The HB-600 Linear Amplifier

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Note: This is an update to the article that originally appeared in Electric Radio (ER) magazine in February, 2012. The figures, schematic and parts list are at the end of this document. The schematic is also available on kg7tr.com. - MB

Introduction

After completing the OctalMania Radio Set described in the August 2011 issue of ER, I started thinking it might be neat to homebrew a linear amplifier to match. That way I could have a 100 percent homebrew SSB station. The Heath SB-201 has been the main amplifier in use here for several years and has proven to be trouble free. Having never built a linear before, I figured the least risky way to go would be to clone the main parts of that popular piece of gear. The amplifier would use a pair of readily available 572Bs in grounded grid. In addition, since 120 volts at 20 amps is the maximum primary power available in my shack it made sense to stay within the power class of the SB-201 as well.

As is my usual practice, I developed a rough vision of what this project would be and started shopping for parts at hamfests. It was apparent right away that I was starting from scratch and didn't have any of the big ticket items to build a linear. Some minor items scavenged from old TU-5 tuning units were on hand, but still needed were tubes, a plate transformer, variable capacitors, a plate choke, new filter caps, and lots of sheet metal items. Then there's taxes and shipping on just about everything that couldn't be picked up at a hamfest. The initial $300 budget for this unit was quickly blown, and the final cost could have purchased a nice used linear. However, as WA6VVL (Dave Ishmael, another avid homebrewer and constant inspiration) pointed out in his last linear project (ER, Nov-Dec 2011), a project like this isn't cheap. But I'm sure Dave would agree that we do this to have fun, not to save money!

Eventually all the parts were collected and construction began. About three months later the project was completed. The homebrew 600 watt amplifier, sporting the unimaginative moniker HB-600, is shown in Figures 1 through 3. It covers 80, 40 and 20 meters. From the outset the amplifier was designed so the OctalMania set could be stacked on top of it as shown in Figure 4. The schematic is provided in Figure 5, and the part lists appears at the end of this article. Research for this project suggested there may be several hams still willing to tackle a homebrew linear these days, so basic construction details are provided in this article. As always, anyone wishing more information on this project is welcome to send me an e-mail.

Mechanical Layout

Like the OctalMania set that goes with it, the amplifier is a big radio. The chassis is 12 X 17 X 3 inches. There was lots of room for heavy duty components and unrestricted cooling air flow. A scrap 10.5 inch rack panel in my sheet metal junk box was used for the back panel, and judicious component placement allowed the holes that were already in it to be utilized. A new panel of the same size was used for the front, and 1.0 X .125 inch angle stock up the sides and front to back across the top yielded a basic box structure that could be wrestled around on the bench. The height above the chassis allowed the tubes to be mounted upright for trouble-free operation. In turn this put the input circuits on the bottom of the chassis, well shielded from the plate circuits.

Looking at the top of the chassis in Figure 2, the muffin fan is only a couple of inches from the tubes and provides plenty of air directly over the glass envelopes. Brackets were attached to the ends of loading capacitor C11 to provide mounting surfaces for plate tuning capacitor C10. At about 350 pf C10 is much larger than needed. The tank circuit resonates at 3.9 MHz with this capacitor right at half rotation, so a 200 or 250 pf variable would have been adequate. Flexible couplings from the old TU-5s, panel bushings and .25 inch shafts were used to drive both variables. The three 20 watt wirewound resistors used in the radio are mounted on square ceramic standoffs, with the 20 ohm unit next to plate choke RFC2 a typical example. These standoffs are again more TU-5 hardware. It's amazing how much of this 70 year old stuff still shows up in junk boxes at hamfests. One of these standoffs was also secured horizontally next to C10 to mount doorknob capacitor C9 in the plate circuit.

The power supply components were mounted on a blank piece of fiberglass board drilled out to accommodate the filter capacitors, bleeder resistors, voltage doubler diodes and multiplier resistors for the plate voltage meter circuit. The board was mounted vertically using a piece of angle stock and placed so that air from the fan makes its way across the bleeder resistors and helps keep them cool. A plastic rod made from an old test probe was fastened between the top of the board and the front panel to provide support.

Relay K2 is an octal plug-in type and was mounted right behind the meters. The other three relays were mounted below chassis. Tank coil L4 was wound on a ceramic form, also rescued from a TU-5 tuning unit. The original mounting brackets and hardware were used to mount it to the front panel. This coil is discussed in more detail later.

Bandswitch S3 is a heavy duty unit made by Radio Switch Corporation. It has two sections but only the one closest to the panel is used to switch the taps on L4. 8-32 screws hold the front of the switch to the front panel, while small brackets are attached to the rear and run down to the chassis for additional support. To get by with a single bandswitch knob, rotation of S3 is transferred below the chassis to S4 using the same technique as the OctalMania transmitter. Servo hardware from the radio control (RC) model hobby does the trick nicely. Two servo wheels were drilled out in the center to .25 inches and then super-glued to the rear of S3's shaft and the front of S4's shaft. .063 steel control rods were then fed through holes in the chassis to link the two wheels using "screw-lock pushrod connectors" mounted at the edges of the wheels.

The plate transformer is quite heavy and required extra support to keep it from flexing the thin chassis. This was accomplished by running a piece of .75 X .063 inch angle stock across the width of the chassis as seen in the bottom view of Figure 2. Two of the transformer's .25 inch mounting studs go through this angle, and the rest of its length is secured with #6 screws every few inches. The result is a very solid base for the transformer. An .063 inch plate was also fastened vertically to this angle to provide a mounting surface for input coils L1, L2, L3 and bandswitch S4. Angle stock attached to the other end of this plate provides a surface to pick up two sheet metal screws through the center of the bottom cover.

Also underneath the chassis can be seen filament choke RFC1. This was bifilar wound from the Amidon FLC-10 kit (www.amidoncorp.com). Shrink fit tubing was used over it to secure the turns in place. The ends of the choke are soldered at one end to a terminal strip and at the other end to the closest tube socket. Relay K4 is mounted at the rear of the chassis and has four coax cables running to it. K1 and K3 are just left of the center of the chassis. With the exception of the input circuits, none of the component placement under the chassis is particularly critical.

For safety, ventilation and RF shielding, the finished amplifier has .063 inch perforated aluminum covers on the top, bottom and both sides as shown in Figure 3. The holes in the perforated metal are .25 inch diameter on .375 inch centers. A 40 X 36 inch sheet of this stock was ordered online from Grainger (www.grainger.com) as part number 5PDA5 and picked up at the local store. It was cut to size using a saber saw with a metal cutting blade. Edges were squared up with files. To provide mounting surfaces, a frame was constructed on the radio using .125 X 1.0 inch aluminum angle and bar stock from the local home improvement store. The angle stock running up the sides was fastened to the front and rear panels using .25 inch diameter screws, nuts and lockwashers. The top and side covers were attached with 8-32 screws into holes drilled and tapped in the frame pieces. The bottom cover was attached to the chassis edges and center brace using #8 sheet metal screws. It took a while to complete all of this metal work but it was well worth it. The frames and covers add considerable torsional strength to the complete radio. This is important when handling a 47 pound radio like this with a 20 pound transformer sitting in one corner.

Circuit Description

Refer to the Figure 5 schematic for this discussion. The basic RF circuitry of the amplifier is similar to the Heath SB-201. When the linear is not keyed, RF input from the exciter at J2 is routed through K4 contacts back out through J1. When the amplifier is keyed by K3, K4 is energized and exciter RF is coupled to the filaments of V1 and V2 through a pi-network matching circuit selected for each band by S4. The filaments are isolated from RF by RFC1. In transmit, grid bias from the wiper of R2 is applied to the tubes through a one ohm meter shunt and RFC3, and can be varied from 0 to -5 volts by R2. The plate circuit is shunt fed nominal 2,400 volts DC through RFC2. RF at the plates is coupled through C9 to the pi-network output circuit. S3 shorts out sections of L4 on 40 and 20 meters, and adds two additional sections of C11 load capacitance on 80 meters. RF output is routed from C11 through K4 to J1. RFC4 is the standard safety choke to keep DC from appearing on the output.

The power supply is a voltage doubler similar to the SB-201, 30L-1 and other popular amplifiers in this power class. Transformer T2 was procured from Surplus Sales of Nebraska, and turned out to be a New Old Stock (NOS) military surplus unit with a 1983 date code and still in the original packaging. With line voltage at 120 volts the no load DC voltage runs about 2,550 volts, dropping to 2,400 volts with the linear keyed and the plates idling at about 90 ma, and then to 2,200 volts or so at 600 watts steady output. The amplifier will actually put out more than 700 watts, but the tubes are rated for 600 watts so that's where I operate it. T2 doesn't even get warm in use, so there are no apparent issues with its power capacity for an amplifier like this that is used primarily for intermittent voice service. The effective capacitance across the plate voltage is 45 µf, so during SSB voice transmission the PEP is easily maintained at 600 watts.

RF is sampled at the grids by a capacitive divider and rectified by D3 to produce ALC voltage for the exciter at J3. This circuit is identical to the SB-201, except that I elected to make the threshold variable. This was accomplished by connecting D3's cathode to a variable +12 volts source and is similar to the 30L-1 implementation. For a given input level, as the wiper is moved toward the ground side of R1 the ALC voltage will become more negative. On the SB-201 the cathode of D3 is tied to a fixed reference of about eight volts. I didn't have a 28 µH choke for RFC3, but in the junk box was an old BC antenna coil. When the slug core was pulled out this coil showed about 28 µH on the ancient Heath Q Meter, so I used it. The 3.3k resistor fit right inside the core and provided convenient leads to solder the Litz wires of the coil to.

The metering circuits are straightforward. “Glitch” diodes are connected across M2 and R9 to protect things in case a tube or other component shorts out. High power DC arcs are especially destructive because a conductive plasma can form that won’t self-quench like AC can do when the polarity reverses. R9 is way oversized and protected by the diodes because this is one resistor you don’t want to burn out during a short circuit event. The 20 ohm resistor in series with RFC2 is also intended to provide some protection in a short circuit. In addition, this is a wirewound resistor so it acts like a choke. Bypassing it on both sides with 2200 pf capacitors provides additional filtering to keep RF out of the power supply. The 10.5 meg precision resistors were used for the plate voltage meter because I had a bunch of them in the junk box. 10 meg resistors could be used with proper selection of the resistor across the meter to provide 3,000 volts full scale.

The secondary of T3 feeds positive and negative full wave rectifiers that in turn feed +12 and -5 volt linear regulators U1 and U2. The +12 volts from U1 is used for the ALC reference as well as the coils of relays K3 and K4. The coil of T/R relay K3 is energized for transmit by grounding the ANT RELAY line at J4 just like any other linear. Since there’s only 12 volts on this line I suppose this linear could be used with modern rigs. One half of the secondary of T3 also feeds reverse connected T4, whose 120 volt winding is half wave rectified, filtered and voltage divided to provide about -58 volts cutoff bias to the tubes in standby. In transmit this bias line is connected by K3 contacts to the wiper of R2, where -5 volts from U2 applied across the pot provides an adjustable bias. Because of the resistances involved, the -58 volts from the standby bias circuit has negligible effect on the voltage at the wiper of R2 in transmit. Another set of contacts on K3 sends +12 volts to the coil of K4 in transmit.

On the power input side of things, a 16 gauge power cord feeds a 10 amp circuit breaker for the plate transformer and a 3 amp breaker for all other circuits. The SB-201 uses two 8 amp breakers for everything, but these each feed a 120 volt winding on the power transformer. With 120 volts input the primaries are in parallel, so the two breakers provide the equivalent of 16 amps of circuit protection. A little math shows that if the amplifier is putting out 600 watts at a typical 60% efficiency, that’s 1,000 watts minimum into the plate power supply. That translates to 8.3 amps at 120 volts. The 10 amp breaker used for the HV supply was a good compromise given that a soft start circuit is used for initial turn on.

S1 energizes K1, which puts AC from the 3 amp breaker on the primaries of T1, T3, and the muffin fan identified as “B” on the schematic. The 200 ohm resistor in series with the fan slows it down a bit for quieter operation. The value of this resistor depends a lot on the individual fan and personal preferences. When S1 is in the on position, green LED D2 illuminates. K1 also makes AC available from the 10 amp breaker to the slow start circuit at S2 and K2. If AC is present and S2 is turned on, AC is applied to T2 primary through the 10 ohm, 20 watt resistor to slowly charge up the high voltage filter capacitor string. AC is also applied through a diode and 1.0 k, 20 watt resistor to the coil of K2, which is shunted by a 4,700 µf capacitor. It takes about three seconds for this capacitor to charge to a voltage high enough to pull in the armature of K2. When this happens the 10 ohm resistor is shorted out by K2 contacts and full AC is applied to T2’s primary, just as the high voltage has reached about 2,400 volts. The steady state DC voltage on the coil of K2 is about 21 volts with S2 on. When S1 or S2 is turned off the coil and capacitor are discharged through a 15 ohm resistor to provide fast turn off. (**NOTE**: The S1 discharge loop was added in February, 2018. When S1 was turned off but S2 was left on, it was taking several seconds for the circuit to discharge and de-energize K2. If S1 was turned back on before this happened, full line voltage was applied to T2. This could trip CB1 or the service protection breaker, and weld the contacts on K1.) The control circuits are designed so that if S1 is off or either circuit breaker is open no high voltage can be generated. S2 can be left on at all times and the soft start feature will still work.

Another set of contacts on K2 illuminates red LED D1 and makes +12 volts available to the coil of K3. This arrangement prevents keying the amplifier and applying grid drive until full high voltage is available. This implementation provides two important protection functions. First, if drive was applied and plate current drawn before K2 closes, the 10 ohm 20 watt resistor in the soft start circuit could burn out due to the extra load. Second, inhibiting grid drive when plate voltage is not present helps prevent exceeding grid dissipation, since without an active plate circuit the grids can draw more current.

The Final Tank Coil

I don't know what TU-5 unit the coil I used came from, but as found it had 30 turns of #14 wire with three taps. The diameter is 2.0 inches and the pitch is 10 turns per inch. It was such a nice piece I just had to find some way I could make it work. Initial estimates of the PA load resistance, inductance and turns required for each band segment were made using handbook equations and on-line tools for pi-networks and air core coils. These calculated values were compared to those calculated for the tank coil dimensions used in the SB-201 as a sanity check. The coil was unwound and then rewound using the same wire in three sections approximating the SB-201 coil.

Since there are always unknown stray inductances and capacitances present in the actual hardware, the cold tuning method described in recent ARRL handbooks was used to further refine coil dimensions. This was done by first having all components in place in the plate, grid and filament circuits, including tubes. With power off, a 2.7k, two watt carbon resistor was connected between the top of RFC2 and ground to simulate the estimated PA load resistance. Then a small amount of RF from my Drake TR-5 solid state radio was fed through a cross needle SWR bridge into the RF output of the linear. The tank capacitors were then adjusted for minimum SWR. The method works because the pi network is bidirectional and power can travel in either direction. 50 ohms at the output is transformed to about 3,000 ohms at the plates when the network is resonated with the right component values. The power can be applied only briefly because once a good match is obtained all of the power coming from the exciter is stepped up to hundreds of volts of RF that is dissipated in the load resistor. And of course you have to run enough power through the SWR bridge to get a useful reading. If a bunch of two watt non-inductive resistors in the 250-500 ohm range were available they could have been connected in series and this would have been less of a problem. During the testing, if a decent match could not be obtained the tap was moved on the coil or the section was rewound. The whole process was time consuming because each coil section affected the other two. But the effort paid off because when the amplifier was powered up the coil dimensions and taps were just right.

With the sizing exercise completed, I removed all of the original wire because it had kinks and solder blobs everywhere from all the experimentation. But this was of no concern because I had a loading coil from an old ARC-5 transmitter that just happened to have a lot of silver plated #14 wire. This wire was removed and immersed in liquid silver polish to remove decades of tarnish. A soft brush was also used to help the process, and it came out shiny bright. The wire was then rinsed, sprayed with 409 cleaner and then rinsed again. The ceramic form and brackets were also scraped, sanded and brushed with 409 cleaner until they were in like new condition. The coil was then tightly wound to the final dimensions using the refurbished wire. As Figure 2 shows, it came out very nice. As a side note, the three rotary switches were also cleaned using the liquid silver polish technique.

The Input Circuits

Although a grounded grid linear can be driven with an untuned input, there are many benefits to using tuned inputs such as greater power sensitivity, less distortion, and easier matching to the exciter. So it was decided at the outset that pi-network input matching would be used. Getting the input circuits configured for each band was similar in scope to the final tank coil. The input impedance of a pair of 572Bs in grounded grid is supposed to be something like 110 ohms according to my 1970 “W6SAI Radio Handbook”. This is the only place I’ve ever seen this figure published. Plugging 110 ohms into pi-network calculators with 50 ohms on the other end and a recommended Q of 2 to 4 produced inductances and capacitances that didn’t really match up with anything used in the SB-200, SB-201, 30L-1 or FL-2100R (It is noted that the input capacitors in the SB-200 are quite different from the SB-201 because of the 11 meter trap in the latter radio, but the 80 and 20 meter coils are actually the same part number). Maybe I was doing something wrong, but rather than try the theoretical calculation route I counted the turns on the coils in the SB-201 and noted the wire gauges. These are wound on .375 inch diameter slug tuned forms. Since I was using slug tuned forms .50 inches in diameter, I reduced the number of turns by 25% for a starting point. That turned out to be pretty close to the final dimensions.

With the slugs in the coils set about half way in, the capacitors were determined next. The TR-5 was used again, this time to put some RF drive into the input circuits through the SWR bridge. A single gang 410 pf BC variable capacitor was tacked between each end and ground of the coil being tested. The amplifier was turned on and keyed with its output connected to a dummy load, and a small amount of RF from the exciter was fed into the input. For this testing I had the plate transformer primary connected to a variac so I could make initial adjustments at low power. The linear’s plate circuit was tuned for maximum output and the BC variables were then tuned around until a good match was obtained. A fixed capacitor was added when I ran out of capacitance on a variable. The coil slugs were also adjusted for best match. In terms of causing a marked dip in SWR, the coil tuning was very broad and really not very effective. Conversely, the capacitor tuning at the point of best match was a lot sharper than I would have expected for these circuits. This might explain why some of the capacitors in the commercial amplifiers have oddball values, and begs the question why so many manufacturers chose to make the coils adjustable instead of the capacitors.

Eventually capacitor and coil combinations were found that yielded matches close to 1:1 at each test frequency, but with caveats. What was observed is that driving a grounded grid amplifier is a compromise affair. For starters, the input SWR is highly dependent on the tuning in the linear’s plate circuit. You can see the SWR dip as the plate is tuned through resonance. So it is important to make sure the plate circuit is adjusted for maximum power output. Another factor is that as drive is increased the linear’s grids begin to draw current as they transition from class AB1 to AB2. This also causes the SWR to change because the effective input impedance is changing as well. And of course as the exciter frequency is changed the SWR will deviate from a perfect match unless the values are changed. This was most apparent on 80 meters. Here the circuit was optimized for 3.9 MHz as a compromise.

The final values of capacitance and inductance were double checked with drive from an SB-102 and the OctalMania transmitter to see how tube rigs with adjustable pi-network outputs would behave, and good matches were still present. The capacitor values differ from all of the commercial linears I could find data on but they were in the ball park, especially compared to the SB-200 which this unit most closely resembles. I suspect the inductance and distributed capacitance of the filament choke has a lot to do with all of this. The Amidon choke is advertised as 26 µH with the bifilar windings in parallel, which is much higher than the ones used in the SB-201 or 30L-1. By the way, for all those who ever fretted over the 20.5 foot length of RG-58 that was initially specified for input to the 30L-1 and then later changed to 4 feet, I tried 3, 6 and 9 foot patch cables from the SWR bridge and did not notice any substantial differences in SWR.

Final Testing and Adjustment

<<Any vacuum tube linear amplifier has lethal voltages inside. Use Caution!!>>

A pair of old Cetron tubes that were pullouts from the SB-201 was used for most of the testing. When it came time to go for full power output it was noticed that one tube was glowing red and the other wasn't. Testing idle plate current on one tube at a time confirmed suspicions that they were not balanced. At this point I decided it was time to try a pair of new Svetlana 572Bs that had been purchased at a hamfest last summer specifically for this project, but when installed they did the same thing. In all fairness the seller never promised they were matched, and they did have different date codes and internal construction. Of course tuning up the amplifier to what looks like full output with tubes that aren't matched means that the hotter tube is doing all the work, and is probably distorting and exceeding its maximum plate dissipation. This is clearly not a good situation.

So in a final act of budget busting a pair of new, matched Chinese tubes were procured for the radio. When these were tested one at a time the idling plate current differed by only one milliamp, as measured across R9 with a DMM. With the linear keyed, bias pot R2 was set for -2 volts as recommended for 572Bs. This gave an idling plate current of about 82 ma, which is close enough to the usual 90 ma quoted for these tubes. The amplifier now easily put out over 600 watts and both tubes stayed the same color. The SWR at the input of the amplifier was also checked again in case the unbalanced tubes had been causing erroneous results, but everything was still matching up fine as before.

As with the SB-201, the linear is tuned for maximum output power using the PA TUNE and PA LOAD capacitors. Everything that has been said about the importance of grid current versus plate loading in a linear applies to the HB-600. The 572B has a maximum rated grid current of 50 ma per tube, or 100 ma for the pair. If the amplifier is driven with no plate voltage at all the maximum grid current is easily exceeded. With plate voltage applied, the grid current decreases as plate tuning is resonated and loading is increased. With insufficient loading it is still possible to exceed 100 ma of grid current. When the amplifier is correctly tuned, a maximum power output of about 600 watts will occur with around 450 ma of plate current. The PA LOAD should then be increased a little beyond this point and PA PLATE repeaked for maximum output.

Under these conditions total grid current for both tubes will less than 50 ma and it will be very difficult to exceed the 100 ma maximum.

ALC threshold pot R1 is set using essentially the same method described in the 30L-1 manual. The exciter has to have enough output power to overdrive the linear (about 60 watts PEP). A two tone audio source is required for this adjustment because CW RF or a single audio tone will not properly activate the ALC circuits in an exciter where PA grid current is rectified to generate the ALC voltage. This includes exciters like the Collins 32S-3, KWM-2, Heath SB series, and the OctalMania. To make the threshold adjustment, set the ALC threshold pot so its wiper is at the +12 volts end and temporarily disconnect the ALC cable from the linear. Then tune and load the exciter and linear to normal full output using a single tone audio or RF signal. Apply a two-tone signal to the input of the exciter, set the meter switch to read ALC and adjust the mic gain so the ALC meter just begins to deflect. Without touching the mic gain, switch to standby, reconnect the ALC cable, rekey the exciter and adjust the linear's ALC threshold pot so that the ALC meter now reads about one-third scale. A more crude adjustment can be made by having the ALC cable connected, talking into the mic and adjusting the linear's ALC pot until the exciter's ALC meter increases its peaks by about a quarter of the meter scale. The whole idea is to make sure the linear's ALC voltage, not the exciter's, controls the output of the pair. This keeps the PEP output at about 600 watts.

Closing Thoughts

The goal of 100% homebrew SSB has been achieved and the HB-600 is on the air. The new 572Bs are doing a good job. A pair of 813s would also have been a good choice since their characteristics in grounded grid (both grids grounded) are very similar to the 572Bs. The high voltage supply is certainly sized right, so I wouldn't be surprised to see a pair of 813s work in this linear just by changing T1 to a 10 volt, 10 amp transformer. WA6VVL has homebrewed a couple of linears with 813s and highly recommends them. And I have to admit I've always liked those great big old WWII tubes, so if I ever do another linear it will use them. In fact, I already bought some at a recent hamfest along with a bunch of sockets.

Once again, if you have any questions or would like more information please feel free to contact me at bohn48@msn.com. Be sure to include HB-600 in your subject line so I can find your message in my inbox.

The HB-600 was acquired by NU6X in May, 2020.

Figure 1: The HB-600 Linear Amplifier, Front and Rear Views

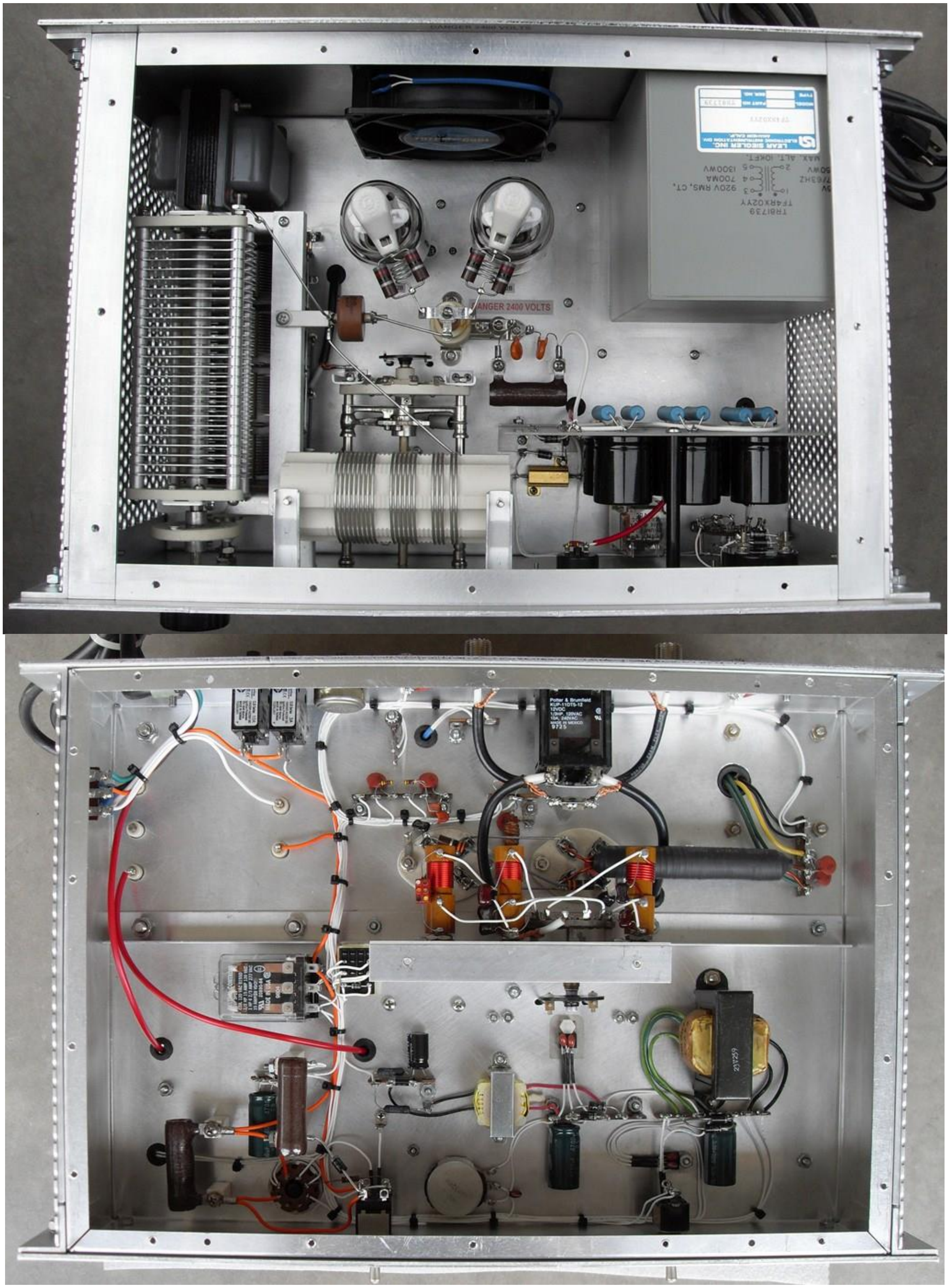

Figure 2: HB-600, Top and Bottom Views

Figure 3: Perforated Sheet Metal Covers Make a Sturdy Box Structure

Figure 4: HB-600 with OctalMania Radio Set Stacked On Top.
A 25 Inch Tower of 100% Homebrew, Hollow-State SSB!

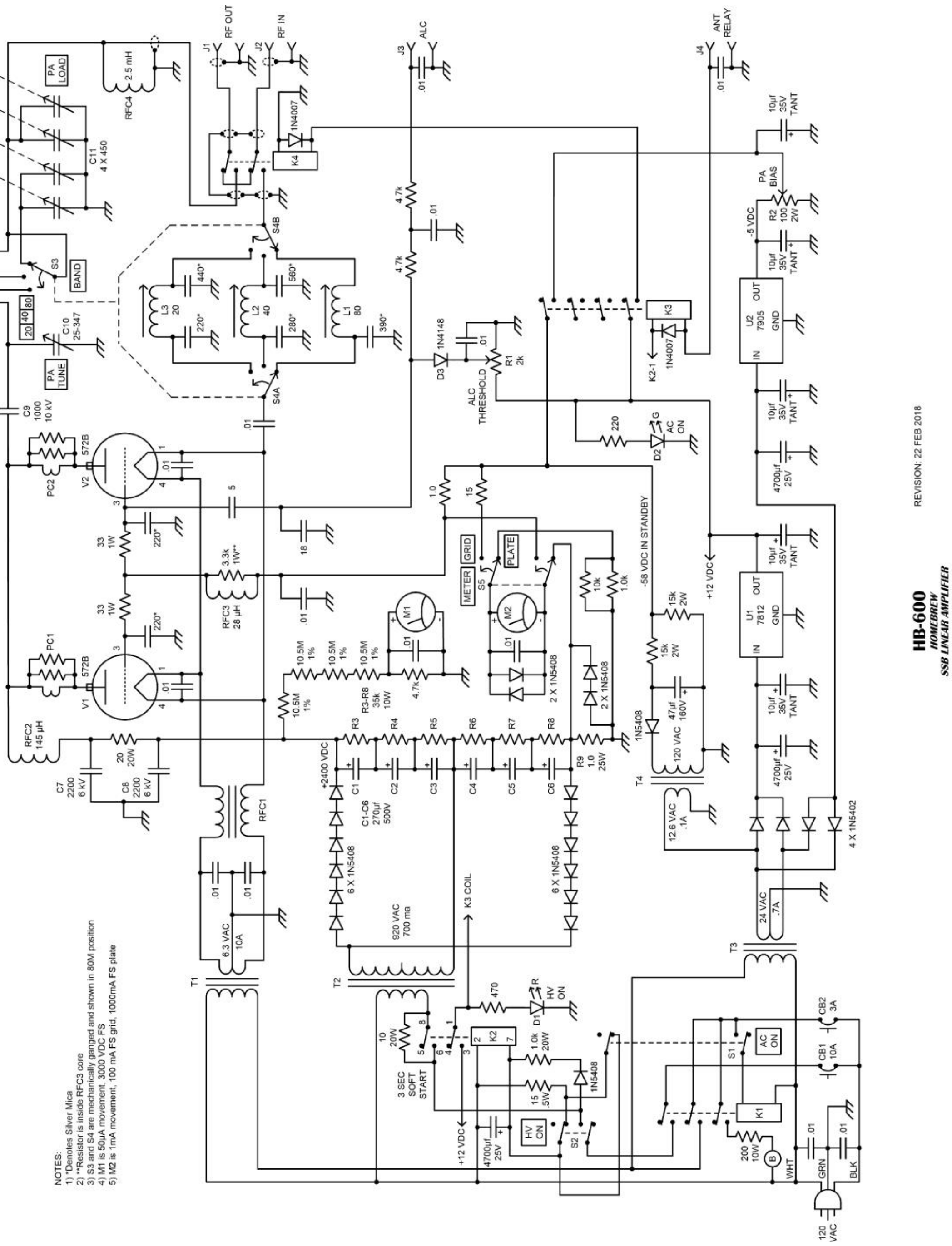

Figure 5: HB-600 Schematic

Parts List for the HB-600 Linear Amplifier

(Parts in parentheses were used in the actual unit)

B	4.25 inch muffin fan, 120 VAC
C1 thru C6	270 µf at 500 VDC, snap in electrolytic (Nichicon LGN2H271MELC40, available from Mouser)
C7, C8	2200 pf at 6 kV disc ceramic (Vishay 564R60GAD22, available from Mouser)
C9	1000 pf at 5 kV minimum doorknob capacitor (10 kV, CFC-HIQ-1000-10 from Surplus Sales of Nebraska)
C10	Transmitting variable, .075 inch minimum spacing, 200 pf max adequate (Johnson 25-347 pf type 154)
C11	Four section, 450 pf per section, BC type variable
CB1	10 amp circuit breaker (Carling CLB-103-11B3ABA, available from Mouser)
CB2	3 amp circuit breaker (Carling CLB-033-11B3ABA, available from Mouser)
D1	Red LED
D2	Green LED
D3	1N914 or 1N4148 silicon signal diode
J1, J2	SO-239 UHF Jack
J3, J4	RCA phono jack
K1	3PDT, contacts 15A at 120 VAC, 120 VAC coil
K2	DPDT, contacts 10A at 120 VAC, 24 VDC coil, 475 ohm
K3	DPDT minimum, contacts 5A at 28 VDC, coil 12 VDC, 150 ohm
K4	DPDT, contacts 10A at 120 VAC, coil 12 VDC, 120 ohm
L1	16 turns #20 close wound on .5 inch diameter slug tuned form, National XR-50
L2	11 turns #20 close wound on .5 diameter inch slug tuned form, National XR-50
L3	7 turns #16 close wound on .5 diameter inch slug tuned form, National XR-50
L4	20 turns tinned #14 on 2 inch diameter, 10 tpi ceramic form from TU-5 tuning unit. Coil wound in sections of 9 turns, 6 turns and 5 turns, .3 inch spacing between each section, 5 turn section has .1 inch spacing (skipped turn) in middle. Full coil for 80, 6 + 5 turns for 40 and 5 turns for 20
M1	50 µa panel meter, calibrated to 3000 VDC full scale
M2	1 ma panel meter, calibrated to 1000 ma full scale for plate and 100 ma for grid
PC1, PC2	4 turns #18, .3 inch diameter, .5 inch long, paralleled by two 82 ohm, 2 watt carbon comp resistors
R1	Panel mount potentiometer, linear taper

R2	Panel mount potentiometer, linear taper, wirewound, 2 watt
R3 thru R8	35 kohm, 10 watt, wirewound (Ohmite 40F35KE, available from Mouser)
R9	1.0 ohm, wirewound, 25 watt, 1% preferred, chassis mount
RFC1	Filament choke, #14 enamel bifilar wound on four inch ferrite rod type R61-050-400 (Amidon FLC-10 kit)
RFC2	Plate choke, 145 µH (National type R-175A). Other suitable chokes available from MFJ Enterprises.
RFC3	Pi-wound choke, 28 µH (made from loopstick BC antenna coil with core removed)
RFC4	Pi-wound choke, 2.5 mH
S1	DPDT toggle, contacts 5A at 120 VAC
S2	DPDT toggle, contacts 10A at 120 VAC
S3	Single pole, 3 position rotary switch, heavy duty (Radio Switch Corp)
S4	Double pole, 3 position rotary switch, mechanically linked to S3
S5	Double pole, 2 position rotary switch
T1	Filament transformer, 115 VAC primary, secondary 6.3 VAC at 10A (Triad F-21A)
T2	Plate transformer, 115 VAC primary, secondary 920 VAC at 700 ma (TR81739 from Surplus Sales of Nebraska)
T3	Control transformer, primary 115 VAC, secondary 24 VAC CT at 700 ma (Thordarson 23V259)
T4	Filament transformer, primary 120 VAC, secondary 12.6 VAC CT at .1A (Xicon 41FG100 available from Mouser)
U1	12 volt positive linear regulator IC, type 7812, TO-220 package, can be mounted directly to chassis
U2	5 volt negative linear regulator IC, type 7905, TO-220 package, requires insulator for mounting to chassis

General Notes for Linear Parts:

1. Fixed capacitors: Capacitors marked with an asterisk are silver mica, 500 volt minimum rating. Capacitors with a plus sign are electrolytic except 10 µf which are tantalum. Unless otherwise noted, all other fixed capacitors are disc ceramic, 500 volt rating minimum.
2. Fixed resistors: Unless otherwise noted, all resistors are 0.25 watt, 5 percent tolerance, carbon composition or carbon film. 0.5 and 1.0 watt are 5 percent tolerance, carbon composition or carbon film. 10 and 20 watt are wire wound.
3. 10.5 meg resistors used in plate voltage meter circuit may be 10 meg, 5%, .25 watt. Select value of 4.7 k across meter to give correct reading.