CMOS Biosensor

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Agenda

- Purpose of Biosensor
- High level overview of the Biosensor
- Previous Work
- Senior Design Team’s contribution to Biosensor
- Future plans for Senior Design Team
What is the purpose of the CMOS Biosensor?

- Identify the presence of brain chemicals and their concentration levels
  - Specifically Nitric Oxide (NO)
  - Can also be used for Dopamine and Serotonin
- Provide real-time chemical image
- Combine Chemistry and Biology with Electrical Engineering
Overview of Biosensor Components

Potentiostat → Trans-impedance Amplifier → Switched Capacitor Amplifier

Memory → DSP → ADC

DAC → Power Amplifier → Antenna

Mixer
Previous Work on CMOS Biosensor

- Potentiostat
- Main Amplifier and Delta Sigma Modulator
- Decimator
Potentiostat

- Detects chemical concentrations via either an oxidation or reduction reaction
- Outputs a current in the pico-ampere scale
- Drives the Transimpedance amplifier
Main Amplifier, Modulator, and Decimator

- Main amplifier increases the magnitude of the voltage signal from the Transimpedance Amplifier (µV to mV)
- Delta-Sigma Modulator converts the analog signal to a digital bit stream
- Decimator filters the digital bit stream by reducing the overall number of bit samples
  - Can be considered a low pass filter
Digital Signal Processor (DSP)

- Senior Design Team responsible for design and layout of this block
- Comprised of two sub-blocks
  - Exponential Moving Average
    - Filters digital input signal
  - Finite Difference
    - Evaluates signal for ideal power down opportunities
Raw Data vs. Filtering Goal
An exponential moving average weighs the incoming sample against the previous average to reduce the impact of noise.

\[ A[t] = \alpha S[t] + (1 - \alpha)A[t - 1] \]

Our design uses two filters back to back for more smoothing.

Incoming data is interleaved so one logical sample delay is separated by 100 clock cycles.
Exponential Moving Average Results

Resampled Raw Data vs. Single Channel Exp. Avg. vs. Simulink Simulation

Time (uSec)

Resampled Raw Data
Filter Output
Simulink Output
Finite Difference

- Finite difference is the digital equivalent of a derivative, allowing us to measure the slope of a signal
- \( f'[t] = f[t] - f[t-1] \)
- By subtracting the finite difference from a threshold value we can determine if an interesting signal is present
Once the finite difference detects an interesting signal, the power-hungry components should be turned on.

The wake signal should have a delay to prevent accidental waking or premature hibernation due to noise.

Implemented using two separate counters and a logic selector. The sleep delay is programmable via a 15-bit register.
DSP Results
Final Layout of DSP

- 600µm x 600µm total area
- 110,000 transistors
- National Semiconductor 0.18µm process
- 900mV source voltage
- 1MHz operating frequency
Future Plans for Senior Design Team

- Research, design, and implement the following:
  - Transimpedance Amplifier
  - Radio Frequency (RF) Amplifier
Questions?