Deyellification of the Johnson Invader 2000

By KB3AHE

Introduction

I am writing this article to share what has been a very interesting and trying experience with anyone who may be planning on restoring and / or using an Invader or Invader 2000. This article is primarily based on using it for AM and Hi-FI AM at that. If done properly you will be rewarded with a very versatile transmitter that is fun to use. Let's face it 250 Watts+ of AM carrier and 1 kW+ of SSB in a table top box at the flip of a switch makes for a very interesting rig!

If you are an originality freak don't even bother to read this article. Leave now and don't waste your time. If you want a good running, fun to use transmitter, then read on. Some of these modifications are quite extensive, but are well worth it in the end. If you have had the chance to work me on the air, or if you have worked the W3F Farfest special event station this year, you have heard my Invader on the air.

The Invader 2000 (especially the earlier ones) are some of the most hateful pieces of S@#% that E.F. Johnson had ever produced. They have many problems that are the nature of the design of the transmitter. Also the underside of the chassis is 10 pounds of S#$% stuffed in a 5 pound bag. I have both an Invader 200 (the low powered version) and an Invader 2000. Both of mine are earlier versions 1960, and 1961. Hopefully some of the design faults have been corrected in the later versions. I have never seen a later one to compare. Johnson has published several letters of upgrades over the years. I suggest you find them and look them over before starting deyellification.

I am not going to sugar coat it, this is a difficult job, and not for the beginning technician. If you are a neophyte or a newbie to tube gear, **DO NOT** even attempt this without the help of an experienced technician to look over your shoulder. This is not a job for the weak at heart or the easily discouraged. Also be very wary that you are dealing with **LETHAL** high voltages inside this box. Since I have done the engineering and head scratching, This will be a lot easier on you than it was for me. An experienced tech/builder should be able to do this in a week or two worth of evenings.

You MUST obtain a manual and a skizmatic for this animal. Also make several copies of the skiz so you can mark them up as you progress along. Some of the manuals had the update/modification sheets with them. Try to get one and also do the factory mods while you're in there. When you are done with the mods, the transmitter should be aligned to the factory specs outlined in the manual.

This article is written for the experienced tech. I am not going to draw a diagram of each and every mod. You should be able to read my descriptions and figure out how to do them.

Many of the mods that I will describe will be for audio, some will be to increase stability, and some will be necessary just to make the blasted, under-engineered piece of crap work right. When completed, you will be rewarded with a really useful transmitter. The transmitter will retain all of its original functions (yes, including CW), except for VOX. But since most of us AMers hate VOX and prefer PTT, this should be of little concern.

As I said earlier, this article is for those who want to use and enjoy their transmitter, and not have it as a shelf queen, part of a collection that you have for bragging rights and have no intention of using. When complete, this transmitter will make beautiful DC-to-Daylight audio!

There is one last consideration before getting into the thick of things. Do not be intimidated in buying one due to the rather rare final tubes. Penta Labs PL-175A's are getting just about impossible to find these days, and very costly if found. However, here is your way out!! Good old reliable, easy to find, 4-400's will plug in and work without any wiring changes. You may want to adjust the screen and bias voltages to get full output, but otherwise they're a drop in replacement!

Audio Mods/Audio Section

Johnson deliberately made the audio bandpass very narrow in these transmitters to escape stray hum and other various noise monsters. Any attempt to broaden out the audio by conventional methods of fattening up the coupling caps is usually met with dismal failure and a really nasty hum in the audio. They have run the audio lines, 120 VAC lines and RF carrying lines all bundled together in one wiring harness, this is the perfect formula for audio disaster if you want HI-FI audio. They also have the mic amp right next to the carrier oscillator with NO shielding! The entire underneath of the chassis is a big mix of RF and AC soup that has to be worked around. Here it comes, take a deep breath and grab your desoldering braid and diagonal cutters!

1. Bulldoze out the entire speech amp/VOX section.

2. Remove everything that is connected to V5, V6, V12, and V13 tube socket pins.

3. Connect the purple wire that carries the PTT signal from the operate switch to low side of the T/R relay coil through a 4.7 k/1 W resistor. This will preserve all of the PTT functions.

4. Remove V12 and V13 (6U8 & 6AL5) tube sockets, replace them with shielded sockets, also acquire tube shields for the tubes that you will install into them.

5. Remove V5, V6, V12, and V13 and toss them into your junk box, you wont be reinstalling them.

6. Build any good basic 12AX7 / 6C4 speech amp/driver circuit into the two shielded sockets that you installed (where the 6U8 and 6AL5 used to be). You can find a good circuit in the amwindow.org technical section. Use 0.047 uF coupling caps instead of the usual 0.1's that we normally use or you will actually have too much bottom end. Yes, that's right, way too much lows at the expense of losing some intelligibility. I used 0.1's and changed them back to 0.047's. Also try to use the lowest valued grid resistor on the mic amp input that you can. If you don't plan to use a D 10-4 and are going to use a dynamic mike, don't go over 2 Megs. Also be sure to put a 4.7k resistor and a 0.047 uF cap in series with the mic input lead to the grid of the first half of the 'AX7. Try to keep your input impedance as low as possible. I also put a small cap (something around 150 to 300 pF) from the grids of the 'AX7 and the grid of the 6C4 to ground. This wont have much effect on your highs, but will help prevent them from picking up stray RF.

7. Now here is where it gets a little different. The 6C4, instead of being a cascaded stage will have to be a cathode follower to match up to the input impedance of the balanced modulator. Here is how it goes: 0.047 uF coupling cap from the plate of the second half of the ‘AX7 to the grid of the 6C4 with a 470 k grid resistor to ground, a 1.8k/1W cathode resistor to ground, a 35 uF non-polarized low-leakage electrolytic cap from the cathode of the 6C4 to the input of the balanced modulator through a 2.5 mH RF choke. Now use a 27k/1W plate resistor to the 300V B+ feeder with at least a 10 uF or higher cap from the plate of the 6C4 directly to ground.

8. Do not install anything back into the sockets where the 12AT7’s were unless you want to stick some dummy tubes in there for show only.

9. This is extremely important!! **DO NOT USE ANY OF THE ORIGINAL AUDIO COAX LINES THAT ARE RUNNING THROUGH THE HARNESS!!!** Snip them off flush with the harness and run new ones away from the main harness. Use a high quality coax and keep the runs as short as possible. I prefer to use a high quality 1/8” silver teflon cable. Any audio runs that are more than 2” long run them in coax and ground the shield at both ends! Run two new pieces of coax from the speech amp to the front panel audio level control, cut the outside jacket off of the cable every few inches and solder the shield braid to a ground lug, you may have to install some. Try to keep these coax runs as short and direct as possible, while staying as far as possible from heavy RF areas and things carrying 120 VAC.
10. If you plan to feed this monster with line level or processed audio, install a jack of your choice on the back where the key jack was and feed the processed audio to the high side of the audio pot. Make the tie-in somewhere near the speech amp instead of running a third coax all the way out to the front panel.

11. Remove one of the now unused VOX adjustment pots from the rear panel and reinstall the key jack in that hole.

12. In doing this you may want to clean off the existing tie point strips next to the audio tubes to use for your mods. This is easier than installing new ones.

13. Finally, if you find that you have too much audio (as I did) or are still picking up a slight, but mysterious hum, substitute a 12AU7 for the 12AX7 and try it again. This will reduce the overall audio gain and you don’t have to change any of the other circuit components.

14. I cant say this enough, the underside of the Invader chassis is a nasty mix of RF soup and powerful AC fields. Use the best construction practices that you know and are able to do. This is absolutely imperative to keep the crap out of the audio. Johnson

originally dealt with it the easy way, by restricting the audio bandpass, so it wouldn't pass the junk through. Once you open up the audio you create a whole new monster that you have to deal with. It isn't easy, but it is doable, as long as you are careful and meticulous in your construction practices. THERE IS NO ROOM FOR JS'S IN THIS PROJECT!!

Balanced Modulator/Crystal Filter

1. You must bypass the crystal filter to get true double sideband AM out of this transmitter, here is how to do it. If you don't, you will get USB and a carrier. You must install a relay to swing the output from the balanced modulator around the crystal filter. I just used a DPDT 6 volt ice cube relay to swing the filter out of the circuit and connect the output of the balanced modulator directly to the input of the 9 Mc amp.

2. You MUST use a DPDT relay and be sure that the crystal filter is completely disconnected and out of the circuit when in the AM mode. I installed a miniature toggle switch in the far upper left corner of the front cover to actuate the relay and took the power from the filament circuit. Also use baby silver teflon coax for the RF lines and keep the lengths as short as possible. You can mount the relay to the divider wall/shield adjacent to the crystal filter.

3. Change the bypass cap at the RF choke on the audio input to the balanced modulator (C-16) from 0.005 uF to something around 500 pF.

Eliminate the ALC!

1. This is the easiest one! Remove the 6T8 tube (V14) and toss it into your junkbox. Do not put anything back into that socket, leave it empty. You wont need and don't want it, even for SSB operation. It is not necessary.

Reliability and Stability Mods

The Invader is plagued with many design flaws that may not have ever shown up if it was always used for SSB, However they will rear their ugly heads and bite a chunk out of your butt when you try to use it for hi-fi AM!! I will try to save you from some of the pitfalls that I have fallen into. Most of these are simply trying to keep the RF where it is supposed to be (and out of everything else). The heavy AM carrier just seems to get back into everything. Others deal with changing levels and other weird problems that I ran into.

1. It should go without saying, but I'm gonna say it anyway: Change out **ALL** of the power supply filter caps to new modern stuff, the highest grade that you can get.

2. Now is the time to test all of the tubes and replace any weak ones. Pay particular attention to the 12BY7 RF driver tube. Both of my rigs have had a low drive problem, and revealed a 12BY7 that was so weak that it wouldn't even move the needle on my emission type tube tester. These rigs are especially hard on the driver tube.

3. Remove the shield from the 12BY7 driver tube and toss it into your junk box, you won't be reinstalling it. This accomplishes two things, the tube runs cooler and lasts longer, and you get a much stronger spot signal for your receiver. When you align the transmitter you can make the slight tuning difference to compensate for it.

4. Solid state the 6X4 bias regulator (V103). This improved regulation. Change the bias filter cap (C-180) from 100 uF to something closer to 200 uF. You will get a slight hum induced back into things from the bias supply and the extra capacitance cures it. This value isn't critical as long as it much larger than the original.

5. Solid state the 5U4 PA screen supply rectifier (V303) and change the primary input tap of that transformer (T303) to the lower input voltage (105v) tap. (black / yellow wire). This will raise the PA screen voltage to something around 550-575 V. This

   helps produce nice positive peaks and good PEP output. The 450 V or so that mine had was just too low for good operation of the PL-175's.

6. I don't feel that solid stating the rest of the supplies are necessary. However, if you wish to, it surely can't hurt, it is totally your choice.

7. Changing the VR tubes to Zener stacks is another one that is up to you. I haven't done it to mine yet, but it would surely help stabilize the bias and +150 V regulated lines. I do plan to do this in the future, but have not done it as of yet.

8. Check BOTH of the large bleeder resistors in the power supply. If both are good, disconnect **one** of them. This decreases regulation slightly, but free up 80-100 Watts of power that the finals can put to better use elsewhere. (like audio peaks)!

9. If yours is an earlier unit, you should do the VFO mods that will be mentioned later in this article.

PA Deck Mods

1. Change the transmit bias regulator (V203) from an 0C2 to an 0B2. This will dramatically reduce the PA static (resting) plate current and give you a little more headroom for peaks. Be sure to reinstall the shield on it to keep the RF out, as it sits right next to the plate tank coil.

2. Here is one that you **ABSOLUTELY MUST DO**: The plate choke / bypass combo in the hi-power final amp is absolutely too small to keep the RF from running out on the HV line and getting back into everything!! If you follow the HV line from the bottom of the plate choke through the chassis, you will find that it connects to a small resistive divider board for the front panel voltmeter function. Connect a 0.01 uF/4-6 kV ceramic disk cap from the HV tab on the divider board to the closest ground you can find. Now, connect a 0.01 uF/1 kV ceramic disk cap from the divided output (to front panel voltmeter) lead to ground. Also remove the two 500 pF bypass caps and the small choke where the HV line comes out of the back on the PA chassis. Substitute a jumper for the little choke coil, and bypass with another 0.01 uF/4-6 kV disk cap to ground.

3. Install 0.01 uF/1 kV ceramic disk caps to the two unbypassed screen terminals on the final PA tubes. (V201 & V202).

4. Install a 0.01 uF/1 kV disk cap from the unbypassed side of the screen choke (L203) to ground.

5. Install 0.01 uF/1 kV disk caps from every terminal of J-202 (amplifier control plug) to ground.

6. Install a 0.01 uF/1 kV disk cap from the unbypassed side of the grid bias choke (L202) to ground.

7. Take this time to check and make sure that all of the RF carrying ground lugs are tight and free of corrosion.

8. Also be sure to clean and oil both of the fan motors while you are in there.

VFO Modifications

I highly recommend doing the factory VFO modifications, as I had a terrible instability problem with mine. It would just keep drifting and never ever settle down. It would also take off and go wherever it felt like and not come back until you retuned it. It was so bad that I had to re-spot just about after every transmission. The factory knew they had a problem and published a mod sheet dated December 1962. After doing the factory VFO mods (and a few of my own) my invader now drifts about 100 Hz during warm up, and doesn't drift more than 100 Hz after an 8 hour running period without the VFO heater!

This is probably one of the hardest parts of this job. The lower VFO box (under the chassis is extremely cramped and tight and quite miserable to work in. This is a tough one, but well worth the effort. The factory also recommends installing a separate filament transformer to keep the VFO tube heater on full time. After the mods, I do not find this to be necessary, and have disconnected the VFO box heater. I have the factory VFO mod sheet and will be happy to send a copy to anyone who wants it if you send me a self-addressed envelope with first-class postage.

Some of the mods outlined here are the factory's and some are mine. Combined they make for an excellent and very stable VFO. Take another deep breath and get ready.

1. Disassemble and remove the upper VFO box from the chassis. Remove its cover and scrub it out well with soap and water and a tooth brush. (this is important to do).

2. After it has dried, place a few drops of light oil on the bearings and shafts of ALL of the variable caps and work the shafts to work it in.

3. Loosen and tighten the mounting screws and nuts of everything in the box to insure an oxidation free contact with the box.

4. Solder a small piece of ground braid (I used the shield braid from RG58 coax) from the front mounting lug to the rear mounting lug of BOTH sides of the main tuning capacitor. Solder another piece of braid (4-5" long) from either one of the rear lugs and leave the other end loose to be connected later.

5. Cut out and remove the original coax that connected the main tuning cap to the VFO tube. Drill another small hole right next to that one (1/8").

6. Drill and install two small standoff insulators in the front panel of the VFO box directly above the screws that mount the geared tuning shaft. (You can tell if yours is a later version if you see these screws already in the front of your VFO box).

7. Now, set that aside and remove the lower VFO box and enclosure. Snip out and discard C47, C48, and C49. It is easier to snip them out than to try to unsolder them out in that tight area. Carefully remove C50 to be reinstalled later.

8. Now back to the upper box. Install C47, C48, and C49 into the insulated stand standoffs that you installed in Step 6.

9. Change C144 from the existing ceramic disk to a high grade silver mica.

10. Carefully reinstall C50 into the upper box compartment. You will be reinstalling C47, 48, 49, and 50 into the same electrical position as the schematic, but moving their physical location to the upper box so all of the frequency determining components are in the same thermal environment. This was the factory's idea to improve stability. Use the highest grade, lowest tolerance caps you can get for this. It is well worth the effort and will pay off in the end. I used all 1% silver micas because I had them.

11. Install a small piece of silver teflon coax from the end of C47 and let the other end hang for now. Feed it out the original hole in the bottom of the box.

12. Install a second piece of baby silver teflon coax from the junction point of C48 and C49 and feed the other end out through the new hole that you drilled in the bottom in Step 5. Be sure that the shield braid is well grounded at the connected end.

13. Scotchbrite all mating surfaces for the box cover to insure good electrical contact and reinstall the cover on the upper VFO box. Route the loose end of the ground braid that you previously installed in Step 4 out through either of the lower rear corners of the box.

14. Reinstall the VFO top box to the chassis, making sure that you carefully route the new coaxes through the bottom, and align the mechanical dial to allow full travel from high end to low end.
15. Install a solder lug to the CLOSEST screw or nut to the VFO box that you can get to and solder the loose end of the hanging ground braid to it, keeping its length as short as possible.

16. Tie in the 2 small coaxes to the corresponding grid and cathode terminals of the VFO tube (V4/6AU6). Be sure to solder their shields to ground on both ends. It is very tight working inside the lower box so be very careful.

17. Reassemble and reinstall the lower VFO box covers and you are done here. (Sigh of relief!)

18. Note that the later schematics show it this way and the earlier ones show the caps in the lower chassis.

Finishing up!!!

The worst is now behind you, take a deep breath, let out a sigh of relief and get ready to reap your rewards! But first there are a few things left to do and go over. Here it comes.

1. Thoroughly read the manual and familiarize yourself with the alignment procedure for this transmitter. Even though this thing is now "Highly Modified" it still aligns exactly like an original. Take your time and do a very thorough alignment, you will be rewarded in the end.

2. With all of these modifications the transmitter still tunes up and operates like an original. The only difference is that the "static plate current" of the finals is reduced. Just use the loading chart from the manual and tune the plate for max dip. With the increased bias on the final, the dip is much more noticeable when tuning up. Maximum output is exactly at the dip on mine, even though the finals have no neutralization circuit.

3. I usually run somewhere around 250 Watts of carrier, which leaves plenty of headroom to make modulation peaks.

4. The audio that mine makes is so good that you may not even want to use any audio processing. That is your option, but a good sounding dynamic mike may be all that you need!

5. Since this rig, like many others, is still somewhat a work in progress, if I find any other interesting modifications or changes I will add updates to these mods. As for now, I am very pleased with its performance and don't plan any other changes.

6. One last thing that I have to go over with everyone is the incoming power line cord! The Invader 2000 is as happy working on 120 or 240 VAC. However when wired for 120 V, the AC neutral leg is tied directly to the chassis! Be sure that the power plug is phased properly or you will definitely be in for a shocking experience, and lots of "ground loop" problems.

Epilog

After talking to many people about the Invader project, the response from most was about the same: "I had one of those things and it never worked very well" or " I had one but never fired it up" or "I used to have one and it barely worked on sideband". After doing the modifications outlined above, mine works very well and never complains. It is now stable, easy to use, and packs a nice punch.

Having finished the restoration just two weeks earlier, it got the proverbial "Trial by Fire" at this year's Gaithersburg Farfest 2005 where it really had to "sing for its supper". All went basically without a hitch or crap out. We were running a straight dynamic mike without any audio processing at all and got many good audio reports. It was transformed from a persnickety piece of s@#$ into a fun rig that is quite pleasant and easy to operate. My Invader 2000 is now one of my favorite transmitters and a definite "keeper" that I have no plans of parting with.

Since I have done all of the head scratching, your restoration should go off without a hitch if you follow my guidelines. If you have one sitting around as display item and not being used, please consider these modifications and "just do it". In the end you will wish you only did it sooner.

De KB3AHE
(sometimes called The Slab Bacon)