Bioelectronics @ Delft

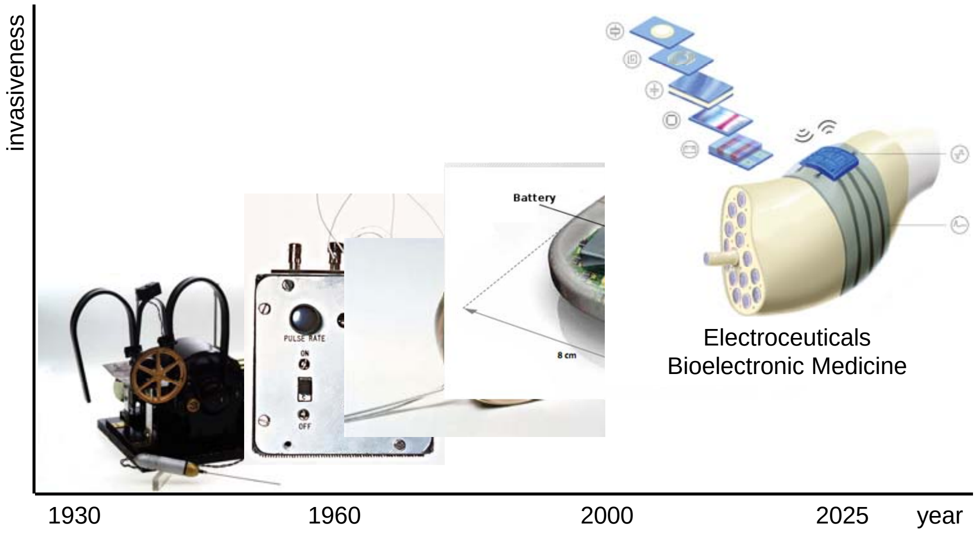
TU Delft

Bioelectronics @ Delft

- Established in 2014;
- Youngest section of EWI-ME
- Mainly involved in theme Health and Well-Being
- Wouter Serdijn (full prof.);
- Vasiliki Giagka (assist. prof.), since Sept. 2015;
- Virgilio Valente (assist. prof.), since Jan. 2018
- Currently 10 PhD students, 2 postdocs, 16 MSc students (EE-ME, BME-BE, Erasmus), and 1 technician

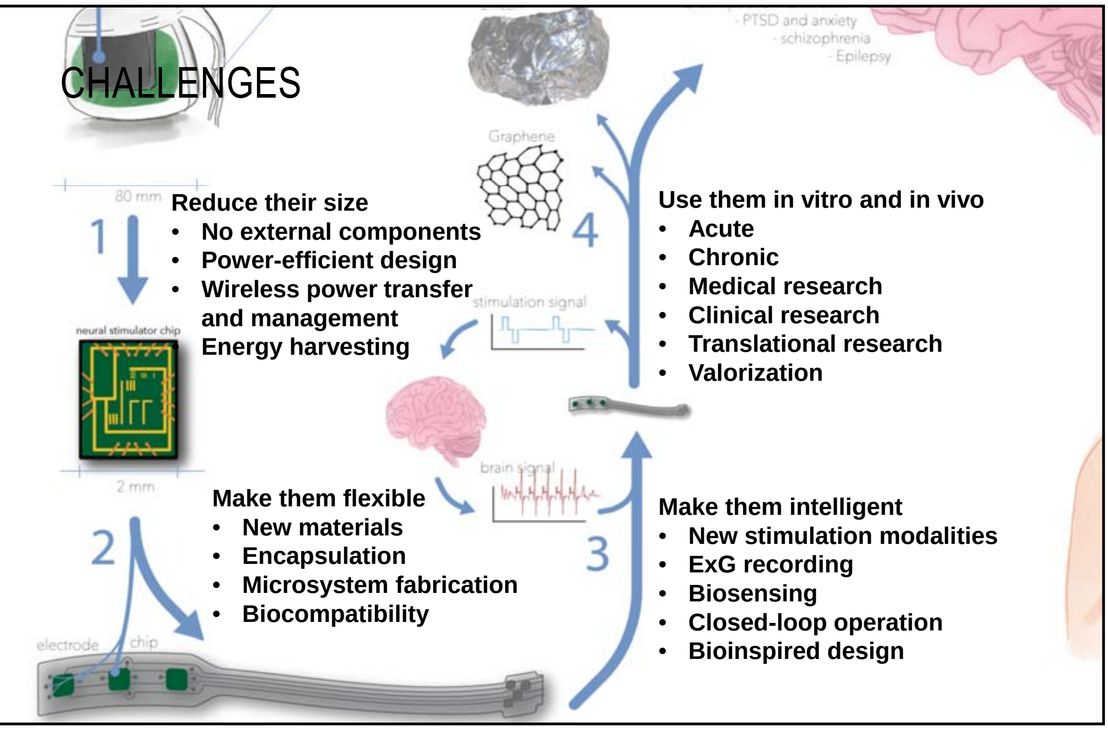
TU Delft

ACTIVE IMPLANTABLE MEDICAL DEVICES:
from stubborn bulky titanium cans to tiny flexible smart injectables



TU Delft 3

CHALLENGES



Reduce their size
- **No external components**
- **Power-efficient design**
- **Wireless power transfer and management**
- **Energy harvesting**

Make them flexible
- **New materials**
- **Encapsulation**
- **Microsystem fabrication**
- **Biocompatibility**

Use them in vitro and in vivo
- **Acute**
- **Chronic**
- **Medical research**
- **Clinical research**
- **Translational research**
- **Valorization**

Make them intelligent
- **New stimulation modalities**
- **ExG recording**
- **Biosensing**
- **Closed-loop operation**
- **Bioinspired design**

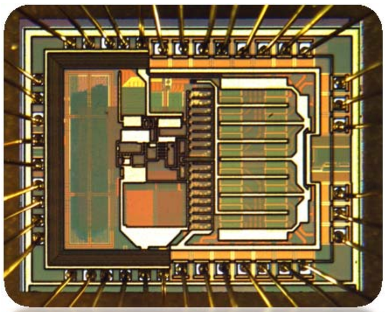
TU Delft

A 16-CHANNEL UHF NEUROSTIMULATOR IC WITH RECORD POWER EFFICIENCY

T-BioCAS'14; BioCAS'13; ISCAS'13; patent app.; ICNPD'12; Springer 2016,

2,1 mm

1,6 mm

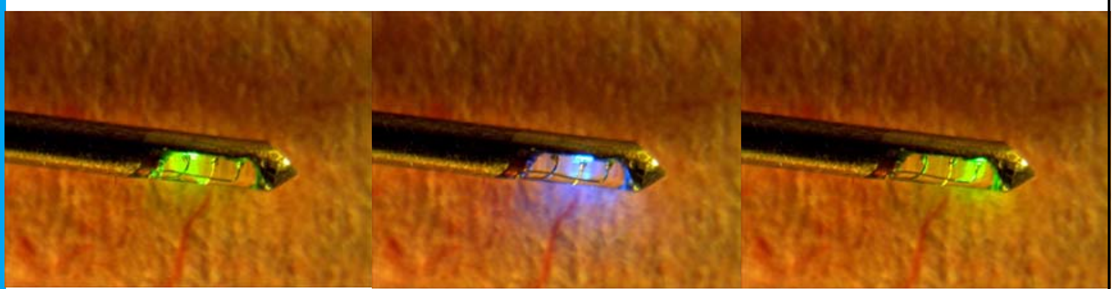


This tiny neurostimulator IC can drive 16 stimulation channels simultaneously with an unprecedented energy efficiency. Designed by Marijn van Dongen. Support by and in collaboration with the SINs consortium

5

OPTOGENETIC STIMULATION: μ-LED NEEDLE REALIZATION

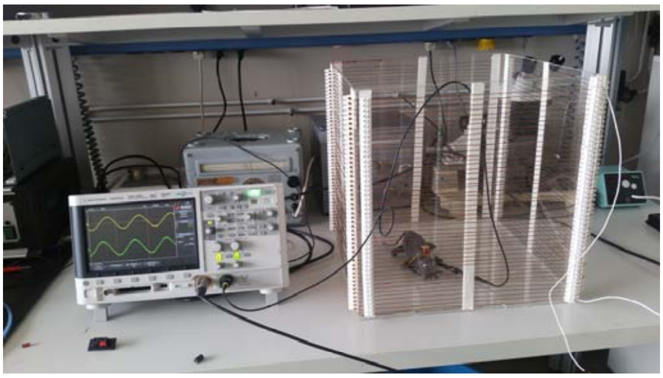
EMBS NER'17, BME'17, Frontiers'16



6

WIRELESSLY POWERED OPTOGENETIC STIMULATION

EMBS NER'17, BME'17, Frontiers'16



Wireless link: transmitter box and the head-mounted receiver

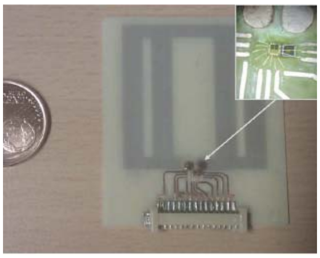
3-D printed head-mounted module

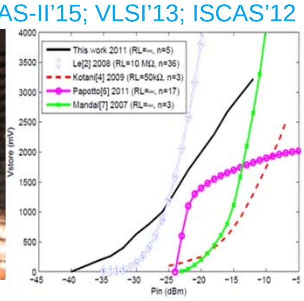
7

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



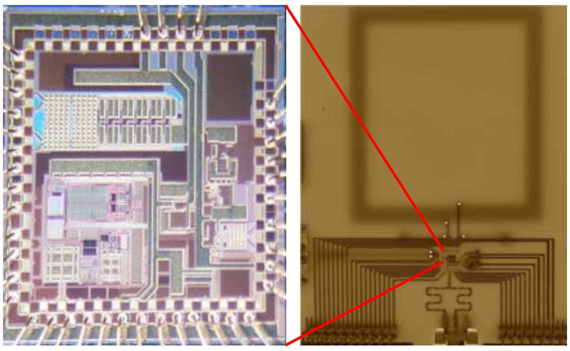


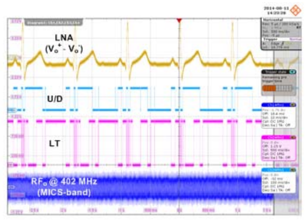
Parameters	This work	T. Le '08 [12]	J. Yi '07 [10]	S. Mandal '07 [15]	G. Papotto '11 [16]
Technology	90 nm	0.25 μm	0.18 μm	0.18 μm	90 nm
Die area	0.029 mm^2	0.4 mm^2	0.084 mm^2	n.a.	0.19 mm^2
Antenna area	21.9 cm^2	30 cm^2	n.a.	37.4 cm^2	no antenna
Frequency	868 MHz	906 MHz	900 MHz	970 MHz	915 MHz
Rectifier stages	5	36	24	2	17
Requirement	Control loop	External pre-charge	Zero V_{TH} transistor	-	Deep n-well
Sensitivity ($R_{load} = \infty$)	-27 dBm for 1V	-22.6 dBm for 2V	n.a.	-17.7 dBm for 0.8V	-24 dBm for 1V
Measured distance	27 meter @ 1.78 W	15 meter @ 4 W	1.1 meter @ 0.32 W	n.a.	none
Max PCE	40% @ -17 dBm	30%$^{(a)}$ @ -8 dBm	26.5 % @ -11 dBm	37%$^{(a)}$ @ -18.7 dBm	16.1% @ -15.83 dBm

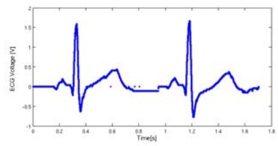
8

AN AUTONOMOUS WIRELESS SENSOR NODE FOR ECG MONITORING

T-BioCAS'16, T-BioCAS'14; ESSCIRC'14; BioCAS'14; TCAS-I'13



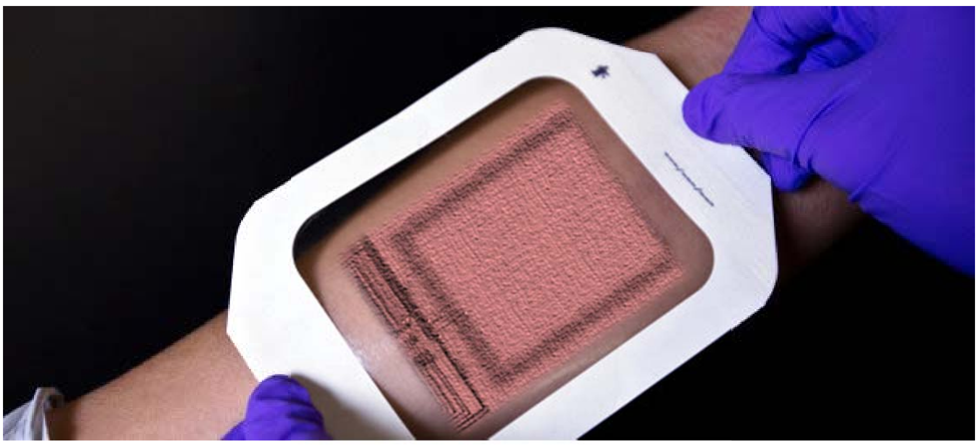




This tiny chip (left) when mounted on a printed circuit board (middle) with electrodes and antennas becomes a batteryless ECG tag allowing the readout and wireless transmission of cardiac signals. Designed by Andre Mansano and Yongjia Li. Support by CNPq and CSC

TUDelft 9

AN AUTONOMOUS WIRELESS SENSOR NODE FOR ECG MONITORING



The tag can be embedded in a smart patch for prediagnostic vital sign monitoring

TUDelft 10

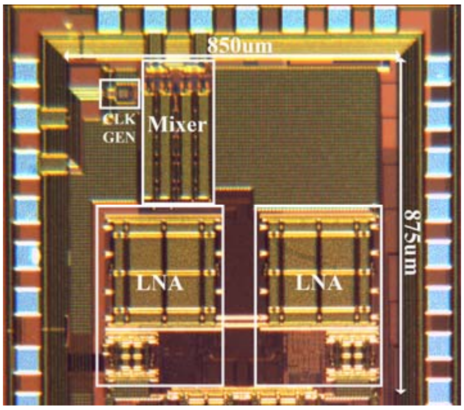
TRANSCUTANEOUS WIRELESS COMMUNICATION

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

TCAS-I 2017; ESSCIRC'14; TCAS-II'15; TCAS-I'14; ISCAS'13

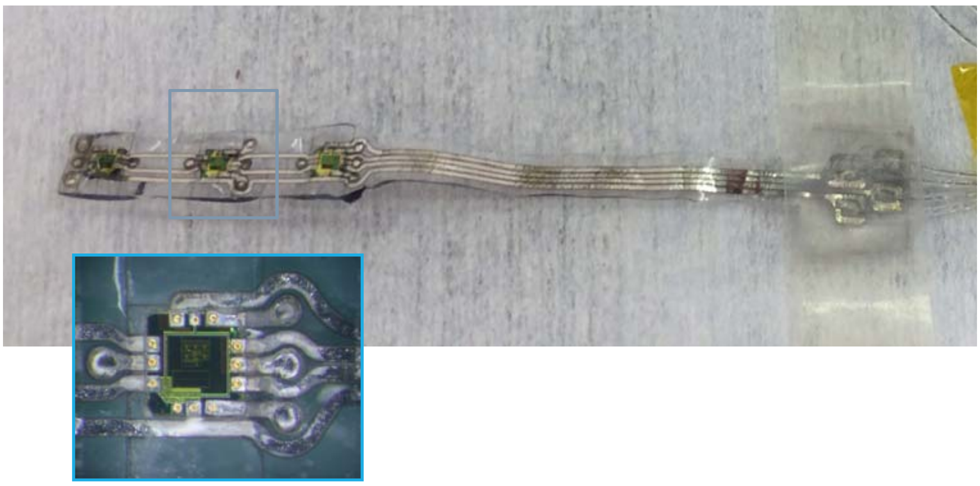
	[17]	[1]	This work
Source	50 Ω	50 Ω	Inductive source
Technology (nm)	65	65	180
Frequency (GHz)	0.2-2.0	5.1-5.9	0.402-0.405
IF BW (MHz)	25	10	0.23
Voltage gain (dB)	19[a]	12[b]	11.6[b]/36.6[a]
R_{SW} (Ω)	5	57	50
NF (dB)	6.5[a]	4.5[b]	14.7[a]
In-band IIP_3 (dBm)	11[a]	NA	3.6[a]
Power consumption (mW)	67[c]	0.4[d]	0.93[d]/1.09[c]
Supply voltage (V)	1.2	1	1.2
Active area (mm^2)	0.13[a]	0.084[b]	0.75[a]

a Passive front-end + 1 stage baseband amplifier.
b Passive front-end.
c LO buffers + 1 stage baseband amplifier.
d LO buffers



ACTIVE ELECTRODE ARRAY FOR EPIDURAL SPINAL CORD STIMULATION

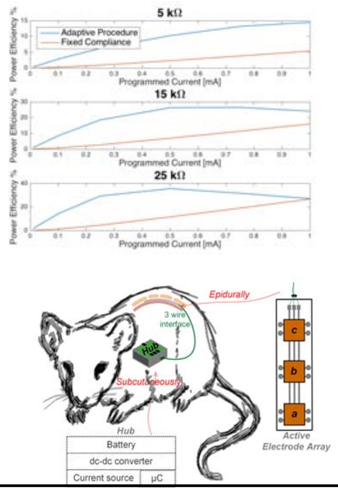
Biomedical Microdevices'15; T-BioCAS'15

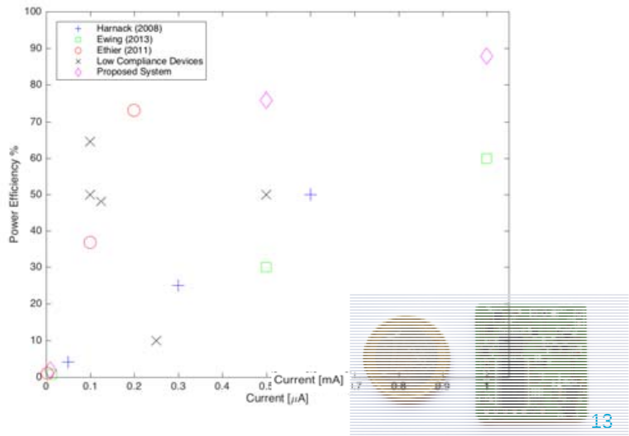


Flexible spinal cord implant that can drive 12 electrodes in any configuration using only 3 wires and offers 25V compliance. Designed by Vasiliki Giagka.

AN IMPLANTABLE SPINAL CORD STIMULATOR WITH ADAPTIVE VOLTAGE COMPLIANCE FOR FREELY MOVING RATS

EMBC'18

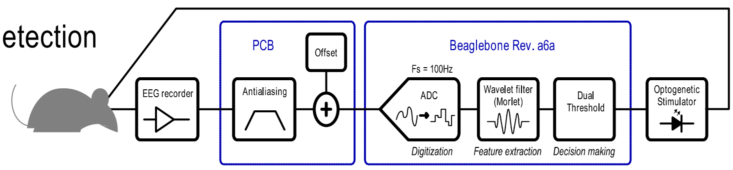


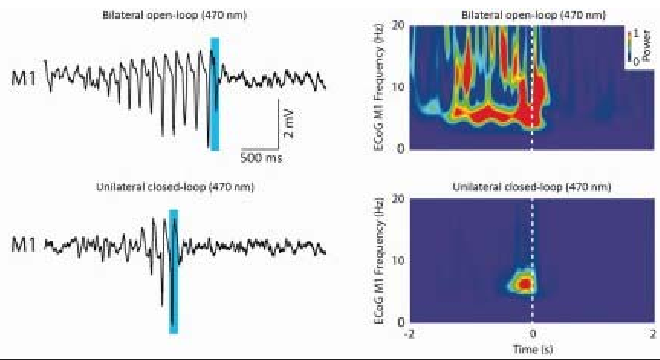


CLOSED-LOOP OPTOGENETIC STIMULATION

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

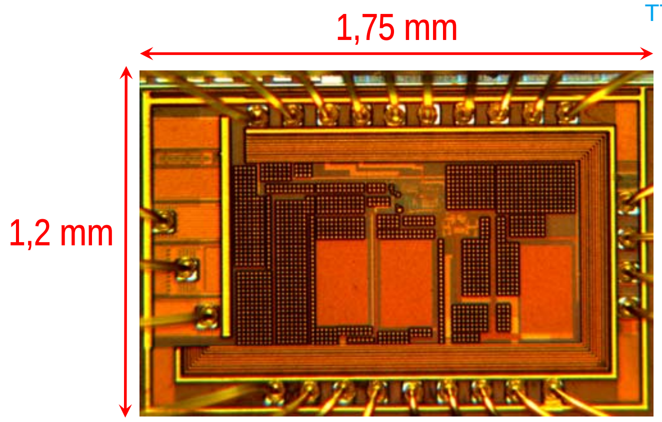
- Realtime seizure detection
- Rapid prototyping
- Cheap hardware





NEURAL RECORDING AMPLIFIER IC

Patent (PCT/NL2017/050061); not yet published; NWO-TTW Demonstrator Grant 2017



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

TU Delft 15

PROJECTS AWARDED IN 2017

- ATiNaRI: Asynchronous Time-domain Neural Recording Interfaces (EU H2020 MSCA)
- ReaSONS2Demo: Realtime Sensing of Neural Signals Demonstrator (NWO Demonstrator Grant)
- AFFIP: Atrial Fibrillation FIngerPrinting: Spotting bio-electrical markers to predict new onset and stage of AF progression (NWO-TTW / Hartstichting)
- Improving pressure ulcer prevention with smart mobility monitoring in healthcare institutions (NWO Takeoff Grant, Phase 1)
- POSITION II: A pilot line for the next generation of smart catheters and implants (EU ECSEL JU)

MARIE CURIE ACTIONS

Demonstrator connecting innovators

STW Hartstichting Partnership

Take-off

ECSEL Joint Undertaking Electronic Components and Systems for European Leadership

TU Delft 16

NeuroDelta

Neurodelta, a multidisciplinary consortium that provides a platform for innovative brain stimulation and monitoring applications in animal and clinical studies

LUMC
TU Delft
Erasmus MC
Kempenhaeghe
Erasmus MC Sophia Kinderziekenhuis
UMC Utrecht
University of Otago New Zealand
inholland university of applied sciences
SINs Small Implantable Neuro Stimulators
BRAIN INNOVATIONS
Wilhelmina Kinderziekenhuis
NETHERLANDS INSTITUTE FOR NEUROSCIENCE Master the mind

TU Delft 17

OTHER COLLABORATIONS

Biosense Webster. a Johnson & Johnson company
ECTM
ImPhys Image to insight Insight in imaging Department of Imaging Physics
UCL
inesc id lisboa
Holst Centre Open Innovation by imec and TNO
Fraunhofer IZM
Pázmány Péter Katolikus Egyetem
MFA
OSYPKA MEDICAL
multichannel systems Innovations in Electrophysiology
ABS APPLIED BIOMEDICAL SYSTEMS
TMSi
Advanced Bionics
HealthTech
G Therapeutics
2B MEDICAL HEALTHCARE PROFESSIONALS
reden research development nederland
Salvia BioElectronics
PHILIPS Research
CorTec
NOWI
Momo Medical

TU Delft 18

EXPANDING THE TEAM

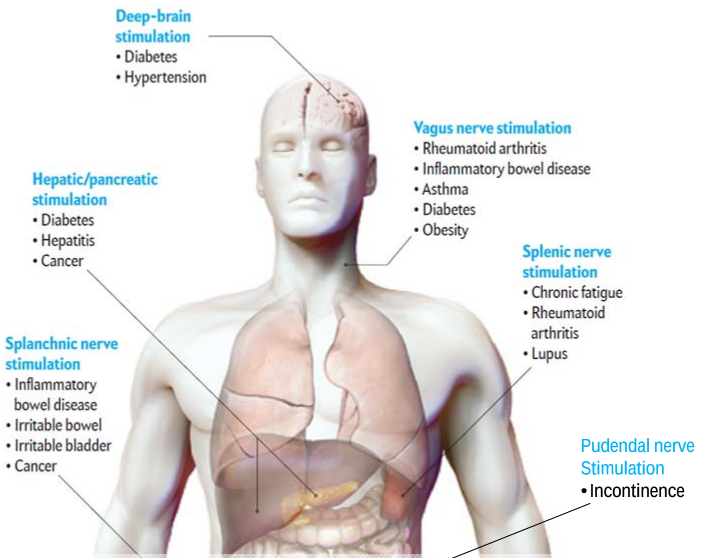
Virgilio Valente,
from January 2018

Can Akgun,
from Sept. 2017
(22 months)

Samaneh Babayan,
From Nov. 2017
(12 months)

TUDelft

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]

TUDelft

MEDICAL IMPACT – SENSES AND CENTRAL NERVOUS SYSTEM

- Restore hearing (cochlear implant)
- Restore sense of balance (vestibular implant)
- Restore sight (retinal 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

TU Delft

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 headaches 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

[Reference: C.O. Oluigbo, A.R. Recai, Addressing Neurological Disorders With Neuromodulation, IEEE Transactions on Biomedical Engineering, Vol. 58, No. 7, July 2011]

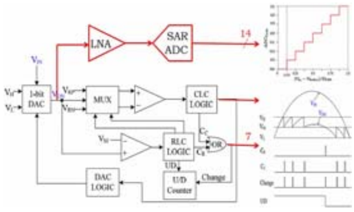
TU Delft

TUDelft

BACKUP SLIDES

TUDelft

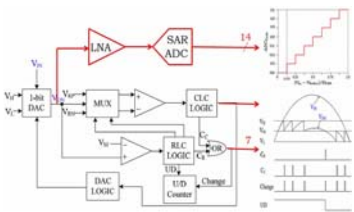
BIOELECTRONICS @ DELFT

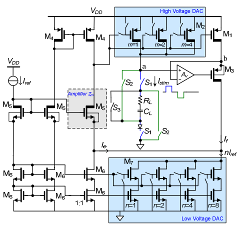


In the Section Bioelectronics we work on functional block diagrams

25

BIOELECTRONICS @ DELFT

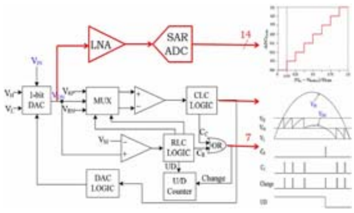


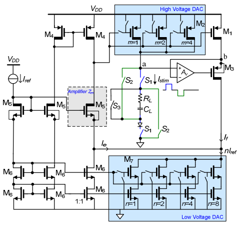
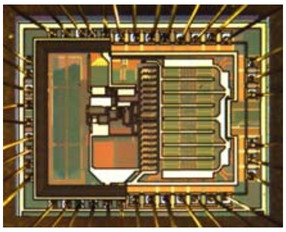


In the Section Bioelectronics we work on functional block diagrams and circuits

26

BIOELECTRONICS @ DELFT

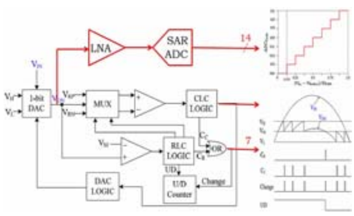


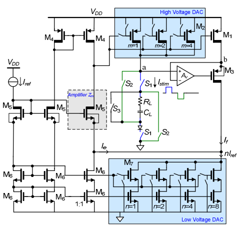
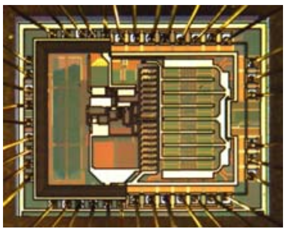
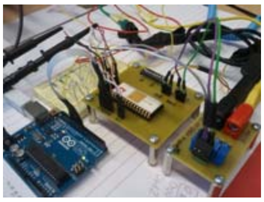
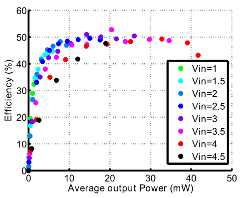



In the Section Bioelectronics we work on functional block diagrams and circuits; we design chips

TUDelft 27

BIOELECTRONICS @ DELFT

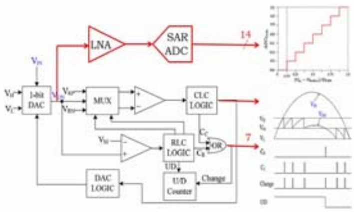


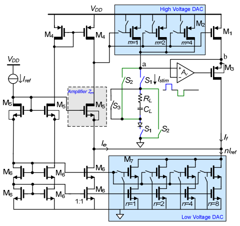





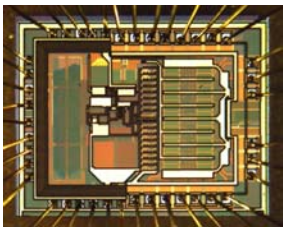
In the Section Bioelectronics we work on functional block diagrams and circuits; we design chips, we test and characterize them;

TUDelft 28

BIOELECTRONICS @ DELFT





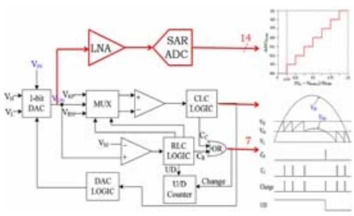


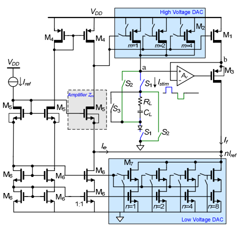
TUDelft

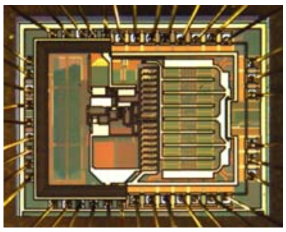
In the Section Bioelectronics we work on functional block diagrams and circuits; we design chips and microsystems

29

BIOELECTRONICS @ DELFT







TUDelft

In the Section Bioelectronics we work on functional block diagrams and circuits; we design chips and microsystems and test these in vitro and in vivo, together with our medical partners

30