A Low-Voltage Low-Power Multi-Channel Neural Interface IC Using Level-Shifted Feedback Technology

ASP-DAC 2019
University Design Contest

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Background

- State-of-the-art neural recording SoCs feature:
  - Analog frontend with low noise and low distortion
  - Thousands of recording channels
  - Usually wireless/battery powered

- Low voltage design is attractive!!!
Level Shifted Feedback (LSFB)

- **Traditional CCIA**
  \[
  V_{ip} \approx V_{on} \approx 0.5V_{DD} \\
  V_{DD} > 2(V_{gs1} + V_{ds0})
  \]

- **CCIA with LSFB**
  \[
  V_{ip} \approx V_{on} - V_{LS} \approx 0.5V_{DD} - V_{LS} \\
  V_{DD} > 2(V_{gs1} + V_{ds0} - V_{LS})
  \]

*Lower supply voltage!!!*

\[
V_{DD} > V_{ip} + V_{gs1} + V_{ds0}
\]

*Assuming output CM voltage is set to 0.5V_{DD} to maximize output swing.*
Implementation

- **LNA**
  - Low power, low noise
  - Telescope OTA with current reusing

- **PGA**
  - Low power, high swing
  - 2-stage OTA

![Diagram of LNA and PGA circuits]
## Measurement Results

<table>
<thead>
<tr>
<th></th>
<th>JSSC’12</th>
<th>TCASI’13</th>
<th>TbioCAS’16</th>
<th>This Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>65nm</td>
<td>180nm</td>
<td>180nm</td>
<td>65nm</td>
</tr>
<tr>
<td>Supply (V)</td>
<td>0.5</td>
<td>1</td>
<td>1.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Area/ch(mm²)</td>
<td>0.013</td>
<td>NA</td>
<td>0.03</td>
<td>0.032</td>
</tr>
<tr>
<td>Power/ch (uW)</td>
<td>5</td>
<td>11.6</td>
<td>9.1</td>
<td>1.07</td>
</tr>
<tr>
<td>GAIN (dB)</td>
<td>NA</td>
<td>NA</td>
<td>52-66</td>
<td>50.75</td>
</tr>
<tr>
<td>BW(Hz)</td>
<td>10k</td>
<td>5.1k</td>
<td>10k</td>
<td>10k</td>
</tr>
<tr>
<td>IRN (uV)</td>
<td>4.9</td>
<td>4.0</td>
<td>4.07</td>
<td>5.18</td>
</tr>
<tr>
<td>NEF/PEF</td>
<td>5.99/17.96</td>
<td>1.9/3.6</td>
<td>3.51/22.2</td>
<td>2.91/5.19</td>
</tr>
</tbody>
</table>

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![Diagram of the chip](image)

**AFE gain (default setting, max gain)**

- **0.1 Hz** to **10 kHz**
  - **Gain**: 50.75 dB

**Input referred noise (V Hz⁻¹)**

- **LFP**: 10Hz - 300Hz
  - **Noise**: 3.83 uVrms
- **AP**: 300Hz - 10kHz
  - **Noise**: 4.22 uVrms