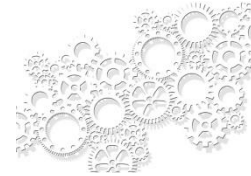
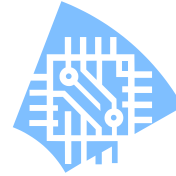




Westsächsische Hochschule Zwickau
University of Applied Sciences



Workshop „Mathematik in Forschung und Lehre“ 2018

Development of a noninvasive brain controlled muscle stimulation system

Marcus Löffler

Contents

- Motivation
- Idea
- Development
- Conclusion

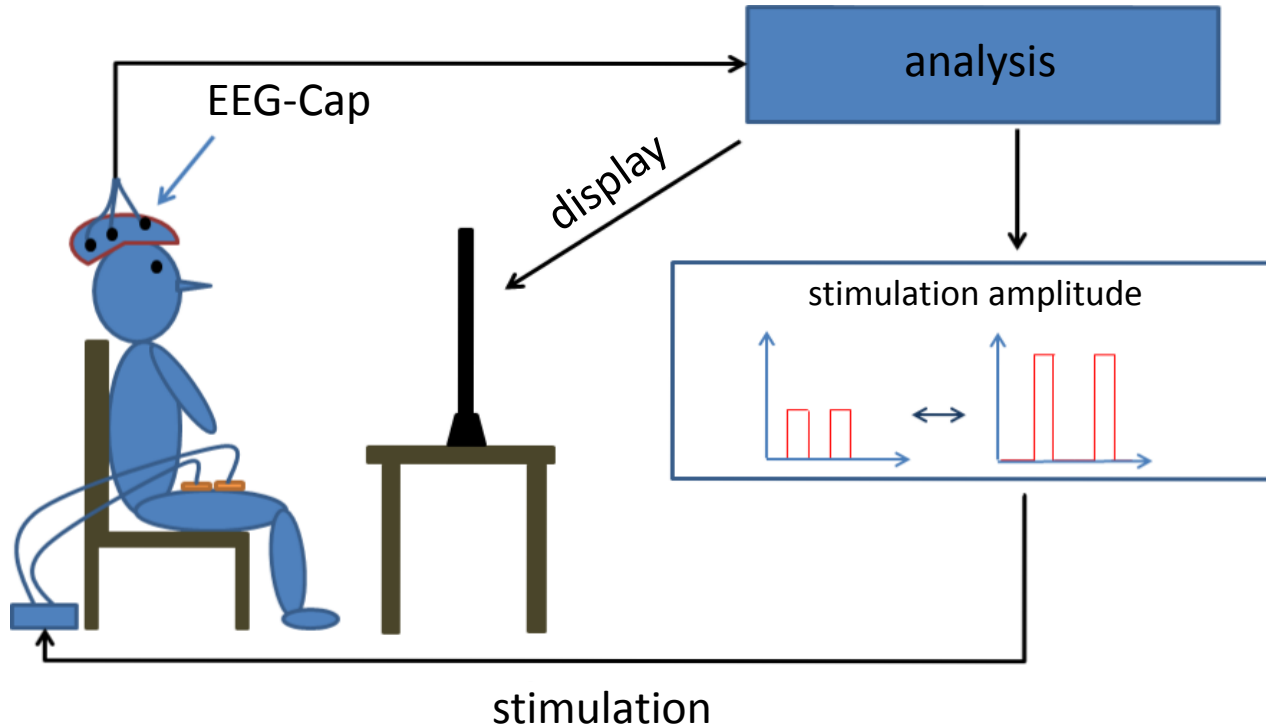
Motivation

- 18,000 people suffer from spinal cord injury every year [1]
- 270,000 people suffer on stroke every year [2]
- physiological and psychological changes can occur [1-3]
- motor disorders, progressive reorganization process in brain [1,4]

Plasticity of the brain

Research question : Is it possible to influence this process positive?

Idea



Development – Main topics

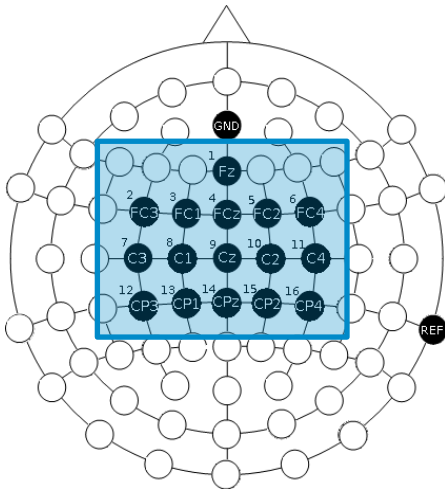
1. Extract the movement with electroencephalogram (EEG)
 - Study literature → Event Related Desynchronization (ERD) and Event Related Synchronizations (ERS)
 - Study with healthy participants and offline evaluation of ERD
 - Feature extraction for online analyses **(Mr. Wetzel)**
2. Muscle activity during different movements
 - Study with healthy participants and evaluation of muscle activity with electromyography (EMG)
 - Analyze the activity of muscles during specific part of movement
3. Development of a flexible muscle stimulation system

Development – EEG-Results

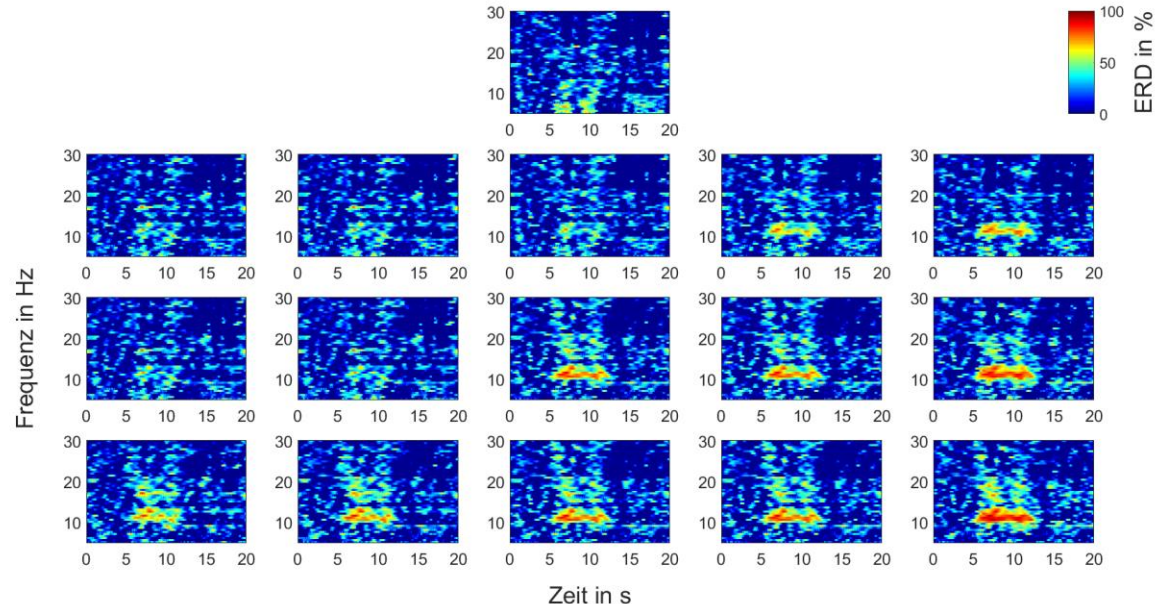
Event related desynchronisation (ERD)

$$ERD = \frac{Leistung_{ref}(f) - Leistung(f,t)}{Leistung_{ref}(f)} \quad (1)$$

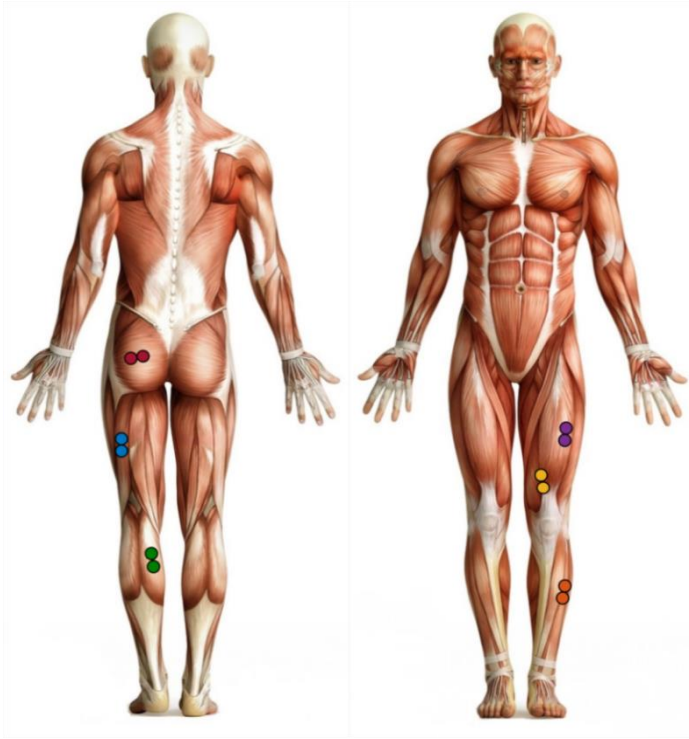
Subject 4: Movement



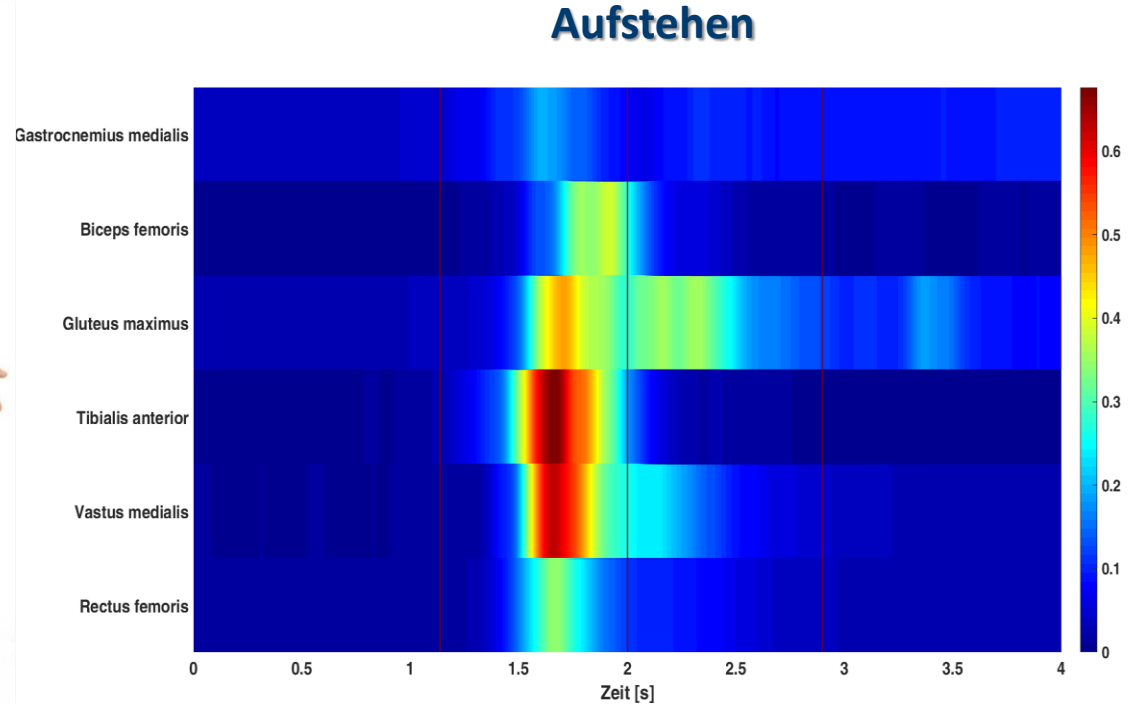
T. Carlson, J.R. Millán, IEEE Robotics & Automation Magazine 20, 65-73 (2013).]



Development – EMG-Results

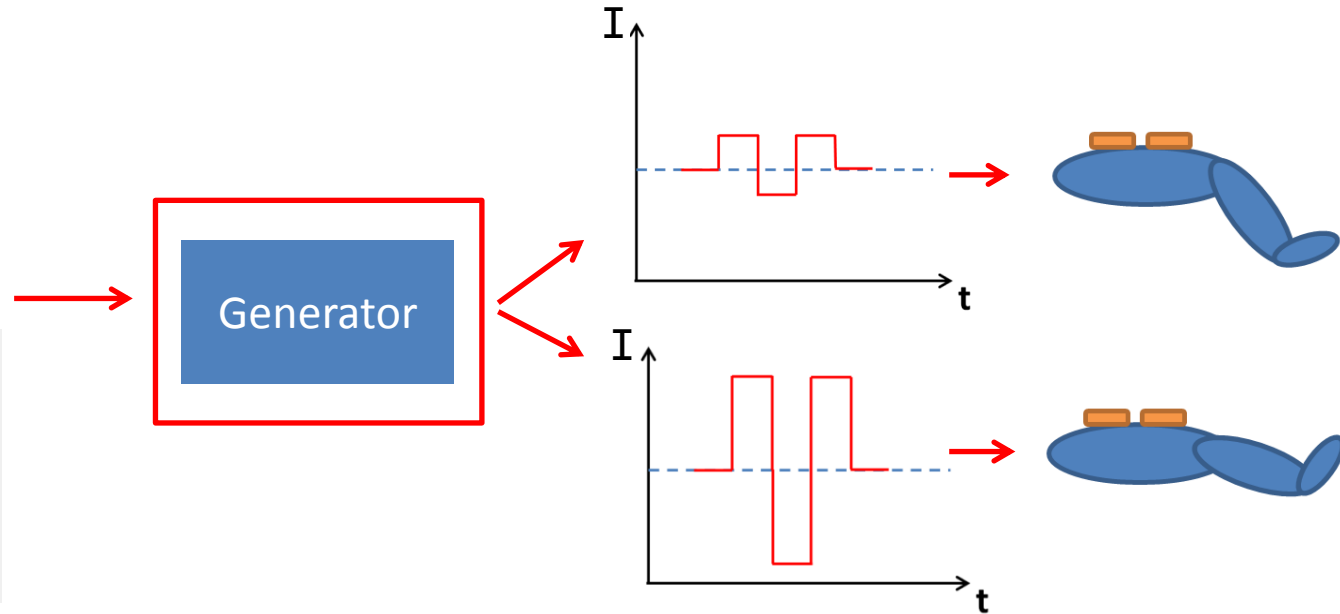
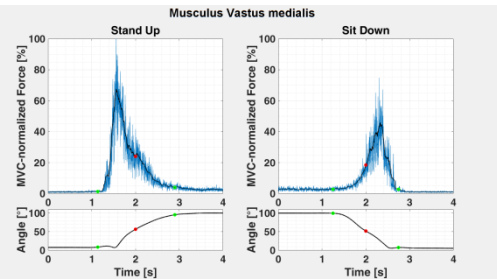
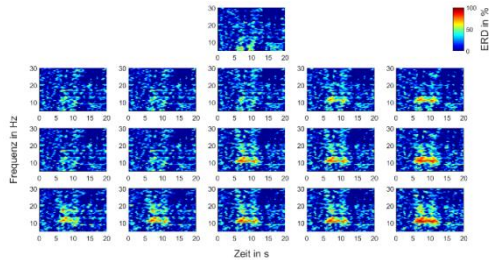


source: www.letsbands.com

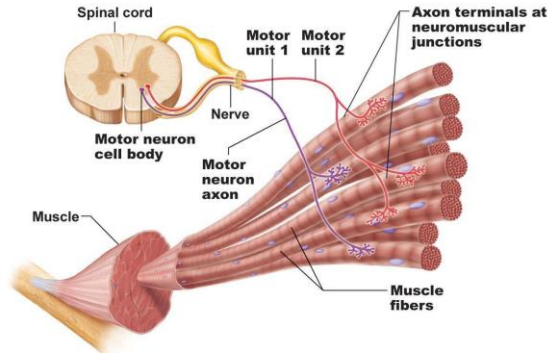


Development – Concept

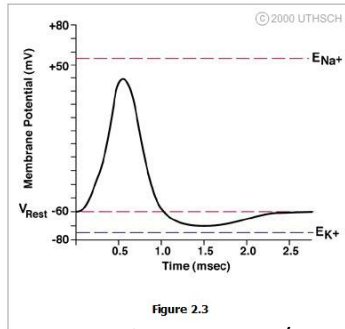
- Development of a system which combines the Brain Computer Interfaces with Functional Electrical Stimulation



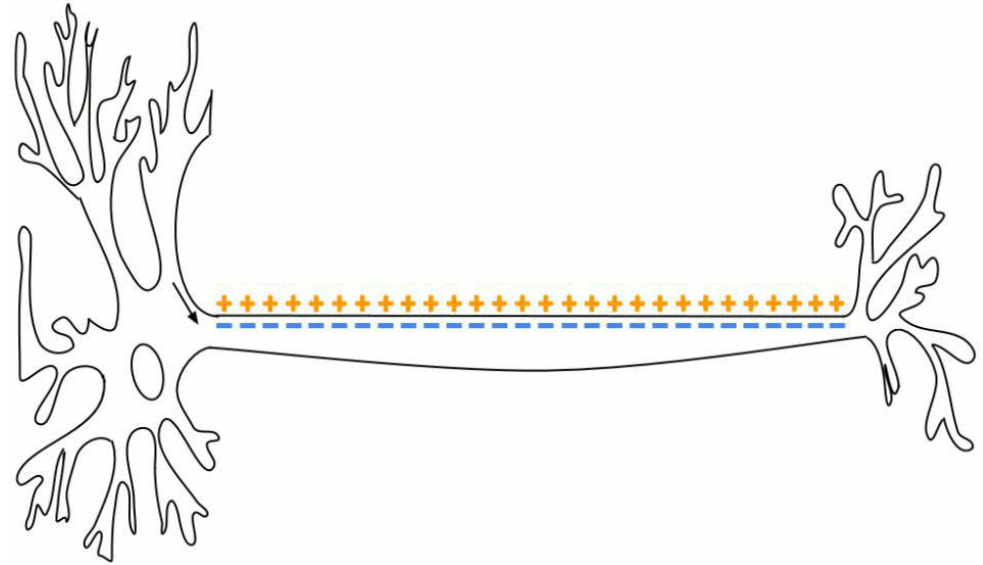
Development – Pulse shape



source: <https://cdn.netzathleten.de/images/-Muskelkontraktion/Muskel-Struktur.jpg>



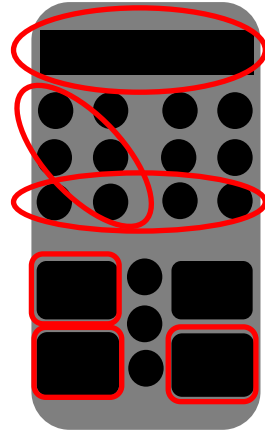
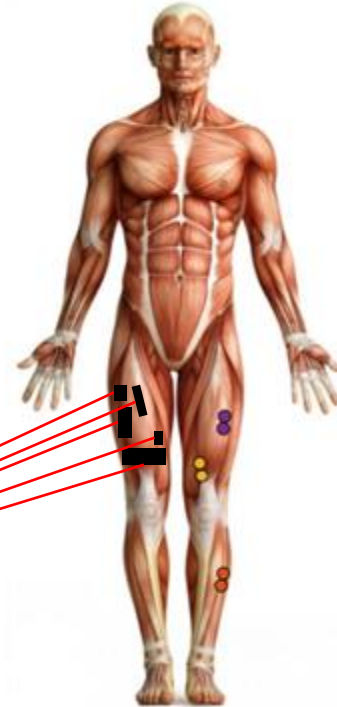
source: <https://nba.uth.tmc.edu/neuroscience/>



source: https://upload.wikimedia.org/wikipedia/commons/9/95/Action_Potential.gif

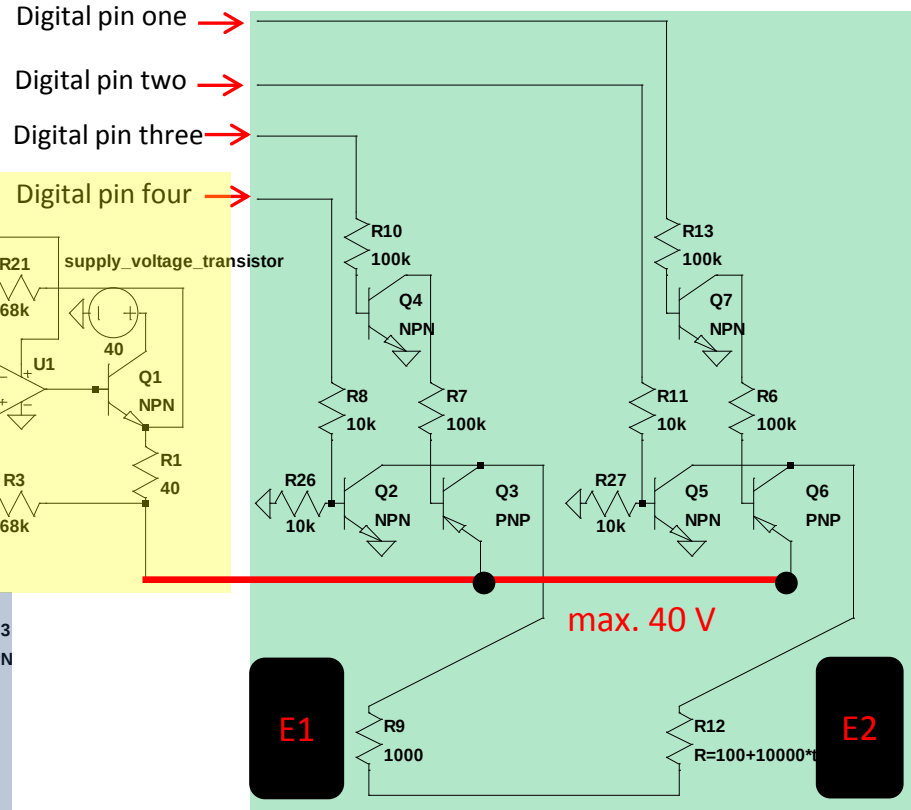
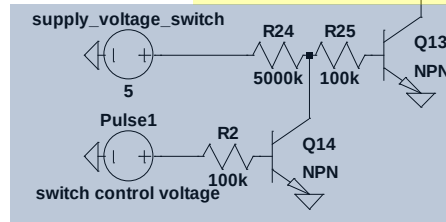
Development – System conditions

- Biphasic pulses to avoid constant ion gradations
- Wide range of possible frequencies
- Fast and flexible system different in and outputs
- Connectable to other systems (e.g. signal amplifier)
- Constant current even if the skin impedance changes
- Multiple channels
- Fast configuration of stimulation patterns
- Safety



www.letsbands.com

8-bit Atmel 2560



Development – Software

Pulse generation

- Output compare interrupt (OCI) of Timer/counter one
 - Interrupt service routine (ISR)

ISR:

Setting the digital pins HIGH or LOW by the use of the general purpose registers

Pulse width :

```
noInterrupts();
TCCR1A = 0;
TCCR1B = 0;
TCNT1 = 0;
OCR1A = 1600;
TCCR1B = ( 1 << CS10);
TIMSK1 = ( 1 << OCIE1A);
interrupts();
```

Four registers regulate: pulse width, frequency

- Timer/Counter (TCNT1)
- Timer/Counter Control Register (TCCR1B)
- Output Compare Register (OCR1A)
- Timer/Counter Interrupts Mask Register (TIMSK)

Bit
(0x81)
Read/Write
Initial Value

7	6	5	4	3	2	1	0	
ICNC1	ICES1	–	WGM13	WGM12	CS12	CS11	CS10	TCCR1B
R/W	R/W	R	R/W	R/W	R/W	R/W	R/W	
0	0	0	0	0	0	0	0	

Table 17-6. Clock Select Bit Description

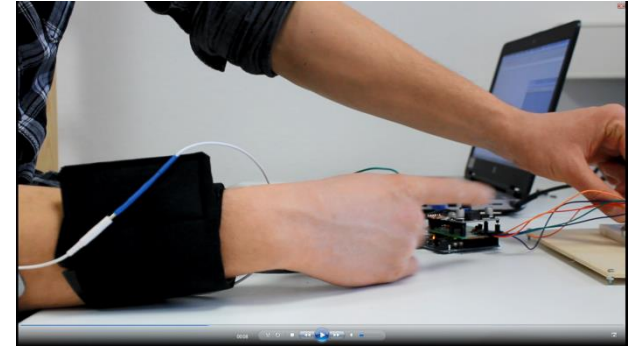
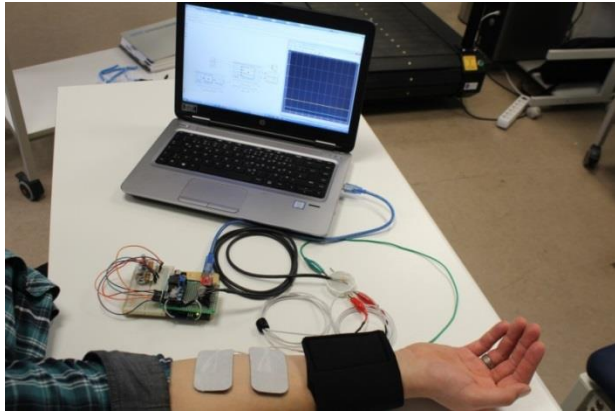
CSn2	CSn1	CSn0	Description
0	0	0	No clock source. (Timer/Counter stopped)
0	0	1	$clk_{I/O}/1$ (No prescaling)
0	1	0	$clk_{I/O}/8$ (From prescaler)
0	1	1	$clk_{I/O}/64$ (From prescaler)
1	0	0	$clk_{I/O}/256$ (From prescaler)
1	0	1	$clk_{I/O}/1024$ (From prescaler)
1	1	0	External clock source on Tn pin. Clock on falling edge
1	1	1	External clock source on Tn pin. Clock on rising edge

Development – First prototype

Developed setup generator

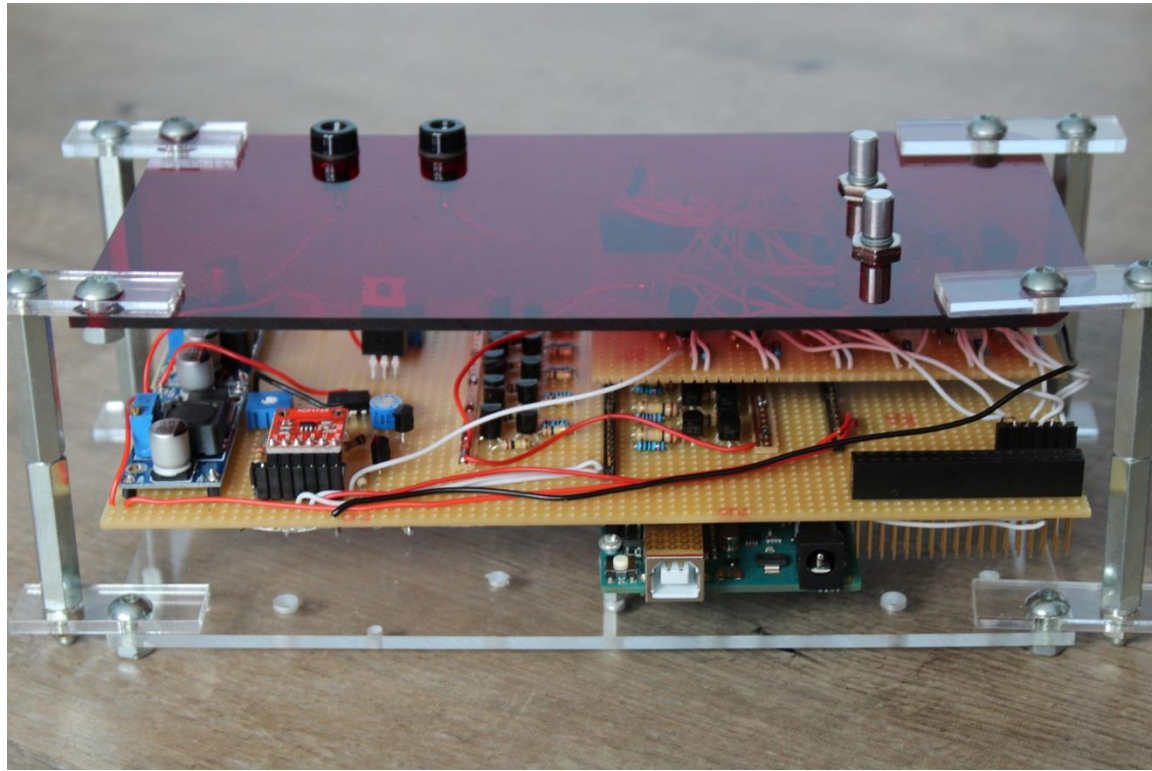


MVI_0955.mp4



- 4 channels
- Good stimulation performance
- Able to change stimulation parameters
- Connectable with the EEG

Development – Second prototype



20180904_113819_edit.mp4

Conclusion

Results

Offline analyses of EEG and EMG on healthy participants



Next steps

Combine online feature extraction with muscle stimulation system

Stimulation prototypes were build



Improve prototype hard- and software, programming user interface,

Tested the prototype on us



Test the prototype with healthy participant

Thanks

**Thank you for your attention
&
I'm happy to answer your questions**

References

- [1]: Eduardo López-Larraz¹, Luis Montesano, Ángel Gil-Agudo, Javier Minguez, Antonio Oliviero: *Evolution of EEG Motor Rhythms after SpinalCord Injury: A Longitudinal Study* . year 2015
- [2]: <https://www.schlaganfall-hilfe.de/der-schlaganfall>
- [3]: M. Bruehlmeier, V. Dietz,¹ K. L. Leenders, U. Roelcke, J. Missimer and A. Curt¹: *How does the human brain deal with a spinal cord injury?*. European Journal of Neuroscience, year 1998
- [4]: Junfang Wu,* Zaorui Zhao,* Boris Sabirzhanov, X Bogdan A. Stoica, Alok Kumar, Tao Luo, Jacob Skovira, and Alan I. Faden : *Spinal Cord Injury Causes Brain Inflammation Associated with Cognitive and Affective Changes: Role of Cell Cycle Pathways* . Neurobiology of Disease, year 2014

pictures

- [5] <https://cdn.sparkfun.com//assets/parts/6/4/3/3/11061-01.jpg>
- [6] <https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcRXWj3AHJlvOi82hhZOelmOvEpjIFS8m8k045nwJjGiBHflouG5A>
- [7] <https://img.staticbg.com/thumb/view/upload/2014/08/SKU154865/SKU154865a.jpg>