The Everyham's Amplifier

By John Stanley, K4ERO

How much power is appropriate for your first HF amplifier? Remember that the effect of RF power is logarithmic, not linear. In terms of S units, 375 W is halfway between 100 W and 1500 W. The 400 to 500 W range for your first linear is a sensible choice that will get you more than halfway to the legal limit at a fraction of the cost.

Many hams have an interest in building a linear amplifier. It may be the most common "homebrew" device in the amateur community other than antennas. Since SSB operations began in the 1950s, every edition of *The ARRL Handbook* has included a design for a linear amplifier. There is interest in a very basic design that will still satisfy the need for more power and provide the joy of building, while providing only the bands and features you want. This amplifier, or family of amplifiers, is an attempt to satisfy that need.

In the February 1966 issue of *QST*, Lew McCoy, W1ICP described "A Low Cost 700 Watt (Input power) Linear Amplifier," which used parts from an old TV set to allow the builder to keep the total cost at between $50 and $75. In October of 1970, he followed up with a "Junker Amplifier" that expanded on the concept with additional tube options and added TR switching. Allowing for inflation, $50 in 1970 would be, perhaps, $400 today. Since $400 is about the lowest price for a working used amplifier, and since the lowest priced new amplifiers are about $800, $300 to $400 seemed like a good target for the homebrewer for whom cost is at least one factor in the decision. Of course, labor costs will not be considered since the joy of building your own equipment is a major motivation, too, but you shouldn't have to pay too much extra for that joy! So, like Lew in 1966, we hope to discover some cost savings.

Project Overview

The design presented here is based on a modular approach. Each of the three major sections (tubes, tuning network, power supply) is somewhat independent and can be changed out separately. In addition, the starting design is "bare bones," containing nothing that is not absolutely essential for the amplifier to work and provide a minimum level of safety against overloads, abuse or accidents. TR switching is included in the most basic design because it gives significant advantages at low cost. For the basic design, each part will be described and its purpose explained.

Several options for the major components are presented with the builder being able to choose what best meets his or her needs and best uses the components available in junk boxes, online, or at hamfests. Many small parts such as resistors and diodes are cheap enough that one need not buy them used. Control transformers and tubes are easy to find through online auction sites. Be sure to check shipping costs on heavy items such as transformers. A parts list for any of the three tube combinations is included at the end of the article.

By shopping carefully, you can avoid the budget being busted by that one essential component costing lots more than expected. Don't overlook acquiring a damaged commercial amplifier or a "basket case" homebrew project — the parts and enclosure hardware available from these are often worth many times the asking price! The sidebar "Using "Surplus" Parts for Your Amplifier" in the **RF Power Amplifiers** chapter of the *Handbook* contains more information about purchasing used and surplus amplifier parts.

The basic amplifier shown in **Figure 1** will get you on the air. Additions and modifications that will improve performance are described at the end of this article. Each of these will stand on its own so that the builder can make changes with a minimum of downtime. Most can be installed in a day, so you need not discontinue using the amp in order to upgrade.

In addition to the material in this article, the CD-ROM also includes photographs of the author's implementation of the amplifier with 811As, a 3-500Z, and a pair of GI-6B tubes.

This article doesn't provide step-by-step kit-style instructions. Instead, there are guidelines and examples that will help you construct your amplifier from the parts you can acquire — this is part of the fun! The basic design is quite tolerant and if you are just getting started, why not try a single-band amplifier first? You can then add and modify and expand the amplifier's capabilities as your own expertise and confidence grow. The path to a homebrew amplifier is never a straight line, but the journey is very rewarding!

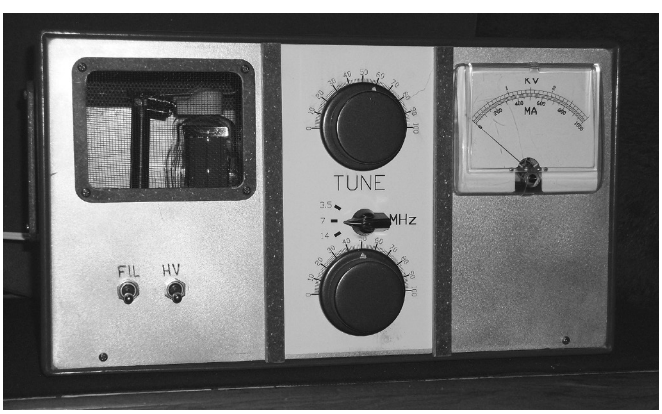

Figure 1 — The front panel of the Everyham's Amplifier. This version is designed to cover three bands (80, 40, and 20 meters). A window is included at left to allow viewing of the tube.

Design Details

The circuit for the amplifier is shown in **Figure 2**. The tubes used in this design are triodes, connected in a grounded-grid configuration. The amplifier can be constructed to use a single 3-500Z or a pair of 811A, 572B, GI-6B or GI-7B tubes. All of these are currently available new or surplus at reasonable cost. The input grid circuit input is driven directly. Tuned input circuits are discussed later as an option.

C3, L1 and C4 form an impedance-matching pi network which transforms the 50-Ω load at the output to the several-thousand-ohm impedance presented by the tube. In addition, this "tank" filters out the harmonics from the tube while passing the desired fundamental signal. An optional band switch, S3, is shown. In its simplest form it shorts out sections of L1 as the operating frequency increases. A single-band design doesn't need S3.

Finding suitable capacitors and coils and the band switch will be a significant part of the total procurement process. This is where you can save a lot by using surplus parts. The parts list specifies certain types, mainly so you will know what to look for, but if you simply buy new parts from the list, you will spend your entire budget on these items alone. You don't need exact values for the circuit to work. Limiting the bands to be covered can greatly relax the coil, capacitor and switch requirements.

When the amplifier is OFF or the trans-

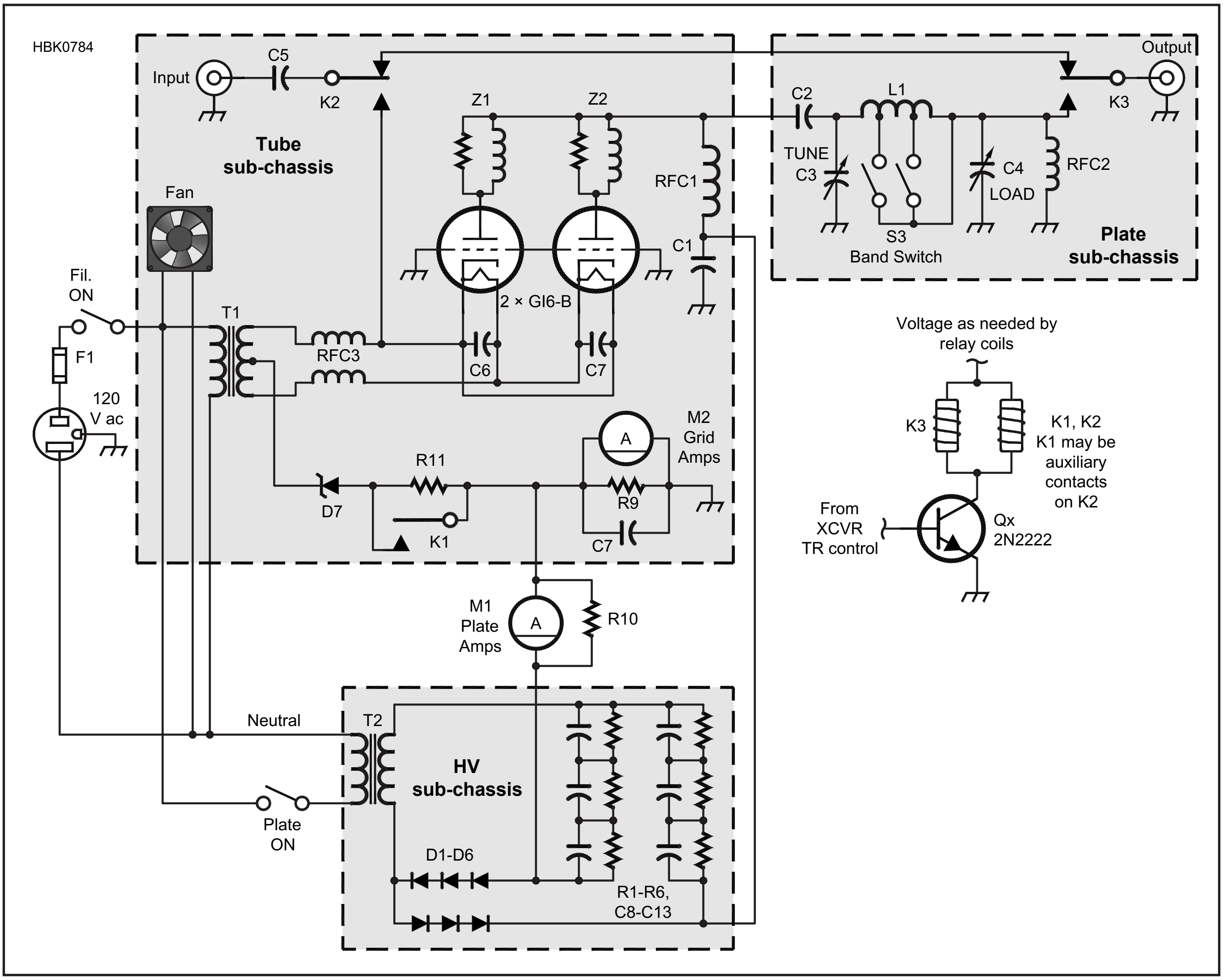

Figure 2 — The schematic of the basic amplifier. The parts list is shown in Table 2 at the end of this article.

ceiver is in receive, the antenna connects directly to the transceiver antenna jack via the two relays as shown in **Figure 3** (K2 and K3 in the main schematic). When the transceiver is in transmit and the amplifier turned on, the transceiver output is routed through the amplifier and amplified.

As part of the TR process, we will want to bias the amplifier off during receive. This saves energy, cools the tube(s) and also removes any RF noise the tube(s) might produce that could get into the receiver. When opened during receive, K1 in Figure 2 lifts the center tap of the filament transformer (tube cathode) from ground. K1 can be a separate relay or an additional set of contacts on the TR relays K2 and K3 if they are internal

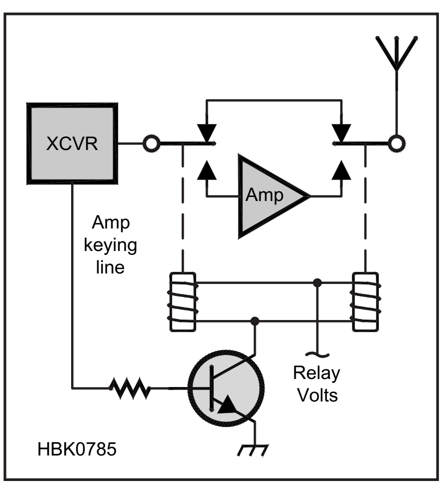

Figure 3 — The TR switching of transmit and receive signals for the basic amplifier is controlled by the transceiver's amplifier keying output signal, assumed here to be a positive voltage to key the amplifier with a suitable current-limiting resistor and relay drive transistor installed in the amplifier.

to the amplifier. Usually a resistor (R11), perhaps 47 kΩ or so, is left between the center tap and ground to provide a dc current path.

The power supply shown is a basic voltage doubler. (See the **Power Sources** chapter of the *Handbook* for information on rectifier and voltage multiplier circuits, as well as an alternative power supply design.) If a high-voltage secondary transformer is available, a rating of 500 VA is required for intermittent service up to 1 kW output. 250 VA ratings are sufficient for intermittent service to 500 W with a voltage quadrupler. Originally, TV transformers were often used for amplifiers of this size. However, they are becoming hard to find and their age leads to insulation breakdown, thus they are not recommended for this project.

For T2, the main power transformer, the basic circuit uses a 480/240 to 120 V "control" transformer with the 480 V winding used as a secondary. Control transformers are used in industry to reduce the plant's 480 V or 240 V equipment wiring to 120 V for the purpose of operating instrumentation and control electronics. These typically have two 240 V windings that can be connected in series for 480 V or run in parallel for higher current. These transformers are commonly available at online auction sites.

Filter capacitors C8-13 are 100 µF, 450 V electrolytics. Avoid capacitors rated for photoflash use. Best of all are "computer grade" types, but they are larger and more expensive. The audiophile tube equipment market has made capacitors available that are rated for continuous power supply duty. (See the section "Optimum Filter Capacitor Size" at the end of this article.)

C8-C13 require voltage-equalizing resistors, which also serve as bleeder resistors to discharge the capacitors when the supply is turned off. The bleeder resistors shown are 47 kΩ, 3 W units although lower resistance, higher wattage resistors will enhance safety by bleeding the voltage more quickly.

The rectifiers are rated at 3 A and 1 kV PIV. Modern rectifiers do not need equalizing resistors and capacitors as seen in older articles and designs. Today, it is cheaper to overrate the diode stack instead.

A meter in the negative lead of the supply monitors the plate current. Several inexpensive options are included in the parts list. A grid current meter is shown with R9 as the sensing resistor and C7 acting as an RF bypass to keep RF out of the meter. Some way to indicate RF output voltage or current is needed, but if you have an external SWR or forward/reflected power meter already, it need not be included in the amp.

Z1 and Z2 are parasitic-suppression chokes that incorporate a lossy element (resistor). These have been proven necessary to prevent VHF parasitic oscillations which can destroy an amplifier. RFC1 feeds dc to the tubes while blocking RF. It is bypassed with C1 to prevent any RF power that gets through the choke from entering the power supply. C2 is the plate dc blocking capacitor which passes RF to the output tank without passing dc.

The circuit works fine without RFC2, but its presence is cheap insurance against the failure of the blocking capacitor, which could put HV dc on the antenna output with deadly results. It and the fuse F1 are the two components not strictly needed, except for safety.

The input is driven directly. Tuned input circuits will be discussed as an option later. We do need C4 and C5 to keep the filament voltage from feeding back into the transceiver or tuner, and to put the RF drive voltage on both ends of the filament. RFC3 feeds filament voltage to the cathode without shorting RF to ground. C6 and C7 keep RF out of the filament transformer. T1 provides the filament voltage for the tube. Zener diode D7 may be needed, depending on the tube type and plate voltage, to keep the resting current below the allowable plate dissipation. A stack of forward biased diodes could work also. See the parts list for the type of Zener required for the tubes chosen.

Construction Notes

Safety First! YOU CAN BE KILLED by coming in contact with the high voltages inside a commercial or homebrew RF amplifier. Please don't take foolish chances. Remember that you cannot go wrong by treating each amplifier as potentially lethal. In addition, do not measure high voltages with test meters and probes that are not rated for those voltages. A flashover can destroy the meter and electrocute you!

For a more thorough treatment of this all-important subject, please review the applicable sections of the **Power Sources** and the **Safety** chapters in the *ARRL Handbook*. This is particularly important for first-time amplifier builders who are not experienced in working around high voltages.

ENCLOSURE AND COOLING

The type of construction chosen will depend on the enclosure (chassis), which is required for good RF performance and for safety reasons. Having a spacious enclosure and an oversized chassis will make construction easier and upgrades simple. If your situation dictates, you can certainly build everything on a single chassis.

If you find an old piece of equipment you can reclaim, that may dictate the layout. Hamfests usually provide a choice of obsolete tube-type lab or medical instrumentation with high quality cabinets at low cost. They may include desirable items such as a blower or meter in addition to the enclosure. The author chose to use a cabinet from an old piece of Heathkit gear, which had no chassis, and so built a front panel and several sub-chassis sections for the various parts of the amplifier. This allows changing out various parts of the circuit easily and even to maintain several different sub-sections to allow experiments with different tubes, frequency ranges or power supply types.

The tube circuit layout will depend on which tube type is chosen. The 811A/572B option is a great place to start. There is just no other option that can compete in price, counting the tubes and sockets. A pair is recommended for this design although up to four tubes in parallel are common in ham-built amplifiers. A single 3-500Z is another popular choice and, for higher power, a pair of them if the power supply is adequately rated. Ceramic sockets are available for the 3-500Z. Surplus Russian triodes such as the GI-6B and GI-7B are becoming popular and one or a pair is commonly used. The sockets will have to be built as described in the construction details or purchased from ham sources.

External anode tubes such as the Russian GI-6B or GI-7B will need a blower. With the 811A or 3-500Z options, a muffin fan blowing on the tubes will allow them to work much harder. This fan also keeps the other components cooler for extended operation. (See the section Tube Amplifier Cooling in the *Handbook* chapter on **RF Power Amplifiers** for additional information on choosing fans and blowers.)

TUBE SUB-CHASSIS

In this design, the tubes and a few closely associated parts are mounted on their own sub-chassis. RFC3 goes under the chassis along with the input circuits. Filament voltage required will depend on which tube(s) are chosen. A dedicated filament transformer is

Figure 4 — Parasitic suppression chokes eliminate VHF oscillation by adding some resistance to the plate circuit at VHF. They consist of a few turns of wire over a resistor. The wire forms an inductor which passes signals at HF but forces VHF and higher-frequency signals through the resistor.

preferred, but if you find a plate transformer with a suitable filament winding, that is okay. RFC1 and C1 are logically located on this same sub-chassis.

The parasitic suppressors, Z1 and Z2, shown in **Figure 4**, are nothing more than 4 turns of wire wound over a 47 Ω resistor. They are attached directly to the tube plate. This point connects to the output tank circuit via C2, the plate dc blocking capacitor.

TUNING NETWORK SUB-CHASSIS

The second sub-chassis carries all of the plate tuning components; C3, C4 and L1 and S3, if used. This is a pi network with a band-switched coil, enabling operation on the 80 to 10 meter bands, or fewer if you choose.

POWER SUPPLY SUB-CHASSIS

The third section is the HV power supply consisting of the power transformer, rectifiers and filter capacitors along with bleeder resistors. The power supply should be included in the enclosure and not built as a separate piece of equipment. Constructing safe high voltage connections between pieces of equipment requires experience and strict attention to safety-related details that may not be obvious to the beginning amplifier builder. For that reason, this basic design assumes an internal power supply.

Rectifiers and filter caps can be mounted on an insulated board, either Plexiglas, other plastic, or an etched PC board. Install that board on top of the transformer for a neat and compact installation. See the Power Supply Notes folder on the *Handbook* CD-ROM for photos and drawings of suggested construction methods. PCB layouts for the *ExpressPCB* fabrication service are also included on the CD-ROM for both the voltage doubler and quadrupler circuits.

Design Options

SAFETY OPTIONS

Including interlocks that will shut off the transmitter when the enclosure or sub-chassis panels are removed to expose high voltage may be desirable. Microswitches in series with the ac power circuits and/or shorting bars that will ground the HV circuits are options.

An interlock on the blower consisting of a pressure switch or air vane that will shut off the amplifier if cooling fails provides good insurance against loss of an expensive tube. Depending on the tube type, this may be highly desirable.

Since your construction method will dictate how interlocks would be applied, you should inspect commercial amplifiers for ideas suitable for adapting to your project. The advice of an experienced amplifier builder would be particularly helpful here.

POWER SUPPLY OPTIONS

The HV power transformer (T2) can be costly. Suitable used power transformers designed for amateur power supplies are available at typical prices between $100 and $200, with new ones even higher. Depending on the voltage of the transformer and that required for the tubes, these may call for a full-wave bridge, a doubler (as shown in Figure 2) or a full-wave center-tapped connection. Each of these circuits are described in the **Power Sources** chapter of the *Handbook*.

Another solution that still uses the simple doubler circuit is to use two control transformers for T2 with the two 480 V windings in series as shown in **Figure 5**. A 500 VA (0.5 kVA) total rating will work fine for intermittent voice service up to 1 kW and a single 250 VA (0.25 kVA) unit will supply 500 W output by quadrupling the output as in the next circuit.

The circuit in **Figure 6** uses a single control transformer with separate 240 V secondary windings. The secondary windings are each connected to their own voltage quadrupler, which are then connected in series. While a

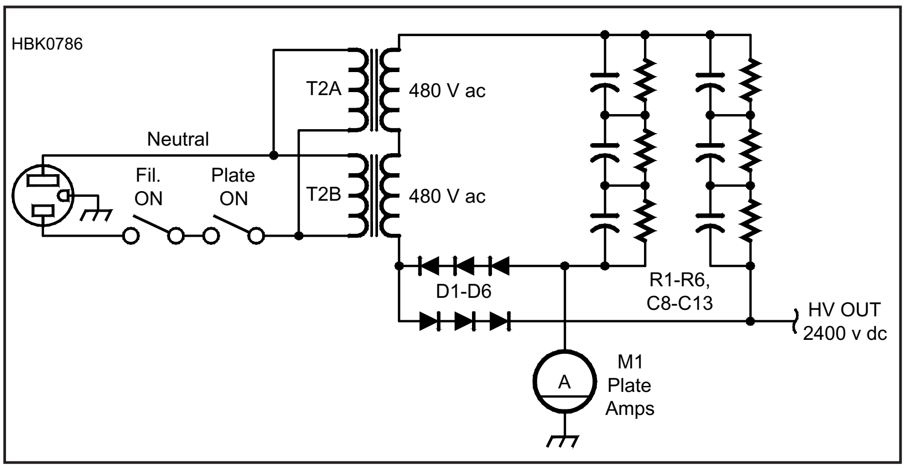

Figure 5 — An alternative power supply using two control transformer secondary windings in series and a voltage doubler.

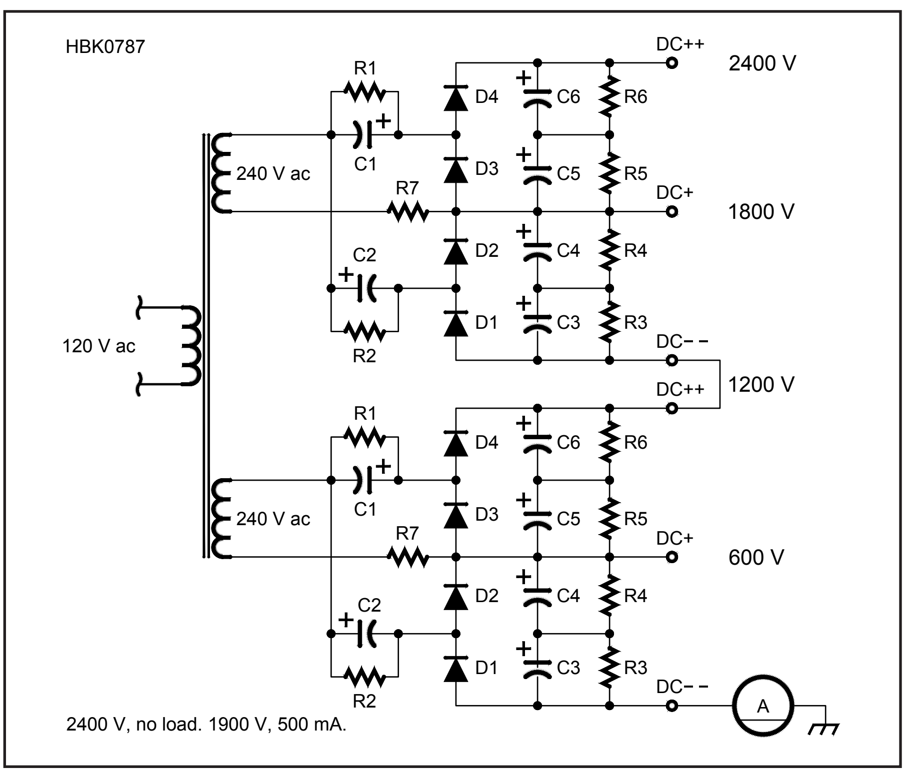

Figure 6 — An alternative power supply using two separate control transformers.

bit more complicated than the simple doubler circuit, it supplies ¼, ½, ¾ or full voltage, which is handy in testing and when substituting different types of tubes. R1 and R2 are optional bleeders — C1 and C2 will discharge through the regular bleeder string. R7 limits the filter inrush current at turn on and may not be needed if the primary fuse does not open from the temporary surge. Each quadrupler could be constructed on its own board or all on one.

FILAMENT OPTIONS

An otherwise ideal filament transformer or a filament winding on a HV transformer may have no center tap. It is possible to use two resistors in place of the center tap as shown in **Figure 7**. A pair of 22 Ω, 2 W resistors works well.

A switching power supply with suitable voltage and current ratings is another option for providing filament voltage as shown in **Figure 8**. It may be cheaper than a transformer and also weighs less. Running filaments from a dc supply reduces hum but with some tubes it causes one side of the cathode (filament) to get hotter than the other. One might want to reverse polarity from time to time. Use a clean dc supply, as one with switching harmonics on the output voltage could produce unwanted sidebands in the amplifier output.

BAND SWITCHING

Some amplifier builders will need only one or, perhaps, two bands. For example, net operators may need only 80 or 40 meters and a single tank coil, L1, for those two bands with a simple switch or even none at all. Some DXers might use only 14, 18 and 21 MHz — a single coil could cover those bands, as well. Many amplifier users however, particularly contesters, will want a quick and convenient way to select all HF bands. This is accomplished by shorting out part of L1 or switching another coil in parallel with it or in place of it.

Figure 9 shows typical band switches that are rated to handle the RF currents and voltages typical of amplifiers. Due to the Q of the tank circuit, the RF current in the switch is much higher than the dc current in the tubes. A good band switch should have contacts rated at 10 amps or more. Clearance between the contacts should be able to sufficient to withstand several thousand volts. Lighter switches will quickly burn up or arc over.

The need for short leads, especially on 12 and 10 meters, will determine parts layout and some compromises may be necessary. Willingness to limit the number of bands (for example, leaving out 160, 30, 17 and/or 12/10 meters) will simplify the design. For those who need unusual frequency coverage (MARS, for example) and who don't need to switch bands quickly, a shorting strap with a movable clip as shown in **Figure 10** is simple and inexpensive. It would be wise to include the safety options mentioned above because changing taps gives access to HV dc or RF voltages inside the amplifier.

TUNED INPUT CIRCUITS

Using tuned inputs to the cathode of the grounded grid linear as shown in **Figure 11** has three advantages:

- It presents a lower SWR to the transceiver.
- It makes it possible to drive the amplifier to full output with lower power.
- It improves the IMD (distortion) of the amplifier.

Nevertheless, there have been successful amplifiers that used untuned inputs as in the basic amplifier circuit. With some tube combinations, such as a pair of GI-6Bs or GI-7Bs you can drive the grids directly with acceptable SWR at the input. With a pair of 811As

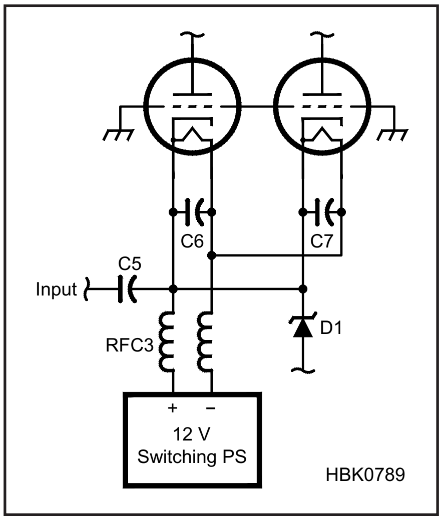

Figure 8 — Using a switching power supply for filament power.

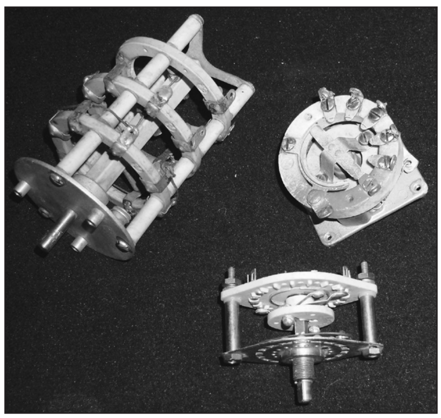

Figure 9 — Heavy-duty ceramic band switches rated for use in an amplifier's output tank circuit.

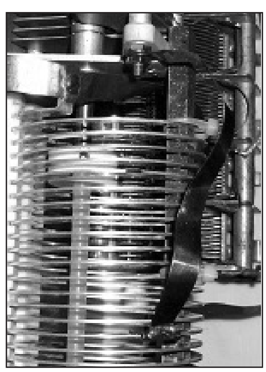

Figure 10 — A movable strap can be used for band switching if rapid band changes are not required. Using this method of changing bands requires strict attention to safety!

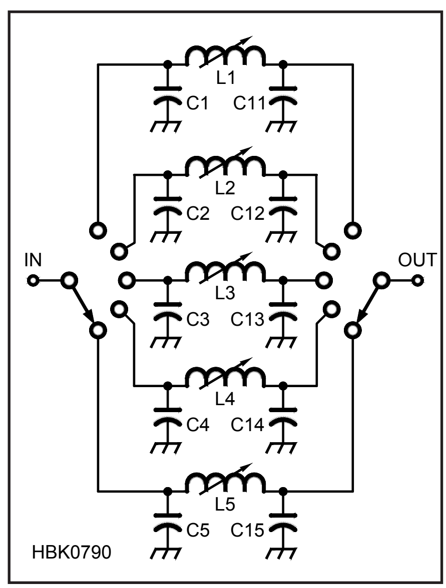

Figure 11 — Typical input tuned circuits using pi networks.

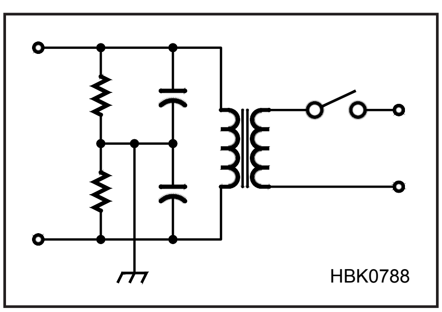

Figure 7 — A method of using two low-value resistors to replace a missing center tap on a filament transformer.

or a single 3-500, adding a resistor of about 120 Ω from input to ground improves the match. Your transceiver may have either a built in or external antenna tuner and if so, you may not need tuned inputs at all and your transceiver can probably supply enough power to drive the cathode directly.

For a few closely spaced bands a single somewhat-broad tuned circuit can work. Tuned inputs in an amplifier covering widely spaced bands will require band switching. It is desirable, but not necessary, to have the input band switch ganged with the main band switch to avoid having the two switches accidentally set to different bands.

The input power levels, combined with lower Q mean that this switch can be much lighter duty than the main band switch. Commonly used circuits are the pi network, shown here, and the tapped coil. In both cases, the input network tunes out the capacitance of the tube input, and it may also transform the resistive input impedance of the tube's cathode circuit to 50 Ω. Suitable values for the components with various tube combinations are included on the CD-ROM.

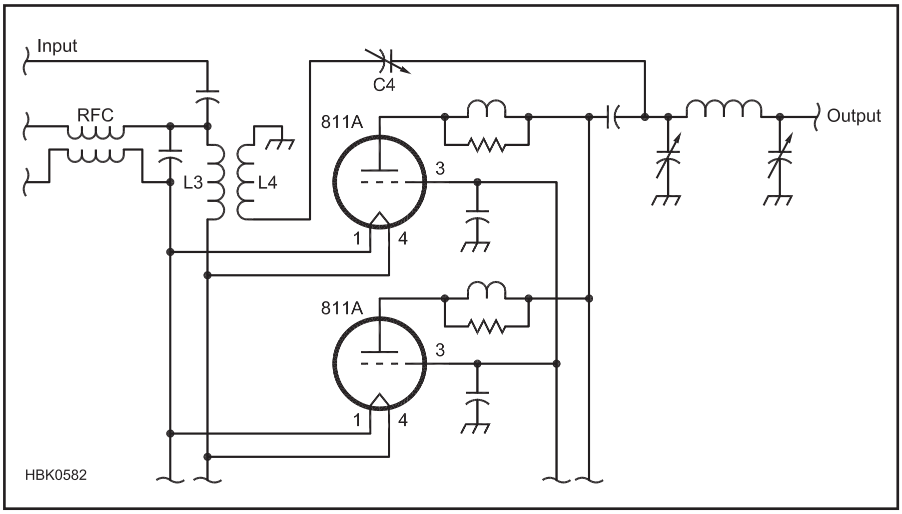

Figure 12 — In this neutralizing method, a broadband transformer (L3, L4) provides the needed out-of-phase signal. L3 is 6 close-wound turns of #14 wire, ½ in. dia. L4 is 5 turns of insulated wire over L3. C4 is 6 pF with 0.06 in. spacing. This circuit was originally featured in June 1961 *QST* and is still found in modern amplifiers using 811A tubes.

BETTER METERING

In addition to the supply current meter shown in the above circuit, metering of the output power (or RF voltage), SWR, and supply voltage are often included. These can each be assigned a separate meter or measured with a single one with a suitable switch and multiple scales. The **Test Measurements and Equipment** chapter of the *Handbook* contains a wealth of information about metering circuits, including how to make custom scales.

Metering the output power, essential for tuning the amp, can be done with an external directional wattmeter, or a similar circuit can be built into the amplifier. The external wattmeter has the advantage of working when you are running without the amplifier and so may be the better choice. Or, if you want that feature, install it in the amplifier, but on the antenna side of the TR relay. Find a published design or copy one from a manufacturer's manual.

NEUTRALIZATION

Many grounded grid amplifiers have been built without neutralization, including the famous Collins 30L-1. However, suitable circuits have long been available and the tuning on the highest frequency bands will be smoother if the neutralization circuit is added. For those using only the lower bands, it may not be worth it. **Figure 12** shows a suitable circuit for this amplifier that is discussed in the Tube Amplifier Stabilization section of the *Handbook* **RF Power Amplifier** chapter. Be aware that if you are receiving through the amplifier without TR switching, neutralization will reduce the receive signal further. It is not recommended to add neutralization without TR switching for that reason.

BETTER PROTECTION AGAINST OVERLOADS

The basic amplifier is protected by fuse F1 in the power supply. Other methods would include circuits to monitor plate and grid currents, air flow, temperature, SWR and turn off the plate supply as needed. This requires that the plate HV switch operate a latching relay. The protection circuits then unlatch the relay and light an indicator indicating the cause of the trip. Check the K8RA amplifier design in the *Handbook* or take a look at what the commercial amplifiers feature.

STEP-START

As part of the overload protection circuits, one can also add a step-start or soft-start for the HV supply as well as a time delay to prevent turning on the HV until the filaments have warmed up. A step-start applies voltage to the HV supply via a resistor for a second or so and then shorts out the resistor. This reduces the peak inrush current in the rectifier diodes and other components at turn on. A legal limit amplifier operating from 240 V is more likely to need this feature than a smaller amplifier.

AUTOMATIC LEVEL CONTROL (ALC)

An ALC circuit detects when grid drive to the tube exceeds a certain level and generates a signal to the transceiver that causes it to reduce output power. If the transceiver itself has ALC, which most do, and if the levels are properly set at maximum output power, there may be no advantage in using ALC. However, when changing bands, etc., the setup may change and the ALC will help to protect against overdrive and distortion while keeping the average power up. Check existing designs and the ALC requirements of the transceiver you are using.

Component Selection

OPTIMUM FILTER CAPACITOR SIZE

When looking at amplifier power supply designs, one finds various sizes of capacitors with the right capacitance and voltage rating for the HV filter capacitors. Here are the tradeoffs between them.

Advantages of using smaller capacitors:

1. The higher the capacitance, the greater the cost. Imported 100 µF, 450V capacitors

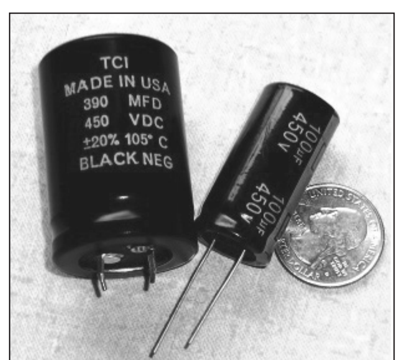

Figure 13— A 390 µF capacitor (left) and a 100 µF capacitor for size comparison.

are about $1 to $1.50 each, from various suppliers. A US-made 390 µF, 450 V capacitor is available from at around $2.50 to $2.75 depending on quantity. (The two capacitors are shown in **Figure 13** for comparison.) Other values at comparable prices can be had from many sources. This price difference is not huge, but with a large string can be significant.

2. Larger capacitors put a greater strain on the rectifier diodes at turn on. The inrush current with the larger caps shown here is at least twice that with the smaller ones, and this could eventually cause the diodes to fail unless a step-start circuit is used (discussed above). In either case, using diodes with an average forward current rating of 3 A is cheap insurance.

3. The stored energy available to do damage in case of a short circuit either in the tube or any of the high voltage circuits is greater with the larger capacitors. Hopefully this will never happen, but tubes do flashover from time to time, as do other circuits. Four times the capacitance makes four times the spark!

4. The larger the capacitors, the longer the discharge time at turn off or else one must use smaller bleeder resistance values so the power loss is greater. Thus, one must sacrifice safety, economy or some of each if the larger caps are used.

5. The larger capacitance units take up more space so the overall size of the supply may have to be bigger. Note that modern electrolytics are smaller than older ones so for replacement purposes, either size will usually fit nicely.

Advantages of the larger capacitors:

1. If the capacitors are too small, the supply voltage and RF output power will drop. At 500 W, 100 µF is sufficient. At a full 1500 W, one may need the larger size to prevent excess voltage drop. These values refer to a string of eight capacitors giving either 12.5 or 48 µF total at 2400 V.

2. With less capacitance, the ripple will be greater. For a typical 500 W linear, the ripple under load will be about 15 V RMS with 100 µF capacitors and about 5 V with the 390 µF capacitors. Transmitting a steady, full-power carrier, one can see the ripple on an oscilloscope with the smaller capacitors, but it isn't a problem with the on-air SSB or CW signal. This ripple value applies to the same eight-capacitor string mentioned above.

Thus, it can be seen that larger is not always better. There is an optimum value for filter capacitors which, while not overly critical, is important. As always, quality is also important. Cheap, tiny capacitors made for photoflash use are not suitable for continuous power supply operation. Nor is it good economy to operate the capacitors very near their rated voltage. Add a few more capacitors to the series string and reduce the voltage across each one. This allows for aging and voltage surges.

TYPICAL VALUES FOR TUNING COMPONENTS

The following values will be about right for a tube amplifier with a plate voltage of 2200 V at a plate current of about 400 mA. Using the *Tube Calculator* and *PI-EL* programs (supplied with the *ARRL Handbook*) will give more exact values based on tube types, voltages and currents. Calculations assume a Q value of 10 below 18 MHz, increasing progressively at higher frequencies to keep plate capacitance values at least as high as the stray capacitances plus tube output capacitance (see **Table 1**).

The plate tune capacitor should have a voltage rating at least equal to the plate voltage. The load capacitor should have a voltage rating of 500 V. Both the tune and load capacitors may consist of a variable capacitor in parallel with some fixed capacitance for the lower bands. The variable capacitance should be at least ⅓ of the total capacitance. Use transmitting type mica or ceramic caps for the fixed capacitors. The table values are the total capacity needed.

Stray capacitance and the tube output capacitance will provide part of the needed plate tuning capacitance. Having some extra capacitance is a good idea, so the components chosen may need to be a bit higher than the values listed to insure sufficient tuning range. For a single-band design it is a good idea to have more than the required capacitance so that actual operation doesn't fall near the extreme setting of the component.

Table 1
Typical Component Values

Freq (MHz)	*1.9*	*3.8*	*7.2*	*10.1*	*14.2*	*18.1*	*21.3*	*24.9*	*28.5*	*50.3*
C3 (Plate Tune, pF)	230	120	65	45	35	30	30	28	27	18
C4 (Plate Load, pF)	950	475	250	180	125	160	180	180	190	120
L1 (µH)	31	16	8.5	6	4	3	2.1	1.6	1.3	0.65

Table 2
Parts List

R1 to R6	Bleeder resistors:	47 kΩ, 3 W metal film
R7, R8	see PS1, PS2	47 Ω, 3 W metal-oxide
R9	Grid current meter shunt:	as needed for full-scale value of M2*
R10	Plate current meter shunt:	as needed for full-scale value of M1*
C1	Plate supply bypass:	0.01 µF, 5 kV ceramic
C2	Plate blocking capacitor:	1000 pF, 5 kV, 5 A, ceramic doorknob
C3	Plate tune capacitor:	10-250 pF, 2 kV variable
C4	Plate load capacitor:	three to five section variable, 20-350 pF/section, sections connected in parallel, 1050-1750 pF total
C5 to C7	Bypass capacitors:	0.0068 µF, 600 V, disc ceramic
C8 to C13	Filter capacitors:	100 µF, 450 V electrolytic
L1	Tank coil:	16 µH for 3.5 MHz 32 µH for 1.8 MHz tapped for other bands (details in text)
Z1,Z2	Parasitic suppressor:	3 turns, ⅜ inch dia. ½ inch long wound on R7 and R8
RFC1	Plate choke:	3.5 -28 MHz: 50 µH, 160 turns #24 AWG wire, ½ inch ceramic form, 3.5 inches long 1.8 -21 MHz: 100 µH, 320 turns #24 AWG wire, ½ inch ceramic form, 7 inches long The Barker & Williamson model 802 plate choke is suitable for use over the entire 1.8-28 MHz range.
RFC2	Safety choke:	25 turns #24 wire on ⅜-inch ferrite rod, #43 mix, 1.5 inches long
RFC3	Filament choke:	bifilar-wound with the winding filling a 4 inch × ⅜ inch ferrite rod (#43 mix) GI-6B or GI-7B: 4 amps, #18AWG wire 811A or 572B: 8 amps, #16AWG wire 3-500Z: 15 amps, #14 AWG wire The Amidon FLC-10 kit is a suitable equivalent.
D1-D6	Rectifiers:	3 A, 1 kV, 1N5408 or equivalent
D7	Cathode bias control:	GI-6B or GI-7B: 30 V, 1 A, Zener diode made of 5 ea 1N5340B (6 V, 5-W Zener) diodes connected in series 811A or 572B: 6.8 V, 10 W Zener diode (1N3999A or NTE5181A) 3-500Z: 6.8 V, 10 W Zener diode (1N3999A or NTE5181A)
M1	Grid current meter:	See text for options, R8 is the meter shunt GI-6B or GI-07B: 1 A 811A or 572B: 500 mA 3-500Z: 500 mA
M2	Plate current meter:	See text for options, R9 is the meter shunt GI-6B or GI-07B: 1 A 811A or 572B: 500 mA 3-500Z: 500 mA
T1	Filament transformer:	See text for options GI-6B/GI-7B: 120 V to 12 V, 4 A 811A/572B: 120 V to 12 V, 8 A 3-500Z: 120 V to 5 V, 15 A
T2	Plate supply transformer:	120 V to 480 V control transformer, 250 to 500 W (VA) (see text for options)
S1, S2	On/Off switches:	SPDT toggle, rated 10 A @ 120 VAC
F1	Primary fuse:	10 A (for tubes described) cartridge fuse Cartridge fuse holder
V1, V2	Vacuum tubes:	Pair of GI-6B or GI-7B triodes Pair of 811A or 572B triodes Single 3-500Z (V1 only)

Tube sockets: 811A or 572B: 4-pin ceramic, 2 required; 3-500Z: 5-pin ceramic, 1 required; GI-6B or GI-7B, see separate article "Constructing Substitutes for GI-6B and GI-7B Sockets - K4ERO" on the CD-ROM
Input and output RF connectors: SO-239 chassis mount
120V blower or muffin fan
2 feet of High Voltage or test lead wire (5 kV insulation minimum)
Heavy-duty, three-wire ac power cord
Strain relief for power cord
*To determine values of meter shunts, see the ARRL Handbook's Test Equipment and Measurements chapter. The procedure is described in the section "Panel Meters"