The output transformer (OT) is expensive to replace, and finding an authentic replacement may be a struggle, so adding extra protection is a wise move when restoring, improving or cloning an amplifier.

Although output transformers are a pretty tough part, there are many stories of amplifiers with a failed or replacement OT, or no OT at all.

Like all parts, adequate cooling is required for the OT. Some amplifiers have a very poor layout of transformers and valves, with parts sandwiched together in close proximity, and with marginal ability for free air movement to allow removal of heat. This situation is compounded in some old amplifiers that were intended for PA use, where output power was often only intermittently needed, or the amp was not often loaded to a maximum level. A restoration can also mean an amplifier used nowadays for guitar or bass could have a much higher continuous output loading than originally intended, and be often cranked in to over-drive.

Amp purchased with no OT.

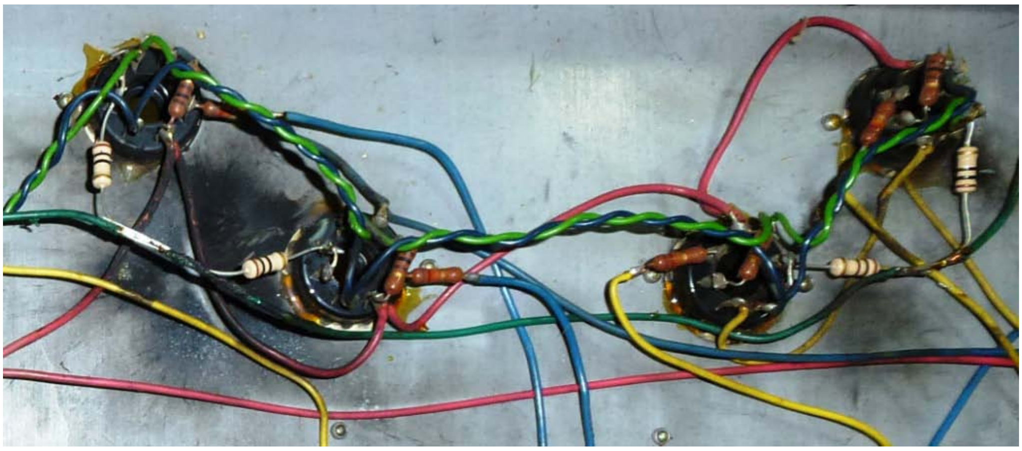
OT sandwiched between output valves and barriers.

Electrical protection of an OT is commonly achieved using over-current and over-voltage protection techniques.

Over-current Protection

Over-current protection of the primary winding as in a single ended (SE) output stage, or primary windings as in push-pull (PP) or ultra-linear (UL) output stages, is often only protected by a power supply fuse on the mains input. Typically, there is a direct connection of the high voltage DC power supply to the OT, either to one end of the OT primary as in a SE stage, or to the primary centre-tap (CT) as in a PP stage.

If at all possible, a power supply fuse on the secondary side of the power transformer should be included as it offers better protection than just a single fuse on the primary side of the power transformer for the many types of fault that can occur in an amp. Valve amp fusing.



Poor man's fusing probably saved the OT in this repaired Fhone amp.

A good example of an over-current inducing fault is the loss of bias voltage in a fixed bias amp which would cause maximum continuous tube current conduction in both half-windings of a PP output stage (loss of bias can be simply from a poor pot wiper or broken pcb trace). A leaky coupling capacitor between driver and output stage can force an output valve grid positive in voltage, and hence also cause a loss of bias to the output valve. Similarly, a failing grid-leak resistor on an output valve, or an output valve going ‘gassy’ can lead to the grid voltage going more positive, and hence a loss of bias voltage, with the current in that valve increasing uncontrollably.

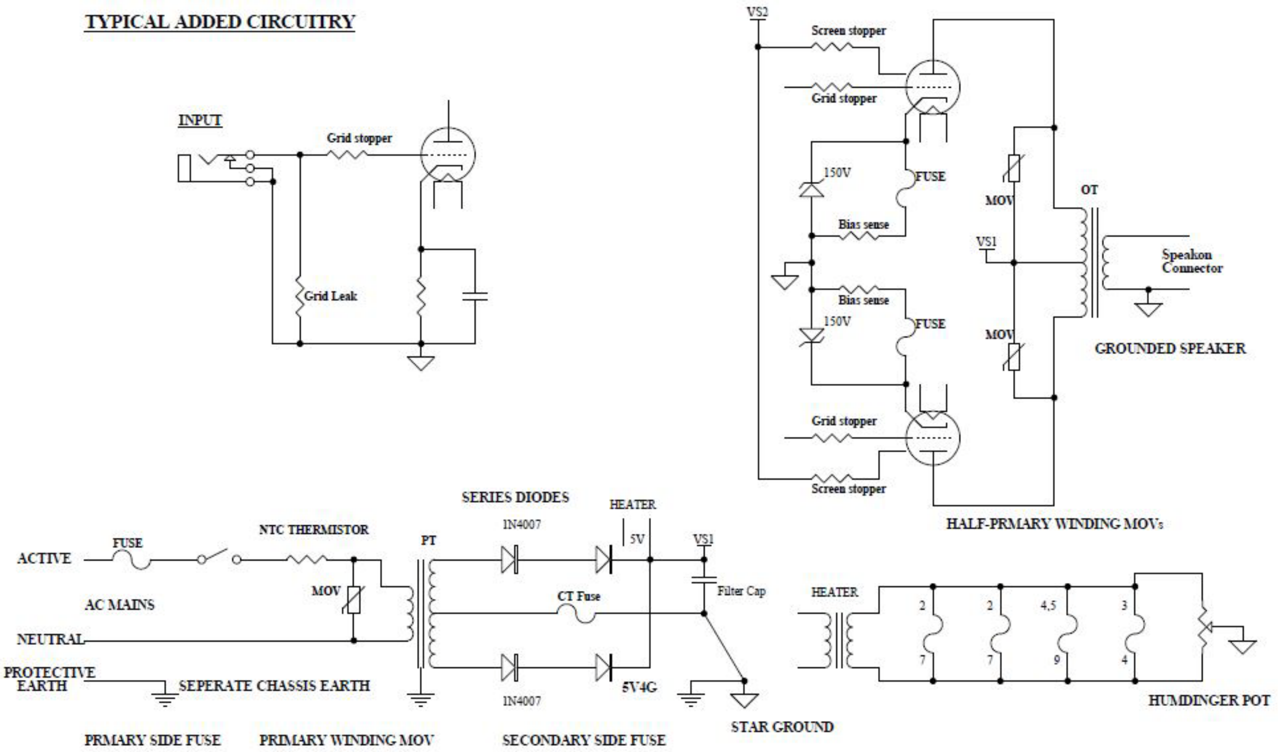
For larger amplifiers, especially those that run parallel valves in the output stage, the addition of a fuse in each valve cathode 'leg' provides much better protection as each cathode fuse rating can be made significantly lower than the secondary side PT power supply fuse rating. Even the low wattage current sense resistor used for idle current bias adjustment for each cathode can be used as a 'poor man’s fuse' – the resistor needs to have a wattage rating just suited to overdrive conditions.

A parallel 150V Zener diode across each cathode ‘fuse’ is preferable. If a cathode fuse fails, and the valve itself is still ok, then the zener diode aims to keep the cathode from rising more than the valve’s cathode-to-heater voltage limit (200V for most valves, although 100V for EL34, and 150V for the KT’s). Initially, high current flows in the cathode circuit and Vak will be low with the fuse still intact. If the bias supply has failed then the grid may be up to 0V and Vgk~0V. When the fuse fails, Vgk will go negative as cathode voltage increases, and Vk will increase to the Zener voltage. If the grid is stuck at 0V, then Vgk ~ -150V and in deep cutoff, so little current flows through the Zener diode, and a normal 1-5W Zener will dissipate little power. If the valve were damaged, and the fuse opened, then the Zener would likewise be damaged (but it is <<$1, so is a fair trade-off).

Fusing of the HT (high tension) DC voltage from the power supply to the OT is not recommended as high DC voltage is prone to tracking across fuse holders and normal 20mm and 3AG fuses don’t have DC voltage ratings, and may well shatter. If such a fuse blew, then it may also generate a high-voltage spike in the OT, depending on the circuit. In addition, if a pentode output stage still has screen voltage applied after the plate voltage has disconnected then the valves will get damaged.

Failure of heater-to-cathode insulation in a cathode biased output tube can force that tube in to full conduction if the heater is grounded (as the bias is forced to 0V), and both tubes in a PP stage with common cathode biasing would also fully conduct. For this fault situation, the current through the OT may not reach damaging levels, but the loading on the power supply transformer may reach damaging levels. If the heater is grounded through a resistor (eg. humdinger), then the fault may not be so severe.

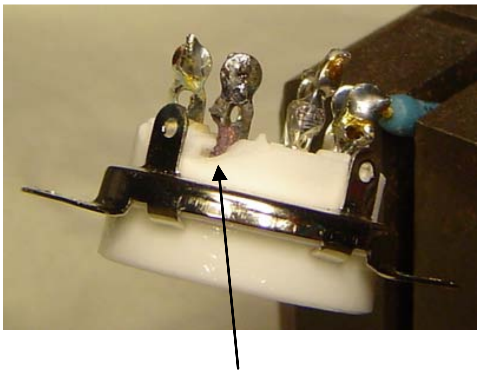
Fault current through the heater can also occur when pin 2 shorts to pin 3 of an output valve (see next section for cause). If the short is sustained (eg. through carbon tracking), and the heater is solidly grounded via a CT connection or direct connection of one side of the heater, then fault current is only limited by the OT and the HT power supply, and protection is from power supply fusing. If the heater is grounded through a fixed resistor humdinger, or humdinger pot, or resistive divider elevated heater – then a pin 2 to pin 3 fault would force the heater voltage to rise towards HT level. Such a fault may then cause heater-cathode failure, and may damage the humdinger or elevated divider resistors and capacitor. A poor-man’s fuse technique can be used for the humdinger fixed resistors or trimpot. For a fixed or pot humdinger configuration, fault current can be fairly high and stress the OT and PT. If the humdinger acts as a poor man’s fuse, then the fault current is stopped, although possibly to the detriment of exceeding the heater-cathode voltage limit.



Cathode biased output stages, and screen 'stopper' resistors can play a major role in reducing fault current levels for some types of over-current fault. Adding screen stoppers in an old amplifier that had none in place is often worthwhile, and can reduce OT over-current stress in UL stages, or triode connected pentode PP stages. Typical parts used for protection in a fixed bias PP stage are shown above.

A valve with a broken base peg can be incorrectly inserted, which could connect the amp's anode circuit to cathode circuit through the valve heater.

Faults can even occur during servicing – note pin in photo.



A meter probe accidently shorted pin 3 of an output valve to a nearby grounded socket holder's earthing tab when the amp was on. The OT half-primary winding inductance ensured the arc continued, even when the probe was quickly removed, and the arc continued for a few seconds eating away at the pin 3 terminal and cracking the ceramic edge, until the only fuse in the amp (PT mains side) blew. The OT survived in this particular case!

Over-voltage protection

Over-voltage protection of an OT is a lot more complex topic. OT's, like power transformers, have windings and winding layers separated by insulation, and each turn of wire is insulated from the next turn by the winding wire's enamel coating. Insulation performance is obviously suitable for normal operating conditions, but can break down if voltage levels become too high. A breakdown of insulation can subsequently cause arcing between turns, or between layers, or between lead-in wires and windings, leading to local heating and either a local short-circuit or an open-circuit within a winding.

OT primary winding over-voltage conditions can arise from:

- instability oscillations.
- abrupt changes in primary winding current causing the inductive winding energy to transfer to the winding's self-capacitance and raise the voltage across the winding.

- being forced by speaker emf applied to the secondary winding.

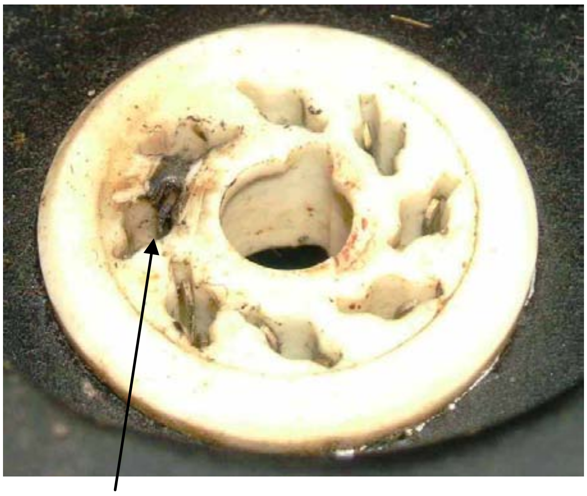
Instability oscillations are mainly due to poorly managed or inadvertent feedback of the amplified signal (either at the OT primary or secondary windings) to an earlier stage. Many guitar amps don't use feedback around the output stage, but poor wiring layout or poor placement of the OT can sometimes cause induced feedback in to sensitive high-impedance points of preamplifier stages. Gross instability could stress the OT, and is likely to be noticed as distortion or noise of some kind. AWV investigated a number of KT66 base flashover failures circa 1950, only to find that constructors had overlaid grid and anode wiring to make a “squegger” oscillator.

Abrupt changes in OT primary winding current can occur for a myriad of reasons, for example:

- when a conducting output valve fails open circuit.
- when an output valve(s) is forced to a short-circuit condition which then blows a fuse.
- when an arc-over occurs on a valve base (eg. between anode and heater pins).
- when a speaker lead is accidently disconnected or a poor quality plug/socket gets twitched.
- when a ‘speaker protector’ such as a fuse blows.
- when a speaker goes open-circuit when over-driven.
- when a speaker is left unconnected and the output stage is over-driven then plate current can reach high levels prior to being driven off fast.
- when cross-over distortion causes one valve in a push-pull stage to be driven in to cut-off, when the other valve is already in cut-off.

If an abrupt change of current in a transformer winding occurs, then the energy in that winding looks for other ways to continue to flow. In a transformer, energy transfers from one winding to another winding when the other winding continues to allow power to flow at the same rate (ie. the other winding is loaded), and there is good coupling between the windings (ie. leakage inductance of each winding is low). If no other windings are loaded, then the inductive energy in the winding transfers to raising the voltage on the windings self-capacitance ($CV^2/2$). Even when other windings are loaded, there will be some energy in the leakage inductance of the winding, which can cause a transient voltage.

Most of the reasons above are related to a one-off fault situation, when just a single overvoltage event occurs. Situations that relate to cross-over-distortion cause repetitive over-voltage transients. Cross-over distortion drives the PP stage valves in to cut-off at the same time, such that the OT primary windings are not loaded. In that situation, the speaker coil’s emf voltage is capable of forcing primary voltage transients.



Arc-over from heater to anode [thanks Ian]

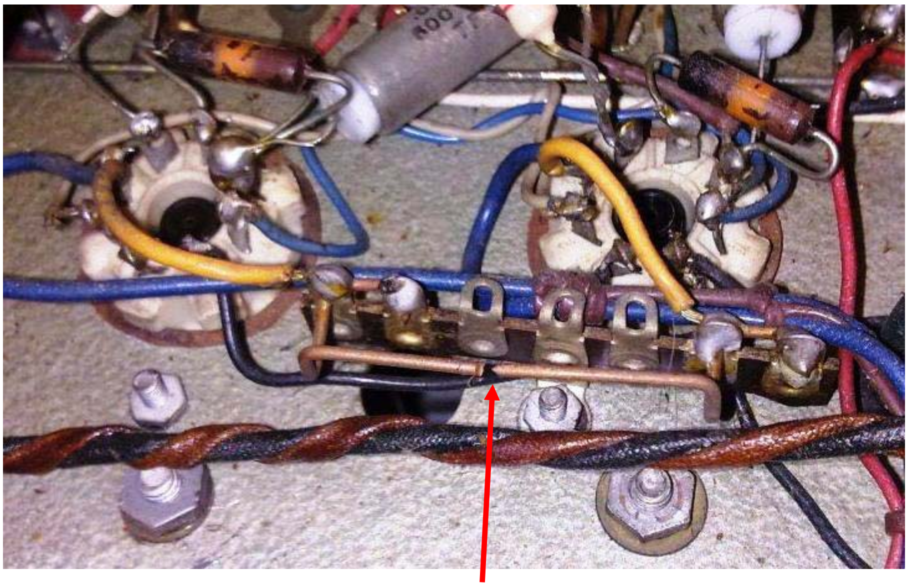
Speaker fusing is not common – with good reason!

For the example of an abruptly disconnected speaker lead, the inductive energy in the OT secondary winding could couple to a primary winding that has a valve conducting, and hence the energy has an escape path that would not likely cause a problem. If the primary winding valves were in cut-off (eg. due to crossover distortion) at the time of the fault then the inductive energy in the faulted winding has no other option than to couple to all OT windings and raise all available stray capacitances within the OT to high voltage spike levels. The inductive energy ($0.5 \times L \times I^2$) is transformed to a voltage rise V across stray capacitances in the OT windings ($0.5 \times C \times V^2$).

A similar example would be when a conducting valve fails abruptly. The current in the primary winding associated with the failed valve forces inductive energy to want to transfer elsewhere. If a speaker is connected then the secondary winding may provide a low-impedance path for the energy to couple to, although the speaker impedance is likely to be high for a single fast transient.

Some circuit designs provide a noticeable loading on OT windings, especially in the context of suppressing high voltage spikes. A resistor-capacitor RC conjunctive filter circuit, or a capacitor, are sometimes applied across an OT primary winding (for PP stages this can be from plate-to-plate, or plate to CT, or plate to ground). These filters were often used to retain stability in amplifiers with feedback, or to shape high-frequency response, but can also provide a significant 'snubbering' effect on any voltage spike level generated across a winding.

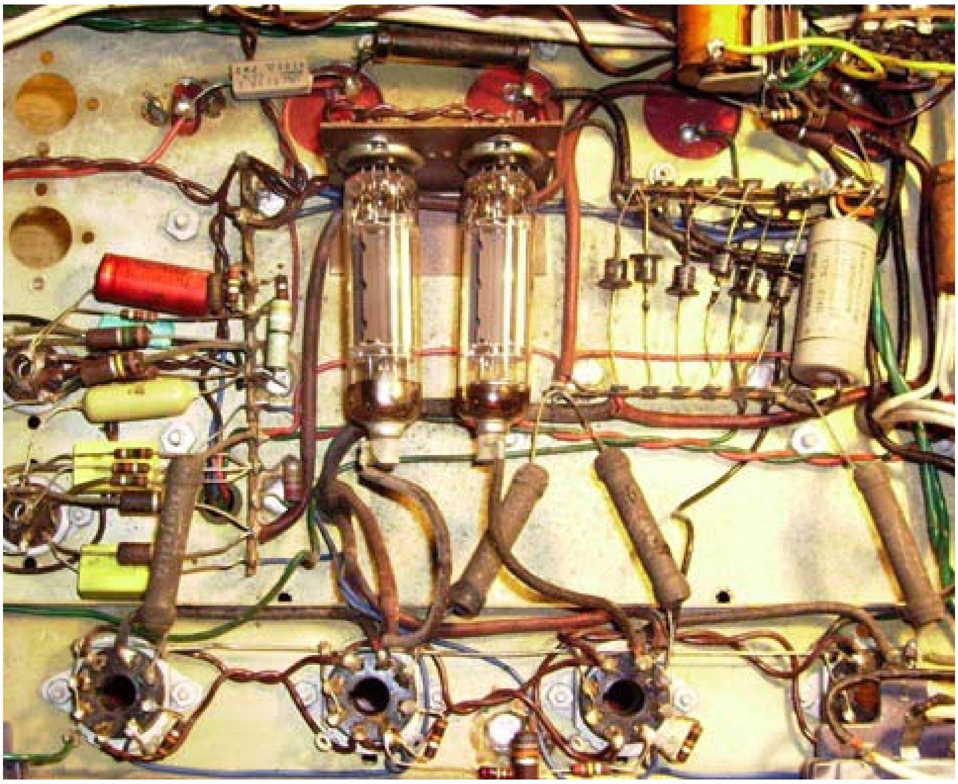
Over-voltage protection was sometimes included in amplifiers, especially Public Address (PA) amplifiers. An example was the 'spark gap' technique, with the gap placed from plate to plate in a PP stage - although crude in form and not very accurate under varying humidity and dust conditions, it probably worked ok and was certainly appropriate for very high powered amplifiers [An approach to audio frequency amplifier design, GEC, 1957]. It may well have saved the OT when a newb foolishly checked if an old amp was still working (video link).



A crude spark gap placed from plate-to-plate.

Gas discharge tubes were widely used in telecommunications for over-voltage suppression, and have been seen in German Dynacord amps connected from plate-to-plate. The gas discharge tube has an arc voltage that varies widely with dV/dt and waveform, and once triggered will significantly clamp the voltage. Thyrectors were used in Traynors.

A more common technique was a 'catch diode' placed from plate to ground, also known as a suppressor, flyback or free-wheeling diode. For older amps this meant using valve diodes, such as the two 6AL3 TV damper diodes placed under the chassis in the Australian Sound and Television 100W A-series PA amp. Solid-state diodes were obviously easier to implement, but often required two or three connected in series to provide a suitable PIV rating and had a reputation for failing. A disadvantage of this technique was that a half-primary winding section was only directly protected for voltage spikes going below 0V relative to CT sitting at B+ voltage level, and the conduction path for the spike current went through the diode and the power supply main filter capacitor back to the CT, which may have been a largish loop.



6AL3 damper valve diode placed from each plate to 0V in a PP amp – and located underneath the chassis!

Another common technique is to place a loading resistor on the OT secondary winding. The value of the loading resistor needs to be high enough so as not to require a large power rating, and not to divert too much power away from the speaker. This is a very simple technique that should provide some suppression of any high voltage spike. Power loss in the loading resistor is inversely proportional to resistance, so an example 820Ω resistor that is 100x a nominal 8Ω speaker impedance would dissipate up to about 1% of the amp's power rating (ie. a 2W resistor should be fine for most amps). If the speaker was disconnected, and a voltage spike across the loading resistor reached say 3x the peak level normally seen, then the loading resistor would transiently dissipate 10% of the amp's power rating. Apart from wasting part of the signal power, and slightly modifying the load impedance seen at the OT secondary, this technique is somewhat soft in nature in that it doesn't force a voltage limit, and choosing a resistance for the loading resistor is a subjective compromise, not an empirical science.

Goldentone made their OT secondary loading resistor into the RYTHYM LIGHT 'feature' on the front panel, which provides about 10% loading, and a touch of non-linear compression due to resistance change.

In recent times, the metal oxide varistor (MOV) has provided another convenient technique for over-voltage clamping. The MOV doesn't conduct current until a voltage threshold is met, and is cheap and available in a wide variety of voltage and energy ratings. However, applying MOV's for over-voltage protection of an OT can get technically detailed.

The MOV clamping characteristic is relatively soft, and the voltage-current tolerance is wide, especially if comparing it to a zener diode or some other kind of solid-state voltage clamp. MOVs are typically used for AC mains protection, but most MOV data sheets provide DC voltage specifications (eg. the Littlefuse LA series at Littelfuse_MOV_LA-34212.pdf). An example 250VAC rated 7mm diameter disk MOV (eg. V250LA4 model) has a continuous DC voltage rating of 330V DC, and a DC voltage operating range from 354V to 473V at a current level of 1mA. Other relevant specifications for that example device are the capacitance of 90pF, the 21 joule rating for a single transient, some characteristic curves of how the clamping voltage increases with current level, and the indefinite repetitive surge current capability. What is missing is the average power dissipation, which is about 0.25W for that size disk.

The wide voltage range for 1mA DC conduction indicates the wide tolerance in voltage that the MOV starts to conduct current and hence present a load (eg. a 354VDC 1mA 'load' is effectively 354kΩ). The capacitance of different devices gets larger as disk diameter increases, but reduces as voltage rating increases. The characteristic curves and max clamping voltage ratings are often for an applied AC voltage, so need to be interpreted with some caution, but do indicate the likely percentage increase in DC clamping voltage as MOV current increases above 1mA.

The indefinite repetitive surge current capability, indicates the current level for a particular pulse width that can be passed without device degradation. The repetition frequency of such a pulse needs to be such that the average power dissipation within the MOV is within rating (7mm disk has a 0.25W typical rating).

MOV's can be placed directly across OT winding sections, such as the primary winding sections from plate to CT in a PP stage, and also across the secondary winding, but need to be designed for the job at hand.

The DC voltage rating at 1mA of a MOV placed across an OT primary winding should be above the maximum B+ power supply level (at high mains voltage and lowest idle current) by at least a good margin, as the MOV should not be loading the OT for the normal situation where the plate pulls its voltage down from B+ to near 0V (and vice-versa where the other plate in a PP stage gets raised to twice the B+ level by transformer action).

Depending on what MOV voltage ratings are available, MOV's can be connected in series to double or triple the DC voltage rating so that it is high enough for the position.

It is difficult to determine the voltage that a transformer winding can withstand before insulation breaks down if the manufacturer specs are unknown. A modern output transformer should be able to withstand at least 1.5 to 2kV, from primary winding to core or other primary half-winding, or to secondary winding. Choosing a MOV, or MOVs, with a 1.5 to 2kV DC clamping voltage for about 1A seems reasonable as that should provide a MOV DC 1mA rating that is well above the B+ level.

For an amp with 500VDC B+, then two or three of the V250LA4 MOVs in series, connected across each OT half-primary winding would be appropriate. Two MOVs would start to load any transient voltage peak rising above 708V to 946V, and if the energy in the transient was sufficient to force the winding voltage to about 2x600= 1200V then the MOVs shunt load the winding with 2x600 =1k2Ω, and pass about 1A. Three MOVs in series are likely to clamp half-winding voltage to below 2kV, so may be the preferred arrangement. If a fault transient was a single pulse of width less than about 8ms, and current up to 1A, then the MOV experiences no degradation. If a repetitive transient was experienced, then it is likely that the max average power level would determine if MOV degradation occurred.

The AC voltage rating of a MOV placed across an OT secondary winding needs to be aligned with the maximum AC signal voltage generated by the amplifier for the speaker impedance used, as the MOV should not be conducting even when max output power is being delivered to the speaker. A 50W max amplifier output in to a 16Ω resistor would generate an AC voltage of 28Vrms, which would indicate a MOV with at least 30-35Vrms 'continuous maximum Vrms' rating should be used. A speaker's impedance varies with frequency and so a 50Vrms MOV would be a better choice of a lower limit MOV rating (the LA range only goes down to 130Vrms, but Varsi have a range down to 11Vrms – www.varsi.si).

Ultra-linear PP stage (RTV&H 1960 100W PA amp). Original RC network from plate to screen. 1Ω cathode sense resistors added. Series MOV-R circuit added to each primary half. No screen stoppers added.

As an example of the energy level in joules that may need to be clamped during a one-time fault event, the primary inductance of hi-fi OTs can provide an upper practical limit of about 100H (P-P). The value of 100H is normally based on an applied excitation sinewave voltage of about 5-10Vrms, so the inductance is likely to be substantially greater for a fault occurring when a high signal level excitation is present. However, if the fault scenario caused an over-current condition in the winding prior to the fault, then the winding inductance may have reduced dramatically due to saturation.

An amplifier's operating current in a primary half-winding may peak at many hundreds of mA, especially for larger power amps. A fault event such as an open-circuit between valve anode pin and socket terminal could cause such a current level step. If a MOV bypass was used for protection, then the operating current level at the time of the fault would continue to flow through the protection MOVs if no other path was available.

For a PP stage with 100H P-P inductance, and a current of 0.4A at the time of the fault, the energy in an OT primary half-winding is (100H/4) x 0.4A x 0.4A / 2 = 2 Joule. A single V250LA4 7mm diameter MOV has a 21 Joule rating, so any practical deployment of MOV's should cope well with that event.

The largest practical winding current could flow if the anode shorted to a heater winding with a grounded CT, in which case the current would be limited by circuit resistances including the OT half-winding resistance, and the effective PT source resistance, and any valve rectifier resistance, and any fault current fusing. That current may exist for some time until a power supply fuse blows. The winding current could be in the 1-10A range, and the inductance of a PP OT is likely to be quite low, so it is difficult to clarify if the winding energy would be substantially greater than for the previous 2 Joule scenario.

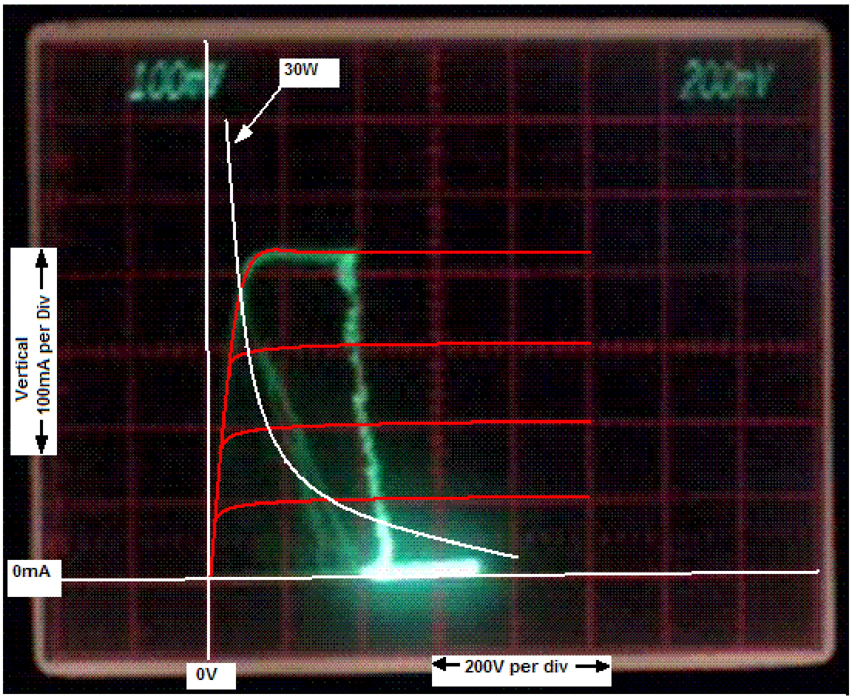
If more than one over-voltage protection technique is used, or MOVs are used on more than one winding, or MOVs are connected in series, then the energy being clamped would spread itself out to multiple protection parts, and hence each part would experience a lower level of power and energy dissipation than if only one part was trying to constrain all of the transient's energy.

The MOV capacitance could be a significant high frequency part for some amp designs, especially for larger MOVs fitted to OT primary windings in hi-fi amps. Where this is of concern, a resistor can be placed in series with the MOV to form a conjunctive R-C filter. The series resistor could be at most a value similar to the winding impedance (eg. 25% of an OT primary impedance when used with a MOV placed from plate to CT), but is preferably a lower value so as not to cause a large increase in clamping voltage at the likely peak fault current that could flow. For example, a 5kΩ PP OT could use a 1.2kΩ series resistor in series with a MOV across each half-winding, but this resistance value would drop 600V if transient MOV current reached 0.5A, in which case the example V250LA4 MOV clamping voltage would be 700-1,000V, so a lower series resistance of at most 470Ω would seem more appropriate. Note that for this example MOV and a 1.2kΩ series resistor, the conjunctive filter corner frequency is over one megahertz.

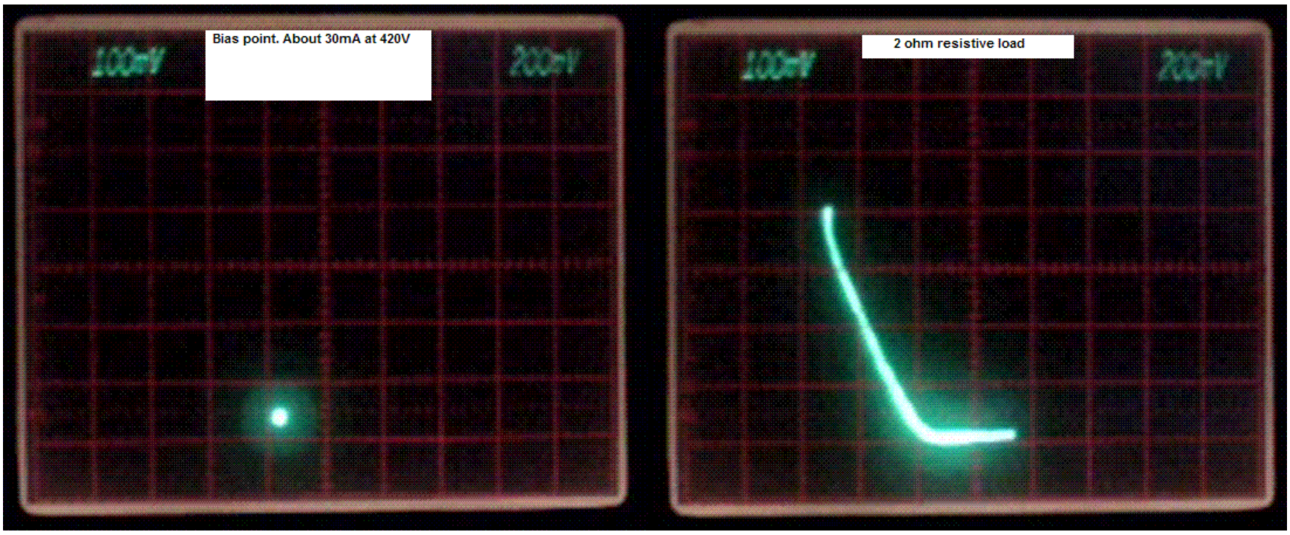
Measurements

In the real world, the plate voltages in a PP stage do not lay themselves simply on a resistive loadline, but fly off to levels below 0V, and levels significantly in excess of twice B+, due to OT winding inductance, speaker load reactance and emf, and unloaded plate conditions when both valves are in cut-off.

Oscilloscope measurements shown below on a Fender 5F6A re-issue using 6L6 tubes (thanks to Loudthud on Music Electronics forum for permission to use his measurements and further discussions on them) clearly indicate the voltage levels experienced at the anode in a fixed-bias PP circuit. The first oscilloscope plot shows a trace for 6L6 plate voltage and cathode current for a sedate guitar input signal (display of the voltage trace is helped by the persistence of the oscilloscope screen). The plot shows superimposed 6L6 datasheet anode current versus grid voltage curves, along with a 30W plate dissipation curve.

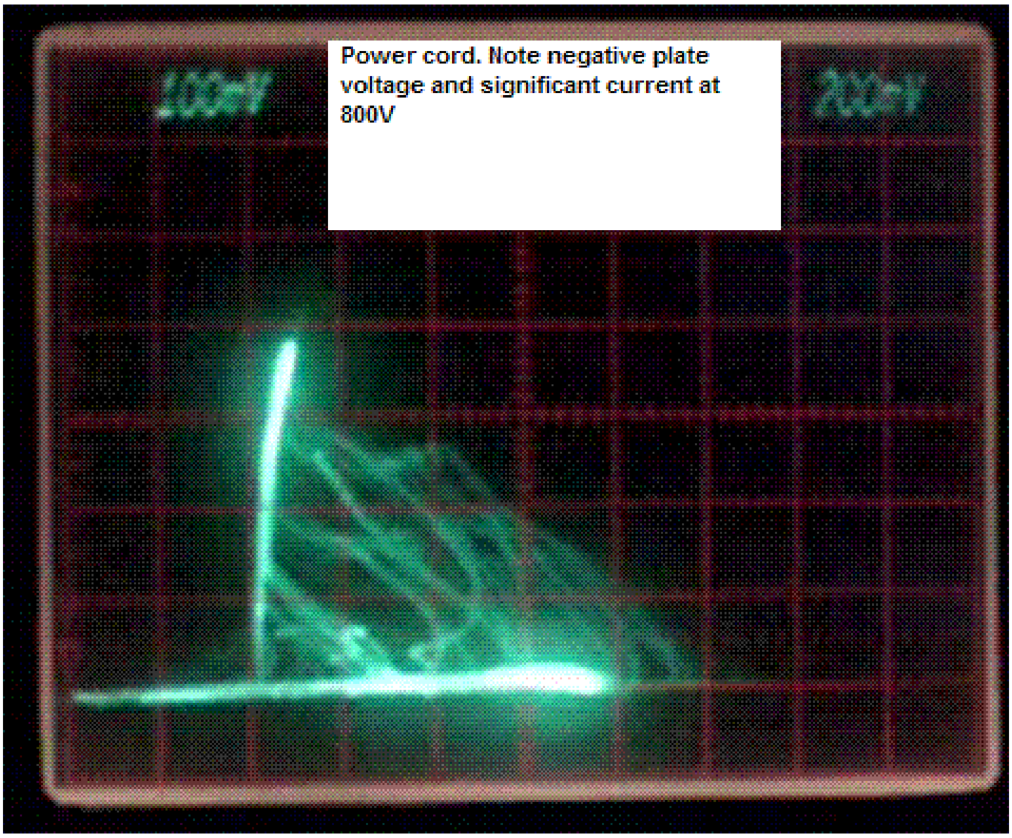


For a reference, the next plot below shows the 6L6 idle operating point at about 420V and 30mA. The 5F6A amp has a choke-fed screen voltage close to the idle anode voltage. The third plot shows the load line being followed when a sinewave signal is applied to a resistive load – the operating point moves away from the idle point, to a lowest anode voltage of about 80V and highest cathode current of about 400mA when being driven in to conduction by the signal, and to a highest anode voltage of about 720V at near zero cathode current when being driven in to cut-off. In this plot the anode voltage moves symmetrically below and above the B+ level (which would sag from 420V to about 400V) and indicates no sign of voltage stress on the OT winding. The peak anode current (and hence OT primary current) would be somewhat less than the measured 400mA cathode current, as the screen current contribution is seen to increase the trace's gradient noticeably as grid conduction conditions are approached.



The 6L6 experiences more dramatic voltage excursions as shown below when a speaker load is used with a more aggressive guitar playing style, but still a long way from extreme over-drive conditions. The plot shows plate voltage extending down to at least -800V, and up to +1100V, which is about -1200V and +700V relative to B+ on the CT of the output transformer.

The 5F6A is likely to be experiencing blocking distortion under high signal level, which causes crossover distortion that would force both valves in to cut-off at the same time for a portion of time.



If used, RC conjunctive filters would influence the actual plate voltages experienced, and MOVs would start to influence plate voltages whenever the MOV voltage reached its clamping level.

Testing for a failed OT

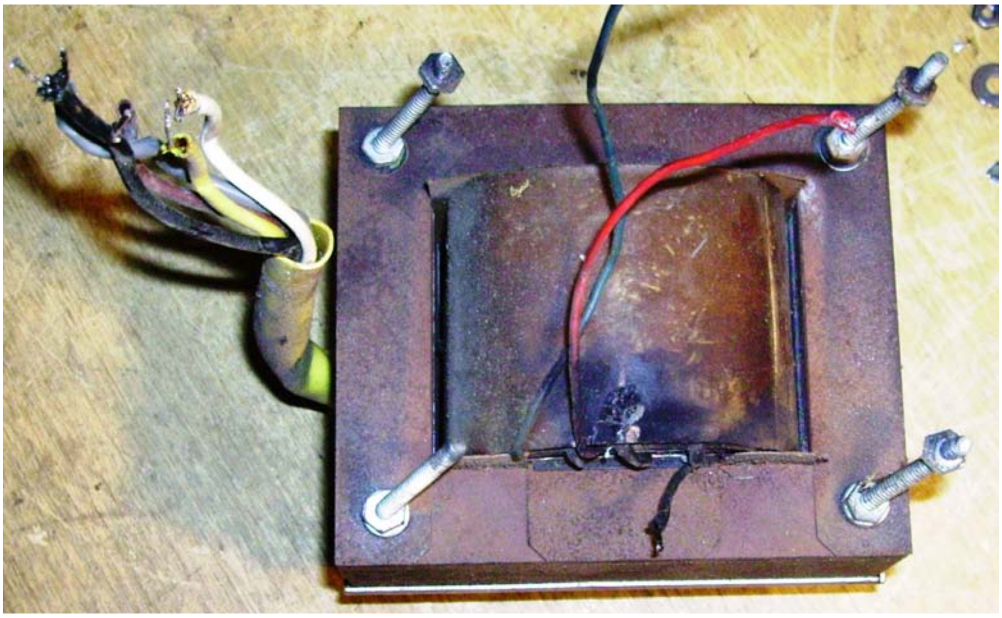
The best first check to do on a suspect OT is to measure the OT's primary and secondary winding resistances using an ohmmeter (resistance range on a multimeter). The primary winding(s) resistance should easily show up on a meter as tens or hundreds of ohm, depending on the power rating of the OT, and is easily measured when the amplifier is off (pulling the output tube or tubes should disconnect all circuitry from an OT's plate terminal, but reference to a circuit schematic is worthwhile). The half-primary windings on a PP OT (CT to each plate terminal) should have similar resistance, but are unlikely to be exactly the same (especially for lower quality PA OT's). The OT secondary windings are likely to measure very low in resistance (disconnect the speaker first), and it may be difficult to determine a winding's resistance as it can look like a short circuit. Connecting the meter probes together can give a zero or close to zero reading, and then measuring the winding resistance may show a slightly higher reading. A high or over-range resistance would likely indicate an open-circuited winding fault.

If there is no obvious winding resistance concern, then the next step is more complicated, and would involve applying say 5VAC to 12VAC (eg. from a power transformer secondary) to the primary winding (or PP half winding), and then measuring the AC voltage on the secondary windings (and on the other half-primary winding). Knowledge of the OT winding impedances can be used to determine the turns ratio's between the primary and secondary windings, and hence the turns ratio and the applied signal voltage can indicate the level of secondary voltage that should be measured. Output transformer MS Excel calculation spreadsheet

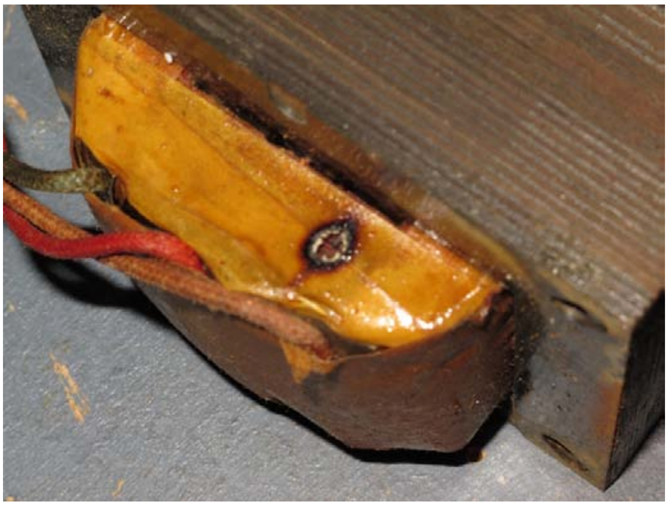
If a reasonable voltage level is not measured across a winding or windings, then there may be an internal short type fault between some turns within one of the windings (ie. an internal short circuit between two adjacent turns within a winding will exhibit a normal winding resistance, but would cause the transformer to lose its voltage transfer ratios between windings on the same core).

Note that symptoms of no 'speaker output' may not be due to the OT even though everything else appears initially to be ok, as highlighted by the discussion in gretschpages.com/forum/ by mrock. And some OT faults may appear to be unfixable, but end up being quite easy to fix as the fault is not internal to windings.

If an OT has failed, then other related parts need to be checked for stress or failure – especially output stage valves, and screen stopper resistors.



A dropped amplifier caused this OT to bend its mounting bolts and short a primary plate wire to chassis – no internal wiring damage, so it's back in the amp and working now.



Arcing from half-primary winding layer edge turns to the other half-winding plate link wire had luckily caused an obvious area of damage that resulted in an open-circuit. The OT was repaired by replacing the link wire, and carefully insulating it (not shown). [Hoffman Amplifiers Forum]

Power transformer and choke-input filtering

On the subject of inductance-related transients, the power transformer windings can generate a transient voltage when winding currents are switched, and similarly for the choke in a choke-input power supply. These transients can stress insulation of the windings themselves, and parts connected to the windings, such as the primary side AC switch, and secondary side fuses, standby switches and diodes.

When the amplifier power switch is turned off, the PT winding currents are stopped abruptly, which could exacerbate arcing on the mains switch contact, leading to increased pitting of the switch contact. This is not such an issue if the PT winding currents are low – such as when the amp is in standby or idling, and if the switch off occurs at the time in the mains cycle where current is not passing through a rectifier diode. A MOV with a suitable voltage rating on the primary side winding, and even MOV's on the secondary side windings could be used to reduce over-voltage transients generated on those windings.

Some amps use a standby switch that opens the PT secondary CT connection to 0V, which could interrupt a large current level through one of the secondary HT windings, especially if the standby switch is toggled a few times and the main filter caps are being charged up under full idle load conditions. The leakage inductance in that winding can stress the standby switch, as well as the diodes, and a MOV across each secondary HT winding would be appropriate.

Adding a silicon diode (one or more 1N4007 in series depending on the HT level) in series with each anode of a diode valve (as shown earlier) can avoid shorting out the power transformer HT secondary winding if the valve diode starts to conduct continuously, or arcs between anode and cathode (eg. gassy tube). Such a fault could go unnoticed, unless it is observed as an increase in hum, or a higher B+ level, when B+ AC and DC voltage is next checked, in which case it should be fixed as soon as possible. A simple indicator of the valve diode working correctly in this situation would be a LED-resistor across each valve diode.

Often a power supply choke has a sizeable filter capacitor on each end of the choke, as in a CLC type filter, where the capacitors dampen any possibility of a transient voltage across the choke due to a fault that abruptly stops choke current. However, if just a choke input filter is used after the rectifier diodes, then a fault could generate a high voltage at the diode-choke node as there is little stray node capacitance to dampen the voltage. GEC recommended an RC snubber across the choke [An approach to audio frequency amplifier design, GEC, 1957]. Some designs add a small capacitance to ground at that node for noise filtering, where for a 10H choke dumping 0.2J (from 200mA current step) into a 10NF capacitor, the voltage on that cap could change by 6kV as $½LI^2$ transfers to $½CV^2$. Some designs add an RC zobel network across the choke to improve the filtering response of the choke (resonant frequency of parallel choke L and zobel C set at ripple frequency so that impedance of "choke" to ripple is higher), and that network can certainly alleviate transient voltages. If a MOV (or zobel network) is added in parallel to the choke then its DC voltage rating needs to accommodate the turn-on condition where one end of the choke is at $+VAC_{pk}$ and the other end is still at 0V, and similarly where one end of the choke is at $-VAC_{pk}$, and other end is at peak B+ (ie. $+VAC_{pk}$), which is more onerous. So a DC voltage rating of at least 2 VAC_{pk} is needed for parts across the choke. Parts from the diode-choke node to ground need a DC voltage rating of at least VAC_{pk}. Those situations are likely to require a series connection of MOVs, and any capacitor is likely to be a physically large metalized plastic type. The resistor in the zobel network is mainly to dampen the resonant Q of the LC, along with choke ESR.

Covering a MOV or in-rush limiting thermistor with a sleeve of heatshrink tubing is a good idea so as to constrain the part if it becomes damaged.