This article briefly discusses a range of topics particularly relevant to the renovation of old public address type valve amplifiers.

Australia had a lot of Public Address style valve amplifiers installed in businesses, schools, public venues, churches etc…., so it's not surprising that they come up regularly on eBay etc. The size of the market meant that large corporations AWA and Philips offered a wide range of off-the-shelf product. Smaller companies making PA systems included electrical equipment manufacturers Paling and Steanes, and most companies making musical amplifiers also made PA models (eg. Eminar, VASE, Fi-Sonic, Lenard etc). The main electronics magazine Radio and Hobbies provided PA amp projects, and many component stores sold those kits, as well as rebadged PA amps from manufacturers.

This article is relevant to any valve amp, especially DIY amps based on magazine articles.

Contents

Back when product safety was not enshrined in Australian Standards, and cost was a hurdle, PA amp circuitry often had minimalist protection and certainly was not designed for signal overloading. PA amp output transformers were commonly designed for 70 or 100V line distribution of speakers, and so had higher impedance output requirements than what typical speaker impedances provide. Some PA amps were exceedingly well designed and made, such as for schools under government contract. Old PA amps still come out of the cupboard after decades of dust gathering, having been put away when they stopped functioning - it was likely cheaper to buy a new solid-state amp than get a repair, or maybe the need for a PA system had dissipated.

Magazine PA adverts and DIY construction articles

A PA amp typically had one or more microphone inputs, as well as inputs for radio and pick-up/record player accessories. Some PA amps included tuner assemblies that could be optioned into the enclosure, as well as a monitor speaker. PA amps often had a power transformer with a wide selection of mains voltage settings, and some had a dual powering capability using a 12VDC electromechanical vibrator. School PAs typically had a bell siren and came in a larger cabinet with record player fitted to the top, along with radio and monitor speaker. The largest fixed Australian PA system known would have rivalled large rock concerts, and included 11x 300W amp chassis in a main cabinet to support 210 remote speakers. The cutest small PA amp in my view was the AWA PA806 – very 'out-there' in its bluey-green and mauve livery, but barely raising 3-4W of output.

If you can get over the aesthetics of a grey hammertone enclosure, or some drab looking metal vented box, and without a saliva-drooling Goldentone style badge, then the valve innards can be renovated to something akin to a good musical guitar, bass or harmonica instrument amplifier. An old PA amp is unlikely to set you back more than $100, so as a first-time learning experience to the world of valve amplifiers, it is far cheaper and much less risky than buying a classic Goldie to sharpen your soldering and circuitry skills on.

How much you understand what you are doing, and how much effort you want to spend, and whether you have some pre-conceived goal of building a classic amplifier clone, are all personal aspects that cannot be generalised. So what this article attempts to illustrate are technical considerations that could or should be in the mind of the renovator, whether the amp is a rusted PA amp or a vintage guitar amp. For starters, a renovated amp really needs to be as fundamentally safe as a new commercial product. Also, a renovation can include some level of preservation, to safe-guard the amp's use for decades to come by applying modern forms of protection.

A 1960's to 70's PA amp should be relatively straight-forward to restore, as parts and wiring should be modern enough to cause no special concern. Beware of pre-1950 amps (ie. only 8-pin valves) as these require experience and dedication to restore due to degraded or suspect wiring and parts, and they may include unusual circuitry (eg. top grid preamp tubes that need a metal screen and transformer driven output valves). But note that a complete and safe renovation can take many days of work, and may uncover many faults and degraded parts, so the effort is more a labour of love than attempting to capitalise on a cheap start.

Due to the complexity of some topics, this article can in general provide only summary details. Reference is made to relevant parts of the ozvalveamps website and other articles for more details. We all have personal preferences in how to do something {I have enclosed my own preferences in curly brackets}. Acronyms include PA (public address), PT (power transformer), OT (output transformer), NTC (negative temperature coefficient resistor), MOV (metal oxide varistor), CT (centre-tap), B+ or HT (high tension voltage supply), ss (solid-state), LCR (L=inductor, C=capacitor, R=resistor), RTV&H (Radio TV & Hobbies magazine).

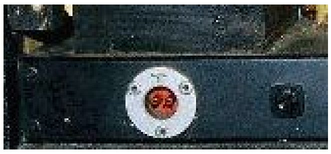
100W PA amp with tuner & monitor speaker

100W school PA

5W AWA PA806

Mains AC safety and protection

This topic is first and foremost a priority for a renovation – even when little is done to the amplifier. Read and understand www.ozvalveamps.org/mains.htm.



XLR-LNE on VASE amp

- Mains socket: Some amps used a special XLR-LNE type mains socket with solid earth pin and shrouded L-N terminals. That connector should be replaced with an IEC socket, or cable (as the earth pin can break off).

  Fitting a new IEC connector, or combined IEC connector, switch and fuse assembly can be a good idea if there is space on the rear or a side panel.

- Mains fuse: Some older amps did not have a fuse, so fitting one is a must. {I prefer to take the mains active directly to the fuse holder terminal, and shroud the fuse holder terminals with heatshrink or bright insulation tape, such as special 3M polyester tapes for transformer manufacture – common PVC tape is prone to loosing adhesion.}

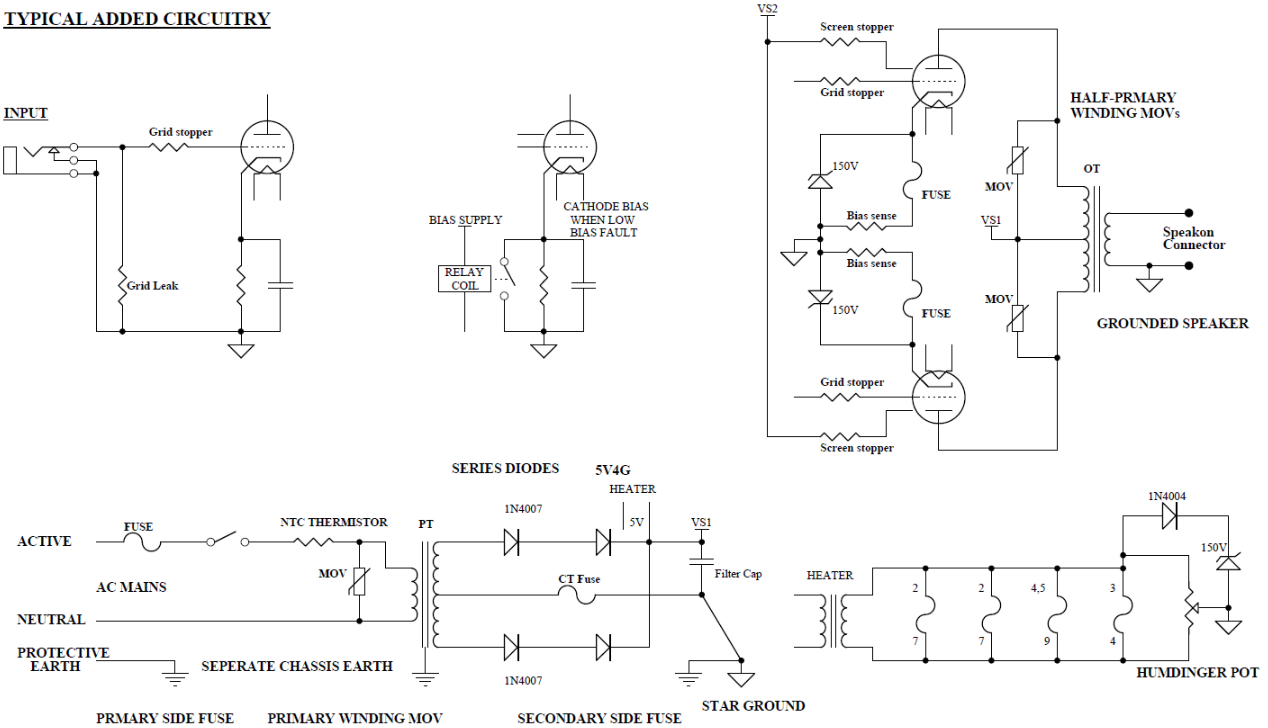
- Mains switch: Many PA amps had no power switch, if they did then typically located on the front panel, and sometimes using a switch located on the rear of the volume pot. Wiring in close proximity to signal circuitry is both a safety and hum risk that needs consideration.
- NTC Thermistor: Many PA amps are of high power rating, and the power transformer can have a large in-rush current at turn-on, due to transformer magnetising current, low primary and secondary winding resistances, cold valve heaters, and when solid-state rectifier diodes are used. Adding a 5 – 15 ohm NTC resistor between the mains switch and the power transformer primary may significantly reduce the stress on primary and secondary side fuses, which may allow a lower rated fuse to be used. Adding an NTC devise requires caution, as NTC selection requires technical design skills, and the device operates at a high temperature and so must be suitably located. See this article on fusing.
- MOV: {I prefer to fit a 275VAC MOV across 230-240V power transformer primary terminals, so as to clamp any spike voltage on the transformer primary when turning it off – this should alleviate power switch arcs that start when the switch contact opens, and hence reduce contact surface degradation.}
- Primary voltage selection: Australia officially now has a 230VAC nominal mains voltage, although most outlets would measure something like 240V or even higher (due in many instances to local solar generation). {There is some risk when using a PT terminal setting less than 240VAC, as a lower setting can make the transformer run hotter, and raise the DC voltages around the amp significantly, especially if the local mains voltage is high.} If a 250V or 260V setting is available, then that can be a method to lower DC voltage levels if trying to match a clone's operating levels.

  A key issue is the measured heater voltage at a valve socket's terminals when all valves are in place – it should preferably be within +/-5% (ie. 6.0 to 6.6V) when the primary tap is correctly set, although it does really depend on how much the mains voltage varies during a day. If the heater voltage is high, such as if a lower primary tap voltage is purposefully used to increase B+, then adding a power resistor in series with the heater winding is a practical and convenient way to lower heater voltage.

  See the testing section later for a method to confirm that power transformer primary magnetising current is acceptably low at nominal mains AC voltage.
- Protective earth: The protective earth wire from the mains inlet (socket or cable) should go directly to a permanent, separate, bolted chassis connection. If at all possible, an appropriate mechanism is to crimp the earth wire to a ring lug for mechanical security, and use a chassis mounting bolt that is not used for mounting a terminal strip, or transformer bell-end, or .... The bolt and nut should be tooth washer secured to the chassis, and an additional washer, tooth washer and nut used to secure the earth wire lug.

  All metal parts in the amplifier should be securely mechanically bolted to the main chassis, so that electrically they form part of the protective earth metalwork. Adding electrical link straps between metalwork may appear to be a pedantic and onerous requirement, and is typically not done, but should be considered, especially for parts that are in close contact with the mains primary wiring.
- The schematic below identifies typical parts that are added to vintage circuits to achieve more robust and refined performance.

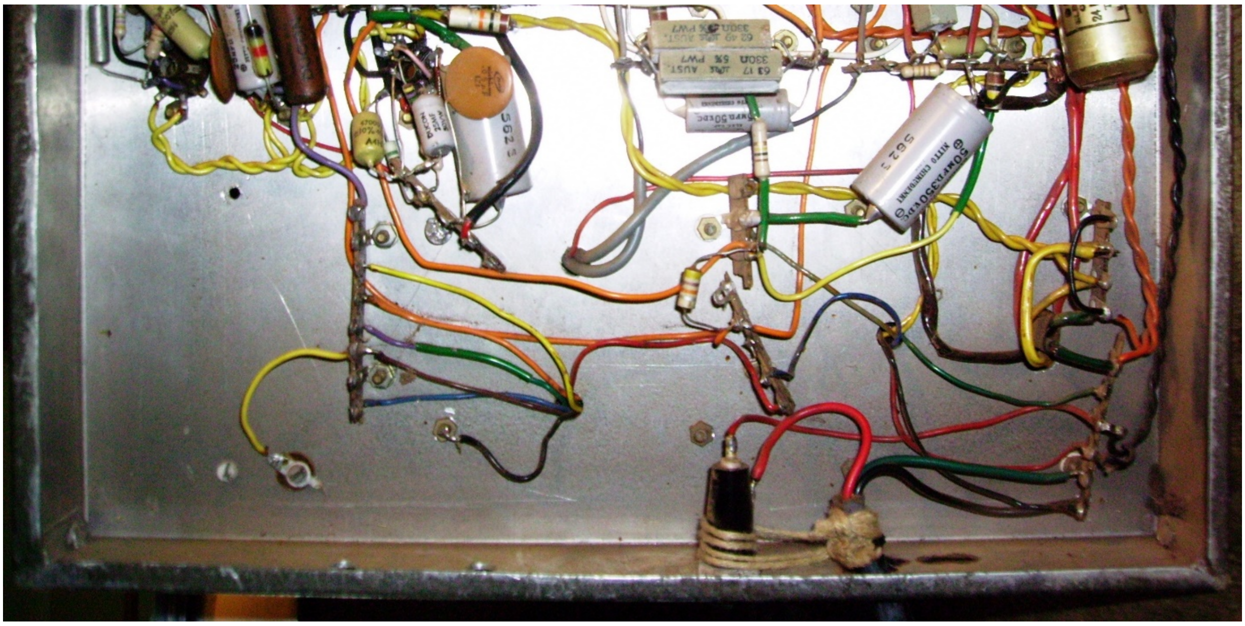
TYPICAL ADDED CIRCUITRY



- Shrouding: Servicing an amp often requires the amp to be on, with fingers and probes near to mains AC wiring and terminals. All exposed line and neutral mains wiring should be shrouded (by heatshrink tubing, or bright insulation tape) so that accidental touching is nigh on impossible.
- Wire insulation: Wire carrying mains AC should be rated for 250VAC, and not hookup wire of unidentified spec. If the existing cable insulation looks old (ie. early rubbery style insulation, or heat stressed pvc type) then replace it. Replacing wiring in a very old amp, especially wiring in to transformers passing through bitumen potting, is an onerous task that can get risky and messy.
- Cable loom separation: Try and separate any mains AC cables from other cables within the amp – including mains wiring going to the power transformer. If mains wiring is run in the same loom then separate the mains wiring and run it in spaghetti or heatshrink tubing. Try and leave one terminal spare on tag strips between mains AC circuitry and other amp circuitry.
- Insulation resistance (IR) testing: Insulation within a power transformer, in old switches, rectifier diodes and coupling caps, can degrade over time. A ‘megger’ (megohmmeter) is a relatively cheap instrument for applying a high voltage (usually 100V, 250V, 500V and 1kVDC) across an insulation barrier (eg. transformer primary winding to secondary winding, or to transformer core) and measuring any leakage current through the insulation or tracking around the insulation. See Testing section later.
- A poor-man’s IR test can be done using a suitable DC voltage supply and a digital voltmeter (DVM). For example, testing the leakage of a capacitor can be done by wiring the capacitor in series with the DVM, and connecting them across a DC voltage supply, with the meter set to measure volts. Leakage current through the capacitor is the measured voltage times the meter's input resistance, typically 10 or 11 Meg Ohm (eg. 10mV or 11mV reading is ~1 nA). Check the DVM specification for the input resistance in DCV mode, or measure it with another DVM, and only use a DCV mode that has that high input resistance. Shunt the meter with a resistor (say 100 K Ohm) to reduce the sensitivity (eg. to 0.1mA) if needed. An in-situ capacitor measurement can be made by unsoldering the positive end of a filter cap and inserting the DVM between the power supply and capacitor positive terminal – after the test, move the DVM positive lead to the capacitor negative lead (gnd) to discharge the cap and measure the capacitor’s discharging voltage level. An isolated adjustable test DC voltage supply can be made from a 12V 4Ah VRLA battery, and modular dc/dc converter like an eBay YH11068A.
- DIY dangers: The picture below is a DIY amp made ~1966 from a kit of parts and based on the RTV&H 1958 magazine 35W PA amplifier article.

  The general assembly of parts and signal wiring is good, but there are many safety hazards waiting for an accident to happen! The AC mains cord is poorly clamped, and there was a 30A mains fuse fitted.

The protective earth wire is soldered to a terminal strip, and the chassis bolt has no mechanical lock-washer and was not very tight. There is no protection of AC and OT primary wires through drilled chassis holes. There was no shrouding of exposed AC mains connections.



High voltage DC safety, protection and filtering

All voltage supplies within the amp, including heaters and the speaker output (which is an AC voltage supply), must be electrically associated to the 0V ground and hence to the chassis and mains protective earth (ie. not floating unconnected). Any voltage above 32VAC/60VDC is typically considered hazardous by safety standards, and care is required in wiring, insulation and shrouding (this includes bias supplies and elevated heaters, just as much as HT high tension voltage rails powering the valve stages). See - www.ozvalveamps.org/safety.htm . Protection is a complex topic – for example see dalmura.com.au/projects/Output%20transformer%20protection.pdf .

- Fusing: It is all too easy for a component or valve fault to end up damaging the power transformer and output transformer due to sustained high current operation, even with an AC mains fuse. At least the PT HT secondary should be fused. This article on fusing provides details on where to fuse and how to determine the fuse rating, and this article on transformer protection provides details on fault causes.
- Valve Diodes: A PA amp may be missing its valve diode, or the power supply capacitance or loading may change due to output stage alterations during renovation or mods. Any proposed valve diode needs to be checked that it is operating within its rated limits – this can be difficult for valve diodes as they have many more operating limits than an ss diode, and some limits are difficult to understand.

  Diode datasheets often indicate maximum supply voltage and load current for a given minimum effective plate supply resistance and a given filter capacitor size. If the amp is operating with a lower supply voltage, lower load current, lower output capacitance, and higher supply resistance, then using that valve diode is fine.

  If your plate supply resistance is lower than rated, or you want to use a higher filter capacitance than rated, then the diode's transient peak plate current (per plate), and the steady-state peak plate current (per plate) shouldn't be exceeded. One way to check diode peak plate current is to use the Duncan Amp Tools program called PSUD2 and simulate the worst-case operating conditions when the mains power of a hot amp is turned off for a few seconds and then turned on again. In that situation, the filter cap will have discharged but the heaters are all hot and so when the amp is turned on again the diode will conduct fully to charge the capacitor and supply the load. Also see Power supply issues for tube amps.

  Configure the PSUD2 circuit to be the same circuit as in the amp (eg. valve type full-wave), and de-select soft-start option, and use a load current that is suitably above the idle current (eg. a cranked output load). Simulate for about 0.2 second and view the peak value of D1 current. The simulation gives an initial transient overshoot, and then settles to steady-state. The screenshot below for a 5Y3GT diode and simple capacitor filter shows the initial transient peak (red) of about 1.5A is less than the 2.5A datasheet limit, however the 440mA continuous peaks are at or above the datasheet continuous (steady state) peak current limit conditions (depending on the datasheet used).

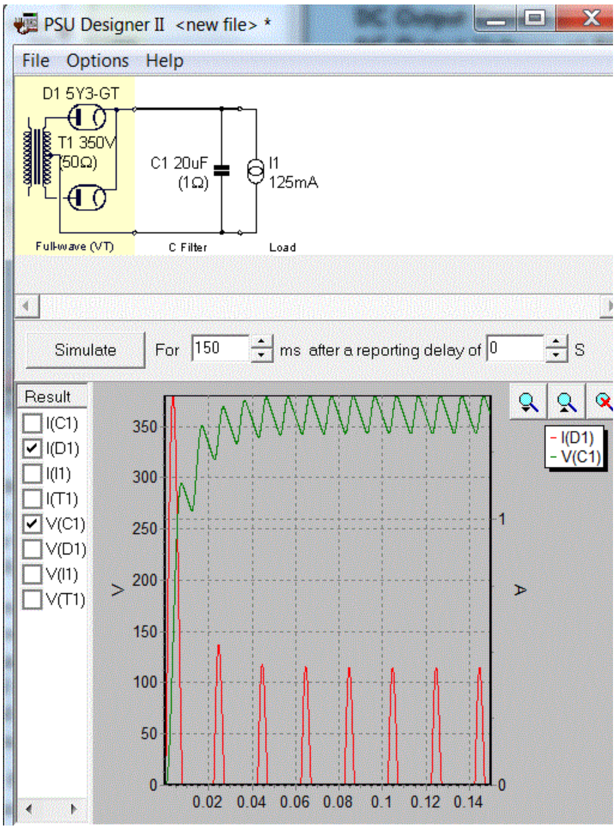
The effective plate supply resistance Rs (also referred to as supply impedance per anode) needs to be measured: Rs = Rsec + Rpri x $(Vsec/Vpri)^2$, where Rsec is secondary HT winding resistance; Rpri is primary winding resistance; Vsec is secondary HT winding voltage; Vpri is primary winding voltage. Rs is then the 'source resistance' associated with the transformer in PSUD2 (PSUD2 allows that to be calculated using the source impedance calculator).

Measuring resistance of an inductive winding may be a problem for some meters – short circuiting the other windings may help with reading accuracy.

PSUD2 doesn't allow parallel plates, so in that situation another diode with about half the voltage drop should be used as an equivalent.

Increasing the capacitance in the PSUD2 example will increase the transient peak at the start of the simulation.

Different manufacturers often had slight differences in specs – the 5Y3GT datasheets may show steady-state peak levels of 400-440mA.



When modifying part values, PSUD2 will give an alert if a peak current limit is exceeded. Preferably cross check that the current limits are the same as in the datasheet.

A valve diode fault that arcs between cathode and anode when supporting reverse voltage can damage the cathode of the valve and stress the power transformer, as it shorts the secondary winding. Adding a 1N4007 diode in series (or 2x series diodes for windings >250VAC) with each valve diode anode avoids damage to the cathode and provides extra protection for the power transformer, and reduces the PIV stress on the valve. Any faulty valve should be replaced as there may be a noticeable increase in hum, and power transformer magnetising current due to rectifier imbalance. See Testing section for a way to check valve diode performance. The B+ can be raised a bit if needed using 'bridging option'.

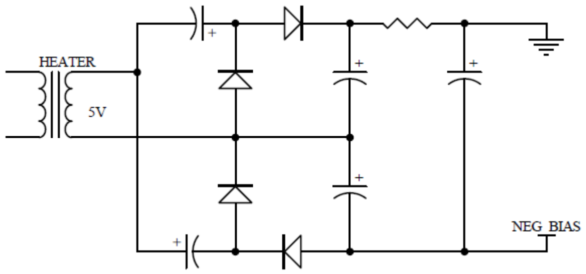
Don't be tempted to connect anything to the typically unused pins 3, 5, and 7, on an octal rectifier valve socket, as pins 2 and 4 can have a very high inverse voltage at the anode, which has the risk of causing arc tracks to the neighbouring pin. Keep the valve socket clean around pins 4 and 6, to avoid any pollution residue from assisting an arc to form. Do not mount any supporting ss diodes to pins 3, 5, 7 as that similarly increases the risk of arcing – preferably add in a small terminal strip.

Rectifier valves with a 6.3V heater (eg. 6V4/EZ80, 6X4, 6X5, 6CA4/EZ81) are typically powered from a secondary winding with CT connected to ground, and as the valve ages the cathode-to-filament interface can become a low resistance or short, which then loads or short-circuits the high voltage secondary winding. This type of fault can be alleviated by disconnecting the heater winding CT, and using a fixed or tuned heater humdinger (as used for hum reduction) connection to ground which should then fail open, or alternatively fusing the high-voltage CT.

If an indirectly heated filament diode is used, and the heater winding has a CT, then connect that CT to the first filter capacitor pos terminal for minimum hum/ripple. In that CT configuration, swapping the heater connections to the pins 2/8 filament terminals can increase/decrease the B+ level a bit if needed.

- Replacing valve diodes with solid-state diodes: This should only be done after carefully considering the changed operating conditions. The B+ level will likely increase noticeably, which may cause a higher idle bias dissipation level, and will cause all power supply and coupling capacitor voltages to see the same high peak level at turn-on, until valves start conducting current. The initial AC mains in-rush current will increase, which may need a higher mains primary fuse rating, and a higher PT secondary fuse rating. Most valve diodes have a much higher PIV than a 1N4007 – so many amplifiers will need 2 series 1kV diodes to replace each valve diode (eg. plate) – aim to use 2 series UF4007 for each 'diode' when PT secondary is greater than 250-0-250V, or 500VAC for a full bridge rectifier. There may be an increase in rectifier noise level, which could be noticeable with common power diode 1N4007, and especially for higher current types like 1N5408, P600K, and bridges like KBU6. If possible, use the UF4007 version, and if more current rating is needed then 2 or more in parallel, however it is unlikely that the current rating of a UF4007 would be exceeded for a typical valve amp B+ supply (use PSUD2). Additional discussion on solid-state diode use in power supplies.

- A spare 5V heater winding can have alternative uses.
  - If the amp needs additional cooling, then the heater can be rectified and filtered and used to power a 'quiet' fan. Small computer fans (eg. 80mm) can operate at below 12V with reduced rpm to allow a low level of air movement within a head.
  - If the B+ supply is too low or too high, then the 5V heating winding can be used to 'buck/subtract' or 'boost/add' to the power transformer HT winding. For a simple bridge rectifier, the heater winding is connected in series with the HT winding. For a common full-wave rectifier, the heater winding is connected in series with the CT tap. A 5V difference is not much, but it is something! Similarly, a retrofit transformer (eg. 240V:24V) can buck or boost the HT winding even more to better suit particular output stage valves or reduce quite high B+ levels that some vintage PA amps used, and PSUD2 can confirm the rms current rating needed of the added winding.
  - If there is no negative bias supply, and fixed bias or partial fixed plus cathode biasing is now wanted, then a 'double-doubler' rectifier filter arrangement can provide about 24V, which could suit valves up to 6CM5 and 6V6.
  - The heater winding can be rectified and stepped up to a constant 12Vdc by a switchmode module for DC heater powering, or to a convenient voltage for a negative bias.



- Solid-state diodes: Vintage solid-state diodes have two main concerns that imho indicate they should be replaced with modern diodes like the 1N4007 or UF4007. One concern is that the early technology was not as robust or have the same ratings margin, and the other concern is long term exposure to over-voltage events from the mains AC and over-current events from failed parts (especially output stage valves). See Testing section for PIV leakage of vintage ss diodes.

- Chokes: Chokes were only common in older PA amps, and were used to avoid hearing excessive hum at a time when capacitor cost and size were limitations. A choke was typically placed in the main B+ power supply filter circuit, or the output stage screen or preamp stage filter circuits. Smaller chokes often failed due to over-current when another part failed. Chokes typically have markings so a replacement can be identified, but if not then choke inductance measurement is not too difficult – dalmura.com.au/projects/Choke%20measurement.pdf .

  Many PA amps run very high HT DC voltage levels that are well in excess of what modern EL34/ 6CA7 and KT88 valves can reliably operate with. Changing the HT filter from a capacitor input to a choke-capacitor LC filter, or a CLC filter (with low input C value), can reduce the HT voltage substantially whilst also lowering hum levels. A choke for that use need only be a few Henry, so a salvaged 240V 9 or 18W flouro choke is a good option as there is likely to be plenty of space under the chassis, or to mount the choke to the side of the power transformer. However, when an amp is turned on and before the output stage valves start conducting, there is almost no load on the power supply and so power supply filter capacitors and signal coupling capacitors still need high voltage ratings – although with some effort this can be alleviated by using a timed standby switch, or a shunt type pre-load - dalmura.com.au/projects/HV DC shunt load.pdf .

  PA amps were not normally designed to have very low hum levels. Noticeable hum is often introduced into output stages due to inadequate screen voltage filtering, especially where the screen voltage is also just the main B+ supply. A low current choke (eg. a few Henry at 20-30mA) is relatively small and easy to fit and can be used to noticeably reduce hum levels on screen, PI and preamp rails, with only a small DC voltage drop incurred.

Better attenuation of 100Hz ripple can be achieved from an LC or CLC filter by adding a capacitor in parallel with the L to achieve a series resonant path with increased impedance at 100Hz. Care is required to use an appropriate voltage rating for the resonant cap, and in selecting its value.

A DIY electronic choke, using a power FET in a gyrator style circuit, is a modern option to easily change from a C to a CLC filter for the main B+ supply, and significantly drops the ripple level of the B+ supply.

- Replacing capacitors: Nearly all types of old (>50yr) capacitor will need to be replaced, especially electrolytic and waxed paper types, and any mustard or chocolate block mica types that have a cracked outer covering. Cheap capacitance meters are readily available to test replacements before use, and indicate if mustards and mica cap values are still ok. Coupling caps that isolate a high DC plate voltage from the next stage's grid voltage should be checked during initial power up (see later testing section) by confirming the terminal at grid voltage is at 0V or fixed bias voltage (depends on circuit type being tested), as most capacitor testers do not apply a high DC voltage to check for leakage (see Testing section later). May need to use a hot air gun to remove wax to see capacitor value and rating.

  Electrolytic caps can be recycled from switchmode power supplies, but if they have had more than about 5 years use, or look in any way stressed (bulging can sides or top), then best to use a new cap. AC mains rated poly caps may not have a DC voltage rating, but can be used for DC voltage up to 140% of the AC rating, although the capacitor datasheet may identify a much higher DC voltage rating.

  {I often install new electrolytic caps, but prefer to leave chassis mounted electrolytic can caps in place to retain an aged look to the amp, and to avoid a largish hole appearing. The cap terminals are usually folded down to keep them out of the way, but can be used as a convenient place to solder a tag strip to. I normally remove any large box shape paper-oil capacitors, such as Duconal type, as they are heavy and may contain hazardous PCB liquid.} List identifying capacitor types with and without PCBs.

  Caution is required to ensure that capacitor voltage ratings are not exceeded – and that preferably extends to initial power up when valve stages aren't loading the power supply nodes (see bleeder section later, and discussion on electrolytic capacitor surge voltage ratings).

  CAUTION. Some power supplies use series connected filter capacitors (such as a doubler rectifier, or two-phase bridge rectifier with negative grounded and CT connected to split capacitor, or when lower voltage rated capacitors are used) with one capacitor fully at an elevated voltage – that entire 'upper' capacitor must be insulated from chassis, especially any larger chassis mount can type. Totally insulate the cap if it isn't already, to avoid accidental contact with its external metal surface, including an extra layer of insulation where clamping, and where the cap may sit on the chassis.

  Series connected filter capacitors also need sufficient voltage rating tolerance to withstand imbalanced voltage sharing during power-up, especially as the capacitors age and their capacitance and leakage current changes. Balancing bleed resistors must also be used, and their voltage and power rating must also allow sufficient margin to avoid failing open (as that typically leads to a failed capacitor) during power up when voltage imbalance can easily occur, as well as from voltage surge with no loading.

  If vintage electrolytic capacitors are to be used, especially before about 1970-80, and they do not show any sign of venting or bulging then it is recommended that measurement is made of capacitance value, leakage current at the rated DC voltage after 1 hour, and capacitor ESR, as a way of confirming fitness for purpose. If there is no room for new caps under the chassis, then it is possible to restuff electrolytic metal can caps, and the ground terminal for the new cap or caps can be taken through the base and connected to an appropriate circuit point rather than at the original can/chassis point.

  Some old amps have historic value and it is possible to make subtle restoration changes such that the original aesthetic appeal of the amp doesn't noticeably change. Restuffing old axial electrolytic caps is sometimes done, due to their dominant size. Some better quality e-caps may have retained sufficient liquid to allow reforming, where a current limited supply allows the oxide layer to recover

  Modern e-caps are much smaller than vintage caps, so confirm the ripple current rating of a new cap is acceptable for the amp (eg. using PSUD2), especially doubler power supplies where ripple frequency is only 50Hz and the ripple current multiplier may be down to circa 0.75-0.8.

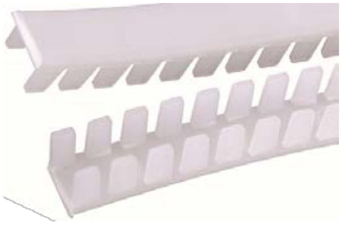
- Regulator circuits were not common in PA amps, as they needed an additional valve and isolated heater supply, but did provide a convenient voltage dropper for output stage screen and preamp supplies from a high B+ supply. The AWA 827 70W amp uses a simple series 6AQ5 (triode strapped) regulator to supply the quad KT66 output stage screens with a nominal 300V dropped from the 600V rail, with a low impedance and attenuated ripple to avoid using a substantial bypass capacitance. The STC 28-SU-208 35W amp uses a similar 6BW6 (triode strapped) series regulator to drop a 600V rail to 300V for 7027 output stage screen and preamp supply. These regulators operate with a ripple filtered grid voltage set at a resistor divided % of the high B+ voltage level, with the cathode voltage varying along the supply load-line for changes in plate ripple voltage as well as cathode current. A high-voltage ss Zener diode can be easily added to provide better DC voltage regulation if needed.
- Shrouding: As with mains AC circuitry, try and shroud or avoid placing exposed hazardous voltage terminals and wires where a technician could easily touch them whilst servicing. Take special care to shroud wiring and terminals for transformers which have no bell-ends and terminals above the chassis.

  Old amps with anode caps rarely used shrouded cap terminals – the amp should not be operated unless a chassis top protective cover is in place.
- Wiring: HT DC supply wiring should be rated for 250VAC - not just be some unidentified hookup wire.

  Wiring from the anodes of the output stage valves to the output transformer should be given extra care to keep them separated from all other wiring (apart from HT DC to output transformer CT), as they can operate at very high AC voltage levels, and can couple signal back in to previous gain stages as a form of inadvertent feedback and hence cause oscillation.

  Not all manufacturers used grommets to protect wires passing through chassis holes. Nylon flexible edging (moveable bushing) for chassis thickness of 1.2-1.6mm is useful to cut and fit to unprotected holes.

  Adding a sleeve of heatshrink over mains or high voltage DC wiring that is in close contact with low voltage DC wiring can be reassuring when wire insulation is not new.

  The OT plate wire connection to the output valve base terminal in higher powered PA amps is sometimes sleeved, and the sleeve may even be glued to the valve base in an attempt to increase creepage and clearance distances. The valve base around the anode (usually pin 3) should be cleaned to remove any traces of pollution or carbon from previous arcing.
- Standby switch: Try and avoid the inclusion of a standby switch in the B+ dc line. Depending on the electrical location of the switch, the switch contact can endure a stressful time when turned on due to contact bounce, and the stress can be exacerbated as the contact becomes pitted.

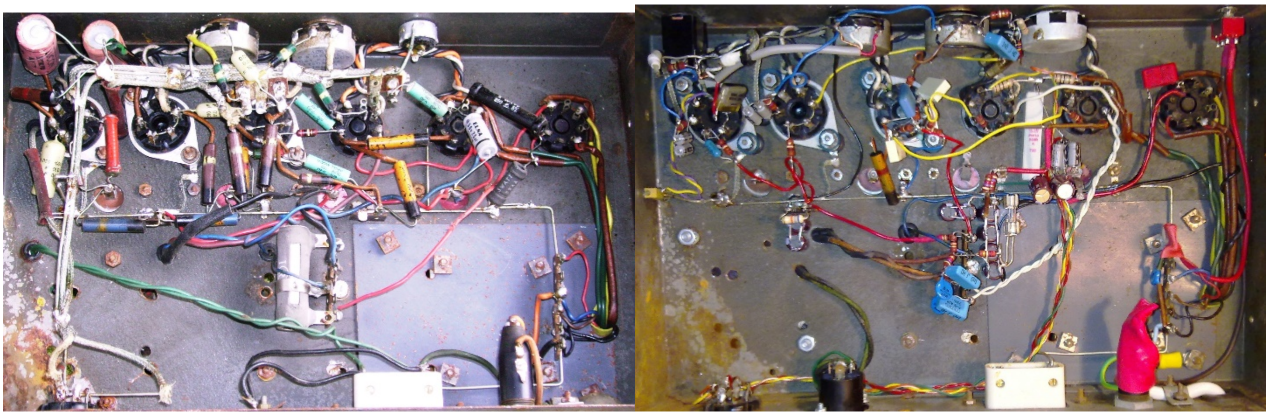
  In a doubler rectifier, any part (switch or fuse) should be located in the capacitor mid-point arm to reduce voltage stress on the part.

  A standby switch in the negative diode bridge link to gnd, and using a CT to generate 50% B+ for output stage screens, can cause the screen filter cap to go negative due to leakage.
- Discharge loading and bleed resistor: Although the HT voltage levels normally fall quickly after an amp is turned off, that won't happen when valves have been removed for testing, or are faulty, unless a discharge resistor is added somewhere along the HT voltage supply circuit. A 100-150kΩ 2W resistor is often all that is needed to reduce HT voltage levels to below 50-60V after 1 minute, which is the aim.
- Series connected filter capacitors, with a voltage balancing resistor across each cap, may act as a suitable bleed resistor.
- A bleed resistor located towards the end of an RCRC style supply distribution chain can constrain the initial peak voltage seen by filter capacitors during power up.

Grounding

Most vintage PA amps use a common chassis grounding system, where a part is connected to the nearest chassis point, such as a bolted lug, or tag strip lug, or thick tinned copper wire looping around the amp and anchored at many points to the chassis, or even exposed shielding around screened cables.

Photo of vintage grounding scheme, and when renovated with a distributed star grounding scheme (tinned copper wiring still in place, but not used).



- Distributed star grounding: See www.ozvalveamps.org/grounding.htm {I prefer this general method, which is nicely described by Merlin in www.valvewizard.co.uk/Grounding.pdf }.
- Transformer shields: The power transformer (PT) often has a single terminal connecting to a shield winding that is placed between the primary and secondary windings, and is often known as an electrostatic shield or screen, or an earth shield (often abbreviated to ES or SH). For some electrical standards, the shield is a protective earth barrier between mains and circuitry. For some applications the shield is used to bypass higher frequency noise currents to chassis and minimise noise coupling to the other side. The output transformer (OT) may also have such a shield. In general it is ok to connect a PT shield to the 0V-chassis main star point, as it can pass both rectifier side and mains side noise. An OT shield passes higher frequency signal currents from the plate side, so connect to output stage 0V.
- Chassis connection: For a star type grounding scheme, connect the 0V from amplifier circuitry to the chassis at one point only. Effectively this can be done from any convenient point on the 0V circuit – although many prefer to do it at the guitar input socket (especially if it is not an isolated case type of socket, but it has the advantage of restraining a remote equipment earth current loop path to just the input stage and chassis). {I often do it at the 0V star point of the output stage, just for convenience}. Don’t use the same chassis connection point as used for the mains PE chassis connection.
- Some types of pot don’t electrically connect the rear cover to the mount, so a ground wire is sometimes seen soldered to the pot rear cover to improve shielding.
- Heater supply: The heater supply to preamp and output stage valves should have a connection to 0V ground. Commonly, the heater winding has a centre-tap connection which is taken directly to ground (ie. 3.15V-0-3.15V winding). With no heater winding centre tap, a humdinger circuit with a 50-100Ω resistor from each heater side to 0V was used (even 3-terminal 50Ω+50Ω resistors may be seen).

  Even when the heater has a CT, changing to a ‘humdinger’ type ground connection using low power rating resistors can achieve a poor-man’s fuse to protect against certain types of failure. When a heater is used for a B+ rectifier such as a 6X4, as well as for signal valves, then a heater-cathode insulation breakdown in the 6X4 will short circuit the B+ via the heater. A similar fault is a pin 2 to 3 arc-over from adjacent heater and anode pins on an output valve, or a valve with broken spigot inserted incorrectly. Although a fuse may blow, the humdinger often burns out first. If the fault, or arc, stops after the humdinger fails, then the heaters may be left floating. If the fault is a permanent short, then the heater would be connected to B+ through whatever parts are in series, and so a valve or valves may fail from heater-cathode shorting – and the fault may persist if a fuse doesn’t blow.

  In some situations, a humdinger pot can trim the level of hum more than just using fixed resistors or a CT connection to 0V. {I have a swag of 0.6W 200Ω trimpots that I use as a tuned humdinger to 0V, to provide hum minimisation and poor-man’s fusing.}

  Some PA amps elevate the AC heater supply to a positive DC voltage by connecting the heater to the output stage cathode bias voltage (eg. AWA PA774, PA806, PA825), or a dedicated filtered dropper from B+ (eg. AWA PA827) – this may lower hum noise for valves with low heater-cathode resistance.

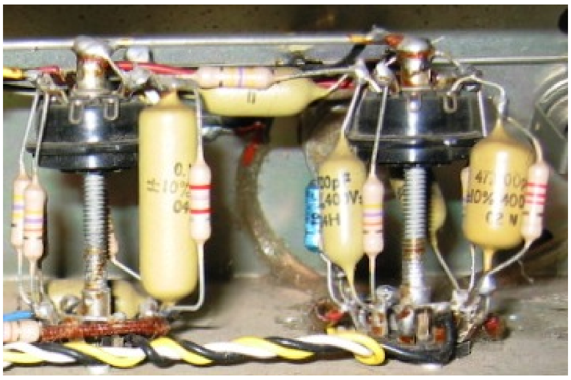
Some PA amps use a DC heater supply derived from the output stage cathode bias circuit, where the heater resistance acts as the cathode bias resistor (eg. AWA PA872, PA1003). The technique avoids the need for a large power resistor under the chassis, and lowers the heater winding current rating, but doesn't eliminate signal voltage on the heater especially when the cathode bias voltage fluctuates during overdriven conditions. {Some modern amps use a rectified and filtered DC voltage to power the heaters, with the aim of alleviating hum noise. I recommend just using standard heater AC powering techniques with a tuned humdinger to 0V, as good quality grounding and layout should achieve adequately low hum levels for guitar amp use. Valve Amplifier Hum article.pdf }

A particular valve's heater may need an elevated DC voltage to keep its heater-cathode voltage within the design centre maximum rating. The valve heater-cathode in a cathodyne phase inverter (PI) circuit is one example needing assessment. {If an elevated heater supply is needed then I prefer to use a capacitor bypassed resistive divider supplied from a low ripple HT DC supply such as a preamp stage.}

If possible, use a noticeably lighter gauge wire than the transformer heater winding wire to distribute a heater around the chassis and to preamp sockets, as lighter gauge wire is easier to twist and position away from other wiring, and if a short circuit occurs at a valve base then the wire insulation may indicate the fault (heat stressed or smoke) and mitigate power transformer heater winding damage.

- Speaker winding: The speaker winding is often floating, or capacitor coupled to ground in a PA amp. One side of the speaker output should be taken to 0V, or chassis (if there is no feedback used).

- Valve spigots: Most 9-pin valve bases have a small tubular metal spigot fixed into the central hole, which was typically connected to a nearby chassis lug in old PA amps, and acts as a shield for signals to reduce hum and feedback. The spigot provides an easy local distributed star ground point for soldering cathode and grid-leak resistors to, and cathode bypass and screen bypass capacitors to. The capacitors in old amps were much larger than modern equivalents, and connecting them to the spigot was often not practical.



Some valve base spigots have a 'tree' attachment to simplify the local connection of parts without having to use connecting wire to nearby tag boards. The photo shows an example of tree spigots.

Output stage issues

Output valves can be very costly to replace or fit if the amp used KT66, KT77, KT88, or 6CA7/EL34 valves, whereas some valves types such as 6CM5, 807, 6BM8, 6V6, 6L6GC, and 7027A are relatively cheaper.

- Leaks and stoppers: Grid stopper resistors were typically not used, or of low value. Overdriving an amp can cause a rapid rise in grid conduction current in certain capacitor coupled stages within an amp, causing objectionably harsh blocking distortion, which is best alleviated by using a substantial grid stopper resistance, and lowering the grid leak resistor value, as well as lowering the coupling capacitor value (as excellent bass response is not normally needed or wanted). Output stage valves can self-oscillate, which is best avoided by using grid and screen stoppers soldered directly to the valve base terminals. Grid stopper values of between 1k and 10k are commonly used, depending on what overdrive character is wanted. When an input signal voltage peak starts to cause grid current to flow, the grid stopper will drop an increasing voltage, which tends to soften the voltage waveform transition between linear operation and signal clipping, and alleviates coupling capacitor charging.

  Grid leak resistor values were often set at the maximum allowed value for a tube: typically 100k for fixed bias (50k for 6550), and 500k for cathode bias (220k for KT88, 6550). Some datasheets allow an extra 20% for resistor tolerance. Adding in or increasing the grid stopper resistance will increase the effective grid leak resistance, so some care is needed to stay within spec. Aged and thermally stressed valves can exhibit an increased grid voltage (ie. the bias voltage gets 'hotter') due to increasing internal gas conduction, which can lead to thermal runaway of the valve. Lowering the grid-leak resistance can alleviate those concerns and extend the service life of the valve from that failure mode. Best to double-check the datasheet for the max grid resistance allowed, and if possible then err on the safe side.

Output stage screen stopper resistors can get a very hard time in guitar amps, and may have been stressed in PA amps (if they had them). It is recommended that any replacement resistors use a higher wattage rating (eg. 2W increased to 5W), and if they were not originally used then new parts added (especially to avoid internal arcing under certain start-up conditions). Hum can be reduced significantly in some amps when a filtered screen supply is used, which can simply be done using a resistive dropper from B+, which will lower the screen voltage and modify the bias level somewhat.

Amps using parallel valves in the output stage, or transmitter type valves such as the 807, are even more prone to self-oscillation, and in addition to adding grid and screen stoppers it is wise to add anode stoppers – which can be a 10Ω resistor or even a ferrite bead slipped over wire connecting to the anode terminal. Some vintage PA amps, like from Selmer, with quad EL34's work fine with NOS valves, but will oscillate/squeal with modern valves as they just use 2 common screen stoppers.

- Biasing: Fixed bias circuits can be improved with extra capacitive filtering, and using full-bridge SS rectifiers (to replace commonly used half-wave circuits), and making the bias setting pot or trimpot failsafe (eg. by connecting wiper to high voltage end of pot with a resistor). Uncommon bias techniques may be found, such as back biasing, and circuits that use preamp valve heaters for the cathode resistor of the output stage (eg. AWA PA872, PA1003, PA1005) which cause high current turn-on stress of output stage valves due to the initial cold heater resistance (a PA1003 showed 150% of idle stress for a few seconds, which can be avoided by adding a 200D7 NTC in series with the heater string).

  Cathode biasing of a quad output stage (eg. AWA PA1005) can benefit from adding a 1N4007 between the output stage common cathode and each side's common grid leak to protect against grid failure.

  Cathode biasing can be changed to fixed bias – this can reduce heat dissipated under the chassis, and can increase effective plate voltage, and change the character of the sound. If a bias winding isn't available on the power transformer, then a capacitor fed bias supply can be added from the HT winding (see education.lenardaudio.com/en/14_valve_amps_6.html), or diode with resistor dropper (caution is needed to achieve a stiff bias voltage that is not significantly influence by varying bias current through any series dropper resistances). Or insert a small mains transformer with 6-9V secondary and power the secondary from the heater, or use a partial cathode/fixed bias scheme.

- Using cheaper valves: Of the small Noval socket output stage valves, the 6GW8 has become expensive. The 6GV8 could be a replacement if an extra 0.5A of heater current was acceptable, as well as rewiring of all pins except 4,5,6, and appreciating there may be some noticeable performance change. Another option is the 6BM8 if an extra 0.25A of heater current was acceptable, as well as rewiring of pins 2,3,7,8 and lowering plate dissipation from 9W to 7W, with the same performance proviso.

  6L6GC are much easier to find and could be used in place of valves like 7027A, 6CA7/EL34, KT66, KT88 – however that will require some technical assessment and may require circuitry and power supply changes, but at least provides an opportunity for the amp to be economically renovated, and practical to maintain in years to come. Although there are heater current and voltage rating issues between near equivalent tubes, removing any connections made to pin 1 and pin 6 is worthwhile as it can allow a wider range of tubes to be fitted at a later time.

- 6L6GC could replace KT66 as heater current is lower, tube width is smaller, and the power and voltage ratings are a bit higher. Idle bias could be set for the higher dissipation capability of the 6L6GC, but that requires increased cooling in the region of the valves. There is little difference in the drive and output transformer requirements, and the power supply used for KT66 should be ok as it would have been typically below 500V. The AWA PA825-9 range of amps used KT66 (the PA827 used a quad).

  6L6GC could typically only replace 6CA7/EL34 or KT88 if the power supply voltages were lowered. That would likely require a change from capacitor input to choke input supply, along with other changes upon assessment. Changing from an EL34 to a 6L6GC can allow a higher OT secondary impedance to be used with a standard speaker (eg. use a 20-25Ω secondary for a 16Ω speaker), as the 6L6GC would be happier with a higher PP loading, and so this can use a higher % of secondary turns on the OT.

  Power supply voltages for 6CA7/EL34 and KT88 were typically well above 500V in a PA amp, and many amps used 700-800V DC levels - caution is advised if modern replica (ie. Russian and Chinese origin) valves are used in such amps – preferably use NOS or deliberately lower the B+ level.

Tube	6V6GTA	6L6GC	7027A	7581A	EL34/6CA7	KT66	KT77	KT88	6550A
P-P Ω *	5k-10k	3k5-6k			3k-6k6	3k5-6k	3k5-6k	3k-6k	3k-6k
Pdiss **	12-14W	30W	35W	35W	25W	25W	25W	35W	42W
Heater	0.45A	0.9A	0.9A	0.9A	1.5A	1.3A	1.4A	1.6A	1.6A
Pin 1***	NC	NC ***	=pin4	NC	g3	Internal	NC	Shield^	NC
Pin 6 ^	NC	NC	=pin5	NC	NC	NC	NC	NC	NC
Pin 8	K+g3	K+g3	K+g3	K+g3	K	K+g3	K+g3	K+g3	K+g3

K = cathode; g3 = screen/grid 3; NC = not connected; Internal = internal connection; Shield = base cover

***** Pentodes operating in fixed bias, pentode mode (ie. not UL or triode modes) can operate over a wide PP range. The range varies with B+ and screen levels, whether feedback is applied, and fixed/cathode bias.

****** Check the max design anode power dissipation for the tube being used, eg. 6L6, 6L6G, 6L6GC have different ratings, as do modern manufactured types (eg. 6550A and 6550C).

*** Making any connection to pin 1 (especially a screen stopper) can be a hazard for metal 6L6 where this pin connects to the metal shell to act as a shield/screen. ^ Not all KT88 have a pin 1 connection to shield.

^ Some valves like KT66, KT88 have No Pin (NP) for pin 6.

Common TV horizontal deflection tubes used for audio amps include 6DQ6A, 6CD6G, and 6CM5/EL36. Apart from the anode top cap connection, these tubes need a much lower screen voltage to work in to the same saturation knee region, and have lower plate power dissipation ratings, but can handle the high plate voltages found in more powerful amps. For example, the 6DQ6A is comparable to the 6CA7/EL34, with a 6.3V 1.2A heater and the same pinouts (except for the anode top, which could be wired to pin 3), however the screen voltage will need to be lowered to about 150V and the anode dissipation limit is only 18W compared to 25W, so idle conditions at least will need some adjustment.

The 6CM5/EL36 has a relatively high 1.25A heater requirement (ie. 8W dissipation), and nominal 12W anode and 4W screen dissipation levels, but datasheet application is not for audio. Philips PA's generically operate with 340V B+, 170V screen, -34V self-bias with 470k grid leak, 10k grid stopper and 47Ω screen stopper and a 1.75kΩ PP loading per pair. If possible, retrofit individual grid bias trimpots, lower the effective grid leak seen by each valve to 180-220k, and add cathode current sense resistors to gain better control of each valve's idle condition. See cooling comments below.

The 6CD6G has a high heater current requirement of 2.5A, and different pinouts, so is not a simple option to consider. The 807 is cheap, but is difficult to retrofit to an amp due to a different base, and need for anode cap terminals and more headroom. Ensure that carefully placed grid, screen and anode stoppers are used with 807 valves, as the amp can easily become an RF transmitter.

Early amps may even use a driver transformer, such as the Philips 952.

- Push-pull valve balanced pairs: Even in guitar amps, the valves in a push-pull output stage should be reasonably balanced for cathode current, so that neither valve is more prone to red-plating, and to provide the output transformer with its best chance for bass frequency response. Fixed (self) bias allows a separate trimpot to be fitted and easily adjust each valve's idle current. Cathode bias requires additional resistance to be added to one side to adjust for balanced idle current – not so easy. Once balanced, either scheme requires each valve to be only used in its socket (and not swapped), but is well worth it to allow pretty much any valve in stock to be used.
- Cathode current sensing: Inserting a current sense resistor in each cathode allows the condition of the

valve to be easily checked over time, and can allow un-matched valves to be used in PP circuits that have bias adjustment. The aim is to set the valve's idle power dissipation (Watt) to no more than the datasheet max design level, and that requires measurement of both cathode idle current, and B+ voltage. {I prefer to always install sense resistors (1Ω or 10Ω), as mis-matched valve current is a major problem with old valves. It is very easy for a valve to be idling way too hot, with the other idling a lot cooler. Even valves sold as 'matched' using valve testers can end up being quite mismatched at the high idle voltages often used in PA amps. The 'balance' between the total idle current through each side in a push-pull output stage also affects the hum and bass performance of the amp – for a 'quad' output stage amp this means the four valves can be swapped around so that sum of idle currents on each side are closest to being equal.}

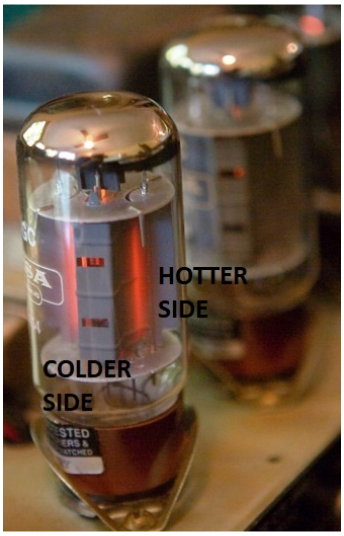
- OT protection: Common forms of OT overvoltage protection used in PA amps were RC filters across each OT primary half-winding, and a flyback diode from each plate to ground. The simplest form of over-current protection, especially for quad and sextet output stages, is to insert a PTC in each cathode (RXE050 for EL34/KT88/6L6GC/6CM5; RXE025 for 807; RXE010 for 6BQ5) and a parallel 68V zener. More details in: dalmura.com.au/projects/Output%20transformer%20protection.pdf .

- Cooling: Some PA amps operate their output stage valves at relatively low idle power, with close to class B operation. A renovated PA amp for guitar use is likely to operate valves at close to max design centre idle power levels, with even higher average power dissipation at high signal level (ie. cranked guitar use). Relocating the amp chassis to a new cabinet needs to ensure adequate cooling, where airflow is more than adequate, and bias the output suitably below the max design power dissipation level for the valves used.

Be careful with 6CM5 /EL36 valves in Philips PA amps, as they were often crammed together, had no bias adjustment, and variation in idle conditions between valves cannot be checked. Although they can cope with high anode dissipation, stressing each valve with >12W anode idle power and cranked screen current is risky with used valves, unless circuit changes are implemented.

Some larger Philips PA's, such as the EV4437, used 6x 6CM5 squished in between the PT and OT, and require care with cooling if relatively high idle power levels are used. That amp can be restored to use 4x or 6x 6CM5, with the 4x option providing perhaps a better loadline for guitar amp use, and of course alleviating the cooling concern.

Try and orient a row of output stage valves such that the colder 'side' of the anode structure faces the colder side of the next valve (rather than facing hotter to hotter). The 'colder' side is typically the box shape with small rectangular holes in it. The 'hotter' side is usually where the join is between the two halves of the anode structure. The photo on the right shows one valve in a row red-plating, to indicate which 'side' is hotter. KT88 MO-V datasheet indicates pins 4 and 8 of each socket should be in line, however different valves have different internal orientations with respect to socket pin orientation.



Clean the glass of output stage valves (but try and retain the markings), as the plate radiates much of its energy directly through the glass (<5 micron wavelength for plate temp of 400-450ºC), rather than being absorbed by the glass, and any dirty covering increases the glass temperature (which is not a good outcome).

Resistors

- Resistor tolerance: Valve amp operation is very tolerant of variation in part values over time. Nearly every part in a valve amp can change by +/-10% without noticeable change in performance. However, if a resistor value is outside of +/-10% then that is a good indication of ageing or stress starting to take its toll, very likely getting worse over time, so is best replaced.

- Although modern ¼ and ½ W resistors can be used for replacing grid leak, grid stopper, and preamp cathode bias parts, it is recommended to generally use 1 or 2W modern metal type resistors elsewhere, as they will have higher voltage ratings and cope better with dissipation levels found in high voltage circuits, and they may also provide lower noise when used in the first stage of high-gain amps. Note that even 1-2W resistors have a maximum voltage rating (likely to be 350-500V), and so 2 series connected resistors may be required for B+ applications, such as for a bleeder resistance.

Preamp stage issues

PA amps often have simple high-gain pentode input stages for Mic inputs, and a following mixer stage where other input channels come in without being pre-amplified by a valve. High level inputs from pickups and radio often have some RC signal filtering and their own input volume pot. The typical stages in a guitar amp are described in - www.ozvalveamps.org/ampstages.htm.

- High gain microphone stage: the typical 2mV sensitivity of a MIC input pre-amplifier is typically too sensitive for guitar input use, and can cause noticeable noise and too much overload distortion.
- An input stage pentode provides a high gain that can generate noticeable microphonic signals (some amps included isolated valve bases - Microphonics%20in%20valves.pdf). Pentodes offer a lot of design possibilities due to selecting screen and anode idle voltages, and modifying the stage gain through anode loading and screen voltage/bias point, and can also be easily modified into triodes, so as to reduce gain. Sometimes both triodes in a 12AX7 are connected as amplifier stages in series. Gain can also be reduced by modifying the plate loading resistance, including using a resistor divider as plate load.
- Even when input stage gain is reduced, hum can ingress in many unanticipated ways.
- Mixer stage: For a guitar amp with no need for a mixer stage, the mixer valve can be repurposed, eg. a gain make-up stage after a tone control circuit or gain pot. The mixer resistors can often be removed.
- Spare valves: Some PA's with multiple inputs may have valves that can be freed up when only one input is needed. A spare 12AX7 triode can be used to parallel an input 12AX7 triode for modified harmonic balance – use a common anode load, and parallel the grids, but use different cathode bias resistances. A spare gain stage can be switched in to circuit using a footswitch, as a boost effect.
- New valve stages: Many larger PA amps have sufficient room to add an extra valve base if needed, or an old electrolytic capacitor can be removed and the hole used to fit a valve base. This can allow an effect such as tremolo, or distortion, to be added.
- Resistors: Amplifier noise is mainly generated in the input stage. Using metal-film 1-2W resistors for the first stage may help lower noise, as well as lowering any grid stopper value.
- PA amps typically use no grid stopper resistor on the microphone input stage, whereas many guitar amps use 47-68k grid stoppers, whereas 10-22k would contribute negligible noise and provide some emi and overload benefit. Try and solder all grid-stoppers with the resistor body very close to the valve base terminal, as this will deter stray feedback and oscillation problems, and EMI pickup. In general for preamp stages, adding a grid stopper can add noise, and lower high frequency response due to RC network formed with the valve's miller capacitance.

  Adding a grid stopper to a cathodyne (also known as a split load or concertina) phase splitter stage can reduce edgy overload distortion, with commonly used values from 100kΩ up to 1MΩ.

  Unless aiming to use particular anode and cathode resistance values to match a commercial or favourite circuit, then retaining the existing resistor values and bias point is usually fine.
- Grid leak biasing: A simple form of bias sometimes found in older amps was to connect the cathode to 0V, and use a high value resistor from grid to 0V. This form of biasing is a bit temperamental as the bias voltage can't be directly measured (anode voltage measurement is the only practical way to determine the bias voltage by reference to plate curves for the valve and a loadline), and can vary with valve quality. Also, high value resistors were prone to high tolerance, and leakage across valve bases can be an influence. An input coupling capacitor is needed for an input stage and the overdrive performance is different to the more common cathode bias circuit, and an input stage may not accommodate pedal inputs too well, so perhaps better to convert such a circuit to cathode bias.
- Aged (well used) valves may exhibit significant grid leakage that can noticeably modify anode/cathode

voltages from what may be expected. For example, reducing a cathode bias resistor value to lower anode voltage may not work if grid leakage current causes noticeable grid bias that dominates total bias.

- Switching between grid-leak and cathode bias is worthwhile if the front panel has room for a switch. A 3PDT can be used to (a) short out the cathode bias, (b) open a short around an additional series resistor in the grid leak, and (c) open a short around an input coupling cap.
- Cathode bypassing: Cathodes were often not bypassed, due perhaps to cost and no need for extra gain. Bypassing the cathode on simple gain stages can be used for tone voicing and extra gain.
- With the prevalence of new or scavenged LEDs, it is very simple to replace a cathode bias resistor and bypass cap with just one LED, which also indicates when the valve is operating. A typical LED has a low incremental resistance at ~ 1mA, equivalent to 20uF at 100Hz, but a LED is not frequency dependant.
- Front panel socket: Sockets for microphone and pickup type inputs were typically placed on rear or side panels of a PA amp, and many sockets are of a type not normally used now. Fitting a ¼" socket (isolated or non-isolated type) often requires large washers to be used to adapt the new socket to the large remnant hole. In many cases it is a better outcome to drill a new hole in the front panel and fit an isolated socket – this is often best done on the left-hand side and may allow a short connection to the input valve base without having to run shielded cable. Preferably fit an isolated socket with an internal switch, or contact that shorts the input when no plug is inserted.

Some older amps may use 2501 microphone sockets (5/8" Amphenol) on the front or rear panels. A simple adaptor is available for a ¼" phone jack.

Volume and Tone pots

PA amps often have a volume pot for each input (eg. mic and pickup), and often only one other pot for tone control, so judicious use of the pots can be important. On the other hand, some PA amps have many inputs, each with their own volume pot, and so the goal is to re-apply some pots to other uses. Some manufacturers used switched tone settings such as bass cut, with the switch on the side or rear panel.

- Gain and master volume: For a guitar amp with single input channel, a PA amp with 2 volume pots can be rewired as gain and master volume pots, so as to allow overdrive of preamp stages within the amp.
- A post PI stage master volume (PPIMV) is typically inserted using a dual-gang pot between the PI stage and the output valve grid-leaks, but does affect feedback if used. That type of PPIMV would likely be needed for AWA PA amps (typically used a floating paraphase PI), and cathodyne and long-tail pair PI stages. A simpler approach can be used for (non-floating) paraphrase PI stages by inserting a single pot between the driver side coupling cap and the resistive divider that connects to the driven PI valve grid, and adjusting the grid leak values to even out the PI loading.
- Single pot tone control: A PA amp tone pot is often just a form of treble cut control that RC loads the anode of a preamp stage. A variety of alternative single-pot tone controls are available, and the tone control can usually be moved to a different circuit stage if needed.
- A single pot Treble Cut/Presence control can be configured by grounding the tone pot wiper and using the CCW pot end for an RC treble cut control, and the CW pot end as part of a separate RC network that shunts the feedback part for a Presence control (ie. treble boost function). Similarly with an input stage pentode, Merlin Blencowe's active treble boost can use one side of a pot, with the other side of the pot used for output RC treble cut. Martin Manning's presonance pot also provides a treble cut/boost function in the feedback circuit with one pot.
- With a deficit of pots on the front panel, a dual concentric pot can provide gain/master volume, or treble/bass control, or speed/depth, or gain/morph.
- With a surfeit of pots or input jacks on the front panel, one spot can be re-assigned to Merlin Blencowe's

MORPH control if an EF86 or 6AU6 pentode is being used. Extra tone and feedback controls are also easy. A buffered effect channel loop can use up two spare spots. It can be very easy to insert a tremolo effect if room is available for depth and rate, and often only one valve is needed for the low frequency oscillator – coupling is usually easiest with a bias wiggler.

- Careful use of shielded cables to a pot, with shield grounded only at the driven valve star point, is recommended to avoid noise and feedback problems due to the often long length of the cable run.
- If a pot doesn't have a connection to one end (ie. the pot is used as a variable resistor) then connect the unused end to the wiper to avoid problems with an intermittent wiper connection.
- A pot is sometimes used as valve grid leak resistor. Intermittent contact of the wiper can cause a crackling noise, which may be alleviated by adding a resistor from wiper to 0V (e.g. 2M2) to maintain a dc conduction path for grid leakage current.

Feedback circuitry

{I often remove any feedback circuitry used in a PA amp, so as to avoid lowering the inherent output impedance of the amp. This means the amp will exhibit a more constant current drive character, which tends to increase the relative power transferred to the speaker at low frequencies near the speaker resonance, and at higher audible frequencies.}

- Around 6dB to 9dB voltage feedback is commonly used for guitar amps. 6dB is easy to set up, as the speaker output voltage with feedback connected is half of that when feedback is disconnected. Do any test with feedback capacitors disconnected, or use a low frequency test signal (eg. 50Hz).
- The sound of the amp can be very influenced by the type of speaker used with the amp (eg. closed or open back loading), and so changing the speaker back loading, and adding some voltage feedback so as to reduce the output impedance, can be used to suit your preference.
- Gain and distortion changes: Removing feedback will raise the voltage gain of the amplifier, and increase the distortion experienced across most of the volume pot range. Most PA amps have too much inherent voltage gain compared to a typical guitar amp, as they were designed for microphone or low-level pickup inputs, so removing feedback only exacerbates that (unless gain/vol pots are used, or other changes are made to lower the gain such as lowering grid leak values or using a different tone control circuit). Guitar amps typically add in distortion in a graceful manner (too clean an amp may lack 'tone'), so removing feedback allows the distortion of the PI and output stages to show up.
- Common feedback resistor: A feedback resistor was often inserted in common to the cathode bias of the preamplifier stage prior to the PI, and was a relatively low value compared to the rest of the cathode resistance – that resistor can be removed if not used for feedback.
- Most AWA PA amps have a feedback circuit that can be modified to a Presence control, such as the PA872, PA1003, PA1005 amps with Bass Cut controls. A switched tone pot can switch in feedback and provide a Presence control. Alternatively, a combined treble cut and Presence pot may be practical.
- Caution is needed whenever feedback is used, as unexpected oscillations above the audio range may not be easy to 'see' without a scope or spectrum analyser. Instability can arise for many reasons, such as no speaker loading, poor wiring or inadvertent coupling, or even output transformer over-drive.

Line output transformer and speaker connection

A line output transformer (OT) can usually be configured to work with a common speaker impedance, and shouldn't be replaced straight away without first exploring its possible application. Some PA amps have a schematic printed on a panel that shows the OT design impedances, however many don't and so require the OT winding turn ratios to be measured, and then the impedances deduced.

- Winding section impedance measurement and calculation: See link for a spreadsheet to insert voltage measurements that allow the turn ratios and impedance of windings to be calculated - OT%20calcs.xls.

  {I connect a 50Hz voltage from a power transformer (eg. 10-40Vrms) to half a primary winding on a PP OT for testing OT turn ratios. This usually gives secondary voltages that are not too small for accurate measurement. I check that the voltage on the other half-primary winding is pretty close to the voltage on the driven half-winding. Use the un-driven half-primary voltage for turn ratio calculations, as the driven winding voltage includes a voltage error due to magnetising current & DCR. Using a 50Hz 'signal' is typically fine for PA OT's and commonly used meters.}

In the spreadsheet, the impedance of a winding section between two secondary taps can be determined by noting the turns between the taps. Insert a voltage for a new winding that ends up calculating that number of turns - the Z (Ω) column gives the impedance of the new winding section.

Transformer manufacturers typically accounted for rated winding currents when specifying impedances, which can cause rated secondary impedances to be 10-15% lower than spreadsheet calculations using turns ratios from unloaded winding voltage measurements.

With PA OT's, a 4-16Ω speaker can often be connected across certain winding taps. The Relative Turns column identifies the % of available secondary turns being used by the speaker (the unused secondary turns are effectively 'dark' turns which can't be practically used).

PA OT's were often designed to generate full power output (eg. 100Vrms across rated load connecting to "100V" secondary winding) with a peak plate voltage swing of 0.71 x B+ (idle voltage). Peak plate voltage swing can't reach B+ (idle voltage) as B+ will sag at full load, and voltage is dropped by output valve plate saturation voltage and OT winding resistance. So the OT typically had a "PP to output" turns ratio of (B+)/(output voltage), which for Philips PA's operating 6CM5 valves with a 100V output meant a 340V/100V = 3.4 turns ratio.

As an example, a Ferguson OP9 15W rated OT model has 125Ω, 250Ω and 500Ω secondary taps, and was designed for PA use. Using the linked spreadsheet, and inputting a signal voltage of 447V for Pri (P-P), and 100V, 70.7V and 50V for the secondaries, and 10,000Ω for Z P-P of primary, will result in the specified secondary impedances. By inputting 1000 'relative turns' for the 100V secondary, the relative turns for the other secondaries are 707 and 500. There is 207 turns difference between the 125Ω and 250Ω taps. Input 20.7V for signal volts on the fourth secondary, and the relative turns will be 207, and the impedance for that winding section will show as 21.4Ω. As such, that 21Ω winding section would likely be fine when loaded with a 16Ω speaker, and would use 21% of the available secondary turns. The OP9 actually has 5k, 6.6k and 10k PP primary taps, so a 16Ω speaker across the 125Ω-250Ω winding segment presents a PP impedance of 6k6 across the 10k taps, and 4k4 across the 6k6 taps.

- Chosen speaker impedance: If a PA OT has winding sections that are close to a standard speaker impedance of 4, 8 or 16Ω then that is a bonus. A calculated impedance somewhat above or below a standard speaker impedance should be acceptable, as it will just present the output stage valves with a similar % higher or lower P-P impedance, and valve amps can accommodate that mismatch easily (especially when one considers that a speaker impedance varies quite a lot with frequency).

  For high power PA amps, where only a low % of secondary turns can be used for a common speaker impedance, or no secondary winding provides a good match, it may be more practical to just choose a 24Ω, 32Ω or even a 48Ω speaker impedance, and to match the amp with a dual or quad speaker cabinet containing 8Ω or 16Ω speakers wired in series.

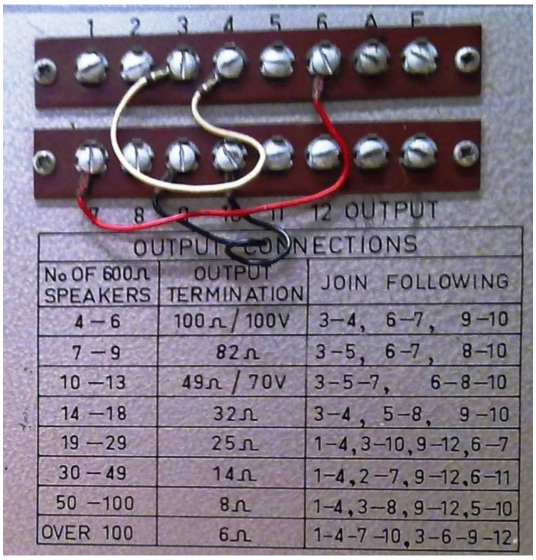
- Another option is to retain an amplifier OT with a 50, 70 or 100V line output transformer, and use a common power transformer as the 'speaker' transformer. For example, the OP9 passes 20W when 100Vrms output is loaded by 500Ω. A 240V:24V power transformer provides a 10:1 turns ratio, which is a 100:1 impedance ratio, so the 500Ω presented to the OP9 is achieved when a 5Ω speaker is loading the 24V winding of the power transformer – so a 4Ω speaker load is fine. For guitar work, a 240V:24V 1A (24VA) power transformer is likely to provide an acceptable frequency response.

- Low power PA amps with typical PA speaker outputs of 50V, 70V and 100V, are unlikely to suit direct speaker connection unless the OT has additional OT output taps, or has a feedback winding (which could then be used for the speaker connection). The common Philips EV4438 (A,B) PA amp has 50V, 70V and 100V winding taps (300Ω, 600Ω, 1200Ω), but also a separate 10V (12Ω) feedback winding, based on a 9.1kΩ PP OT for 6GW8 / ECL86 valves. The Philips 976B and 928 have the same 50/70/100V windings but have a separate 2 ohm feedback winding made from 2 parallel winding sections - which can be separated in to 2 windings and connected in series to make an 8Ω output.

  Guitar amps usually have a restricted frequency operating range compared with hi-fi amps, which allows a 'mismatched' OT to be used with almost no noticeable difference. As such, a guitar amp wanting a 5kΩ PP to 8Ω speaker OT could use an OT specified at 2.5kΩ PP to 4Ω (but use an 8Ω speaker), or an OT specified at 10kΩ PP to 16Ω (but use an 8Ω speaker).

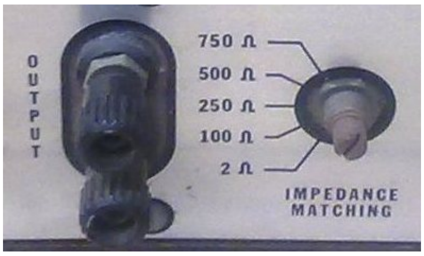
- Separating winding sections: Sometimes a PA OT has multiple secondary winding sections that have equal numbers of turns. If the impedance of those sections suits a speaker impedance then they can be separated at the tap terminals and then reconnected as parallel windings, so that a higher % of secondary turns are used to transfer the signal to the speaker (eg. AWA PA1005). This is a practical modification as the signal voltage level is not too high, and any accidental shorting of wires within the OT should not damage the amp. The common AWA PA1003 has 4 winding sections each of about 21Ω, which can be rewired in parallel even though there is about 5% difference in turns ratio.

  Some larger PA OT's (eg. AWA PA1001-2), provide split windings to rear panel terminals that allow use of all secondary windings for a range of presented output impedances. The 6Ω configuration on the right has four 6Ω winding groups connected in parallel. The four 6Ω groups connected in series give 100Ω.



AWA PA1001 OT winding configurations.

- Speaker sockets: Many PA amps used screw or banana terminals for speaker connections. Sometimes an unused terminal or socket on the rear panel of the amp can be removed, and the hole used to fit a new speaker connector such as a ¼" socket. High power PA amps really should use a Speakon type socket, as the signal voltage is likely to be hazardous, and the connector is a lot more reliable (but will require a 24mm hole punch, or some laborious hole making). If only one ¼" socket is used, then it is recommended that it short out the transformer secondary winding with no jack inserted.



- Speaker selectors: Any type of speaker selector or impedance level switch should be removed or bypassed, to eliminate the chance of the output being disconnected (even for a very short time when switching positions, or due to a dirty switch contact).
- Unused wires connected to output taps are best removed if possible, or coiled up and tucked away, to avoid accidental coupling of signal to preamp stages.
- Megger test: Similar to the power transformer, insulation within an output transformer can degrade over time due to influences like pollution, moisture ingress and overheating. A 'megger' is a relatively cheap instrument for applying a high voltage to primary windings and measuring if there is any leakage current to earth or to the speaker side windings. See 'Testing section'.

Mechanical & electrical issues

- Enclosures/head cabinets: Many PA amps have lost part of their original enclosure, or their enclosure or chassis may be corroded, and so a new enclosure or cabinet may be needed. Some smaller chassis can be configured into a new combo cabinet with a speaker, or an old ss combo can be used as a surrogate. New front panels can be made using traffolyte - or perhaps use a colour print with contact covering for a temporary fix. Ensure that valve cooling is not compromised.
- Transformer mounting: Any mounting bolt that passes through a hole in a transformer core has the capability of forming a shorted turn for core flux (especially via bell-ends or a chassis and bell-end). Vintage transformers typically have a fibre washer at one or both ends of each mounting bolt, and may have spaghetti insulation over the bolt within the core, and these should be retained if relocating the transformer, or checked to see if correctly in place.
- Rubber feet: Many PA amps have no mounting feet. Adding rubber type pads or feet can reduce microphonic feedback, improve airflow under the chassis, and avoid the amp scraping on surfaces.
- Microphonics of input stage: See - Microphonics%20in%20valves.pdf .

- Valve base pins: Visual inspection of valve base pins, or rocking of a valve with signal applied, can show up broken and splayed socket pins. It is an onerous job to swap out a valve base, so it can be worthwhile trying to cinch up a splayed pin (carefully as pin segments may crack), or swap out just a bad pin (ie. sacrificing another valve base of same type).
- An electrical contact type cleaner spray applied carefully into socket pins can help lubricate and avoid signal glitch problems, especially for output stage valves where heat can move the pin. Seat and re-seat each valve to wipe the contact area of the pins and socket terminals. Similarly, clean any accessible switch contact surfaces with a spray.
- Stuck knobs may need the grub screw soaked in RP7 or WD40, and a home-made knob puller.
- Mending valves: Clean the glass on power tubes to assist cooling. Avoid rubbing off the label to help identification of the valve later on (although an etched code won't rub off and will identify the valve). Using a black permanent marker on the glass top to mark the valve won't adversely affect cooling. Some early noval valves (eg. 6M5) showed silver migration tracking along the glass between pins.

  A loose Bakelite base, or metal top cap, can be secured using RTV or engineering-grade, neutral-cure, silicon rubber – which will handle the temperature at those positions. A broken centre peg can be partly rebuilt to hopefully avoid incorrect insertion, and a strip or dot of white-out on the side of the base can aid alignment when inserting.

  If the heater of an octal valve doesn't work then re-solder the tip of the heater pins in the valve base, just in case the heater wire has become disconnected within a pin (I saved an EL34 this way).
- Mending transformers: Failed power or output transformers may be repairable, depending on the failure mode and any damage. Any repaired transformer should certainly be checked for insulation resistance between windings and to case/core, and should be checked for temperature rise in operation. Rewinding a transformer can also be an option.

  Sometimes the fault is external to the actual coil layers, and can be located by removing the bell ends and carefully peeling back insulation tape to locate the wire feeding into a coil winding. This type of repair does require experience with electrical insulation, as the repair needs to return the transformer to a safe condition.

  Sometimes a winding section goes open-circuit. If a PT had a dual primary with two 0-115V windings connected in series, and one of those windings was open, then the amp could be powered from a step-down transformer using just the good 0-115V primary winding. Similarly, if a PT had a HT-0-HT secondary, and one of those half windings was open, then the rectifier could be modified to a full-bridge and fed from the good 0-HT winding – an existing valve rectifier can be changed to a full bridge by adding ss diodes such as 1N4007. Although the remaining good winding may need to carry more current, the effective rms current increase may still be well within the winding's capability.

  Sometimes an alternative vintage transformer can be re-housed within the original transformer's bell-ends, and effectively look the same. {A Fhone 120W amp with a faulty Trimax TP5739 PT was repaired using a Philips 2006 PT from an EV4437A by swapping over the bell-ends and terminal strip, and modifying the rectifier from full-bridge to doubler, and minor adjustment of bias supply}.
- If the amp is grimy or needs to look as good as possible, and access is available to a suitably large ultrasonic bath and a controlled heating environment (oven), then ultrasonic cleaning should be considered. Transformers and chokes must be removed, but surprisingly pretty much all other parts can stay as is. See www.audiokarma.org/forums/index.php?threads/a-tube-amp-restoration-walk-through.655366/ for an excellent reference. [I haven't done this yet!]
- Some terminals on terminal strips and pots and valve bases won't easily take solder due to surface corrosion. Try to scrape all surfaces of the terminal before tinning with solder – this can sometimes take a few goes at scrapping and tinning before solder will properly adhere to the terminal.
- Speaker cone repair: Crease and minor tears can be repaired using a PVA type glue (eg. Helmar Acid Free Glue from Spotlight dries clear and flexible, won't yellow, and is meant for dense paper) to bond edges together, or to bond a strip or panel of paper (eg. cut from old speaker cone) over a tear or lost

section. Keep the added weight to absolute minimum, and keep a similar flexibility, and aim to cover any holes that allow air to pass.

History

- Historical info: There are still PA amps being 'discovered' with little in the way of model or manufacturer identification, or of uncommon models from known manufacturers. Try and photograph the original condition of the PA amp and make a schematic before starting any renovation, as that is of great assistance to those interested in the history of early Australian amps.

  Some amps come with a schematic diagram printed on their baseplate, which can then be photographed. A custom schematic can be easily made for an amp from a similar on-line schematic, and using MS Paint to remove parts from the image that aren't correct, and move sections around, and then print the image and use a pen to hand-draw the corrections in, and then photograph or scan the drawing into an image file (eg. a black-white gif image).

- Dating: There are many ways to assist dating an amp. Some parts have actual dates - Rola parts are an exemplary example - but other parts with codes need the code interpreted. For valve codes (sometimes a small etched code in the glass, or printed on the glass or base) – see frank.pocnet.net/other/Philips/PhilipsCodeListAB-v10.pdf, and MOV GEC date coding.pdf for MOV/GEC (eg. KT66), and pax-comm.com/rcadates.pdf for RCA, and tctubes.com/telefunken-date-codes.aspx for Telefunken. AWV (Amalgamated Wireless Valve – a joint venture of RCA and AWA, which itself had rights to Marconi and Telefunken) made valves (marked as Mullard, Radiotron, Miniwatt) use a glass printed number above the valve model label for day of month, and a two letter code below the valve model label for year and month, with G to H for 1957-8, J to N for years 1959-1963, and P to Z for years 1964 to 1974, and the months were A to M (the letter I and O aren't used). www.guitarhq.com/pots.html may help for US part dating.

  Mustard caps were introduced into Australia in 1959, and then made at Hendon from 1963 (Philips C296 polyester) with a 3 or 4 alphanumeric code (first 1 or 2 characters are month code) then the year as the 2nd or 3rd digit, and H as the last character (H for Hendon), and Philips/Mullard made these caps in Europe from 1958, although early versions were also red in colour and may not have had a factory code at the end. UCC and Anocap polyester, and Ducon electrolytic and polyester often have a 4 digit code with the last 2 digits being the year. Many British parts have a standard 2 letter datecode for year then month (eg. TCC & Dubilier caps, Welwyn trimpots) – similar to AWV, with K=1954, P=1958 and V=1964, and month is from A to M (I & O not used) or A to L. Hunts caps use a WHITSUNDAY three letter code, where the letters refer to 1234567890, and the first or last letter is the year of the decade, and the other two letters are the week of the year. IRC and Welwyn wire-wound resistors can have a 3 or 4 digit code, with the first 2 digits being the year, and the second 2 digits the week of the year. Aerostat pots may have 3 digits (MYY). Rola Plessey and MSP speakers have their own codes.

  Erie ¼ & ½ W (1955 on) | Erie 1W Morganite 1W (carbon comp) | Philips 1W Cracked carbon (1960 on) | IRC PW5 Ceramic encased WW (1960 on) | IRC PW7 (1960 on)

  Magazine adverts and part catalogs from the era can help identify when certain parts first became commercially available (eg. particular models of PT and OT parts). Some amps have books written about them (eg. Goldentone, Marshall, Vox etc.) that include a lot of dating information. Some websites have collated serial numbers with dates and models, such as www.ozvalveamps.org/eminar.htm. Caution is required in dating, as even large manufacturers may have used old stock, and servicing over the decades can introduce new parts.

- Valve labels can be rubbed off, making identification difficult. Look carefully for any additional codes – eg. the code I63 B9K3 on the 12AX7/ECC83, and the Xf4 B6A3 on the EL34.

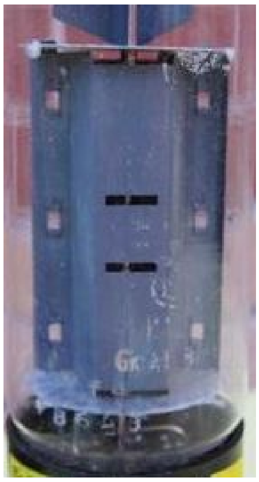
The Philips code list identifies Xf as EL34, and B is Mullard Blackburn, and 6 as the year (probably 1966), A as January, and 3 as the 3rd week in January. The heater pins can be identified using an ohm-meter, and a 5V or 6.3V power supply used to pass heater current, and then the current measured to narrow in on a model (eg. 6.3V at 200mA for EF86). Some output valves have internally interconnected pins (eg. 1&4, 5&6 for 7027A).

12AX7 date code (courtesy Effectrode Thermionic)

Plate, screen and grid structures can be seen coming through the mica separator, with lead-out wires traced to pins in Noval and some valve bases. Some internal structures clearly show the outside anode of a large pentode and a small triode (eg. 6BM8), or a dual small triode (eg. 12AX7). Diodes usually have a different anode structure, and fewer struts connecting to base pins. Use Google images for example photos.

EF86 has a characteristic outer tubular screen covering internal parts, and has a special metal shielding structure in the base for the heaters.

Valves with a higher anode dissipation spec will be in a physically larger glass structure, so many valves that are larger than say a 12AX7 are likely to be used for output stages or diodes.



- Missing valves: This is not uncommon with old amps. Comparison with other amps is a good start to decide what valves were fitted. Identifying input sockets, heater pins, cathodes, anodes, and the sequence of valve stages in an amp is usually easy given a little experience, even if it takes a few rough sketches to make a good schematic. Apart from the ubiquitous 12AX7 and 12AU7, the EF86 was a commonly used input stage valve, and 6N8 or 6AN8 were also not uncommon 9-pin valves, and 6AU6 and 6AV6 were common 7-pin valves. Octal preamp tubes were likely 6J7 pentode (6K7, 6L7 could substitute) with top-cap grid, and 6SN7 dual triode. Some output stage valves have specific connections to certain pins, which can narrow the guess, although care is needed as unused valve pins are often used for tags to solder to. Diode valve models may be more difficult to deduce, and require assessment of the amp's load current requirement and a guess at the 5V heater current rating.
- Unbranded amps: Unbranded older amps were not uncommon, and it may only be the case style or parts that distinguish an amp as Australian (or from New Zealand). Many types of kitset were available, as well as cases and parts, so it is not uncommon to see well made DIY amps, and amps made by small electrical service businesses and those supplying PA gear rental services. Kitset amps would likely be from an RTV&H magazine project, or from a Mullard type reference project.

Testing

- Never plug an unrestored old amp, or old amp of unknown service history, into AC mains power as the amp could be an electrocution risk and could cause damage to critical parts within the amp.

Before initial power-up, preferably:

- make a schematic of the amp if there isn't one available, or double check if any circuit changes have been made from a known schematic.
- check power transformer and output transformer primary windings for insulation resistance to transformer core/chassis, and to secondary windings at 500V-1kVDC. Check AC mains circuit for correct active/neutral and protective earth continuity (especially to all metal panels and assemblies within the amp), and for clearance and insulation resistance integrity (I use 1kVdc for 240Vac circuitry).

- check valves in a tester (to show if a valve is obviously bad) or in another amplifier.
- check coupling capacitors for leakage, and resistor values for gross drift, and confirm fuse values.
- check that electrolytic capacitors have been replaced correctly, or reformed to rated voltage.
- check there is a resistive loading path for B+ level capacitor voltages to discharge in to when the mains AC is turned off and there are no valves in place.
- connect a power resistor as a speaker load to the output transformer secondary, and short circuit the input signal line.
- disconnect any global feedback connection (if used) from the output transformer back to an earlier stage (to avoid strange behaviour if the feedback is not correctly implemented).
- a light-bulb tester is considered a minimum requirement by many on initial power up – see http://www.ozvalveamps.org/mains.htm. See - www.ozvalveamps.org/repairs/electrocaps.htm. Note that this form of testing still has risks, such as from allowing excessive B+ rail voltages on rail decoupling caps and stage coupling caps, if valves have been removed or are not working. This can be exacerbated for choke-input filtered B+ rails, where rail voltage could be very high if the output stage valves are removed.

  {I prefer to use a variac to confirm a low AC current up to rated AC voltage with no rectifier in, and then to add in rectifier(s) and bring up the DC voltage levels in steps, starting from a low level, and checking voltages around all the circuit parts. For example, a cautious approach may include:

  - Remove all valves and rectifier diodes so that all power transformer secondary windings have no significant loading, and that no internal power supply capacitors will charge up. Use a cheap plug-in mains power meter to measure incoming mains voltage and current. Plug the amp in to the variac output, and connect variac input to the mains meter. With initial low variac output setting, confirm each power transformer secondary winding voltage is present. Increase variac setting and confirm mains current remains low (eg. <0.1A) up to normal mains level into the amp. Remove variac, and connect amp direct to mains, and note the primary winding magnetising current.
  - With power off, add in rectifier diodes and lower the variac back down to min. If the rectifier is a valve diode then insert a dummy rectifier valve using ss (solid-state) diodes (very useful for this situation). Check that a relatively low DC voltage is measured at all anode and screen pins (those pins are connected by resistors to the B+ power supply rails, and have supposedly no current through them so there should be negligible voltage drop to any anode or screen pin, depending on the loading impedance of the voltmeter). Disconnect the power and check that the DC voltage gradually subsides – consistent with the typical bleeder resistor that is across B+ (or through balancing resistors across series connected filter caps).
  - Raise the variac level and confirm a complementary rise in DC voltage at all anode and screen terminals. Note that the meter has a high internal resistance and so there will be some voltage drop, eg. across large anode resistance values. Whilst increasing the variac in steps, check for any noticeable voltage drop across power supply dropper resistors. Check that ground referenced circuits such as valve grids and cathodes measure 0V (except for fixed bias grids which should measure a negative voltage). Be careful not to raise the variac to a level that exceeds the voltage rating of any electrolytic or coupling cap, especially of preamp stages which normally run at a much lower DC voltage than the output stage. With B+ up at nominal level, turn off power and check the time for B+ to fall below about 60Vdc – it should be less than 60 seconds (otherwise carefully discharge the B+ supply and connect a bleeder resistance across B+).
  - Raising the voltage slowly and in steps also allows capacitors to reform at a low charge rate, and that can take time. Any vintage e-cap should be checked for leakage current at its working voltage in the circuit – this typically requires inserting a 1kΩ resistor in series with capacitor and clipping a handheld multimeter across the resistor – leakage current should subside to typically below 100uA (100mV) but this can vary with capacitance value, voltage rating, and age.
  - Rising from a low voltage helps electrolytic capacitors form back up if they have been dormant for a few years, and restrains supply voltages from exceeding capacitor voltage limits as there is no loading from valves. Testing operation at close to max capacitor voltage ratings is used to confirm no breakdown or noticeable leakage of parts. A coupling cap typically has one terminal at B+ of

the previous stage (connected through the anode resistor), and the other terminal is at 0V (connected through grid leak resistor), and measurement of some voltage above 0V across the grid leak resistor could indicate a leaky coupling capacitor (eg. see C1, C3, C4, C6 on the example schematic below).

- When the basic wiring and parts seem fine, then signal valves can be inserted. Preferably start with ss diodes, a low variac setting and no output stage valves. Check that dc operating levels on each stage are as expected for low B+, and then raise the variac in steps to confirm the dc levels are ok for the nominal B+ operating voltage. Look for any continuous change in anode DCV that may indicate a gassy valve – for a common input stage, the anode DCV may keep dropping as grid voltage rises above 0V – this can be confirmed by shorting across the grid-leak resistor and seeing if the anode voltage steps up. Then add the output stage valves, add a resistive load to the speaker output, and again bring up the variac in steps, confirming that cathode currents and anode power dissipation are increasing as B+ increases (tweaking fixed bias level if used). Again, check for any continuous increase in cathode current that may be due to a gassy valve. With all signal stages operating at nominal levels using the variac to set nominal B+, then the ss diodes can be swapped out for valve diodes – these diodes won't start conducting till about 40% mains voltage on the variac, and there will be a delay as the valve heaters come up to temperature.
- With the amp operating nominally using a variac, then the variac can be removed and nominal mains directly applied. It's worthwhile taking a set of dc operating voltage measurements for main parts, including output stage idle current levels (to allow valve dissipation levels to be calculated) – to use as a benchmark. Measure the input grid voltage on each output stage valve to confirm negligible grid current conduction – for cathode bias the input grid would be close to 0.0V – for self-bias the voltage drop across the grid leak should be low (eg. < 0.5uA via 220kΩ is < 0.1V).
- When connecting any global feedback circuit, initially insert additional series resistance with the feedback resistor from the output/speaker (insert about 10x the feedback resistance) and test that a low level of amplified output signal reduces the output level when feedback is connected (otherwise the feedback phasing is incorrect). See the Feedback section.
- Swapping out valves with untested old types can be a risk, especially output stage valves and diode valves, and a variac allows bias levels to be initially checked at relatively low power levels. Valve diodes can be tested for reverse voltage arcing by temporarily connecting a LED and 220k series resistor, in parallel with the protection ss diode(s) so that if the valve diode arcs then the LED flashes on (LED cathode to valve diode anode), but arc current is constrained by the 220k resistor – the variac is useful to increase the operating voltage whilst checking for arc indication. Also see valve diode section for maintenance testing of PIV and on-voltage balance.
- If a variac fails, it can apply a high voltage to the amp – never rely on the variac for safe operation.

- Electrical probing: Try and use a long-shank hook-clip type probe such as a 1kV rated Grabber for the positive voltage probe of a voltmeter, to avoid accidentally shorting different circuits (eg. from long metal tipped multimeter probes reaching in to valve base pins past bare wire leads), and to keep your hand well away (short clip probes are a little worrying!).

  A voltmeter or oscilloscope probe can add a significant load to the circuit being measured. Your voltmeter or probe specification should indicate its loading when on a particular DC volts or AC volts range. High impedance points of a circuit, such as valve input and screen grids, and valve anodes that have high B+ supply resistance, and preamp voltage supplies, can be prone to measurement error when the probe is added, and can change amplifier output level.

  One workaround for a grid circuit is to make the grid leak resistor into a voltage divider by temporarily adding say a 10kΩ in between 0V and the grid leak resistor, and then measuring across the added 10kΩ. The divider workaround can be used for measuring anodes and preamp supplies – eg. use a 22MΩ & 22kΩ divider, measuring the 1000:1 signal across the 22kΩ connected to 0V. The bleed resistor across the main B+ rail can be made in to a 100:1 divider to allow safer probing of B+ and also to extend to a maintenance socket for external probing (see later for bias measurements).

  Some meters that measure resistance use a pulse technique, giving strange readings for inductors and transformers – for transformers, the untested windings can be shorted so that the inductance of the measured winding is supressed to its effective leakage inductance for easier resistance measurement. Keep fingers off probes and parts when measuring high resistances, as the reading can be modified.

- Mechanical probing: Old and diy amps can have poor electrical solder joints, poor valve socket pins, poor components, and poor wiring layout. With the amp on, volume up, and connected to a speaker, 'chopsticking' is a useful method to mechanically move or apply pressure to parts and wiring to check for noises that can originate due to a bad part or joint causing small transient shifts in DC levels within the amp. Care is needed to separate microphonic noise from noise due to bad parts or joints. Wiggling preamp valves in their sockets can also identify poor socket contacts.
- Output stage bias measurement: There are a few practical ways to measure an output stage valve's idle voltage and idle current, as the start of calculating the power dissipation and then modifying the bias conditions to some target level. Some people measure just the plate current and relate that to the datasheet plate dissipation limit (eg. and set plate dissipation to a certain %, such as from 60% up to 100%). Some people measure just the cathode current and relate that to the datasheet plate+screen dissipation limit (eg. and set dissipation to a certain %, such as from 60% up to 100%). Randall Aiken gives a detailed description of methods. Commercial bias probes use a few techniques to make it easy.
- During restoration, I highly recommend using the cathode current sensing method. Some amps have an octal socket located on the rear chassis panel for connection to a separate radio or preamp unit. Wiring to the socket terminals is preferably removed, as some pins may be at hazardous B+ voltages. For maintenance purposes once the amp is installed in a cabinet, an Octal socket or smaller 5-pin vintage speaker socket can be used for convenient probing of bias and B+ operating levels within the amp. {For a cathode biased amp, I typically connect 0V, common cathode node, cathode 1, cathode 2, and a 100:1 divided B+ voltage to the socket, as that gives all the information needed to calculate idle dissipation in each output stage valve.}
- Always check that the mains AC plug is disconnected, and the HT DC cap voltages are low, BEFORE doing any physical work on the amp, including soldering or moving parts around.
- The following test instruments are commonly used for valve amp restoration:
- A multimeter (digital or analog) that can at least safely measure to 600VDC and RMS AC, and has at least a 1MΩ input impedance. Better meters allow measurement of mV levels, DC only levels, AC only levels, have about 10MΩ input impedance for voltage measurements, and can measure AC voltage over a wide frequency range. Circuit currents are usually measured by the voltage across a circuit resistance (to avoid breaking a circuit path to insert a current meter). Using more than one meter can help keep an eye on a few circuit voltages during testing without having to move probes around – and there are now quite a few really cheap multimeters with excellent performance {I have 2 Aneng AN8009 for that purpose, and often end up using 3-4 meters when testing}.
- An oscilloscope of some kind. This could be an older analog unit, or new digital unit, or even just a cheap USB soundcard with a diy probe and PC software (eg. REW).
- Although I have analog & digital oscilloscopes, I typically just use a soundcard type interface with a 100:1 probe and REW software as this provides many functions including a waveform generator, a waveform scope, and a spectrum analyser to view the noise floor and distortion harmonics. This setup also provides impedance measurement of passive parts like capacitors, inductors and transformers.
- Caution is required with the probe, due to high DC voltages that pervade a valve amp, and that can easily exceed a scope or probe's input voltage rating. Preferably use a meter to measure DC levels, and use the scope just for AC measurements on a grounded or low DC voltage circuit. Preferably connect the probe before applying power. Preferably use a series high-voltage capacitor (eg. 1-2kV 10nF) connected between the circuit and probe, and only with a scope in DC measurement mode (to maintain a dc path from the probe tip to measurement ground, as a typical scope AC measurement mode inserts an internal capacitor into the circuit).
- A sinewave and squarewave signal source. This can be a commercial or diy or cheap ebay unit, or could be via a USB soundcard with free software, or even a portable audio player with pre-recorded tones. A soundcard generated square wave may have limited bandwidth for some kinds of audio testing.
- An insulation resistance meter (often referred to as a 'megger'). Use for checking leakage current arising when a high DC voltage is applied across an insulation barrier – such as with power and output transformer windings, ss and valve rectifier diodes, and coupling capacitors. Typical test voltages are 100V, 250V, 500V and 1kVdc. This tool can be dangerous to use, and can damage parts if not used

correctly, but can also give confidence that parts are 'doing their job' when it comes to insulation resistance and withstanding the applied test voltage. If coupling or B+ filter capacitors are being tested, then confirm the megger generates DCV, and use a DVM as a discharge path after the test is stopped as the capacitor needs to be carefully discharged.

- A variac, and a piggy-back AC mains meter (for checking AC mains voltage and current and real power). The cheap modern AC power monitors are very convenient for safely checking AC mains current and voltage, and transformer magnetising current, although current measurement may not be very accurate due to the high crest factor of many amplifier power supplies. I connect the AC power monitor to the mains (not to the variac output), so the current level includes the variac magnetising current, and the variac dial voltage then provides the approximate voltage applied to the amp.
- A work bench with code compliant AC mains sockets with protective earth, and with residual current detection circuit breaker protection (ie. earth leakage protection).
- A soldering iron. A low power model, and a high power model for chassis work, can be convenient, or a modern electronic unit with settable tip temperature is good for all sorts of electronic work. Some soldering irons have optional tips that are very fine and pointy for surface-mount parts – that type of tip can be very handy for special jobs. Sometimes having another soldering iron for 'brute force' jobs is convenient, such as when needing two irons to adequately heat up a chassis tab.
- Custom power supplies are sometimes convenient for special tasks. I have a 500Vdc supply with variac control for reforming electrolytic capacitors. I use a vintage valve tester with switched heater voltage levels from 1V to 117Vac to act as a mains frequency voltage supply for testing turns ratios on output transformers, and power for a choke inductance measurement jig. I also use a simple plug-pack with approximate 12Vac output and crocodile clips on the long output lead to make quick turns-ratio tests on transformer windings.
- Fault-finding: If an old amp has only been partly restored, then many faults could still exist, and fault finding could be difficult and frustrating. No sound output, weak or distorted or crackly sound, or strange sounds at different pot settings, can be caused by a wide variety of issues. Luck may allow a quick fix by reading a few forum posts on similar or identical symptoms, but if possible the amp should be thoroughly checked and tested for normal operation and suitably restored parts.
- It can be easy for valve amps to uncontrollably oscillate due to accidental feedback of large voltage signals to preamp circuitry. Output stage anode wiring, and PA speaker wiring, typically have very high signal voltages. As a quirky example, a speaker's coil has been known to capacitively couple signal to the floating speaker basket, and then to a nearby reverb tank coil – oscillation only occurred at high signal levels and gain, and was stopped by grounding the speaker basket.

  What may seem like adequate separation of a few inches can be enough to cause a problem, and may only show at high volume pot settings with treble tone up. With a dummy resistor load, and no input signal, oscillation can be observed as a rapid increase in output AC voltage (if your meter is good at higher frequencies, or with a scope), or a sagging of B+. This is where a software spectrum analyser can be a great help during testing, as oscillation peaks can be noticed emerging out of the noise floor at low signal levels. If layout or wiring route changes are restricted, then try grounded thin-metal shielding. Some power and output transformers are "flat mounted", with windings and terminals exposed underneath the chassis, which can easily cause signals to couple into nearby preamp circuitry.

Expensive vintage amps

Any vintage valve amplifier, whether a hacked PA amp or an expensive and rare Goldentone or imported Gibson or Fender, has the same basic issues relating to restoration for safety and to reduce the risk of failure or collateral damage of internal parts. Imho, at least be aware of the risks, even if no changes are made.

Some owners refrain from doing any restoration actions, due to a fear of devaluation. This is a risk, and forum threads arise when an unrestored amplifier suddenly stops working, and the diagnosis is a failed power or output transformer. Not only is the amplifier then devalued, but also incurs a substantial cost to 'fix'.

Most owners only succumb to allowing electrolytic capacitors being replaced, and output stage valves being biased by a non-invasive bias probe or just installing new 'balanced' output stage valves. This doesn't protect the amp into the future from commonly appreciated risks.

Every amp is somewhat different, and is worth assessing for risks. Some risks can be alleviated by preventative maintenance, and so are always worth the effort. In general, I recommend the following minimum alterations, to help protect the transformers from failing rectifier diode and output stage valves, as the changes are reversible and effectively invisible under the chassis:

- Valve rectifier diodes protected by adding series 1N4007 diodes (see High voltage DC safety, protection and filtering section).
- Fusing the power transformer secondary B+ supply (see this article on fusing). The fuse value may have been determined by others (search google), or a forum can be asked for assistance.
- As the next level of recommended 'protection', the idle power dissipation in each output valve should be periodically checked. If you don't have a valve bias probe to make non-invasive measurements, then a cathode current sense resistor typically needs to be installed (see Output stage issues section).

A further recommended protective action is the reversible addition of over-voltage limiting across the output transformer (see dalmura.com.au/projects/Output%20transformer%20protection.pdf).

Solid state PA amps

Vintage solid state PA amps typically use an output transformer to provide a range of output level connections – with common levels being 50V, 71V and 100V, and a lower voltage that aligns with a standard speaker impedance like 4 or 8 ohm (eg. a 15.5V tap provides 60W into a 4Ω speaker).

Early ss PA amps used only germanium PNP transistors (AWA PA 746), and are still worthy of restoration.

More modern ss PA amps are not as easy to repurpose as valve amps, as the primary side push-pull winding impedance of the output transformer is very low – eg. 2.8Ω PP for a TOA A-1061 60W amp, and 7.2Ω PP for a TOA A-512 120W amp. The output transformer can be 'turned around' such that the output 0-50V-100V secondary winding becomes the primary PP winding with CT. The TOA A-1061 OT then becomes a 60W 240Ω PP with a 4Ω output (or 480Ω PP with an 8Ω output, or even a 960Ω PP with a 16Ω output). Such low levels of primary PP impedance would need line output TV valves, or the OPT used between speaker and a vintage valve PA amp with 'line level' output transformer.

The TOA A-1061 power transformer includes a 9A at 14.2VAC winding, which is acceptable to power the high current heaters of line-output valves such as 6CM5 and 6CD6G (heaters in series). A double-tripler or quadrupler type rectifier-filter could provide sufficient B+ and screen supply, however the design of such an amp would not be trivial, however it would leverage off the chassis and transformers.

Example Circuit

The schematic of an AWA PA774 amplifier is shown below, along with a renovated schematic for comparison (Microsoft Paint drawn alterations). Renovation changes are just examples of what can be done.

The original amp has no mains fuse or switch, and a floating speaker. A microphone preamp stage (V1A) is followed by a mixer stage (V1B), with the MIC and Phono volume controls mixed together. The renovated schematic repurposes the Phono volume pot across the global feedback resistor R9 to provide treble boost, and the Phono tone pot across the MIC volume pot to provide treble cut.

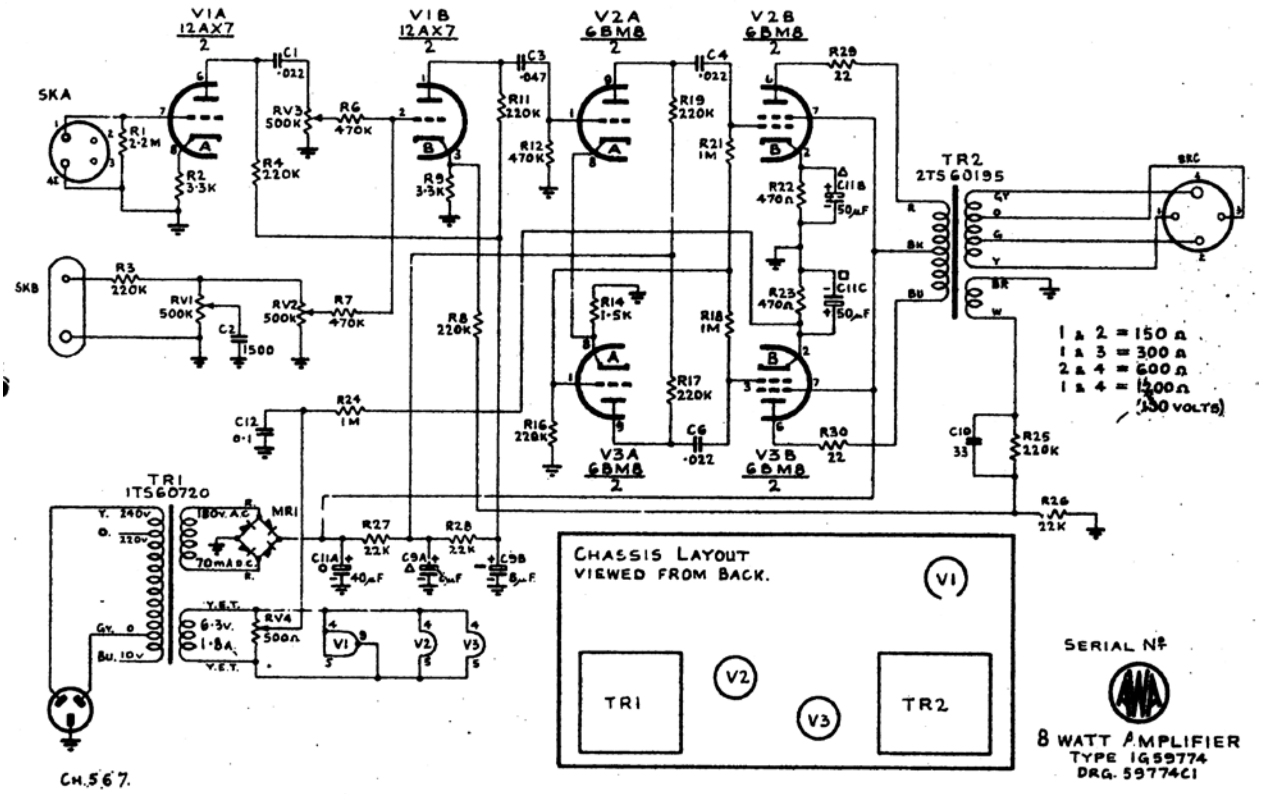
The renovated amp has a typical guitar input circuit (V1A cathode is not bypassed, but could be), with grid stoppers for V1A and V1B. Coupling cap sizes have been reduced. The 6dB feedback circuit is retained but the compensation cap removed, and a 100kΩ trimpot in the floating para-phase splitter for AC balance can be added for minimising output 2nd harmonic distortion. 22mVrms at top of RV3 (with max setting) provides peak 5.2W output.

Screen stoppers have been added to V2B, V3B. The split cathode resistor configuration was replaced by a common resistor with bypass, and separate 10Ω bias sense resistors to each cathode.

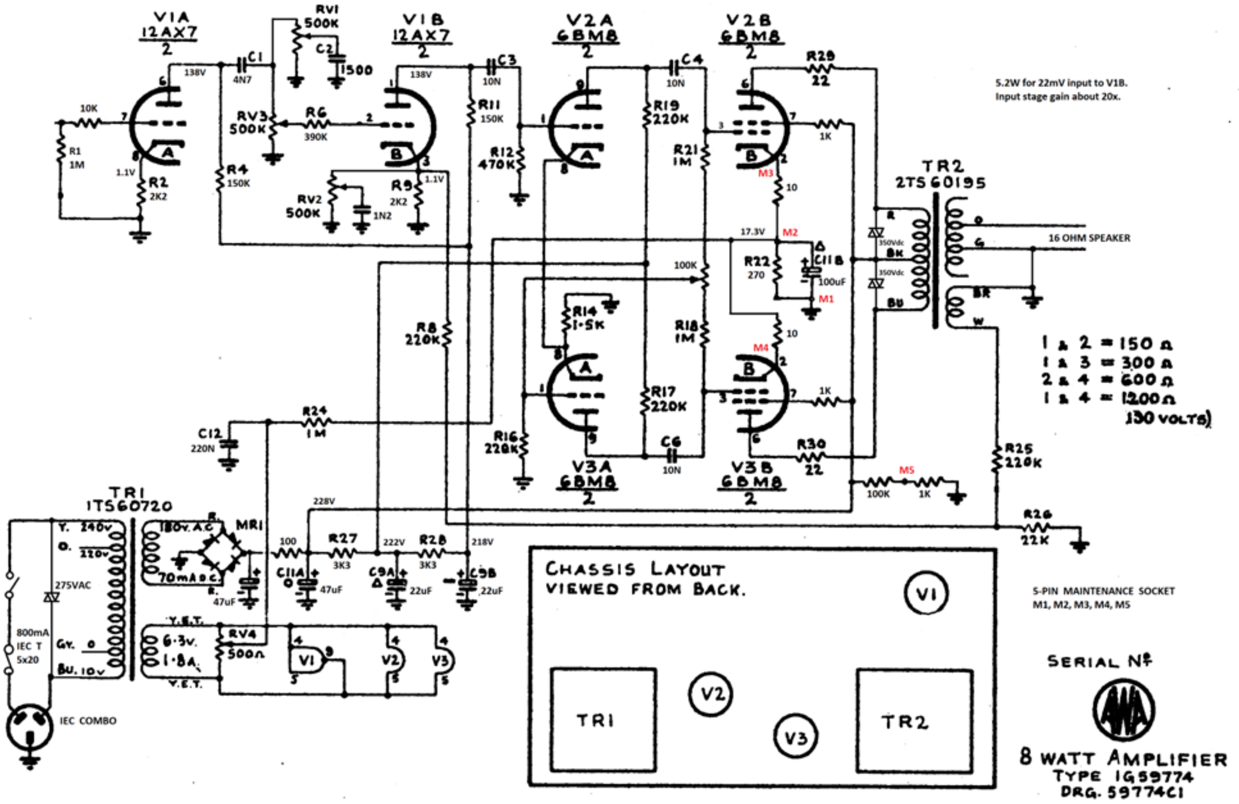
The design speaker loading should be about 25Ω when using the 150Ω-300Ω winding section, but using a 16Ω speaker is fine. A matched but used set of 6BM8 gave 5.2W into 16Ω at onset of soft clipping.

Voltage supply levels for the preamps were kept as high as possible, with lower ripple levels due to higher filter capacitance values being available. Hum and noise were fairly low given the dc elevated heater, a distributed star grounding and rail filtering scheme that used the valve socket spigots, isolated input socket, AC mains wiring localised to rear corner, and removal of unused OT wiring.

Additional protection items added were an IEC combo mains socket-fuse-switch-indicator, a PT primary MOV, OT primary half-winding MOVs, and shorting socket on the OT secondary. A 5-pin socket was added to allow external metering of common cathode bias voltage, each cathode current sense resistor for the output stage, and sensing of the main B+ rail voltage (÷ 100) using a 100k-1k bleed resistor divider.



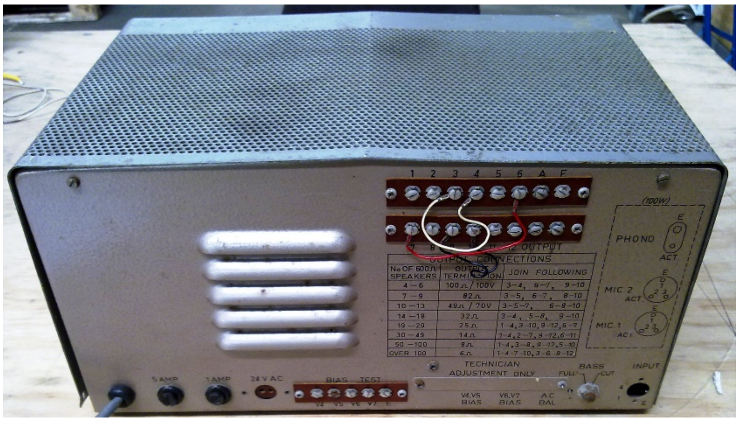
Original



Modified

Rogues Gallery

Circa 1952; unbranded; uncommon mic sockets on front; no mains fuse or switch.



Rear of AWA PA1001; multiple speaker screw terminals; bass cut switch. Inputs on side panel.

Small AWA 8W PA774.

Eminar made instrument amps, PA amps and speakers.

Not the typical connectors one would find on a modern amp!

Steanes/Philips, circa early 1950's. Philips took over Steanes from mid-1950's, and some Philips amps replaced Steanes badge, and cut off the bottom of front label for their rebadged amps.

Steanes PA. Circa mid 1950. Typical Steanes/ Philips rear connections with switched speaker impedances. Just before Philips took over formally.

[Preservation Audio] has a large collection of PA amp images and all things audio – a visit is highly recommended.

The [linked webpage] lists a wide variety of PA, guitar and hi-fi amps (>50) that I have restored, including a detailed document on each restoration.

Typical looking late Philips PA and rear connections. Layout & input labels. 100V line output only.

12W AWA PA1005

AWA 70W PA827 – retrofitted front panel socket and power switch. .

PYE S20A amp with lots of professional PA features.

RTV&H magazine 100W PA amp – DIY kitset – circa early 1960's.

Unbranded 10W PA amp, circa mid 1960's.

1958 RTV&H 35W PA – DIY, most likely from a kit of parts.

VASE made instrument amps & speakers, and a few PA amps – PA100 amp circa 1970.

Australian Sound Systems 100W school PA, 1960's.

AWA 1G8241 12W PA circa 1950

STC used a large upright PA layout, along with Ferguson transformers for a range of amps from 20W to 60W.

Steanes (then Philips) 976B 8W PA – mid 1950's

AWA PA872 20W PA – circa 1964.

Holy grail of PA amps – 300W from Australian Sound & Television system for SECV. Well used!

Older PA with hazardous terminals; hardened and crumbling rubberized wire insulation; & optional DC powering with vibrator. Circa mid 1940's Australian Sound Systems A13.