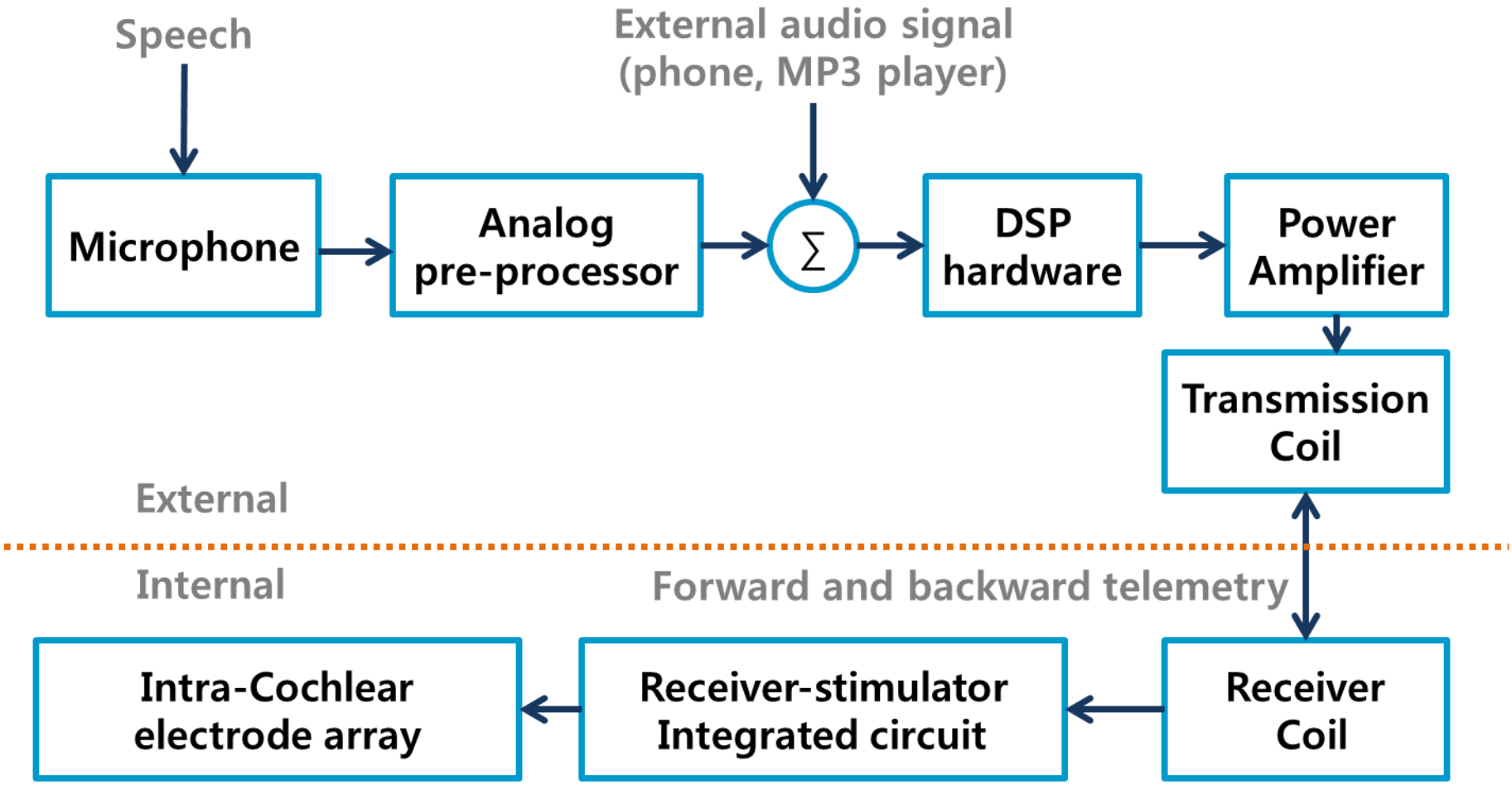
Today

- Review
  - Intracochlear electrode array
- Questions on homeworks or projects?
- System continued
  - Digital filtering
  - Mapping
  - Telemetry
  - stimulator

Review

In block diagram form,

- A brief conceptual block diagram



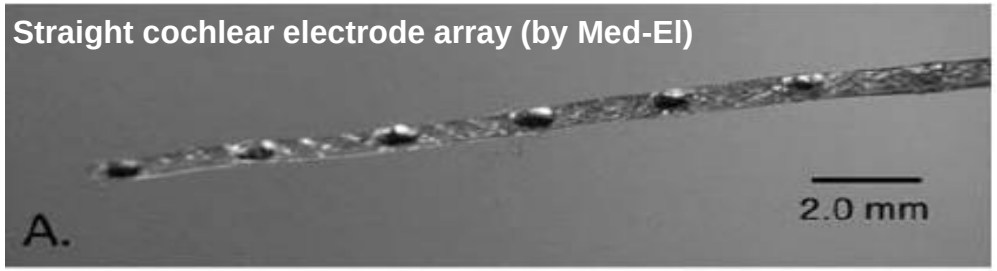
Spatial Specificity

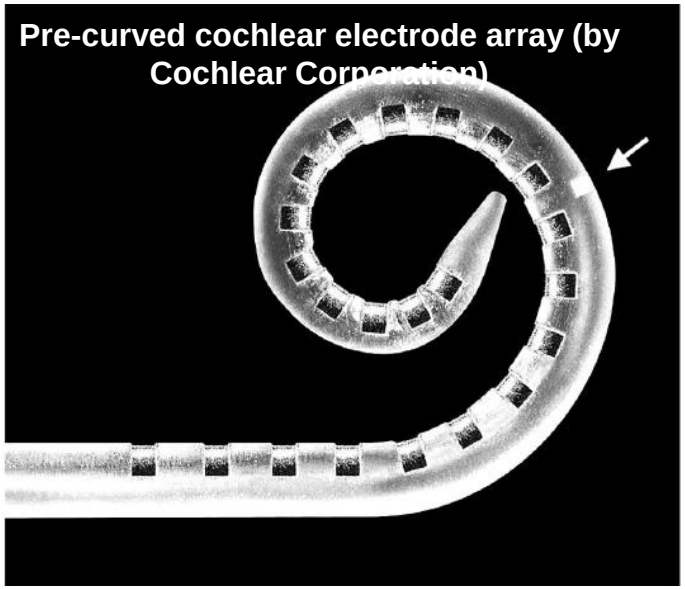
- the degree of spread of neural activity across a place in cochlea that responds to a stimuli from an electrode site
- Spatial specificity of stimulation depends on…
  - The number and distribution of surviving ganglion cells
  - Whether neural processes peripheral to the ganglion cells are present or not
  - The proximity of the electrodes to the target neurons
  - The electrode coupling configuration (monopolar, bipolar)

Straight vs. Pre-curved

■ Types of cochlear electrode array

- **Straight vs Pre-curved**





- Straight types
  - Deep insertion
  - Far from target cells
  - Lateral wall insertion

- Pre-curved types
  - Close to target cells
  - Using stylet or sheath to insert
  - Perimodiolar insertion

Peri-modiolar Placement

- Positioning of electrodes in ST
  - Place close to inner wall of ST to minimize the distance between electrodes and SG
    - Maximize the number of largely non-overlapping populations of neurons
    - Improve spatial specificity of stimulation
    - Reduce threshold voltage
    - Increase battery life

Performance vs. Number of channels

- **8 is enough**

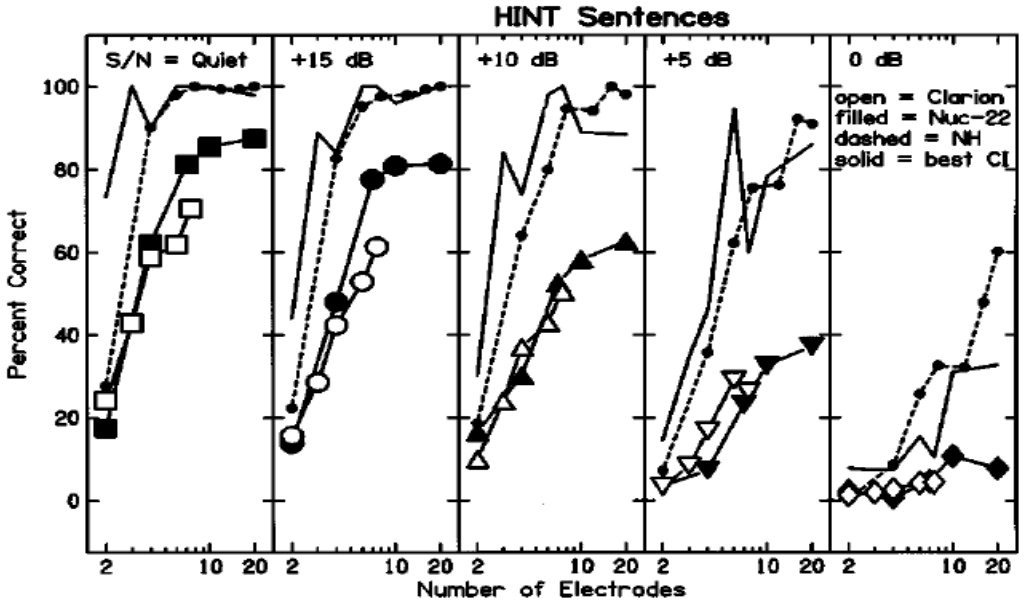
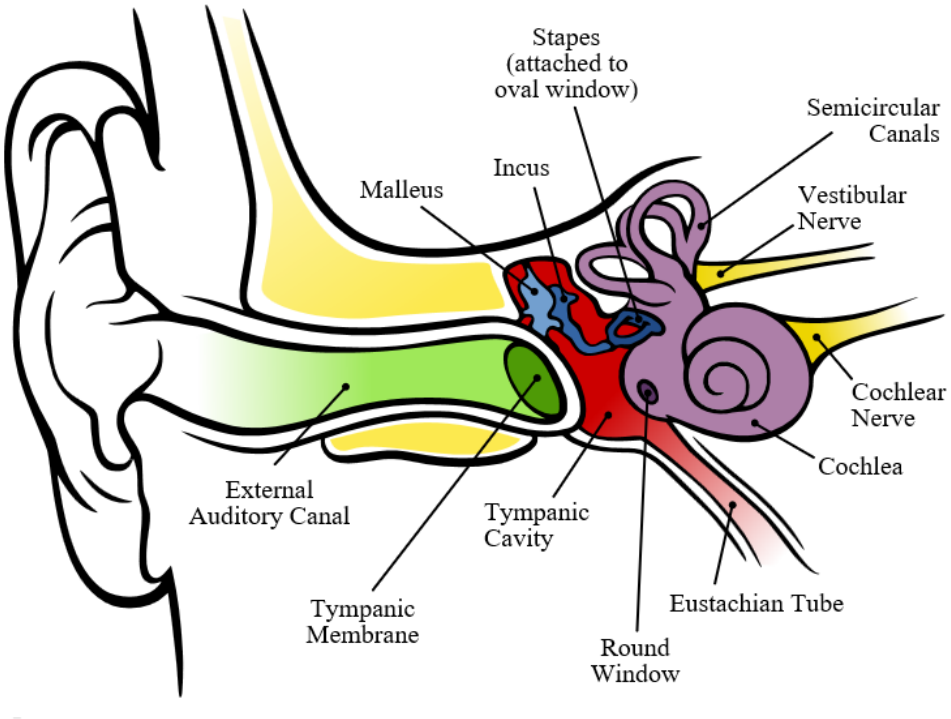


FIG. 4. Recognition of HINT sentences as a function of the number of spectral channels for normal-hearing listeners (dashed line with small filled symbols) or as a function of the number of electrodes used with Nucleus-22 cochlear implant listeners (filled symbols) and Clarion cochlear implant listeners (open symbols). The solid line plots the best performance level across all 19 cochlear implant listeners. From left to right the panels present consonant recognition as a function of decreasing signal-to-noise ratio.

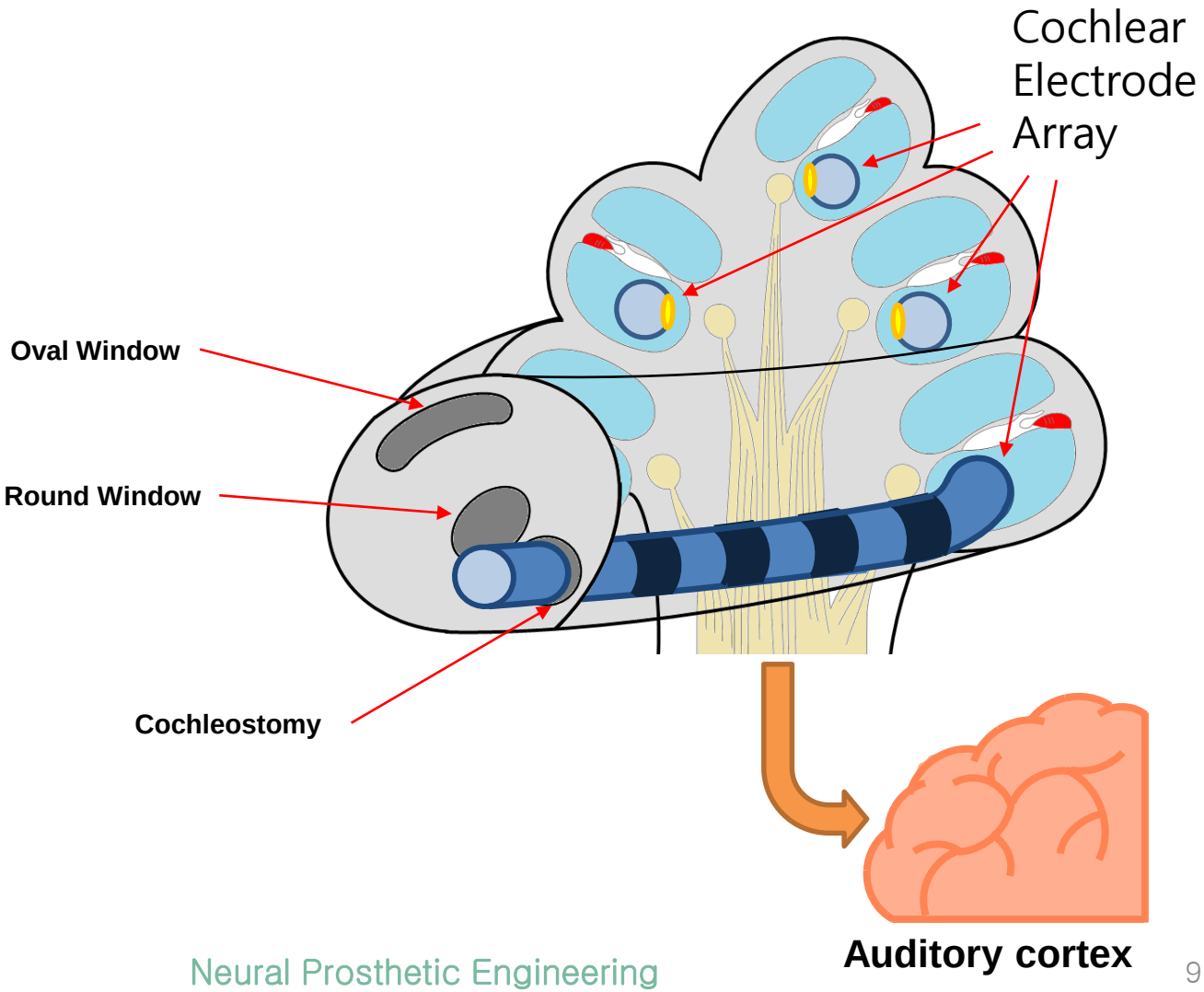
L.M.Friesen et al., J. Acoust. Soc. Am, 2001

Auditory system



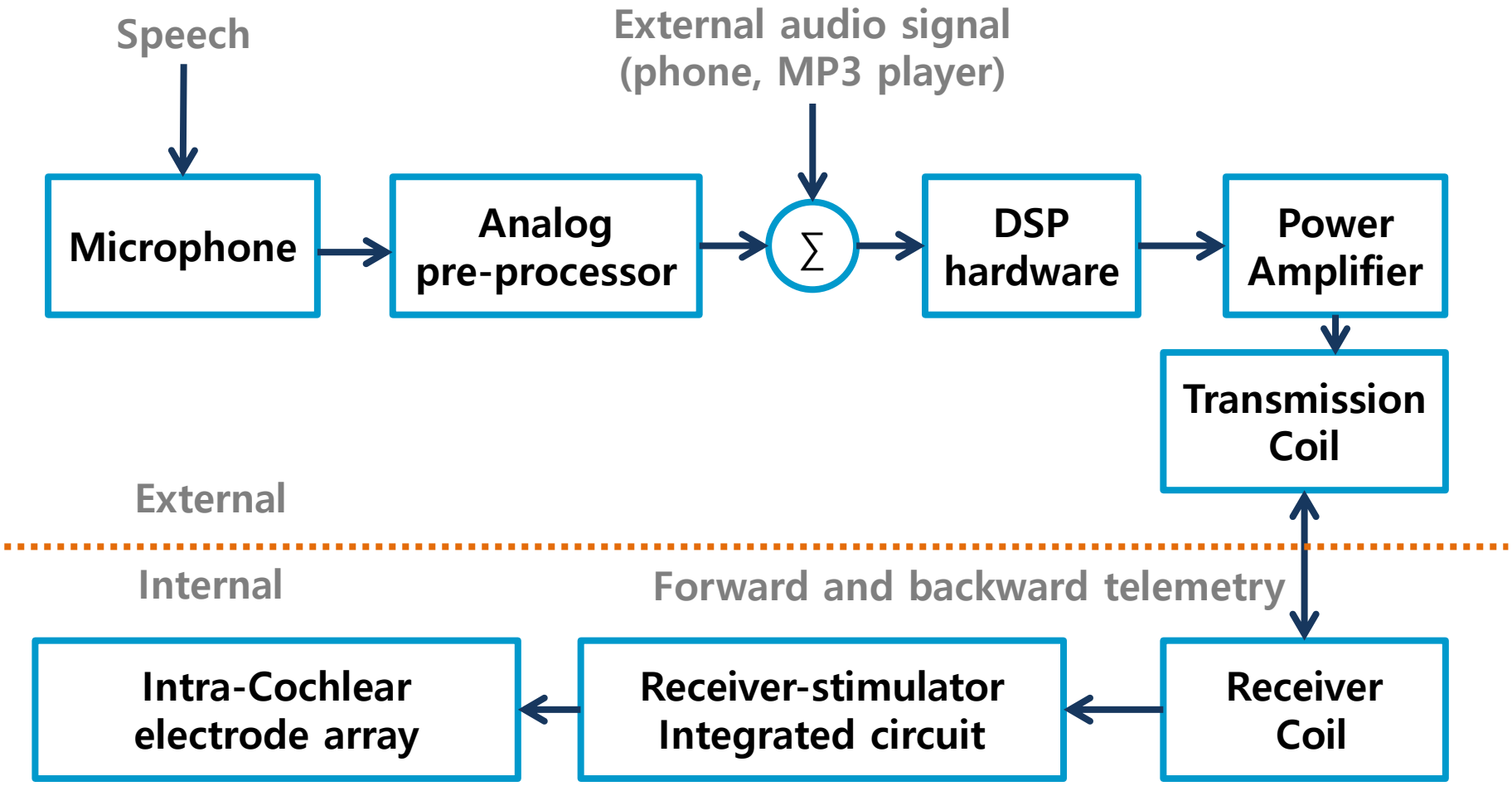
Auditory system – Wikipedia

Cochleostomy and round window approach



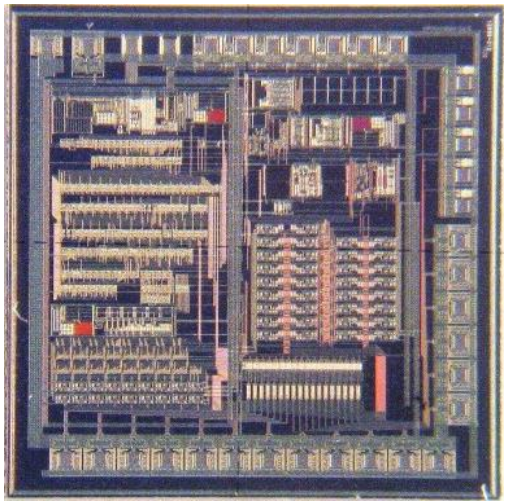
Cochlear Implant System & Circuit

A Brief Conceptual Block Diagram

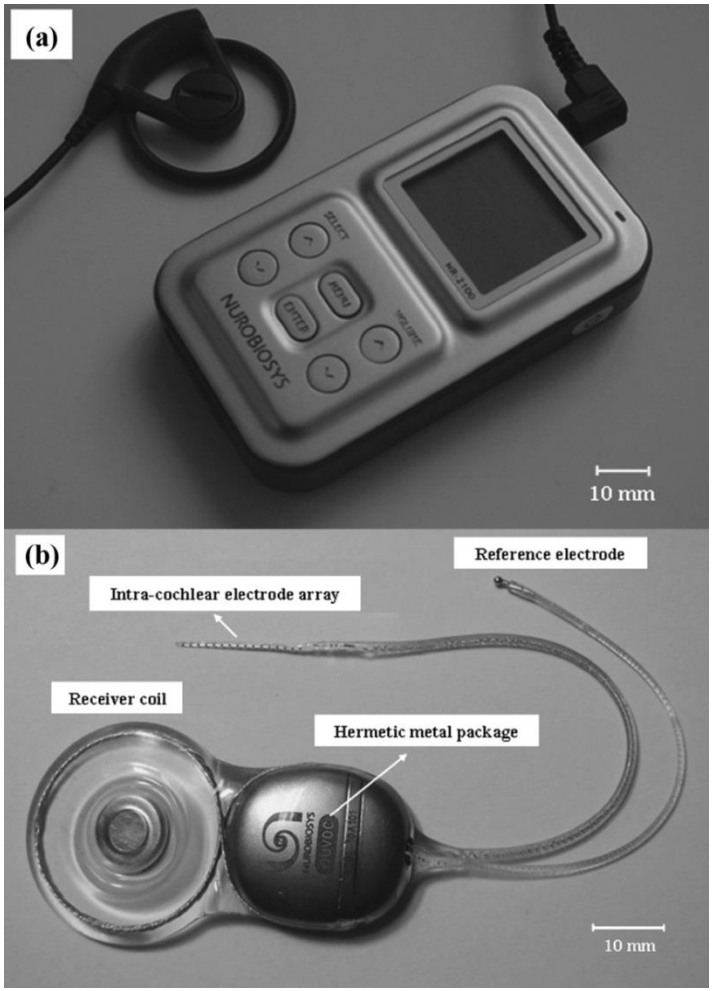


Cochlear Implant

- **Components in cochlear implant**
  - Microphone
  - DSP processor
  - Inductive coil
  - ASIC chip
  - Electrode arrays
  - …

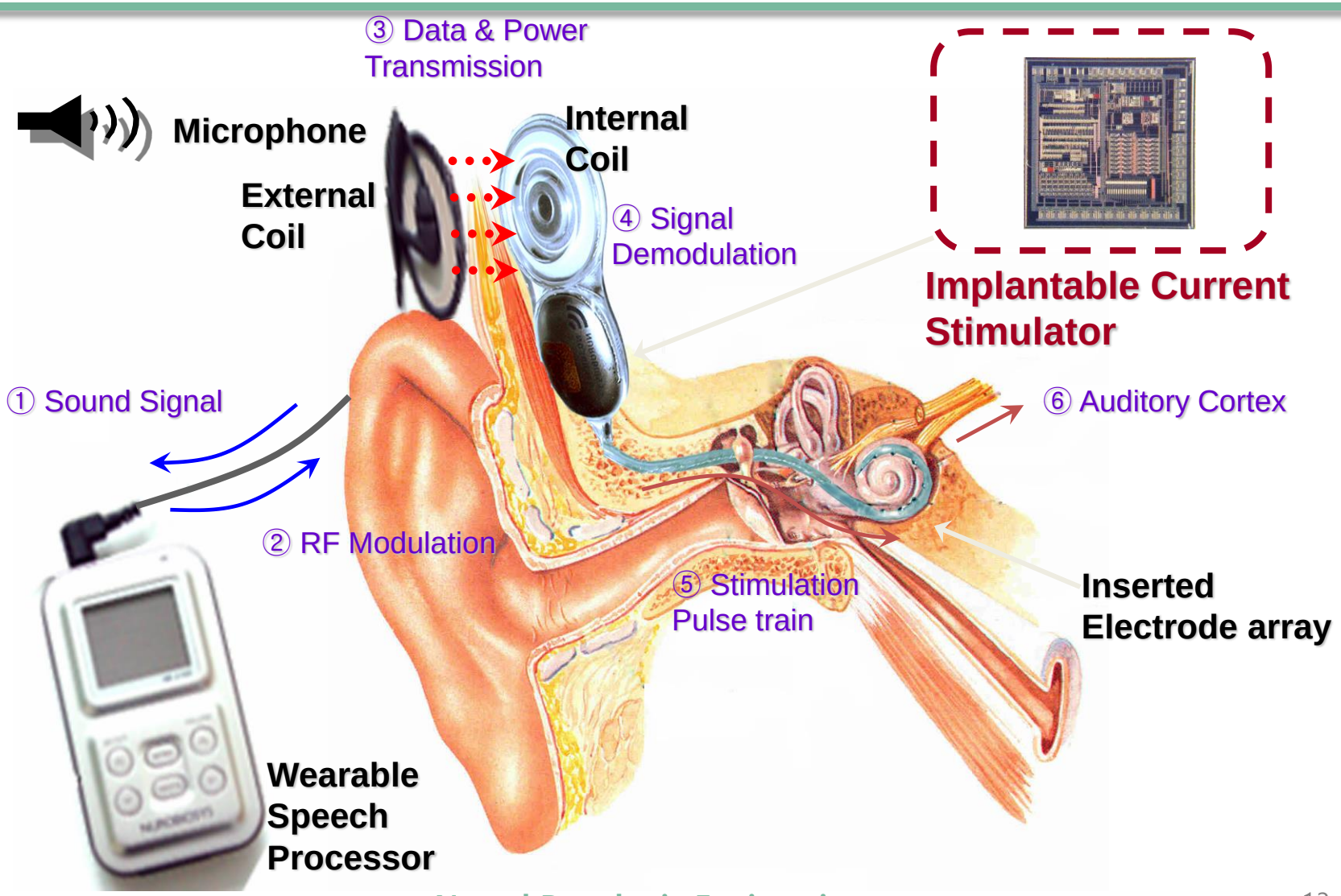


Current stimulator chip



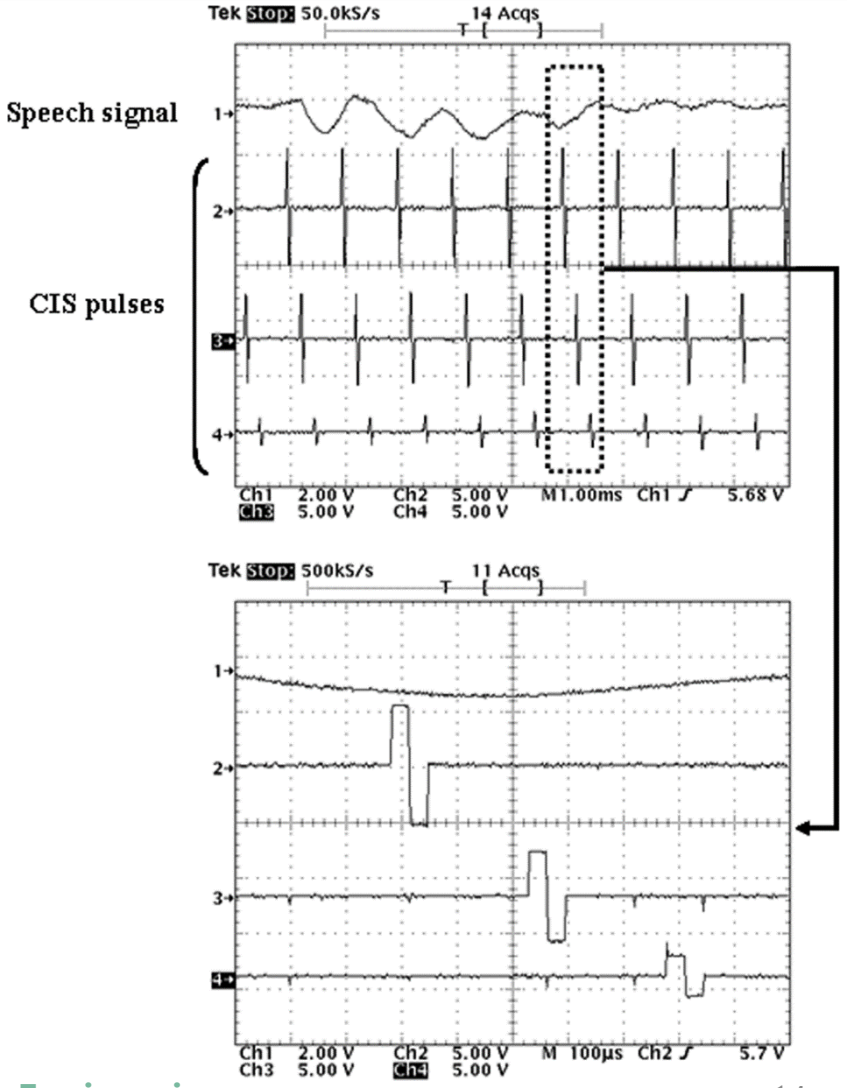
Nurobiosys Corp., Korea

Cochlear Implant – General System Overview

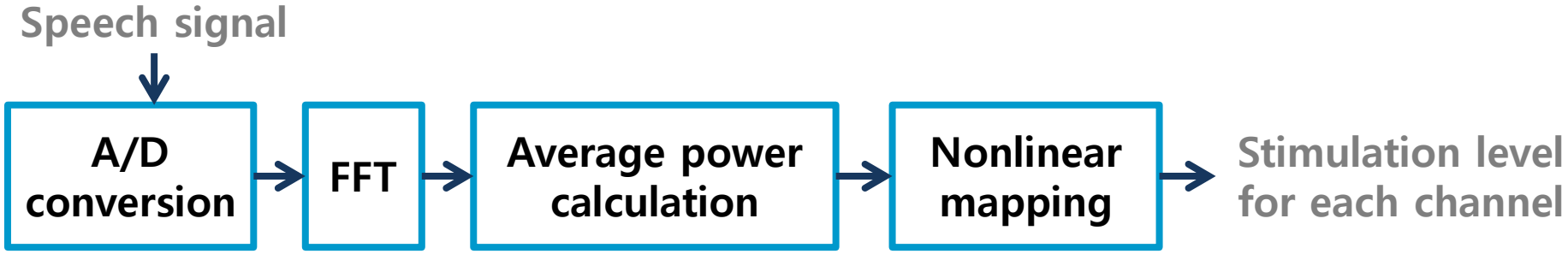


Trying to make these waveforms appear at the electrodes

- Waveforms at various points in the system. Top trace in each panel shows a speech input measured at an output node of the analog preprocessor, and the bottom three traces in each panel show stimuli for the three of the eight channels of stimulation The lower panel shows the interlacing of stimulus pulses across channels using an expanded time scale. The segment shown is indicated by the dotted rectangle in the upper panel.



Signal Processing performed within the DSP hardware.

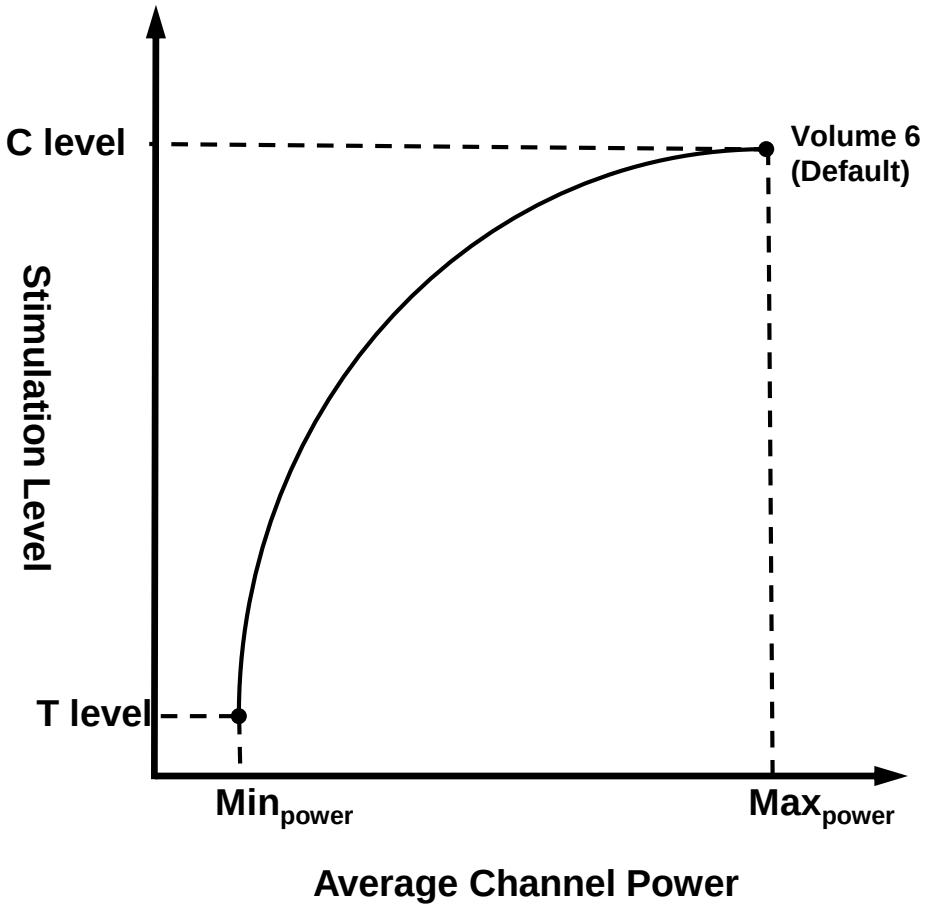


- **A/D conversion**
  - Ex) 10 bit ADC with Sampling frequency of 17 kHz
- **FFT (Fast Fourier Transform)**
  - Power spectral density extraction
  - Transform time domain into frequency domain
- **Average power calculation (the channel-to-frequency allocation rule)**

$$Average\ channel\ power = \frac{\sum power\ spectral\ density\ of\ one\ channel}{band\ size\ (\#\ of\ spectral\ peaks) of\ one\ channel}$$

- **Nonlinear mapping**
  - Stimulation level = log (average channel power)

Mapping



- Log mapping
  - Log. mapping is to define the stimulation level according to the average channel power.
  - Power low function is used.

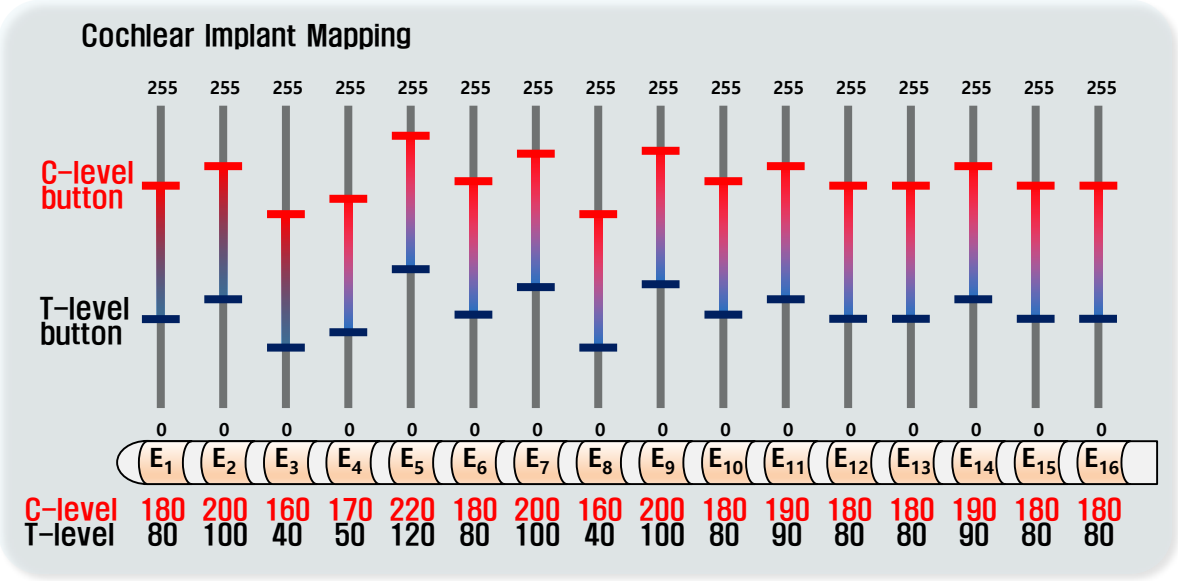
$$y = Ax^p + B$$

$$where\ A = \frac{C - T}{x^p{}_{max} - x^p{}_{min}},$$

$$B = T - Ax^p{}_{min},$$

$$p = 0.2$$

MAPPING–EXAMPLE

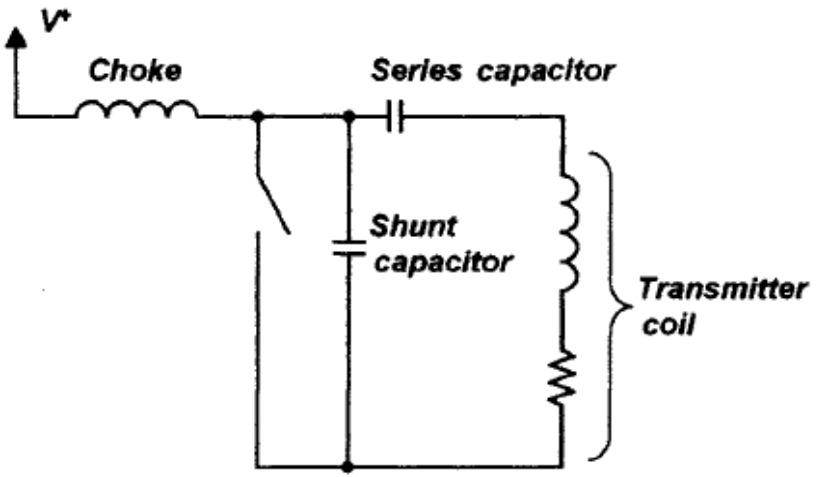


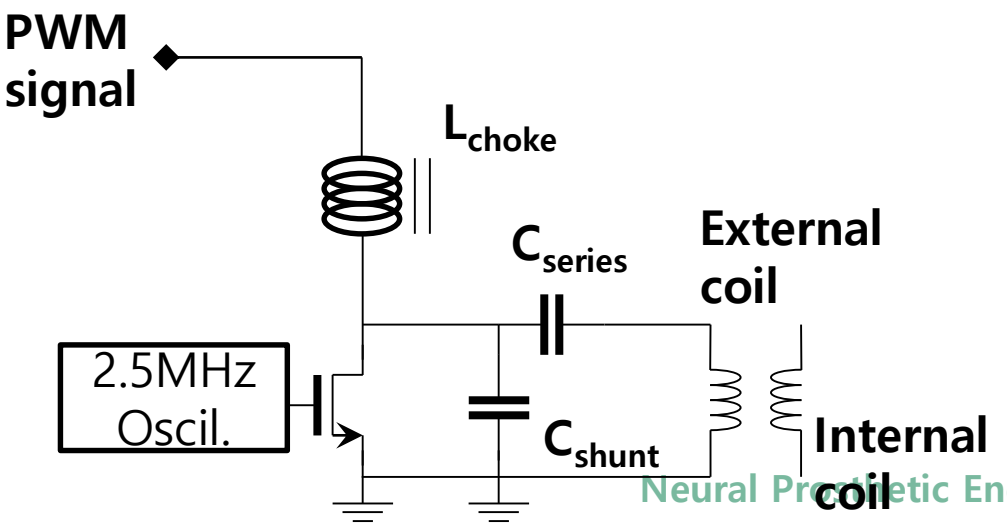
Frequency Allocation

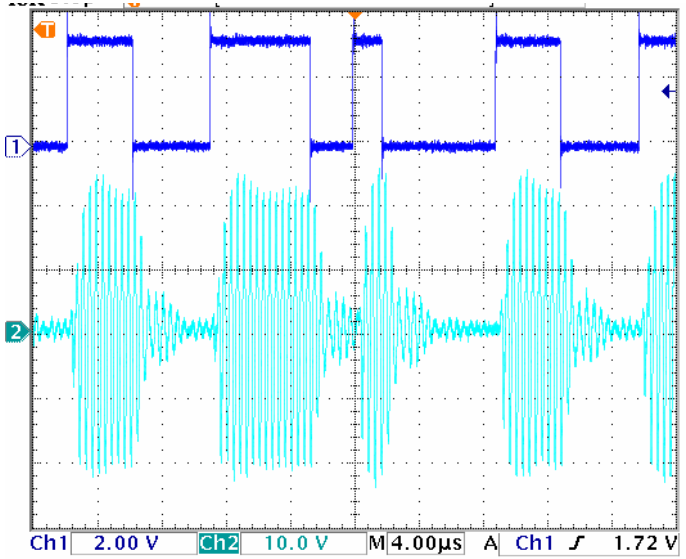
Electrode	Frequency range (Hz)
E_1	300- 450
E_2	400-550
E_3	550-700
E_4	700-850
E_5	850-1000
E_6	1000-1250
E_7	1250-1500
E_8	1500-1800
E_9	1800-2200
E_{10}	2200-2600
E_{11}	2600-3200
E_{12}	3200-3800
E_{13}	3800-4600
E_{14}	4600-5500
E_{15}	5500-6500
E_{16}	6500-7800

Power Amplifier

- Class E amplifier
  - Class E operation: the loss in the switching element of the converter becomes **very low**.

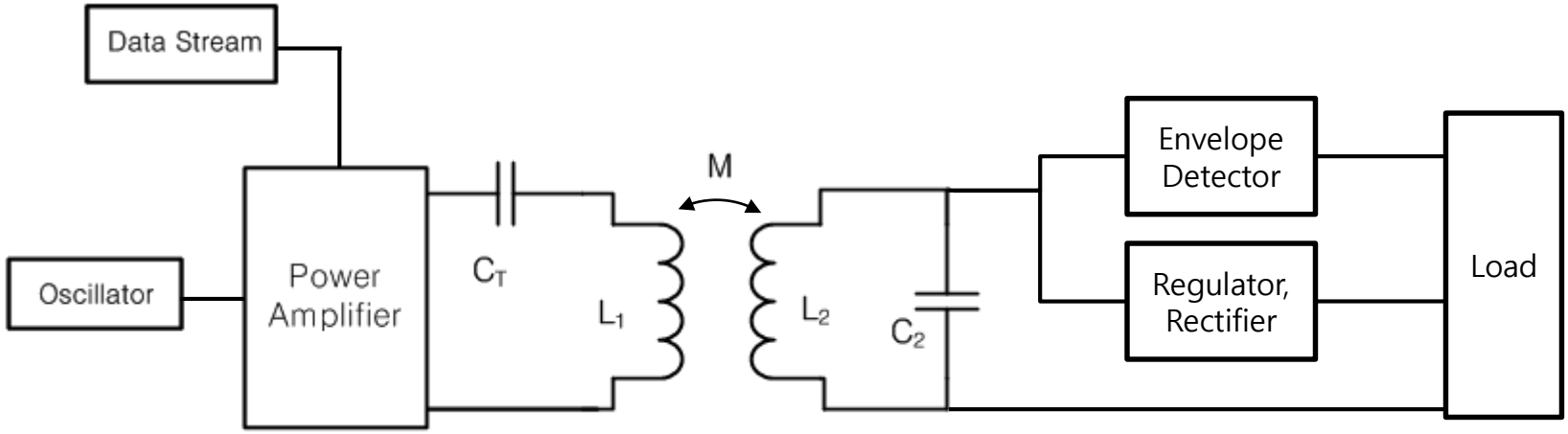




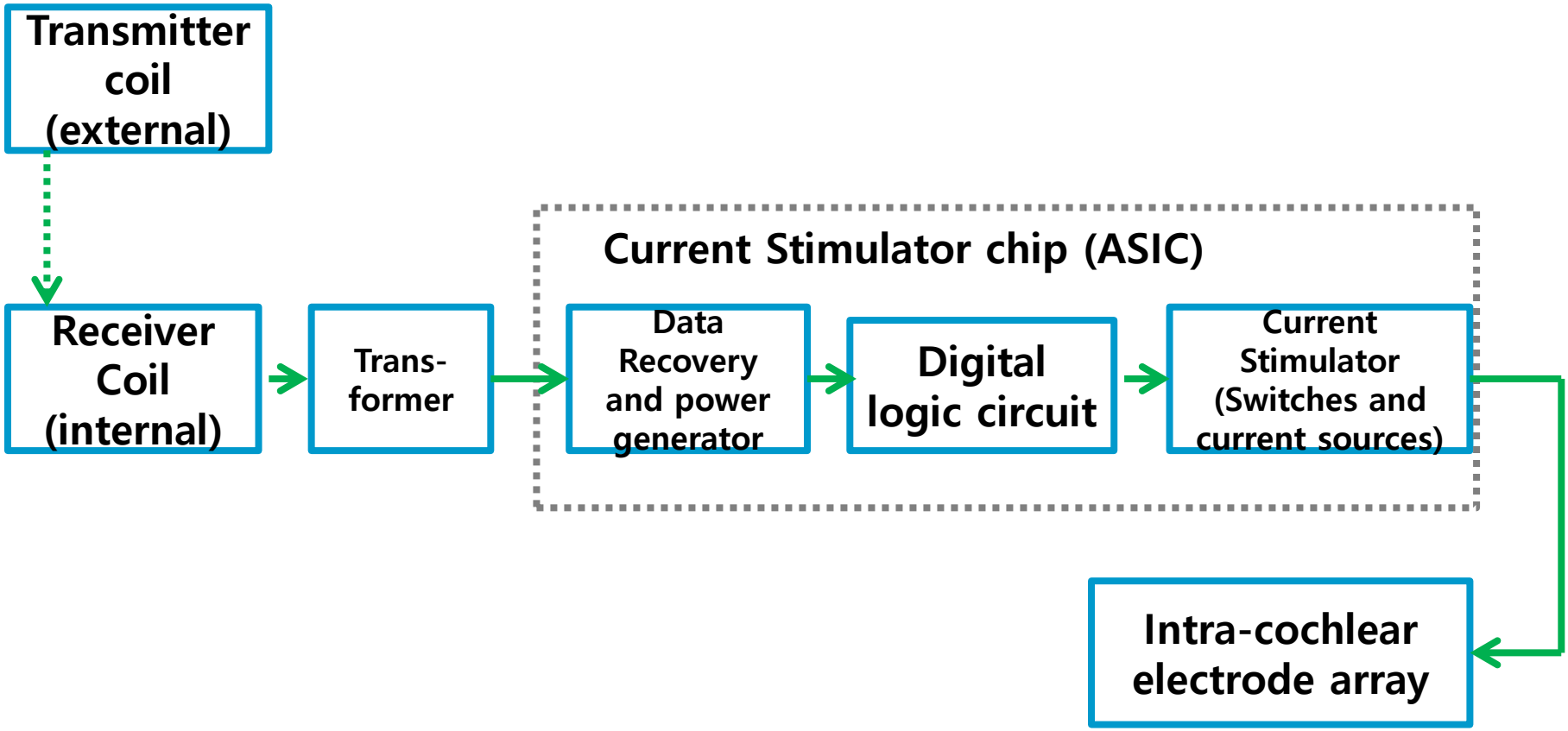


Telemetry-later-use separate file

- Data can be transferred via inductive link simultaneously with power
- Bi-directional Telemetry

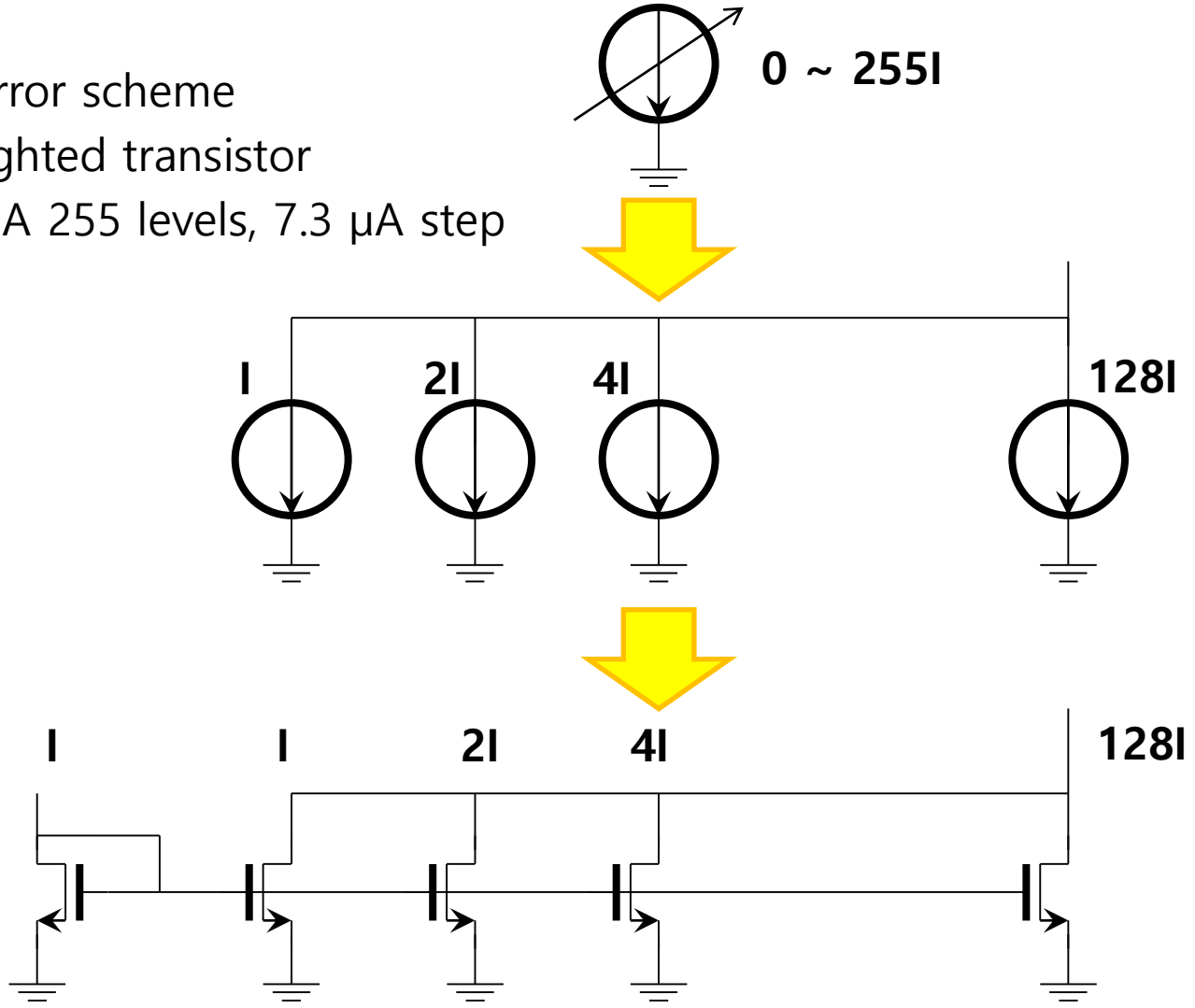


Block Diagram of the Internal Device



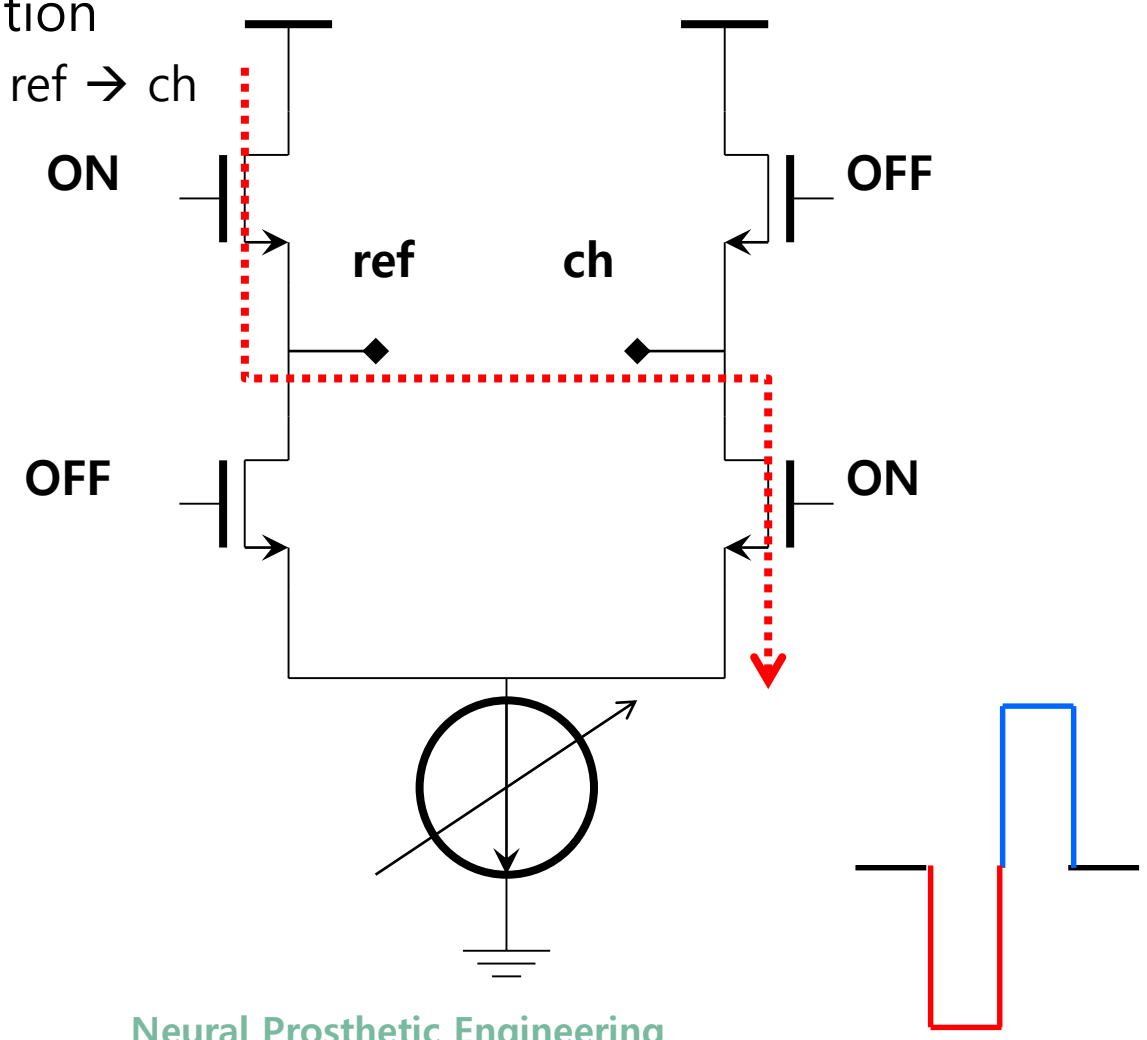
Current source

- Current mirror scheme
- Binary-weighted transistor
- 0 ~ 1.86 mA 255 levels, 7.3 μA step



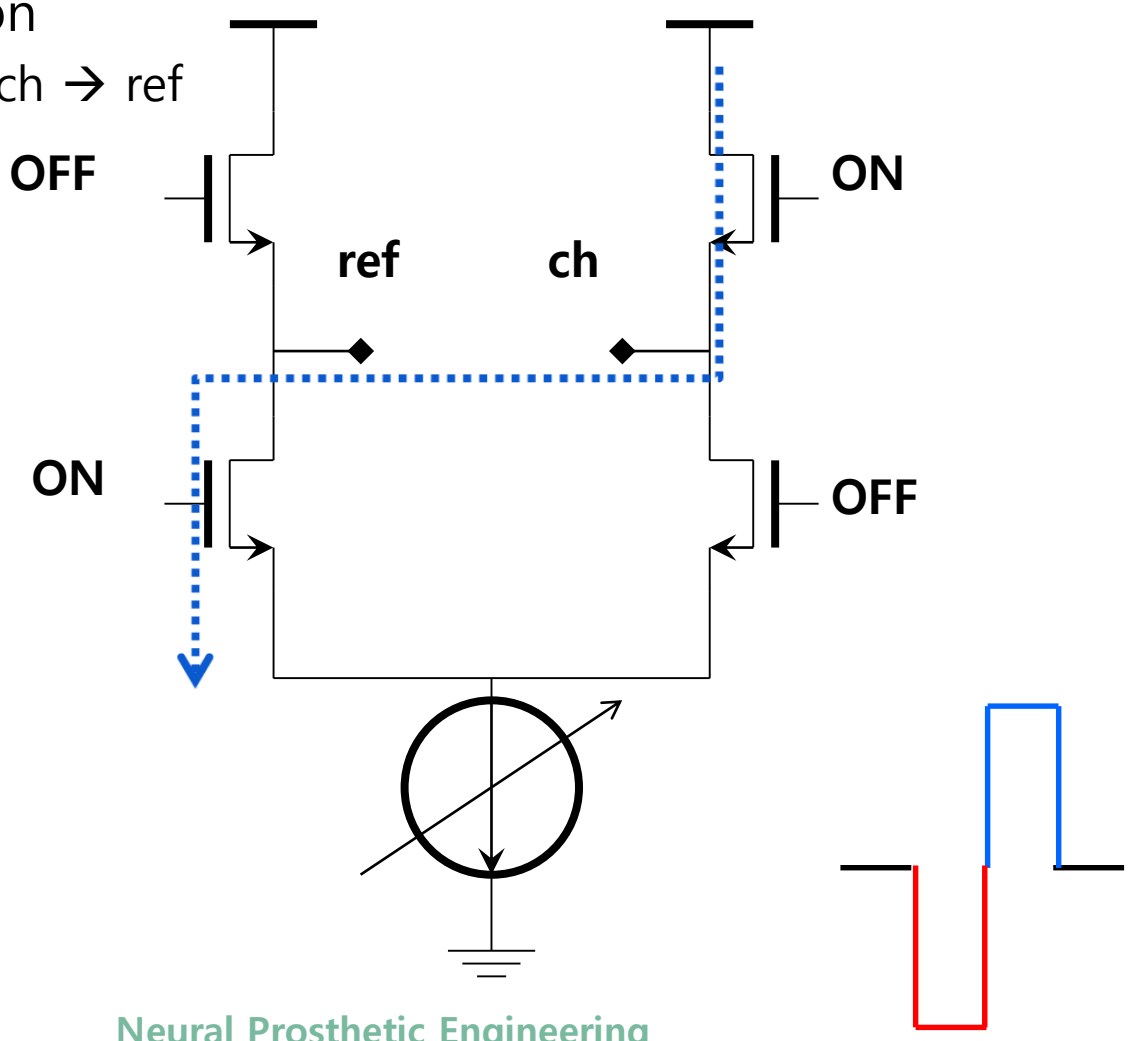
Current Stimulator

- Cathodic stimulation
  - Current flow – ref → ch



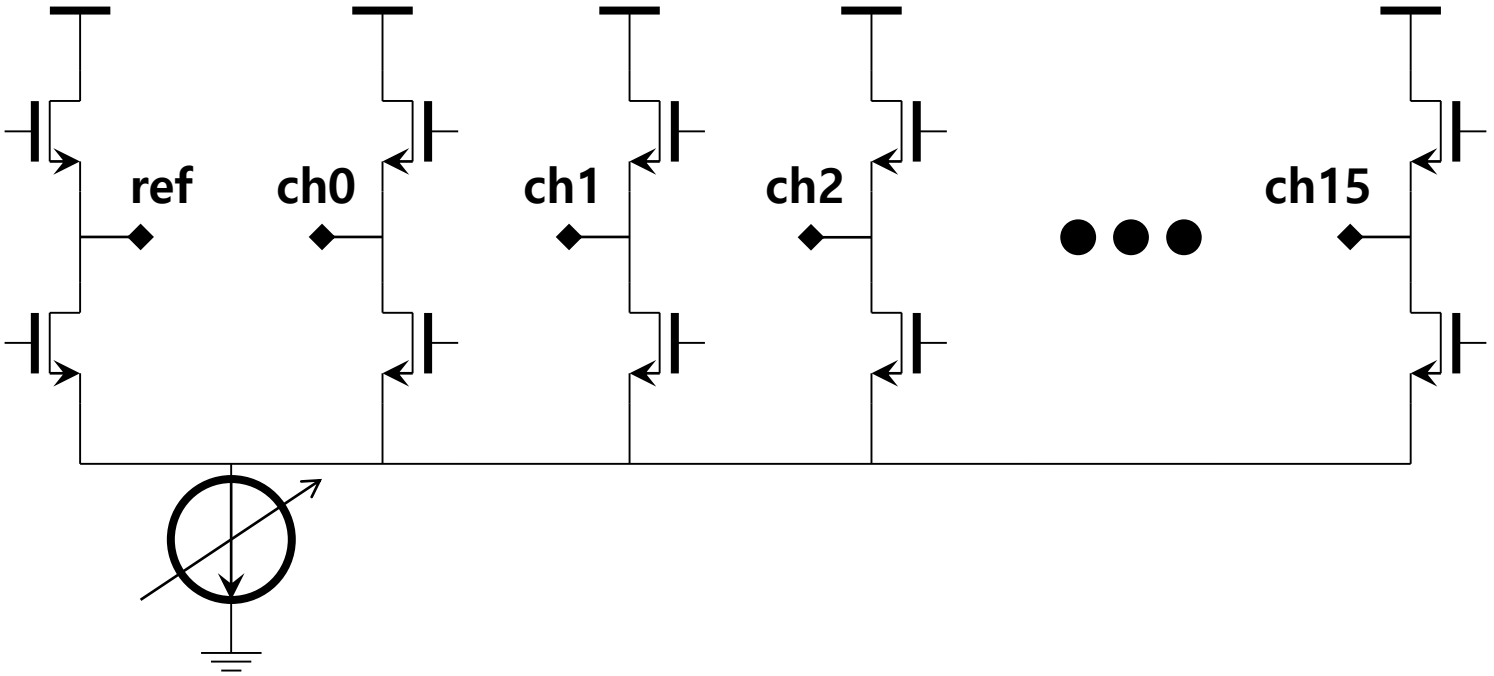
Current Stimulator

- Anodic stimulation
  - Current flow – ch → ref



Current Stimulator

- Overall schematic



Result

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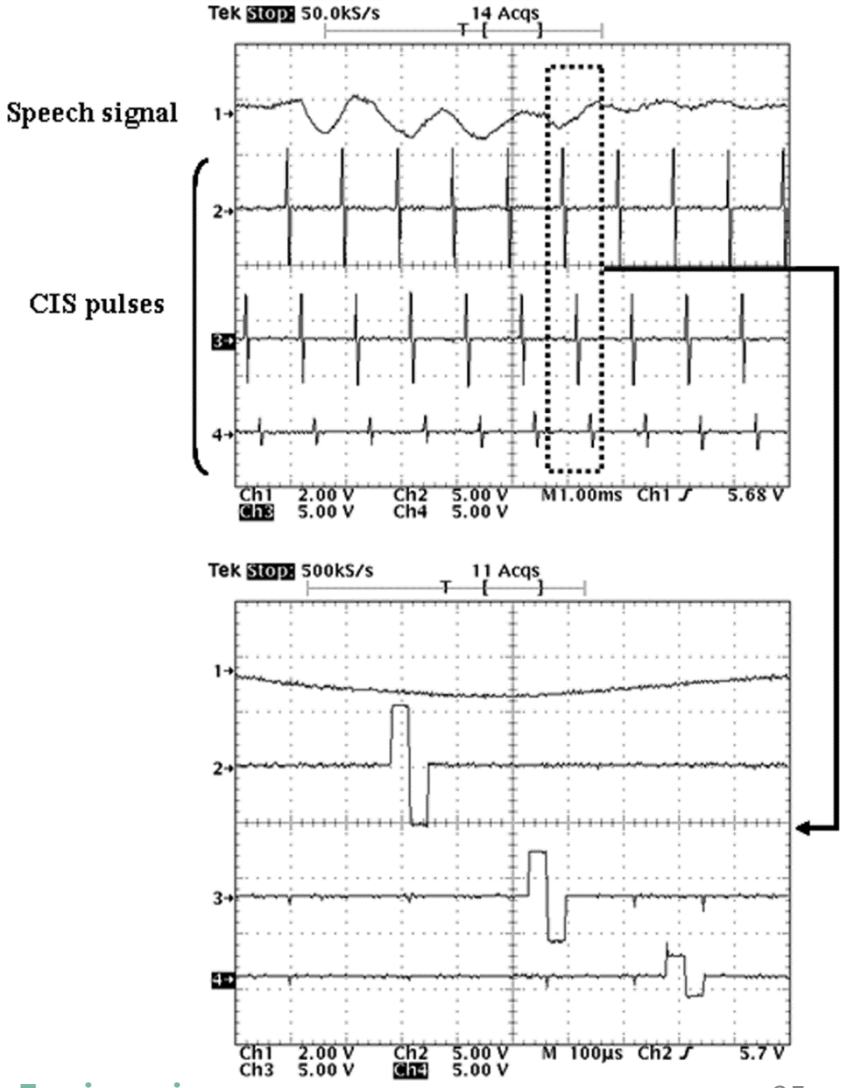

Reference

- F.G.Zeng et al., (IEEE Reviews in Biomedical Engineering, 2008)
- P.C.Loizou, (IEEE Engineering in Medicine and biology, 1999)
- B. Wilson et al., (Nature, 1991)
- D.Riss et al., (Otology & Neurotology, 2011)
- N.B.Frederigue, (Brazilian J. Otorhinolaryngology, 2003)