



# Fundamentals of EEG Technology

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# Objectives

The learner will:

- Review the basic principles of the 10/20 System and differential amplification
- Gain an understanding of the acquisition of digital EEG waveforms
- Understand the process and utility of digital calibration
- Appreciate the optimal use of instrument controls (sensitivity and filters)
- Acquire an awareness of safety issues



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**Program:** 42nd Congress of the Canadian Neurological Sciences Federation

**Title of Presentation:** **Fundamentals of EEG Technology, with an emphasis on digital techniques**

**Presenter's Name:** **Susan R. Rahey**

I have/had a financial interest/arrangement or affiliation with one or more organizations that could be perceived as a real or apparent conflict of interest in the context of the subject of this presentation.

**Affiliation/Financial interest**

**Name of organization(s)**

Grant/Research support

N/A

Consultant

N/A

Speaker's Bureau

N/A

Major stock shareholder

N/A

Other financial/material support

N/A

***“Electroencephalography is like a beautiful park  
with a sign posted at the entrance:***

***For Persons With Total Commitment Only”***

***Ernst Niedermeyer, MD; AJET Vol.24, #2, June 1984, p.72***

# “The Ten Twenty Electrode System of the International Federation”



Who?



- Dr. Herbert Jasper, Montreal Neurological Institute
  - The National Hospital, Queen Square
  - Dr. F. Gibbs and colleagues in Boston and Chicago
  - Drs. Schwab and Abbott, Massachusetts General Hospital, Boston

# “The Ten Twenty Electrode System of the International Federation”

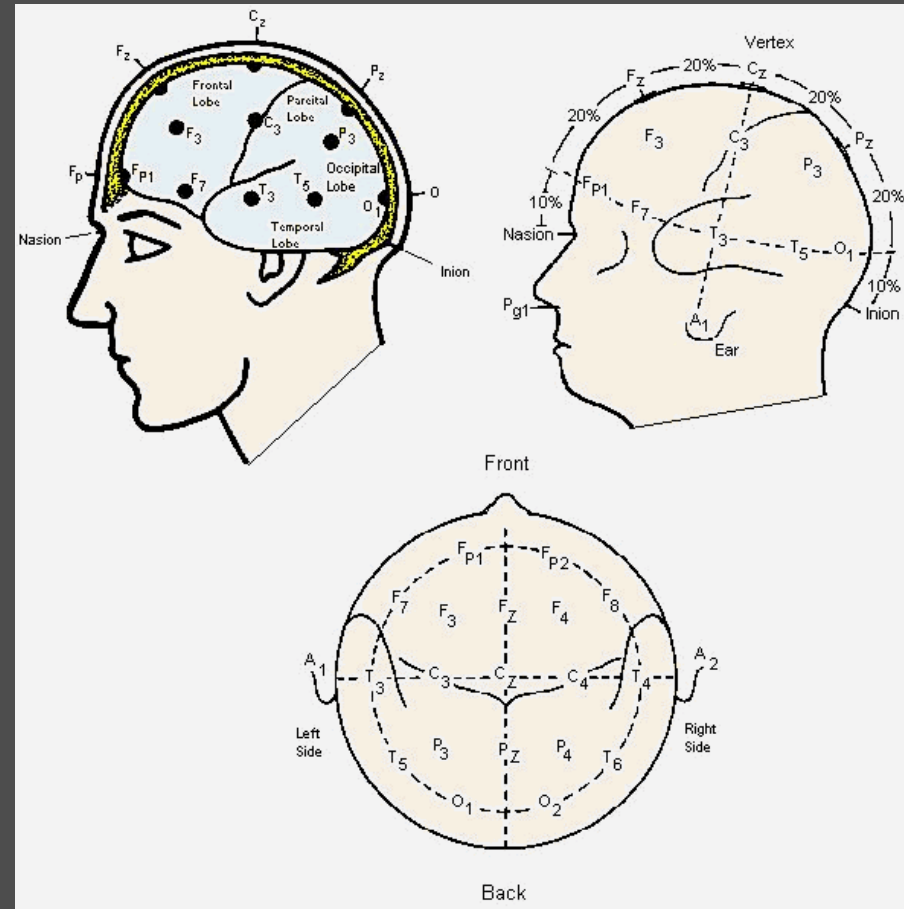
## Why?

- “Make more comparable the results obtained in various laboratories
- Facilitate the communication between laboratories, in the literature, and with referring physicians who become familiar with the localization of EEG abnormalities in terms of these standard landmarks”

# “The Ten Twenty Electrode System of the International Federation”

## How?

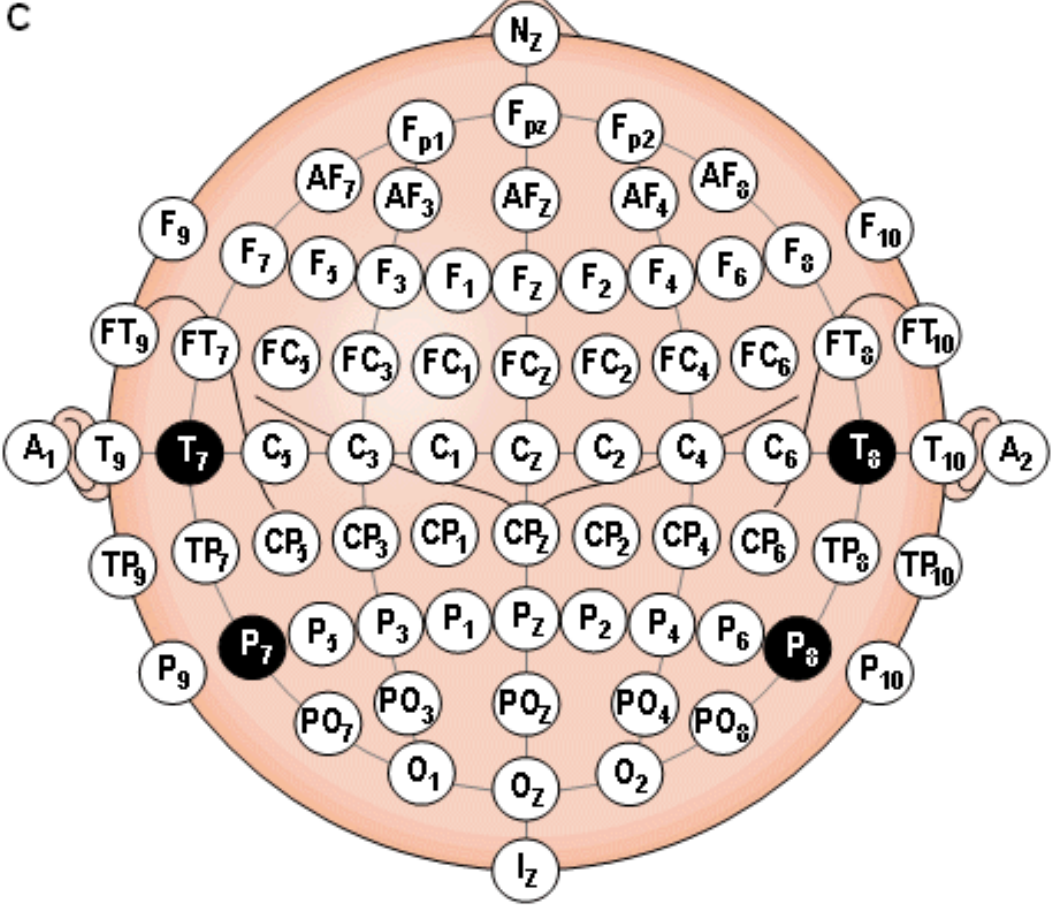
- Measured location
- Common nomenclature
- Sequenced measurements



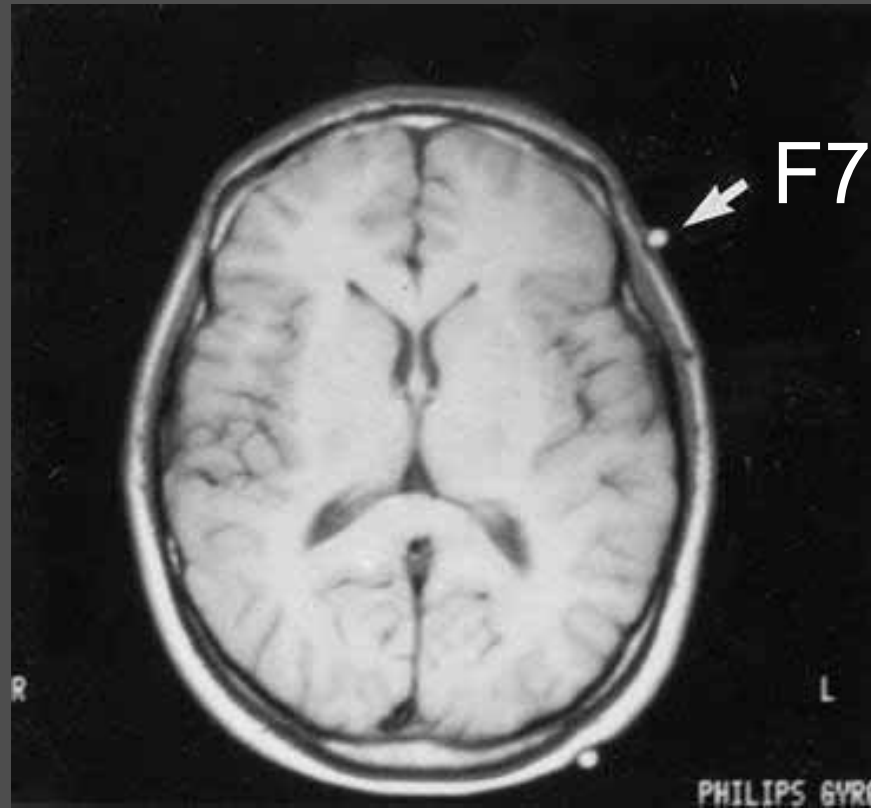
# “The Ten Twenty Electrode System of the International Federation”

“ Additional electrodes may be placed  
between any of these principal standard  
positions for especially refined localization  
studies”

C

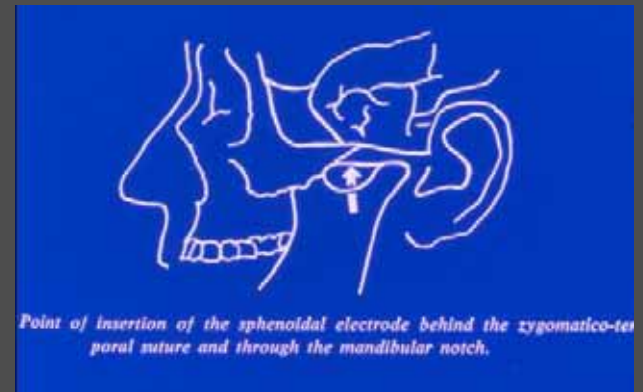


# Additional Localizing Electrodes?



# Additional Localizing Electrodes

- T1/T2 (Silverman)
- Mandibular Notch
- Sphenoidal
- Nasopharyngeal

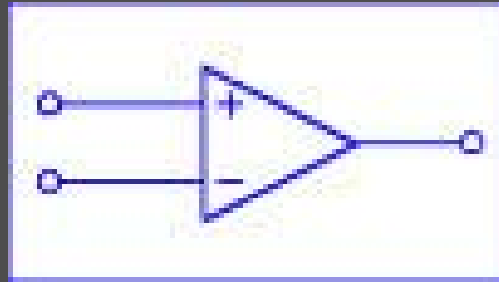


# Teaching Points

- Use correct nomenclature
- Understand when additional electrodes are required and where to place them
- Recognize the importance of accurate head measurement and electrode placement

# Differential Amplifiers

## Analog *and* Digital



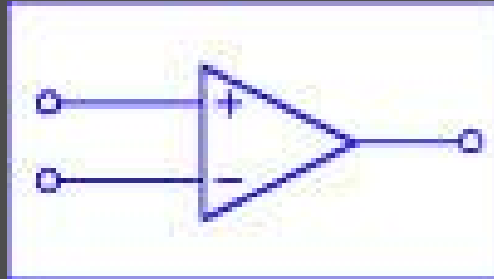
- The voltage displayed is the ***difference*** between the two channel inputs
- When there is a voltage difference between inputs, one electrode will be more negative or more positive than the other

# Differential Amplification: Digital EEG

The voltage of the displayed waveform is the algebraic sum of the difference between input one, minus the reference, and input two, minus the reference



# Differential Amplification



For ALL EEG instruments:

- when input 1 is more negative than input 2, the deflection of the waveform is **UP**
- when input 2 is more negative than input 1, the deflection of the waveform is **DOWN**

# Differential Amplification

## Teaching Points:

- Voltage displayed is the difference between two active electrodes
- In digital EEG, the system reference does not contribute to the waveforms displayed in reformatted montages
- Not every upward wave is generated by a surface negative potential

# Digital EEG Acquisition



- Analog or “paper” recording
  - Filters and amplifiers process EEG signals which drive ink-writing pens
  - Electrical signal is continuous and uninterrupted
- Digital EEG Recording
  - “Source” signal sampled in time at a rate required to resolve a particular signal, or waveform, as determined by engineering theory
  - The digital signal is discontinuous

# Digital EEG Acquisition

## Analog to Digital Converter

ADC transforms the analog signal to a series of discrete, discontinuous data points separated by equal intervals of time.

– Key concepts:

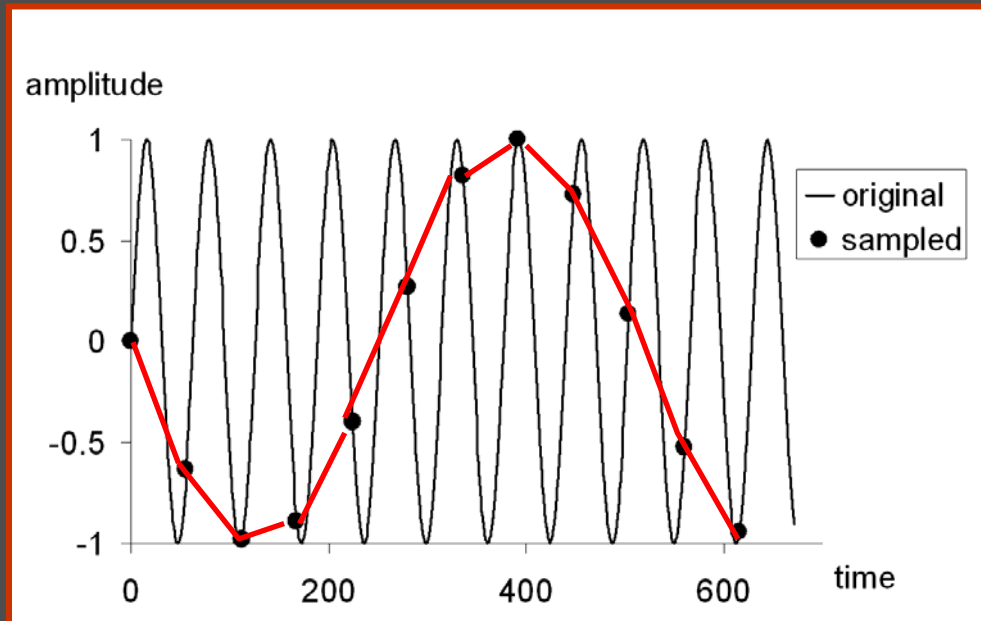
- Sampling rate
- The number of amplitude levels that can be resolved (bits)

# Sampling Rate

- The rate at which the waveform is sampled in order to convert it into a numerical format
  - must be at least twice the highest frequency in the EEG waveforms to be recorded (Nyquist Theorem).
  - ***Aliasing*** occurs when a signal is undersampled.

# Aliasing

- Aliasing occurs when a signal is sampled too slowly to resolve its frequency content
- The resulting samples form a signal whose frequency is lower than that of the original signal



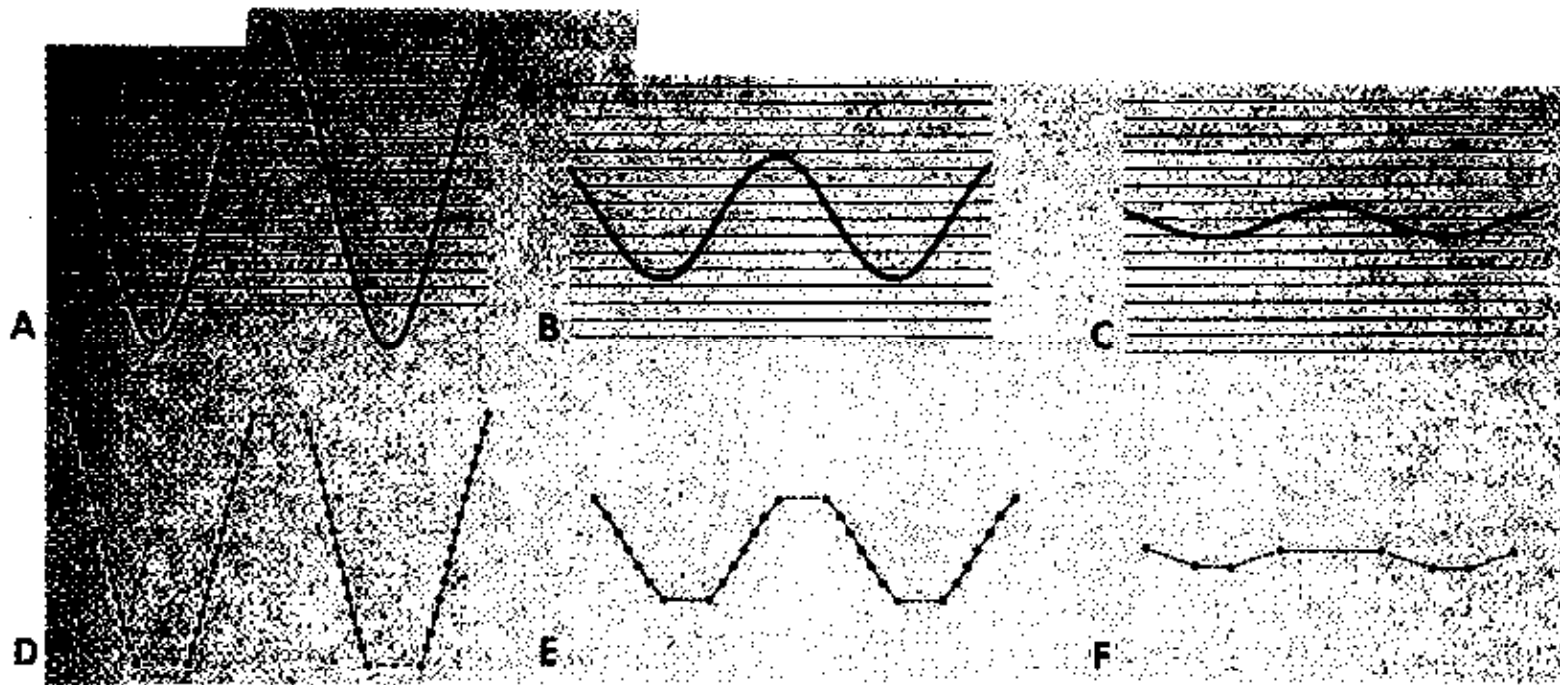
# Amplitude Resolution

- The number of amplitude levels is expressed in terms of “bits”
- A measure of how finely the voltage can be subdivided when measured.

# Amplitude Resolution

- Too few bits make it more likely that that relatively large changes can go undetected and very small amplitude changes can be overrepresented.
- Minimal Standard in Canada = 12 bits, ie  $2^{12}$ , (or greater) with the ability to resolve voltage to  $0.5\mu\text{V}$

# Amplitude Resolution



# Monitor Resolution

- The number of pixels in each direction that can be used to fill in points on the EEG signal
- Insufficient pixels will have the effect of mimicking a reduced sampling rate and displaying incomplete data

Canadian guidelines require 1024 X 768, recommend 1280 X 1024

# Teaching Points

Understand the effects on waveform *display* of:

- The features of ADC, including sampling rate and vertical resolution
- Monitor choice (size AND resolution)

# Calibration

## Analog

- A known voltage applied simultaneously to all inputs, each with identical sensitivity and filter settings, to detect instrument faults or setting errors
  - Electrical and mechanical baselines
  - Sensitivity
  - Filters
  - Time axis alignment
  - Pen spacing
  - Pen damping
  - Noise level
  - Paper speed
  - Performed before and after each recording

## Digital

- A known voltage applied across all inputs to permit accurate amplitude measurement and display of recorded signals. May be manual or automatic
- May be performed daily or weekly or at longer intervals, dependent on lab and/or national standards
- Preexisting calibration file is attached to each individual recording

# Advantages of Digital EEG

- Montage reformatting
- Editing channels
- Lots of channels!!
- Off-line manipulation of montages, filters, sensitivity and time display (“paper speed”)

# Montage Reformatting

- A single common reference (“system reference”) is used as the second input (“G2”) in the differential amplifier for each channel
- To reformat: the value of the reference is subtracted from each electrode

# Montage Reformatting

- Activity recorded at the reference is thus “cancelled out” and cannot contaminate the activity displayed using the various reformatting montages



- Virtually limitless options!

# Montage Reformatting



Data in all channels may be compromised if the system reference is disrupted or is of high impedance

Note: Organisation of Societies for Electrophysiological Technology and Canadian Association of Electroneurophysiology Technologists Guidelines for Digital EEG Recording

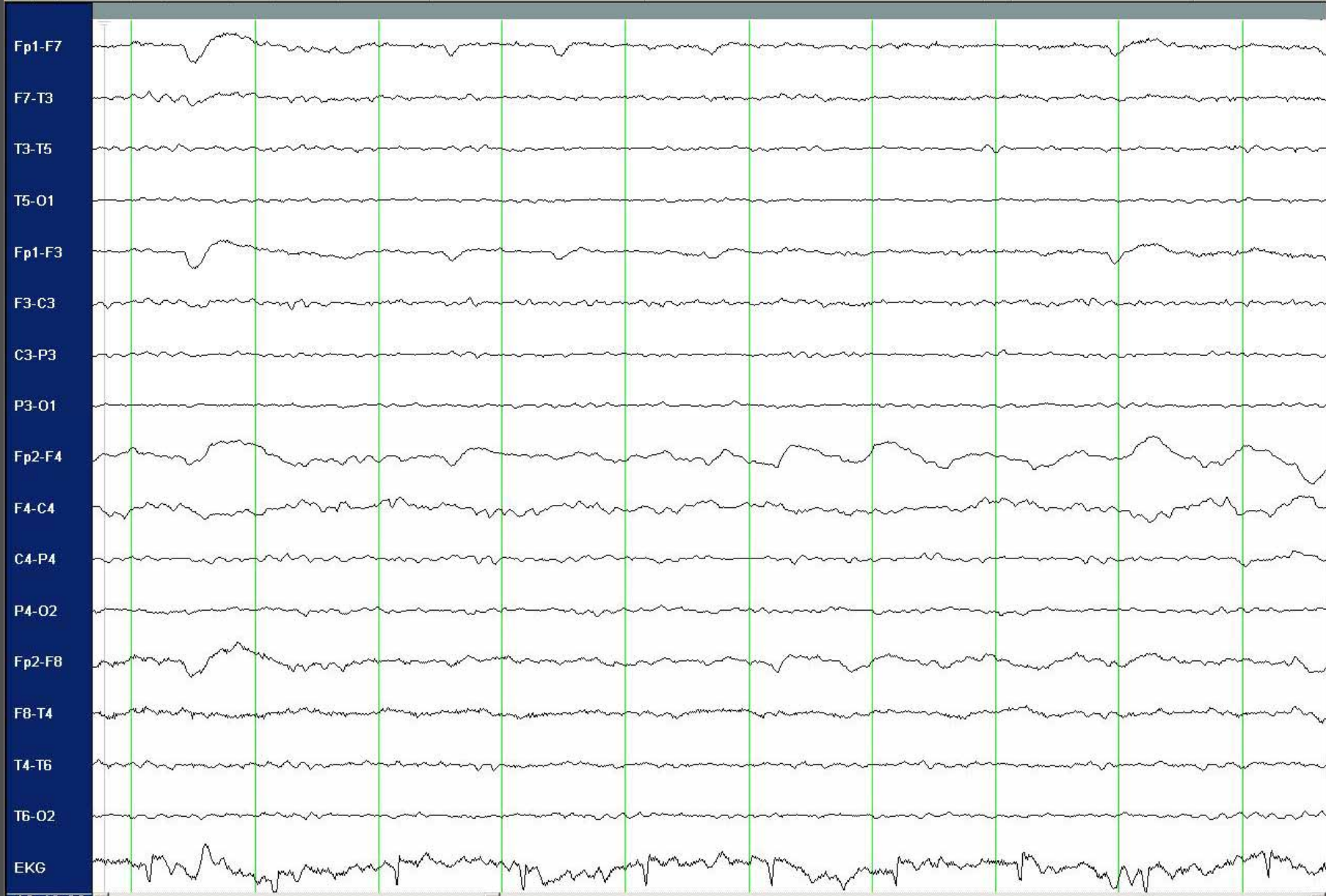
# Digital EEG Instrumentation: Sensitivity

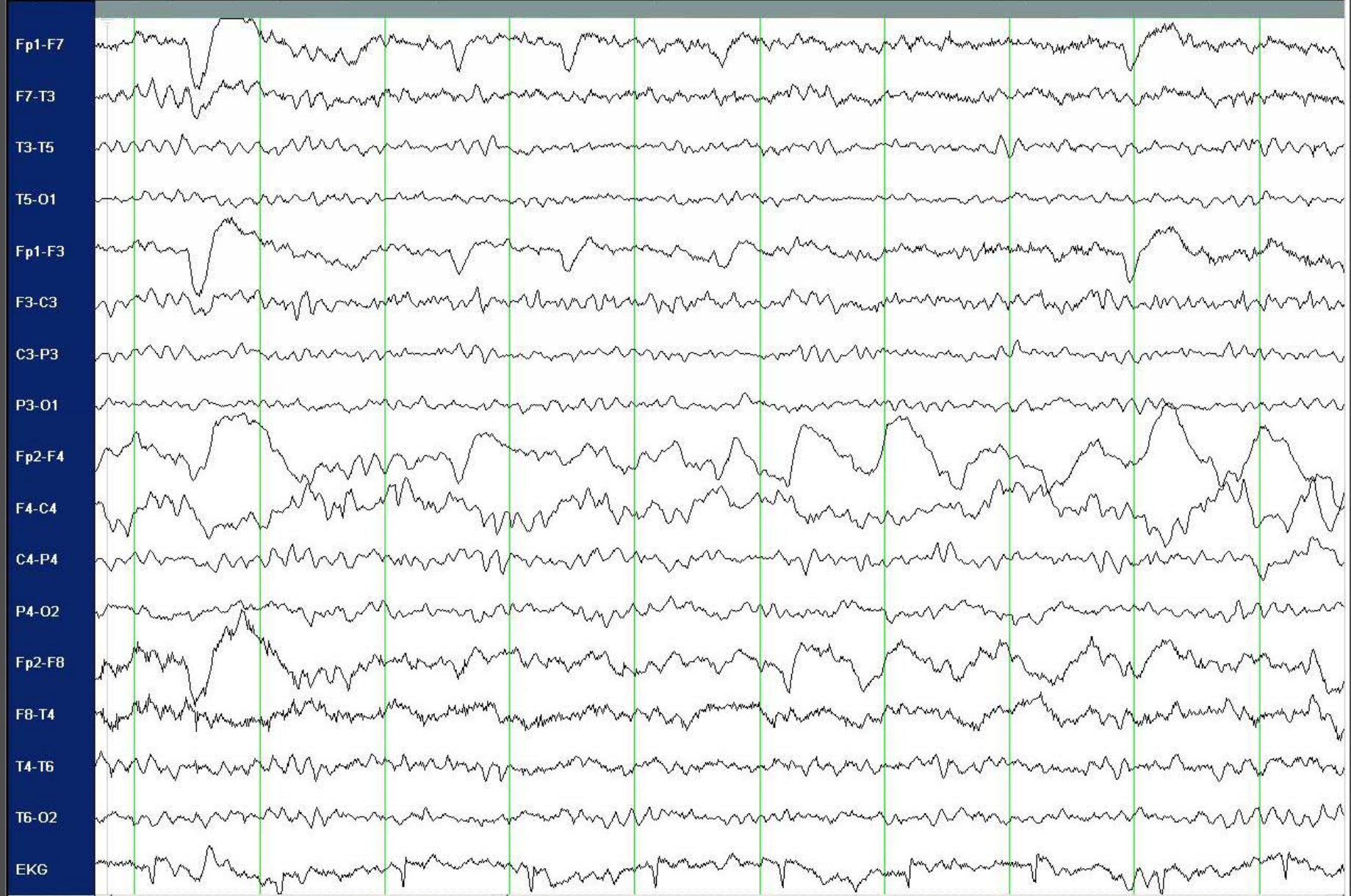
- Ratio of input voltage to the signal deflection produced
- Setting with a higher numerical value means lower amplification
- Can be adjusted on and off-line as required for clarity

# Digital EEG Instrumentation: Sensitivity

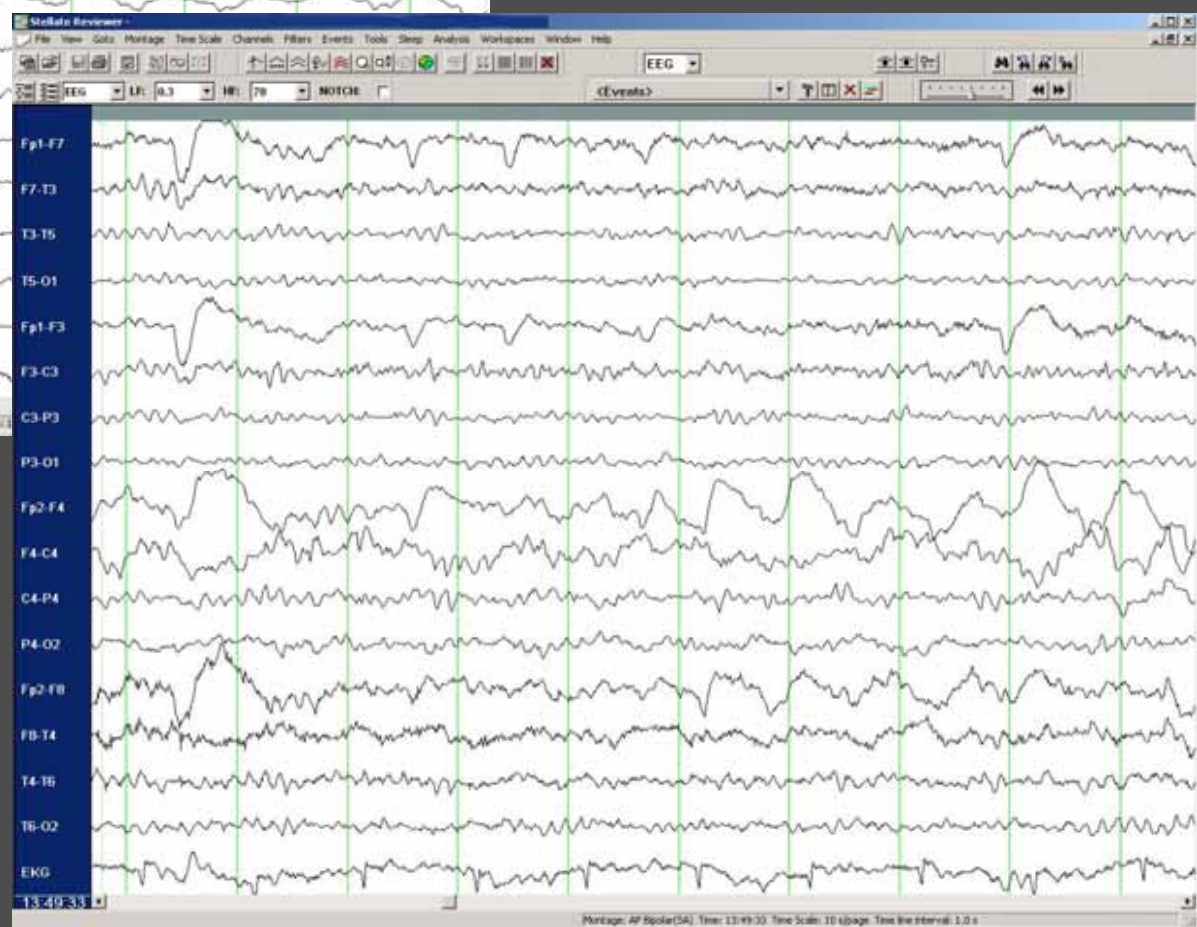
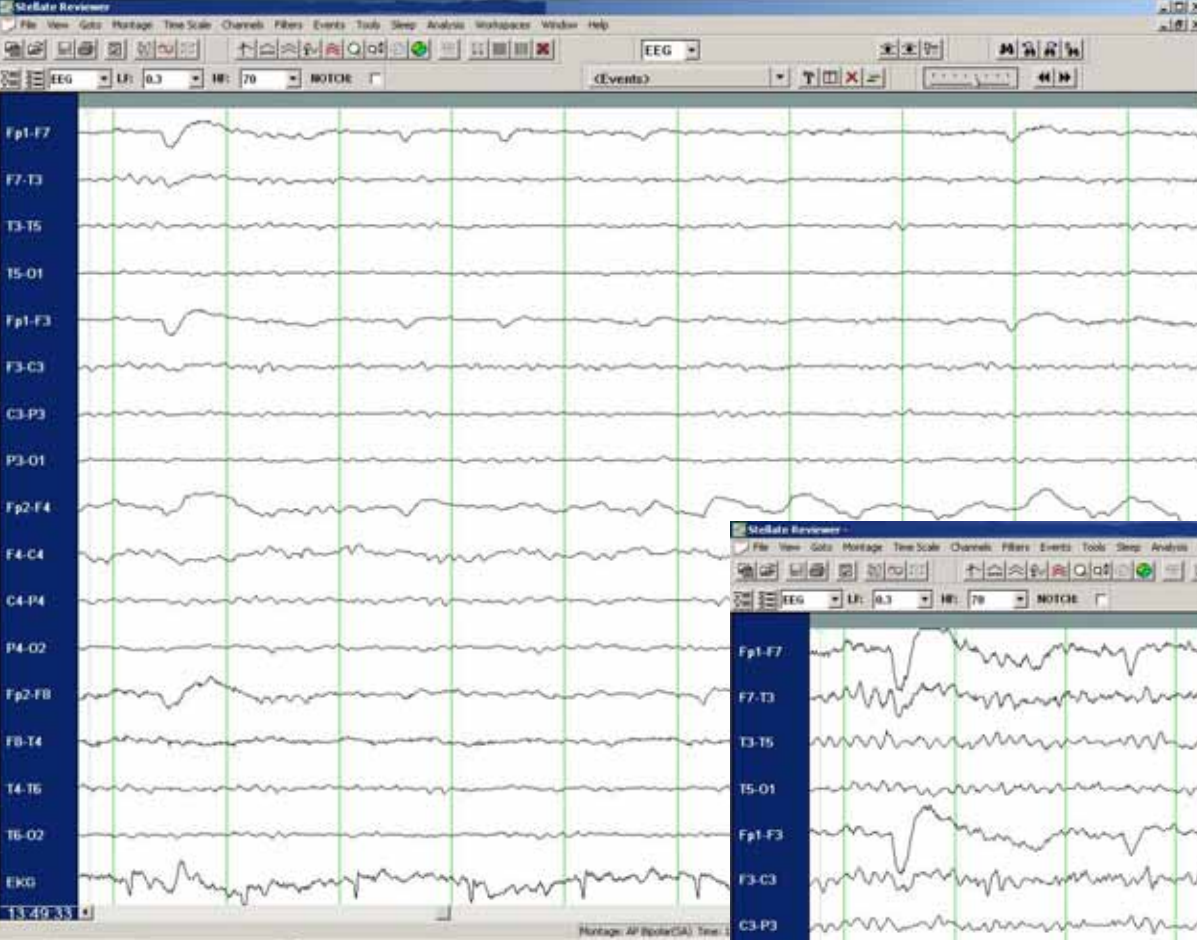


The sensitivity setting on a Digital EEG is recorded automatically and is not annotated and may not be displayed. Failure to confirm the display sensitivity may lead to inaccurate interpretation of results, for example.....





13:49:33



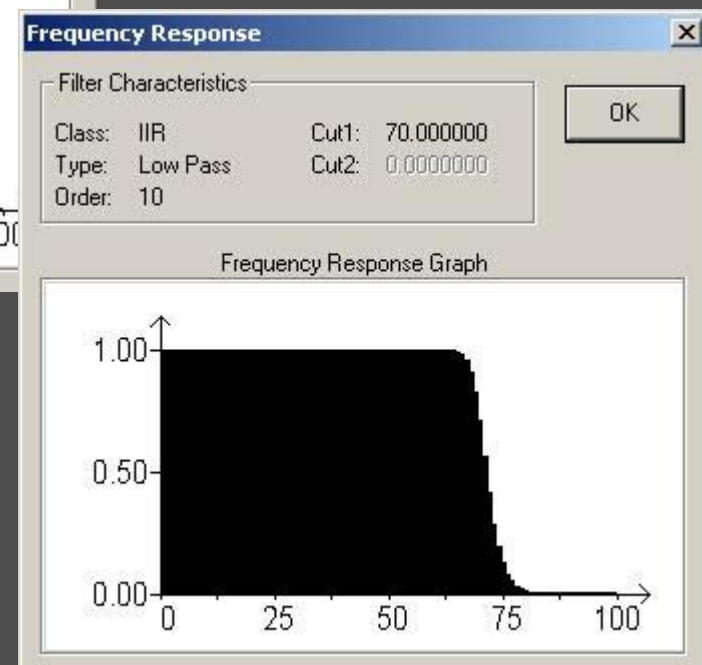
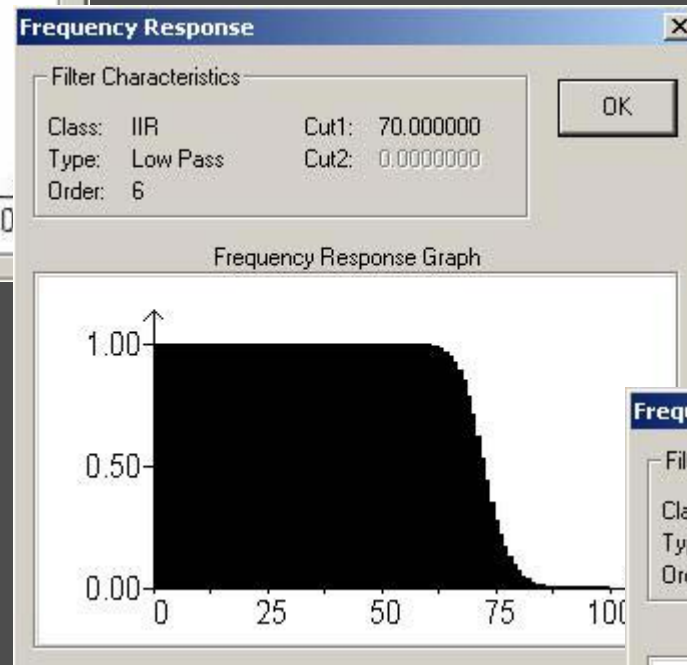
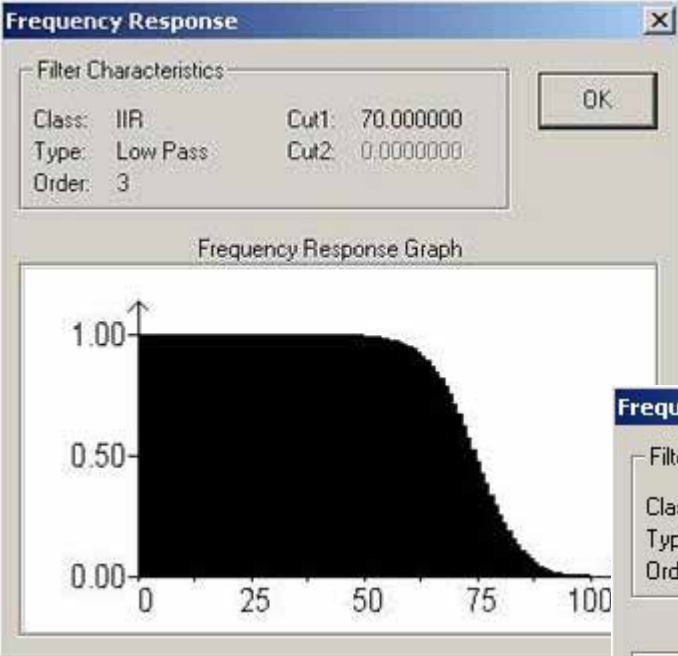
# Digital EEG Instrumentation: Filters

- Digital and Analog filters establish the bandwidth of the recording. Digital filters have no effect on the source data.
- There are three common approaches to digital filtering:
  - FIR (finite impulse response)
  - IIR (infinite impulse response)\*
  - Frequency domain filtering

# Digital EEG Instrumentation: Filters

- The roll off of a digital filter is determined by the “order” . Order refers to the number of points that are averaged by the filter at any one time
- Do not assume that all filters have the same order or that the frequency response curve of a digital EEG filter is identical to that of an analog filter of the same magnitude, for example....





higher number = steeper roll-off

# Digital EEG: Weakness/ Shortcomings

- Compatibility issues
- Physician as technologist
- Blind faith in technology
- Cost!

# Compatibility

- Software is proprietary
- Conversion programs cost money
- Not everyone has access to the same quality of computer hardware

# Physician as Technologist

The role of the EEGer has changed from that of passive recipient of data to active manipulation of raw data

- choosing montages
- applying filters
- adjusting sensitivity settings



# Blind Faith in Technology

- Not all software programs are equal
- Know your system
- “Turnkey” systems and “traces as observed” may be good but may not always be good for you – or the patient
- Computers crash

# Cost

- Storage is cheap

BUT

- Upgrades can cost big money!

Hint: Buy the software warranty and maybe even the hardware warranty if it's offered!

# Safety

## Electrical Safety:

- Ensure that a proper maintenance schedule is established and adhered to
- Discuss safety issues with staff
- NEVER ignore the presence of 60 Hz contamination



## Infection Control:

- Review laboratory infection control policies in light of institutional policies
- Never assume that patients are not at risk in your laboratory

## Other potential liability issues:

- HV and photic stimulation in pregnancy
- Driving after sleep deprived EEG

# References/ Suggested Readings

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