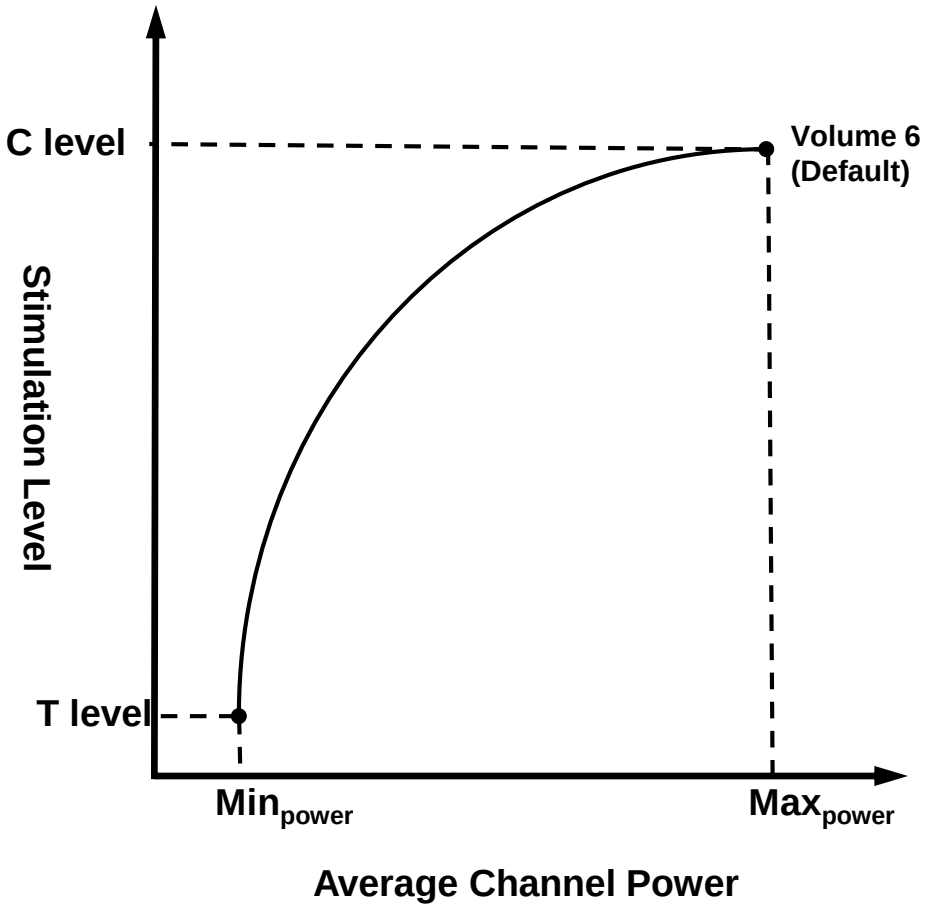
Today

- Homework due today
- Question on projects?
- Review
  - Digital filtering
  - Mapping
  - stimulator
- System continued
  - Telemetry
- Speech Processing Strategies

Review

Mapping



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

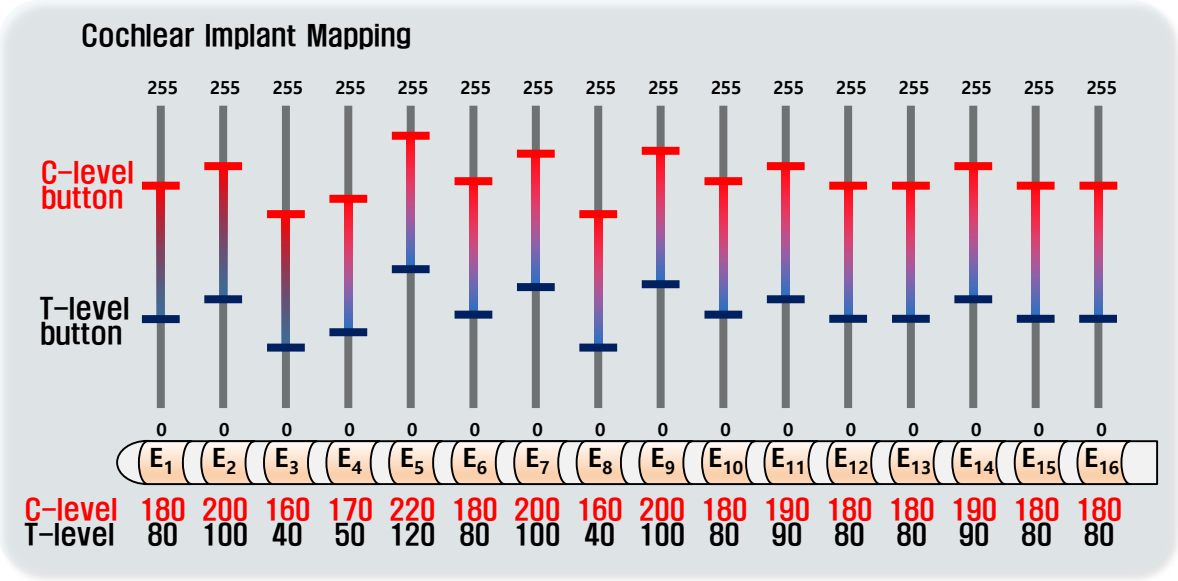
$$y = Ax^p + B$$

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

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

$$p = 0.2$$

MAPPING–EXAMPLE

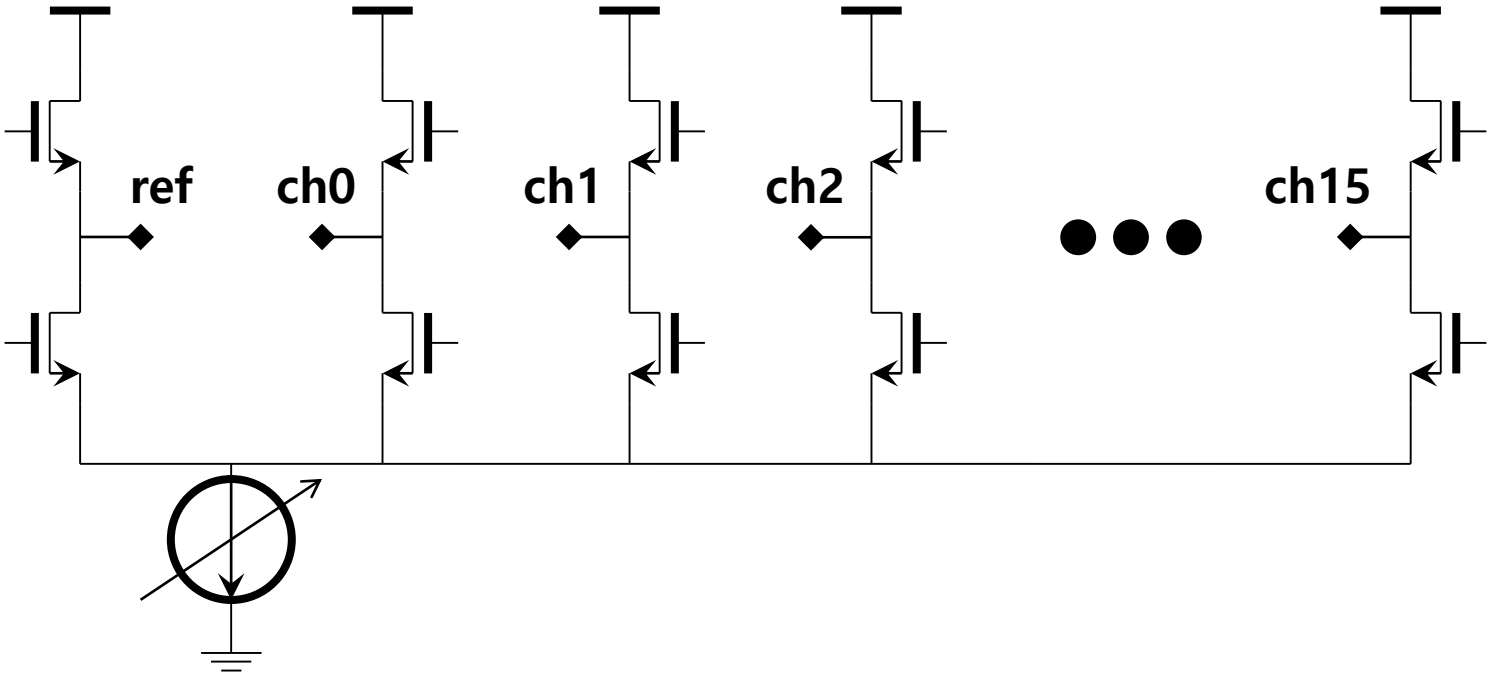


Frequency Allocation

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

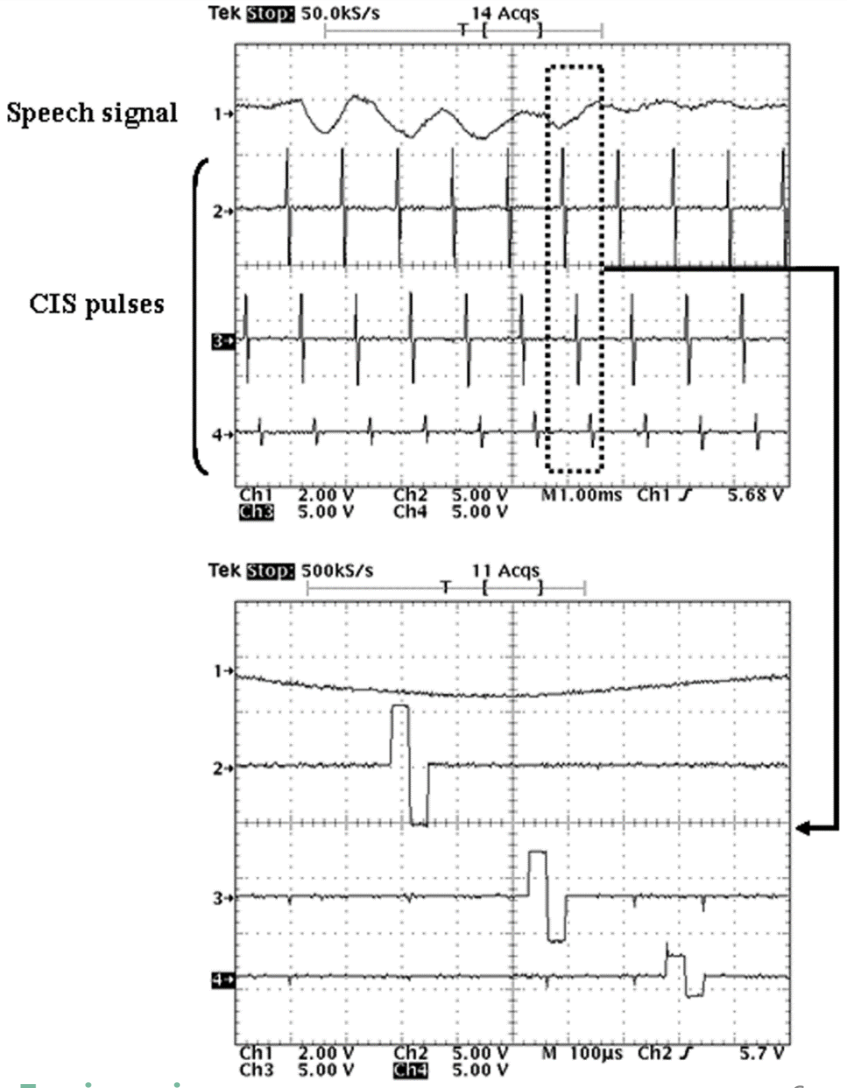
Current Stimulator

- Overall schematic



Result

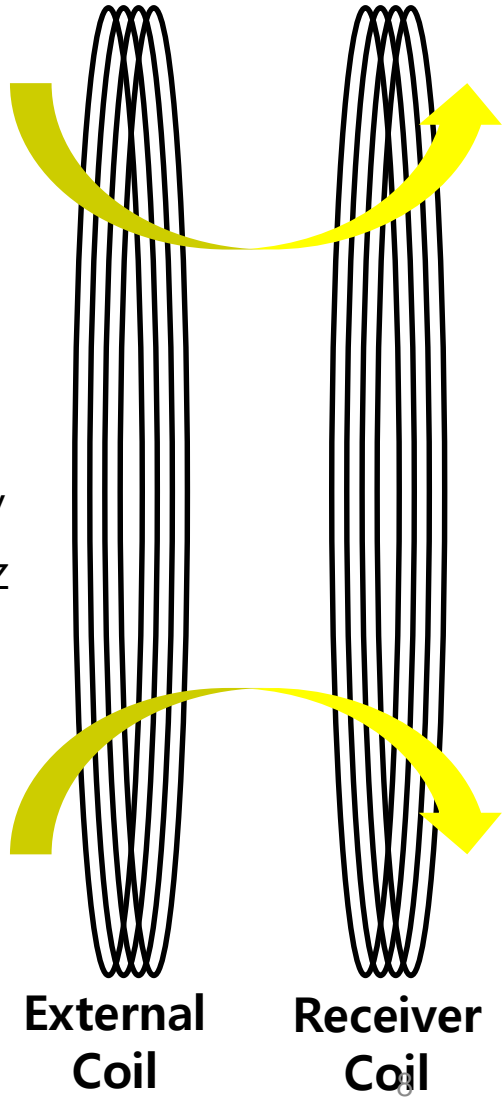
- Waveforms at various points in the system. Top trace in each panel shows a speech input measured at an output node of the analog preprocessor, and the bottom three traces in each panel show stimuli for the three of the eight channels of stimulation The lower panel shows the interlacing of stimulus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



telemetry

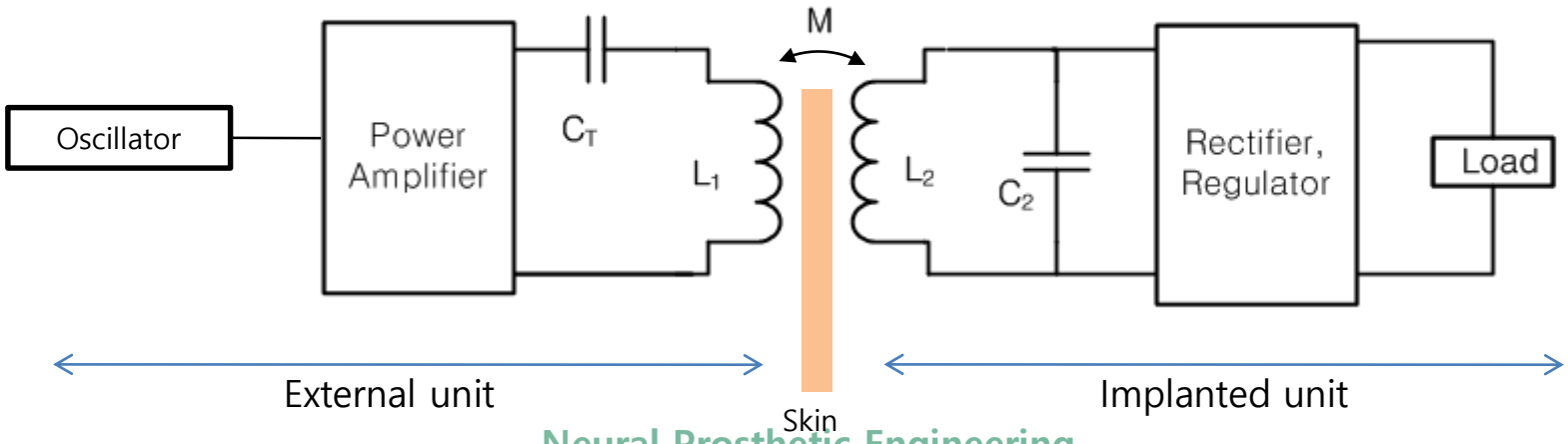
Inductive Links

- Inductive Link
  - All power and communication is provided through the **inductive link**
- The frequency of operation
  - Coil size, adequate system bandwidth for data telemetry
  - Coil losses dramatically increase with increasing frequency
  - Choose lowest frequency possible (typical range : 100 kHz ~ 50 MHz)



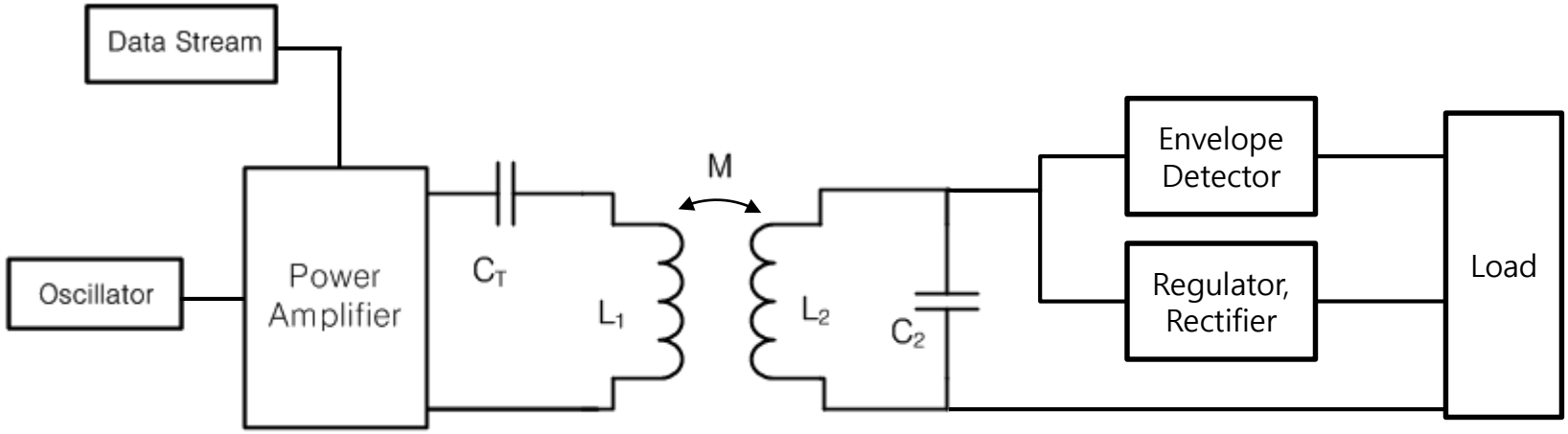
Wireless Power Delivery through Inductive Link

- Inductive Link
  - A pair of coil (one implanted , the other on the skin) form a loosely coupled air-core transformer across the skin barrier
  - AC Current on External coil creates EM field
  - Implanted coil captures a portion of this field and current is produced
  - Power is delivered to implanted device



Simultaneous Data Transmittance

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

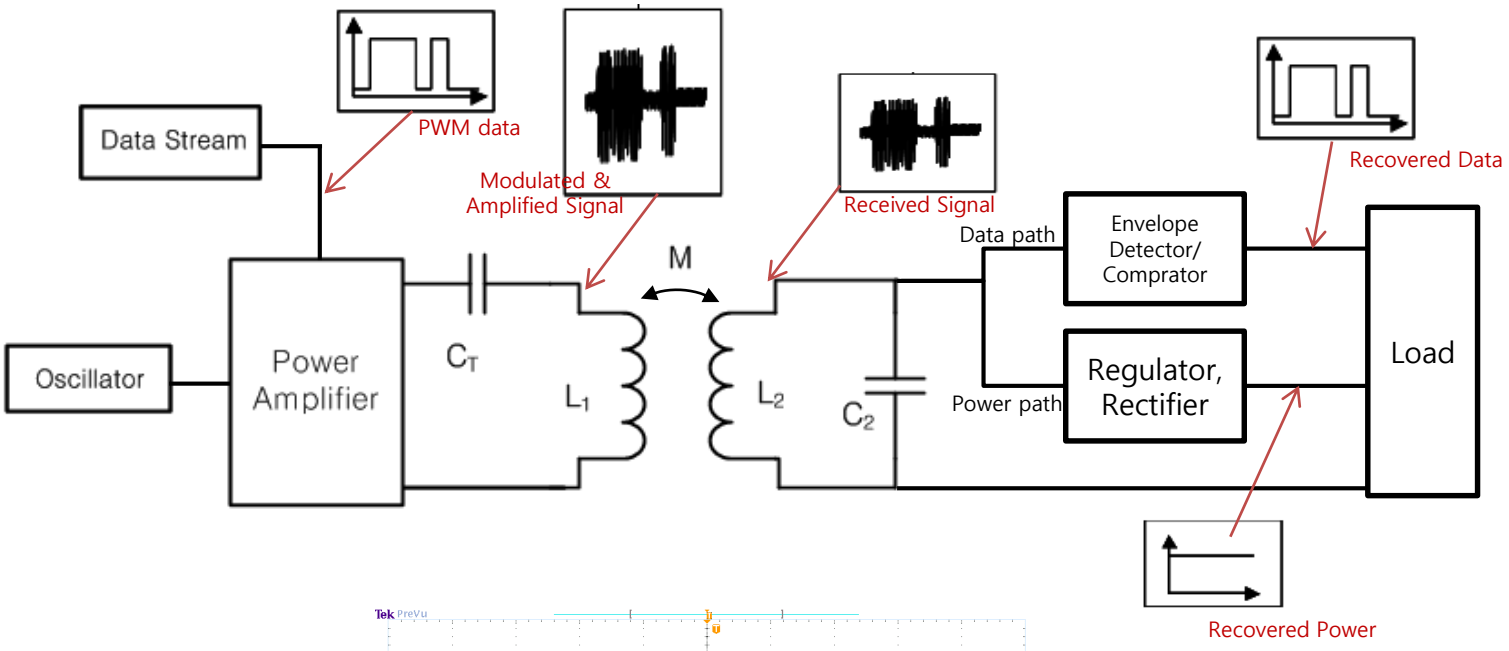


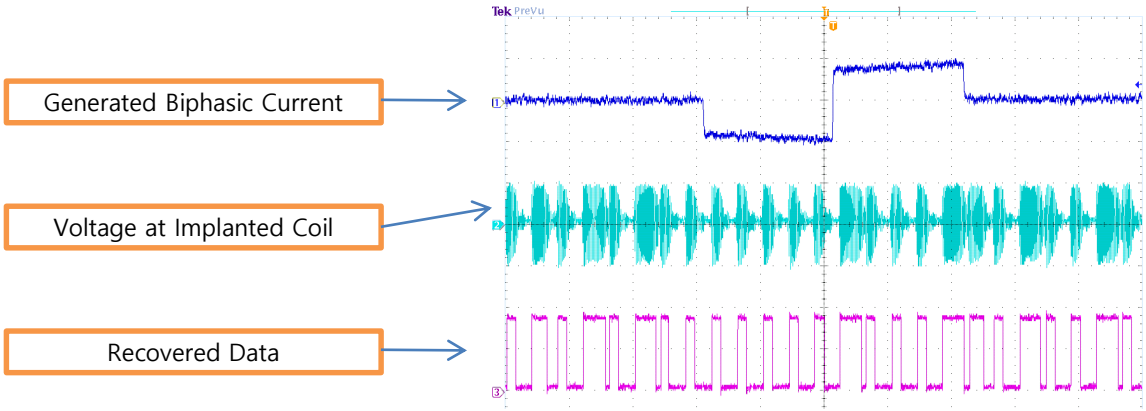
Data Telemetry – down link

- Downlink
  - Binary data for controlling the implanted circuit is generated
  - Data is modulated using a carrier
    - PWM (Pulse Width Modulation)
  - Received signal in implanted coil is bifurcated: data and power
  - Original data is reconstructed by data decoding circuit (Envelope detector and comparator)
  - Waveforms in next page

Data Telemetry – Inductive Link

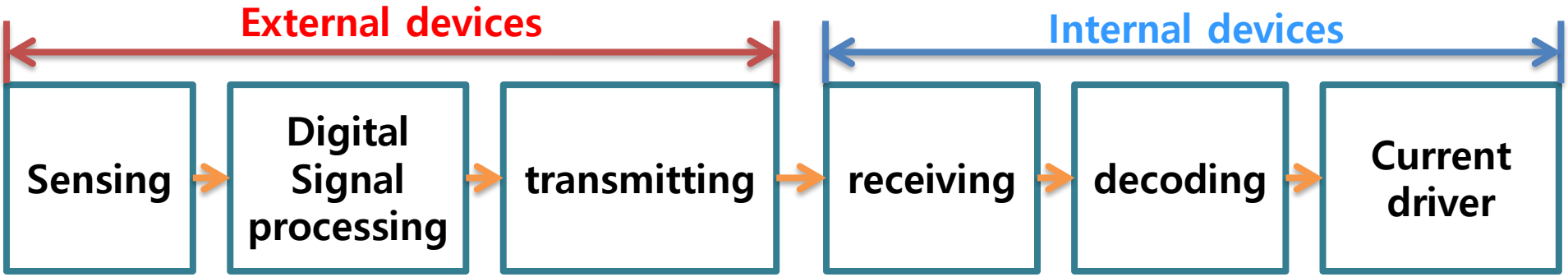
- Downlink using PWM scheme





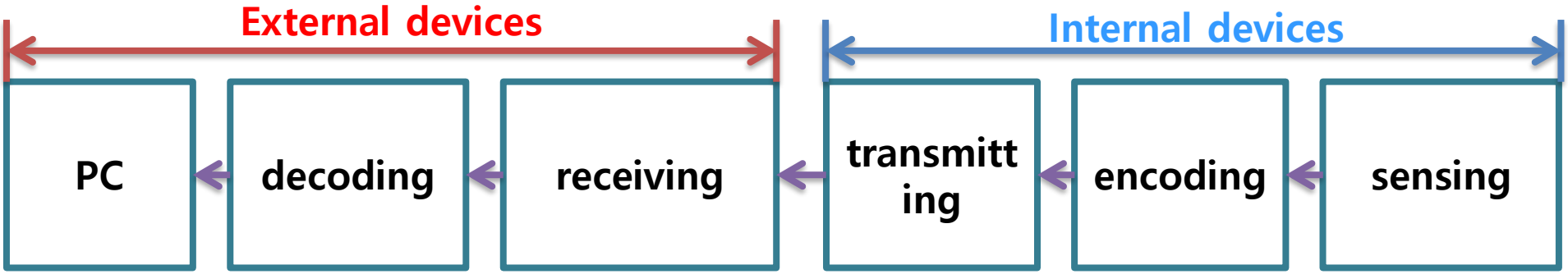
Backward telemetry

❖Forward telemetry



❖Backward telemetry

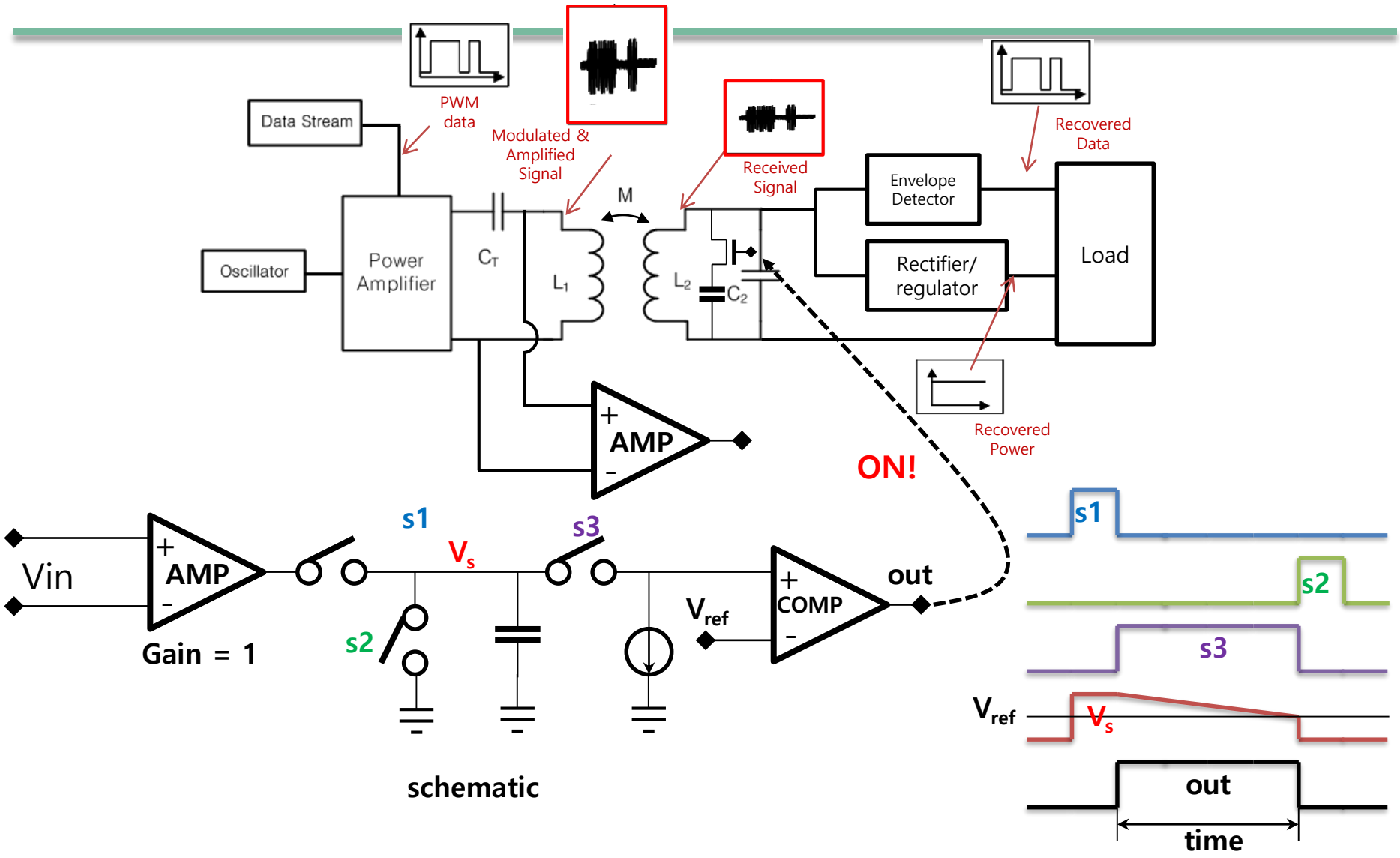
- Transfer data of the implanted device into the outside world – **status of implanted device, neural activities, information of electrodes.**



Back Telemetry

- Back Telemetry (Bidirectional link)
  - Transmission of data from the implanted components to speech processor
  - Purpose : Assessment of physiological condition of the auditory nerve and device integrity
  - Information on back telemetry
    - Electrode impedance
    - Power check
    - Neural response telemetry (NRT)
  - High-fidelity recordings of intracochlear evoked potentials require high sampling rates, high resolution, rapid recovery of the recording amplifiers from the saturation produced by the presentation of stimulus pulses

Backward telemetry



Wireless Powering – Inductive Link

- Limitations
  - Power efficiency is low
    - max. ~50% at 10mm distance
  - Efficiency is highly sensitive to coil distance and misalignment
    - Magnet for aligning coil is not MRI-safe
  - Applicable only for short distance (<20mm)

Energy Harvesting

- Energy harvesting is the process by which energy is derived from external sources and stored for small, wireless devices.
- Sources (examples)
  - Ambient-radiation
  - Biomechanical
  - Photovoltaic
  - Piezoelectric
  - Thermoelectrics
  - Blood sugar

Safety Concerns: SAR

- Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field;
- It is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg).
- SAR is usually averaged either over the whole body, or over a small sample volume (typically 1 g or 10 g of tissue). The value cited is then the maximum level measured in the body part studied over the stated volume or mass.
- SAR measures exposure to fields between 100 kHz and 10 GHz (known as radio waves). It is commonly used to measure power absorbed from mobile phones and during MRI scans.
- The value will depend heavily on the geometry of the part of the body that is exposed to the RF energy, and on the exact location and geometry of the RF source. Thus tests must be made with each specific source, such as a mobile phone model, and at the intended position of use.
- SAR caused by cell phones in the market is around 1W/Kg

$$\mathrm{SAR} = \frac{1}{V}\int_{\mathrm{sample}} \frac{\sigma(\mathbf{r})|\mathbf{E}(\mathbf{r})|^2}{\rho(\mathbf{r})}\,d\mathbf{r}$$

σ : electrical conductivity
E : RMS electric field
ρ : sample density V: Volume

SAR – Simulations of Retina Implant

- Field absorption can cause thermal elevation of surrounding tissue
- Quantitative analysis is required before designing telemetric system
  - Simulation using 1mm-resolution of Human Body Model, imitating more than 20 types of tissue
  - External coil for retinal implant
  - Diameter 37 mm
  - 2 centimeter distance @ 2MHz

- Simulation Results
  - Maximum SAR was less than 0.1 W/Kg
  - Temperature rise at the implanted coil ~ 0.35 degree at the tissue ~0.15 degree

V. Singh et. al., *Specific Absorption Rate and Current Densities in the Human Eye and Head Induced by the Telemetry Link of an Epiretinal Prosthesis*, IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 57, NO. 10, OCTOBER 2009.

V. Singh et. al., *On the Thermal Elevation of a 60-Electrode Epiretinal Prosthesis for the Blind*, IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS, VOL. 2, NO. 4, DECEMBER 2008.