Fender Tweed Deluxe (5E3)

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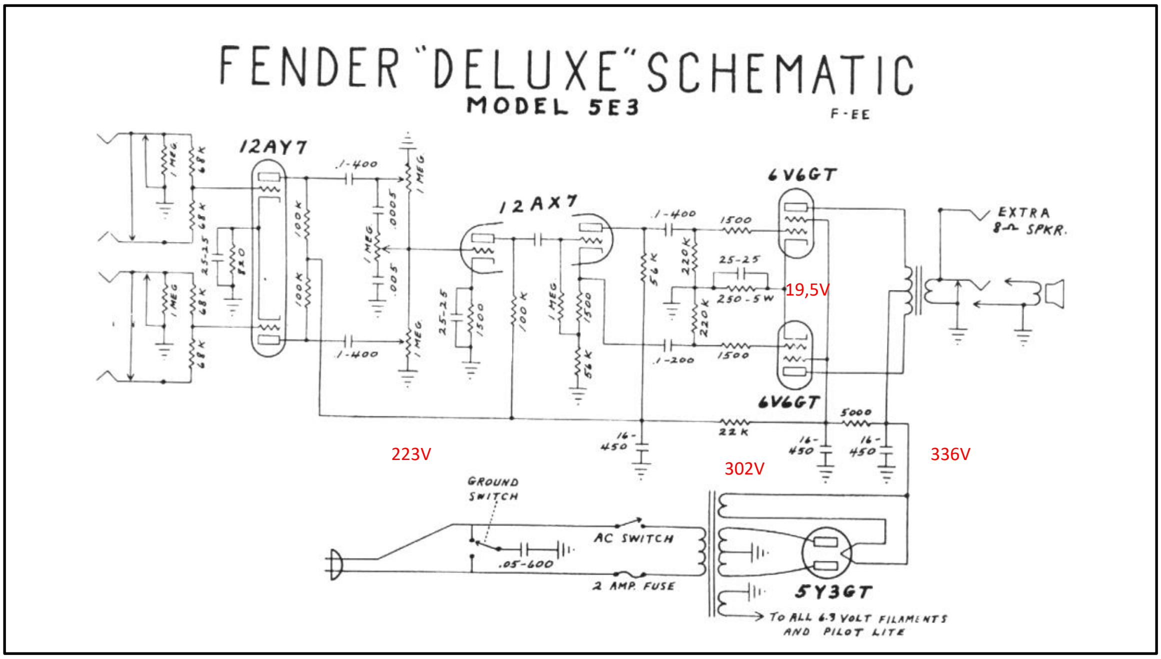
Hichtum, 06-05-2023



Here is the Fender (Tweed) Deluxe 5E3 schematic. The original fender Deluxe model 5E3 was in production between 1955 and 1960.

Voltages are measured on my amplifier using the ClassicTone # 40-18078 power transformer and # 40-18022 output transformer. Sadly, those transformers are no longer made as ClassicTone has closed shop.

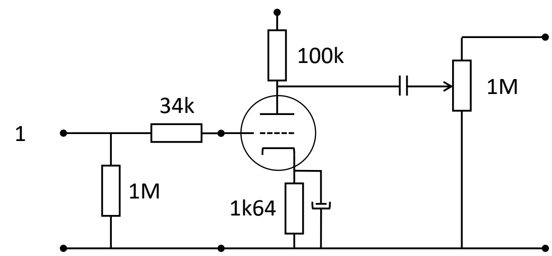
The power transformer has a "lower" high-voltage winding of 330 – 0 – 330 Volt. This results in relatively low voltages throughout the amplifier which is something I prefer. Most exact replica's of power transformers from the 1950s and 60s result in voltages that are way over spec and an amplifier that runs very hot. Sound quality is debatable but, I like the way my lower voltage amp sounds.

What is special about the 5E3 Tweed Deluxe:

- No overall feedback.
- Tube rectified using a relatively high impedance direct heated rectifier tube (5Y3GT).
- Relatively low power supply filter capacity.
- Cathode bias push-pull output stage using 6V6GT output tubes.

- Cathodyne phase inverter (also known as 'split load' or 'concertina inverter', see: https://www.valvewizard.co.uk/cathodyne.html).
- Unusual volume control setup (wiper connected to preamp tube anode => volume control varies preamp tube load!).
- All controls (2x volume and 1x tone) are interactive with each other.
- 12" speaker built into a resonant pine cabinet with semi floating baffle. The baffle is connected to the cabinet with 2 screws on top and bottom side (4 screws in total).
- Output power between 12 and 15 Watt.

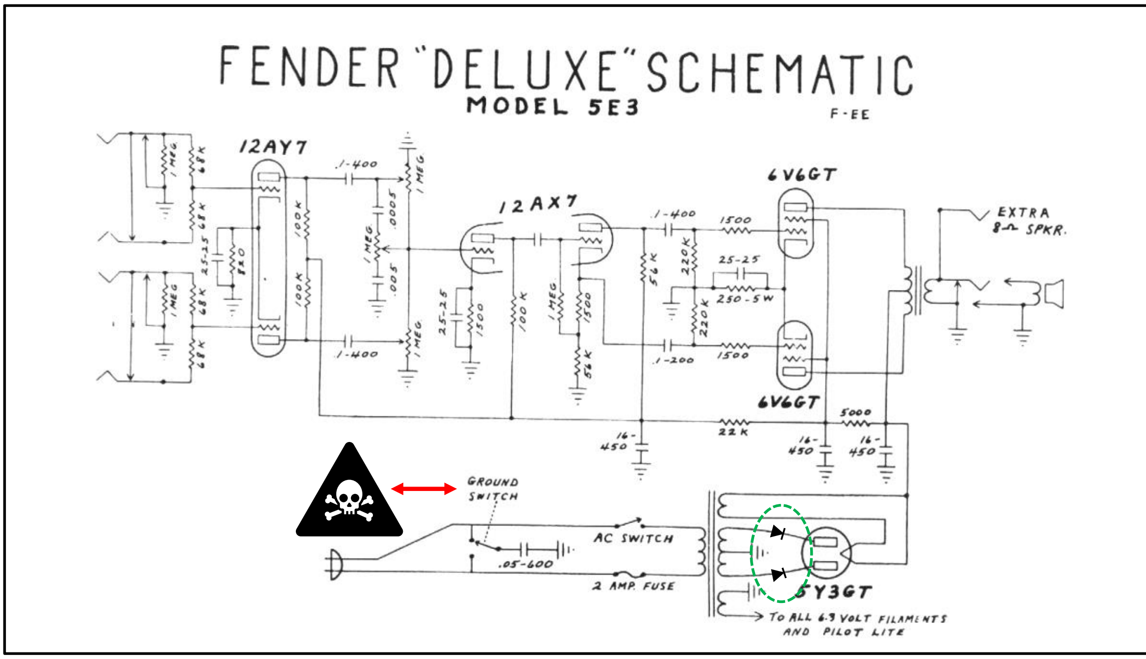
Simplified 12AY7 input stage:



Note: the volume control is actually a varying load control. This means that changing the volume setting will change the load that the 12AY7 (no European equivalent) tube sees. Once the other and the tone control are factored in, everything gets interactive. Changing one knob will affect the other channel's volume setting and the tonal balance. This sounds unpractical. In reality the sweet spot is easily found.

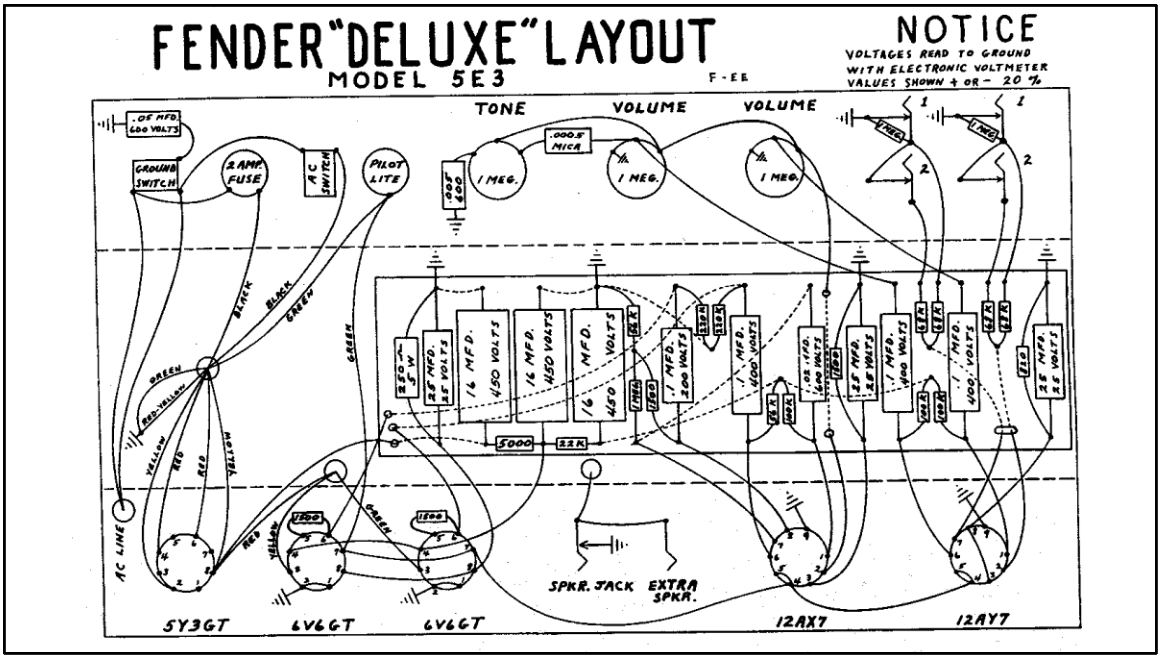
The way the preamp is wired results in a unique amplifier behaviour. The volume responds very much like an on-off control. The way I work with this:

- Plug into the bright channel. This is the channel with the tone control.
- Set the amp for tone. This will probably result in too much volume.
- Adjust volume on the guitar to suit the playing situation. This will result in a sweet tone and allows you to turn op the volume on the guitar for solos or a more distorted/compressed sound.
- If tone is too bright, plug into the "normal" channel.
- I only use the "hi" inputs. The "low" impedance inputs attenuate and load the guitar and sound less lively to me.



The modifications I did on the original schematic:

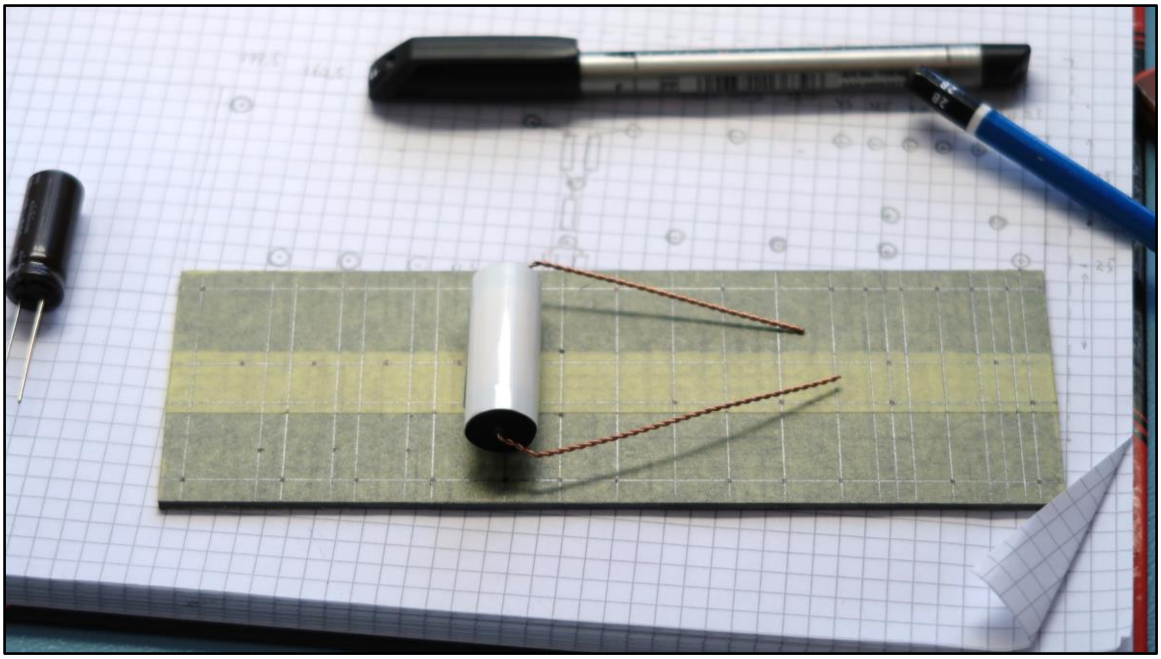
- Add a silicon diode in series with each leg of the rectifier tube. I don't think it has a sonic downside. The upside is that a shorted rectifier tube does not short out the complete power supply. It may save the power transformer in case of rectifier tube failure. Mod is depicted in the green dotted circle on the schematic.
- Do not ever connect a ground switch! This is potentially very dangerous. **A ground switch as depicted in the original Fender schematic should never be used.** Failure of the ground capacitor may connect main phase to chassis (and guitarist) which can be deadly.
- Use a 3-wire power chord and connect the earth (green/yellow wire) to amplifier chassis.
- No need for a stand by switch. There are no direct coupled stages that may fail during warmup. The 5Y3GT rectifier tube works almost instantaneously but the tubes handle the plate voltage with cold cathodes without any problems.



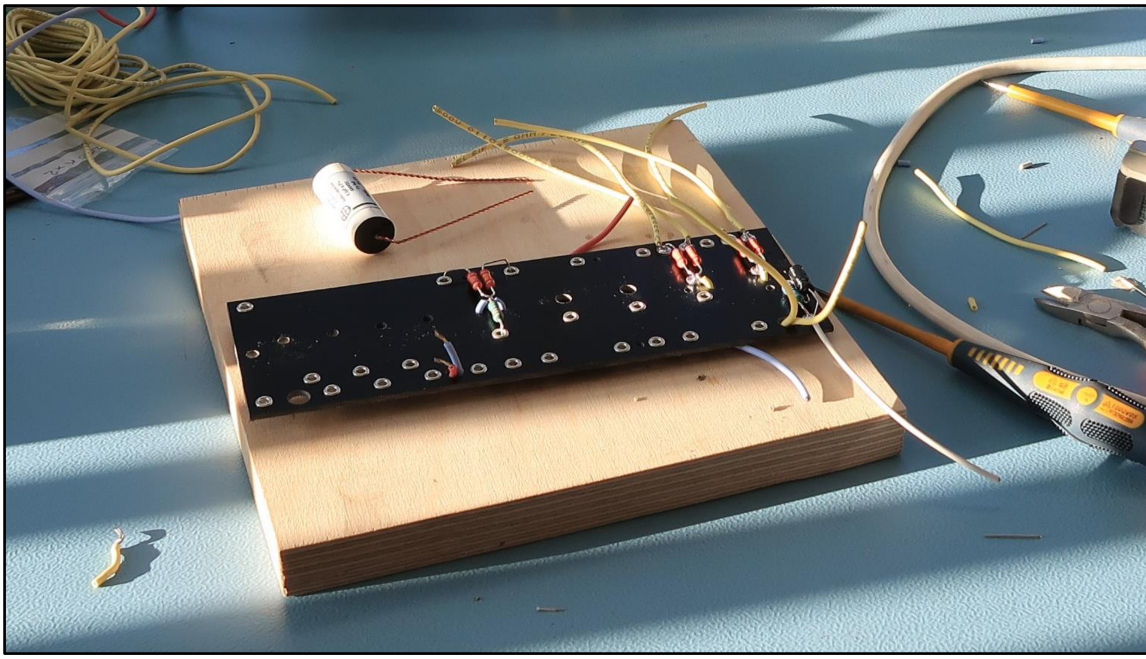
The original Fender layout for the 5E3 amplifier. It works but it has a lot of signal currents running through the metal chassis.

My modifications to the Fender layout:

- No AC and no DC currents through the amplifier chassis. All currents run through wires.
- Keep signal and current loops as small as possible.
- Mains earth is connected to chassis.
- One single audio earth connection to chassis.
- Use radial electrolytic caps throughout the amplifier. Radial caps are more common.
- Use metal film or wire wound resistors in any place that carries DC currents.
- No use of carbon composition resistors. They can produce weird random noises and drift in value within years of use. I simply do not like them.
- Use glass fibre component boards and not the original phenolic board material.



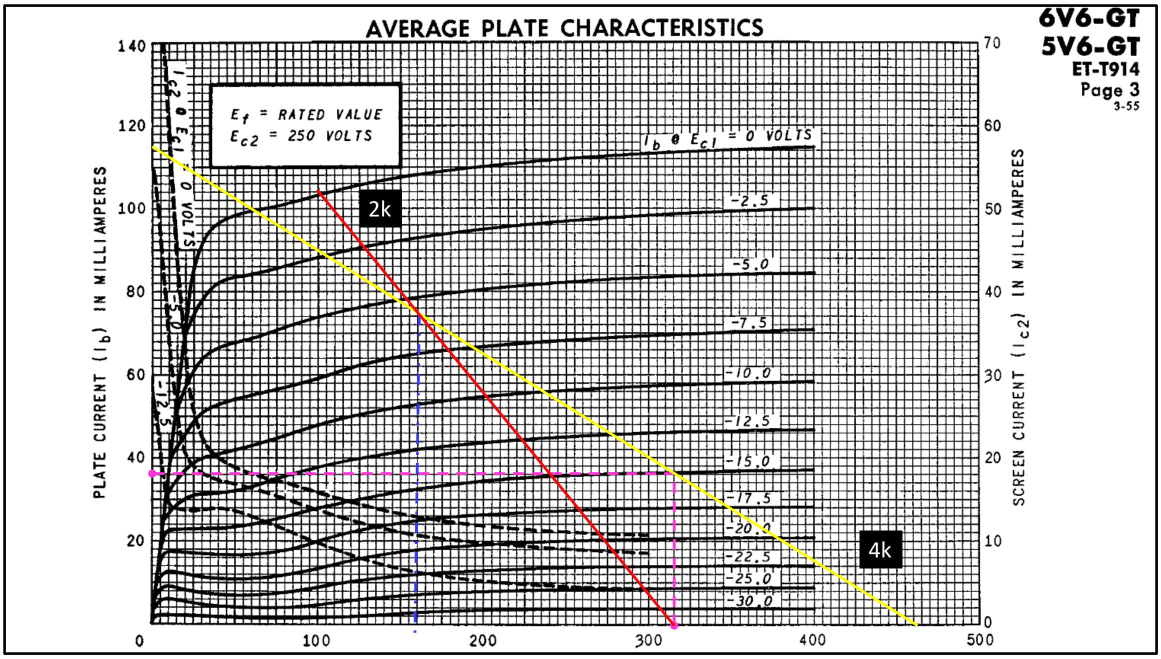
I like working out the amplifier layout by hand.



Work in progress…

The result of my build.

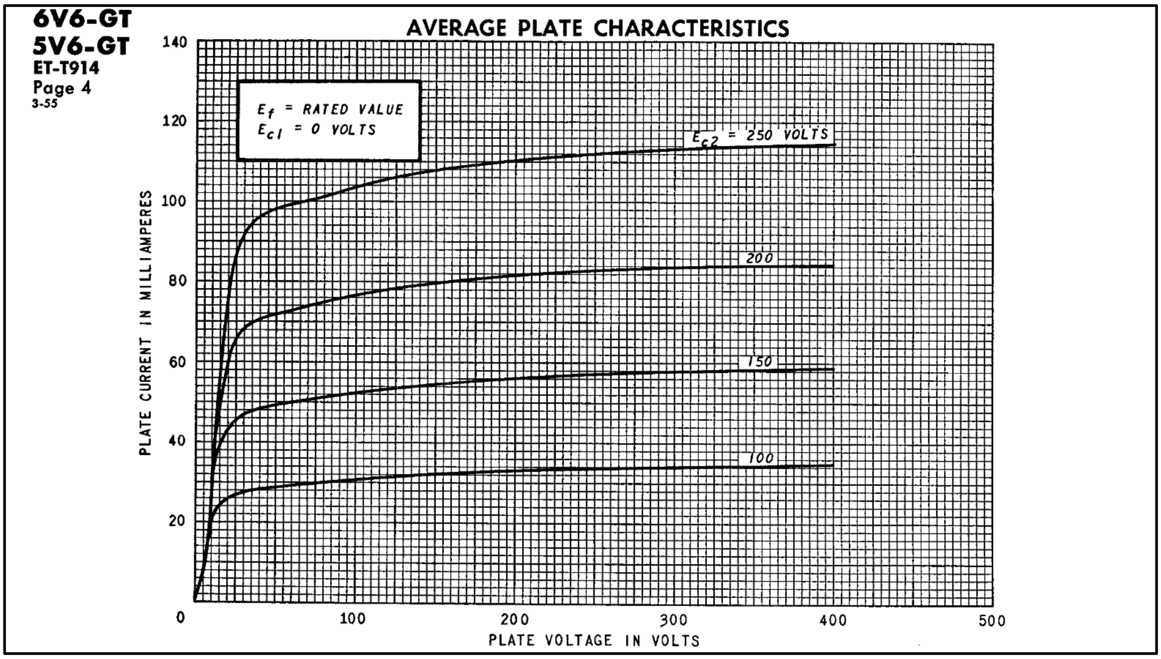
Note there is a switch next to the speaker outputs which remains unused. The output transformer has a single 8 Ohm output winding. No impedance switch required here. The switch could be usefull when performing experiments with other output transformers.



Output tube setting and load lines.

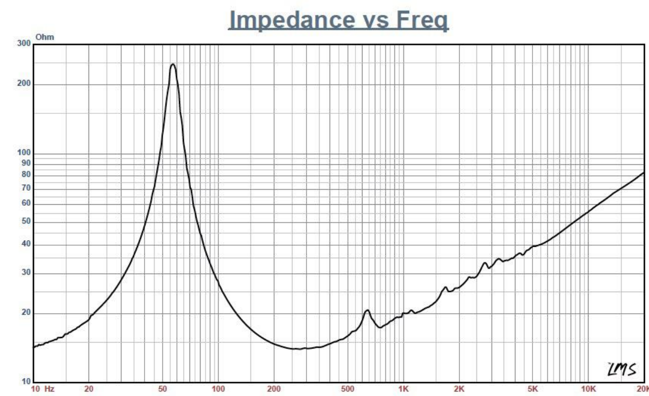
Note: This is a 6V6GT beam tetrode curve diagram at Ec2 = 250V (screen grid voltage). My amp runs the screen closer to 300 Volt. Increasing the screen grid voltage will raise the position of the Ec1 = 0V line. In fact, raising the screen grid voltage will more ore less “inflate” the Ec1 (V grid 1) curves. This is why my amplifier runs at a cathode voltage of 19,5 Volts given the same current and plate voltage as indicated in the diagram above. Increasing the screen voltage from 250V to 300V will push the G1 grid curves up (more cathode current given the same G1 and Anode voltages).

The effect of screen grid voltage on tube characteristics can be seen on the next slide.



The effect of screen grid voltage on the Vgk (Ec1) = 0 Volt line.

Speaker impedance

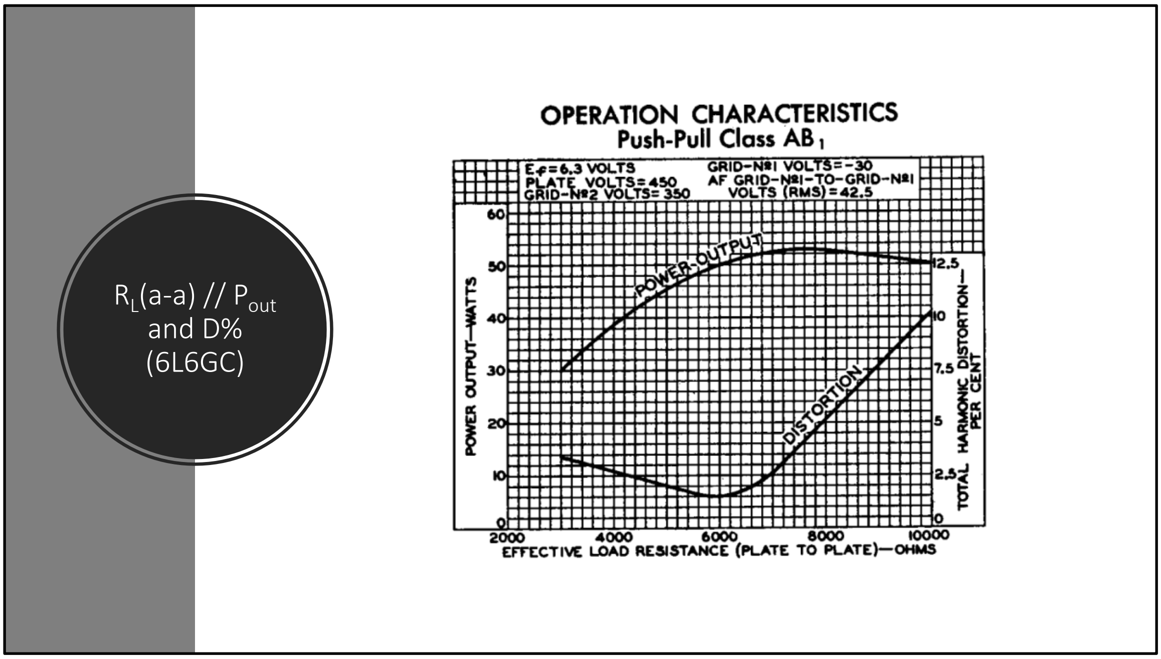


This part is in response to a question regarding the connection of a loudspeaker impedance to a guitar amplifier that is different from the impedance as indicated on the back of the amplifier.

So: what happens when you connect a 4 Ohm load to the 8 Ohm connection of your amplifier. Or what about a 16 Ohm load on the 8 Ohm connection?

Well, the reality is that most, if not all, guitar speakers already have an impedance that shows significant variance over the frequency range.

Above is the frequency / impedance diagram of a 16 Ohm Celestion Greenback speaker. Note the impedance varies between 8 and 250 Ohms.

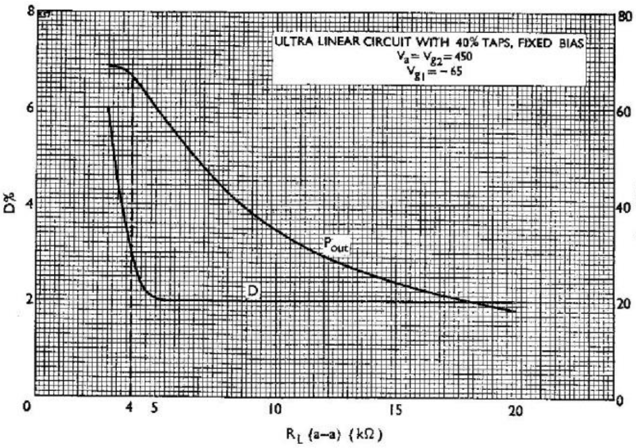


The output transformer will couple the loudspeaker load to the output tube anodes using a fixed impedance-ratio. A variation in speaker load will therefore result in a variation of the anode load that the output tubes “see”.

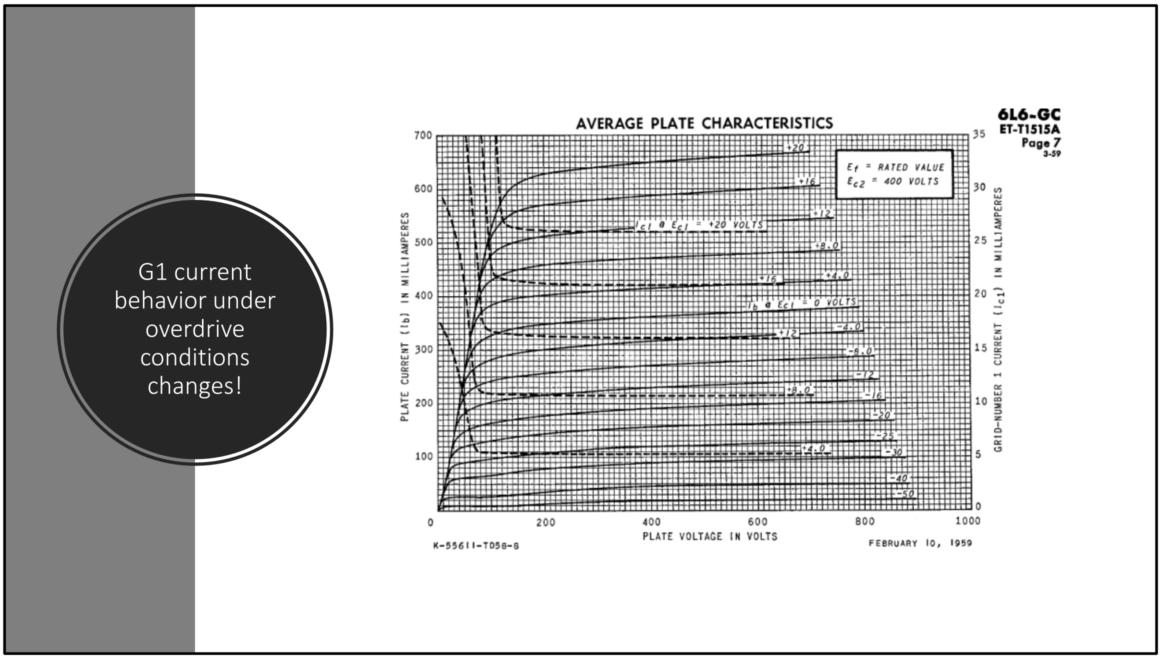
Changing the output tube anode load will change the amount of output power and distortion behaviour of the output stage. This is indicated in the figure above.

The result is that the output power and distortion of a guitar amplifier will change when the connected load is changed. Even an 8 Ohm speaker connected to the 8 Ohm output of an amplifier will result in different power levels over the frequency range because of the varying impedance of the speaker.

R_L(a-a) // P_{out} and D% (KT88)



Another example of changing output power and distortion as a function of anode load. This time for the KT88 tube. This can all be found in the tube spec sheets.



Changing speaker load will change the anode load curve. Look at the yellow and red load lines of slide 9. Lowering the connected load will result in a steeper load curve. This means that the load curve will hit the Vgk=0 Volt line (Ec1 = 0 Volt line in the diagram) at a different point in the diagram.

Does this matter? Yes!

Why?

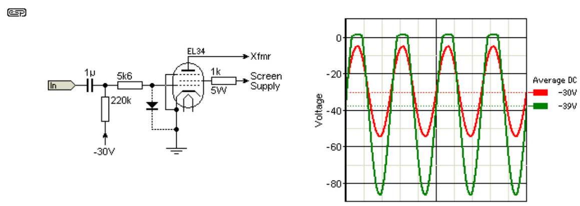
Tube amplifier output stages are commonly overdriven. Grid 1 current behaviour under overdrive (grid 1 tries to go above 0V) changes significantly. If the load line intersects with the Vgk=0 Volt line above the knee in the tetrode (or pentode) characteristics, grid 1 current will peak. If the load line intersects with the Vgk = 0 Volt line above the knee (on the right side of the knee), a lot less grid current will be drawn.

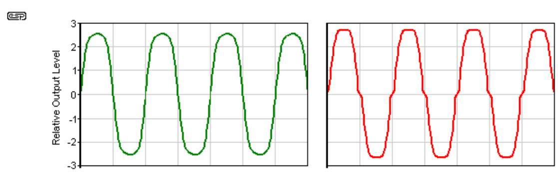
The amount of G1 current as a function of anode voltage is shown in the figure above. Note the steep increase in G1 current on the left side of the knee in the characteristics.

Grid 1 current will charge the coupling capacitor between the phase inverter and the output tube. This can, and will, result in output tube bias shift. Under significant overdrive, the output will be biased more negative because G1 is starting to draw electrons (negative charge) from the cathode. Depending on grid stopper and grid leak resistor values, the end result will be some form of cross-over distortion. The sonic impact of this effect will depend on amplifier topology and component values.

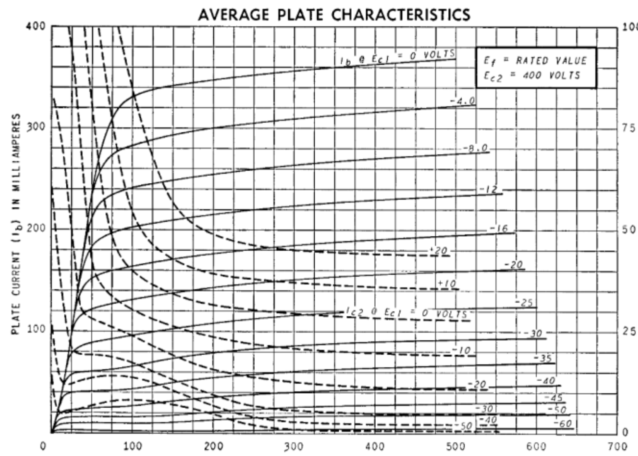
In general it can be concluded that overdrive behaviour will change when a different load is connected to the output of the amplifier.

G1 current => blocking (cross over) distortion (bron: https://sound-au.com/valves/analysis.html)



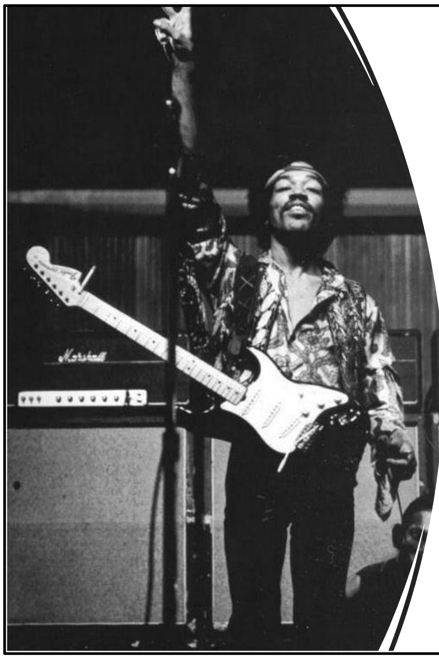


G2 current behavior under overdrive conditions changes (6L6GC)



Changing speaker load will also change G2 current under overdrive conditions. The mechanism is similar to the G1 current explanation although G2 current does not result in cross-over distortion.

The effect may be audible. It will definitely change the amount of power that is dissipated by G2 (screen grid). Increasing the anode load will result in a flatter load line. A flatter load line will intersect with the Vgk=0 Volt line at a point that is more toward, or even below, the knee in the characteristics. This will increase G2 current and therefore G2 power dissipation. G2 is relatively fragile. Lowering amplifier load will therefore result in more G2 wear of even tube failure under prolonged severe overdrive conditions.



Conclusion

- Changing speaker load will change:
  - Power output.
  - Distortion and compression behaviour.
  - G1 and G2 current at full output.
- Up to 100% mismatch is deemed OK!
- At low output a lot will be OK.
- Be careful with historic amps.

So, the conclusion:

- Speaker load is not constant. It changes a lot over the frequency range. The amplifier can handle this.
- Connecting a different load than indicated on the amplifier output will change amplifier behaviour.
- The amplification factor will change. Amplifier distortion and the amount of output power will also change.
- There is probably no harm done as long as the output stage is not overdriven.
- When overdriving the amp, it is probably better to connect a lower impedance speaker than the indication on the amplifier output (4 Ohm speaker connected to 8 Ohm output).
- Try to avoid it on very vintage amps. The story goes that winding insulation may breakdown under high voltage peaks when connecting a higher load than specified at the amplifier output.
- Always connect a load to your amplifier!!! Some amplifiers become unstable when no load is connected. Output transformers and output tube can and will fail if the amp is operated without a load.
- Personal experience (totally not representative): I have seen people operate modern 100W Marshall tube amps at full output without a load connected. In this

case the speaker connection had been tampered with resulting in no (infinite) load. The guitar player kept switching the amp on an off standby and kept playing his guitar with the amp volume all the way up. I could here the output transformer singing (magnetostriction). The amp lived, it is now one of my own and it works perfectly.

- Don’t sweat is too much. Amps can handle a lot of abuse and sometimes they fail out of nowhere. If anyone has more real world experience on the matter I am very interested in hearing it. Thanks!