

Only the Transducer Should Limit the Dynamics of the Measurement Chain

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Niels-Jørgen Jacobsen, Ole Thorhauge Andersen, Birger Kriegbaum,
Lars Munch Kofoed, Anders Eriksen

Brüel & Kjær Sound & Vibration Measurements A/S, Nærum, Denmark

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Problem, Consequences and Challenge

Problem:

- High-quality transducers have for the last 3-4 decades clearly outperformed high-quality data acquisition systems as regards dynamic range
- There has been a large gap between the theoretical and practical obtainable dynamic ranges of data acquisition systems

Consequences:

- Trial runs are required to avoid overload and under range situations
- Repeated measurements and changing of input ranges are required
- Some measurements are impossible to perform

Challenge:

- One input range that matches the dynamic range of the transducers!

Dynamic Range

Definition of Dynamic Range (DR): $DR = 20 \times \log \frac{V_{FS}}{V_N}$ [dB]

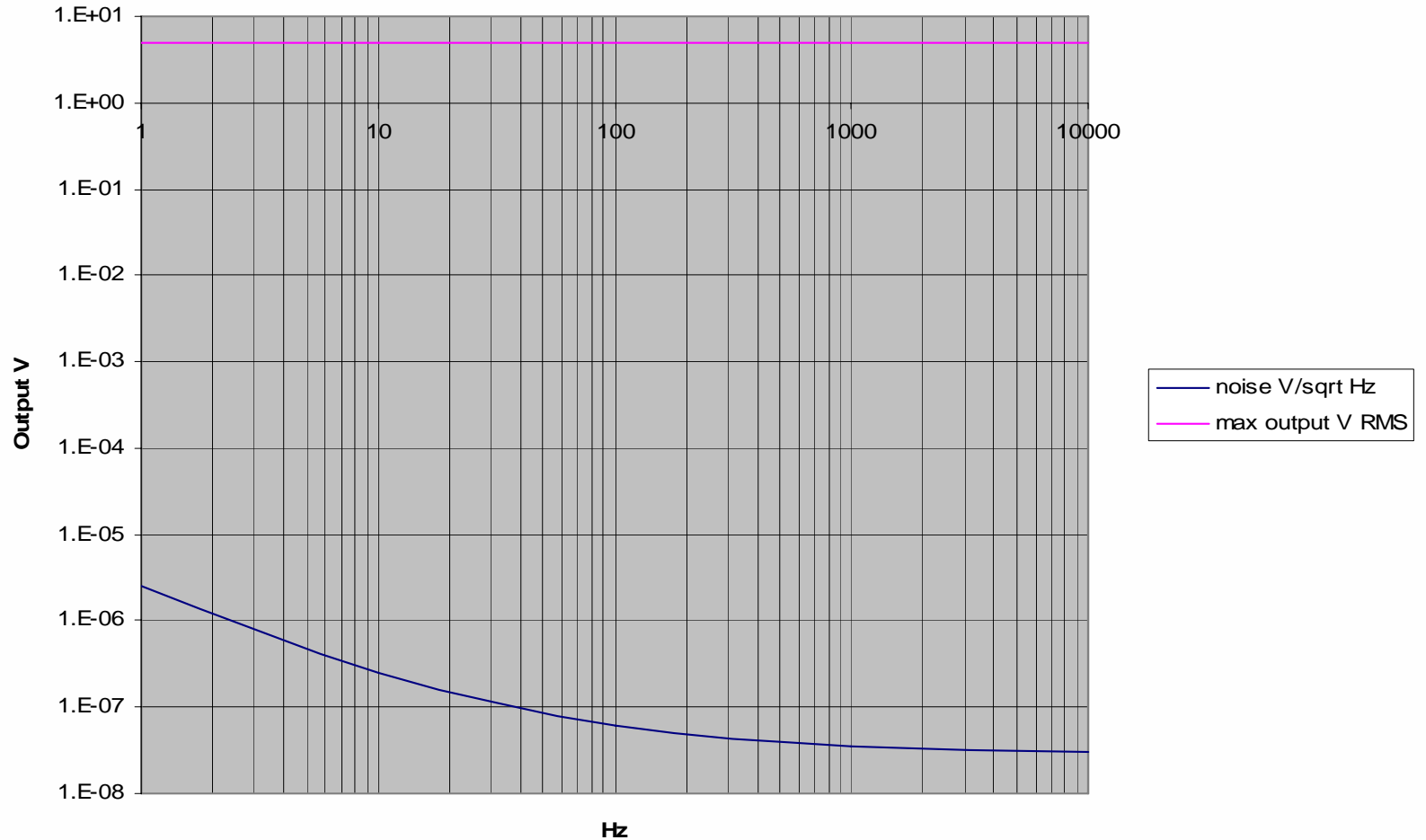
V_{FS} : RMS value of full-scale sine wave; V_N : RMS value of noise floor

Dynamic ranges of a high-quality DeltaTron®/IEPE transducer:

Bandwidth [Hz]	25.6k	1024	24	6	1
V_{FS} [V_{RMS}]	5				
V_N [V_{RMS}]	3u	608n	93n	47n	19n
DR [dB]	124	138	154	160	168

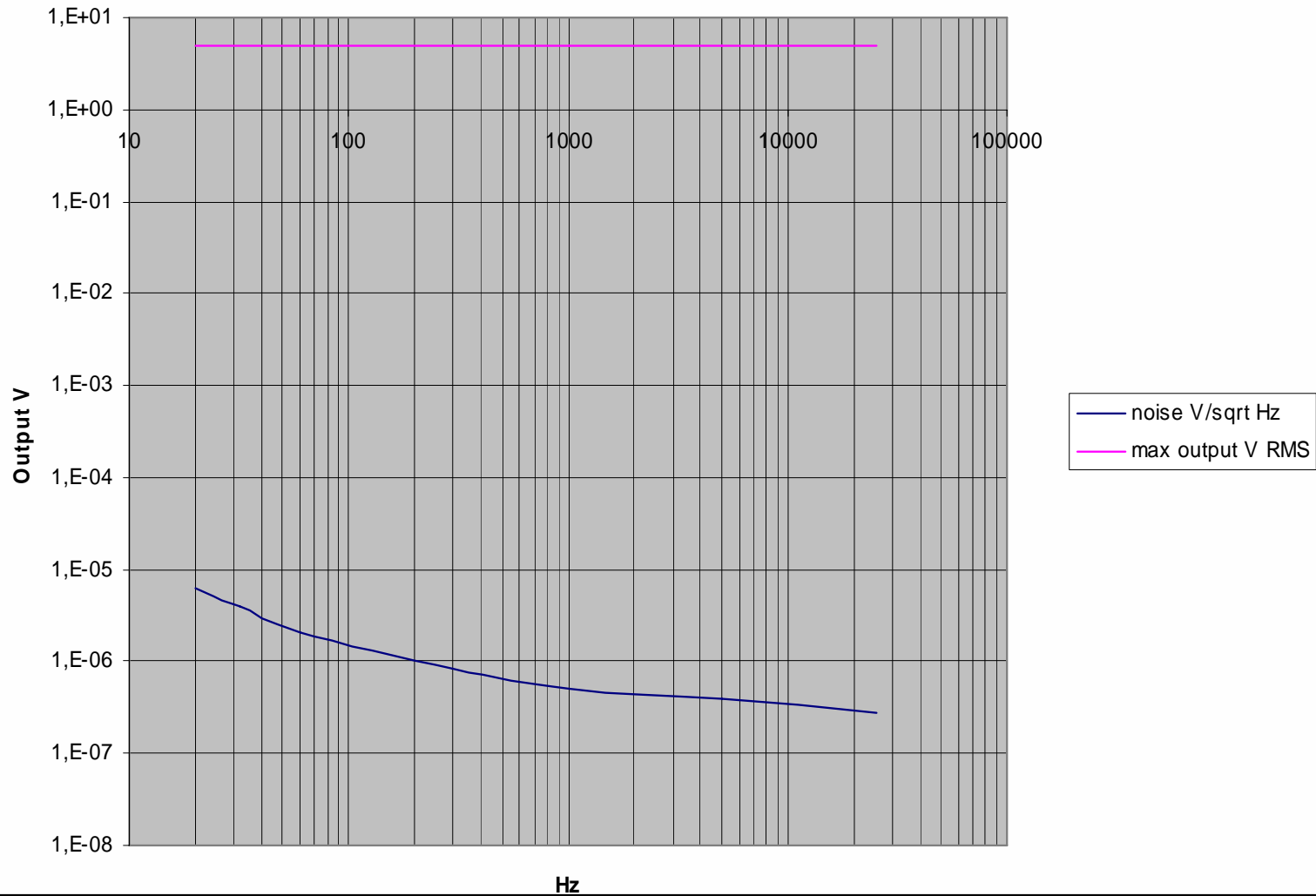
Dynamic Range Accelerometer

Dynamic range 4508-001 10 mV/g



Dynamic Range Microphone

Dynamic range 4955 1,2V/Pa - 20dB gain



Dynamic Range of Transducers and ADCs

Acquisition performance over the last 30 -40 years!

Range: 25.6 kHz

Dynamic range of
Deltatron®/IEPE transducers:
3 μ V to 5 V ~ 124 dB

Dynamic range of
high-quality ADCs:

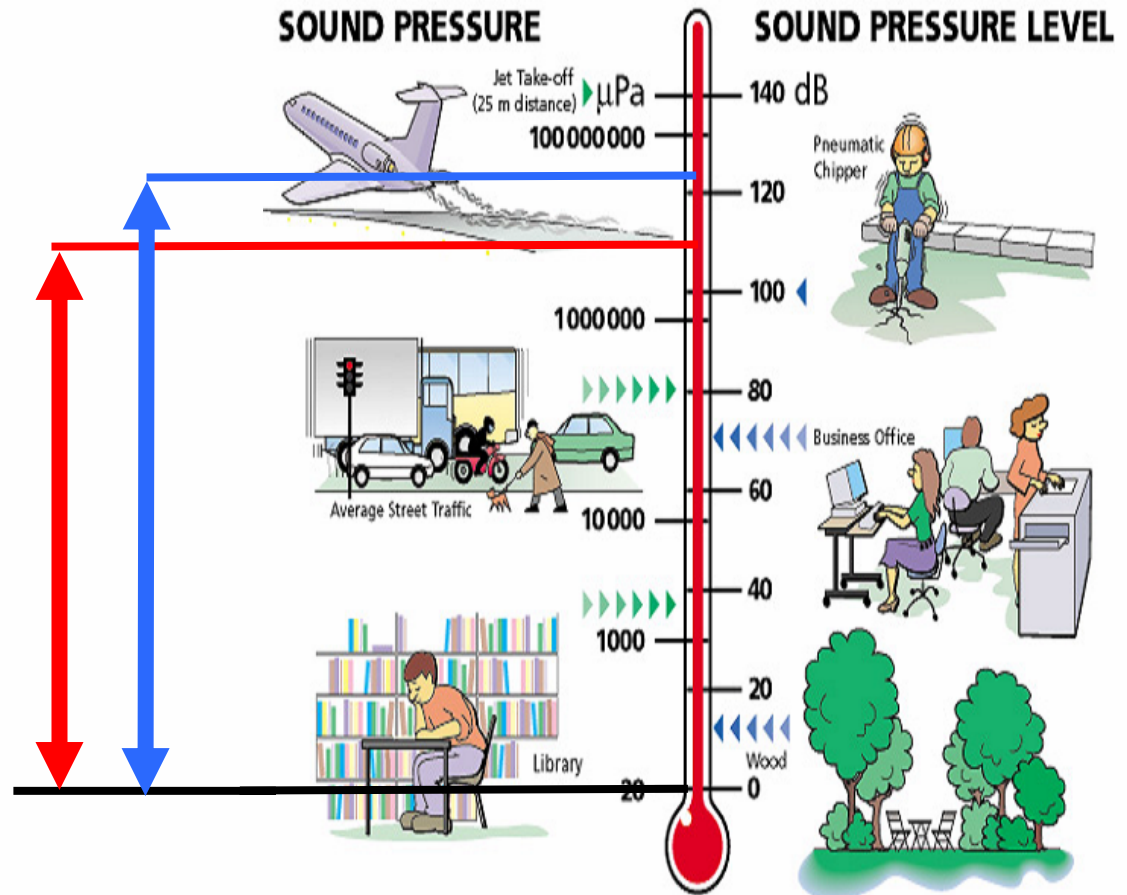
1970 ~ 60 dB (10-12 Bit)

1980 ~ 70 dB (14-16 Bit)

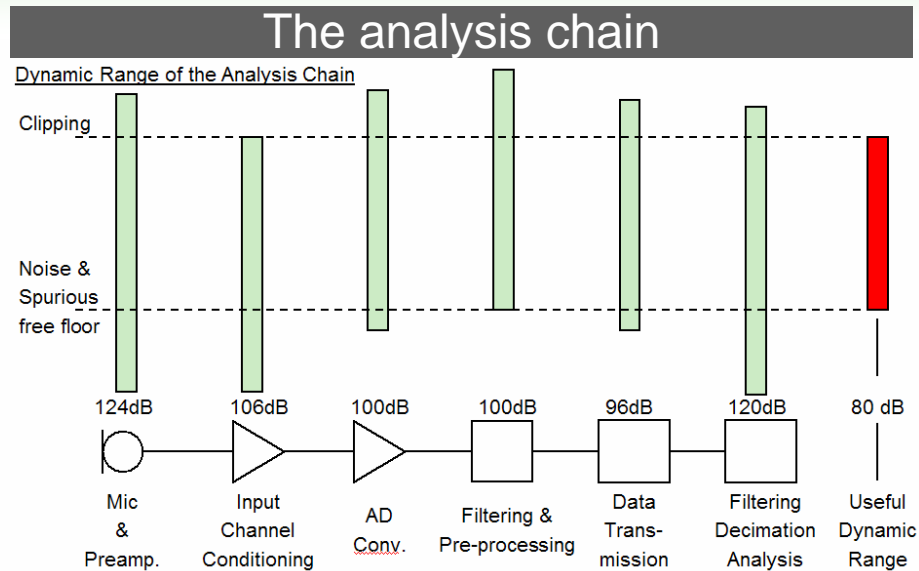
1990 ~ 80 dB (16 Bit)

2000 ~ 100 dB (24 Bit)

2005 ~ 110 dB (24 Bit)



Analysis Chain Imperfections



Factors limiting the dynamic range:

- **Clipping level and noise floor**
- **Harmonic distortion** caused by non-linearities in the analog signal conditioning
- **Cross-talk** caused by inter-channel coupling
- **Spurious signals** caused by various phenomena (power supply, clock circuits etc.)
- **ADC resolution** quantization errors (typically 16 or 24 bit)
- **ADC non-linearity** causing digital distortion due to uneven quantization steps
- **Aliasing** due to signal contents higher than the Nyquist frequency
- **DSP imperfections** throughout the complete digital analysis chain

Overcoming the Analysis Chain Imperfections

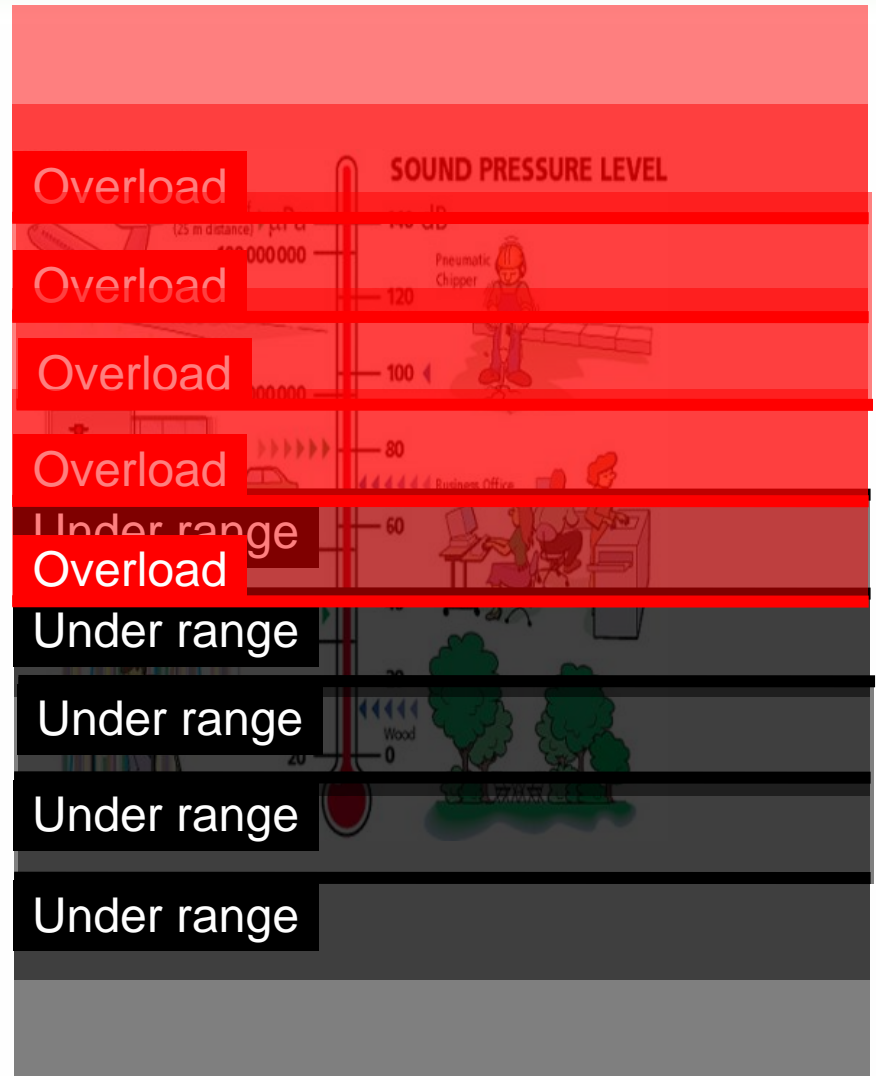
How to “compensate” for the dynamics of the transducer?

Use an input attenuator



Drawback:

A high risk of poor measurements due to overload and underrange situations!



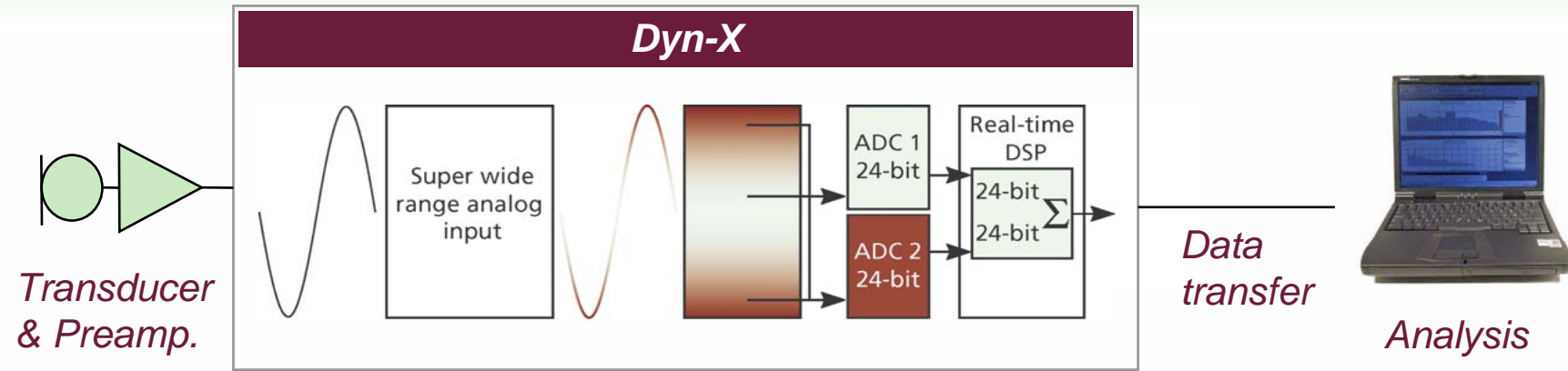
Potential Dynamic Range of a 24-bit System

$$DR = 20 \times \log \left(2^N \times \sqrt{\frac{F_S}{2 \times F_{NBW}}} \right) \text{ [dB]}, F_S = 65.536 \text{ Hz}$$

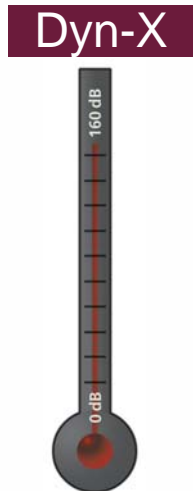
N: Quantization in bits; F_S : Sampling frequency; NBW: Effective narrowband analysis bandwidth

N [bits]	Resolution	Dynamic Range [dB]				
		F_{NBW} [Hz]				
		32768	1024	24	6	1
16	65.536	96	111	128	134	141
20	1.048.576	120	135	152	158	166
24	16.777.216	144	160	176	182	190

New Technology – Dyn-X



Simplified block diagram of Dyn-X input channel

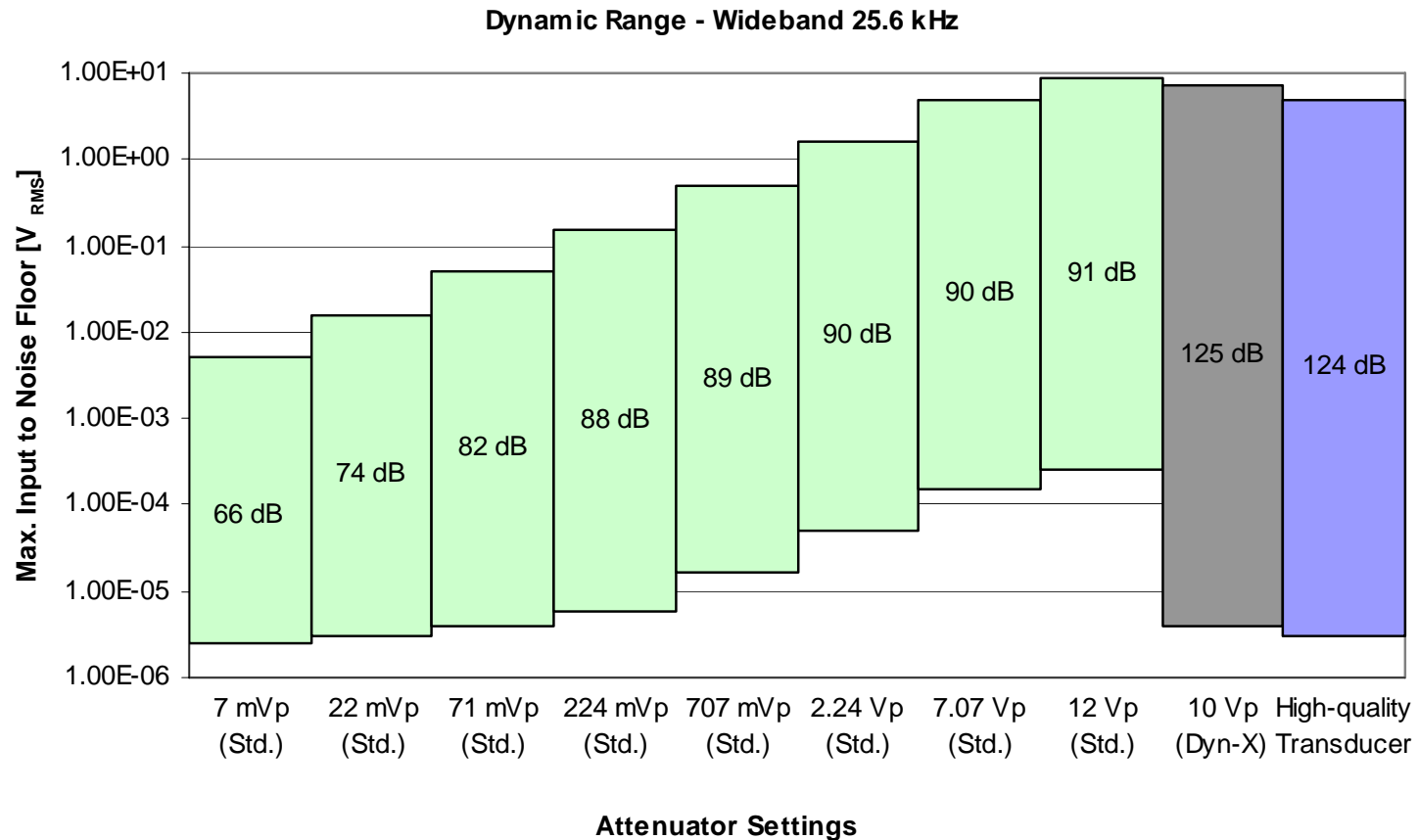


Dynamic range for complete analysis chain:

- 125 dB Broadband Lin (10 Hz – 25.6 kHz)
- 161 dB Narrowband Lin (6 Hz BW e.g. 25.6 kHz FFT with 6400 lines and Hanning weighting)
- Real-time correction of:
Gain, phase and offset errors

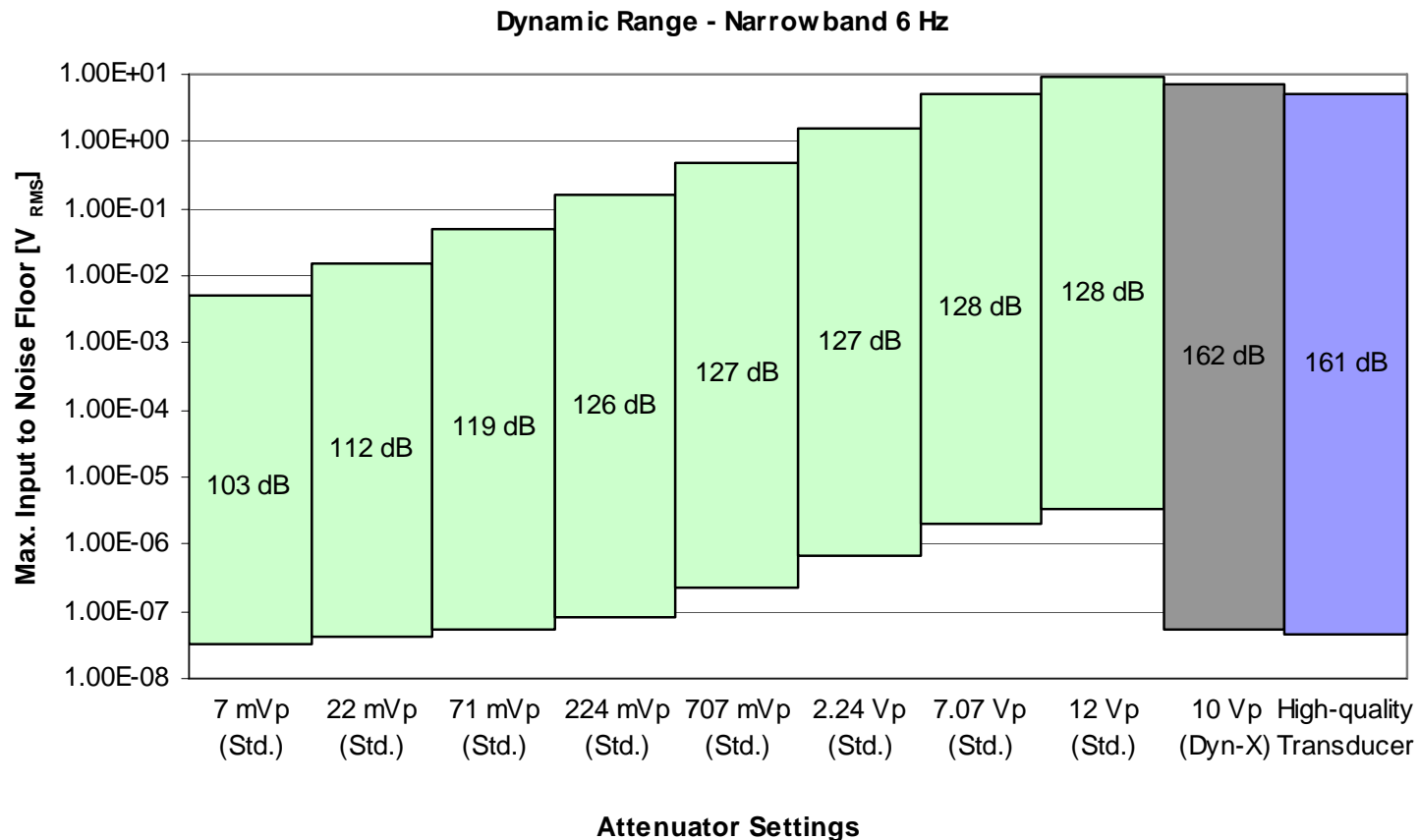
Dynamic Range Comparison – 25.6 kHz

Dynamic Range of Dyn-X technology vs. standard 24-bit high-quality input module



Dynamic Range Comparison – 6 Hz

Dynamic Range of Dyn-X technology vs. standard 24-bit high-quality input module

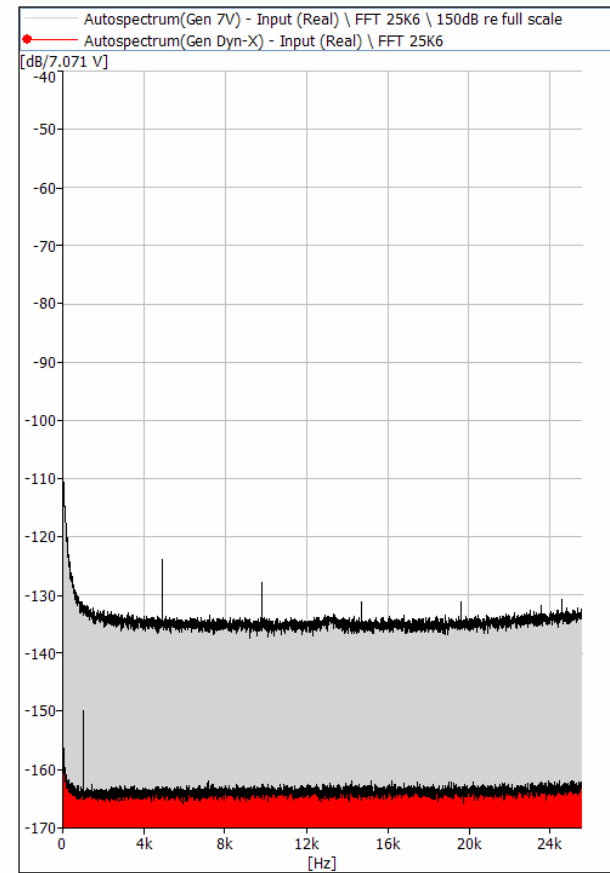
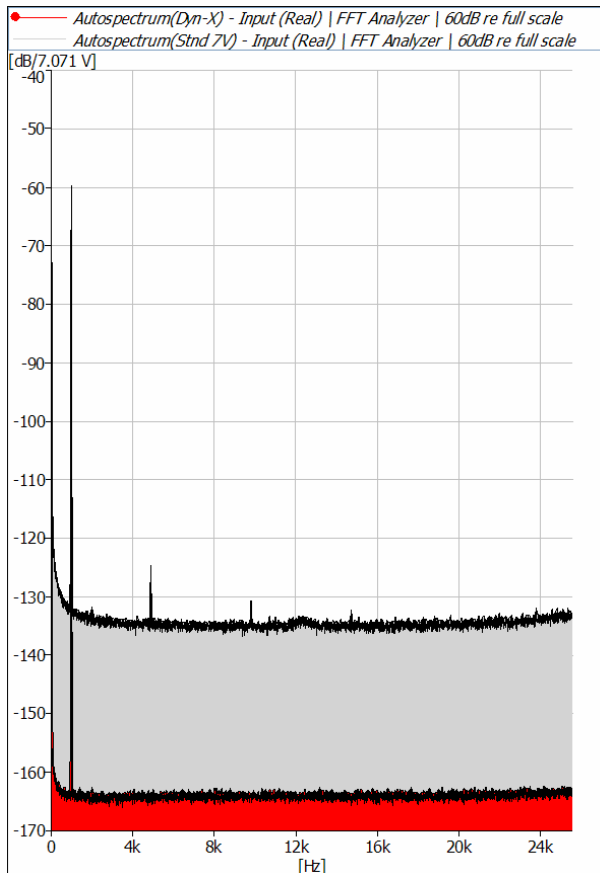


Generator Measurement Example (Frequency)

Analysis: FFT 25.6 kHz, 6400 Lines, Hanning, 6 Hz NBW

Signal: 1 kHz sine wave att. 60dB ($7 \text{ mV}_{\text{RMS}}$) and 150dB ($0.22 \text{ uV}_{\text{RMS}}$) rel. 7 V_{RMS}

Input setting: $10 \text{ V}_{\text{peak}}$ (Dyn-X); $7 \text{ V}_{\text{peak}}$ (Std. Input Module)

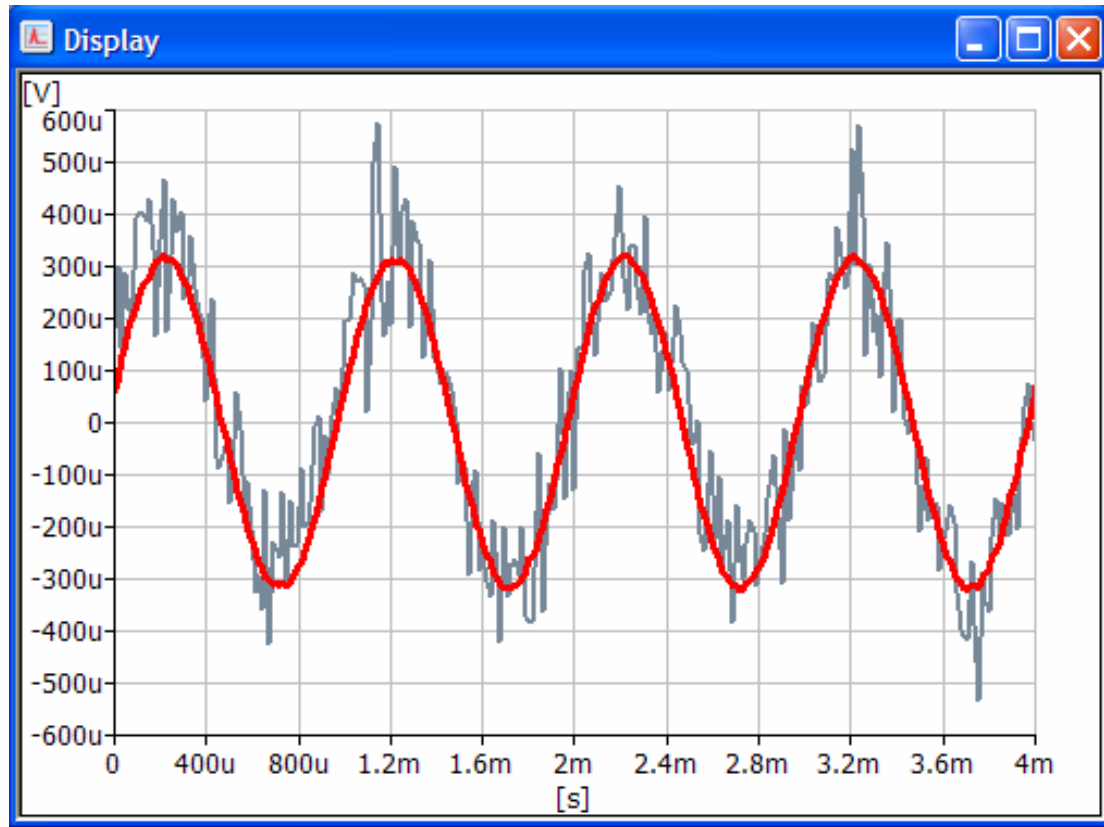


Generator Measurement Example (Time)

Analysis: FFT 25.6 kHz, 6400 Lines, Hanning, 6 Hz NBW

Signal: 1 kHz sine wave att. 90dB ($0.22 \text{ mV}_{\text{RMS}}$) rel. 7 V_{RMS}

Input setting: $10 \text{ V}_{\text{peak}}$ (Dyn-X); $7 \text{ V}_{\text{peak}}$ (Std. Input Module)

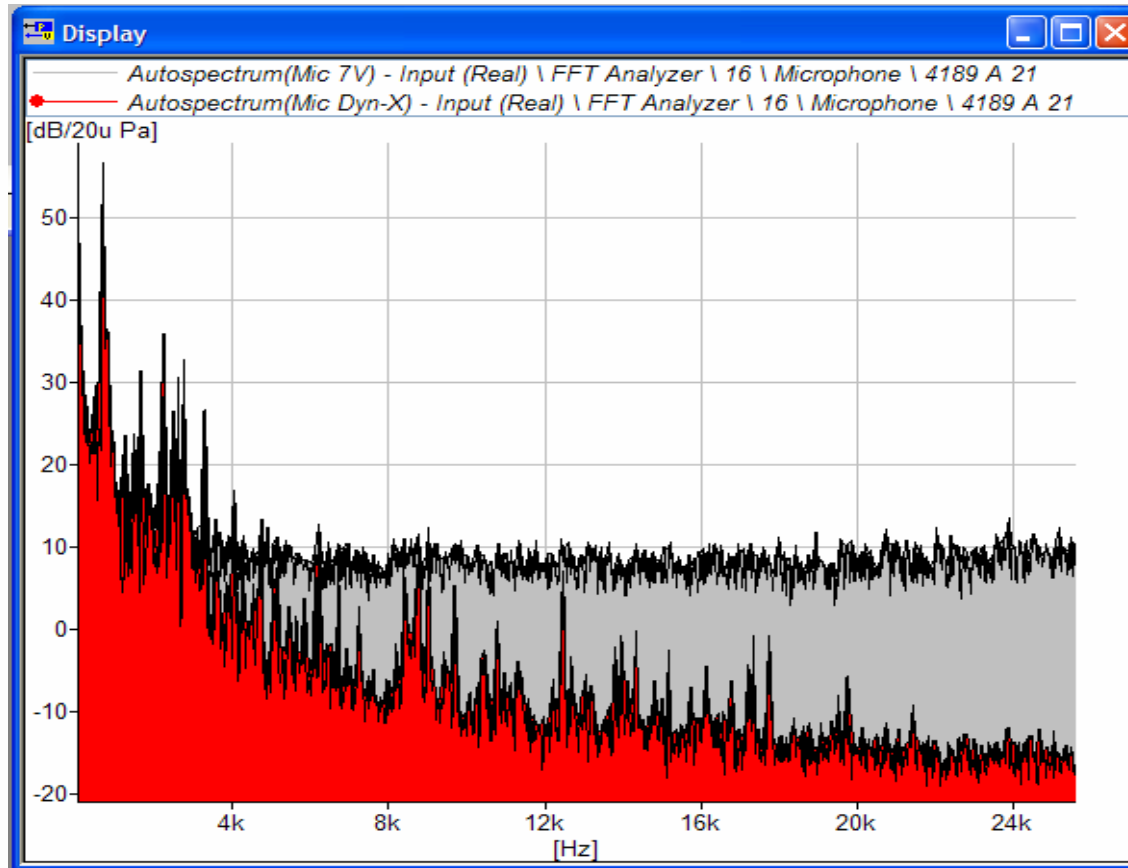


Microphone Measurement Example

Analysis: FFT 25.6 kHz, 1600 Lines, Hanning, 24 Hz NBW

Signal: Noise in standard office environment with person whistling

Input setting: 10 V_{peak} (Dyn-X); 7 V_{peak} (Std. Input Module)



Dyn-X User Benefits – No Input Attenuators

No more trial runs! ***Gone are the days of trial runs, overloads and underrange situations.***

No more overloads! ***Gone are the days of repeating measurements and setting input ranges***

Accuracy, Safety and Efficiency

When you need to get the measurement right first time

- Crash testing
- Destructive testing
- Heavy machinery - run up/coast down

When signal levels are unknown

- Run up/down
- Destructive testing
- Field testing
- Trouble shooting

When time is limited

- Test cells
- Wind tunnels

High-dynamic applications

- Structural measurements (operational)
- Impulsive testing, room acoustics

The only thing you can do wrong - is to use the wrong transducer!

Where there's minimal user interaction

- Road testing
- Flight testing
- Untrained operator

When testing is unattended

- Monitoring
- Production line testing

When overview of the measurement scenario is difficult

- When measuring many channels
- In-car testing
- Sound, vibration and other parameters involved

Conclusions

- High-quality transducers have for the last 30 – 40 years outperformed analysis systems with regard to linearity and dynamic performance being able to deliver a noise- and distortion- free signal over a dynamic range of 124 dB broadband and 160 dB narrowband. Consequently:
 - An input attenuator has been required but has also increased the risk of overload and under range situations and has forced the user to constantly pay attention to the measurement
 - Some measurements has been impossible to perform
- With the new Dyn-X technology the entire measurement and analysis chain from the transducer to the analysis results for the first time matches or outperforms the transducer used for measurement. Consequently:
 - The input attenuator can be eliminated resulting in accurate, safe and efficient measurements
 - Selection of the right transducer is now the single most critical issue