Signal-To-Noise Ratio in motherboards

Acknowledgement: This paper borrows some material from public domain internet website: http://www.sengpielaudio.com/TableOfSoundPressureLevels.htm

Introduction

Essential requirement for an enjoyable audio experience is a distortion-free and noise-free, dynamic reproduction of musical material. So that from quiet passages to the orchestral crescendo, all we hear is the actual music in it's unblemished form.

It would be beneficial to support the above statement with some measurable quantities, that would help to understand what factors, and to what degree affect the quality of the acoustical experience. Simplifying the approach, we could nominate three major factors: our hearing, our environment, and the audio equipment – in this case we are focusing on a computer's ability to meet certain Signal-To-Noise Ratio (SNR) requirement.

Our Hearing

We could start by saying: "loud is good". Sure, but only to a point. I would certainly hope, that my hearing ability would last me to the old days, and like it or not, I need to understand what can go wrong, if I keep carelessly cranking up the volume knob.

How loud is dangerous?
Typical dbA levels

190 dBA	Heavy weapons, 10 m behind the weapon (maximum level)
180 dBA	Toy pistol fired close to ear (maximum level)
170 dBA	Slap on the ear, fire cracker explodes on shoulder, small arms at a distance of 50 cm (maximum level)
160 dBA	Hammer stroke on brass tubing or steel plate at 1 m distance, airbag deployment very close at a distance of 30 cm (maximum level)
150 dBA	Hammer stroke in a smithy at 5 m distance (maximum level)
130 dBA	Loud hand clapping at 1 m distance (maximum level)
120 dBA	Whistle at 1 m distance, test run of a jet at 15 m distance
	Threshold of pain, above this fast-acting hearing damage in short action is possible
115 dBA	Take-off sound of planes at 10 m distance
110 dBA	Siren at 10 m distance, frequent sound level in discotheques and close to loudspeakers at rock concerts, violin close to the ear of an orchestra musicians (maximum level)
105 dBA	Chain saw at 1 m distance, banging car door at 1 m distance (maximum level), racing car at 40 m distance, possible level with music head phones
100 dBA	Frequent level with music via head phones, jack hammer at 10 m distance
95 dBA	Loud crying, hand circular saw at 1 m distance
90 dBA	Angle grinder outside at 1 m distance
	Over a duration of 40 hours a week hearing damage is possible
85 dBA	2-stroke chain-saw at 10 m distance, loud WC flush at 1 m distance
80 dBA	Very loud traffic noise of passing lorries at 7.5 m distance, high traffic on an expressway at 25 m distance
75 dBA	Passing car at 7.5 m distance, un-silenced wood shredder at 10 m distance
70 dBA	Level close to a main road by day, quiet hair dryer at 1 m distance to ear
65 dBA	**Bad risk of heart circulation disease at constant impact is possible**
60 dBA	Noisy lawn mower at 10 m distance
55 dBA	Low volume of radio or TV at 1 m distance, noisy vacuum cleaner at 10 m distance
50 dBA	Refrigerator at 1 m distance, bird twitter outside at 15 m distance
45 dBA	Noise of normal living; talking, or radio in the background
40 dBA	**Distraction when learning or concentration is possible**
35 dBA	Very quiet room fan at low speed at 1 m distance
25 dBA	Sound of breathing at 1 m distance
0 dB	Auditory threshold

One glance at the table presented above draws attention to the **115dB SPL level as the threshold of pain**.

No need to panic yet. It turns out, that we can turn the volume knob high, provided, we keep the loud passages to short durations in time – see table below. This SPL level essentially reflects THX specifications, allowing subwoofer peak SPL to reach the 115dB level. To put this SPL level in perspective, if I used a 90dB/1W/1m efficient speaker, I would need ~270W amplifier connected to it, to achieve 115dB SPL.

Seems to me, that we have just established a sensible upper limit of a dynamic range, we would hope to be achievable in home listening room.

Permissible Exposure Time Guidelines – Sound Pressure Level - SPL

How long can a person endure a certain noise level before hearing impairment occurs?

Sound Pressure Level	Sound pressure	Permissible Exposure Time
115 dB	11.2 Pa	0.46875 minutes (~30 sec)
112 dB	7.96 Pa	0.9375 minutes (~1 min)
109 dB	5.64 Pa	1.875 minutes (< 2 min)
106 dB	3.99 Pa	3.75 minutes (< 4 min)
103 dB	2.83 Pa	7.5 minutes
100 dB	2.00 Pa	15 minutes
97 dB	1.42 Pa	30 minutes
94 dB – – – – – – – – – –	1.00 Pa – – – – – –	1 hour – – – – – – – – – – – – – –
91 dB	0.71 Pa	2 hours
88 dB	0.50 Pa	4 hours
85 dB	0.36 Pa	8 hours
82 dB	0.25 Pa	16 hours

Accepted guidelines for recommended permissible exposure time for continuous time weighted average noise, according to **NIOSH-AINSI** and CDC.
For every 3 dB sound pressure level (SPL) over 85 dB, the permissible exposure time is cut in half – before damage to our hearing can occur.
NIOSH = National Institute for Occupational Safety and Health and
CDC = Centers for Disease Control and Prevention.
OSHA = Occupational Safety and Health Administration.
This may not represent a worldwide view of the subject.
Noise is an increasing public health problem and can have the following adverse health effects: hearing loss, sleep disturbances, cardiovascular and psychophysiological problems, performance reduction, annoyance responses, and adverse social behaviour.
A person feels and judges sound events by exposure time, spectral composition, temporal structure, sound level, information content and subjective mental attitude.

Our Environment

What's the opposite limit then, one may ask?. I would peg a 25dB SPL level, as the quietest level you can achieve, at night time, when external noises are at their minimum too. This would be equivalent to a background in a TV studio – see Table of Sound Levels below.

Table of sound levels L (loudness) and corresponding sound pressure and sound intensity			
Sound Sources (Noise) Examples with distance	Sound Pressure Level L_p dB SPL	Sound Pressure p N/m^2 = Pa sound field quantity	Sound Intensity I W/m^2 sound energy quantity
Jet aircraft, 50 m away	140	200	100
Threshold of pain	130	63.2	10
Threshold of discomfort	120	20	1
Chainsaw, 1 m distance	110	6.3	0.1
Disco, 1 m from speaker	100	2	0.01
Diesel truck, 10 m away	90	0.6	[illegible]
Kerbside of busy road, 5 m	80	0.2	[illegible]
Vacuum cleaner, distance 1 m	70	0.0	[illegible]
Conversational speech, 1 m	60	0.02	[illegible]
Average home	50	0.0063	0.0000001
Quiet library	40	0.002	0.00000001
Quiet bedroom at night	30	0.00063	0.000000001
Background in TV studio	20	0.0002	0.0000000001
Rustling leaves in the distance	10	0.000063	0.00000000001
Threshold of hearing	0	0.00002	0.000000000001

115dB - 25dB = 90dB
This is achievable
Dynamic Range in a
theoretical home

Comparing the "threshold of pain" level with "quiescent noise at night" level, we conclude, that the all-important dynamic range window provided by a theoretical home environment is **approx. 90dB.** Interestingly, 96dB dynamic range is a theoretical limit of a CD (16bit/44.1kHz) technology.

It may be possible to achieve a very low level of noise in a household by using double-glazed windows, extra insulation in the walls/floors/ceiling, turning off fridges and other electrical appliances with fans/motors/switching power supplies in them. Perhaps applying all these extra precautions would bring the background household noise to the level comparable with a TV studio.

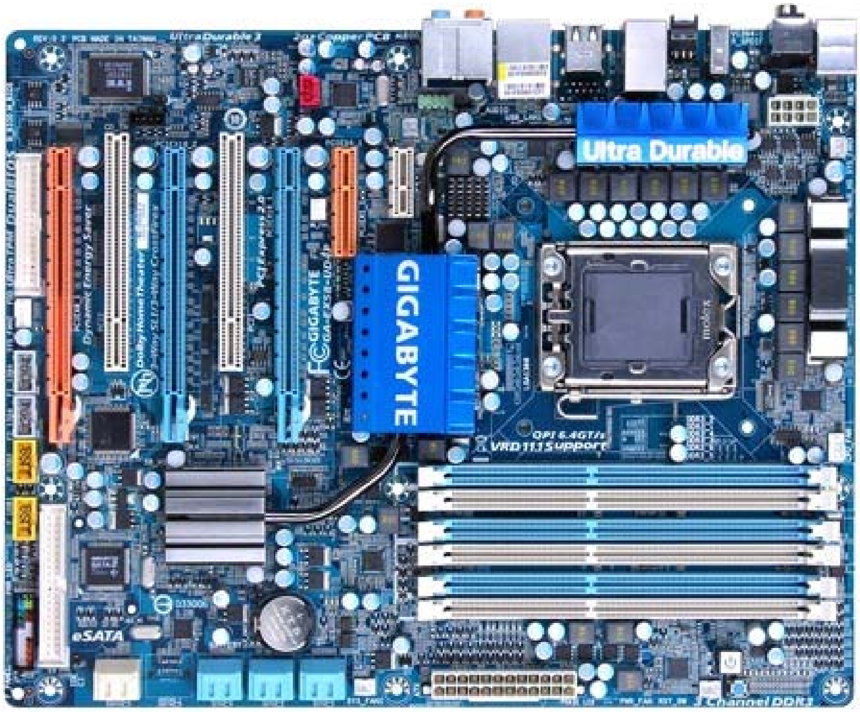
What happens if you try to play sounds, that are quieter than 25dB "quiescent noise"?. Well, depends on exactly what type sounds you try to play, and exactly what type of quiescent noise is present, but generally, it'll become increasingly difficult to pick up the sounds. Not to mention, that the experience of enjoyable listening has deteriorated to sheer struggle. Still, it would be desirable, that our audio equipment provided some margin (6-10dB for example) over the 90dB window dynamics achievable in our theoretical home environment.

This is where we need to examine the performance level of a PC equipped with an internal sound card or a PCI-style sound card.

SNR of a typical, contemporary PC

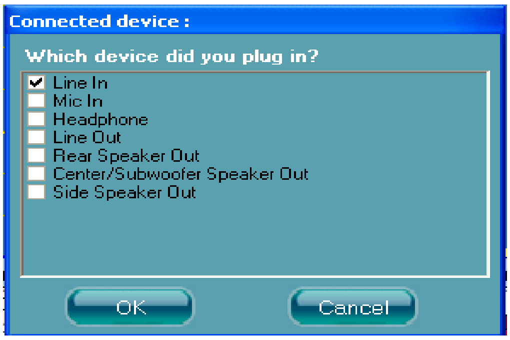
This test can be easily performed by any SoundEasy owner. I run this test on a computer with an internal (motherboard) sound device with ALC889A HD codec. To make things really difficult and revealing more broadband S/N performance, I run this test without the A-weighting filter.

The internal sound card is looped-back for audio – the line output is connected back to line input. Then the Spectrum Analyser is run simultaneously as a Generator and Analyser. The generator section generates 1000Hz tone, which is looped back to the Analyser input, all with 24-bit depth. This way, I tested both processes: DAC on the Generator side, and ADC on the Analyser side. Yes, I introduced **two conversions at the same time**, which is the worst-case scenario from signal quality point of view. The motherboard is Gigabyte GA-EX58-UD4P, socket LGA1366.
http://www.gigabyte.com.au/products/product-page.aspx?pid=2986#sp



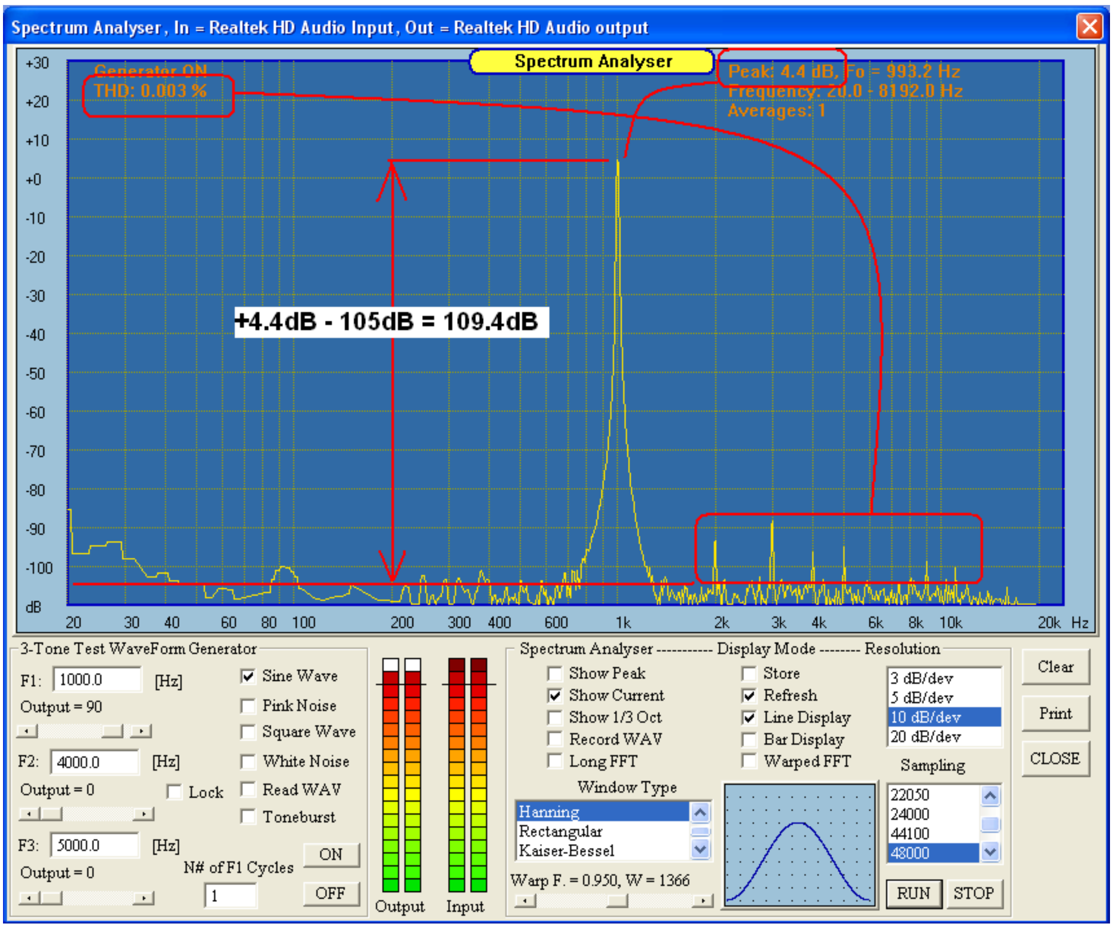
Playback and Record level settings for 2-speaker codec configuration. Obviously, for SNR measurements, I need to make sure, that my sine wave generator plays maximum undistorted output level.

Here is the connection on the back panel.



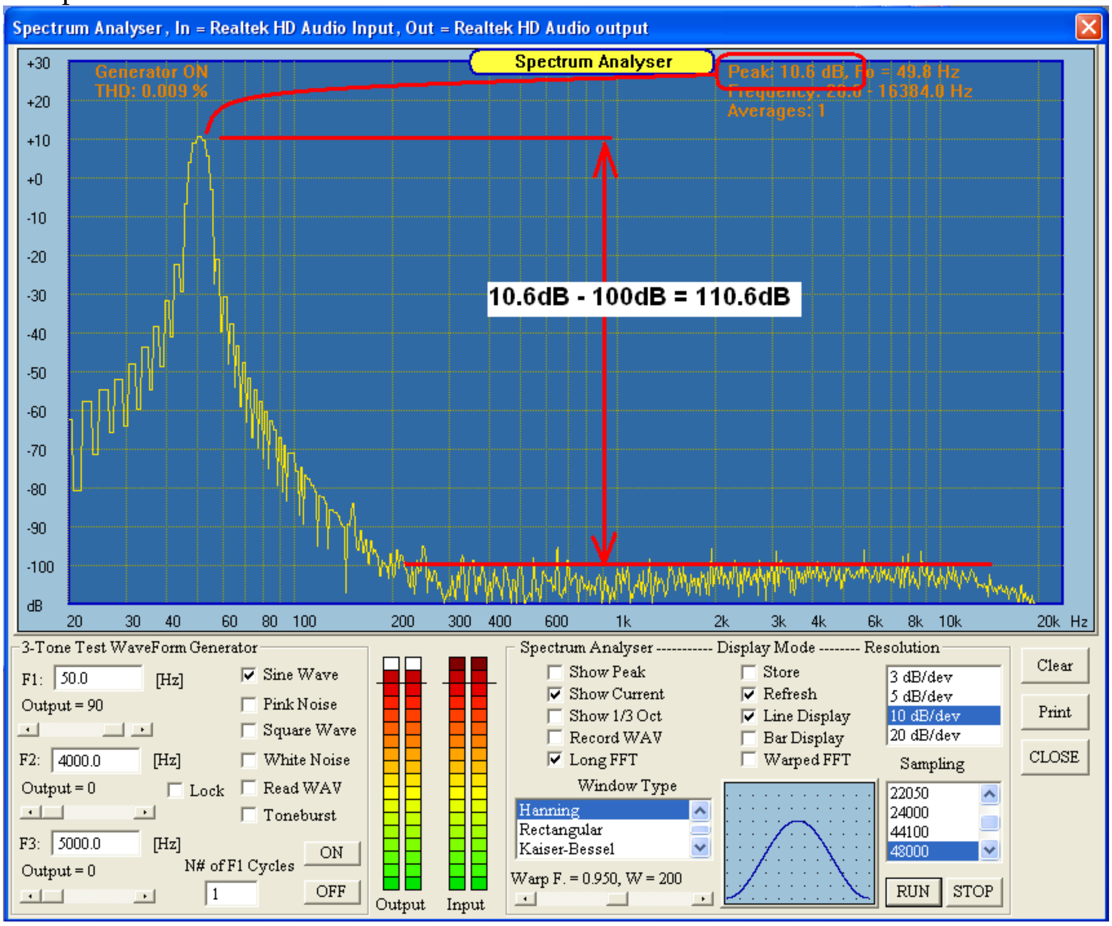
And the Signal-to-Noise result? – as shown on the SoundEasy screen shot below, the result is actually surprisingly good. The unweighted SNR figure comes above 109dB from 40Hz-24kHz.

Adding the typically required A-weighting filter, would completely remove low-frequency low-level noise below 40Hz, extending the SNR performance figure of the sound card to full audio bandwidth.

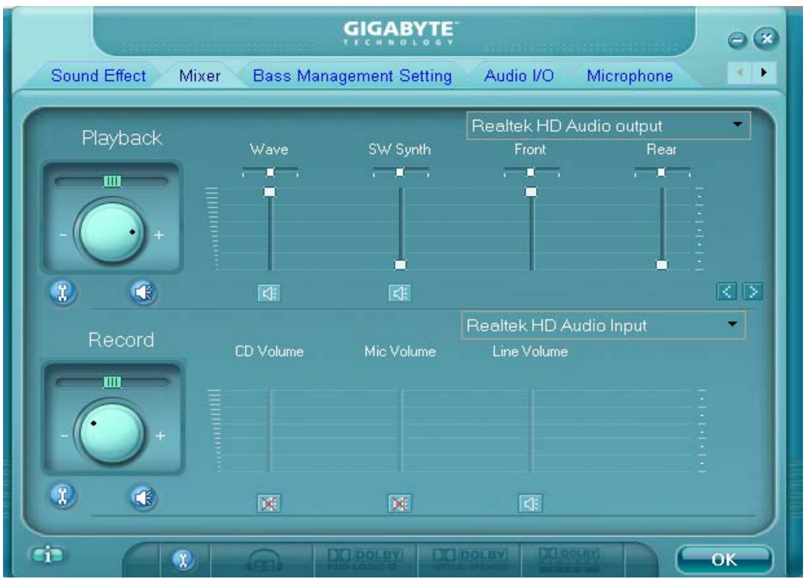


This motherboard compares very favourably with a typical CD-player for SNR performance and THD performance.

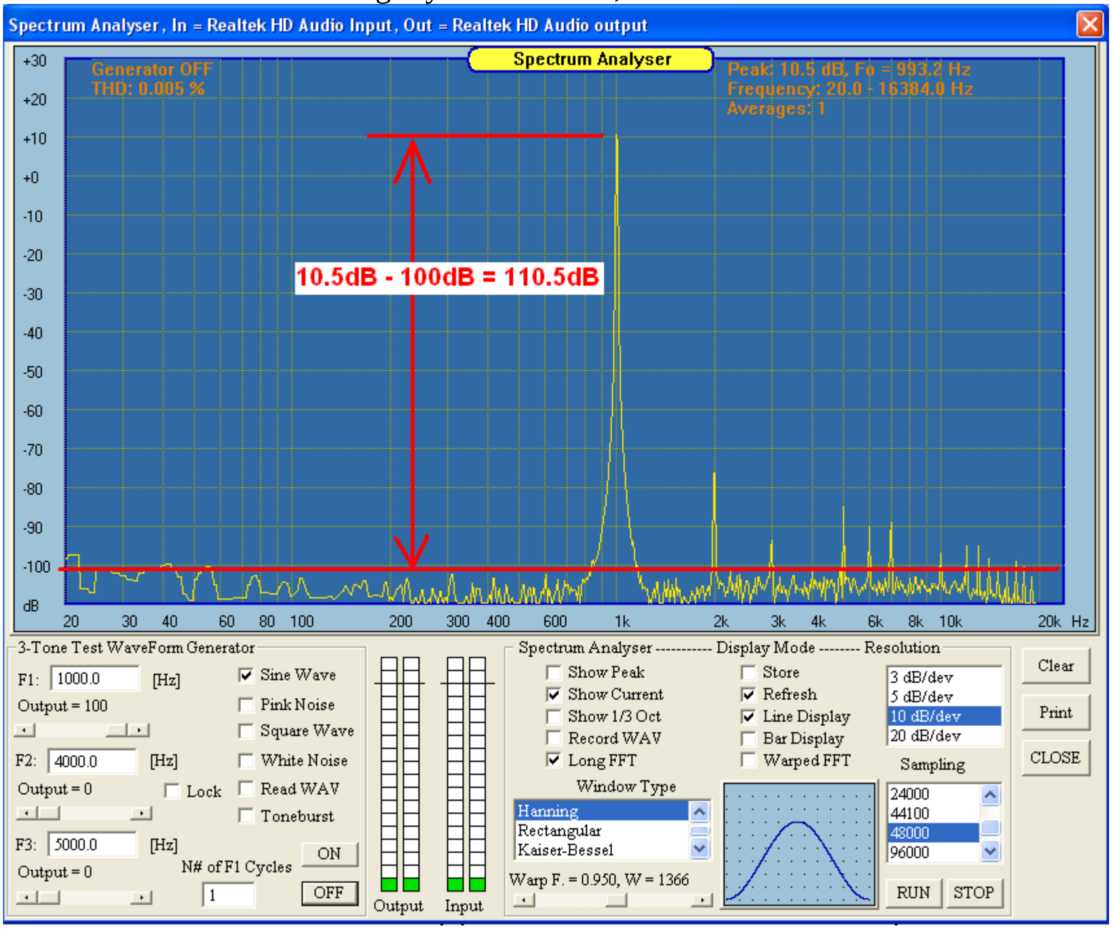
Here is another SNR = 110.6dB for a 50Hz signal and a “Long FFT” setting – again, exceptional result.



If you are prepared to optimize Playback and Record gain settings – see below,



You will be able to obtain slightly better results, like this one:



It is noticeable, that all three spectrograms presented above, display total absence of 50/60Hz hum. This is understandable, as the audio link runs only from output to input of the same device. Therefore significant ground loop is not able to develop. One would need to pay attention when connecting an external CD player, DVD player, PayTV decoder and so on… so that undesirable ground loops would not develop and deteriorate SNR.

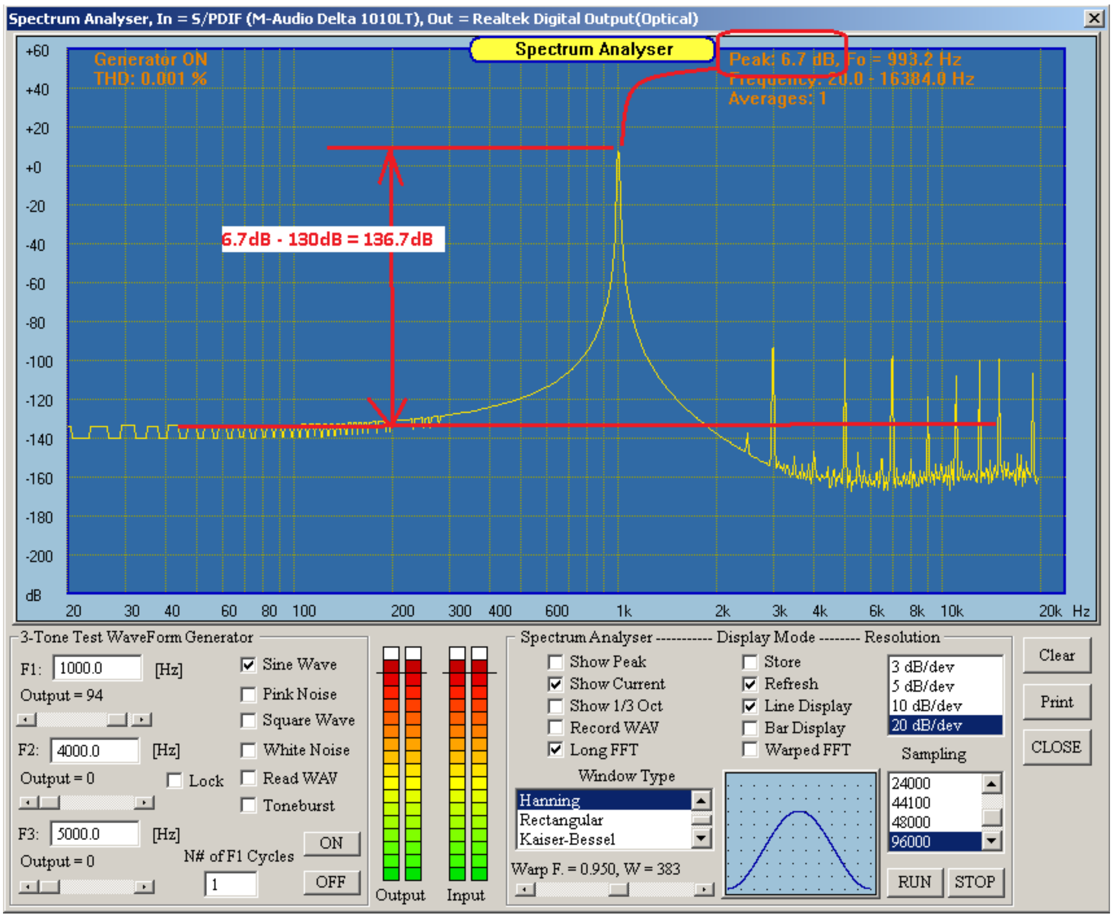
How come the computers become so good in audio performance?.

A good answer can be found on PE board Techtalk:
http://techtalk.parts-express.com/showthread.php?233726-Need-a-summarized-lesson-on-digital-audio-and-DACs

"…..Now, because of the advent of WHQL (Windows Hardware Quality Labs, requirements placed on ALL PC manufacturers), audio in a modern PC has been significantly improved over the last 5 years. Today's PC Audio Codecs (codec = DAC + ADC + DSP in one chip) have significantly better fidelity that even most USB based cards or even those Creative add-in cards. However, you won't see Creative advertising that point. The PC Audio codecs from IDT (forerly Sigmatel), Realtek, and Conexant (formerly Analog Devices) easily approach >100dB SNR, >94dB Dynamic Range, and better than 0.01% THD+N across the spectrum 20Hz-20KHz. These numbers are phenomenal, especially given the improvement over such a short timeframe….."

SNR in SPDIF connection

Unfortunately, I was unable to conduct apple-to-apple measurement of SNR in SPDIF mode. This is because the motherboard does not have SPDIF input. The next best thing was to connect SPDIF of the motherboard output to SPDIF of Delta1010LT input and run the spectrum analyser. Here is the result with 20dB/div SPL scale setting and 96kHz sampling rate.

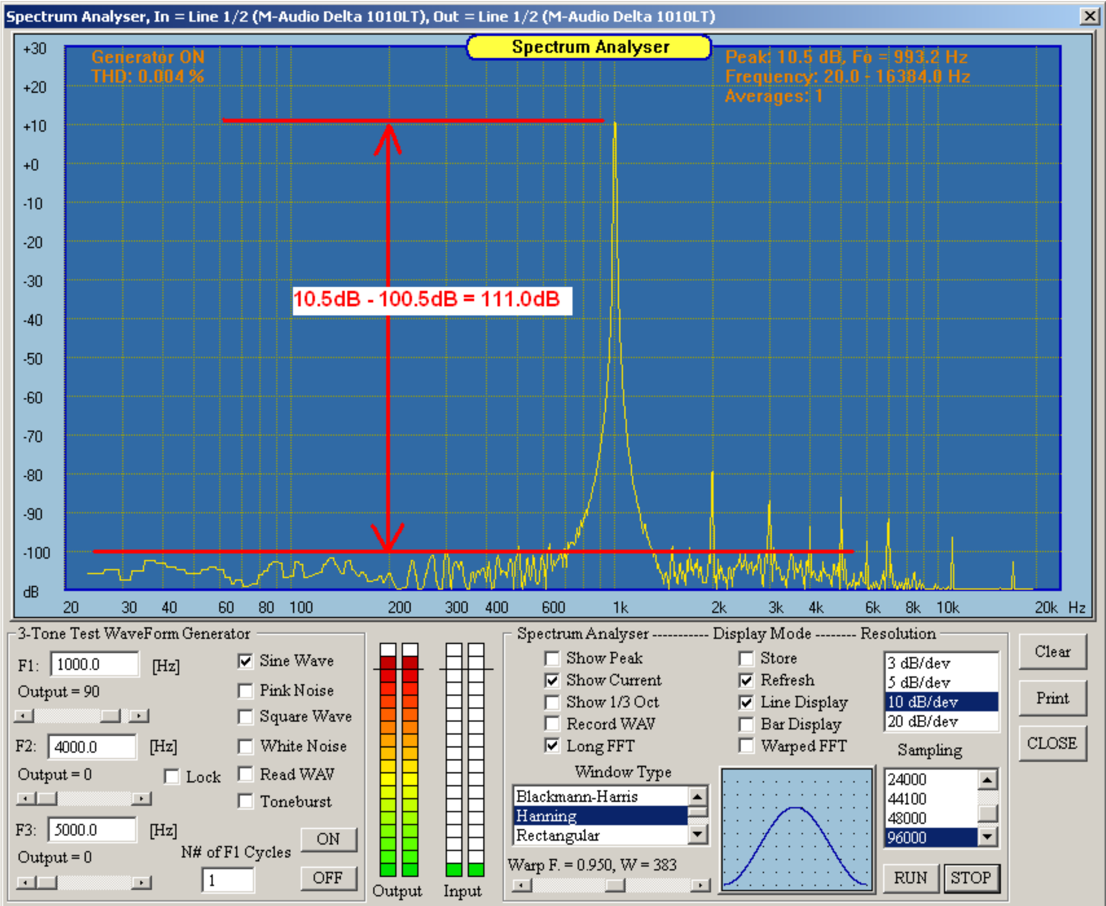


It looks asymmetrical, and on the low-side the SNR is estimated to be 136dB. On the high-side, it seems to be around 155dB.

SNR of Delta1010LT analogue connection

Just to complete this brief discussion on SNR levels encountered in a contemporary PC, I have measured Delta1010LT sound card using the same method as previous tests, and obviously with analogue link between input and output of the Delta1010LT card. Sampling rate was set to 96kHz.

The result is very similar to the motherboard test, and is 111.0dBfor THD of 0.004% – see picture below.



Delta1010LT SNR test

Technical information about on-board Realtek codecs

http://www.hardwaresecrets.com/article/Audio-Codec-Comparison-Table/520/2.

It is evident from the table below, that motherboard audio: ALC889 (released in 2008) or ALC898 (released in 2011) exemplify what becomes a norm in contemporary PC.

I can confirm, that the ALC889 actually measures very well, when input and outputs are driven to full capabilities – see measurements above.

Another implementation example is the http://www.asrock.com/mb/Intel/X79%20Extreme3/ is LGA 2011 Socket and has ALC898 codec and 2 PCI slots.

Model	Channels	Input Resolution	Output Resolution	Input Max. Sampling Rate	Output Max. Sampling Rate	Input SNR	Output SNR
ALC101	2	16-bit	16-bit	48 kHz	48 kHz	70 dB	75 dB
ALC202	2	18-bit	20-bit	48 kHz	96 kHz	85 dB	90 dB
ALC203	2	18-bit	20-bit	48 kHz	96 kHz	90 dB	100 dB
ALC250	2	18-bit	20-bit	48 kHz	96 kHz	92 dB	100 dB
ALC260	2	20-bit	24-bit	96 kHz	192 kHz	90 dB	95 dB
ALC262	4	20-bit	24-bit	96 kHz	192 kHz	90 dB	100 dB
ALC268	4	20-bit	24-bit	96 kHz	192 kHz	90 dB	95 dB
ALC269	4	24-bit	24-bit	96 kHz	192 kHz	98 dB	98 dB
ALC650	5.1	18-bit	20-bit	48 kHz	96 kHz	85 dB	90 dB
ALC655	5.1	16-bit	16-bit	48 kHz	48 kHz	86 dB	86 dB
ALC658	5.1	18-bit	20-bit	48 kHz	96 kHz	92 dB	96 dB
ALC662	5.1	20-bit	24-bit	96 kHz	96 kHz	90 dB	98 dB
ALC850	7.1	16-bit	16-bit	48 kHz	48 kHz	86 dB	92 dB
ALC861	7.1	16-bit	24-bit	96 kHz	96 kHz	82 dB	90 dB
ALC861-VD-GR	7.1	24-bit	24-bit	96 kHz	96 kHz	85 dB	95 dB
ALC880	7.1	20-bit	24-bit	96 kHz	192 kHz	85 dB	100 dB
ALC880D	7.1	20-bit	24-bit	96 KHz	192 KHz	85 dB	100 dB
ALC882	7.1+2	20-bit	24-bit	96 kHz	192 kHz	90 dB	101 dB
ALC883	7.1+2	24-bit	24-bit	96 kHz	192 kHz	85 dB	95 dB
ALC885	7.1+2	24-bit	24-bit	192 kHz	192 kHz	101 dB	106 dB
ALC887	7.1	24-bit	24-bit	192 KHz	192 KHz	90 dB	97 dB
ALC888	7.1+2	24-bit	24-bit	96 kHz	192 kHz	90 dB	97 dB
ALC888S	7.1+2	20-bit	24-bit	96 kHz	192 kHz	90 dB	97 dB
ALC888DD	7.1+2	24-bit	24-bit	96 kHz	192 kHz	90 dB	97 dB
ALC888S-VC	7.1+2	24-bit	24-bit	192 KHz	192 KHz	90 dB	97 dB
ALC888-VC2-GR	7.1+2	24-bit	24-bit	192 KHz	192 KHz	90 dB	97 dB
ALC888S-VD	7.1+2	24-bit	24-bit	192 KHz	192 KHz	90 dB	97 dB
ALC889	7.1+2	24-bit	24-bit	192 kHz	192 kHz	104 dB	108 dB
ALC892	7.1+2	24-bit	24-bit	192 KHz	192 KHz	90 dB	97 dB
ALC898	7.1+2	24-bit	24-bit	192 kHz	192 kHz	104 dB	110 dB

Conclusions

Having briefly considered human hearing ability and practicality of a household listening environment, we concluded, that given some effort, our acoustical environment may be able to achieve a 90dB dynamic window into which we attempt to play our music.

In terms of equipment, namely the PC motherboard, the available SNR is around 110dB. In this particular example, the equipment noise is 20dB below the quietest environmental noise. This level of performance is on par with a good quality audio equipment and easily qualifies this particular PC to become an audio server – the source of high quality music in home audio chain.

Thank you for reading.

Bohdan