Getting Started with the MapleSim Control Design Toolbox

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This document was produced using Maple and DocBook.

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Introduction

The MapleSim[™] Control Design Toolbox provides the necessary control design tools to extend the plant modeling capabilities of MapleSim. Using a symbolic approach, you can design, analyze, and test control systems.

You can also use the technical documentation tools available with MapleSim to document your design decisions.

Features of this toolbox include:

- · Model linearization
- Standard PID tuning techniques: Ziegler-Nichols time response, Ziegler-Nichols frequency response and Cohen-Coon
- Advanced PID tuning techniques: Dominant pole placement, pole placement in a specified region, and gain and phase margin
- State Feedback Control: Single input pole placement (Ackermann), multiple input pole placement, and LQR
- State Estimation: Single output pole placement (Ackermann), multiple output pole placement, and Kalman filter
- Access to commands in the ControlDesign and DynamicSystems packages in $Maple^{TM}$

Scope of Model Support

MapleSim Control Design Toolbox is a very comprehensive modeling tool where it is possible to design linear controllers for models created in MapleSim. The Control Design Toolbox linearizes systems of any complexity, including systems of DAEs of any index.

Systems that contain any type of discontinuity, including discrete transforms, switches, logic gates, relational and Boolean operations are not supported by the current release of this product.

1 Getting Started

1.1 Getting Help

In Maple, enter ?ControlDesign at a prompt in a worksheet.

1.2 Using the MapleSim Control Design Templates

The MapleSim Control Design Toolbox provides templates in the form of a Maple worksheet for linearizing MapleSim models and creating PID controllers. These templates contain pre-built embedded components that allow you to generate a linearized representation of your model subsystems, as well as custom components of your system controllers.

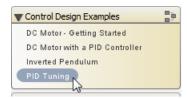
Viewing MapleSim Control Design Examples

Toolbox examples are available in the Control Design Examples palette in MapleSim.

Each example includes a linearization or PID tuning template in its **Attachments** palette.

To view an example:

1. In the **Control Design Examples** palette at the left side of the MapleSim window, click the entry for the model that you want to view.



- 2. Under the **Project** tab, expand the **Attachments** palette and then expand **Documents**.
- 3. Right-click (Control-click for Macintosh®) PIDTuning and select View. The template opens in Maple.

Some models include additional documents, such as templates that show model equations or define custom components. You can open any of these documents by right- or **Control**-clicking its entry and selecting **View**.

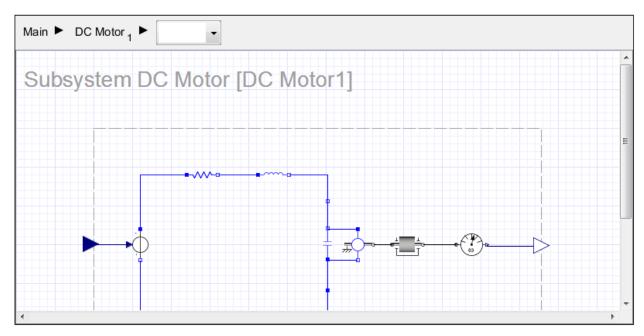
1.3 Example: DC Motor

In this example, you will generate a linearized state-space model of the models you created in MapleSim. You will then use this linearized model to create and tune a PID controller.

Generating a Linearized Model

To generate a linearized model:

- 1. In the Control Design Examples palette, open the DC Motor Getting Started model.
- 2. Click **Templates** () in the **Main Toolbar** and from the list, select **Linearization**.
- 3. In the **Attachment** field, enter **Linearized Motor** as the worksheet name and click **Create Attachment**. Your MapleSim model opens in the **MapleSim Linearization Template** in Maple.
- 4. Using the navigation controls above the model, browse to the **DC Motor** subsystem.



- Click Load Selected Subsystem. The Variable and Parameter Management fields are populated with information specific to the subsystem.
- 6. You can now have Maple automatically calculate an equilibrium point to be used as a linearization point or you can clear the use equilibrium point check box to have the model linearized about the initial point.
 To manually specify the values of the DAE, Input and Output variables, and Parameters, enter the values into appropriate value columns. Alternatively, to calculate the equilibrium point automatically, select use equilibrium point.
 Also, to enable Baumgarte stabilization during linearization of the constraint equations, select use Baumgarte.

For this example, select use equilibrium point.

- 7. Click **Linearize** to generate the linearized model. The **Linearized Model** and **Variable Mapping** fields are automatically updated. In the **Linearized Model** display area, you can select and view the matrices of your linearized model. In the **Variable Mapping** fields you can now select and view the state, input, and output mappings.
- 8. Scroll to the bottom of the template and under **Create Component** in the **Component Name** field, you can enter a custom name for the linearized model, e.g. **MyMotor** for this example, or accept the default name shown in the worksheet. In the description field, you can add more information about your model.
- 9. Click **Create** to create the linearized state-space model. A custom component with the specified component name (e.g. **MyMotor**) now appears in the **Components** palette of the **Definitions** tab in MapleSim.
- 10. Close the **Linearization Template** and return to the **DC Motor** model in MapleSim.

Creating a Custom Controller

To create a custom controller:

- 1. In the Navigation Toolbar, click Main to browse to the top level of your model.
- Under the **Definitions** tab, the **MyMotor** custom component is found in the **Components** menu. Place the **MyMotor** custom component in the model workspace.
- 3. Click **Templates** () in the **Main Toolbar** and from the list, select **PID Tuning**.
- 4. In the **Attachments** field, enter **Motor PID** as the worksheet name and click **Create Attachment**. Your MapleSim model opens in the **PID Tuning Template** in Maple.

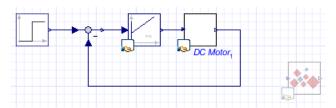
- 5. In the **Linearized Model** section of the template, select the linearized model **MyMotor** from the drop-down list. The system is converted to a DynamicSystems object and stored in the **zStateSpace** variable.
- 6. In the **Controller Design** section, you can select the tuning method and controller type you want to create. For this example, design a **PID** controller using the modified Ziegler-Nichols (MZN) Time Domain tuning method:

From the **Method** drop-down menu, select **Ziegler-Nichols Time Domain (MZN)**. From the **Controller** drop-down menu, select **PID**. If additional information is required for your control design method, the fields below these menus will be populated and you can enter the required information.

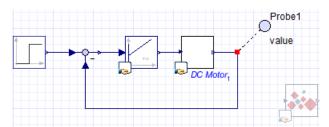
- 7. Click **Design Controller**.
- 8. Next, in the **Export to MapleSim** subsection, enter **MyPID**, and then click **Export to MapleSim**. A custom component generates and exports to MapleSim.
- 9. You can view the Modelica® code generated for the custom component in the Modelica subsection.
- 10. In the **Analysis** section, you can use the plotting tools to analyze properties such as Zero pole, Bode (magnitude and phase), Step Response, and Nyquist.

To simulate your model using the MyPID custom component:

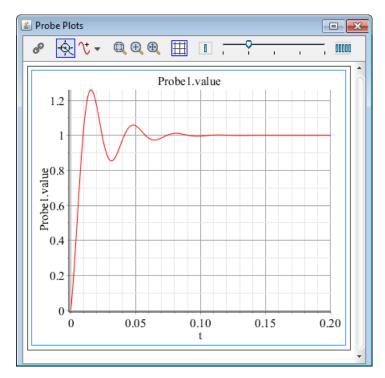
- 1. Return to your MapleSim model.
- 2. Select the **MyMotor** custom component and click **Disable** (**②**) to exclude it from the next simulation.
- 3. Under the **Definitions** tab, the **MyPID** custom component is found in the **Components** menu. Place the **MyPID** custom component in the **Model Workspace**.
- 4. In the **Libraries** tab, expand the **Signal Blocks** → **Common** menu and drag **Feedback** and **Step** signal components in the **Model Workspace**.
- 5. Connect the components to your model, as shown below.



- 6. Select **Probe** () from the **Model Workspace Toolbar** and then click the connection line between the **DC Motor** and **Feedback** component.
- 7. Click the probe once to position it.



- 8. In the Inspector tab, select Real.
- 9. Click **Run Simulation** () in the **Main Toolbar** to simulate your model. When the simulation is complete, the following graph appears.



You can change the parameters of your controller directly in your model in MapleSim by selecting the PID controller component and editing the parameters in the **Inspector** tab.

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