Audio CODEC testing using A-weighting digital filter

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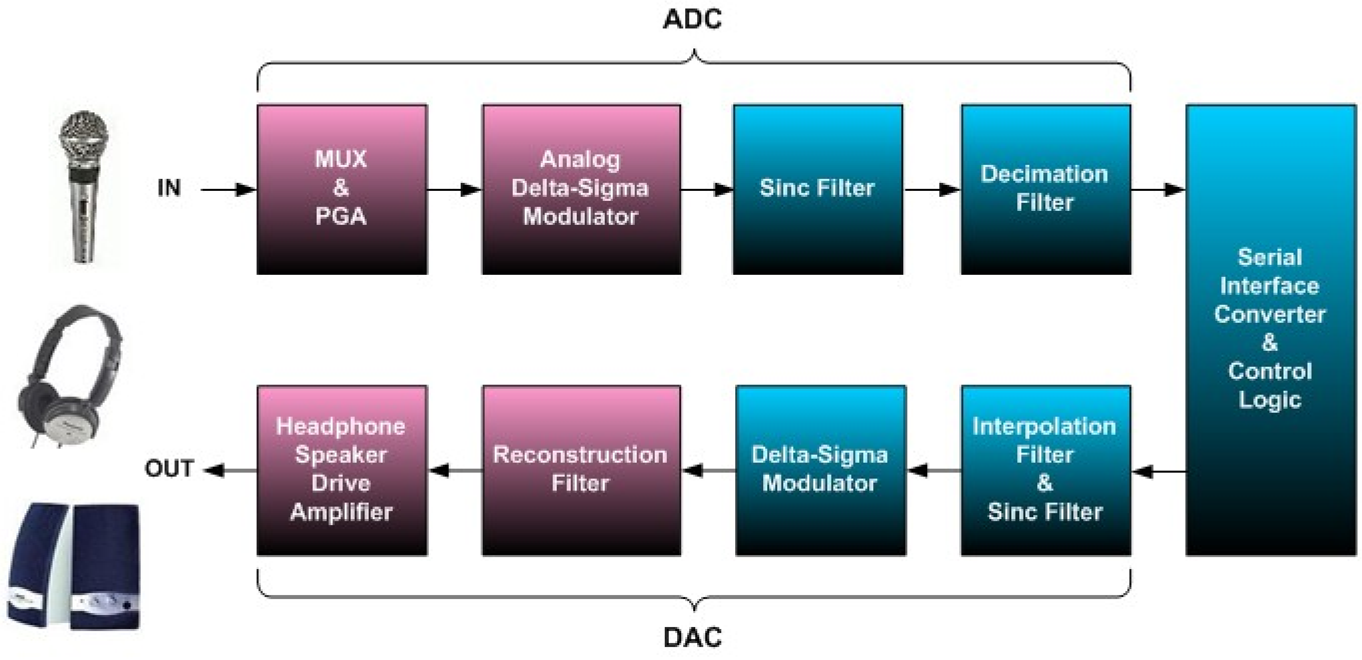
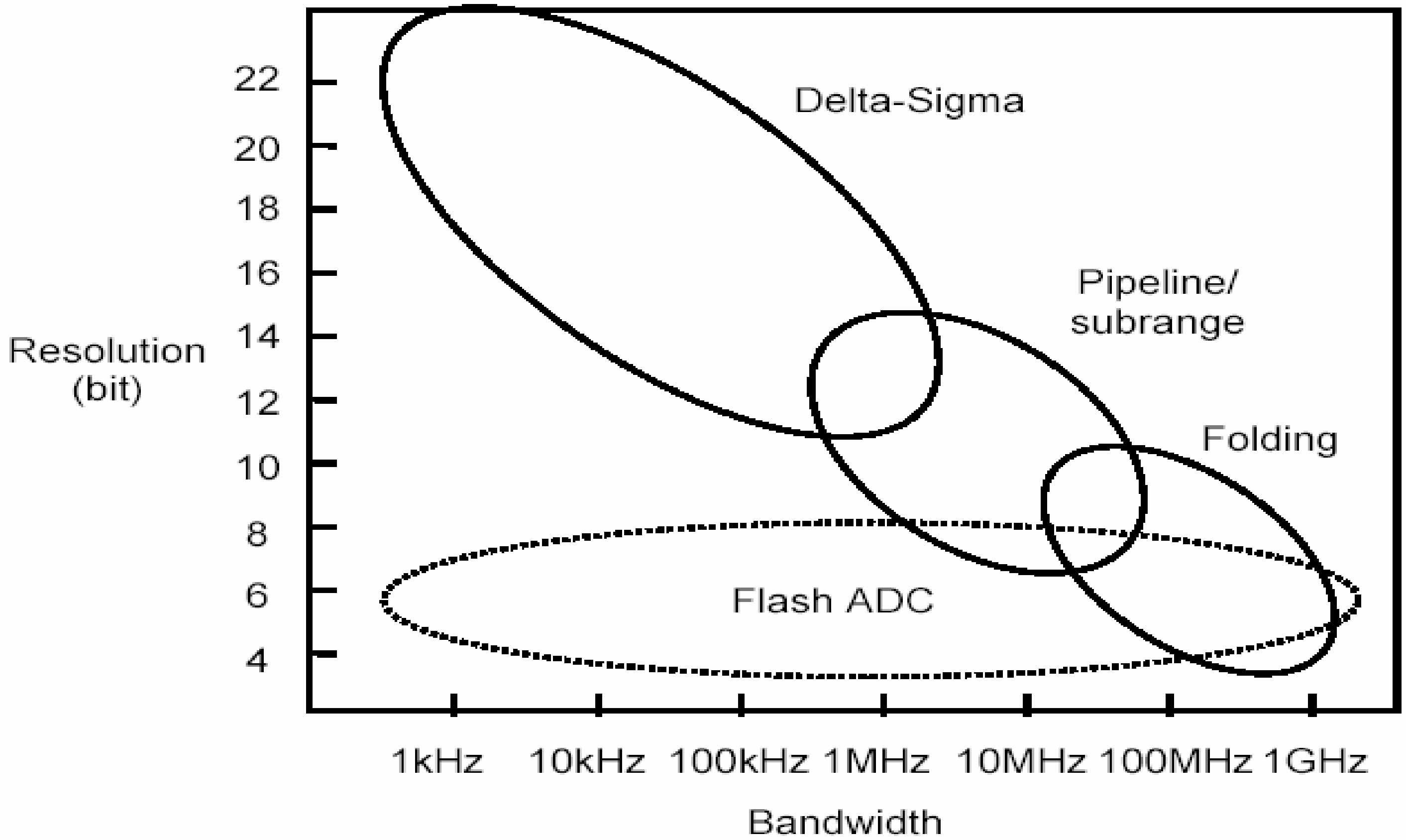
Audio CODEC



- Audio CODEC is a widely used IP in the mobile world.
  - ► Digital convergence consumer electronics such as MP3, cellular phone, PDA, PMP, digital camera...

Audio CODEC bandwidth



Test items

- DAC path

  i) SNR(48K/96K192K) → A-weighted

  ii) Dynamic range (DR) → A-weighted

  iii) THD

  iv) Cross talk

  v) etc.

- ADC path

  i) SNR(48K/96K) → A-weighted

  ii) THD

  iii) Cross talk

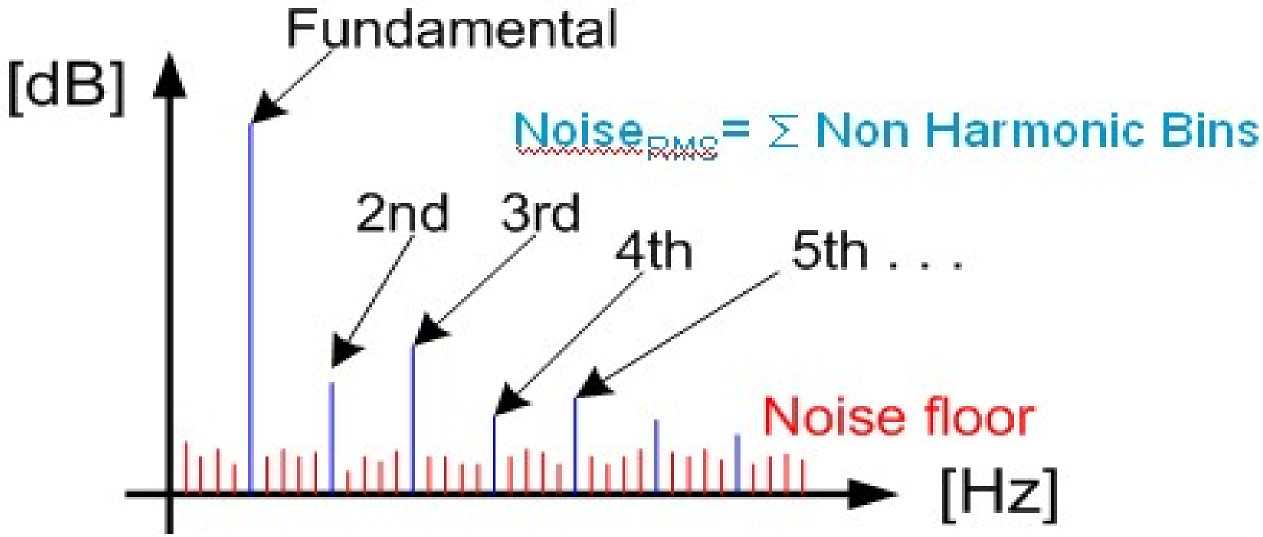
  iv) etc.

"Wolfson datasheet"

Signal to noise ratio

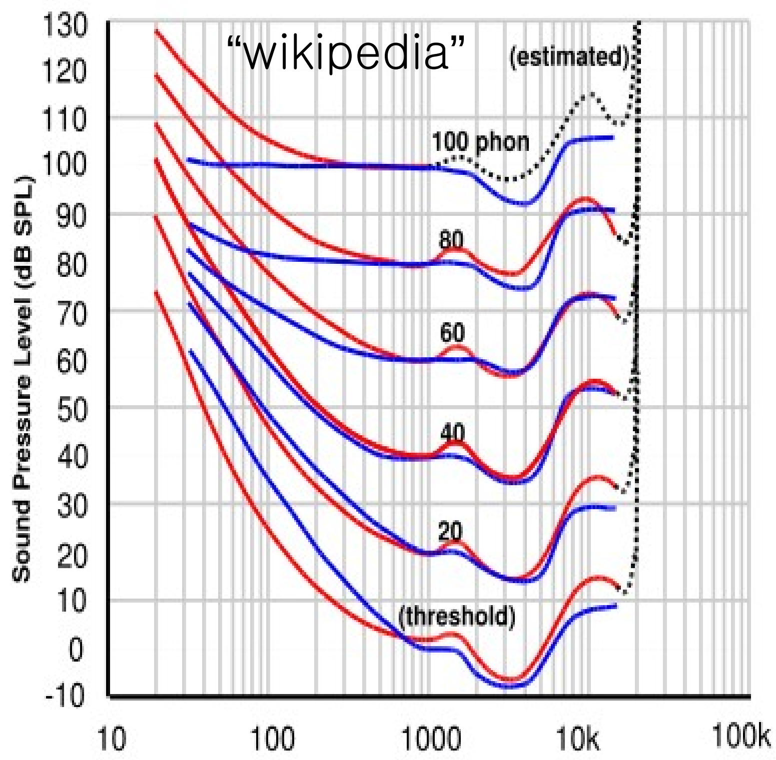
$$SNR = 20\log\frac{\sqrt{\sum v_i^{\,2}}}{\sqrt{v_{fund}^{\,2}}}$$

$$THD = 20\log\frac{\sqrt{\sum (v_1^{\,2} + v_2^{\,2} \cdots + v_n^{\,2})}}{\sqrt{v_{fund}^{\,2}}}$$



Equal loudness contour

- The A-Weighting function has been based on Fletcher-Munson curves.



Equal-loudness contours (red) (from ISO 226 :2003 revision)
Fletcher- Munson curves shown (blue) for comparison

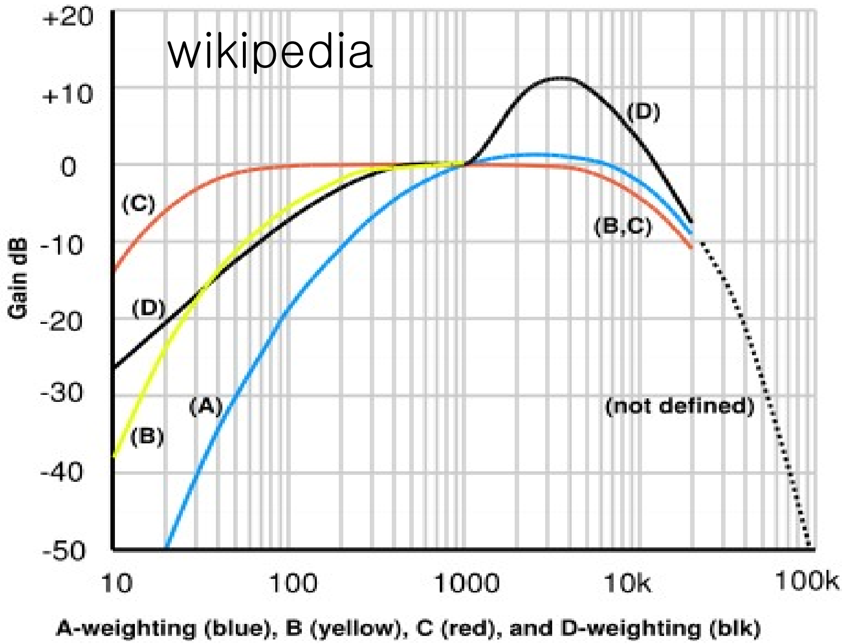
- Measure of sound pressure, for which a listener perceives a constant loudness over the frequency spectrum.

- First measured by Fletcher and Munson using headphones, called "Fletcher-Munson curves"

* The phon : perceived loudness level for pure tones
* 1 phon is 1 dB SPL at a frequency of 1 kHz.
* sound pressure (dB SPL),

Common weightings

- The A–weighting emphasizes frequencies around 3~6 kHz where the human ear is most sensitive.



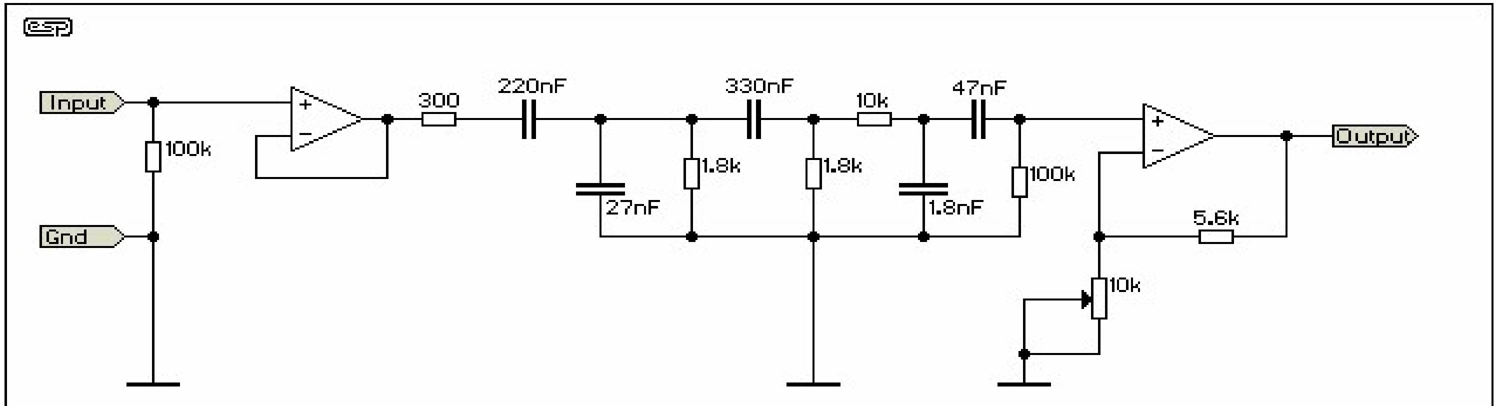
- Weighting filters
  A → pure tone
  B,C → louder sound
  D → air craft noise

A–weighting filter transfer function

$$H(s)=\frac{4\pi^2 12200^2 s^4}{(s+2\pi 20.6)^2(s+2\pi 12200)^2(s+2\pi 107.7)(s+2\pi 738)}$$

Circuit and measurement unit

- Simple A-weighting circuit requires premium op amps, accurate passive elements and calibration for low noise levels.



"Rod Elliott – ESP"

Audio precision

- Audio precision is used for a standard measurement unit in the audio world.

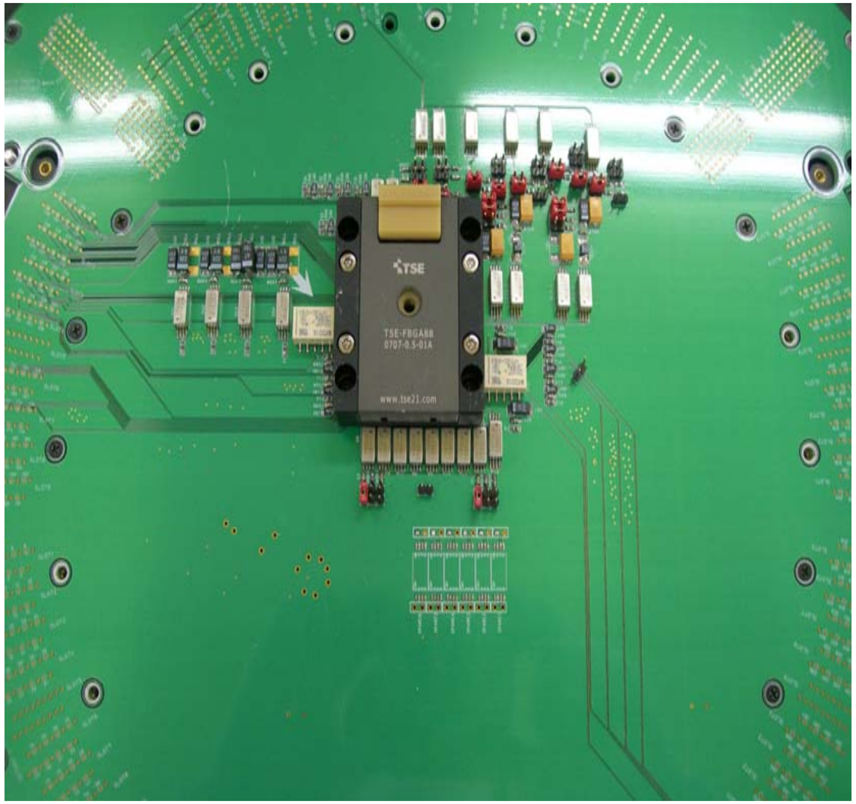
Problem

- The A-weighting function is not supported in the ATE.
- An analog filter is necessary for DAC path.
  → Premium op amps, accurate passive elements and filter calibration.
  → High resolution signal filtering should be tuned well.
- A digital filter is necessary for ADC path weighting function.
- A space problem is expected in the multi site SOC test board.
- Analog filter calibration & correlation should be considered in the multi site.

→ Lots of job are required to use the A-weighting function.

Test board

Well-tuned board is a prerequisite for the high resolution signal interface.

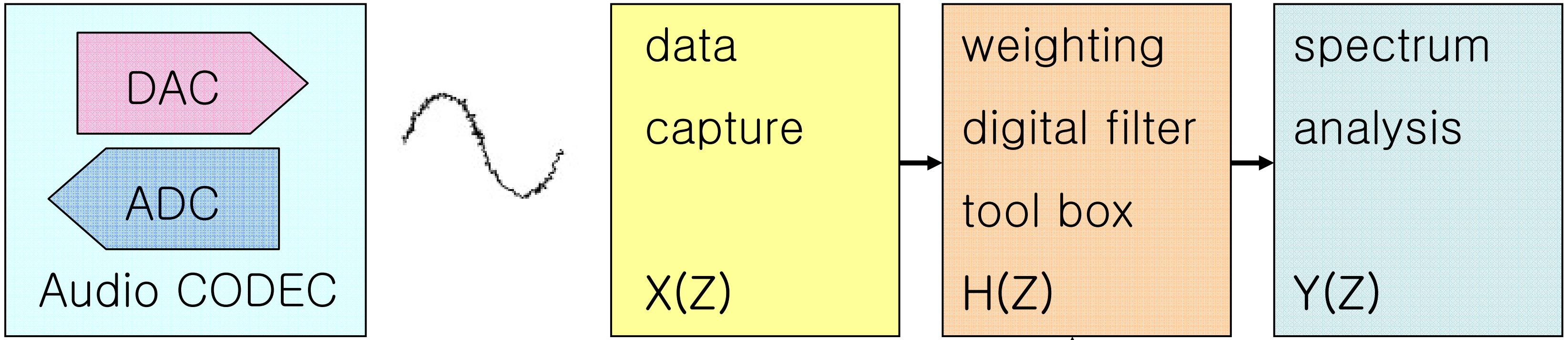


Layout rule of thumb.

1. Analog and digital ground should be zero impedance connection.
2. Digital signal should not cross over analog signal and reference.
3. Decoupling capacitors should be as close as possible to IC.
4. etc...

Test configuration

- Audio CODEC signal is captured based on the coherent sampling.
- The captured signal is processed using a digital filter tool box.
- The processed signal is analyzed and calculated.



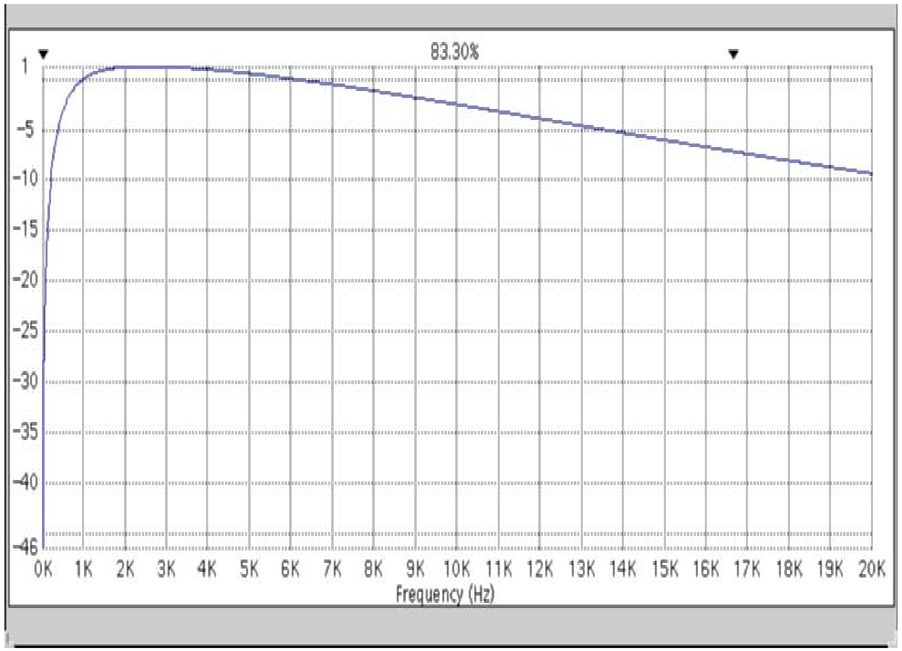
Y(Z)=H(Z)X(Z)

The test condition is considered to optimize the filter value and the captured signal.

Filter generation

- The A-weighting filter is made using the below transfer function.

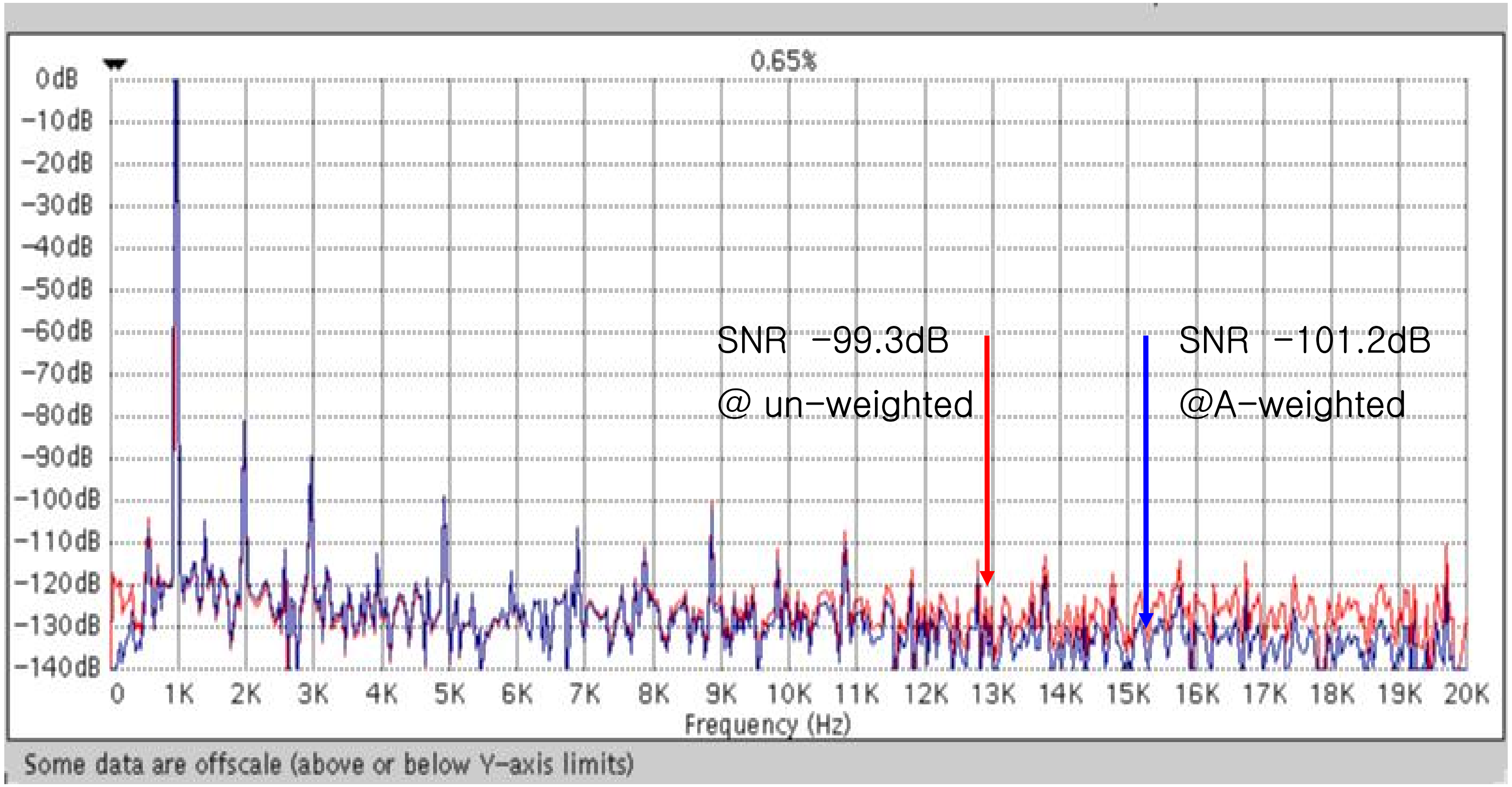
$$H(s) = \frac{4\pi^2 12200^2 s^4}{(s+2\pi 20.6)^2 (s+2\pi 12200)^2 (s+2\pi 107.7)(s+2\pi 738)}$$



Frequency (Hz)	A- weighting (dB)	Frequency (Hz)	A- weighting (dB)
20	-50.5	1600	1
40	-34.6	2000	1.2
80	-22.5	2500	1.3
100	-19.1	4000	1
160	-13.4	5000	0.5
200	-10.9	8000	-1.1
400	-4.8	10000	-2.5
500	-3.2	12500	-4.3
800	-0.8	16000	-6.6
1000	0	20000	-9.3

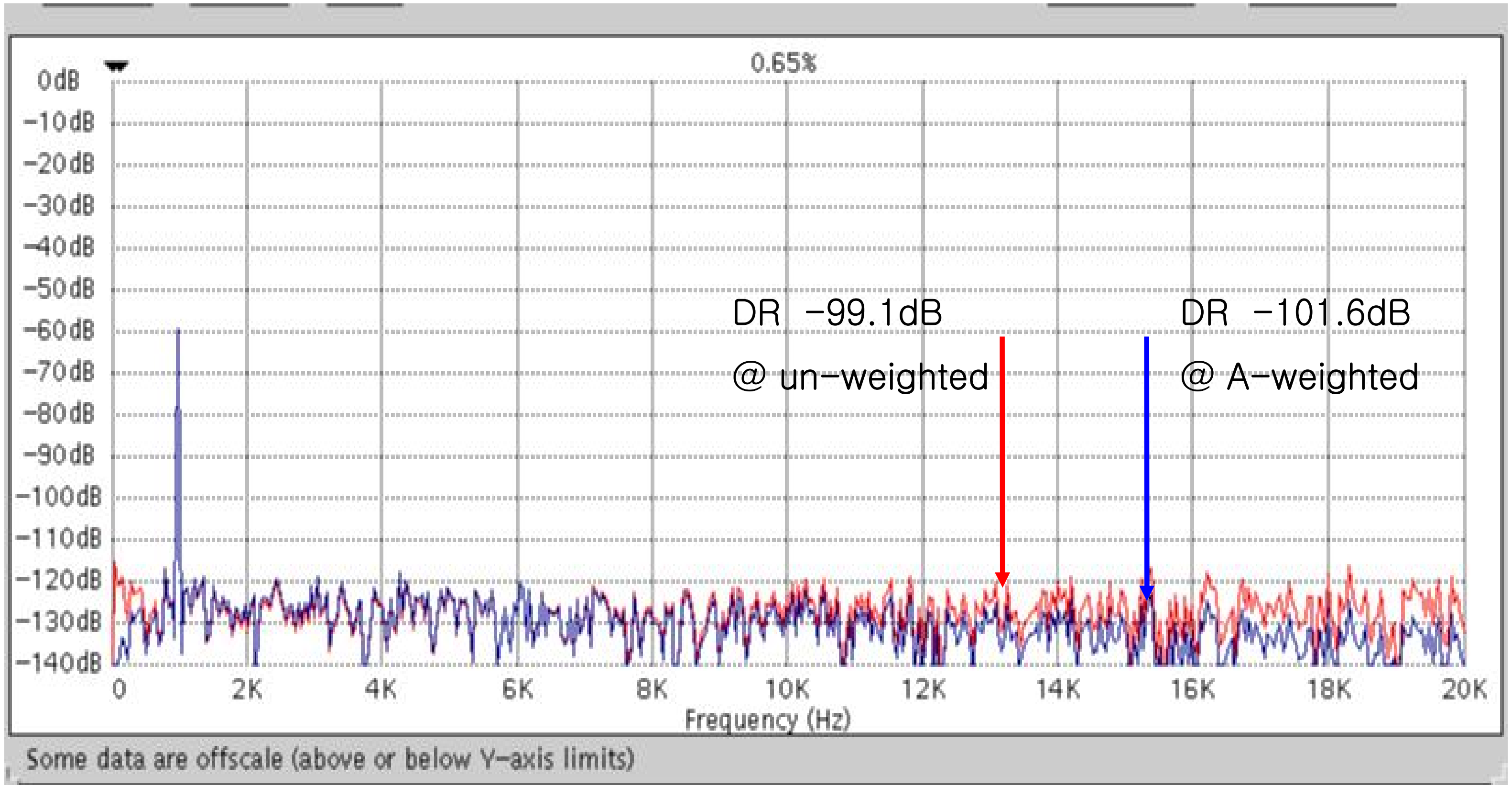
Result (I) : SNR/ICN

- A-weighted spectrum shows that noise floor follows the human ear model.
- Lab testing result is 102.7dB in the A-weighted condition and 100.5dB in the un-weighted condition.



Result (II) : Dynamic range

- Dynamic range spectrum also shows the A-weighting is matched well.
- Lab testing result is 102.5dB in the A-weighted condition.



Conclusion

- Software filtering but matched well with the lab test result.
- Frequency response optimization to the test condition.
- Easy data comparison between filtered and unfiltered data.
- No characteristic variation in the environmental influence such as temperature variation, voltage variation.
- No hardware burden.
  i) No space burden in the multi site test .
  ii) No filter calibration and correlation in the multi site test .
- The human ear model is applied and estimated in the ATE