Approaching towards an integrated active EEG electrode:

Scaling from meters to millimeters

The entire electronics size should be equal to one electrode

Besides the EEG electrode, it should have:

- Integrated Power Converter: To ensure the indefinite use of the energy from the TEG and use it as a high potential and reliable power source

- Low Power Integrated Amplifier: Making EEG signal ready for processing

Proposed Systematic Design for Low Power and Low Area Power Converter for Thermal Generator

In body application, output voltage of a regular TEG is about 20mV!

- CL: dependence on output voltage variations which should be less than 10%

- Voltage variation = Energy

- The energy value is depend on fs

- LS should be large enough to not be saturated. fs will be the largest possible standard inductance in an area of 4mm to 4.8mm

- In an impedance matched system, Vin=0mV, Cs limit variation at input to 10mV

- Writing equations for statics, dynamics, leakages, parasitics and buffer losses, the optimum point for fs and switch sizes was found (graph). With 20kHz, optimum frequency, Vt=0.2mV which is huge. With slight deviation the optimum is fs=20kHz and Vt=100mV with 2mm by 1.2mm and CL=200nF with area of 1mm by 0.5mm.

At 20kHz the optimum widths for NMOS and PMOS are 25mm and 6mm, respectively, which poses large parasitics that can be problematic. So, we selected the corner of optimum region with reasonable widths 6mm and 2mm, respectively.

Increasing switching voltage results in lower switch resistance while higher dynamic losses. From the graph at 20kHz we found that voltage doubler can be eliminated at the expense of bigger switches. Which mean 50% area reduction, simpler design and lower power consumption.

Comparison of our design with the state of the art

<table>
<thead>
<tr>
<th>Component</th>
<th>Proposed Systematic Design</th>
<th>State of the Art</th>
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</thead>
<tbody>
<tr>
<td>Voltage Variation</td>
<td>~1 V/mV</td>
<td>~1 V/mV</td>
</tr>
<tr>
<td>Power Efficiency</td>
<td>&gt;50%</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>Area</td>
<td>1.6mm²</td>
<td>2.5mm²</td>
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</tbody>
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Conclusion and Future works

- With the design of a high efficient integrated power converter and a low power amplifier, we are approaching towards implementing an active EEG electrode with the size of an electrode.

- A design methodology was proposed to implement high efficiency power converters for bio-medical applications.

- The generic design methodology is suitable across different power converter (inductor based converters) specifications.

- The design of piezoelectric converter and amplifier remains to be finalized and will be sent to fabrication with the Thermoelectric converter.

- A fully electrical startup system for the thermal generator converter is under implementation.

- A fully integrated switch capacitor solution for thermal generator is under development.