



A Wireless Neural Stimulation Platform for High-Density Arrays

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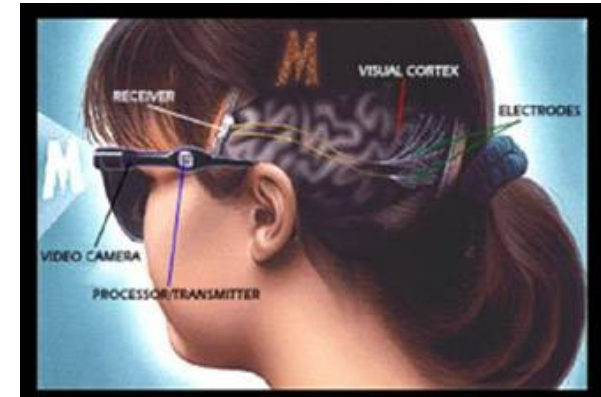
Faculty Advisor: Dr. Maysam Ghovanloo

Motivation



Applications

- Sensory (including visual and auditory) neuroprosthetics.
- New tools for neuroscience research.

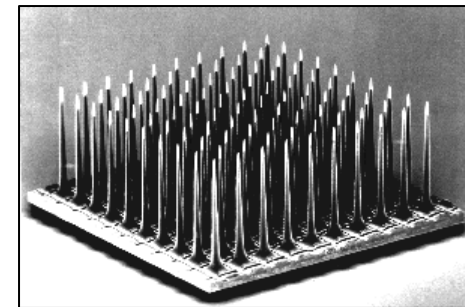
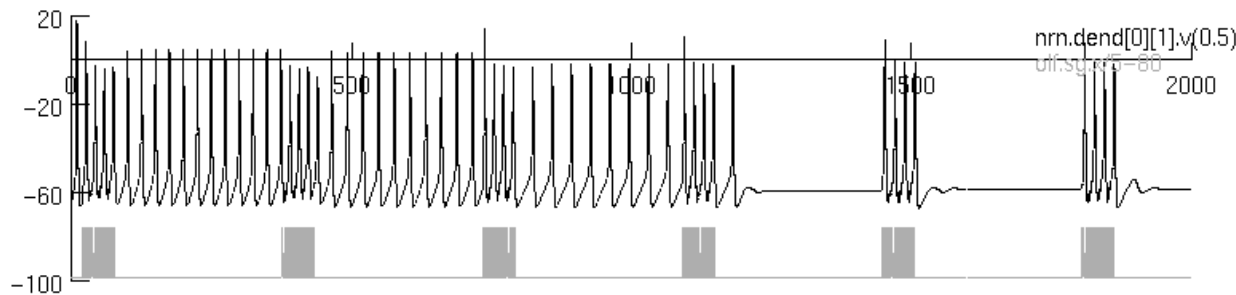


Illinois Institute of Technology

Requirements

- Wireless data and power transmission
- High-density stimulator arrays (100s of sites)
- Flexible software architecture for transformation/modulation algorithm development

Background: Neural Signals



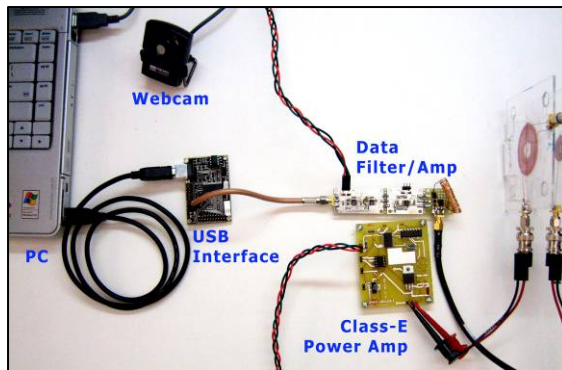
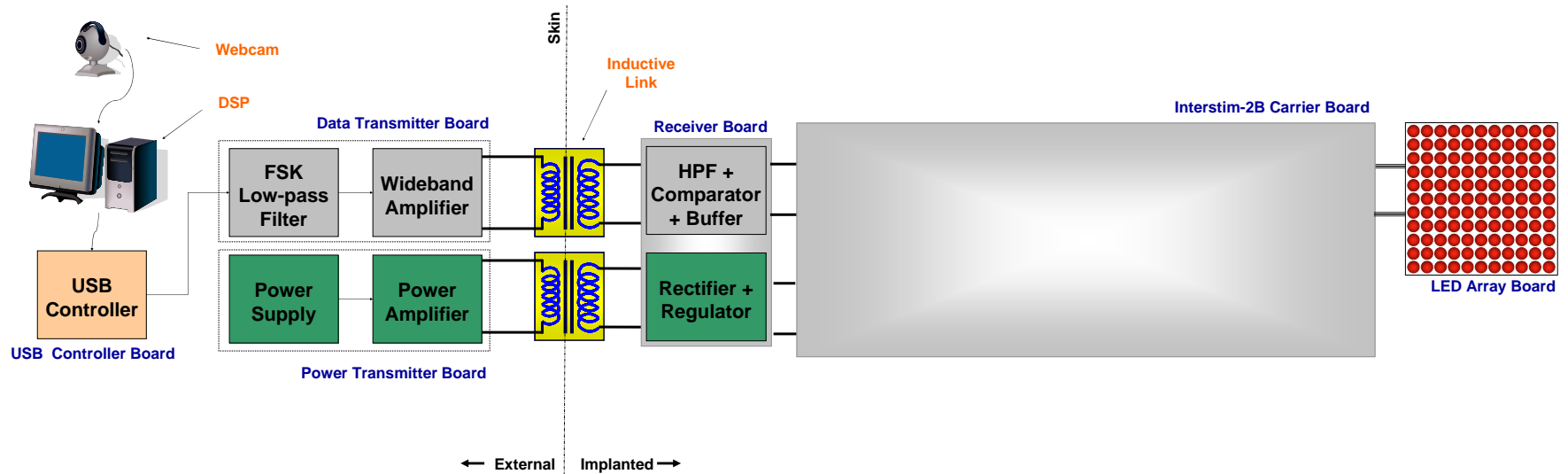
University of Utah
Electrode Array

Example natural neural signal

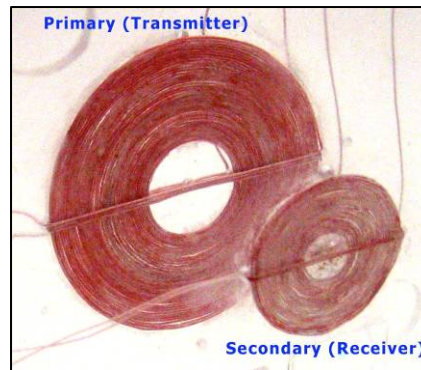
From: <http://math.arizona.edu/~herrera/html/05hh3.html>

- Encoded as frequency-modulated electrochemical pulse bursts (known as “spikes”).
- In most cases, frequency directly corresponds to stimulus intensity.
- Micromachined 2D probe arrays are frequently used in experiments to generate artificial stimulus spikes in the cerebral cortex.

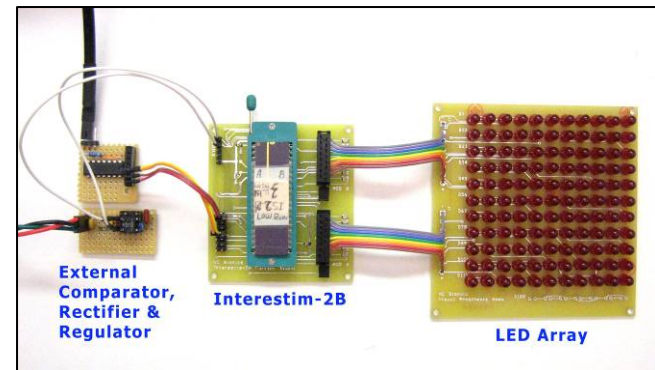
System Overview



PC & transmitter



Power & data coils

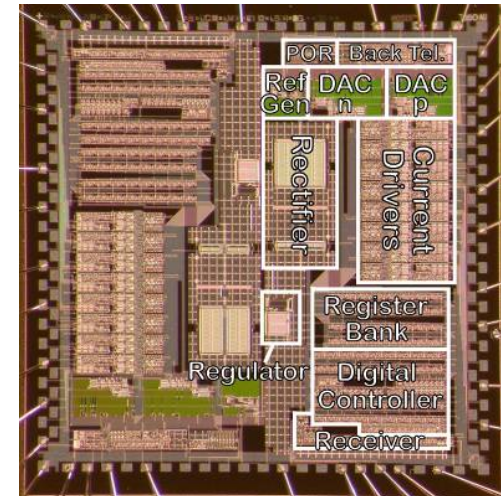


Interstim-2B and LED array

Interestim-2B



- Developed by Dr. Ghovanloo
- Highly versatile microstimulator with a variety of stimulation schemes.
- 64 stimulation sites per chip
- Chips can be operated together in parallel for more sites
- Controlled-current stimulation up to $270\mu\text{A}$
- 4.6 x 4.6 mm die size

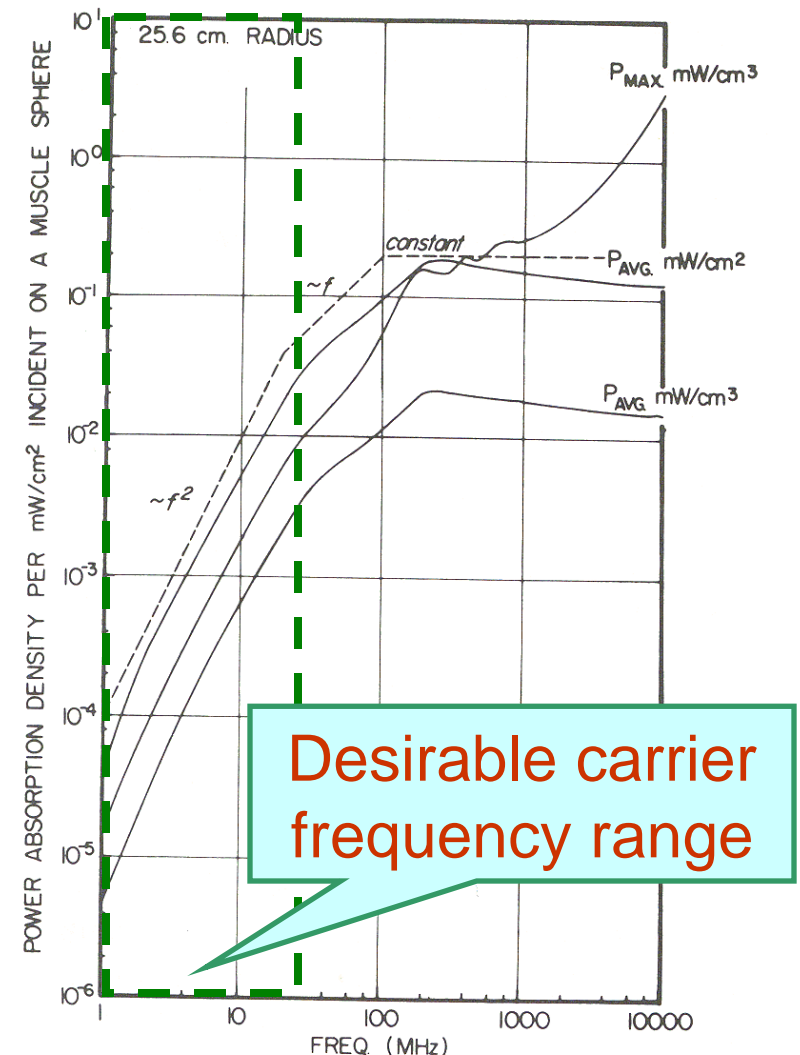


Interestim-2B
Microphotograph

Low Power Carrier Frequency



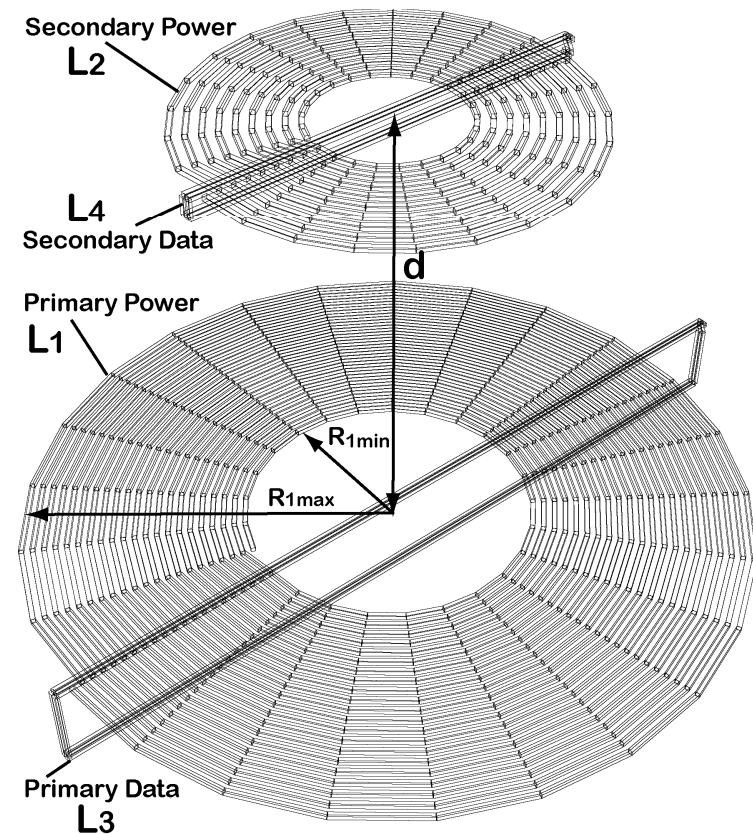
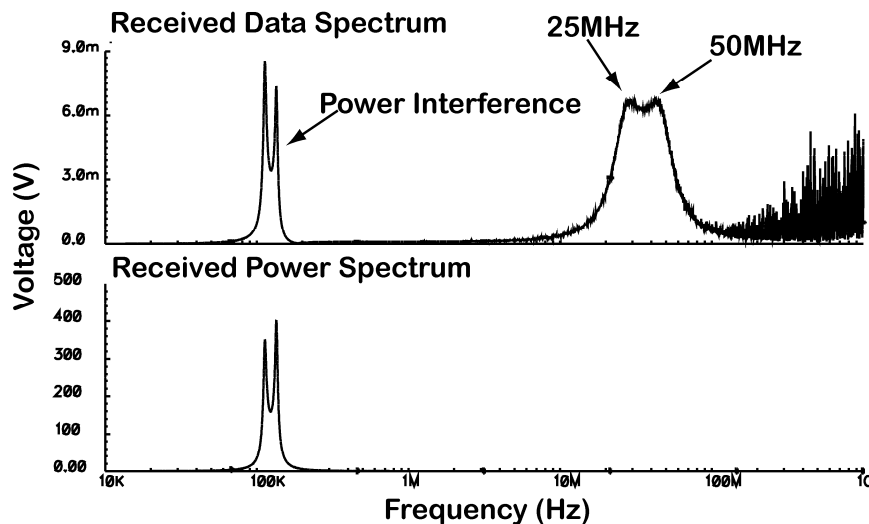
- Power carrier must be as low as possible
- More power loss in the power transmission and conditioning circuitry at higher frequency.
- $1\text{MHz} < \text{Carrier Frequency} < 20\text{MHz}$ Average density of electromagnetic power absorption in tissue increases as f^2 .
- But high data rate requires higher carrier frequency!



Dual-coil Approach



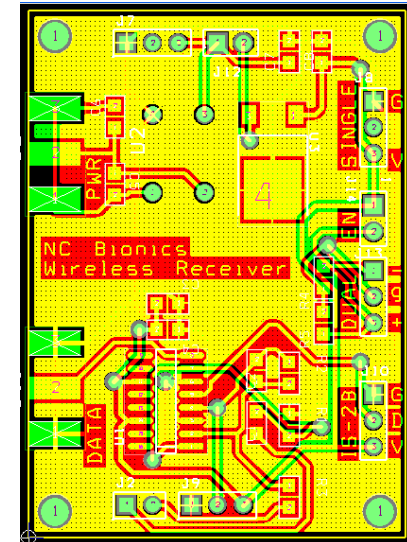
- Optimize the geometry and orientation of the power and data coils to:
 - Maximize direct-coupling
 - Minimize cross-coupling



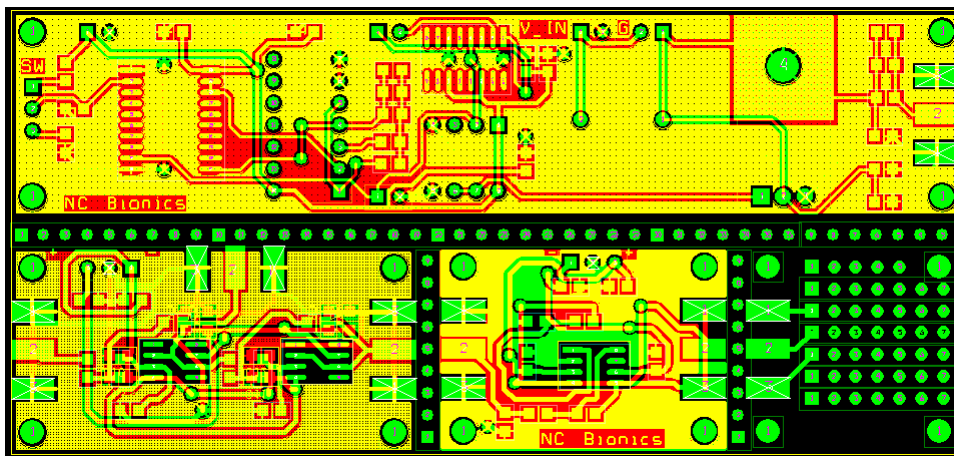
Wireless Power & Data Transmission



- Separate coils at different carrier frequencies for power and data
 - Power: low carrier frequency, low electromagnetic energy absorption
 - Data: high carrier frequencies, high throughput
- Frequency-shift keyed (FSK) modulation
- Power generated by Class-E amplifier

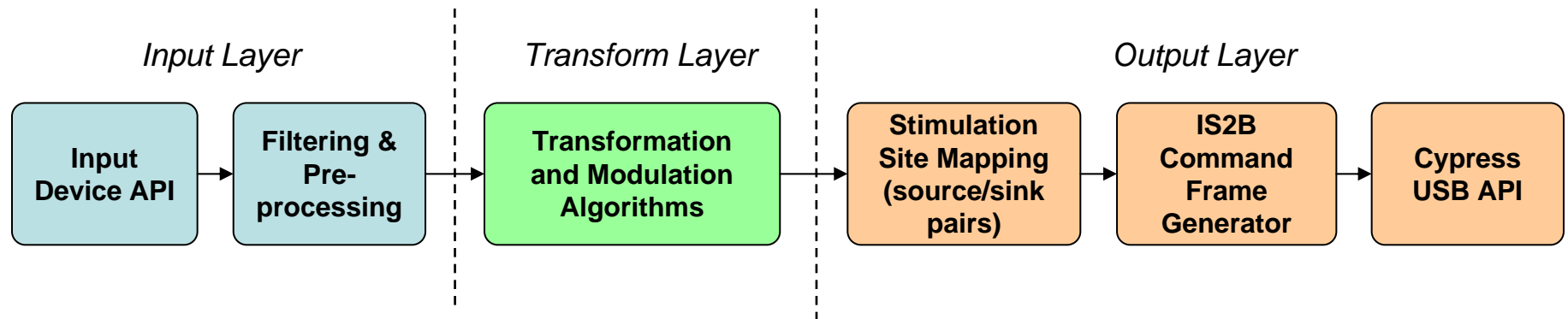


Power/Data Receiver Board

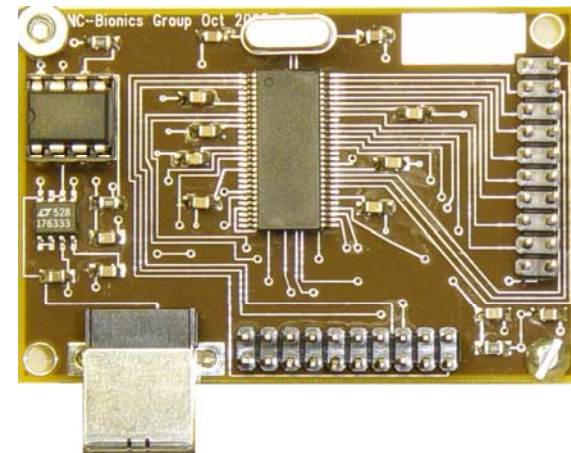


Power/Data Transmitter Board

Software Organization



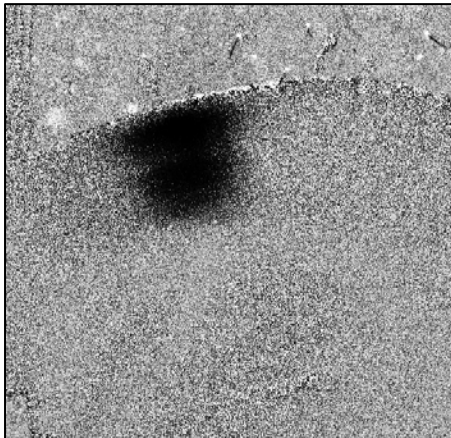
- 3 Layers:
 - Input Layer: Device-specific Interface
 - Output Layer: IS2B / USB Interface
 - Transform Layer: Device-independent algorithms
- USB 2.0 High-speed Interface



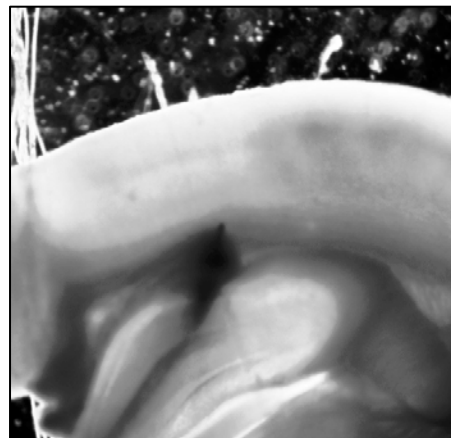
In Vitro Stimulation Results



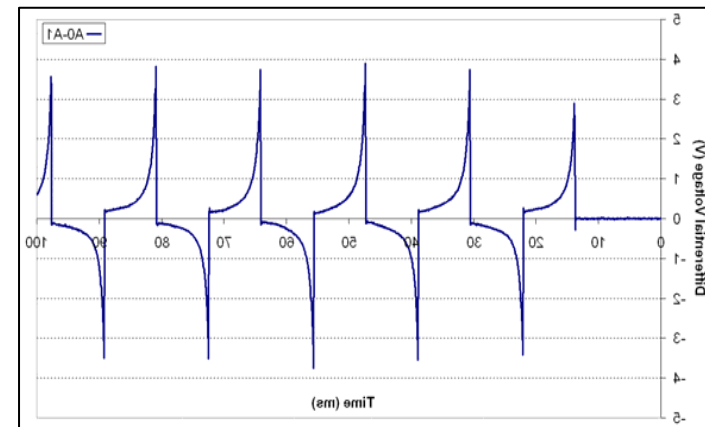
- Tests performed at UNC-CH Systems Neuroscience Laboratory using Intrinsic Optical Signal (IOS) measurements.
- Using microwire probes, successfully demonstrated biphasic stimulation of rat brain tissue slice.



IOS showing extracellular ion conc. changes



Tissue sample at 400x

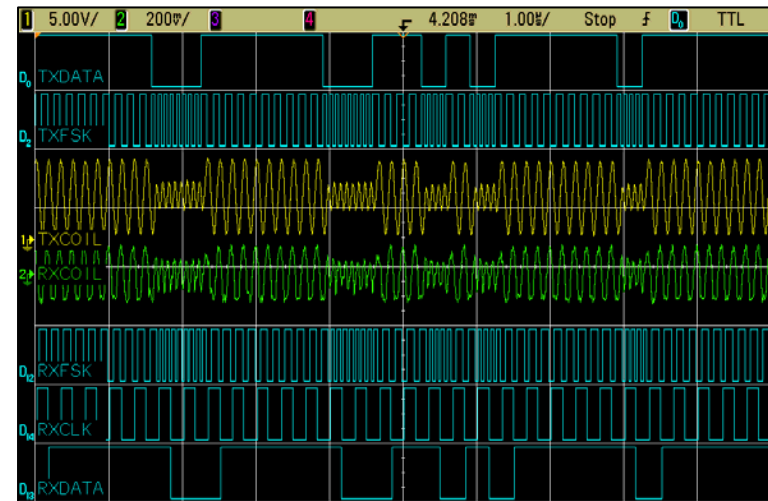


Biphasic stimulation waveform

Data Transmission Results



- Successfully transmitted FSK data to Interestim-2B
- Interestim-2B reliably determines data and synchronization clock signals
- Significant power interference when transmitting power and data simultaneously
 - Working to further separate power and data frequencies to remedy this

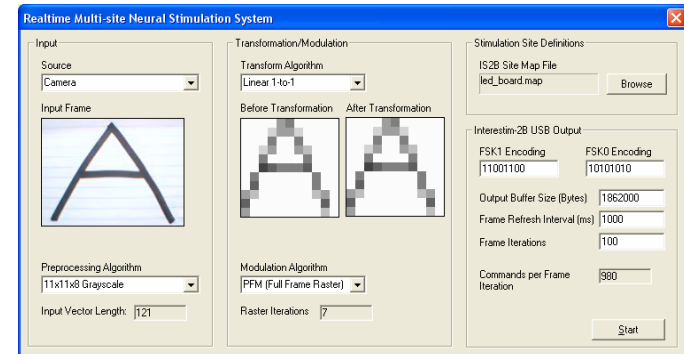


Top digital traces: transmitted data
Middle analog traces: transmit and receive coil signals
Bottom digital traces: decoded data

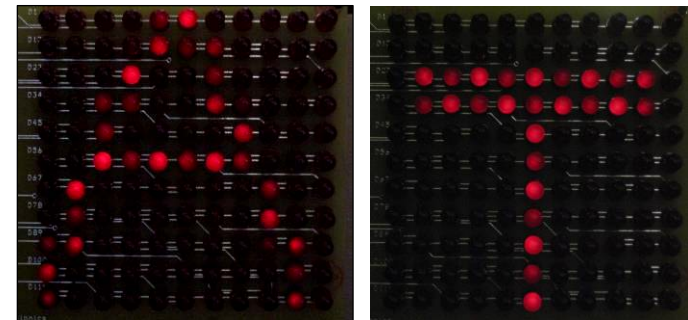
Visual Prosthesis Demo Results



- LED test matrix “displays” stimulation currents
- Each LED corresponds to a unique current path
- Successfully modulated data from a webcam into PFM stimulation across the 11 x 11 matrix.



Windows GUI configured to stimulate based on input from a webcam



LED matrix responding to a handwritten “A” and “T” in front of the camera

Future Work



- Improve power carrier suppression in data signals
- Develop software to run on USB-equipped handheld computers such as PDAs
- Test wireless system *in vivo*

Acknowledgements



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- Undergraduate Research Office
- Dr. Ozturk and the organizers of the symposium
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