[CL-20]

Requirements and Specifications

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0. CONTENTS

1. DOCUMENT SCOPE

The goal of this document is to define the purpose of the project and detail the requirements and specifications so that the client knows all the details of the product. Additionally, other teams may know the specifications and use the program.

This document sets out the background, technical specifications, test requirements and regulations about the project.

In background there is a brief introduction, the different measures that the system is going to measure and an introduction to the different types of amplifiers, although this system is only for type D. Finally similar products that currently exist are exposed.

In technical specifications the system is described and physical, operational and final product specifications are listed.

In the test requirements, different tests that the user can do to verify the correct operation of the system are exposed.

2. BACKGROUND

2.1. *Introduction*

The goal of our product is to measure audio quality of amplifiers. So, we are going to design and built all the necessary instruments to measure the fulfillment of the specifications.
The principal measures we are going to offer are:

- Frequency response.
- Harmonic distortion (THD).
- Gain and power estimation.

Additionally, to expand this project, we will add two more measures:

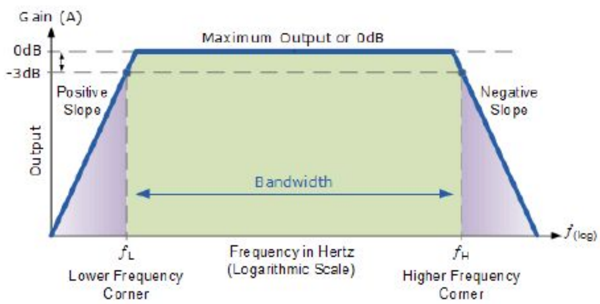
- Harmonic distortion plus noise (THD + N).
- Intermodulation distortion (IMD).

To make this possible, we are going to design and implement a program in matlab with the necessary virtual instruments to measure the quality of the audio amplifiers.

2.2. *State of the art*

So, now we are going to explain the main measures we are going to offer:

Frequency response
Audio frequencies range from about 20Hz to 20kHz, so amplifier must have a good frequency response over this range. Audio systems with a flat response over this range seem to sound the most natural. The most conventional stereo audio amplifiers specify a frequency flatness tolerance of +/- 3 dB.



Gain

As we can see in the frequency response curve, the gain is another important factor to estimate the quality of an audio amplifier. We can express the amplitude gains as:

$$G(dB)=20\log_{10}\left(\frac{Vout}{Vin}\right)$$

Vout and Vin represents the output voltage and the input voltage in an audio amplifier respectively. And we can express the power gain as:

$$G(dB)=10\log_{10}\left(\frac{Pout}{Pin}\right)$$

Pout and Pin represents the output power and the input power in an audio amplifier respectively.

THD+N (Total Harmonic Distortion and Noise)

An other type of measurement is THD+N (Total Harmonic Distortion and Noise) which is a very useful method because it captures so many common forms of imperfection. The amplifier under test is driven with an ultra low distortion sine wave, typically 1kHz. The output of the amplifier is connected to a test load and audio analyzer that contains a notch filter to remove the sine wave signal. To measure distortion we can take into account noise or not so we have to formulas to apply in our measurements:

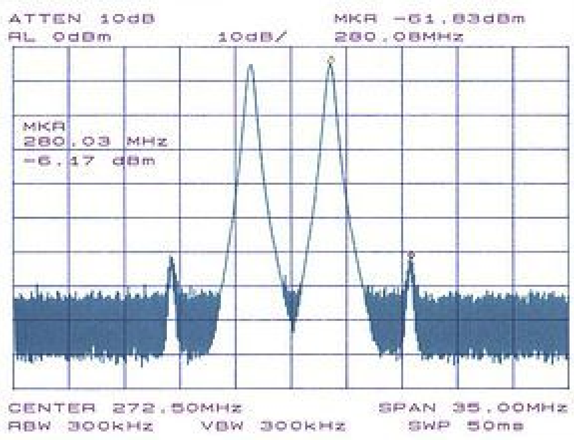
$$\text{THD + N} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \ldots + V_n^2 + V_{noise}^2}}{V_s}$$

$$\text{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \ldots + V_n^2}}{V_s}$$

V_s = Signal Amplitude (RMS Volts)
V_2 = Second Harmonic Amplitude (RMS Volts)
V_n = nth Harmonic Amplitude (RMS Volts)
V_{noise} = RMS value of noise over measurement bandwidth

IMD (Intermodulation distortion)

Intermodulation distortion is a measurement of non-linearity in response to two or more signals. The IMD between frequency components will form additional components at frequencies that are not just at harmonic frequencies.



A frequency spectrum plot showing intermodulation between two signals at 270 and 275 MHz. Visible intermodulation products are seen as small spurs at 265 and 280 MHz.

IMD is measured just like the harmonic distortion but instead of the power of the harmonics, the one of the new frequencies that appear.

The different classes of audio amplifiers are:

Class A

Class A [Figure 1] consumes high continuous currents from its power supply, which implies heat that has to be dissipated. That signifies low performance since a lot of energy is lost, instead, they provide a lot of quality. The distortion in this type of amplifiers is minimal. That class is used in audio circuits and high-end appliances.

Its efficiency is between 20 % and 30 %.

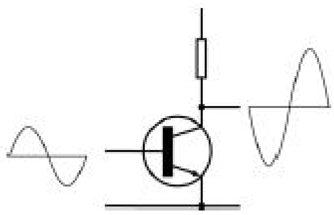


Figure 1: Class A Amplifier

Class B

Class B [Figure 2], also called "Push-Pull", is characterized by having almost zero intensity through its transistors when there is no signal at the circuit input. The consumption is lower than in class A although the quality also decreases. Despite its obvious strength, the odds of seeing an amplifier of this class are low. The reason for this is known as "cross distortion". This is a delay in the handoff between the devices controlling the positive and negative parts of the waveform. That class is used in telephone systems and portable security transmitters. Its eciency is between 75 % and 85 %.

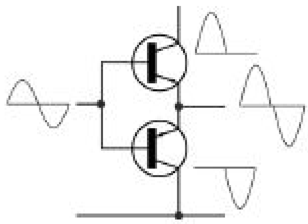


Figure 2: Class B Amplifier

Class A/B

Class A/B combines the best of Classes A and B to create an amplifier without the drawbacks of either (with large signals they behave like a class B, but with small signals, they do not present the zero-crossing distortion of class B).
This class is the most common in audio because of having high quality and performance. Its eciency is between 50 % and 70 %.

Class C

Class C [Figure 3] is very similar to B. It differs in that its state of rest is located in the saturation zone with high current. The class C amplifier is exclusive for RF signals. The main feature of this amplifier is that the active element conducts less than 180º, from a sinusoidal signal applied to its input. That is, it amplifies only a portion of the signal. Due to the polarization of this class of amplifier, there is a very strong distortion in the signal. For that reason, they are not suitable for use as audio amplifiers. Its eciency is between 75 % and 85 %.

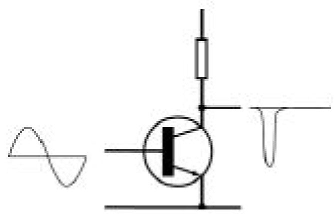


Figure 3: Class C Amplifier

Class D

Class D [Figure 4] amplifiers have high energy performance, in some cases higher than 90 percent, which reduces the necessary surface area of heat sinks, and therefore the overall size and weight of the circuit. The problem they have is that they generate electromagnetic radiation, they are full of coils and they need a thorough design since it can interfere virtually with everything nearby. Its efficiency is over 90 %.

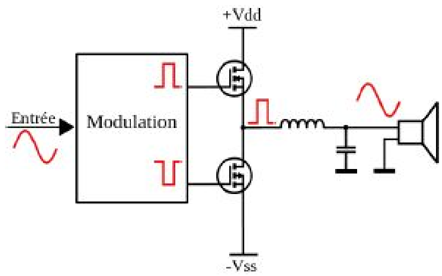


Figure 4: Class D Amplifier

2.3. *Benchmarking*

As we say, we want to make a system which its main functionality is to measure the quality of an audio amplifier, so it would be as an audio analyzer. In the market we can find a lot of audio analyzers. Some of these are:

Keysight U8903B Performance Audio Analyzer

This audio analyzer perform multi-functional and higher performance audio measurements, make high accuracy, time-domain audio signal analysis with extra-wide bandwidth up to 1.5 MHz. Simultaneously measure and view up to eight audio channels on a single screen in real time and easily characterize and meet audio quality standards. This analyzer is a good example of a high quality audio analyzer but the cost of the analyzer rounds 13000$, and this can be a cons.

APx500 Flex Audio Analyzer

This analyzer is actually a virtual audio analyzer with a high quality interface. The principle measurements of this audio analyzer are:

- 2 channel ASIO interface
- File Analysis
- Sequence Mode
- Input Signal Monitors (including FFT monitor)
- Level & Gain
- THD+N
- Loudspeaker Production Test (including Rub & Buzz)
- Stepped Frequency Sweep
- Pass / Fail Measurement
- Signal Acquisition Measurement

The con we can say about this is the price, it costs around 3000$ it's still an expensive product.

So, we can say that this products may offer more options than ours but the key of our product it would be the price (probably the cheapest one) and the facility to use.

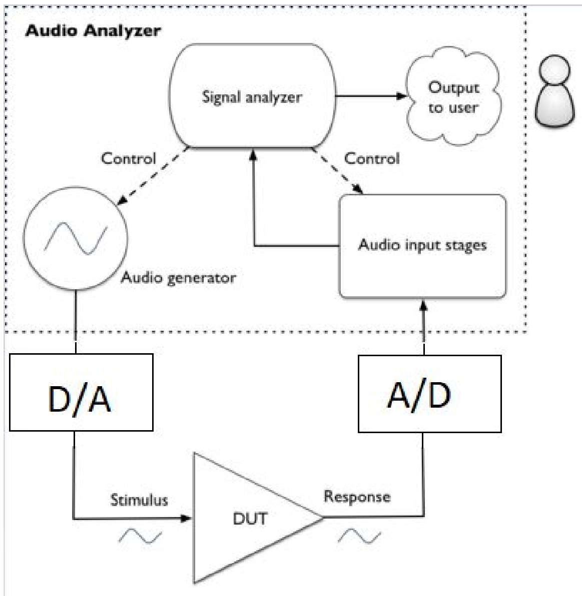
3. TECHNICAL SPECIFICATIONS

3.1. *System description:*

What we are going to do is to perform and implement a system to measure the quality of amplifiers. To do this, we are going to built a virtual instrumentation program using matlab.

Our product will measure some specifications as frequency response (between 20Hz-20kHz), harmonic distortion (>0.1%), the power and gain estimation, the IMD (Intermodulation Distortion), THD+N (Total harmonic distortion and noise).

The program it would be an interface where the user have the option to try which measure he wants to do showing the corresponding graphic of each measurement, and the option to put the main input parameters of the signal user wants to measure.



3.2. *Physical and operational specifications:*

- Operating systems and computer architecture:
  - Windows 10, Linux Ubuntu or IOS
  - Matlab R2019b
- Sound Devices:
  - 96 kHz / 24 bits
- Material: Test cable.
- User environment: industrial and domestic.
- Aesthetic restrictions: easy to use with an understandable and functional interface.

3.3. *Final product specifications:*

The final product is going to be an application using matlab without using any toolbox. The client just need a PC with matlab installed to use our program. The interface, as we mentioned is going to be a window with the virtual instrumentation to be able to measure the power (2W over 8Ω) and gain estimation, the frequency response curve, THD, IMD and THD+N.

So, the product is going to be a window with a graphic of the frequency response and buttons of each measurement (THD, THD+N, FR, Gain and IMD) and a screen where the user as we mentioned is going to be able to modify the parameters they need and recalculate each measurement he wants. The only fixed parameter is the sampling rate, which should be 40 kHz (twice the input audio signal bandwidth).

The ranges of the input audio signal parameters are:

- Frequency bandwidth: 20 - 20kHz +/-1dB
- Power: 2W over 8Ω
- Signal amplitude: 50 - 500 mVpp
- Linearity: THD < 0.2%; THD+N < 10%
- Energy efficiency > 80%

In our case, the unique cost possible is the time we need to do the project, because it is a software program and we have a free licence to use matlab.

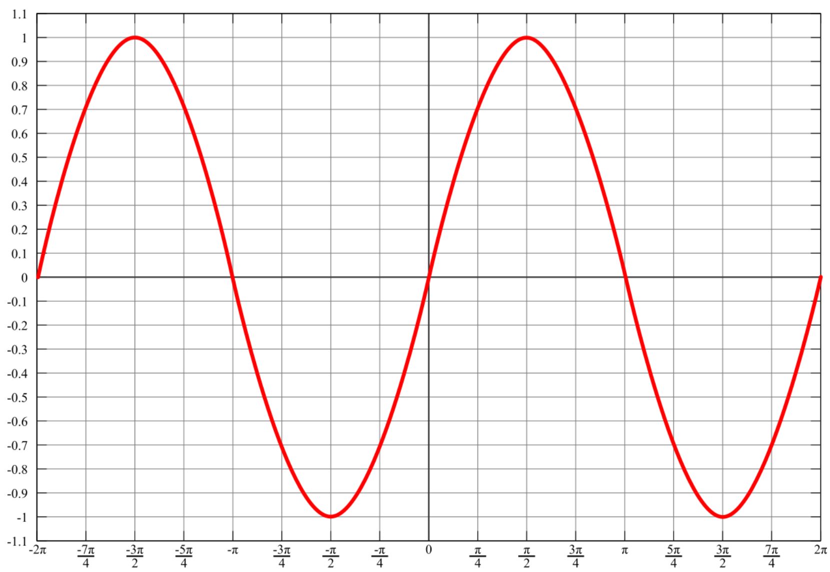
4. TEST REQUIREMENTS

By means of the test proposed below, the user will be able to confirm the correct functioning of the program.

Through these small tests, the user can verify that the results of the Matlab program correspond to the real ones. It must be taken into account that there could be a minimum error between both values due to the instruments and components used.

Test 1 - Frequency response:

To prove our results we are going to generate a sinusoid in the input with different frequencies (between 20 Hz and 20KHz). Then, with all the results obtained, we are going to unify all the amplitudes in the output doing an interpolation and observing the result.



Test 2 - Harmonic Distortion with Noise (THD + N) and Harmonic Distortion (THD):
We are going to generate a sinusoid of 1KHz and through a cable or an amplifier, see if in the output there are any harmonics in 2, 3, 4, etc… kHz or using a sinusoid of 2 KHz and see it there are any harmonics at 4 ,6 ,8, etc… kHz.
Using the following formulas we are going to see if we obtain logic values (THD<0.2%).

$$\mathrm{THD + N} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \ldots + V_n^2 + V_{noise}^2}}{V_s}$$

$$\mathrm{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \ldots + V_n^2}}{V_s}$$

V_s = Signal Amplitude (RMS Volts)
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V_{noise} = RMS value of noise over measurement bandwidth

Test 3 - Gain and Power Estimation

Using a cable we are going to see the amplitude of the signal generated in the output and prove that gain is approximately 1.

Test 4 - Intermodulation distortion (IMD):
To prove this measurement we are going to generate two signals with known frequencies, and like this, we can calculate the two frequencies generated at the output of our system due to the intermodulation product.

5. REGULATIONS

Finally, we are going to enumerate regulations[1] about our program.

1. Software products that are used by clients must have the corresponding license.
2. The clients may in no case make a copy of the software products.
3. In case a client uses our products without license may give rise to a law sanction.

1 https://www.incibe.es/sites/default/files/contenidos/dosieres/proteccion-puesto-trabajo/proteccion-puesto-trabajo-normativa-corporativa-de-software-legal.pdf

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