An Improved Reference Filter for Audio Regulators

Walt Jung
11/11/2021

This brief note focuses on very simple improvements to the voltage reference within an audio regulator. It can be used most effectively within a working Super Regulator (SR), as well as any previous regulator of a similar topology.

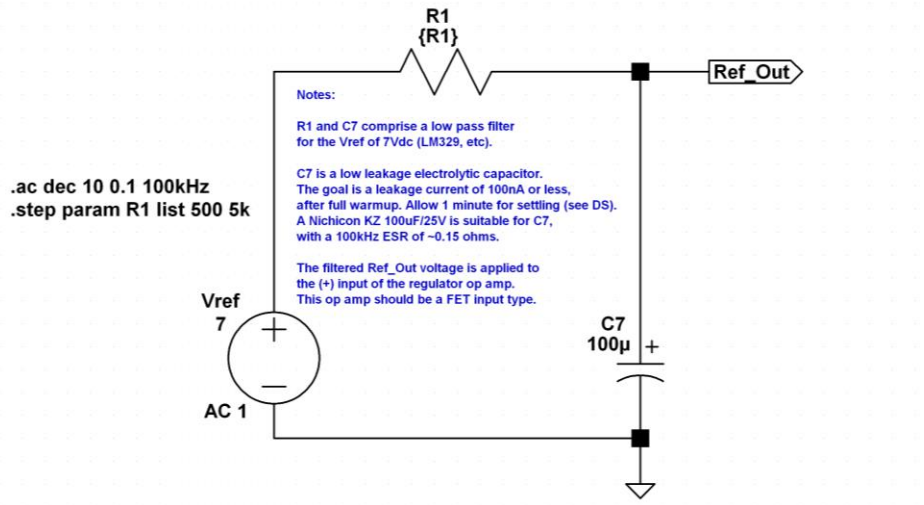
Figure 1 is the basic setup. Under test here is a basic reference filter used in a "SR2020" positive regulator, similar in many regards to the *Audio-Electronics* issue 4/2000 circuit.

Figure 1: A Spice Test Circuit Demonstrates Improved Filtering

Figure 1 **at the right is an LTSpice test circuit which explores the properties of the simple low pass filter R1 and C7.**

In past versions of the SR, this RC network was typically either 500Ω plus 100µF (or 120µF), making a nominal RC time constant of (5 x 10^2)(1 x 10^-4) = 0.05 sec. This computes to a low frequency corner of 3.2Hz.

While this is below the audible audio range, it doesn't give us a good perspective on just how much filtering of noise within the audio range occurs.



Discussion:

The improved filter uses two key techniques to allow an order of magnitude improvement in filtering. R1 is raised from 500 Ω to 5k Ω, which accounts for a 20dB improvement in noise reduction, with the same nominal C7 value. But for a higher 5k Ω value to be most effective, C7 must show low leakage at the applied 7V DC bias. A 25V (or more) rating helps in this regard, since electrolytic caps typically have much lower leakage when operated at a fraction of the rated DC voltage. In this case the bias is less than 1/3 a rated specification of 25V.

Several Nichicon UKZ 100µF/25V caps were tested with a series resistance of 10k Ω, and showed voltage drops of 2mV or less. For these conditions, 1mV drop across 10k Ω

corresponds to 100nA, or equivalent to 0.1µA of current. Nichicon type UFG samples were almost as low in tested DC leakage.

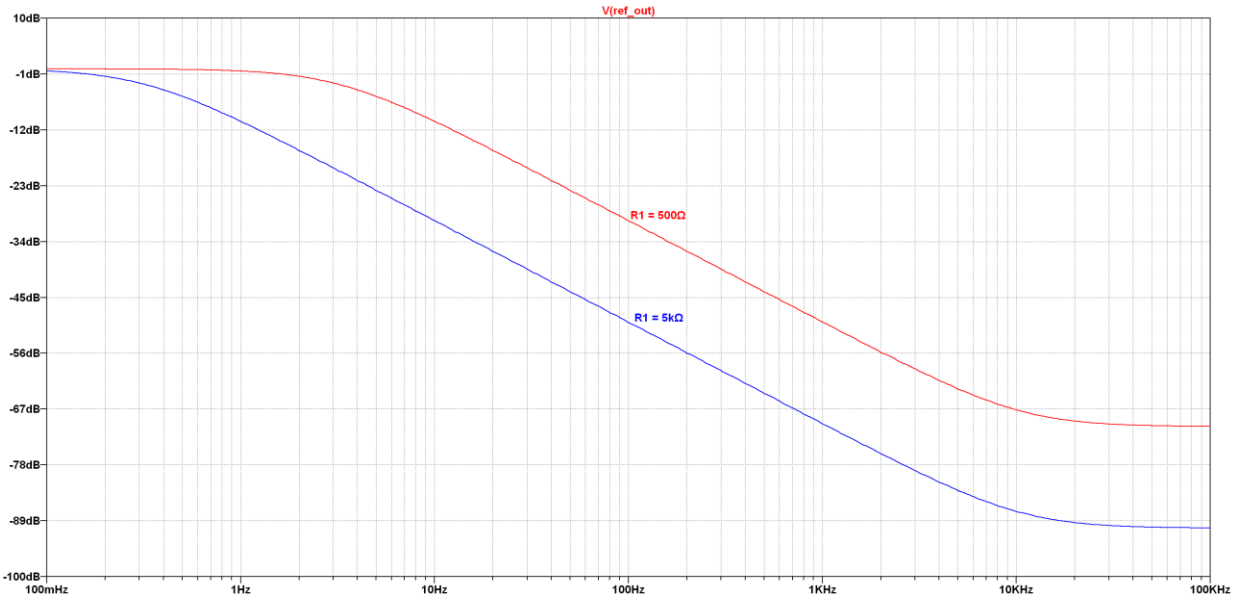
These capacitor types are typically rated for leakage of ~0.01CV, or 3uA (see DS for details), after one minute of warmup. The caps evaluated all did much better than this, which could be due in part to the test conditions of ~7V applied DC, well below actual rated voltage. After full warmup, of course!

So, carefully selected filter caps can allow for higher R1 values within such a filter. While either of the two types can be used, a reasonable value for R1 should still be below 10kΩ or less. An R1 value of 5kΩ is suggested, along with the UKZ 100µF/25V for C7.

A second caveat is that such a higher value of R1 resistance should only be used with FET input op amps. For example, the AD825. The goal here is to keep any additional DC offset due to R1 to less than 1mV, while still taking advantage of the AC filter improvements demonstrated in ***Figure 2***.

Figure 2: A Family of Noise Reduction Plots with Two R1 Values

In the *Fig. 1* circuit, R1 was stepped from 500 Ω to 5k Ω, and the resulting attenuation vs. frequency is plotted below within *Figure 2*. For C7, the known ESR value at 100kHz was used, i.e., 0.150 Ω. As can be noted, this causes the highest frequency plots to reach a plateau as the ESR dominates the level of attenuation achieved. Across the middle audio range, noise is rejected by an additional 20dB (blue R1 trace, lower).



Summary:

These changes to the regulator noise filter are simple, and can be implemented by anyone if the limitations are observed. If other electrolytics are used, they should be tested for low leakage, as noted above.