Lead Dress in Tube Amps

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Lead dress in tube amps is a tough subject. Just moving wires around inside a chassis with a wooden stick can cause otherwise-intractable hum or oscillation, or cure it. How do you know what wire to put where?

1. You have to know what signal is on each wire. Important classes of signals are:

- AC power wires (emitter wires)
- AC heater wires (emitter wires)
- signal ground (quieting and shielding wires)
- power ground (resistive coupling wires)
- power supply (resistive coupling wires)
- rectifier wires, both power and ground side (the ultimate evil for interference!)
- grid wires (sensitive input wires)
- plate wires (both emitters and inputs)
- screen wires (input wires)
- chassis - not really a wire, but a connector that's electrically connected. Could be a resistive coupling emitter, could also be a shield.

2. You also have to know what the *magnetic field* emitters are. These are all transfomers and chokes and any high current wires.

3. Wires are sensitive in proportion to how high the impedances are that they connect. A wire's impedance may be thought of as the larger of the wire's resistance itself, or the smallest impedance to which it connects at either of its ends. So a wire to ground may be thought of as only the wire resistance, a wire connecting a plate to a grid is the plate's impedance. An open input wire is the input grid resistor's impedance. A wire to an otherwise open grid is an very high impedance indeed.

4. Wires are sensitive to disturbance in proportion to how much gain is available between the grid wire and the output of the amp. For example, the input grids are hypersensitive, the output tube grids are only mildly sensitive. Screen grids are mildly sensitive, plates only slightly.

Crosstalk is picked up three ways: capacitively, inductively, and by shared resistance. Capactive pickup is maximized by wires close together and parallel, with high voltages on one wire and high sensitivity on the other. It is minimized by wires far apart, nonparallel or crossing at right angles, and by electrically grounded shielding between the wires.

Inductive pickup is maximized by large loops of wire sharing a lot of common loop area, one of which carries high currents and high frequencies and one of which is sensitive. It is minimized by making current loops small (hey! twisted pair!), by making loops NOT share loop area, and by distance. Notice that shielding signal wires in a loop will not shield the wires from inductive pickup if the loop shares a lot of common area with a high current interfering loop. Soft iron between the two loops helps, but is not as good as minimal loop area and not sharing loop area.

Both capacitive and inductive pickup are inverse square law emitters. That is, if you double the distance, the crosstalk goes down by a factor of four. This is why there is such a premium on getting sensitive wires far away from emitting wires.

Resistive crosstalk happens whenever two signal currents share the same wire. The resistance of the wire converts both currents to voltages, and if one of the signals happens to be an input signal, then the other signal gets inserted into the input.

Those are the basics. How do you apply them systematically? Easy in concept, complex in execution.

1. Sensitive input wires far away from emitter wires
   This is why input jacks are usually at the farthest end of the chassis from the AC line input and power transformer. Inside the chassis, keep the grid wires away from the succeeding plate wires, and run signals on short, direct wires from one stage to the next. Circuit stages should progress from smallest to largest signals as you go toward the output end of the chassis. If you keep the wires apart, minimizing crosstalk is easiest. Putting an input wire near the output stage is begging for intractible oscillation. Shield sensitive wires if they simply have to travel through high signal level territory. The best way to keep sensitive wires away from other things is to make them short and direct.
2. Sensitive input wire loops small and far away from magnetic emitters and high current loops. Very importantly, make high current loops small by wire routing and twisting. The best examples of high current loops are the AC line input and heater wires. These are both large signal, large current loops. They should be routed on wires which are twisted pairs so that the area of the loop the wires enclose is the smallest possible, and so the residual fields tend to cancel because of the twisting. Output transformer primary and secondary wires are another good example.
3. No shared resistive coupling wires. That statement almost implies star grounding. Power ground returns are like sewers, carrying the used electricity back to the power supply for recycling. If there is only a single, shared sewer, it takes some complex routing and careful thought to keep the heavy-industry sewage from fouling up the sensitive light duty stuff. Separate sewer lines are not the only way, but they are sure and simple in concept.

Using the chassis for a ground return is a bad idea. It's big, it's everywhere, and it's hard to predict where the sewage came from; and it makes big, untwistable loops with every wire that connects to it. However, if you have the chassis grounded one place only, then it becomes a fairly effective shield. Wires near the chassis are stitched down to the chassis by capacitive connections to it like Gulliver in Lilliput, and this connection helps eat the capacitive radiation from the wire. Chassis are usually steel, and high current wires near the chassis have much of their magnetic radiation shorted by the ferromagnetic steel. High impedance wires like input grid wires can be loaded down by the parasitic capacitance of running right next to a chassis.

The "complex in execution" is because you have to know and think about each wire, and how it relates to all the other wires and conductors near it.