Frank Leegstra - TS 2017

tubes.audio/riaa - Tante RIAA - E88CC RIAA Amplifier

The goal of this years project was to design and build a RIAA turntable amplifier. Vinyl records can still produce a wonderful sound that is not easy to beat by digital sound. If done right, vinyl produces a very relaxed and laid-back sound.

Initial requirements

- Have at least 500mV output with MM cardridges, giving 5mV input @ 1khz
- Input impedance 47K
- RIAA curve +/- 0.5dB

Design considerations

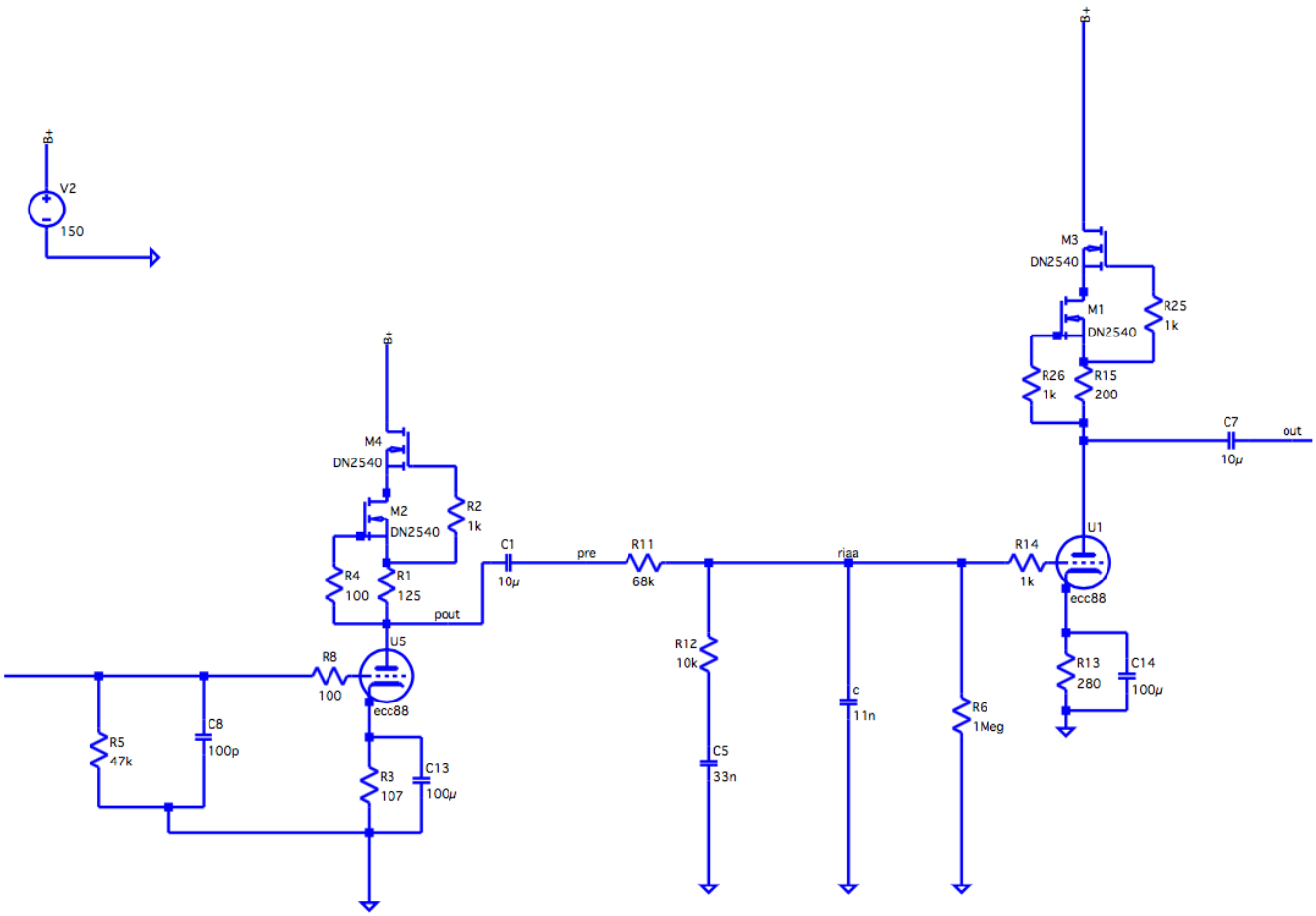
1. Make sure that RIAA correction is not influenced too much by tube rolling and aging
    - Output impedance of gain stage(s) should be at least 5x smaller than riaa filtering circuits impedance
2. Make sure input capacitance is not too high for minimal high frequency roll-off
    - Choose a tube with relatively low input capacitance. Don't forget to look at Miller capacitance in the calculation
3. Make sure the amp doesn't produce too much noise
    - Choose a tube with relatively high gm, to reduce shot noise
    - Choose a tube with relative low iA, to reduce flicker noise
    - The first gain stage will dominate S/N figures, so if possible choose a high gain tube
    - Design for lower resistor values where possible
4. Make sure to keep distortion levels as low as possible and make 2nd harmonic dominant if possible
5. Be careful with the grounding scheme. The sensitivity of the circuit will induce hum easily.
6. Have enough headroom to handle input peeks from vinyl hicks and clicks

Design choices

- Use a (FET) CCS for both gain stages:
    - This will minimise distortion (4) and maximise gain (3)
    - CCS has a high ZOut, however its paralleled to plate resistance (Rp) of the tube. Pick a tube with relatively low Rp to keep RIAA resistor values low enough (2) and maintain RIAA correctness (1).
- Use E88CC/ECC88:
    - Has a high gm (3)
    - Can work with lower anode currents (3)
    - This results in low EIN values
    - Has relatively low input capacitance (2)
    - Two stages provide just enough gain (33 x 33) to get 500mV output
    - Provides enough headroom (6)

Schematic

After extensive LTSpice simulation the following schematic gave the best results in terms of simulated distortion and noise figures. I have tried multiple active and passive scenarios.



Operating point

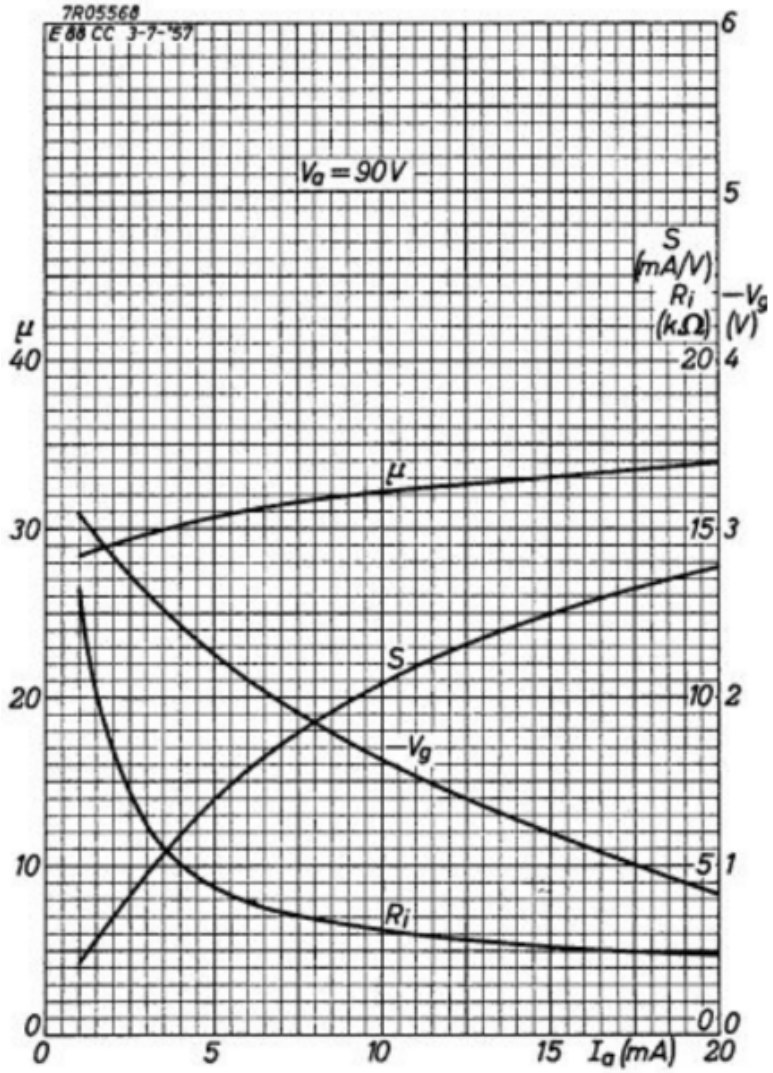
I did a lot of experimentation with the operating point. The trick with the E88CC in this circuit is to balance out three of its parameters:

1. Gm
2. Gain
3. Ia

It's tricky to find the right balance, because the parameters can be conflicting:

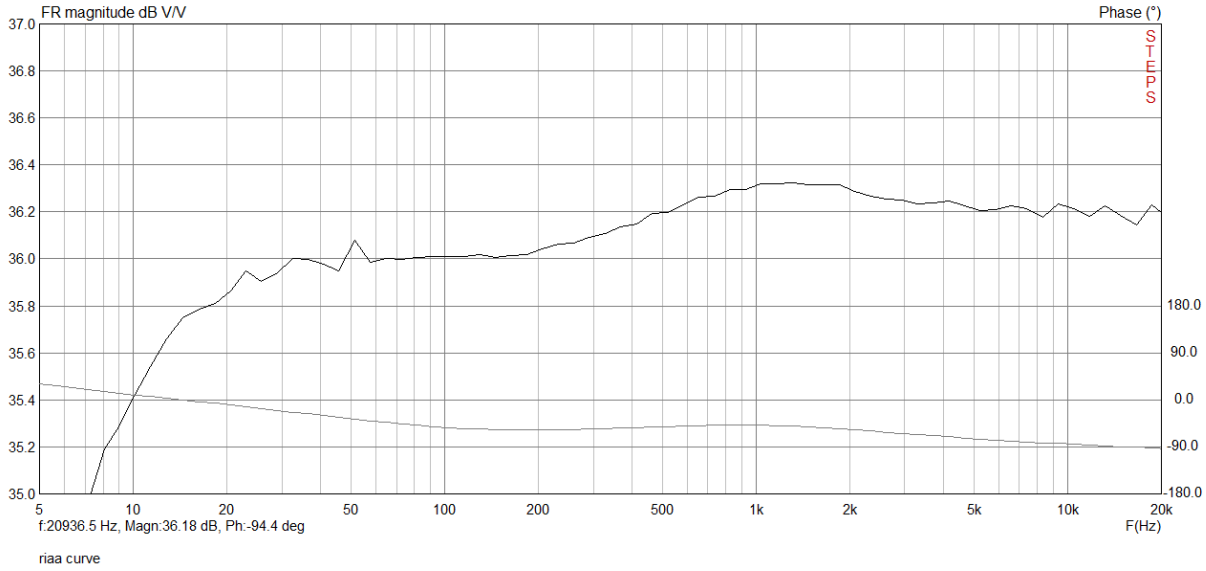
- Higher Ia will increase gain and gm, resulting in lower shot noise, however
- Higher Ia will also produce more flicker noise
- Distortion figures fluctuate at different operating points (ranging from 0.01% to 0,1%)

I ended up somewhere in the 10mA region on the first tube to get a good balance between the three. However, if gain is not a big issue, it might be an option to pick a value below 5mA.



Measurements

RIAA correction +/- 0.15dB.



THD < 0.02%