Why A Servo Engineer Gets Involved In Hearing

- My son had a sudden and severe hearing loss in one ear.
- A year later, I sneezed and became deaf in one ear.
The Engineer’s Need to Understand

- No medical background, but experienced in:
  - Audio
  - Instrumentation & sensors
  - Closed loop control systems
A Personal Note

- Son's loss due to neural damage
  - Probably due to a virus
  - Could not be corrected

- My loss due to closing of outer ear canal
  - Excessively narrow due to genetics
  - Totally closed when I sneezed
  - Fully corrected by an operation
Hearing Capabilities

- Discern the direction from where a particular sound is emanating from without seeing
- Single out a particular person's voice in a crowded room full of people speaking
Hearing Range

- Hear a pin drop in a dead silent room
- Converse with someone while a train is passing overhead.
In Engineering Terms

- 110 dB Range
- Equivalent to a 19 bit Digital to Analog Converter
Automatic Gain Control (AGC)

- Outer Ear
  - Instantaneous Response
- Middle Ear
  - Fast Response
- Neural
  - Slow Response
The hearing system combines the ears with the brain to provide:

- Unbelievable dynamic range
- Directivity
- Selectivity
The Typical Hearing Test

- Do you hear this?
- How about this?
- And this?
What’s Wrong With That?

- Only full octave steps measured
- Only discrete levels measured
- Neural response not tested
- Non-interactive
A Better Test

- Interactive
- Tests the neural range as well
- More frequencies tested
- Uses off the shelf equipment
Kemco Test Equipment

- Audio oscillator
- Ordinary decade resistor attenuator
- Ordinary headphones
- Optional oscilloscope
The Kemco Test

- For a given frequency, subject adjusts volume until tone no longer heard
- At a maximum volume, subject adjusts frequency until tone no longer heard
- Allows sufficient time to check neural response
Test Results Presentation

Hearing Test Results
(Chris Early)

Frequency (Hz)
dB
Right Ear (dB)
Left Ear (dB)
HearX vs. Kemco Comparison

Kemco vs. HearX Test

-100 -80 -60 -40 -20 0 20 1 10 100 1000 10000
Frequency (Hz)

dB
HearX dB Left Ear
Kemco dB Left Ear
Log. (Kemco dB Left Ear)
Log. (HearX dB Left Ear)
What To Look For In Test Results

- Frequency band consistent with one’s age
- Good balance between ears (< 6 dB)
- Less than 20 dB loss from the norm

Balance is more important than loss (my opinion)
## Data Sheets

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Conclusion

- The hearing system from an engineering viewpoint is indeed remarkable.

- My study of hearing led to a more sophisticated hearing test than those currently used.
Dual Axis (Quadrature) Closed Loop Drive
Dual Axis (Co-Linear) Closed Loop Drive
PA / Megaphone / Hearing Aid