

Modified method for design of the low-frequency audio driver

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Abstract–The purpose of this study is to illustrate how different kinds of speakers impact on audio amplifiers and their output parameters. For this study using specific parameters of the output load. Results obtained in this study relate to complex real load.

Keywords –amplification, speaker, frequency response

I. STATE OF THE PROBLEM

The condition of the problem raises the question – is it necessary to design the driver stage to be taken into account characteristic impedance of the load? The expected response will show how accurate is the design of the amplifier when the impedance characteristic is not given. A detailed account of this feature shows the influence of parallel resonance in low frequency region. This resonance frequency is caused by the mechanical properties of the speakers. I will do some software simulations and numerical experiments to show you how the resonance of the load affects the linear response of the amplifier.



fig.1.1. Chosen load speaker model 12M/4631G00

For the purpose of numerical experiments I choose a “midrange” speaker, model 12M/4631G00. Its impedance characteristic is shown on fig. 1.1., which shows the resonance of the system.

To confirm the recommended impedance characteristic is necessary to carry out numerical simulation. For the purposes of numerical experiments I will use the following data:

- Force factor [Bl] 5.3 Tm
- Mechanical resistance [Rms] 0.55 kg/s
- Movingmass [Mms] 6.5 g
- Suspensioncompliance [Cms] 0.69 mm/N
- DC resistance [Re] 3.2 Ω
- Voicecoilinductance [Le] 0.22 mH

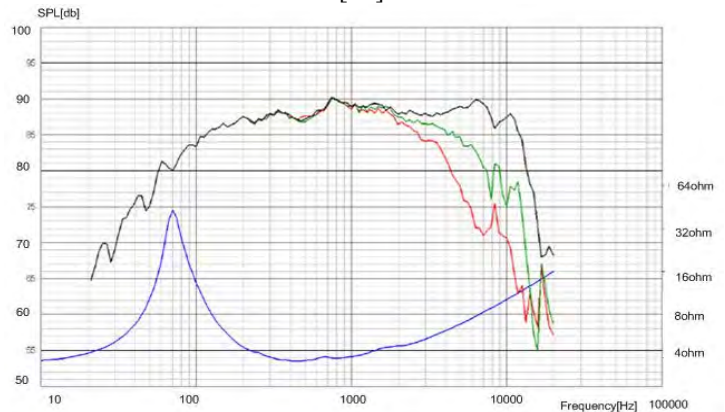


fig.1.2. From references to speaker Midrange – 12M/4631G00[7]

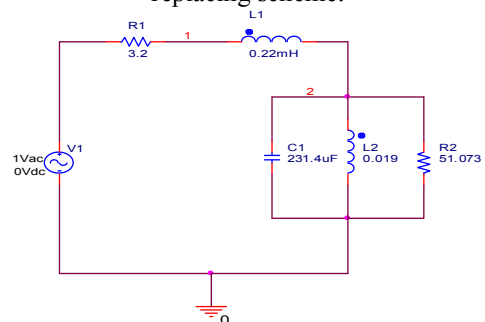
These parameters can be substituted for an equivalent scheme, which presents the speaker with an additional parallel circuit (C1, R2, L2), which characterize certain mechanical resonance of the system. The values for each parameter is determined by the familiar expressions [6]:

$$R_2 = \frac{(B.L)^2}{R_{ms}}, L_2 = C_{ms} \cdot (B.L)^2, C_2 = \frac{M_{ms}}{(B.L)^2} \quad (1)$$

For the purposes of the study (research) it is necessary to convert the resulting parallel circuit. For this purpose the well-known expressions will be used[2]:

$$R_2 = \frac{G^2}{G_2^2 + B_2^2}, X_s = \frac{B^2}{G_2^2 + B_2^2}, G_2 = \frac{1}{R_2} \quad (2)$$

After this transformation we get the following equivalent replacing scheme:



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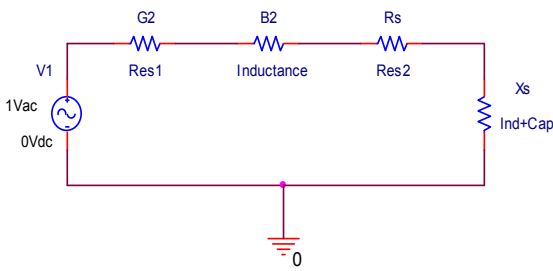


fig. 1.3. Convert parallel to serial circuit

After examine the mentioned parameters with the software, Mathcad I get a result that shows the change of electrical resistance of the speaker when changing its working frequency.

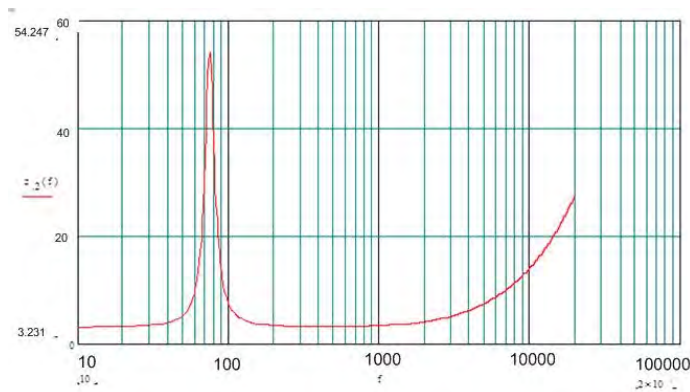


fig.1.4. For determining the impedance characteristics of the load Midrange – 12M/4631G00 I did the numerical experiment with MathCAD

Comparison of results from numerical simulation with those from the manufacturer indicates identical to the load. In consequence we can use the resulting parameters to modify the methodology of Scientifically LF driver stage. For that purpose the values obtained for R2, L2, C2 are replaced by the equivalent model of Pic.1.4.

II. DESIGNING THE DRIVER STAGE

When design the driver stage, the following initial parameters need to be set:

- Input impedance $R_{in}=30k\Omega$;
- Bandwidth - $f_i=40Hz$ $f_h=17KHz$;
- The distortion coefficient – $M_I = ?$
- Input volgate – $U_{in} = 0.7V$;
- Impedance characteristics of the load – $Z_{load}(f)$

A. Choice of principle scheme

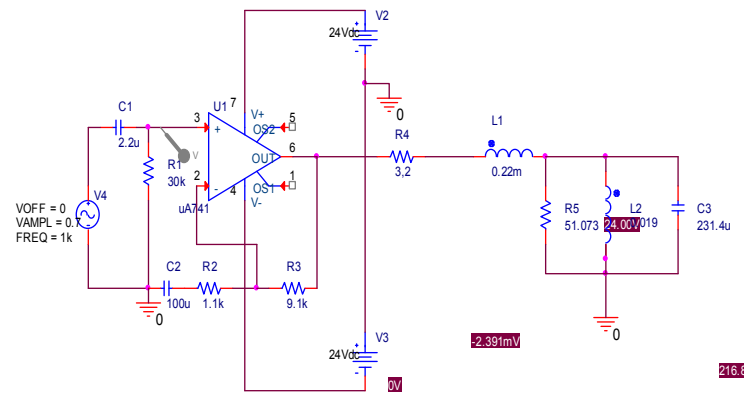


fig.1.5. Principal schematic of the driver stage

Selected scheme is a non-inverting audio amplifier filled with uA741. The difference in this article is the loading of the amplifier with a complex load, which changes the output parameters. To read this change in the design process we have to read all the parameters of the load in the design methodology.

B. Define the amplification of the audio stage

To determine the amplification coefficient we are going to use this familiar equation:

$$A_U = \frac{U_l}{U_{in}} \quad (3)$$

where:

- U_l - efficiency load voltage;
- U_{in} - efficiency input voltage.

C. Determination of the input impedance of the audio amplifier:

$$Z_{in}(f) = \frac{R_1 \cdot R_{inOU}}{R_1 + R_{inOU}} - j \cdot \frac{1}{2 \cdot \pi \cdot f \cdot C_1}$$

$$\approx R_1 - j \cdot \frac{1}{2 \cdot \pi \cdot f \cdot C_1} \quad (4)$$

where:

R_{inOU} - input resistance for the selected operational amplifier. When we choose the correct amplifier this resistance must execute the expression: $R_{inOU} \gg R_{in}$;

D. Determining the value of the resistor R1.

$$A_U = 1 + \frac{R_3}{Z_{in}} = 1 + \frac{R_3}{R_1 - j \cdot \frac{1}{2 \cdot \pi \cdot f \cdot C_2}} \Rightarrow$$

$$R_1 - j \cdot \frac{1}{2 \cdot \pi \cdot f \cdot C_2} = \frac{R_3}{A_U - 1} \Rightarrow$$

$$R_1(f) = \frac{R_3}{A_U - 1} + j \cdot \frac{1}{2 \cdot \pi \cdot f \cdot C_2} \quad (5)$$

Resulting expression shows that the resistor is dependent on frequency.

E. Determination of the dissipation power of resistance R1:

$$P_{R1}(f) = \frac{U_{in}^2}{R_1^2 + \left(\frac{1}{2 \cdot \pi \cdot f \cdot C_2}\right)^2} \cdot R_1 \quad (6)$$

After calculating equation.5 and equation.6 we record the nearest larger value. When calculation we get the result - R1 = 30kΩ

F. Determination of the required output voltage for operational amplifier

To determine this parameter the equality must be given:

$$U_{max\ OU} = U_{I\ max} + U_{linou} \quad (7)$$

where:

$$U_{linou} = 2 \div 3V$$

It is well-known that all operational amplifiers are produced with relatively low supply voltage $U_{max\ OU} \leq \pm 18 \div \pm 25V$. This limits the stage. For this output signal of the operational amplifier further includes raising the output voltage. For that reason we choose the supply voltage to be 44V, this requires an additional scheme to reduce ten siongripped (the supply) to the operational amplifier.

G. Determine the value of each capacitors C1 and C2.

Capacity C1 is determined by the expression (7):

$$C_1 \geq \frac{1}{2 \cdot \pi \cdot f_1 \cdot R_1 \cdot \sqrt{M_1^2 - 1}} \quad (7)$$

After calculating (7) the nearest larger standard value is recorded. Objectives of the program study the size of the capacitor C1=2.2 uF

Capacity of capacitor C2 is determined by the expression:

$$C_2 \geq \frac{1}{2 \cdot \pi \cdot f_1 \cdot R_3 \cdot \sqrt{M_1^2 - 1}} \quad (8)$$

After calculating (4) the nearest larger standard value is recorded. For the purpose of the numerical experiment value of the capacitor will be C2=100 uF

H. Determination of operating voltage for each of the capacitors C1 and C2.

Considering the frequency characteristics of the load for voltage U_{C1} we can summarize the following equation [1] [2] [3] and [4]:

$$U_{c1} = U_{c2} \geq (3 \div 5) \cdot U_{in\ max} \quad (9)$$

After calculating (9) the nearest larger standard value is recorded. Operating voltage of C1 and C2 comply with the maximum input level - 1.096V when we choose an operating voltage of 25V and a working temperature of 105° C

I. Produce a model for simulation program

The equivalent replacement scheme of the speaker load up the audio step, which is the purpose of our study or this will show how to change the operation of the amplifier with the following parameters of the load. The size of each R2, L2, C1 is determined by expressions. (1).

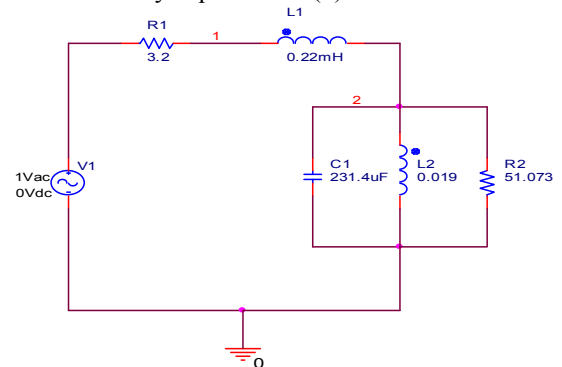


fig. 1.6. Equivalent scheme of replacement speaker

After we determine the load, we should calculate all parameters of the amplifier (fig.1.5.). We get the values for each of the elements after calculate expressions 4. to 9. The model for simulation is made for software "Proteus" fig.1.5. With this model we examine: the resulting gain, frequency response and level of output noise. In that way we study how the output level is changed in the presence of complex load audio amplifier.

III. RESULTS OF THE PROGRAM SIMULATION

Result of the analog analysis



fig.2.1. Define the maximum amplification of the audio stage

This is analog analysis which shows the input and the output signal level. There is a 10-fold amplification of the input signal.

The frequency response

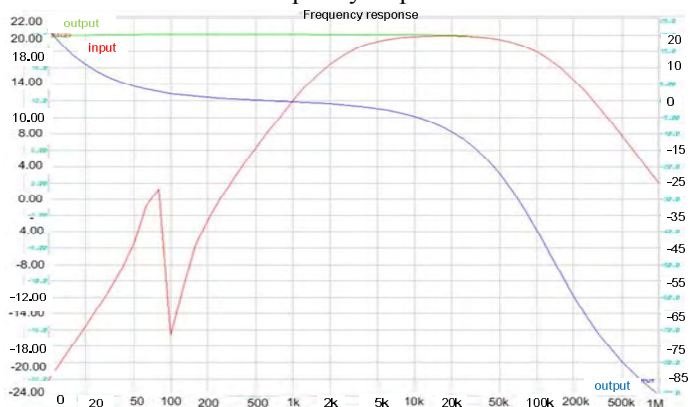


fig.2.2. Program simulation to determine the frequency response

Frequency response, exhibited here shows that the linear region of the step is covered in a range of 10Hz to about 100kHz, but when loaded with complex impedance of the speaker there is drop at a frequency less below 1kHz.

Distortion analysis

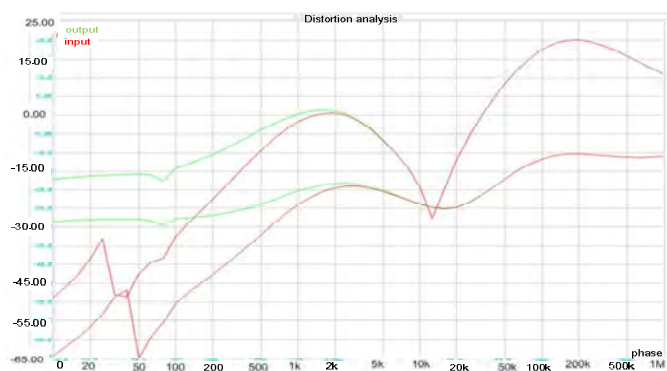
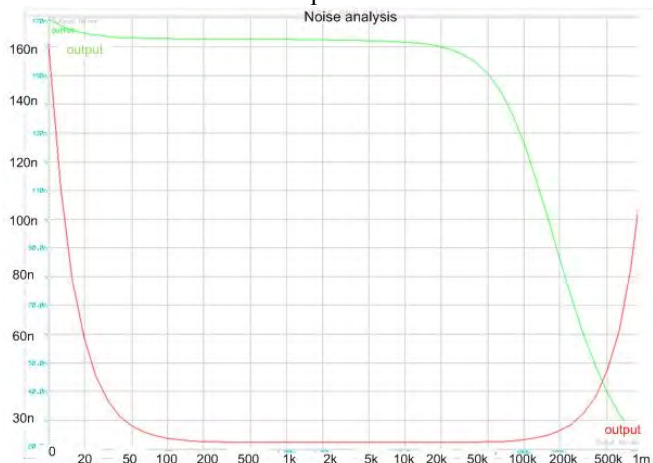


Fig.2.3. Numerical simulation of amplification distortion

Amplification system has a nonlinear form for compensation during the resonance.

Outputnoise



Pic.3.4. Numerical simulation of the output noise

The change of the output noise amplifier 45nV compared with the input, which is observed 29nV fold increase in noise.

IV. CONCLUSION

When design the driver stage high frequency speaker response must be considered. In the process of designing, this change determines parameters such as choice of supply voltage and amplitude of the output voltage.

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