen currents than the 222. That means you'll have to adjust the resistor that runs from screen to high voltage supply somewhat to get the proper voltage. A 24A has an amplification factor, μ, of 400 to 630. But a 222 provides only 125 to 270. That means a 24A will give you give you much louder signals if you attempt to use it in a 222 circuit. You may want to reduce the 24A screen voltages to reduce the gain if you find that the signal is so loud that you're getting distortion or worse.



You can substitute later pentodes for earlier ones if you provide the proper filament voltages. Differences in gain and required voltages may mean changes in the circuit for best operation, but you should find that the circuit works with almost no changes at all. About the only thing to remember in choosing a modern tube, is to remember that an old circuit that calls for a "super-control" or "variable-mu" pentode should be replaced by a "remote-cutoff" pentode. A "normal" pentode in modern terminology would be called a "sharp-cutoff" pentode.

If your circuit doesn't seem to perform well, then start measuring voltages on the pins of the tube and compare them with the tube manual. Adjust resistances to provide the proper voltages. Just about anything will work, and that's the first step. Get it working. Then you can dig into old textbooks and learn how to get the best performance from that tube.

Books You Should Acquire for Your Reference Library

Vacuum Tube References:

Almost any electronics book published prior to 1970 will teach you the basics of vacuum tubes in greater depth than I can here. One of the most important tools in building anything is to assemble a reference library so that you can profit from other people's experiences. Here are a few books that I've found helpful. A few have been reprinted, but most are available from used book dealers.

ARRL – The Radio Amateur's Handbook – almost any edition from the 1960's back to the 20's. Basic theory and application. Extensive tube specifications and basing diagrams.

Eastman, Austin V – Fundamentals of Vacuum Tubes, McGraw-Hill, several editions available (3rd edition appeared in 1949) – excellent detailed electrical engineering text covering all types of tubes with minimal math

Langford-Smith, F – Radiotron Designer's Handbook, several editions available (The 4th ed from 1953 is a monster reference worth having)

Moyer & Wostrel – Radio Receiving Tubes, 1929, somewhat of a rare book, but quite excellent reference on early tubes for the advanced experimenter

Reich, Herbert J – Theory & Applications of Electron Tubes, several editions available (2rd edition appeared in 1944) – another excellent detailed electrical engineering text covering all types of tubes with minimal math

Terman, Fred – almost any book covers basic tube theory and application – books by "Mr Radio Engineer" are common, inexpensive, and among the best published: Fundamentals of Radio 1938, Electronic & Radio Engineering 1932 through 1955, Radio Engineer's Handbook 1943, Measurements in Radio Engineering 1935, Electronic Measurments 1952

Henney, Keith – Radio Engineering Handbook – 3rd edition 1941 (common), loaded with valuable information of all types

Misc – tube manuals by RCA, GE, Sylvania and others – detailed specifications and some basic application theory – several have been reprinted for radio historians, but most are commonly available from out-of-print book dealers

Early Technical Journal Articles on Detection

A few references from my notes on detectors and the history of their development...

Electronics Magazine

- Nov 1930 – p 386 Terman: linear detection
- May 1931 – p 641 Chaffee: detection

Experimental Wireless & Wireless Engineer

- March 1929 p 135 2-29 p 71 Biedermann: Effect of Anode-Grid Capacitance in Anode-Bend Rectifiers
- November 1929 p 596 Barclay: Numerical Estimation of Grid Rectification for Small Signal Amplitudes
- 1931 vol 8 p 648 Greenwood: linear detection
- 1931 vol 8 p 424 Jackson: detection
- April 1932 p 202 Lucas: Graphical Solution of Detector Problems
- 1932 vol 9 p 384 Turner: detection
- 1933 vol 10 p 123 Beidermann: linear detection
- 1933 vol 10 p 548 Fisher: detection
- 1935 vol 12 p 17 Marique: linear detection
- November 1935 p 595 Cocking: Detector Input Circuit
- 1939 vol 16 p 330 Williams & Fairweather: linear detection

Proceedings of the Institute of Radio Engineers

- Feb 1927 vol 15 p 113 Theoretical & Experimental Investigation of Detection for Small Signals
- Feb 1928 vol 15 p113 Chaffee & Browning: Detection for Small Signals

May 1928 vol 17 p 593 Ballantine: Detection by Grid Rectification with the High-Vacuum Tube
June 1928 Vol 16 p 822 Nelson: Detection with the Four-Electrode Tube
Oct 1928 Vol 16 p 1384 Terman: Some Principles of Grid-leak Grid-condenser Detection
Jan 1929 vol 17 p 149 Terman & Googin: Detection Characteristics of Three-element Vacuum Tubes
July 1929 vol 17 p 1153 Ballantine: detection at high signal voltages
December 1930 vol 18 p 2160 Terman & Morgan: Some Properties of Grid Leak Power Detection

QST Magazine
March 1927 p 30 Cabot: Detection – Grid or Plate
July 1929 p4 3 anonymous: knowledgeable criticism of detector design in the superhet receiver design presented in March 1929

Tube Numbering System

The earliest manufacturers of vacuum tubes in the U.S. labeled their tubes with whatever name or number came to mind: a General Electric VT11, a Western Electric VT2, a deForest CF185.

When RCA was incorporated in the early 1920's to move the radio industry forward, a new nomenclature appeared. A UV tube, a UV201 for instance, had four short pins on a bayonet base. A UX tube base had a four long pins for use in bayonet or more modern friction fit sockets. Some manufacturers still went their own way creating unique bases and numbers like the Westinghouse WD11.

In 1927 the new UY base had five long pins, the "five-pronger". The first tube to use it was the UY227. The first digit denoted manufacturer: a UY201 from RCA, a UY301 from Cunningham, a UY401 from deForest – all were exactly the same tube.

About 1932 it became apparent that new vacuum tubes would need more pins. All the prefix nonsense was dropped in favor of an industry-wide standard number. Tubes were manufactured with 5, 6 or 7 prong bases, and sported numbers like 36, 57, or 78. The old numbers such as UY227 or UY224A were now called '27 or '24A.

In 1935 with the introduction of metal shell tubes, a new octal basing system was introduced along with a new numbering system. The first digit revealed filament voltage, and the last digit was a count of electrode leads. For instance the 6C5, was a 6.3 volt filament triode with 5 elements: 2 filament leads, a plate, a grid, and a cathode. Some tubes like the 6F5 also had a grid connection on their top as far away from the base as possible. Later versions of the same tube brought the grid out through a pin on the base, making it a "single ended" tube. The 6F5 was doubled ended, but an "S" was added so that the single ended variety was known as 6SF5.

In scrounging for old tubes, keep these changes in mind. A UV201A is the same as a UV301A which is the same as a '01A. The different types may have different envelope shapes, but they're essentially the same tube.

TABLE I.—RADIO RECEIVING TUBE AVERAGE CHARACTERISTICS
Reference footnotes are at end of table (page 69)

Tube	Use	Filament amperes	Plate, volts	Plate, milliamperes	Negative grid bias, volts		Plate resistance, ohms	Mutual conductance, micromhos	Amplification factor	Screen voltage, volts	Power output, milliwatts	Load impedance, ohms
					D.C. on fil.	A.C. on fil.						
1.1-volt direct-current filament detector and amplifier tubes												
WD11*	Det. ampl.[a]	0.25	90	2.5	4.5	....	15,500	425	6.6			
		0.25	135	3.0	10.5	....	15,000	440	6.6			
WD12*	Det. ampl.[a]	0.25	90	2.5	4.5	....	15.500	425	6.6			
		0.25	135	3.0	10.5	....	15,000	440	6.6			
864*	Det. ampl.[a]	0.25	90	2.5	4.5	....	15,500	425	6.6	Identical with WD11 and WD12, except that 864 is a non-microphonic tube		
1.5-volt alternating- or direct-current filament amplifier tube												
26*	Ampl.	1.05	135	5.5	9.0	10.0	7,600	1,100	8.3	.....	80.0	8,800
2-volt direct-current filament detector and amplifier tubes												
15†	Det.-osc.	0.22	135	1.85	1.5	....	800,000	625	500	67.5		
30*	Det. ampl.[a]	0.06	90	2.5	4.5	....	11,000	850				
		0.06	180	3.1	13.5	....	10,300	900	9.3			
32*	Biased det. R.-F. ampl.	0.06	174[b]	.....[c]	3.0	....	....	......	....	67.5		
		0.06	180	1.7	6.0	....	1,200,000	650	780	67.5		
34*	Variable mu	0.06	135	2.8	3.0	....	600,000	600	360	67.5		
2-volt direct-current filament power amplifier tubes												
19*	Pow. ampl. class B	0.26	135	27.0[l]	0	....	....	......	....	.....	2,100	10,000[m]
31*	Power ampl.	0.130	135	8.0	22.5	....	4,100	925	....	.....	185	7,000
		0.130	180	12.3	30.0	....	3,600	1,050	3.8	.....	375	5,700
33*	Power ampl.	0.26	135	14.5	13.5	....	50,000	1,450	70.0	135	700	7,000
49*	Power ampl. Class A	0.12	135	6.0	20.0	....	4,000	1,125	4.5	.....	170	8,000
	Power ampl. Class B	0.12	180	4–28	0	....	....	......	....	.....	3,000	9,000

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RADIO CONSTRUCTION AND REPAIRING
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2.5-volt alternating- or direct-current filament detector and amplifier tubes

24A†	Biased det. R.-F. ampl.	1.75	275[d]	....[c]	5.0	5.0	....	......	....	20–45		
		1.75	180	4.0	3.0	3.0	40,000	1,000	400	90.0	....	100,000
27†	Ampl.	1.75	180	5.0	13.5	13.5	9,000	1,000	9.0	.....	165	18,700
27†	Biased det.[a]	1.75	250[f]	....[c]	30.0	30.0						
29†	Det.	1.00	180	4.5	3.0	....	20,700	1,450	30.0			
35†	Variable mu	1.75	250	6.5	3.0	3.0	350,000	1,050	370	90.0		
51†	Variable mu ampl.	1.75	250	6.3	3.0	3.0	360,000	1,110	400	90.0		
53†	Class B ampl.	2.0	300	12–70	0	....	....	......	....	.....	10,000	10,000
55†	Diode triode	1.0	250	8.0	20.0	20.0	7,500	1,100	8.3	.....	200	20,000
56†	Biased det.[a] ampl.	1.0	250[f]	....[c]								
		1.0	250	5.0	20.0	20.0	9,500	1,450	13.8			
57†	R.-F. ampl. biased det.	1.0	250	2.0	3.0	3.0	1,500,000	1,225	1,500	100		
		1.0	275[d]	....[e]	6.0	6.0	....	......	....	.....	....	250,000
58†	Variable mu	1.0	250	8.2	3.0	3.0	800,000	1,600	1,280	100		
90†	2-grid detector	1.0	250	3.5	0	....	10,000	1,400	14.0	.....	....	100,000
2A7†	Pentagrid det.-osc.	0.8	250	4.0	3.0	....	300,000	475[n]	....	100	Anode grid, 250 volts	
2B7†	Duplex diode pentode	0.8	250	6.0	3.0	....	800,000	1,000	800	100		

2.5-volt alternating- or direct-current filament power amplifier tubes

45*	Power ampl.	1.5	250	34.0	48.5	50.0	1,750	2,000	3.5	.....	1,600	3,900
46*	Class A ampl.[g]	1.75	250	22.0	31.5	33.0	2,380	2,350	5.6	.....	1,250	6,400
	Class B ampl.[h]	1.75	300	8–70	0.0	0.0	....	......	....	.....	16,000	1,300
		1.75	400	12–75	0.0	0.0	....	......	....	.....	20,000[i]	1,450[j]
47*	Power pentode	1.75	250	31.0	15.0	16.5	60,000	2,500	150	250	2,500	7,000
59†	3-grid pow. ampl. Class A triode	2.0	250	30.0	28	....	2,200	2,750	6.0	.....	1,250	5,000
	Class A pentode	2.0	250	35.0	18	....	40,000	2,500	100	250	2,500	7,000
	Class B triode	2.0	400	30–75	0	....	....	......	....	.....	20,000	6,000
2A3*	Triode power ampl. class A	2.5	250	60.0	42	42.0	765	5,500	4.2	.....	3.5	2,500
95	Power ampl. pentode	1.75	250	34.0	16.5	16.5	100,000	2,200	220	250	3.0	7,000
2A5†												

3-volt filament detector and amplifier tubes

401* d.c.	Det. ampl.	1.5	90	4.2	4.5	....	9,400	870	8.6			
485† a.c.	Det. ampl.	1.25	90	5.0	3.0	....	10,800	1,150	12.5			
		1.25	120	6.0	4.0	....	9,300	1,350	12.5			

TABLE I.—RADIO RECEIVING TUBE AVERAGE CHARACTERISTICS.—(*Continued*)

Tube	Use	Filament amperes	Plate, volts	Plate, milliamperes	Negative grid bias, volts: D.C. on fil.	Negative grid bias, volts: A.C. on fil.	Plate resistance, ohms	Mutual conductance, micromhos	Amplification factor	Screen voltage, volts	Power output, milliwatts	Load impedance, ohms
						3.3-volt direct-current filament detector and amplifier tubes						
22*	R.-F. ampl.	0.132	135	3.3	1.5	....	600,000	480	290	67.5		
	A.-F. ampl.		180[k]	0.3	0.75	....	2,000,000	170	350	22.5		
99*	Det.[a] ampl.	0.063	45	1.5	+A	....	17,000	370	6.6			
			90	2.5	4.5	....	15,500	425	6.6	.....	7.0	15,500
						3.3-volt direct-current filament power amplifier						
20*	Power ampl.	0.132	135	6.5	22.5	....	6,300	525	3.3	.....	110	6,500
						5-volt direct-current filament detector and amplifier tubes						
90A*	Det.	0.25	45	1.5	−A	....	30,000	666	20.0			
01A*	Det.[a] ampl.	0.25	90	2.5	4.5	....	11,000	725	8.0	.....	15.0	11,000
		0.25	135	3.0	9.0	....	10,000	800	8.0	.....	55.0	20,000
12A*	Det.[a] ampl.	0.25	90	5.2	4.5	....	5,600	1,500	8.5	.....	30.0	5,600
		0.25	135	6.2	9.0	....	5,300	1,600	8.5	.....	115	8,700
		0.25	180	7.6	13.5	....	5,000	1,700	8.5	.....	260	10,800
40*	Voltage ampl.	0.25	180[k]	0.2	3.0	....	150,000	200	30.0	.....	....	250,000
						5-volt alternating- or direct-current filament power amplifiers						
71A*	Power ampl.	0.25	180	20.0	40.5	43.0	1,850	1,620	3.0	.....	700	5,350
GA*	Power pentode	0.25	180	25.0	10.0	....	30,000	2,000	60.0	180	800	7,000
182B*	Power ampl.	1.25	200	20.0	45.0	....	2,000	1,500	3.0			
183*	Power ampl.	1.25	250	26.0	65.0	....	1,500	2,000	3.0			

6.3-volt alternating- or direct-current filament detector and amplifier tubes

36†	R.-F. ampl.	0.3	180	3.1	3.0	....	350,000	1,050	370	90.0		
	Biased det.	0.3	135[d]	....[e]	6.0	....	....	......	....	67.5		
37†	Ampl.	0.3	180	4.7	13.5	....	10,000	900	9.0	.....	75.0	20,000
	Biased det.[a]	0.3	135	....[c]	15.5							
39†	Variable mu	0.3	180	4.5	3.0	....	750,000	1,000	750	90.0		
69†	Det.	0.30	180	4.5	3.0	....	20,700	1,450	30.0			
75†	Duplex diode triode	0.3	250	0.8	2.0	....	91,000	1,100	100			
77†	R.-F. pentode	0.3	250	2.3	3.0	....	1,500,000	1,250	1,500	100		
78†	R.-F. ampl.	0.3	250	10.5	3.0	....	600,000	1,450	990	125		
85†	Duplex diode triode	0.3	180	6.5	12.0	....	9,000	1,000	9.0	.....	100	20,000
92†	2-grid det.	0.4	250	3.5	0	....	10,000	1,400	14.0	.....	....	100,000
6A7†	Pentagrid det.-osc.	0.8	250	4.0	3.0	....	300,000	475[n]	....	100	Anode grid, 250 volts	
6B7†	Duplex diode pentode	0.3	250	6.0	3.0	....	800,000	1,000	800	100		

6.3-volt alternating- or direct-current filament power amplifier tubes

38†	Power ampl.	0.30	135	9.0	13.5	....	102,000	975	100	135	525	13,500
41†	Power pentode	0.60	167.5	17.0	12.5	....	120,000	1,800	215	167.5	1,200	11,000
42†	Power pentode	0.65	250	34	16.5	....	100,000	2,200	220	250	3,000	9,000
44†	R.-F. ampl.	0.3	180	6.4	3.0	....	410,000	1,050	430	90.0		
52*	Power ampl. Class A	0.3	100	42.0	0	....	....	......	5.0	.....	1,500	2,000
	Power ampl. Class B		180	6–40	0	....	....	......	......	.....	6,000	9,000
79†	Class B ampl.	0.6	180	44.0[l]	0	....	....	......	......	.....	5,500	10,000[m]
89†	Class A triode	0.4	160	17.0	20.0	....	3,000	1,570	4.7	.....	300	7,000
	Class A pentode		180	20.0	18.0	....	82,500	1,635	135	180	1,500	8,000
	Class B triode		180	6–50	0	....	....	......	......	.....	6,000	9,000
LA*	Power ampl.	0.3	135	12.0	9.0	....	53,000	1,900	100	135	700	9,500

7.5-volt alternating- or direct-current filament power amplifier tubes

10*	Power ampl.	1.25	350	16.0	27.0	31.0	5,150	1,550	8.0	.....	900	11,000
		1.25	425	18.0	35.0	39.0	5,000	1,600	8.0	.....	1,600	10,200
50*	Power ampl.	1.25	350	45.0	59.0	63.0	1,900	2,000	3.8	.....	2,400	4,100
		1.25	450	55.0	80.0	84.0	1,800	2,100	3.8	.....	4,600	4,350

14-volt direct-current filament power amplifier tubes

18†	Power pentode	0.3	250	34.0	16.5	....	100,000	2,200	220	250	3,000	7,000

TABLE I.—RADIO RECEIVING TUBE AVERAGE CHARACTERISTICS.—(*Continued*)

Tube	Use	Filament amperes	Plate, volts	Plate, milliamperes	Negative grid bias, volts		Plate resistance, ohms	Mutual conductance, micromhos	Amplification factor	Screen voltage, volts	Power output, milliwatts	Load impedance, ohms
					D.C. on fil.	A.C. on fil.						
15-volt alternating-current filament detector and amplifier tubes												
22†	R.-F. ampl.	0.35	135	1.0	....	1.0	700,000	570	400	30.0		
26†	Det.	0.35	90	7.5	....	1.5	9,000	1,165	10.5			
28†	Det. ampl.	0.35	90	7.5	....	1.5	9,000	1,165	10.5			
32†	Voltage ampl.	0.35	135	1.5	....	3.0	32,000	940	30.0			
48†	Det. ampl.	0.35	90	4.5	....	4.5	9,200	1,185	10.9			
15-volt alternating-current filament power amplifier tubes												
30†	Power ampl.	0.35	180	22.0	....	27.0	3,500	1,085	3.8			
40†	Power ampl.	0.35	180	21.0	....	40.5	2,000	1,500	3.0			
25-volt alternating- or direct-current filament power amplifier tubes												
43†	Power pentode	0.3	135	34.0	20.0	....	35,000	2,300	80.0	135	2,000	4,500
30-volt alternating- or direct-current filament power amplifier tubes												
48†	Power ampl. tetrode	0.4	125	50.0	22.5	....	10,000	2,800	28.0	100	2,500	2,000

Rectifier Tubes

Tube	Use	Maximum voltage ratings: Filament volts	Maximum voltage ratings: R.M.S. volts per plate	Maximum voltage ratings: Max. peak inverse volts	Maximum voltage ratings: D.C. drop volts	Current ratings: Fil. amperes	Current ratings: Average output, milli-amperes	Current ratings: Max. peak, milliamperes
	2.5-volt alternating-current filament rectifier tubes							
82*	Full-wave mercury vapor.........	2.5	500	1,400	15	3.0	125	400
866*	Half-wave mercury vapor.........	2.5	...	7,500	..	5.0	...	600
	5-volt alternating-current filament rectifier tubes							
80*	Full wave......................	5.0	450	.....	..	2.0	125	
80M*	Full-wave mercury vapor.........	5.0	450	1,250	15	2.0	125	250
83*	Full-wave mercury vapor.........	5.0	500	1,400	15	3.0	250	800
5Z3†	Full wave......................	5.0	500	1,500	..	3.0	250	
	6.3-volt direct-current filament rectifier tubes							
6Z3†	Half wave......................	6.3	350	1,500	..	0.3	50	
	6.3-volt alternating- or direct-current filament rectifier tubes							
1†	Half-wave mercury vapor.........	6.3	350	1,500	15	0.3	50	200
84† / 6Z4	Full wave......................	6.3	225	.....	..	0.5	50	125 per plate
98†	Full-wave mercury vapor.........	6.3	350	1,500	15	0.5	50	100
	7.5-volt alternating-current filament rectifier tubes							
81*	Half wave......................	7.5	700	.....	..	1.25	85	
81M*	Half-wave mercury vapor.........	7.5	750	1,050	15	1.25	85	175

RECTIFIER TUBES.—(*Continued*)

Tube	Use	Maximum voltage ratings				Current ratings		
		Filament volts	R.M.S. volts per plate	Max. peak inverse volts	D.C. drop volts	Fil. amperes	Average output, milli-amperes	Max. peak, milliamperes
10-volt alternating- or direct-current filament rectifier tubes								
96†	Half-wave mercury vapor........	10.0	350	1,500	15	0.3	100	400
12-volt direct-current filament rectifier tubes								
12Z3†	Half wave....................	12.0	350	.....	..	0.3	50	
25-volt alternating- or direct-current filament rectifier tubes								
25Z5*	Full wave....................	25.0	125	.....	..	0.3	100	200 per plate
Gaseous-type rectifier tubes—no filament								
BA	Full wave....................	....	...	350	..	....	...	350
BH	Full wave....................	....	...	350	..	....	...	125
BR	Half wave....................	....	...	600	..	....	...	50

REGULATOR TUBES (GLOW DISCHARGE TYPE)

Type	Use	Voltage		Current	
		Starting volts D.C.	Operating volts D.C.	Operating milli-amperes D.C.	Maximum milli-amperes D.C.
874	Volt reg.	125	90	10–50	50
		Current regulator (ballast tube)			
876	Current reg.	...	40–60	1,700	
886	Current reg.	...	40–60	2,050	

* Filament cathode.
† Heater cathode.
[a] For grid-leak detection—plate volts 45, grid return to + filament.
[b] Applied through plate-coupling resistance of 100,000 ohms.
[c] Plate current to be adjusted to 0.2 milliampere with no signal.
[d] Applied through plate-coupling resistance of 250,000 ohms or 500-henry choke coil shunted by 0.25 megohm resistance.
[e] Plate current to be adjusted to 0.1 milliampere with no signal.
[f] Applied through plate-coupling resistance of 50,000 ohms.
[g] Grid next to plate tied to plate.
[h] Two grids tied together.
[i] For two tubes with 40 volts R.M.S. applied to each grid.
[j] Load resistance per tube.
[k] Applied through plate-coupling resistance of 250,000 ohms.
[l] 50 volts R.M.S. applied to two grids.
[m] Plate to plate.
[n] This value is the conversion conductance which is the ratio of the I.-F. component of the output current to the R.-F. component of the signal voltage.

General Types of Radio Tubes. — The following tabular grouping of the various tubes according to construction serves to bring out their distinguishing features:

Two-element tubes (diodes):
- Gaseous rectifier — types 82, Raytheon.
- Vacuum rectifier — types 80, 81.
- Hot-cathode mercury-vapor rectifier.

Three-element tubes (triodes):
- Detectors.
- Amplifiers.
- Power output.
- Power oscillators.
- Alternating-current tubes.
- Low voltage, high current —type 226.
- Separate heater—type 227.

Four-element tubes (tetrodes):
- Screen-grid types.

Five-element tubes (pentodes):
- Pentodes and combinations.
  - Duplex diodes.
  - Duplex triodes.

The following descriptions consider, first, the construction features of the principal types of tubes developed recently, and, secondly, their applications. Most of the new tubes are based either on the variable mu or on the pentode type.

CONSTRUCTION FEATURES

Tetrode or Screen-grid Tube. – In a tetrode tube, also called a four-electrode, four-element tube, or a screen-grid tube, a fourth electrode or screen is placed in the tube between the plate and grid. This type of construction is used to eliminate as much as possible the grid-to-plate capacity inside the tube which is the cause of excess regeneration or feed-back. As a result, intricate circuits and balancing difficulties are largely eliminated. In addition the reduction of the internal grid-to-plate capacity permits the attainment of a degree of amplification which is many times that possible from three element tubes. Screen-grid or tetrode tubes are represented by types 24A, 32, and 35.

Super-control Amplifier or Variable-mu Tube. – This tube is a modified form of the screen-grid type and is intended to decrease the cross-talk and cross-modulation which appear in the radio-frequency amplifying stages of a radio receiver. Cross-talk and cross-modulation result when an interfering signal comes in on the carrier wave to which the receiver is tuned because the radio-frequency amplifying tubes act partly as detectors when a very strong signal is received or when volume is reduced by increasing the grid-bias voltage.

The distinguishing characteristic of the variable-mu tube is its ability to operate with minimum distortion over a wide range on either large or small input voltages. This characteristic is obtained by designing the tube so that its amplification factor varies with a change in grid-bias voltage. The control grid, in this tube, is of the usual wire-coil type but is wound with the turns close together at the ends of the coil and spaced farther apart at the middle. On weak signals and low grid-bias voltages the tube shows characteristics essentially the same as if the control-grid wire turns were spaced uniformly. At large values of grid-bias voltage, however, the plate current is greater and decreases less rapidly than in the usual screen-grid type of tube under the same conditions of operation, this effect being due chiefly to the coarse winding of the grid. Because of this relation between plate current and grid voltage the tube is suited for operation over a wide range of input voltage, particularly in receivers provided with automatic volume control. Variable-mu tubes are represented by types 34, 35, 39, 51, and 58. (See also Pentodes.)

Class A Amplifier. – This is an amplifier in which the grid bias voltage and the grid-signal voltage are at such values that the flow of plate current is continuous. A class A amplifier has low efficiency and a low output capacity.

Class B Power-amplifier Tubes. – In class B amplification the tube is grid-biased in such a way that with no grid excitation the plate current is reduced almost to zero. As a result, the plate current ceases during much of the negative half cycle when a signal voltage is applied, flowing only on the least negative swings of the signal voltage. If a single tube is operated under these conditions, the output will show harmonic distortion; but, if two tubes are operated in a balanced pushpull circuit, certain harmonic distortion is eliminated almost entirely. The distortion present in the output, however, is always higher for the usual range of signal voltage than that produced by the usual audio amplifier operated with tubes having the same maximum power-output rating. In addition, the power supply unit must be designed for satisfactory voltage regulation under wide variation of plate current. The outstanding advantage of the class B amplifier is its capacity to deliver the power necessary for an extended volume range. Tubes which can be used for class B audio-power amplifier service are represented by types 46, 49, 52, 59, and 89. A class B amplifier has medium efficiency and a medium output capacity.

Class C Amplifier. – This is an amplifier in which the tube is operated with the grid-bias voltage beyond the cut-off value. The plate current then is zero when no signal voltage is applied to the grid. Even when a signal-grid voltage is applied, the plate current-flows for less than one-half of each cycle. A class C amplifier has high efficiency and a high output capacity.

Pentodes. – In any radio tube an electron traveling at high speed may knock off other electrons when it hits the plate. These free electrons eventually are attracted back to the plate, in a two- or three-element tube, because there is no other positive element. In a screen-grid tube, however, the positive screen may attract the free electrons, particularly when the plate voltage is momentarily less than the screen voltage. Such attraction reduces the plate current. As a result, the amount by which the plate current can be reduced is limited considerably. The remedy for this condition is found in the insertion of a *fifth electrode*, called a *suppressor grid*, between the screen and the plate, the suppressor grid generally being connected to the cathode. Because of this connection the suppressor grid is negative with respect to the plate and hence serves to repel the free electrons toward the plate.

At the present time the effect of the suppressor grid in pentode tubes is utilized in several different ways. In pentodes of such types as 34 and 39, intended for radio-frequency amplification, the suppressor is connected inside the glass bulb to the filament. The action of the suppressor eliminates the effect of free electrons in limiting the allowable voltage variation at low levels of plate voltage. That is, the tube can be operated to give high voltage amplification at values of plate voltages which are relatively low and may even be less than the screen voltage.

In pentodes, such as types 33, 38, and 47, intended for power output services, the suppressor is connected inside the bulb to the filament. The action of the suppressor eliminates the effect of free electrons in limiting the power output. Thus a large power output with high gain may be obtained, because the allowable variation in plate voltage is greater. In some types both a suppressor and a screen are inserted between the grid and plate.

In pentodes such as types 57 and 58 the suppressor is provided with a separate base-pin terminal. With this construction, special control effects are available by varying the voltage impressed on the suppressor; for example, obtaining reduced selectivity for local reception.

Spray-shield Tubes. – The standard method of shielding a radio tube consists in isolating the tube within a metal can or compartment. In an effort to overcome the disadvantages of such a combination of tube and can, the spray-shield tube, in which the shield is part of the tube itself, was developed. The shield consists of metallic zinc and is applied to the outside of the glass bulb by blowing zinc vapor against the glass. This type of tube is manufactured exclusively by the Grigsby Grunow Company for use in Majestic receivers.

APPLICATIONS OF TUBES

Radio-frequency Amplifier and Detector Tubes. – The tubes in this group may be classified as variable-mu and pentode, pentode, and triode. In the variable-mu and pentode class are the types 34, 39, 44, and 58; types 15 and 57 are pentodes; and type 56 is a triode.

Type 34 is a variable-mu radio-frequency pentode designed for operation in 2-volt battery receivers. Types 39 and 44 are variable-mu radio-frequency pentodes differing chiefly from each other in that type 44 has a wider cut-off or greater range of extended control. Type 58 is a variable-mu radio-frequency pentode having the suppressor grid brought out to a separate base pin. Type 15 is an indirectly heated radio-frequency pentode for service as a detector oscillator in battery-operated receivers. Type 57 is a sharp cut-off radio frequency pentode with a separate external connection for the suppressor grid. Type 56 is a triode having high mutual conductance. The heaters of types 56, 57, and 58 are designed for low wattage, requiring one ampere of alternating current at 2.5 volts.

Special Detector Tubes. – In this class are types 55, 75, and 85. These tubes are similar in construction, consisting of a set of triode elements – that is, grid, cathode, and plate – with two auxiliary collectors around the cathode, which can be used as either half-wave or full-wave rectifiers. Because of this construction the tube is called a duo-diode-triode. With a tube of this type it is possible to obtain separately the functions of rectification, automatic volume control, and triode. amplification from one tube. When sufficient radio-frequency voltage is supplied to the diode portion, enough rectified voltage is delivered for the control of radio-frequency amplifying tubes of the variable-mu type in the radio-frequency amplifier. Type 75 is a double-diode high-mu triode suitable for use as a diode detector and a triode amplifier with an amplification factor of 100.

Types 2B7 and 6B7 are duplex-diode pentodes, identical except for the heater rating. The two diode units are not connected with each other or with the pentode unit except for the cathode sleeve which is common to all. The diode units by their rectifier or detector action can supply signal voltage to the pentode unit, and also to the radio-frequency or intermediate-frequency stages for the regulation of the voltage amplification, to maintain a constant carrier-wave voltage input at the detector.

Types 2A7 and 6A7 are pentagrid converters, identical except for the heater rating. These tubes are made with five grids, number one being the oscillator grid, number two the anode grid, numbers three and five the screen grids connected together, and number four the control grid. The tube is intended for use as a detector oscillator to provide an oscillator output which is uniform over a wide range of grid-bias values.

Power-amplifier Tubes. – The tubes in this group may be classified as pentode, class B, combination, and triode. In the pentode class are types 33, 38, 41, 42, 43, 48, LA, and 2A5. Class B includes types 19, 46, 49, 52, and 79. The combination tubes are types 59 and 89. The triode tube is type 2A3.

Type 33 is designed for use as a power amplifier in the output stage of battery-operated receivers and can produce a greater power output than a three-electrode power amplifier having the same plate current.

The chief differences among the pentode types 38, 41, 42, and LA are power output and power sensitivity. In the case of power sensitivity where plate current need not be considered, the control grid-bias voltage may be taken as an index of the power sensitivity when compared with the power output obtainable. That is, for tubes having comparable power outputs, the tube having the lowest grid bias would have the highest power sensitivity. These tubes, except type LA, are provided with indirectly heated cathodes. Types 43 and 48 are power-output pentodes of the indirectly heated cathode type, designed primarily to give large power outputs at low plate voltages, as in 110-volt direct-current radio receivers. Type 2A5 (type 95) is a power amplifier with an indirect heater, for use in the audio-output stage of alternating-current receivers employing a pentode-power stage. As a class A power amplifier the tube can be used either singly or in push-pull combination. It is capable of large power output with a relatively small input-signal voltage.

Type 19 is a class B tube containing two triode elements designed for a small grid-bias voltage to accommodate a range of plate voltages and to secure maximum efficiency by reduction of input-grid power; it can be used as a "driver" with tube type 30. Type 46 is a filament tube having the control grid and screen grid brought out to separate base pins. For zero-bias voltage in class B operation the two grids are connected together to serve as a control grid. If the screen grid is connected to the plate this tube may be used as a triode "driver" for a stage of class B amplification. The construction of tube type 49 is similar to that of the other class tubes except that the filament is rated at 2 volts.

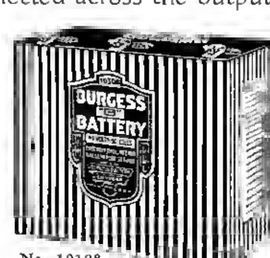
Type 52 is similar to type 46, except that it is in a different filament-voltage section. Type 79 is a class B output tube, with an indirectly heated cathode, consisting of two sets of class B elements in one glass envelope; consequently it functions as a stage of class B tubes.

Type 59 is an indirectly heated power-output tube having the control grid, screen grid, and suppressor grid brought out to separate base pins. By means of these separate connections the tube can be used as a class A power-pentode output tube, a triode-driver tube for class B amplification, or as a class B tube. As a class A pentode the suppressor grid should be connected to the cathode externally. As a triode the screen and suppressor grids are connected to the plate externally. For zero-bias class B operation the control and screen grids are connected together externally and serve as the control grid, the suppressor grid being connected externally to the plate. Type 89 is similar to type 59 except that it is in a different filament-voltage section.

Type 2A3 is a class A triode amplifier provided with a large number of coated filaments arranged in series-parallel combination to give a large cathode area, which results in unusually high mutual conductance and low plate resistance. As a straight class A amplifier, one type 2A3 tube is the equivalent in power output of two type 45 tubes.

Rectifier Tubes. – Types 82 and 83 are mercury-vapor rectifiers having filament cathodes. These tubes have a low internal voltage drop and the ability to handle the large 'peak currents required by class B amplifiers. The chief difference between the two types, aside from the filament voltage, is that type 83 will deliver approximately twice as much current as type 82.

Type 1 is a half-wave vacuum rectifier with an indirectly heated cathode and is designed for use in series-operated alternating-current or direct-current radio receivers or in B eliminators for automobile radio receivers; it can be used to replace indirectly heated half-wave mercury-vapor rectifiers designed for the same service. Type 84 is an indirectly heated full wave vacuum rectifier designed for use in B eliminators for automobile radio receivers. It can be used to replace indirectly heated full-wave mercury-vapor rectifiers intended for the same service. Type 25Z5 is a twin-cathode full-wave rectifier or voltage-doubler tube designed for use in series-operated alternating-current receivers. With an alternating-current input voltage at 115 volts it will deliver 160 volts when two 8-microfarad condensers are connected across the output circuit, without the use of a high-voltage transformer.



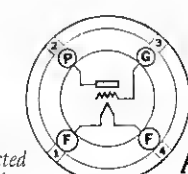
No. 10308

Triode Tubes for Experimenters - Typical Operation Specs

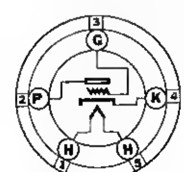
type	*filament power voltage & current*	*plate voltage volts*	*negative grid bias volts*	*plate current mA*	*plate resistance ohms*	*trans-conductance µmhos*	*mu voltage gain*	*basing*
201A	5V @ .25A DC	90-135	4.5-9.0	3-10	10,000	800	8.0	4-prong (A)
	very popular early triode – low gain – high filament power – nasty microphonics – somewhat expensive – for advanced experimentation							
'30	2V @ .06A DC	90-180	4.5-13.5	3	10,500	900	9.3	4-prong (A)
	direct replacement for 201A – low filament power – intended for battery operation – limited production – not easy to find							
1H4G	2V @ .06A DC	90-180	4.5-13.5	3	10,500	900	9.3	octal (C)
	direct replacement for '30 – identical specifications but supplied in a different glass envelope with an octal base							
'27	2.5V @ 1.75A AC	250	21-30	5.2	9,250	975	9.0	5-prong (B)
	first modern triode with cathode separate from AC heated filament – no microphonics – relatively common – great tube for experimentation if you can find a suitable filament transformer							

UV bases had four short pins or "prongs" for use in bayonet sockets. UX bases had four long pins for use in bayonet or friction fit sockets. UY bases had five long pins for friction fit sockets.

Filaments are connected to larger pins



A



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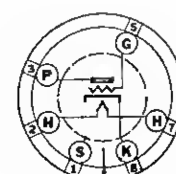
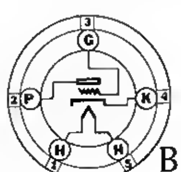


C

Tube basing diagrams are always drawn as seen from the base. In other words if you're wiring a tube socket from the underside of a chassis, this is the diagram you need. Pin numbers run clockwise.

Triode Tubes for Experimenters - Typical Operation Specs

type	*filament power voltage & current*	*plate voltage volts*	*negative grid bias volts*	*plate current mA*	*plate resistance ohms*	*trans-conductance µmhos*	*mu voltage gain*	*basing*
56	2.5V @ 1A AC	250	5-13.5	2.5-5	9,500	1,450	13.8	5-prong (B)
	essentially an improved '27 with smaller filament power needs and somewhat higher gain – not produced for all that long but not that hard to find							
76	6.3V @ .3A AC	100-250	5-13.5	2.5-5	9,500	1,450	13.8	5-prong (B)
	just a 56 with the modern 6 volt filament – readily available, new and used							
6C5	6.3V @ .3A AC	250	8	8	10,000	2,000	20	octal (C)
	my favorite - very common metal envelope tube introduced about 1935 – filaments powered with very common transformers – improved gain							
6C4	6.3V @ .15A AC	250	8.5	10.5	7,700	2,200	17	7-pin miniature (D)
	common inexpensive miniature tube produced to the very end – works well but is a power tube – plate current too much for headphones – could damage phones unless plate voltages reduced or output coupling used							



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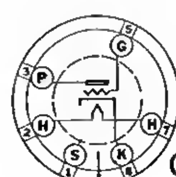

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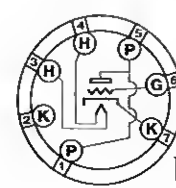
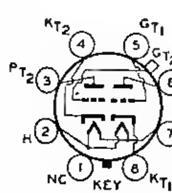


D

Tube basing diagrams are always drawn as seen from the base. In other words if you're wiring a tube socket from the underside of a chassis, this is the diagram you need. Pin numbers run clockwise.

Triode Tubes for Experimenters - Typical Operation Specs

type	*filament power voltage & current*	*plate voltage volts*	*negative grid bias volts*	*plate current mA*	*plate resistance ohms*	*trans-conductance µmhos*	*mu voltage gain*	*basing*
6C8G	6.3V @ .3A AC	250	4.5	3.2	22,500	1,600	36	octal (E)
	dual triode – considered high gain in the early 1930's							
6F8G	6.3V @ .3A AC	250	8	8	10,000	2,000	20	octal (F)
	dual triode - each section is essentially a 6C5							
6J5	6.3V @ .3A AC	90-250	0-8	10	6,700	3,000	20	octal (G)
	metal - variation of the 6C5 – greater transconductance – lower plate resistance allows higher plate currents							
6SN7	6.3V @ .3A AC	90-250	0-8	10	6,700	3,000	20	octal (H)
	metal & glass - very common - almost like having two 6J5's inside of one glass envelope – very common – great tube to start with							



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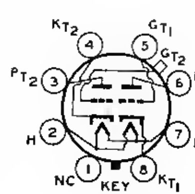

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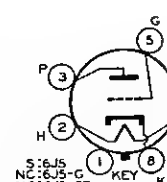

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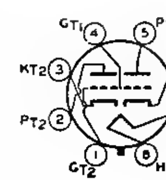
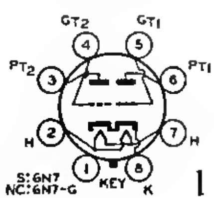


H

Tube basing diagrams are always drawn as seen from the base. In other words if you're wiring a tube socket from the underside of a chassis, this is the diagram you need. Pin numbers run clockwise.

Triode Tubes for Experimenters - Typical Operation Specs

type	filament power voltage & current	plate voltage volts	negative grid bias volts	plate current mA	plate resistance ohms	trans-conductance µmhos	mu voltage gain	basing
6N7	6.3V @ .8A AC	250	5	6	11,300	3,100	35	octal (I)
	metal - dual power triode capable of 5.5 watts output – only one cathode, common to both triodes							
6K5	6.3V @ .3A AC	100-250	?	1	78,000	900	70	octal (J)
	metal - very high gain metal tube – not all that common - low plate current							
19	2V @ .26A DC	135	0	5	10,000 ptp			6-Prong (K)
	class B twin power triode - battery powered filaments - designed for push-pull audio output - used in the "Twinplex" - essentially a 1J6G							
6SQ7	6.3V @ .3A AC	250	2	1.1	85,000	1,175	100	octal (L)
	metal - triode plus two diodes used in "All American Five" receivers as detector/audio amp/avc - very high voltage gain the grand daddy of the 6AV6 and the 12AX7 twin triode							



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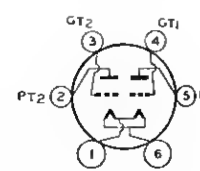

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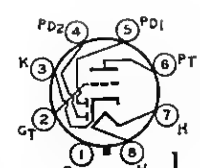
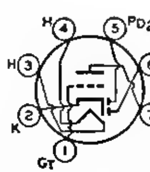


L

Tube basing diagrams are always drawn as seen from the base. In other words if you're wiring a tube socket from the underside of a chassis, this is the diagram you need. Pin numbers run clockwise.

Triode Tubes for Experimenters - Typical Operation Specs

type	filament power voltage & current	plate voltage volts	negative grid bias volts	plate current mA	plate resistance ohms	trans-conductance µmhos	mu voltage gains	basing
6AV6	6.3V @ .3A AC	250	2	1.2	62,500	1,600	100	7 pin miniature (M)
	miniature - high gain triode with two diodes - descendant of 6SQ7							
12AX7	6.3V @ .3A AC	250	2	1.2	62,500	1,600	100	9 pin miniature (N)
	miniature - two 6AV6 triodes in a single envelope - sometimes hard to find and expensive - coveted by adherents to the "vacuum tube stereo" religion							
12AU7	6.3V @ .3A AC	250	8.5	10.5	7,700	2,200	17	9 pin miniature (N)
	miniature - dual medium gain triode - capable of moderate power output - a workhorse of the electronics industry for years - very common							
12AT7	6.3V @ .3A AC	250	0-5	10	10,900	5,500	60	9 pin miniature (N)
	miniature - dual high gain triode - sort of a higher gain version of the 12AU7 - a workhorse of the electronics industry for years - very common							



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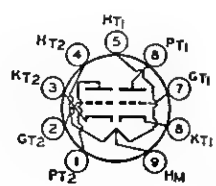


N

Tube basing diagrams are always drawn as seen from the base. In other words if you're wiring a tube socket from the underside of a chassis, this is the diagram you need. Pin numbers run clockwise.

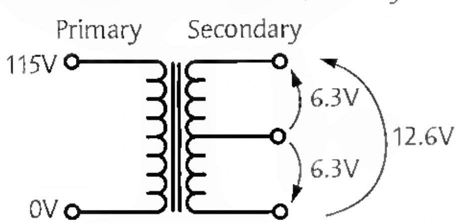
A Simple Power Supply

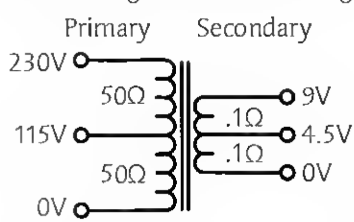
Our simple tube radios need low filament voltages at sizeable currents and higher voltage at very modest currents. You could supply 6.3 volts to the filaments from a 6 volt motorcycle battery, ni-cads or something similar. And you could create a "B" battery of 90 volts by soldering ten 9-volt transistor batteries in series. But for not much more money you can create a solid state power supply that will never need replacing because you plug it into an outlet – into the "mains".

In the "old" days, not many years ago, you could get transformers which took in 120 volts and spewed out 6.3 volts and as much as 700 volts. The high voltage could be rectified into pulsating DC by rectifier tubes and filtered to remove the pulses. Those transformers are still with us, but they can run from $20 to $200 new depending on how much power you need. On the other hand, I've seen the same kinds of transformers, used, often stripped from old televisions going for a dollar at flea markets. Sometimes for free.

But assuming you don't like either option, there's a third solution. Locate a supplier of components to experimenters. There are many. Check electronics magazine advertising or search the internet. In their catalog you'll probably find low voltage transfomers manufactured in Asia for use in solid state gear. A pair of these low cost transformers will give you what you want.

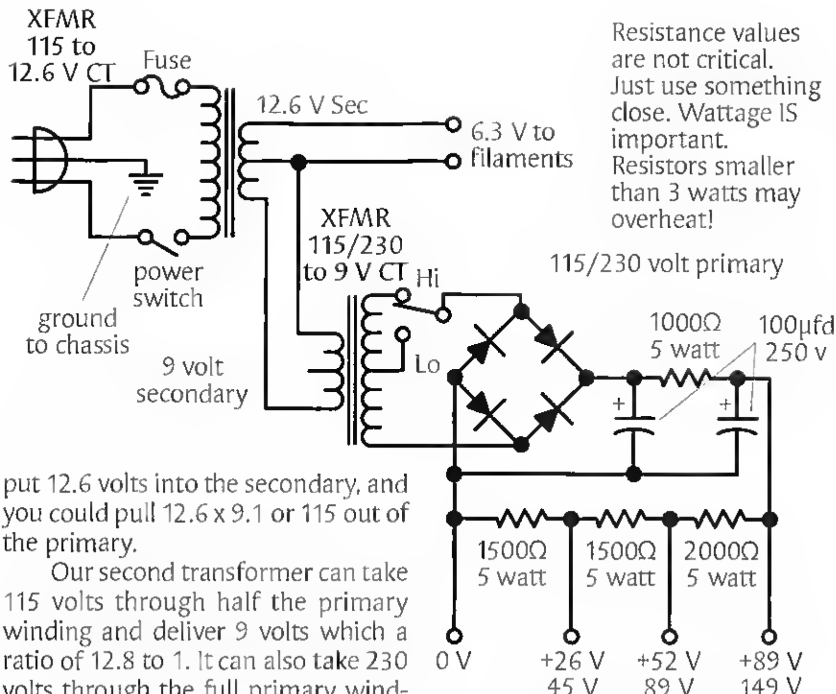
For about $12 I ordered a 115 to 12.6 volt center-tapped transformer and a 230/115 to 9 volt center transformer. When you feed 120 volts into the primary of the first transformer, you get two sets of 6.3 volt current out of the secondary. One of the 6.3 supplies is used to power the tube filaments. The other 6.3 volts is fed into the 9 volt secondary winding of the second transformer. Coming out of what was originally the primary you get either 86 or 172 volt AC (or thereabouts) that you can rectify and filter for the plates.





If this sounds confusing, you need to get familiar with the concepts behind transformers. The voltages going into one winding and those coming out the other(s) are related by the number of turns on each winding. If you push 120 volts into a primary winding having 100 turns, you'll find that a secondary winding having 50 turns will deliver 60 volts. The ratio of winding turns is 2:1, so the input/output voltage ratio must be 2:1.

You don't really need to know how many turns make up each winding. You can figure it out from the voltage ratings. If you have a 115 volt primary and a 12.6 volt secondary, just divide 115 by 12.6 on your pocket calculator to get 9.1. And since transformers work either way, you could



Voltages available low & high under no-load conditions

put 12.6 volts into the secondary, and you could pull 12.6 x 9.1 or 115 out of the primary.

Our second transformer can take 115 volts through half the primary winding and deliver 9 volts which a ratio of 12.8 to 1. It can also take 230 volts through the full primary winding and give 9 volts, or a ratio of 25.6 to 1.

If you put 9 volts into the intended secondary winding, you can pull off 9 x 12.8 or 115 volts from half the primary winding or 230 from the full winding. You're just moving electrical energy through the transformer in reverse.

But what happens if you take 6.3 volts from the secondary of our first transformer and feed it to the 9 volt winding of the secondary transformer? What will you get coming out of the primary side? Simple. Just multiply the 6.3 volts by the ratios. Half the primary winding will deliver 6.3 x 12.8 or about 81 volts. If you use the full primary winding, you get 6.3 x 25.6, or about 162 volts. The exact voltage you get will depend on the voltage going in, the exact winding ratios, and losses within the transformer. Supposedly these transformers were wound for 115 volt power. Around here, I pull about 120 volts out of the wall. You might get 118. The exact voltages that come out of your power supply will depend on all these variables. But the real voltages will be fairly close to the calculated values.

By mixing and matching different transformers you can almost create the power transformer you need for your tubes even though the transformers were designed for transistors.

The 12.6 volt transformer had unmarked leads. The first problem to solve was to determine which leads were the primary and which the secondary. Solution? The primary will be the higher resistance. Why? Because the primary handles small currents, smaller wire with higher resistance is used to wind the primary. The secondary generates 12.6 volts at 2 amps. With that kind of current, just one ohm of resistance will produce a 2 volt drop. So you know the secondary must have less than one ohm of resistance. To find the center tap, put your volt-ohmmeter on its lowest scale. Clip one lead to to one of the wires. If the resistances to each of the other two wires are identical, the clipped lead is on the center tap. If the resistance between the two outside leads of the winding is, say 150 ohms, then you'll read 75 ohms between the center tap and each outside leg. It's a matter of a couple of measurements and simple logic. Draw a diagram on paper if you find it confusing. A picture always seems to help me.

If your meter doesn't have a low enough scale to measure that kind of resistance accurately, you can wire up the primary, which should be easy to measure, plug it into an outlet and measure secondary AC voltages to find the center tap.

The same measurement method is used to decode the leads of the 9V center-tapped (CT) transformer. Here, you feed 6.3 volts from the secondary of the 12.6 volt transformer into the original 9 volt secondary winding of the second transformer. You're feeding power in reverse through the windings. If you use your voltmeter to measure AC voltage from the center tap to one side of the original winding, you should see about 86 volts with 120 volts in. If you measure across the whole winding, you should see twice that: about 172 volts. If you were to feed nine volts into the nine volt winding, you would measure the full 115 and 230 volts on the primary as expected. But because you're feeding less than nine volts to the nine volt winding, you'll get less voltage out the other side.

WARNING! Don't feed excess voltage into a winding. For instance, it would be okay to put 6.3 volts or 9 volts into a nine volt winding, but you run the grave risk of burning out the transformer should you put more than 9 volts into the 9 volt winding in an attempt to get more than 115 or 230 volts out the other side. And don't accidentally get the primary and secondary winding mixed up and try putting 115 volts into the 9 or 12 volt winding. You'll probably blow a circuit breaker, burn wiring, or possibly burn the transformer.

In the schematic shown I finally decided to make a dual voltage supply. By putting a switch in the 115/230 volt winding of the 9 volt trans-

IMPORTANT NOTE!

You may have noticed that not all terms used in this booklet are defined or explained in detail. This information can be found in numerous radio books. Almost any old electronics book, for instance, will explain such concepts as transconductance and plate resistance.

Other references, to Nagoaka for instance, may take more research. But I've seen references to his inductance formulas in ham radio books, Radio Physics by Ghirardi and early publications from the National Bureau of Standards. The information is available. But you must look for it.

Like a college professor, these EXPERIMENTER booklets are meant to throw ideas at you and get you interested enough to teach yourself. Consider information in this publications merely as a starting point for your own investigations. Read! Experiment! Read some more! You can't help but learn something new!

former I could get a range of low voltages – 26, 52, 87 volts – or a higher range for other tubes – 45, 89, 149 volts.

It's important to use high wattage resistors in the voltage divider string and between the filter capacitors. A lot of current flows at all times, and that means a lot of heat is generated. If you use the small wattage resistors, the most common variety, they will be smoking in a matter of minutes.

You can join resistors to make up values if needed. You can put five 10,000 ohm 1 watt resistors in parallel to give a resistor with 2,000 ohms at 5 watts. For resistors in parallel, resistances divide and wattages add.

You could solder five 270 ohm 1 watt resistors together in series to get 1350 ohms at 5 watts. Here, resistances multiply and wattages add. The 1350 value is short of the 1500 I used, but is close enough.

The nine volt transformer I used was rated at one amp of secondary current. Nine volts times one amp gives 9 watts. If the output voltage is roughly 90 volts, that means that the maximum output current is roughly 9 watts divided by 90 volts, or 1/10 amp, or 100 milliamps (mA = thousandths of an amp). And 100 mA is much more than you'll need.

The 6.3 volts pulled off the secondary of the first transformer really needs no other treatment. Just feed the current to the filaments through twisted wire. Twisting reduces the amount of AC hum that can be picked up by other wires in your radio.

The high voltage coming off the reversed 115/230 to 9 volt transformer is AC. You must convert it to DC with a full wave bridge rectifier. Today, that's easy to do. You can get power diodes or rectifiers for pennies that will do the job. Get diodes with 200 PIV (peak inverse volts) or greater and a current capacity of 250 mA or more. In my prototype unit, I used 1000 PIV 1 amp diodes. Geez... They were so cheap I think I bought a hundred for about $6.

Next, you take the pulsating direct current into a 100 mfd capacitor costing about a dollar through a resistor to provide a load, into a second capacitor for more filtering and finally into a resistive voltage divider. The two capacitors and 1000 ohm resistor form a simple resistive-capacitive RC filter that eliminates the pulses coming out of the full wave bridge rectifier. The voltage divider provides a solid load that helps filtering, but will also give you a choice of output voltages.

In my supply I used a 1000 ohm resistor between the capacitors. I measured about 104 volts going into the resistor, but only 87 coming out. From Ohm's Law it's easy to calculate the voltage drop of 17 volts (104 minus 87) divided by 1000 ohms to get 17 milliamps of current flowing. In order not to overheat the resistor you must use a resistor of sufficient size. The 17 volts times 17 milliamps (.017 amps) gives .289 watts. Or another way: 17 volts x 17 volts / 1000 ohms = .289. A half watt resistor would do, but I found a huge 10 watter in my junk box and used it.

$$I = \frac{104\text{–}87V}{1000\Omega} = 17 \text{ mA}$$

$$W = VI = 17V \text{ X } .017A = .289 \text{ Watts}$$

$$W = \frac{V^2}{R} = \frac{17 \text{ X } 17}{1000} = .289 \text{ Watts}$$

On the high voltage range, I measured 179 volts on the first capacitor, and 149 volts on the the second capacitor. The voltage drop across the 1000 ohms resistor here comes to 30 volts, and means 30 mA of current is flowing. That calculates to .9 watts.

I recommend using larger wattage resistors. I prefer five watters, although you probably get by with 3 watters. Larger sizes will heat less. And you must remember that these measurements were taken with no radio attached. When you start drawing plate current, even more heat will be generated in these components.

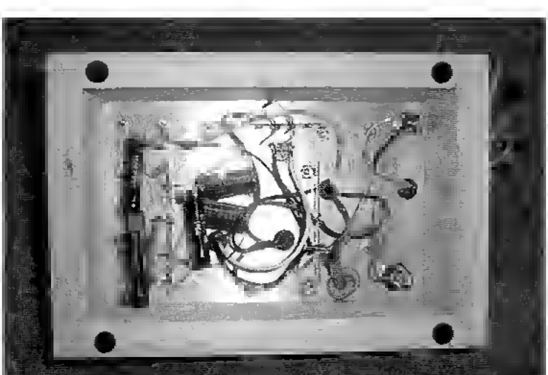
The voltage divider was built up from a 2000, 1500, and 1500 ohm resistor. These resistors in series give 5000 ohms, which at 87 volts draw about 17 mA of current. (Again use Ohm's Law here: a simple, extremely useful formula!) The resistors in the string were chosen to give voltages similar to those supplied by early batteries: 22-1/2, 45 and 90 volts. I don't even think these batteries are manufactured anymore. But who cares. You have a "battery" that will never need replacing.

If the above calculations are con-

Low Power Tube Experimenter's Power Supply

Common 1x4 dimension lumber was used to build a simple box with glue and brads with outside dimensions of 6-1/2" x 9-1/2". A panel was cut from .050" aluminum and attached with #6 x 3/8" hex head sheet metal screws. Get a box of these screws and a 1/4" nut driver to make your breadboard experiments extremely fast and convenient.

Components include the essential 9 and 12 volt transformers discussed in the text, six standard plastic binding posts, a pair of subminiature toggle switches costing about a dollar each, an old three wire computer power cord, terminal strips, junk box resistors, etc. You could get by with homemade binding posts if you mount them on a strip of wood or plastic to insulate them from one another. Most of the other components can be purchased new at modest prices or improvised.

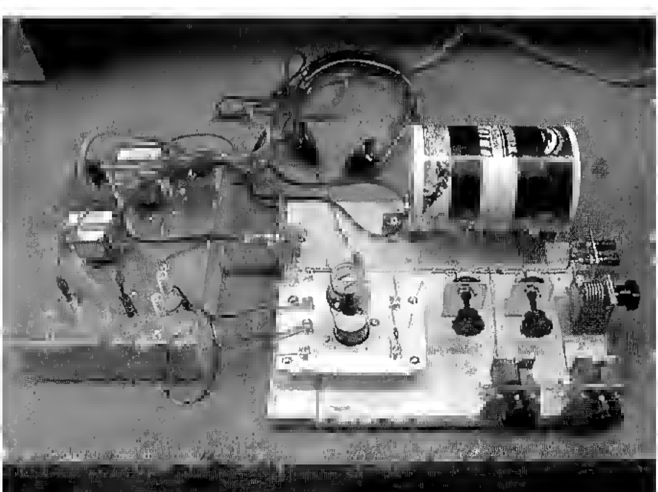


fusing to you, then you MUST get familiar with Ohm's Law, power dissipation, and resistive voltage dividers. These topics are discussed in a hundreds of books published over the last hundred years. And review high school algebra, if necessary, so you can rearrange the simple formulas to allow you to calculate what you need to know. These simple formulas are as essential (and maybe more so) than just about any fancy piece of test gear.

You can breadboard the power supply in less than an hour, but it will be a dangerous machine with exposed terminals and wires running every which way. The smart thing to do is to put all the potentially dangerous components on the underside of an aluminum panel where you cannot accidentally stick your fingers. Put a three-wire power cord on the supply and attach the green ground wire to the metal chassis. If something goes wrong inside the supply, the voltage will go directly to ground through green wire, rather than through you to ground. And you should always fuse the power coming in just in case of trouble. You don't want the thing to start smoking or worse.

This little power supply has a major drawback: poor regulation. If you start drawing large amounts of current, the high voltage will drop dramatically. The 87 volts under no load will drop to 77 when the plates of your tube draw 10 mA. So this little supply is good only for simple one- and two-tube receivers. When you get into more complicated radios, you'll need to build a fancier power supply. But that's a topic for another edition of EXPERIMENTER.

This simple supply should be able to deliver enough power for a simple three tube radio driving earphones. Any tube capable of powering a loudspeaker will need more current than this power supply can reliably deliver. But this little unit will allow you to run all kinds of experiments with 6 volt vacuum tubes, the most common variety, in a greater variety of electronic circuits than you'll have time to try in a month of Sundays.



The simple power supply powering a 76 vacuum tube (early 1930's) with 6.3 volts for the filaments and 48 volts to the plate.

A Demonstration Radio

(proof that the crazy ideas presented in this book really do work!)

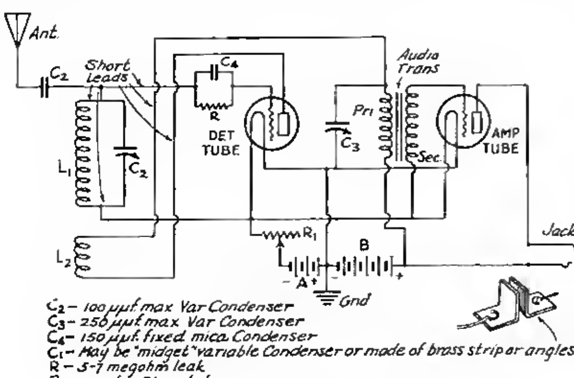
I needed to build a variable oscillator for use in a superheterodyne receiver based on 1929 state-of-the-art now under construction. Since I could not find a small enough authentic pre-1930 variable capacitor, I decided to build one.

But just to prove some of the assertions I make in this booklet, I decided first to use it in a pre-1930 radio circuit modified for a later tube.

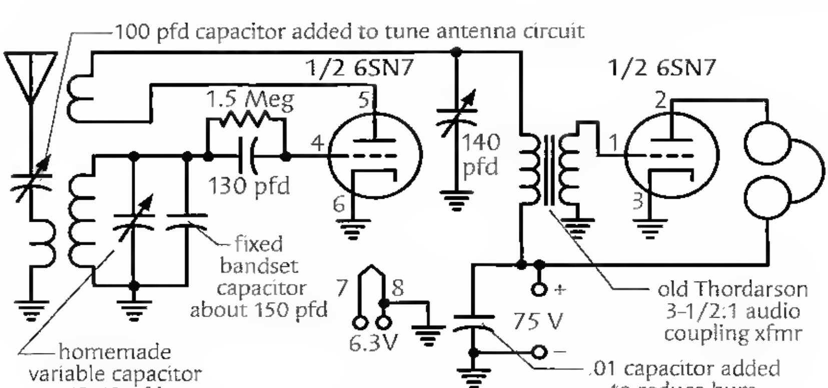
From the 1927 Radio Amateur's Handbook I took the schematic of a typical regenerative receiver almost all amateurs were using at the time. The first triode detector, most often a 201A, used tickler feedback with a throttling capacitor for regeneration control. An audio transformer fed the audio signal into the grid of the second early triode without any grid bias. B-battery was fed directly through the headphones to the plate of the second tube.

a homebrew variable capacitor 13-42 pfd

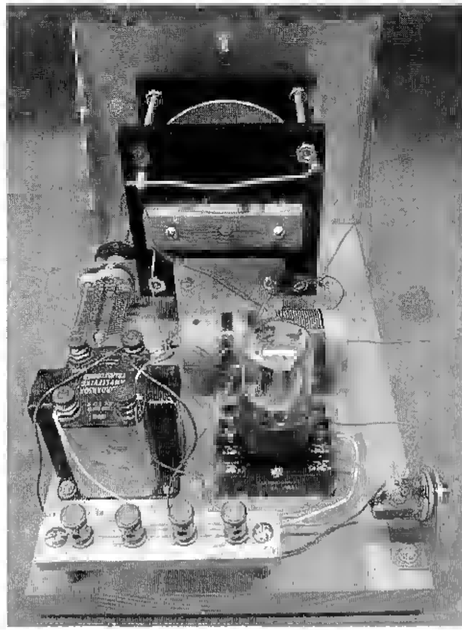
The first step was to redraw the schematic. There wasn't much to change. Just ground the cathodes. Eliminate the batteries. I decided to use a 6SN7 dual triode with an octal base. Grid leak components were the first to be found in the



CIRCUIT OF THE BREADBOARD RECEIVER



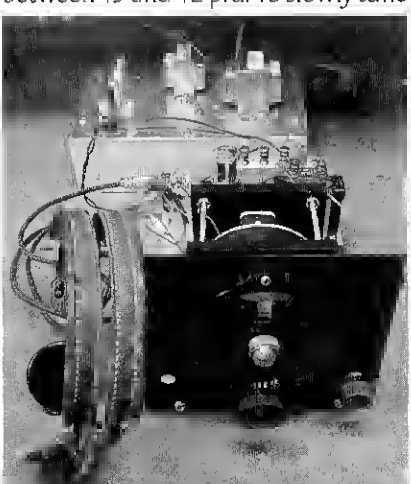
Octal Tube Version of 1927 Receiver



A National Type B dial drive was mounted to a .050 aluminum plate bent with a simple brake. The capacitor of 3/8" fleamarket Bakelite™, aluminum plates, and threaded rod was mounted on brackets. Other salvaged components, including a rare 1925 Thordarson interstage transformer were quickly wired together resulting in this 80 meter amateur receiver. Signals came almost the instant I applied power! I have to wonder how it would performed if I were to adjust the coils and create a better layout. Perhaps in a later edition of EXPERIMENTER, *I can provide the details of building such a capacitor and with it a receiver that far outperforms any crystal set.*

junk box: 1.5 megohm and 130 pfd. No special values.

I spaced the plates out on the homemade variable capacitor and measured the unit on a laboratory bridge to find that capacitance varied between 13 and 42 pfd. To slowly tune the 80 meter band, a simple computer spread sheet version of the resonance formula told me that I needed to put about 150 pfd and a coil with 10.8 µh inductance in parallel with the variable.



The simple power supply easily drives this experimental radio. At 45 volts the receiver worked sluggishly. At 75 volts signals were easily heard.

I found a 1.3" diameter cardboard tube that I think was once the center of a roll of fax paper, and plugged that value into a spreadsheeted version of the Nagoaka inductance formula for a single layer solenoid. Nagoaka told me to wind 20 turns in one inch to get 10.8 µh. So that I did, adding two additional coils: 5 turns for tickler and 11 turns for antenna.

I bolted the variable capacitor to a National Type B dial drive recently discovered at a hamfest (an electronic flea market). And I used a Thordarson "Amplifying Transformer" with a 3-1/2 to 1 turns ratio produced in the 20's. Other transformers would have worked, but this baby had been on the shelf for several years and I wanted to try it.

The throttling capacitor was a filthy beat-up unit I recovered from a hamfest cardboard box for a dime. The mechanics included a homemade panel bearing that had once been a potentiometer and a phenolic universal joint stripped from a junk oscillator two years ago.

After an hour of drilling, pounding, soldering and swearing, the ugly thing was ready to try. I got out my box of octal pulls (used octal tubes), and found a 6SN7. Next, I put the tube under the faucet to wash off the mud, and plugged it into the socket. Test it? Naw. Waste of time.

When I hooked up the simple power supply described earlier and flipped the switch, I could see the filaments light up. Rotating the controls I could hear noise, but not much else. So I turned on my signal generator, put it on the 80 meter band, in effect creating an artificial radio station. It almost blew the headphones off my ears! When connected to an antenna through a variable capacitor, sideband signals came in. With a few minutes of tinkering I was able to clear up the signals and listen in on the conversations. Amazing!

So how was the performance? Not great. The volume was not very loud, and there was more hum than I've experienced with other receivers, and it wasn't coming from the power supply. A bypass capacitor on the B+ lead of the audio transformer lead eliminated most of it. Grid bias might increase gain. And then, again, maybe the 6SN7 was on its last legs when it was pulled out of service.

Regeneration was too touchy, but that's to be expected. I had made no adjustments to the tickler. In fact I had just slapped the receiver together, by guess and by golly, put voltage to it, and got signals. AND THAT'S MY POINT. Quit making excuses, and build one. Just about any tube of any quality will work. You'll receive radio signals. And it doesn't cost a lot of money. Build parts. Use what you have and what you can scrounge.

Geez... Wouldn't it be nice to be able to buy a bunch of these classic 1929 dial drives not at $1.47 but at ANY price?

Once you experience the excitement of building a simple tube receiver (much like the first time you heard a crystal set), you'll be eager to make all the adjustments and improvements needed to make it sit up and sing.

YOU can build incredible radios with tubes!

Vacuum tubes are to the electronics industry what steam locomotives are to the railroading industry: hot, inefficient maintenance headaches.

But like a steam locomotive, a tube has a simple fascinating charm that no high-tech chip can match.

You must try building a simple radio with tubes! It's easy, and it's cheap. (And don't tell me that doesn't appeal to you...) Do you remember the excitement when you built your first crystal set? This is even better.

The secrets you need to build very early, simple radios with common tubes are here: what substitutions to make, how to modify the circuit, how to build a power supply, and more. It's really very easy! And you've gotta try it!

This is your passport to loads of inexpensive fun exploring the early days of radio. Get a copy of this, and get started!

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