GETTING BETTER WITH ELECTROCEUTICALS
Bioelectronics at Delft University of Technology
Wouter A. Serdijn
16-11-2016
In the Section Bioelectronics we work on functional block diagrams

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NEUROSTIMULATORS

The future

Use new circuit techniques and alternative forms of stimulation to:

1. Make implants fully implantable in the head
   • Drastically decrease their power consumption
   • Make them flexible

2. Make implants smart
   • Close the loop by including feedback

A 16-CHANNEL UHF NEUROSTIMULATOR IC WITH RECORD POWER EFFICIENCY

This tiny neurostimulator IC can drive 16 stimulation channels simultaneously with an unprecedented energy efficiency. Designed by Marijn van Dongen. Support by and in collaboration with the SiNs consortium.
ACTIVE ELECTRODE ARRAY FOR EPIDURAL SPINAL CORD STIMULATION

- Communication using 3 wires:
  - Power
  - Data
  - Stimulus current (amplitude, duration and timing, externally defined)
- All electrodes (12+return) can be selected in any configuration
- 25 V output voltage compliance
- Interleaved stimulation

NEURAL RECORDING AMPLIFIER IC

An additive companding neural recording amplifier IC that can read tiny neural signals on top of the stimulus and artefact, by Cees-Jeroen Bes, in collaboration with LUMC-ENT. Support by STW, TMSi, AB-Sys, 2BMedical and HealthTech
AN AUTONOMOUS WIRELESS SENSOR NODE FOR ECG MONITORING

This tiny chip (left) when mounted on a printed circuit board (middle) with electrodes and antennas becomes a batteryless ECG tag allowing the readout and wireless transmission of cardiac signals. Designed by Andre Mansano and Yongjia Li. Support by CNPq and CSC.

The tag can be embedded in a smart patch for prediagnostic vital sign monitoring.
CLOSED-LOOP OPTOGENETIC STIMULATION

In early optogenetic stimulation (of mice), the loop was closed via the neuroscientist who would press a button and thereby apply an optical stimulus.

CLOSED-LOOP OPTOGENETIC STIMULATION

- Realtime seizure detection
- Rapid prototyping
- Cheap hardware
CLOSED-LOOP OPTOGENETIC STIMULATION

EMBC’16; Annals of Neurology’15; BioCAS’14

- Example of working detection
- Works well for petit-mal seizures
- More measurements needed to assess performance for grand mal

TRANSCUTANEOUS WIRELESS COMMUNICATION

A 402 MHZ PASSIVE RECEIVER FRONT-END FOR IEEE 802.15.6 WBAN STANDARD

TCAS-I, upcoming; ESSCIRC’14, TCAS-II’15; TCAS-I’14; ISCAS’13

<table>
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<th></th>
<th>[17]</th>
<th>[1]</th>
<th>This work</th>
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<tbody>
<tr>
<td>Source</td>
<td>50 Ω</td>
<td>50 Ω</td>
<td>Inductive source</td>
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<tr>
<td>Technology (nm)</td>
<td>65</td>
<td>65</td>
<td>180</td>
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<tr>
<td>Frequency (GHz)</td>
<td>0.2-2.0</td>
<td>5.1-5.9</td>
<td>0.402-0.405</td>
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<td>IF BW (MHz)</td>
<td>25</td>
<td>10</td>
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<tr>
<td>Voltage gain (dB)</td>
<td>19a</td>
<td>12b</td>
<td>11.0/36.6a</td>
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<tr>
<td>Rsp (Ω)</td>
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<td>57</td>
<td>50</td>
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<tr>
<td>NF (dB)</td>
<td>6.5a</td>
<td>4.3b</td>
<td>14.7a</td>
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<td>In-band IP1 (dBm)</td>
<td>11a</td>
<td>NA</td>
<td>3.6a</td>
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<tr>
<td>Power consumption (mW)</td>
<td>67a</td>
<td>0.4b</td>
<td>0.939/1.09f</td>
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<tr>
<td>Supply voltage (V)</td>
<td>1.3</td>
<td>1</td>
<td>1.2</td>
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<tr>
<td>Active area (mm²)</td>
<td>0.13a</td>
<td>0.084b</td>
<td>0.75a</td>
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a Passive front-end + 1 stage baseband amplifier.
b Passive front-end.
c LO buffers + 1 stage baseband amplifier.
d LO buffers
**RF ENERGY HARVESTING**

Co-Design of a CMOS Rectifier and Small Loop Antenna for Highly Sensitive RF Energy Harvesters

JSSC'2014; TCAS-II'15; VLSI'13; ISCAS'12

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<tr>
<td>Technology</td>
<td>90 nm</td>
<td>0.25 µm</td>
<td>0.18 µm</td>
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<tr>
<td>Die area</td>
<td>0.029 mm²</td>
<td>0.1 mm²</td>
<td>0.084 mm²</td>
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<td>Antenna area</td>
<td>21.9 cm²</td>
<td>30 cm²</td>
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<td>37.4 cm²</td>
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<td>Frequency</td>
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<td>900 MHz</td>
<td>970 MHz</td>
<td>915 MHz</td>
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<td>Rectifier stages</td>
<td>5</td>
<td>36</td>
<td>24</td>
<td>2</td>
<td>17</td>
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<tr>
<td>Requirements</td>
<td>Closed loop</td>
<td>External pre-charge</td>
<td>Zero Volt transition</td>
<td>-</td>
<td>Deep DC bias</td>
</tr>
<tr>
<td>Sensitivity (R&lt;sub&gt;load&lt;/sub&gt; = ∞)</td>
<td>-27 dBm for 1V</td>
<td>-22.6 dBm for 2V</td>
<td>n.a.</td>
<td>-17.7 dBm for 0.8V</td>
<td>-24 dBm for 1V</td>
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<tr>
<td>Measured distance</td>
<td>27 meter @ 1.75 W</td>
<td>15 meter @ 4 W</td>
<td>1.1 meter @ 0.32 W</td>
<td>n.a.</td>
<td>none</td>
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<tr>
<td>Max PCE</td>
<td>49% @ -17 dBm</td>
<td>30% @ -0.8 dBm</td>
<td>26.5% @ -11 dBm</td>
<td>37% @ -18.7 dBm</td>
<td>16.1% @ -15.83 dBm</td>
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**OPTOGENETIC STIMULATION (2): μ-LED NEEDLE REALIZATION**

(Picture blurred, patent pending)
WIRELESSLY POWERED OPTOGENETIC STIMULATION

Wireless link: transmitter box and the head-mounted receiver

3-D printed head-mounted module

1. reduce the size and power consumption of the pulse generator
   - Neurostimulator chip

2. remove the leads
   - Combine pulse generator & electrodes

3. make the chip more intelligent
   - Let the chip listen to the brain signals via the electrodes and take decisions about the needed stimulation

4. PDE3 and anxiety
   - schizophrenia
   - Epilepsy

Design a flexible brain implant for the effective treatment of tinnitus, epilepsy, and addiction which serves as a platform for various types of implantables

- use silicon and graphene as base materials
- electrodes
- electronic circuits
- to measure the brain signals
- to electrically stimulate tissue and organs
- to power and control the implant
- battery foil
- conductive polymer for the antenna
- for RF energy harvesting
- wireless communication

Closed-loop operation
Neurodelta, a multidisciplinary consortium that provides a platform for innovative brain stimulation and monitoring applications in animal and clinical studies.

MEDICAL IMPACT – PERIPHERAL NERVOUS SYSTEM

[Reference: Kevin J. Tracey: Electronic Medicine Fights Disease – Stimulation of the nervous system could replace drugs for inflammatory and autoimmune conditions, Scientific American, March 2015]
MEDICAL IMPACT – SENSES AND CENTRAL NERVOUS SYSTEM

- Restore hearing (cochlear implant)
- Restore sense of balance (vestibular implant)
- Restore sight (ocular implant)
- Restore smell and taste (olfactory implant)
- Better understanding of the central nervous system
- Better treatment of pain (spinal cord implant)
- Better understanding of the brain
- Better brain-machine interfaces


MEDICAL IMPACT – THE BRAIN

Better treatment of brain disorders
- Better treat tinnitus and auditory hallucinations
- Better treat addictions (a.o. alcoholism)
- Better treat essential tremor, Parkinson, dystonia
- Better treat urge incontinence
- Better treat migraine, cluster headache and other forms of headache
- Better treat psychoneuroimmunological disorders
- Better treat chronic, phantom and neuropathic pain
- Better treat depression, mania
- Better treat OCD spectrum disorders
- Better treat PTSD and anxiety
- Better treat schizophrenia
- Better treat epilepsy
- Treat autism
- Treat dementia, including Alzheimer’s disease
- Treat Tourette’s syndrome, minimally conscious state (MCS) after traumatic brain injury, obesity, anorexia