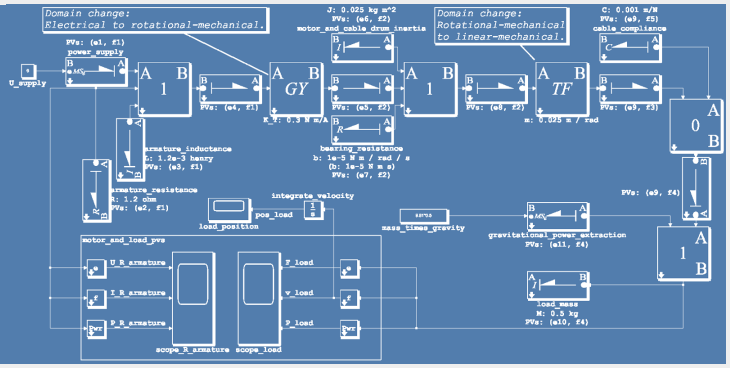
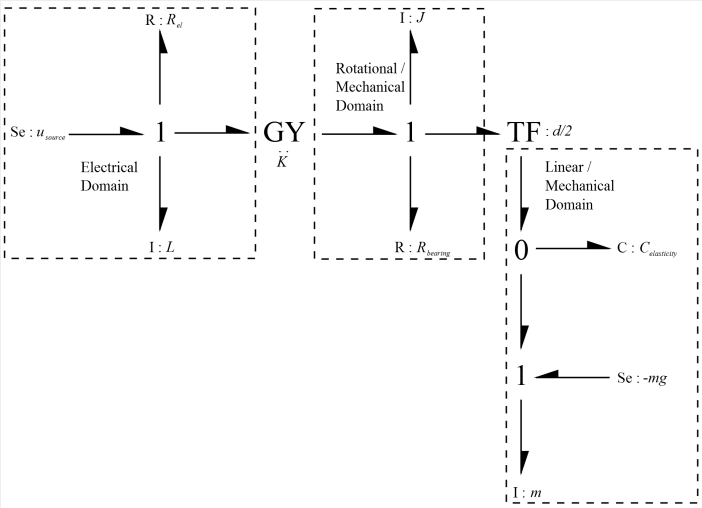
SIMBUS BONDGRAPHS™

PHYSICAL SYSTEMS MODELING IN MATLAB® AND SIMULINK® USING BOND GRAPHS

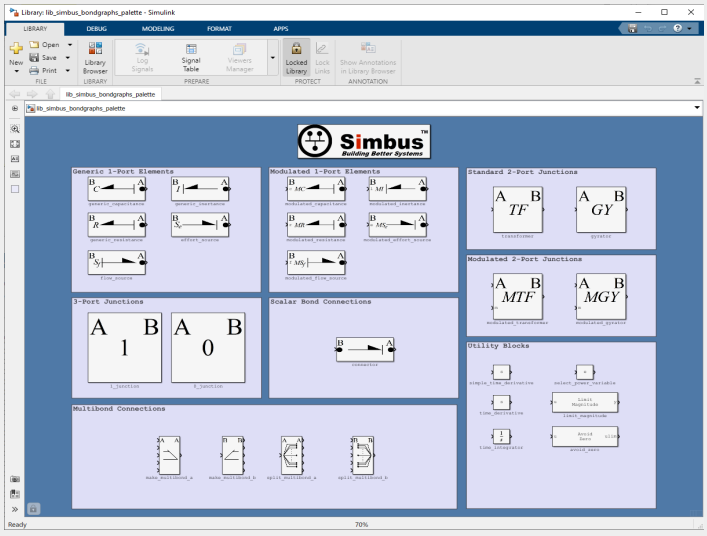


OVERVIEW

Simbus Bondgraphs is an add–on to MATLAB® and Simulink® and has been designed by Simbus Ltd. for engineers, scientists, educators, and students to model the dynamics of physical systems using **Bond Graphs** like the one shown below.



Simbus Bondgraphs is composed of MATLAB functions and a Simulink library (shown below).



Bond Graphs are graphical descriptions of physical system dynamic behavior. The notation was invented and elaborated at the Massachusetts Institute of Technology **by engineers and for engineers**. It is now taught to engineering students around the world.

Bond Graphs represent **energy flows** between elements and also the transformation of one form of energy to another. They provide a domain-neutral representation for creating models of **multidomain dynamic systems**.

BENEFITS

Simbus Bondgraphs gives you the benefits of Bond Graph notation in Simulink, the premier modeling and simulation environment.

This makes Simbus Bondgraphs ideal for:

- **Modeling Complex Machinery:** Combining electrical, mechanical, hydraulic, pneumatic, and other domains enables modeling of vehicles, power-generation and power grids, robots, drones, material handling systems, etc., as well as biological, microscale, and nanoscale systems.
- **Early-Stage Systems Engineering:** This includes phase 0 / phase A, trade-off studies, requirements discovery, subsystem definition, conceptual design, etc. and is conducted by a multidisciplinary team. Good communication across the disciplines and the need to quickly explore the effects of architectural and parameter changes are facets of these phases. Successful communication is aided by using a common and meaningful notation of system representation. Simbus Bondgraphs provides the consistent and common notation of Bond Graphs as well as supporting a high degree of architectural and parametric reconfigurability.
- **Failure Studies:** Understanding how unmanaged energy flows can result in component failure and how failure effects can propagate is an important part of safety engineering. Simbus Bondgraphs helps you explore how effects in one physical domain can cause failures in another.

Simbus® Building Better Systems

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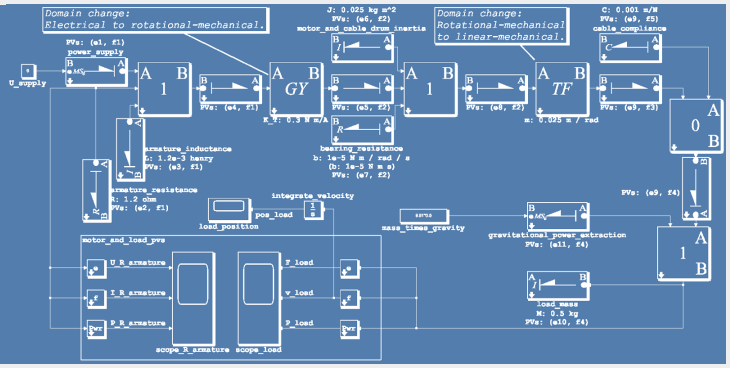
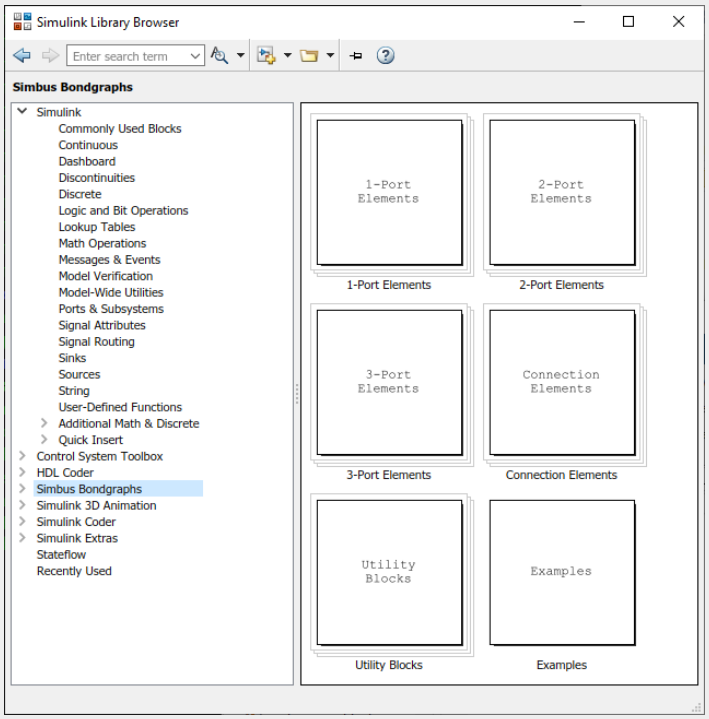


- **Control System and Algorithm Design:** Control design is all about how to manage energy flows. The energy flow representation permits physics-based design approaches that result in efficient control systems and other algorithms such as failure-detection, isolation, and recovery schemes. Multi-resolution modeling is also supported where low-order dynamic models (often used for controllers and fault detection algorithms) can be obtained pictorially from existing Bond Graphs. Similarly, more detailed models can be elaborated from low-order models during later-stage systems engineering.
- **Learning Bond Graphs:** Simbus Bondgraphs provides an accessible interface with built-in documentation making it accessible to students and professional engineers alike. The turn-around time for creating and simulating models makes Simbus Bondgraphs **ideal for academics** to teach Bond Graphs using MATLAB and Simulink and for student laboratory and homework assignments.



Key Features

You can construct models of physical systems of arbitrary complexity using the elements provided in the Simulink library using a developer license. You can share these models with users if they have a (free) run-time license.

Library Elements

The current version of the library includes:

- **1-Port Elements:** These include sources / sinks, energy storage / release, and energy dissipation elements. These elements provide the low-level dynamics of any physical system. Energy is provided to and absorbed from the rest of the system through their connections to 2-port and 3-port junctions. Modulated variants of these elements (where the key parameter is specified externally) are also provided.
- **2-Port Junctions:** Used to transform energy variables (for implementing devices such as gear trains and electrical transformers) or to convert energy from one physical domain to another for multidomain systems. Modulated 2-port junctions are also provided.
- **3-Port Junctions:** Used to create networks of elements in series or parallel. Most systems contain both series and parallel aspects.
- **Multibonds:** It is sometimes convenient to group power flows into vectors (such as in 3-phase electrical networks or to describe 3D motion). Simbus Bondgraphs includes blocks to create and to split multibonds.

Simbus Bondgraphs also includes various utility blocks including:

- **Time Derivative Blocks:** Sometimes it is useful to compute the derivative of a signal in Simulink. Simbus Bondgraphs includes both simple Δy/Δt and frequency-limited implementations.

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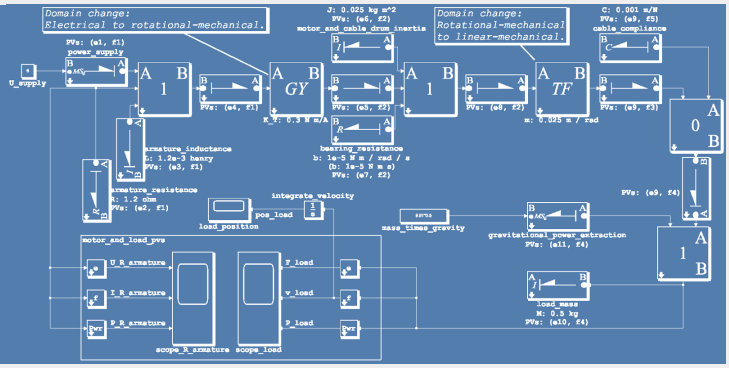
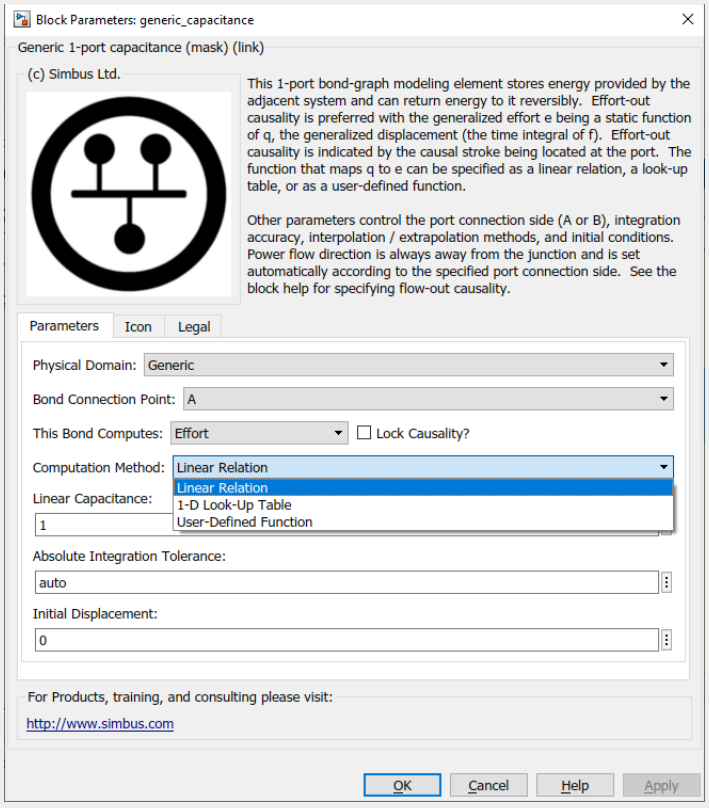


- **Power Variable Selector:** Monitoring of the underlying model variables is as simple as connecting this block to a bond.
- **Blocks to avoid singular conditions:** Sometimes it is necessary to limit the values of parameters that cause singularities to occur during model simulation. Simbus Bondgraphs provides blocks and associated MATLAB functions to help avoid these conditions.



User-Customization

Simbus Bondgraphs provides a high-degree of user-customization.

- Linear and Nonlinear Behaviors: You can specify linear and nonlinear behaviors for either the whole of your model or for portions of it. Nonlinear behaviors can be specified through user-defined nonlinear functions or through look-up tables.
- Empirical data can be used to parameterize elements to replicate behavior of real components and equipment.
- Subsystems: Package your models into shareable subsystems using Simulink's subsystem capability.

MATLAB and Simulink Integration

Simbus Bondgraphs comes with a MATLAB-based application programming interface (API) for interacting with your Bond Graph models programmatically. This API can be used in your own MATLAB programs to modify and optimize your Bond Graphs according to your own criteria.

Simbus Bondgraphs also makes use of the algebraic loop-solving capabilities of Simulink permitting simulation of reduced-order models and static models with no dynamics.

Simbus Bondgraphs does not rely on an C / C++ code or other low-level languages ensuring that MathWorks Simulink Coder™ can optimize code that is automatically generated from your models.

Share your models with your customers – they can run them using a free run-time license available from the Simbus Web site.

Model Sharing

You may share your completed models with others who do not have a developer license for Simbus Bondgraphs. Just point them to the Simbus Web site where they can get a free run-time license.

Library of Examples

Numerous extensively-documented examples have been provided to illustrate the power of Simbus Bondgraphs. These examples include networks of electrical elements to multidomain electromechanical systems and more.

Visit the Simbus web-site periodically to check for new and updated examples.

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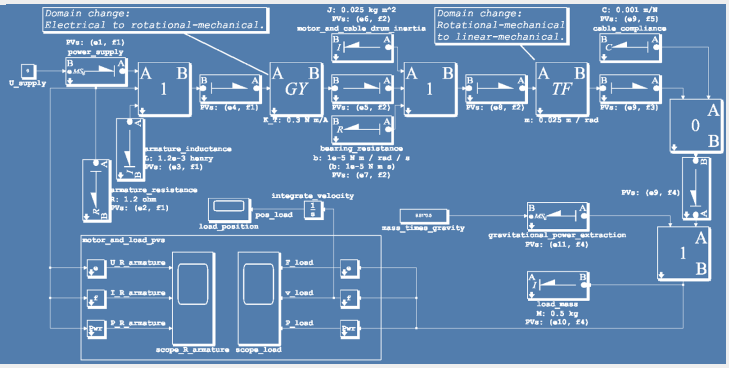

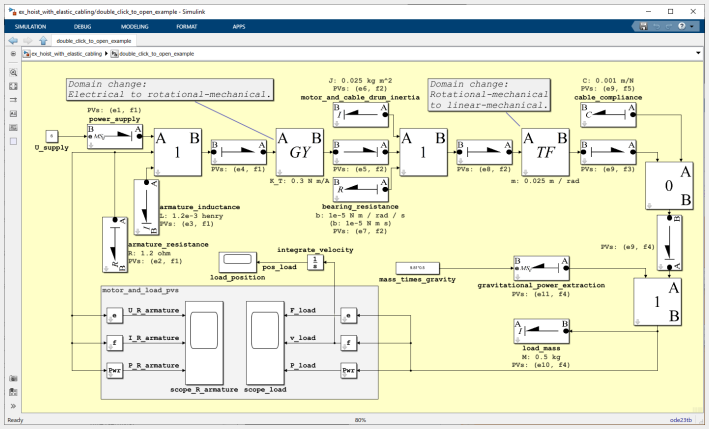

Licensing

There are two classes of licenses available:

- **Developer License:** This license class permits you to create, modify, and execute models containing Simbus Bondgraphs elements.
- **Run-Time License:** This license class permits you to execute models containing Simbus Bondgraphs elements. Run-Time licenses are free and are available from the Simbus Web site.

All Simbus product licensing is on an annual basis (we also provide an additional grace period for each license so that you have adequate time to install the license file on your platform). Each license is for a specific end-user / specific platform combination.

Reduced licensing rates are available for academic and student customers. Please see the Simbus Web site for more details.

On-Going Support

All licensees are permitted to download the latest release of the products from the Simbus Web site. Feature and quality-improvement updates will be made periodically.

Platform Availability

Simbus Bondgraphs is available for the following platforms currently:

- Microsoft® Windows® 10 and Windows® 11,
- Ubuntu® 18.04 LTS and Ubuntu® 20.04 LTS.

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