Industrial Automation and Robotics

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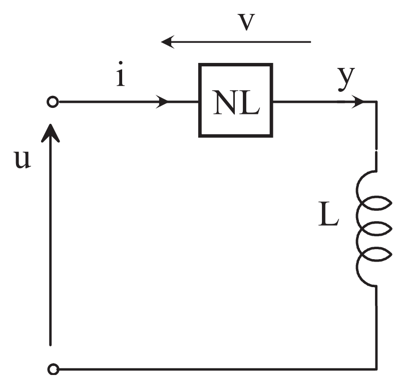
Warnings

- This file consists of **8** pages (including cover).
- During the exam you are not allowed to exit the room for any other reason than handing your work or withdrawing from the exam.
- You are not allowed to withdraw from the exam during the first 30 minutes.
- During the exam you are not allowed to consult books or any kind of notes.
- You are not allowed to use calculators with graphic display.
- Solutions and answers can be given **either in English or in Italian**.
- Solutions and answers must be given **exclusively in the reserved space**. Only in the case of corrections, or if the space is not sufficient, use the back of the front cover.
- The clarity and the order of the answers will be considered in the evaluation.
- At the end of the test you have to **hand this file only**. Every other sheet you may hand will not be taken into consideration.

EXERCISE 1

Consider the electrical network sketched in the picture:



where the nonlinear element NL enforces the following relation between the current i passing through it and the corresponding voltage v across it:

$$v = i^3$$

1. Write the equations of the dynamic system that describes the electrical network. Then, setting $L = 1$, identify the equilibrium point corresponding to the constant input $u = \bar{u} = 8$

2. Write the equations of the linearized system around the equilibrium state previously obtained and derive the expression of the corresponding transfer function.

3. Sketch the step response of the linearized system previously obtained.

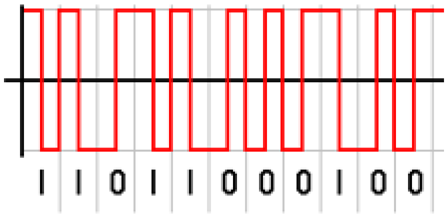
4. For the linearized system, suppose that an input $\delta u(t) = \sin(t)$ is assigned. Without going through the mathematical computations, explain how the expression of the output, after an initial transient, can be computed.

EXERCISE 2

1. Consider the Ladder Diagram programming language for PLCs. Explain what is a normal timer and how it works. How is this timer reset?

2. Consider now a drilling machine: when a **START** button is pressed, the drilling machine starts moving down (variable **GODOWN** is true) and the spindle (variable **SPINDLE**) is turned on. When the drill reaches a bottom position (variable **BOTTOM** is true) the machine stops its motion downwards (variable **GODOWN** is false), while the spindle is still on. The machine remains in such position for 10 s to make the hole, after which it moves upwards (variable **GOUP** is true). When the drill reaches an upper position (variable **UP** is true) it stops and the spindle is turned off. Program the system with a Ladder Diagram code.

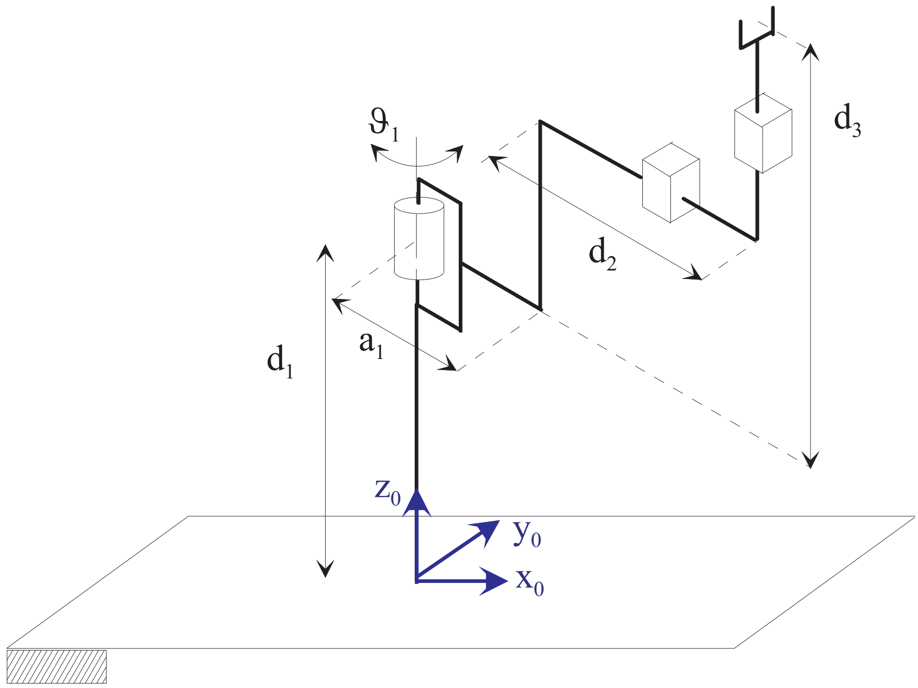
3. In a communication protocol for a digital network what are the elements defined by the physical layer? What type of line coding is represented in the following picture?



4. With reference to the medium access control, explain why the CSMA/CD protocol (used in Ethernet) is not suitable for real time applications, while the token bus (or token ring) is suitable.

EXERCISE 3

Consider the following robot manipulator with 3 joints (rotational, prismatic and prismatic):



1. Find the expression of the direct kinematics of the robot, in terms of the position coordinates of the end effector with respect to the joint variables ϑ_1, d_2, and d_3.

2. Explain what is a homogeneous transformation matrix. For the specific manipulator of this exercise, what is the expression of the fourth coloumn of the homogeneous transformation matrix from the frame 0 to a frame with origin at the end effector?

3. Write the expression of the Jacobian of the manipulator of this exercise.

4. Characterize the singularities of the manipulator of this exercise.