MSPS Practical

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1 Experiment 1

The given capacitive circuit is a high pass filter. For the first order LTI system time constant is numerically denoted by tau = R*C. Time constant helps us to find out how long it will take a capacitor to charge to a certain voltage level It is time taken by capacitor to charge till 63.2 percent of applied Voltage. High pass filter allows the signals of high frequency to pass and block the low frequency signals. High pass filter can be constructed by joining the capacitor and resistor in series.

Series RL circuit -
In this circuit resistor and the capacitor are connected in series. The time constant of an RL circuit is defined as the time taken by the current to reach its maximum value that had maintained during its initial rate of rise. The time constant of a series RL circuit equal to the ratio of value of inductor to the value of resistance. Since, reactance is Xl = 2*pi*f*L, for low frequency(f) the inductive reactance will be low and so there will not be any voltage drop across inductor, the output voltage across resistor will be same as input voltage. Therefore series RL circuit will act as inductor circuit. Transfer function of RL circuit is V0(s)/Vi(s) = 1/(S+1).

2 Experiment-2

Q.1 What would you expect the steady-state velocity of the system to be if a step input of 2000 N were applied at t = 0?
Ans.
From newtons second law we have, dv/dt = (F-bv)/M.
M is the mass, v is velocity and F is force, b is damping cofficient.
At steady state, the change in velocity will be zero. i.e. dv/dt = 0.
Therefore, F = bv
F = 2000N
b = 40 N*sec/m
2000 = 40*v
v= 50 m/sec.

Q.2 Why do this step input and the ramp input with saturation we simulated have the same steady state velocity?
Ans.The step input is similar to saturated ramp input, because when steady state is reached, both step input and saturated ramp input have fixed value(input value). Therefore, if we apply same force to same system (under idential condition), then system will attain the same velocity. That is why we get same steady state velocity.

Q.3 Using which input, the step or the ramp with saturation, would you expect the system to reach its steady-state velocity more quickly?
Ans. With step input the system will reach it's steady state velocity more quickly. Because, saturated ramp input will take more time to reach it's saturation value whereas step input reaches to it's fixed value quickly.

3 Experiment 3

Muscle stretch reflex is an involuntary action. It is based on a negative feedback system. When there is a shart tap on the patella tendon, a stretch in the extensor muscle will be experienced. Because the tendon is attached to the extensor muscle. Stretch in extensor muscle activates muscle spindle. Muscle spindles are stretch receptors. Stretch receptor generates the neural impulse which is carried by afferent nerve fiber to the spinal cord. Motor neurons in spinal cord gets activate and sends another neural impulse through efferent nerve fiber to thigs muscles. Which then shows contraction. Take P as property of any system, then

$$\frac{\partial P}{\partial t} = 0$$

represents the steady state. Because in steady state the property remains fix with time. Steady state analysis is important because when a system(network or circuit) reaches to steady state, there we can neglect the transient effect, which makes the calculation simple. The operating point at steady state is point of equilibrium. In real physiological system a true static equilibrium never exists because regulated variable is affected by signals like cardiac rhythms and interaction with other organs. Muscle stretch reflex is mainly useful during the diagnosis of neurodegenerative disease such as Parkinson's Disease, MS etc. Data generated from muscle streth reflex model will for analysing resting tremor and reflex latency. In this experiment instead of solving graphical method for obtaining the operating point, we just used simulink xy graph for determining operating point.

There exist two component of stretch reflex, one is dynamic component and second is static component. There are two types of intra fusal muscle fibre

- nuclear chain fiber - Static component
- nuclear bag fiber - Dynamic Component

4 Experiment-4

There are four types of lung volume

- Tidal volume (symbol VT or TV) is the lung volume representing the normal volume of air displaced between normal inhalation and exhalation. It's approximately 500 ml per inspiration.
- Inspiratory reserve (IRV) is the amount of extra air inhaled — above tidal volume — during a forceful breath in.
- Expiratory reserve (ERV) is the amount of extra air above anormal breath exhaled during a forceful breath out.
- Residual volumes (RV) is the amount of air that remains in a person's lungs after fully exhaling

The lung mechanics model describes the relationships between various pressures (P), air flow volumes (Q), air flow resistance (R), and compliances (C) of air flow compartments in respiration system. For a mechanical system with spring, compliance determines the extent to which spring will be compressed or extended. It is inverse to elastic modulous of the spring. More compliance less stiff the spring. In Lungs, Pulmonary Compliance implies the extent to which the lungs/chest will expand per unit increase in TransPulmonary Pressure Airway resistance is the resistance offered to the passage of airflow through the track.

KVL : It is Kirchhoffs Voltage Law and states that in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop.

KCL : It is Kirchoff's Current Law. It states that the sum of all currents entering a node equals to the sum of all currents leaving it.

5 Experiment-5

In neuromuscular reflex model, initially upperarm is at horizontal plane and and forearm is at 135 degree from upper arm. At t = 0 a weight/load is added in this system. Due to weight an external torque(Mx(t)) will be exerted in the arm. In response to it, muscles will exert an internal torque M(t). There are two parts of nerve, sensory unit and motor unit. Beta is feedback sensitivity gain. With increase in beta, the response becomes more oscillatory. Also increase in beta will descrease the steady state value of the response.

For different values of Beta we have damping given below -

- Beta = 50 : Overdamped
- Beta = 100 : Slightly underdamped
- Beta = 150 : Underdamped

Damping is used to reduce the oscillations. There are three types of damping-

- Underdamped system :This type of system attain the equilibrium very quickly but oscillate about the value for a while before settling System will oscillate before reaching to equiliribium. Here, $0 < \zeta < 1$
- Critically damped : In this, the equilibrium is attained as quickly as possible without oscillations. $\zeta = 1$
- Overdamped : This system moves towards the equilibrium value very slowly. $\zeta > 1$

There are two components of stretch reflex, dynamic component and static component. The two components of stretch reflex is due to the reason that intra fusal muscle fibres are of two type. Nuclear bag fibre and nuclear chain fibre. Nuclear bag fibre gives dynamic component and nuclear chain fibre gives static component.

6 Experiment-6

Medical ventilators are required when a person can't breath on their own. Most often ventilators are required -

- During the surgery.
- Recovery from surgery.
- Difficulty in breathing due to lung disease.

Ventialtors works by removing CO_2 and blowing oxygen into the lungs through airway. BTPS is body temperature pressure saturation and STPD is standard temperature pressure dry. BTPS is the unit of flow rate and CO_2 metabolic rate is expressed in STPD. BTPS can be converted into STPD using equation.

$$(760 * V_{STPD})/273 = [(P_B - 47)V_{BPTS}]/310$$

Hypoxia is the condition when partial pressure of O_2 becomes less than 70mmHg. In apnea there is no movement of inhalation muscles and volume of lungs remains unchanged.

Given below are the area of brain that controls respiration-

- medullary inspiratory center, located in the medulla oblongata.
- The pheumotaxic area, located in the pons.
- The apneustic area, also located in the pons.

Chemoreceptors senses the changes in CO2, O2 and PH in the body. Respiratory controller inclues Chemoreceptors, neural circuit in lower brain,respiratory muscles and neural driver of brethe. The respiratory controller shows linear response to CO_2 in physiological range. When there is increase in P_{CO_2} the ventialtor output increases. However, when there is increase in P_{O_2} the ventialtion descreases. The main job of respiratory controller is to maintain an equiliribium between P_{O_2} and P_{CO_2}. External controller (Ventialtors) will be required if human body can't maintain the equiliribium between O_2 and CO_2 pressure.

Metabolic hyperbola - According to equation $P_{ACO_2} = P_{ICO_2} + (863 * V_{CO2})/V_A$, Partial pressure of CO_2 and alveolar ventilation are hyperbolacilly related that's why it is called Metabolic hyperbola.

Due to low value of total ventilation, the partial pressure of CO_2 in the lungs will be high and the partial pressure of O_2 will be low. These level of P_{CO_2} and P_{O_2} will tell the controller to produce high ventilation (VE_{out}), which descrease P_{CO_2} and inprove P_{O_2} level. When the P_{CO_2} and P_{O_2} reaches to an equiliribium point and VE become equal to VE_{out}, the simulation terminates.

7 Experiment-7

The need of medical ventilator arises when there is lung injury or a damaged airway or any pulmonary disease.Mechanical Ventilation provides proper inhalation and exhalation of air. The proper knowledge of stress/strain in the airway tissues is important to prevent any further damage to the person undergoing Mechanical Ventilation. This is done using Transient Response.

- In both the case(open loop and closed loop) the ratio between the pressure at Alveoli and Airway Opening gives us the simplified Transfer Function. As in the simplified model, we replace all Compliances(Lung, Chest wall and Shunt) with 1 single compliance and all Resistances with 1 single resistance. These make our model considerably simpler and easier to understand. (Closed loop just introduces a feedback loop that modifies the input Airway opening pressure according to the Alveoli pressure).
- The first order model used a step function input, in which, the output in the open and closed loop differed in their steady state values(reduced in closed loop) because of the feedback applied.
- The undamped, underdamped, critically damped and overdamped response in second order impulse response differed as per properties of Damping as mentioned in the theory(Peak Amplitude decreases from Underdamped to Overdamped).

8 Experiment-8

Nyquist plot is a ploar plot of frequency response of a linear system. It is used to see whether the system is stable or unstable. Z transform is used to convert discrete signal in time domain to frequency domain. Analysis in frequency domain allows us

- to determine the region of lesser noise
- to determine the response of a system to different frequency
- analysis of non linear function becomes easy in frequency domain

From the graph, below the natural frequency, increase in frequency shows the increase in gain. But after crossing natural frequency the gain descreases with increase in frequency.

9 Experiment-9

In the case of type 2 diabetes, insulin in the blood regulate the blood glucose. It is not possible to treat type 2 diabetes patient with insulin. They are prescribed the steps like healthy eating, regular exercise, weight loss etc.

Excessive glucose is stored in the liver and muscle in the form of glycogen. Insulin is produced by beta cells of pancreatic islets in pancreas.

Regulation of glucose by body
Low glucose level - Liver is stimulated by glucagon from alpha cell in pancreas to release glucose.

High glucose level - Beta cells of pancreas start secreting insulin, which stimulates fat cell to takein glucose from the blood.

From the graph given in experiment we can infer that -
In a healthy person, there exists an equiliribium between the glucose production and glucose consumption rate. If the insulin level is low and glucose level is high then it's the case of type 1 diabetes. For type 2 diabetes the insulin remains high but glucose level also remains high.

To check blood glucose A1C test is performed. It gives an average levels of blood glucose. A1C test is also called blood sugar.

10 Experiment-10

Saccade is the fast eye movement involving quickly movement of eye from one image to another. There are five types of eye movement -

- fast eye movements
- smooth pursuit eye movement
- vestibular ocular movements
- vergence eye movements
- optokinetic eye movements

Extra ocular muscles are responsible for movement and stability of eye. There are six extra ocular muscles ,they are - Medial Rectus, Lateral Rectus, Superior Rectus , Inferior Rectus, Superior Oblique, Inferior Oblique.

Muscles which moves eye in particular direction are known as agonist. The muscles which moves the eye in opposite direction of agonist is antagonist. Muscle which moves eye in same direction is called synergist. saccade is very quick movement of both eye betweeen two or more phase of fixation in the same direction. Since the gain margin from the bode plot is large, therefore the system is stable. K is the stiffness cofficient. When the value of stiffness cofficient (K) increases from 10 to 100 the value of steady state gain descreases from 0.1 to 0.001.

Peak velocity : is the maximum velocity gain during saccade.

Latency : It is the time taken by the CNS to provide signal to eyeball for the eye movement.

Bode plot : In bode plot we represent the frequency response of a system by two plots, gain curve and phase curve. Logarithmic scale is used to represent the gain curve and linear scale for phase curves.

Gain margin : GM = 0 - G dB. For calculating gain margin, we need to mark the frequency at which the phase is 180 degree, then mark the gain at the same frequency.