Experiment no. 6

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Date:

Attestation:

AIM:

1. Study of :
    a. Auto-tuning.
    b. Proof of Recursive Least Square Algorithm.
    c. Constrained Optimisation.
    d. Model Reduction.
2. Parameter Estimation using INSTACAL data acquisition software and system identification toolbox of MATLAB.

Software used: MATLAB

Theory, Procedure and Results

c. Constrained Optimisation:

In mathematical optimization, constrained optimization (in some contexts called constraint optimization) is the process of optimizing an objective function with respect to some variables in the presence of constraints on those variables. The objective function is either a cost function or energy function which is to be minimized, or a reward function or utility function, which is to be maximized. Constraints can be either hard constraints which set conditions for the variables that are required to be satisfied, or soft constraints which have some variable values that are penalized in the objective function if, and based on the extent that, the conditions on the variables are not satisfied.

We will look at an example,

Example :

A manufacturer wants to maximize the volume of the material stored in a circular tank subject to condition that the material used for the tank is constant,

$$A_0 = \frac{2\pi d^2}{4} + \pi d h$$

We aim to maximize: V(d,h), and Ao is given.

a. Auto-tuning:

This method is not carried out continuously but is only done when the operator feels that the current set of tuning parameters is not performing well.

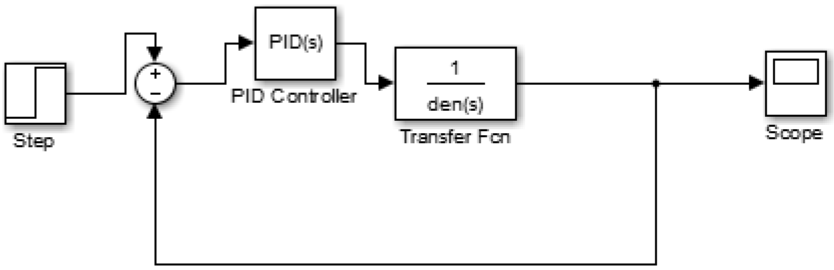
There are two parameters that play a very important role in Auto-tuning of a PID controller:
1. Ultimate Gain.
2. Ultimate Frequency/Period.

$$\text{Ultimate Gain} = K_u = \frac{1}{M}$$

$$\text{Ultimate Period} = P_u = \frac{2\pi}{\omega_{co}}$$

M = Gain.

Here is the block diagram of a PID auto-tuning experiment conducted:

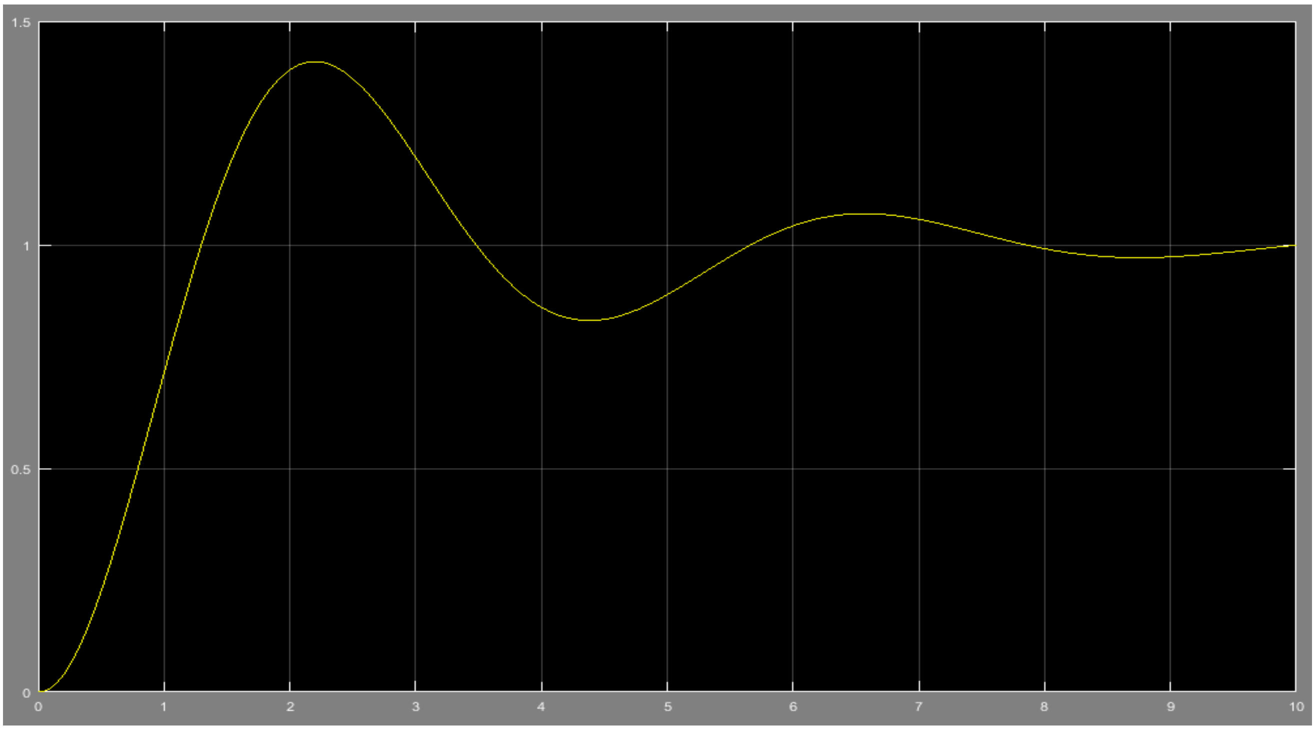


We find the gain and phase crossover frequency of the transfer function using the ***margin*** command.

Then we tune the parameters using the Z-N tuning methods.

The given T.F is $\frac{1}{(s+1)^3}$.

The response is as follows:

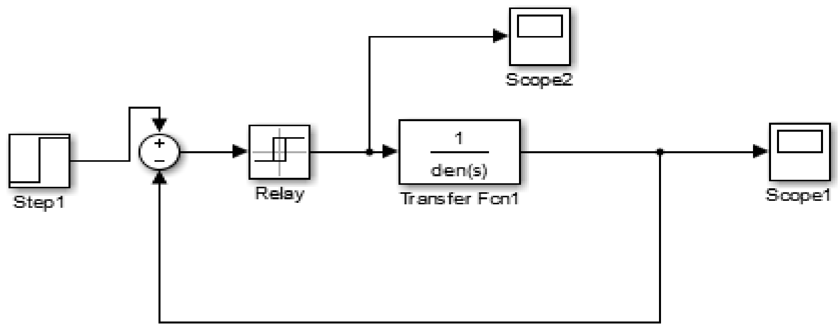


Relay Feedback Method:

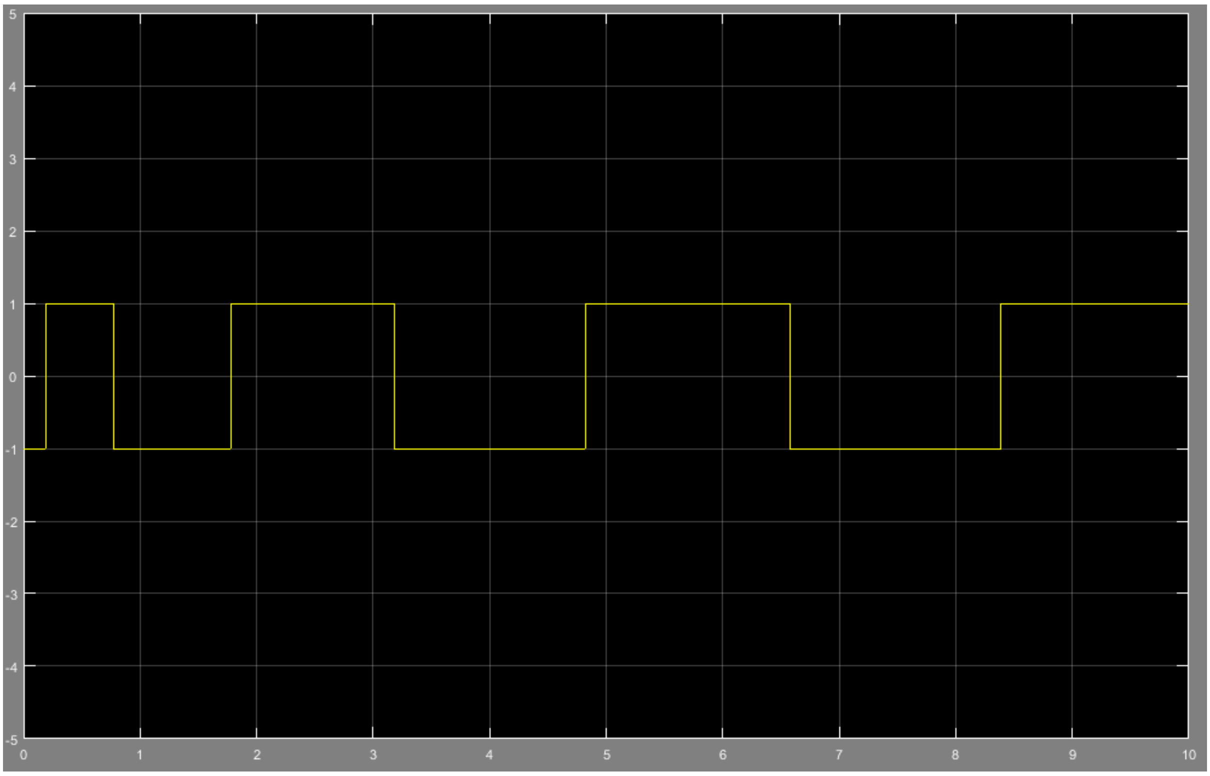
The only significance of this method is, it is simple and avoids tedious methods to find the constants used in Z-N tuning methods.
In fact the ZN tuning scheme, where the controller gain is experimentally determined to just bring the plant to the brink of instability is a form of model identification. All tuning schemes contain a model identification component, but the more popular ones just streamline and disguise that part better. The entire tedious procedure of trial and error is simply to establish the value of the gain that introduces half a cycle delay when operating under feedback. This is known as the ultimate gain Ku and is related to the point where the Nyquist curve of the plant first cuts the real axis. The problem is of course, is that we rarely have the luxury of the Nyquist curve on the factory floor, hence the experimentation required.

A relay is basically an electromagnetic switch.

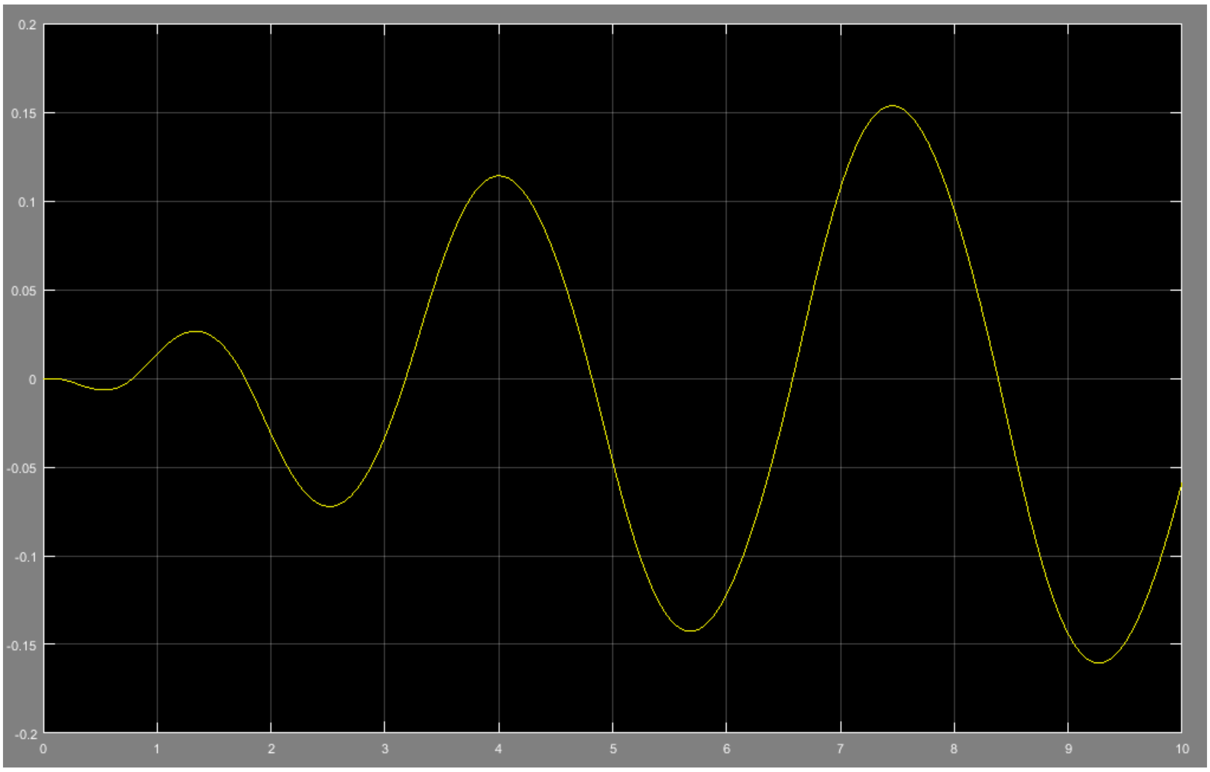
The basic block diagram of the relay feedback model is as follows:



Once we run the simulation. We can see that the relay has the following output:



The plant output is:



The amplitude is the ***2a*** value used in finding the ultimate gain as follows:

$$k_u = \frac{4d}{\pi a}$$

The ***d*** is found from the relay output. Same as above, the relay output amplitude is ***2d***.

b. Proof of Recursive Least Squares Algorithm (Exploring its connection to Kalman Filtering):

d. Model Reduction:

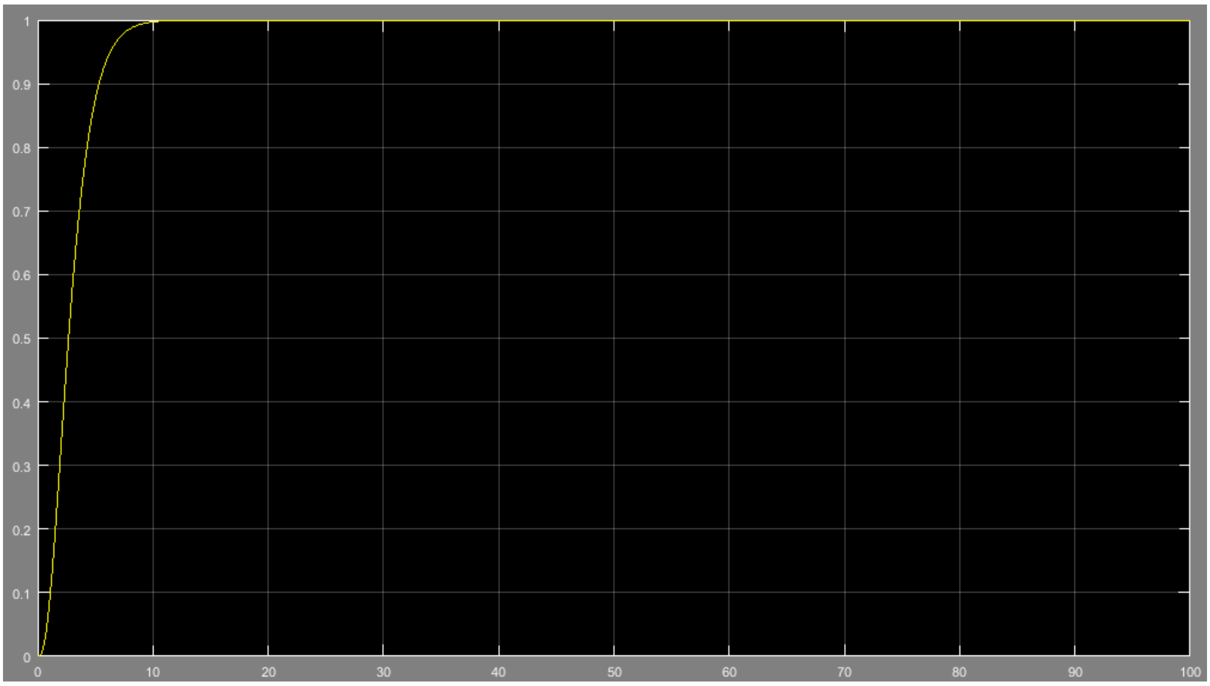
When analyzing and controlling large-scale systems, it is extremely important to develop efficient modeling processes. The key dynamic elements must be identified and spurious dynamic elements eliminated. This allows the controls engineer to implement the optimal control strategy for the problem at hand. Model reduction techniques provide an extremely effective way to address this requirement.

Some control system design methods require the use of all of the system's states. Without the use of model reduction techniques the full state control system design would be too large to practically implement. States that would be included within the controller might also be outside the bandwidth of the servos or actuators. This might generate an ill-conditioned problem. The use of model reduction methods provides a way to generate full state controller solutions of reduced size, and to further simplify these full state feedback solutions once they have been generated.

We use the concept of IMC to tackle this problem.
We are given a 3rd order transfer function.
Then we do the parameter estimation and find the corresponding FOPTD process.

Given TF = $\frac{1}{(s+1)^3}$;   FOPTD process = $\frac{1}{1.76s+1}\,e^{1.36}$.

The output of the actual TF is as follows:



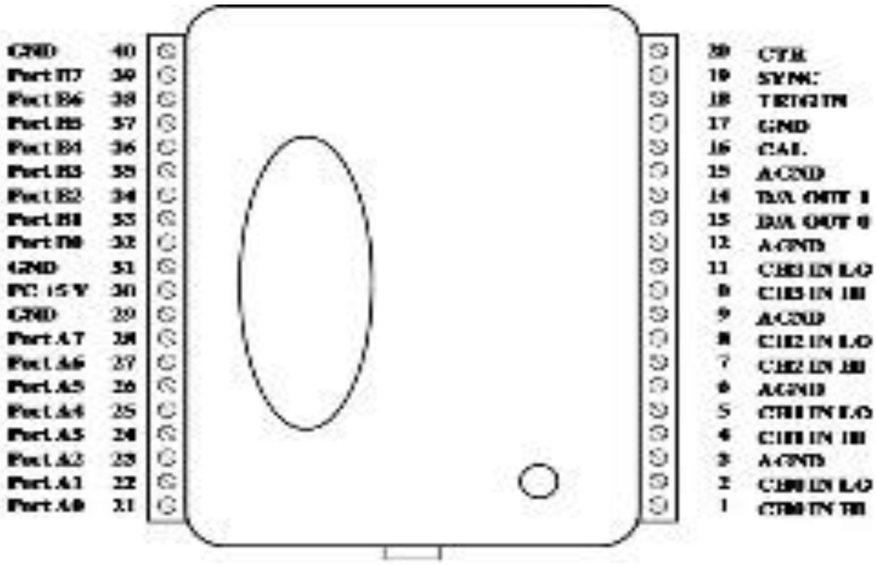
The output of the corresponding reduced model is:

Both the responses are very close to each other.

2. Parameter Estimation using INSTACAL and MATLAB:

We use USB 1208FS. It’s a low cost, usb based DAQ module with 12 bit input.

The Pin diagram is as follows:



This is a DAQ device used with the MATLAB data acquisition toolbox.
In our experiment we use a simple RC circuit and try to find the parameters R and C using MATLAB.

The parameters were already known, the only aim was to find the transfer function.

We feed a slowly increasing potential across the network and note the reading in real time.

The output was taken across the Capacitor, thus it is a low pass filter. Therefore the transfer function will be:

$$G(s) = \frac{1}{RCs + 1}$$

We were given, R = 10 kOhms.
C = 0.1 micro-farad.

After estimation we found that the transfer function was :

$$G(s) = \frac{1}{0.00121s+1}.$$

Inferences:

1. The Ziegler-Nichols method uses a closed controller loop & requires the following steps: Bring system to steady state operation. Put on P control. Introduce a set point change and vary gain until system oscillates continuously. This frequency is ω and M is the amplitude ratio.
2. In Relay Feedback method, the advantages are: We avoid a tedious trial and error search for the ultimate gain. We avoid operating near the instability limit. The procedure is easy to automate.
3. RLS algorithm is one of the most popular methods used because of its simplicity of use and speed of convergence.
4. We use the model reduction model to reduce the complexity of the model and mode it in real time without stressing the plant for Gain and other parameters.