Lecture Three

The Electroencephalography

Introduction

The EEG is an electrophysiological technique for the recording of electrical activity arising from the human brain. Given its superb temporal sensitivity, the main utility of EEG is in the evaluation of dynamic cerebral functioning. EEG is particularly useful for evaluating patients with suspected seizures, epilepsy, and unusual spells.

EEG has also been adopted for several other clinical indications. For example, EEG may be used to monitor the depth of anesthesia during surgical procedures; and has been proved quite helpful in monitoring for potential complications such as ischemia or infarction. EEG waveforms may also be averaged, giving rise to evoked potentials (EPs) and event-related potentials (ERPs), potentials that represent neural activity of interest that is temporally related to a specific stimulus. EPs and ERPs are used in clinical practice and research for analysis of visual, auditory, somatosensory, and higher cognitive functioning.

EEG Generations

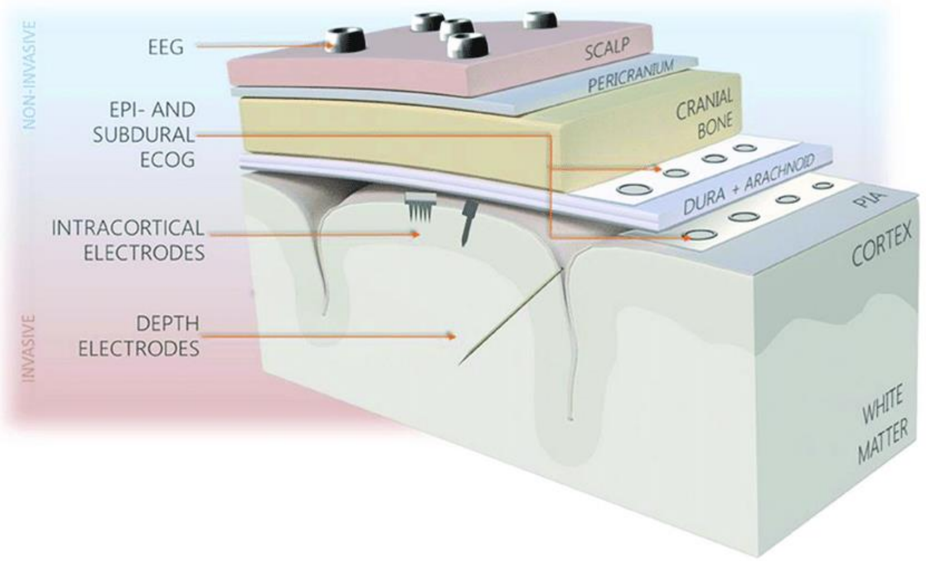
The EEG is thought to be primarily generated by cortical pyramidal neurons in the cerebral cortex that are oriented perpendicularly to the brain's surface. The neural activity detectable by the EEG is the summation of the excitatory and inhibitory postsynaptic potentials of relatively large groups of neurons firing synchronously.

The EEG signal is composed of electrical rhythms and transient discharges which are distinguished by location, frequency, amplitude, form, periodicity and functional properties. The EEG signals from the brain are recorded, then amplified and converted to a digital signal for further processing. EEG machines have a notch filter sharply tuned at 50Hz so as to eliminate main frequency interference. The EEG is recorded according to the international 10-20 Electrode system. EEG signal voltage amplitudes ranges 1 to 100µv peak to peak at low frequencies (1 to 50 Hz) at the surface of scalp.

An unfortunate reality of EEG is that cerebral activity may be overwhelmed by other electrical activity generated by the body or in the environment. To be seen on the scalp surface, the miniscule, cerebrally generated EEG voltages must first pass through multiple biological filters that both reduce signal amplitude and spread the EEG activity out more widely than its original source vector. Cerebral voltages must traverse the brain, CSF, meninges, the skull, and skin prior to reaching the recording site where they can be detected.

Additionally, other biologically generated electrical activity (by scalp muscles, the eyes, the tongue, and even the distant heart) creates massive voltage potentials that frequently overwhelm and obscure the cerebral activity. Temporary detachments of the recording electrodes (called “electrode pop” artifact) can further erode the EEG, or even imitate brain rhythms and seizures.

Fortunately, artifacts possess many distinguishing characteristics that are readily identifiable by well-trained, careful observers.



EEG Waves

Generally, there are four wave groups (alpha, beta, theta, and delta). The EEG rhythm and waveforms are varied by the position of electrode placements on certain parts of the brain (fig.1).

Alpha wave occurs at a frequency between 7.5 and 13Hz. The alpha waves are produced when a person is in a conscious, relaxed state with eyes closed; the activity is suppressed when the eyes are open. The amplitude of the alpha rhythm is largest and intensely occurs in the occipital region and can be best recorded at parietal and frontal regions of the scalp.

Beta waves normally occur in the frequency range of 14-30Hz and sometimes even as high as 50Hz for intense activity. Beta waves activities are present when people are alert or anxious, with their eyes open.

Theta potentials are large amplitude, low frequency between 3.5 and 7.5Hz waves. Theta is abnormal in alert adults but seen during sleep, and small children. Theta waves occur mainly in the parietal and temporal region.

Delta waves have the largest amplitudes and the lowest frequency in less than 3.5Hz. It is normal rhythm for infants less than one year old and in adults in deep sleep. This wave can thus occur solely within the cortex, independent of the activities in lower regions of the brain.

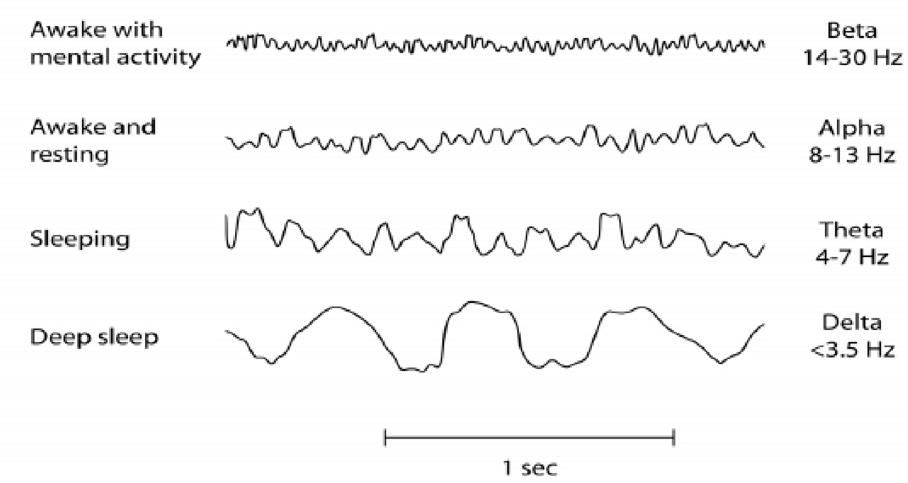
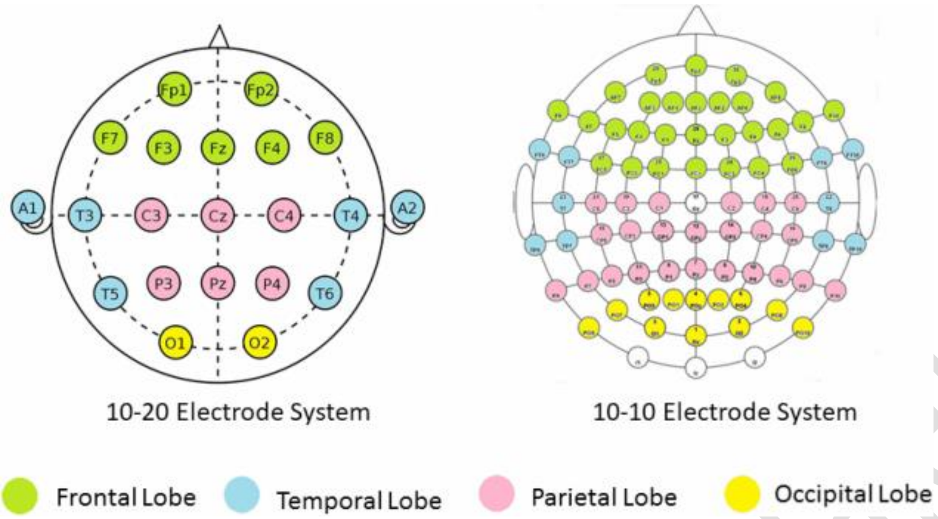


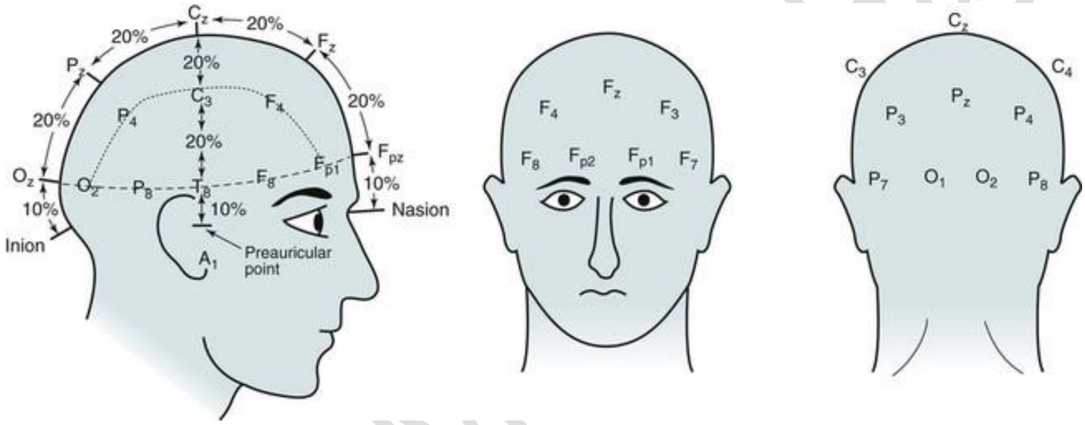
Fig.1: EEG waves

The 10-20 system of electrode placement

The 10-20 System of Electrode Placement is a method used to describe the location of scalp electrodes used to record the EEG using a machine called an electroencephalograph. The 10-20 system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex. Each point on this figure to the left indicates a possible electrode position. Each site has a letter (to identify the lobe) and a number or another letter to identify the hemisphere location. The letters F, T, C, P, and O stand for Frontal, Temporal, Central, Parietal and Occipital. (Note that there is no "central lobe", but this is just used for identification purposes.) Even numbers (2,4,6,8) refer to the right hemisphere and odd numbers (1,3,5,7) refer to the left hemisphere. The z refers to an electrode placed on the midline. Also note that the smaller the number, the closer the position is to the midline.

Nasion: point between the forehead and nose. Inion: Bump at back of skull.





EEG electrodes transfer ionic currents from cerebral tissue into electrical currents used in EEG preamplifiers. The electrical characteristics are determined primarily by the type of metal used. The traditional wet electrodes consisted in Ag/AgCl ring-shaped electrodes, and the dry electrodes consisted in:

- Active gold-coated single pin electrode;
- Hybrid (capacitive/conductive) multiple-spikes based electrode;
- Passive solid-gel based electrode.

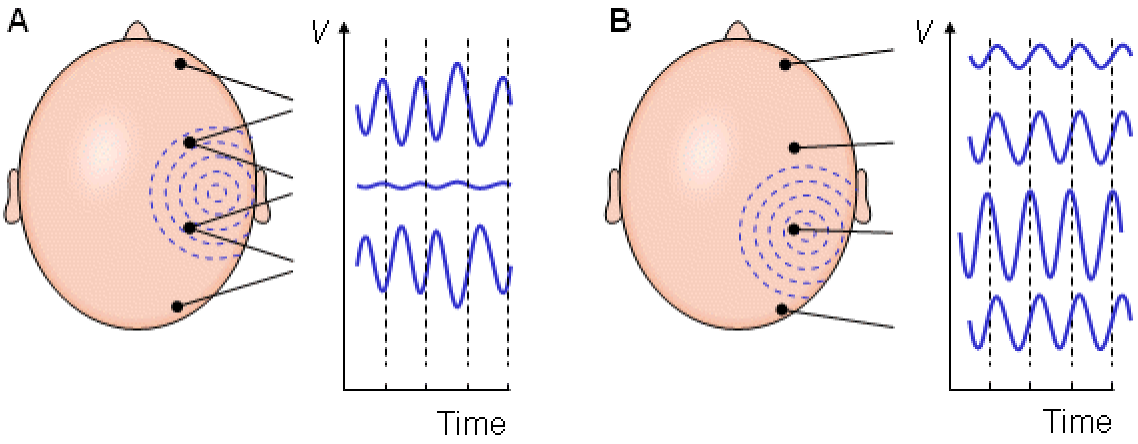
4 Electrode types

Basic recording system

Electrode arrangements may be either unipolar or bipolar. A unipolar arrangement is composed of a number of scalp leads connected to a common indifference point such as earlobe. Hence one electrode is common to all channels. A bipolar arrangement is achieved by the interconnection of scalp electrodes.

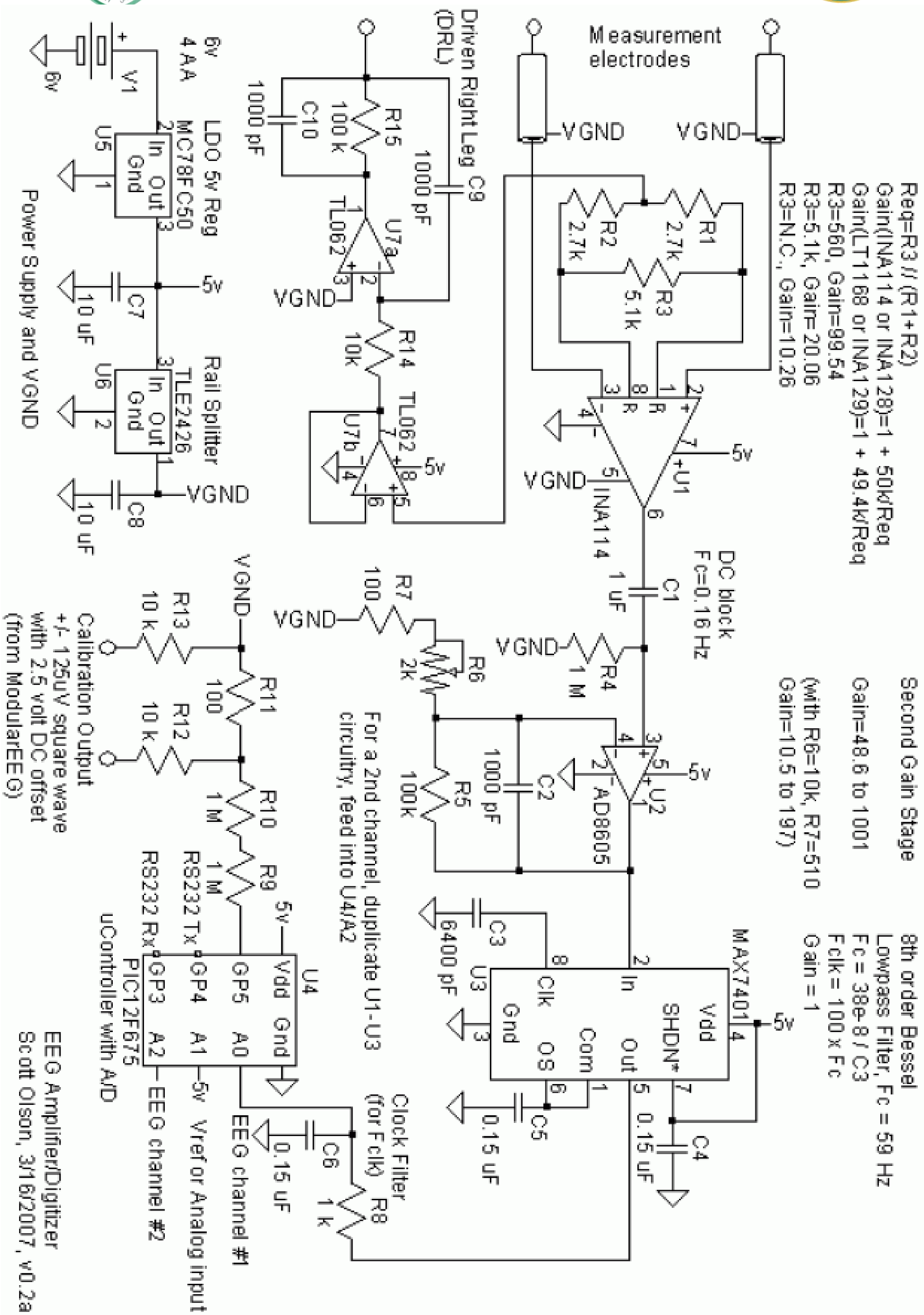
Referential: The potential difference is measured between an active electrode and an inactive reference electrode.

Bipolar: The potential difference is measured between two active electrodes.



The EEG recording technique involve following:

1. Biopotential pick-up: cranial or cerebral surface transducer electrodes.
2. EEG signal conditioning: transducer output amplification and filtering (0.1 to 100Hz)
3. EEG signal recording: signal displayed on graphic recorder or display.
4. EEG signal analysis: visual or computer interpretation of resting EEG.


Measurement electrodes
VGND
Req=R3 // (R1+R2)
Gain(INA114 or INA128)=1 + 50k/Req
Gain(LT1168 or INA129)=1 + 49.4k/Req
R3=560, Gain=99.54
R3=5.1k, Gain=20.06
R3=N.C., Gain=10.26
R1 2.7k
R2 2.7k
R3 5.1k
INA114
U1
Driven Right Leg (DRL)
C9 1000 pF
R15 100 k
C10 1000 pF
U7a TL062
R14 10k
U7b TL062
5v
DC block
Fc=0.16 Hz
C1 1 uF
R4 1 M
Second Gain Stage
Gain=48.6 to 1001
(with R6=10k, R7=510
Gain=10.5 to 197)
R7 100
R6 2k
R5 100k
C2 1000 pF
AD8605
U2
8th order Bessel
Lowpass Filter, Fc = 59 Hz
Fc = 38e-8 / C3
Fclk = 100 x Fc
Gain = 1
MAX7401
U3
C3 6400 pF
C4 0.15 uF
C5 0.15 uF
Clock Filter
(for Fclk)
R8 1 k
C6 0.15 uF
For a 2nd channel, duplicate U1-U3
circuitry, feed into U4/A2
R11 100
R13 10 k
R12 10 k
R10 1 M
R9 1 M
Calibration Output
+/- 125uV square wave
with 2.5 volt DC offset
(from ModularEEG)
U4
PIC12F675
uController with A/D
RS232 Tx
RS232 Rx
EEG channel #1
EEG channel #2
Vref or Analog input
6v
4 AA
V1
LDO 5v Reg
MC78FC50
U5
C7 10 uF
Rail Splitter
TLE2426
U6
C8 10 uF
Power Supply and VGND
EEG Amplifier/Digitizer
Scott Olson, 3/16/2007, v0.2a