# Mathematical modeling for pulmonary system

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**Abstract:** Electrical analogy of pulmonary circulation is studied of pulmonary circulation by using a electrical analogy. In this model describing the R and C network. In order to predict electronic circuit preview of pulmonary circulation. This mathematical modeling has been done. To do so electrical analogy of pulmonary circulation predicted. MATLAB and LABVIEW software are used for analysis purposes.

**Introduction:** The diagnosis and treatment of cardiopulmonary disease may be improved by using mathematical models of the cardiovascular and pulmonary system. Pulmonary circulation is an indistinguishable part of circulatory system that converts deoxygenated blood to oxygenated blood by the action of lungs. The Right ventricle pumps blood to pulmonary arteries those take blood to lungs points where alveoli's helps the exchange of gases in blood and then this oxygenated blood with the help of pulmonary veins reaches at left atrium which is end point of pulmonary circulation. But in work extended pulmonary circulation, that starts from right Atrium and ends at left ventricle has been taken so as to design the effective proposed mathematical model of pulmonary circulation may be designed that contain systemic effect also. To design the mathematical model first step followed is to design an electrical analogous of extended pulmonary circulation. According to the behaviors of various parts (heart chambers and lungs) of circulation, it is decided to take heart chamber and lungs as capacitor, heart valves as diode or forward resistance and pulmonary arteries & veins as pulmonary vascular resistances. To design the proposed mathematical two approaches are use. Firstly conventional transfer function approaches to check the step response for system stability. Secondly State Space Analysis model is designed to check mathematically the blood flow behavior at every point of circulation taken for model.

A model of pulmonary system that accurately describes various heart and lungs parameters in the R and C network form. The pulmonary vascular system is a low pressure system comparing the pressure in the pulmonary artery aorta[5]. In this model input flow of blood is taken as current. In this model we use the two approaches to solve equation governing the blood flow in human pulmonary circulation. This method is simple and can give high degree of precision.

**Mathematical formulation:**

Mathematical modeling is the process of combing quantity data with a qualitative. Understanding to produce an explanatory and predictive . We discrete the pulmonary circulation as five node model. Shown in fig. model equally divided into three parts, right part of heart, in middle lungs and pulmonary blood vessels and left part of heart. In proposed model of pulmonary circulation by considering heart valve as resistance to blood flow according to [1].

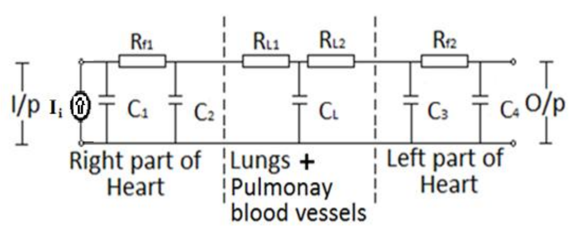


Figure: Proposed model of pulmonary circulation by considering heart valve as resistance to blood flow

**Description:**

$I_i$ : input current (blood per unit time)

O/p: output current (blood per unit time)

C1: capacitance for Right Atria

C2: capacitance for Right Ventricle v

C3: capacitance for Left Atria

C4: capacitance for Left Ventricle

CL: capacitance for Lungs

Rf1: forward resistance for right Atrioventricular valve

Rf2: forward resistance for left Atrioventricular valve

RL1: resistance of pulmonary arteries (from right ventricle to lungs)

RL2: resistance of pulmonary veins (from lungs to left Atria)

**TECHNIQUES USED TO DESIGN MTHEMATICAL MODEL:**

(1)Transfer function technique

(2)State variable analysis

**(1)Transfer function(T.F) technique**:

T.F approach is used to simplify the mathematical calculation of pulmonary system. The T.F is defined as

$$T.F=\frac{Laplace\ \ transfer\ \ function\ \ of\ output}{Laplace\ \ transfer\ \ function\ \ of\ input}=\frac{Cs}{Rs}$$

Cs is the output of blood coming from the pulmonary circulation and Rs is the input of deoxygenated blood enters into the heart.

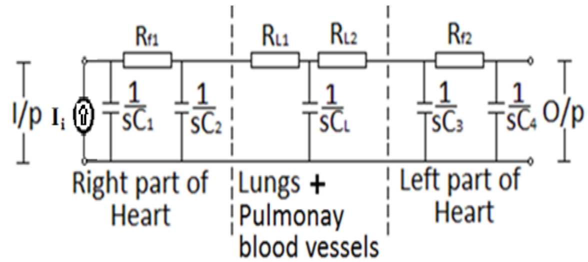


Figure: Laplace transformation of proposed circuit

To Norton equivalent circuit one must know Short Circuit current flowing through the output terminals on removing load impedance and short circuiting those terminals where it was connected

$$I_N = \frac{V_{th}}{Z_{th}}$$

So to get $I_N$ we have to find $V_{th}$ and $Z_{th}$ by taking 1/sC4 as load impedance.

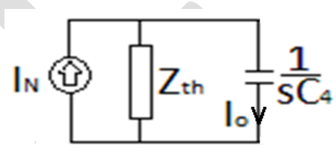


Figure: Norton equivalent circuit of proposed circuit

**(2)State variable analysis**:

In state variable analysis method we are used nine variable(five voltage variable and four current variable) from mesh analysis.

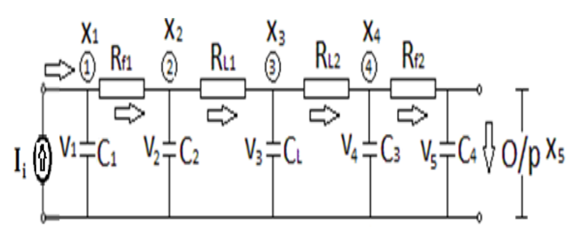


Figure: proposed circuit with state variable and numbering of nodes State Variables

**State variables are:**

X1=V1; X2=V2; X3=V3; X4=V4;

X5=V5; X6=I6; X7=I7; X8=I8;

X9=I9;

**Criterion to predicting parameters**

The first step in creating a model of the pulmonary circulation is to choose appropriate mechanical-to-electrical conversion factors. The heart is electro-mechanical pump. Since typical pressure values for the heart are on the order of 100 mmHg and convenient voltage ranges of operation for components in our process scale with 100mV, we set 1mmHg ≡ 1mV. A choice for volume velocity or flow of 1ml/s = 1nA yields 1mmHg/(1ml/s) ≡ 1MΩ. Since the typical period of a heart beat is 1s, the capacitance values in our circuit are near (1s/ (1MΩ)) = 1μF [18].

**Software formulation for analysis of system**

To plot system behavior with time and with various pressure and volume designed few programs. The few programs are related to application of MAT-Lab and others to LABVIEW software to plot system behavior effectively. The programs deal with step response and to analyze the state equation.

**Result**

On analysis of Transfer function a graph has been developed between current (blood flow/time) and time. The blood flow across the left ventricle rises similarly as the exponential function and becomes constant at certain level. As assumes my proposed model up to left ventricle and tried to design the mathematical model by taking C4 representing left ventricle as load so no ventricle emptisation occurs i.e. no exponential decay is present in result.

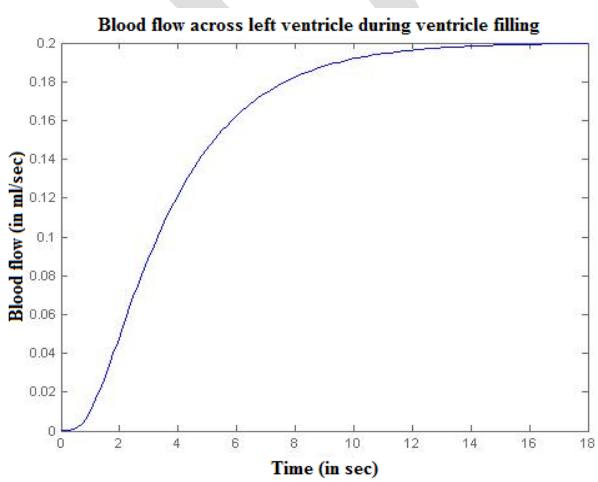


Figure :Blood flow characteristics of ventricle filling for proposed model

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