Calculating Audio Amplifier Dissipation with Music Sources

P Marshall

Marshall Choong Audio www.marshallchoong.co.uk London, England

Advanced loudspeaker systems often employ integrated multi channel amplification with electronic crossovers and complex equalisation. In the design process of these systems, it eventually becomes desirable to calculate the suspected worst case individual amplifier heat dissipation with any music track. A simple formula is derived that uses digitised music analysis tools available using the open source audio editor, Audacity.

Introduction

This work stems from a general interest in the statistical properties of digitised music with a view to achieving a better understanding of how audio amplifiers may be optimising more appropriately when reproducing music.

It becomes of more interest in multi amplifier systems where each amplifier is dedicated to one directly driven driver.

With the formulae and method to follow, we can calculate the individual amplifier dissipations for any music track or sample.

Figure 1. below shows the relevant details of a class B amplifier. Its gain is variable and is normally set so that the output signal is at the clipping point of the digital signal, Vin, that is the worst case. Vin is normalised to be in the range of 0 - 1.

The equation to follow requires the following variables.

1. V+ is the positive supply rail, V- is assumed to be a mirror of the positive supply.

2. Vh is the amplifier maximum voltage output before clipping

3. Rload is the loudspeaker driver rated impedance.

4. 'rms' is the rms value of a music sample normalised to a range of 0-1, provided by a suitable Digital Audio Workstation such as Audacity.

5. 'av' is the music sample average value normalised as above. Audacity can be programmed to provide this as will be explained in the appendix.

6. The peak digital signal is required to enable the maximum amplifier gain to be calculated without clipping.

Equation 1). is used to calculate the amplifier dissipation

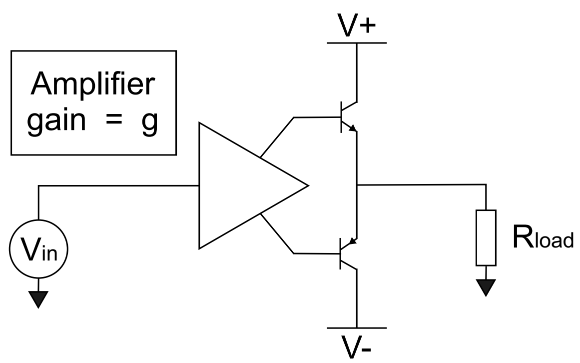

Figure 1.

Amplifier Dissipation with Music Signals:

Amplifier Dissipation = (g / R_{load}) * (Vs * av - g * rms^2)	(1)

Example 1: Constant Sine wave

Source is a sine wave, 1v peak, and output signal = 10 v peak

Vs = 32, g = 10, Rload = 4, rms = 0.7071, mean value = 0.6366

Amp Dissipation **= (10/4) * (32 * 0.6366 - 10 * 0.7071^2)**

= 38.43 W

(Enter the same values in the appendix, Eq. 2 or 3 to confirm the above answer.)

Example 2: Music Track

Vs = 32, Rload = 4, rms value = 0.0966, mean value = 0.0438

Digital peak value = 0.539

Amplifier peak voltage is 29 v, 3 v below supply voltage .

Maximum value for g = (32 - 3) / 0.538 = 53.9

Amp Dissipation **= (53.9 / 4) * (32*0.0438 - 53.9 * 0.0966^2)**

= 12.109 W (in this case, maximum power at clipping point)

In multi channel calculations, it is normal to apply suitable classic low and high pass filters to the music sample to emulate crossover networks before measuring the rms, average and peak values.

Derivation of Equation 1:

Let V = Amplifier Supply Voltage
g = Amplifier gain
s = Normalised sample (value range 0 - 1)
R = Load Resistance
n = number of samples

a). Mean value of all samples = $\frac{\sum s}{n}$ = av   eq. 1

b). RMS value of all samples = $\sqrt{\frac{\sum s^2}{n}}$ = rms   eq. 2

For each sample, normalised dissipation $= (V - s) * (s / R)$ s = 0 to 1

$= V*s/R - s^2/R$

Dissipation per sample in output stage $= V*g*s/R - g^2*s^2/R$

rearrange $= g/R * (V*s - g^2 * s^2)$

c). Summing all samples

$$\text{Dissipation} = \frac{\sum \frac{g * V * s}{R}}{n} - \frac{\sum \frac{g^2 * s^2}{R}}{n}$$

d). Substitute from eq.1) & eq 2). rms^2 = $\frac{\sum s^2}{n}$ and mean value = $\frac{\sum s}{n}$

also noting that

$$\frac{\sum \frac{g * V}{R}}{n} = \frac{g * V}{R} \quad \text{and} \quad \frac{\sum \frac{g^2}{R}}{n} = \frac{g^2}{R}$$

since g, V, and R are constants.

e). Final substitutions give :

Dissipation = $(g / R) * (V * av - g * rms^2)$

Using Audacity To Determine RMS, Mean and peak values

Prepare the Nyquist file used for calculating mean values according to the Appendix, page 1.

1. Load the music file to be tested as a stereo track.

2. Select the whole file using 'CTRL A' and select Analyze >> Measure RMS
   The results are in dB so convert to linear 0-1 values using the formula

$$\text{Linear value} = 10^{dB/20}$$

3. Now select Tools >> Nyquist Prompt..
   select Load >> "mono_mean_s_2.ny" script
   select "OK" and the 2 mean values for Left and Right are displayed.

4. Select "Analyze" >> Amplitude... with the output set to Peak Linear and 4 decimal places, click OK. Note the digital peak values for Left and Right.

** Note the amplifier maximum output level is = g * (digital peak value). Decide upon the amplifier maximum clipping level, for example 3 v below V+ therefore the maximum value for g is :

$$\text{maximum value for g} = \frac{Vs - 3}{\text{digital peak value}}$$

Appendix Page 1:

Nyqist Script   "mono_mean_s_2.ny"

Copy and paste the following script into "Notepad" and save in the "Audacity" folder using the above file name.

```
;debugflags trace

(defun mono-avg (mono-sig samples)
  (let* ((srate (snd-srate mono-sig))
        (dur (/ samples srate))
        (integral (integrate (s-abs mono-sig)))
        (avg (snd-sref integral (/ (1- samples) srate))))
    ;Nyquist implementation of 'integrate' requires normalizing
    ; against duration (seconds).
    (print (/ avg dur))))

; Test it...
(multichan-expand #'mono-avg *track* len)
""
```

Appendix Page 2:

Amplifier Dissipation with Sinusoidal signals:

These equations are included for reference.

Using the class B amplifier model in Figure 2. amplifier and load dissipation with sinusoidal signals is straightforward using equations 1) and 2) below.

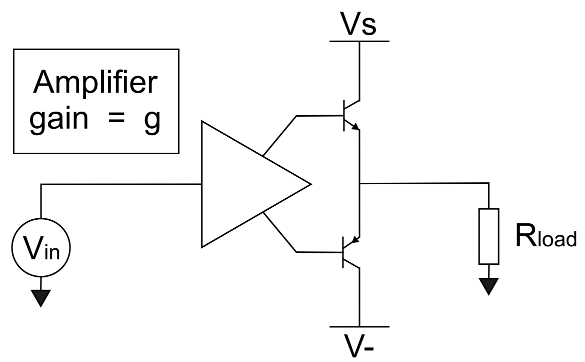

Figure 2.

Equation 2:
Vp = Peak sine wave output

Amp Dissipation = 2/Rload (Vp*Vs / (pi) - Vp^2 / 4) (1)

Alternative, Equation 3:

Total Power = Vs*2*0.45*Vp*0.7071/Rload
Load Power = (Vp*0.7071)^2 / Rload

Amp Dissipation = Total Power - Load Power (2)

(Source : https://www.updatemydynaco.com/documents/Class_B_Amplifier_Dissipation_Calculations.pdf)