Calculation Report: Monolithic Power Amplifier PRO-Q2

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1 Introduction

In this calculation report, the monolithic power amplifier is determined and calculated.

2 Monolithic Power Amplifier

2.1 Requirements

The power amplifier has the following specifications:

- Input impedance of at least 50kΩ
- Output power: 15W sine in $R_{load} = 8\Omega$ at 1kHz
- Frequency range: 10Hz to 100kHz (-3 dB) at $P_{load} = 0.5W$ in 8Ω

2.2 Chosen Power Amplifier

For the power amplifier, the LM1875 (Farnell-code: 1468913) was chosen. This specific power amplifier has been chosen because the LM1875 meets the specified requirements. The amplifier is also designed to suppress low-frequency noise such as the 50Hz hum originating from the mains, as seen in figure 7 of the datasheet. This is an important property when it comes to the performance of audio amplifiers.

2.3 Calculations

Since the LM1875 is used as an inverting amplifier, the impedance Z_{in} will be equal to R_1 as depicted in the following diagram.

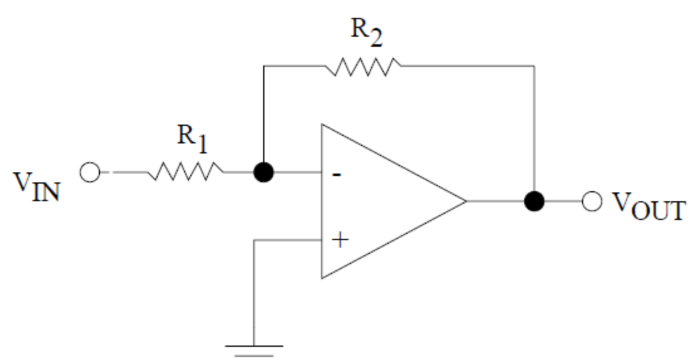

Figure 1: Inverting amplifier diagram

Z_{in} is required to be at least 50kΩ. Thus, the chosen value of R_1 will have to be at least 50kΩ in order to meet the specified requirement.

For determining the maximum output voltage and current, it is assumed the amplifier drives an 8Ω load at 15W.

The formula for the power equals to:

$$P = U \cdot I \tag{1}$$

Therefore the following formulas can be derived:

$$U_{OUT,eff} = \sqrt{P \cdot R} = \sqrt{15 \cdot 8} = 11V \tag{2}$$

$$U_{OUT,max} = U_{OUT,eff} \cdot \sqrt{2} = 15.556V \tag{3}$$

$$I_{OUT,eff} = \sqrt{\frac{P}{R}} = \sqrt{\frac{15}{8}} = 1.37A \tag{4}$$

$$I_{OUT,max} = I_{OUT,eff} \cdot \sqrt{2} = 1.94A \tag{5}$$

The amplifier has a bandwidth of 70kHz at 20W output power. However, the desired dynamic range of 10Hz to 100kHz can be easily achieved at lower power outputs. No additional calculations need to be done for the power amplifier in order to realize a frequency range of 10Hz to 100kHz. The dynamic range can be controlled through software since the filters on the preamplifier are controlled by the digital control unit. According to the datasheet from LM1875 [1] the supply voltage needs to be approximately ±18V to accomodate to the 15W output power.

With this information, the voltage gain can be determined by using the following formula:

$$A = \frac{U_{out}}{U_{in}} \tag{6}$$

Since $U_{out} = U_{out,max} = 15{,}556$V and $U_{in} = 18$V (the voltage delivered by the supply), the gain will be $\frac{15{,}556}{18} \approx 0.864$. Expressed in decibels, this is equal to $20 \cdot \log(\frac{15{,}556}{18}) \approx -1.27$dB.

It is now possible to deduce the output impedance $\mathrm{Z_{out}}$ by using the following equation:

$$\frac{U_{out}}{U_{in}} = \frac{Z_{out}}{Z_{in}} \tag{7}$$

Filling in the known values, $\mathrm{Z_{out}}$ can be determined as follows:

$$\frac{15,556}{18} = \frac{Z_{out}}{50 \cdot 10^3} \Longrightarrow Z_{out} = 50 \cdot 10^3 \cdot \frac{15,556}{18} \approx 43211\Omega \tag{8}$$

References

[1] Texas Instruments. (2004, May). "*LM1875 20W Audio Power Amplifier*" [online]. Available: http://www.farnell.com/datasheets/1703151.pdf [April 3, 2015].

Calculation Report: Heat Sink Power Amplifier PRO-Q2

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1 Introduction

In this calculation report the heat sink of the selected monolithic power amplifier is determined and calculated.

2 Calculation: Heat Sink Power Amplifier

The power amplifier that is chosen for the active loudspeaker is LM1875 (Farnell-code: 1468913).

Fig. 1 gives insight on how the heat sink and power amplifier will look like when connected with each other.

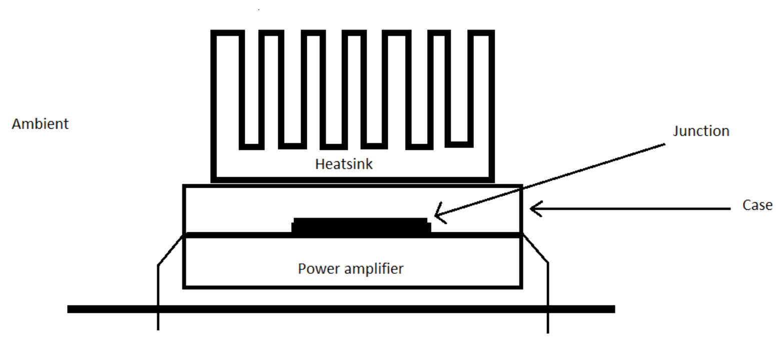

Figure 1: A sketch of the heat sink and power amplifier together

Imagine that the maximum junction temperature of the power amplifier can reach up to 150°C and that the ambient temperature goes up to 25°C. The power dissipation for an 18V power supply and an output power of 15W is equal to 10W. The power dissipation can be found in a graph called "Power Dissipation vs Power Output" in the datasheet of LM1875. The total junction-to-ambient thermal resistance must be less than[1]:

$$\theta_{ja} = \frac{T_{JMAX} - T_{AMB}}{P_Q} = \frac{150 - 25}{10} = 12,5000^{o}C/W \quad (1)$$

- $T_{JMAX}$is the maximum junction temperature that the power amplifier can handle before overheating and shutting down.
- $T_{AMB}$is the ambient temperature of the power amplifier.
- P_Q is the quiescent power dissipation of the power amplifier.

The thermal resistance of a metal-metal interface when dry is equal to:

$$\theta_{metal-to-metal} = 1,2^{o}C/W \quad (2)$$

The thermal resistance of the heat sink is equal to:

$$\theta_{heatsink} = \theta_{ja} - \theta_{metal-to-metal} = 12,5^{\text{o}}C/W - 1,2^{\text{o}}C/W = 11,3^{\text{o}}C/W \quad (3)$$

To check whether the calculations are correct, the temperature of the junction is determined as a result of the thermal resistance.

The formula used to calculate the maximum average power of the power amplifier, LM1875, is found in the datasheet. The maximum average power that the power amplifier will be required to dissipate before overheating is approximately [1]:

$$P_d MAX = \frac{V_S^2}{2\pi^2 R_L} + P_Q = \frac{18^2}{2\pi^2 \cdot 8} + 10 \approx 12.05W \quad (4)$$

- V_S is the total power supply voltage across the power amplifier.
- R_L is the load resistance.
- P_Q is the quiescent power dissipation of the amplifier. The power dissipation can be found in a graph called "Power Dissipation vs Power Output" in the datasheet of the LM1875.

$$P_Q = 10W \quad (5)$$

The new maximum junction temperature is:

$$T_{JMAX} = P_d MAX \cdot \theta_{ja} = 12,05 \cdot 12,5 = 150,625^{\text{o}}C \quad (6)$$

150.625°C is slightly higher than 150°C and therefore the new junction-to-ambient thermal resistance equals to:

$$\theta_{ja} = \frac{150,625 - 25}{10} = 12,5625^{\text{o}}C/W \quad (7)$$

The new ϑ_{ja} (12.5625°C/W) is approximately equal to 12.5000°C/W, which means that the calculations of the heat sink meets the required specifications.

Therefore the new thermal resistance of the heat sink is equal to:

$$\theta_{heatsink} = \theta_{ja} - \theta_{metal-to-metal} = 12.5625^{\text{o}}C/W - 1,2^{\text{o}}C/W = 11.3625^{\text{o}}C/W \quad (8)$$

A heat sink with a thermal resistance lower than 11.3625ºC/W must be used in order for the power amplifier, LM1875, to function properly without overheating and shutting down. The heat sink that is chosen for the power amplifier is FISCHER ELEKTRONIK SK 129 50,8 STS (Farnell-code: 1319813). It is chosen for this heat sink because the thermal resistance of this heat sink is 5,3ºC/W, which is lower than 11.3625ºC/W.

References

[1] Texas Instruments. (2004, May). "*LM1875 20W Audio Power Amplifier*" [online]. Available: http://www.farnell.com/datasheets/1703151.pdf [April 3, 2015].

Calculation Report: Power Supply PRO-Q2

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1 Introduction

In this calculation report a transformer is selected and the efficiency of the power supply is determined.

2 Power supply

2.1 Requirements

The power supply has the following specifications:

- Input: 230V AC
- Output: 2x 18V DC (25W), 2x 15V DC, 1x 5V DC
- Regulator type: Linear
- Energy efficiency: 80% or higher

2.2 Power supply design

The power amplifier needs a supply of ±18V DC. To accomodate for this the power supply will consist of a power transformer with one primary winding and two secondary windings. After the transformer comes a bridge rectifier which converts the AC signal to DC. Then finally the signal will pass through several filter capacitors to smooth out the voltage. Optionally an inductor can be used in-between the filter capacitors and the bridge rectifier to reduce the inrush current.

The preamplifier will run off ±15V DC which is provided by a regulator stage after the power supply. The same thing goes for the digital systems which will run off 5V DC.

2.3 Calculations

2.3.1 Power transformer

The winding turn ratio between the primary and the secondary windings of the transformer is equal to the voltage ratio.

$$\frac{U_p}{U_s} = \frac{N_p}{N_s} \tag{1}$$

The primary voltage is 230V and the secondary voltage is 18V.

$$\frac{N_p}{N_s} = \frac{230}{18} \tag{2}$$

The transformer current per secondary winding is equal to:

$$I = \frac{P}{2U} = \frac{25}{36} = 0.694A \tag{3}$$

2.3.2 Power efficiency

The energy efficiency of the power supply needs to be 80% or more. The 0.7V voltage drop of the bridge rectifier makes the power supply about 4% less efficient.

$$\eta = \frac{19 - 0.7}{19} = 0.96 \tag{4}$$

There will also be energy loss in the power transformer. The power transformer we chose is 87% efficient[2].

The linear regulators used to power the preamplifier and the digital systems are very inefficient, but since these parts of the audio system consume very little energy compared to the power amplifier, the loss is neglectable. The power amplifier's power is not regulated.

$$\eta_{total} = 0.87 \cdot 0.96 = 0.8352 \tag{5}$$

The overall efficiency of the power supply is about 84%.

2.4 Selection of power transformer

A toroidal power transformer was chosen because it is more efficient than traditional transformers. The primary voltage is 230V and the secondary voltages are both 18V.

This transformer meets the specifications[2]:

- Multicomp MCTA050/18 (Farnell code: 9530380)

The nominal current of the secondary windings of this transformer is equal to 0.420A while the power amplifier drains 0.694A from the supply at max power. The capacitors in the power supply will smooth out the load on the transformer so it does not exceed the nominal current.

References

[1] Texas Instruments. (2004, May). "*LM1875 20W Audio Power Amplifier*" [online]. Available: http://www.farnell.com/datasheets/1703151.pdf [April 3, 2015].

[2] Multicomp. (2014, June). "*Toroidal Transformers, General Purpose*" [online]. Available: http://www.farnell.com/datasheets/1829278.pdf [April 15, 2015]