Hum it for me: Thomas Vox Amps

The Thomas Organ Vox amplifiers in the Beatle-Royal Guardsman-Buckingham-Viscount line have a deserved reputation for always having a little hum. This is a fallout of the time they were designed and the conflicting design restraints inside the amps.

How to fix it – just the facts

1. Isolate the input jacks from the chassis and carry the jack ground over to the preamp PCB on an new, added wire from the jacks' sleeve connection to the PCB.
2. Three-wire ground the preamp and power amp chassis, including a new wire in the cable between the two to carry the additional safety ground wire.
3. Add a new ground wire to the power chassis' power supply ground to carry the return current from all indicator bulbs on the preamp chassis

Items 2 and 3 need new wires in the cable between the two chassis, and as a practical matter this requires replacement of the cable connectors with new connectors.

Here's why

Thomas designed them at a time when three-wire AC power was in its infancy so most consumer equipment had to use two wire ground. A three-wire plug might not be available. They used a two-chassis approach to the amplifier line. These things interacted in a way that compromised their grounding and low-noise performance.

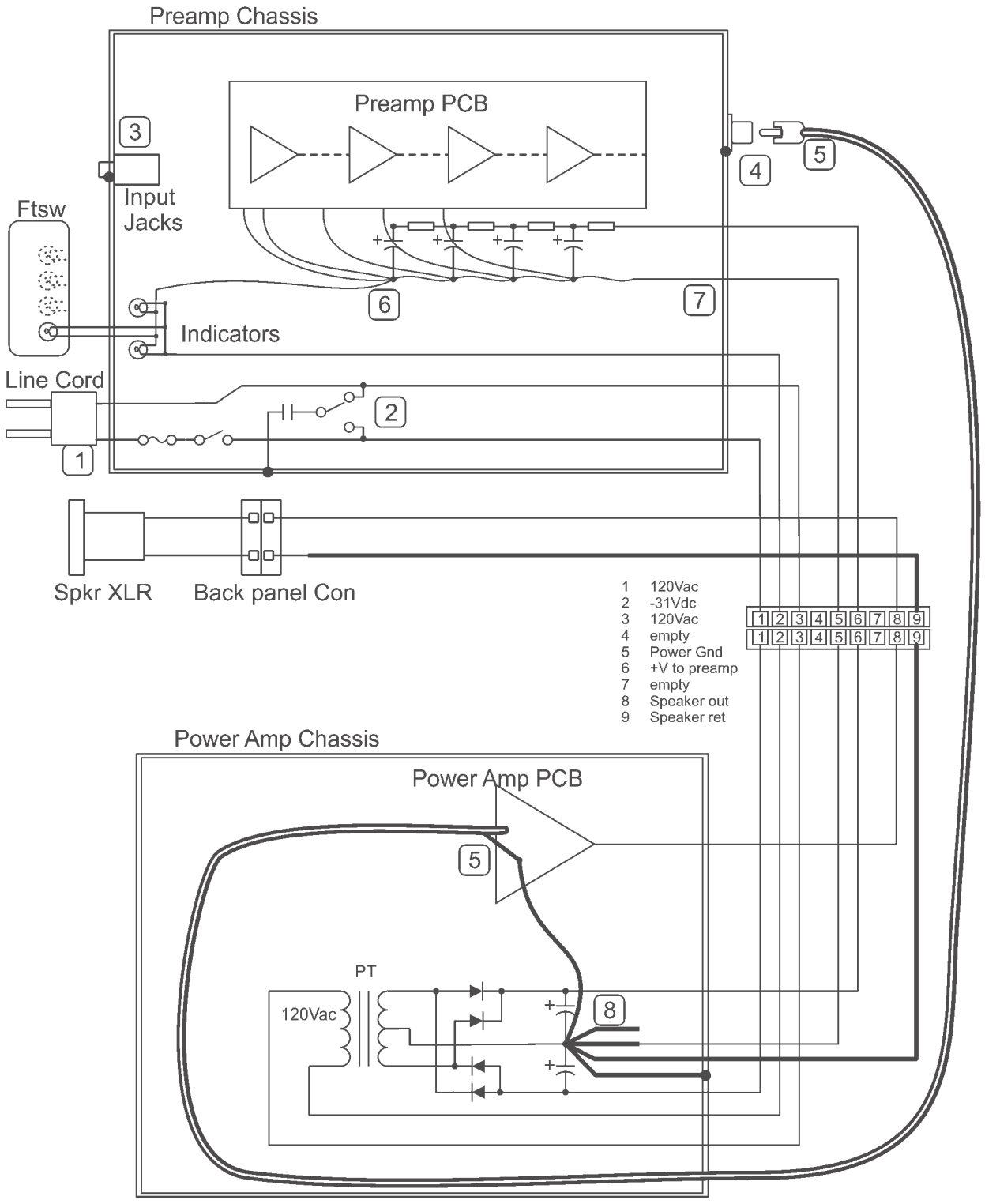
Thomas split the amplifiers into a preamp chassis and a power amp chassis, connected by a cable. The preamp chassis has all of the low-level signal amplification and user controls, the power chassis has all of the power supply and power amplifier, and no user controls at all. The technical difficulties of having two chassis connected by a cable and only a two-wire AC power connection made for many places for hum to creep into the amps.

For reference, take a look at the grounding map of the Thomas Organ “Big Head” amps on the next page. This drawing highlights only the grounding related matters, leaving most of the wiring out.

The preamp chassis [1] has all the controls. The two-wire AC power required a line reverse switch [2]. The small AC current that the line reverse switch let through flowed into the metal preamp chassis shell. This had the result that the preamp chassis had a small AC voltage induced on it from this current.

In single-chassis amps with this kind of AC leakage, the ground reference for the preamps and power amps float on top of the chassis ground, so there is no differential voltage to be amplified. The two-chassis setup made this much harder to deal with.

The metal chassis shell needs to be attached to some reference voltage in the circuit for best shielding, and that is usually done by attaching it to signal ground in a two-wire AC power setup. This can be, and often is done by attaching a metal-bushing input or output jack to the sheet metal chassis and letting the normal grounding of that jack take care of attaching the sheet metal to signal ground. This is what is found in all of the “Big Head” series from Thomas as shown in [3] and [4], where they attached both input jacks and the preamp output jack to the metal shell.



However, there is no connection from the power supply ground for the preamp circuits [7] to the metal shell of the preamp at all. Instead, the preamp power ground is carried on one wire of the cable to the

power supply star ground [8]. This is confusing because I can find no documentation of this connection of preamp power ground to the power supply ground, nor its wiring in the cable, for any of the models for which I have the factory documentation. It's there in the real amplifiers, just not documented in the service literature.

That might even be a reasonable approach to grounding, except that the cable to the power amp from the preamp [5] carries a significant amount of DC current from the output of the preamp circuit. It's not a signal output, running with zero DC level, but an AC signal riding on between one and four volts of DC, and carrying several milliamperes of DC current to the power amp input. There reasonably has to be several milliamperes of DC offset on that cable from the DC voltage it's carrying with the output signal. And since the preamp shell has AC leakage on it, it carries that AC leakage as well to the power amp input. This results in an audible amount of hum in the output to the speakers.

The DC power ground to the preamp circuits [7] contributes to the hum problems caused by the AC leakage on the preamp shell. It is likely that the preamp ground reference on the preamp PCB has a significant DC offset from the power supply star ground at [8], but little AC offset since it's not referenced to the preamp shell, except through the power supply wire to the power amp PCB, then through the shield of the RCA cable to the preamp output. That makes for the AC leakage on the shell being effectively added to the input voltage at the input jacks, and the preamplifier amplifying the shell offset voltage.

But even after developing fixes for the AC hum, a stubborn 120Hz sawtooth ripple remained on the preamp output. Sawtoothed ripple is an indication that the original source of the noise is the DC power supply. Since the noise went away with the RCA cable unplugged, the source of the noise had to be the preamp chassis, not the power amp.

The source was the indicator lights. The on/off and standby indicators, and the indicator lamps in footswitch modules with indicators are all powered by the raw -31Vdc supply from the power chassis. This voltage has a ripple voltage on it that varies with load, but it's always there. The indicator lights are resistive when they're up to temperature, and that means their current is a replica of the voltage across them, including any ripple on the voltage across them. This is a small fraction of the total voltage, but humans can hear ripple, but not DC. The indicator lights were fed -31Vdc, but their return current [6] flows through the same wire that carries the preamp DC current [7]. The resistance of the wires and cables is small, but it's not zero, and so the ripple shows up as a sawtoothed ground shift to the preamp circuits, which duly amplify it and send it along to the power amp.

How to fix it - expanded

The things get really quiet in terms of hum if you

1. **Isolate the input jacks from the chassis** and carry the jack ground over to the preamp PCB on an added wire. This was in fact something that Thomas Organ did as a field fix for hum in their Westminister bass amps. They sent repair centers kits containing (at least) insulating washers to isolate the input jacks from the shell, and wires to connect the sleeve contact on the jack to the signal ground on the preamp PCB.

   I found that replacing the metal-bushing jacks with nylon-bushing jacks and wiring the grounds did the same thing. Both Switchcraft and Amphenol make a nylon-bushing phone jack that will mount in the same holes as the existing metal jacks, and use the same hardware.

   Going further requires you to replace the cable connectors to do a good, workmanlike job. If you're not into some skilled hardware replacement, stop there and live with the hum that remains. If you hate remaining hum, or have the skills and/or money to do the remaining fixes,

forge ahead.

2. **Eliminate the AC hum from the line reverse switch** through the “death cap”. This requires you to change the AC power system to a three-wire AC cord and safety ground. It is futile and dangerous to mess with the line reverse switch setup unless you're going to do a third-wire safety ground; and, if you decide to go thee-wire, you will need to replace the 9-pin connector in the cable, as expanded below.

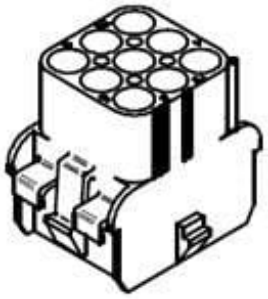
   WARNING! Do NOT try to rewire your AC power wiring unless you already know that you can do it safely. If you have to wonder whether you already know how to do this safely, you do not know how. The AC power wiring changes are demanding and dangerous if done wrong, involving as they do changes to AC mains power wiring.

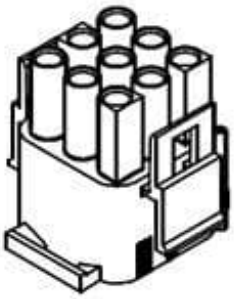
3. **Eliminate the ripple current from the indicator bulbs** by running a separate ground return for the “On” and “Stand By” indicator lights and any indicators on the footswitch in the cable to the power amp. I recommend adding this wire to position 4 in the connector. This step is hard to do because you probably don't have access to the proper pins and crimpers to add new pins to the plastic cable connectors that Thomas used. I know I don't, and I both know how to look for them, and use them if I found them.

What about the power amp? Nothing needed. It's essentially hum free as is. The hum comes from the funny grounding of the preamp chassis and the two-wire AC connection.

Connector replacement

If you're going to do this, get a set of 9-position connectors and the matching crimping pins, and make up new connectors to replace the connector in the middle of the cable between the two chassis. The connectors are cheap (~US$0.75 each) and so are the pins to go in them. Crimping the old wires into new connector pins is a tough go the first time you do it, but maybe you can get some techie friend with experience to help you through it. A techie friend may even have the appropriate crimping tool.





If you have to buy a crimping tool, that is probably a reasonable expense. Decent crimping tools that can be made to work for the kind of wire pins that will be needed can be had for as little as US$15.00 at the time of this writing. Amazon and ebay will have many sellers of reasonably priced crimping tools. A tool costing US$30-$40 will be a suitable bench tool for many years. Consider the price of the tool part of the price of repairing your amp.

The connector companies sell industrial-grade hand crimpers good for zillions of cycles at prices up to US$200-$500, but you don't need that long-term reliability, as making a new connector set for your amp will require maybe two dozen crimps total.

Here are some links for how to do it. Youtube has others.

https://learn.sparkfun.com/tutorials/working-with-wire/how-to-crimp-an-electrical-connector

http://www.instructables.com/id/How-to-Make-A-Quality-Crimped-Joint/

You could theoretically hack in a separate wire or two outside the cable connector, but it's a jury-rigged solution that probably builds in reliability and other problems later as well as making it difficult to service the amp for anyone else. If you're fixing this, replace the connectors so you can do it right.

The sketches show the kind of connector you want. The illustration is of the Molex MLX power connector series. They are inexpensive, widely available, and easy to use, barring that difficulty in crimping wires. AMP makes the “Universal Mate-N-Lok” series which is very similar. Do not go to super cheap or unsable connectors, as these connectors carry 120Vac and speaker currents up to 12A. Cheap connectors can be false economy, just as not using the right crimping tool can be. You really don't want one of the 120Vac or speaker output wires getting loose from the cable and shorting to things.

Mouser Electronics has the Molex connectors at the time of this writing: their part numbers are

538-50-84-2092 (receptacle, left; need 1 ea)
538-50-84-1090 (plug, right; need 1 ea)
538-02-08-1002 (female crimp-on wire contact; need nine, buy 12 to allow for mistakes)
538-02-08-2004 (male crimp-on wire contact; need nine, buy 12 to allow for mistakes)
The whole set can be bought for under US$8.00 plus shipping at the time this was written.