Fusion of Biology, Brain Science and Information Communication Technology

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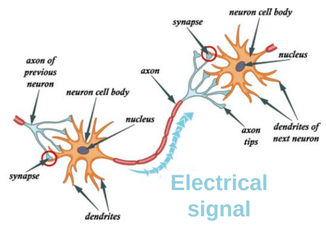
Research Background and Goal

Background

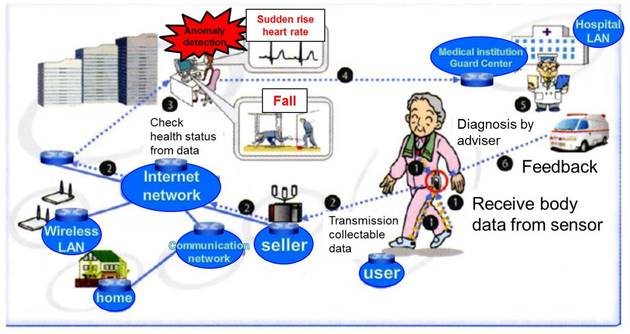
Treating method of severe mental disorder
Development of new BMI (Brain Machine Interface)



Deep research of neural signal and synaptic signal is needed !

Goal

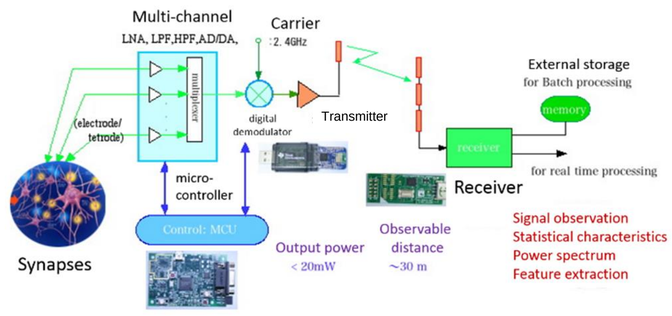
Development of device obtaining minute signals



Future application of synapse informatics

Research subjects

- Reliable ADC
- Power supply circuit
- System requirement
- Implementation



System configuration for realizing synapse informatics

Reliable ADC Design

SAR ADC using redundancy

Proposed solution

Using Fibonacci sequence for p(k): $p(k) = F_{M-k+1}$

Binary weight: 64 32 16 8 4 2 1 (×2)

Radix 1.8 weight: 34.0 18.9 10.5 5.8 3.2 1.8 1 (×1.8)

Fibonacci weight (Radix 1.62 weight): 13 8 5 3 2 1 1 (×1.62 = Golden ratio)

Property converging to “Golden ratio”

Realize **radix 1.62 weight** by using **only integers** !

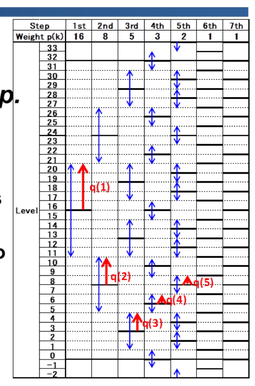
Effectiveness of this method

Discovered properties of this method!!

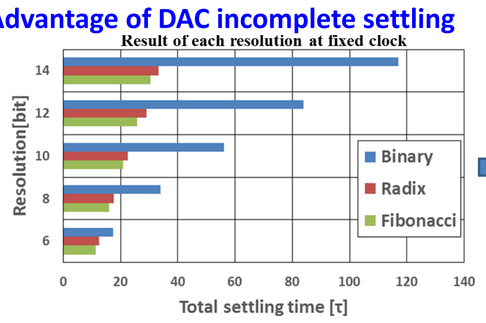
1. *q(k) is always Fibonacci number.*
2. *q(k) is exactly in contact q(k+1) without overlap.*

Property2 proves…

- **Reliable design**
  q(k) covers wide input range by minimum steps
- **Radix standard**
  Standard of redundant SAR ADC is Golden ratio



Advantage of DAC incomplete settling

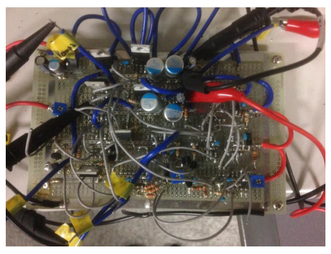


Fibonacci SAR ADC is faster than radix SAR ADC!

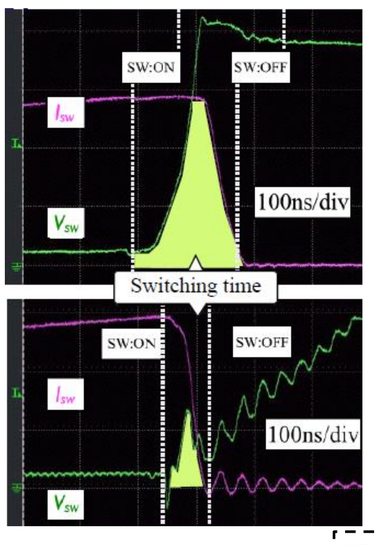
Improvement of Power Supply Circuits

High efficiency

- Previous work
  – To confirm simulation result of basic SIDO converter operation using ZVS-PWM control
- This work
  – To implement ZVS-PWM control into SISO boost converter



Comparison of switching waveforms



Boost SISO without ZVS

Power loss $P_{SW} = 102mV$

Switching loss P_{sw} $P_{sw} = \frac{1}{6} \cdot V \cdot I \cdot \Delta t$

Boost SISO with ZVS

Power loss $P_{SW} = 16mV$

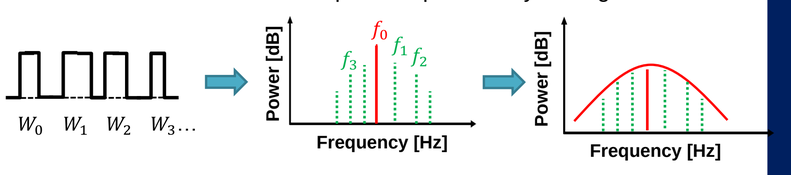
84% reduction

SISO···Single Input Single Output
SIDO···Single Input Dual Output

EMI reduction

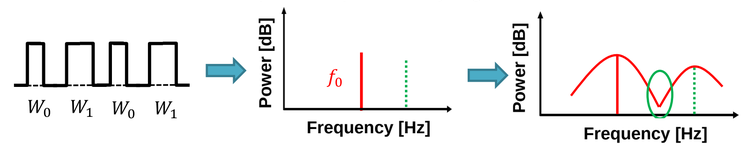
Conventional method

- Generation of continuous-pattern spectrum by analog modulation



Proposed method

- Generation of two-pattern spectrum by digital modulation



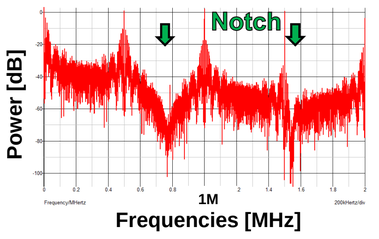
Notch
Frequency bands of no spread noise

Effectiveness verification with simulation

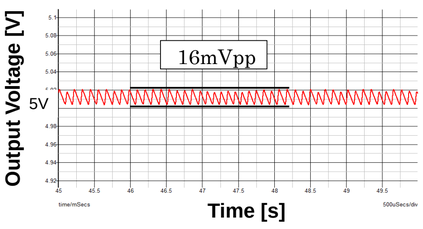
Feedback signal spectrum

Notch generation
Noise rejection at radio frequency

EMI reduction (-5dB)
Meet regulation



Output voltage of Switching converter



Small ripple (0.3%)
Stable power circuit

System Requirement

Fusion of biology, brain science and electronics

To get beneficial information from activity change of neurons and synapses nearby a probe

System requires as following:

1. **Measurement of activity voltage at synapse**
2. **Drebrins gather at synapse**
3. **Degrees of gliosis are few**

Relevant patents at above research

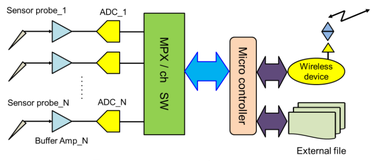
Patent : 2014-164695 (IP26-015)
Inventor : T. Shirao, Y. Ishizuka, H. Yamazaki
Development name : Specific quantification methods of Drebrin A and Drebrin E

Transmission Device

Transmission experiment of prototype device

Develop sub-system to realize coding/decoding signal transmission and communication

【System Configuration】
・ADC：24 bit Δ-Σ type ADC
Variable between 250 sps and 16K sps
・8-ch Multiplexer
・Wireless transmission：
Bluetooth 2.1+EDR class 1 Output



Transmission system diagram

①Acquisition and transmission of electroencephalogram signal (EEG sensor
②Monitoring

Realize transmission at distance over dozens of meters !

Prototype transmission device (with EGG sensor probe)

Future Works

Our challenge is underway

◆ **Reliable ADC**
–Verification with actual equipment

◆ **Power supply circuit**
–High-efficiency・noise guard
–Analysis of notch characteristic
–ZVS-PWM control implementation into SIDO boost-boost converter

◆ **System requirement consideration**
– Characterization of neural and synaptic signals
– Program development to extract features
– Extraction of changing pattern around electrode

◆ **Design and prototype of data transmission**
–Neural signal acquisition
–More small-scale transmission device realization