Stimulus-Artefact Resistant Low-Power Low-Noise CMOS Amplifier for ECAP Measurement

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Neural Recording Amplifier for Next-Generation Epi-retinal Vision Prosthesis

Epiretinal implants for the blind are designed to pass electrical current through electrode arrays into large groups of surviving retinal neurons. Electrical excitation of the retina results in neuronal action potentials, and their summation is known as the electrically evoked compound action potential (ECAP). This thesis work covers the design and simulation of a CMOS operational amplifier to be incorporated onto a next-generation vision prosthesis integrated circuit.

ECAPs and Stimulus Artefacts (SAs)

The ECAP would provide an objective measure of a vision prosthesis ability to elicit light in a vision prosthesis recipient. However, to date, ECAP measurements of live human retina has not been thoroughly investigated. The Australian Vision Prosthesis Group (UNSW) seeks to conduct ECAP measurements with their vision prosthesis.

ECAP Response in Monkey and Guinea Pig

ECAP recording is a proven technology in cochlea implants (NRTM Cochlear Ltd., NRITM Advanced Bionics). However these systems suffer from SA contamination of the ECAP signal. To prevent SA induced amplifier saturation, the gain of such systems are typically set lower than the optimal level to amplify the small ECAP signal (~100 μV). These commercial systems are hindered by low SNR and require sophisticated DSP techniques to recover the ECAP.

SA Minimisation

The proposed amplifier operates with higher gain, thereby increasing SNR, by employing a reset phase during electrical stimulation. During reset, the amplifier is disconnected and the electrode SA is tracked by a hold capacitor. When the amplifier is reconnected to the electrodes (user defined) the SA is electrically subtracted from the electrode signal resulting in better sensitivity to the ECAP.

Amplifier Topology Design

Three cascaded, reset-switched, low-input offset, low charge-injection, capacitive-feedback operational amplifiers have been designed and simulated in the Austriamicrosystems 0.35μm H35B4D3 process using the Cadence Design Environment.

Amplifier Comparison

<table>
<thead>
<tr>
<th>Author</th>
<th>Power (uW)</th>
<th>Input-referred Noise (μVrms)</th>
<th>Gain (dB)</th>
<th>Bandwidth (kHz)</th>
<th>Area (mm²)</th>
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<tr>
<td>Olsson</td>
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<td>9.2</td>
<td>36.9</td>
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<td>0.18</td>
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<td>Farschi</td>
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<td>Mohseni</td>
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<td>7.1</td>
<td>43.7</td>
<td>0.1 - 10</td>
<td>0.11</td>
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<td>6.6</td>
<td>50-80</td>
<td>10</td>
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Key Features of the Amplifier Thesis Design

- Lowest power.
- Fully-differential (1st & 2nd stage) for improved linearity, power-supply & common-mode rejection.
- 2-bit digitally controlled gain.
- Low input-referred noise.
- Wide 10 kHz bandwidth.

Conclusion

The ECAP amplifier, combined with an ADC, telemetry system and software interface, will be the first implementation of an ECAP measurement system for the retina. Such a system will provide important information on the effectiveness of prosthetic vision.

[1] C. Sekirnjak et al., Electrical stimulation of mammalian retinal ganglion cells with epiretinal implants for the blind are designed to pass electrical current through electrode arrays into large groups of surviving retinal neurons. Electrical excitation of the retina results in neuronal action potentials, and their summation is known as the electrically evoked compound action potential (ECAP). This thesis work covers the design and simulation of a CMOS operational amplifier to be incorporated onto a next-generation vision prosthesis integrated circuit.

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