

# Order Analysis Testing

NI Days 2009

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*Test Solutions at Work*

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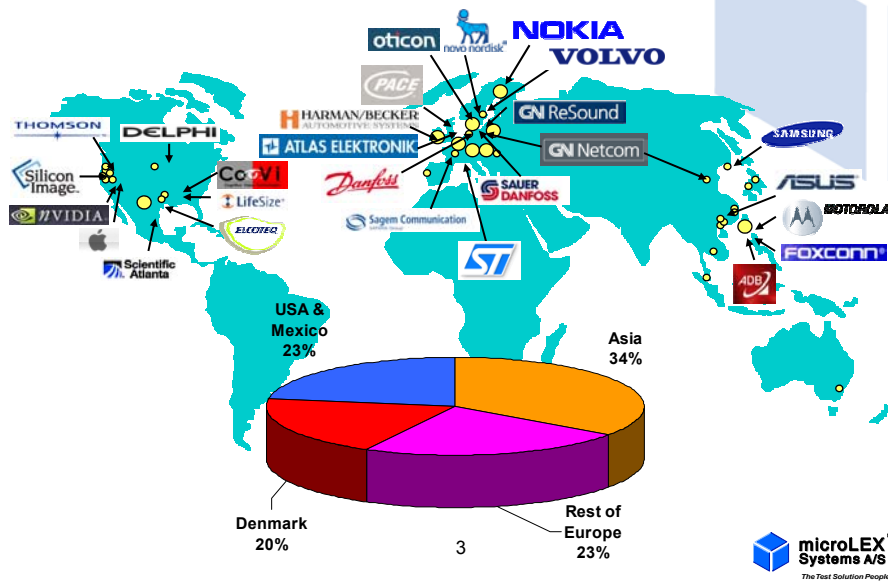
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## microLEX company profile

- Started July 1992.
- NI company since February 2008.
- Today 16 engineers with a professional background from *DELTA*, National Instruments, Brüel & Kjær, etc.
- Operates as a supplier of
  - Automatic test systems like VideoMASTER, HearMASTER.
  - System engineering within audio and video testing.
- Own software basis > 180 person years of efforts.

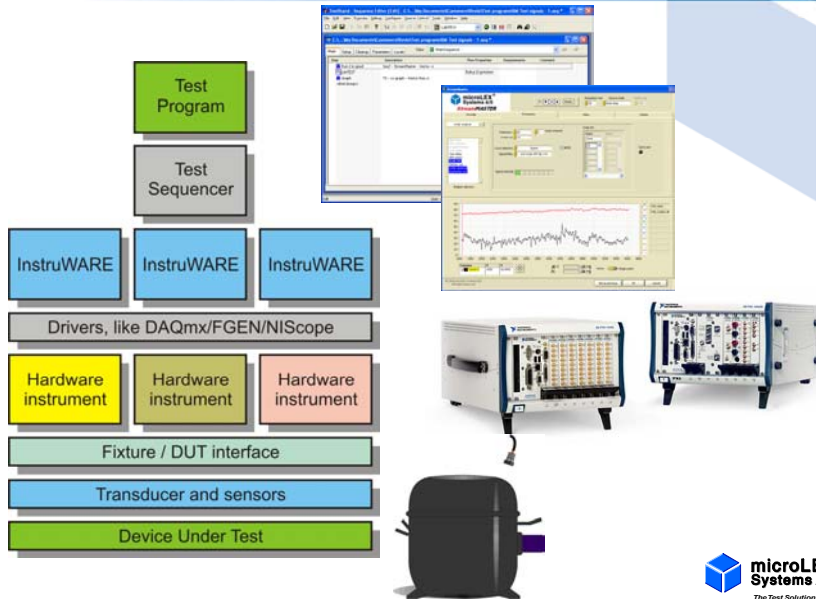
## Customers 2007



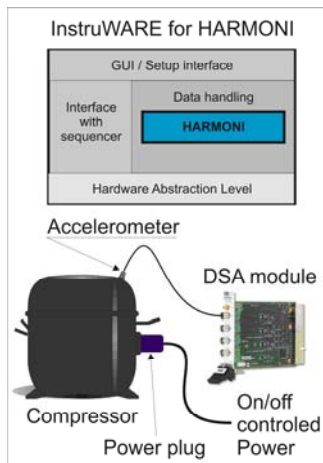
## Program

- Introduction
- Testing Rotating Machinery
  - Order Analysis
  - Order Analysis plug-in for StreamMASTER (demo)
- Sound measurements using M-Series
  - What to consider if using M-Series for audio testing

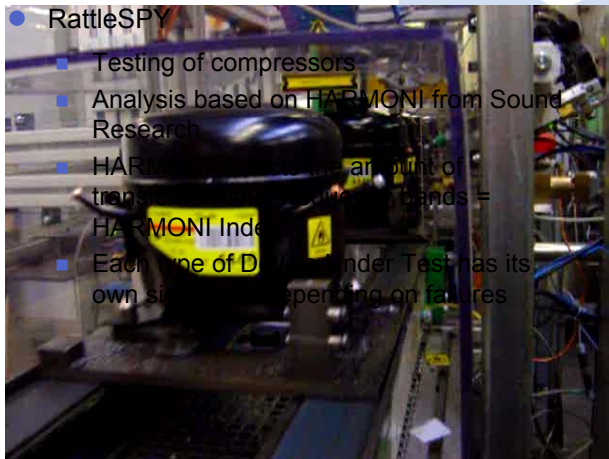
# Structure of a microLEX test system



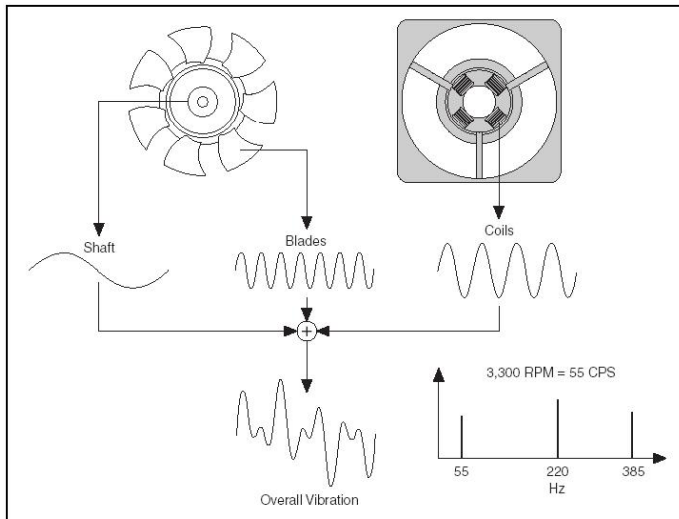
## Rotating machinery - tested with HARMONI



- **RattleSPY**
  - Testing of compressors
  - Analysis based on HARMONI from Sound Research
  - HARMONI calculates the amount of transmitted vibration bands = HARMONI Index
  - Each type of Device Under Test has its own signal depending on failures



## Rotating machinery – constant speed



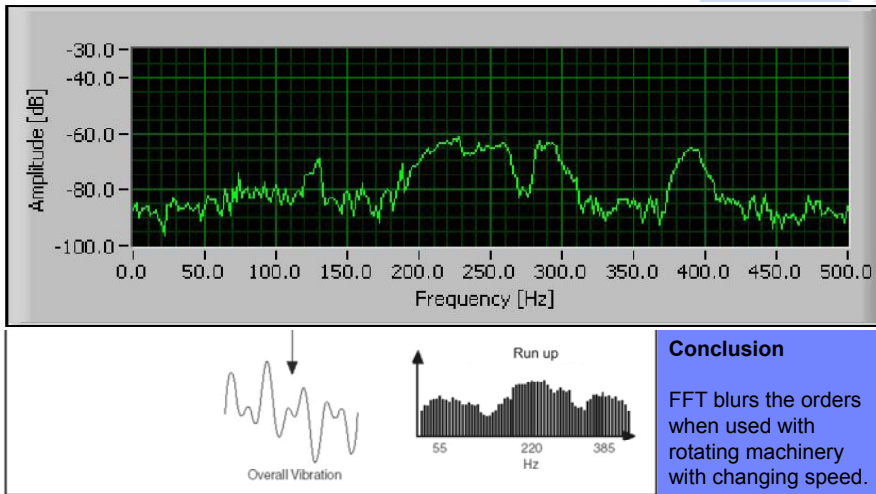
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## Rotating machinery – failure mechanism

- Example of failures
  - Cracks in parts.
  - Broken parts.
  - Unbalance.
  - Bearings unbalanced.
  - Friction in bearings.
  - Level of grease/oil.
  - Gaskets.
  - Loose parts.
- Typical symptoms
  - Change in resonance frequency of faulty parts.
  - Change in acoustic noise pattern.
  - Change in heat dissipation profile.
- Resonance frequency of parts
  - A resonance is provoked when the stimuli hit it or its sub-harmonics.
  - => Machinery must run up / down to provoke a fault to show itself.

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## Rotating machinery – changing speed



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## Rotating machinery – Order Analysis

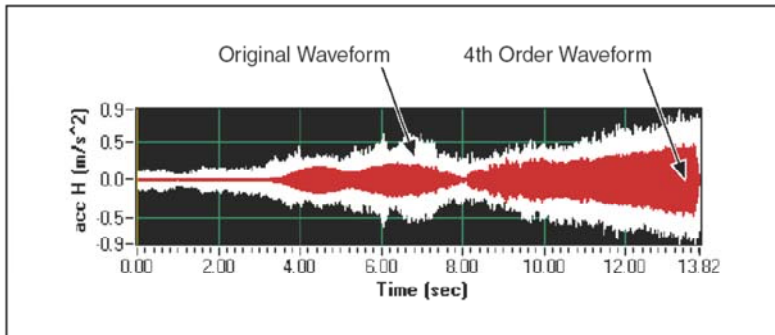
- Plot the amplitude versus the normalized rotational speed.
- The first order is the shaft speed.
- The second order is the amplitude of what is running twice the speed of the shaft.
- Etc.



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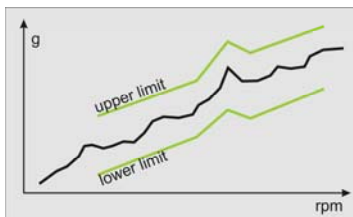
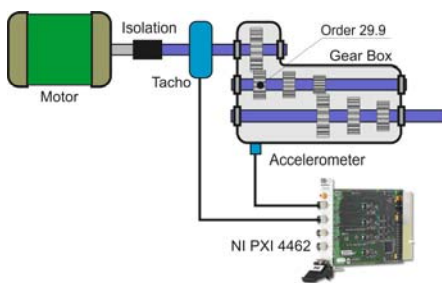
# Order Tracking

- Testing a specific item by locking to an Order
  - Run-up in speed.
  - Compare the amplitude versus time/rpm with a tunnel limit.
  - Cracks, unbalance, friction in the specific item will make it fail.



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## Example: Testing a transmission box

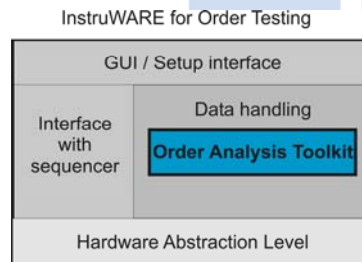


- Order tracking of individual cogwheels.
- Gearbox run by an electromotor.
- Individual orders and group of orders are tested against tunnel limits .
- Run-up in one gear can take minutes
  - Sequential testing: Recording first and analys afterwards.
  - Streaming/real-time testing.

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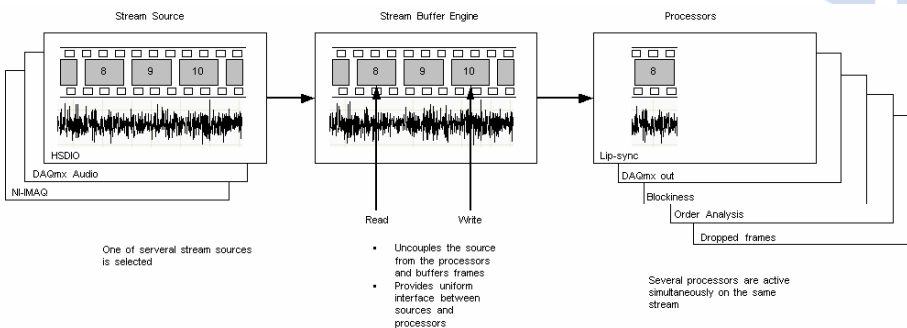
# StreamMASTER (development title)

- InstruWARE type for testing of streaming signals (audio and video).
- Tests of signals of long duration (opposite to one-shot).
- Sub-results are available continuously after a small delay.
- Plug-in for various applications will be available.
- Plug-in for testing of rotating machinery: Order Analysis Toolkit from NI Sound & Vibration Tool.



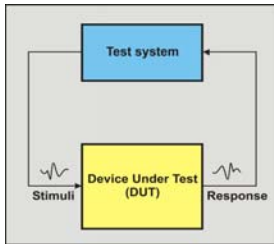
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## StreamMASTER - Architecture

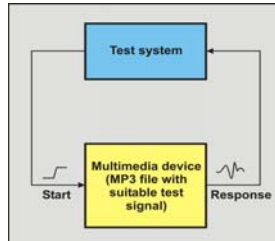


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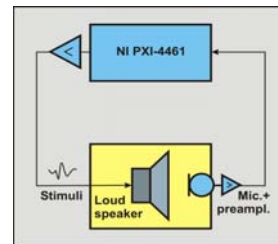
# Classic Audio Testing



General test setup



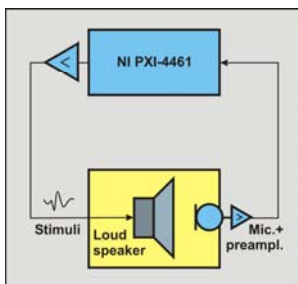
Ex: Audio test



Ex: Acoustic test

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## NI PXI-4461 as an audio measurement instrument



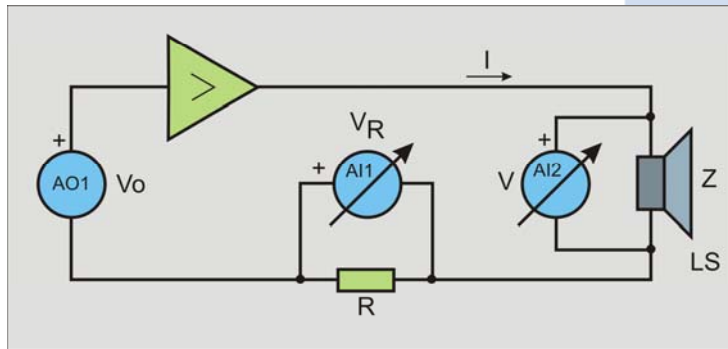
### NI PXI-4461 features

- Price: DKK 26.399
- 2 input channels
- 2 output channels
- 24-bit resolution – 118 dB dynamic range
- Simultaneous sampling/update
- Up to 204.8 kSa/s
- AC/DC coupling
- Range settings from  $\pm 316$  mV to 42.4 V
- IEPE (ICP, CCP)  
CCP: Constant Current Power
- Variable anti-aliasing filters





## Ex: Loudspeaker impedance



$$Z = V / I = V / (V_R / R)$$

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## M-Series as analog in- / output modules

- Analog input
  - 16/18 bit A/D, 500KSa/s (1M/16bit)
  - Input range: 100mV – 10V
  - 8-80 AI channels
  - 40 KHz LP filter
- Analog output
  - Max. 4 outputs (+/- 10V)
  - 16 bit D/A, 2.86 MSa/s



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## M-Series: Audio considerations

- One A/D converter
  - Pseudo Simultaneous Sampling
  - Settling time 1  $\mu$ s – 50  $\mu$ s (w. filter)
- Maximum 18 bit ADC (4461: 24 bits)
- Common 40 KHz LP Filter
- No AC coupling
- No ICP



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## M-Series: Other features

- Digital I/O
  - Up to 32 bit dynamic I/O
  - Up to 16 bit static I/O
- Counters
  - 2 counters, 32 bit
- Frequency Generator
  - 6.25 kHz – 10 MHz
- Miscellaneous
  - Analog/Digital triggers
  - PCI, PCIe, PXI, PXIe, USB (25 different modules)
  - Price: ~3.500 → ~15.000 DKK



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# Sound measurements using M-Series

## PXI-6280 features

- DKK 11.149
- 16 Analog Input
- 18 bit resolution
- 625 kSa/s
- Input ranges:  $\pm 10$ , 5, 2, 1, 0, 0.2, 0.1 V
- 40 kHz programmable low-pass filter  
or  
8  $\mu$ s settling time for 1 LSB
- 24 Digital I/O
- Two 32-bit, 80 MHz counter
- SHC68 Connector

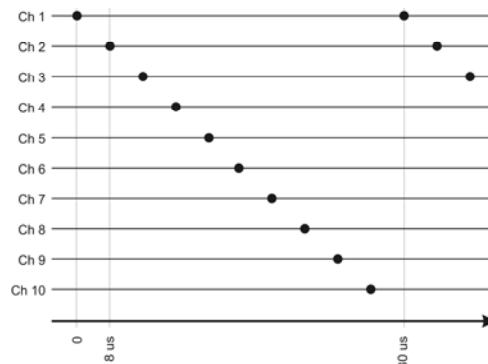


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## 6280 for audio measurements

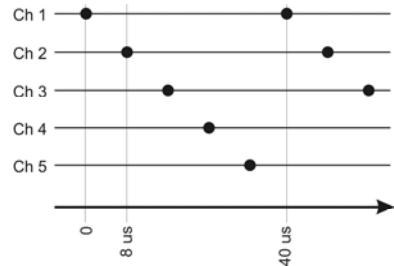
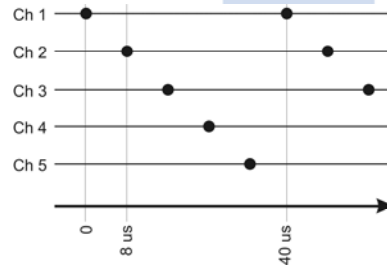
### Requirements:

- 10 channels that need to be compared in pairs.
- BW: 100 Hz to 10 kHz
- > 65 dB accuracy
- Environment with a lot of mechanical and electrical noise, also above 10 kHz.
- Parasitic capacitance:  
8  $\mu$ s for 1 LSB: 108 dB
- 10 Chan scan => Sample freq.:  
 $\leq 1/(80 \mu\text{s}) \leq 12.5 \text{ kSa/s}$



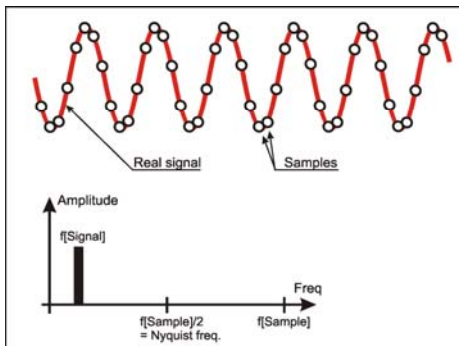
## 6280 for audio measurements

- Alternative solution with two 6280, each using five channels.
- 5 Chan scan => Sample freq.:  $\leq 1/(40 \text{ us}) \leq \mathbf{25 \text{ kSa/s}}$  with settling to better than 1 LSB corresponds to 108 dB
- => OK
- Settles to better than 65 dB
- Sample frequency > 2 times highest frequency (10 kHz)

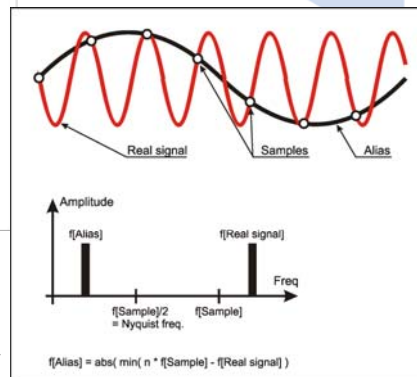


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## Audio measurements needs



Sample frequency >  
2 x max. frequency



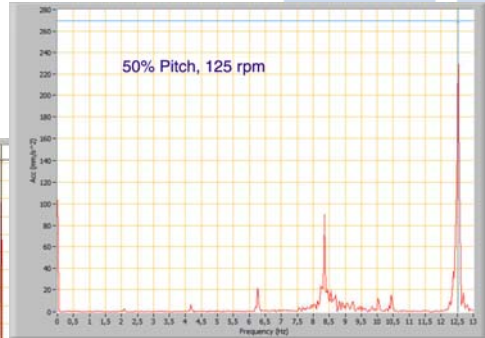
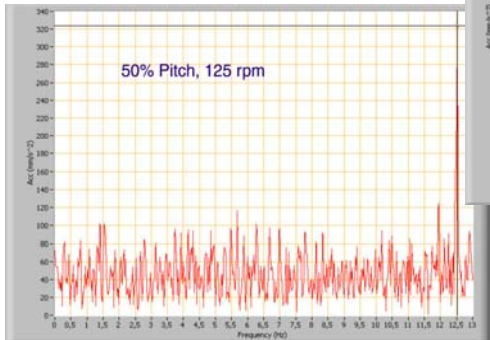
Anti-aliasing filter

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# Audio measurements needs

- Alias and resolution

NI-6036E, 16 bits, no filter

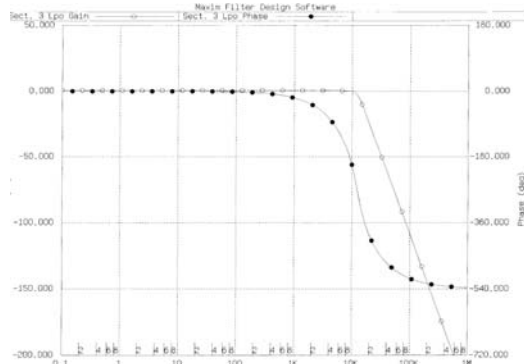
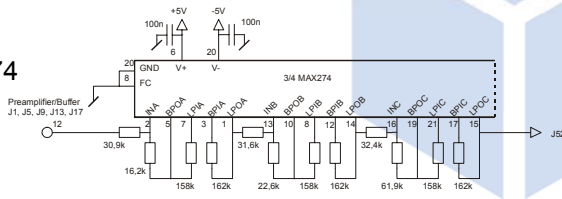


NI-9233, 24 bits, anti-alias filter



## Filter

- Filter based on MAX274
- 6'th order
- $\pm 0.5$  dB within 100 Hz to 10 kHz
- $\leq -60$  dB at 40 kHz



## 6280 for audio measurements - compromise

- Anti-alias filter: 6'th order with  $\Rightarrow < 60 \text{ dB @ } 40 \text{ kHz}$
- Sampling with  $40 \text{ kSa/s}$
- $\tau$  (caused by parasite components)
  - Settling to 1 LSB =  $2^{-18}$  within  $8 \text{ us}$
  - Settling time caused by first order parasite component ( $\tau = R \cdot C$ )
  - $2^{-18} = \exp(-8\text{us}/\tau) \Leftrightarrow \tau = 8\text{us}/(18 \cdot \ln(2)) = 0.64\text{us}$
- Shorter settling time can cause cross talk corresponding with:
  - 5 channels are scanning with  $40.000 \cdot 5 = 200.000 \text{ times/sec.}$   
 $\Rightarrow \text{settling time} = 5 \text{ us.}$
  - $2^{-b} = \exp(-5\text{us}/\tau) \Leftrightarrow b = 5\text{us}/0.64\text{us}/\ln(2) = 11.3 \text{ bit}$
  - 11.3 bit corresponds with:  $20 \cdot \text{Log}(2^{11.3}) = 67.9 \text{ dB.}$

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## Economy comparison

### DAS

- 2 x PXI 4462      52,798 kr.
- 1x PXI 4461      26,399 kr.
- Total per system    79,197 kr.
- For 10 systems    791,970 kr.

### M-Series

- 2 x PXI 6280      22,298 kr.
- 1 x PXI 6221      4,349 kr.
- Filter+ICP+Cond.    35,000 kr.
- Total per system    61,647 kr.
- For 10 systems    616,470 kr.
- HW development    150,000 kr.
- Total                766,470 kr.
- **Saved                25,500 kr.**

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## Conclusions: M-Series for audio applications

M-Series modules are:

- Very good modules with a lot of features
- High value for money
- Can be used for audio measurements.
  - But consider
    - Scans and sample times
    - Channels
    - Anti-alias
    - ICP
    - AC-coupling

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