Department of Electronics and Telecommunications

University of Moratuwa

BM2012 Modelling and Analysis of Physiological Systems

Assignment1

Simulation of Respiratory Mechanics

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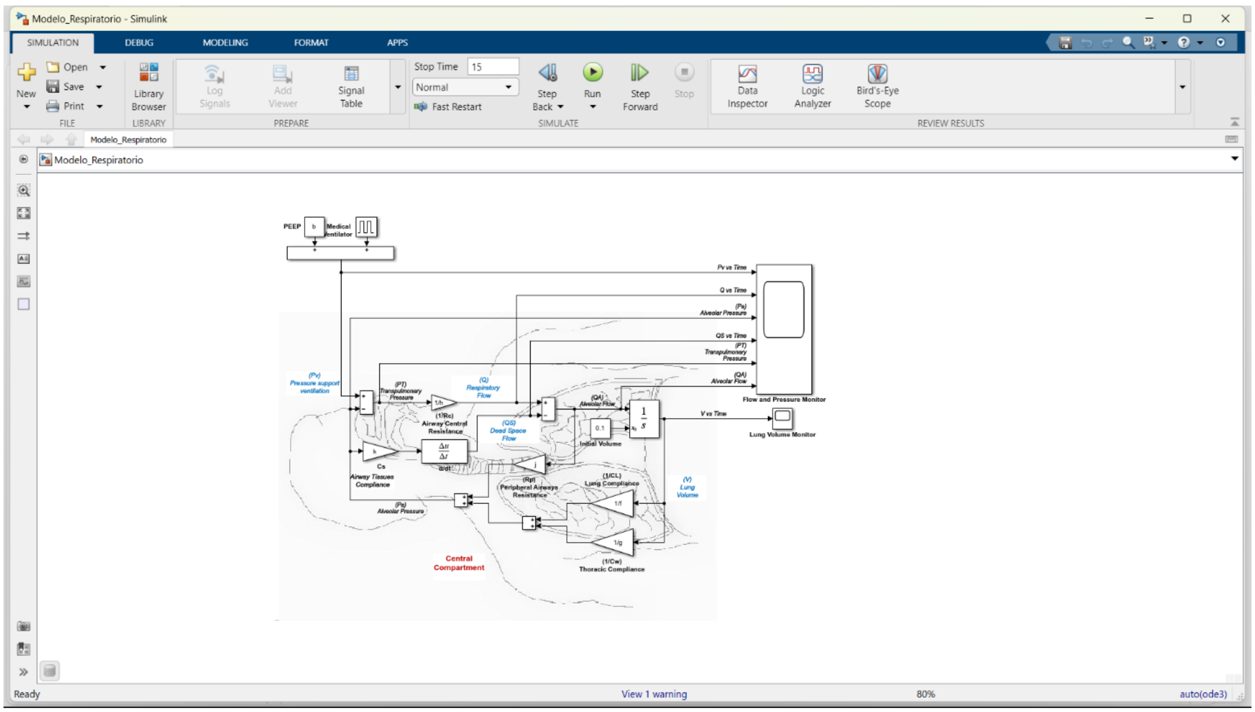
Introduction

This assignment delves into the simulation of respiratory mechanics utilizing a MATLAB-based simulator developed by David Leonardo Rodriguez Sarmiento and Daniela Acevedo Guerrero (2020). Through this simulation platform, the effects of various pulmonary conditions—normal respiration, restrictive pulmonary disease, and obstructive pulmonary disease—on ventilatory parameters and gas exchange will be investigated. Analyzing alterations in minute ventilation and ventilator settings under each condition aims to unravel the physiological mechanisms driving respiratory dysfunction and their implications for ventilator management strategies.



1. Normal Respiration

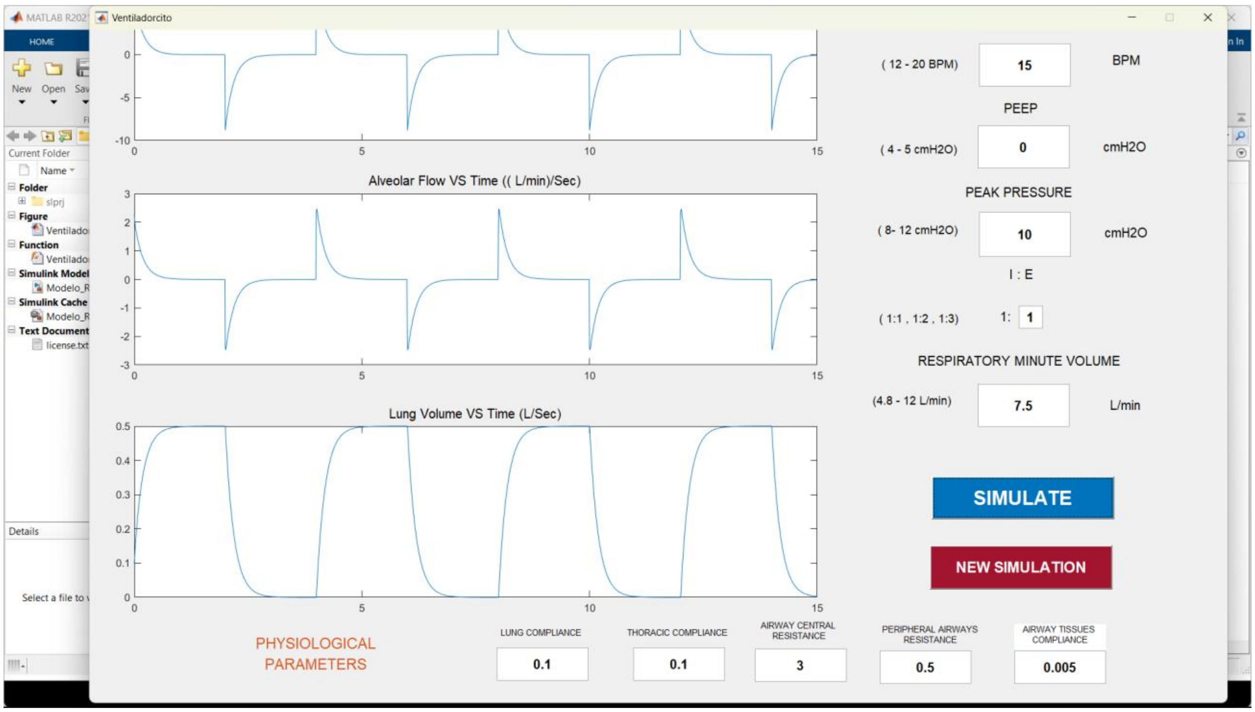
Here are the typical values for an individual under normal respiration condition.

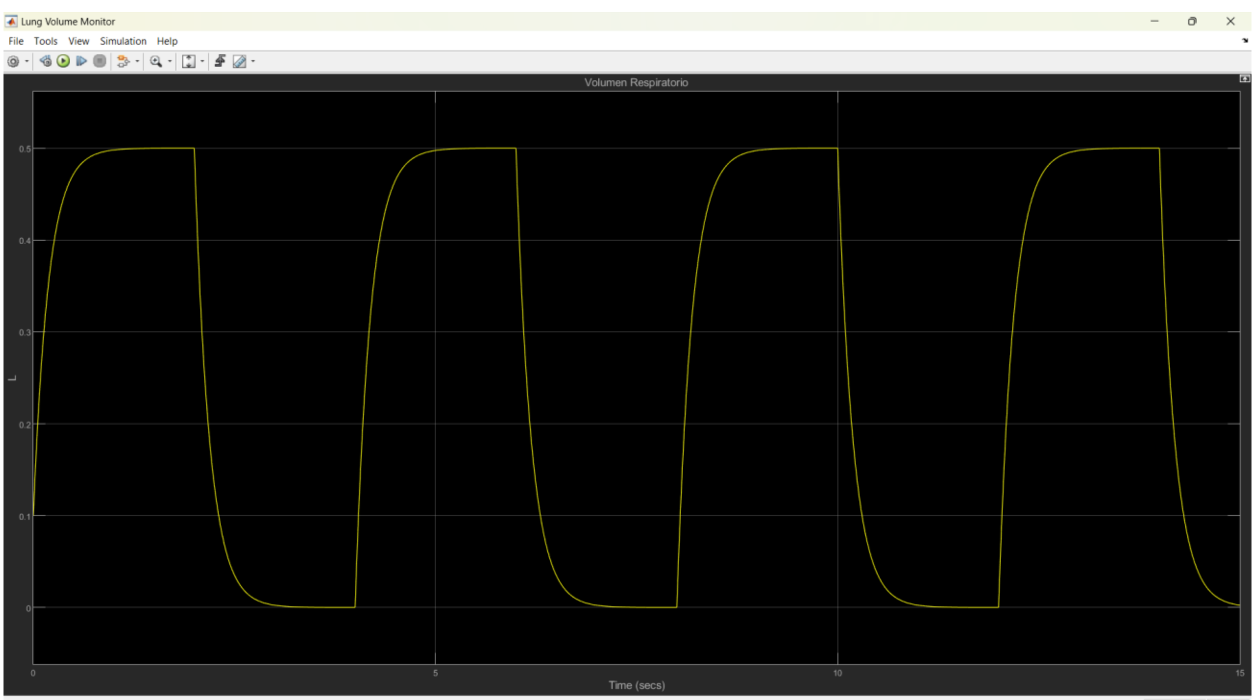
- Central airway resistance (R_C) = 3 cmH$_2$0/(L/S)
- Peripheral airway resistance (R_P) = 0.5 cmH$_2$0/(L/S)
- Lungs and chest wall (Thoracic) Compliance (C_L and C_W) = 0.1 L/cmH$_2$0
- Airway tissue compliance = 0.005 L/cmH$_2$0

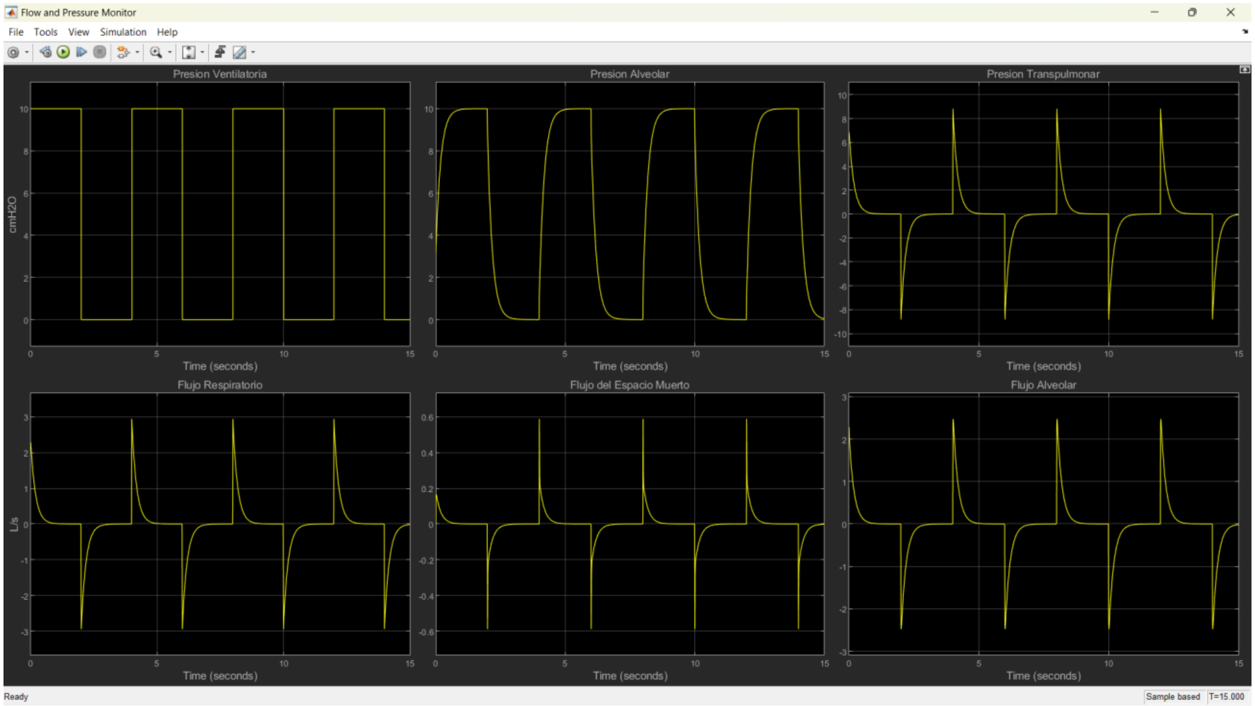
Applied ventilator conditions:

- Breathing frequency = 15 BPM
- PEEP= 0 cmH_20
- Peak pressure = 10 cmH_20

Results:







2. Restrictive pulmonary disease

Restrictive pulmonary disease occurs due to a decrease in pulmonary compliance. This reduction in compliance leads to diminished lung capacity and functional residual capacity (FRC), impeding adequate airflow during inhalation. In this condition both lung compliance and thoracic compliance can be decreased. There for the tidal volume and minute ventilation decrease.

Central airway resistance, peripheral airway resistance and airway tissue compliance do not affect under restrictive pulmonary disease.

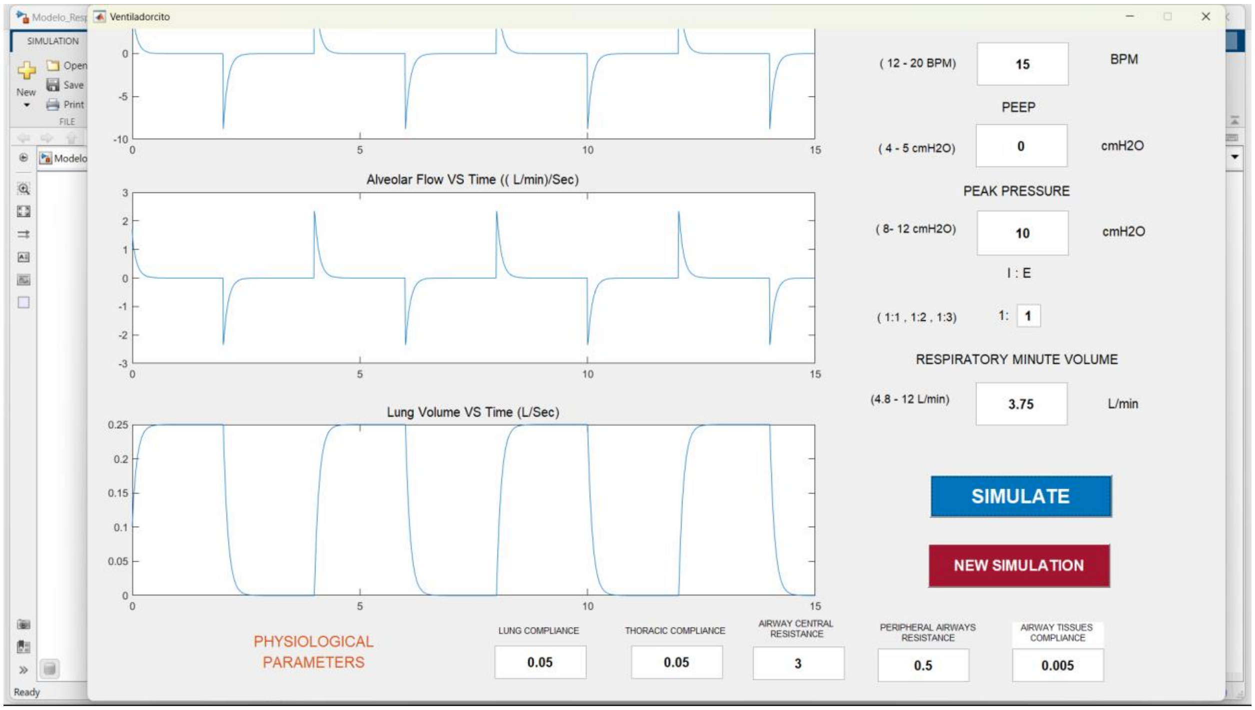
Values for an individual under restrictive pulmonary disease condition.

- Central airway resistance (R_C) = 3 $cmH_20/(L/S)$
- Peripheral airway resistance (R_P) = 0.5 $cmH_20/(L/S)$
- Lungs and chest wall (Thoracic) Compliance (C_L and C_W) = 0.05 L/cmH_20
- Airway tissue compliance = 0.005 L/cmH_20

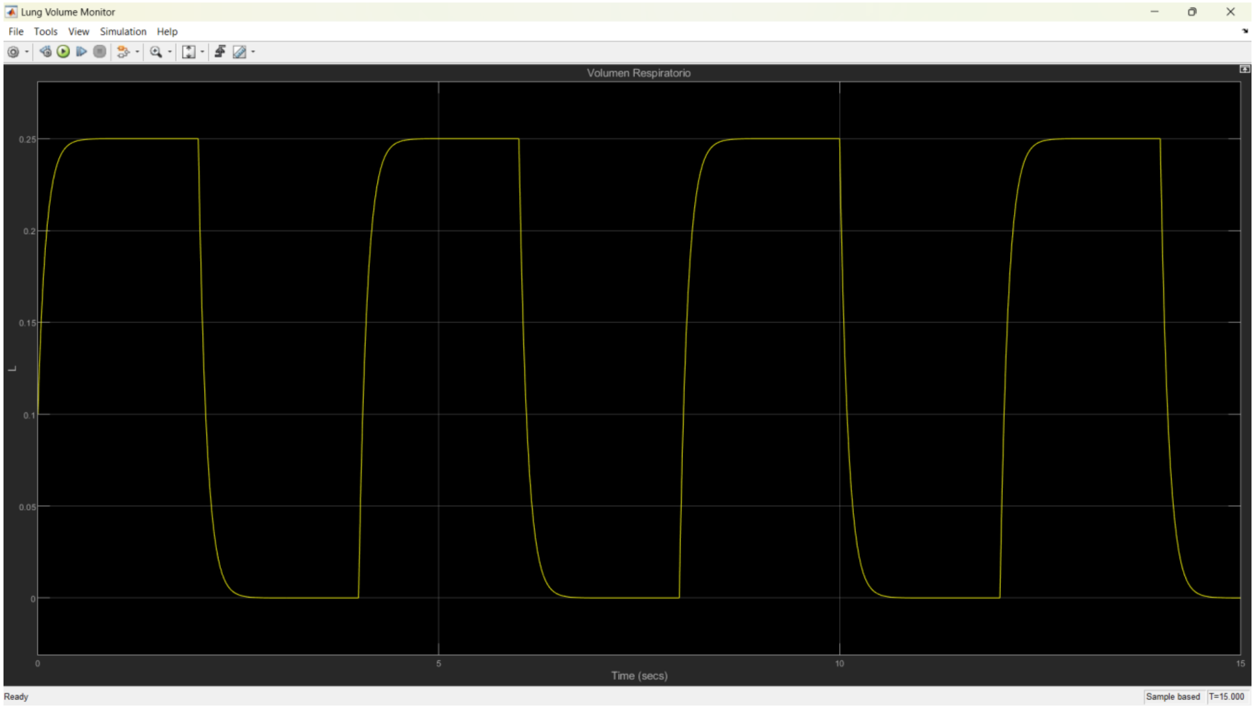
Applied ventilator conditions:

- Breathing frequency = 15 BPM
- PEEP= 0 cmH_20
- Peak pressure = 10 cmH_20

Results :


Ventiladorcito
Alveolar Flow VS Time ((L/min)/Sec)
Lung Volume VS Time (L/Sec)
(12 - 20 BPM)
15
BPM
PEEP
(4 - 5 cmH2O)
0
cmH2O
PEAK PRESSURE
(8- 12 cmH2O)
10
cmH2O
I : E
(1:1 , 1:2 , 1:3)
1: 1
RESPIRATORY MINUTE VOLUME
(4.8 - 12 L/min)
3.75
L/min
SIMULATE
NEW SIMULATION
PHYSIOLOGICAL PARAMETERS
LUNG COMPLIANCE
0.05
THORACIC COMPLIANCE
0.05
AIRWAY CENTRAL RESISTANCE
3
PERIPHERAL AIRWAYS RESISTANCE
0.5
AIRWAY TISSUES COMPLIANCE
0.005


Flow and Pressure Monitor
File Tools View Simulation Help
Presion Ventilatoria
Presion Alveolar
Presion Transpulmonar
cmH2O
Time (seconds)
Flujo Respiratorio
Flujo del Espacio Muerto
Flujo Alveolar
L/s
Ready
Sample based
T=15.000



Observations (compared to normal condition):

- Respiratory Minuet volume has reduced.
- Lung Volume has reduced.
- No change in respiratory flow, dead space flow, alveolar Pressure and alveolar flow, and transpulmonary pressure.

Therefore, we should increase the breathing frequency of the ventilator to make sure patient get enough ventilation. We increase the peep because there's an increased risk of alveolar collapse at end-expiration due to decreased lung compliance.

3. Obstructive pulmonary disease

Obstructive pulmonary disease (OPD) manifests as increased airway resistance, primarily due to factors such as inflammation, bronchoconstriction, mucus hypersecretion, and structural alterations in airway walls.

In obstructive pulmonary diseases, heightened resistivity within central and peripheral airways impedes respiratory airflow. This increased airway resistance leads to a pronounced decrease in alveolar pressure during forced expiration, potentially precipitating airway collapse. Furthermore, the diminished airflow through alveoli, attributable to elevated airway resistance, results in a concomitant reduction in the concentration of oxygen reaching the bloodstream.

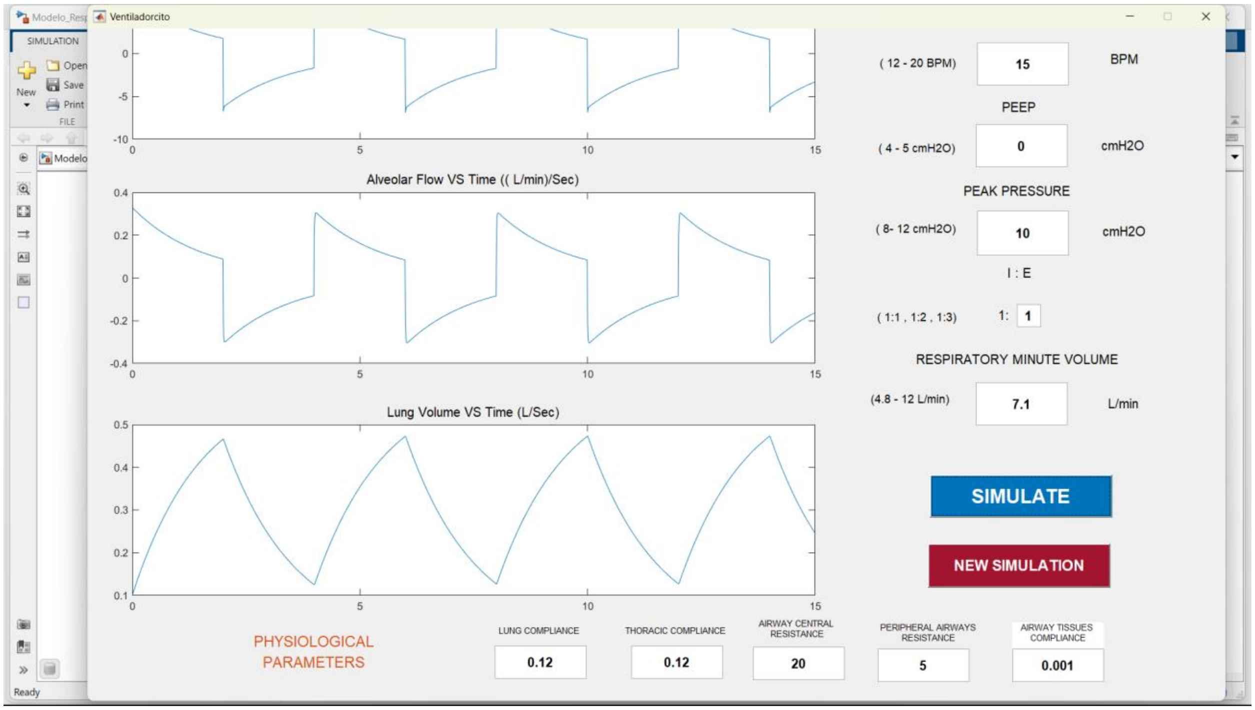
Values for an individual under obstructive pulmonary disease condition.

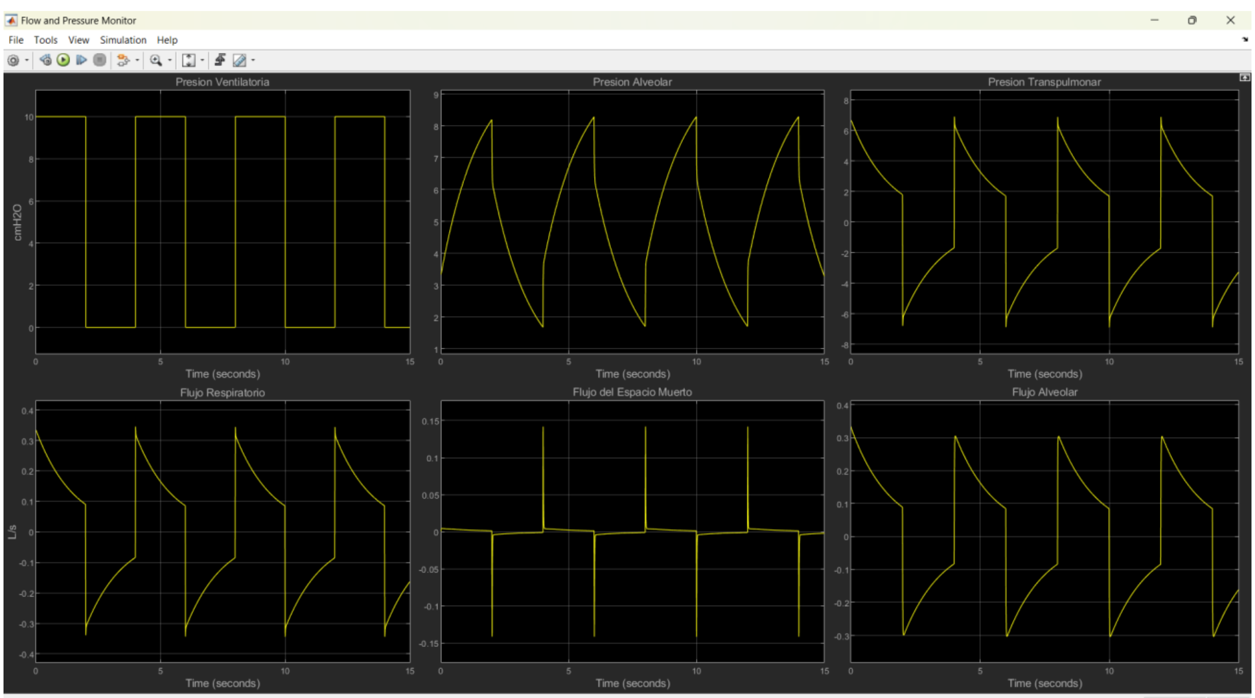
- Central airway resistance (R_C) = 20 $cmH_20/(L/S)$
- Peripheral airway resistance (R_P) = 5 $cmH_20/(L/S)$
- Lungs and chest wall (Thoracic) Compliance (C_L and C_W) = 0.12 L/cmH_20
- Airway tissue compliance = 0.001 L/cmH_20

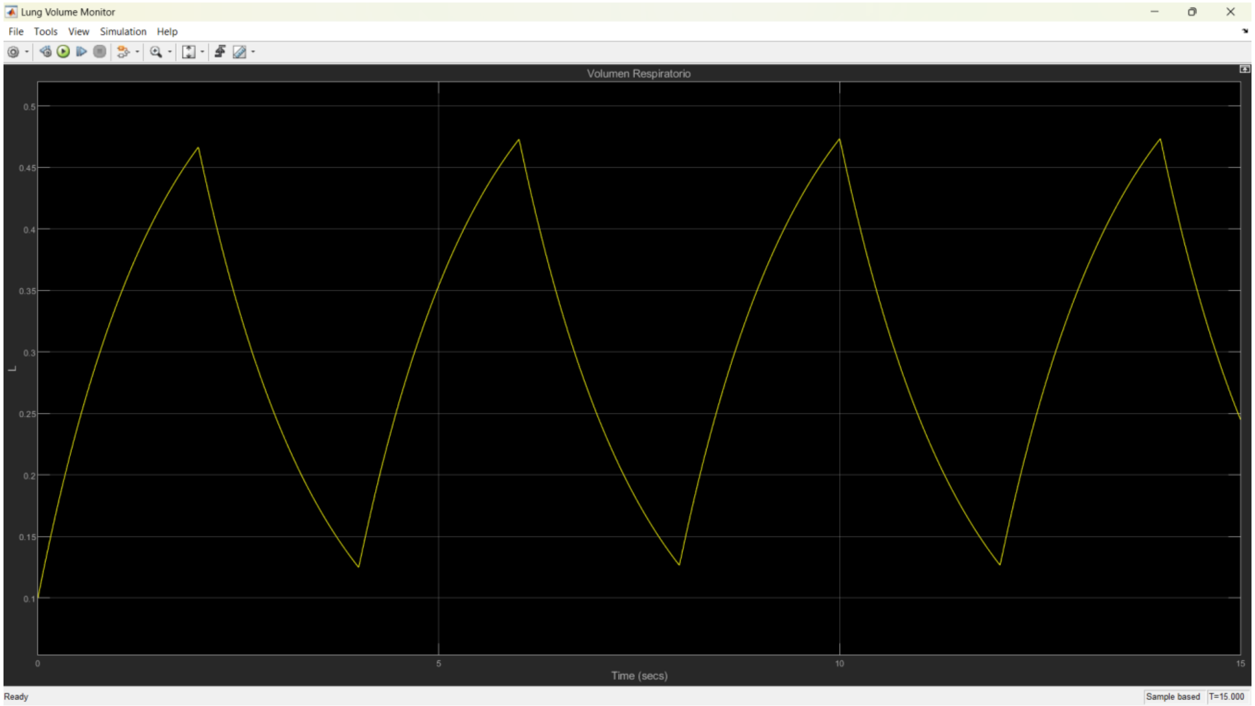
Applied ventilator conditions:

- Breathing frequency = 15 BPM
- PEEP= 0 cmH_20
- Peak pressure = 10

Results :







Observations (compared to normal condition):

- Respiratory Minuet volume has reduced.
- Lung Volume has reduced.
- Respiratory flow, dead space flow, alveolar Pressure and alveolar flow, and Trans pulmonary pressure has reduced.

Ventilator settings require adjustment in obstructive pulmonary disease. Peak pressure should be reduced to avoid barotrauma, while PEEP needs to be raised to maintain alveolar patency at the end of expiration. Additionally, the respiratory rate may need to be elevated to ensure sufficient ventilation, but caution is necessary to prevent excessive respiratory frequency and the development of auto-PEEP.

Differences in minute ventilation

In normal respiration, minute ventilation typically remains within expected ranges, with efficient gas exchange and adequate airflow due to normal lung compliance and airway resistance. However, in restrictive pulmonary disease, where lung compliance is reduced, minute ventilation decreases as the lungs cannot expand fully, resulting in diminished tidal volumes. Although central and peripheral airway resistances remain unchanged, the overall reduction in lung capacity and functional residual capacity (FRC) contributes to a decrease in minute ventilation.

In obstructive pulmonary disease, increased airway resistance significantly impacts minute ventilation. While lung compliance might remain within normal ranges, the heightened resistivity in central and peripheral airways impedes airflow, resulting in reduced tidal volumes and overall ventilation. Additionally, the elevated airway resistance leads to a steep drop in alveolar pressure during forced expiration, further compromising ventilation efficiency.

Overall, minute ventilation varies across the simulated conditions, reflecting the distinct effects of normal respiration, restrictive pulmonary disease, and obstructive pulmonary disease on respiratory mechanics and gas exchange. Understanding these differences is crucial for optimizing ventilator management and ensuring adequate ventilation in patients with pulmonary diseases.