INTRAMUSCULAR ELECTRODES AND THEIR USE IN MYOELECTRIC PROSTHESES

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ECE 5030 Final Presentation

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Agenda

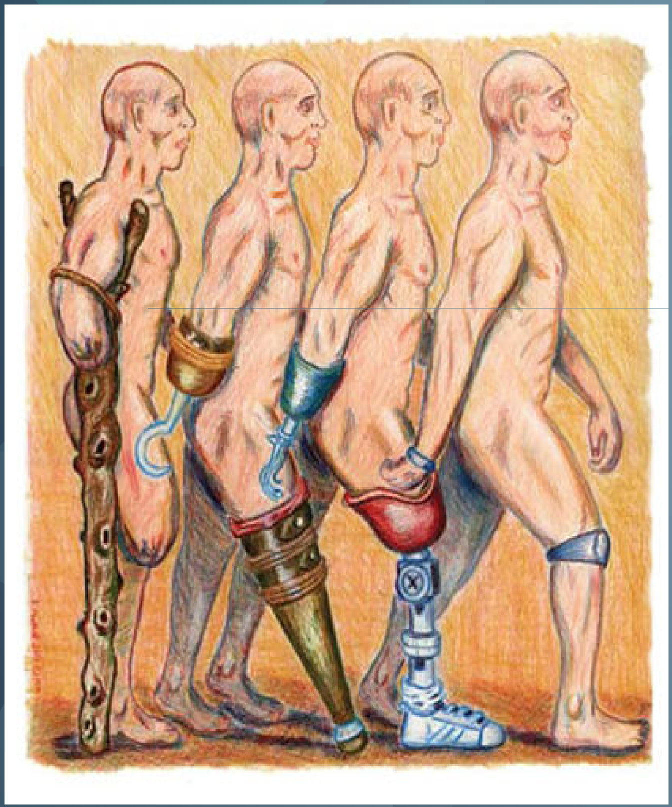
- Motivation
- Introduction to prosthetics
- Surface vs. intramuscular electrode comparison
- Implants and biology
- IMES system
- Brain-machine interfaces
- Ethics
- Q & A

Motivation

- Personal interest in human/machine interfaces
- Amazing scientific achievements

- What is more important?
  - Engineering of the prosthesis
  - Obtaining/analyzing signals

Evolution of prosthesis



Egypt (1070BC – 664 BC)

Götz von Berlichingen (1508)

"Clapper leg" (1816)

(2000's)

Myoelectric prosthesis

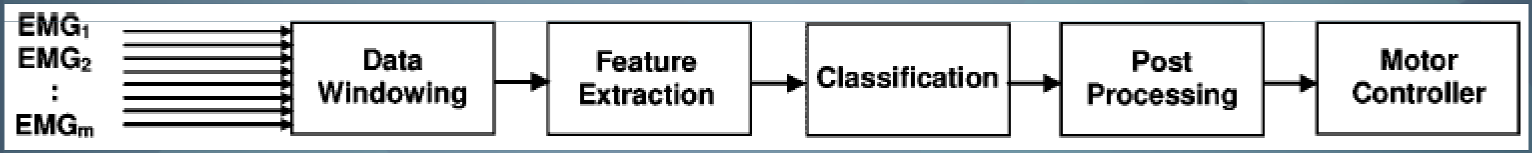
- EMG signals from muscles within residual limb used to operate an electric motor-driven prosthesis
  - Targeted Reinnervation for high-level amputees
- How to use EMG signals? → control approach
- Surface vs Intramuscular electrodes

Control approaches to drive prostheses[1]

1. One muscle – one function
   - Most primitive and direct
   - Must learn to associate a particular control motion to a specific prosthesis function
2. One pattern of EMG activity – one function
   - Muscles produce relatively distinct EMG patterns for different movements
   - A pattern must be stored for every movement
3. Internal/forward dynamic model
   - EMG signals from residual muscles used to predict muscle activation in an anatomically correct biomechanical muscle model of the intact limb
   - Require focal EMG records from many small muscles

One pattern of EMG activity – one function model

- Residual muscles produce relatively distinct EMG patterns for different movements of phantom limb
- Studies have shown good performance
- Pattern recognition/classification problem



  - Classifiers: AR filters, fuzzy logic, Markov models, linear discriminant methods, nearest-neighbor, neural networks…
  - Post processing: majority voting
- Model depends on measuring EMG patterns

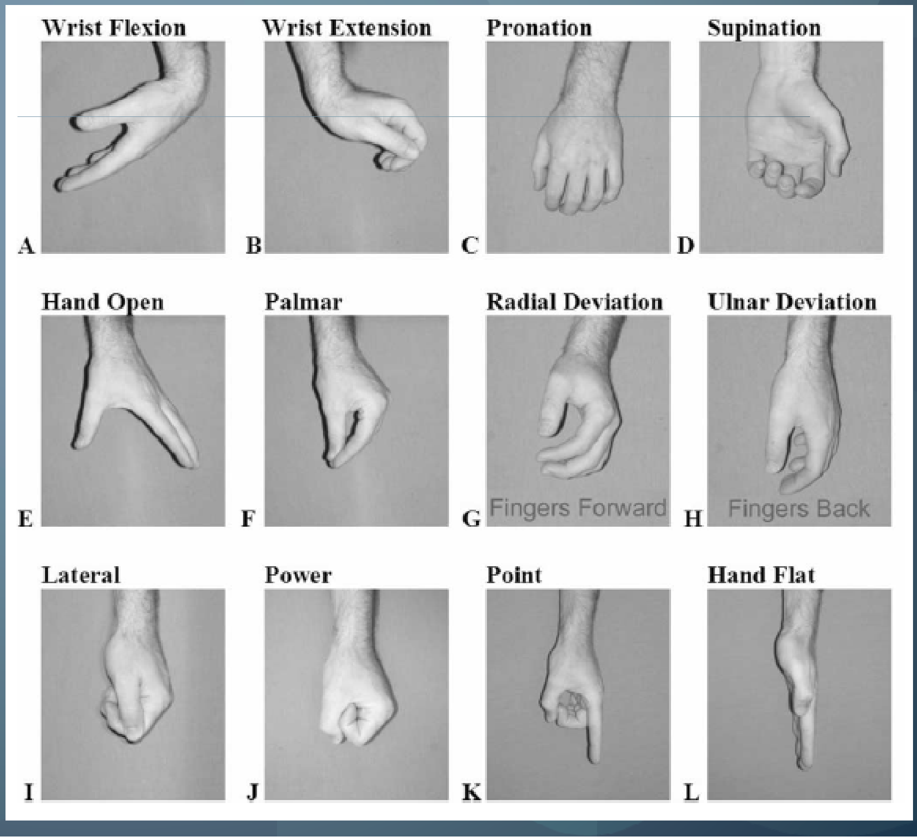
  → electrodes are very important!

Surface or intramuscular electrodes?

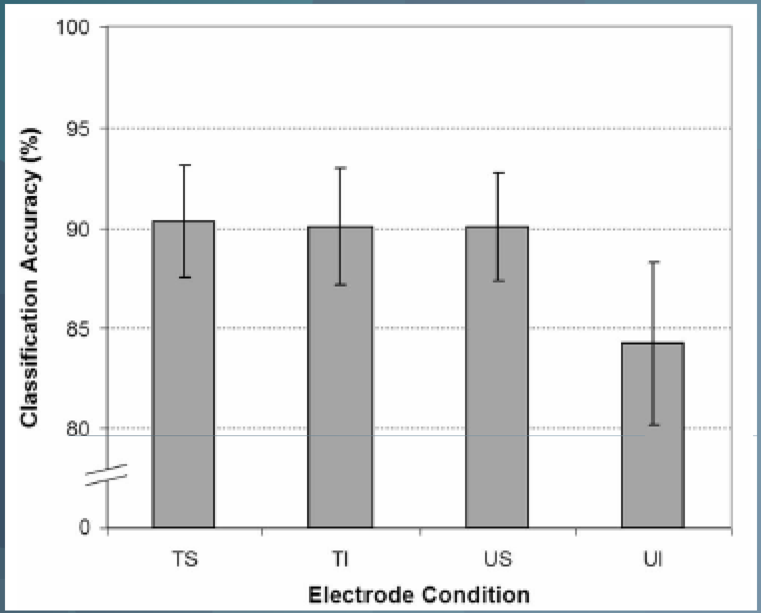
- Surface electrode advantages
  - Cheap, noninvasive, large pickup area (take advantage of crosstalk to help pattern recognition classifiers)
- Intramuscular electrode advantages
  - Record at consistent sites, record focally, reduce cross talk
- Statistically, there is no performance difference

A comparison of the Effects of Electrode Implantation and Targeting on Pattern Classification Accuracy for Prosthesis Control[2]

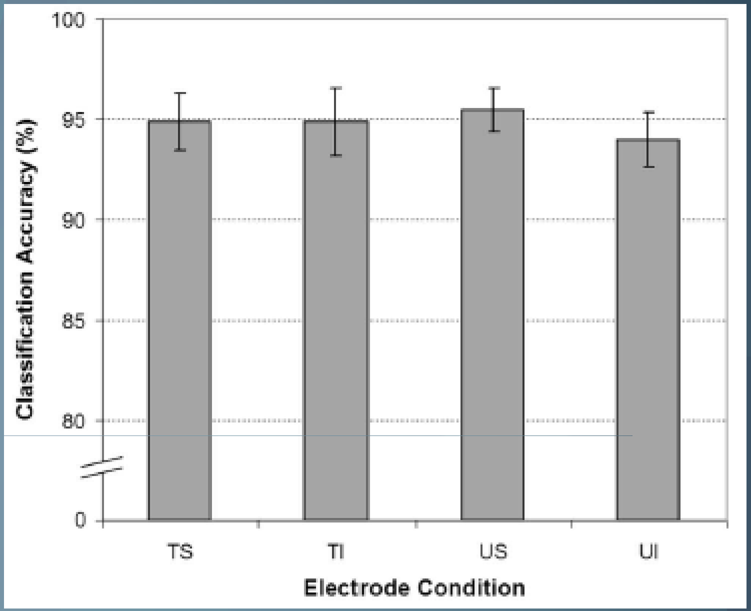
- Investigated four electrode conditions
  - Targeted surface (TS), targeted intramuscular (TI), untargeted surface (US), untargeted intramuscular (TU)
- Considered 12 movement classes
- Used 8 electrodes (channels)



Effect of electrode condition



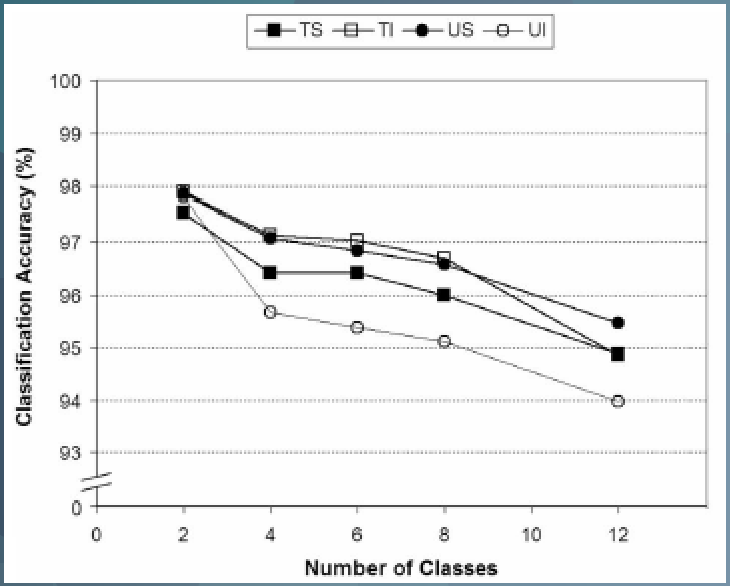
Only EMG amplitude feature

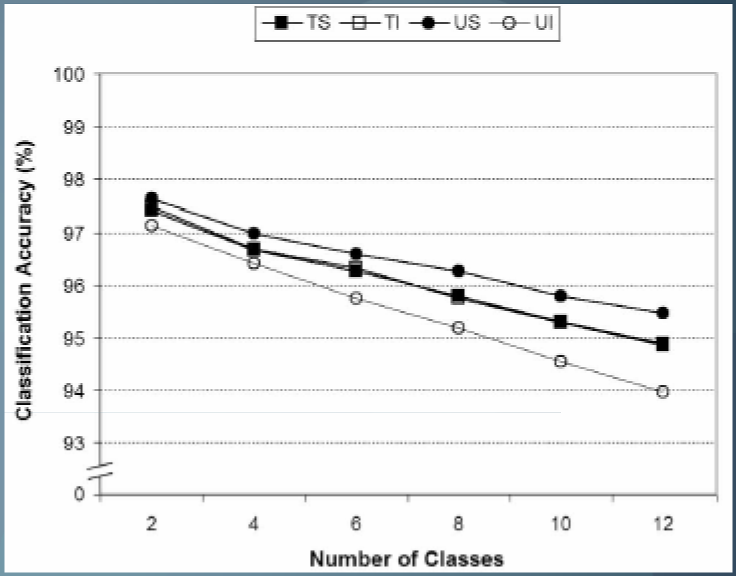


EMG amplitude + TD features + AR coefficients

- If only amplitude feature used, make sure intramuscular electrodes are targeted
- Use multiple features to increase classification accuracy for all
- No advantage of targeting specific muscles with surface electrodes

Effect of class number





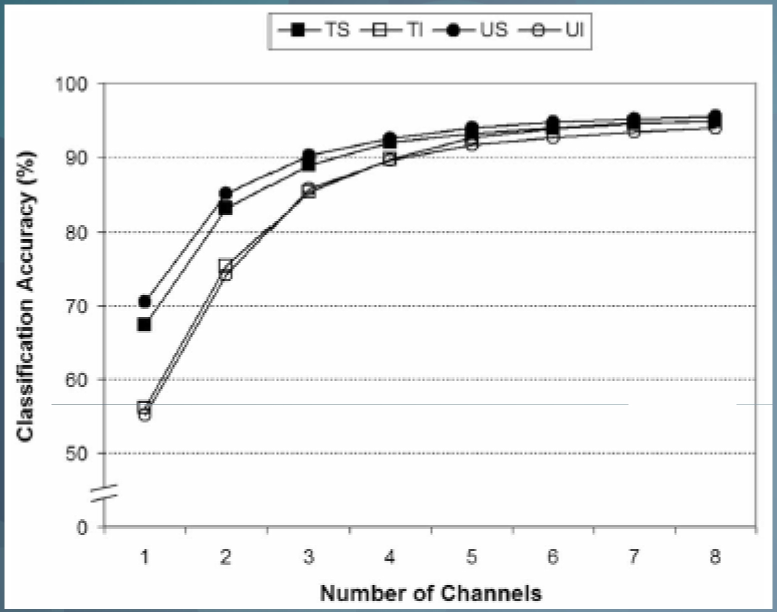
Class subsets chosen based on clinical criteria

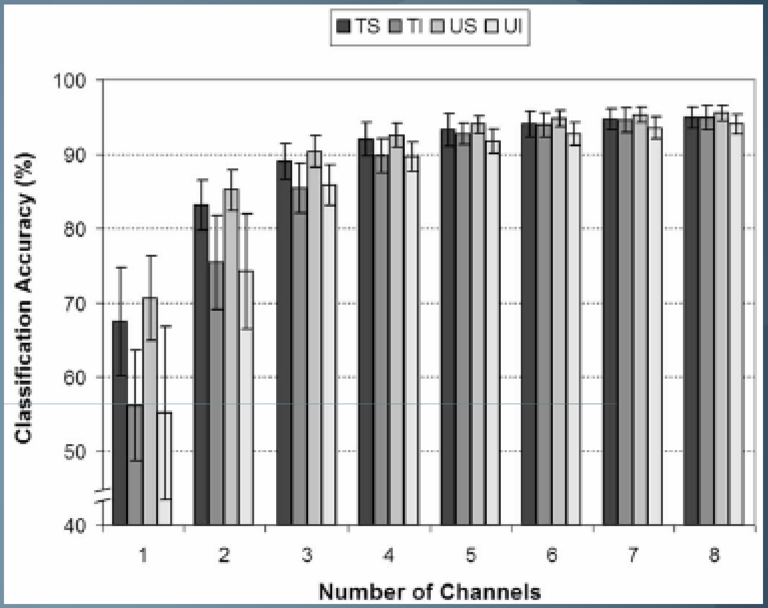
Class subsets chosen randomly

- Classifier can more accurately separate classes in less dense feature space
- Potential for success of myoelectrically controlled multifunctional prostheses

All classes and features used

Effect of channel number





- More channels enable better accuracy due to more information available
- However there is diminishing returns especially after 3-4 channels
- Intramuscular electrodes more affected by loss of channels, regardless of T or U
- Rule of thumb: add channels that provide the most new information to classifier

Takeaways

- Choice between surface and implanted electrodes should be based on clinical factors
  - Comfort, cost, consistency of contact, consistency of repeatability (location), signal robustness, skin impedance changes
- Number of electrodes, their placement (T/U) and distribution is dependent on the chosen control approach
  - There is no one “right” way

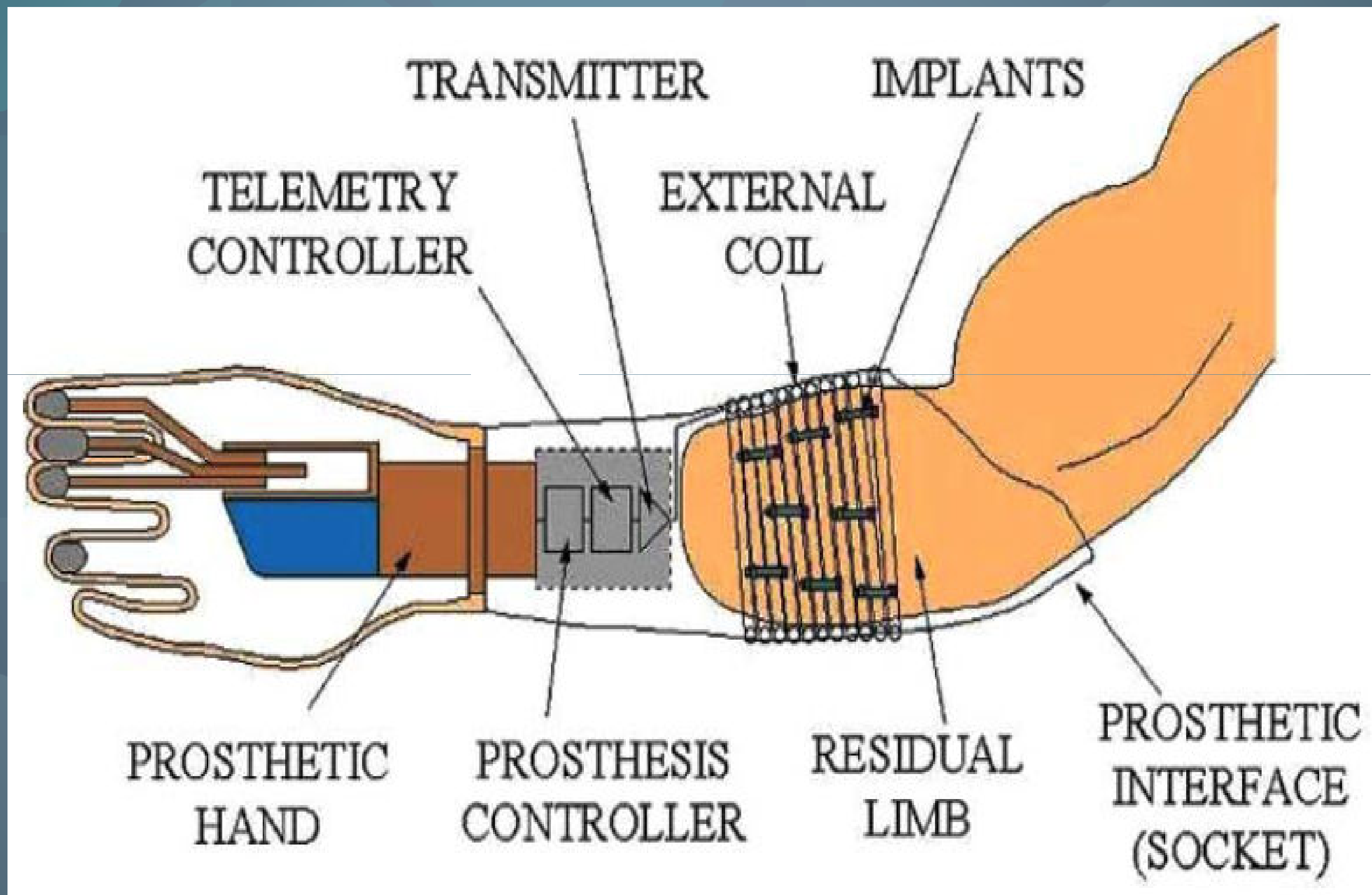
Implants and biology

- Fibrous encapsulation from inflammatory response[3]
  - Thickness and cellular morphology function of:
    - Implant's shape, surface texture, materials
  - Increase in resistivity of surrounding tissues
    - Implications greater for stimulated electrodes
      - Faradaic reactions, altered current flow patterns
- Tissue damage [4]
  - J < 10uA/mm2 – no damage, J > 50uA/mm2 - damage
  - Cause of damage: electrochemical reactions
    - contact between electrode metal and tissue

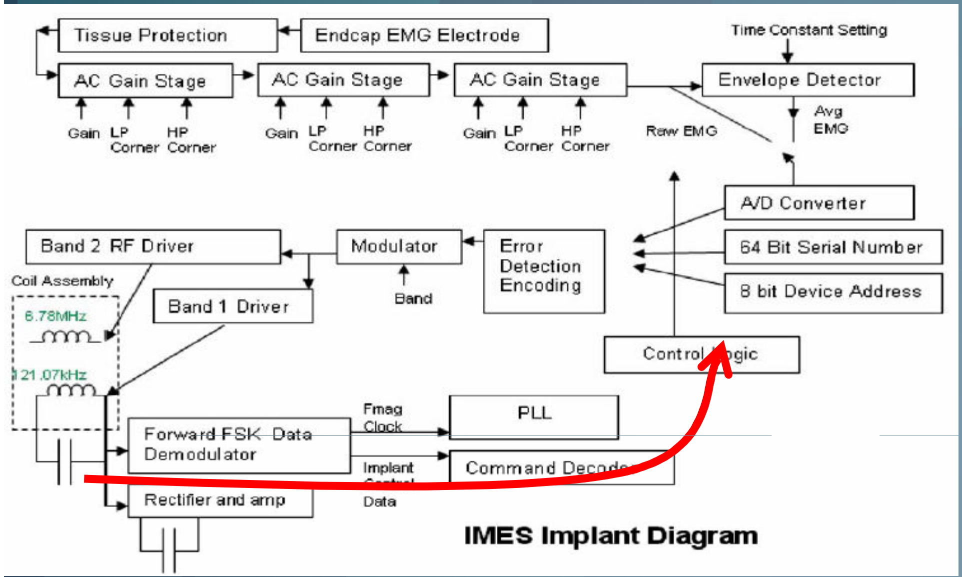
Implantable Myoelectric Sensors (IMESs) for Intramuscular Electromygram Recording[1]

- Highlights
  - Multichannel EMG sensor system, up to 32 IMES
  - Two-way wireless communication with prosthesis
  - Robust and reliable system due to implantation
    - No…: Electrode liftoff, skin impedance changes, movement artifacts, non-repeatable electrode placements, wire breakage
  - Long term measurements possible
  - Focal, independent EMGs from different muscles
    - Localized pickup area, ~5mm in radius around each IME
  - Accommodates raw EMG and integrated EMG
    - Pattern, internal model and direct control
  - EMG measurements comparable in both time and frequency domain to clinical EMG systems

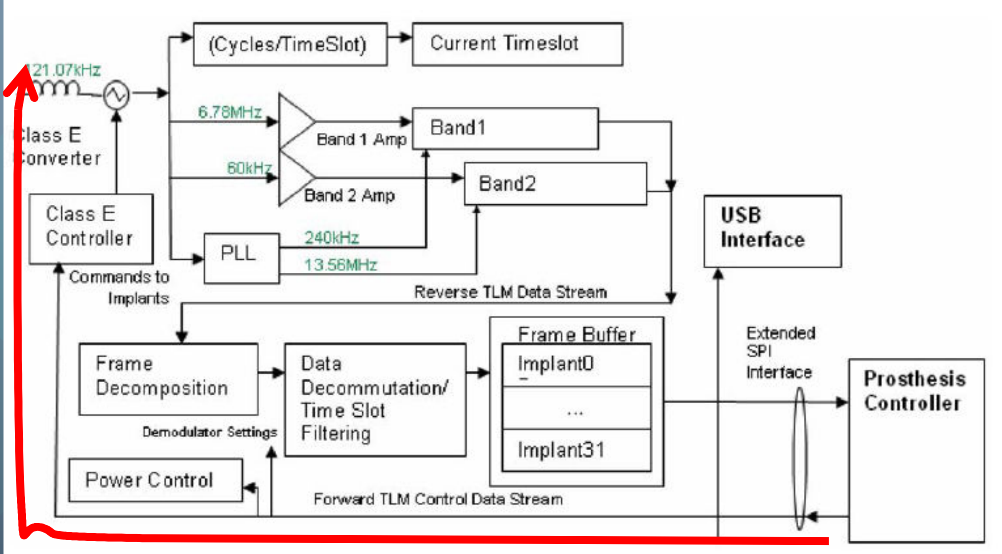
IMES system overview



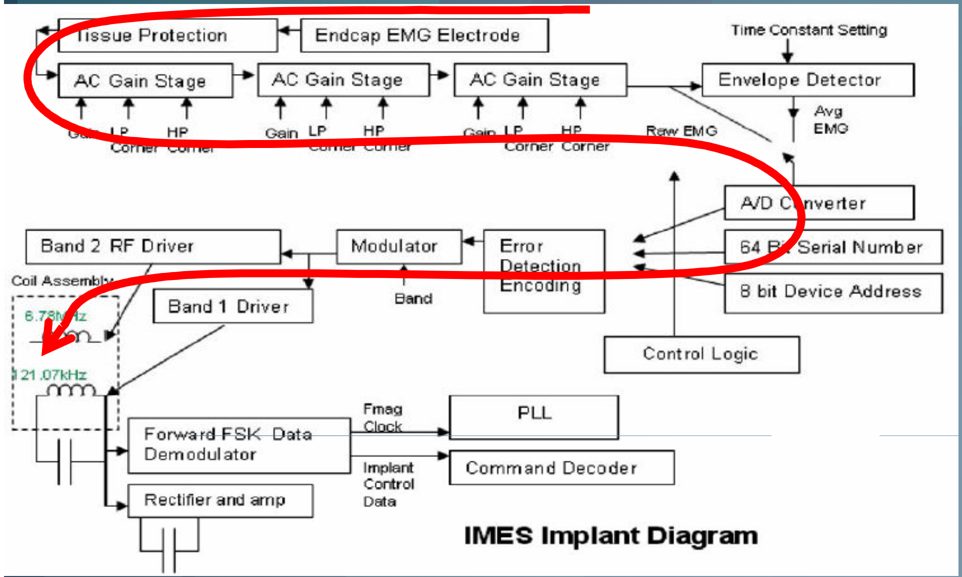
IMES telemetry paths



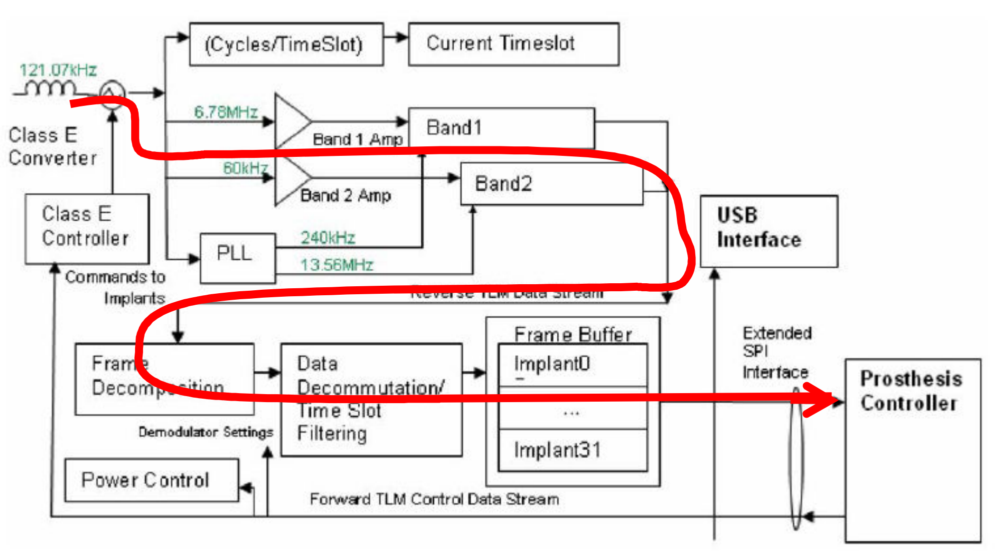
Forward (inward) telemetry



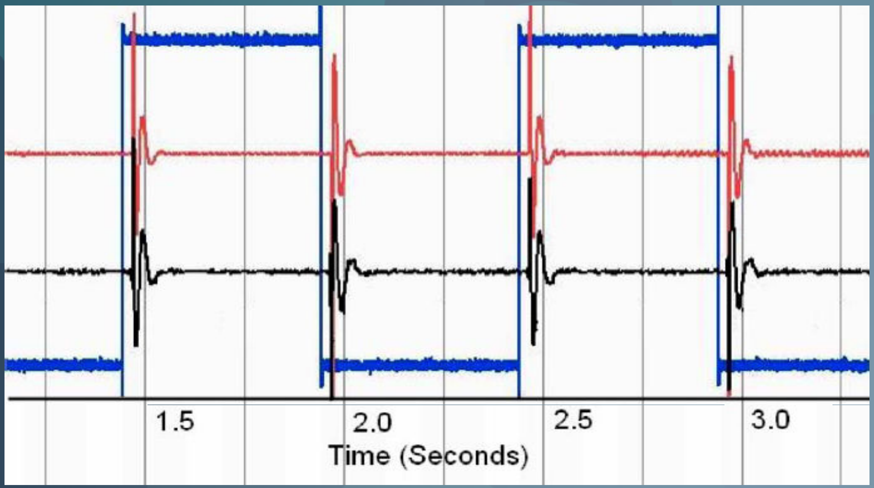
IMES telemetry paths



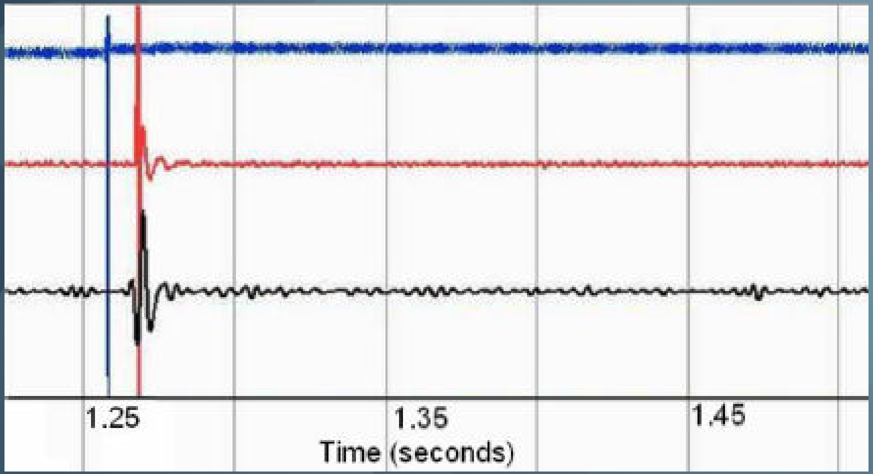
Reverse (outward) telemetry



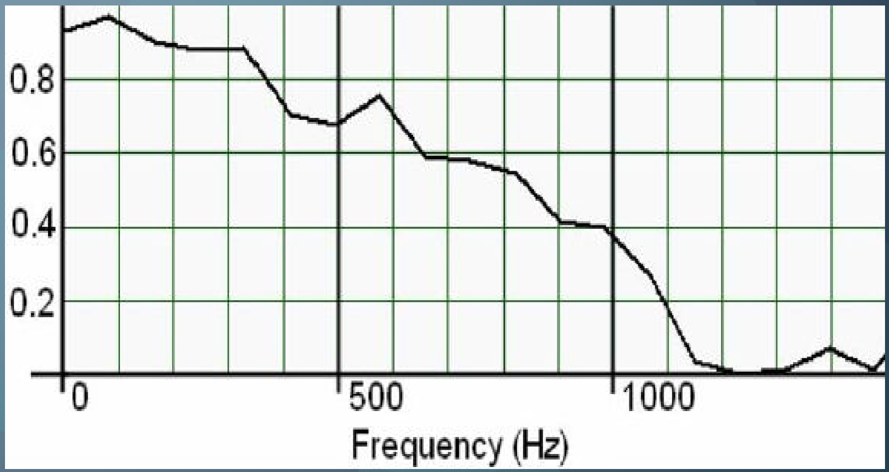
IMES vs TeleMyo 2400



Step response, cross correlation=0.85
IMES(black) TeleMyo (red)



Impulse response, cross correlation=0.767
IMES(black) TeleMyo (red)



Magnitude-squared coherence

Brain-Machine Interfaces (BMI)

Applications [5]

- Deep brain stimulation – "brain pacemaker"
  - Parkinson's disease, depression, Tourette syndrome
- Cochlear implants
  - Acoustic signals converted to electrical impulses that directly stimulate auditory nerve
- Retinal implants
  - Recorded visual signals stimulate remaining cells of retina
  - Alternatively, external signals recorded by camera are sent to an implant directly interfaced with optic nerve
- **Motor prostheses**

Implant Ethics

"the study of ethical aspects of the lasting introduction of technological devices into the human body"[6]

- Issues regarding implantations in general
  - Donation
  - End of life
  - Enhancement
  - Mental change and personal identity
  - Cultural effects

Q & A

...for listening

Citations

[1] Weir, R.F.; Troyk, P.R.; DeMichele, G.A.; Kerns, D.A.; Schorsch, J.F.; Maas, H., "Implantable Myoelectric Sensors (IMESs) for Intramuscular Electromyogram Recording," *Biomedical Engineering, IEEE Transactions on* , vol.56, no.1, pp.159-171, Jan. 2009

[2] Farrell, T.R.; Weir, R., "A Comparison of the Effects of Electrode Implantation and Targeting on Pattern Classification Accuracy for Prosthesis Control," *Biomedical Engineering, IEEE Transactions on* , vol.55, no.9, pp.2198-2211, Sept. 2008

[3] Grill, W., Mortimer, J., "Electrical Properties of Implant Encapsulation Tissue," *Ann. Biomed. Eng.,* vol. 22, pp.23-33, 1994

[4] Mortimer, J.; Kaufman, D.; Roessmann, U., "Intramuscular electrical stimulation: Tissue damage," *Ann. Biomed. Eng.*, vol.8, no.3, pp.235-244, 1980

[5] Clausen, Jens. "Man, machine and in between." *Nature* 457.7233 (2009): 1080-081. Print.

[6] Hansson, S.O., "Implant Ethics," *Journal of Medical Ethics,* vol.31, no.31, pp.519-525, 2004