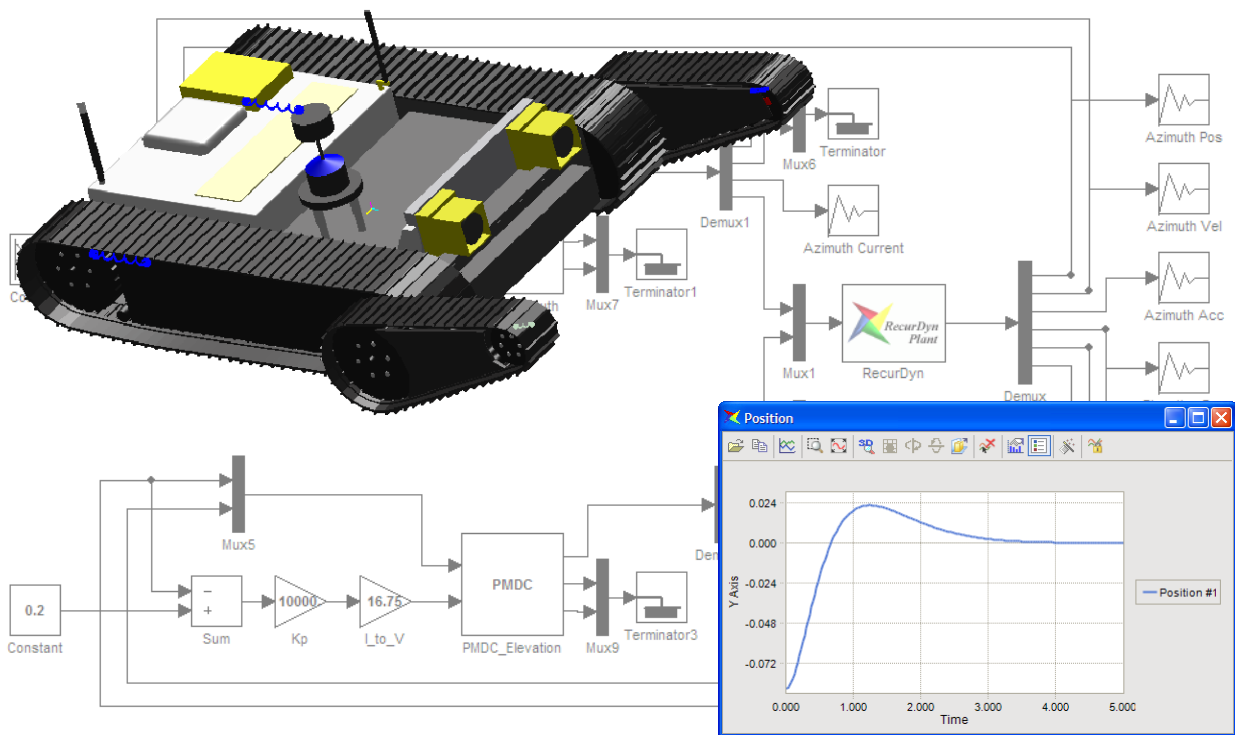


# Simulating Computer-Controlled Multibody Dynamic Systems



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# Problems with Simulating Mechanical and Control Systems Separately

Today’s increasingly sophisticated products often consist of a mechanical system controlled by a microprocessor-based control system. But creating virtual prototypes of these products using traditional simulation approaches is difficult for various reasons. Typically, a mechanical engineer can develop a good mechanical model using Multibody Dynamics (MBD) simulation software, but including an over-simplified control scheme in the model yields useless results. Meanwhile, a controls engineer can design a controller using control systems modeling software, but without a realistic model of the plant (the mechanical system), the controller design will be poor.

Recently, however, new technology has been created which allows simulation of both complex nonlinear mechanical systems and their controllers together. With this new technology, the control system designers can efficiently test pre-developed control algorithms at an early design stage with highly nonlinear dynamic models. And mechanical engineers can quickly simulate their models using the developed control systems before costly prototypes are built. To simplify the workflow, both types of engineers can make changes to separate parts of the same model.

## Overview of an Integrated Solution

Practically all control systems that are implemented today are based on computer control. A computer-controlled system can be described schematically as shown in Figure 1. Outputs from the plant are continuous time signals and are converted into digital signals with analog-to-digital (A-D) converters. The conversion process is performed and controlled by the chosen sampling time. The system computer interprets the converted signals, processes the measurements using a control algorithm, and outputs new digital signals. The generated signals from the control algorithm are converted back into analog signals for plant input by a digital-analog (D-A) converter. The real time clock in the computer synchronizes all these events.

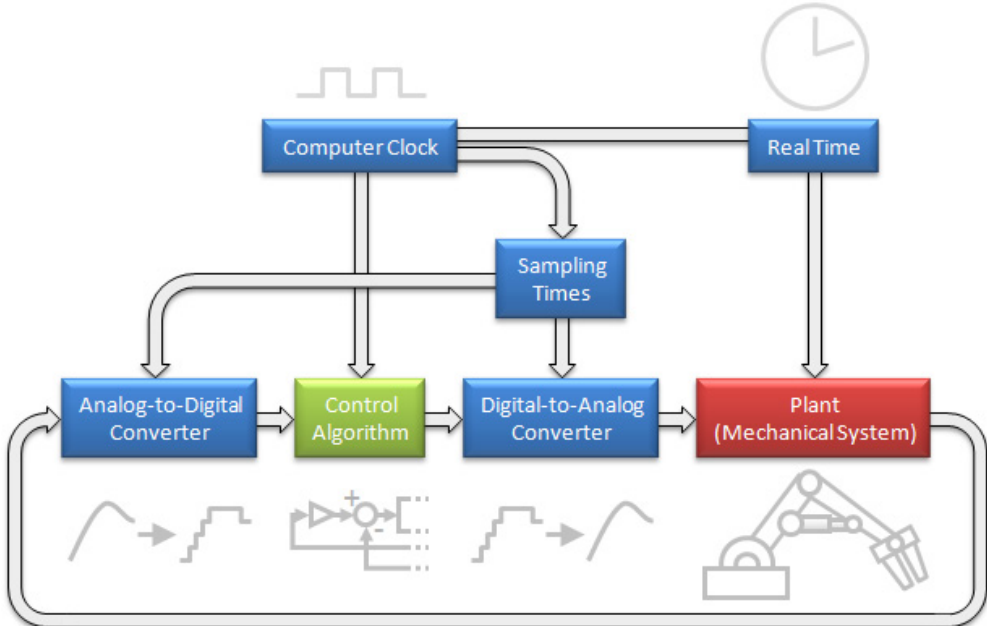


Figure 1: Schematic diagram of a computer-controlled system.

With new simulation technology, the above system can be simulated. In one approach, the control algorithm can be easily designed by control design application software and the plant can be constructed by multibody dynamics (MBD) simulation software. An interface toolkit is required to communicate between the control system design and MBD simulation software. The schematic diagram of this approach is shown in Figure 2. During the co-simulation between the MBD simulation software and the control system design software, the result outputs from each tool are passed to the other at a constant sampling time. Thus the outputs from the MBD simulation software are assumed to remain at the same value during the sampling period.

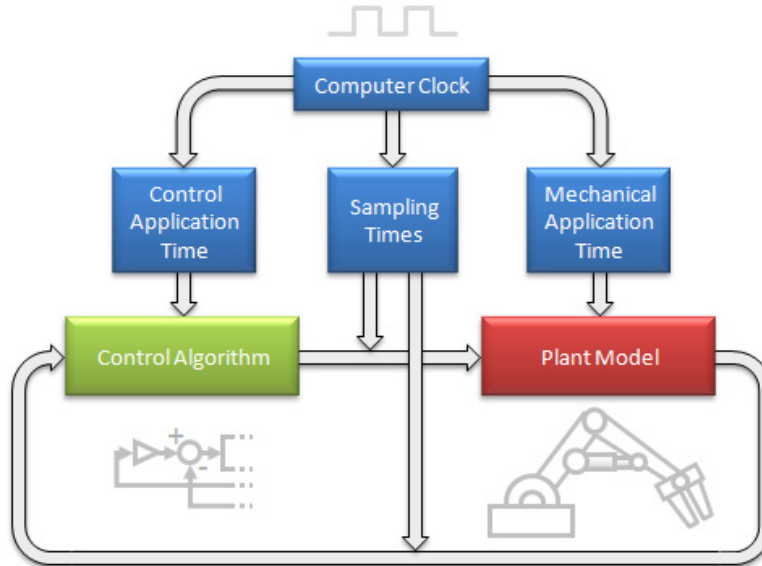


Figure 2: Schematic diagram of simulation approach.

## A Simple but Illustrative Example: Balancing an Inverted Pendulum

A classic example which a control system can be applied to is the inverted pendulum. Shown below is the model which will be used for this example. The pendulum is mounted on the base with a revolute joint, and the base slides sideways. An axial force is applied to the base. The control system will control this axial force in order to keep the pendulum upright.

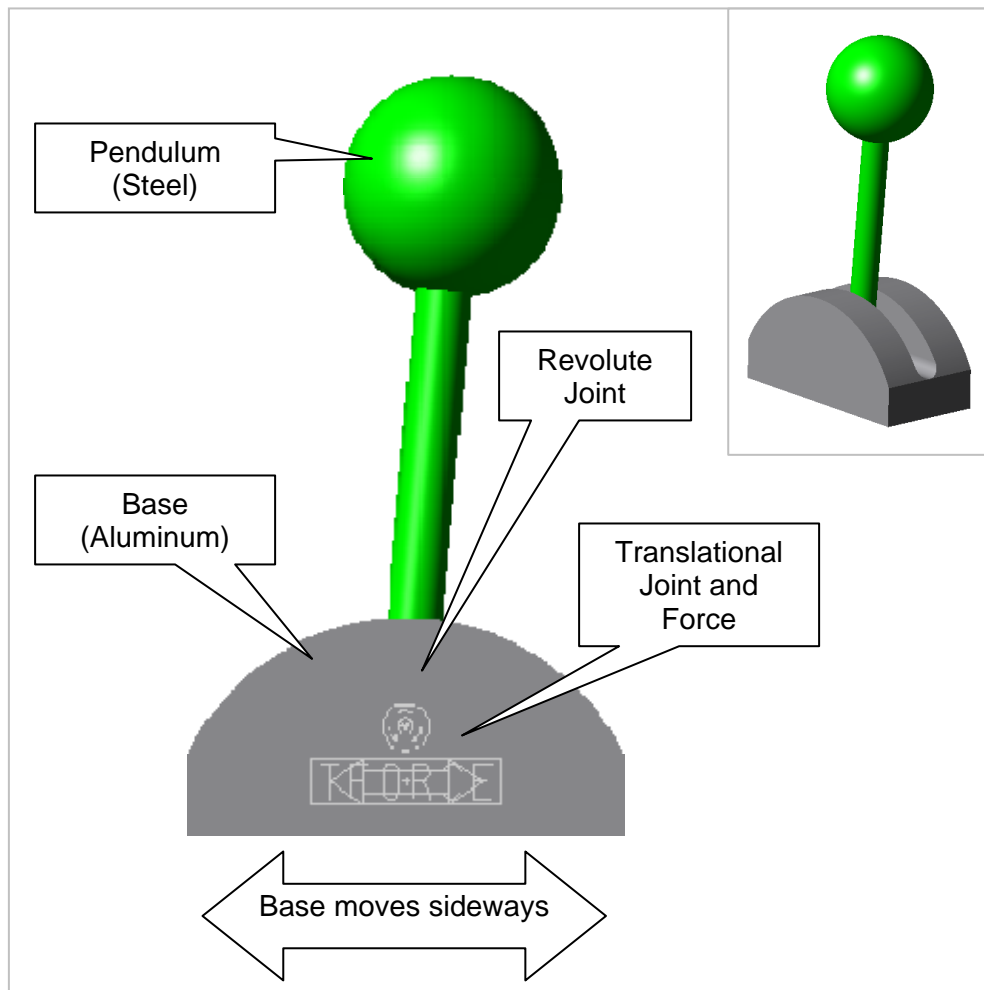


Figure 3: Inverted catapult model used in this example.

The pendulum starts offset at a 5 degree angle (from vertical) to perturb the system. The model will be simulated for 5 seconds.

## Initial Simulation: No Control

The initial simulation of the pendulum shows that without any control system (zero force applied), the pendulum simply falls under the influence of gravity.

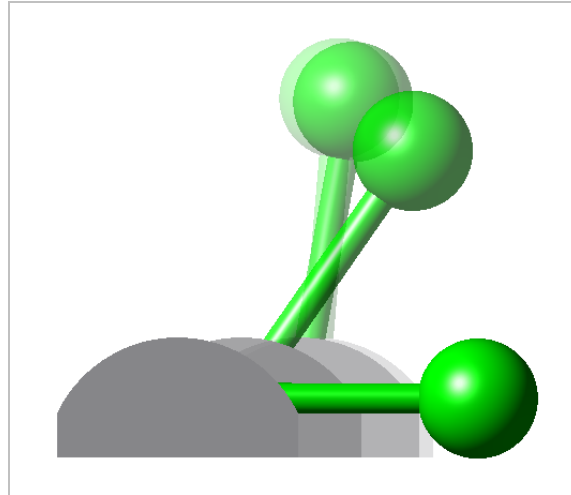


Figure 4: Pendulum with no control.

## Proportional Control

A Proportional (P) control system was then created to interact with the mechanical system, or “plant”. The inputs and outputs to and from the plant are shown below.

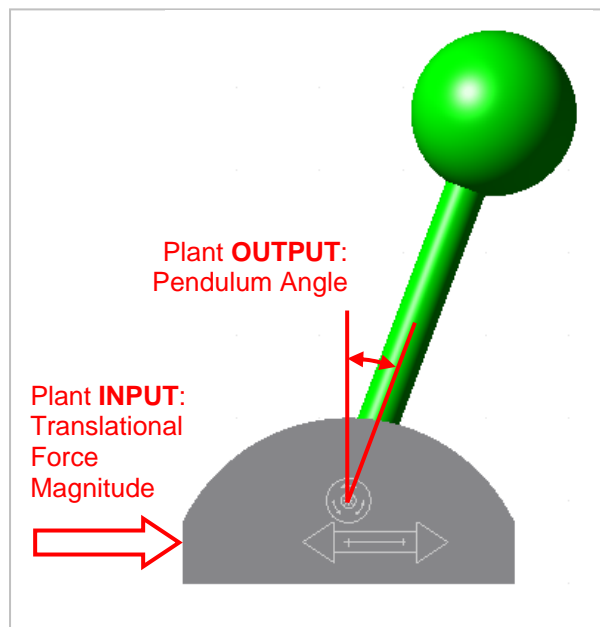


Figure 5: Definition of plant inputs and outputs used to communicate with the control system.

Shown below is the P control system used for the simulation, as well as the results. The P control system is able to keep the pendulum upright. However the pendulum never stays in the upright position, oscillating from side to side with little attenuation.

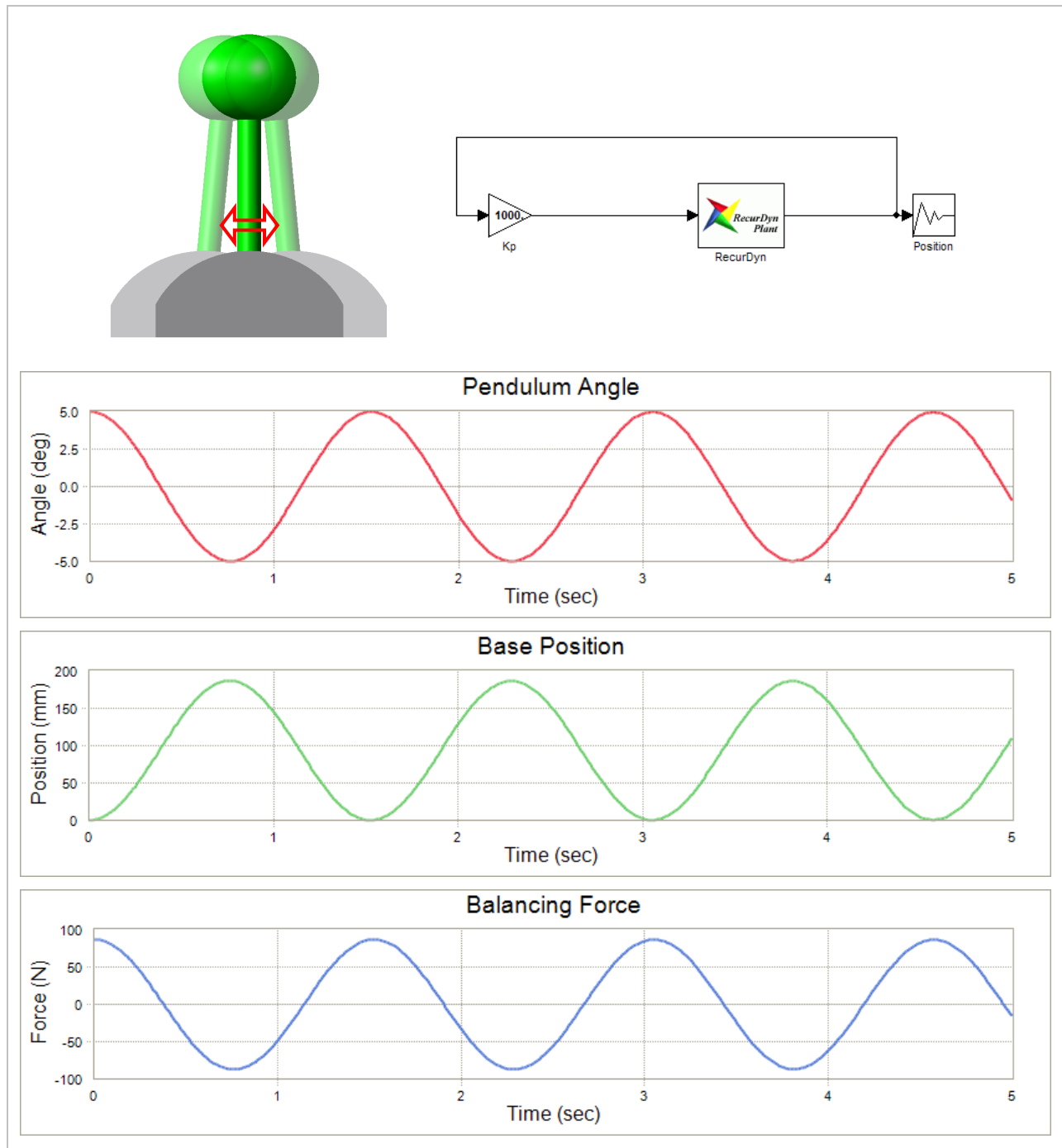


Figure 6: P control system and results.

## Proportional-Derivative Control

To alleviate the oscillation of the pendulum, the P control system was modified to include derivative control. The resulting Proportional-Derivative (PD) control system is shown below (an additional plant output, the angular velocity of the pendulum, was added to enable the derivative control loop to be added.).

The results, below, show that the pendulum with PD control no longer oscillates as before. However, the entire system drifts to the right in order to maintain an upright position.

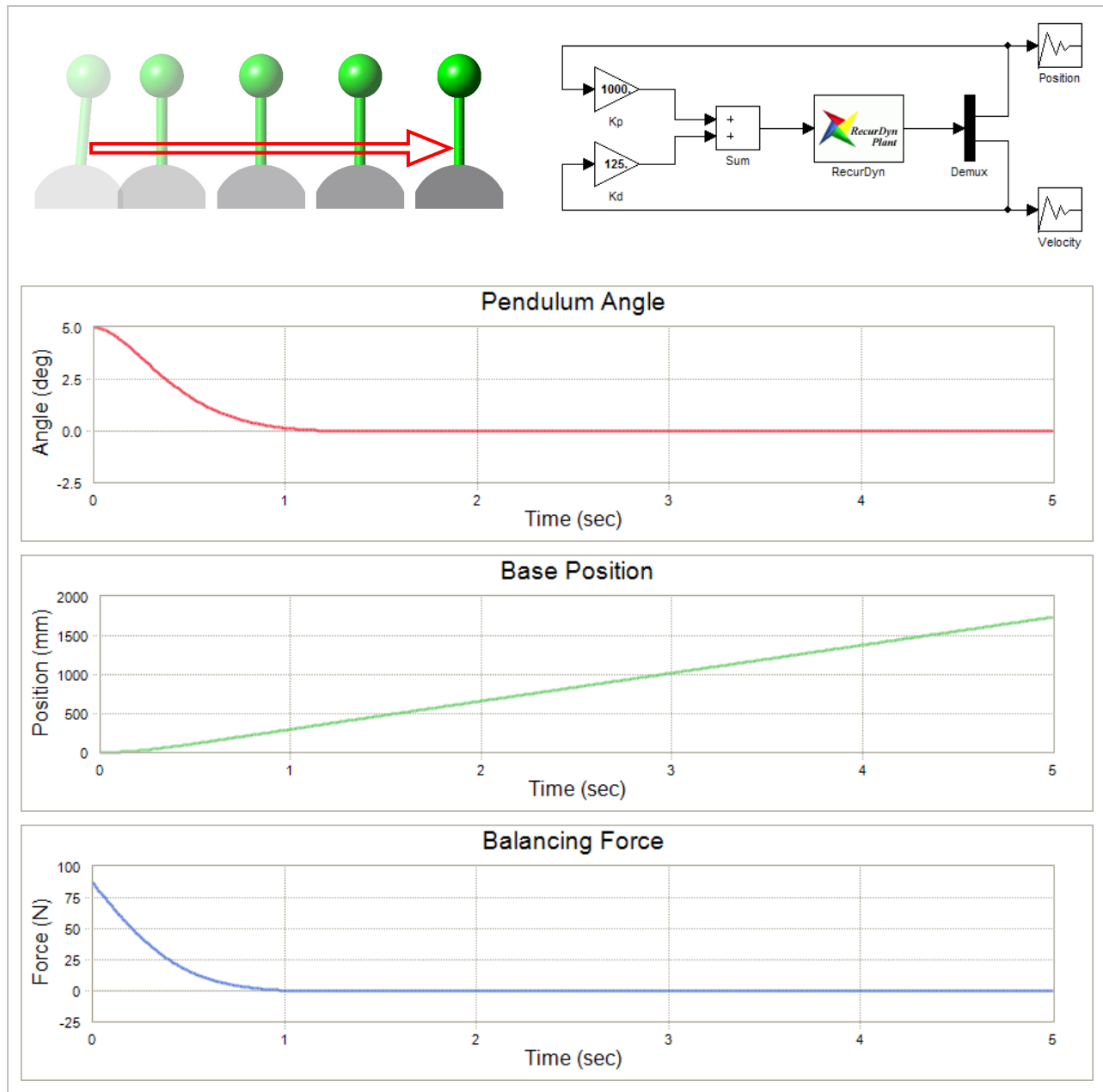


Figure 7: PD control system and results.

## Proportional-Integral-Derivative Control

To get rid of the drifting problem seen with the PD control system, an Integral control loop was added to create a Proportional-Integral-Derivative (PID) control system, as shown below.

The performance of the PID control improved. Although there is some overshoot in the angle of the pendulum, it settles into a maintained upright position. And the base approaches a standstill instead of drifting off as before.

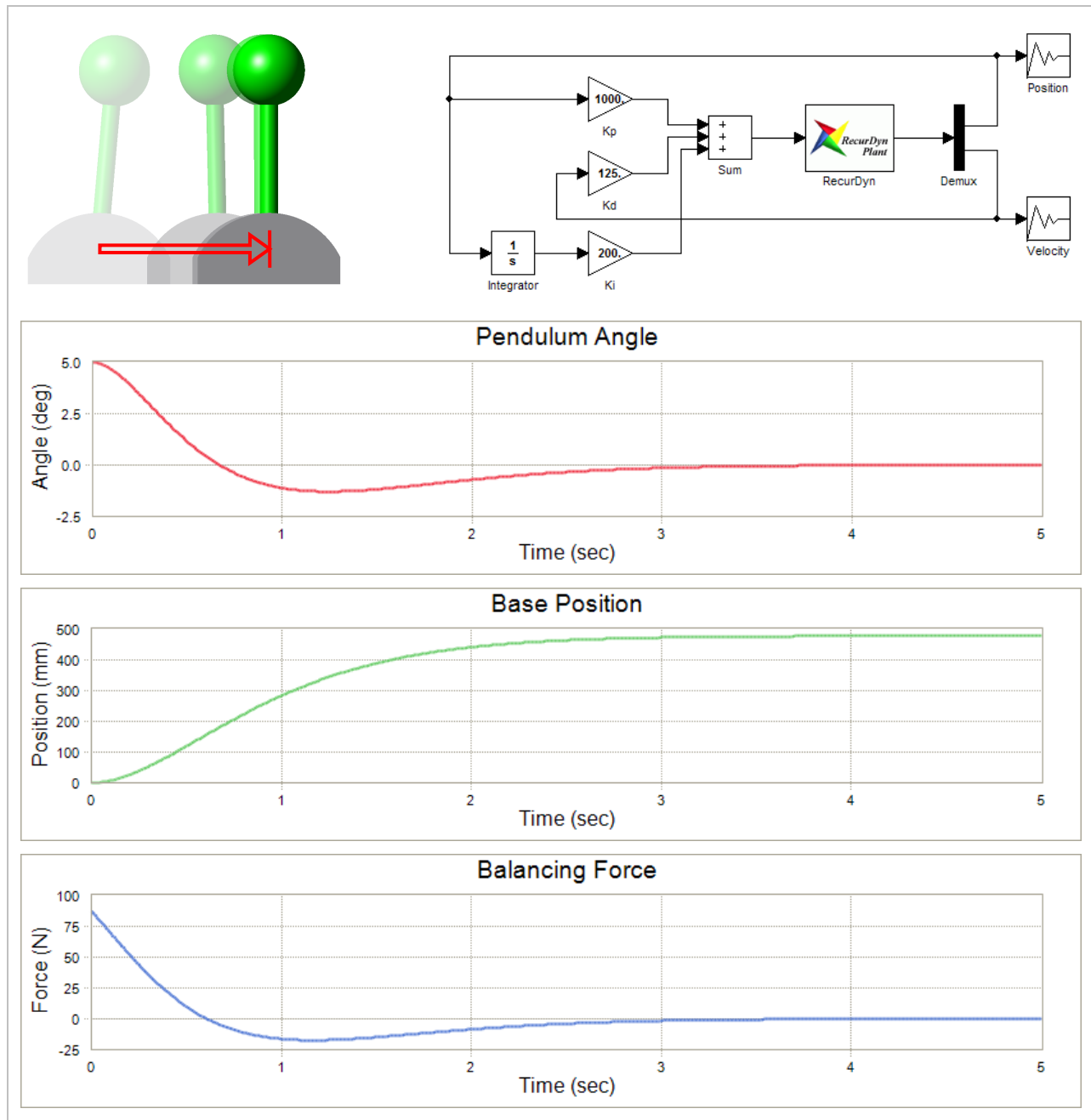


Figure 8: PID control system and results.



## Conclusion

The results from the simulation of this simple system illustrate clearly the capabilities now available to analysts and design engineers. Applying the technology to more complex systems can offer greater benefit in streamlining the parallel design process of control systems and the mechanical systems they interact with. Using this simulation approach also fosters multidisciplinary interaction by allowing both mechanical engineers and controls engineers to work on different parts of the same model.

The MBD simulation software used for this example was RecurDyn Multibody Dynamics Simulation. Using the RecurDyn Control Interface Toolkit, users can connect the model to control systems created in MATLAB. Alternatively, users can also design control systems within RecurDyn CoLink, which provides an integrated environment for control system design and simulation.

If you would like to find out more information about this technology, you can:

- Visit [www.motionport.com/index.aspx?page=RecurDyn-Controls-Link](http://www.motionport.com/index.aspx?page=RecurDyn-Controls-Link). You can also see an animation of the pendulum results there.
- Call us at 734.572.9630 to discuss how simulating your product can help your company.
- Send us an e-mail at [info@motionport.com](mailto:info@motionport.com) and describe what you want to do.