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APPLICATION NOTE: HSAP2041

THIS APPLICATION CAN BE DONE USING:

PRODUCTS
Block Diagram
RIDE
ImPro Lab
VIDSP Studio
VIDSP Suite
OORVL Design Studio

Closed-Loop Control System

Overview

A closed-loop control system is one in which an input forcing function is determined in part by the system response. The measured response of a physical system is compared with a desired response. The difference between these two responses initiates actions that will result in the actual response of the system to approach the desired response. This in turn drives the difference signal toward zero. Typically the difference signal is processed by another physical system, which is called a compensator, a controller, or a filter for real-time control system applications.

The task of a control system designer is to specify the processing that is to be accomplished in the controller. The Hypersignal Block Diagram and Hypersignal RIDE products can both be used to facilitate the design and implementation of a closed-loop control system.

Product Specific Information

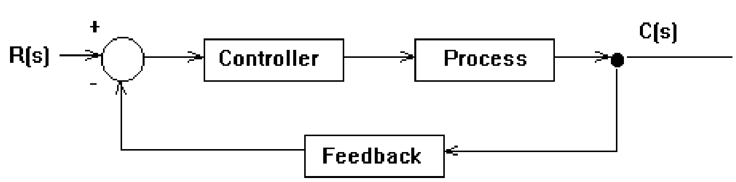
Hypersignal Block Diagram is a visual-based design environment which allows you to quickly model and simulate many design algorithms. Hypersignal RIDE is a superset of the Hypersignal Block Diagram product, and as such, contains all of its simulation capabilities and functionality. RIDE additionally provides the capability of creating real-time DSP applications by simply connecting block function icons together with a mouse. Custom block functions are easily added to both packages through use of an included Block Wizard utility.

The block diagram approach used by both packages allows for convenient implementation of a closed-loop control system. Hypersignal RIDE directly supports a wide variety of DSPs and DSP/acquisition hardware, and can be used to target DSP/data acquisition hardware systems for real-time control system applications.

Detailed Description

This design example will demonstrate how the Hypersignal Block Diagram or Hypersignal RIDE application can be used to implement a closed-loop control system.

A closed-loop control system can be represented by the general block diagram shown below:



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In this configuration a feedback component is applied together with the input R. The difference between the input and feedback signals is applied to the controller. In responding to this difference, the controller acts on the process forcing C to change in the direction that will reduce the difference between the input signal and the feedback component. This, in turn, will reduce the input to the process and result in a smaller change in C. This chain of events continues until a time is reached when C approximately equals R.

A closed-loop system is able to regulate itself in the presence of disturbance or variations in its own characteristics. In this respect, a closed-loop system has a distinct advantage over an open-loop system.

The control system in this example is governed by the following equation:

$$H(z) = \frac{(0.368 + 0.264z^{-1})}{(1 - 1.368z^{-1} + 0.368z^{-2})}$$

Implementation

The closed-loop control system described by the equation above will be implemented in a Block Diagram simulation worksheet by using low-level block functions.

The following block functions and hierarchy blocks are used in this example:

Block Function	Description
Constant Generator	Unit step generation
Delay	Delay line
Subtract	Input - feedback
Gain	Control system gain
Buffer	Data buffer accumulation
Hierarchy Biquad (hierarchy worksksheet)	Controller
Text Display	Show calculations
Single-Channel Display	Graphical display

Block Functions used in the Closed-Loop Control System

As shown in the figure below, the unit step response of a closed loop control system is computed by hitting the control system with a unit step input signal. The unit step is generated by a Constant Generator block which is delayed by one sample. The feedback component of the closed-loop system is represented by a Recursion block. The difference between the unit step input and the feedback component is computed by the Subtract block. This difference is then fed into the Controller which is represented by the Hierarchy Biquad hierarchy block function.

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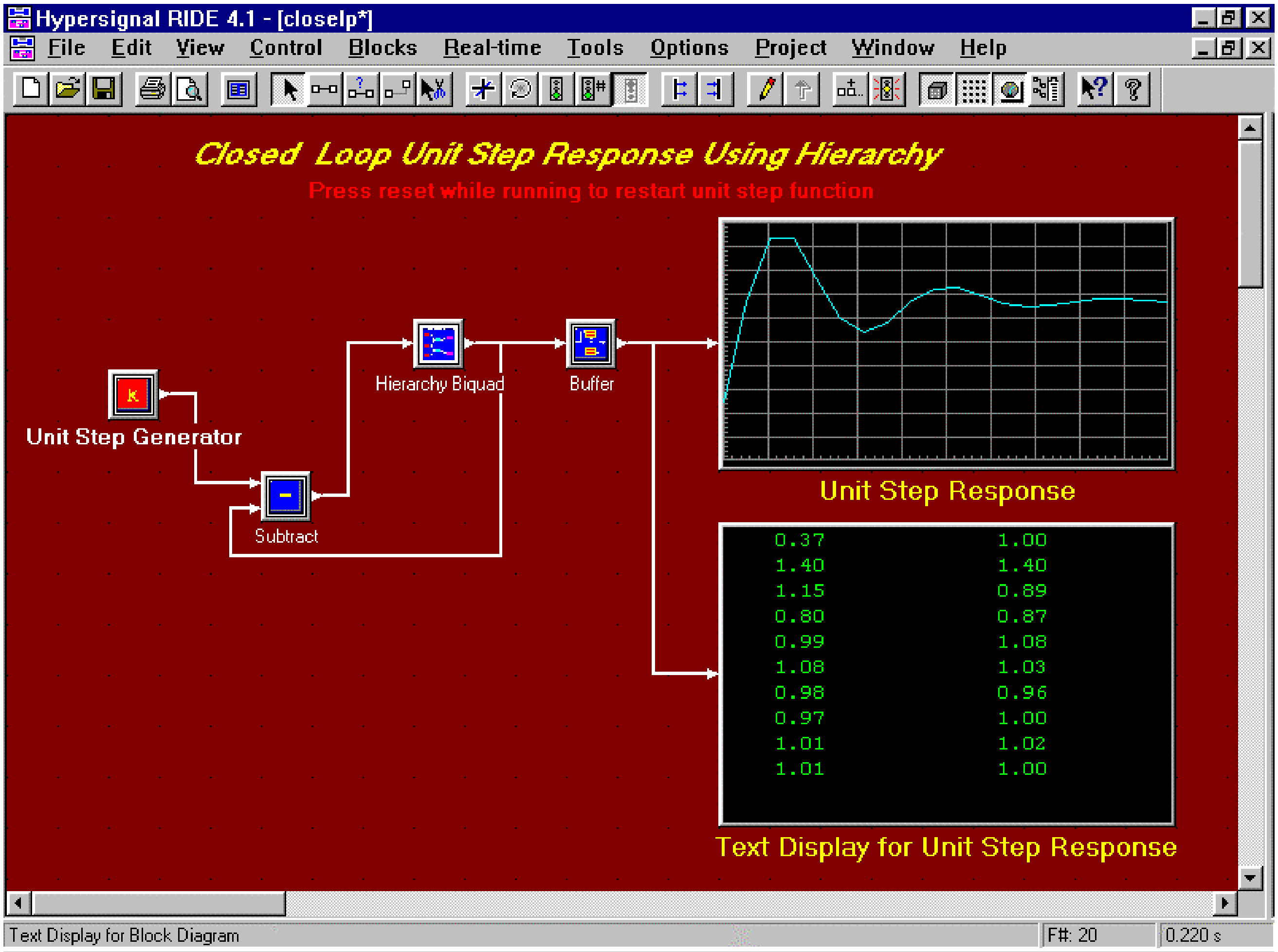

Unit Step Response of Closed-Loop Control System

The framesize for this implementation has been chosen to be a frame of one data sample. For display purposes a Buffer block has been used to store 20 data values at a time. When the Block Diagram worksheet has executed 20 frames, the Buffer block will release its frame of data to a Text Display block and a Single-Channel Display block.

It can be seen from both the graphical and text displays that the system is reaching a steady-state. If the worksheet is allowed to run for another 20 frames it can be shown that the system settles at a constant value of one, therebye matching the input signal.

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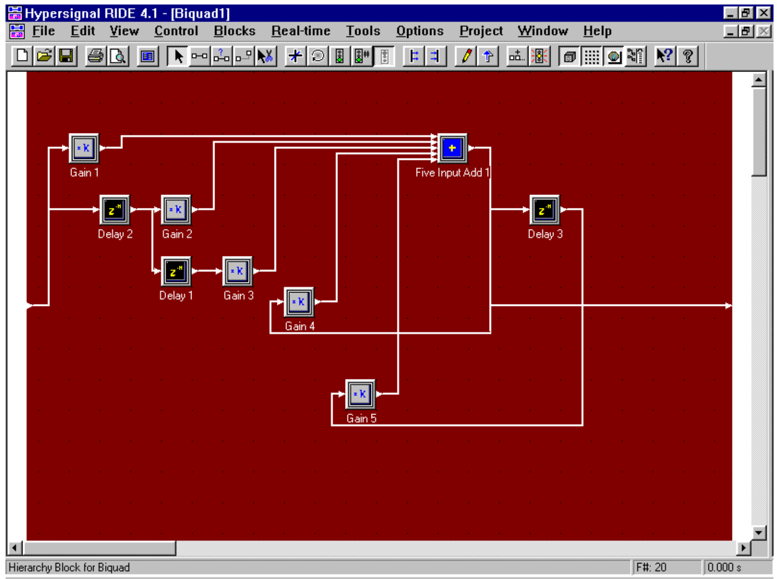

Biquad Implementation of Controller

The controller hierarchy block worksheet is made up from the low-level blocks shown in the figure above. The gain parameters for this worksheet are obtained from the transfer function of the control system.

Applications

The implementation of a closed-loop control system is quickly achieved with Hypersignal Block Diagram and Hypersignal RIDE software. By simply creating a block diagram representation of the desired control systems algorithm via block function icons and line connections you can easily implement many control system applications.

References

1. Charles L. Phillips and H. Troy Nagle, Digital Control System Analysis and Design, Prentice-Hall International, Inc., 1990.

2. Ramakant Gayakwad and Leonard Sokoloff, Analog and Digital Control Systems, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1988.

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