



# THE REMARKABLE HUMAN EAR

AN ENGINEER'S  
VIEWPOINT

By Martin Kanner

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# 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

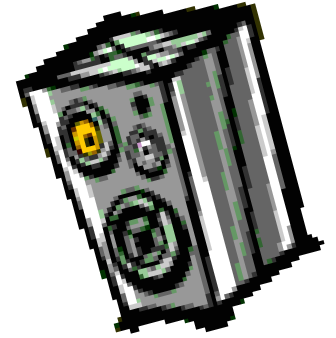
- No medical background, but experienced in:
  - Audio
  - Instrumentation & sensors
  - Closed loop control systems



# 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



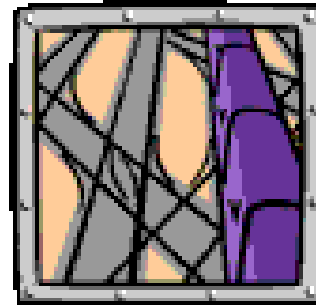
- Discern the direction from where a particular sound is emanating from without seeing
- Single out a particular person's voice in a crowded room full of people speaking



# Hearing Range



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

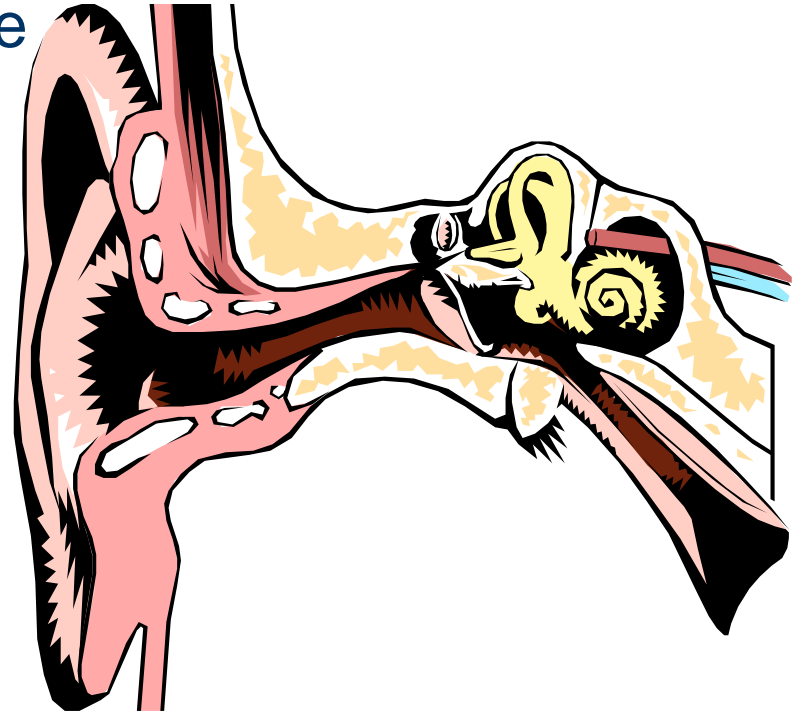


# In Engineering Terms

- 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





# Hearing System = Ears + Brain

- 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

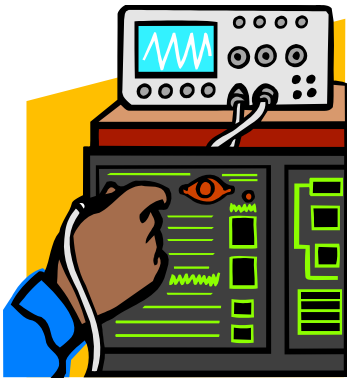
# A Better Test

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

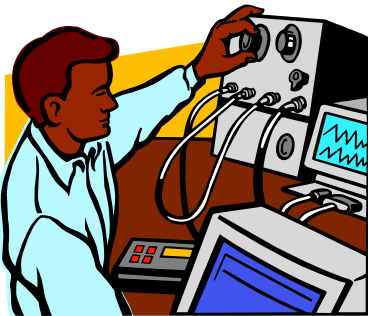


# Kemco Test Equipment

- Audio oscillator
- Ordinary decade resistor attenuator
- Ordinary headphones
- Optional oscilloscope

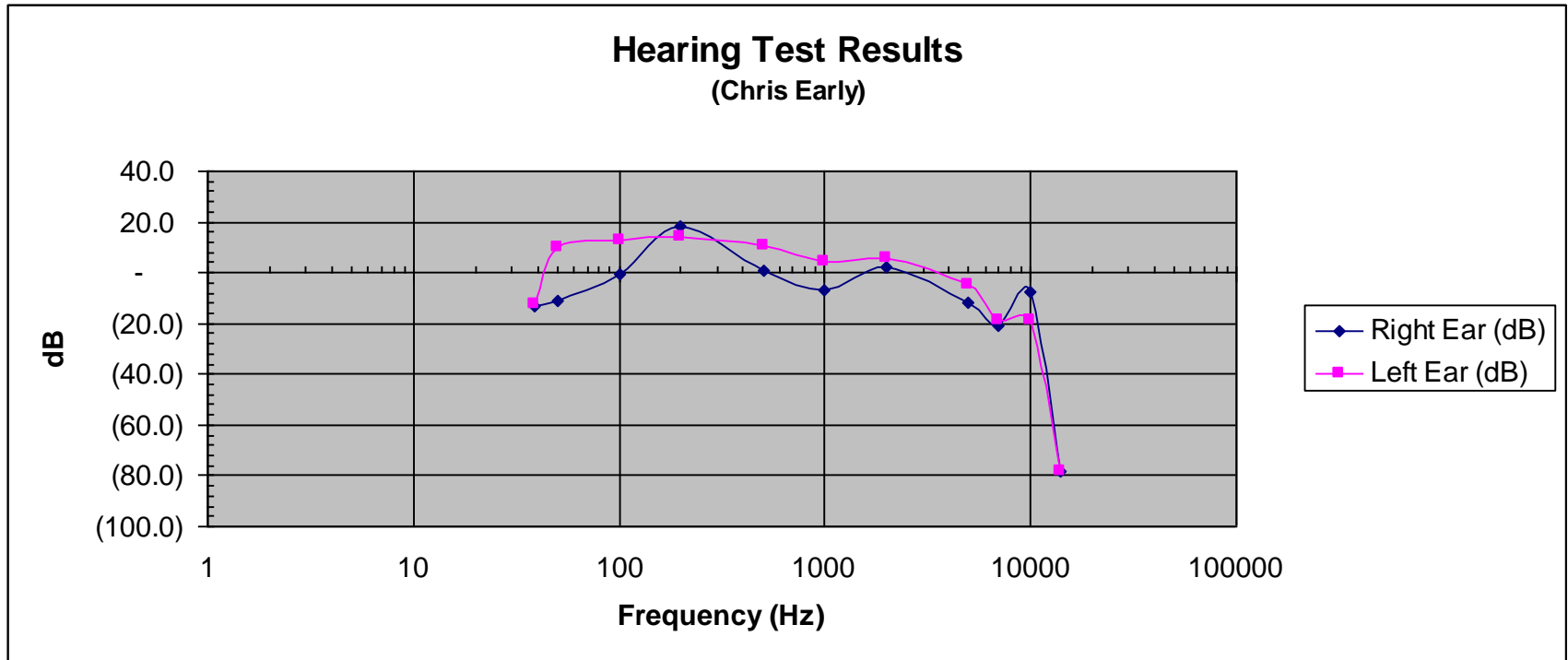


# The Kemco Test

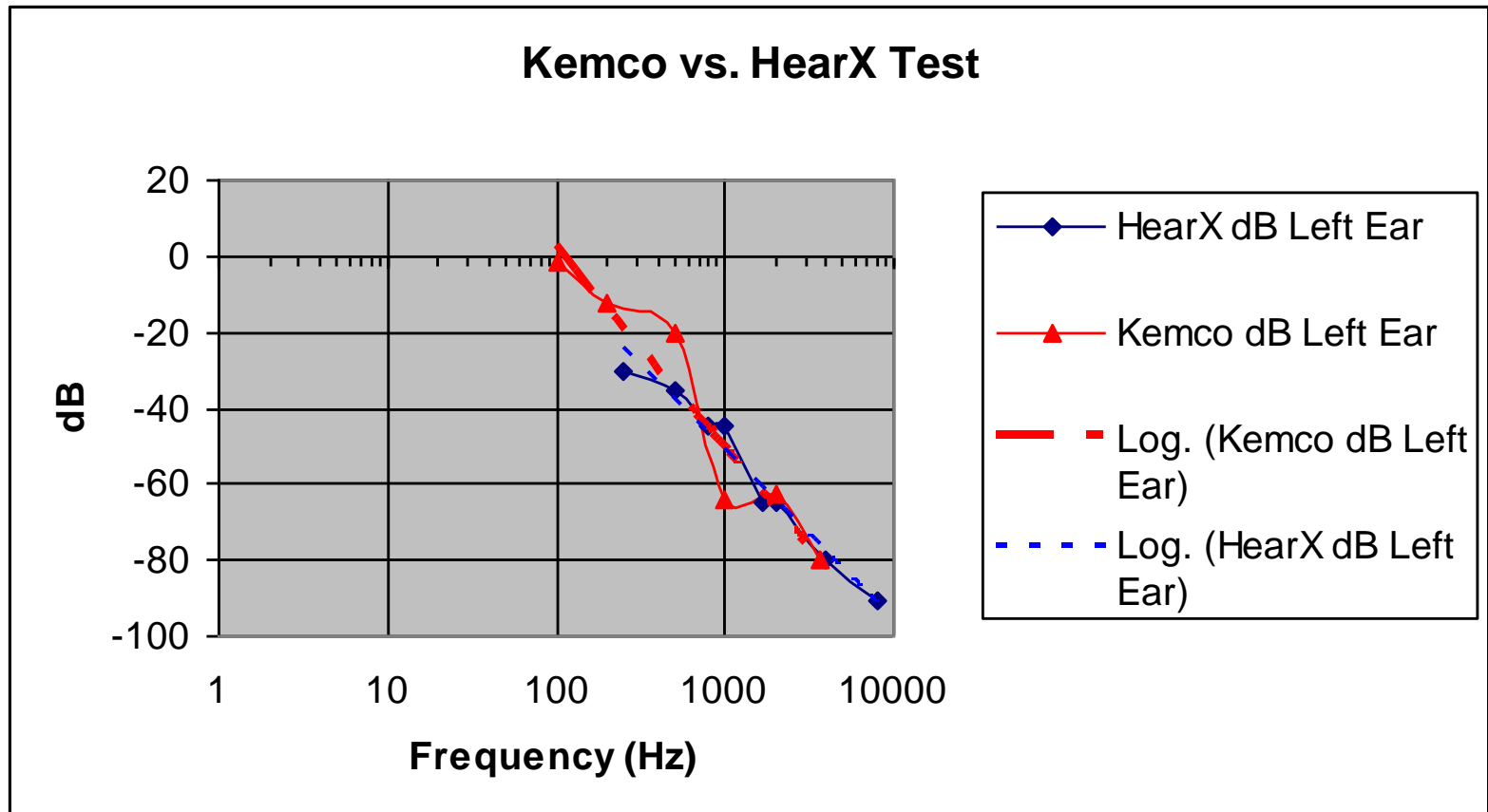


- For a given frequency, subject adjusts volume until tone no longer heard
- At a maximum volume, subject adjusts frequency until tone no longer heard
- Allows sufficient time to check neural response

# Test Results Presentation



# HearX vs. Kemco Comparison





# 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

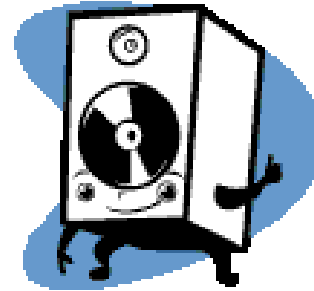


Balance is more important than loss (my opinion)

# Data Sheets

		Right				Left			
Freq.	Corr	Atten #	Voltage	dB Measured	Right Ear (dB)	Atten #	Voltage	dB Measured	Left Ear (dB)
39	68	6	3.70	(81.2)	(13.2)	6	3.40	-80.5	-12.5
50	68	6	3.00	(79.4)	(11.4)	5	2.70	-58.4	9.6
100	40	4	3.83	(40.6)	(0.6)	3	8.70	-27.0	13.0
200	35	3	2.60	(16.5)	18.5	3	4.20	-20.7	14.3
500	18	3	2.90	(17.5)	0.5	2	7.00	-7.4	10.6
1000	0	2	6.50	(6.7)	(6.7)	2	1.80	4.4	4.4
2000	0	2	2.40	1.9	1.9	2	1.60	5.5	5.5
5000	0	3	1.50	(11.7)	(11.7)	2	5.40	-5.1	-5.1
7000	0	3	4.30	(20.9)	(20.9)	3	3.50	-19.1	-19.1
10000	0	2	7.44	(7.9)	(7.9)	3	3.50	-19.1	-19.1
14000	0	6	2.70	(78.5)	(78.5)	6	2.70	-78.5	-78.5

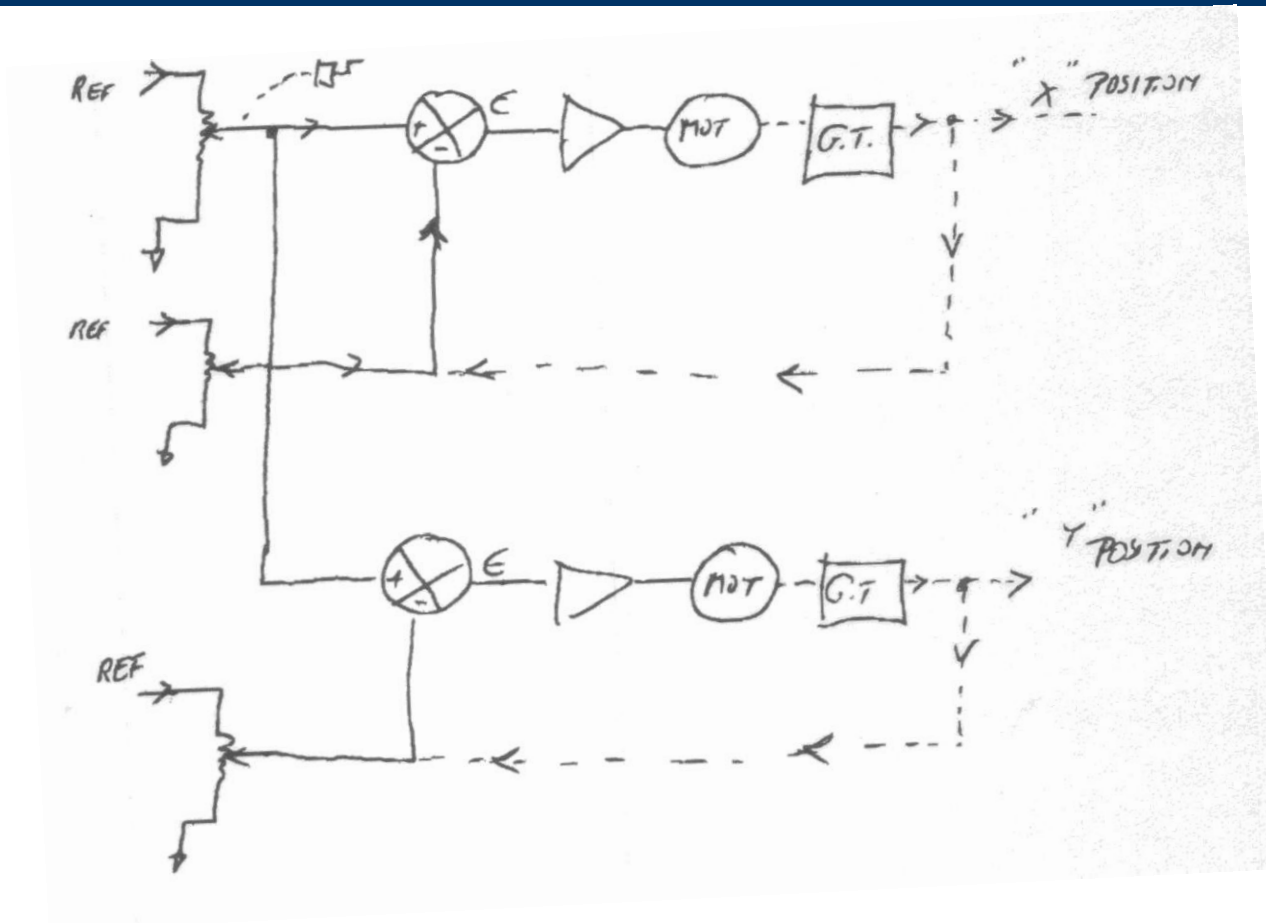
# Conclusion



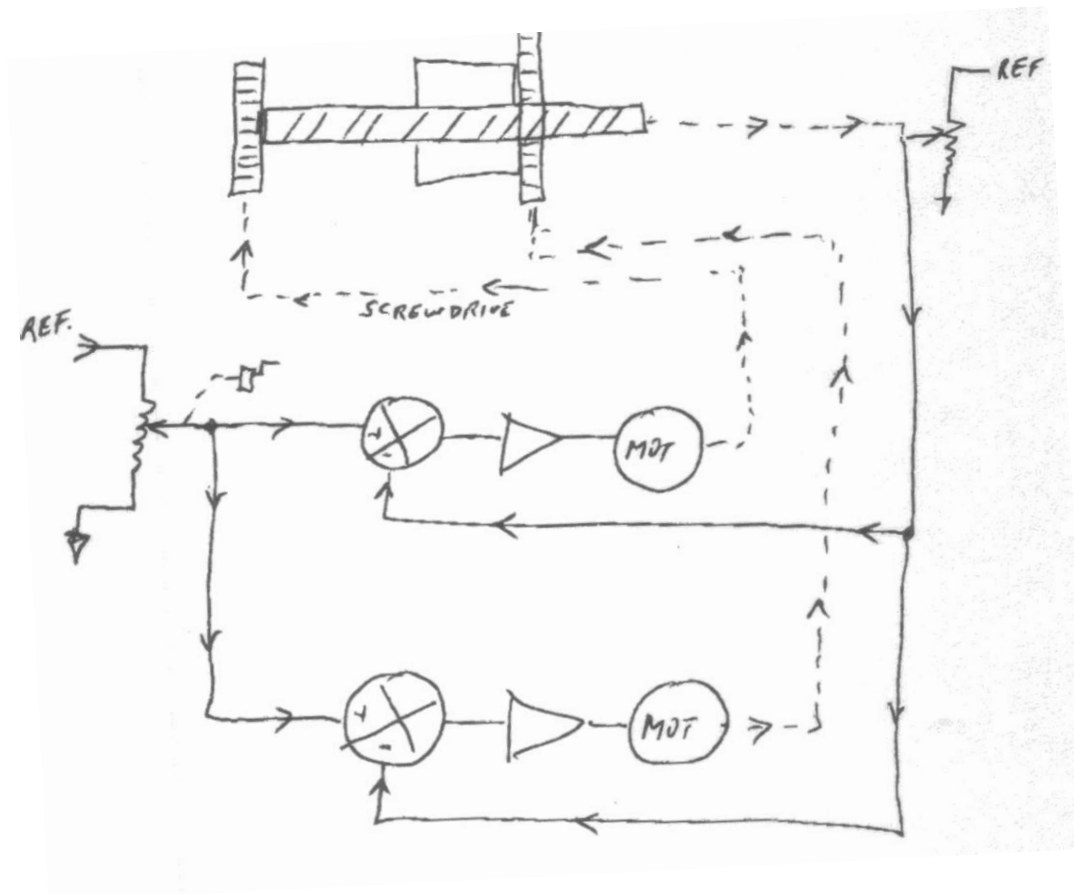
- The hearing system from an engineering view point is indeed remarkable.
- My study of hearing led to a more sophisticated hearing test than those currently used.



# Dual Axis (Quadrature) Closed Loop Drive



# Dual Axis (Co-Linear) Closed Loop Drive



# PA / Megaphone / Hearing Aid

