Troubleshooting Tutorial

Tools Required:

- RCA shorting plugs (Fabricate using Radio Shack # 274-339)
- Digital Voltmeter
- Soldering Iron & Associated items
- Screw drivers, Pliers (including needle nose), wire cutters & stripper
- Wire Jumpers (Radio Shack # 270-180)
- 100 ohm 2watt resistor
- 20 replacement fuses as specified (not larger nor smaller)
- Documentation (schematic diagrams and parts list) for defective component – Note: if you are repairing a defective Dynaco amplifier or preamplifier you will find a full operator's manual for all Dynaco tube products at our website (www.curcioaudio.com)

General Discussion

In this document, I hope to provide you with some methods and techniques that will guide you to repair most any problem in your vacuum tube based component. However, it is absolutely critical that you are certain that you have the skills to safely operate the tools recommended and that you always remember that you will be working with lethal voltages. The electrolytic capacitors will continue to store and present even after you have removed the power and disconnected the line cord. Once again, always assume that lethal voltages are present and work accordingly. That means never place yourself in a position to be the conductor between the circuit and ground (let the jumper become the more direct current path).

The most effective technique for the diagnosis of problems with your components is the **Isolation & Elimination** method. With this methodology, we will initially eliminate the functional components until we isolate the defective component, section, subsection and finally the part. For example, if you have hum in your system, it is important to determine if the hum is being generated inside one of the components (power amplifier, preamplifier, turntable, etc) or is being injected into one of the components for poor shielding or thru the power line, among other paths. Using the Isolation & Elimination methodology, we would first place RCA shorting plugs at the input to the power amplifier and observe the effect. If the hum is still present, it is safe to eliminate everything but the power amplifier and associated components. If the hum has been eliminated, you can safely conclude that the problem exists upstream of the power amplifier. Next the preamp would be reconnected to the power amplifier and all sources removed from the preamp. Then, RCA shorting plugs would be inserted into a line input

(not the phono input right now), that line input selected, power applied. If the hum is present, the problem is near the preamp line stage. - if not, the RCA shorting jacks would be placed now at the phono inputs. Again, select the phono from the selector switch and observe – hum or no hum; phono is implicated or not. Once you have identified the problem component it is time to dig into that component and begin the I&E process again to zero in on the defective part or parts.
Using the isolation & elimination technique, it is possible for you to identify and repair many problems with your vacuum tube based system. However it is very important that you do not make assumptions and skip the top tier isolation steps. I have been doing this for many years and still continue to cause myself hours of wasted time by thinking that I already “know” which component is at fault.

One huge benefit of working on two channel components is the ability to compare the operation and measurements of the “good” channel to the defective channel. The differences can be very informative in locating the defective part in the non-working channel. During the course of this discussion you will be asked to switch the tubes from channel to channel as an isolation technique. In general, if the problem moves with the part switch, the part is defective. However if the problem remains in the same channel, the parts are probably OK and the fault lies in the circuitry associated with that channel. This also applies to voltage measurements - you can compare the readings from channel to channel to help you understand what is expected vs. what is defective.

Isolation & Elimination – Find the defective component

Unless you have a single component that simply won’t power up, it will be necessary to isolate the component causing the problem. Regardless if the problem is hum, hiss, or any other sonic defect, in the beginning your loudspeakers have been your only instrument telling you something is not right. To be sure to identify the correct component, a pair of RCA shorting plugs is your most important tool. RCA shorting plugs can be fabricated by connecting the inner (+) terminal to the outer (-) terminal of a standard RCA plug. Take the time now to create a pair. They insure that you are not injecting the defect into the component under consideration - many times referred to as the Device Under Test (DUT). Given the typically high input impedance of most tube circuits, simply leaving the inputs open will probably cause stray signals to mislead your investigation. FYI – the output should be connected as it would be normally (e.g. in a power amplifiers the speakers are connected).

The steps are as follows:

1. Power Off
2. Starting at the power amplifier, remove the connections at the input and place the RCA shorting plugs into the inputs.
3. Apply power and observe. It is important to make note of any changes that have surfaced as a result of the test. For example, did the hum or hiss change? Changes indicate that the problem may be interactive and not solely the result of one defective component.
4. If the problem has been eliminated, it is reasonable to conclude that the DUT and all components downstream (towards the loudspeakers) are not defective and that the defective component has yet to be identified.
5. Power Off.
6. Reconnect the interconnects from preamp to power amplifier and remove all of the inputs from the preamplifier. Place the RCA shorting plugs into one of the line inputs of the preamplifier (for example, the tuner input) and select that input. Power up the system and observe. If the problem is eliminated, place the RCA shorting plugs in the phono inputs and select the phono (to determine if the phono amplifier is the source).

Digging In

Review the following sections to best describe your problem. If you simply have an amplifier that won’t power up, there is obviously no need to isolate it from the other components. However finding the defect within the component will require the I&E methodology. Otherwise, begin with your RCA shorting plugs to find the problem component.

DEAD - Won't Power Up or Trips Fuse (Preamps & Power Amplifiers)

1. Insure that you actually have power at the plug (try a lamp or another component connected to the same receptacle).

2. Is the power switch in the ON position

3. Check the fuse – if the fuse has tripped it is possible but not probable that it was a fluke. More likely is that something in the power supply is defective and has caused an over current condition causing the fuse to trip. Replace the fuse with another of identical rating (not larger unless you want your valuable audio component to become the fuse). During all the tests that follow it is very important to observe the time required for the fuse to trip. Make note if the fuse trips immediately or is delayed for a few seconds.
4. Replace the fuse, power up, and observe.

5. **If the fuse trips slowly** (unit stays powered for a few seconds and then the fuse trips) you can have some confidence (but not complete) that the power transformer is not the problem.
a. If the fuse trips (slowly) and your component incorporates vacuum tube rectifier, remove the tube rectifier and the output tubes, replace the fuse, power up again and observe. The fuse should not trip (if it trips again the transformer probably has a few shorted turns and this is as good as defective). Now install a new rectifier tube. Replace the fuse, power up, and observe. If the fuse does not trip you have probably eliminated the power supply
b. If you are servicing a power amplifier return the original output tubes. Replace the fuse and power up. Observe the output tubes – if any one or more of them appear to overheat (as evidenced by a reddish color of the tube plate) the tubes or the bias supply is suspect. Pull the tubes and leave the sockets empty. Power up and observe – if the fuse does not trip replace the tubes with new tubes and try the test again. If the problem remains, proceed to the Power Amplifier Output section.

6. **If the fuse trips immediately** the problem is most likely in the power supply section. This is actually good news (and very common) because there are only a few components that comprise the power supply and fewer still that have a high probability to be defective. You are about to open up your amplifier and expose yourself to potentially lethal voltages. Please be aware of this and do not make

any assumptions about the voltage level present except that it is there and can be fatal.
a. It is absolutely mandatory that you remove the line cord from the power receptacle before you continue.
b. Remove the cover and locate the power supply section. This is the area near the power transformer, power electrolytic capacitors, and power diodes (or vacuum tube rectifier if so equipped).
c. Get two of your jumper cables and the 100 ohm resistor. Clip one end of one of the clip leads to the chassis; connect the other end to the 100 ohm resistor. Connect one end of the other clip lead to the remaining lead of the 100 ohm resistor. Connect the remaining end of the second clip lead to the metal shaft of your screwdriver. For about 10 seconds each, touch each leg of every diode with the blade of the screwdriver and then repeat again. You are basically discharging each capacitor thru the resistor until they have fully discharged.
d. Wait a minute or so (to give the shorting leads time to fully discharge each path) and test the condition of every diode. This can be done by checking the resistance of each diode in both directions (red probe on one component lead and black probe on the other lead of the component and then reversing the probes). The ohmmeter should be set to the 2K ohm setting (or use the diode check setting if your meter has this feature). Diodes that read less than 10 ohms or not within a few percent in both directions should be considered defective and replaced.
e. Test the resistance of the electrolytic capacitors relative to ground. Place the black probe of your digital voltmeter on the "-" lead of the electrolytic capacitor (almost always the same point as the chassis but not always) and place the red probe lead on the "+" lead of the capacitor. The voltmeter will require a few seconds to charge the capacitor (only about 9 volts) and during this time the reading will not be stable. After a few seconds the reading will stabilize. Make note of this reading – it should be at least a few K Ohms. I would be suspect of resistance readings of less than 5K ohms and in this case it would be a good idea to remove the capacitor and repeat the test with the cap out of the circuit. If it now passes, there is clearly a problem inside one of the amplifier stages (or in the regulator of regulated designs). If the capacitor now fails out of circuit, replace it with another – be sure to observe the voltage rating. Repeat this for each electrolytic capacitor.

7. **If the fuse does not trip at all**, instead of a short, you may have an open circuit. Defective component possibilities include the power transformer, rectifiers (vacuum tube or diode), or open electrolytic capacitors (however in this case you would probably be having a lot of hum too). The best way to identify the defect is to make a sequential series of voltage measurements while the unit is on – in other

words, this is very dangerous. The purpose of the transformer is to take that 120 VAC from our power company (via the line cord, power switch, and fuse) and convert it to both higher AC voltages (for the tube plates) and lower AC voltages (for the tube filaments and bias). The rectifier (weather ss or tube) converts that AC voltage from the transformer to DC when the amplifier circuit is looking for DC (the filaments are usually fine with AC – not so the plates and bias). The rectifiers convert the AC to DC by removing only half of the AC waveform – what's left is a huge 120 cycle (notice that it is 2 X 60 Hz) single polarity pulses. Those electrolytic caps and chokes (sometimes – not always) following the rectifiers are there to smooth out that ripple. That is why one major source of HUM is an open capacitor. This is important because we are going to follow the signal from AC line to the capacitor. It is also important to know how to use your voltmeter to measure both AC Volts and DC Volts – setting your voltmeter incorrectly will lead you (us) astray. OK – lets go:

a. It is absolutely mandatory that you remove the line cord from the power receptacle before you continue.

b. Remove the cover and locate the power supply section. This is the area near the power transformer, power electrolytic capacitors, and power diodes (or vacuum tube rectifier if so equipped) and choke (if so equipped).

c. Plug in your amplifier and power up.

d. Set your voltmeter to AC Volts and 500VAC range. Measure the voltage <u>across each of the windings</u> including primary and secondary windings of the power transformer <u>one at a time</u>. Measure from same color to same color (for example red to red) and note the readings. Primary windings (the 120 VAC ones) are usually identified as black. The High Voltage secondary is usually identified as red leads. The filament secondary windings are usually green (for the 6 and 12 volt windings) and yellow (for the 5 volt windings). Failure to get 120VAC on the primary winding may suggest either a defective fuse, power switch or line cord – check those if you fail to obtain 120 VAC on the transformer primary leads. If you successfully measure 120 VAC at the primary winding but fail to get an AC voltage reading on <u>any</u> of the secondary windings, you probably have a defective power transformer.

e. Assuming that you obtained relatively reasonable voltages on <u>all</u> of the secondary windings, it is time to check the rectifier(s). Regardless if it is solid state or tube, set your voltmeter to DC Volts and connect the negative lead to the chassis. Measure the DC voltage at the junction where the rectifiers meet the first electrolytic capacitor. If the voltage is nearly zero, shut down your amplifier, disconnect the line cord from the AC mains, and discharge the electrolytic caps (probably not necessary but do it anyway). Replace the rectifiers. Power up again and check for the presence of the DC voltage. If the voltages are not there the problem may be (but is not likely) the electrolytic capacitor (although at this point there should be some DC voltage present if not the correct voltage). Disconnect line cord and replace the capacitor.

8. If at this point you have not isolated the defective component (actually not likely since over 95% of power up problems are located in the portions of the amplifier we have just examined) I strongly suggest contacting us here at CAE or finding a local technician who is familiar with tube circuits (this may prove to be your most difficult task).

Power Amplifier Output Section (Power Amplifiers Only)

The power amplifier output stage consists of the Output tubes, Output transformer, and associated power supply sections. These include the Filament supply, HV DC supply, frequently a negative control grid (G1) supply that is very often adjustable (this is the bias adjust pots), and less frequently a screen grid (G2) supply (but most often the screen grid is connected to the ultralinear taps on the output transformer. **When there is a problem in the output section the amplifier will either fail to bias (too much or too little current) properly or deliver little or no power to the loudspeakers.**

First – it is important to know that in nearly all power amplifiers, the static operation of the output stage (that is to say when there is no signal present and the amplifier is idling) is completely determined by only four voltages. These are: the voltage at the anode (plate), the voltage at the control grid (G1), the voltage at the cathode (usually at or near ground potential), and in tetrodes or pentodes, the voltage at the screen grid (G2). If you amplifier is tripping fuses (after a few seconds) or cannot achieve the correct bias current, the only factors responsible are the tubes themselves or that one or more of the three voltages (plate, control grid, screen grid) is not correct (or that there is oscillation probably originating in the driver stage – we'll get to that in a moment).

If the problem is only in one channel, exchange both tubes from one channel with the both tubes from the other channel. If the problem moves with the tubes, replace the tubes – if it stays with the same channel as before it's time to diagnose the inside of amplifier.

Digging Into the Output Section

I will assume that you have performed the series of tests in the "DEAD - Won't Power Up" sections 1 thru 3. If you have determined that the excessive current that is causing the fuse to trip is in the output stage (from section 5a) **remove the output tubes** and prepare to take a series of voltage measurements.

1. Unplug the amplifier and remove the cover. Please be aware that although the line cord is not connected, it is likely that lethal voltages still exist due to the storage of the electrolytic capacitors. In other words be very careful – these voltages are lethal.

2. Remove the cover to gain access to the tube socket pins of the output tubes. Be sure you have a copy of the documentation in order to identify the pins associated with each tube element. Remove the output tubes.

3. On Dynaco power amplifiers (and other brands as well) there is a small value (usually less than 15 ohms at 3 watt) power resistor connected from the cathode and suppressor grid to ground. Current through this resistor results in a voltage that the user measures to set the proper bias in the output stage. If this resistor is subjected to high currents it will open thereby making it impossible to set the bias current (no place for the current to flow). As a first step, always check the value of this resistor (there is at least one per channel connected to the cathode of the output tubes) to insure that is has not been damaged or changed value.

4. Connect the black (-) lead of your voltmeter to the chassis. Connect the red (+) lead of your voltmeter to the pin representing the plate (pin 3 for 6CA7's and 6550's). Apply power and record the voltage. (This may take a few minutes if you have vacuum tube rectifiers). Power Down. If you have determined that the voltage is zero or low, the problem is probably in the HV power supply section (transformer, rectifiers or electrolytic capacitor). Proceed to section DEAD - Won't Power Up" Section 7 to isolate the defective power supply component. If you find the voltages high (within 10%) this is not a problem (at this time).

5. Connect the red (+) lead of your voltmeter to the pin representing the screen grid G2 (pin 4 for 6CA7's and 6550's). Your black voltmeter lead should be connected to the amplifier chassis. Apply power and record the voltage. (This may take a few minutes if you have vacuum tube rectifiers). Power Down. In ultralinear amplifies this voltage will be nearly identical to the plate voltage previously

measured. In fixed bias pentode operation, this voltage is usually provided via regulator or through a RC section from the main power supply and is critical to establishing the correct bias. If it is only 10% high, the amplifier will not be able to bias properly. If the voltage is sourced from an RC section inside the main HV power supply, discharge the capacitor completely as described previously and check the resistance of the resistor to the requirement. If your amplifier is using a regulated screen supply (all Audio Research and CAE power amplifiers) please call us directly for the next steps. In this case I would suggest contacting us here at CAE or a local technician familiar with tube amplifiers.

6. Connect the red (+) lead of your voltmeter to the pin representing the control grid G1 (pin 5 for 6CA7's and 6550's). Apply power and record the voltage. (This may take a few minutes if you have vacuum tube rectifiers). Do not power down at this time but locate the bias adjustment potentiometer and rotate it through its entire range. Record the voltage at both ends of the adjustment. <u>Power down</u>. Depending upon the amplifier, this voltage is usually generated from a transformer winding fed to a simple single diode rectifier (almost always a solid state rectifier) filtered with a capacitor and then fed to a series or resistors to the one or more bias adjustment potentiometers. (Another scheme is fixed bias where the output tube cathode is raised off ground via a small value resistor and the cathode voltage then becomes positive relative to a grid voltage of zero volts). If the voltage range does not cover a range from about –20 volts to – 35 volts (or more) the bias supply is defective. Power down and begin checking the aforementioned components in the bias supply for defects. Given their small costs, it may be more prudent to replace the diode and capacitors.

At this point you if you have not identified the defective component, I strongly suggest contacting us here at CAE or finding a local technician capable of servicing vacuum tube equipment.

Hum (Preamps & Power Amplifiers)

Hum can come from many sources both internal and external. One of the main causes of hum are ground loops – caused when a circuit has more than one ground path for the power supply or signal currents to follow. The IR drop associated with each path will be different and therefore result in a voltage differential within the circuit. This of course will be amplified and is usually presented in the form of 60 Hz or 120Hz hum. It is also very common that there will be more than one source of hum - this can lead to chasing one's tail since the shotgun approach can introduce additional ground loops. Therefore is very important that we follow the isolation and elimination methodology.

The three prong line cords found on some equipment cause one of the most common sources of ground loop hum. The ground loop is set up when the equipment grounds are connected via the signal interconnect and then again connected via another path through the AC line cords third prong ground lead. I have found that when a system is suffering from hum, it is worth the time to insert the ground isolators (available from any hardware store) on to each line cord with the three wire plug. In this way this particular ground loop is eliminated. This is always a good first step as it eliminates this from the "tail chasing" exercise.

The three prong problem is one of several external causes can be addressed so simply and quickly and therefore it makes sense to first eliminate those.

- Install ground isolating adaptors (available at any hardware store) on any component that has been equipped with three prong power plugs. Power up and note the effect. Has it been eliminated (or reduced)? If there is an improvement keep the adaptors permanently in place. (Personally, I always remove the ground connection from all of my components since with high end equipment utilizing power transformers, there is virtually no danger whatsoever and it eliminates a continual source of hum generating problems)
- Turn off any nearby fluorescent or dimmer operated lighting fixture
- Replace the interconnects – many esoteric interconnects are virtually ineffective shielding. Try simple cheap interconnects from Radio Shack or similar - not a permanent solution but it will help you isolate the source of the problem.

If after you have isolated the external sources and the hum remains, it is time to begin to identify which component is generating the hum internally. Once again the RCA shorting plug is a very valuable tool in the I&E methodology.

Start at the power amplifier. Remove the input connections from the power amplifier and insert the RCA shorting plugs. If the hum remains, the problem is inside the power amplifier. If it is present in one channel, try switching all the tubes from channel to the other. If it follows the tubes they should be replaced. If the hum is in both channels it is likely a defect in the power supply filtering circuit – the rectifier or more likely the power supply electrolytic capacitors.

If the hum is eliminated, reconnect the preamplifier to the power amplifier. Remove all inputs from the preamp but otherwise keep the connections in place from the preamp output through to and including the loudspeakers. Insert a pair of RCA shorting plugs into a preamp line level input (say the tuner input) and select that input. Turn on your system and observe. Rotate the volume control from fully attenuated to full up. If the hum remains the problem is in the preamp line stage (or interconnect but hopefully you have eliminated that possibility earlier). If the hum is disappears, you can assume that the problem is further back (towards the source). Next, place the RCA shorting plugs into the phono input and select that input. Once again, power up and observe. The presence of hum now points to the phono stage inside of the preamp. Otherwise it is due to turntable, arm, cartridge grounding and / or shielding.

If from the above series of tests you identify that the source of hum is internal to your preamp, the most likely causes are the tubes or power supply. If the hum is only present in one channel, switch all the tubes from channel to channel to confirm. If the hum moves with the tubes, they should be replaced. If the hum remains with the same channel, or is present in both channels, there are only a few components responsible. (I will assume you have eliminated the tubes per our earlier discussion). In order of likelihood take the following steps in sequence and check the results after each step:

- Replace the rectifier tube (in amplifiers so equipped).
- Replace the electrolytic capacitor. In Dynaco equipment and in many others, the electrolytic capacitor is a 4” (approximately) tall 1.5” diameter metal “can”. It has four terminals (usually) and is connected to ground via four “tabs” that feed thru a cutout in the chassis. These capacitors are notorious for failing. When they fail open, hum results and when they fail in the short mode, fuse tripping results. A telltale sign that they are either defective or well on their way to becoming defective is a brown power that is evident near one or more of the terminals. If you see this power at any time, order a replacement.

Other sources of hum, especially with DIY constructed preamps are improper grounding (internal ground loops) or shielding. The range of possibilities is simply to great to address in this paper and therefore I recommend contacting us directly for personal guidance.

If at this point you have not eliminated the hum, it is time to call in a skilled technician. You may feel free to contact us here at CAE or find a local technician experienced in tube technology.

Hiss

Hiss is really noise and can come from any number of sources but mostly the tubes themselves or cathode or plate resistors. In feedback designs, it becomes difficult to identify the effective stage because the loop obscures the test. In this case we therefore recommend switching the tubes from channel to channel. If the noise follows the tubes we recommend replacing the tubes. If it does not follow the tubes, you may want to consider replacing the cathode and plate resistors – there is a limited number and is probably easier to simply replace all of them than trying each stage in succession.

Channel Imbalance

Left to right channel imbalance is very similar to hiss in its casual conditions. Once again switch the tubes from channel to channel to identify to isolate the defective area. If you determine that the tubes are the cause, replace the tubes. Other causes can be very elusive including problems inside local or global feedback loops. This can be very difficult to identify and we suggest contacting us here at CAE or a local qualified technician.