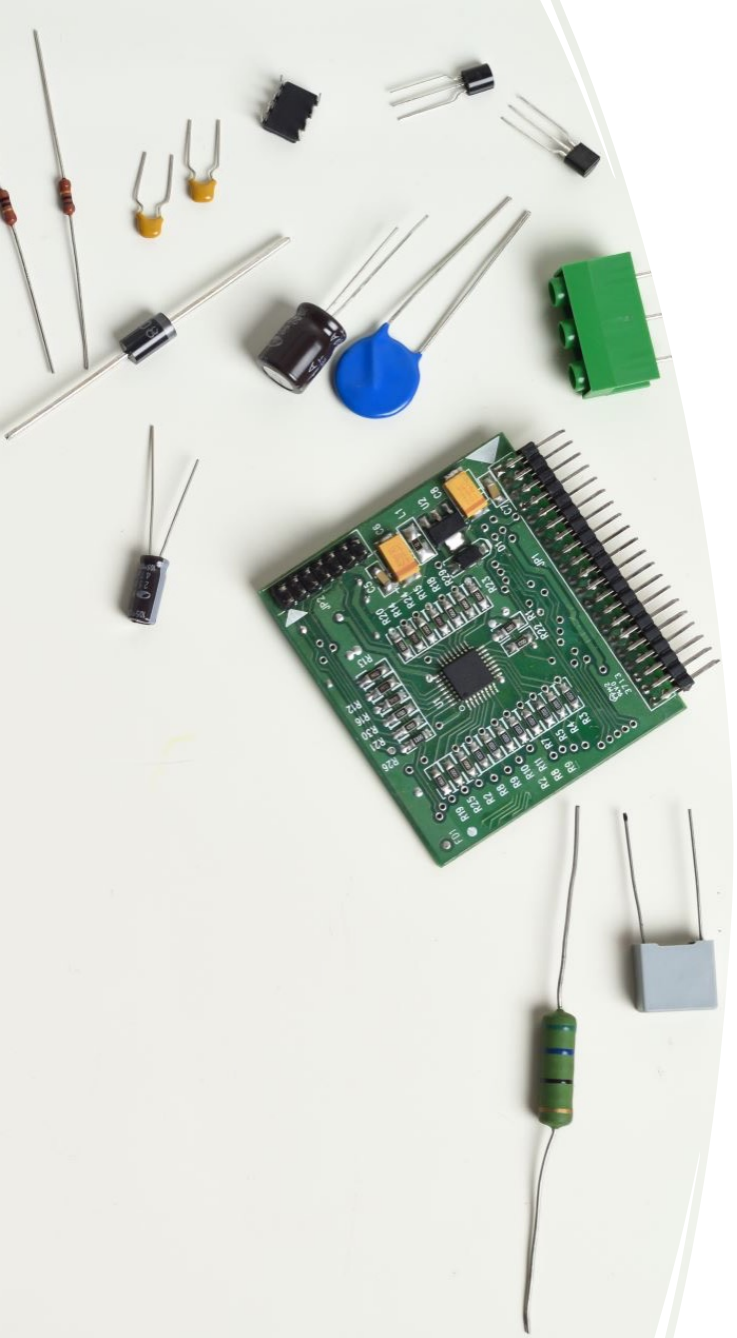


Sensors, Transducers, and Ancillary Equipment

Robertson Chapter 8

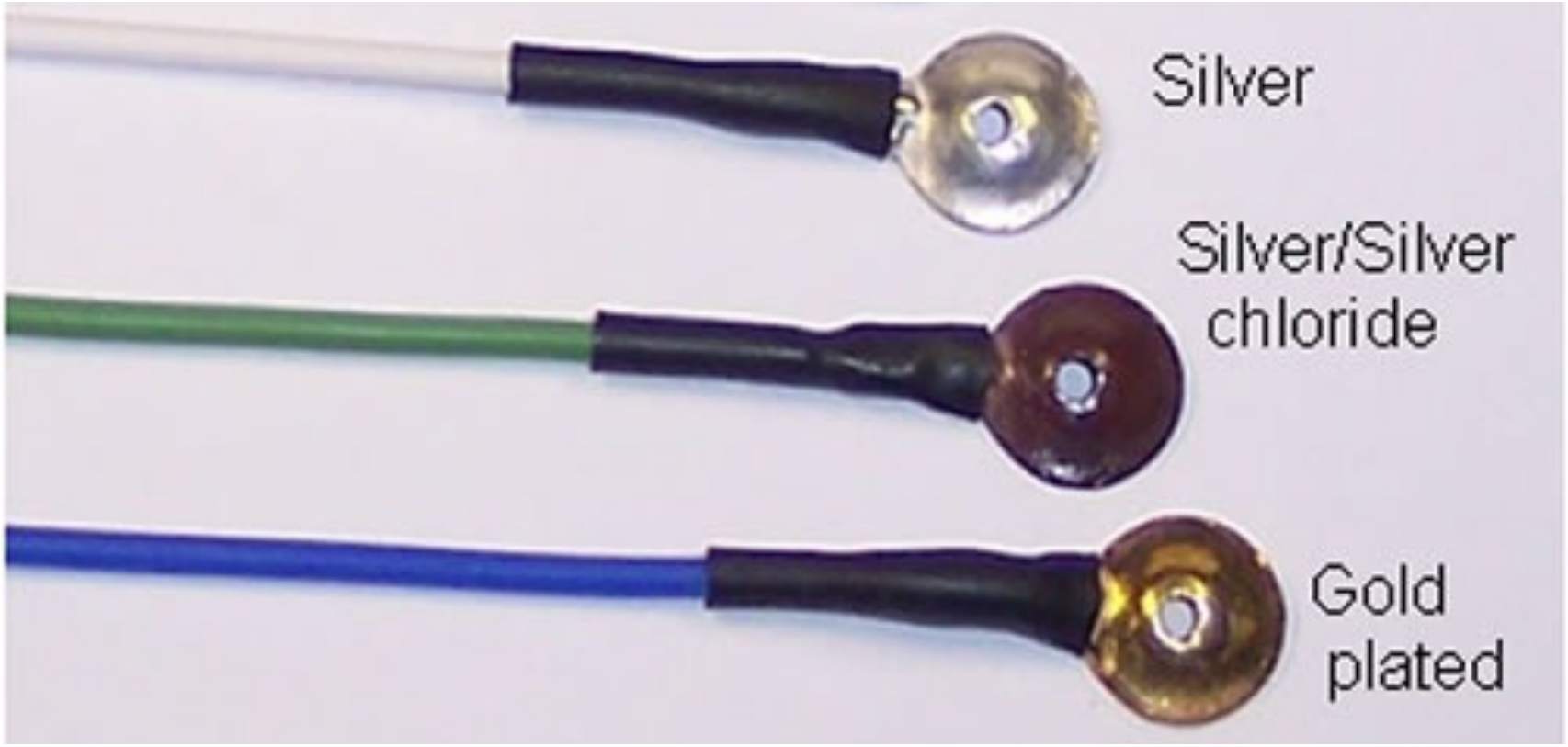
Surface Electrodes

- EEG typically amplified 20,000 times for visual display
- Electrodes = 1st and most important in patient-recorder interface
- Never mix electrodes made from different materials

Commonly Used Metals

- Most commonly used:
  - Gold-plated silver
  - Silver
  - Silver-silver chloride
- Used because of conductivity
- Application technique more important than the metal type
- Gold-plated electrodes are most commonly used in PSG
  - Should not be used if plating is chipped, cracked, or scratched because it causes artifact

Commonly Used Metals



Electrode Cups

- Stamped electrode cups are thinner and slightly bigger cup
  - Less durable
- Casted-style cups are thicker and smaller capacity
  - More durable
- Size
  - Adults = 10 mm in diameter
  - Pediatrics = 6 mm in diameter

Electrode Wires

- Also known as leads or lead wires
- Attach to cup electrodes
- Lead wires insulated with thin polytetrafluoroethylene are durable but tangle easy
- Thicker insulation may tangle less but not as sturdy

Specific Use for Electrodes

- Cup electrodes typically used for EEG and EOG
- Many labs use disposable stick-on patch electrodes for EMG and ECG
  - But can use cup electrodes for these parameters
- Facility decision to use disposable or reusable leads
  - Single use vs. multiple use

Electrode Connectors

- Must use sensors with a connector matching the sleep system used
- Connectors
  - Consult user manual for PSG system for proper connector
  - Most commonly used = 1.5-mm touchproof connectors
    - Also known as recessed-female connectors

Connectors

1.5-mm
Touchproof

2-pin 1-mm
Keyhole

1/8-inch
(3.5-mm)
male phone

Connectors

RCA
connector

RJ11
connector

DIN
connector

Jumpers

- Typically used for “linked” mastoid references
- Allows signals to be referenced together to eliminate common artifact on both references
  - Helpful with ECG artifact
- Linking the mastoids also known as double referencing
  - Signals cancel each other out

Disposable Vs. Reusable Sensors

- Disposable
  - Single patient use
  - Do not require cleaning
  - More expensive
- Reusable
  - Multiple uses
  - Require cleaning and disinfection between applications
  - Less costly
  - Typically, higher quality signals

Cleaning Sensors

- Cleaning = Removal of foreign material from electrode cup
  - Uses water, detergent/soap, and mild scrubbing
  - First step before disinfection/sterilization
- Disinfection = Elimination of most pathogenic microorganisms (except bacterial spores)
  - Uses liquid chemicals (glutaraldehyde, sodium hypochlorite) or pasteurization (hot water)
- Sterilization = Complete elimination of all forms of microbial life, including spores
  - Uses physical or chemical processes such as autoclaving, ethylene oxide, or liquid chemicals

Cleaning Sensors

- Semicritical vs. Noncritical items
  - Noncritical = Electrodes and sensors that come in contact with intact skin and not mucous membranes
    - Require only low-level disinfection
  - Semicritical = Electrodes and sensors that come in contact with non-intact skin or mucous membranes
    - Require high-level disinfection

Interfacing Electrodes

- Derivations
  - Electrode inputs on head boxes form at least 2 types of derivations:
    - Referential = Measure difference in potential between 1 active electrode and 1 inactive electrode
    - Bipolar = Measure difference in potentials between 2 active electrodes
  - May be additional inputs for body temperature sensors, SpO2 sensors, nasal pressure devices, and other transducers

Operation, Use and Limitations of Surface Electrodes

- Site prep and proper electrode application essential for high-quality, low-noise recordings
- Improper cleaning of electrode sites leads to high impedances
  - Impedance = Combo of resistance and capacitance
    - Resistance = Electrical barrier
    - Capacitance = Ability of material to store electrical charge

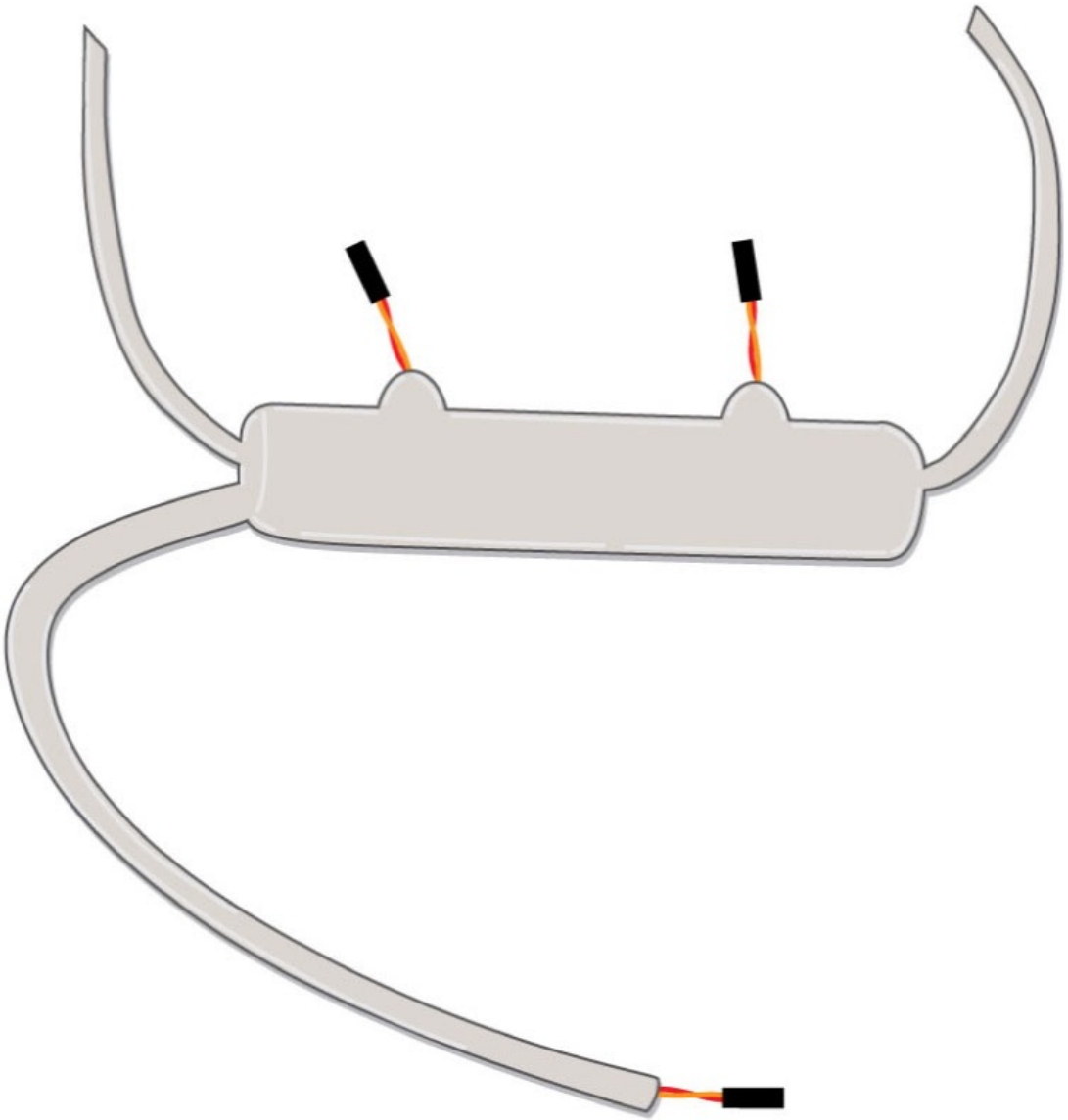
Operation, Use and Limitations of Surface Electrodes

- Clean electrode site with alcohol to remove oil, then use abrading compound to remove dead skin cells
- Apply conductive paste/gel to electrode
- EEG = Recording of summed ionic flux from brain's neural activity
- EOG = Electrical changes occurring during eye movements as result of corneoretinal potential difference
- EMG = Recording of electrical impulses of muscle groups at rest and during contraction
- ECG = Electrical conduction through heart

Monitoring Airflow

- 2 most common methods to monitor airflow:
  - Thermal sensors
    - Detects airflow based on temperature changes
    - Used to detect apneas
  - Nasal pressure monitoring
    - Detects fluctuations in pressure caused by inspiration and expiration
    - Used to detect hypopneas and RERAs

Thermistor



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Monitoring Respiratory Effort

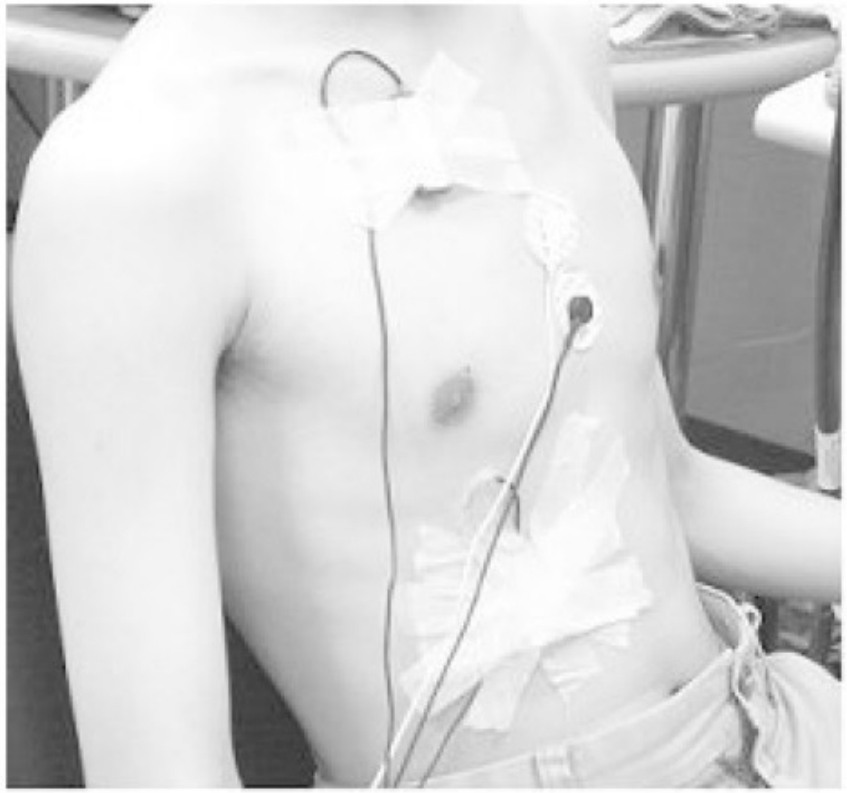
- Most common methods:
  - Respiratory inductive plethysmography (RIP)
  - Piezo technology
  - Diaphragmatic and intercostal EMG
- Other methods:
  - Mercury-filled strain gauges
  - Impedance pneumography

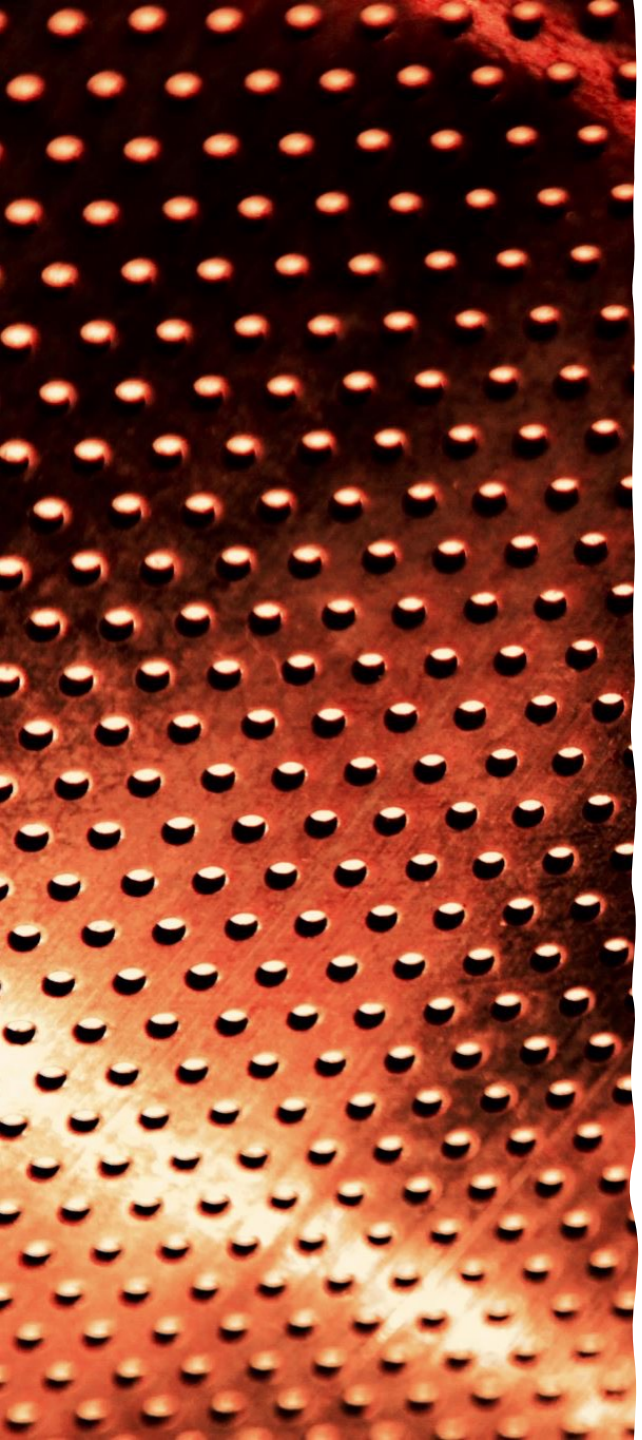
Piezo Technology

- Piezo-electric crystals are artificial or naturally occurring crystals that produce a charge output when compressed, flexed, or subjected to sheer forces
  - When stress removed, electrical output stops
- Piezo belts measure tension where crystal is located
  - May have issues of accuracy when patient moves or false paradoxing

Diaphragmatic and Intercostal EMG

- Apply electrodes over intercostal spaces and upper abdomen
- Used to differentiate between central and noncentral respiratory events
- Reliability limited by proper electrode placement



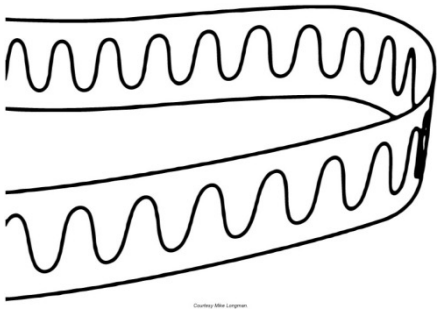


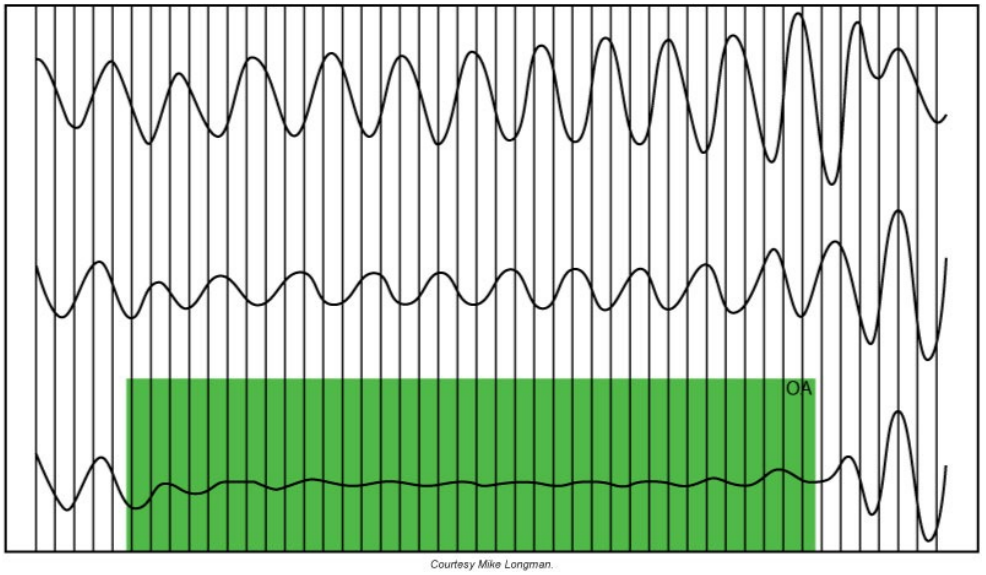
Respiratory Inductive Plethysmography (RIP)

- Senses changes in cross-sectional area of rib cage and abdominal areas during breathing cycle
- Sensor consists of belt with wire woven or sewn in sine wave or zigzag pattern
- Creates magnetic field with module with circuit board, oscillator, and battery that passes weak current through wire
- More comfortable for patient
- Some include sum channel, useful for detecting paradoxical breathing

Respiratory Inductive Plethysmography (RIP)

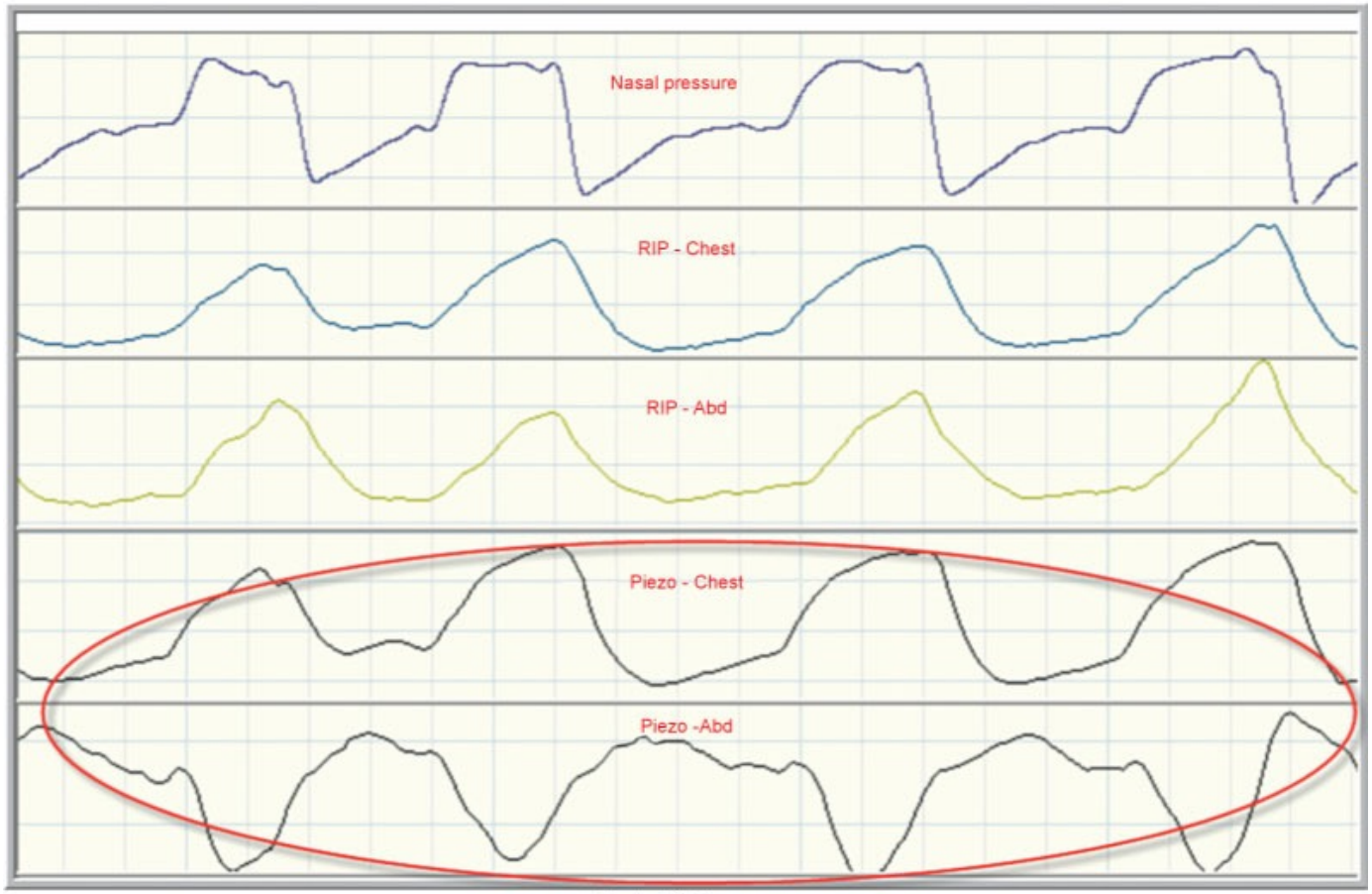
- Signal can be calibrated or uncalibrated
  - Calibrated represent actual volume of airflow





Sum channel flattens or diminishes when chest and abdomen paradox.

RIP Vs. Piezo



Courtesy Mike Longman.

Snore Microphones and Sensors

- Microphone converts sound into small analog voltage
  - Most common types:
    - Electret
      - Dielectric material permanently electrically charged or polarized
      - Forms the diaphragm and its distance from plate causes voltage to be induced
      - Requires power source
    - Piezoelectric
      - Responds to vibrations on skin near upper airway
      - Does not require power source
    - Dynamic
      - Operate with moveable diaphragm displaced by sound wave
        - Movement creates voltage change proportional to power of sound wave
      - Does not require power source

Recording Body Position

- Important for determining if SDB is positional
- Can be monitored via video or through body position sensor
- Sensors provide data based on gravity
  - Must be placed in center of chest for accuracy

Audiovisual Monitoring and Recording

- Essential component of sleep study
- Video cameras are either fixed focus or pan-tilt-zoom
- Need infrared to see patient in dark
- 2 audio monitoring systems:
  - One-way communication from microphone to computer
    - On at all times to hear patient
  - Audio intercom system between control room and patient room

Differentiating Signal Types

- Bioelectric signals = Summed ionic flux generated by groups of cells or polarity of one anatomic location relative to another on an organ
  - Uses surface electrodes
- Transduced signals = Come from transducer that converts 1 type of energy to another
  - Converts mechanical energy to electrical energy
- Ancillary equipment = Any device that can process data on its own and interfaced with sleep system
  - EtCO2 and SpO2

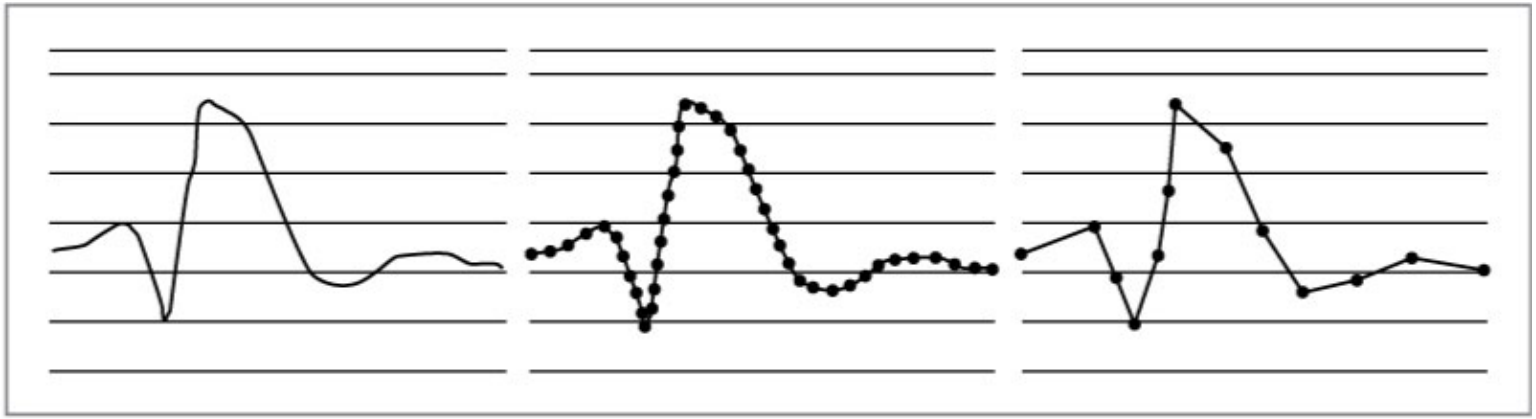
Selecting an AC or DC Amplifier

- Rapidly fluctuating signals use AC amplifier
  - EEG, EOG, EMG, and ECG
  - Have HFF and LFF controls
- Slow-moving or constant variables use DC amplifier
  - PAP pressure readings and EtCO2
  - Has HFF but not LFF

Sample Rate Requirements

- Analog-to-digital (A-to-D) conversion converts analog waveforms into series of numerical values for recording and display
- Sampling rate = Sampling frequency
  - Expressed in Hz
  - Higher sampling rate increases data resolution and file size

Signal Aliasing

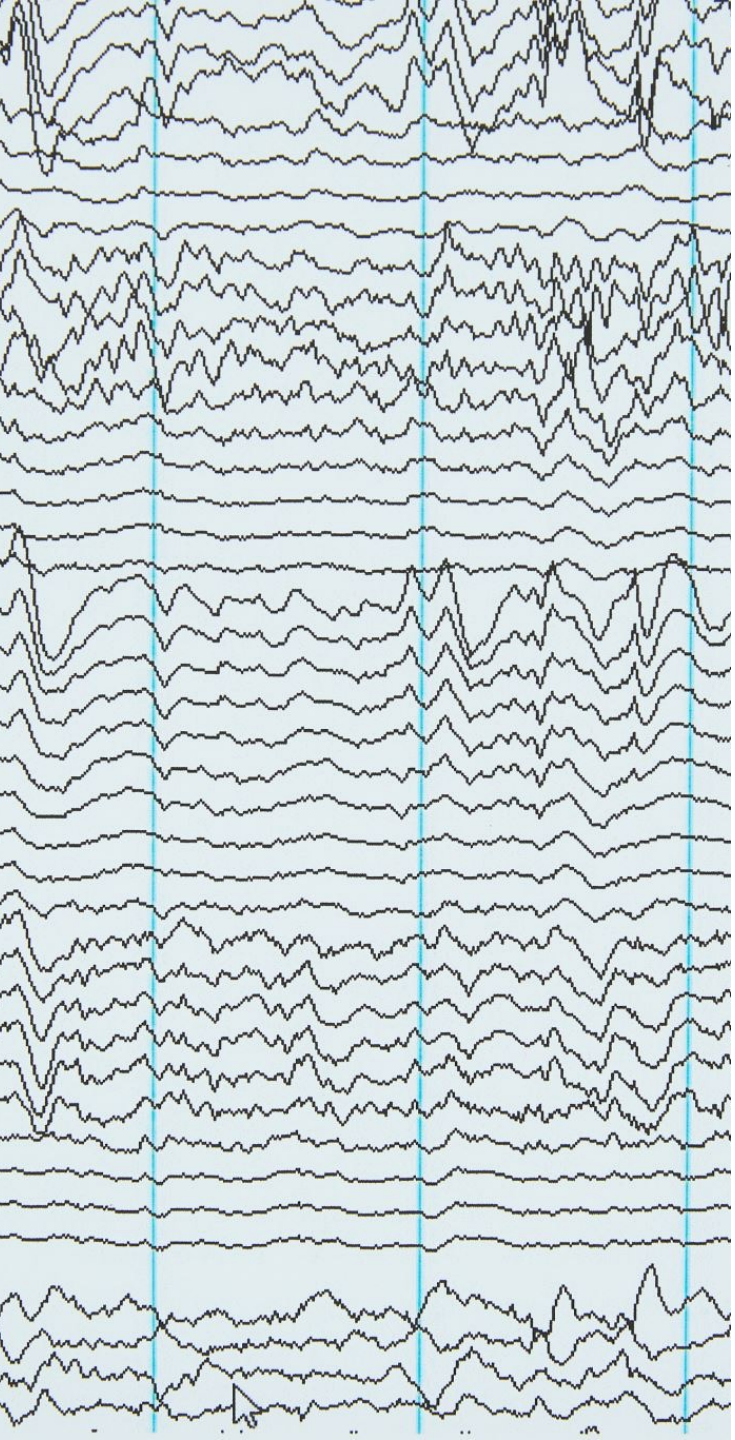


Courtesy Mike Longman.

Original analog waveform

Sampled at 240

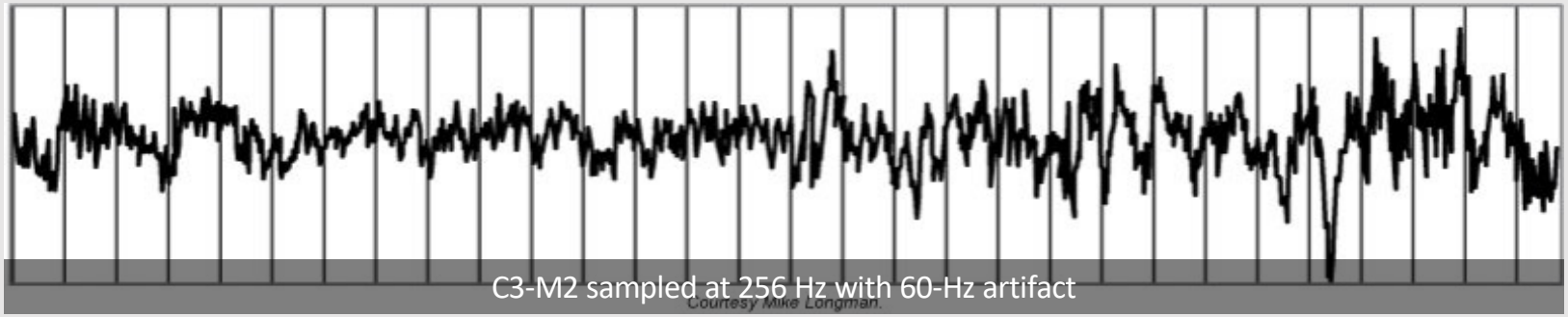
Sampled at 50



EEG Signals

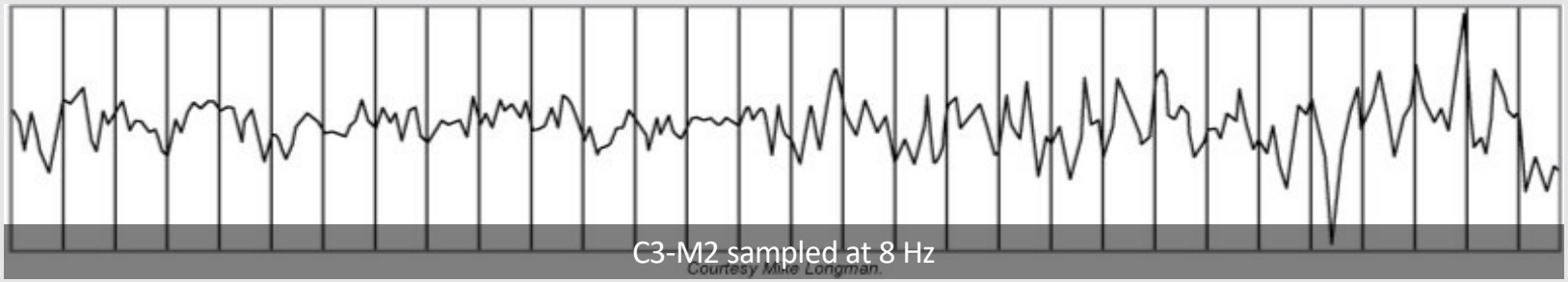
- Require much higher sample frequency
- Nyquist-Shannon sampling theorem = Signal can be digitized and later restored to analog value if signal sampled at frequency greater than 2x the highest frequency contained in the signal
- AASM has specifications on minimal sample rates for PSG signals

EEG Signals



C3-M2 sampled at 256 Hz with 60-Hz artifact

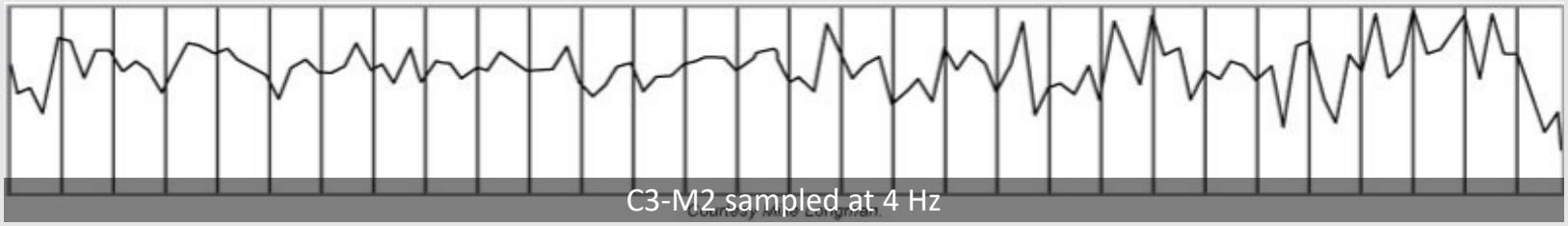
Courtesy Mike Longman.



C3-M2 sampled at 8 Hz

Courtesy Mike Longman.

EEG Signals



C3-M2 sampled at 4 Hz

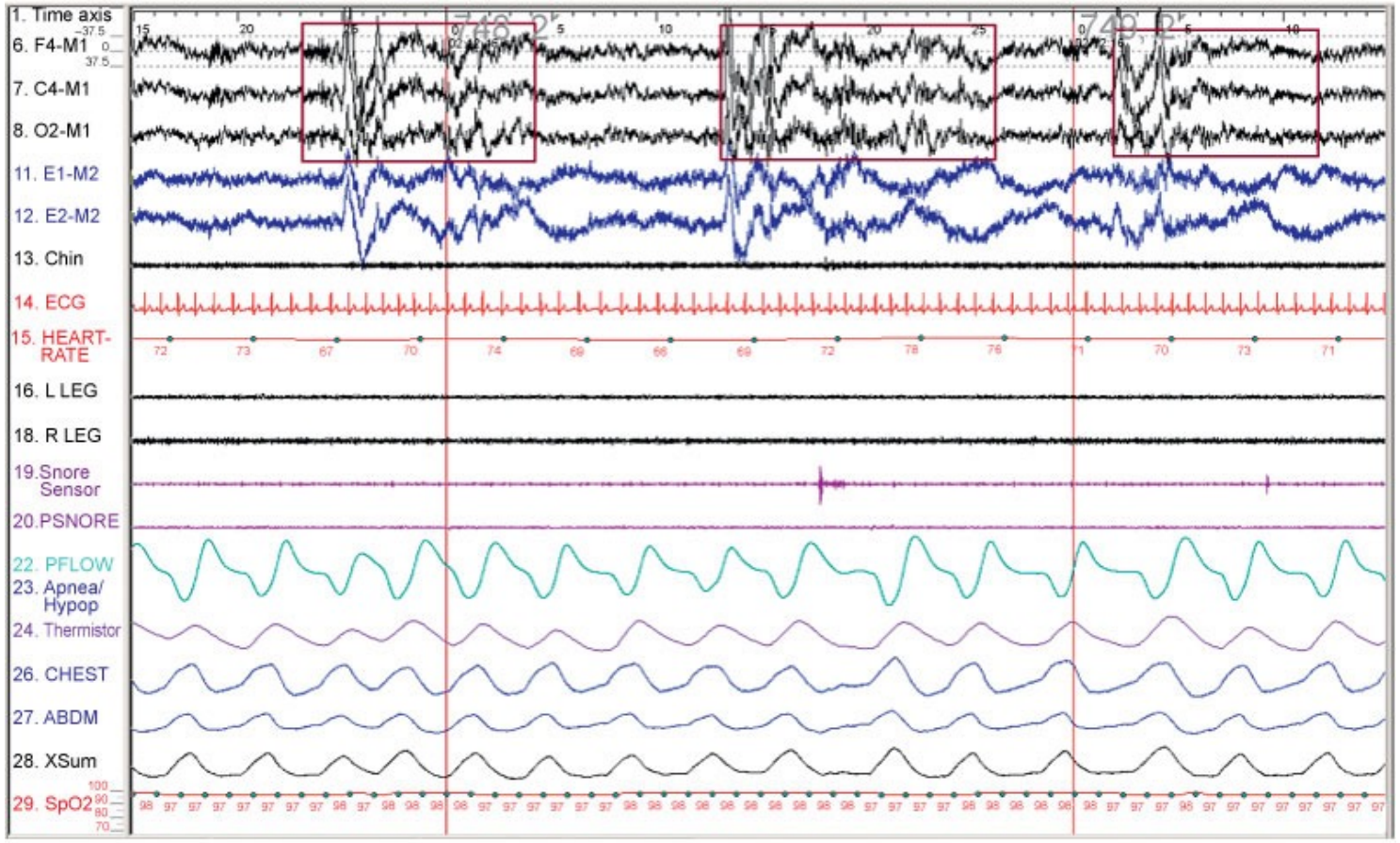
Ancillary Recorder Signals, Equipment, and Methodology

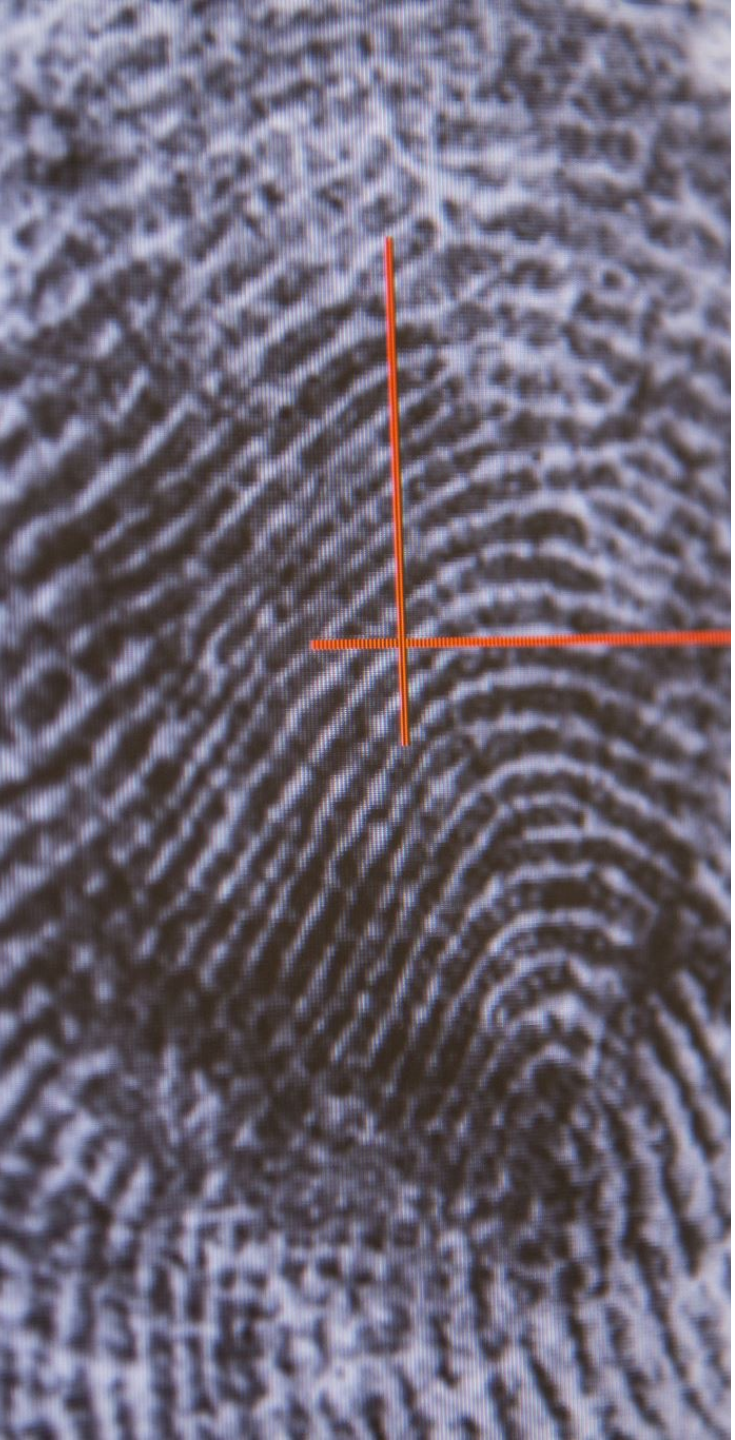
- Esophageal manometry = Gold standard for assessing respiratory effort
  - Quantifies intrathoracic pressure changes
  - Not widely used in the clinical setting as it is invasive and may not be well tolerated
  - Very useful for detecting RERAs and diagnosing UARS

Recording and Understanding the Cyclic Alternating Pattern

- Also known as CAP
- Long-lasting periodic activity of 2 alternate EEG patterns consisting of transient arousals
- Divided into 2 phases:
  - Phase A
    - Greater arousal level
  - Phase B
    - Lesser arousal level
- Non-CAP = Prolonged stationary condition of sleep and arousal stability

CAP





Overview of Pulse Oximetry

- Non-invasive and indirect method to monitor saturation of hemoglobin
- Expressed as SpO2
- Sensor can be placed on fingertip, earlobe, toe, or forehead
  - Most sleep labs use fingertip sensors
- Shines light at 2 wavelengths
  - Red
  - Infrared

Overview of Pulse Oximetry

- Calculates light absorption at the 2 wavelengths to calculate portion of Hb saturated with O2
- May cause inaccurate readings:
  - Poor perfusion
  - Anemia
  - CO poisoning
  - Movement
  - Nail polish
  - Dark-pigmented skin

Interfacing Ancillary Devices

- External device has output connection on back of device which gets connected to DC box connected to acquisition system
- Analog signal gets converted to digital signal
- Analog output = 0-1 V DC signal
- Each device has high and low output values
  - Low output = 0 V
  - High output = 1 V