CALCULATING NOISE IN SYSTEMS USING THE TRIPATH TECHNOLOGY DRIVER AMPLIFIERS

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Overview

The most immediate impact of Tripath Technology's Digital Power Processing™ (DPP™) is through its breakthrough true digital amplifier, the Class-T amp. Class-T amps offer decisive advantages over the Class-A, Class- AB and Class-D amplifiers prevalent in today's audio systems by delivering the fidelity of Class-AB with the efficiency of Class-D. The purpose of this Application Note is to help in delivering this quality along with a low noise floor.

Summary

Output noise of a TA0102A or TA0103A based amplifier versus gain and input resistance, R_{IN}, are presented. A hypothetical system is analyzed to minimize output noise from the Tripath Technology TA0102A amplifier under different system constraints. A general equation for this hypothetical system is derived.

Output Noise Versus Input Resistance

The TA0102A audio amplifier drivers support variable gain by appropriate selection of input resistance, R_{IN}, according to the following equation:

$Av = 387 \times 10^3/(R_{IN} + 5000)$ for TA0102A
$Av = 538 \times 10^3/(R_{IN} + 5000)$ for TA0103A

The TA0102A/0103A exhibit a maximum gain of 77 (or approximately 38dB) and 108 (41 dB) when the input resistance, R_{IN}, is set to 0Ω. However, this gain setting will result in maximum noise appearing at the output. This can be seen in the attached graph entitled Output Noise versus R_{IN}. This plot represents the output noise of a "typical" device.

Figure 1 illustrates that a selection of RIN greater than about 15-20KΩ will result in minimum A-weighted noise, while the flat noise output is minimized above approximately 50KΩ. If overall system gain is not a constraint, Tripath Technology utilizes an input resistance of 22.1KΩ. NOTE: it may seem counterintuitive that larger resistor values produce lower noise. While it is true that the input resistor adds noise proportional to the square root of the resistor value, the overall gain of the TA0102A/0103A decreases inversely with this resistor value. This causes an overall reduction in total output noise.

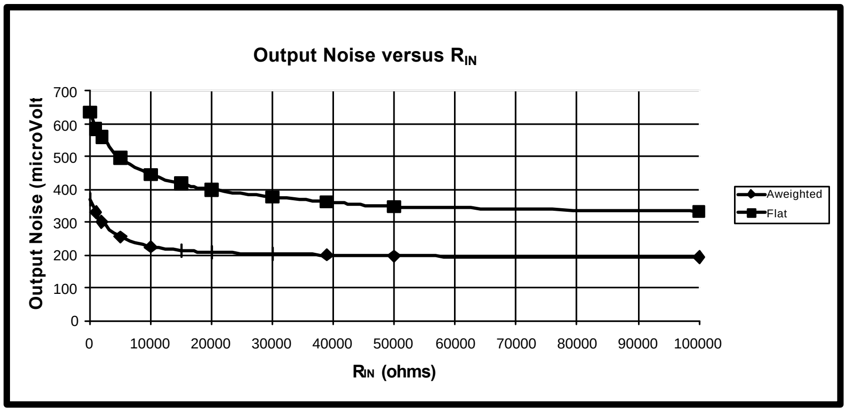

Figure 1: Output Noise versus R_{IN}

Output Noise Versus Gain

Utilizing the R_{IN} versus Noise data and the gain equation, given above, a plot of Output Noise vs. Gain can be generated. Such a plot is displayed below for a "worst case" device.

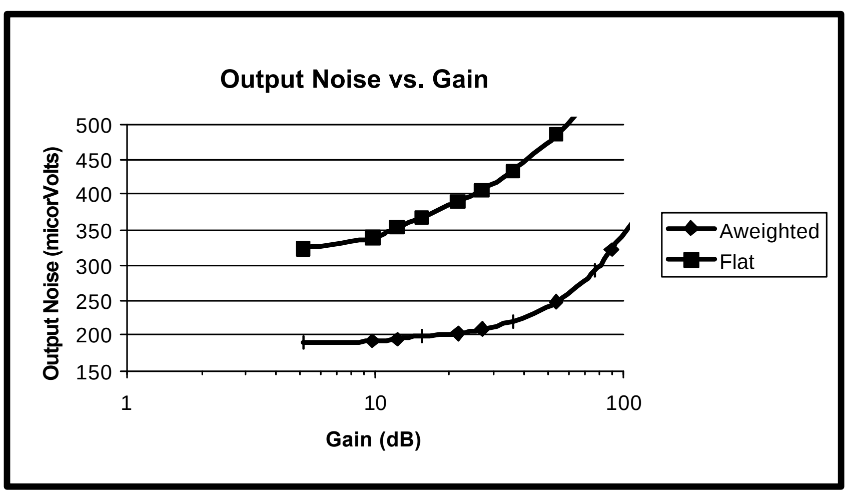

Figure 2: Output Noise versus Gain

Hypothetical System Analysis

The following analysis applies to a simple system comprised of a combined preamplifier and volume control, feeding the TA0102A/0103A audio driver amplifier. The system model appears below:

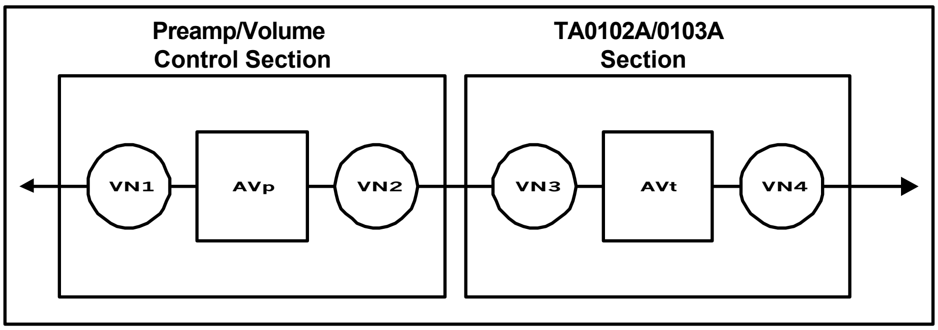

Figure 3: Amplifier system model

A gain stage of gain AVp (AVp = gain at normal listening level) plus two noise sources (VN1, VN2) are used to model the volume control circuit and preamplifier circuitry. This block's output noise at two settings of AVp is important. Those settings are 0 gain (volume setting at minimum) and average listening volume in normal situations. For this particular volume control and preamplifier arrangement the assumed values (from a fabricated spec sheet) for these conditions are 7uV output noise at zero volume setting and 12.5uV at normal listening volume. Assuming non-correlated noise sources, the value of VN2 is clearly 7uV and the value of VN1 can be calculated by using the RMS sum of noise components as follows:

- $12.5 = (7^2 + (AVp \times VN1)^2)^{.5}$.

This produces a calculated value for VN1 of $(12.5^2 - 7^2)^{.5}/(AVp) = 10.3/AVp$. These values will obviously vary depending on the particulars of the volume control and preamplifier selected. Hence, other systems will have different values of VN1 and VN2 from the numbers presented here. Reference to the specs for the preamplifier/volume control section will generally be required to derive these values for any particular system.

Analyzing the TA0102A (0103A) section can be done similarly. The curves of Output Noise versus Gain given above for flat noise spectrum would yield a value for VN3 and VN4 as follows. VN4 represents the output noise when the TA0102A (0103A) is configured with 0 gain. This corresponds to approximately 195uV A-weighted noise at the output. With a gain of 53.8 and no noise generators, which preempts the volume control on its input, the

TA0102A produces approximately 250uV of noise. Thus the value of VN3 can be inferred again from the RMS sum of noise components as follows:

- $250 = (195^2 + (53.8 \times Vn3)^2)^{.5}$.

Solving for Vn3 yields a value of 2.91uV.

VN3 and VN4 are uncorrelated, arising from fundamental semiconductor noise. Hence, they are also uncorrelated with VN1 and VN2. At average listening volumes, the noise of the entire system with uncorrelated noise sources is then the RMS sum of all noise components:

- $Vout = (195^2 + (AVt \times 2.91)^2 + (AVt \times 7)^2 + (AVt \times AVp \times 10.3/AVp)^2)^{.5}$

For a system with a required gain of 31.6 in the TA0102A, the output noise will therefore be

- $Vout = (195^2 + (31.6^2 \times 2.91^2) + (31.6^2 + 7^2) + (31.6^2 \times 10.3^2))^{.5}$

  = 448uV

Moving some of the gain from theTA0102A into the preamplifier stage can reduce this noise. Moving all of the gain to the preamplifier stage and having unity gain in the TA0102A would result in minimum noise of:

- $Vout = (195^2 + 2.91^2 + 7^2 + (31.6 \times 10.3)^2)^{.5}$

  = 379uV

This situation may not be optimal for a number of reasons. For example: assume the TA0102A is operated at +/- 33V and the previous stage is operated at +/-15V (with the desired output of the first stage not exceeding +/-12V for good distortion). The TA0102A would then need to be set for a minimum gain of 33/12 = 2.75 to maintain the overall system gain of 31.6. Such a system would exhibit the identical noise to the minimum above of:

- $Vout = (195^2 + (2.91^2 \times 2.75^2) + 7^2 \times 2.75^2 + (10.3^2 \times 31.6^2))^{.5}$

  =380uV

In attempting to minimize noise, system constraints (such as dynamic range of each stage) may influence the final split of overall gain between the first and second stage. Some additional observations of this particular system are as follows:

- Inserting an additional amplifier between the preamplifier/volume control and TA0102A will produce more noise than the analysis immediately above.

Putting gain as “early” in the design as possible will minimize noise. If there are stages of amplification prior to the preamplifier/volume control, their noise is lumped into noise source VN1. In this particular example, the minimum noise of 379uV has two primary sources: VN1 and VN4 (the TA0102A output noise). Inspection of the details prior to the preamplifier/volume control stage may identify a situation where inserting a gain stage prior to this could reduce overall system noise.

Conclusion

The following equation, derived above, can be used to analyze an arbitrary split of such gain for a generalized combination of a preamplifier and the TA0102 amplifier.

- $Vout = (195^2 + (AVt \times 2.91)^2 + (AVt \times 7)^2 + (AVt \times AVp \times VN1)^2)^{.5}$

In this equation, VN1 and VN2 are the characteristic noise components of a specific preamplifier. They can be calculated for any preamplifier/volume control in the same way as this application note does for this hypothetical preamplifier by referencing the appropriate data sheet for that preamp.

If the system design requires absolute minimum noise, this equation demonstrates the need to put all the gain in the first amplification stage. If tradeoffs beyond noise are important, this equation can be used to analyze different situations to make appropriate engineering tradeoffs across all aspects of the design. Furthermore, expanding this concept to include previous stages where gain could be increased may allow for even further reductions in overall system noise.

These same techniques can be applied to the TA0103A based designs as well. In either case, minimum system noise can be a part of designs that bring the breakthrough efficiency, power, and fidelity of Tripath Technology’s Class-T Digital Power Processing™ (DPP™) technology to your products.