An Energy Efficient Epileptic Seizure Detector

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Presented by

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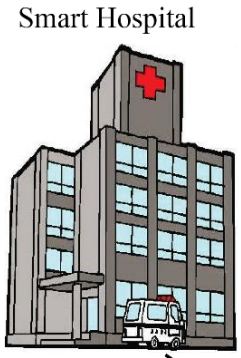
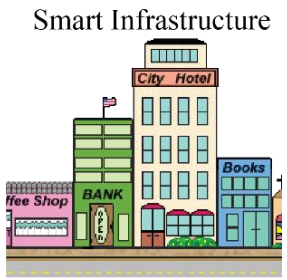
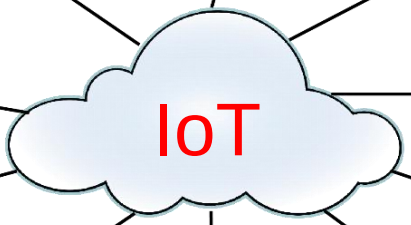
Outline of the talk

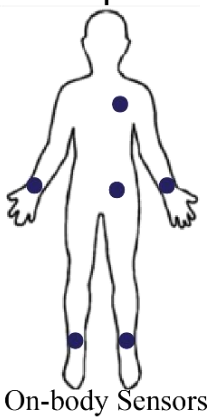
- Introduction
- Novel Contributions
- Proposed Architecture of the Seizure Detector
- Design of the Seizure Detector
- Modelling and Implementation
- Experimental Results
- Conclusions and Future Research

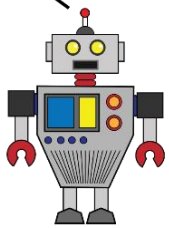
Smart Healthcare





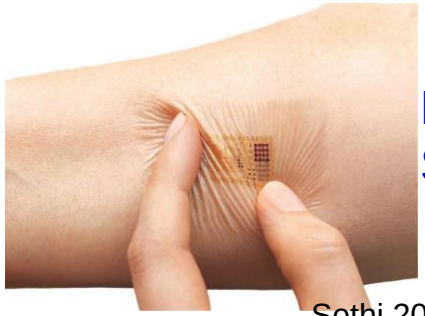






Fitness Trackers

Headband with Embedded Neurosensors



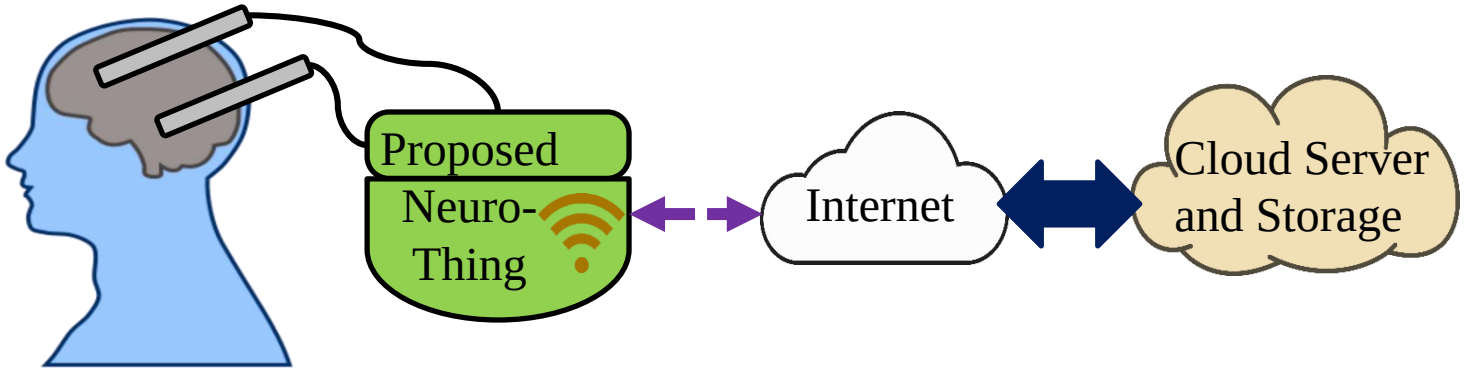
Embedded Skin Patches

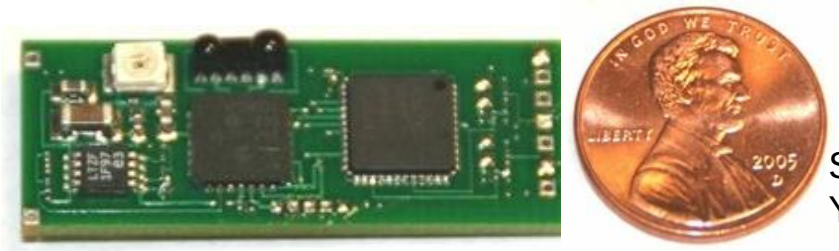
Sethi 2017: JECE 2017

Quality and sustainable healthcare with limited resources.

Source: Mohanty 2016, CE Magazine July 2016

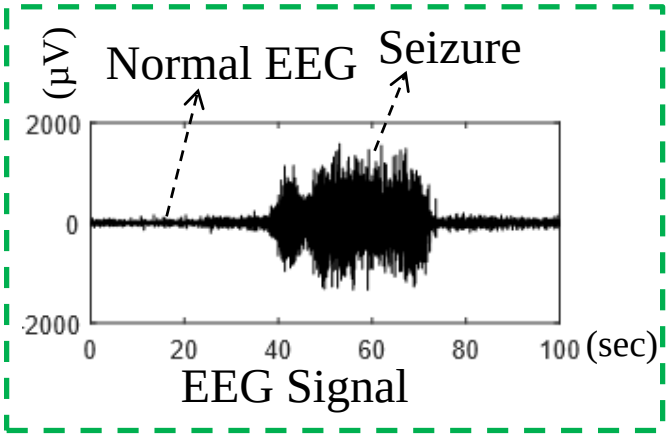
Smart Healthcare – Automatic Seizure Detection

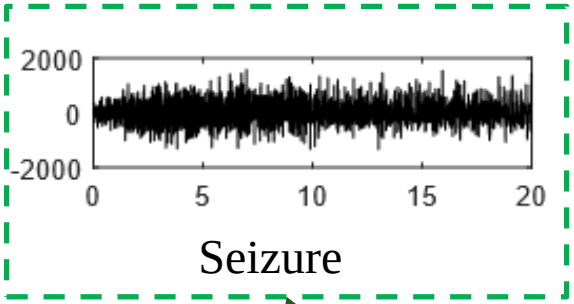


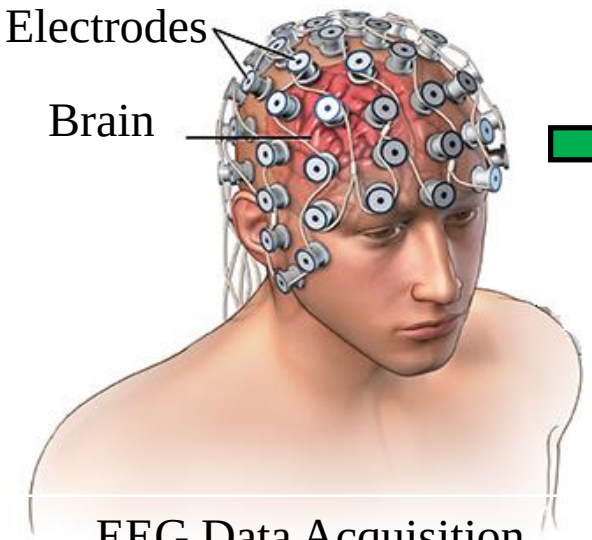


Source: Zaveri, Yale University

Smart Healthcare – Automatic Seizure Detection

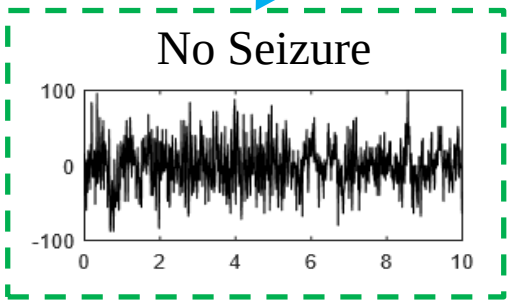






Accurate Energy-Efficient Seizure Detector

Seizure Detection



EEG Data Acquisition | Seizure Detection Algorithm | Detection of Seizure

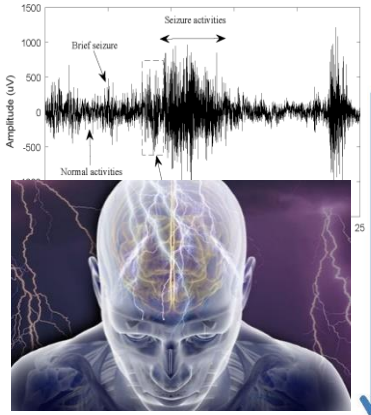
Seizure Detection

- A seizure is the manifestation of an abnormal hyper-synchronous disturbance of a population of cortical neurons.
- Anti-epileptic drugs are used to control seizure. 30% of epilepsy patients remain refractory to medication.
- Epileptic surgery leads to the damage of eloquent cortex and creates neurological deficit.
- There has been a trend towards developing fully implantable devices for automatic monitoring and warning of seizures.

Novel Contributions of This Paper

- A novel and highly effective algorithm (SRA) is introduced to remove unwanted signals and noise, which considerably enhances the performance of the detector.
- There is a considerable reduction in power consumption (12 %-18%) compared to existing methods.
- A Simulink® based prototype of the architecture is implemented.

Seizure Detection – Big Picture



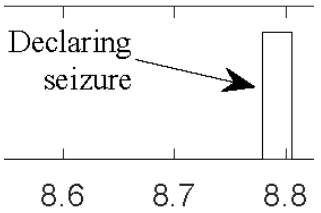
EEG Signal

Input Signal

Clock

Over-excitation Threshold

Signal Rejection Algorithm (SRA)



Over-excitation Detection Circuit

Count Seizure Activity

Declare Seizure Event

Seizure prediction

Seizure Activity Characterization

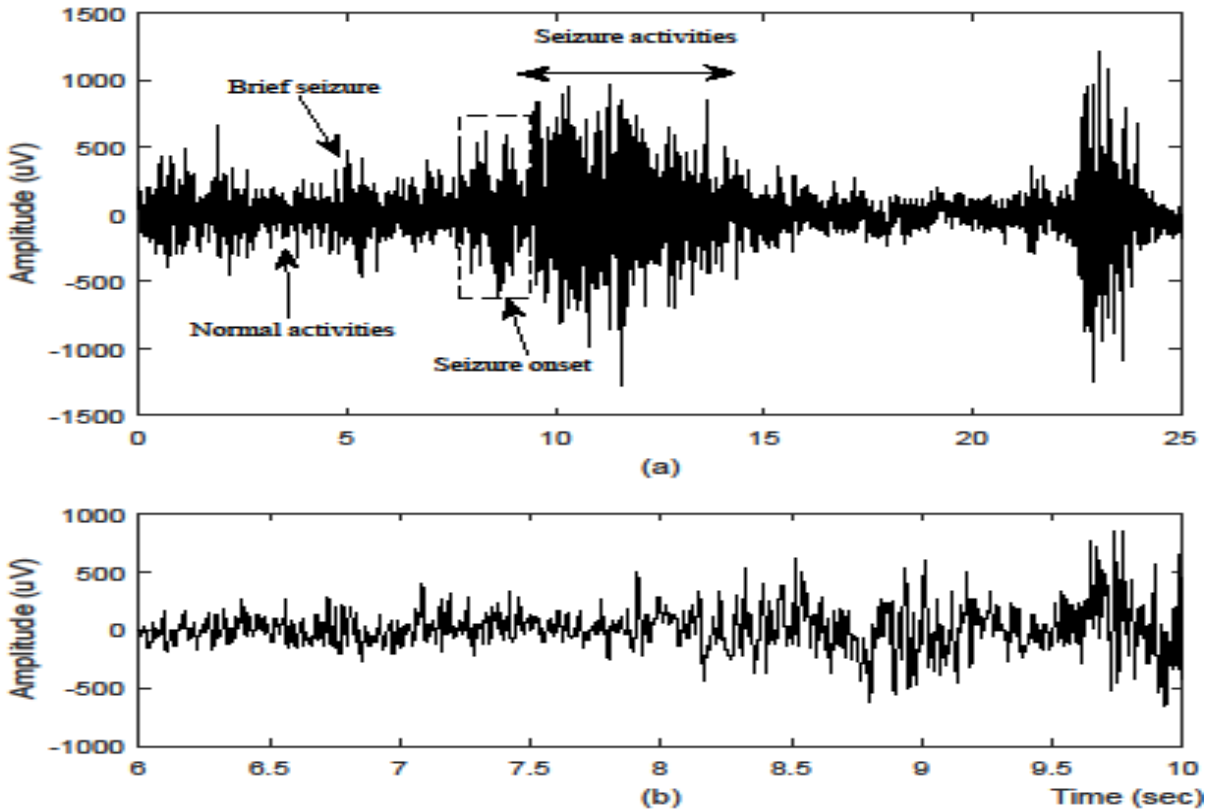


Fig.1 Seizure activity characterization (a) Invasive Electroencephalography (EEG) of an epileptic seizure (b) zoom inset 6-10 seconds

Proposed Seizure Detector Architecture

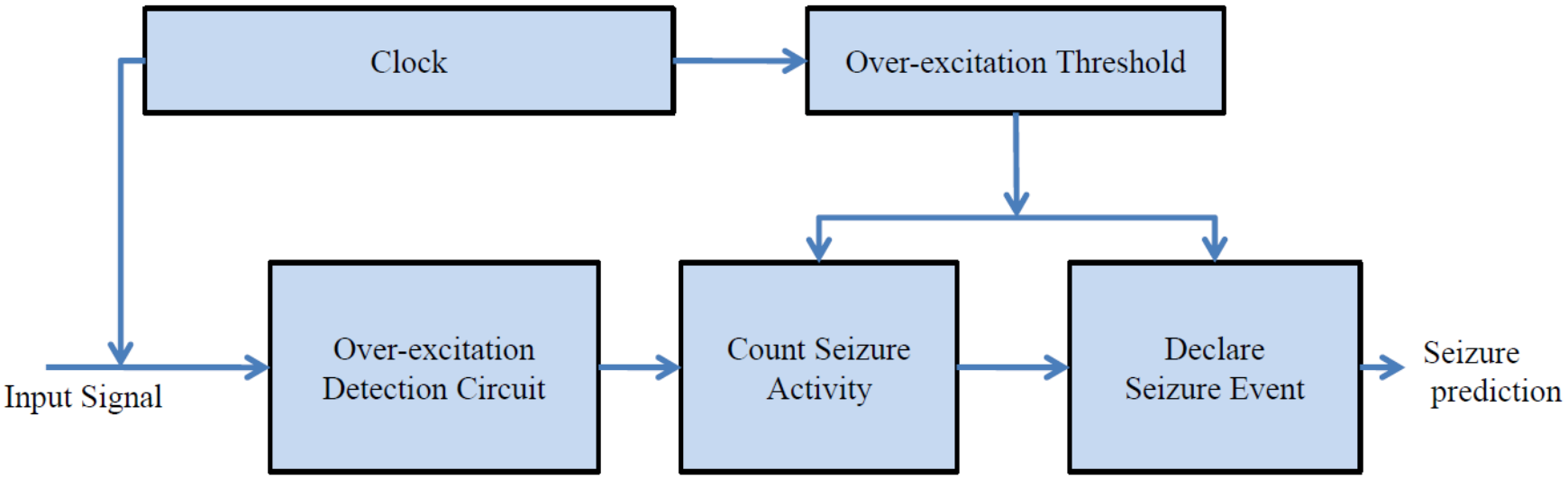


Fig. 2. Proposed architecture of the seizure detector

Design Flow

- Modulator
- Adjustable Gain Amplifier
- Filter
- Voltage Level Detector
- Signal Rejection Algorithm

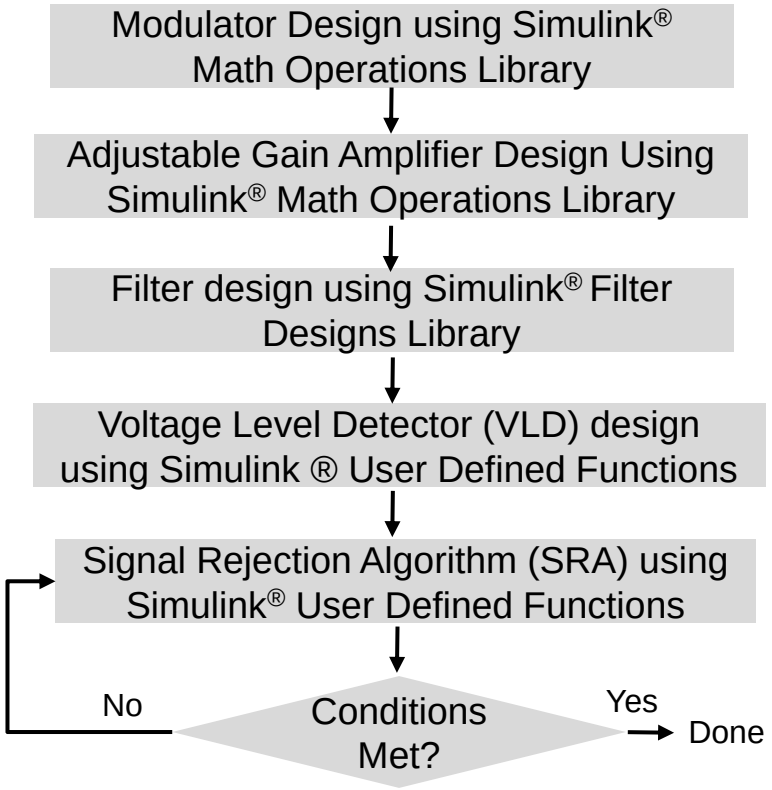


Fig. 3 Proposed design flow of the of the seizure detector

Hyper-synchronous Signal Detection Circuit

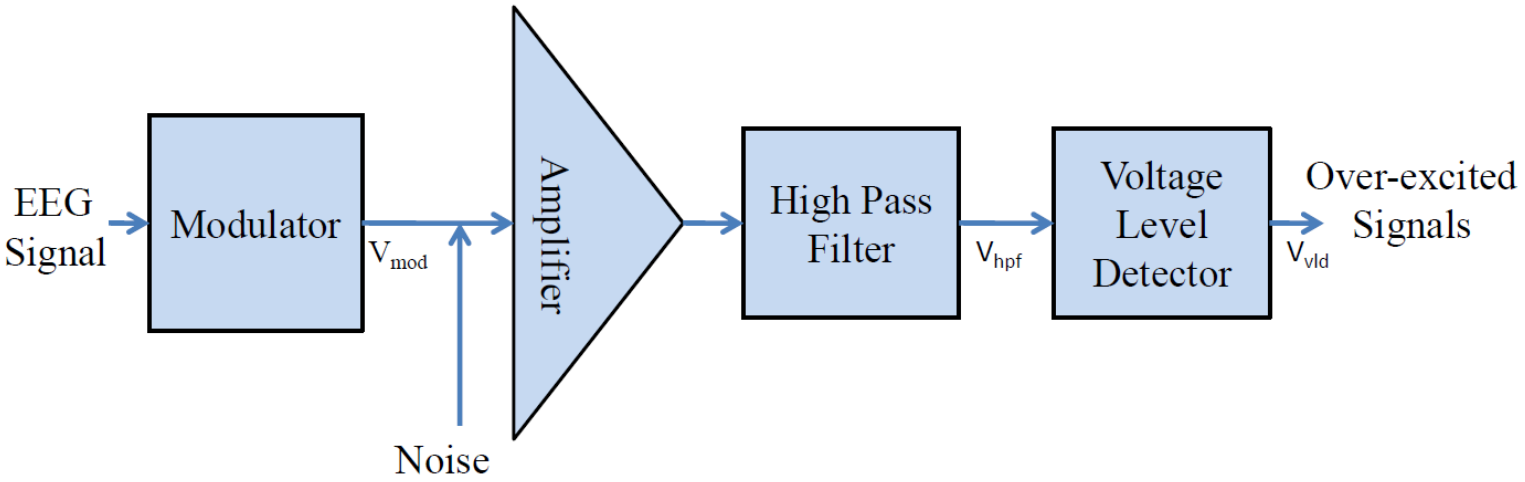


Fig. 4 Proposed hypersynchronous signal detection circuit

- Due to low amplitude range of neural signals, they need to be amplified prior to analysis.
- High pass filter attenuates low frequency signals and noise.

Signal Rejection Algorithm (SRA)

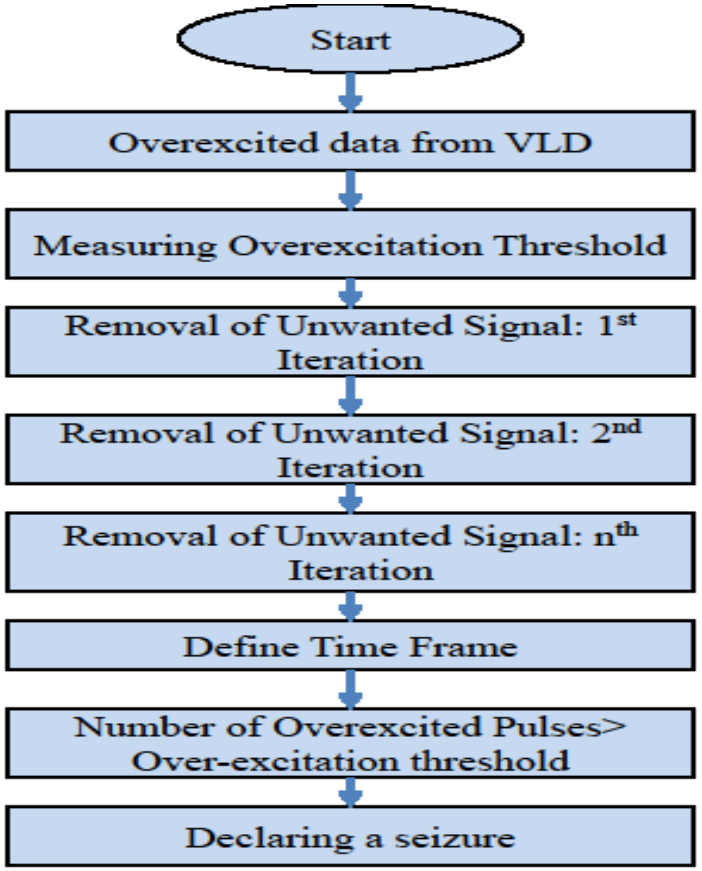


Fig. 5 Flowchart showing the detection of seizure from overexcited signal.

Signal Rejection Algorithm (SRA)

- The SRA algorithm is highly effective in removing unwanted pulses and noise.
- In a time frame, this algorithm eliminates spurious pulses if they fall below the defined threshold.
- If the number of hyper-synchronous pulses exceeds the threshold number, the seizure detector locks its VSE to 1, indicating a seizure.

Modelling and Implementation of the Proposed Detector

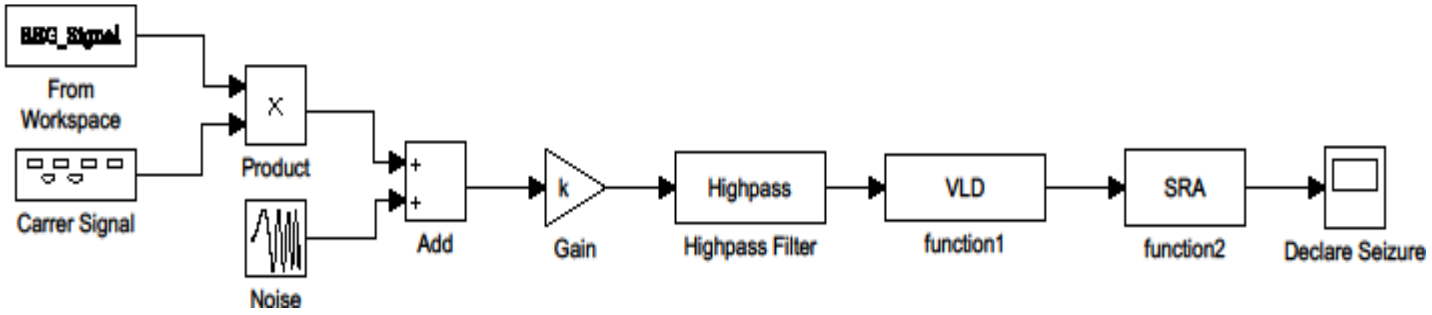


Fig. 6 Simulink model for the proposed seizure detector

- VLD uses a Simulink user defined function, has a maximum and minimum value.
- A threshold number of hyper-synchronous pulses define a seizure onset.

Power Measurement Set-up

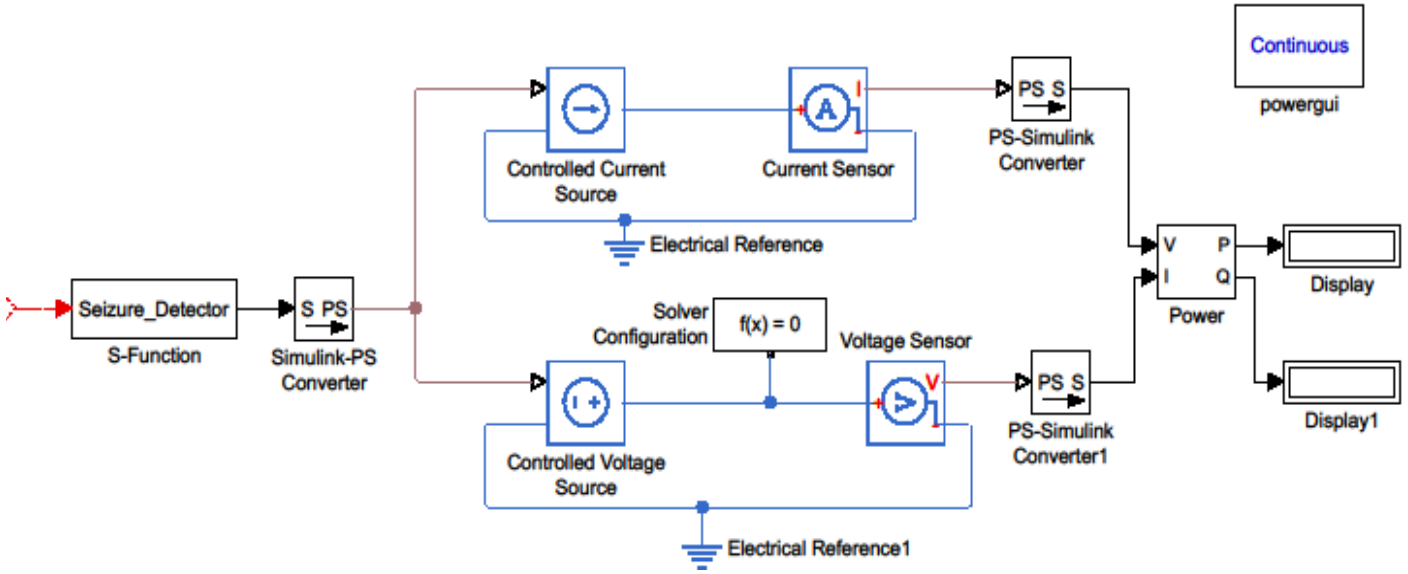


Fig. 7 Power measurement of the seizure detector

- In this design, the pattern independent method has been adopted.
- The design is considered a black box and current and voltage values are considered from the design, in order to calculate power.

Experimental Results

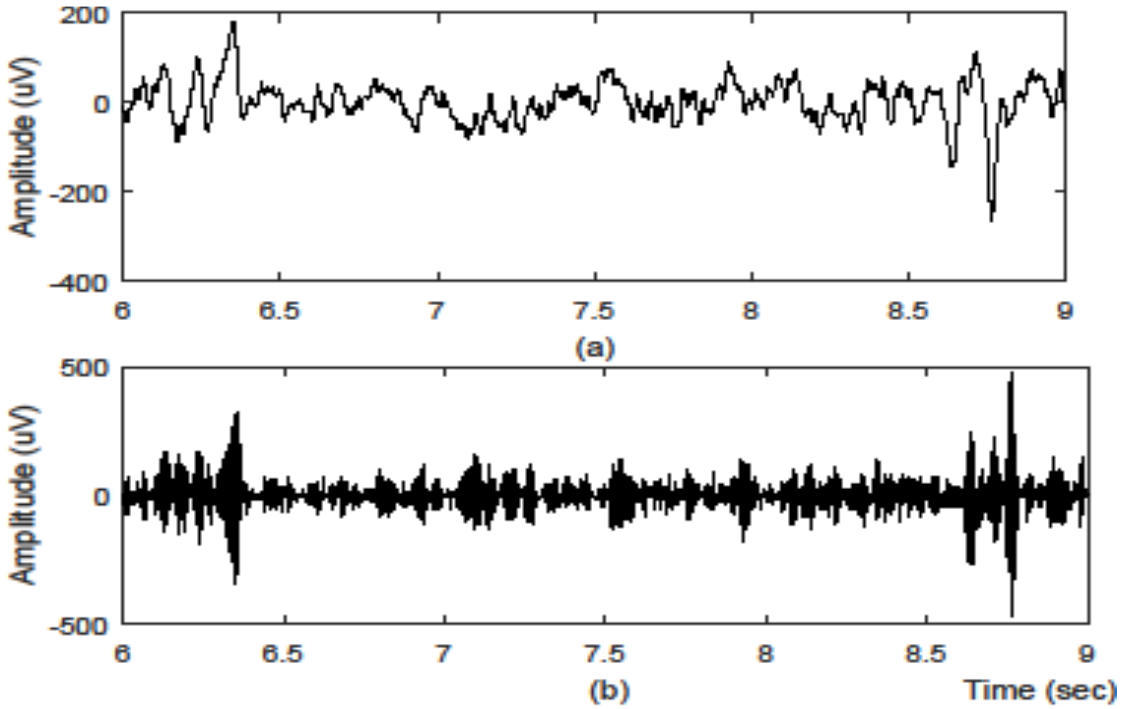


Fig. 8. Transient analysis (a) Zoom inset 6-9 seconds of input EEG signal (b) Modulated Signals

Experimental Results

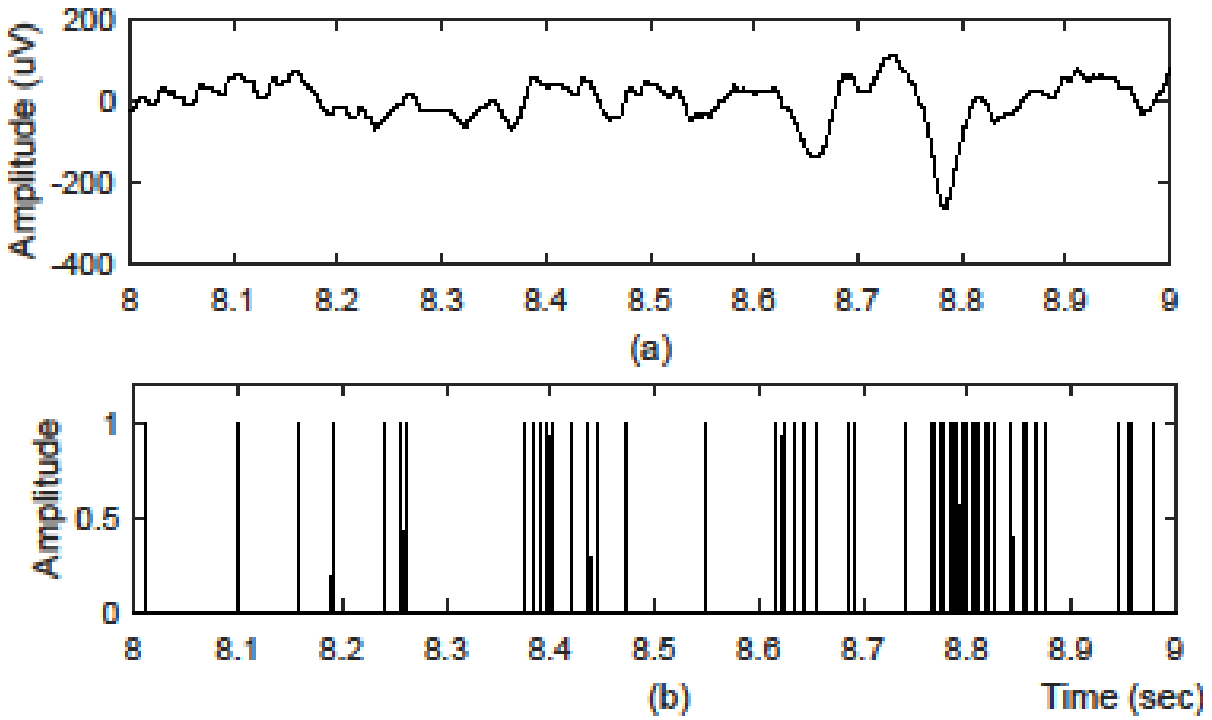


Fig. 8. Transient analysis (a) Zoom inset 8-9 seconds of input EEG signal (b) Output of VLD

Experimental Results

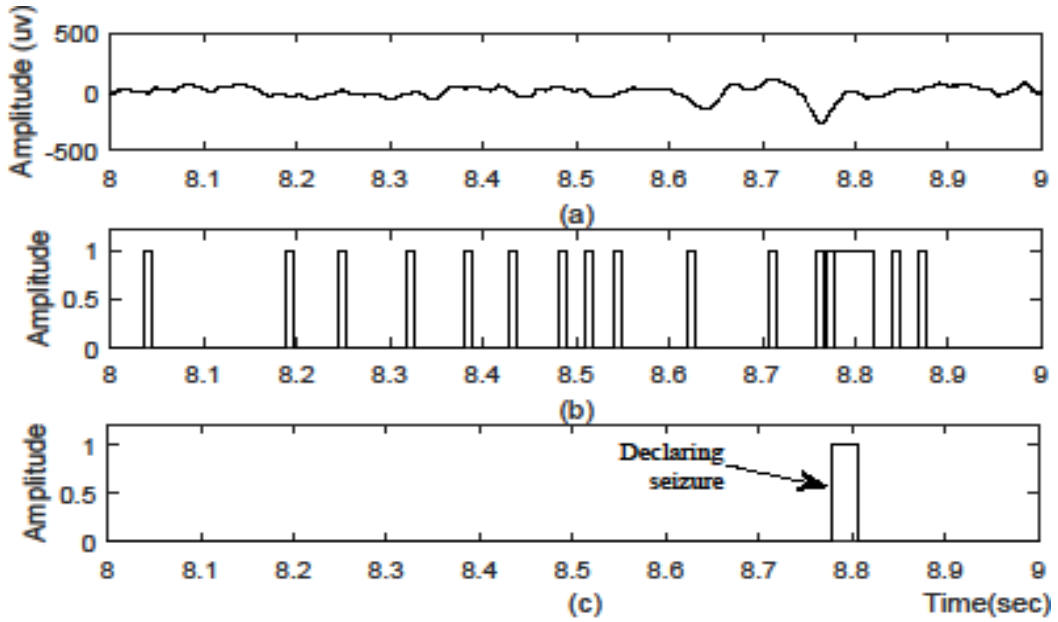


Fig. 8. Transient analysis (a) Zoom inset 8-9 seconds of input EEG signal (b) Output of SRA after first iteration (b) Output of SRA after nth iteration and detection of seizure onset

Experimental Results

Table 1. Simulation Data of the Proposed Seizure Detector

Parameter	Value
Seizure Frequency (Minimum)	5 Hz
Seizure Frequency (Minimum)	25 HZ
VLD (Average Lower Threshold)	210 mV
VLD (Average Upper Threshold)	380 mV
Total power consumption	6.18 µW

Conclusions and Future Research

- The rejection algorithm employed by SRA minimizes false detection, and improves seizure detection accuracy.
- There is a considerable reduction in power consumption (12 %-18%) compared to existing methods.
- Future research involves generating a probabilistic pattern of EEG abnormalities and combining it with proposed architecture for the seizure onset detector.

Thank You !!!

Slides Available at:

http://www.smohanty.org