Respiratory Rate Monitoring Sensor

(in the context of Covid19)

Let’s observe our Breathe..

By-
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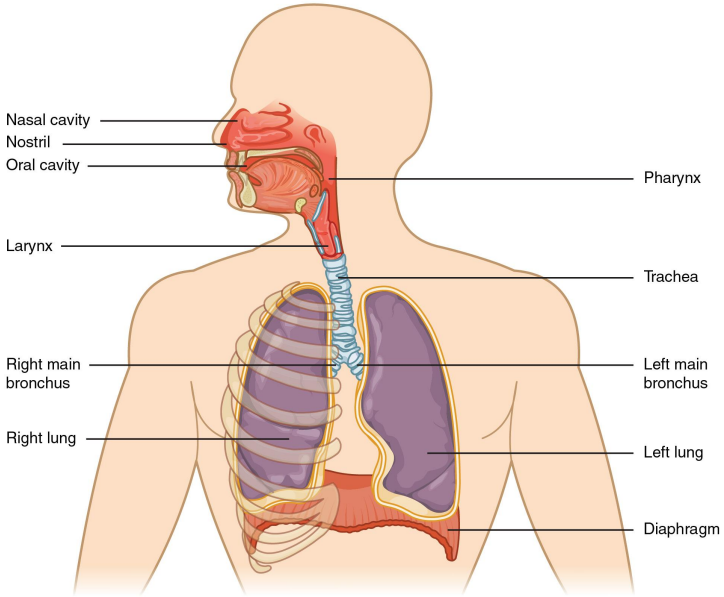
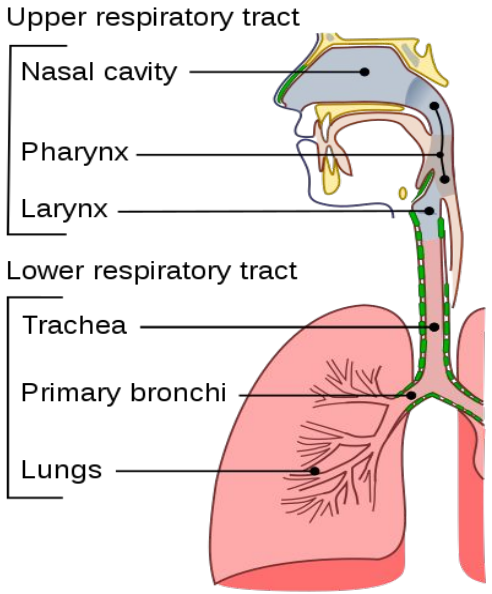
Respiration 101:

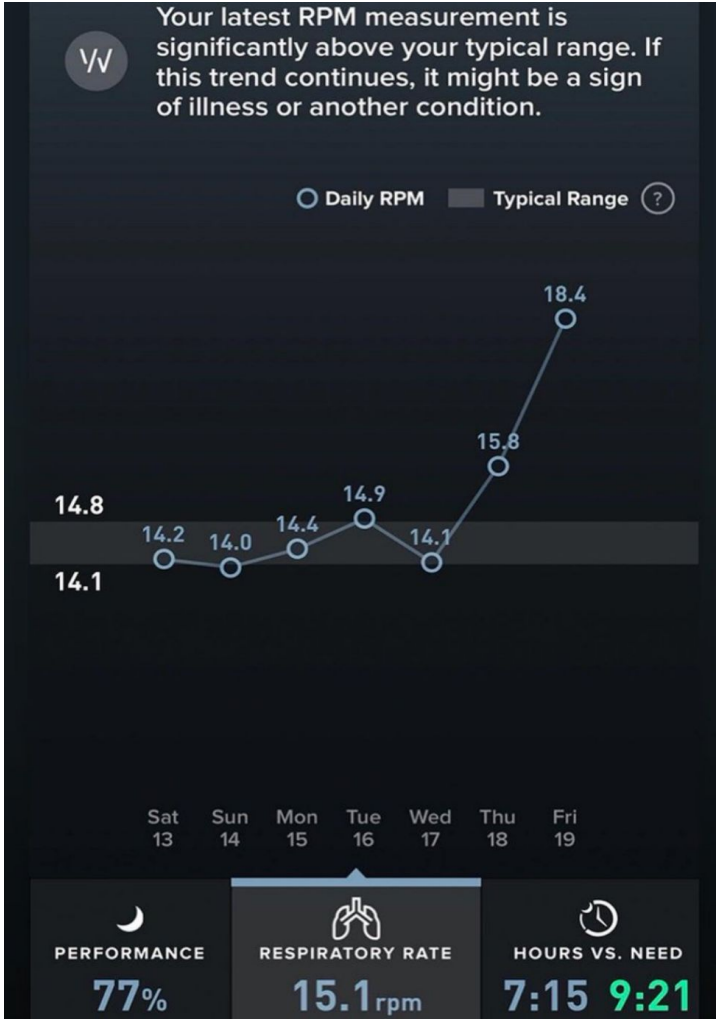
- Respiration provides our cells much needed O2 for metabolic activity and removes the CO2 generated in the process.
- Autonomous Nervous System signals the diaphragm to expand and contract in cycles.
- Oxygen rich Air pass travels down through the trachea to the down to bronchioles and interact with RBC via Alveoli….
- 15 <=Respiratory Rate (RR) <= 25 times a minute.



COVID19 and RR:

- Unlike Common cold which is a Upper Respiratory tract infection, Covid19 is a Lower Respiratory tract infection.
- It affects the alveoli.. As the number of properly functioning alveoli decreases RR increases substantially from normal baseline value of a person.
- RR can be used for early detection of COVID19 infection.





courtesy:
Whoop wearables

However the RR often gets ignored for early COVID19 detection .... due to unavailability of proper devices...

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Primarily there are 7 contact based noninvasive techniques by which we measure RR

1)Respiratory Airflow

2)Respiratory Sounds

3)Air temperature

4)Air humidity

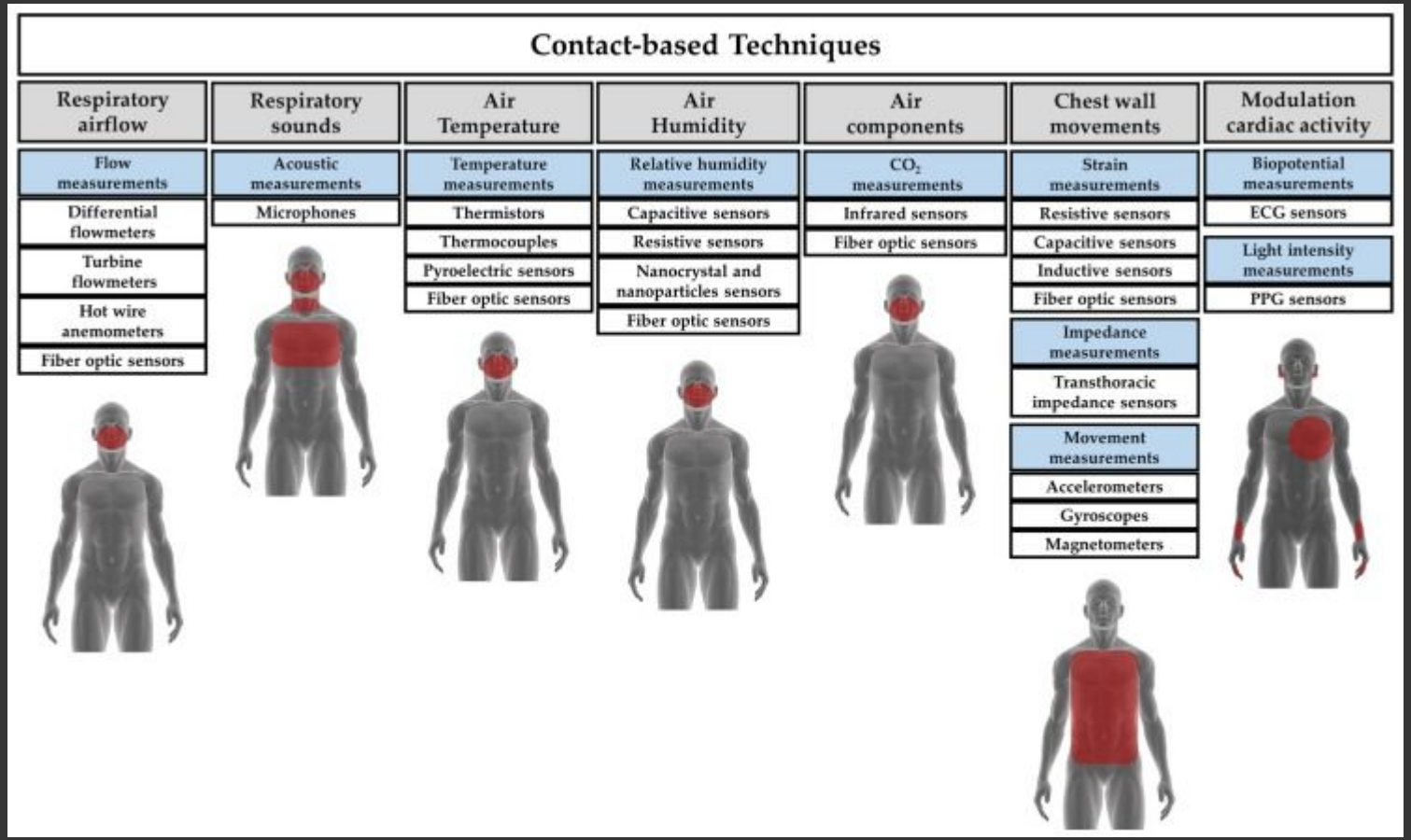
5)Air components

6)Chest wall movement

7)Modulation of cardiac activity- using ECG (electrocardiography**) and PPG (**photoplethysmography**) sensors**

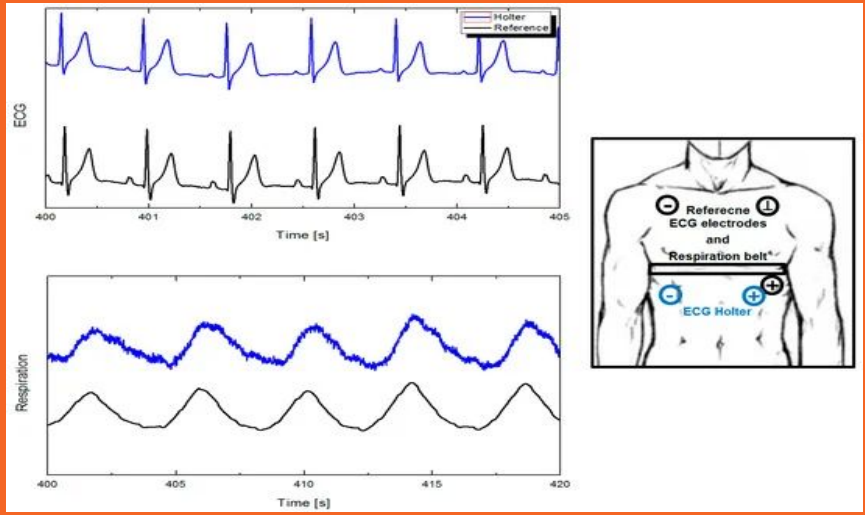
There has been a recent surge in integrating ECG based RR sensors into wearables !!

My Primary focus will be on ECG based RR measuring Sensors.


Contact-based Techniques
Respiratory airflow
Flow measurements
Differential flowmeters
Turbine flowmeters
Hot wire anemometers
Fiber optic sensors
Respiratory sounds
Acoustic measurements
Microphones
Air Temperature
Temperature measurements
Thermistors
Thermocouples
Pyroelectric sensors
Fiber optic sensors
Air Humidity
Relative humidity measurements
Capacitive sensors
Resistive sensors
Nanocrystal and nanoparticles sensors
Fiber optic sensors
Air components
CO_2 measurements
Infrared sensors
Fiber optic sensors
Chest wall movements
Strain measurements
Resistive sensors
Capacitive sensors
Inductive sensors
Fiber optic sensors
Impedance measurements
Transthoracic impedance sensors
Movement measurements
Accelerometers
Gyroscopes
Magnetometers
Modulation cardiac activity
Biopotential measurements
ECG sensors
Light intensity measurements
PPG sensors

What is ECG ?

- ECG is a measure of the **electrical activity** generated by the action potentials in heart muscle at each heartbeat.
- ECG signal is typically acquired by measuring the voltage difference between two or more points on the body surface over time.
- ECG electrode placement is standardized to guarantee uniformity in data collected from an ECG which is used for further analysis.



Characteristic of ECG circuit

I. The device should be able to deal with ***weak differential potentials*** in the range of 0.5mV to 5mV plus the ***dc components*** and the common mode voltages.

II. The device should be able to detect the weak ionic current from the body surface and convert it into an electrical signal to be processed further.

III. The front-end amplifier of the device should be able to amplify sufficiently the ECG signal while rejecting common mode voltages.

IV. The device must provide electrical isolation and protect the patient from electrical shock.

V. The instrument should have a large overall gain for the signal to be strong enough for Post analysis of the signal.

VI. **The instrument should provide sufficiently correct filtering stages for eliminating unwanted interferences and dc components**.

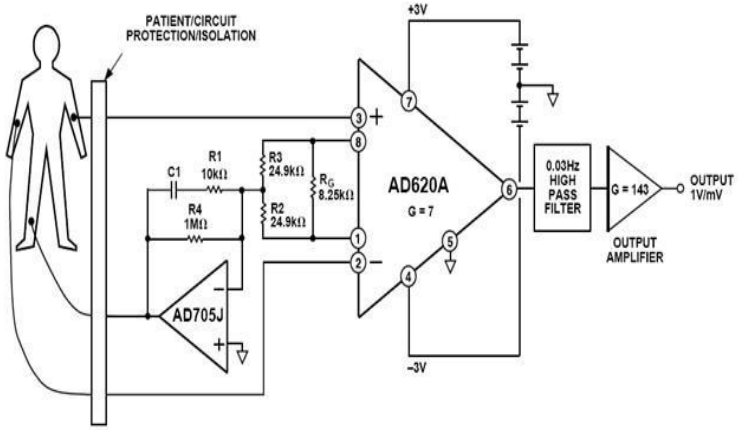


Figure 36. A Medical ECG Monitor Circuit

***The ECG hardware* carries out the following function in sequence:**

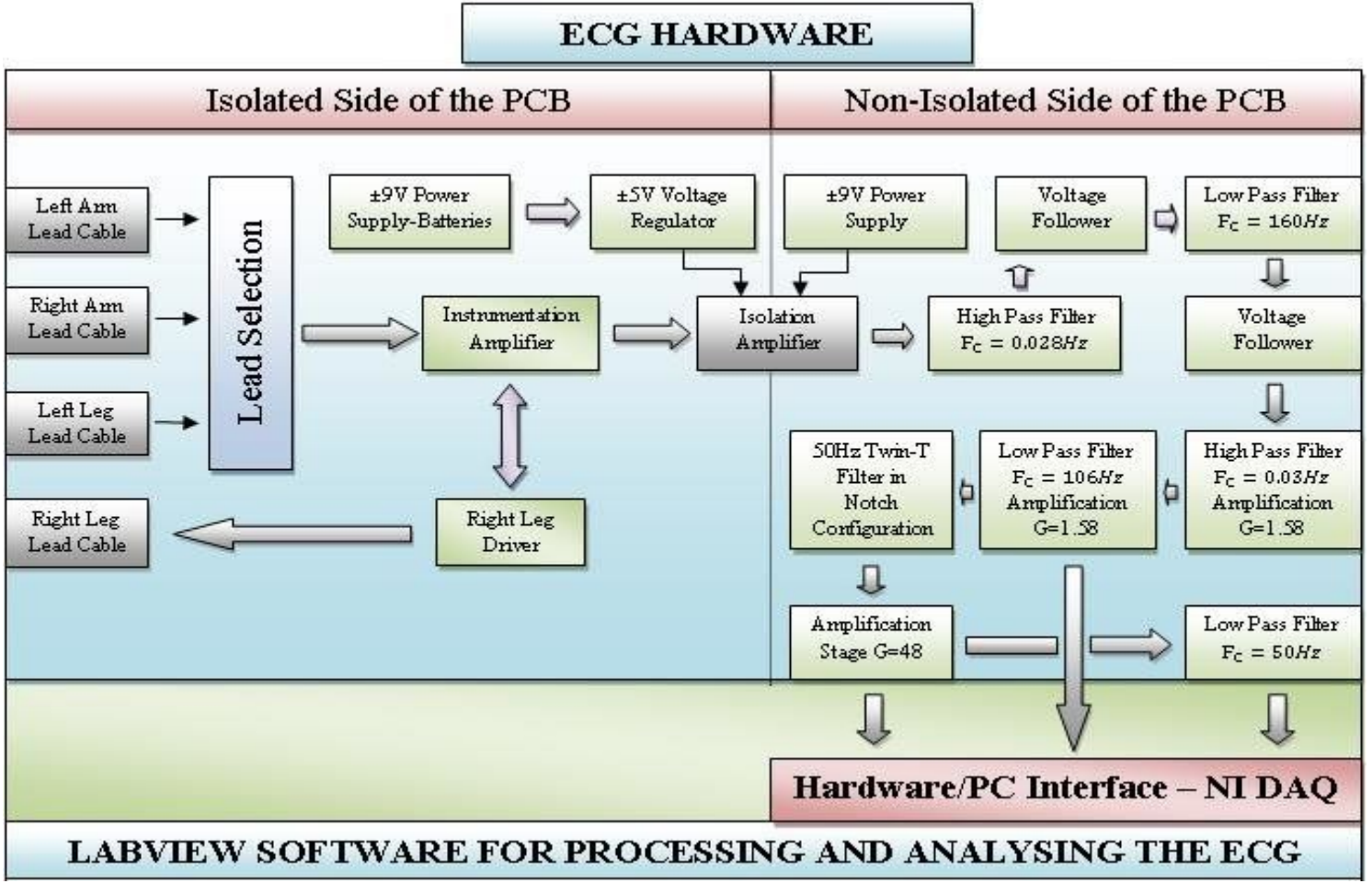
1)Detect the electrical potentials from the body surface.

2)Transmit them into the pre-amplification stage of the circuit for amplification followed by common mode voltage rejection.

3)Filtering of any unwanted frequency signals that may interfere with the ECG signal, setting the required bandwidths for monitoring ECG recordings

4)Amplifying the filtered ECG signal further to be sufficiently strong for transmission to the PC via Data Acquisition (DAQ).

- For final monitoring and analysis of the recordings the hardware is separated into two sides, the **isolated side** and the **non-isolated** side due to the inclusion of **an isolation amplifier which offers protection to the patient from electrical shock**.


ECG HARDWARE
Isolated Side of the PCB
Non-Isolated Side of the PCB
Left Arm Lead Cable
Right Arm Lead Cable
Left Leg Lead Cable
Right Leg Lead Cable
Lead Selection
±9V Power Supply-Batteries
±5V Voltage Regulator
Instrumentation Amplifier
Right Leg Driver
±9V Power Supply
Isolation Amplifier
Voltage Follower
Low Pass Filter Fc = 160Hz
High Pass Filter Fc = 0.028Hz
Voltage Follower
50Hz Twin-T Filter in Notch Configuration
Low Pass Filter Fc = 106Hz Amplification G=1.58
High Pass Filter Fc = 0.03Hz Amplification G=1.58
Amplification Stage G=48
Low Pass Filter Fc = 50Hz
Hardware/PC Interface – NI DAQ
LABVIEW SOFTWARE FOR PROCESSING AND ANALYSING THE ECG

The **isolated side** which is in contact with the patient consists of ***two main stages***:

1)The **lead selection stage** for selecting which lead to record

2)The **pre-amplification stage** for amplifying the signal and rejecting common mode voltages.

The isolated side is powered by ±5V dual supply delivered from two 9V.

- Four electrodes are attached to the patient's upper and lower limbs.
    - The three electrodes attached to the patient's Left arm (LA), Right arm (RA) and Left leg (LL) are used for **detecting the ionic current from the body surface**
    - The fourth electrode is attached to the Right leg (RL), output of the right leg driver **used as the reference electrode** to measure the potential difference between a pair of three electrodes.

The **differential potentials** are then transmitted into the lead selection stage.

The differential potentials plus common mode voltages and dc potentials are then transmitted into the differential inputs of the amplifier which amplifies the differential potentials while it rejects common mode voltages.

— The ***non-isolated side*** consists of 5 stages for further processing the ECG signal.

1)The first stage consists of a high and low pass filter for unwanted low and high-frequency modulation components and setting the first bandwidth of the hardware.

In this stage,a first order active high pass filter with a **lower cutoff frequency of 0.028 Hz** is used.

Right after the high pass filter, a 2nd order active low pass filter with a **high cutoff frequency of 160 Hz** is used to eliminate high unwanted frequency components above its cutoff frequency and set to the higher frequency of the circuit's bandwidth.

A bandwidth of 0.028Hz to 160 Hz is created.

2)The second stage is composed of two **Sallen & Key Butterworth high pass filters of second and third order**. At this stage, second bandwidth of 0.03Hz to 106 Hz is created and used for ECG recordings where all the components of the ECG are left intact.

3)The third stage includes a **Twin-T 50Hz Notch filter** which is used to attenuate as much as possible the most harmful interference to the ECG signal, i.e. that of the 50Hz electric field.

4)The fourth stage of the non-isolated side includes a final amplification stage for giving the final enhancement to the signal to be strong enough to be transmitted to the PC for analysis.

5)Transferring the signal to DAQ

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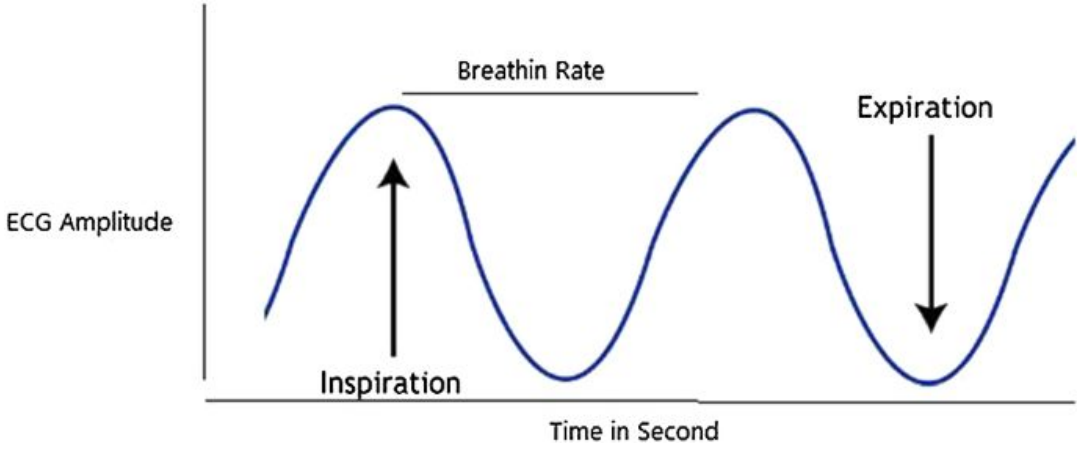
- The ***ECG signal is affected by the frequency modulation*** caused by the **increase of the heart rate during the inspiration phase and its decrease during the expiration phase.**



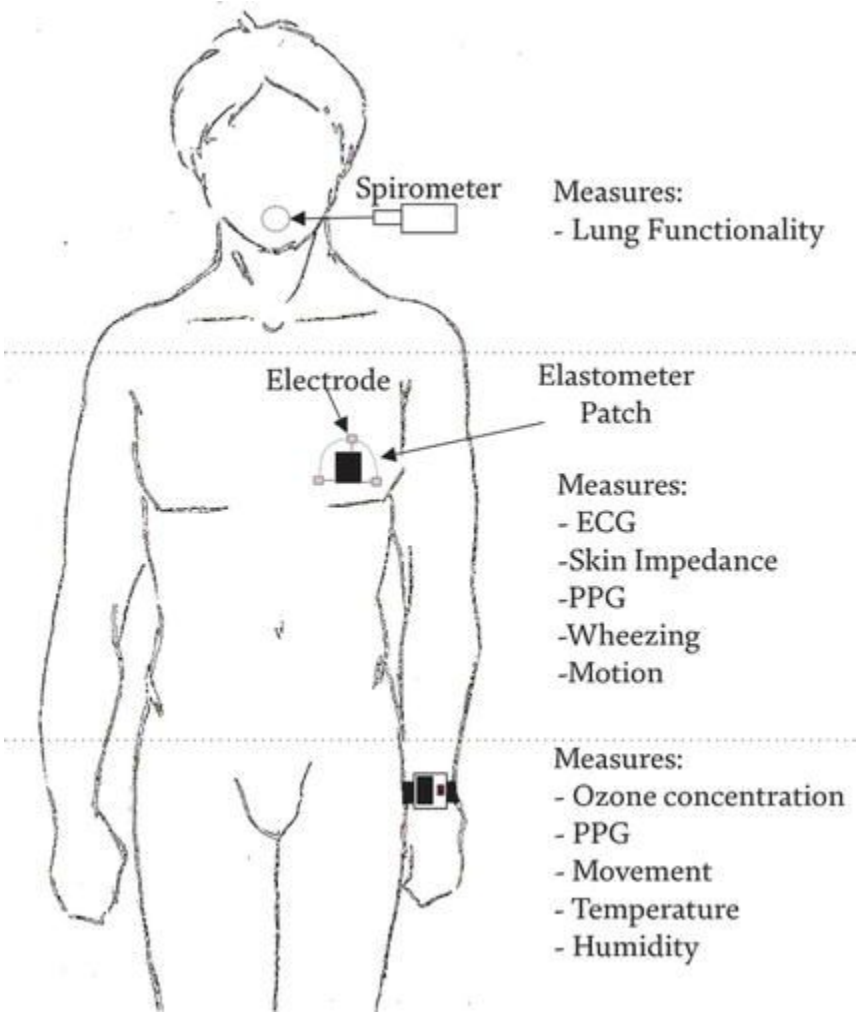
- Methods based on frequency modulation of the ECG signal are recognized with the **RSA** acronym (i.e., respiratory sinus arrhythmia).

- Other Data Fusion techniques
  - **Naïve Bayes Inference**
  - **Static Kalman Filter Data Fusion**
  - **Dynamic Kalman Filter Data Fusion**

  Can be applied.

Accuracy in the measurement of RR can also be increased by incorporating other sensors...

This allows for continuous Monitoring of Key parameters of human body….



Low Invasiveness

Good Integration in wearable systems

Low energy consumption

Low Cost

Pros

High Sensitivity to movements unrelated to breathing

Decrease in quality of the ECG and PPG due to poor probe adherence to skin

Easy distortion of signals from environmental noises..

Cons

Of the ECG based RR technique

- Researches are going on to tackle these problems with the help of ML and deep neural techniques..

- There has been a tremendous growth built around ***Biosensors*** for Continuous data monitoring
- It provides us chances to detect Health problems before even their symptoms is shown...
- It is finding tremendous use in Sports and health based analytics industries

The SENSational future is NEAR !!!

- **The biosensors market was valued at $17,500.0 million in 2018**
- **It is expected to reach $38,600.2 million by 2026, registering a CAGR of 10.4% from 2019 to 2026.**

Courtesy:

1) Whoops
2) https://core.ac.uk/download/pdf/199199084.pdf
3) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6132375/
4) And My group members Abhinav Aggarwal (190025) and Shresth Grover (190820)

THANK YOU.... !!!