

Reduction, Telemetry, and Processing of Neural Data for an Implantable Data Acquisition System

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Neural Data Acquisition

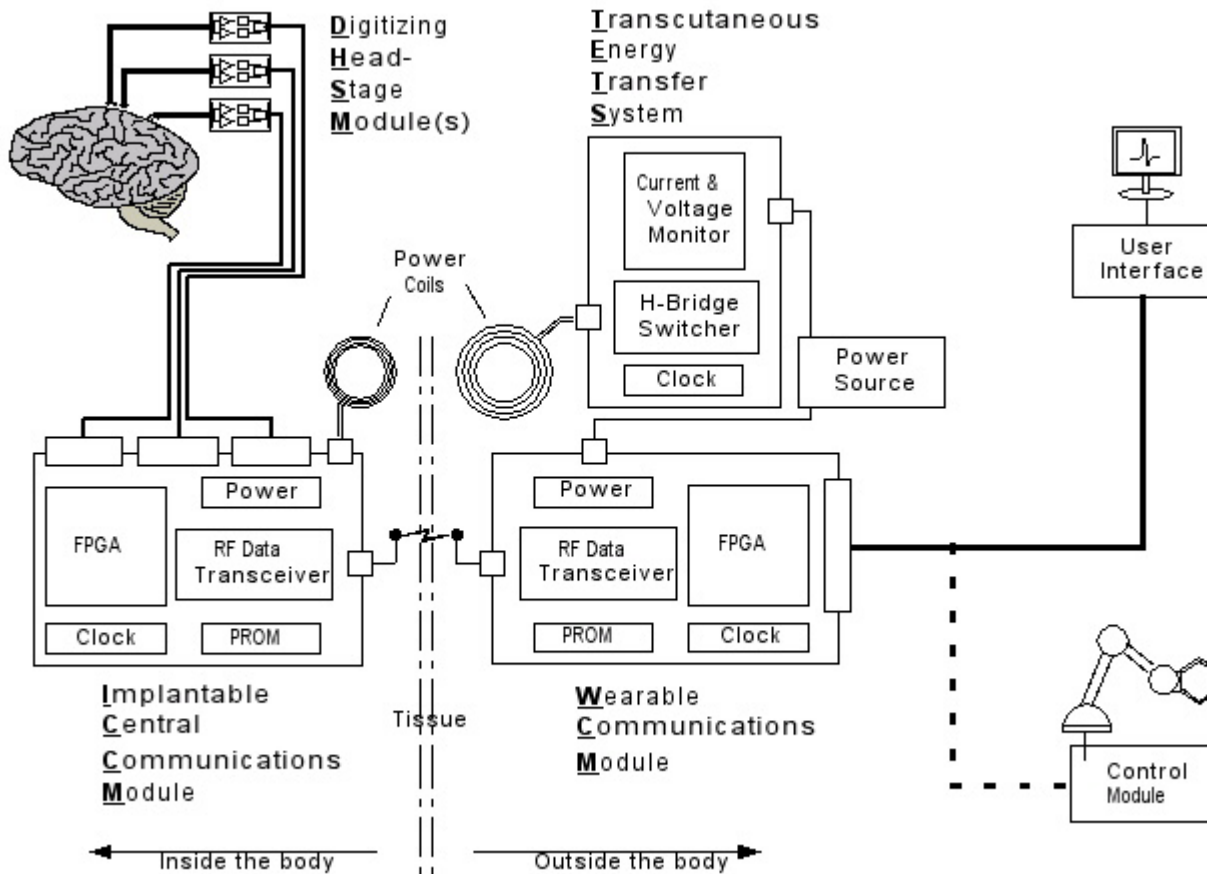
- Research environment
- Brain-machine interface
 - Restore motor function

Why Implantable?

Reduction, Telemetry, and Processing of Neural Data for an *Implantable*
Data Acquisition System

- Alternative: percutaneous (“through the skin”) connections
 - Chronic break in skin increases likelihood of infection
 - Tethering effect of wires provides unnatural restraint

System Overview



Flow of Commands and Configuration Information

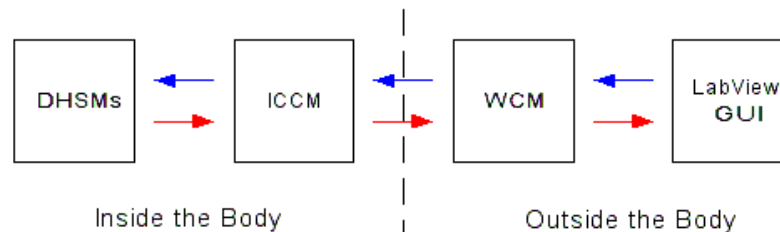
Flow of Neural Data

DHSM=Digitizing Headstage Module

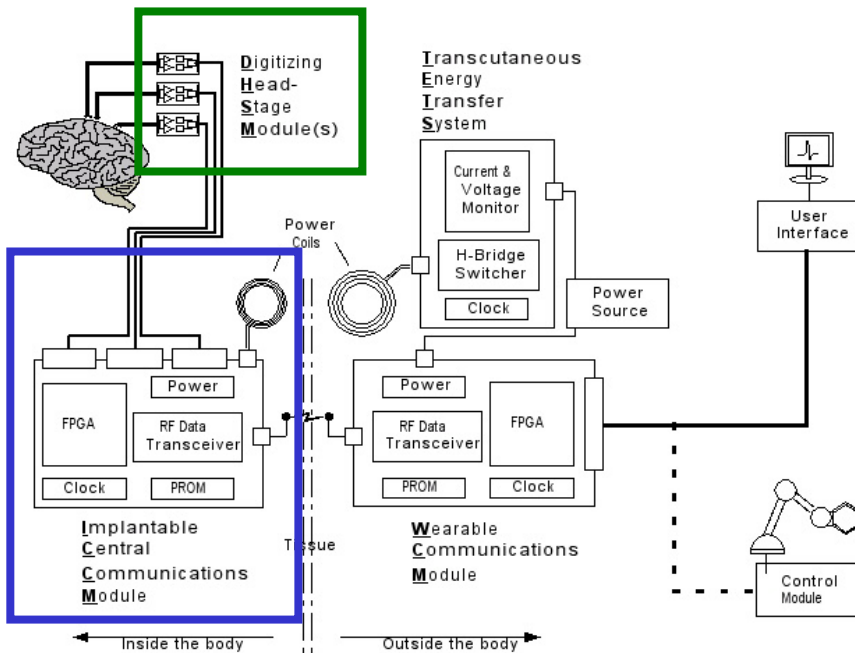
ICCM=Implantable Central Communications Module

WCM=Wearable Communications Module

GUI=Graphical User Interface



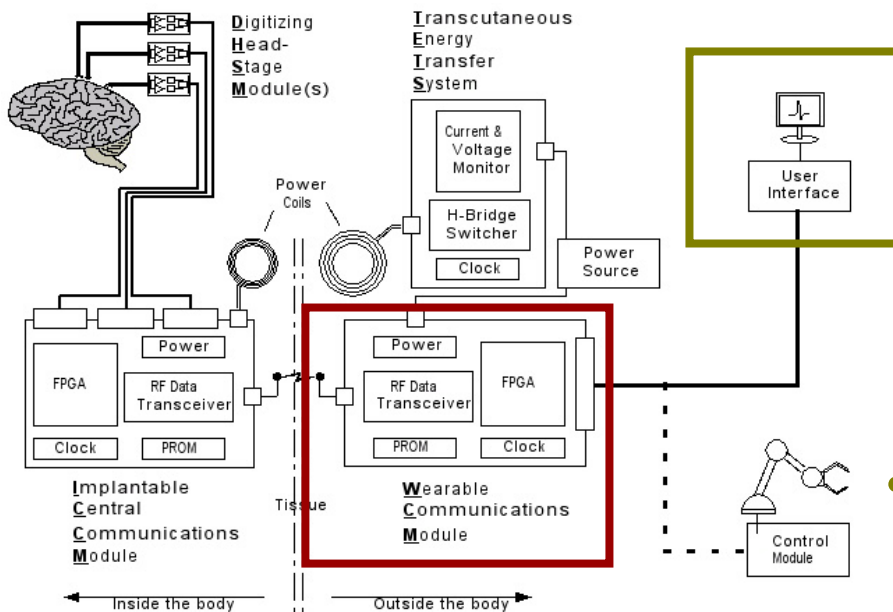
System Overview: Implanted Modules



- Digitizing Headstage Module (DHSM)
 - filters, amplifies, and digitizes 32 channels of neural data
- Implantable Central Communications Module (ICCM)
 - performs data reduction and transmits data out of the body
 - powered transcutaneously

DHSM=Digitizing Headstage Module
 ICCM=Implantable Central Communications Module

System Overview: External Modules

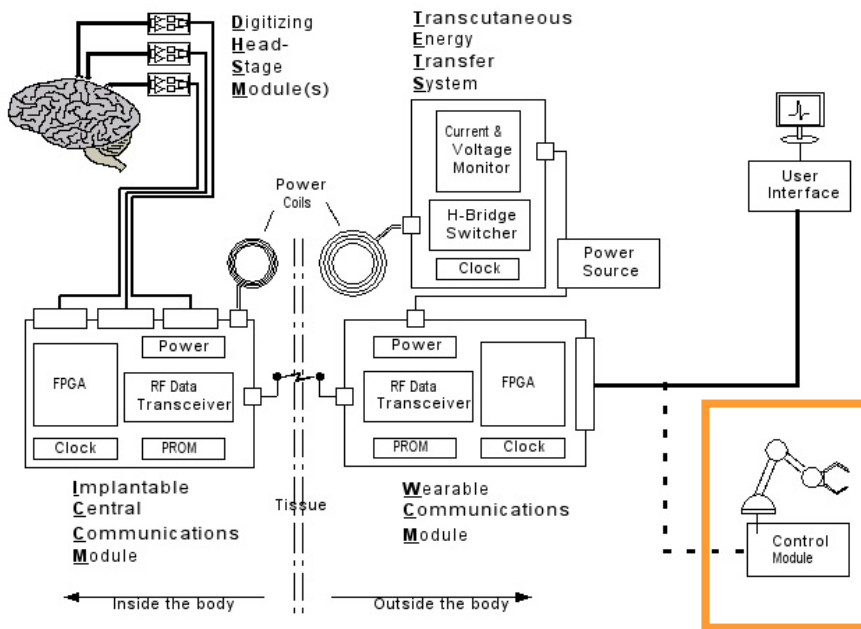


- **Wearable Communications Module (WCM)**
 - sends commands and configuration information to the ICCM
 - receives data from the ICCM
 - performs additional processing
- **User Interface**
 - sends commands to WCM
 - displays, stores, and processes data

ICCM=Implantable Central Communications Module

WCM=Wearable Communications Module

Brain-Machine Interface Application



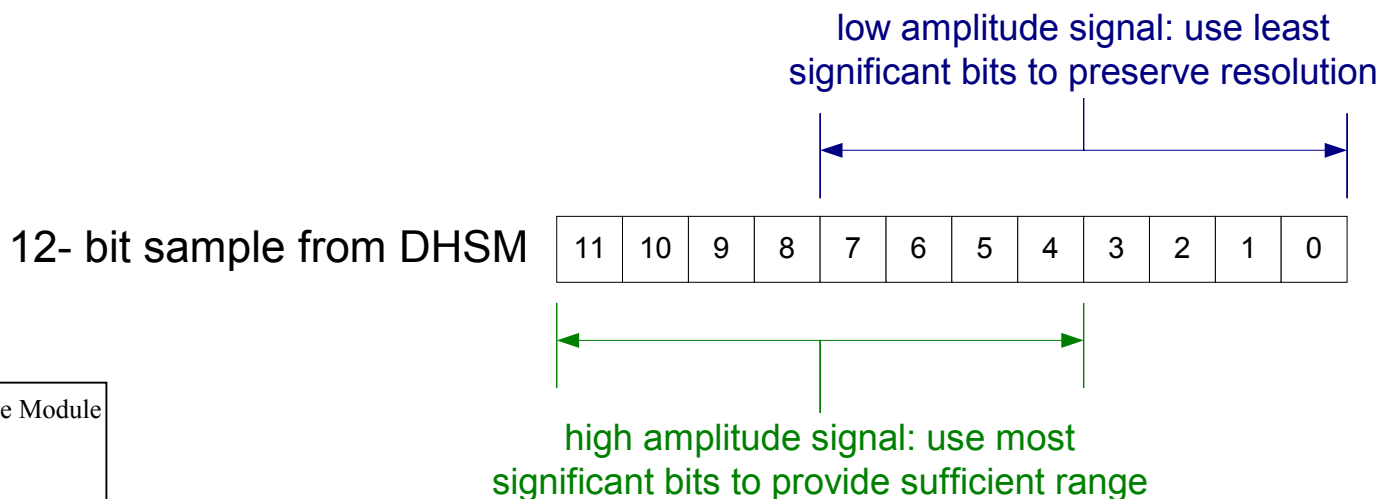
- Use acquired neural data to control a machine
 - robotic/prosthetic arm, wheelchair, computer cursor
- Map neural data (eg, sorted 50ms bincounts) to control commands

Challenges of an Implanted System

- Getting power into the body
- Getting data out of the body
 - Telemetry
 - High data rate \longrightarrow high frequency
 - Low tissue absorption/attenuation \longrightarrow low frequency
 - 916.5 MHz, 1 megabit/second
 - Data Reduction
 - Channels sampled at 31.25 kHz
 - 96 channels vs \sim 3 channels

Data Reduction: Automatic Bit Selection

- DHSMs provide 12-bit samples
- ICCM selects “best” 8 bits
 - Provide highest resolution while still providing sufficient range on a given channel



DHSM=Digitizing Headstage Module

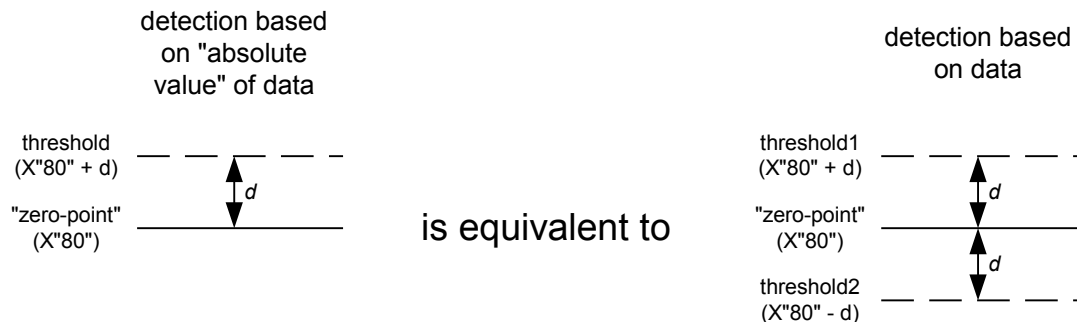
ICCM=Implantable Central
Communications Module

Data Reduction: Output Modes

- Only output information that is of interest/importance
 - Generally relates to spiking activity
- Four output modes
 - Streaming data for a single channel
 - Extracted spikes
 - One millisecond bincounts
 - Streaming data with extracted spikes

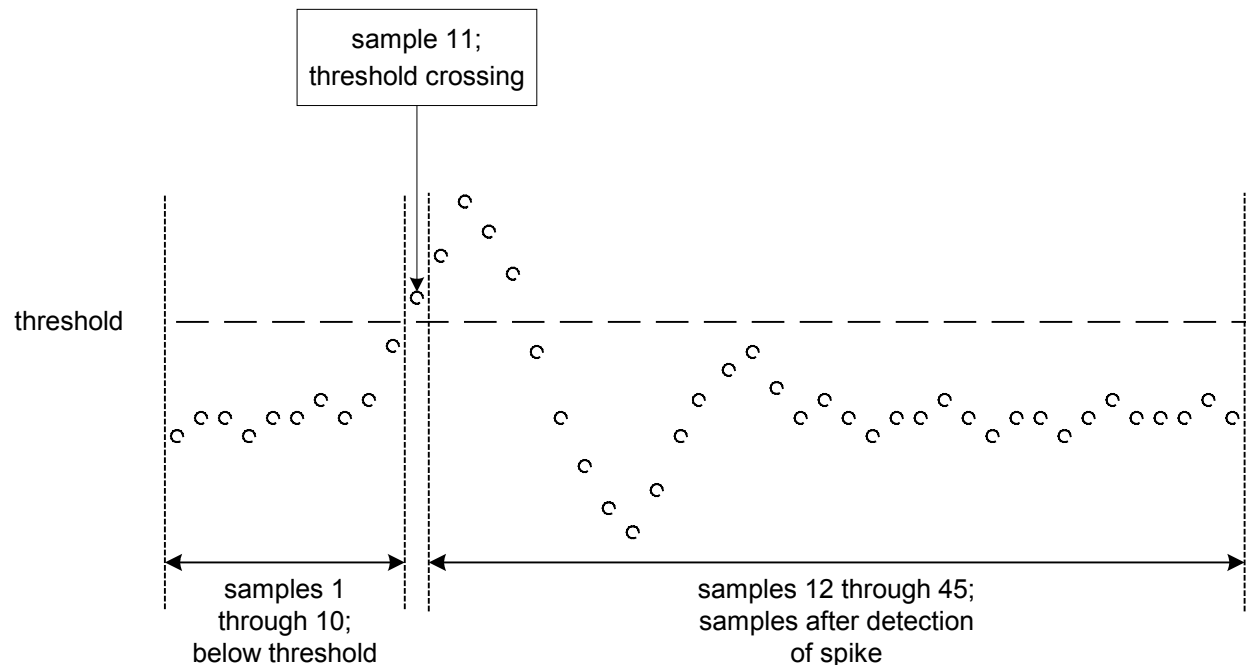
Spike Detection

- Threshold for a given channel is based on mean deviation from channel mean
 - Threshold for channel $X = \alpha * \text{mean}(\text{abs}(\text{"zero-mean" data on channel X}))$
 - α is a user-defined parameter
- Threshold is applied to absolute value of "zero-mean" samples \longrightarrow "dual threshold"



Spike Extraction

- Channel number and timestamp
- 45 samples of waveform per extracted spike
 - 10 samples before threshold crossing



Spike Sorting

- Necessary information
 - Channel number
 - Timing information
 - Waveform shape information

Spike Sorting

- Template Generation
 - Performed by software separate from WCM
 - Templates sent back to and stored in WCM
- Real-time Template Matching
 - Performed within the WCM
 - Output sorted 50ms bins

Telemetry: Bidirectional

- WCM to ICCM: Commands every 50ms
- ICCM to WCM: Data in response to commands

ICCM=Implantable Central
Communications Module

WCM=Wearable Communications
Module

Telemetry: Transmit Engine

- Generate a single stream of data
- Packet assembly
- 8b/10b encoding (byte \longrightarrow 10-bit symbol)
- Send bitstream serially to transceiver

Telemetry: Receive Engine

- Bit recovery
- Decoding
- Packet disassembly

Telemetry: Antenna

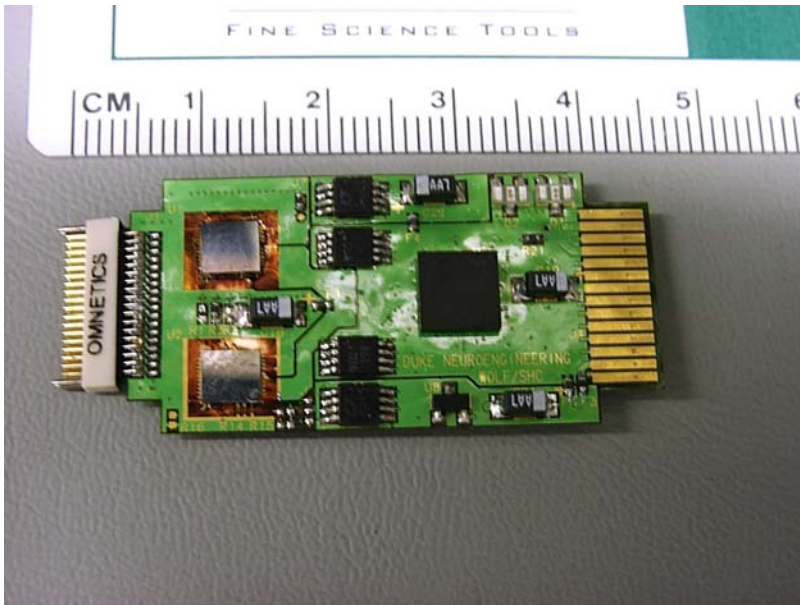
- ICCM must be implantable
- Sufficient range



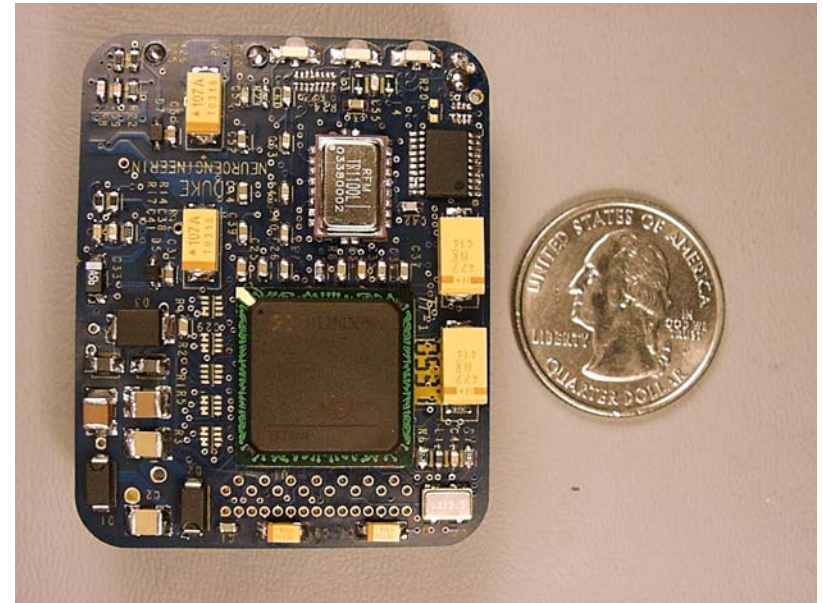
Future Work

- Evaluate performance
 - Spike detection, extraction, sorting
 - Telemetry
- Implant the system

Demo



DHSM



ICCM/WCM



User Interface

DHSM=Digitizing Headstage Module

ICCM=Implantable Central Communications Module

WCM=Wearable Communications Module