Negative Feedback Amplifier with embedded Positive Feedback Booster

Apparatus for amplification using low gain vacuum tubes

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Why used low gain tubes?

- Traditionally OTL amplifiers are using high gain frontend tubes such as pentode or high gain triode tube or with cascading several median gain tubes usually triodes.
- The overall slew rate will be low, and construction of high power amplifier will be restricted.
- The gain of low gain tube can be boosted to same level as high gain tube but with some advantages.

Low gain tubes increased slew rate

- Higher slew rate can be achieved using low gain since there are fewer cascading stages and components that will lower the slew rate.
- A pairs of 6SN7 tubes with 2 gain stage can achieve only about 100 (10*10).
- With negative feedback of 10 times, it reduced the overall gain to 10, which is clearly not sufficiently for normal listening.
- Thus the overall gain needs to be increased to the same level as traditional amplifier to be useful.

Introducing the concept of Positive Feedback 1/2

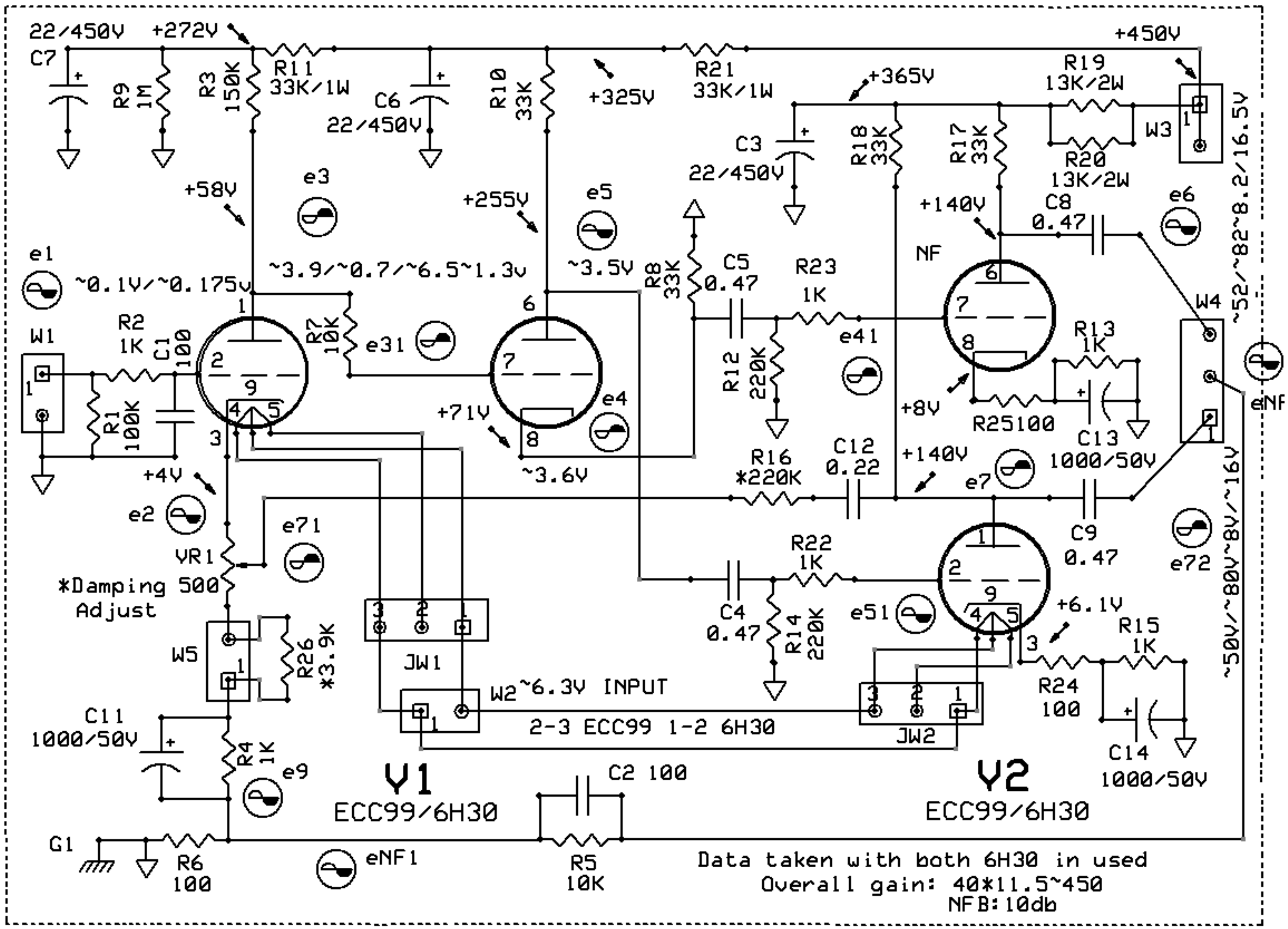

Fig.1 OTL amp driver using low gain tubes with boosted gain

Introducing the concept of Positive Feedback 2/2

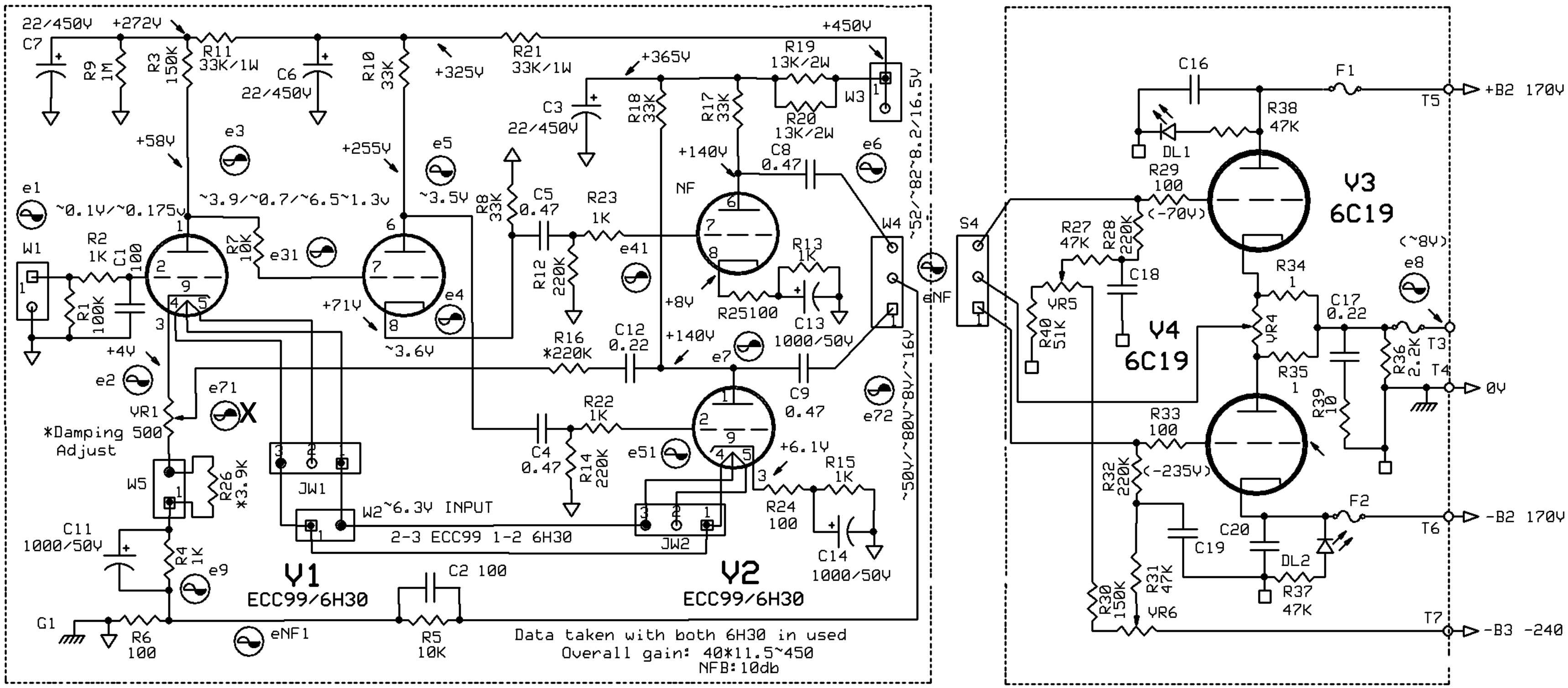

Fig.2 OTL amp using low gain tubes with boosted gain

Positive feedback boosted the low gain of V1 to level of high gain tube used in classic OTL but with some advantages. If the circuit marked X is removed, it is not much different from traditional OTL amplifier with only global negative feedback. For more theory you can read the article, this amp can fit in the mechanism descript here:

Ref: POSITIVE FEEDBACK GAIN-ENHANCEMENT TECHNIQUES FOR AMPLIFIER DESIGN

Note : 5687 as V1 and 6SN7 as V2 are also used, the measurement is not much different but sounds much better to me.

Working Details A

- A small portion of anti-phase signal e71 is derived from e7, this tap is chosen so that the driver output signal is least affected
- This signal e71 is subtracted from e2, input at cathode V1, resulted e9 < e2, e9 = e2 - e71, thus effectively increased the gain of stage.
- The higher the overall gain the better will be the Damping Factor, DF

Working Details B

- VR1 is adjusted to obtain desired gain, thus Damping Factor.
- As the load is applied to output, this caused the in-phase negative feedback signal eNF1 to decrease, the result is that stage gain will be increased as load increased.
- In addition, the action further increased stage gain as e71 is increased as descript before.
- During positive phase, the upper driver tube has lesser gain, so eNF1 will be greater hence the stage gain is greater.

Working Details C

- During negative phase, eNF1 is lesser as the bottom driver tube has greater gain, when the load is small. The stage gain is automatically adjusted using the amount of eNF1 and e71 derived.

Practical Circuit 1/2

- 6H30 or ECC99 has a gain of 15/20 respectively. As operated in class A mode in driver circuit it can achieve 70% gain 12/16.
- With positive feedback in circuit, the front end 6H30 has a gain of 40 and ECC99 gain of 55 whereas the driver has a gain of 11 and 16 respectively.
- The overall gain is thus greater than 450, a reduction of gain of 10 by negative feedback is possible.

Practical Circuit 2/2

- The damping does not solely depended on the negative feedback loop, but it level is boosted to a great extent by positive feedback loop, even to extent of negative resistance if over adjusted.
- The output is automatically balanced as there are sufficient gain derived from dual positive and negative actions to drive to the full output when the traditional amplifier circuit would had exhausted any further gains.
- The frontend stage maintained the stage gain of about 40 throughout various output and load.
- The result is less distortion at higher output.

Data Measured

- The input at frontend stage is ~0.1V, and output is ~0.7V when the load is 2K, output is ~8V.
- The stage gain is therefore 0.7/0.1=7
- When the load is increased to 8 Ohms, the stage output increased to ~3.9V, output is ~8V. The stage gain has increased to 3.9/0.1=39
- When the input is increased to ~0.175V, the stage output is ~1.3V, stage gain = 1.3/0.175=7.5, output is ~16V, load is 2K

Data Measured - Frontend Stage

- When the load 8 Ohms is applied, output is ~16V, stage output increased to ~6.5V, stage gain = 6.5/0.175=37.
- These data show that the stage gain is depended on the load applied to output. The higher the load the greater is stage gain.

Data Measured - Driver Stage

- For the driver stage, when load is 2K, output is ~8V, stage output is ~8-8.2V, stage gain =8/0.6 = 13
- When the load is 8 Ohms, output is ~8V, the driver output is ~50-52V, driver input is ~3.5/3.6, stage gain = 50/3.5 = 14
- When the load is 8 Ohms, output is ~16V, the driver output is ~80-82V, input is ~6.2-6.4, stage gain is 80/6.2 =13.
- These data show the driver stage gain is almost constant.

Conclusions – from feasible points of views

- As gain is derived from Positive Feedback the components values are kept low so Slew rate will be higher than negative feedback amplifier
- Damping factor and distortion will be much better than traditional negative feedback amplifier as the required gain to for operation especially at heavy load is not exhausted.
- Negative feedback is fixed at the level by listening without compromising the sound quality or property too much as damping can be adjusted separately with ease to desired level.

Pros and Cons / Safety Concern

- If the negative feedback loop fails, this OTL driver will oscillate, causing high drive output at driver output and also the speaker output
- Remember many things can happen to traditional amp once the NFB fails
- One the other hand, the oscillation will be of low frequent and less the 30 Hz which is less harmful than a high pitch one.
- Positive feedback is limited to maximum operating level of the driver tubes and hence maximum positive feedback possible the amp allow to operate.
- Also since not a lot of negative feedback in used, the open loop gain is not as high as traditional OTL
- Thus the sound frequency and level is not as damaging to our ears as one imagined
- If the negative feedback failure due to the output stage which usually is, the oscillation is confined to driver stage and hence it does not matter much.
- It deems necessary for the oscillation to be detected and circuit shuts down to prevent any damages but If the amp can sustain this type of oscillation under test it is a safer amp than one totally unknown in these respects.