Title: **Automatic Control I: Basics of Computer Control**

Course: **Laboratory Experiments 4 (CSE411)**

Lab No.: **11** ***Category:*** **Automatic Control**

Date: **21/2/2023** ***Due:*** **27/2/2023** ***Time:*** **4 Hours**

Objectives:

1. To get familiar with FEEDBACK Co. Magnetic Levitation System.
2. To understand how the real-time kernel control for Mag Lev works.
3. To know the basics of digital and computer control systems.
4. To study how different types of controllers are implemented for Mag Lev system.

Hardware Requirements:

- ✓ Feedback 33-006 Magnetic Levitation System.
- ✓ PC.

Software Requirement:

- ✓ MATLAB R2018 or higher.
- ✓ Simulink.

Pre-lab:

1. What is a real-time system?
2. What are the basic blocks of a computer-controlled system?
3. How are analog controllers transformed into digital controllers?

Part 1: Mag Lev System Block Diagram:

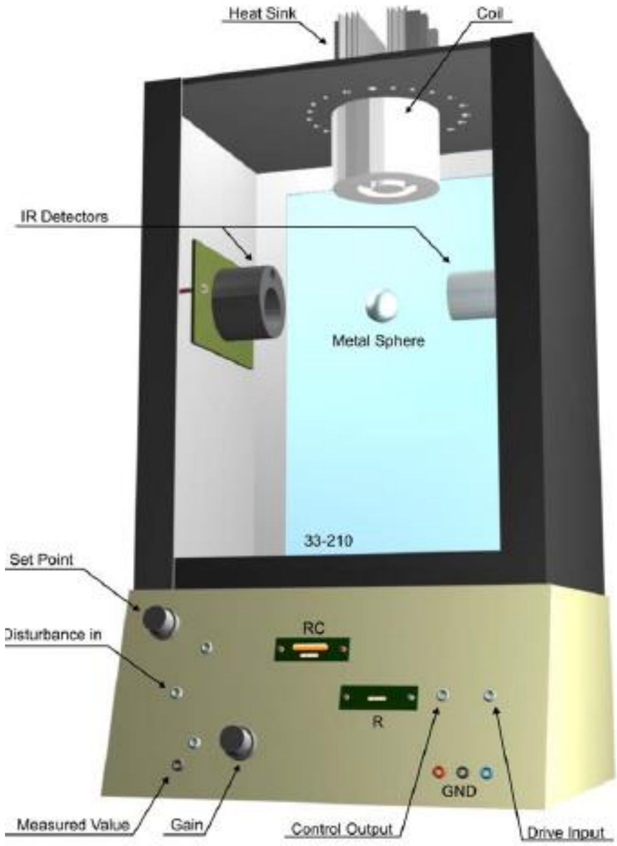

Figure 1 Mechanical Assembly of Magnetic Levitation System

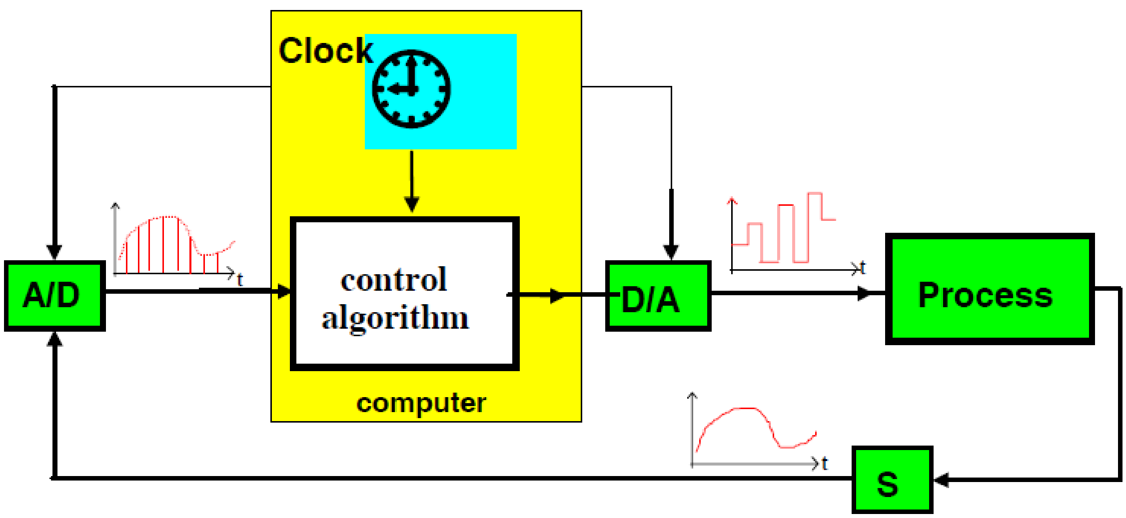

Figure 2 Mag Lev System Block Diagram

1. The system uses a digital computer to provide compensation.
2. The ball position signal provided by the infrared sensors is converted to a digital signal by A/D.
3. The computer receives the digitized signal and processes an error between this and the desired signal from MATLAB.

4. The clock supplies a pulse every T_0 seconds, and the A/D converter sends a number to the computer every time an interrupt arrives.
5. The time between successive conversions of the signal to digital form is called the sampling period (T_0).
6. The error is passed to the control algorithm (e.g. PID) to provide a control signal.
7. The control algorithm and the conversion operation are controlled by the software clock.
8. The control algorithm computes the value of the control variable and sends it as a number to the D/A converter.
9. The control signal is converted back to analog form using D/A.

Part 2: Real-Time Task of Mag Lev System:

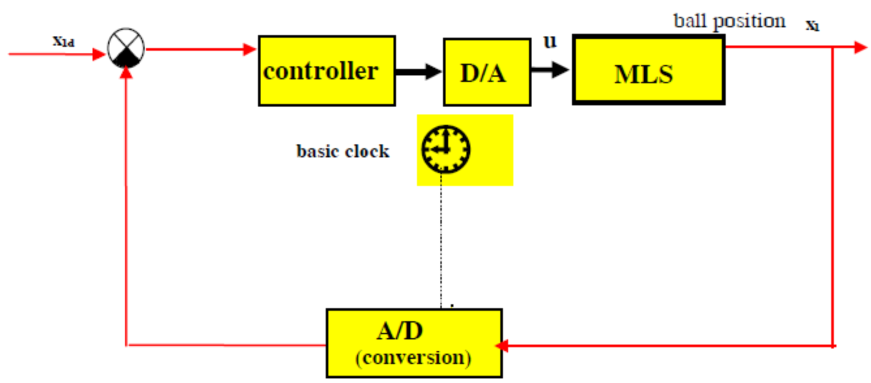

Figure 3 Sytem Software Clock Operation

1. A software timer is used to supply interrupts for the system. The basic clock activates the periodic sampling of analogue-to-digital (A/D) conversion and synchronizes the computation of controller outputs (u) and periodic digital-to-analogue (D/A) conversion as in Figure 3.
2. The Magnetic Levitation System is controlled in real-time. **"Real-time is an operating mode of a computer system in which the programs for the processing of data arriving from peripherals are permanently ready, so that their results will be available within predetermined periods of time. The arrival times of the data can be randomly distributed or be already determined depending on the different applications."**
3. The real-time software Mag Lev system is structured around particular internal signals (events) into a set of tasks. Each task implements the processing required by a corresponding event.

4. A task scheduler recognizes the events and activates or suspends the tasks. In the simplest case, when all tasks require processing at the same frequency, a sequential organization of the tasks can be implemented.
5. The time frame of each task is fixed. It is assumed that the longest task job takes no longer than the period of time generated by the software timer. (Figure 4)
6. A list of real-time tasks creating an environment suitable for developing digital controllers for the Magnetic Levitation System is given in Table 1.

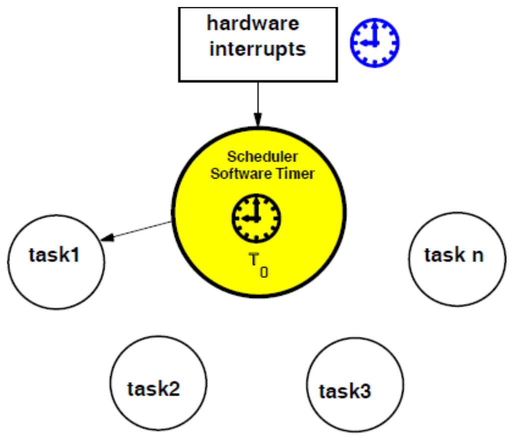

Figure 4 System Task Scheduler

Table 1 Tasks of Controller Software

Data Acquisition Task	Reads analogue and digital inputs from all input lines.
Control Task	Calculates the control output.
Output Task	Transfers the controls to the output devices.
Communication Task	Transmits the shared data between RTK and MATLAB.
Self-diagnostic Task	Checks the operation of the scheduler.

7. Real-time tasks and the task scheduler are organized in the form of a real-time kernel (RTK) which supervises the set of real-time tasks. Several control algorithms can be embedded in the real-time kernel activated by a hardware clock.
8. Two levels of priority are determined: higher priority for real-time tasks and lower priority for MS-Windows tasks.
9. When RTK tasks are performed, the code allocation mechanism of MS-Windows is blocked. Time slots available between the processing of higher priority tasks are used for tasks of lower priority.

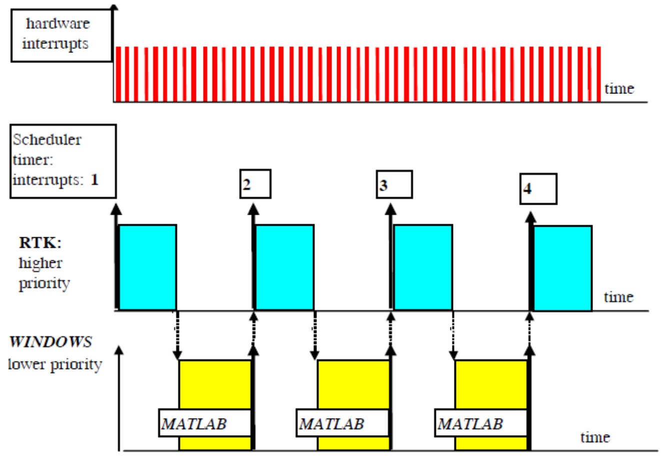

Figure 5 Real-Time Task Priority

Part 3: Compare PID and Tustin Digital Filter Performance:

1. The Simulink model logs data in a 6-row matrix 'Hist' that stores data as follows:

Table 2 Signal Information Format

`Hist (:,1)`	Time instants.
`Hist (:,2)`	Ball position.
`Hist (:,3)`	Velocity computed from the ball position.
`Hist (:,4)`	Second ADC input signal (coil current, control signal, ...).
`Hist (:,5)`	Computed control variable.
`Hist (:,6)`	Computed desired reference.

2. Compare the time domain performance for both controllers.

Assignment (On Lab):

1. For the provided data of the PID controller, plot the ball position vs. the desired reference. In addition, plot the control variable. Mention your comments.
2. Repeat for the Tustin controller.

Technical References:

1. Magnetic Levitation System; Getting Started: 33-006. Feedback Instruments.
2. Magnetic Levitation Control Experiments 33-942S. Feedback Instruments.
3. Modeling and Control of a Magnetic Levitation System. Marwan K. Abbadi and Winfred Anakwa.