TROUBLE SHOOTING TRANSFORMER (AC) POWERED ELECTRONICS
By Curt Lutz

Transformer-powered electronic equipment offers many advantages, when trouble-shooting, compared to AC/DC (non-transformer-powered) equipment. AC/DC equipment usually has series-string filament circuits, and many of these radios or amplifiers have one side of the AC line connected to the chassis (we call that a "Hot Chassis"). It is very important to utilize a VIT (Variable Isolation Transformer) when servicing any AC/DC equipment, to prevent electrical shock, as well as electrical shorts between grounded test equipment and the hot chassis.

It is a good idea to use a VIT when working on any AC-powered, or AC/DC-powered equipment. You also are urged to remove any metal items from your fingers and wrists, which can be hazardous when operating equipment with potentially lethal voltages. Your work bench should be non-metallic and have an insulated surface, such as wood, plastic or Formica.

Test equipment is required for trouble shooting and repair of this old tube-type equipment. Follows (in order of importance) is a listing of some of the test equipment items to consider when setting up a test bench:

VIT Variable Isolation Transformer.

TOOLS Various hand tools, soldering iron, plus wire, solder, and PARTS.

VTVM Vacuum Tube Volt Meter.

SG RF Signal Generator (most also have AF test output).

TT Tube Tester..

ST Signal Tracer (many useful test features).

AC Meter Sensitive AC Voltmeter (to meter output when aligning radios).

DOCUMENTATION Schematic and technical data for the equipment you plan to restore, a tube manual and a tube substitution manual.

When buying or bidding on transformer-powered old equipment, take time to visually inspect the item(s); look at external condition, check power cord, look at chassis for damages, missing parts/components/tubes, etc. Check for overheated parts, such as power transformers, chokes, corroded and or leaky capacitors, examine visible wiring and speaker condition – watch for speaker cone damages. Also, be certain to confirm operating voltage for the item; some of the old radios were built for operation from 32 Volt DC power, yet they had standard two prong plugs, so they appeared to be built for

AC line use. Most of the 32 Volt sets are found at farm auctions, but they can appear in city auctions and sometimes on ebay (without warning from seller).
Be aware that some of those 32 Volt DC sets may have been powered up from a 120 Volt AC line, which usually results in vaporizing most or all the tube filaments.

So, you bought an old AC-operated radio or amplifier. First suggestion is:

DO NOT PLUG IT IN. You can save a lot of time and dollars by following a series of tests before applying any power to the item.

Using a good quality VTVM Ohm meter, we can test for many problems before any power is applied to the equipment, often avoiding smoke from those already failed components, including power transformers, electrolytic capacitors, and vacuum tubes.

When ready to begin, get the chassis and speaker out of the cabinet and do a cleaning of the equipment. Most old chassis and speakers are loaded with spider webs and house dust, sometimes mouse droppings and nests. Generally, the best way to get the most dirt out of the set is to use compressed air and a nozzle with a small orfice to blow out the dirt. Use a small paint brush to loosen dirt that is stuck onto chassis and parts. Do use care with compressed air on the speaker, as excessive pressure can blow holes or tear through paper cones.

This is the time to perform a more thorough visual inspection, checking for wires with missing insulation, any wire leads that are broken off or floating, bare component leads that are sorting to other leads, terminals or chassis.

At some point you should get copies of the data covering the equipment; best if you can get the correct schematic and all the other printed data covering the make and model you are examining. In addition, you will often need a tube manual, especially when the schematic does not identify tube pin numbers (related to internal tube element terminations).

If you have access to a tube tester, remove each tube, clean it and test it. Be sure you set the filament voltage correctly for each tube, before inserting any tube into a socket on the tester. Always test for shorts before testing for merit. Don’t worry about any tube that tests weak, as these can be handled later if necessary. When finished testing tubes, you may place each back into the proper socket, EXCEPT the RECTIFIER tube, which should be left out of the equipment until resistance and some other tests are completed.

Be certain to check that each tube is the correct type that belongs in that particular socket. It is not unusual that I find tubes switched or a wrong tube in one or more of the sockets. Keep in mind that some tubes can be replaced with a substitute, so a wrong tube might still be able to function if the technician made an acceptable substitution. The tube manual and a tube substitution manual are the best way to check on proper or improper substitutions.

Resistance measurements can identify many possible defects in most any old tube type electronic equipment. By making these resistance checks, you can locate most components that may have failed (some may have opened, others could be shorted). If you start restoring one of these old units without conducting these resistance tests, you might waste many hours replacing parts, then find that there are some problems that cannot be repaired, such as open or shorted transformers, manufacturers special coils and other items that might only be available if you can find another identical chassis to cannibalize for parts.

Take your VTVM and set it for OHMS (to make resistance measurements). For the continuity tests, select the lowest Ohms range that will provide a resistance reading.

Check out the speaker and output transformer at this point. Speakers may be Dynamic or PM (Permanent Magnet) type, some bolted to the chassis, others attached to the cabinet, some with wiring and no plug, others will have a plug so they can easily be unplugged for testing.

PM Speakers are much simpler to test, as they do not have any field coil. For PM Speakers, you should do a thorough visual inspection to make certain they can be serviced. First gently check the cone motion with your two thumbs pushing the cone near the voice coil; you can usually feel and voice coil drag or scratching on the pole piece, indicating that the speaker voice coil form is damaged, or the centering spyder is loose or missing. Next check the outer edge of the cone, to make certain that it is still glued down all the way around the rim of the speaker frame. If necessary, this can be re-glued, using clear silicone sealant to re-attach. Check the cone for any holes, tears or breaks in the paper; then use clear silicone to repair these damages. DO NOT USE SPEAKER CEMENT, as this (like model airplane glue) adhesive will harden and warp the cone.

Now it is time to make some tests of the speaker and output transformer. Some output transformers will be mounted on the speaker frame, others will be located on top or underneath the chassis. In any case, one of the quickest ways to test the output transformer and speaker is to connect the output of an audio generator across the primary of the output transformer; set the generator at highest output (most put out at least 1 Volt AC) and, set frequency at 400 Hz, or 1,000 Hz. With equipment that has a single output tube, connect one generator lead to the plate terminal of the output tube and the other generator lead to the screen terminal of that output tube.

If you have push-pull output tubes, do this test from one of the tubes, then from the other. You should get audio from the speaker when conducting each test. If you get no audio from the speaker, you have one of several problems, so get ready to make some resistance/continuity tests with the Ohmmeter. First test the output transformer primary; if it has push-pull output tubes, test for continuity from the center tap of the transformer to one output tube plate, then from same center tap to the output tube plate. If this tests good (somewhere between 100 Ohms to 400 Ohms each section), next tests require unsoldering one of the two secondary leads from the speaker. After disconnecting this single lead, test resistance across the two secondary leads of the output transformer. This will be very low resistance if good, no continuity if open. the secondary is OK, then check resistance across the voice coil of the speaker. Again, this will be only a few Ohms if good, or no continuity if open.

If you have a Dynamic Speaker (these will have a Field Coil), you now need to test the field coil for continuity; First check your schematic to see where the field coil is terminated, especially if you have a set with the speaker cable wired into the speaker and chassis without any way to unplug it. Using your Ohmmeter, measure across that field coil starting on a low resistance range and switching to a higher range until you get a resistance reading; you should see a reading of somewhere between 500 Ohms and 2,000 Ohms. Most of the dynamic speakers will show a resistance of between 800 Ohms and 1,500 Ohms. If you get a reading higher than 2,000 Ohms, the field coil is probably open and the speaker is useless.

Now, examine the line cord and plug for missing insulation, cracks, hardened insulation, any splices between the chassis and plug, etc., and replace if necessary. Connect one meter lead to one side of the AC plug, then check for continuity to the other end of this side of the line cord in the chassis; likewise, move the common test lead to the other spade of the plug, then check for continuity to the other AC line wire under the chassis.

Next, operate the ON/OFF switch to the OFF position, connect the Ohmmeter across the two line cord pins, and it should check open circuit; then operate the power switch to the ON position, and you should get continuity (line cord through the power transformer primary). Resistance should not be ZERO, but somewhere around 5 to 20 Ohms.

Turn the chassis bottoms up, connect the common test lead to B-, which would be the center tap of the power transformer HV secondary, then test resistance to each of the rectifier socket plate connections (use schematic and/or tube manual to identify those rectifier plate terminations at this socket). Resistance from each plate terminal to the HV center tap will usually be about 50 to 100 Ohms, and one side will usually read slightly higher than the other). If there is any more than a two or three percent difference, you probably have an open or a shorted HV winding in that transformer.

In many of the early transformer-powered receivers and amplifiers, B Minus was not connected directly to the chassis, and these units will have from one to five or so resistors connected into the B minus circuit. Most had two or three wirewound resistors connected from the HV center tap to chassis ground, often these were a single resistor with several taps. These power resistors often have one or more sections that have burned out (opened), so it is important to check each section or resistor to be certain that all resistances here are approximately the correct value. These “BIAS RESISTORS” in the B- wiring are extremely important to the correct operation of the equipment, so check them with your Ohmmeter for at least + or – 10% or better.

If you want to do more resistance measurements, just put your Ohmmeter leads across each resistor, and switch the meter to an appropriate range to test for the specified resistor value. Usually, resistors of higher value (such as 470,000 Ohms through 2 or 3 megohms) will be most likely to have failed – generally they either are open or have significantly increased in value. Replace a resistor only if it has changed 10% or more in measured value.

You can also use the Ohmmeter to measure the volume control and tone control potentiometers. First, measure across the control to see if it is close to the specified resistance. Next, leave the common lead connected to the bottom of the control and connect the other test lead to the arm connection (middle one on virtually all pots), and watching the meter, rotate the control from counter-clockwise to fully clockwise; you should see resistance go from near zero Ohms to the reading you got when measuring across the entire pot.

Another resistance check should be made from B+ to B- (or chassis ground). Use Ohmmeter on high range, connect common lead to ground or B-, then touch positive probe to measure from positive end of each electrolytic capacitor; Ohmmeter should initially show low resistance, then swing toward infinity, so you should reduce the range one, two or three steps until the meter shows a resistance that is no longer changing. Do this for each of the filter capacitors in the unit, keeping in mind that none of these (stabilized) resistance readings should be below 5,000 Ohms.

Using the correct schematic, you can also make resistance measurements of most all the Antenna, RF, (and in superheterodyne receivers), the IF and Oscillator transformers. Most of the coil windings in these transformers will read from 5 or 10 Ohms to as high as 50 or 100 Ohms. Some of the windings used in local oscillator transformers might read only an Ohm or three. However, none of these should read Zero Ohms.

In most of the old equipment, it will be obvious if someone has replaced parts, usually capacitors and especially filter capacitors. Most previously repaired old radios or amplifiers will have mechanically poor connections and often have very poor solder connections; most will have heavy filter capacitors hanging from a group of wires, often without any real physical support. Check to be certain that they did not parallel any replacement caps with the old or original capacitors. If they did not completely disconnect one side of the old capacitors, normally the + (positive) side, this needs to be corrected at some point before you finish restoration.

So . . . where do we go from here? Up to this point we have been making tests to determine whether this equipment is worth restoring, so, no matter what our resistance and continuity measurements have found, we probably will want to move forward with power up tests. First step is to get your VTVM set to read voltages, starting with AC voltage measurements.

Leave the rectifier out of it's socket for all these next measurements. Set your Variable Isolation Transformer variac so you have zero volts output, then plug your chassis power cord into the output socket of the VIT. Here is where we really need to carefully watch what happens when we start applying low AC voltage to the equipment. So, with the item plugged into the VIT, and the equipment on/off switch in the ON position, carefully observing the output current meter of the VIT, slowly rotate the variac in the clockwise direction. If you have any serious shorts in the power transformer primary, or secondary windings, you will likely see excessive current appearing on the VIT power output meter, sometimes when you have only applied a few Volts to the chassis; just quickly back up the variac to zero, so you do not damage the VIT (and/or the equipment being powered).

There are two other possibilities when you start applying AC power:

1. If you have zero current on the VIT output meter, after very slowly moving the variac from zero to 115 Volts, you have an open circuit somewhere. In this event, there is an open in the primary wiring or the power transformer primary winding is open. What we should have is continuity from one pin of the AC plug, through the line cord to one primary lead of the power transformer, then from the other primary lead of this transformer to the ON/OFF switch, and from the other terminal of the ON/OFF switch back through the other conductor of the line cord to the remaining pin of that AC plug.

2. The equipment load (VIT output current) slowly increases as you slowly bring up the applied voltage from zero to about 115 Volts; also, tube filaments should warm up and panel lights should operate. This is, of course, the desired result of applying AC power to the equipment. At this point, with line voltage supplied to the equipment, we have low voltages (filament and panel lamp voltages) plus high AC voltage should be present at the plate terminals of the rectifier socket.

OK, assuming that the previous power up went as in No, 2 above, we need to be careful with the next tests, so as to avoid electrical shock. With the equipment powered up, check to be certain your VTVM is set to AC Volts and you have it on a 500 Volt range. Connect the VTVM common cable to the chassis, and touch the probe to one plate terminal of the rectifier socket. AC Voltage here can be between 200 and 400 Volts, depending on the power transformer utilized. Next, move the positive probe to the other plate terminal of the rectifier socket, where the AC voltage should be very close to what you saw on the other plate terminal.

Next, being careful where you touch the unit, leave the VTVM on AC Volts, but change to a 10 Volt or 15 Volt scale. First, connect the VTVM common lead to one filament terminal of the rectifier socket (schematic or tube manual to determine which tube socket pins on this rectifier socket to use); then touch the other test lead to the remaining filament terminal of that socket. If the rectifier is a 5-Series, you should read about 5 Volts, but probably closer to 6 Volts since the rectifier is not loading the winding at this point.

Next step is to test the other filament voltage, at any tube socket that holds a 6-Series tube. Connect the common test lead to one side of the filament string (check schematic or tube manual as to the two filament terminals needed). Then touch the other test lead probe to the other filament terminal. You should read between 6 and 7 Volts for most equipment (if it uses 6-Series vacuum tubes).

Keep in mind that rectifiers that employ directly-heated filaments, in which the filament is the emitter (cathode), those radios required a separate, isolated filament winding on the power transformer just for the rectifier tube; this is because any directly-heated rectifier filament will have B+ on it, which cannot be coupled to any other tube filament circuits.

You will run across some receivers that were built using an indirectly-heated rectifier, such as a 6X4, 6X5, 84, or any of about a dozen such rectifier tubes. This was done in an effort to lower the cost of power transformers. Zenith and many other manufacturers started using this arrangement in the late 1930s and early 1940s. Basically, in these sets, all the tubes filaments were operated from a single secondary filament winding of the power transformer.

At this point we have completed most tests that are possible before powering up the equipment with operational HV DC circuits. So . . . with the equipment still connected to the variac, turn the variac to zero, insert the rectifier tube in it's socket, then very slowly bring the variac up, while watching the VIT output current meter. Understand that the rectifier tube will only start conducting (to provide positive B voltage), when the filament gets hot enough to start emitting electrons – probably when filament supply voltage rises to around 70 to 80% (4 volts or so). When the rectifier starts to conduct, B+ voltage will rise and be fed to most of the plates and screens of other tubes in the equipment. We need to be prepared to remove input power quickly, if the B current is excessive, due to bad filter capacitors, or any other shorted or defective wiring or components.

If the equipment seems to be operating without excessive input power, you might hear some 120 Hz hum (full-wave rectification of 60 Hz AC produces 120 Hz pulses), while half-wave rectification produces 60 Hz pulses). Virtually all transformer powered equipment uses full wave rectifiers, while most AC/DC equipment will have half-wave rectification. If you experience objectionable hum, it is time to replace all electrolytic capacitors (those filters that are supposed to take out most of the hum). Again, be certain that any old electrolytic capacitors are disconnected, and no replacement capacitors should be paralleled with any old ones. Be careful to install polarized electrolytic capacitors correctly, otherwise you will damage them, and perhaps other components, when power is applied.

If we have completed all the above tests and necessary parts replacements, this would be a good time to put the rectifier tube back in it's socket, set the VIT to zero output, plug the equipment into the VIT, then slowly bring up the output to 117 Volts. Just keep an eye on the VIT output current meter, just in case the unit begins to draw excessive line current; if you see excessive line current, instantly reverse the variac to zero, then you must proceed with more resistance measurements to localize and identify the problem.

Most of the time, the equipment will start working at this point, and you should continue with checking each band, each control, tuner function, etc. To complete the electronic restoration, you should now power down the unit and carefully replace all the paper-dielectric capacitors. Most early radios used capacitors that had waxed-paper dielectric and were dipped in bees wax; newer capacitors were the same inside, but many were enclosed in plastic or were dipped in an insulating coating. In any event, any paper-dielectric capacitors eventually will absorb some moisture and develop leakage, such that all these types should be replaced if you want the equipment to perform like new and be reliable.

DO NOT REPLACE any mica or ceramic capacitors, unless you find one that has opened, shorted, or developed leakage; these types almost never fail, so, replacing these types is generally a waste of time and materials.

When replacing capacitors, particularly those that appear to have been replaced at some point in the past life of the equipment, be sure to check each capacitor for value and working voltage ratings, against the schematic and/or parts list. I often find that capacitors have been replaced with incorrect value caps, and sometimes with capacitors that have lower than required voltage ratings. Also, it is not unusual to find that some replacement capacitors were installed incorrectly (with one lead connected to the wrong point in the circuit).

If you have completed all the above, now is the time to again power up the equipment using the VIT as the power source. Set your VTVM on DC Volts and always start with it set to a 400 Volt range or higher. What we should now do, is connect the common lead of the VTVM to chassis ground (B-), then test for correct operating voltages at all tube sockets. We want to determine if approximately correct DC voltages are present on each tube element, especially the plate, screen and cathode connections on each tube socket. If we find any voltage that is way higher than it should be, or much lower than specified, we will need to conduct further voltage tests and, usually, power it down and make measurements with the Ohmmeter, to isolate the problem part(s), Some schematics show most of the nominal operating voltages right near the tube socket terminations, some show normal voltages on a chart, either on the schematic or another page of data. Unfortunately, some schematics do not provide any voltage information, so the tube manual should be used to help you find the plate, screen, cathode and some control grid terminations for the various tubes.

Assuming that your equipment seems to be working at this point, you have only a few more steps to complete the electronic restoration. Don’t worry about tubes that check weak on the tube tester, unless the tube is used as the rectifier or a final audio output amplifier. Most of the other vacuum tubes in receivers are operating as class A voltage amplifiers, and will be fine as long as they test at least one-half of the tube tester merit amount.

Soldering skills are needed when removing or installing parts. The tip of the iron needs to be kept clean and tinned. When starting to heat a joint, it is proper to touch the tip to the joint, then touch the end of solder to the junction of the termination and the edge of the iron tip. The joint needs to have melted solder contact at this juncture, then apply solder to the heated terminal/wires, etc. Properly soldered joints should have smooth flow of solder over the metal terminals, wires, etc., without any appearance of a non-flowing coverage. Do not blow on soldered connections, and do not have any fan blowing across your work when soldering; it is important that solder cools naturally, as moving air cools the outside of the solder very quickly and may cause cold joints (crystallization of the solder). I see many radios in which someone installed replacement parts that had 2” or 3” long leads, and did not shorten them, even though the leads were much longer than required to connect between points that might have been only an inch or so apart. This is not a good idea, especially in the RF and IF stages of a receiver. I also suggest that when installing capacitors, you orient them physically such that the printed data is visible without having to rotate them (the value and voltage ratings of each part should easily be visible without having to bend them or twist them).

If restoring a radio receiver, and everything is now operational, it would be a good idea to perform final testing and alignment of the equipment. You need a good signal generator for IF and then for RF signals, plus a way to measure AVC (Automatic Volume Control) voltage, or, aural output to the speaker voice coil. Many early radios did not have AVC, so these will require a sensitive AC meter to display the output voltage across the speaker voice coil. This method of measuring can be used on virtually any old radio, be it a TRF or Superheterodyne, with or without AVC. When aligning, the volume control should be kept full open, and the signal generator output should be kept as low as possible, with visible level indication on a low AC Meter scale (usually use a 0.1 or 0.3 Volt full scale range). If using AVC voltage for peaking alignment, you can do this with most any VTVM, using a low minus DC range, usually a -5 Volt range will do. You will need to locate the AVC bus in the radio, attach the common VTVM lead to the chassis and the DC lead to that AVC bus. Again, AVC is a negative DC voltage, derived from the rectified audio signal output of the aural detector.

In the late 1920s, some manufacturers of AC-powered radios or other tube type equipment included a fuse in the primary power line coming into the devices. This was wonderful in that it provided protection for the power transformer and other power supply components, in case of a short or any excessive current that might damage the power transformer. Many units without a fuse did have a short occur in the B supply, which often caused the rectifier to arc over, which then produced smoke from the power transformer; it was not unusual for the radio to catch fire, sometimes setting the house on fire. The point is that, after these early tube type gear, most equipment was built without any fuse protection, and the result was a lot of destroyed rectifier tubes and power transformers. I suggest that you install a fuse holder in the rear flange of the chassis of any AC/transformer-powered tube type equipment.

I probably have fused more than a thousand units, and, while one or two of them developed a problem that blew the fuse, so far I have not had any power transformer smoke in any of my fuse-protected devices. I use a step drill bit to drill the hole usually 5/8” diameter (some require a ½” hole), for a standard (3AG) type fuseholder; the 3AG fuses measure 1-1/4” long and ¼” diameter and are available at most any auto parts or hardware store. I use only fast-blow fuses of 1, 1-1/2 or 2 Amp rating, except in some large amplifiers or 15 tube and larger radios, you might need a 3 Amp fuse or larger. Rule of thumb for sizing a fast blow fuse is to make it as close to double the operating current as possible; for example, if the device consumes ½ Amp nominal, use a 1 Amp fuse, if it consumes ¾ Amp, use a 1.5 Amp fuse, if it consumes 1 Amp, use a 2 Amp fuse, etc.

I do not suggest fusing for AC/DC (non transformer-powered) equipment. Most of these units have no place to install a fuseholder on the top or back of the chassis. Also, this type equipment almost always uses series-string filaments, and most any short that would draw excessive current will result in a filament failure (usually in the rectifier), which, in effect, serves as a fuse (and, probably would have failed even if you had fused it).

We could go on for ten more pages, but will end the restoration discourse at this point.

Sincerely,
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