Audio Measurements Workshop (part 2)

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1 Overview

- Theory.
  - * No theory today. See slides of part 1.
- Quick intro to some tools
  - * jaaa, jnoisemeter
  - * python, numpy, scipy, pyaudiotools
  - * matplotlib, pyqtgraphics
- Howto measure
  - * Noise levels, S/N ratio
  - * Frequency response
  - * Harmonic distortion
  - * Intermodulation distortion
- Practice as we go along.

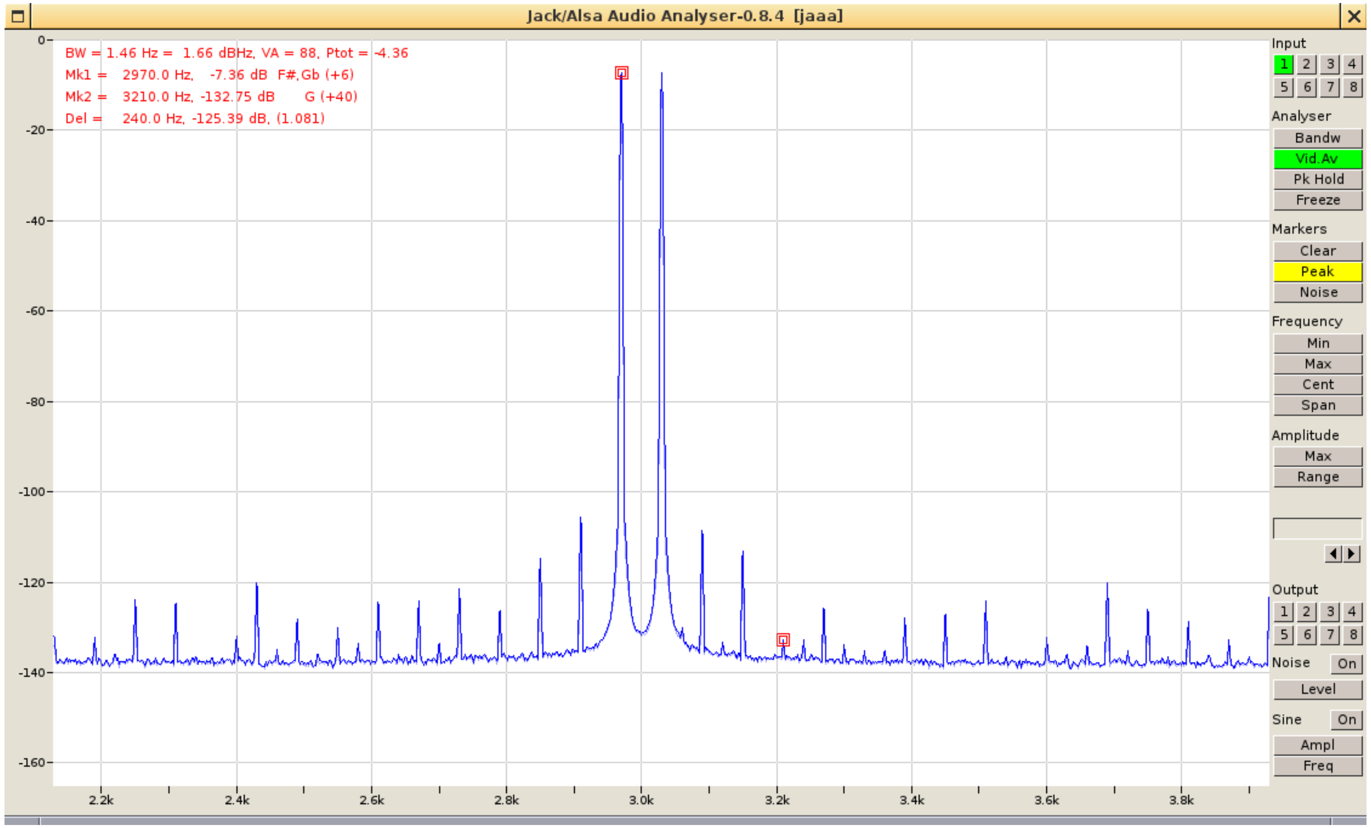
2 Philosofical issues (again)

- Why measure things ?
  - * Verify your design and programming.
  - * Have you been ripped off ?
  - * To know limits and create a level of confidence.
  - * Curiosity.

- Always expect the unexpected. It happens. If your measurements are exactly as you imagined they would be, then
  - * Congratulations !
  - * It's time to verify things and ask some questions.

- It's very easy to overlook things and get completely wrong results.
  - – Always double check and ask yourself 'can this be true', and if yes, how ?

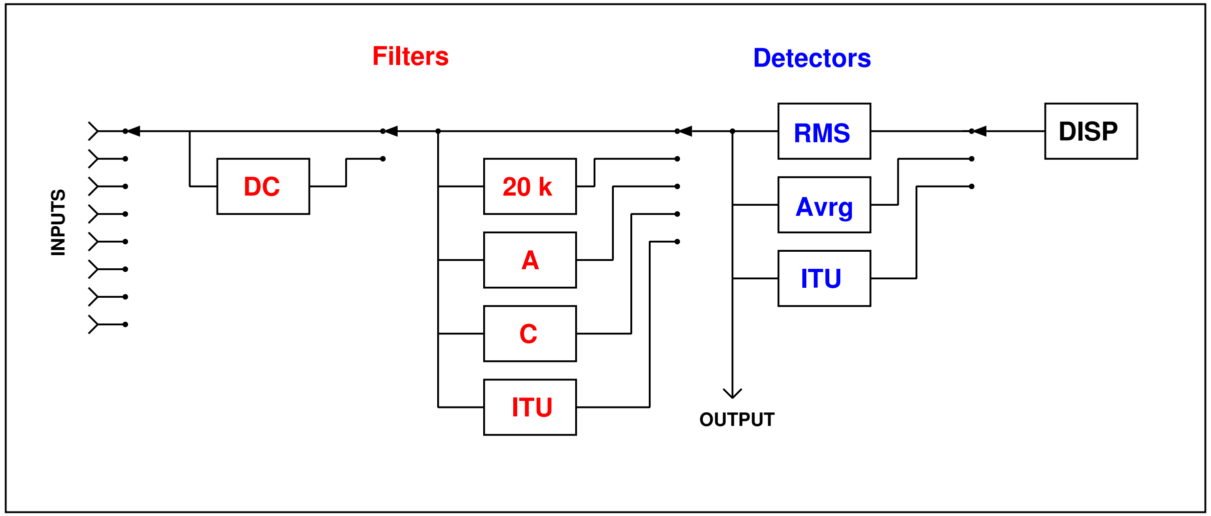
3 Jaaa

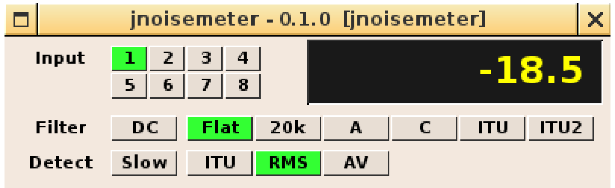


```
BW = 1.46 Hz =  1.66 dBHz, VA = 88, Ptot = -4.36
Mk1 =   2970.0 Hz,   -7.36 dB  F#,Gb (+6)
Mk2 =   3210.0 Hz, -132.75 dB      G (+40)
Del =    240.0 Hz, -125.39 dB, (1.081)
```

- Technical spectrum analyser.
- Accurately measure sine waves in noise and noise density.

Jnoisemeter




jnoisemeter - 0.1.0 [jnoisemeter]

Input 1 2 3 4 5 6 7 8 — selected: 1

-18.5

Filter DC Flat 20k A C ITU ITU2 — selected: Flat

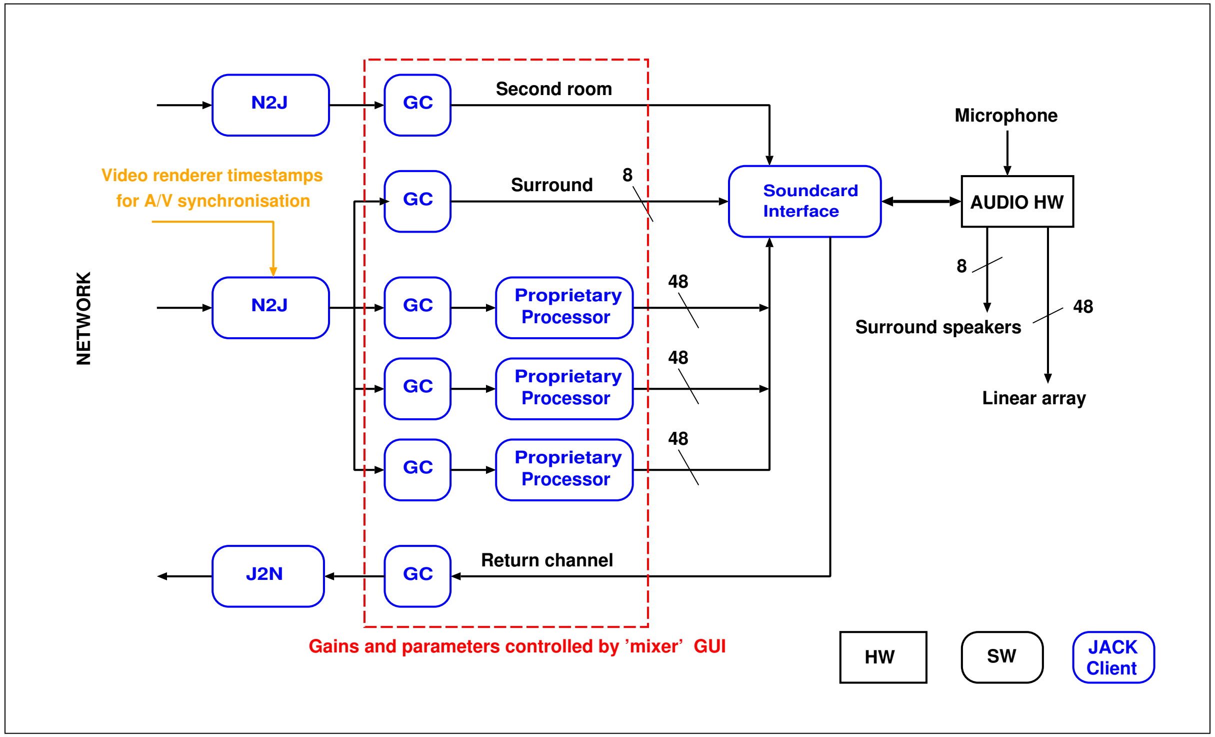
Detect Slow ITU RMS AV — selected: RMS

- Measure noise according to various standards.
- Filtered signal available at output.

5 Python and friends

- python : interpreted OO language, many extensions.
  - numpy : efficient calculations on arrays of any dimension.
  - scipy : scientific computation
  - matplotlib, pyqtgraph : 2d and 3d plotting.
  - pyqt : Qt bindings to python, much easier to use than plain Qt.
- pyaudiotools : collection of python classes for audio.
  - AudioFile : read/write audio files to/from numpy arrays.
  - JackSignal : Jack client, generate and capture arbitrary test signals from/to numpy arrays.
  - Vresampler : Resampling of numpy arrays.
  - Others not directly targeted at measurement.
- Combining all these makes it easy to create ad-hoc automated measuring tools of any comlexity.

6 Other uses of pyaudiotools : quickly build complex audio systems



- All Jack modules are python classes.
- All parameters controlled by PyQt Gui.
- Complete system runs on Linux, OSX and Windows.

7 Matplotlib

- Versatile python library for 2d and 3d plotting, actively developed.

- Some combined DSP/plotting code inherited from early releases, better ignore this. Current development concentrates on plotting only.

- Requires some getting used to, mainly because there are 3 APIs and these get mixed up in documentation and example code.
  - pylab : high level, stateful, MatLab style one-liners. DEPRECATED
  - pyplot : medium level, stateful, for interactive use.
  - object oriented : full control, required when combining with PyQt as pyplot uses a viewer which has its own event loop (and there can be only one).

- Advice: study the OO API.

8 Pyqtgraph

- Python library for scientific/engineering data visualisation.
  - High quality presentation of complex data.
  - Complex interactive multiple-view displays.
  - Very efficient, 3D graphics use OpenGL.
  - Integrates perfectly with PyQt, adds its own set of specialised widgets.

- Adds some high level functionality:
  - LabView style flowchart of processing modules.
  - Parameter tree with graphic editor.

- Lots of 'not yet implemented' details, but actively developed.

- Advice: keep an eye on this.

9 Noise levels and S/N ratio

- One tool: jnoisemter.
- For a valid measurement you need:
  - defined BW or filter,
  - RMS or ITU response,
  - defined conditions: gain, source impedance, . . .
- Look at the spectrum as well:
  - is what what you measure really noise ?
  - is the spectrum what you expect (usually white) ?
- S/N ratio = working level / noise level.
- 'Dynamic range' = maximum level / noise level.

10 Frequency response

- The 'analog method': frequency sweep, measure output.
  - Need to coordinate sweep rate and detector speed.
- Single sample impulse and FFT.
  - Fast and accurate.
  - Also provides the impulse response.
  - Very low energy test signal, requires good S/N ratio.
- Log sweep, deconvolution and FFT.
  - High energy test signal, also works on noisy systems.
  - The same method can be used for speakers, room IRs etc.

11 Harmonic distortion

- For a valid measurement, test conditions need to be defined.
- The analog method: sine wave test signal, filter out fundamental frequency and measure what remains (with jnoismeter).
  - The result is THD + noise.
  - Check the spectrum !
- Measure harmonics selectively using spectrum analyser or DSP code.
  - Usually 2nd and 3th harmonics dominate, but check higher ones.
- Analog electronics usually distorts most at higher levels.
- Exception: crossover distortion in power amplifiers.
- Digital electronics (AD/DA converters) can show high distortion at all levels, including very low ones.
- In digital domain, avoid 'round' frequencies.

12 Intermodulation distortion

- Test signal with two sine waves, F1, F2, measure level of
  - 2nd order IM: F1 - F2
  - 3th order IM: 2 * F1 - F2, 2 * F2 - F1
  - Higher order: k1 * F1 + k2 * F2, order = $|k1| + |k2|$
- SMPTE : F1 = 7 kHz, F2 = 60 Hz, amplitude 4 times that of F1, measurement relative to level of F1.
- DIN : F1 = 8 kHz, F2 = 250 Hz, amplitude 4 times that of F1, measurement relative to level of F1.
- IEC : F2 = F1 + 60 Hz, same amplitude, can be done at different frequencies. Measurement relative to sum of F1 and F2 level.
- In digital domain, avoid 'round' frequencies.