Brain Computer Interfacing:

Steady State Visually Evoked Potential

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Brief Overview

Recap

- **What is SSVEP?**
- **What are we doing with SSVEP?**
- **Covariance Matrices**
- **Clusters**

Algorithm 1

- Cluster covariance matrices in ‘some space’
- Find the centroid of these clusters

Algorithm 2

- Compute ‘distances’ between matrix centers and an EEG epoch to be classified
- The center that gives the least distance is the class which the epoch is classified as belonging to

Progress

Accomplishments

- Outlier removal from EEG epochs training set.
- Filtering of EEG Signals

Outlier Removal

Outlier Removal

- Riemannian potato approach is used.
- A reference covariance matrix is estimated, by using a distance metric between trials adaptively.
- Any trial that lies too far, i.e. beyond a certain threshold, from the reference matrix in terms of the distance metric used is rejected.
- Z-score thresholding is done as:

$$z(\delta_i) = \frac{\delta_i - \mu}{\sigma} > z_{th}$$

Outlier Removal

- The reference point could be estimated in an adaptive manner during the whole recording session according to the following equation:

$$\overline{C}_{t+1} = (\overline{C}_t)^{1/2}\left[(\overline{C}_t)^{-1/2} C (\overline{C}_t)^{-1/2}\right]^{1/\alpha} (\overline{C}_t)^{1/2}$$

- The threshold '*th*' is estimated based on the mean μ and standard deviation of the distance to the reference matrix defined :

$$th = \mu + 2.5\sigma$$

- Through cross-validation, though, the z-score threshold is set to z'*th*' = 2.2

- Because of good sensitivity of Riemannian metric, the artefacts lie several standard deviations away from the reference.

Algorithmic Briefing

Algorithm 3

Issues with using Algorithm 1 and 2 only.

- Cues for the onset and offset of EEG epochs must be provided.
- EEG Epoch size is not well defined and is seemingly arbitrary
- Thus no optimum can be quantified

Algorithm 3

Outline

- Make epoch size variable
- Predict class repeatedly
- Check how frequently the predictor classifies one class
- Define a threshold (even empirically will do)
- Compare frequency of class prediction with the threshold
- Predict a class only if this confidence is above the threshold.

Robustness

- Outline appears to be only expanding dataset for algorithm 1 and algorithm 2
- Is adding a threshold enough?
- Have to increase robustness
- Done by considering trajectories of covariance matrices in epochs.

Algorithm 3

Consider

- D epochs, indexed by

$$J(d) = d-(D-1), d-(D-2), \ldots, d-1, d$$

- Let the gradient of the trajectory of the j^{th} covariance matrix to the predicted center in the epoch set be given as

$$\delta_{\overline{k}}(j) - \delta_{\overline{k}}(j-1)$$

- Where

$$\delta_{\overline{k}}(j) = \frac{\delta(\hat{\Sigma}_j, \Sigma_\mu^{(\overline{k})})}{\sum_{k=1}^{K} \delta(\hat{\Sigma}_j, \Sigma_\mu^{(k)})}$$

Algorithm 3

- The trajectory of the epochs must be towards the center
- The sum of all the D epochs' gradients must be negative.

$$\tilde{\delta}_{\overline{k}} = \sum_{j=d-D+2}^{d} \delta_{\overline{k}}(j) - \delta_{\overline{k}}(j-1) < 0$$

- Accuracies can be improved with this condition
- Cue onset and offset is not required.

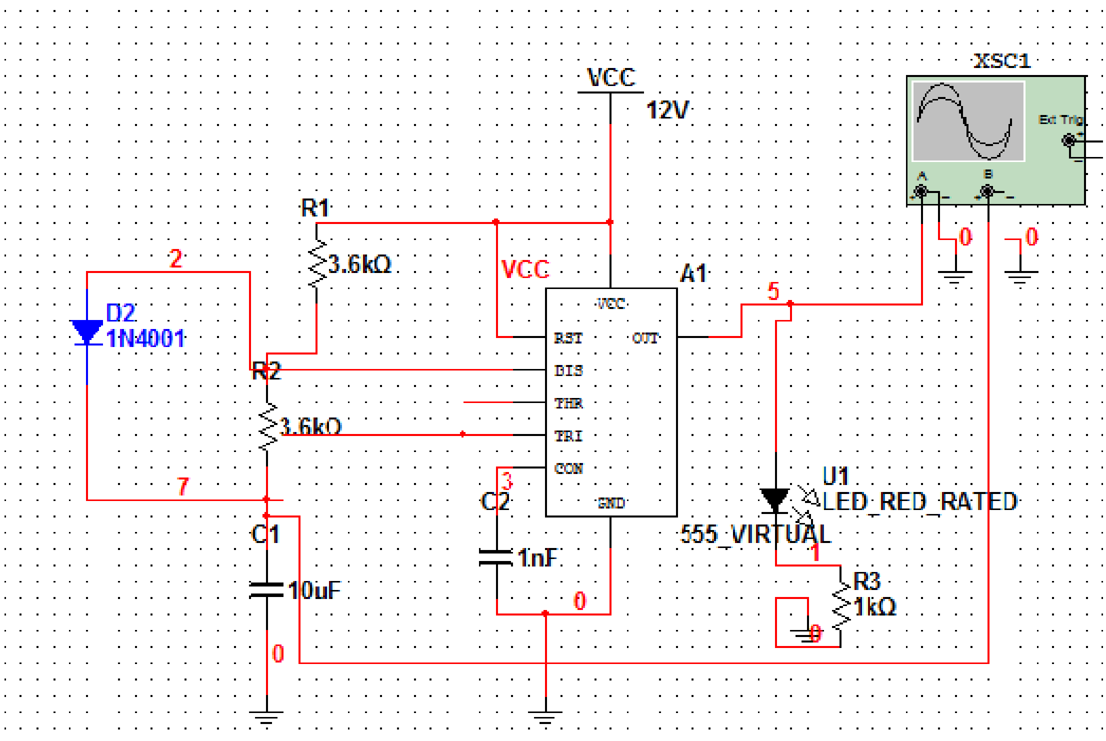
LED Array

Led Array (The 555 timer)

- 555 timer IC in an Astable mode to produce a very stable **555 Oscillator** circuit .

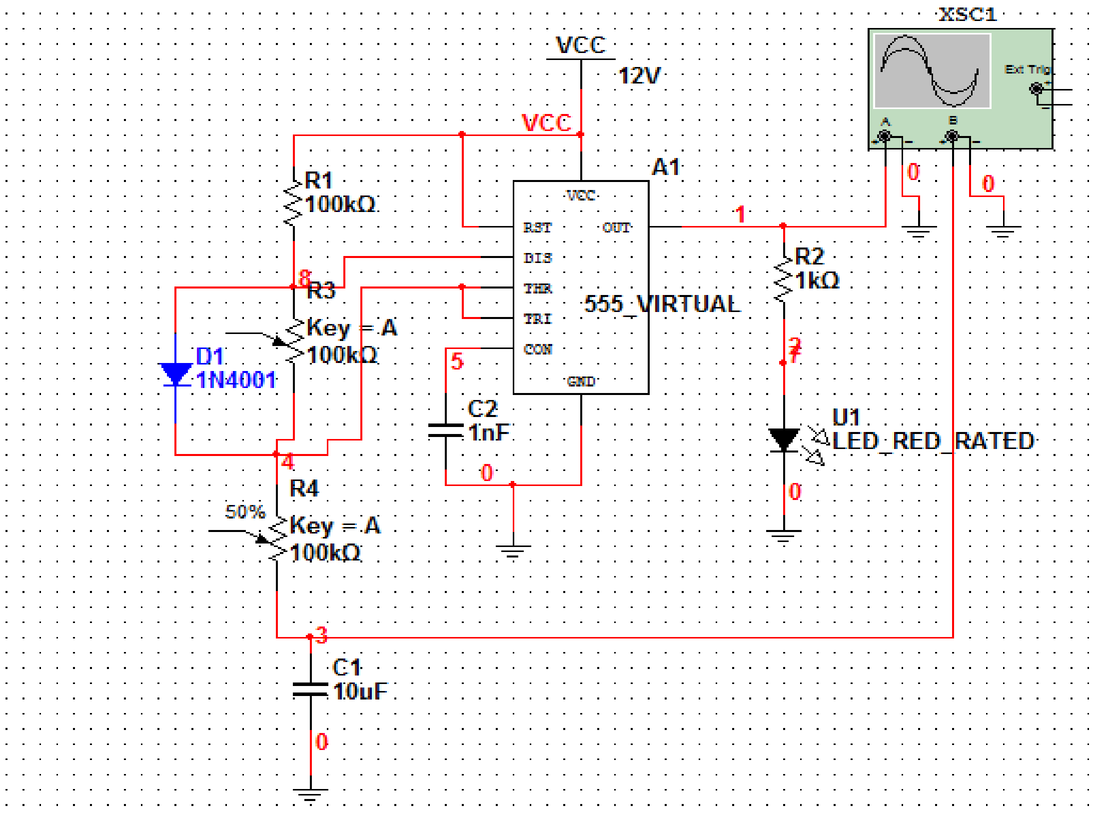
- Whose output frequency can be adjusted by means of an externally connected RC tank circuit.

50% Duty cycle



50% Duty Cycle Frequency Equation

- $T_{on} = 0.693\ (R_1 + Rv)C$
- $T_{off} = 0.693\ (R_2 + Rv)C$
- $T = T_{on} + Tof_f$
- $f = \dfrac{1}{0.693(2R_2)C}$



XSC1
Ext Trig
A
B
VCC
12V
VCC
A1
VCC
RST
OUT
DIS
THR
TRI
CON
GND
555_VIRTUAL
R1
100kΩ
R2
1kΩ
R3
Key = A
100kΩ
D1
1N4001
C2
1nF
U1
LED_RED_RATED
R4
50%
Key = A
100kΩ
C1
10uF

Next steps

Assignment 1: LED array module

Assignment 2: Recording of own EEG dataset

Assignment 3: Classification using curve based method

Thank You