Bouncing Ball Experiment
Operating Instructions

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Introduction:

The Bouncing Ball Experiment is a precision electromechanical instrument for investigating nonlinear dynamics. A piston in the base of the instrument moves in response to a command waveform (typically a sine wave). An elastic ball bounces on the piston and exhibits a surprisingly wide range of dynamic behaviors. For example, resonance, sub-harmonic resonance, and chaos are all observable even though the model is extremely simple. The piston is actuated with a vertical linear motor, and the ball is constrained by a teflon bushing to move on a stainless steel rod.

A high-resolution eddy current sensor is used to measure the piston position for monitoring and feedback through an internal high bandwidth PD controller. The user can augment or replace the internal controller with an external controller through easy-to-use BNC connections and front panel controls. In addition, an acoustic pick-up embedded in the piston reliably detects impacts of the ball on the piston. This impact detector can be used to construct Poincare maps, nonlinear observers, and feedback controllers.

System Specifications:

- External Controller Capability
- Internal High Bandwidth PD Controller
- High-Resolution Eddy Current Sensor
- Reference Control BNC Input
- Multiple Control BNC Outputs
- Open/Closed Loop Capability
- Acoustic Ball Piston Impact Detector used to Construct Poincare Maps, Nonlinear Observers, and Feedback Controllers

Coil Specifications:

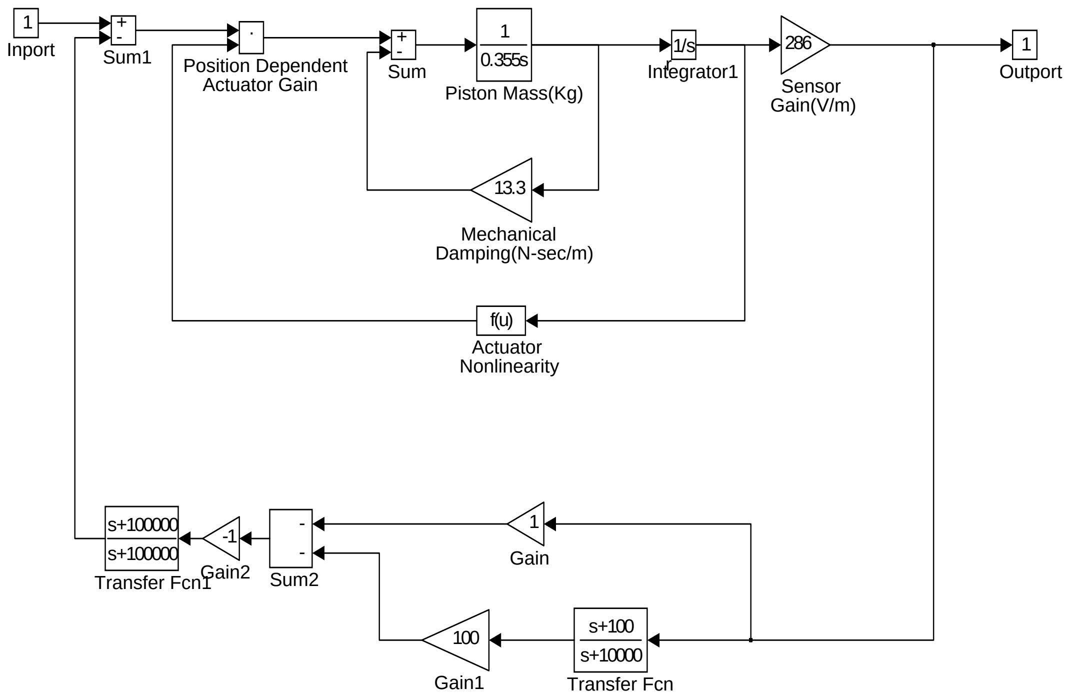
- Resistance of Coil: 6.31 Ohms
- Inductance of Coil: 3.7 mH
- Number of Layers: 8
- Number of turns: 75±4

AC Adapter:

- Input : 100-240V ~1.5A 50-60Hz
- Output : 18VDC ~ 3.9A

System Parameters:

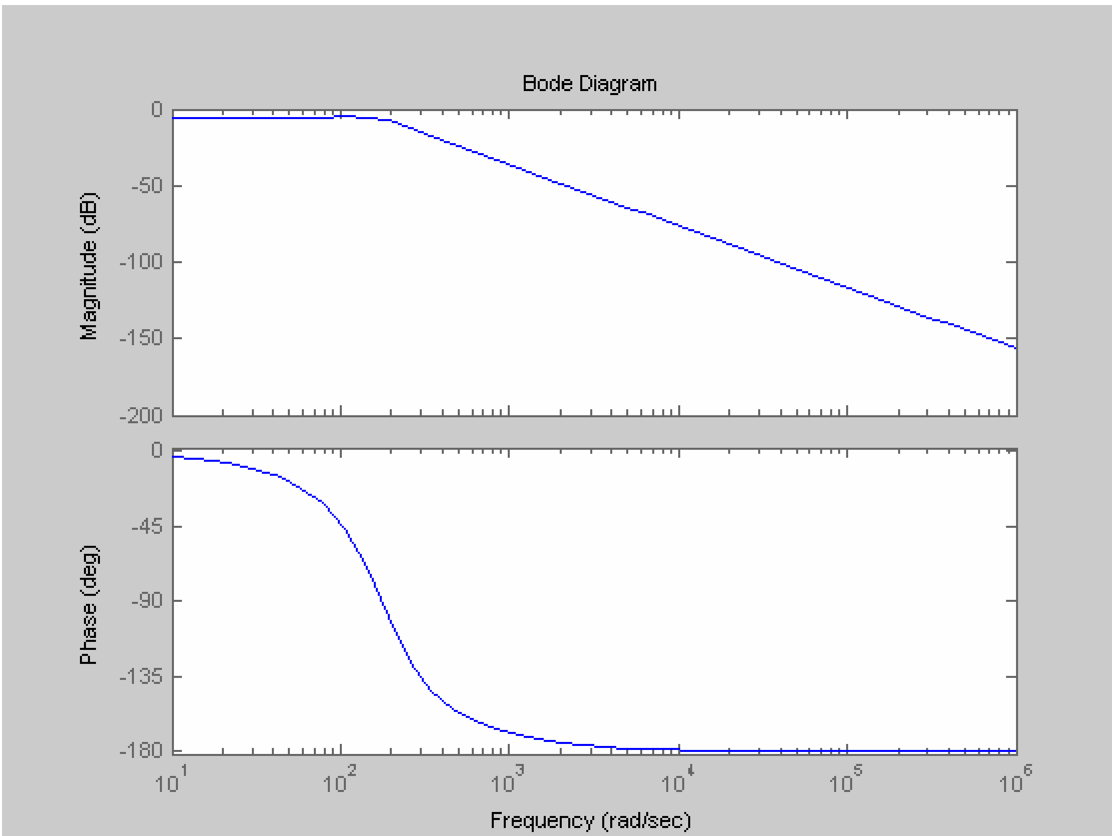
This section provides a system model of the Bouncing Ball Experiment. This model was developed using MATLAB-Simulink.



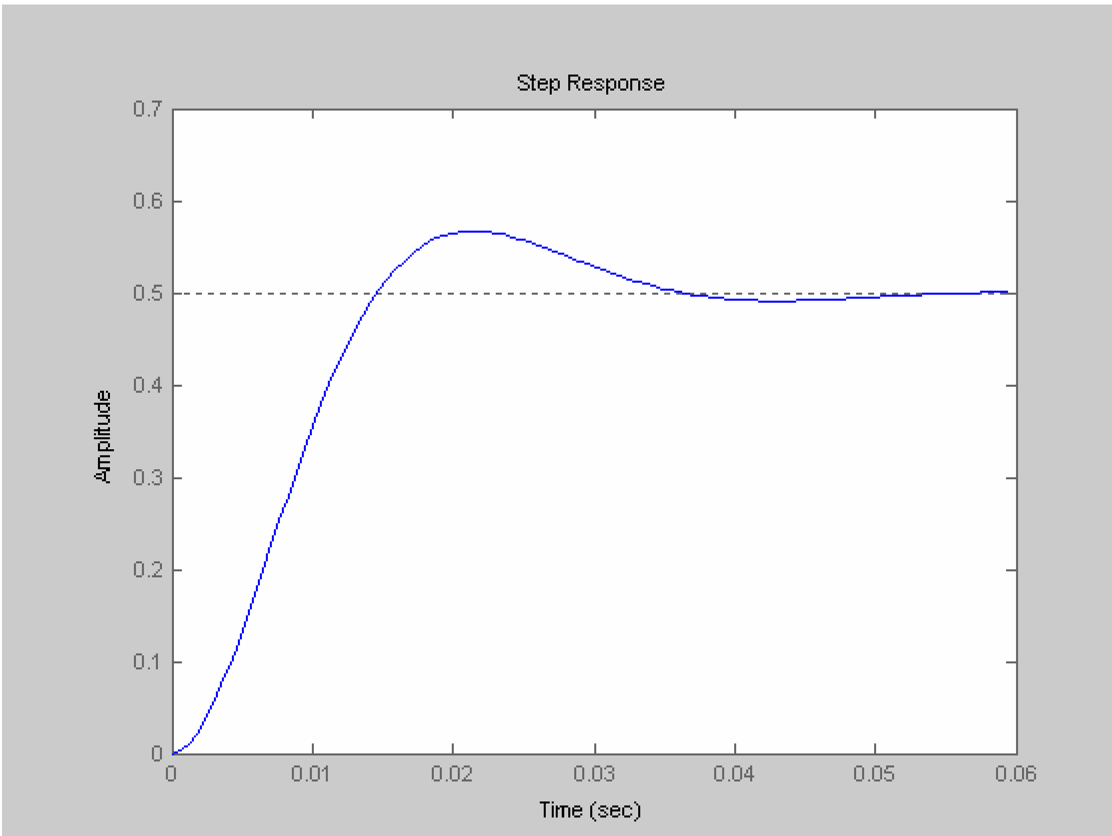
Block Diagram of the Bouncing Ball Experiment

The bouncing ball on a sinusoidally vibrating piston has become a classical nonlinear dynamical system. Although described by extremely simple evolution equations, the bouncing ball exhibits stable and unstable periodic motion, period doubling, and Smale horseshoes. Moreover, the experiment is useful in understanding the effect of approximations made in deriving the idealized dynamics.

The following figure provides the frequency response of the piston motion in response to a reference input. The plots provide system characteristics such as bandwidth, gain and phase margins, and closed-loop stability of the system.



This next figure provides the step response (time domain transient behavior) of the piston. Again, the plot provides system characteristics such as rise time, settling time and the steady state error of the closed loop system.



Recommended Readings

1. T. L. Vincent, A.I. Mees, Controlling a Bouncing Ball, Int. J. of Bifurcation and Chaos, 10, No. 3, pp. 579-592 , 2000

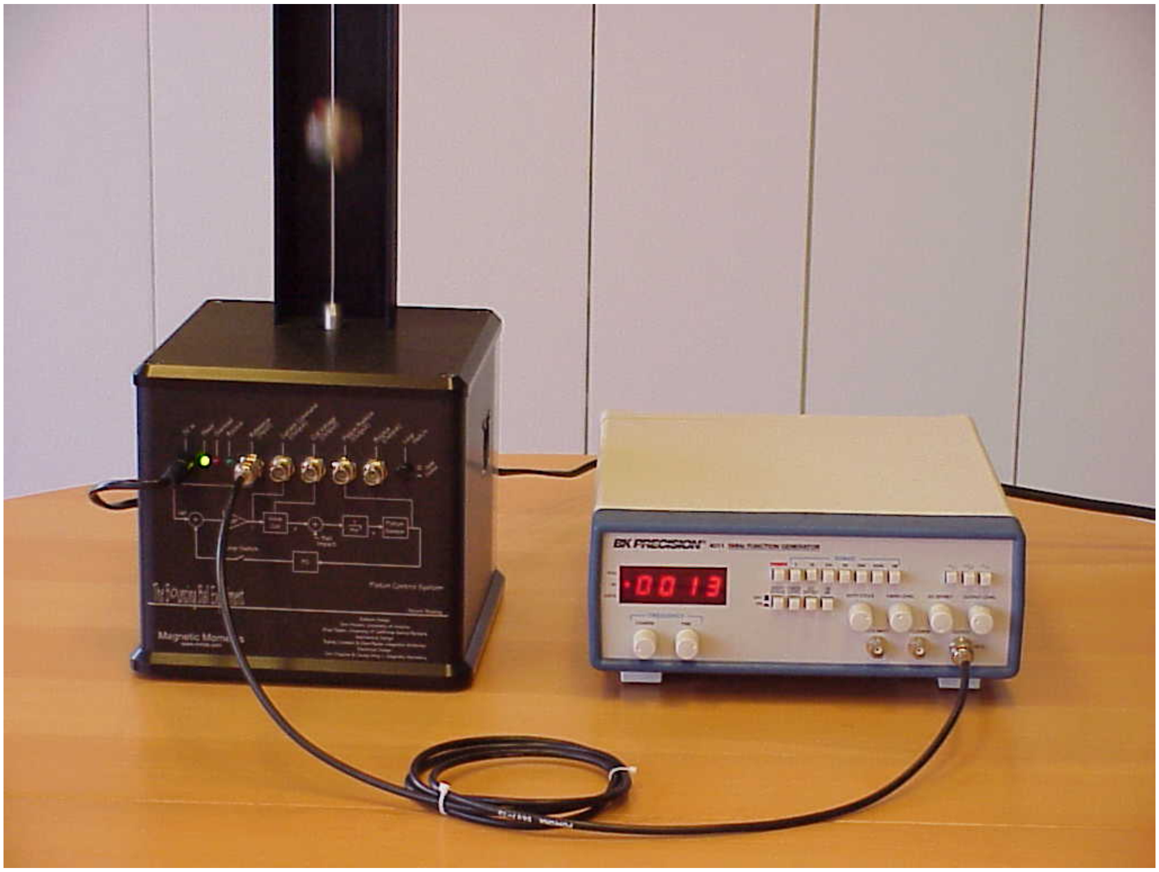
2. J. Ghosh and B. Paden, Control of 2-periodic motion for bouncing ball using frequency modulation, Proceedings of the American Control Conference, San Diego, CA, pp. 4048-4050, June 1999.

3. T. L. Vincent, Control Using Chaos, IEEE Control Systems 17: pp. 65-76, 1997.

4. J. Guckenheimer and P. Holmes, Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields, Applied Mathematical Science No. 42, Springer Verlag, New York, Heidelberg, Berlin 1992.

5. Z. Kowalik, M. Franaszek and P. Pieranski, Self-reanimating chaos in the bouncing ball system. Phys. Rev. A 37, 4016 1988.

6. P. Pieranski, Direct evidence for the suppression of period doubling in the bouncing ball model. Phys. Rev. A 37, 1782, 1988.



Setup Procedure for Sinusoidal Piston Motion:

Interconnect the unit and test equipment as shown in the above figure.

1. Connect the AC adapter to the “DC In” input of the front panel.
2. Plug the power cord to a 50-60 Hz power source.
3. Close the “Loop Switch”
4. Verify that the green power indicator is on.
5. Prior to connecting the Function Generator adjust the frequency between 10 and 15 Hz with minimum amplitude.
6. Turn “OFF” the power of the Function Generator.
7. Connect the output of the Function Generator to the “Reference Input” located in the front panel of the Bouncing Ball Experiment.
8. Turn “ON” the power of the Function Generator.
9. Gradually adjust the amplitude of the Function Generator for a desired bounce.
10. Notice the elastic ball bouncing on the piston exhibiting a wide range of dynamic behaviors