

Control System Toolbox 9.1

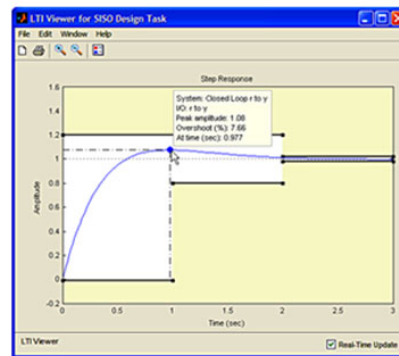
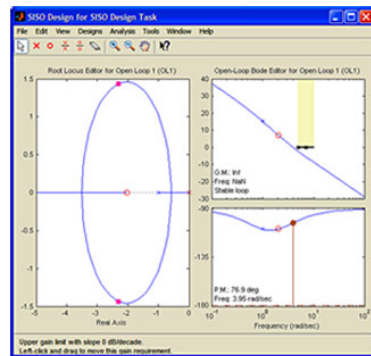
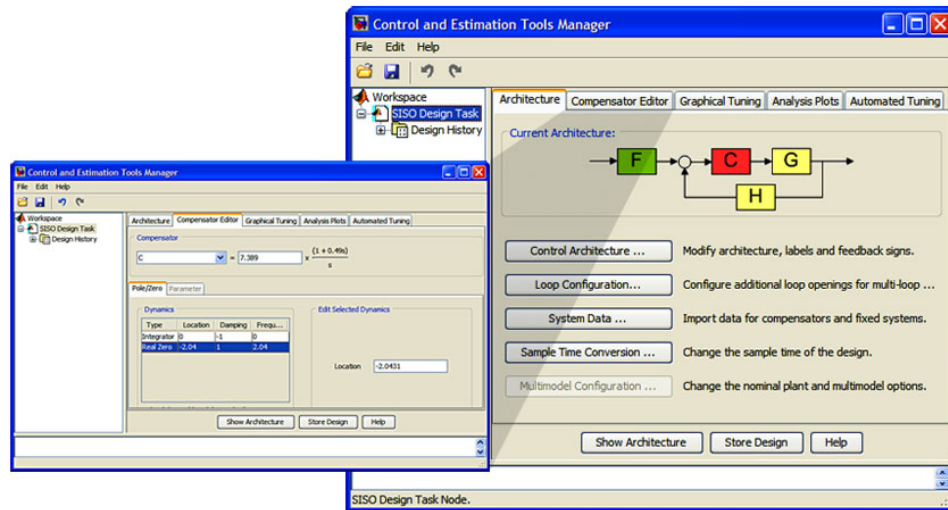
Design and analyze control systems

Introduction

Control System Toolbox™ provides industry-standard algorithms and tools for systematically analyzing, designing, and tuning linear control systems. You can specify your system as a transfer function, state-space, pole-zero-gain, or frequency-response model. Interactive tools and command-line functions, such as step response plot and Bode plot, let you visualize system behavior in time domain and frequency domain. You can tune compensator parameters using automatic PID controller tuning, Bode loop shaping, root locus method, LQR/LQG design, and other interactive and automated techniques. You can validate your design by verifying rise time, overshoot, settling time, gain and phase margins, and other requirements.

Key Features

- Transfer-function, state-space, pole-zero-gain, and frequency-response models of linear systems
- Series, parallel, feedback, and general block-diagram connection of linear models
- Step response, Nyquist plot, and other time- and frequency-domain tools for analyzing stability and performance measures
- Root locus, Bode diagrams, LQR, LQG, and other classical and state-space control system design techniques
- Automatic tuning of PID controllers
- Model representation conversion, continuous-time model discretization, and low-order approximation of high-order systems
- LAPACK and SLICOT algorithms optimized for accuracy and performance



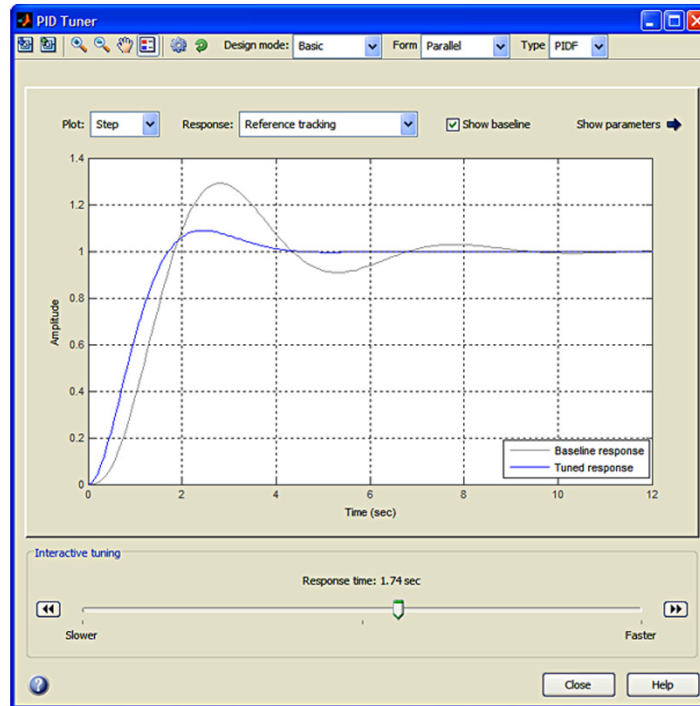
Control and Estimation Tools Manager (top), a workflow-based GUI that lets you interactively analyze, design, and tune controllers. Available tools include root locus, Bode, and step-response plots (bottom).

Working with Control System Toolbox

Linear control techniques are the foundation of control system design and analysis. Control System Toolbox lets you create and manipulate the linear models of your control system. Using interactive visualization tools, you can analyze these models to gain insight into your control system's behavior, performance, and limitations. You can also systematically tune control system parameters using single-input/single-output (SISO) and multi-input/multi-output (MIMO) design techniques.

Linear models from Control System Toolbox can be used in other control design products, such as [Robust Control Toolbox™](#) and [Model Predictive Control Toolbox™](#). You can use [Simulink Control Design™](#) together with Control System Toolbox for control system design and analysis in [Simulink®](#).

$$C = K_p + \frac{K_i}{s} + \frac{K_d s}{T_f s + 1}$$



Tuning a PID controller C , defined by the equation, with the PID Tuner GUI. You can automatically calculate an initial design and then interactively adjust the response time to recompute PID gains.

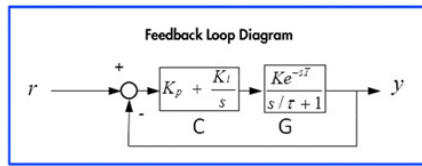
Creating and Manipulating Linear Models

Control System Toolbox lets you create and manipulate linear models of your control system as objects. All standard model representations are supported, including transfer function, zero-pole-gain, explicit and descriptor state space, and frequency-response data. Linear models can be SISO or MIMO, and continuous or discrete. You can represent PID controllers as PID objects. In addition, you can accurately model and simulate systems with time delays, including feedback loops with delays.

Control System Toolbox provides commands for:

- Performing arithmetic on linear models
- Building complex block diagrams by connecting simple models in series, parallel, or feedback
- Discretizing continuous-time models
- Computing low-order approximations of high-order models

Building a linear model of your plant is usually the first step in designing a control system. If no linear model is available, you can build one by fitting test data using [System Identification Toolbox™](#), or by linearizing a Simulink model using Simulink Control Design. Once you have created a linear model, you can use Control System Toolbox to analyze it and design a controller.

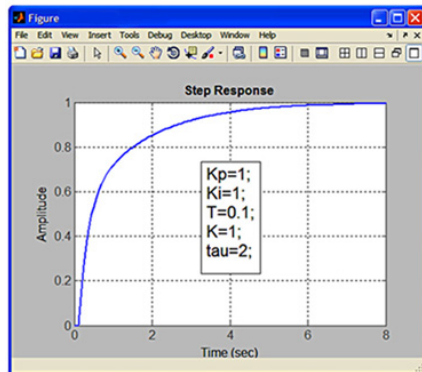


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% Code that creates and
% analyzes the feedback system

% Specify s as Laplace variable
s=tf('s');
% Create PI controller
C=pid(Kp,Ki);
% Create plant transfer function
G=exp(-s*T)*K/(s/tau + 1);
% Form feedback loop
CL=feedback(C*ss(G),1);
% Calculate and plot step response
step(CL)

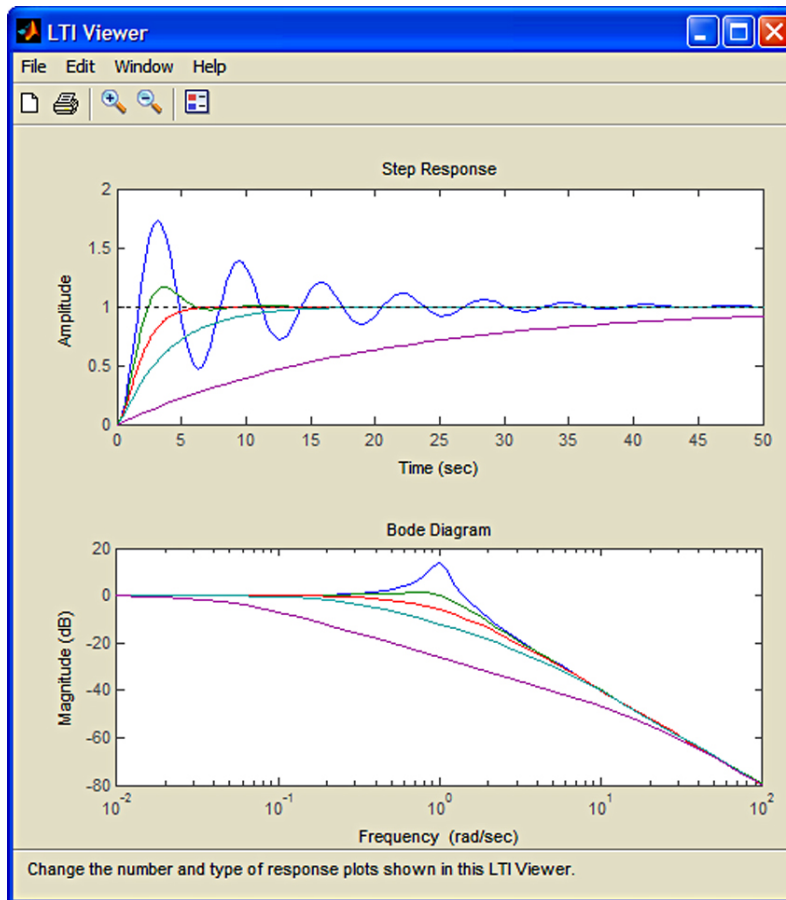
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MATLAB code for creating and analyzing a feedback loop with controller C and plant model G . The plant is modeled as a first-order transfer function with a delay of T seconds.

Analyzing Models

Control System Toolbox provides extensive GUIs and command-line functions for analyzing linear models. Using the LTI Viewer GUI, you can view and compare the time and frequency responses of several linear models at once. You can also inspect key performance parameters, such as rise time, settling time, maximum overshoot, and stability margins. Available plots include step response, impulse response, Bode, Nichols, Nyquist, singular value, and pole-zero. You can simulate the response to user-defined inputs and initial conditions to further investigate system performance.



LTI Viewer GUI, an interactive tool for analyzing linear models in the time and frequency domains. You can compare several linear models at once using a variety of time-domain and frequency-domain plots.

Tuning Control Systems

Control System Toolbox lets you systematically tune control system parameters using SISO and MIMO design techniques.

Tuning PID Controllers

Control System Toolbox provides [tools for manipulating and tuning PID controllers](#) through the PID Tuner GUI or command-line functions. You can:

- Use PID objects to represent continuous-time or discrete-time PID controllers in standard or parallel form
- Automatically tune PID gains to balance performance and robustness
- Specify tuning parameters, such as desired response time and phase margin

Tuning SISO Controllers

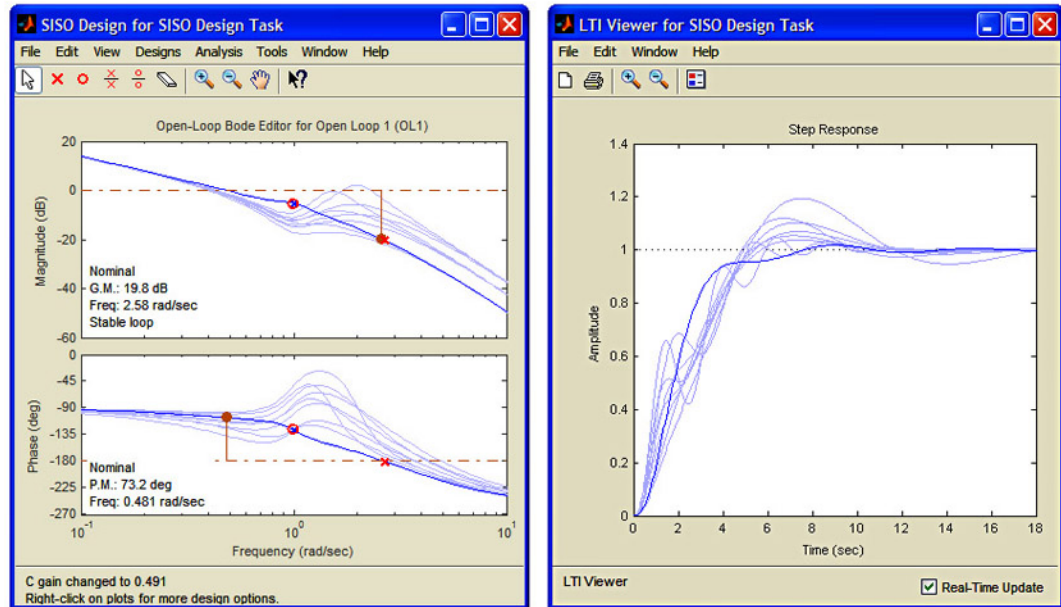
The SISO Design Tool in Control System Toolbox lets you the design and analyze SISO control systems. You can:

- Design common control components, such as PIDs, lead/lag networks, and notch filters
- Graphically tune SISO loops using classical tools, such as root locus, Bode diagrams, and Nichols charts
- Monitor closed-loop responses and performance requirements in real time while tuning your controller
- Evaluate design factors, such as choice of sample time and controller complexity

In addition to standard model representations, such as transfer function and frequency-response data, the SISO Design Tool supports systems with time delays. You can also work with several plant models simultaneously to evaluate your control design for different operating conditions.

Simulink Control Design extends Control System Toolbox by enabling you to tune controllers in Simulink that consist of several SISO loops. You can close SISO loops sequentially, visualize loop interactions, and iteratively tune each loop for best overall performance. Simulink Control Design lets you export the tuned parameters directly to Simulink for further design validation through nonlinear simulation.

When used with [Simulink Design Optimization™](#), the SISO Design Tool lets you optimize the control system parameters to enforce time and frequency-based performance requirements. When used with Robust Control Toolbox, it lets you automatically shape open-loop responses using H-infinity algorithms.



Tuning a single controller for several plant models with the SISO Design Tool.

Tuning MIMO Controllers

Control System Toolbox supports established methods for MIMO design, including LQR/LQG and pole-placement algorithms. It also provides tools for designing observers, including Kalman filters.

Resources

Product Details, Demos, and System Requirements

www.mathworks.com/products/control

Trial Software

www.mathworks.com/trialrequest

Sales

www.mathworks.com/contactsales

Technical Support

www.mathworks.com/support

Online User Community

www.mathworks.com/matlabcentral

Training Services

www.mathworks.com/training

Third-Party Products and Services

www.mathworks.com/connections

Worldwide Contacts

www.mathworks.com/contact