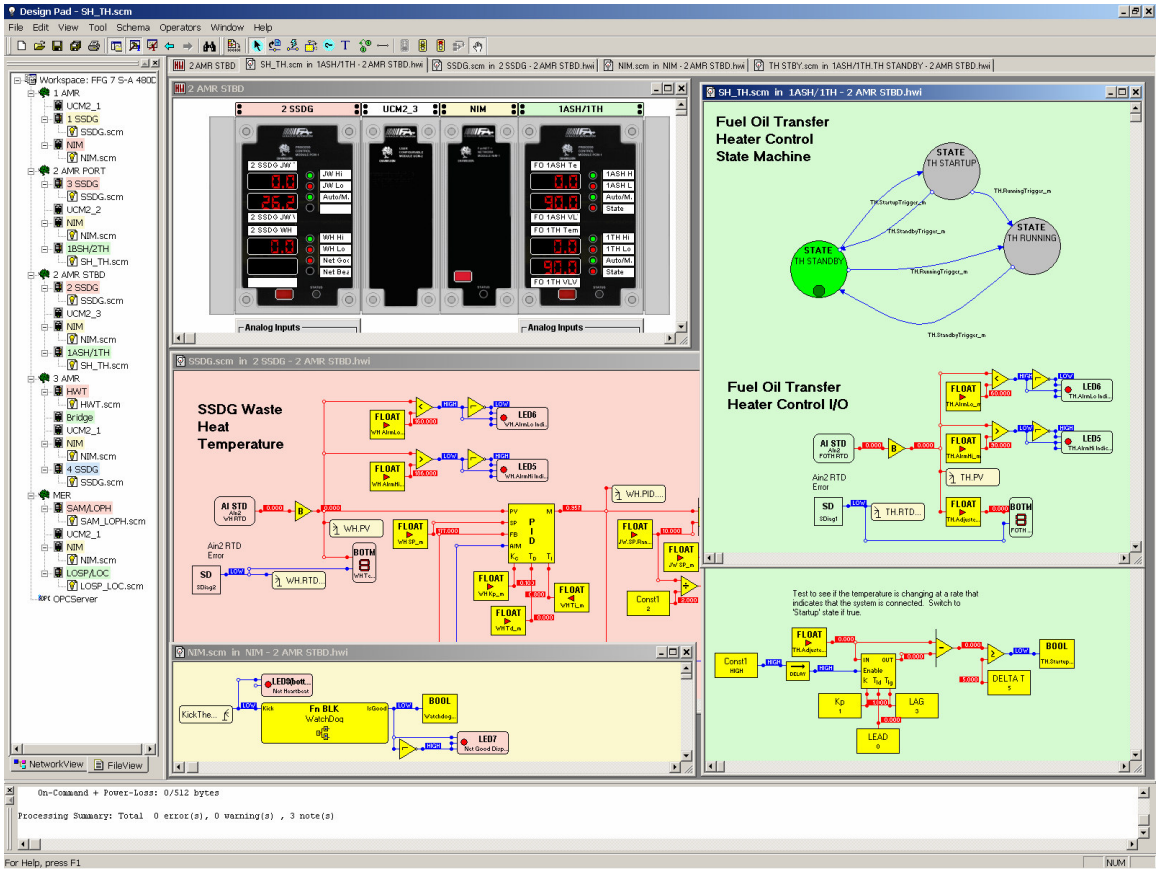
FAIRMOUNT AUTOMATION

Design Pad G3
Instruction Bulletin

A programming guide for Fairmount Automation controller products



Fairmount Automation Controllers

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1. CONTENTS

This instruction bulletin describes the *Design Pad G3*® software package used to program Fairmount Automation's programmable automation controller products.

What's new in *Design Pad G3*?

This new third-generation version of *Design Pad* contains a number of features that were not available in prior versions. Whenever a new feature is described in the documentation, you will find the *new feature graphic* (shown to the right) in the right margin of the bulletin.

Some of the new features found in *Design Pad G3* include:

- Support for multiple controller platforms, including
  a) Chameleon Family of Programmable Automation Controllers
  b) FAC2000 Multi-Loop Process Controller

- Hardware-independent schema development

- Facility to create custom function blocks (using sub-schemas)

- Built-in support for state transition diagrams (a generalized form of sequential function blocks)

- New schema editing features, including
  a) Undo/redo support
  b) Alignment grid for operator I/O pins
  c) Drop-down menus for quick operator access

- Several new operators, including
  a) Data logging (*e.g.,* Snapshot Recorder, Strip-chart Recorder)
  b) Time management (*e.g.,* Time-of-Day, Stop-Watch Timer, Calendar, etc.)
  c) Arithmetic (*e.g.,* Trigonometric Sine, Trigonometric Cosine, Modulo, Rounding)
  d) Logic (*e.g.,* Digital Hysteresis, D-Flip Flop, Delay Timer, etc.)
  e) Analog/Digital variables with local, module, and global scope
  f) Hardware (*e.g.,* Quadrature Decoder, Pushbutton, LED Indicator, etc.)
  g) Built-in Test (*e.g.,* Self-Diagnostic, Internal Temperature, Reset Count)

- Configuration support for open industrial networking protocols, including
  a) Modbus
  b) LonTalk
  c) Ethernet/IP
  d) ProfiBUS

- Human Machine Interface (HMI) documents

- Object searching

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2. INTRODUCTION TO *Design Pad G3*™

Design Pad G3 is a graphical programming environment for Fairmount Automation Programmable Automation Controllers—including the *Chameleon* family of modular hybrid controller products and the *FAC-2000* multi-loop digital process controller. *Design Pad G3* makes programming control schemes for the target hardware as easy as connecting functional operator blocks together. Over 120 such *operators* are provided, including controller blocks, signal conditioning functions, comparison blocks, math operations, logic functions, data converters, diagnostic and data logging blocks, networking operators, and hardware components. The hardware blocks provide access to the available controller hardware, including a variety of analog I/O, digital I/O, displays, buttons, communication channels, timers, and built-in test information.

Design Pad G3 provides the control engineer with complete design flexibility. Each operator has various user-configurable properties that define their behavior. And there are virtually no restrictions on how the functional operators can be interconnected. Moreover, this third-generation version also gives engineers the power to create their own operators and re-use them again and again. It also provides state-transition diagramming functionality to conveniently define machine behavior and implement control sequences.

Perhaps the best way to illustrate the power and flexibility of *Design Pad G3* is by example. A typical *Design Pad* "program" implementing a simple PID control strategy to regulate a thermal process is shown in Figure 2.1. In the control *schema*, a *PID* operator (the large block at the center of the figure) acts to maintain the process variable measured by the

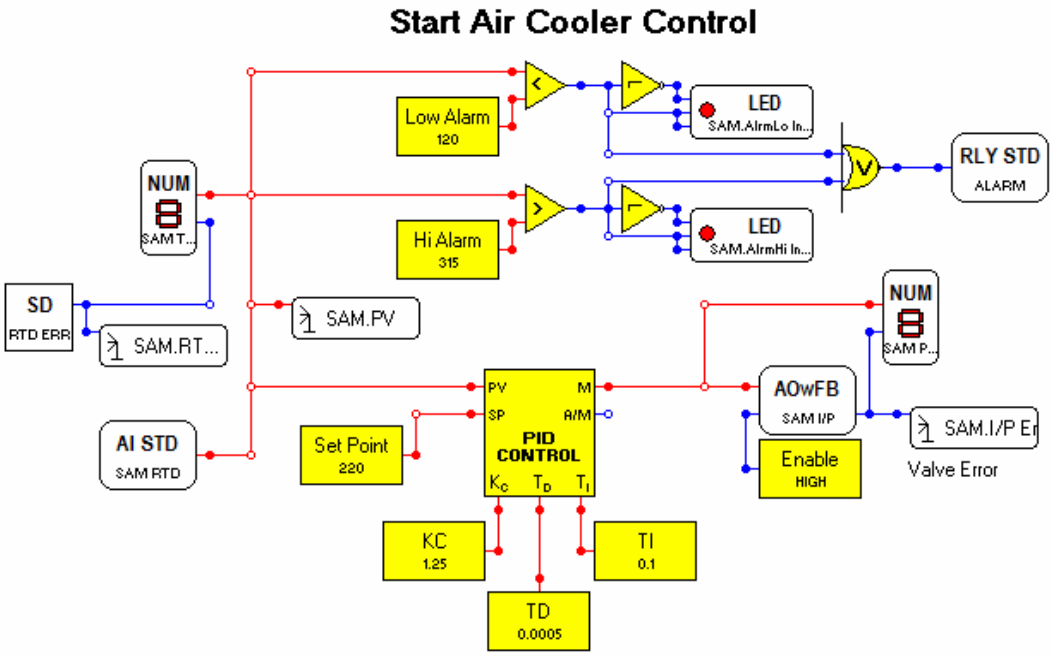


Figure 2.1. A typical *Design Pad G3* "program": a schema diagram of a simple PID control strategy.

Analog Input block at a set point of 220 degrees. In the diagram, an *Analog Input* operator is connected to the Process Variable—PV—input of the *PID* operator. And, a *Constant* operator—labeled "Set-Point"—is connected to the Set Point—SP—input of the *PID* operator. Also connected to the *PID* operator are three *Constant* operators setting the PID operator's proportional gain (unitless), derivative time (in minutes), and integral time (in minutes) to 1.25, 0.0005, and 0.1, respectively.

The schema diagram of Figure 2.1 further specifies that the process value is to be displayed on the controller faceplate, as shown by the connection between the *Analog Input* operator and the *Numeric Display* operator. The boolean (blue) input of the *Numeric Display* operator determines if the value to be displayed should remain steady or flash on and off (flashing is a useful means to draw attention to a fault condition for example). In the schema, the *Flashing* input of the *Numeric Display* block is connected to the output of a *Self-Diagnostic* operator (e.g., Built-In Test) that is configured to scan for an RTD measurement fault. If a fault (*e.g.,* short-circuit) is detected, the *Self-Diagnostic* output will be `HIGH` and the *Numeric Display* will flash on and off.

The *Analog Input* operator is also connected to *Greater-Than* and *Less-Than* blocks that compare the process variable to alarm limits. The comparator blocks in turn feed *LED* blocks that indicate if the process value is within range (solid green) or out of bounds (flashing red). The output of each comparator block is connected directly to an *LED* block's *Red* (middle) and *Flash* (bottom) input pins, and thru a *NOT* gate to an *LED* block's *Green* (top) input pin. For example, if the process measurement were less than 120 degrees, the *Less-Than* block would evaluate to `TRUE` and trigger its corresponding *LED* block to flash red, while the *Greater-Than* block would evaluate to `FALSE` and set its corresponding *LED* block to solid green.

The outputs of the comparator blocks are connected to an *OR* gate that in turn drives a *Relay* hardware operator. If the process is out of range, the relay will activate. (This relay could be tied to an audible alarm that would alert plant personnel that unsafe operating conditions have been reached.)

The output *M* of the *PID* block (the control signal) is fed to a *Numeric Display* operator and an *Analog Output with Feedback* (*AOwFB*) hardware block. The *AOwFB* operator is associated with the physical hardware that is wired to the valve actuator used to regulate the physical process. In addition, the hardware is internally wired to feed the generated output signal back to itself. The *AOwFB* operator compares the desired output it is to generate to the feedback signal it receives; if it detects a sustained difference between the two, it declares an error condition (its error output goes `HIGH`). This is a useful arrangement for fault-detection.

The control schema in Figure 2.1 also includes three broadcast operators used to transmit various signals over a communications network. These values could be used by other networked controllers or displayed on a remote Human Machine Interface (HMI). In the schema, two digital broadcasters are used to signal I/O faults (from the *Self Diagnostic* operator and the *Analog Output with Feedback* operator), and one analog broadcaster is used to transmit the process variable (measured by the *Analog Input* block).

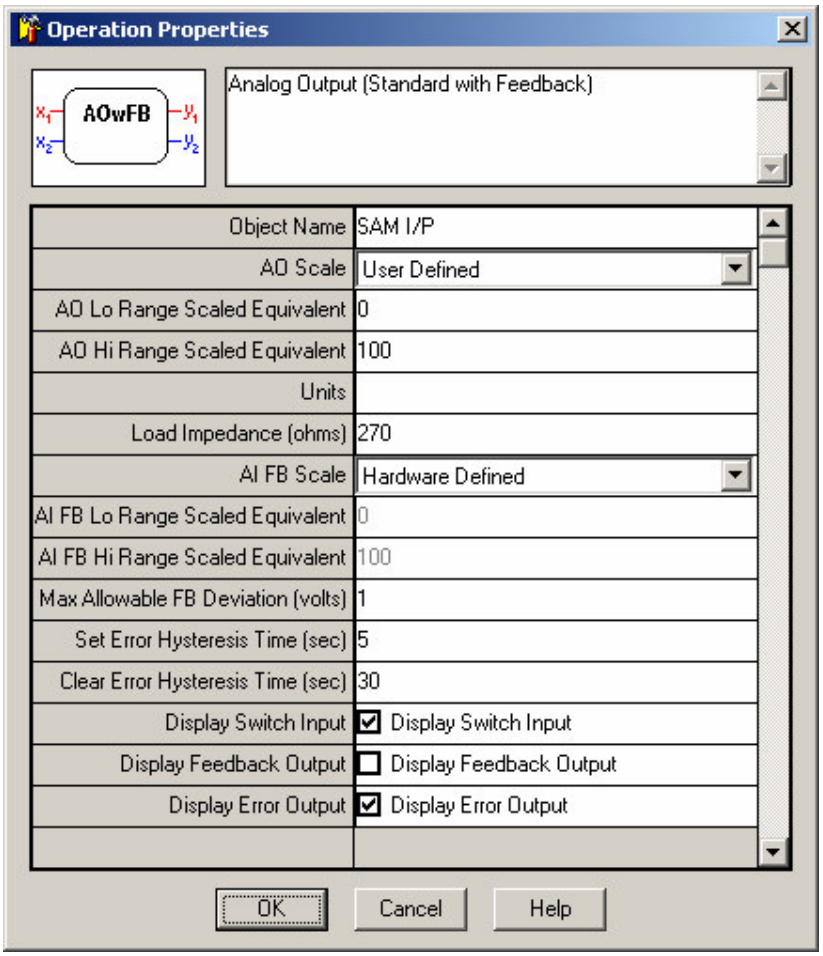


Figure 2.2. Property sheet for the *Analog Output with Feedback* operator of Figure 2.1.

All of the operators in the schema diagram of Figure 2.1 have user-definable properties. For example, Figure 2.2 illustrates the property sheet for the *Analog Output with Feedback* operator. It shows that the desired output must deviate from the feedback signal by more than 1 Volt for a period of 5 seconds for the error condition to be triggered. (These are defined by the *"Max Allowable FB Deviation (volts)"* property and the *"Set Error Hysteresis Time (sec)"* property.) If an error condition is indeed detected, the signals must be within 1V for 30 seconds in order for the error to be cleared (as specified by the *"Clear Error Hysteresis Time (sec)"* property). As shown in Figure 2.2, the schema also limits the output range to be within 0-100% (as defined by the *"Aout Maximum Value"* and *"Aout Minimum Value"* properties).

The preceding description of the schema shown in Figure 2.1 refers to hardware elements in generic terms. For instance, the narrative indicates that the temperature process variable measurement is provided by an *Analog Input* block. But it does not indicate which specific analog input hardware resource is tied to the generic *Analog Input* operator. In other words, it does not specify what the physical signal source for the *Analog Input* block is (*i.e.,* which hardware module and input channel the corresponding sensor is physically wired to). The operator's property sheet—shown in Figure 2.3—does not provide a means to link the

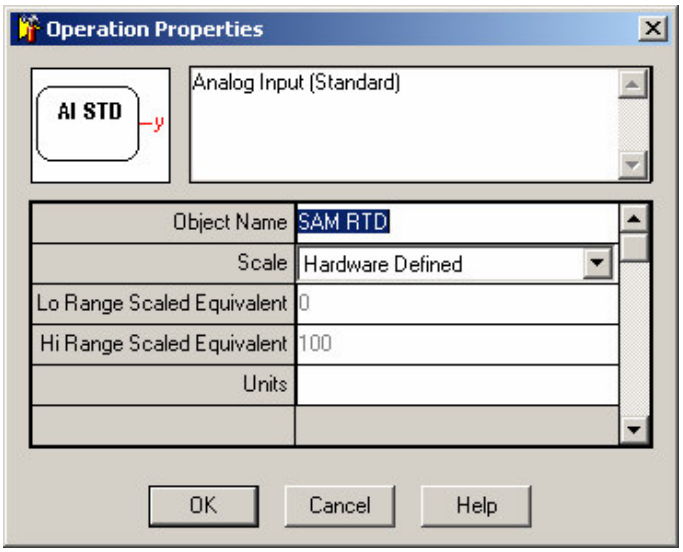


Figure 2.3. Property sheet for the *Analog Input* operator of Figure 2.1.

operator to a hardware resource. In fact, a schema document in and of itself provides no such mechanism. Instead, in *Design Pad G3*, the association between generic hardware operators included in a *schema* document and specific hardware resources found in a controller are maintained in a separate document called the *Hardware Interface* file. Segregating the control algorithm from hardware associations promotes program re-use since the same schema document can be used again in again in a variety of hardware configurations. If the control algorithm must be revised, only one file needs to be changed—the single schema document.

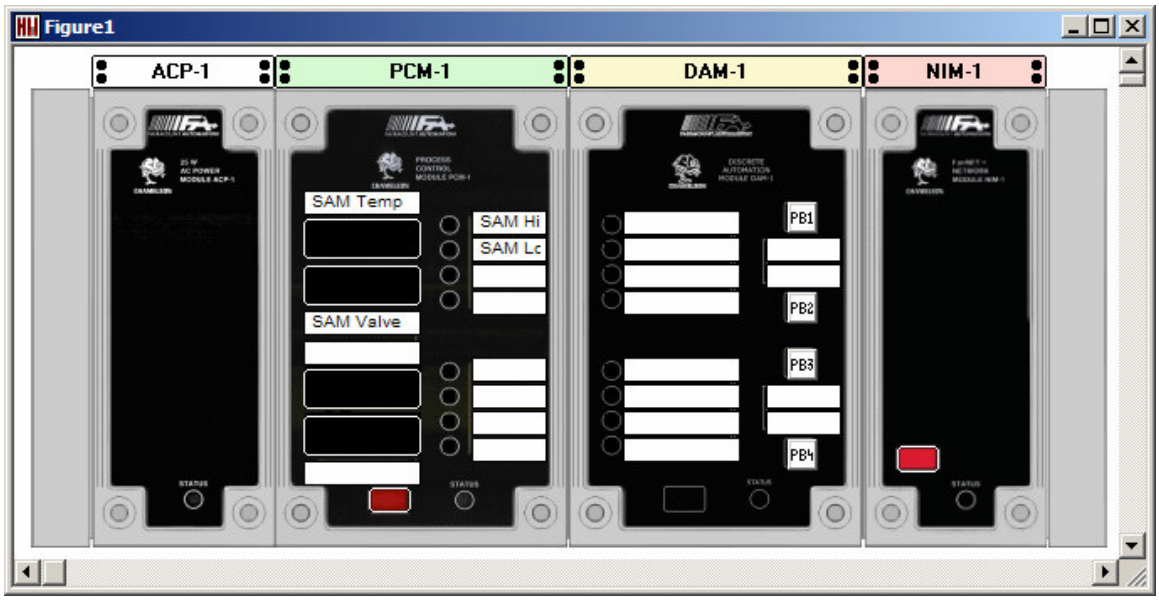


Figure 2.4. *Hardware Interface* document associated with *schema* of Figure 2.1.

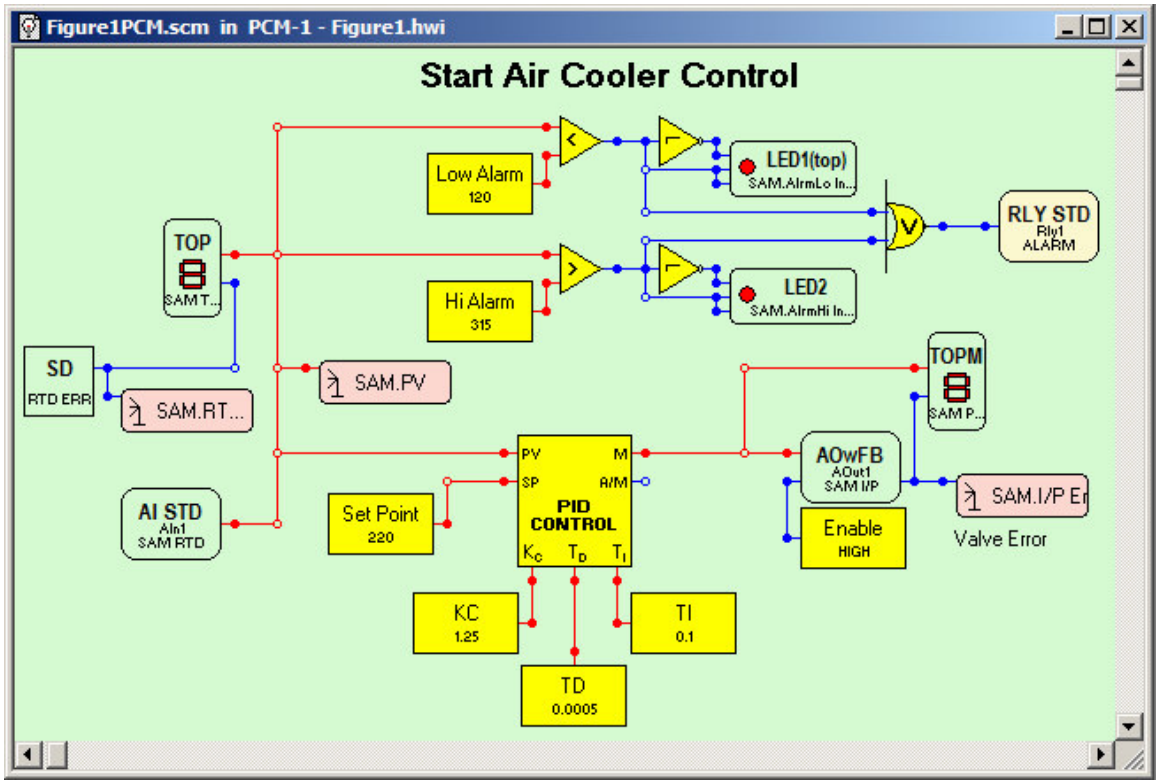


Figure 2.5. Schema document of Figure 2.1 linked to PCM-1 module in hardware interface document of Figure 2.4.

A sample hardware interface file that references the schema document of Figure 2.1 is shown in Figure 2.4. The figure shows a hardware configuration consisting of four Chameleon modules—an AC Power Module (ACP-1), a Process Control Module (PCM-1), a Discrete Automation Module (DAM-1), and a Network Interface Module (NIM-1). A different color is assigned to each module's title bar to easily identify associations between the module, schema documents, and hardware resources. Figure 2.5 shows the same schema document of Figure 2.1 now linked to the PCM-1 module. Note that the background color in the Figure 2.5 schema view matches the PCM-1 module's title bar color shown in Figure 2.4. Note also that in the Figure 2.1 view of the schema document, all of the hardware operators have a white background and a generic label, indicating that they have not been linked to any specific hardware resources. In the Figure 2.5 view of the same schema document, the hardware operators have now been linked to specific hardware resources. Those associations are reflected by labels that specify the hardware resource and by a background color that identifies which module provides that hardware resource. For example, the background color of the Relay operator is yellow to reflect that the hardware resource is physically housed in the DAM-1 module. In addition, the operator is now labeled "Rly1" to indicate that DAM-1 output channel 1 is linked to the operator. (The DAM-1 module has 8 relay outputs.) Similarly, the Analog Input operator is colored green and labeled "TOP" to indicate that it is linked the top numeric display of the PCM-1 module. The three broadcast operators in the schema have a pink background color to indicate that they are linked to the NIM-1 module—the signal values will be transmitted over the RS-485 network that the NIM-1 module is attached to. The examples cited above are of hardware resources that are only available in the selected modules. That is, the *Analog Input* operator could only be linked to the PCM-1 module since neither the DAM-1 nor the NIM-1 modules have analog input resources. Likewise, only the DAM-1 module provides relay outputs, and only the NIM-1 module provides networking connectivity. However, both the PCM-1 and DAM-1 modules provide LED indicator resources. In the schema of Figure 2.5, both LED operators have been linked to the PCM-1 module (as indicated by their green background), but they could have been linked to the DAM-1 LED resources.

Other than the ACP-1, all modules in Figure 2.4 are capable of executing the control schema of Figure 2.1. In this example, the schema document was linked to the PCM-1 module. But it could have been linked to either the DAM-1 or NIM-1 for execution in one of those modules.

The control schema shown in Figure 2.1 and corresponding hardware configuration shown in Figure 2.4 represent the first step in the controller programming process. The next step is to download the controller configuration into the device. *Design Pad G3* has built-in functionality that provides two-way communication between a personal computer and Fairmount Automation's controller hardware. Once you have completed your schema design and hardware configuration, simply connect your computer to the controller[1] and choose the Export Schema item on the Communications menu.

[1] The FAC-2000 controller connects to a PC via serial cable. Chameleon products have a built-in infra-red interface for wireless line-of-sight connectivity with a PC's IRDA port. If the PC does not have an IRDA port, serial port to IRDA adapter cables are readily available.

3. GETTING STARTED

Hardware and Software Requirements

To use *Design Pad G3*, your computer must have:

- An 80586 (or compatible) CPU or greater
- 16MB (or more) of RAM
- A hard disk with 16MB of available disk space
- A serial communications port (to interface with the controller)
- A CD-ROM drive or *Internet* connection (for installation)
- Windows 98 or higher
- A Windows-compatible mouse

Installation

To install Design Pad G3 on your computer, visit the download area of our website at:

http://www.fairmountautomation.com/download/release.htm

and click on the *Design Pad G3* link corresponding to the desired version. When prompted with the File Download dialog box shown in Figure 3.1 below, click the *Save* button to store the installation archive (`.zip`) in a temporary folder on your computer. After saving the file, open it and extract all the files in the archive into the temporary folder. Then execute the `Setup.exe` program to begin the installation process.

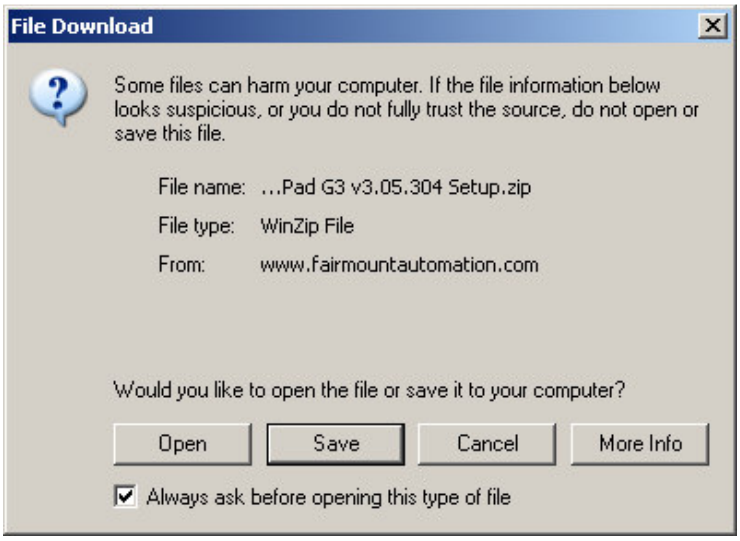


Figure 3.1. File Download dialog prompt displayed when retrieving Design Pad G3 installation archive.

You will be prompted with a series of dialog boxes at each step of the installation process. The first is the Welcome dialog shown in Figure 3.2 below. To ensure the installation proceeds without any problems, all other Windows programs should be closed before continuing with the process. If other programs are running, click the *Cancel* button to quit *Setup* and then close any programs that are running before proceeding. Once all other programs have been closed, run `Setup.exe` again and click the *Next* button on the *Welcome* dialog.

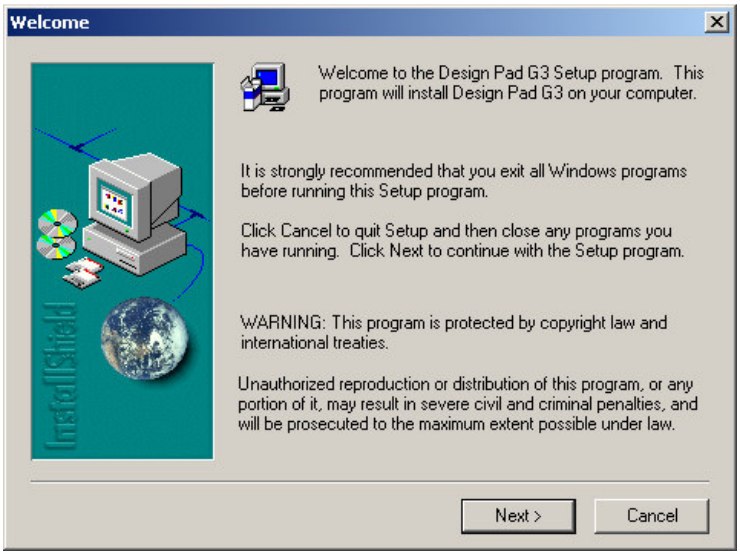


Figure 3.2. Installation welcome screen.

Next, you will be prompted with the Software License Agreement dialog shown in Figure 3.3. Please read all licensing terms carefully before proceeding. If you agree with the

license terms, click the *Yes* button to continue. The software may not be installed unless you accept these terms.

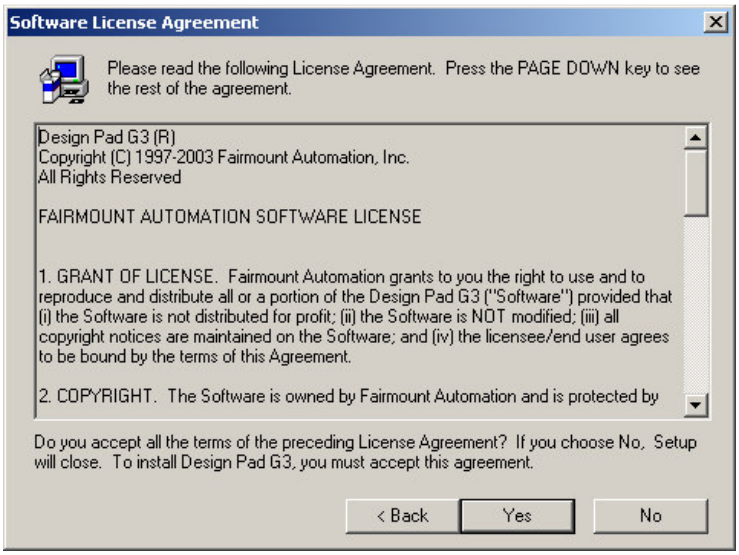


Figure 3.3. Software License Agreement dialog. License terms must be accepted before installation can proceed.

Next, you will be prompted with the Choose Destination Location dialog shown in Figure 3.4 to select the folder where the software is to be installed. The default location is typically `C:\Program Files\Fairmount Automation`. To select a different location, click the *Browse* button.

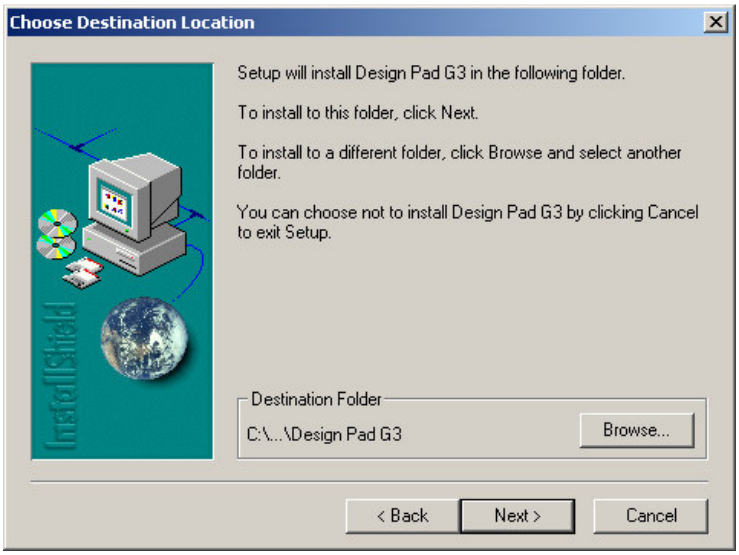


Figure 3.4. Choose Destination Location dialog used to select the folder where the software is to be installed.

Next, you will be prompted with the Select Components dialog shown in Figure 3.5. By default all modules are selected for installation. If you would like to exclude a component from the installation, click on the check mark next to it.

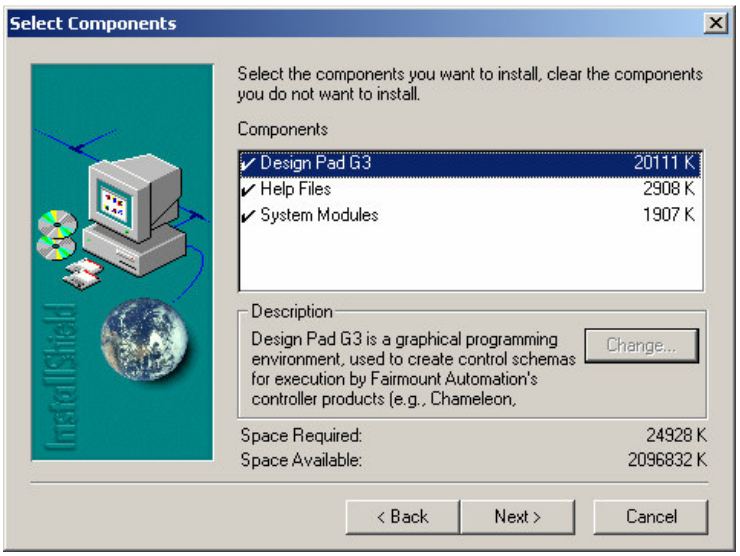


Figure 3.5. Select Components dialog used to identify the software modules that are to be installed.

The software will then proceed to install the selected components in the desired destination folder. When the process is finished, the Setup Complete dialog of Figure 3.6 will be displayed. Click the Finish button to exit the installation program..

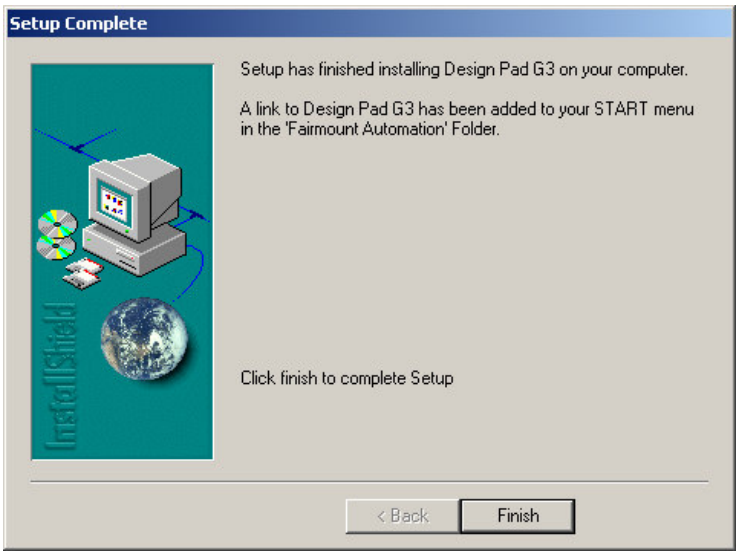


Figure 3.6. Setup Complete dialog indicates installation success.

Licensing

The *Design Pad G3* software will not execute without a valid license file. When you first run *Design Pad G3* on an unlicensed computer, you will be prompted with the dialog box shown in Figure 3.7. The dialog box presents you with a software key that you must e-mail to *Licensing@FairmountAutomation.com* in order to obtain a license file. Clicking the *E-mail Key* button will launch your e-mail program and prepare a message for you to send. Alternatively, you can save the key file and subsequently manually attach it to an e-mail message.

Shortly after sending your request, you should receive an e-mail response with an attached license file named `DESIGN PAD G3 LICENSE.DAT`. Save the attached file in the computer's `\WINDOWS` (or `\WINNT`) directory. When you save the file, you should be prompted to overwrite an existing 0-byte file with the same name—click YES. If you are not prompted to overwrite an existing file, then something is wrong. You either did not generate the key file from the computer where you are attempting to store the license, or you are not storing it in the proper location. Once you save the license file in the appropriate directory, you should no longer see the dialog of Figure 3.7 when you execute *Design Pad G3*.

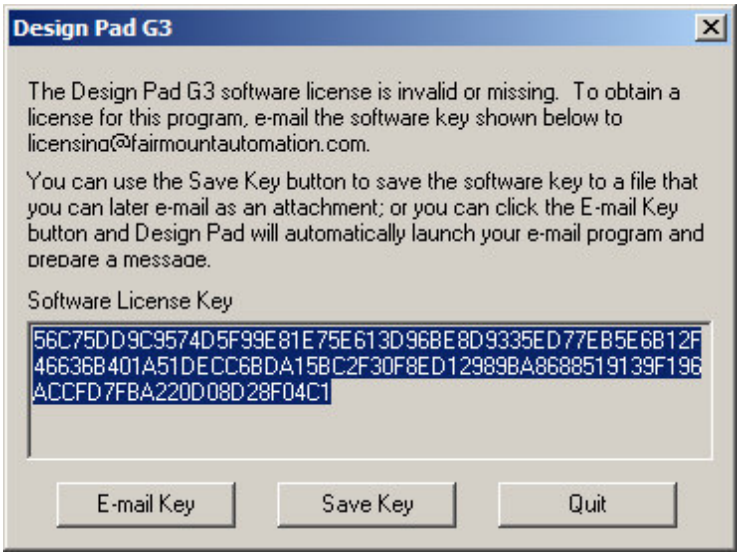


Figure 3.7. Property sheet for the *Analog Input* operator of Figure 2.1.

4. PROGRAMMING WITH *DESIGN PAD G3*

Fairmount Automation's controller products are programmed with a graphical programming software package call *Design Pad G3*. All "programming" is done graphically—by "drawing" connections between functional operator blocks (see Figure 2.1 for a sample "program").

Design Pad G3 supports well over 120 operators, including

- Controllers (*e.g.,* PID controller, lead-lag controller)
- Data Conversion (*e.g.,* binary to decimal)
- Data Logging (*e.g.*, strip-chart recorder, snap-shot recorder)
- Diagnostic (*e.g.,* breakpoint, module position)
- Signal Generators (*e.g.*, ramp profile, pulse-width modulation)
- Logic (*e.g.*, NAND gate, XOR gate, RS flip flop)
- Math (*e.g.,* addition, multiplication, exponential, trigonometric sine)
- Signal Comparators (*e.g.,* high/low alarm, equality, less or equal)
- Signal Conditioning (*e.g.,* characterizer, rate limiter, track & hold)
- Signal Switching (*e.g.,* A/B Switch, demultiplexer, min/max selector)
- Signal Reference (*e.g.,* variable, constant)
- Sub-Schemas (*e.g.,* custom function-block, state diagram)
- Hardware I/O resources (*e.g.*, analog input, relay output)
- Hardware U/I resources (*e.g.,* numeric display, pushbutton)
- Hardware Timing Resources (*e.g.,* alarm clock, calendar, stop watch, timer)
- Hardware Built-in Test (*e.g.,* self-diagnostic, module hardware info)
- Networking Operators (*e.g.*, Modbus register coil, LonTalk network variable)

A detailed description of all the operators available in *Design Pad G3* is provided in section 0 of this instruction bulletin.

The collection of operators and their associated interconnections is called a control *schema*. The schema diagram represents the actual program that will be executed on the target controller hardware. The specific controller configuration identifying the available hardware elements is defined in a separate document called the *hardware interface* file. The sections that follow describe how to create a hardware configuration and associated control schema(s), as well as how to download the control algorithms into the actual controller hardware.

Creating a Hardware Interface File

A *hardware interface* file defines the type and arrangement of hardware resources that constitute a controller node. For example, a controller node could take the form of a standalone *FAC-2000* device, as shown in Figure 4.1. Alternatively, a controller node could be made up of several *Chameleon* modules as shown in Figure 2.4. This section provides a description of how the document illustrated in Figure 2.4 was created.

New Document

Step 1. Create and Name a New Hardware Interface Document

To create a hardware interface file, choose the New Document item from the File menu (or press the New Document button on the speed bar menu). Then, select the Hardware Interface item from the New Document dialog of Figure 4.2. *Design Pad G3* will create a blank hardware interface document, as shown in Figure 4.3. Each window in the *Design Pad G3* client area holds a distinct document, allowing you to work on multiple documents simultaneously. A tab control below the toolbar menu, allows you to quickly select a desired document from all of the currently open documents. You can also switch between documents by simultaneously pressing the `CTRL-TAB` keys.

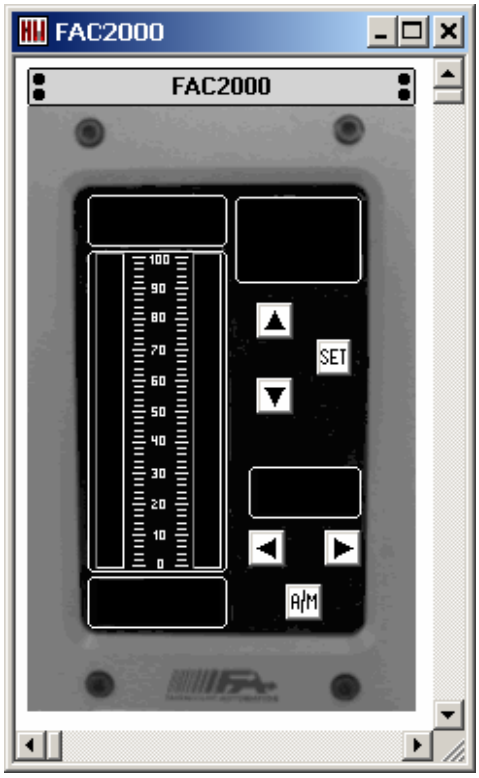


Figure 4.1. *Hardware interface* file for stand-alone *FAC-2000* controller.

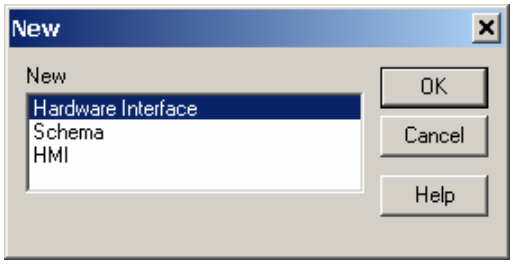


Figure 4.2. New document dialog.

Save Document

Open Document

Before you begin adding controller modules to the hardware interface document, first use the Save Document As item in the File menu to name your configuration document and save it to disk. In the File Open/Save dialog shown Figure 4.4, name your blank hardware interface document '`Figure1.hwi`' and press the Save button. Be sure to regularly save your documents to disk as you develop and make changes to your designs. To save documents, use the Save Document item in the File menu; to retrieve them, use the Open Document item in the File menu. (As an alternative to using the menu items, you may press the speed-bar buttons shown to the left.)

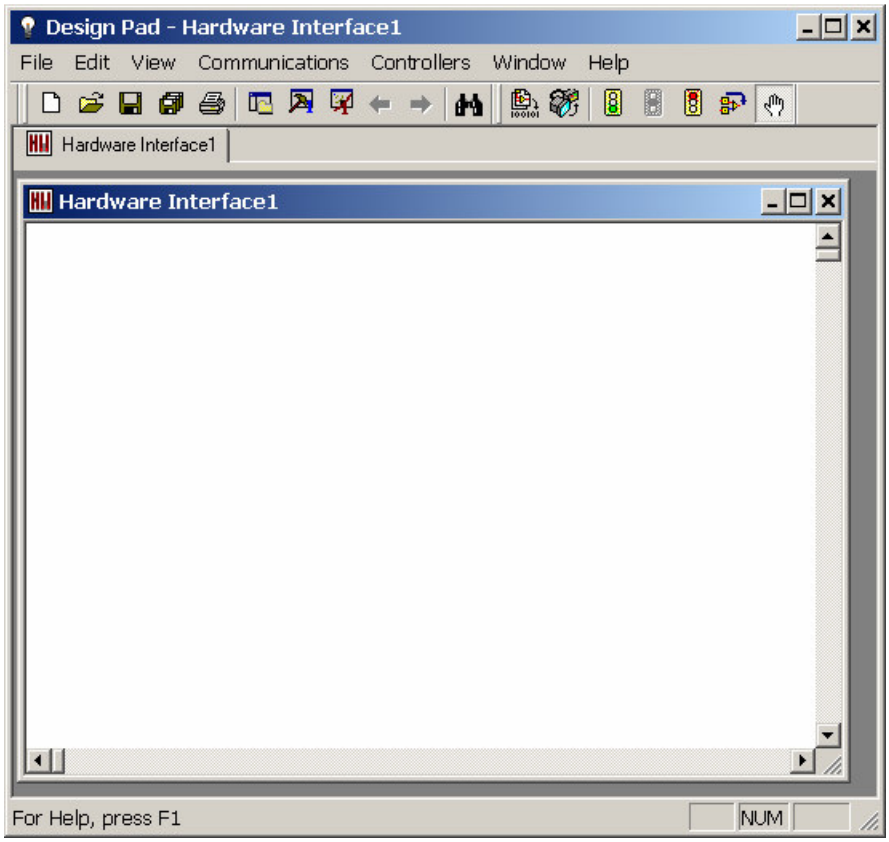


Figure 4.3. Design Pad G3 environment with blank hardware interface document.

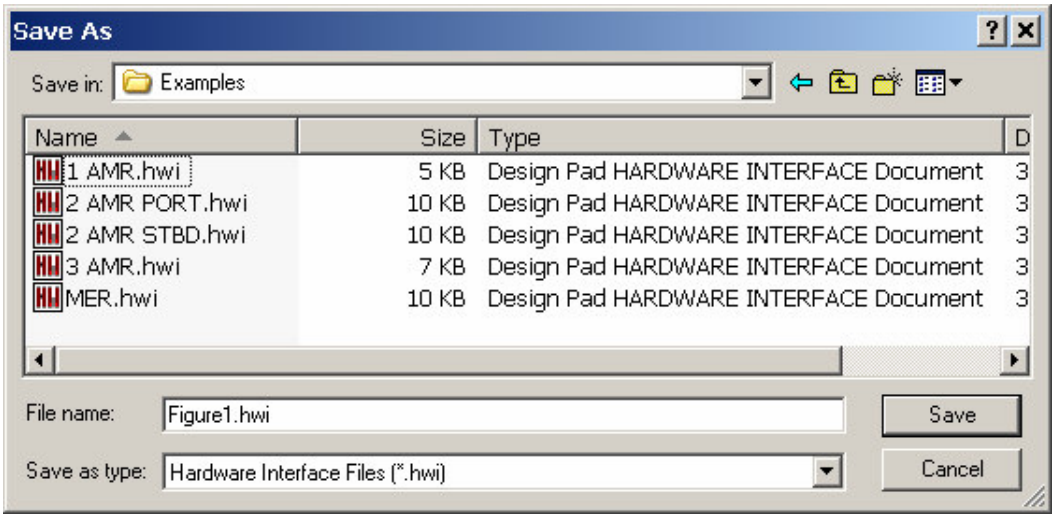


Figure 4.4. Save As dialog box

Design Pad G3 maintains a list of recently opened documents. To open a document that you have used recently, select the Recent Files item in the File menu. A sub-menu will appear listing the most recently opened documents. If the document you wish to open is on the list, select it. (You can change the number of entries in the recent-file list in the Preferences dialog—see section 0.)

Design Pad G3 has an auto-recovery feature designed to recover unsaved changes to documents after an abnormal program termination. When the auto-recovery feature is enabled (see section 0), *Design Pad G3* saves copies of open documents at regular intervals. When you first execute *Design Pad G3*, it checks to see if it terminated abnormally during a prior session (*e.g.*, due to power interruption). If it detects an abnormal termination, it prompts you if you would like to attempt to recover unsaved changes to documents.

Design Pad G3 can also automatically create a back-up copy of a hardware interface document before saving any changes to the file. For example, when you save changes to the `Figure1.hwi` file, *Design Pad G3* first makes a copy of the existing file (and saves the copy as `Figure1.bwi`) before overwriting `Figure1.hwi` with any changes made to it. This feature could be useful if you have saved changes to a document but later decide you want to discard those changes and revert to the back-up version of the schema. To disable the auto-backup feature, see section 0.

NOTE: Schema documents use `.scm` as the file extension and `.bcm` as the backup file extension. Human-Machine Interface (HMI) documents use `.hmi` as the file extension and `.bmi` as the backup file extension. If you need to revert to a backup version of a document, locate the appropriate file and change its backup extension to its original extension.

Step 2. Insert Controller Modules

You can now begin configuring the controller hardware by inserting desired hardware modules into the blank document of Figure 4.3. The Controllers menu contains all the hardware modules supported by *Design Pad G3*, grouped by product family (*e.g.*, Chameleon, FAC-2000).

To duplicate the controller configuration shown in Figure 2.4, select the 25W AC Power (ACP-1) item, in the Controllers → Chameleon menu. An image of the faceplate of the Chameleon ACP-1 module will appear in the blank document. As you select the other modules shown in Figure 2.4 from the Controllers → Chameleon, their corresponding faceplate images will be appended in the rightmost position. If you would like to rearrange the module order in the controller node, you can simply click on a module and drag it to the desired position.

Step 3. Label each Controller Module

Design Pad G3 assigns each hardware module a default label as they are inserted into the document. You can modify the default label by clicking the right mouse button on the appropriate module and selecting the Module Options item from the drop-down menu. Try right-clicking on the PCM-1 module, bring up the Module Options dialog box, and enter "PCM-1" in the Module Name edit control. Do the same for the ACP-1, DAM-1, and NIM-1 modules. Note that different settings are available for each module type (but all provide a *Module Name* setting). The configuration settings available for each module type are described in detail in SECTION XX.

Creating a Control Schema

A *schema* is a collection of interconnected functional operator blocks that form a control strategy. It is a graphical block-diagram that represents the algorithm that is to be executed on the target controller hardware. A sample schema is shown in Figure 2.1. This section provides a step-by-step description of how you could synthesize that schema.

Step 1. Create and Name a New Schema Document

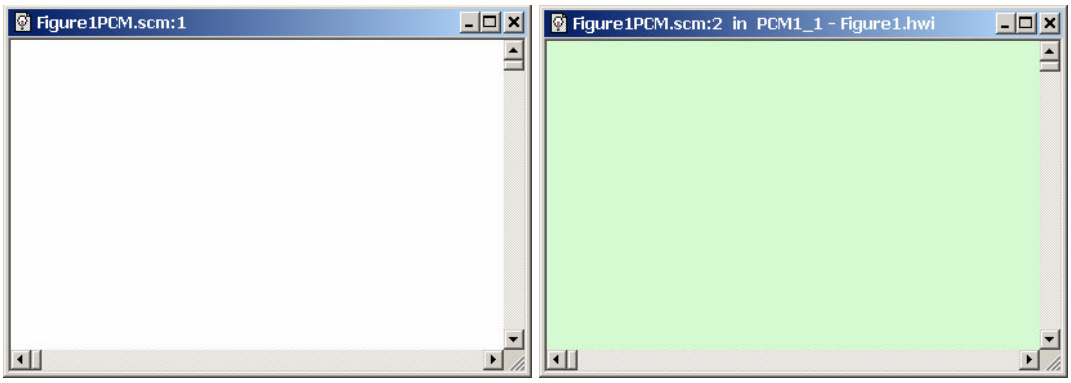


Figure 4.5. (a) Blank schema document "Figure1PCM.scm"; (b) same schema document associated with module "PCM1_1" in hardware interface "Figure1.hwi" of **Figure 2.4**.

To begin the design process, choose the New Document item in the File menu (or press the New Document button on the speed-bar menu). When *Design Pad* prompts you for the document type (as shown in dialog of Figure 4.2), choose the schema option. *Design Pad* will respond with a blank schema document window. Before you begin adding operators to the schema document, use the Save Document As item in the File menu to name your document and save it to disk. In the File Open/Save dialog shown in Figure 4.4, name your blank schema document '`Figure1PCM.scm`' and press the Save button. Your blank document should resemble the one shown in Figure 4.5(a).

The background color of the blank schema document that you just created is white, indicating that it has not been associated with any specific hardware target module. The schema must be associated with a hardware module in order for it to be executed by that hardware module. Not having a schema link does not necessarily mean that the module is idle since it could still provide access to its hardware resources (*e.g.,* analog input, RS-232 communications port, pushbutton, *etc.*) to adjacent modules that do have schema associations.

To associate the new schema that you just created with the PCM-1 hardware module of

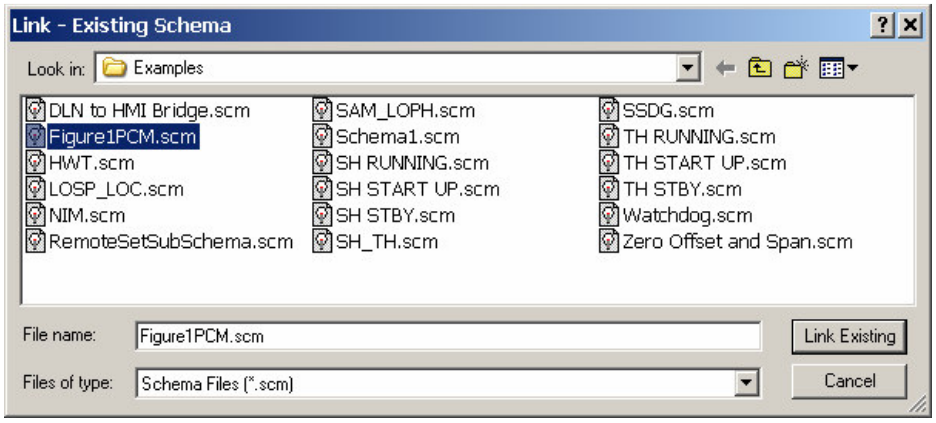


Figure 4.6. The Link Existing Schema dialog.

Figure 2.4, click the right mouse button on the "PCM-1" faceplate image and select the Link Existing Schema item from the drop-down menu. Then, select the "Figure1PCM.scm" schema document that you just created, as shown in Figure 4.6. Once you have associated the schema document with a hardware module, you can open the schema by double-clicking on the module faceplate image (you can also right-click on the image and select Open Linked Schema from the drop-down menu).

Notice that the background color—light green—of the linked schema document (shown in Figure 4.5(b)) matches the background color of the corresponding hardware module's title bar (shown in Figure 2.4). Notice also that the window title bar of the linked schema document—labeled "Figure1PCM.scm:2 in PCM-1 – Figure1.hwi"—includes the file name ("Figure1PCM.scm"), as well as the module name ("PCM-1") and hardware interface file name ("Figure1.hwi") where the schema will execute. The window title bar of Figure 4.5(a) only provides the schema document file name since it is not linked to any hardware module.

Figure 4.5(a) and Figure 4.5(b) represent two views of the same "Figure1PCM.scm" document (as indicated by the ":1" and ":2" suffixes on the file names). If you make a change in one view of the document, it is simultaneously reflected in the other view.

As a shortcut to creating a new schema, linking it to a hardware module, and then opening the file again, you can simply right click on the module faceplate image and select the Link New Schema item from the drop-down menu.

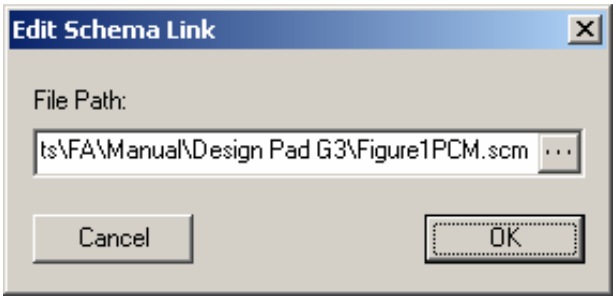


Figure 4.7. Edit Schema Link dialog.

The hardware interface file stores a link to the schema file as a relative file path. Clearly, if the schema document filename is changed outside of the *Design Pad G3* environment (*e.g.,* using *Windows Explorer*), or if the schema document is moved to a different directory, the link stored in the hardware interface file will no longer be valid. Double-clicking on the module faceplate or selecting the Open Linked Schema menu item will no longer work properly. Processing the node configuration and/or attempting to download a program to the target hardware will also fail. To restore the document association, you can select the Edit Schema Link item from the drop-down menu and manually edit the file path (see Figure 4.7). If you need to search for the desired file, click the Browse button (illustrated in the left margin and located to the right of the edit control in the dialog box).

The association between a module in the hardware interface file and a schema document can be removed altogether by selecting the Unlink Schema item from the drop-down menu.

Step 2. Insert Functional Operator Blocks

You are now ready to begin creating a control schema. To begin, you will want to insert functional operator blocks into a blank schema document. The Operators menu contains all the operator blocks available in *Design Pad G3*, grouped by functionality (*e.g.*, controller blocks, signal conditioning functions, logic operators). You can also access the available operators by clicking the right-mouse button anywhere in the background area of the schema document to activate the drop-down menu shown in Figure 4.8. Each operator is described in detail in the operator reference section of this instruction bulletin (section 0).

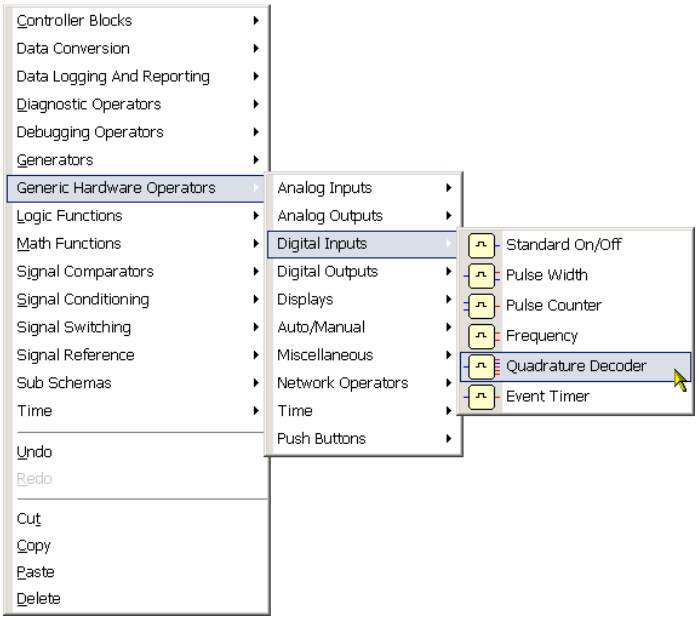


Figure 4.8. Drop-down menu activated with mouse right-click on schema document background.

Under the Controller Blocks sub-menu of the Operators menu, choose the PID Controller item. *Design Pad G3* will attach a *PID operator* object to your cursor, and will "drop" it wherever you click the left mouse button. Thus, to position the PID block, move your cursor to the center of the document window and click the left mouse button.

Next, activate the drop-down menu of Figure 4.8 and choose Generic Hardware Operators → Analog Inputs → Standard. *Design Pad G3* will attach the selected operator to your cursor until you press the left mouse button to release it. Position the *Analog Input* operator below and to left of PID operator block, as shown in Figure 4.9. Note that generic hardware operator is assigned a default name—"AInStd1" in this case. This name is just a label for the operator block and does not directly correspond to the physical hardware resource that the operator is associated with (*i.e.,* "AinStd1" does not

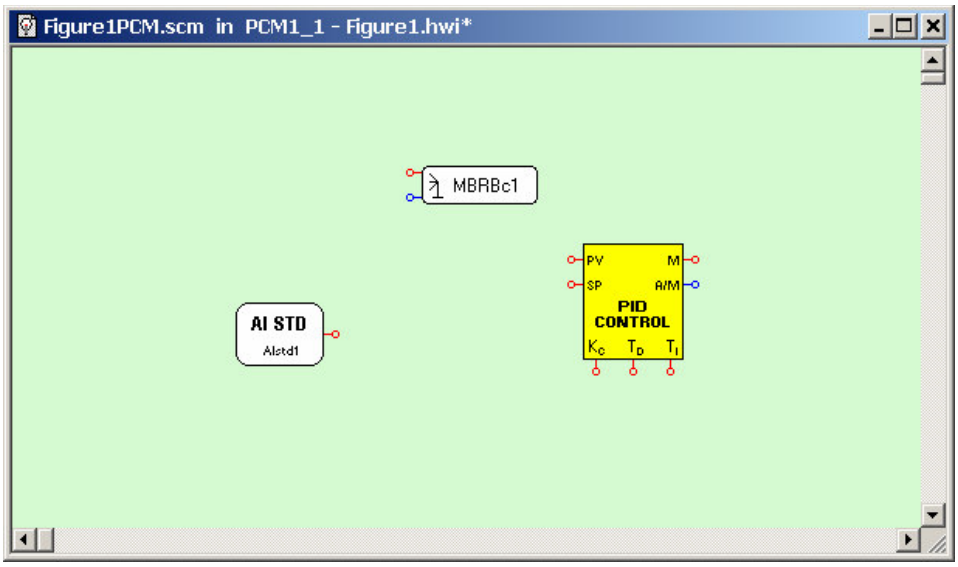


Figure 4.9. Initial stage of schema development.

mean that the signal source for the operator is some input channel number 1). In fact, at this point, the *Analog Input* operator is not linked to any specific hardware resource in any module (section 0 describes how to make this link).

Continuing with schema design, insert a *Modbus Register Broadcast* operator (Generic Hardware Operators → Network Operators → Modbus → Register Broadcast (Analog)) above the *Analog Input* block. At this point, your schema diagram should resemble the schema shown in Figure 4.9. You can change the position of any operator by "dragging" it. (With the Selection tool active, position the cursor within the operator and click the left mouse button. Hold the mouse button down while moving the cursor to the desired location, and then release the mouse button.) You can also change the position of several operators and signals at the same time. First, select the operators you wish to reposition by holding down the SHIFT key as you click the left mouse button on each object. Then, just drag the objects to their new location—simultaneously hold down the left mouse button and the SHIFT key on your keyboard while moving the cursor to the desired screen position.

Selection Tool

Design Pad G3 also provides a selection box feature that is useful for selecting multiple operator objects at the same time. To activate the selection box, click the left mouse button over schema background—a location in the schema that does not contain an operator block, a signal wire, a text block, or any other object. Then, as you move the mouse (while holding the left button down), *Design Pad G3* displays a rectangular box—the selection box. When you release the left mouse button, *Design Pad G3* will select all the objects that are inside the selection box. (You can also select all schema objects by using the Edit → Select All menu item or the CTRL-A hot key.)

As illustrated in Figure 4.9, your schema should have three operators *(PID controller, Analog Input, and Register Broadcast*) with no connections between them. You could now continue adding the remaining operators in Figure 2.1, or you could begin making

connections between the existing blocks. The next subsection describes the process of connecting operators.

Step 3. Connect Operator Blocks

The next step in the schema design process is to make connections between the operator blocks. That is, to feed the output of one operator to the input of another. *Design Pad G3* supports two signal types: analog signals (floating point values) drawn in red, and digital signals (boolean values, *i.e.,* true/false or high/low) drawn in blue. These signal types cannot be directly mixed—you may not connect an analog signal to a digital one. (However, *Design Pad* does provide operators to convert from one type to the other.)

Operator blocks have input and/or output pins (I/O) that serve as connection points or "hot-spots". An I/O pin can be an operator input, or an operator output, but not both. It is drawn as a short line attached to a small circle: . An unfilled circle indicates that the pin is not connected. When the pin is connected, *Design Pad G3* fills in the circle: . (*Design Pad G3* will not draw the circle—filled or unfilled—if the Operator "Hot-Spots" item in the View menu is not selected. This can be useful when printing a schema.)

While every operator has at least one I/O pin, most have both input and output pins. For instance, the *PID* operator has 5 analog inputs (SP, PV, Kc, Ti, and Td); an analog output (M); and, a digital output (A/M), as shown in Figure 4.9. The *Analog Input* operator has a single analog output, and the *Modbus Register Broadcast* operator has two input pins (one analog and one digital).

New Signal Tool

The PID control schema of Figure 2.1 was designed under the assumption that sensor measurements from an external process are sampled by an analog input hardware resource of the controller. Therefore, the *Analog Input* operator signal was fed to the process variable (PV) input of the *PID controller* block. To make this connection in your schema, select the New Signal tool from the Tools menu (or press the corresponding button on the toolbar menu). Position the cursor over the output pin of the *Analog Input* block, click the left mouse button, and move the cursor away from the operator. You should notice that a signal "wire" now connects the *Analog Input* block to the cursor—*Design Pad* has switched into *wiring* mode. You can control the configuration of the signal wire with the mouse as follows:

- If you left-click on white space, a signal joint will be created, and you will remain in wiring mode. Signal joints, or "hot-spots" are useful when reshaping a signal. (*Design Pad G3* will not draw the signal joints if the Signal "Hot-Spots" item in the View menu is not selected. This can be useful when printing a schema.)

- If you click the right mouse button while in wiring mode, the last signal joint will be deleted. If no signal joints remain, the wire will be removed, and *Design Pad G3* will switch out of wiring mode and into normal mode.

- If you double-click the right mouse button, all signal joints will be deleted, the wire will be removed, and *Design Pad G3* will switch into normal mode (out of wiring mode)

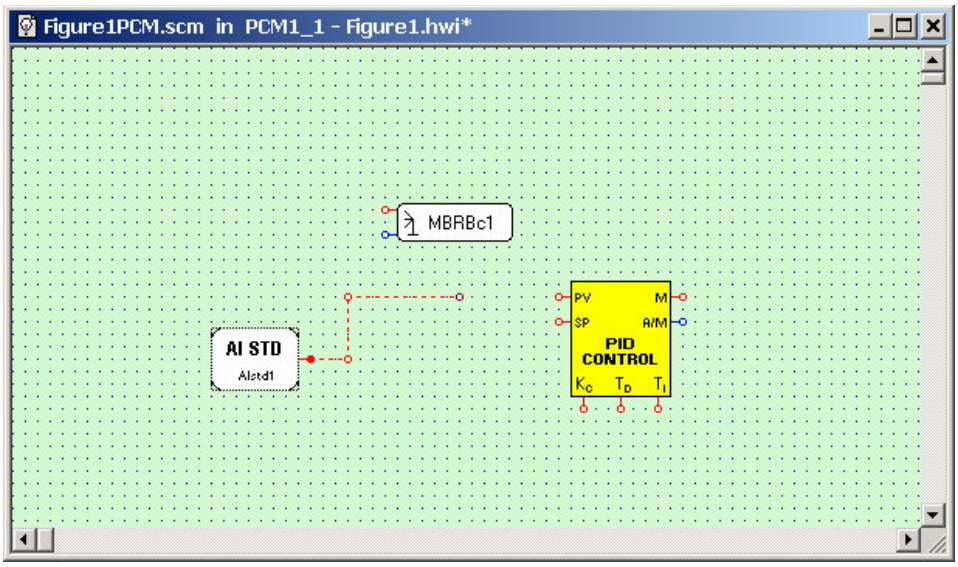


Figure 4.10. The *Analog Input* operator is about to be connected to the Process Variable (PV) input of the *PID Controller* operator.

- If you click the left mouse button while the cursor is positioned over an operator I/O pin, the wire will be connected to that pin, and *Design Pad G3* will switch into normal mode (out of wiring mode).

- If you click the left mouse button while the cursor is positioned over another signal, the two signals will be connected, and *Design Pad G3* will switch into normal mode (out of wiring mode).

Figure 4.10 illustrates the connection process. A signal wire has been connected to the output of the *Analog Input* object. The cursor holds the active signal wire and is moving toward the PV input of the PID block. When the cursor is positioned over the PV input pin, the left mouse button will be clicked, thereby connecting the two blocks.

When a new signal is being created, *Design Pad G3* displays the signal wire as linear dashed segments, with signal joints between segments. The dashed line indicates that the signal is *selected*. Signals that are not selected are drawn as solid lines. (A similar convention is used for operators as well—the outline of an operator is solid when not selected and dotted when selected.)

By default, schema documents have a blank background. However, when you are creating a schema, you may find it convenient to display a grid in the background (Figure 4.10 has the grid on). The grid can be a useful alignment tool when you are arranging objects. To activate the background grid, select the Grid item from the View menu. You can remove the grid by selecting the Grid item again.

The *PID* and *Analog Input* operators of your schema should now have a wire connecting them. The next step is to connect the same signal to the *Register Broadcast* operator. Position the cursor on the analog input pin of *the Register Broadcast* operator and click the left mouse button. While in wiring mode, move the cursor down until it is directly

over the existing signal wire, and click the left mouse button again to make the connection.

The next section takes up the topic of operator properties and completes the process of creating the sample schema of Figure 2.1.

Modifying Operator Properties

Every operator block has a list of user-definable properties. These properties determine the characteristics and behavior of each operator. For instance, the 'Initial State' property of the *PID* operator determines the startup mode—automatic or manual. The *Moving Average* operator has a property that sets the number of signal samples to consider in the computation of the mean. And, a property of the *Multiplication* operator establishes the number of input signals that the operator can process. The properties of every operator are described in detail in the operator reference section of this instruction bulletin (section 0).

Design Pad G3 organizes the properties of each operator object with individual property sheets (see Figure 2.2 for an example). The property sheet contains a description of the operator and a two-column table of object parameters. Each row in the table contains the name of the property (left column) and the corresponding text, numeric, or boolean value assigned to that property (right column). To view the property sheet of an object, activate the Selection Tool, position the cursor on the object, and double-click the left mouse button.

With this brief introduction to operator properties, you are ready to resume the process of creating the schema of Figure 2.1. Activate the property sheet for the *Analog Input* object (using the Selection Tool double-click the left mouse button on the object). Recalling that this schema was designed to regulate a thermal process, name the object 'SAM RTD' and set the scale property to "Hardware Defined". This scale property indicates that the input's signal range is defined by the hardware configuration. Section 0 describes how hardware resources are configured. See the operator reference section of this instruction bulletin for more information on *Analog Input* operator properties.

Continuing with the sample schema design, insert an *Analog Constant* operator from the Operators → Signal Reference menu, and position it just above and to the right of the *Analog Input* object. This *Constant* object will serve as the set-point signal for the *PID Controller* block. Connect the *Constant* object to the SP (set-point) input of the *PID Controller* block. Next, retrieve the property sheet for this object and change the operator name to "Set-Point" and value to 220. With this arrangement, the *PID Controller* block will generate a control signal aimed at maintaining the temperature at 220 degrees.

You are now prepared to complete the schema illustrated in Figure 2.1. Search the Operators menu for all of the function blocks and arrange them as shown in the figure. Double-click on each block to view its property sheet and become familiar with how you can customize the schema (refer to section 0 for a full description of each operator and associated properties). Make assumptions about the water-level process you are controlling and adjust the operator properties accordingly.

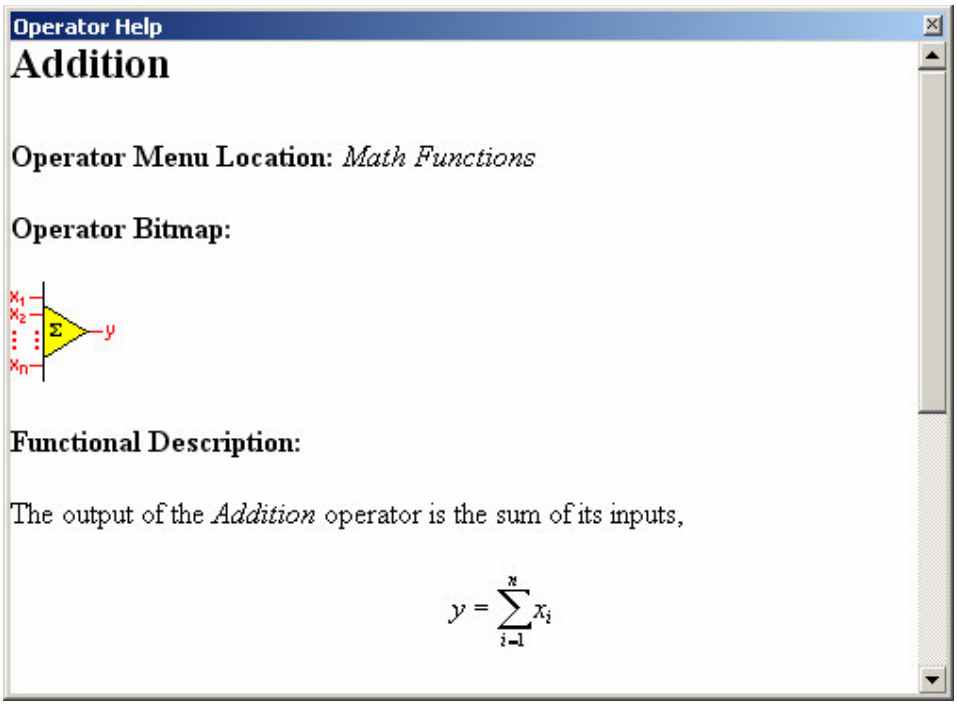


Figure 4.11. Operator Help Window.

Viewing the Operator Help Reference

View Operator Help Window

Design Pad G3 provides integrated help reference for all its operators. To view the operator help, select the Popup Help Window item from the View menu. Design Pad G3 will display a window and fill its contents with the help reference for the currently selected operator. Every time a new operator is selected, its help reference sheet will be automatically displayed in this window. The reference sheet explains the operator's functional behavior and provides a description of each operator property. For example, the help reference sheet for the Addition operator is shown in Figure 4.11.

The Operator Help window can be docked within the application client area (by default, it is docked at the bottom of the screen). The window is always drawn in front of other document windows. To hide it, select the Popup Help Window item from the View menu again, or click the close box on the top-right corner of the window.

Associating Generic Hardware Operators with Specific Module Hardware Resources

When you first inserted *generic* hardware operators into your schema document, they were drawn with a white background (*e.g.,* the *Analog Input* and *Register Broadcast* operators in Figure 4.9). We use the term *generic* here to mean that the hardware operators are not

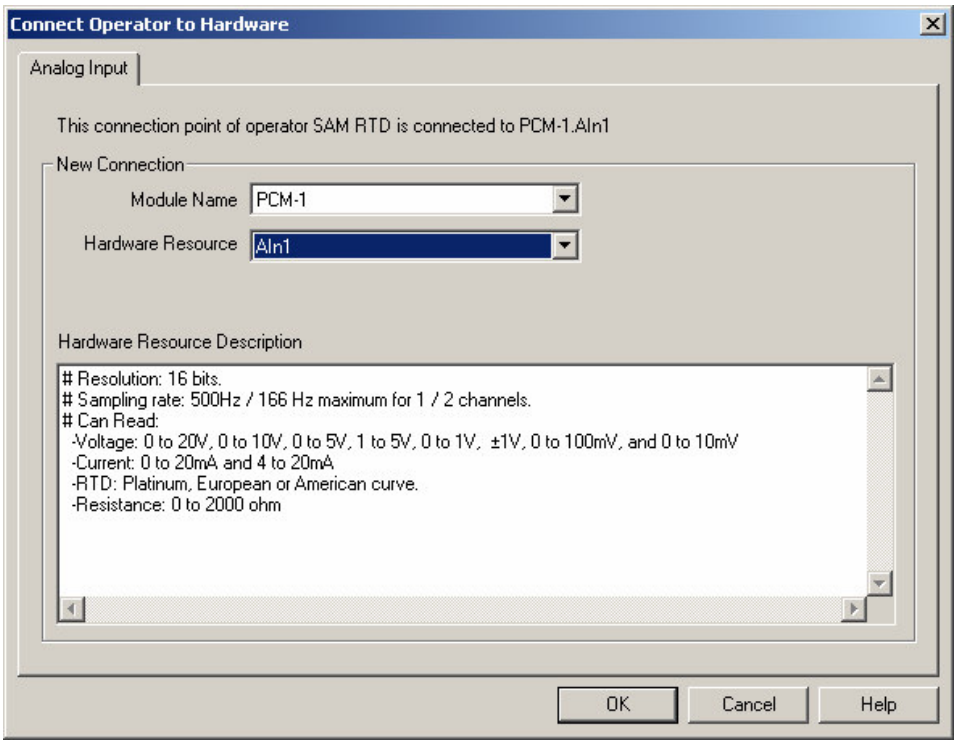


Figure 4.12. Connect Operator to Hardware Dialog.

associated with any specific physical hardware resources. At this stage of the controller configuration process, you have not yet specified which module and which analog input channel within that module serves as the signal source for the *Analog Input* operator (i.e., what input channel the RTD sensor is wired to).

4.1.1 Linking Hardware Operators to Hardware Resources

In order to link a generic hardware operator to a specific hardware resource, the schema document must be linked with a controller module in a hardware interface document. (Recall that if the schema document has a white background, it isn't linked to a controller module—see Section 0.) The modules included in a hardware interface document define the hardware resources that are available for linking to the hardware operator.

To associate the generic *Analog Input* hardware operator in your schema document with a specific analog input hardware resource, click the right mouse button on the operator image and select the Connect To Hardware item from the drop-down menu. (Note that if the schema document is not linked to a hardware interface document, the Connect To Hardware command will not appear in the drop-down menu.) *Design Pad G3* will display the Connect Operator to Hardware dialog box shown in Figure 4.12. The dialog box contains a combo box labeled "Module Name" that lists the modules available in the controller node that contain hardware resources that can be linked to the selected operator. In this example, only the PCM-1 module contains analog input resources, so the drop-down combo only contains the PCM-1 module as a possible selection. The dialog box contains a second drop-down combo labeled "Hardware Resource" that lists the available hardware resources within the selected module. The Hardware Resource combo also contains a selection labeled "Not

connected to hardware"—select this option if you wish to disconnect an operator from its associated hardware resource.

The Connect Operator To Hardware dialog box also displays a detailed description of each available hardware resource. For example, Figure 4.12 provides a description of analog input channel 1 for a Chameleon PCM-1 module. It indicates that the input has 16 bits of resolution, can be sampled at rates up to 500Hz, and can read a variety of signals (current, voltage, RTD). As you change the Hardware Resource combo setting, the description will change according to the selection. For example, in the PCM-1 module, the description for analog input channels 1 and 2 is different than the description of 3 and 4 since they have different physical characteristics.

To complete the connection, select the PCM-1 module's "AIn2" hardware resource and click the OK button. The background color of the *Analog Input* operator will change to light green to indicate that the PCM-1 module is the source of the analog input operator signal. Next, connect the *Relay* operator to the output channel 3 of the DAM-1 module as follows:

1. Click the right mouse button on the Relay operator
2. Select the Connect To Hardware item from the drop-down menu
3. Select the DAM-1 module in the Module Name combo
4. Select output channel 3 in the Hardware Resource combo
5. Click the OK button

The background color of the Relay operator should now change to light yellow, corresponding to the title bar color of the DAM-1 module. Follow the same procedure to connect all of the other hardware operators to specific resources in the available modules.

4.1.2 Linking Hardware Resources to Hardware Operators

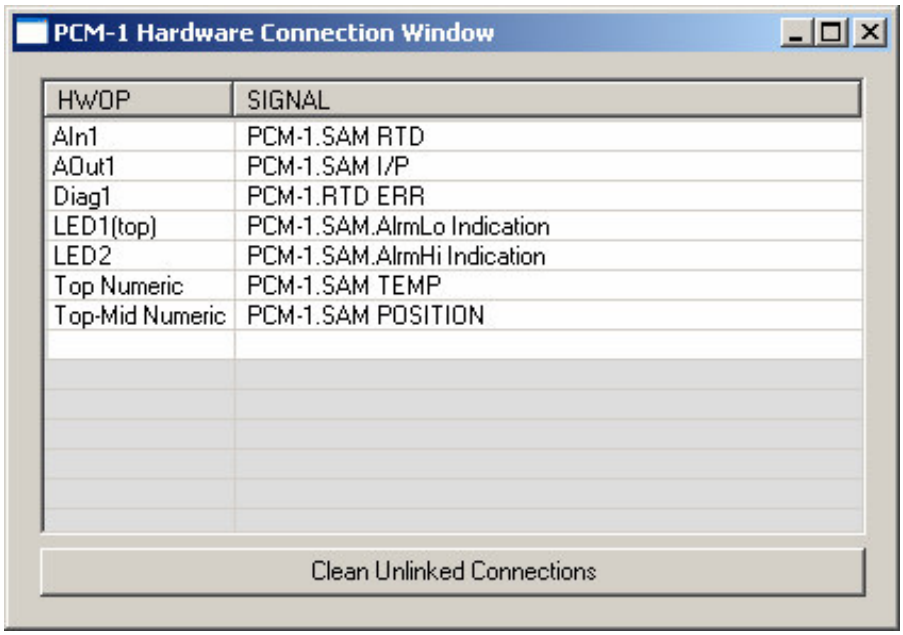


Figure 4.13. Module Hardware Connection Window Dialog.

As schemas grow in size and complexity, it may become cumbersome to determine which module's hardware resources have been linked to schema operators. It is often useful to be able to view a list of all module hardware resources that are referenced by associated schema documents. You can view such a list by clicking the right mouse button on the desired module and selecting the Hardware Connection Window item from the drop-down menu (note that this menu option is only available in modules that have user-accessible hardware resources). Figure 4.13 shows the hardware connection list for the PCM-1 module of the hardware interface file shown in Figure 2.4. You can double-click on any entry in the list to edit the connection (double-clicking an entry activates the Connect Hardware Resource to Operator dialog described below).

You can also create a new link between resource and operator by double-clicking on the empty row in the Hardware Connection Window dialog of Figure 4.13 (the last *active* row with a white background). Note that the previous section described how to link a hardware operator in a schema to a hardware resource in a module. This section describes how to link a hardware resource to an operator. (The link between operator and resource is the same regardless of how it is formed. However, in some instances it may be convenient to first select the operator and then the resource. In other cases, selecting the resource first and then the operator may be the preferred approach.)

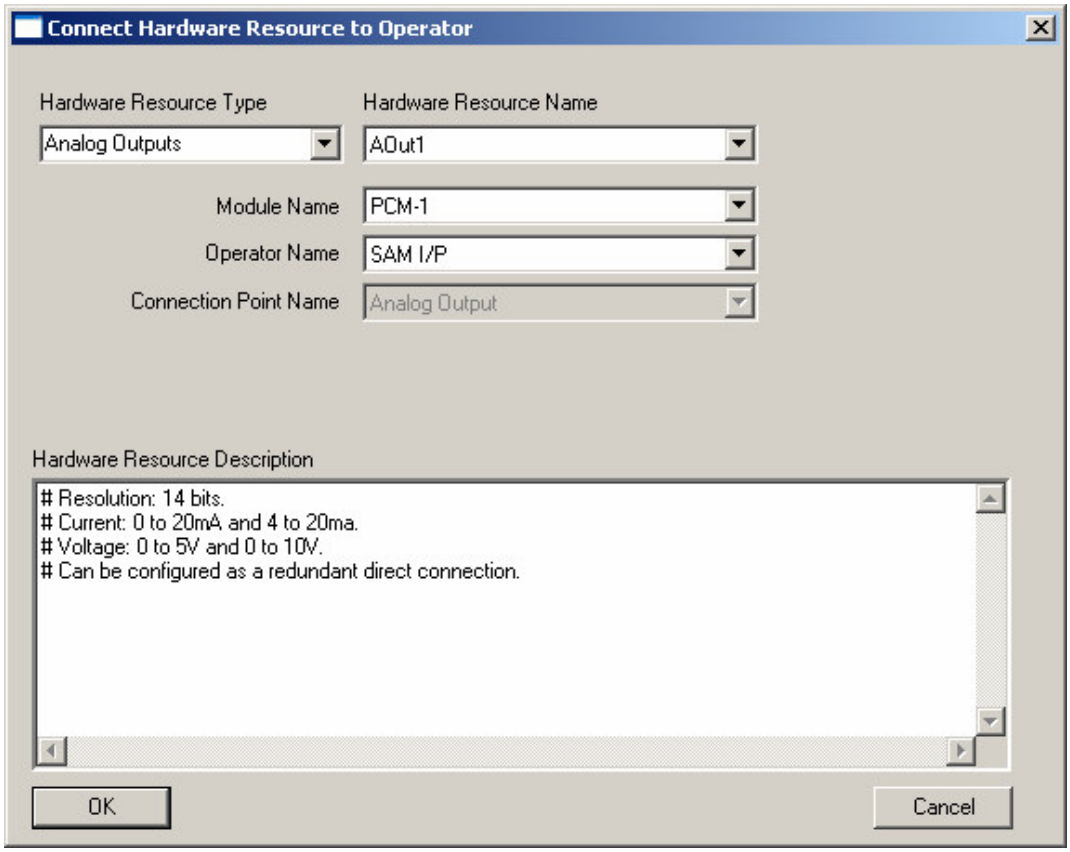


Figure 4.14. Connect Hardware Resource To Operator Dialog.

Double-clicking on the last empty row activates the Connect Hardware Resource To Operator dialog shown in Figure 4.14. To create a resource/operator link, first select the resource type (*e.g.,* Analog Outputs.) and then the corresponding channel (*e.g.,* `AOut1`). The dialog will then populate the Module Name and Operator Name combo boxes with any available operators that can be connected to the desired resource.

The links between schema operators and module hardware resources are stored in the hardware interface file. (The hardware interface file references linked operators by their user-defined *Object Name* property.) Because schema documents and hardware interface documents are stored separately, some of these hardware associations may be inadvertently broken. This could occur for example, if a schema document is edited while a hardware interface file that references that schema is not concurrently open. Consider a *Design Pad G3* session where the `Figure1PCM.scm` schema of Figure 2.5 is opened for editing independently of the `Figure1.hwi` hardware interface document of Figure 2.4. (such that the schema background color is white). Suppose that the *Object Name* property of the *Analog Input* operator is changed from "SAM RTD" to "SAM TEMP". Then, when the Figure1.hwi document is opened, it will still reference a connection to an operator named "SAM RTD" that no longer exists. Note that if the *Object Name* property of the schema operator is changed while the hardware interface file is also open (such that the schema background color is non-white) the link is automatically updated.

The Clean Unlinked Connections button in the Hardware Connection Window of Figure 4.13 dialog will search thru the list of module hardware associations and remove any link referencing an operator that can no longer be found.

4.1.3 Hardware-Independent Programming

Maintaining independence between the control algorithm (the schema document) and the hardware configuration (the interface document) promotes program re-use. The same control algorithm can be used again and again in different hardware configurations. If a change needs to be made to the algorithm, only one file—the schema document—needs to be modified. Figure 4.15(a) shows a simple example of a hardware configuration file with one Chameleon PCM-1 module and one Chameleon DAM-1. The two modules are linked to the same schema document meaning that each module will simultaneously execute the same algorithm. In this example, the algorithm simply compares an analog input signal to a threshold and activates a relay when the threshold is exceeded. Figure 4.15(b) shows one view of the schema document linked to the PCM-1 module (the schema background color is light green). Figure 4.15(c) shows another view of the same schema document linked to the DAM-1 module (the schema background color is yellow). If we make a change to the

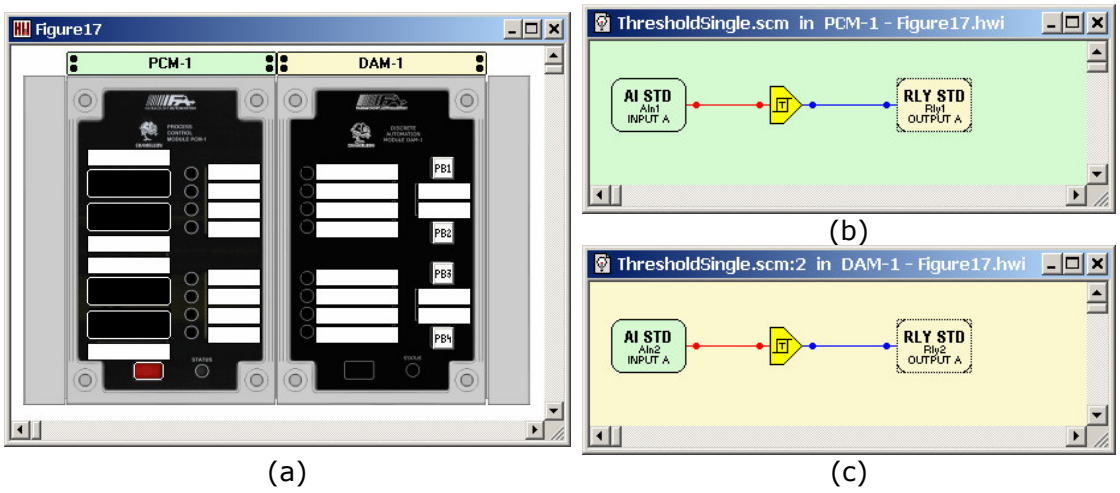


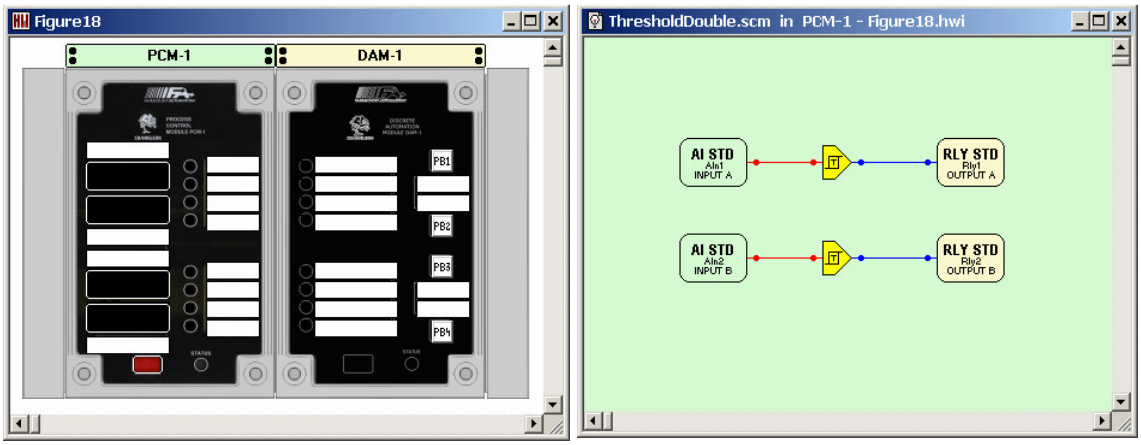
Figure 4.15. Illustration of hardware-independent programming: (a) Hardware interface document with Chameleon PCM-1 module and Chameleon DAM-1 module; (b) schema document linked to PCM-1 module; (c) same schema document linked to DAM-1 module.

schema document—say increase the threshold value—that change will be immediately reflected in the algorithm's execution by both modules.

In the Figure 4.15(b) configuration, the *Analog Input* operator is linked to the PCM-1 module's AIn1 resource, and the *Relay* operator is linked to the DAM-1 module's Rly1 resource. In the Figure 4.15(c) configuration, the *Analog Input* operator is linked to the PCM-1 module's Ain2 resource, and the Relay operator is linked to the DAM-1 module's

Rly2 resource. This is reflected by the background color of each operator and their respective label.

In the Figure 4.15 configuration, the controller node is monitoring two analog signals and activating two relay outputs, with each module equally sharing the computational burden. The same objective could be achieved with the configuration shown in Figure 4.16. In that implementation, the same I/O points are used but only the PCM-1 module will execute a schema (the DAM-1 module has no schema linked to it). The single schema monitors both inputs, compares to thresholds, and activates the relay outputs. With this arrangement, the entire computational burden of the control algorithm is borne by the PCM-1 module.



(a) (b)

Figure 4.16. Equivalent implementation of Figure 4.15 implementation with all computation performed in the PCM-1 module. The DAM-1 module does not have a schema linked to it.

(Clearly, in this example the computational burden is negligible in either case. The statement is a relative characterization between the two implementations.

Correcting Signal Wiring Mistakes

Connection Tool

Design Pad G3 provides two signal wiring tools to correct connection errors: a Connection tool and a Signal Segment Zap tool. The Connection tool provides a means to connect and disconnect signals from operator I/O pins. To disconnect a signal from a pin, position the cursor over the pin, press (and hold down) the left mouse button, and drag the wire off the pin. (Of course, the Connection tool should be active as you do this.) You should notice that as you remove the wire from the pin, the pin joint changes to an unfilled circle: ⊸. To reconnect the signal to another I/O pin, continue to drag the wire until the cursor is positioned over the pin, the release the left mouse button. You should notice that the pin joint of the newly connected pin has changed to a filled-in circle: ●.

Signal Segment Zap Tool

The Signal Segment Zap tool provides a means to remove signal wire segments. To "zap" part of a signal wire, activate the Signal Segment Zap tool, position the cursor over the segment you would like to remove, and click the left mouse button. If you are interested in removing an entire signal, rather than a single segment, you can select the signal (use the Selection tool) and press the DELETE key on your keyboard. (Alternatively, you could choose the Delete item from the Edit menu.)

The *Design Pad G3* Edit Menu

In addition to the signal editing tools described in previous sections, *Design Pad G3* provides several menu-driven commands to edit a schema. These commands are described below.

Undo/Redo

Design Pad G3 now provides the capability to undo and redo past commands. If you make a mistake as you modify your schema (e.g., delete an operator) and wish to revert to the previous document state (e.g., before the operator was deleted), select the Undo item from the Edit menu (or type CTRL-Z on the keyboard). Design Pad G3 maintains a history of 256 commands that can be "undone". If you perform an undo operation (or several undo operations), and then decide you would like to revert to the *changed* document state, select the Redo item from the Edit menu (or type CTRL-Y on the keyboard).

Cut/Copy/Paste

Design Pad G3 now provides the capability to cut and/or copy objects from a schema document and then paste them into the same document or into another schema document. The Cut command in the Edit menu (CTRL-X), removes selected objects and places them on the *Clipboard*. The Copy command (CTRL-C) also places selected objects on the clipboard but leaves them intact. The Paste command (CTRL-V) inserts objects on the clipboard into the schema document. Pasted objects are generally exact duplicates of the originals with some minor exception. For instance, if you copy an *Analog Input* block, *Design Pad G3* will change the operator's name so that it remains unique. (Hardware operators of the same type must have different names.)

Selecting Multiple Schema Objects

Design Pad G3 provides a selection box feature that is useful for selecting multiple operator objects at the same time. To activate the selection box, click the left mouse button over schema document—a location in the schema that does not contain an operator block, a signal wire, a text block, or any other object. Then, as you move the mouse (while holding the left button down), *Design Pad G3* displays a rectangular box—the selection box. When you release the left mouse button, *Design Pad G3* will select all the objects that are inside the selection box.

Selecting All Schema Objects

Occasionally, it may be useful to select all the operators and signals in a schema. To do so, activate the Select All item from the Edit menu. *Design Pad G3* will then draw all the schema

objects in their selected state: Operators will be drawn with a dotted border and signals will be drawn as dashed linear segments.

Deleting Operators and Signals

The Delete command mentioned in section 0 works with operators as well as signals. If you wish to remove an operator from your schema, select the operator with the Selection Tool and choose the Delete item from the Edit menu. (If an operator or a signal is selected, it can also be removed from the schema using the DELETE key on your keyboard.)

Removing Unconnected Signals

Remove Disconnected Signals Tool

Design Pad G3 can automatically remove any signals (or signal segments) that are not connected to anything. If you have several extraneous signals, choose the Remove Disconnected Signals item from the Edit menu, and *Design Pad G3* will eliminate all the unnecessary signal segments.

Perpendicular Signal Mode

Design Pad G3 does not restrict how schema signals are laid out—signal segments can be drawn at any angle. However, schemas often "look" better if signals are drawn as horizontal and vertical line segments perpendicular to each other. (The example schema of Figure 2.1 is drawn this way.) *Design Pad G3* offers a drawing mode in which signals are restricted to horizontal and vertical planes. You can activate this mode by selecting the Perpendicular Signal Mode item from the Edit menu. You can return to normal drawing mode by selecting the same menu item again (i.e., the menu item toggles perpendicular mode on or off).

Snap-To-Grid Mode

Design Pad G3 does not restrict how operators are positioned in a schema document. The fine layout granularity that the software provides can sometimes make it difficult to align operators and connect their I/O pins. Displaying a background grid in the schema document (select Grid in the View menu) is helpful but often is not sufficient for easy operator alignment. Design Pad G3 now provides a snap-to-grid feature that aligns all objects—including operators, I/O pins, and signals—to the coarser background grid. When you activate this mode (select Snap-To-Grid from the Edit menu), all of the operator I/O points are positioned on grid points.

Arranging Operator I/O Pins

Pin Rotate Tool

Occasionally, the default location of an operator's I/O pin proves to be inconvenient for a desired schema layout. For instance, in the schema shown in Figure 2.1, the output pin of the *Analog Constant* operator named "TD" is above the operator (rather than to the left of the object—its default location.) In addition, the input pins of the *Numeric Display* operator that is connected to the *Analog Input* block were shifted to the right of the object, as opposed to their default left-of-object positions. These changes were made with *Design Pad G3's* Pin Rotate tool. The tool is so named because it rotates the I/O pin locations from one side of an object to an adjacent side (in the clockwise direction). To change the position of an operator's I/O pin, activate the Pin Rotate tool, position the mouse cursor over the object of interest, and click the left mouse button. Each time you click on the object with this tool, the object's I/O pins will rotate clockwise. All operators can be rotated, but most only support 180° rotation. A few operators can have their I/O pins rotated in 90° increments.

Adding Text to a Schema

Text Tool

You can add descriptive text to a *Design Pad G3* schema using the Text Tool. For example, in Figure 2.1, we added the title block "Start Air Cooler Control." To insert text into a schema, select the Text Tool; then, click and hold down the left mouse button. As you move the mouse, a rectangle outline will follow the Text Tool pointer. When you release the mouse button, the *Text Block Properties* dialog will appear on the screen (see Figure 4.17) containing the default text string: "Place your text here."

In the *Text Block Properties* dialog, type the text you wish to display in the *Text* edit box. Select the desired font and text alignment with the *Font* button and *Text Alignment* combo, respectively. And, if you would like the text to automatically wrap at the edges of the text rectangle outline, check the *Auto Text-Wrapping* checkbox. When you press the OK button, the text you entered in the Text edit box will be displayed within the text rectangle outline.

Design Pad G3 now provides automatic text substitution for a few select keywords. Available keywords include the module name, company name, author name, and other properties that are associated with the schema and/or hardware interface documents. Whenever those properties are changed, the textbox is automatically updated to reflect the change. To take advantage of this feature, simply select from the available keywords in the drop-down combo-box and click the Insert Keyword button. The keyword will be inserted into the edit box; you can type any text around the keyword to form a phrase or sentence. For instance, the string "Schema to execute in $Module", resolves to "Schema to execute in PCM-1" for the hardware interface and schema document pair shown in Figure 2.4 and Figure 2.5.

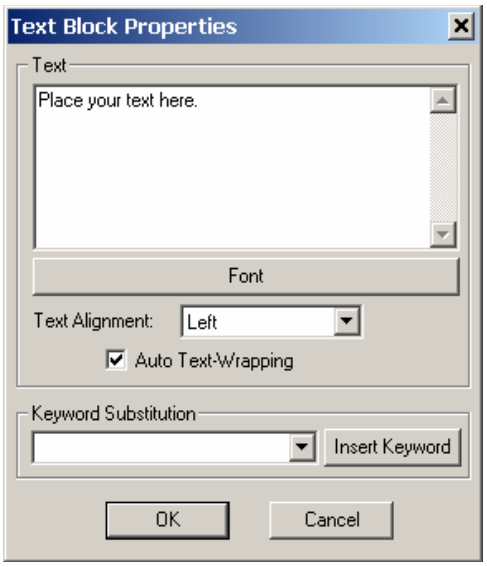


Figure 4.17. Text block properties dialog.

If you wish to reposition the text, activate the Selection Tool, position the cursor on the text, and drag the block to a new position with the left mouse button. If you wish to resize the text rectangle, activate the Selection Tool and position the pointer on one of the rectangle corners. Click the left mouse button and drag the rectangle corner to a new position. You should notice that the rectangle outline changes as you drag the mouse.

Configuring Hardware Resources

The preceding sections describe how to create hardware interface and schema documents, how to link these documents together, and how to associate schema document hardware operators to module hardware resources in the hardware interface file(s). This section describes how hardware resources are configured. For example, the analog input channels of a Chameleon Process Control Module (PCM-1) can measure current, voltage, and resistance, and interface to RTD sensors.

To configure a hardware resource, right click on the desired module in the hardware interface document and select the Configure Hardware item from the drop-down menu. Then select the desired resource from the cascading menu items as shown in Figure 4.18. Each resource type has a set of properties that can be configured. For example, right-click on the PCM-1 module in the `Figure1.hwi` hardware interface file, and select the Configure Hardware→Analog Inputs→ AIn1 menu item from the drop down menu. Design Pad G3 will display the Hardware Resource Properties dialog as shown in Figure 4.19.). The property sheet contains a two-column table of hardware resource parameters. Each row in the table contains the name of the property (left column) and the corresponding text, numeric, or boolean value assigned to that property (right column).

Specific information about each user-configurable hardware resource is provided in section 0. Each hardware resource property is described in detail.

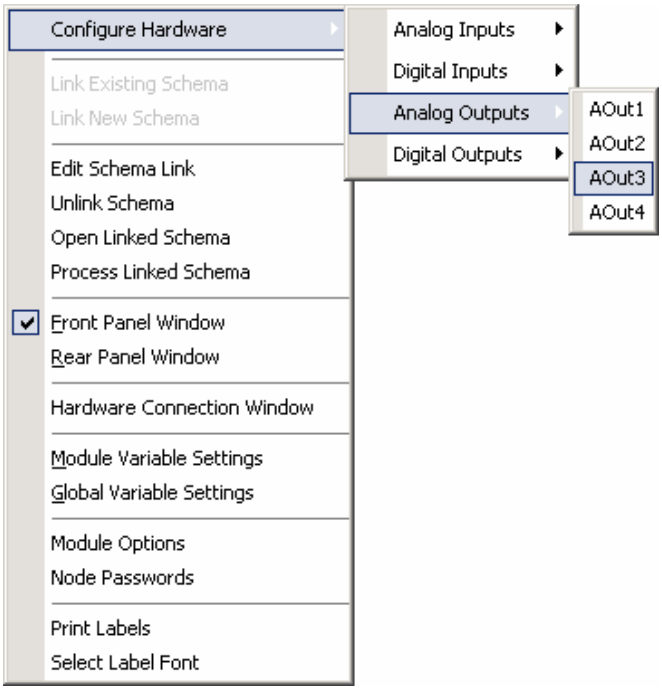


Figure 4.18. Cascading drop-down menu to configure hardware resources.

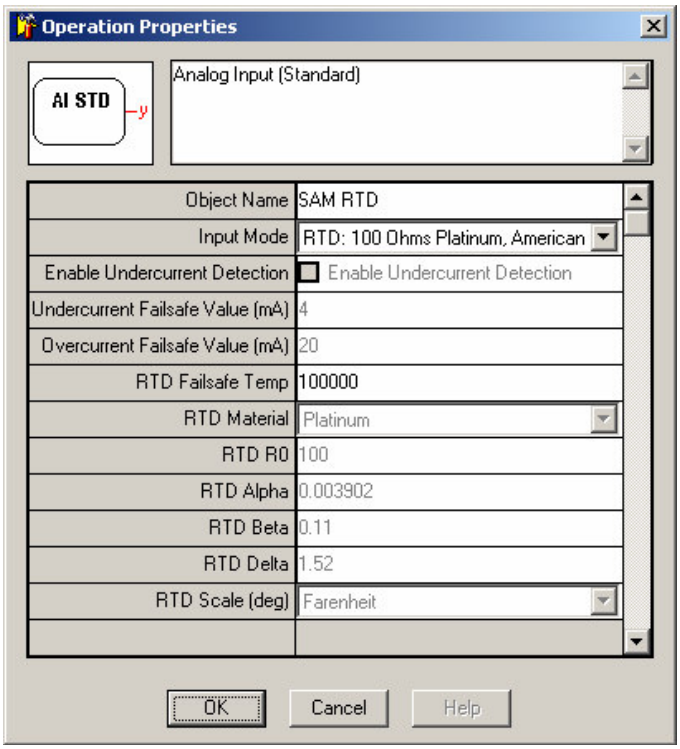


Figure 4.19. Hardware Resource Properties Dialog.

Editing and Printing Faceplate Signal Labels

Chameleon module faceplates include sleeves to insert user-defined signal labels. Perforated label sheets designed for industrial use are available from Fairmount Automation. The label sheets contain a variety of perforated label sizes and shapes corresponding to sleeve sizes and shapes available in Chameleon modules.

To define the signal name, simply click on the desired label location in the hardware interface file module and type it in. For example, the tag just above the top-numeric display of the PCM-1 module in the hardware interface file shown in Figure 2.4 is labeled "SAM Temp". The label indicates to the plant operator that the value shown on the numeric display represents the SAM temperature.

To select the font used to print the signal labels, right-click on the module in the hardware interface file and choose the Select Label Font item from the drop-down menu.

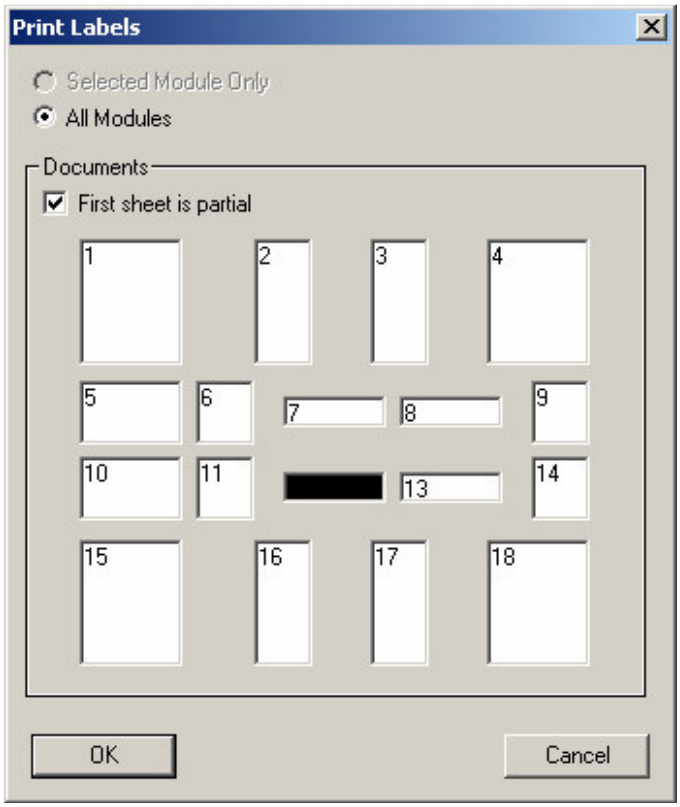


Figure 4.20. Print Labels Dialog.

To print out the signal tags on the special perforated label sheets, select the Print item from the File menu, and then select Print Labels. *Design Pad G3* will display the Print Labels dialog shown in Figure 4.20. The dialog allows you to identify labels that have been previously used and are not available for printing. To disable printing to a particular location, click on that label position in the dialog. To re-enable printing to a disabled

location, click on it again. For example, label position number 12 in Figure 4.20 has been disabled for printing as indicated by the black

Proper alignment of the label sheet in the printer is needed to ensure that the text printed on the labels is visible thru the faceplate sleeves. In order to achieve proper label sheet alignment, *Design Pad G3* must be calibrated to your printer—every printer is different. To calibrate *Design Pad G3* to your particular printer follow the procedure below:

1. Select the Align Label Sheets item from the File menu. Design Pad G3 will display Label Sheet Printer Alignment dialog shown in Figure 4.21.

2. Load perforated label half-sheets onto the printer's manual feed tray. (Note that two label sheets are included on each standard 8.5" x 11" piece of paper—the paper is perforated along the center of the page. The perforation along the centerline must be torn such that label sheets are fed to the printer individually rather than as sets of two.) The non-perforated edge of the label half-sheet should enter the printer first in order to avoid slight page rotation resulting from imperfections on the perforated edge of the sheet. The sheet should also be oriented such that the perforated arrow on the middle of the page points from left to right. (The perforated arrow is enclosed by the labels located in positions 8, 9, 13, and 14 of Figure 4.20. When the arrow is pointing in the correct direction, it will be located on the right side of the label sheet.)

3. Click the Print Test Page (No Offsets) button on the Label Sheet Printer Alignment dialog. *Design Pad G3* will print out four sets of gradated crosshairs that should generally align with perforated crosshairs on the label sheet.

4. Each tick of the gradated crosshair represents 0.015 inches. Measure the number of ticks horizontally separating the center of the printed crosshair and the center of the perforated crosshair. Multiply the number of ticks by 0.015 and record the result in the X-Pos edit control of the Align Label Sheets dialog. (If the printed crosshairs are left of the perforated ones, the offset should be negative; otherwise it should be positive.)

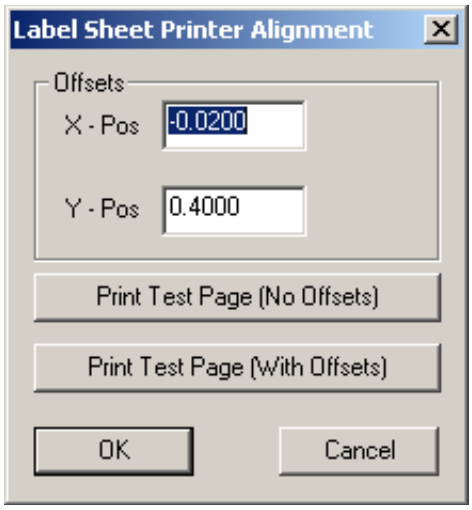


Figure 4.21. Align Label Sheets Dialog.

5. Measure the number of ticks vertically separating the center of the printed crosshair and the center of the perforated crosshair. Multiply the number of ticks by 0.015 and record the result in the Y-Pos edit control of the Label Sheet Printer Alignment dialog. (If the printed crosshairs are below of the perforated ones, the offset should be negative; otherwise it should be positive.)

6. Load another label half-sheet onto the printer's manual feed tray and click the Print Test Page (With Offsets) button in the Label Sheet Printer Alignment dialog. *Design Pad G3* will print another set of crosshairs—this time they should align perfectly with the perforated crosshairs. If they do not, go back to step 2 and repeat the process. (Note that the Print Calibration Adjustment Page button prints the crosshairs without offsets and the Print Calibration Test Page button

Schema Properties

It is often useful to record general information about a schema design, such as a title, author, drawing revision, etc. This information can be entered in the schema properties dialog box shown in Figure 4.22. (To view this dialog box, select the Schema Properties item from the Schema menu.) *Design Pad G3* automatically records the date the schema was first created and the date it was last modified. It also records the *Design Pad G3* version used to create

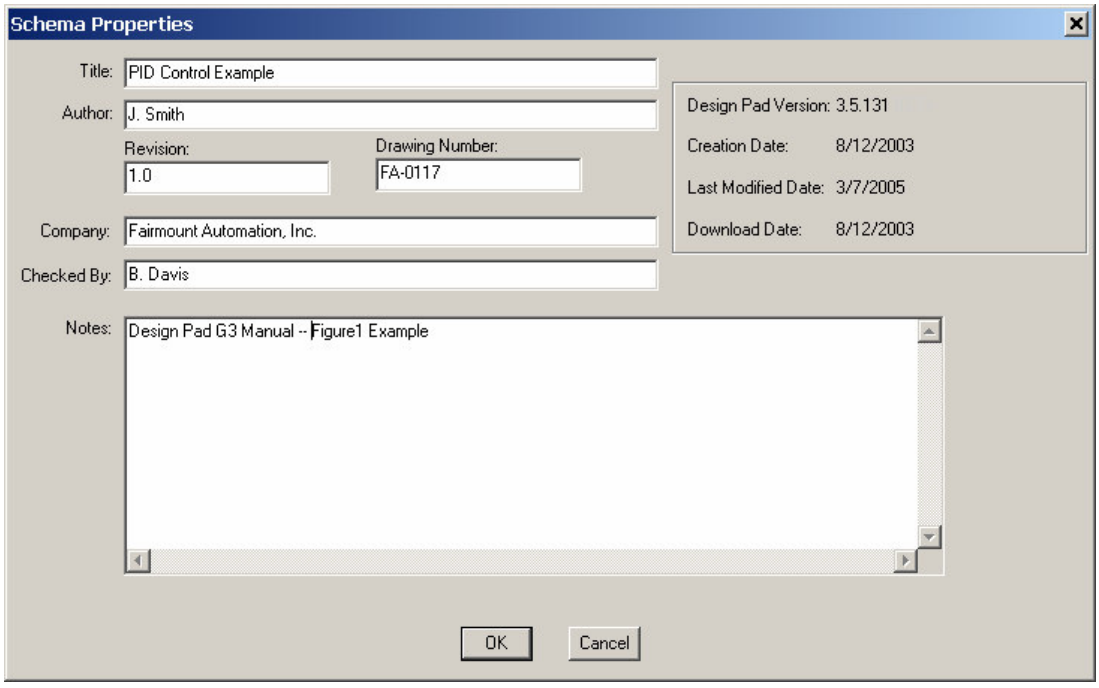


Figure 4.22. The schema properties dialog box.

the schema.

Protecting your Work

Design Pad G3 offers a mechanism for password protecting documents to prevent unauthorized access to your intellectual work. To protect a schema document, select the Password Lock item from Schema menu. *Design Pad* will display the Password Lock dialog shown in Figure 4.23. The dialog box contains three text boxes: you enter the old password (if applicable) in the first, and the new password in the second two. If the document has not been protected yet, leave the "Old Password" edit box blank. Otherwise, you need to provide the old password before *Design Pad* will accept a new one. In either case, you must enter the new password twice in order to lower the probability that a typing error occurred.

The Password Lock dialog box (Figure 4.23) also allows you to specify the access privileges while a document is locked. At minimum, unauthorized users will be unable to view or edit a locked document. But you can also prevent unauthorized users from running a simulation of the locked document, or exporting the locked document into a controller (by selecting the appropriate check boxes in Figure 4.23).

When *Design Pad G3* opens a password-protected file, it displays a blank document and disables all editing functions (Figure 4.24 shows a locked schema document). In order to unlock the document, click anywhere within document's client window. *Design Pad G3* will then prompt you to enter the password and will unlock the document if the correct one is provided.

If you wish to remove password protection from a schema document that has been protected, select the Password Lock item from the Schema menu. Then, enter the old password in the appropriate edit box and leave the other two edit boxes blank (see Figure 4.23).

Figure 4.23. The Password Lock dialog.

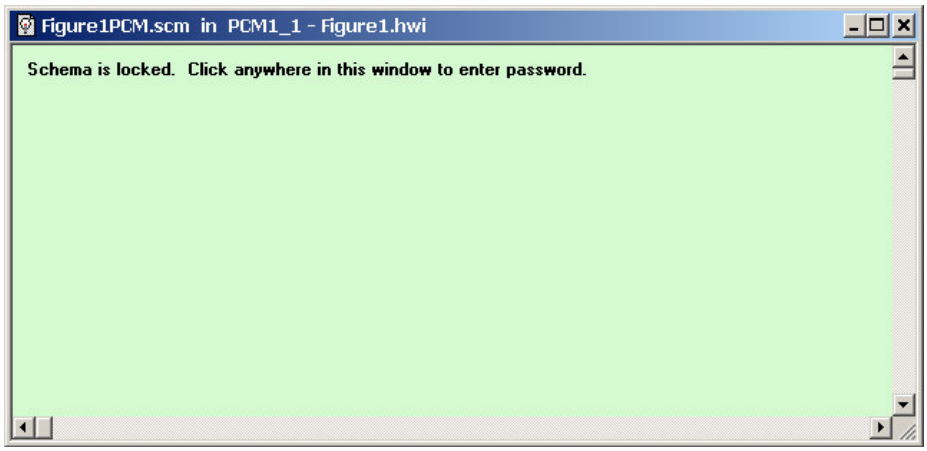


Figure 4.24. When Design Pad opens a locked schema document it does not display its contents.

Hardware interface files may also be password-protected.

5. Sub-Schemas

Most computer languages use the concept of a subroutine or function to logically divide a program into smaller, more manageable tasks. Dividing a program into various functions makes it more readable, eliminates repetition, and promotes re-use. By storing a function (or collection of related functions) in a stand-alone file, the same source code file can be incorporated again and again into various different programs. Whenever the implementation of a particular function is updated, the changes are automatically reflected in all of the programs that reference the source file. By contrast, if every program where to maintain their own copy of each function, a change to a function would have to be duplicated in every program.

In the *Design Pad G3* graphical programming environment, the concept of a subroutine is implemented thru the use of sub-schemas. A sub-schema is a schema within a schema. It is a standalone document—itself a collection of operators and interconnections—that executes within a parent schema document. Sub-schema documents can themselves contain other sub-schemas, thereby creating a hierarchical execution structure.

Design Pad G3 currently supports two types of sub-schema documents: function-block sub-schemas and state sub-schemas. A function block sub-schema is simply a collection interconnected functional operators with defined inputs and outputs (see section 0 for a more detailed description). State sub-schemas are associated with state-transition diagrams and are described in section 0. Future versions of *Design Pad* will also support ladder-logic sub-schemas and standard C-language sub-schemas.

In textual computer languages, a function is provided with a list of arguments (e.g., parameters or variables) to be accessed and/or manipulated within the function body. The argument list represents inputs to, and/or outputs from, the function. The variables in the argument list provide a mechanism to link the function with its caller. That is, *variable* arguments are the glue that binds different program segments.

Design Pad G3 provides *Variable* operators to serve this same binding purpose in the function-block realm. They allow you to access and/or manipulate the same signal from multiple program locations—be it schemas executing in different modules in a node or sub-schemas executing in the same module.

Variable Operators

The *Variable* operator stores a signal value that can change during schema execution. For instance, it may store a system set-point or a tuning parameter that a plant operator or design engineer may wish to modify at runtime (while the controller is executing).

As indicated in the previous section, what makes *Variable* operators particularly useful is that multiple of them can reference the very same signal, and thereby serve to bind separate program segments. Multiple *Variable* operators will reference the

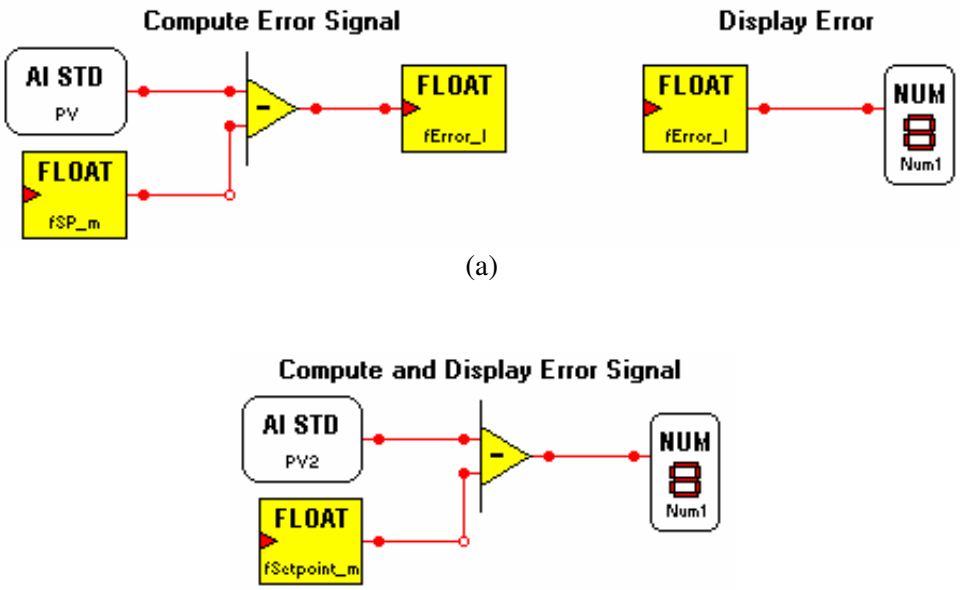


Figure 5.1. (a) Sample use of Variable operator referencing the same signal. (b) Equivalent schema circuit.

same signal value if they have the same *name* and *scope*. In the sample schema pictured in Figure 5.1, an error signal is computed and stored in a *Variable* named `fError_l`. Another *Variable* operator elsewhere in the schema has the same name, `fError_l`, and is used to source a *Numeric Display* operator. While the two *Variable* operators are distinct objects in the schema, they reference the very same error signal—namely the difference between process (PV) and setpoint (SP) signals, so that the value computed by the *Subtraction* operator is shown on the *Numeric Display*.

In other words, the two instances of the `fError_l` variable are akin to explicitly connecting a signal wire between the output of the *Subtraction* operator and the input of the *Numeric Display* operator as shown in Figure 5.1b.

The use of *Variable* operators as virtual signal connections is a good technique for making schemas more readable. It offers an alternative to direct connections, thereby avoiding situations where signals must cross over each other or where long connections must be used to zigzag around other objects.

But *Variable* operators not only serve to bind signals within the same schema, they can also bind signals across schemas and/or across modules in a node. In other words, they allow a signal computed in one schema or module, to be referenced in another schema or module. *Variable* operators have a *scope* attribute that determines their access range—*Local*, *Module*, or *Global*. A variable with *Local* scope may only be referenced within the same schema document. A variable with *Module* scope may be referenced within any schema executing in the same module (*i.e.*, the *parent* schema linked to the module, any of its sub-schemas, or any of its sub-schemas' sub-

schemas.). A variable with *Global* scope may be referenced within any schema executing within any module in the same node.

The signal name that a Variable operator references is specified in its property window (*i.e.,* set the *Signal Name* property to the desired text string). *Design Pad G3* automatically appends the characters "`_l`", "`_m`", or "`_g`" to the *Variable* signal name according to its scope, *Local*, *Module*, or *Global*, respectively.

Variable operators for two data-types are available: *Float Variables* store analog signals and *Boolean Variables* store digital Signals. In addition to binding signals from disparate schemas, *Boolean Variable* operators also serve as the triggering mechanism to initiate a transition in a state-transition diagram (see section 0 for more information).

The sample schema of Figure 5.1 includes one instance of *Float Variable* `fError_l` where the input pin is visible and the output pin is not; and one instance where the reverse it true. In the first instance, the variable is said to be of type *Input-Only* and in the second instance *Output-Only*. (A *Variable* operator may also be of type *Input-Output* where both pins are visible, or *None* where neither pin is visible.) An *Input-Only* (or *Input-Output) Variable* operator, sets the signal value that it references equal to the value of its input pin. Great care must be taken when two or more distinct *Input* type *Variable* operators represent the same signal. Consider the schema of Figure 5.2 in which two distinct *Variable* operators representing the same signal—`fSignal_m`—are fed by different constant values.

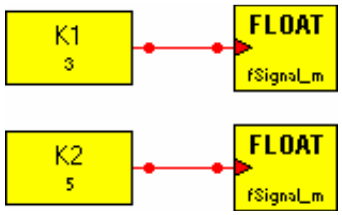


Figure 5.2. Two input Variables represent the same signal. What value will the signal be set to?

If a device were to execute the schema of Figure 5.2, what value (3 or 5) would `fSignal_m` assume? The answer is not definitive—it depends on which operator executes last. In fact, if the schema contained several other operators, the result would be even more unpredictable as it is possible that the execution order could have one *Variable* compute first, then other operators, then the second *Variable*, then other operators. So the signal value could be 3 during part of the computation cycle (for some operators) and 5 during another part of the cycle (for other operators).

Design Pad G3 explicitly disallows the same variable signal from being set in multiple locations within the same schema. That is, an error is issued at compile-time

when the schema above is processed. However, the ability to set the same signal from different sub-schemas is very much desirable so *Design Pad G3* allows it. For example, it may be desirable to set the same signal to a different value depending on which state sub-schema is currently active.

Function-Block Sub-Schemas

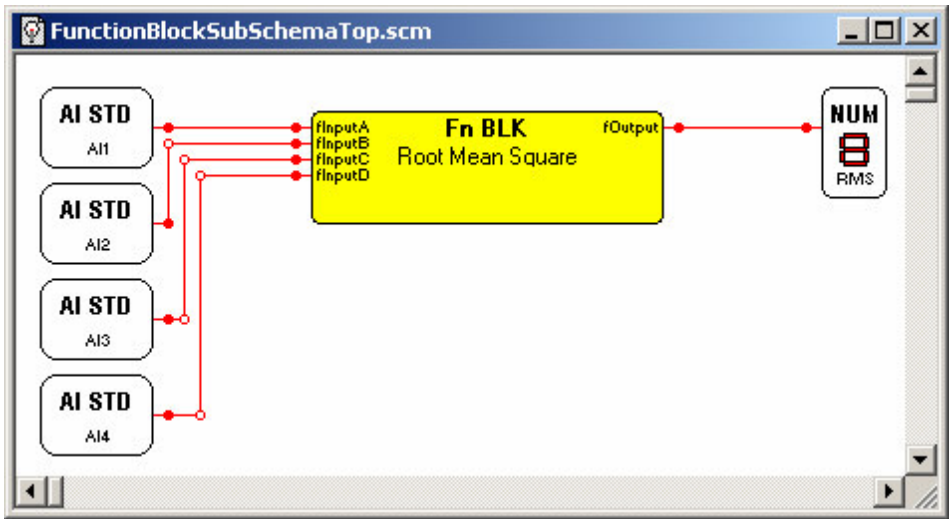
A function block sub-schema is a standalone schema that can execute as part of another schema. The sub-schema is itself a collection interconnected functional operators with defined inputs and outputs. It allows you to create your own custom operator, as you can specify its input/output signature (quantity/type) as well as its functional behavior (I/O mapping).

Sub-schemas are stored as distinct `.scm` files. They are standalone schemas that can be referenced again and again by other schema documents. A *Function Block Sub-Schema* operator serves as the graphical representation of a sub-schema document. The operator resides within the *parent* schema that uses the sub-schema document—the operator references the sub-schema (akin to a function call in a textual programming language).

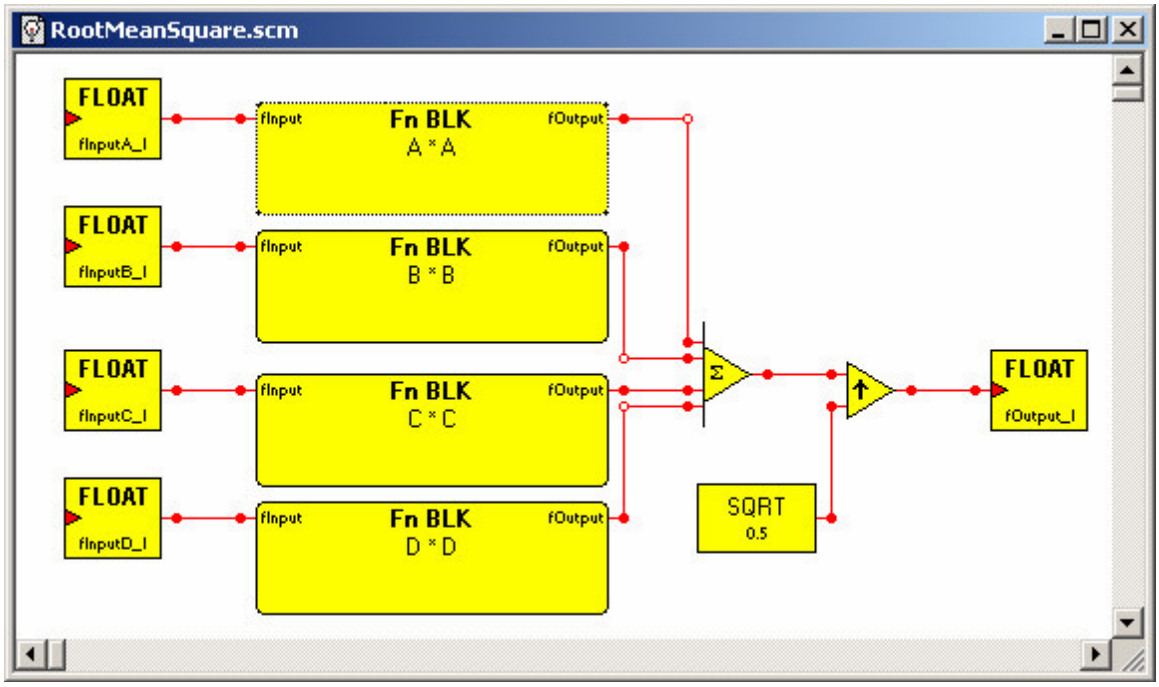
For example, the schema diagram of Figure 5.3a contains a single *Function Block Sub-Schema* operator with four analog inputs and one analog output. The operator references the sub-schema document of Figure 5.3b which computes the root mean square (RMS) of its inputs and applies the result to its output (*i.e.*, it computes the square root of the sum of the squares of the inputs).

Each input pin in the parent schema's *Function Block Sub-Schema* operator graphic corresponds to a like-named *Float Variable* operator in the sub-schema. For instance, the input labeled "`fInputA`" in the sub-schema graphic corresponds to the variable named "`fInputA`". So when the sub-schema computes, the variable named "`fInputA`" takes on the value applied to the *Function Block Sub-Schema* operator input pin labeled "`fInputA`".

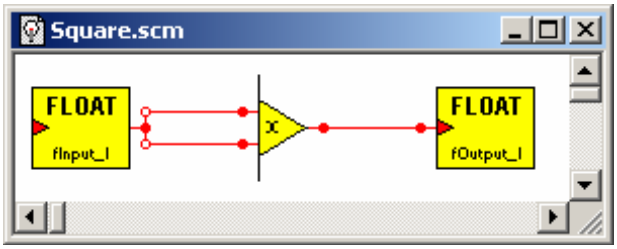
The RMS sub-schema itself contains four *Function Block Sub-Schema* operators. Each sub-schema operator computes the square of its input signal as shown in Figure 5.3c: Although the operator labels are different (*i.e.,* "`A * A`", "`B * B`", "`C * C`", and "`D * D`"), they all reference the same sub-schema document named "`Square.scm`" (Figure 5.3c).



(a)



(b)



(c)

Figure 5.3. (a) Sample schema with function block sub-schema. (b) sub-schema document referenced by function block sub-schema operator in (a). (c) sub-schema document referenced by function block sub-schema operators in (b).

A *Function Block Sub-Schema* operator must be *linked to* or associated with a schema (.scm) file that contains the desired functional behavior. In the example of Figure 5.3, the sub-schema operator labeled "Root Mean Square" in Figure (A) is linked to the `RootMeanSquare.scm` schema of Figure B, and the four sub-schema operators in Figure (B) are individually linked to the `Square.scm` schema of Figure (C). Each sub-schema operator in Figure (B) represents a distinct instance of the `Square.scm` schema.

Unlike most operators, the *Function Block Sub-Schema* is not configured thru a property sheet. Instead, its configuration is defined by attributes of the linked schema file (*e.g.*, quantity and type of I/O) and thru a drop-down menu. This drop-down menu is accessed by right-clicking on the operator icon graphic. It contains commands to manage the operator's link to a schema file. For instance, to link an existing schema file to the operator, select the *Link Existing Schema* item, and use the *File Open* dialog to select the desired file.

The schema link is stored as a relative file path to the parent schema. The link can be manually edited by selecting the *Edit Schema Link* item from the drop-down menu. This command is useful if the schema file is renamed or moved to a different directory outside of the *Design Pad G3*environment. The schema link can be removed altogether by selecting the *Unlink Schema* item from the drop-down menu.

Once a schema file is associated with a *Function Block Sub-Schema* operator, the file can be opened by double-clicking the left mouse button on the sub-schema graphic. The file can also be opened by selecting the *Open Linked Schema* item from the drop-down menu.

As indicated above, the operator's input and output pins correspond to like-named *Variable* operators in the linked sub-schema file. The input-pin type (*e.g.*, analog or digital) must also correspond to the data-type of the *Variable* operator (*e.g.*, Float or Boolean). Variables in the sub-schema file that are to serve as sub-schema inputs or sub-schema outputs must be explicitly identified as such. This is done within the *Sub-Schema Setup* dialog—to view the dialog select the *Sub-Schema Setup* item from the *Schema* menu. The dialog box (shown in Figure 5.4) contains a list control (top left quadrant) and two list-boxes (top right quadrant) that identify sub-schema inputs and outputs. The list control on the left contains all sub-schema file *Variable* operators of *Local* scope (only variables with local scope can serve as sub-schema I/O). The two list-boxes on the right contain the subset of variables that are to serve as I/O. The ordering of the variables in the list-boxes corresponds to the ordering of the I/O pins in the sub-schema operator graphic. To change the pin order, simply drag the variable name from one position in the list-box to another. To identify a variable as a sub-schema input or output, select "YES" in the combo-box in the appropriate column and then click the *Update* button. (The changes are then reflected in the list-boxes on the right.)

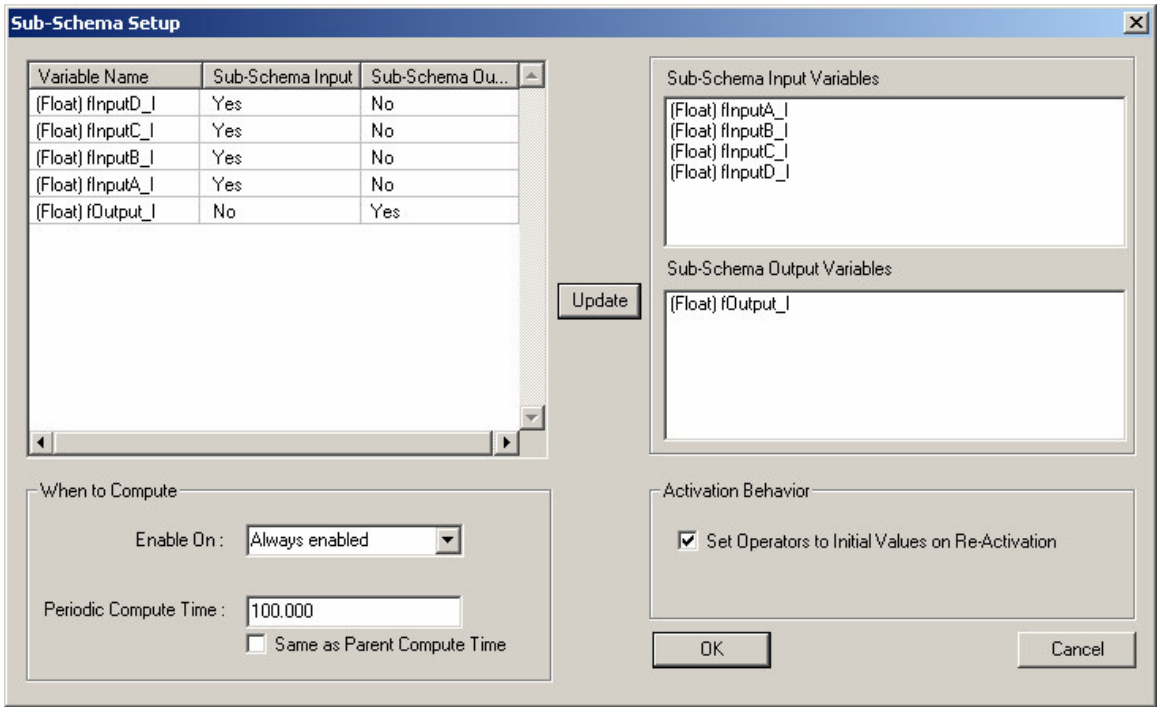


Figure 5.4. Sub-Schema Setup Dialog

Function Block Sub-Schema operators can be configured to execute conditionally or periodically. (This is defined in the *When to Compute* group control located in the lower left quadrant of the *Sub-Schema Setup* dialog). The *Enable On* combo determines when the underlying sub-schema file is to execute. If set to *Always Enabled*, the sub-schema will execute periodically, with a user-defined updated rate (the *Periodic Compute Time*).

The sub-schema can be configured to execute at the same frequency as its parent schema executes or at a different user-specified frequency. Sub-schemas cannot execute more frequently than their parent schemas. If the user-defined periodic compute time for the sub-schema is less than the periodic compute time of the parent schema, the sub-schema will execute whenever the parent schema executes.

When the *Enable On* property is set for conditional execution the operator will include a digital input pin that dictates when the underlying sub-schema file is to execute. If set to *Rising Edge*, the sub-schema will execute at the instant that the digital input switches from LOW to HIGH. If set to *Falling Edge*, the sub-schema will execute at the instant that the digital input switches from HIGH to LOW. If set to *Active High* or *Active Low*, the sub-schema will execute whenever the input is HIGH or LOW, respectively.

State-Transition Diagrams and State Sub-Schemas

A state-transition diagram (or finite state diagram) is a useful tool to graphically describe the behavior of a system. The diagram describes a system as a collection of distinct operational states and defines events or conditions that trigger a transition from one state to another. In the context of a control algorithm, each state represents a set of commands (or outputs) that the controller is to generate. The controller executes that same command set until a given condition is satisfied. When the condition is met, the controller shifts to a new state where it executes a different command set.

Design Pad G3 provides built-in support to create state-transition diagrams as part of a *schema* document. A state-transition diagram in *Design Pad G3* consists of a set of *State Sub-Schema* operators interconnected by directed arcs (transitions). Each *State Sub-Schema* operator is associated with a sub-schema document that executes while the operator is *active*. Only a single state within a connected state-transition diagram may be active at any instant of time. The system will *transition* from the active state to another state when a logical condition associated with the transition arc that connects the two states is met. For example, consider a state-transition diagram having two states, *A* and *B,* and a transition arc *T* that connects state *A* to state *B*. The system will exit active state *A* to enter state *B* when transition *T* is true.

As indicated above, only a single *State Sub-Schema* operator within a state-transition diagram may be active at a given time instant. However, a schema may contain multiple disjoint state-transition diagrams that execute concurrently. (A schema may then contain multiple *State Sub-Schema* operators that are active at the same time, provided that they belong to disjoint state-transition diagrams.)

Each *State Sub-Schema* operator must be *linked to* or associated with a schema (`.scm`) file that contains the desired functional behavior to be executed while the operator is active. The sub-schema file is itself a collection of interconnected graphical operators that may include other *State Sub-Schema* operators and/or *Function Block Sub-Schema* operators (which may themselves contain sub-schema operators).

Unlike most operators, the *State Sub-Schema* operator is not configured thru a property sheet. Instead, its configuration is defined by attributes of the linked schema file and thru a drop-down menu. This drop-down menu is accessed by right-clicking on the operator icon graphic (*i.e.*, the circle). It contains various commands to manage the operator's link to a schema file. For instance, to link an existing schema file to the operator, select the *Link Existing Schema* item, and use the *File Open* dialog to select the desired file.

The schema link is stored as a relative file path to the parent schema. The link can be manually edited by selecting the *Edit Schema Link* item from the drop-down menu. This command is useful if the schema file is renamed or moved to a different

directory outside of the *Design Pad G3*environment. The schema link can be removed altogether by selecting the *Unlink Schema* item from the drop-down menu.

Once a schema file is associated with a *State Sub-Schema* operator, the file can be opened by double-clicking the left mouse button on the sub-schema graphic. The file can also be opened by selecting the *Open Linked Schema* item from the drop-down menu.

Every connected state-transition diagram must define a single state to serve as its *Initial State*. This state will be the active state when the schema first begins executing. When a *State Sub-Schema* operator is designated as the *Initial State* its graphic (gray circle) is stamped with a dark green dot. *Design Pad G3* will issue an error on processing if no state has been designated as the initial state or if more than one state has been designated as such.

Each transition arc must be associated with a *Boolean Variable* operator. The transition takes effect when the associated variable's value is HIGH. To associate a transition with a *Boolean Variable* operator, double-click on the arc to view the *Transition Properties* dialog shown in Figure 5.5. To make the link, first select the *Scope* of the *Boolean Variable* to populate the *Variable* drop-down combo. If the *Scope* is set to *Local*, then the drop-down combo will contain only *Boolean Variable* operators of *Local* scope found in the schema containing the transition arc. If the *Scope* is set to *Module*, then the drop-down combo will contain all *Boolean Variable* operators of *Module* scope found in any schema related to the module that includes the schema that contains the transition arc (including the parent schema linked to the module and any of its descendent sub-schemas). If the *Scope* is set to *Global*, then the drop-down combo will contain all *Boolean Variable* operators of *Global* scope found in any schema related to the node that includes the schema that contains the transition arc (including the parent schema linked to each module in the node as well as any of their descendent sub-schemas).

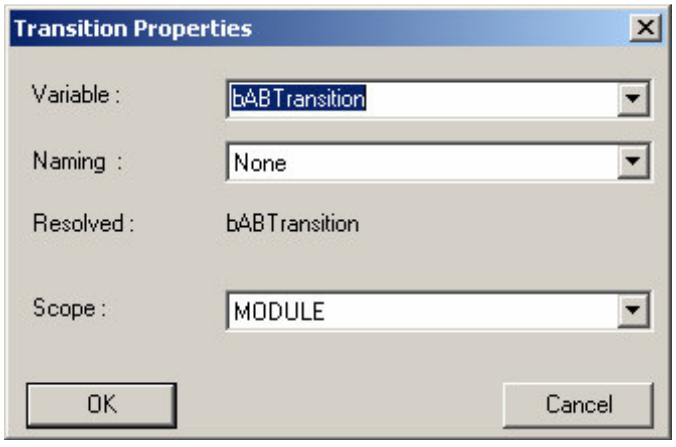


Figure 5.5. Transition Properties Dialog

When a state is activated (*i.e.*, when the system transitions into that state) the operators in the underlying sub-schema file can be configured to re-initialize or to continue executing where they left off when the state was last active. This distinction applies only to operators that have *memory*, meaning that the computation of their output value depends on information from the past. The *Addition* operator for instance has no memory since its output at time *t* is simply the sum of its inputs at time *t*. The *Delay Element* operator however does have memory since its current output value is equal to a past input value. For example, consider a sub-schema that contains a *Delay Element* operator that has its *Time Delay Multiple* property set to 1. If the sub-schema is configured to re-initialize upon activation, then the *Delay* operator's initial output will be equal to its user-defined initial condition. If the sub-schema is configured to retain its state upon activation, then the *Delay* operator's initial output will be equal to the input value it sampled just before the state last became inactive.

The activation behavior of a sub-schema is defined in its *Sub-Schema Setup* dialog—to view the dialog select the *Sub-Schema Setup* item from the *Schema* menu. The dialog contains a check-box control in its bottom left quadrant to set the initialization behavior. The other settings in the dialog box do not affect the behavior of the schema when linked to a *State Sub-Schema* operator.

The concepts described above are best illustrated by example. Consider a hardware interface file consisting of a Chameleon node with one ACP-1 AC Power Module and one DAM-2 Discrete Automation Module linked to the schema shown in Figure 5.6. The schema contains a single state transition diagram with three *State Sub-Schema* operators, labeled *A*, *B*, and *C*. State *A* is designated as the initial state as indicated by the dark-green stamp in its graphic. The system can transition from state *A* to state *B*, from *B* to *A*, from *A* to *C*, and from *C* to *B*, as indicated by the directed arcs that connect the states. The transition arcs are labeled with the name of a *Boolean Variable* operator that they are associated with (for instance, the arc from *A* to *B* is associated with the *Boolean Variable* named `bABTransition`). The transition occurs when the associated *Variable* operator value is HIGH.

When a State Sub-Schema operator is initially inserted into a schema diagram, it is assigned a generic label by *Design Pad G3*. To assign a custom label, right-click on the operator and select the Set State Label item from the drop-down menu. (This was done to label the states in the schema of Figure 5.6.)

The schema diagram of Figure 5.6 contains a state transition diagram as well as other operators to execute digital logic (two *Digital Input* operators feed an *AND Gate* block which feeds an *LED Display* operator). At each computation interval, the schema of Figure 5.6 executes these digital logic functions as well as all of the operators contained in the sub-schema file linked to the currently active *State Sub-Schema* operator.

Each of the states in the Figure 5.6 schema is linked to the sub-schema files shown in Figure 5.7. State *A* is linked to `StateA.scm` (Figure 5.7a); state *B* is linked to `StateB.scm` (Figure 5.7b); and state *C* is linked to `StateC.scm` (Figure 5.7c).

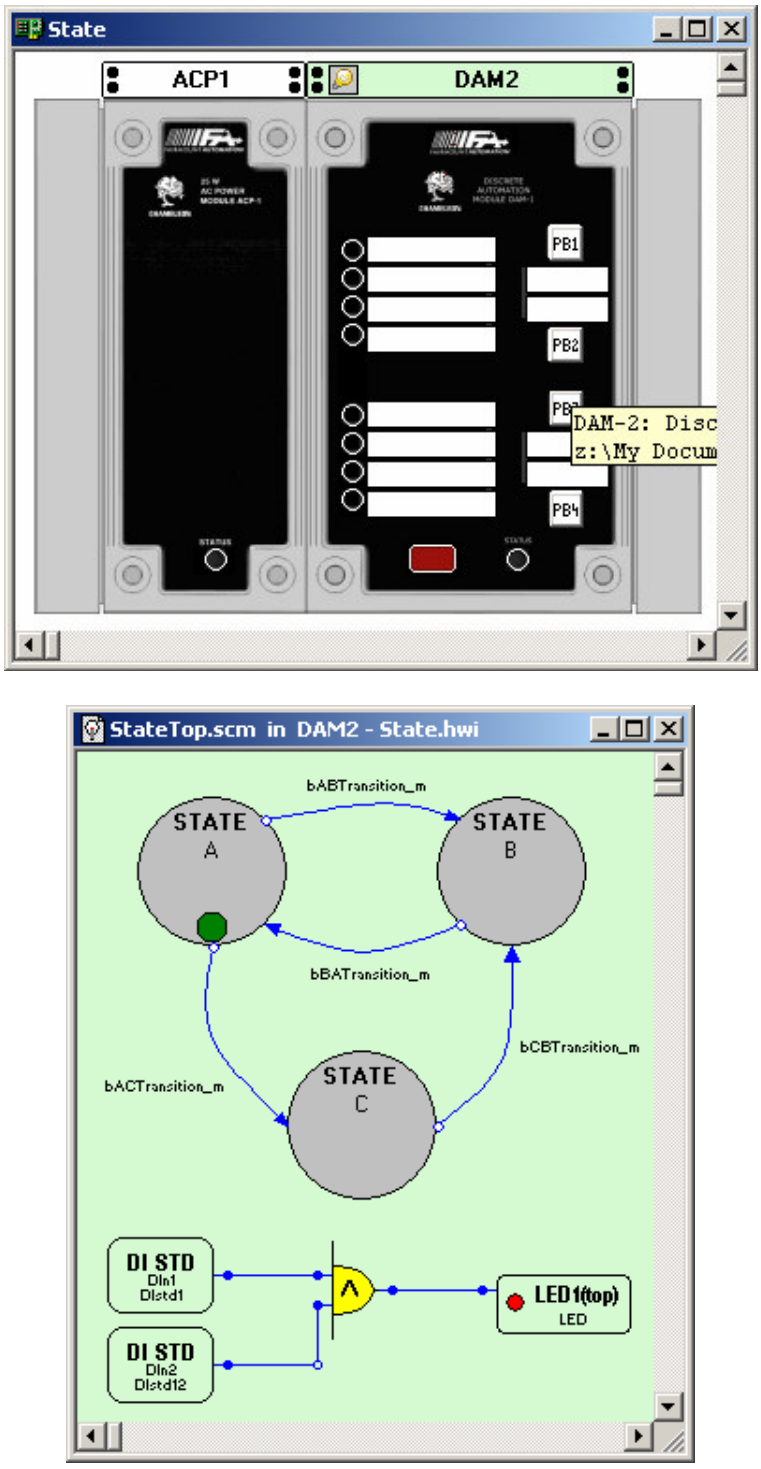
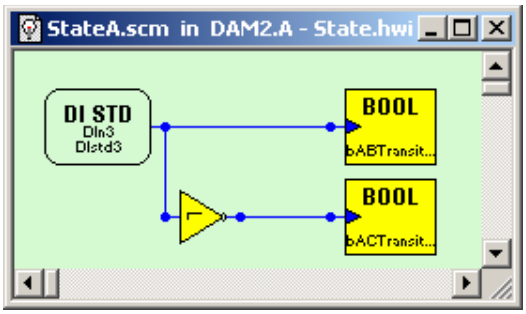
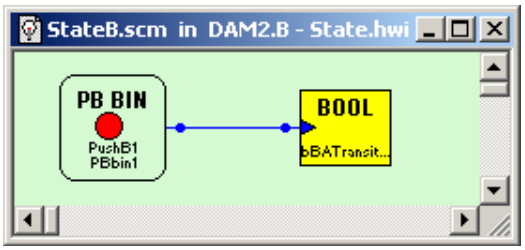


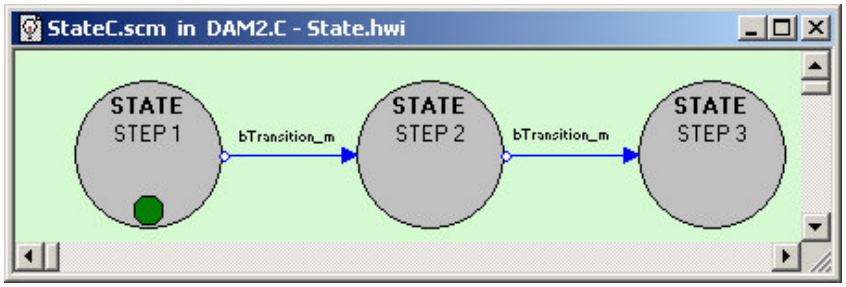
Figure 5.6. Sample hardware interface file and linked top-level schema with state transition diagram.



(a)



(b)

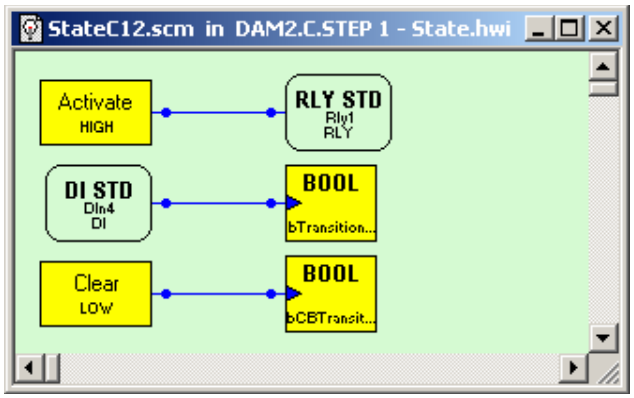


(c)

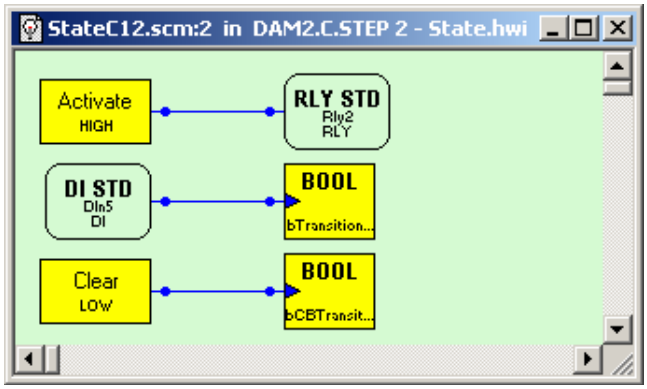
Figure 5.7. State sub-schema documents linked to State Sub-Schema operators in top-level schema of Figure 5.6.

When the schema of Figure 5.6 first executes (*i.e.*, when the hardware powers up), state *A* is active. In the underlying sub-schema for state *A* (Figure 5.7a), a *Digital Input* operator associated with the DAM-2 module's DI Channel 3 drives two *Boolean Variable* operators. These variables, named `bABTransition` and `bACTransition` are associated with transitions from state *A* to state *B* and state *A* to state *C*, respectively. When DI Channel 3 in the DAM-2 module is ON, the output of the *Digital Input* operator is HIGH, thereby setting variables `bABTransition` HIGH, and `bACTransition` LOW. With `bABTransition` HIGH the system transitions from state *A* to state *B*. (State *A* as implemented can be thought of as an *IF...THEN* statement: if DI Channel 3 is OFF, execute state *C*, otherwise execute state *B*.)

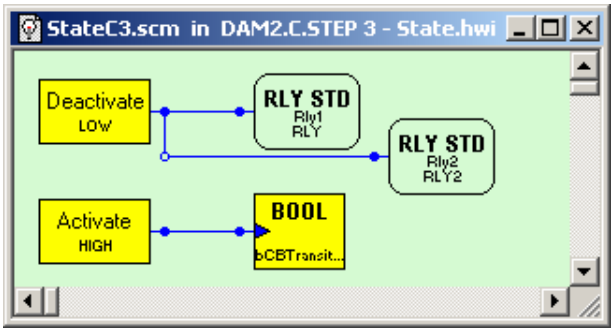
The sub-schema associated with state *B* and shown in Figure 5.7b simply monitors the DAM-2 module's top push-button and initiates a transition back to state *A* when the button is pressed.



(a)



(b)



(c)

Figure 5.8. State sub-schema documents linked to the State Sub-Schema operators in the StateC.scm sub-schema of Figure 5.7c.

The sub-schema associated with state *C* and shown in Figure 5.7c itself contains another state-transition diagram that executes a three-step command sequence. The sub-schema files associated with each state (labeled *Step 1*, *Step 2*, and *Step 3*) are shown in Figure 5.8.

Note that the same schema file (`StateC12.scm`) is associated with states *Step 1* and *Step 2*. The schema activates a relay and monitors a digital input to initiate a transition. When the schema is associated with state *Step 1*—Figure 5.8a—the *Relay*

operator is linked to the DAM-2 module's DO Channel 1 and the *Digital Input* operator is linked to the DAM-2 module's DI Channel 4. When the same sub-schema document is associated with state *Step 2*—Figure 5.8b—the *Relay* operator is linked to the DAM-2 module's DO Channel 2 and the *Digital Input* operator is linked to the DAM-2 module's DI Channel 5.

The schema file associated with State *Step 3* (`StateC3.scm`) is shown in Figure 5.8c. It de-activates the two relay outputs activated during the earlier steps in the sequence, and sets the *Boolean Variable* operator named `bCBTransition` to HIGH. The latter action causes the state-transition diagram in its parent schema (Figure 5.6) to switch from executing state *C* to executing state *B*.

The schema file `StateC3.scm` is configured to re-initialize its operators upon activation. As a result, each time the system enters state *C* in Figure 5.7c, the entire sequence executes (first state *Step 1*, then state *Step 2*, and then state *Step 3*). If the schema file were not configured to re-initialize upon activation, then the system would immediately resume executing *Step 3*.

Sub-Schema Namespaces

A key motivation behind the use of sub-schemas is that they promote program re-use. The idea is that re-using *code* can drastically reduce development and testing time. Moreover, if a bug is ever found within a sub-schema, it only needs to be corrected in one place, thereby simplifying code management. In this section, we introduce the concept of sub-schema *namespaces* as a means of promoting re-use.

But before taking up the subject of sub-schema *namespaces*, we shall consider the role of Variable *scope*. Proper selection of variable scope is a critical factor in maintaining re-usable code. The operator scope should have the minimum range required to achieve the desired objective. If a variable is not needed outside of the schema in which it resides, it should be assigned *Local* scope. This avoids the possibility that when a sub-schema is re-used in a different application, a variable with *Module* or *Global* scope is not inadvertently bound to another variable with the same name and scope in the other application.

The available scope settings on their own are sometimes not sufficient to achieve re-use. For instance, consider an application where four identical machines are to be controlled. The ideal approach from a re-usability standpoint is to implement the algorithm in a sub-schema and to reference that same sub-schema four times.

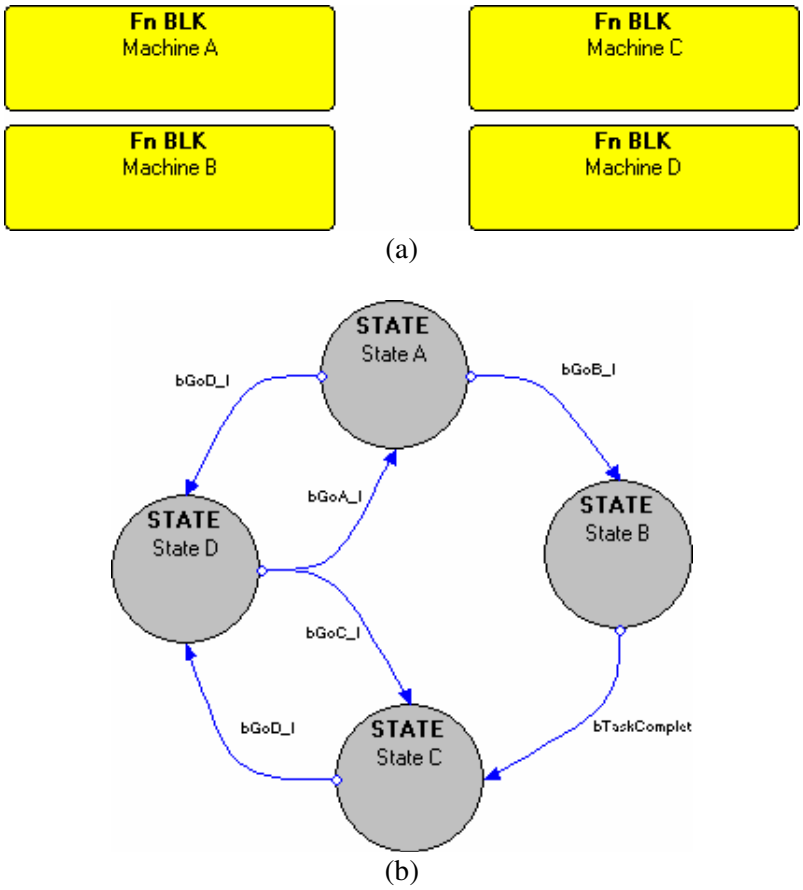


Figure 5.9. (a) Example schema with four function-block sub-schema operators each referencing the schema in (b) with state-transition diagram having a transition (labeled `bTaskComplete_m`) that is linked to a Boolean variable of module scope.

Suppose the algorithm were best implemented as a state diagram, as shown below, with a transition bound to a *Boolean Variable* named `bTaskComplete_m` having *module* scope.

Suppose the variable `bTaskComplete_m` necessarily had to have *module* scope because its state (LOW or HIGH) could only be determined within the sub-schema file associated with state operator labeled *State B*. But the assignment of *module* scope to `bTaskComplete_m` creates a problem. Remember that the same state-diagram is to be referenced by the four sub-schemas, meaning that four distinct instances of this same state diagram are to execute concurrently and independently. However, because `bTaskComplete_m` has *module* scope, every appearance of that variable is interpreted as a reference to the very same signal. As a result, *Design Pad G3*will bind together each and every instance of the `bTaskComplete_m` transition, such that machine operation will be incorrectly coupled and the schemas will not execute as expected.

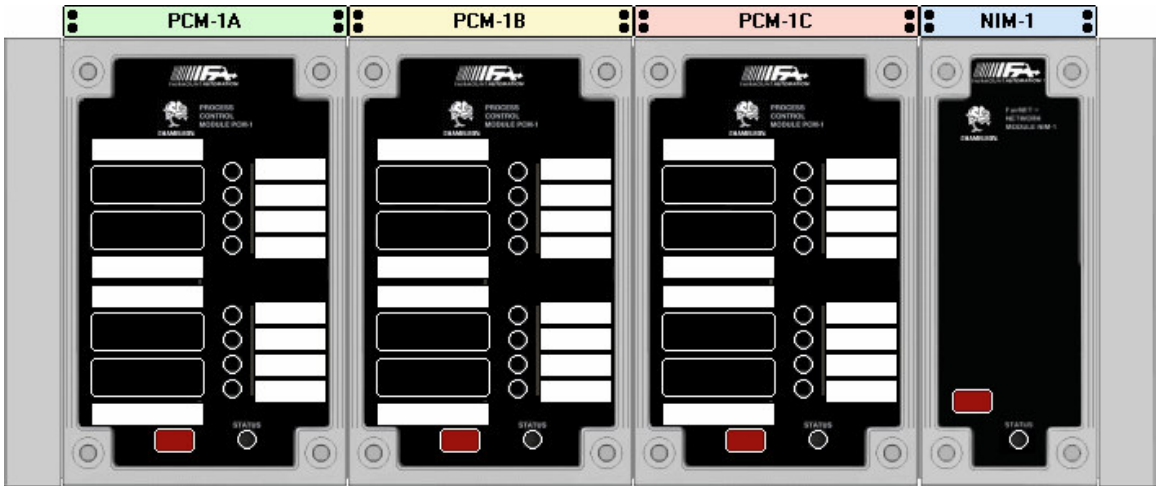
This problem can be solved by using sub-schema *namespaces* and the *Prepend Name* property of *Variable* operators. As its label implies, the *Prepend Name* property prefixes the variable name with the node name, module name, sub-schema namespace, or a combination of these. The resolved name (i.e., the combination of the *Prepend Name* and *Signal Name* properties) can then be used to uniquely identify a variable reference.

The problem in the example described above can be rectified by activating the *Namespace* property of the *Function Block Sub-Schema* operators, setting the *Prepend Name* property of the `bTaskComplete_m` to *Namespace*, and setting the *Naming* drop-down combo in the *Transition Properties* dialog box to *Namespace*. Then, the resolved names for the problematic operators would be unique: `Machine A.bTaskComplete_m`, `Machine B.bTaskComplete_m`, `Machine C.bTaskComplete_m`, and `Machine D.bTaskComplete_m`.

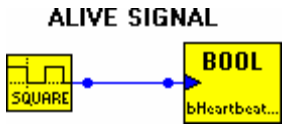
Another example usage of the *Prepend Name* property to promote program re-use is shown in Figure 5.10. Consider the hardware interface file consisting of three PCM-1 modules and one NIM-1 module as shown in Figure 5.10a. The NIM-1 module is to monitor the health of the three PCM-1 modules that are to control identical machines. Since each of the PCM-1 modules perform an identical function, it is desirable to associate them all to the same schema file. This schema file generates a heartbeat signal to be monitored by the NIM-1 module, as shown in Figure 5.10b:

The heartbeat signal, named `bHeartbeat_g` is assigned *Global* scope so that it is accessible from the NIM-1 module. But if the same schema is assigned to the three PCM-1 modules, each module would attempt to set the value of the same global variable named `bHeartbeat_g`. In order for the heartbeat signal variable to be unique to the module that sources it, the *Prepend Name* property of the variable must be set to *Module* so that the module name is used as a prefix to the signal name. The fully resolved name will be `PCM-1A.bHeartbeat_g`, `PCM-1B.bHeartbeat_g`, or `PCM-1C.bHeartbeat_g`.

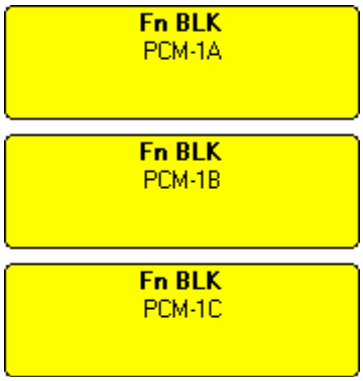
Then, the schema linked to the NIM-1 module should contain three namespace-enabled *Function Block Sub-Schema* operators with names to match the module names as show in Figure 5.10c. Each of these *Function Block Sub-Schema* operators can then be linked to the same sub-schema file (shown in Figure 5.10d) that contains a circuit used to monitor the heartbeat signal:



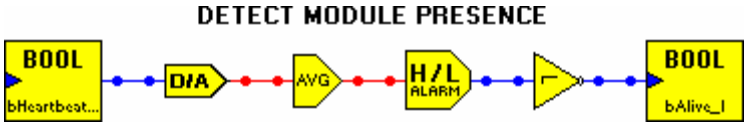
(a)



(b)



(c)



(d)

Figure 5.10. (a) Hardware interface file with 3 PCM-1 modules and 1 NIM-1 module; (b) Schema linked to each PCM-1 module; (c) Schema linked to NIM-1 module; (d) Sub-Schema document linked to each Function-Block Sub-Schema operator in (c).

Note that in the sub-schema of Figure 5.10d, the *Prepend Name* property of the `bHeartbeat_g` operator is set to *Namespace*, such that its name is prefixed with the name of the corresponding sub-schema operator in Figure 5.10c. The fully resolved

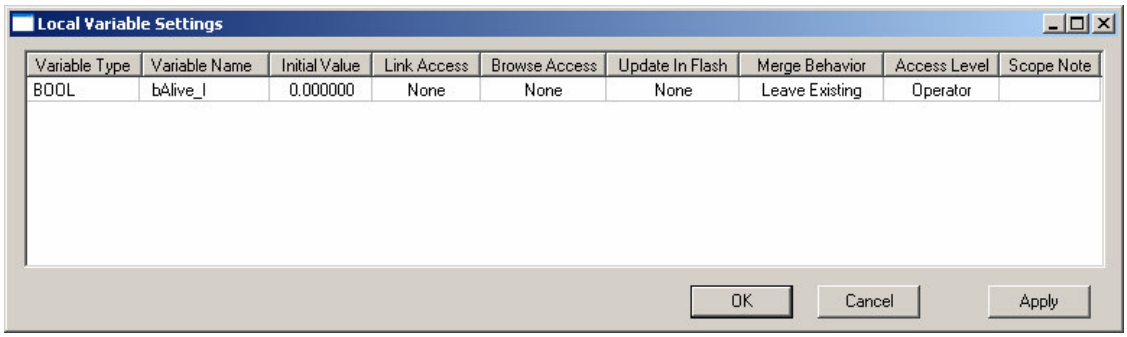


Figure 5.11. Variable Settings Dialog.

name will be `PCM-1A.bHeartbeat_g`, `PCM-1B.bHeartbeat_g`, or `PCM-1C.bHeartbeat_g`, to match the source signal names.

Variable Operator Properties and Settings

Like all other operators, *Variable* operators have various attributes that may be specified in their *Operator Properties* dialog. In addition to these properties, *Variable* operators have several other settings that are inherited from the common signal that they reference. Recall that several *Variable* operators may reference the same signal—attributes of this common signal apply to all *Variable* operators that reference it. Why are there attributes associated with the common signal (i.e., with the set of *Variable* operators) rather than with an individual operator? Asked another way, why aren't all attributes simply set from each *Variable* operator's property sheet?

Consider a schema with a state-transition diagram containing three states. Suppose that each state's associated sub-schema document had an output-only, module-scope *Variable* operator that referenced the same parameter signal, call it `fParam_m`. By definition, the output of each *Variable* operator must be the same, namely the value of the `fParam_m` signal. But how is the value of `fParam_m` assigned if the *Variable* operators that reference the signal are all output-only and not computed within the schema? The answer is that the value of `fParam_m` will remain constant at its initial value. This initial value setting is a property that must be common to all variable operators that reference the signal. Specifying the initial value in the property sheet of each individual operator would be error prone, as different values could be set for the same signal.

The common *Variable* operator attributes are specified in the *Variable Settings* dialog (see Figure 5.11). Access to the dialog depends on the *scope* of the *Variable* operator. Variables of *Local* scope pertain to the single schema document in which they exist. As such, their common properties are stored within the schema document and the *Variable Settings* dialog is accessed from the Schema menu (select the *Local Variable*

Settings item). Variables of *Module* and *Global* scope pertain to multiple schema documents linked to a common hardware interface configuration. As a result, their common properties are stored within the hardware interface file and the *Variable Settings* dialog is accessed from the module drop-down menu in the hardware interface file view. For *Variable* operators with *Module* scope, select the *Module Variable Settings* item from the drop-down menu; for *Variable* operators with *Global* scope, select the *Global Variable Settings* item.

Consider a schema having a *Variable* operator with *module* scope that references a signal named `fSignal_m`. Suppose the schema were linked to two modules in a hardware interface file, say "Module A" and "Module B". Since the *Variable* operator is of *module* scope, it represents a distinct signal within each module. That is, `fSignal_m` in "Module A" is not the same variable as `fSignal_m` in "Module B". As such, they can be assigned different initial values (among other attributes) in the *Module Variable Settings* dialog for each module.

For a description of the attributes that may be configured thru the *Variable Settings* dialog, please see the operator reference section for the *Variable* operator.

Searching for Objects

Search Tool

As the use of sub-schemas grows within a project, it may become difficult to track object usage. For example, it may be difficult to remember every reference to a particular signal or every usage of a particular operator. *Design Pad G3* provides a powerful facility to search for operators using its Find In Schema dialog shown in Figure 5.12. To execute a search, select the Find In Schema item in the Edit menu. You can execute simple searches such as locating every instance of a particular operator type (e.g., *A/B Switch* or *Multiplication* block), or locating all objects assigned a particular label. Or you can execute more complex searches using conditional logic, such as finding all *Boolean Variable* operators having local scope and referencing a signal with a name starting with "`bVar`".

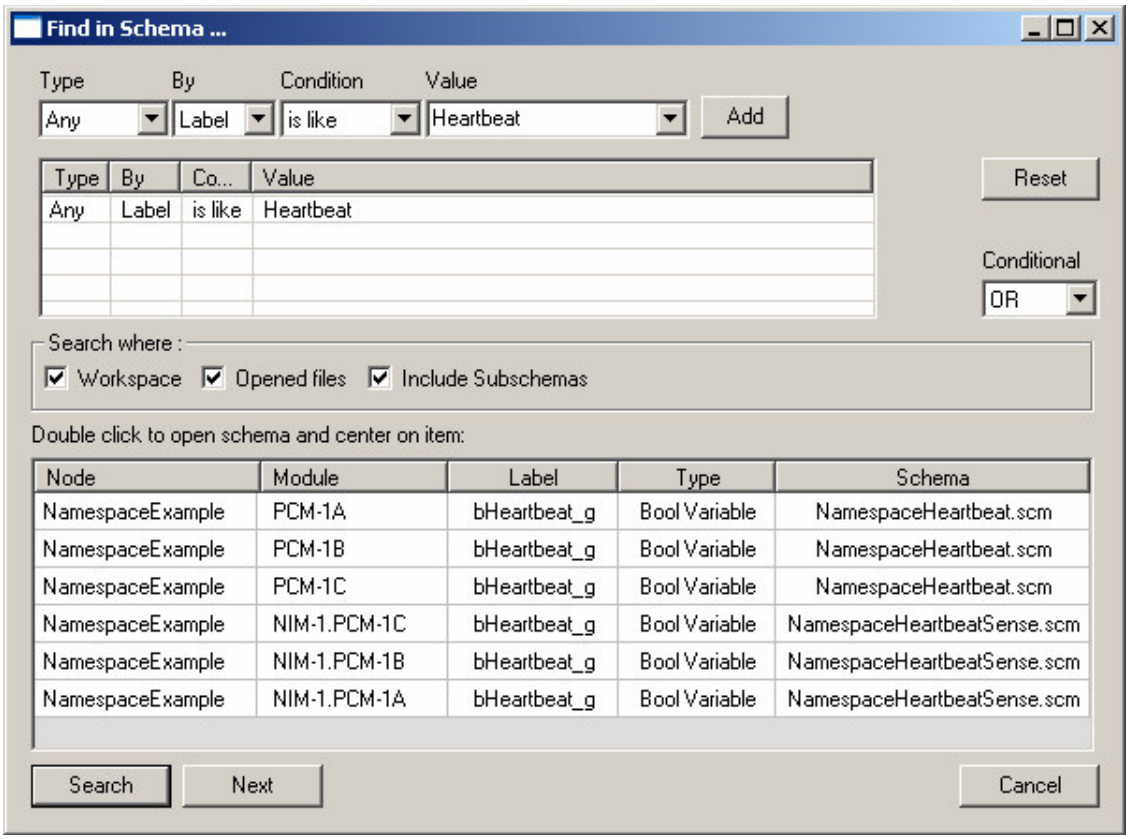


Figure 5.12. Find in Schema Dialog.

You synthesize the search criteria using the combo boxes at the top of the dialog. First select the type of object you wish to search for in the Type combo box. The available options are *Any*, *Operator*, *Hardware*, or *Variable*, where *Operator* refers to any operator type other than a *Hardware* or *Variable* operator. Next, indicate what to search by—an operator's label or its type, or in the case of a *Variable* operator, its scope. Next, select the matching condition: when searching for a label string, the available options are "is like" or "exactly matches", "starts with", or "ends with". Lastly, indicate the target value to search for. After making the combo box selections, click the Add button to incorporate the search term into the search criteria list control below the combo boxes. Multiple search terms can be included in the search criteria list control such that only those objects meeting all the search terms should be included in the result set (AND conditional) or all objects that meet any of the search terms should be included in the search set (OR conditional). Once all the search terms have been added to the search criteria list control, click the Search button at the bottom of the dialog to populate the result set list control. Double-clicking on any entry in the result set list control will open the schema document that contains the object and will highlight the selected object.

To execute the search such that only those objects that meet all the search terms are included in the result set, set the Conditional combo to AND. To execute the search such that all objects that meet any of the search terms are included in the result set, set the Conditional combo to OR. To clear the search criteria, click the Reset button.

For example, to locate every instance of an *Analog Input* operator, set the Type combo to *Any*, set the By combo to *Type*, set the Condition combo to *is like*, and set the Value combo to *Analog Input*. Then click the Add button followed by the Search button.

To further narrow the search to *Analog Input* operators containing the string "Press" in its label, set the Type combo to *Any*, set the By combo to *Label*, set the Condition combo to *is like*, and set the Value combo to "Press". Then click the Add button such that the search criteria list control contains two search terms—the one just added as well as the one added in the previous example. To execute the search, set the Conditional combo to "AND" and click the Search button.

6. Managing Schemas and Networks in a Workspace

Design Pad G3 can be used to configure a single control station or a distributed network of multiple controllers. *Design Pad G3* uses *workspaces* to organize the collection of hardware configurations and control schemas that form a multi-station control strategy. Workspaces can be used to organize any collection of documents—even documents that are loosely related or not related at all.

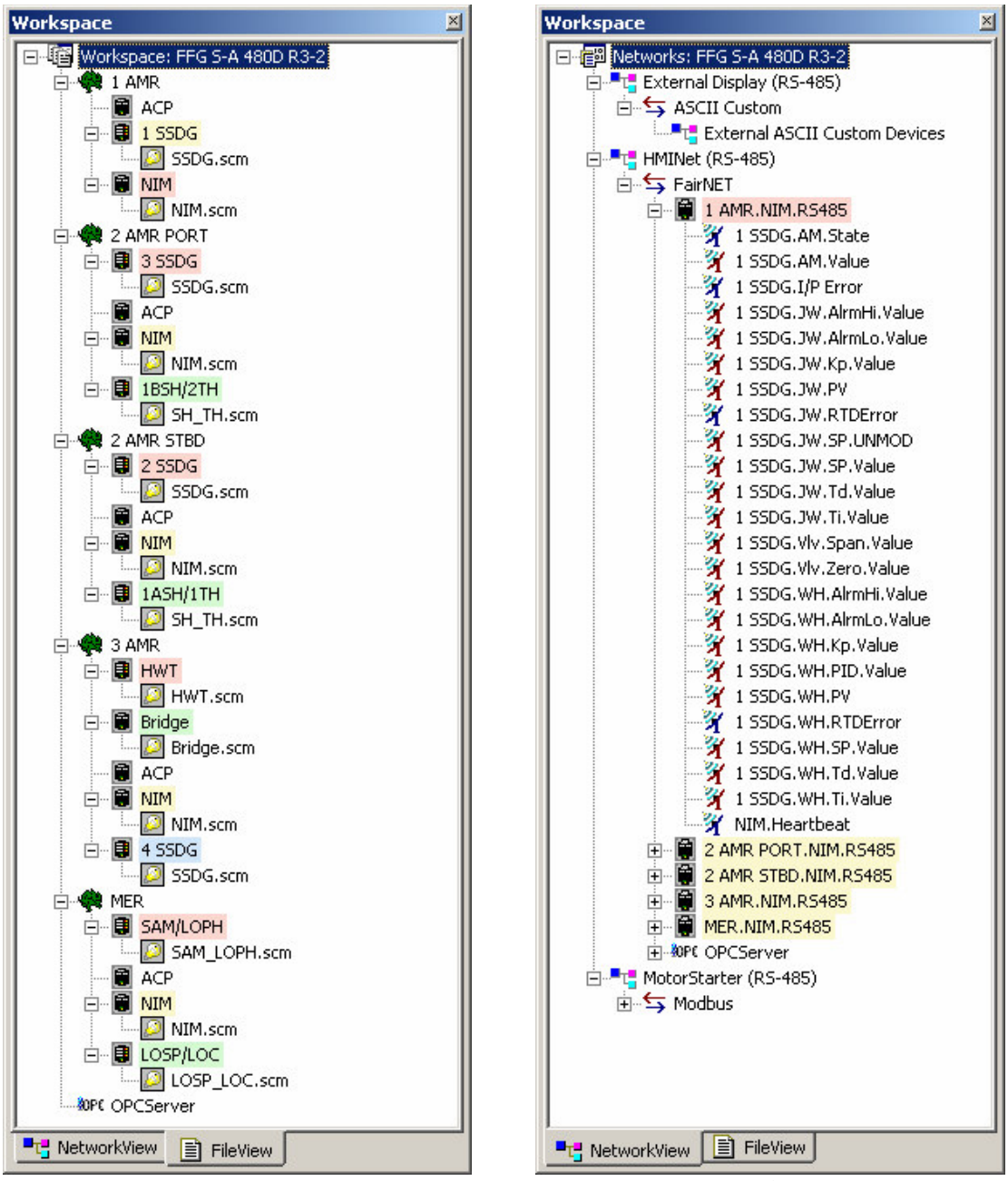
In addition to organizing documents, workspaces provide a means to configure communication networks, to configure OPC server gateways, and to communicate with devices on a controller network. (An OPC server is a standalone software item that serves as a gateway between a controller network and a PC network. It is often used to link controllers to Human Machine Interface (HMI) software executing on a PC.)

This section describes document management in workspaces. Section 1 describes network configuration and OPC server configuration, and section 7 describes PC-to-controller communication via *Design Pad G3*.

The Workspace Window

View Workspace Window

The workspace document exists within the workspace window—a window normally docked on the left side of the application's client area (see Figure 6.1). To view the workspace window, select the Workspace item from the View menu. It may sometimes be useful to hide the workspace window to provide more room on the screen to view other documents. To hide the workspace window, select the Workspace item from the View menu (or click on the window's close button). Notice that the Workspace item on the View menu toggles the visible state of the workspace window (when the window is visible, the menu item is checked, otherwise it is unchecked). The visible state of the workspace window can also be toggled with the toolbar menu button shown to the left.



(a) (b)

Figure 6.1. The workspace window, including (a) the *File-View* tab and (b) the *Network-View* tab.

Note: Hiding the workspace window does not close a *workspace* document—a *workspace* is still active while the workspace window is hidden.

The workspace window is always displayed on top of other windows in the *Design Pad G3* application. By default, it is docked on the left side of the screen. But it can be positioned (and resized) anywhere on the screen—it can be docked at the top, bottom, left side or right side of the client area or it can be floating anywhere on your computer screen (even outside

of the application's client area). If the workspace window is docked and you wish to position it elsewhere, click on the window handle (two raised lines adjacent to the close button) and drag it to the desired location. To resize the workspace window while it is docked, click the right mouse button on the inner edge of the window and drag it to the desired location. When the workspace window is floating, you can resize it as you would any other window.

The workspace window is used to manage a collection of documents (e.g., schemas, hardware configurations, human-machine interfaces) and controller communication networks. The workspace window has two sections: the *Files* section and the *Networks* section. A sample workspace window is shown in Figure 6.1—Figure 6.1a displays the workspace with the *Files* tab active, and Figure 6.1b displays the workspace with the *Networks* tab active. The files section lists all of the hardware interface files, schema documents, HMI documents, and OPC server configuration files that are part of the *workspace*. To activate the files section, click on the *Files* tab. The networks section of the workspace window lists all the communication networks that the workspace manages. To activate the networks section, click on the *Networks* tab.

Organizing Documents in the Workspace

The sample workspace shown in Figure 6.2 organizes schema documents for control stations regulating several processes in multiple plants of the same facility (in this case, the steam propulsion plants in a conventional aircraft carrier of the U.S. Navy Fleet, the USS JOHN F. KENNEDY). The workspace—named CV-67—maintains all the schemas for the eight boilers (four spaces) that power the ship. It uses folders to organize the schemas into meaningful groups—much like an operating system uses folders to group related files. For instance, the sample workspace of Figure 6.2 contains four top-level folders, one for each main machinery space in the ship (named *MMR1*, *MMR2*, *MMR3*, and *MMR4*). Each top-level folder contains three sub-folders named *Boiler A, Boiler B*, and *Feed Pumps*. The *Feed Pumps* sub-folder contains the three hardware interface files and associated schemas for the three control stations that regulate the feed pumps in the machinery space. The *Boiler A* and *Boiler B* sub-folders contain the hardware interface files and associated schemas for the control stations housed in the main machinery control room.

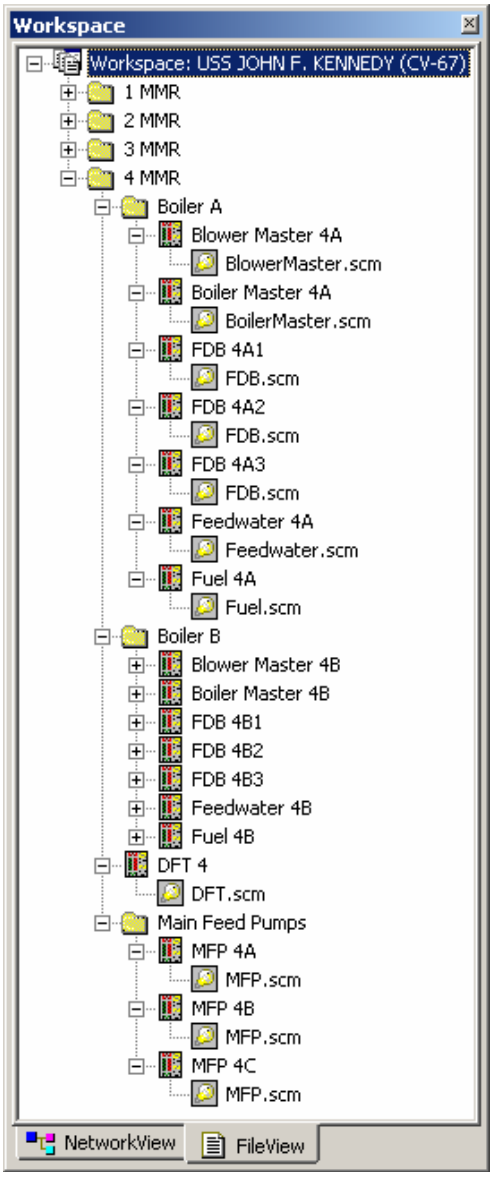


Figure 6.2. A sample workspace.

Clearly, the grouping of schemas within a workspace is arbitrary. In the sample workspace, we could have chosen to eliminate all sub-folders, and maintained only the top-level folders corresponding to each main machinery room. For that matter, we could have eliminated using folders altogether and maintained all the hardware interface files and associated schemas at the workspace root. Another approach would be to maintain four separate workspace documents—one for each machinery space. Or we could have combined the sample workspace with workspaces for other steam-powered aircraft carriers, or with workspaces for controls systems on all surface ships.

The benefit of maintaining several systems within the same workspace is that you can easily access all the hardware interface files, human-machine interface files, and schema documents in the workspace. To open a document, you simply double-click on the corresponding item in the workspace window. You don't need to search your drive directories for the desired file—the workspace knows where each file is located. The drawback of maintaining a workspace with many schemas is that it may become needlessly complex.

Working with Workspaces

6.1.1 Creating a new Workspace

To create a new workspace, select the New Workspace item from the File menu. *Design Pad G3* prompts you for the workspace name and the directory where you would like to store the workspace document. The new workspace document will be saved with a `.dpw` file

extension. *Design Pad G3* will also create a corresponding workspace environment file—with a `.wen` file extension. It will use the environment file to restore the *Design Pad G3* state the next time you use the workspace. Among other things, it will use the environment file to automatically open any documents that are open when you close the workspace.

6.1.2 Opening and Closing Workspaces

Design Pad G3 can only have a single workspace document open at any given time. If you would like to open a workspace document, you must first close the workspace document you are presently working with. To close a workspace, select the Close Workspace item from the File menu. If necessary, *Design Pad G3* will prompt you to save changes to the workspace before closing it. Occasionally, you may be surprised that *Design Pad G3* prompts you to save changes to the workspace. While you may not have made any changes to the workspace explicitly, any changes you made to the documents referenced in the workspace may alter workspace settings. In general, when *Design Pad G3* prompts you to save changes to the workspace, you should respond affirmatively, unless you are certain that you want to discard your recent work.

When *Design Pad G3* closes a workspace, it also closes all other open documents and their associated windows. If necessary, *Design Pad G3* will prompt you to save any changes you may have made to a document before closing it.

To open an existing workspace, select the Open Workspace item from the File menu. *Design Pad G3* will provide you with the familiar Windows Open File dialog where you can browse for the desired workspace. If a workspace is open when you attempt to open another one, *Design Pad G3* will first close the open workspace (and, if necessary, prompt you to save any changes) and then prompt for the new workspace to open.

Design Pad G3 maintains a list of recently opened workspace documents in the Recent Workspaces item of the File menu. To open a recently-accessed workspace document, select the Recent Workspaces item in the File menu. A sub-menu will appear listing the four most recently opened workspace documents. If the workspace you wish to open is on the list, select it. (You can change the number of entries in the recent-file list—see section 0.)

6.1.3 Saving the Workspace

As you modify the workspace, you should periodically save your changes to permanent storage. To save the workspace, select the Save Workspace item in the File menu. When you save the workspace, *Design Pad G3* will only record any changes made to the workspace itself; it will not save any modifications you may have made to other documents (hardware interface files, schema files, HMI files, *etc.*).

Design Pad G3 automatically creates a back-up copy of a workspace document before it saves any changes. For example, when you save changes to the workspace named `workspace.dpw`, *Design Pad G3* first makes a copy of the existing file (and saves the

	Chameleon Hardware Interface Document
	FAC2000 Hardware Interface Document
	Chameleon Module (part of Hardware Interface)
	Schema Document
	Human Machine Interface Document
OPC	OPC Server Configuration

Figure 6.3. Workspace File-View Icons.

copy as `workspace.bwk`) before overwriting `workspace.dpw` with the changes that you made to it. This feature could be useful if you have saved changes to a workspace but later decide you want to discard those changes and revert to the back-up version. To disable the auto-backup feature, see section 0.

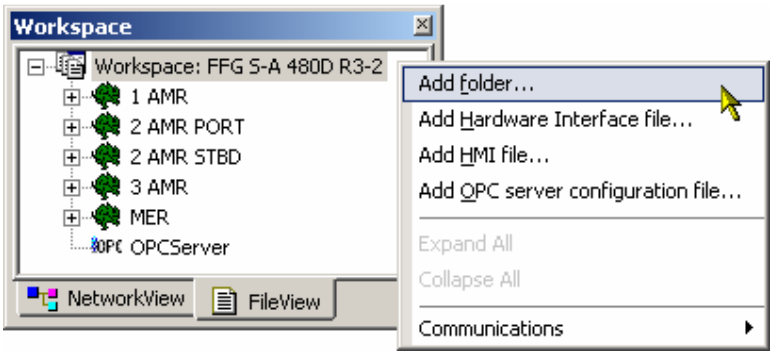
Workspace File View

The workspace window has two views: a *File View* (Figure 6.1a) and a *Network View* (Figure 6.1b). The file view displays all of the hardware configuration files, schema documents, HMI documents, and OPC server configuration files that are referenced in the workspace. It organizes these documents in a graphical hierarchical tree format, using folders to group related files. The file view displays the name of each document alongside a small graphic that indicates the type of document it is:

Once you have created a workspace document (section 6.1.1), you can begin adding documents and folders into the workspace.

6.1.4 Using Workspace Folders

Workspace folders serve to group related documents together, much like directories serve to group related files on a disk drive.



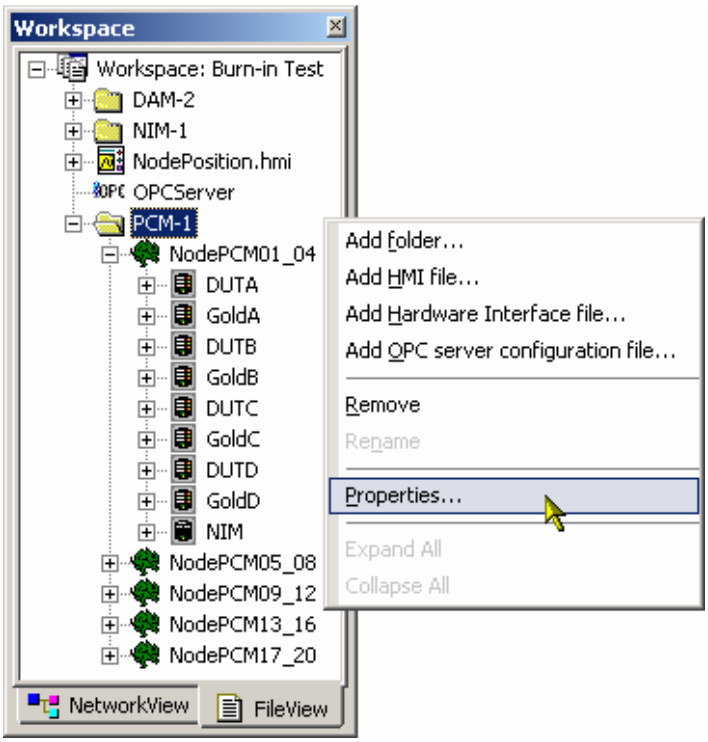
To add a folder to the workspace, first make the *File View* active (click on the *Files* tab in the workspace window). Next, click the right mouse button on the workspace label (the

root node) and select the Add Folder item from the drop-down menu. Then, after *Design Pad G3* inserts a new folder into the workspace, enter the desired folder name.

You can also add a folder to another folder (*i.e.,* as a sub-folder). To do so, right-click on the folder name and select the Add Folder item from the drop-down menu. As before, you need to rename the folder after *Design Pad G3* inserts it into the workspace—use the Rename item from the folder drop-down menu.

After you have added folders to the workspace, you can re-arrange the workspace folder structure using drag and drop. That is, you can select a folder, drag it to a new location, and release it there. For instance, you can move a sub-folder to the workspace root node, or you can move a folder into another folder. Of course, when you drag a folder to a new location, the folder contents move with it.

You can remove a folder from the workspace altogether by right-clicking on the folder and selecting the Remove item from the drop-down menu. When you remove a folder from the workspace, the folder and all of its contents (including sub-folders and their contents) are also removed from the workspace. To ensure that you did not inadvertently choose to remove a folder, *Design Pad G3* will prompt you to confirm you selection before proceeding.



You can add information about a folder in the Folder Properties dialog box. To view the folder properties, right-click on the folder and select Folder Properties item from the drop-down menu. The Folder Properties dialog box (Figure 6.4) displays the folder name along with notes about the folder. You can use the *Notes* field to add information about the folder contents. For example, you could explain the relationships between the schema documents in the folder (*e.g.*, how they work together, *etc.*)

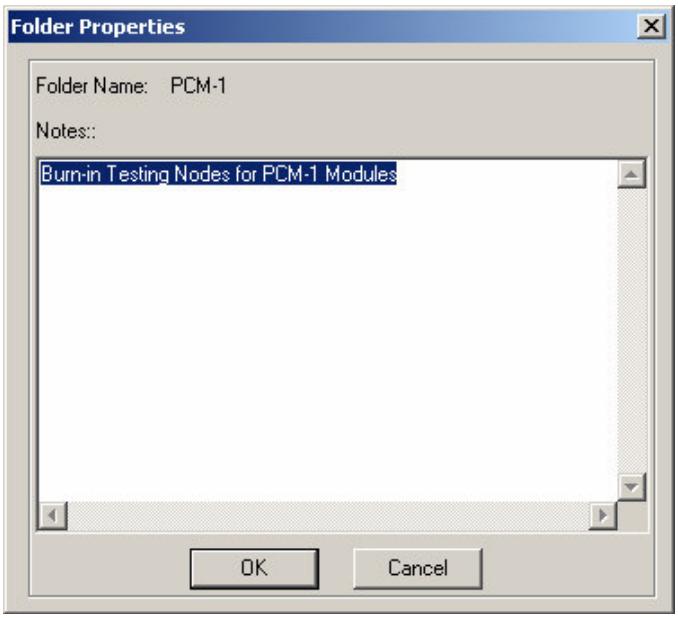


Figure 6.4. Folder properties dialog used to record notes about the contents of the folder.

6.1.5 Adding Documents to the Workspace

In *Design Pad G3*, you can add three types of document files to the workspace: hardware interface files, human-machine interface (HMI) files, and OPC-server configuration files: Hardware Interface files were described in section 0; they represent the target hardware configuration and associated schemas (control algorithms) that said hardware is to execute. HMI files offer graphical user-interface (GUI) resources to convey control system operation on a PC platform (see section **Error! Reference source not found.**). They are not intended for use in a controller. OPC server configuration files (described in section 1) contain all the requisite information to establish a gateway between a *FairNET* controller network and a third-party PC-based HMI package (*e.g.*, Wonderware, ICAS, *etc.*).

To begin adding documents to the workspace, you must first activate the *File View* tab on the workspace window. Then, right-click on the root workspace node (or a folder in the workspace) and select the appropriate item from the drop down menu. If you choose the Add Hardware Interface Files item or Add HMI Files item, *Design Pad G3* will display the familiar Windows Open File dialog, where you can browse for and select the document file(s) you wish to add to the workspace. If you choose the Add OPC-Server Configuration File item, *Design Pad G3* will insert a blank OPC server item into the workspace with a default name. To change the default name, right-click on the OPC server item, select Rename from the drop-down menu, and type a new name.

Note: When adding hardware interface files or HMI files, you can select multiple documents in the Windows Open File dialog using the SHIFT and CTRL keys. All the selected documents will be added to the workspace root or workspace folder.

Note: Use drag-and-drop if you need to re-organize the workspace documents (*e.g.*, move a document from one workspace folder to another).

Hardware Interface files (`.hwi`) files and HMI (`.hmi`) files referenced in the workspace do not need to reside in the same disk directory as the workspace (`.dpw`). They can be located in different directories, in different drives, and/or in different computers on a local area network. The workspace file records a link to each document referenced in the workspace, rather than incorporating the document files within the workspace file. Since only a link is recorded, a problem could arise if the document referenced in the workspace no longer exists or has been moved to another location. If *Design Pad G3* cannot locate a file referenced in the workspace, it will prompt you for its new location. (You can remove a document from the workspace by right-clicking the document name in the workspace window and selecting the Remove item from the drop-down menu.)

The workspace *File View* offers a convenient location to access your files. You can open a document referenced in the workspace simply by double-clicking on the document name in the workspace window (or you can right-click on the workspace item and select Open File from the drop down menu). You can also perform a number of functions with the workspace documents without opening them at all. For instance, you can process (compile) a controller configuration or export it to a control station. The available commands are displayed in a drop-down menu when you right-click on the document name.

Workspace Network View

The *Network View* displays all the communication networks that are part of the workspace (see Figure 6.1b). It organizes the communication networks in a graphical hierarchical tree format. The workspace is the root node of this tree and the physical networks it contains are its first-level sub-nodes. Each physical network can have a list of entries representing logical networks (i.e., communication protocols) that execute over the physical network. Each logical network in turn can have a list of entries representing device network interfaces (*e.g.*, control station, PC, etc.) that communicate over the channel. Each device network interface in turn can have list entries representing the signals that the device is to transmit on the associated network.

For example, the workspace shown in Figure 6.1b contains three RS-485 physical networks named: *External Display*, *HMINet*, and *Motor Starter*. Each physical network has a single logical network associated with it. A custom ASCII protocol is used on the *External Display* physical network; the *FairNET* protocol is employed on *HMINet*; and the *Modbus* protocol is used in the *Motor Starter* network. Although RS-485 based physical networks may only have a single logical network attached to them, other physical network channels (e.g., Ethernet) may have multiple logical networks attached (*i.e.*, multiple protocols may execute over the same channel).

	Physical Network
	Logical Network
	Network Interface (Chameleon Module)
	Network Interface (FAC2000 Controller)
	Network Interface (OPC Server / PC)
	Analog Signal
	Discrete Signal
	Mixed Signal (e.g., ASCII string, data structure, etc.)

Figure 6.5. Workspace Network-View Icons.

Six devices are part of the *FairNET* logical network executing on the *HMINet* physical network. Five of these six devices are Chameleon RS-485 Network Interface Modules (NIM-1) configured to execute the *FairNET* protocol. The other device is a PC equipped with an RS-485 port and the FairNET OPC Server gateway software. In Figure 6.1b, the first device network interface on the *HMINet : FairNET* network (labeled 1 AMR.NIM.RS485) will source 24 signals. Five of the signals are discrete values and nineteen are analog values.

Each item in the *Network View* pane has descriptive text alongside a small graphic that indicates the type of entry it is. Figure 6.5 lists the network view entries and associated graphic icons.

The next section in this bulletin describes how to add and configure networks to the workspace and how to associate schemas, HMI documents, and OPC servers with each network.

7. Processing a Node Configuration

A node configuration includes the definition of the hardware modules that constitute a controller node, the schema files associated with each module, and specific hardware configuration settings for each module.

Before the node configuration can be downloaded into the target hardware, it must be processed into an executable form and translated into a format that is readable by the control engine in the target hardware.

Schema Compilation

A schema diagram is a representation of a control algorithm (or an algorithm fragment) to be executed by the controller hardware. In order for the algorithm to be executed, it must be translated or compiled into a form that the central processing unit (CPU) of the device can understand. *Design Pad G3* has a built-in compiler that does just that.

Process Schema

A schema can be processed individually as a standalone document, or it can be compiled during node configuration processing. To process an individual schema document, select the Process Schema item in the Schema menu. Alternatively, you can press the corresponding button on the speed-bar menu (shown to the right.) *Design Pad* will then convert your schema into executable form.

Process All Schemas

To process all of the schema documents associated with a hardware interface file, select the desired `.hwi` document and click the Process All Schemas button in the speed-bar menu.

During the compilation process, *Design Pad G3* checks for errors or anomalies in your schema(s). For instance, *Design Pad G3* will alert you if you have left an input pin disconnected or if you have combined an analog signal with a digital one. All of the errors and warnings that *Design Pad G3* may issue during compilation are described in the following section.

View Message Window

Design Pad G3 displays compilation errors, warnings, and notes in its Message window. Each line in the message window refers to an individual compilation error, warning, or note. When you select an item in the message window, *Design Pad G3* will highlight the corresponding offending object(s) and/or signal(s) in the relevant schema document. *Design Pad G3* will also re-center the schema view so that the highlighted object(s) appear at the center of the document window. You can toggle the visible state of the message window (shown or hidden) from the view menu. When you make the message window visible, *Design Pad G3* displays a check mark next to the Message Window item in the View menu; it removes the check mark when the window is not visible. You can also toggle the visible state of the message window by pressing the corresponding button on the toolbar menu (shown to the right).

The message window is always displayed on top of other windows in the *Design Pad G3* application environment. By default, it is docked on the bottom-left side of the screen. But it can be positioned (and resized) anywhere on the screen—it can be docked at the top, bottom, left side or right side of the client area or it can be floating anywhere on your computer screen (even outside of the application's client message). If the message window is docked and you wish to position it elsewhere, click on the window handle (two raised lines adjacent to the close button) and drag it to the desired location. To resize the message window while it is docked, click the right mouse button on the inner edge of the window and drag it to the desired location. When the message window is floating, you can resize it as you would any other window.

Schema Errors and Warnings

While processing a schema diagram, *Design Pad G3* checks for various trouble conditions. Design Pad G3 will issue a processing error if a fundamental connectivity rule is violated such that signal computation is ambiguous (e.g., an output pin feeds another output pin). Design Pad G3 will also issue an error if some configuration setting could lead to a run-time fault condition.

Design Pad G3 will issue a warning if an arrangement of objects is technically allowable but could potentially produce unexpected results. For example, failing to connect a generic Analog Input operator to a specific AI hardware resource would not create a run-time fault condition as the controller can execute the "desired" program without any problem. But the output of the Analog Input operator would remain fixed at 0 rather than track the physical signal connected to the hardware.

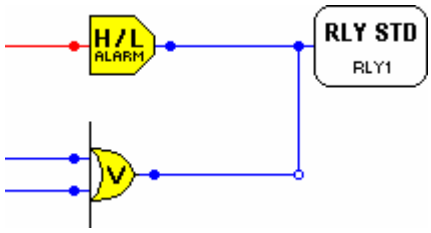
Design Pad G3 will issue a note if something in the schema may require programmer attention but is generally inconsequential (e.g., the schema includes an operator that is not used).

The errors, warnings, and notes that *Design Pad G3* may issue are described below.

Error: Signal wire contains loop. Signal wires should be used to connect operator I/O pins. This error is issued if a schema signal is connected to itself.

Error: Object has one or more unconnected input pins. Certain operators have input pins that must be connected in order to function properly. For instance, the *PID Controller* operator must have all of its five inputs connected in order to compute its control output signal. This error is issued if an input pin that must be connected is not connected. (This error is not issued if the object is not used at all. That is, if none of its I/O pins are connected.)

Error: Signal is connected to multiple output pins. A signal wire represents data flow from one operator to another—the output signal of one operator being fed to the input of another. The same output signal can be fed to multiple input pins. However, multiple outputs may not be combined—they may not feed the same input. The schema fragment shown below exhibits this error condition. The outputs of the *High/Low Alarm* operator and of the *Logical OR* operator are both fed to Relay 1. Since *Design Pad G3* cannot discern which output should drive the relay, it issues an error.

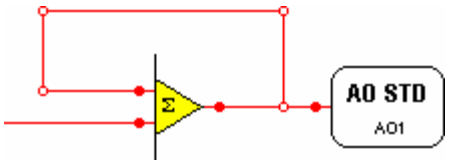


Error: Signal connects input pins only. A signal wire represents data flow from one operator to another—the output signal of one operator being fed to the input of another. An input pin of one operator may not feed the input of another operator. This error is issued when an output pin is not part of a wired connection.

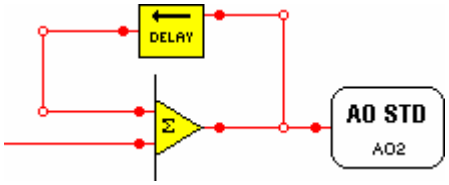
Error: Signal wire does not connect output pin to input pin. Signal wires should connect the output pin of one operator to the input pin of another. Otherwise, the wire has no effect. *Design Pad* issues a warning if a signal wire does not make an input/output connection.

Error: Cannot combine an analog signal with a digital (boolean) signal. *Design Pad G3* supports two signal types: analog signal (floating point values) drawn in red and digital signals (LOW or HIGH) drawn in blue. *Design Pad G3* issues an error if the signal types are combined. (*Design Pad G3* provides operators to convert from one signal type to another. See the operator reference section of this instruction bulletin for more details.)

Error: Objects form an algebraic loop (use delay elements to implement feedback). Algebraic loops are circular references that cannot be resolved by the *Design Pad G3* compiler. For instance, consider the schema shown below, where the output of an *Addition* operator is fed back to one of its inputs:



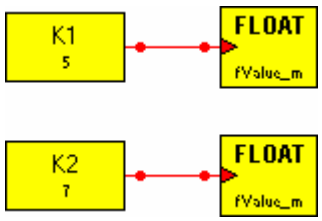
The operator output at time *t* is equal to the sum of its inputs, $y(t) = x_1(t) + x_2(t)$. And, we have $x_1(t) = y(t)$, so the diagram above attempts to compute $y(t) = y(t) + x_2(t)$. But, the computation of the output value cannot be a function of its present value, resulting in an error condition. The correct way to implement feedback is to include a *Delay* operator in the feedback path, as shown below.



With this arrangement, the output value is a function of its previous value, $y(t) = y(t - \Delta t) + x_2(t)$

Error: Sub-schema links form a loop.. The preceeding error description identified the problem with algebraic loops. Such circular references could also span operators within a schema and function-block sub-schema. Design Pad G3 issues an error when it identifies an algebraic loop spanning multiple schemas.

Error: Multiple input-type variables found with the same name. Only one input type variable with the same name allowed per schema. *Design Pad G3* allows the same signal value to be referenced by multiple Variable operators. Read access to the signal value is provided by the output pin of each Variable operator. Write access to the signal value is provided by the input pin of the Variable operator.. An attempt to write or set the value of the same signal at multiple operators could produce unexpected results. For example, in the schema fragment below, the same variable signal is set to a value of 5 and to a value of 7. If Design Pad G3 were to process this operator configuration, the signal fValue_m could take on either value—depending on which operator executes last.



Design Pad G3 will issue an error when the same signal is set by multiple Variable operators in the same schema. Note that the same signal may be set to different values in different schemas (if the signal is of module or global scope). This is often desirable, but could lead to unpredictable results similar to the example above. Setting a signal value in multiple locations should always be done with care. In general, it should only be done in mutually exclusive state sub-schemas, or by using the Variable operator's Enable input pin to ensure that the signal is not set to different values at the same time.

Error: Sub-schema contains errors. If an operator arrangement within a sub-schema document contains an error, the sub-schema operator that references that sub-schema document is also flagged with an error. The error can only be corrected within the sub-schema document.

Error: Network contains two or more broadcast operators with duplicate signal names. All broadcast operators within a communications network must have unique signal names. This error is issued if the schemas assigned to a network contain two or more broadcast operators with the same signal name. Signal names are case-sensitive, meaning

that *Design Pad* considers *OilPressure*, *oilPressure*, and *OILPRESSURE* to be unique signal names.

Error: Could not open sub-schema file. File is missing or has invalid format.. A function Block Sub-Schema operator or State Sub Schema operator contains a reference (or link) to a standalone schema document. The link is stored as a relative file path. Design Pad G3 will issue an error, if the file that is referenced cannot be found at that location. An error is also issued if the file is found but cannot be interpreted due to an invalid file format (possibly because it was created with an incompatible version of Design Pad).

Warning: Schema contains a hardware object which is not linked to any hardware resource. Schema documents are hardware independent—they can be associated with different hardware targets. To maintain hardware independence, schemas use *generic* hardware operators that are subsequently linked to a specific hardware resource. The hardware resource link is stored in the hardware interface document (not the schema document). A generic hardware operator that has not been associated with a specific hardware resource will retain its white background color. Otherwise, its background color will match the title-bar of the module that contains the specific resource it is linked to. Design Pad G3 issues a warning if a generic hardware operator has not been linked to a specific hardware resource. While the controller will be able to execute the schema, results may not be as expected. For example, if an analog input operator is not linked to a specific resource, its output will be 0 (or the low end of the user-defined signal range). If a relay output operator is not linked to a specific relay hardware resource, then no relay will be activated / de-activated by that operator.

Warning: Periodic compute time is less than parent schema's compute rate. The execution of a function block sub-schema depends upon the execution of its parent schema. The sub-schema can only execute when its parent executes—it cannot execute more frequently than its parent. If a sub-schema is configured to compute more frequently than its parent does, it will only execute as frequently as the parent does..

Warning: Periodic compute time is a not a multiple of parent schema's compute rate. The execution of a function block sub-schema depends upon the execution of its parent schema. The sub-schema can only execute when its parent executes—it cannot execute more frequently than its parent. If a sub-schema is configured for periodic computation, its periodicity should be a multiple of the parent schema's computing periodicity (loop-time). If the parent-schema executes at 100ms intervals, and the sub-schema is configured to execute at 150ms intervals, then the controller will execute the schemas as follows:

Time	Parent Schema Executes?	Sub-Schema Executes?
50ms	No	No
100ms	Yes	No
150ms	No	No
200ms	Yes	Yes
250ms	No	No
300ms	Yes	Yes
400ms	Yes	No

500ms	Yes	Yes
600ms	Yes	Yes

Design Pad G3 will issue a warning when the .sub-schema execution periodicity is not an integer multiple of its parent. Although the controller can execute with such a configuration as indicated in the example above, Design Pad G3 assumes that the designer does not intend to have out-of-phase computation.

Warning: Global/Module Variable is being set multiple times.. Variable operators serve to store a signal value. Multiple variable operators can reference the very same signal—if they have the same signal name and scope. When the common signal value is set by one operator it is immediately available at all other operators (that reference that signal). If multiple variable operators attempt to set the value of the signal during the same computation loop, results can be unpredictable. Variable operators that reference the same signal should only write the signal value under mutually exclusive conditions (e.g., within mutually exclusive state sub-schemas).

Note: Object is not used. Objects that have no I/O pin connections have no effect during schema program execution. *Design Pad G3* issues a note if a schema contains any unused objects. These unused objects are optimized out during processing and do not affect controller performance.

Note: Object has one or more unconnected input pins. Certain operators can be processed even if one or more of their input pins are not connected. For instance, the digital input of a *Bargraph Display* operator need not be connected for a signal to be displayed on a *FAC-2000* LED bargraph display. *Design Pad G3* issues a note if a pin is not connected, in case the open connection was unintended. (This note is not issued if the object is not used at all. That is, if none of its I/O pins are connected. Most operators that have pins that do not require connections usually have a property setting to show/hide that pin. When the pin is not displayed, *Design Pad G3* will not issue this note.)

Note: Object has an unconnected output pin. In general, operator objects generate an output signal based on their inputs. *Design Pad* will issue a warning if an object has an unconnected output pin and one or more of its input pins are connected. While this condition does not represent an error—the schema can still be executed—it may not have been intended by the schema designer.

8. OPERATOR REFERENCE

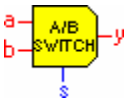
This section provides a detailed description of each operator available in *Design Pad G3*.

The documentation for each operator includes a functional description, a property list, comments (if applicable), a 'see also' section, and the *Design Pad G3* menu location. The functional description explains what the operator does and how it works. The property list describes in detail the user-defined parameters associated with the operator. The comments section indicates any exceptional information particular to the operator. The 'see also' section refers the reader to related operators that may be of interest.

A/B SWITCH

Operator Menu Location: *Signal Switching*

Operator Bitmap:



Functional Description:

The *A/B Switch* operator selects between two signals. Its output *y* is defined by

$$y = \begin{cases} a & \text{if} \quad s = 0 \\ \\ b & \text{if} \quad s = 1 \end{cases}$$

where *s* is a digital selector input, and where *a* and *b* are analog inputs.

User-Defined Properties:

Object Name. A string label that identifies the operator

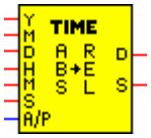
Comments: None.

See Also: Multiplexer, Demultiplexer

ABSOLUTE TO RELATIVE TIME

Operator Menu Location: *Time*

Operator Bitmap:



Functional Description:

The *Absolute to Relative Time* operator converts a date/time fully defined with MM/DD/YYYY and HH:MM:SS into a relative representation consisting of the number of days and seconds since the epoch (midnight on December 31, 1999).

The operator has three inputs for the absolute date, including the year (x_1), month (x_2), and day (x_3). And three inputs for the absolute time, including the hour (x_4), minutes (x_5), seconds (x_6). If the time is represented in 12-hour mode, a seventh input x_7 is used to indicate if the time is before noon (AM) or after noon (PM). A LOW value represents AM and a HIGH value represents PM.

The operator has two outputs: the number of days (y_1) and seconds (y_2) since the epoch corresponding to the date/time represented by inputs, $x_1,...,x_7$. The number-of-seconds output refers to the fractional part of a day and can range from 0 to 60×60×24-1=86,399.

Using a relative representation for a date/time is convenient for performing date arithmetic (*e.g.*, finding the difference between two dates). An *inverse* operator is available to convert the relative date/time representation into an absolute one—see the *Relative To Absolute Time* operator.

User-Defined Properties:

Object Name. A string label that identifies the operator

Absolute Time Format. The time format represented by inputs $x_4,...,x_7$; either 12-hour or 24-hour.

Comments: None.

See Also:
Relative To Absolute Time, Calendar, Time-of-Day Clock, Alarm Clock

ABSOLUTE VALUE

Operator Menu Location: *Math Functions*

Operator Bitmap:

Functional Description:

The output of the *Absolute Value* operator is the numerical value of its input without regard to its sign. The functional relationship can be expressed as

$$y = | x | = \begin{cases} x & \text{if} \quad x \geq 0 \\ \\ -x & \text{if} \quad x < 0 \end{cases}$$

where y is output and x is the input.

User-Defined Properties:

Object Name. A string label that identifies the operator

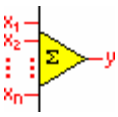
Comments: None.

See Also:
Addition, Subtraction, Multiplication, Division, Power, Exponent

ADDITION

Operator Menu Location: *Math Functions*

Operator Bitmap:



Functional Description:

The output of the *Addition* operator is the sum of its inputs,

$$y = \sum_{i=1}^{n} x_i$$

where y is the output, $x_i (i = 1,...,n)$ are the inputs, and n is the number of inputs. *Design Pad G3* assumes that $x_i \equiv 0$ if input pin i is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Inputs. The number of input pins n, where $2 \le n \le 6$

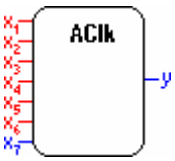
Comments: None.

See Also:
Subtraction, Absolute Value, Multiplication, Division, Power, Unit Conversion

ALARM CLOCK

Operator Menu Location: *Generic Hardware Operators* → *Time*

Operator Bitmap:



Functional Description:

The *Alarm Clock* generic hardware operator provides access to a real-time clock resource in the physical hardware. When the generic operator is linked to a specific hardware resource, the operator provides alarming functionality based on the time of day.

The operator can be configured to "alarm" at a user-specified time-of-day, with user-specified frequency and user-specified duration. An alarm condition is reflected with a HIGH output value; the output remains LOW otherwise.

The time of day to alarm can be fixed (defined in the operator properties), or can be set by external inputs, x_1 (hour), x_2 (minute), x_3 (second). The duration of the alarm can also be fixed (property settings), or set by external inputs x_4 (hours), x_5 (minutes), and x_6 (seconds). The external inputs have precedence over the property settings—if one of these inputs is connected, its corresponding property setting is ignored.

The operator can be configured to signal a single time alarm event, or repeat the alarm at user-specified intervals. The operator can be configured to alarm every day (at the time of day and for the duration defined by the property settings or external input values), every weekday, every weekend day, once per week, once per month, or once per year.

Enable input x_7 activates (HIGH) or deactivates (LOW) the alarm. The alarm output remains LOW whenever the enable input is LOW, even if the alarm condition is met (*e.g.*, the current time of day matches the alarming setting).

For example, suppose the operator is configured to alarm at 10:30AM for 30 minutes. If at 10:30AM enable input x_7 is LOW, output y will remain LOW. If at 10:45AM enable input x_7 switches to HIGH, output y will also switch to HIGH (since the alarming condition is being met). The output will remain HIGH for 15 minutes provided that the operator remains enabled ($x_7 = HIGH$).

User-Defined Properties:

Object Name. A string label that identifies the operator

Alarm Frequency. Defines the periodicity of alarming. It can assume the following values: 'Once per day', 'Weekdays', 'Weekends', 'Monthly on specified day', 'Weekly on specified day of week', 'Yearly on specified day and month', or 'Once on specified day, month, and year'.

Day. Used in conjunction with the *Alarm Frequency* setting above to define the day that the operator is to alarm. Applies only when *Alarm Frequency* setting is 'Monthly on specified day', 'Yearly on specified day and month', or 'Once on specified day, month and year'.

Day of Week. Used in conjunction with the *Alarm Frequency* setting above to define the day of week that the operator is to alarm. Applies only when *Alarm Frequency* setting is 'Weekly on specified day of week'.

Month. Used in conjunction with the *Alarm Frequency* setting above to define the month that the operator is to alarm. Applies only when *Alarm Frequency* setting is 'Yearly on specified day and month', or 'Once on specified day, month and year'.

Year. Used in conjunction with the *Alarm Frequency* setting above to define the year that the operator is to alarm. Applies only when *Alarm Frequency* setting is 'Once on specified day, month, and year'.

Display Start Time Inputs. This property determines if input pins x_1, x_2, and x_3 are visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pins are visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked). When the pins are connected, the *Start Time* properties listed below are ignored.

Start Time (hr). The hour (of day) that the alarm is to be triggered. Value must be in the range 0-23 and is ignored if input x_1 is connected.

Start Time (min). The minute (of the hour) that the alarm is to be triggered. Value must be in the range 0-59 and is ignored if input x_2 is connected.

Start Time (sec). The second (of the minute) that the alarm is to be triggered. Value must be in the range 0-59 and is ignored if input x_3 is connected.

Display Duration Inputs. This property determines if input pins x_4, x_5, and x_6 are visible in the schema diagram. *Design Pad G3* issues a warning upon processing the

schema when the pins are visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked). When the pins are connected, the *Alarm Duration* properties listed below are ignored.

Alarm Duration (hr). The number of hours that the alarm is to remain triggered. Value must be in the range 0-23 and is ignored if input x_4 is connected.

Alarm Duration (min). The number of minutes that the alarm is to remain triggered. Value must be in the range 0-59 and is ignored if input x_5 is connected.

Alarm Duration (sec). The number of seconds that the alarm is to remain triggered. Value must be in the range 0-59 and is ignored if input x_6 is connected.

Display Enabled Input. This property determines if the enable input pin x_7 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments: None.

See Also: Stop Watch, Calendar, Time-of-Day Clock

ALPHANUMERIC DISPLAY

Operator Menu Location: *Generic Hardware Operators* → *Displays*

Operator Bitmap:

Functional Description:

The *Alpha-Numeric Display* generic hardware operator provides access to an alphanumeric text display resource in the physical hardware. When the generic operator is linked to a specific hardware resource, it will utilize that resource to display a user-defined text message.

The operator has two inputs: a boolean input x_1 that determines if the text message is to be displayed, and an analog input x_2 used to embed numeric values in the text message.

The text message to be displayed is formed by combining two character strings (operator properties *Text Before Number* and *Text After Number*) with the numeric value from analog input x_2. In other words, the text message is a concatenation of

[*Text Before Number*] + [*Value from Input* x_2] + [*Text After Number*]

If analog input x_2 is not used (*i.e.*, if no connection is made to it) the text message that will be displayed is the character string defined in the *Text Before Number* property (the *Text After Number* property will not be used).

When the operator is activated (input x_1 is HIGH), the user-defined text message will be scrolled from left to right in the physical display. For a hardware resource with *n* characters, the last *n* characters of the message will remain on the display after scrolling completes. The duration of the scrolling period (the *Entry Time*), and the time the message remains on the display (the *Hold Time*), are properties of the operator.

Multiple generic *Alpha-Numeric Display* operators can be linked to the same hardware resource. Messages can be assigned a user-defined priority level ranging from 1 to 3. Messages with a higher priority number have precedence over messages with a lower priority number.
While the operator remains active ($x_1 = HIGH$), the text message may repeatedly scroll across the display. The number of times the message is to repeat is a user-configurable

property of the operator ranging from 0 to 255. If the repeat property is set to 255, the text message will be displayed indefinitely (as long as the message is active). This display count resets when $x_1 = LOW$. Once the operator is reactivated, it will the display the message again and repeat for the user-defined repeat count.

Each text display hardware resource maintains a queue of messages to display. Each queue is sorted based on the priority levels of the messages it contains. The message at the top of the queue is displayed first. After the hold time elapses, the message is removed from the queue and the next message is displayed. If a message is to be repeated, it is re-inserted into the queue, immediately following all messages of equal priority. A message with the number repeat property set to 255 will not be removed from the queue while input x_1 is high (it will be displayed indefinitely). Note that a message will not be displayed while messages of higher priority remain in the queue.

User-Defined Properties:

Text Before Number. Text message (or part of text message) to be displayed on the alphanumeric hardware resource when input signal x_1 is HIGH. If input x_2 is connected, the text message to be displayed is a combination of this property, the numeric value x_2, and the *Text After Number* property below. Otherwise, if input x_2 is not connected, this property defines the full text to be displayed.

Text After Number. The part of text message to be displayed that follows the numeric value of input x_2.

Number of Significant Digits to Display. The number of significant digits to use when displaying the numeric value x_2. This property is ignored if input x_2 is not connected.

Justification. The justification of the characters that remain on the screen after the scrolling time expires: *Left*, *Right*, or *Centered*. (This property applies only for text messages whose length does not exceed the number of characters of the physical hardware resource.)

Presentation. The style used to present the message: *Steady*, *Flash*, or *Fade*.

Number Repeat. The number of times to repeat the message while the operator is activated (input x_1 is HIGH). If this property is set to 0, the message will be displayed once; if it is set to 1, the message will be displayed twice; if it is set to 2, the message will be displayed three times; and so on. If this property is set to 255, the message will remain on the display as long as input x_1 remains HIGH.

Entry Time. The amount of time (in milliseconds) required to scroll the entire message across the display (also called the *scrolling period*).

Hold Time. The amount of time (in milliseconds) to hold the message on the display after the scrolling period is completed.

Priority. The message priority level: an integer in the range [1,3]. Messages of priority 1 have the lowest priority; messages of priority 3 have the highest priority.

Brightness. A brightness setting for the physical display in the range [0-15], with 15 indicating maximum brightness.

Display Enable Input. This property determines if input pin x_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Analog Input. This property determines if input pin x_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments:

- Multiple *Alpha-Numeric Display* operators linked to the same display resource may be active simultaneously. Each active message will be displayed only if all other active messages of higher priority (on the same target line) have been removed from the message queue.

- If a low-priority message is placed in the message queue, and the queue contains a higher priority message with the *Number Repeat* property set to 255, the low-priority message may never be displayed. (The higher priority message will be displayed until it is deactivated.)

- Modules with alphanumeric display hardware resources may use those resources to display system messages. These system messages may be assigned priority values that are larger than user-defined priorities. As a result, user messages may not be displayed while system messages are displayed.

See Also: Numeric Display, Bargraph Display, LED Display

ANALOG INPUT (STANDARD)

Operator Menu Location: *Generic Hardware Operators* → *Analog Inputs*

Operator Bitmap:

Functional Description:

The *Standard Analog Input* generic hardware operator provides access to an analog input channel resource in the physical hardware. When the generic operator is linked to a specific hardware resource, its output value will correspond to the physical signal connected to that resource.
The operator can provide the raw signal value, in the unit of measure defined by the hardware configuration (*e.g.*, 4-20mA, 0-10V, *etc.*). Alternatively, it can be configured to automatically map the raw signal into a user-defined representation as follows

$$y = x_{ul} + \frac{(x - x_{rl})(x_{uh} - x_{ul})}{x_{rh} - x_{rl}}.$$

Here, y is the operator output, x is the raw signal value, x_{rl} and x_{rh} represent the nominal range for the raw signal (*e.g.*, $x_{rl} = 4\,\text{mA}$, $x_{rh} = 20\,\text{mA}$), x_{ul} is the user-defined value corresponding to x_{rl}, and x_{uh} is the user-defined value corresponding to x_{rh}. For example, suppose the hardware is configured to read a 4-20mA signal and is attached to a pressure transmitter with a dynamic range of 0-5800psi. Then, the operator would convert a reading of x=8mA to

$$y = 0\text{psi} + \frac{(8\text{mA} - 4\text{mA})(5800\text{psi} - 0\text{psi})}{20\text{mA} - 4\text{mA}} = 1450\text{psi}.$$

User-Defined Properties:

Object Name. A string label that identifies the operator.

Scale. Either *Hardware Defined* or *User Defined*. In *Hardware Defined* mode, the operator output is the raw signal value in the unit of measure defined by the hardware configuration. In *User Defined* mode, the operator maps the raw signal into the user-defined scaling range.

Lo Range Scaled Equivalent. The operator representation of a signal at the low end of the hardware range when *User Defined* mode is selected.

Hi Range Scaled Equivalent. The operator representation of a signal at the high end of the hardware range when *User Defined* mode is selected.

Units. Engineering units label used for readability.

Comments:

- The x_{ul} value may be greater than the x_{uh} value.

- If the input signal is outside of the nominal hardware range, the operator representation may be outside of the user-defined range. For example, suppose the user-defined mappings are set to 0 and 100 and the hardware resource is configured for 4-20mA signals. A reading of 0mA, will be mapped to -25 (substitute x=0, $x_{ul} = 0$, $x_{uh} = 100$, $x_{rl} = 4\,\text{mA}$, and $x_{rh} = 20\,\text{mA}$ into the equation above).

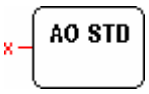
See Also:

Analog Output (Standard), Digital Input (Standard), Digital Input (Frequency Counter)

ANALOG OUTPUT (STANDARD)

Operator Menu Location: *Generic Hardware Operators* → *Analog Outputs*

Operator Bitmap:



Functional Description:

The *Standard Analog Output* generic hardware operator provides access to an analog output channel resource in the physical hardware. When the generic operator is linked to a specific hardware resource, it causes that hardware resource to generate a physical signal corresponding to its input pin value.

The operator can treat the input value as the raw signal value to reproduce, in the unit of measure defined by the hardware configuration (*e.g.*, 4-20mA, 0-10V, *etc*..) For example, if the input pin value is 4, the operator will generate a 4V signal when the hardware is configured for 0-5V. It will also produce a 4V signal if the hardware range is configured 0-10V. And it will generate 4mA signal if the hardware range is set to 4-20mA. Alternatively, the operator can be configured to automatically map the input pin value from a user-defined range to the physical signal range, as follows

$$y = x_{rl} + \frac{(x_{rh} - x_{rl})(x - x_{ul})}{x_{uh} - x_{ul}}.$$

Here, y is the output value generated by the physical hardware resource, x is the operator's input value, x_{rl} and x_{rh} represent the hardware configuration's raw signal range (*e.g.*, $x_{rl} = 4\,\text{mA}$, $x_{rh} = 20\,\text{mA}$), x_{ul} is the user-defined value corresponding to x_{rl}, and x_{uh} is the user-defined value corresponding to x_{rh}. For example, suppose the hardware is configured to produce a 4-20mA signal and is attached to an actuator with a 0-100% stroke range. Then, if the input value were 55%, the operator would generate an output of

$$y = 4\text{mA} + \frac{(20\text{mA} - 4\text{mA})(55\% - 0\%)}{100\% - 0\%} = 12.8\text{mA}.$$

User-Defined Properties:

Object Name. A string label that identifies the operator.

Scale. Either *Hardware Defined* or *User Defined*. In *Hardware Defined* mode, the operator generated output matches the input pin value in the unit of measure defined by the hardware configuration. In *User Defined* mode, the operator maps the input value within a user-defined scaling range linearly proportional to the physical signal range.

Lo Range Scaled Equivalent. The input signal value corresponding to the low end of the physical signal range that the output is to generate when *User Defined* mode is selected.

Hi Range Scaled Equivalent. The input signal value corresponding to the high end of the physical signal range that the output is to generate when *User Defined* mode is selected.

Units. Engineering units label used for readability

Comments:

- The x_{ul} value may be greater than the x_{uh} value.

- If the input signal range is outside of the user-defined range, the physical signal may also be outside of the hardware configuration range. For example, suppose the user-defined mappings are set to 0 and 100 and the hardware resource is configured as a 4-20mA output. If the input to the operator is 110, the operator will command the hardware to generate an output of 21.6mA (substitute x=110, $x_{rl} = 4\,\text{mA}$, $x_{rh} = 20\,\text{mA}$, $x_{ul} = 0$, and $x_{uh} = 100\,\text{mA}$ into the equation above). Note that the hardware output may not be able to reproduce the commanded output (depending on the hardware implementation, it may saturate at some value between 20mA and 21.6mA).

See Also:

Analog Output (Standard with Feedback), Analog Input (Standard)

ANALOG OUTPUT (STANDARD WITH FEEDBACK)

Operator Menu Location: *Generic Hardware Operators* → *Analog Outputs*

Operator Bitmap:

Functional Description:

The *Standard Analog Output with Feedback* generic hardware operator provides access to an analog output channel resource in the physical hardware. Feedback is provided by a dedicated analog input channel resource associated with the output resource.

When the generic operator is linked to a specific hardware resource, the operator commands that hardware resource to generate a physical signal corresponding to its input x_1 (provided that its enable digital input x_2 is HIGH; when x_2 is LOW the hardware output resource is turned off).

The operator can treat the input value x_1 as the raw signal value to reproduce, in the unit of measure defined by the hardware configuration (*e.g.*, 4-20mA, 0-10V, *etc*.) For example, if $x_1 = 4$, the operator will generate a 4V signal when the hardware is configured for 0-5V operation. It will also produce a 4V signal if the hardware range is configured 0-10V operation. And it will generate 4mA signal if the hardware range is set to 4-20mA mode.

Alternatively, the operator can be configured to automatically map the input value x_1 from a user-defined range to the configured physical signal range, as follows

$$AO = x_{rl} + \frac{(x_{rh} - x_{rl})(x_1 - x_{ul})}{x_{uh} - x_{ul}}.$$

Here, *AO* is the output signal value to be generated by the physical hardware resource, x_1 is the operator's command input value, x_{rl} and x_{rh} represent the hardware configuration's raw signal range (*e.g.*, $x_{rl} = 4\,\text{mA}$, $x_{rh} = 20\,\text{mA}$), x_{ul} is the user-defined value corresponding to x_{rl}, and x_{uh} is the user-defined value corresponding to x_{rh}. For example, suppose the hardware is configured for 4-20mA operation such that $x_{rl} = 4\,\text{mA}$, $x_{rh} = 20\,\text{mA}$, and the corresponding user-configured range is set to $x_{ul} = 0\%$ and $x_{uh} = 100\%$. Then, if the command input were $x_1 = 50\%$, the physical output will be *AO*=12mA.

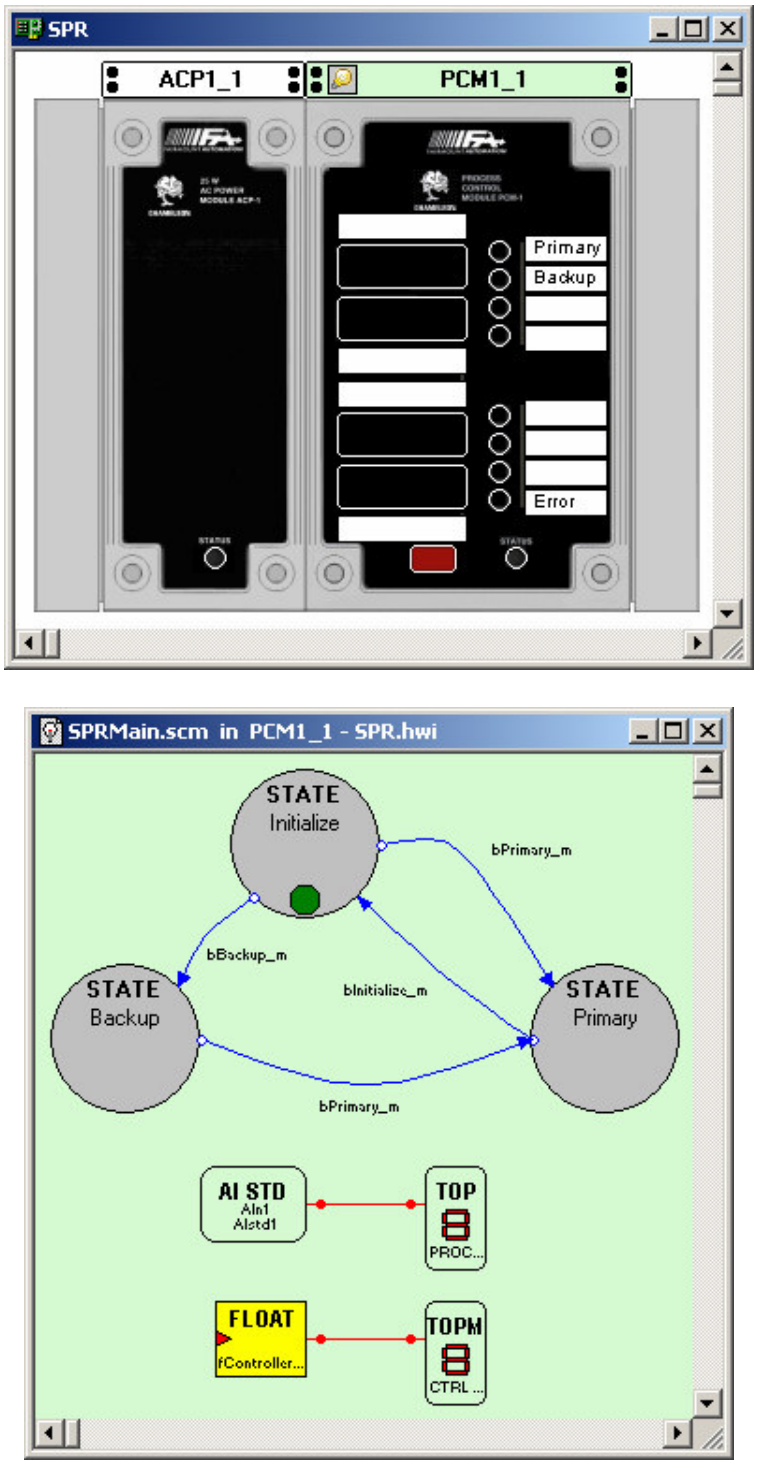
The operator output y_1 is a feedback signal—a measurement of the actual output value that is generated by the hardware. Output y_1 can be configured to simply provide the raw feedback signal value (unscaled), or it can automatically map the feedback signal to a user-defined range:

$$y_1 = \begin{cases} fb & \text{if mode is hardware defined} \\ fb_{rl} + \dfrac{(fb_{rh} - fb_{rl})(fb - fb_{ul})}{fb_{uh} - fb_{ul}} & \text{if mode is user defined} \end{cases}$$

Here, *fb* is the feedback signal in the unit of measure that the hardware is configured for, fb_{rl} and fb_{rh} represent the nominal range for the raw feedback signal, (*e.g.*, $fb_{rl} = 4\,\text{mA}$, $fb_{rh} = 20\,\text{mA}$), fb_{ul} is the user-defined value corresponding to fb_{rl}, and fb_{uh} is the user-defined value corresponding to fb_{rh}.

The purpose of the feedback signal is to ascertain that the hardware circuitry is correctly generating the command input. Deviation from the command input could be used to signal a system fault (*e.g.*, hardware failure, wiring problem, *etc*..) If the output resource is redundantly wired to an actuator (*i.e.*, another output resource is wired in parallel to the same actuator), the feedback signal represents a measurement of the output command to the actuator (regardless of which resource is driving that actuator).

Error output y_2 is HIGH when a feedback error occurs and LOW otherwise. A feedback error occurs when the output is turned on (*i.e.*, x_2=HIGH) and the feedback signal deviates from the commanded output signal for a sustained period of time. (The feedback signal is said to deviate from the command signal if the difference between the two exceeds a user-specified tolerance. The deviation time period is also a user-specified setting.) Once an error condition is flagged, the error will not be cleared until the command output matches the feedback signal for a user-specified period of time. (The feedback signal is said to match the command signal if the difference between the two is less than this tolerance setting.)

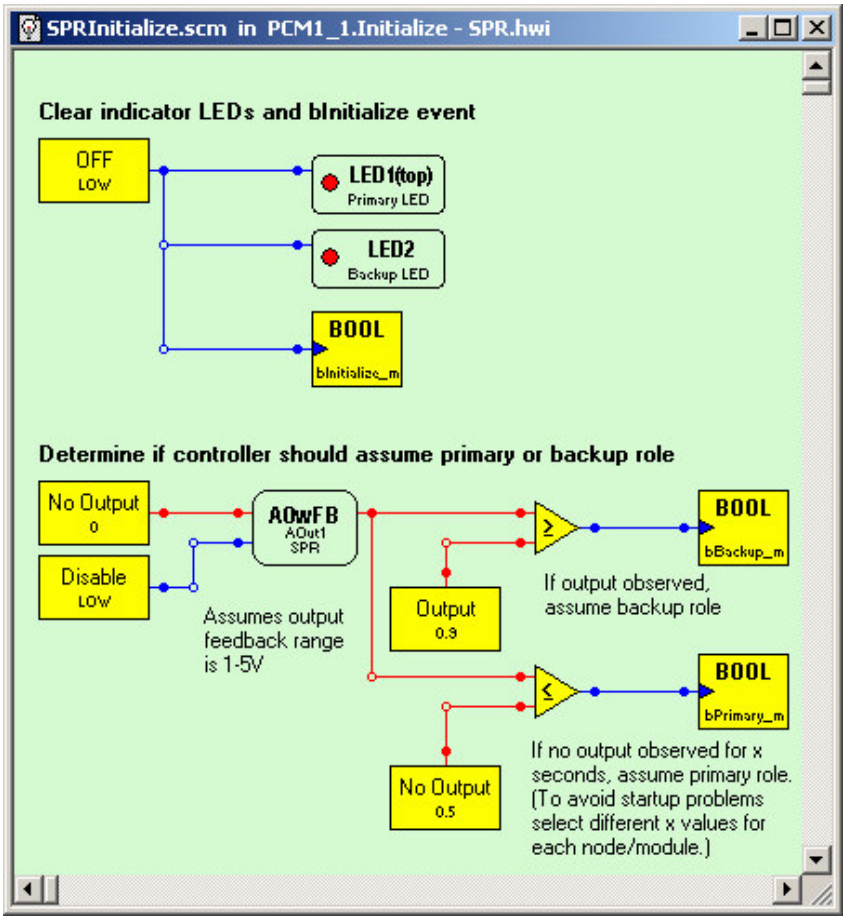


Hardware Interface File and Associated Schema Linked to PCM-1 Module

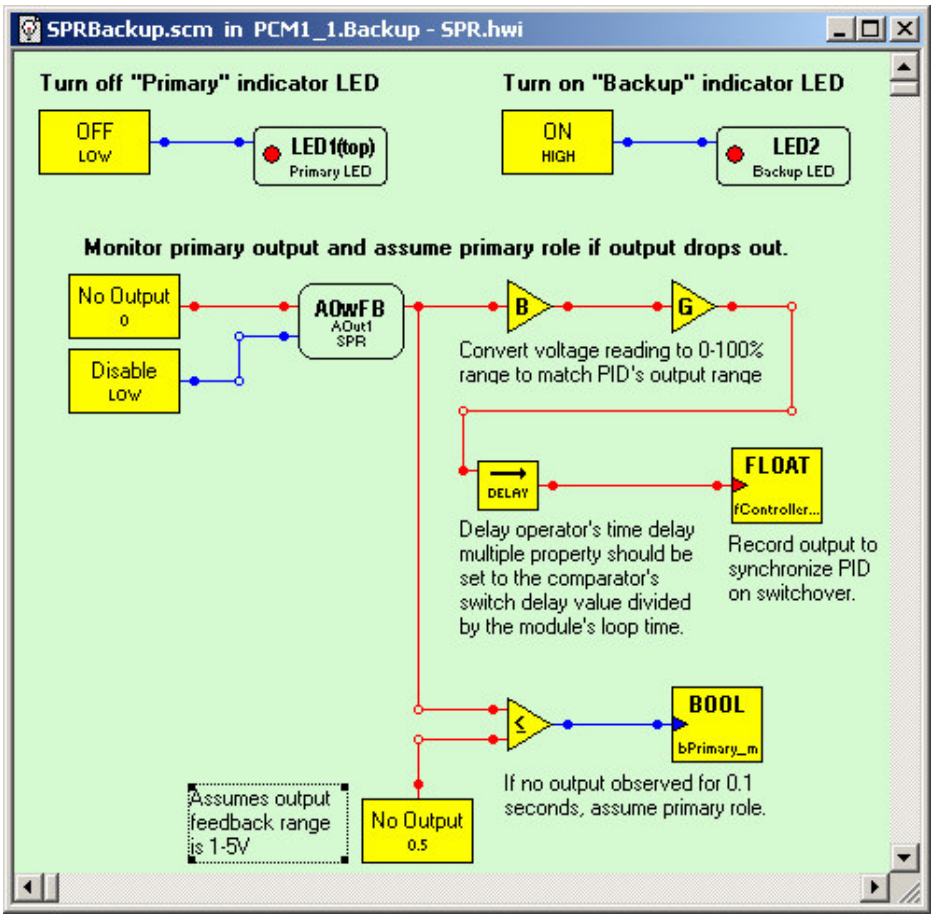
An example usage of this operator configured to serve as a redundant output is illustrated with the node configuration file and corresponding schema files shown in the figures below. The node configuration figure demonstrates a basic Fairmount Automation

Chameleon node consisting of a 25W AC Power Supply Module (ACP-1) and a Process Control Module (PCM-1). In this example two such identically configured nodes are assumed to each have a single output channel wired in parallel to the same actuator. Each node also has a single input channel wired in parallel to the same sensor. The two nodes are to work in redundant fashion (one serving as a backup to the other) to control a process loop using a PID scheme. If the primary node should fail, the backup node should assume control over the process loop. For fast loops, the switch-over time needs to be very short and there should be little disruption to the output signal.

The PCM-1 module of each node is to execute the schema shown in the figure, with a state-transition diagram consisting of three states: *Initialize*, *Backup*, and *Primary*. When a node powers up, it begins executing in the *Initialize* state—the sub-schema corresponding to this state is shown in figure (a). In the sub-schema, a generic *Analog Output with Feedback* operator linked to analog output channel 1 in the PCM-1 module has its output turned off ($x_2 =$ LOW). Its feedback signal is monitored to determine if the state of the other node's output. If the other output is on, the parent schema transitions to the *Backup* state; otherwise it transitions to the *Primary* state.

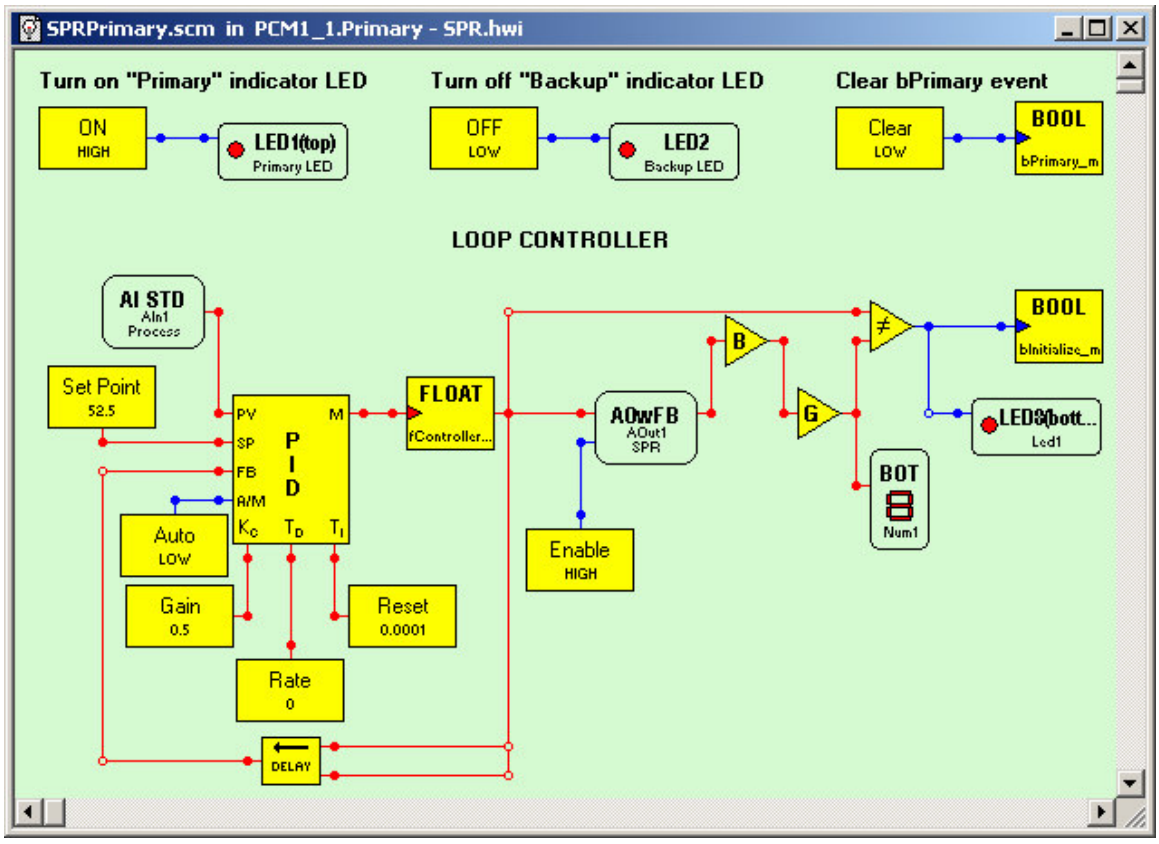


(a) Initialize State Sub-Schema



(b) Backup State Sub-Schema

The *Backup* state sub-schema, shown in figure (b), contains another generic *Analog Output with Feedback* operator that has been linked to the same specific hardware resource in the PCM-1 module (analog output channel 1). In this state, the output remains off ($x_2 = \text{LOW}$) since the other node is driving the actuator. The feedback signal is tracked (stored in the *Float Variable* operator labeled `fControllerOutput_m`) in order to provide bumpless transfer if/when the node assumes control of the process loop. If the other node's output drops below the normal operating range (1-5V) the *Bool Variable* operator labeled `bPrimary_m` will be set to HIGH and the parent schema will transition from the *Backup* state to the *Primary* state and assume control.



(c) Primary State Sub-Schema

The *Primary* state sub-schema, shown in figure (c), contains yet another generic *Analog Output with Feedback* operator linked to PCM-1 output channel 1. In this state, the output is turned on and fed by the *PID Controller with External Feedback* block. Note that when the *Primary* state first executes, the PID feedback input is initialized with the value in the *Float Variable* operator labeled `fControllerOutput_m`—the other node's output value that had been tracked in the *Backup* state. This ensures a bumpless output transition when the node assumes control over the process. In the *Primary* state, the PID command output is compared to the feedback signal and if a sustained deviation is detected, the node will transition into the *Initialize* state.

User-Defined Properties:

Object Name. A string label that identifies the operator

AO Scale. Either *Hardware Defined* or *User Defined*. In *Hardware Defined* mode, operator generates output to match input x_1 value in the unit of measure defined by the hardware configuration. In *User Defined* mode, maps the input value within user-defined scaling range (x_{ul}, x_{uh}) to the physical signal range (x_{rl}, x_{rh}).

AO Lo-Range Scaled Equivalent. The input signal value corresponding to the low end of the physical signal range that the output is to generate when *User Defined* mode is selected

AO Hi-Range Scaled Equivalent. The input signal value corresponding to the high end of the physical signal range that the output is to generate when *User Defined* mode is selected

Units. Engineering units label used for readability.

AI Scale. Scaling mode for analog input feedback—either *Hardware Defined* or *User Defined*. In *Hardware Defined* mode, provides the raw feedback signal value in the unit of measure defined by the hardware configuration. In *User Defined* mode, maps raw feedback signal to user-defined scaling range.

AI Lo-Range Scaled Equivalent. The operator representation of the feedback signal at the low end of the hardware range when *User Defined* mode is selected

AI Hi-Range Scaled Equivalent. The operator representation of the feedback signal at the high end of the hardware range when *User Defined* mode is selected

Max Allowable FB Deviation. Maximum difference between commanded output value and feedback signal in absolute units. If difference is exceeded for sustained period, fault condition is reported on output y_2.

Set Error Hysteresis Time. Amount of time in seconds that output command signal must deviate from feedback signal before error is reported on output y_2.

Clear Error Hysteresis Time. Amount of time in seconds that output command signal must agree with feedback signal before error is cleared on output y_2.

Display Switch Input. Determines if input pin x_2 is displayed on the screen. The pin must be displayed if a virtual signal wire is connected to it.

Display Feedback Output. Determines if output pin y_1 is displayed on the screen. The pin must be displayed if a virtual signal wire is connected to it.

Display Error Output. Determines if output pin y_2 is displayed on the screen. The pin must be displayed if a virtual signal wire is connected to it.

Comments:

- The x_{ul} value may be greater than the x_{uh} value.

- If input x_1 is outside of the user-defined range (x_{ul}, x_{uh}), the physical output signal may also be outside of the hardware configuration range (x_{rl}, x_{rh}). For example, suppose the user-defined AO mappings are set to 0 and 100 and the hardware resource is configured as a 4-20mA output. If $x_1 = 110$, the operator will command the hardware to generate an output of 21.6mA (substitute $x_1 = 110$, $x_{rl} = 4\,\text{mA}$, $x_{rh} = 20\,\text{mA}$, $x_{ul} = 0$, and $x_{uh} = 100\,\text{mA}$ into the equation above). Note that the hardware output may not be able to reproduce the commanded output (depending on the hardware implementation, it may saturate at some value between 20mA and 21.6mA).

- The fb_{ul} value may be greater than the fb_{uh} value.

- If the feedback signal is outside of the nominal hardware range, the operator representation may be outside of the user-defined range. For example, suppose the user-defined mappings are set to 0 and 100 and the hardware resource is configured for 4-20mA signals. A reading of 0mA, will be mapped to -25 (substitute *fb*=0, $fb_{ul} = 0$, $fb_{uh} = 100$, $fb_{rl} = 4\,\text{mA}$, and $fb_{rh} = 20\,\text{mA}$ into the equation above.

See Also:
Analog Output (Standard), Analog Input (Standard)

A/D CONVERSION

Operator Menu Location: *Data Conversion*

Operator Bitmap:

Functional Description:

Design Pad G3 supports two signal types—analog signals (floating point values) drawn in red, and digital signals (boolean values, *i.e.*, true/false or high/low) drawn in blue. These signal types cannot be directly mixed—analog signals may not be directly connected to digital ones. But, analog signals may be converted into digital ones (and vice-versa). The *A/D Conversion* operator converts a floating-point analog value into a HIGH/LOW boolean value. The boolean output *y* of the A/D Conversion operator is

$$y = \begin{cases} \text{LOW} & \text{if } x < |Z| \\ \text{HIGH} & \text{otherwise} \end{cases}$$

where x is the analog input value and Z is the conversion threshold.

User-Defined Properties:

Object Name. A string label that identifies the operator

Z. The maximum magnitude of the analog input equivalent to the boolean LOW

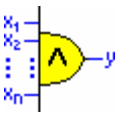
Comments: None.

See Also:
D/A Conversion, Decimal To Binary Conversion, Binary To Decimal Conversion

AND-GATE

Operator Menu Location: *Logic Functions*

Operator Bitmap:



Functional Description:

The output of the *AND Gate* operator is the logical *AND* of its inputs,

$$y = x_1 \wedge x_2 \wedge \Lambda \wedge x_i,$$

where y is the output, $x_i (i = 1,...,n)$ are the inputs, and n is the number of inputs. The operator output state is HIGH if all inputs are HIGH. If any input is LOW, the output is LOW. Below is the truth table for a 3-input AND-gate:

x_1	x_2	x_3	y
LOW	LOW	LOW	LOW
LOW	LOW	HIGH	LOW
LOW	HIGH	LOW	LOW
LOW	HIGH	HIGH	LOW
HIGH	LOW	LOW	LOW
HIGH	LOW	HIGH	LOW
HIGH	HIGH	LOW	LOW
HIGH	HIGH	HIGH	HIGH

Design Pad G3 assumes that $x_i \circ HIGH$, if input pin i is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Inputs. The number of input pins n, where $2 \le n \le 6$

Comments: None.

See Also:

NAND Gate, OR Gate, NOR Gate, NOT Gate, XOR Gate, XNOR Gate

AUTO/MANUAL (A/M) BUTTON

Operator Menu Location: *Generic Hardware Operators* → *Auto/Manual*

Operator Bitmap:

Functional Description:

The *Auto/Manual Button* operator provides a smooth transition between *automatic* and *manual* modes of operation. When in automatic mode, the operator output is equal to its primary input, *i.e.*, *y*=*x*. When in manual mode, the operator output value is manually adjusted using with front-panel controls (*e.g.*, keypad buttons).

The operator's boolean output *b* indicates the mode: it is HIGH when the operator is in *manual* mode; it is LOW when the operator is in *automatic* mode.

When the operator transitions from automatic mode to manual mode, its output *y* remains at the transition value until manually modified (e.g., from front panel buttons).

When the operator switches from manual mode to automatic mode, the transition may be abrupt or smooth (bumpless). If the bumpless transfer property is not selected, the output will switch instantly from the manual output to the automatic output. When the bumpless transfer property is checked, the transition from manual to automatic is guaranteed to be smooth. The nature of the transition (*i.e.*, the transfer profile) can be either exponential or linear.

Let S_{am} be the difference between the manual output and the automatic output at the instant the operator switches from manual to automatic, $t = t_{am}$. Under an exponential transfer profile, the operator output will be (approximately)

$$y(t) = x(t) + S_{am} e^{-60(t-t_{am})/r} \quad \forall t \geq t_{am}$$

where r is a time constant expressed in minutes. Under a linear transfer profile, the operator output will be (approximately)

$$y(t) = \begin{cases} x(t) + \max[0, S_{am} - r(t-t_{am})] & \text{if} \quad S_{am} > 0 \\ \\ x(t) + \min[0, S_{am} - r(t-t_{am})] & \text{if} \quad S_{am} < 0 \end{cases}$$

where *r* is a linear decay rate expressed in (input) units/minute.

Generally, a person will use a keypad button to switch a control station from operating in automatic mode to operating in manual mode (and vice versa). You would also typically rely on a person to make manual output adjustments. However, under certain conditions you may wish to automatically switch the A/M operator from one mode to another—and automatically adjust the "manual" output—without user involvement. The *A/M Button* operator has two secondary inputs that allow you to do just that. You can use digital input x_{so} to automatically set the auto/manual operating mode. And you can use analog input x_{mo} to automatically set the "manual" output. These two inputs are edge-triggered, meaning that they override the keypad buttons and affect the operator output only when their value changes. While these inputs remain fixed, they do not affect the outputs.

When the operator is in manual mode and input x_{so} switches from HIGH (manual) to LOW (auto), the operator will switch into automatic mode and its output $y(t)$ will (over time) match its input $x(t)$. (If the bumpless transfer feature is enabled, the output will vary according to the equations above.) If the operator is in automatic mode and input x_{so} switches from HIGH (manual) to LOW (auto), then it will remain in automatic mode.

When the operator is in automatic mode and input x_{so} switches from LOW (auto) to HIGH (manual) at time t_o, the operator will switch into manual mode and its output $y(t)$ will move toward the value of input x_{mo} at the time of the switch. The transfer of the output–from $y = y(t_o)$ to $y = x_{mo}(t_o)$—occurs in increments and is rate-limited by a *Key Repeat Time* property, Δ_{KRAM}. The output will vary as if a user pressed a A/M keypad button to switch to manual and then pressed—and held down—an arrow keypad button until the output reached a desired value, $x_{mo}(t_o)$. Mathematically, we can express this as:

$$y(t) = \begin{cases} x_{mo}(t_o) & \text{if} \quad t > t_o + \Delta_{KRAM} \dfrac{x_{mo}(t_o) - y(t_o)}{M} \\ y(t_o) + M \dfrac{t - t_o}{\Delta_{KRAM}} & \text{if} \quad t_o \le t \le t_o + \Delta_{KRAM} \dfrac{x_{mo}(t_o) - y(t_o)}{M} \end{cases},$$

Whenever the manual-override input x_{mo} changes value, the output will move toward that value according to the equation above. (Of course, this occurs only while the operator is in manual mode; otherwise, the x_{mo} input is ignored). In order for the manual input x_{mo} to affect the output, its value must change. Moreover, the magnitude of the change must exceed the *Manual Input Activation Threshold* A_T over a period of time called the *Manual Input Activation Time T*. In other words,

$$| x_{mo}(t) - x_{mo}(t_o) | \geq A_T \forall t \in (t_o, T]$$

must be satisfied in for the manual output to begin moving toward $x_{mo}(t_o)$.

Do keypad buttons on the hardware faceplate have precedence over the inputs x_{so} and x_{mo}? The answer is that the operator will follow its most recent command. If it is commanded by its inputs to automatically adjust its manual output value, it will do so. If in the process of automatically adjusting the manual output value a person presses one of the arrow keys, the *A/M Button* operator will follow the key commands. It will not resume its automatic adjustments unless input x_{mo} changes value—remember that this input is edge-triggered!

In *Design Pad G3* the *A/M Button* operator doubles as a special networking operator designed to synchronize the operation of multiple A/M stations. You link the *A/M Button* operator to a communications channel to broadcast its outputs over a controller network and to receive information from one or more *Remote A/M* operators from other stations on the network. Together, the network-enabled *A/M Button* operator and *Remote A/M* operators offer synchronized auto/manual functionality between multiple stations. For example, consider the case where one station contains a network-enabled *A/M Button* operator and two other stations on the same controller network each contain a corresponding *Remote A/M* operator. If you switch any one of the three stations from automatic mode to manual mode, the other two stations will also switch to manual operation. If you then adjust the manual output from any one of the three stations, the other two will match that manual output. If you switch any one of the stations back into automatic mode, the other two stations will also switch into automatic mode. When the stations operate in automatic mode, the output signal of the remote A/M operators will follow the output of the A/M operator.

In order to associate an *A/M Button* operator in one schema to a *Remote A/M* operator in another, you must match their signal name property. If you want to associate multiple remote A/M operators with an A/M operator, then you set the signal name property of all operators to the same case-sensitive character string.

User-Defined Properties:

Signal Name. A string label that identifies the operator. When networking is enabled, this character string is used to associate (synchronize) an A/M operator in one schema with remote A/M operator in other schemas.

Initial State. The operator mode (auto or manual) on startup (at time *t*=0).

Initial Value. The analog output value on startup (at time *t*=0). Applicable only if the initial state is set to manual.

Minimum. The minimum analog output value. Applies to both auto and manual modes.

Maximum. The maximum analog output value. Applies to both auto and manual modes.

Increment Magnitude. The magnitude of manual output increments when in manual mode. The manual output will be incremented or decremented by this parameter when (i) a person presses an increment/decrement keypad button on the hardware front panel (ii) input x_{mo} changes value (see *Manual Input Activation Threshold* property and *Manual Input Activation Hysteresis* property).

Bumpless Transfer. When the operator switches from manual mode to automatic mode, the output signal may differ from input *x*. If this property is not checked, there may be a discontinuity in the output. When bumpless transfer is checked, the transition from manual to automatic is guaranteed to be smooth.

Transfer Profile. When the bumpless transfer property is set, the output will transition smoothly from manual mode to automatic mode. This property characterizes the nature of the transition: *exponential* or *linear*. When the exponential profile is selected, the difference between the manual output and automatic output will decay exponentially. When the linear profile is selected, the difference will decay linearly.

Transfer Rate. The rate at which the difference between manual output and automatic output will decay when the bumpless transfer property is set. When the exponential profile is selected, this parameter defines the exponential decay rate expressed in minutes. When the linear profile is selected, this parameter defines the linear decay rate in input units/minute.

Use Alphanumerics. When this property is selected, the output value will be presented on the alphanumeric displays while the operator is in manual mode.

Number of Significant Digits to Display. The number of significant digits to use when displaying the manual output on the alphanumeric displays.

Lock in Manual State. When this property is selected, the operator will only function in manual mode. A person will not be able to switch it into automatic operation.

Display Manual Input. This property determines if input pin x_{mo} is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when

the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Manual Input Activation Threshold. When the A/M operator is in manual mode, the output can be adjusted automatically using input x_{mo}. In order for automatic adjustments to begin, the manual input must change value. The magnitude of the change must exceed this parameter. (And it must exceed this value for a period of time defined by the *Manual Input Activation Time* property below.)

Manual Input Activation Time. When the A/M operator is in manual mode, the output can be adjusted automatically using input x_{mo}. In order for automatic adjustments to begin, the manual input must change value. The magnitude of the change must exceed a threshold value over a period of time (in milliseconds) defined by this parameter.

Key Repeat Time.

Comments: None.

See Also: Remote A/M Button

BARGRAPH DISPLAY

Operator Menu Location: *Generic Hardware Operators → Displays*

Operator Bitmap:

Functional Description:

The *Bargraph Display* generic hardware operator provides access to a bargraph display resource in the physical hardware. When the generic operator is linked to a specific hardware resource, it will command that resource to indicate signal values on the display.

Bargraph hardware resources are a collection of LED elements used to visually represent a signal magnitude. The number of LED elements determine the resolution of the display. Typically, the number of elements illuminated is proportional to the signal value. Alternatively, bargraphs can be programmed to illuminate a variable-height band of LEDs above, below, or centered about the signal value of interest.

The number of LEDs illuminated on the bargraph hardware resource, N_I, is proportional to input signal x_3,

$$N_I = \begin{cases} 0 & if \quad x_3 < x_{\min} \\ N_T \dfrac{x_3 - x_{\min}}{x_{\max} - x_{\min}} & if \quad x_{\min} \le x_3 \le x_{\max} \\ N_T & if \quad x_3 > x_{\max} \end{cases}$$

where N_T is the total number of LED elements in the physical bargraph resource, $x_{\min}$ is the minimum input signal value and $x_{\max}$ is the maximum input signal value. (Parameters $x_{\min}$ and $x_{\max}$ are properties of this operator.) For example, if $N_T = 40$, $x_{\min} = 0\%$, $x_{\max} = 100\%$, and $x_3(t) = 50\%$, 20 LED elements will be illuminated (half of the total elements in the display).

The example above demonstrates the typical configuration of the bargraph display operator. In certain applications however, the user may wish to activate a band of LEDs not necessarily anchored at the bottom reference point. The *Bargraph Display* operator

allows the signal value (x_3) to be displayed relative to a reference point input x_1. In fact, signal x_3 may be displayed above, below, or centered about the reference point x_1. (The alignment—above, center, or below—is a property of this operator.)

If the alignment property is set to *Above*, the number of LEDs that are illuminated is

$$N_I = \begin{cases} 0 & \text{if} \quad x_1 > x_{\max} \quad \text{OR} \quad x_3 < x_{\min} \\ N_T - N_T \dfrac{x_1 - x_{\min}}{x_{\max} - x_{\min}} & \text{if} \quad \begin{array}{l} x_3 > x_{\max} + x_{\min} - x_1 \quad \text{AND} \\ x_{\min} \le x_1 \le x_{\max} \end{array} \\ N_T \dfrac{x_3 - x_{\min}}{x_{\max} - x_{\min}} & \text{otherwise} \end{cases}$$

The equation above indicates the following:

- No LEDs are illuminated if the reference point input x_1 is above the maximum signal value.
- No LEDs are activated if the signal value x_3 is less than minimum signal value.
- The maximum number of LEDs that can be illuminated is

$$N_{\max} = N_T - N_T \frac{x_1 - x_{\min}}{x_{\max} - x_{\min}}$$

  For example, if $N_T = 40$, $x_{\min} = 0\%$, $x_{\max} = 100\%$, and $x_1(t) = 50\%$, the maximum number of LEDs that can be activated is 20.

- In general, the number of LEDs illuminated is

$$N_I = N_T \frac{x_3 - x_{\min}}{x_{\max} - x_{\min}}$$

  When the result of this formula is $N_I > N_{\max}$, $N_{\max}$ LED elements are illuminated

Similarly, when the alignment property is set to *Below*, the number of LEDs that are illuminated is

$$N_I = \begin{cases} 0 & \text{if} \quad x_1 < x_{\min} \quad \text{OR} \quad x_3 < x_{\min} \\ N_T - N_T \dfrac{x_1 - x_{\min}}{x_{\max} - x_{\min}} & \text{if} \quad \begin{array}{l} x_3 > x_{\max} + x_{\min} - x_1 \quad \text{AND} \\ x_{\min} \le x_1 \le x_{\max} \end{array} \\ N_T \dfrac{x_3 - x_{\min}}{x_{\max} - x_{\min}} & \text{otherwise} \end{cases}$$

When the alignment property is set to *Center*, the signal value is centered with respect to the reference point. The maximum number of LED elements that can be illuminated is

$$N_{\max} = N_T - N_T \frac{\left| x_1 - \dfrac{x_{\max} - x_{\min}}{2} \right| - x_{\min}}{x_{\max} - x_{\min}}$$

The number of LED elements illuminated is

$$N_I = \begin{cases} 0 & \text{if} \quad x_3 < x_{\min} \\ N_T \dfrac{x_3 - x_{\min}}{x_{\max} - x_{\min}} & \text{if} \quad N_T \dfrac{x_3 - x_{\min}}{x_{\max} - x_{\min}} < N_{\max} \\ N_{\max} & \text{otherwise} \end{cases}$$

Digital input x_2 controls the presentation of the signal on the display. If $x_2 = \text{HIGH}$, the bargraph will flash; otherwise, if $x_2 = \text{LOW}$, the bargraph display will be steady. Flashing a bargraph display may be useful to indicate particular operating states. For instance, it could be used to indicate that a process is in *Manual* mode, or that some alarm condition has arisen.

Analog inputs x_4 and x_5 represent bargraph alarm limits.

When multiple generic *Bargraph Display* operators are linked to the same specific hardware resource (*e.g.*, the same physical display), the display will cycle between each operator input value set. The digital output *y* of the operator is HIGH while the physical hardware is currently displaying its input value x_3 (*e.g.*, while the operator is active). Digital output *y* is LOW while the operator is inactive. When a resource is shared between multiple operators, it is a good idea to indicate what value is currently being displayed. This can be done by connecting output *y* to an *LED Display* operator. For

example, the same physical display can be used to indicate both a process variable and a process setpoint. In the schema diagram below, both process and setpoint values are displayed on the Chameleon PCM-1 top numeric display. The top LED is lit while the process variable is displayed and the second LED is lit when the process setpoint is displayed.

User-Defined Properties:

Object Name. A string label that identifies the operator

Alignment. This property determines how input signal x_3 is displayed relative to reference point x_1: *Above*, *Centered*, or *Below*.

Minimum. The minimum input signal value, $x_{\min}$. It corresponds to having no LED elements illuminated on the bargraph display.

Maximum. The maximum input signal value, $x_{\max}$. It corresponds to having all LED elements illuminated on the bargraph display.

Brightness. A brightness setting for the physical display in the range [0-15], with 15 indicating maximum brightness.

Active Period. The period of time (in milliseconds) that the physical display will show input x_3 of this operator if the resource is shared. This parameter has no effect if the resource is not shared.

Display Reference Input. This property determines if input pin x_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Blinking Input. This property determines if input pin x_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Output. This property determines if output pin *y* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Low Alarm Input. This property determines if input pin x_4 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display High Alarm Input. This property determines if input pin x_5 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments:

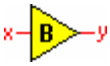
- The minimum value $x_{\min}$ must be greater than the maximum value $x_{\max}$.
- If input x_1 is not connected, *Design Pad G3* assumes that $x_1 = LOW$.
- *Design Pad G3* will issue an error on processing if an input pin x_3 is not connected.

See Also:
Numeric Display, Alpha-Numeric Display, LED Display

BIAS

Operator Menu Location: *Signal Conditioning*

Operator Bitmap:



Functional Description:

The *Bias* operator adds a constant value to its input. Its output is

$$y = x+B$$

where y is the output, x is the input, and B is the biasing term.

Design Pad G3 will issue an error on processing if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Bias. The biasing term B

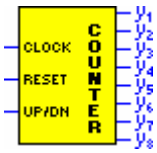
Comments: None.

See Also: Gain, Unit Conversion, Addition, Subtraction

BINARY COUNTER

Operator Menu Location: *Logic Functions*

Operator Bitmap:



Functional Description:

The *Binary Counter* operator is a digital counter that adjusts its output value with each clock pulse. It has three digital inputs, *CLK*, *RST*, and *U/D*; and eight digital outputs $y_i (i = 1,2,...,8)$. The digital outputs are the binary representation of the counter state, *S*, an integer in the range $[S_{\min}, S_{\max}]$. Parameters $S_{\min}$ and $S_{\max}$ are user-defined properties of the operator that must satisfy $0 \le S_{\min} \le S_{\max} \le 255$.

The counter state, *S*, is updated with the rising edge of the *CLK* input. If *Up/Down* input *U/D* is HIGH the output count is incremented by one. If *U/D*=LOW, then the output count is decremented by one. Mathematically, the output state can be expressed as follows:

$$S(t_{clk}) = \begin{cases} S(t_{clk} - \Delta t) + 1 & \text{if} \quad U/D = \text{HIGH} \ \text{ AND } \ S \neq S_{\max} \\ S_{\min} & \text{if} \quad U/D = \text{HIGH} \ \text{ AND } \ S = S_{\max} \\ S(t_{clk} - \Delta t) - 1 & \text{if} \quad U/D = LOW \ \text{ AND } \ S \neq S_{\min} \\ S_{\max} & \text{if} \quad U/D = LOW \ \text{ AND } \ S = S_{\min} \end{cases}$$

where t_{clk} is the time instant that *CLK* changes from LOW to HIGH.

In addition, the counter state is reset to its minimum value, *i.e.*, $S = S_{\min}$ whenever the *RST* input is HIGH.

User-Defined Properties:

Object Name. A string label that identifies the operator

Min. Value (0-255). The minimum counter state, $S_{\min}$

Max. Value (0-255). The maximum counter state, $S_{\max}$

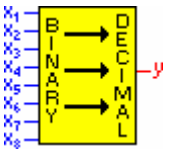
Comments: None.

See Also: Binary to Decimal Conversion

BINARY TO DECIMAL CONVERSION

Operator Menu Location: *Data Conversion*

Operator Bitmap:



Functional Description:

The *Binary to Decimal Conversion* block accepts eight digital inputs x_i (i=1,2,...,8), and computes its base-10 representation y. Two of the operator properties, $y_{\min}$ and $y_{\max}$, define the range of the output signal. They are used to map the base-10 representation of the eight input signals into an analog value between $y_{\min}$ and $y_{\max}$. The mapping is

$$y = \frac{255 - X_{10}}{x_{\max} - m_{\min}} + x_{\min}$$

where X_{10} is the base-10 representation of the eight digital input signals, x_i (i=1,2,...,8).

User-Defined Properties:

Object Name. A string label that identifies the operator

Minimum (0) Value. The input value corresponding to a base-10 output value of 0 ($x_{\min}$).

Maximum (255) Value. The input value corresponding to a base-10 output value of 255 ($x_{\max}$).

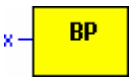
Comments: None.

See Also:
Binary to Decimal Conversion, Multiplexer, Demultiplexer, A/D Conversion, D/A Conversion

BREAKPOINT

Operator Menu Location: *Diagnostic Operators*

Operator Bitmap:



Functional Description:

The *Breakpoint* operator pauses a *Design Pad G3* simulation upon a programmatic trigger event.

Design Pad G3 provides an integrated simulation environment wherein a node configuration—including the hardware definition and associated schema files—may be simulated in near real-time. The toolbar speed-buttons shown below control the simulation execution.

A simulation may be manually started (green traffic light), manually paused (yellow traffic light), and manually stopped (red traffic light). After a simulation run is paused, it may be resumed at full-speed (green traffic light), or it may be commanded to execute a single compute-loop or scan (single-step button).

The *Breakpoint* operator has a single digital input that is used to trigger a programmatic simulation pause. This enable input may be configured to trigger on the detection of an edge (rising or falling) or on a logic state (LOW or HIGH).

Pausing a simulation programmatically (using the *Breakpoint* operator) may be very useful to debug a difficult sequencing problem for instance. Once paused, the single-step button can then be used to execute one compute-loop or scan at a time. As always, all operator output values are refreshed on the screen after each compute-loop.
The rightmost speed-button on the toolbar shown above (the hand) is used to enable or disable all *Breakpoint* operators. When all disabled (hand depressed) a *Breakpoint* will not pause a simulation even if triggered. Disabling breakpoint operators may be preferable to removing them from the schema altogether (or disconnecting their input pins) when they are temporarily unneeded.

A *Breakpoint* operator is only useful within the *Design Pad G3* environment. It does nothing in the target hardware—in fact it is automatically removed from the node configuration file that is exported to the target hardware.

User-Defined Properties:

Object Name. A string label that identifies the operator

Enable On. The input condition that triggers the breakpoint (simulation pausing action). Maybe be: *Rising Edge* (*i.e.*, input switches from LOW to HIGH), *Falling Edge* (*i.e.*, input switches from HIGH to LOW), *Active* LOW or *Active* HIGH.

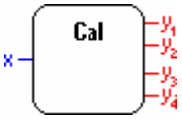
Comments:
None

See Also:
None

CALENDAR

Operator Menu Location: *Generic Hardware Operators* → *Time*

Operator Bitmap:



Functional Description:

The *Calendar* generic hardware operator provides access to a real-time clock resource in the physical hardware. When the generic operator is linked to a specific hardware resource, the operator reports the current date.

Output y_1 is the current year. Output y_2 is the current month (range 1-12). Output y_3 is the current day of the month (range 1-31). And output y_4 is the current day of the week, where 1 = Sunday, 2 = Monday, ..., 7 = Saturday.

The operator has a track & hold input which freezes its outputs while HIGH; while the input is LOW, the outputs track the real-time clock. The hold feature is useful to maintain the date that an event occurred.

User-Defined Properties:

Object Name. A string label that identifies the operator

Display Track & Hold Input. This property determines if the track & hold input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

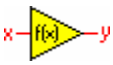
Comments: None.

See Also: Time-of-Day Clock, Set Clock, Alarm Clock, Stop-Watch

CHARACTERIZER

Operator Menu Location: *Signal Conditioning*

Operator Bitmap:



Functional Description:

The *characterizer* operator is a piecewise-linear interpolation mapping. Its output y is defined by

$$y = y_i + (y_{i+1} - y_i)\frac{x - x_i}{x_{i+1} - x_i}, \qquad \text{if } x_i \le x \le x_{i+1}, \qquad i=0,1,...,N$$

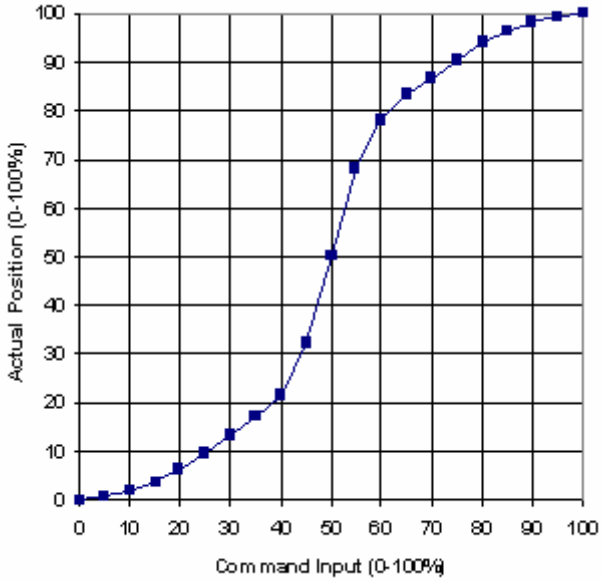
where x is the input, N is the number of points in the mapping (user-defined), and $\{(x_i, y_i) | x_i < x_{i+1}\}$ is an N-point user-defined data set to be interpolated.

Design Pad G3 will issue an error on processing if the input pin is not connected.

The *Characterizer* operator is ideally suited for situations where an accurate mathematical model of equipment operation is not available, but measurement data is. For instance, consider a process loop with a proportional valve actuator with a marked non-linear response throughout its range of operation. Assume that experiments characterizing its performance yield the following test data:

Command Input	Actual Position
0.0	0.0
5.0	0.9
10.0	1.9
15.0	3.8
20.0	6.2
25.0	9.7
30.0	13.3
35.0	17.0
40.0	21.6
45.0	32.3
50.0	50.2
55.0	68.1
60.0	77.9
65.0	83.1

70.0	86.7
75.0	90.5
80.0	94.0
85.0	96.4
90.0	98.3
95.0	99.2
100.0	100.0



In the table, the values in the left column represent the position the valve was commanded to reach (0-100% its range of operation). The data in the right column is the measured steady-state valve position in response to the corresponding command input. A pronounced non-linear valve response (such as the one shown in the preceding graph) may adversely affect overall system performance. PID tuning constants that yield good performance when the valve is operating in its linear range may yield inadequate performance when the valve is operating in its saturation region. You can address this problem by adding a *Characterizer* operator between the *PID* block and the *Analog Output* block. You could set up the *Characterizer* operator to invert the valve operating characteristics, thereby linearizing the process loop. The required *Characterizer* data set (the inverse of the valve performance data) is reproduced here. With this arrangement, the characterizer and valve positioner combination would respond to PID command signals linearly. For example, a PID output of 77.9% will be translated (by the characterizer) into a command input (to the valve) of 60.0%. When this 60.0% command input is applied to the valve, the resulting valve position will be 77.9%.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Points. The number of points in the characterization mapping

X Increment. The default increment for x-coordinates in the mapping (applied by pressing the "Generate X and Y Coordinates using X and Y Increments" button)

Y Increment. The default increment for y-coordinates in the mapping (applied by pressing the "Generate X and Y Coordinates using X and Y Increments" button)

X and Y Coordinates. Data set to interpolate

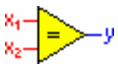
Comments:
The data abscissas must be monotonically increasing:

$$x_i \leq x_{i+1} \forall i = (1,2,...,N).$$

COMPARATOR: =

Operator Menu Location: *Signal Comparators*

Operator Bitmap:



Functional Description:

The *Equality Comparator* operator compares two analog input signals. Its digital output is set HIGH if the signals are equal (*i.e.*, within a user-defined dead-band); and it is set LOW if they are not. The output state will change only if the equality/inequality condition is maintained for a user-specified length of time—the switching dead-time. That is, the output is defined by

$$y = \begin{cases} \text{HIGH} & \text{if} \quad \left|x_1(\bar{t}) - x_2(\bar{t})\right| \le B \quad \forall \bar{t} \in [t, t-T] \\ \text{LOW} & \text{if} \quad \left|x_1(\bar{t}) - x_2(\bar{t})\right| > B \quad \forall \bar{t} \in [t, t-T] \\ y(t-\Delta t) & \text{otherwise} \end{cases}$$

where y is the digital output, x_1 and x_2 are the analog inputs, B is the equality dead-band, T is the switching dead-time, Δt is the loop sampling time, and where $|\cdot|$ denotes the absolute value operator.

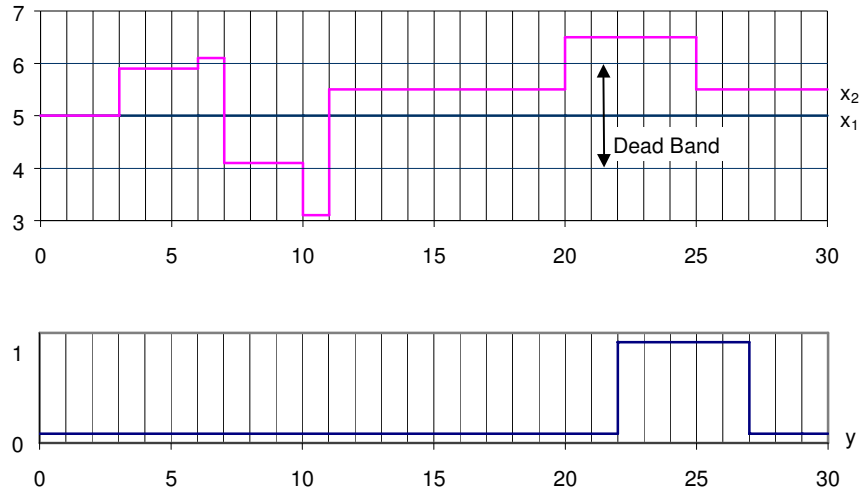
For example, suppose that the initial output is $y(0)=0$, input signal x_1 is fixed $(x_1 \equiv 5.0)$, the dead-band is set to $B=1.0$, the switching dead-time is set to $T=2$ seconds, and signal x_2 has the following profile:

$$x_2(t) = \begin{cases} 5.0 & 0 \le t < 3 \\ 5.9 & 3 \le t < 6 \\ 6.1 & 6 \le t < 7 \\ 4.1 & 7 \le t < 10 \\ 3.1 & 10 \le t < 11 \\ 5.5 & 11 \le t < 20 \\ 6.5 & 20 \le t < 25 \\ 5.5 & t \ge 25 \end{cases}$$

Under these conditions, the output of the *Equality Comparator* will be

$$y(t) = \begin{cases} \text{LOW} & 0 \le t < 2 \\ \text{HIGH} & 2 \le t < 22 \\ \text{LOW} & 22 \le t < 27 \\ \text{HIGH} & t \ge 27 \end{cases}$$

A plot of the input signals and a plot of the operator output are shown next.



Initially, the output is $y(0)$=LOW (as specified by the initial condition property). The output remains LOW, until two seconds elapse (the switching dead-time). The output goes high after two seconds, $y(2)$=*HIGH*, and remains HIGH while $x_2(t) = 5.9$ because the input signals are within the dead-band B=1.0. It also remains HIGH while $x_2(t) = 6.1$ because the inequality condition is not maintained for at least two seconds. Similarly, it remains HIGH while $x_2(t) = 4.1$ (within dead-band) and while $x_2(t) = 3.1$ (inequality condition not maintained for two seconds). At t=20 seconds, the input signals satisfy the inequality condition, but the output does not switch to LOW until t=22 seconds. (when the input signals have remained unequal for at least two seconds.) Likewise, the output will go HIGH (and remain HIGH thereafter) at t=27 seconds.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time t=0)

Dead Band. The equality dead-band, B

Switching Dead-Time. The length of time a signal must satisfy the equality (inequality) condition, for the output to switch from LOW to HIGH (from HIGH to

LOW). The switching dead-time is denoted by *T* in the equation above, and is expressed in seconds.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The equality dead-band must be greater than or equal to zero, $B \geq 0$
- The switching dead-time must be greater than or equal to zero, $T \geq 0$

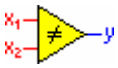
See Also:

≠, >, ≥, <, and ≤ Comparators; High/Low Alarm; Thresholding

COMPARATOR: ≠

Operator Menu Location: *Signal Comparators*

Operator Bitmap:



Functional Description:

The *Inequality Comparator* operator compares two analog input signals. Its digital output is set LOW if the signals are equal (*i.e.*, within a user-defined dead-band); and it is set HIGH if they are not. The output state will change only if the inequality/equality condition is maintained for a user-specified length of time—the switching dead-time. That is, the output is defined by

$$y = \begin{cases} \text{LOW} & \text{if} \quad \left|x_1(\bar{t}) - x_2(\bar{t})\right| \le B \quad \forall \bar{t} \in [t, t-T] \\ \text{HIGH} & \text{if} \quad \left|x_1(\bar{t}) - x_2(\bar{t})\right| > B \quad \forall \bar{t} \in [t, t-T] \\ y(t-\Delta t) & \text{otherwise} \end{cases}$$

where y is the digital output, x_1 and x_2 are the analog inputs, B is the equality dead-band, T is the switching dead-time, Δt is the loop sampling time, and where $|\cdot|$ denotes the absolute value operator.

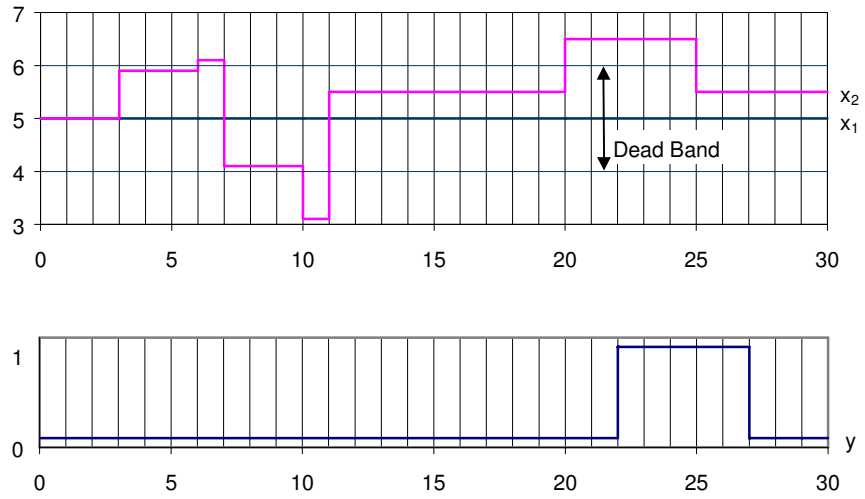
For example, suppose that the initial output is $y(0)=0$, input signal x_1 is fixed $(x_1 \equiv 5.0)$, the dead-band is set to $B=1.0$, the switching dead-time is set to $T=2$ seconds, and signal x_2 has the following profile:

$$x_2(t) = \begin{cases} 5.0 & 0 \le t < 3 \\ 5.9 & 3 \le t < 6 \\ 6.1 & 6 \le t < 7 \\ 4.1 & 7 \le t < 10 \\ 3.1 & 10 \le t < 11 \\ 5.5 & 11 \le t < 20 \\ 6.5 & 20 \le t < 25 \\ 5.5 & t \ge 25 \end{cases}$$

Under these conditions, the output of the *Equality Comparator* will be

$$y(t) = \begin{cases} LOW & 0 \le t < 22 \\ HIGH & 22 \le t < 27 \\ LOW & t \ge 27 \end{cases}$$

A plot of the input signals and a plot of the operator output are shown next.



Initially, the output is $y(0)=LOW$ (as specified by the initial condition property). It remains LOW while $x_2(t) = 5.0$ since the signals are equal to each other. It also remains LOW while $x_2(t) = 5.9$ because the input signals are within the dead-band B=1.0. And, it remains LOW while $x_2(t) = 6.1$ because the inequality condition is not maintained for at least two seconds. Similarly, the output stays LOW while $x_2(t) = 4.1$ (signals within dead-band), while $x_2(t) = 3.1$ (inequality condition not maintained for two seconds), and while $x_2(t) = 5.5$ (signals within dead-band). The output does not switch to HIGH until t=22, when the two signals are not equal for more than two seconds. At time t=25 seconds, the input signals satisfy the equality condition, but the output does not switch to LOW until t=27 seconds. The output remains LOW thereafter.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time t=0)

Dead Band. The equality dead-band, B

Switching Dead-Time. The length of time a signal must satisfy the inequality (equality) condition, for the output to switch from LOW to HIGH (from HIGH to LOW). The switching dead-time is denoted by *T* in the equation above, and is expressed in seconds.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The equality dead-band must be greater than or equal to zero, $B \geq 0$
- The switching dead-time must be greater than or equal to zero, $T \geq 0$

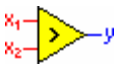
See Also:

=, >, ≥, <, and ≤ Comparators; High/Low Alarm; Thresholding

COMPARATOR: >

Operator Menu Location: *Signal Comparators*

Operator Bitmap:



Functional Description:

The *Greater-Than Comparator* operator compares two analog input signals. Its digital output is set HIGH if input x_1 exceeds x_2, and it is set to LOW otherwise. The output state will change only if the evaluated (>) condition is maintained for a user-specified length of time—the switching dead-time. That is, the output is defined by

$$y = \begin{cases} \text{HIGH} & \text{if} \quad x_1(\bar{t}) > x_2(\bar{t}) \quad \forall \bar{t} \in [t, t-T] \\ \text{LOW} & \text{if} \quad x_1(\bar{t}) + B \le x_2(\bar{t}) \quad \forall \bar{t} \in [t, t-T] \\ y(t-\Delta t) & \text{otherwise} \end{cases}$$

where y is the digital output, x_1 and x_2 are the analog inputs, B is the comparison dead-band, T is the switching dead-time, and Δt is the loop sampling time.

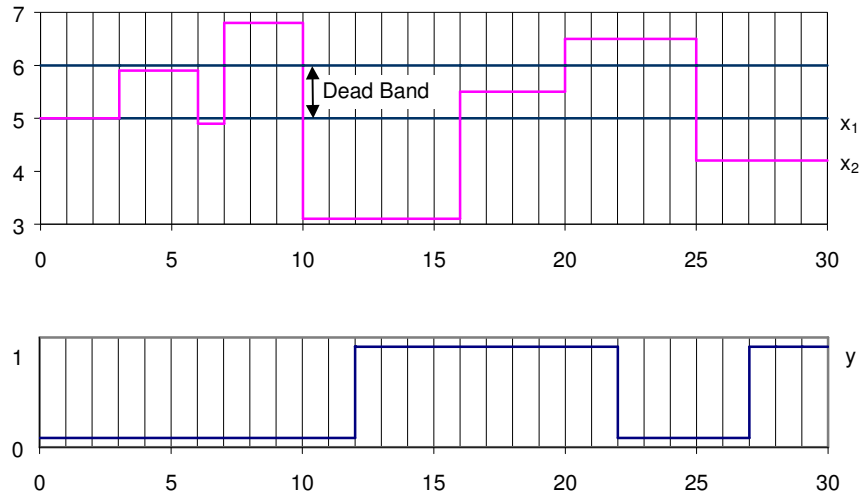
For example, suppose that the initial output is $y(0)=0$, input signal x_1 is fixed $(x_1 \equiv 5.0)$, the dead-band is set to $B=1.0$, the switching dead-time is set to $T=2$ seconds, and signal x_2 has the following profile:

$$x_2(t) = \begin{cases} 5.0 & 0 \le t < 3 \\ 5.9 & 3 \le t < 6 \\ 4.9 & 6 \le t < 7 \\ 6.8 & 7 \le t < 10 \\ 3.1 & 10 \le t < 16 \\ 5.5 & 16 \le t < 20 \\ 6.5 & 20 \le t < 25 \\ 5.2 & t \ge 25 \end{cases}$$

Under these conditions, the output of the *Greater-Than Comparator* will be

$$y(t) = \begin{cases} \text{LOW} & 0 \le t < 12 \\ \text{HIGH} & 12 \le t < 22 \\ \text{LOW} & 22 \le t < 27 \\ \text{HIGH} & t \ge 27 \end{cases}$$

A plot of the input signals and a plot of the operator output are shown next.



Initially, the output is $y(0)=LOW$ (as specified by the initial condition property). It remains LOW while $x_2(t) = 5.0$ and while $x_2(t) = 5.9$ since the greater-than condition is not met. It also remains LOW while $x_2(t) = 4.9$ because the greater-than condition is not maintained for at least two seconds. The output does not switch to HIGH until t=12, when $x_1(t) > x_2(t)$ for more than two seconds. The output remains HIGH while $x_2(t) = 5.5$ because the greater-than condition is met (within the dead-band, *i.e.*, 5.0 + 1.0 > 5.5). At time t=20 seconds, input x_1 is less than x_2, but the output does not switch to LOW until t=22 seconds (when the less-than condition has been maintained for at least two seconds). The output will switch to HIGH (and remain HIGH thereafter) at time t=27 seconds.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time t=0)

Dead Band. The dead-band, B

Switching Dead-Time. The length of time a signal must satisfy the comparison condition, for the output to switch from LOW to HIGH (from HIGH to LOW). The switching dead-time is denoted by T in the equation above, and is expressed in seconds.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The dead-band must be greater than or equal to zero, $B \geq 0$
- The switching dead-time must be greater than or equal to zero, $T \geq 0$

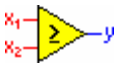
See Also:

=, ≠, ≥, <, and ≤ Comparators; High/Low Alarm; Thresholding

COMPARATOR: ≥

Operator Menu Location: *Signal Comparators*

Operator Bitmap:



Functional Description:

The *Greater-or-Equal Comparator* operator compares two analog input signals. Its digital output is set HIGH if input x_1 exceeds x_2, and it is set to LOW otherwise. The output state will change only if the evaluated (≥) condition is maintained for a user-specified length of time—the switching dead-time. That is, the output is defined by

$$y = \begin{cases} \text{HIGH} & \text{if} \quad x_1(\bar{t}) \geq x_2(\bar{t}) \quad \forall \bar{t} \in [t, t-T] \\ \text{LOW} & \text{if} \quad x_1(\bar{t}) + B < x_2(\bar{t}) \quad \forall \bar{t} \in [t, t-T] \\ y(t-\Delta t) & \text{otherwise} \end{cases}$$

where y is the digital output, x_1 and x_2 are the analog inputs, B is the comparison dead-band, T is the switching dead-time, and Δt is the loop sampling time.

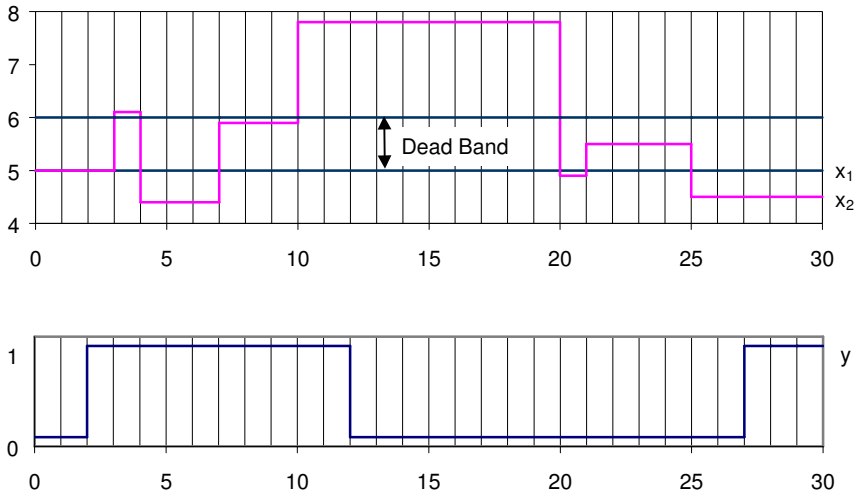
For example, suppose that the initial output is $y(0)=0$, input signal x_1 is fixed $(x_1 \equiv 5.0)$, the dead-band is set to $B=1.0$, the switching dead-time is set to $T=2$ seconds, and signal x_2 has the following profile:

$$x_2(t) = \begin{cases} 5.0 & 0 \leq t < 3 \\ 6.1 & 3 \leq t < 4 \\ 4.4 & 4 \leq t < 7 \\ 5.9 & 7 \leq t < 10 \\ 7.8 & 10 \leq t < 20 \\ 4.9 & 20 \leq t < 21 \\ 5.5 & 21 \leq t < 25 \\ 4.5 & t \geq 25 \end{cases}$$

Under these conditions, the output of the *Greater-Than Comparator* will be

$$y(t) = \begin{cases} \text{LOW} & 0 \le t < 2 \\ \text{HIGH} & 2 \le t < 12 \\ \text{LOW} & 12 \le t < 27 \\ \text{HIGH} & t \ge 27 \end{cases}$$

A plot of the input signals and a plot of the operator output are shown next.



Initially, the output is $y(0)=LOW$ (as specified by the initial condition property). The output remains LOW for the first two seconds (the switching dead-time). It goes HIGH after two seconds because the greater-or-equal condition is satisfied. It remains HIGH while $x_2(t) = 6.1$ because the less-than condition is not maintained for at least two seconds. It also remains HIGH while $x_2(t) = 5.9$ because the greater-or-equal condition is satisfied (within the dead-band, *i.e.*, 5.0 + 1.0 > 5.9) The output does not switch to LOW until t=12, when $x_1(t) + B < x_2(t)$ holds for more than two seconds. The output remains LOW while $x_2(t) = 4.9$ because the greater-than condition is not maintained for at least two seconds. At time t=25 seconds, input x_1 is greater than x_2, but the output does not switch to HIGH until t=27 seconds (when the greater-or-equal condition has been maintained for at least two seconds).

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time t=0)

Dead Band. The dead-band, B

Switching Dead-Time. The length of time a signal must satisfy the comparison condition, for the output to switch from LOW to HIGH (from HIGH to LOW). The switching dead-time is denoted by T in the equation above, and is expressed in seconds.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The dead-band must be greater than or equal to zero, $B \geq 0$
- The switching dead-time must be greater than or equal to zero, $T \geq 0$

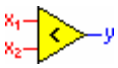
See Also:

=, ≠, >, <, and ≤ Comparators; High/Low Alarm; Thresholding

COMPARATOR: <

Operator Menu Location: *Signal Comparators*

Operator Bitmap:



Functional Description:

The *Less-Than Comparator* operator compares two analog input signals. Its digital output is set HIGH if input x_1 is less than x_2, and it is set to LOW otherwise. The output state will change only if the evaluated (<) condition is maintained for a user-specified length of time—the switching dead-time. That is, the output is defined by

$$y = \begin{cases} \text{HIGH} & \text{if} \quad x_1(\bar{t}) < x_2(\bar{t}) \quad \forall \bar{t} \in [t, t-T] \\ \text{LOW} & \text{if} \quad x_1(\bar{t}) - B \geq x_2(\bar{t}) \quad \forall \bar{t} \in [t, t-T] \\ y(t-\Delta t) & \text{otherwise} \end{cases}$$

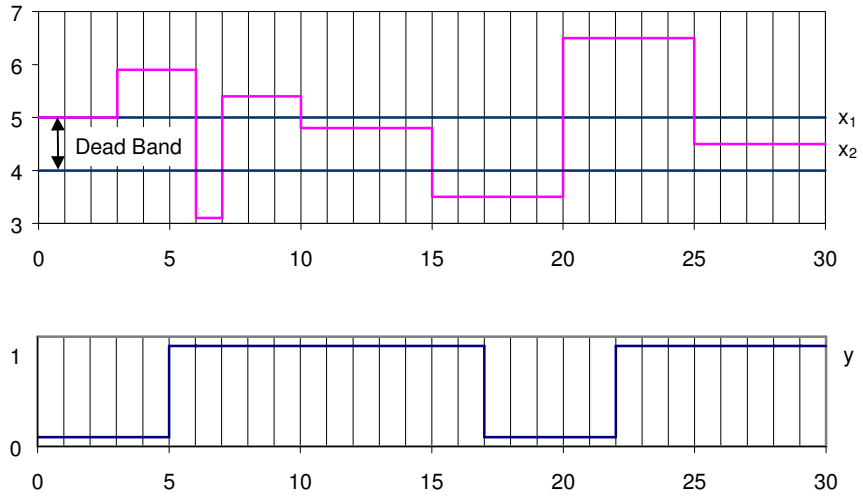
where y is the digital output, x_1 and x_2 are the analog inputs, B is the comparison dead-band, T is the switching dead-time, and Δt is the loop sampling time.
For example, suppose that the initial output is $y(0)=0$, input signal x_1 is fixed $(x_1 \equiv 5.0)$, the dead-band is set to $B=1.0$, the switching dead-time is set to $T=2$ seconds, and signal x_2 has the following profile:

$$x_2(t) = \begin{cases} 5.0 & 0 \leq t < 3 \\ 5.9 & 3 \leq t < 6 \\ 3.1 & 6 \leq t < 7 \\ 5.4 & 7 \leq t < 10 \\ 4.8 & 10 \leq t < 15 \\ 3.5 & 15 \leq t < 20 \\ 6.5 & 20 \leq t < 25 \\ 4.5 & t \geq 25 \end{cases}$$

Under these conditions, the output of the *Less-Than Comparator* will be

$$y(t) = \begin{cases} \text{LOW} & 0 \le t < 5 \\ \text{HIGH} & 5 \le t < 17 \\ \text{LOW} & 17 \le t < 22 \\ \text{HIGH} & t \ge 22 \end{cases}$$

A plot of the input signals and a plot of the operator output are shown next.



Initially, the output is $y(0)=LOW$ (as specified by the initial condition property). It remains LOW while $x_2(t) = 5.0$ because the less-than condition is not met. At t=3 seconds, the less-than condition is satisfied, but the output does not switch to HIGH until t=5 seconds (after the condition is maintained for at least two seconds). The output remains HIGH while $x_2(t) = 3.1$ because the greater-than condition is not maintained for at least two seconds. And, the output remains HIGH while $x_2(t) = 4.8$ because the input signals satisfy the less than condition (within the dead-band, *i.e.*, 5.0 + 1.0 < 4.8). The output goes LOW at t=17 seconds since $x_1(t) + B \ge x_2(t)$ for two consecutive seconds. It switches back to HIGH (and remains HIGH thereafter) at t=22, when $x_1(t) < x_2(t)$ for two consecutive seconds.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time t=0)

Dead Band. The dead-band, B

Switching Dead-Time. The length of time a signal must satisfy the comparison condition, for the output to switch from LOW to HIGH (from HIGH to LOW). The

switching dead-time is denoted by T in the equation above, and is expressed in seconds.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The dead-band must be greater than or equal to zero, $B \geq 0$
- The switching dead-time must be greater than or equal to zero, $T \geq 0$

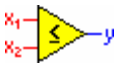
See Also:

=, ≠, >, ≥, and ≤ Comparators; High/Low Alarm; Thresholding

COMPARATOR: ≤

Operator Menu Location: *Signal Comparators*

Operator Bitmap:



Functional Description:

The *Less-or-Equal Comparator* operator compares two analog input signals. Its digital output is set HIGH if input x_1 is less or equal to x_2, and it is set to LOW otherwise. The output state will change only if the evaluated (≤) condition is maintained for a user-specified length of time—the switching dead-time. That is, the output is defined by

$$y = \begin{cases} \text{HIGH} & \text{if} \quad x_1(\bar{t}) \le x_2(\bar{t}) \quad \forall \bar{t} \in [t, t-T] \\ \text{LOW} & \text{if} \quad x_1(\bar{t}) - B > x_2(\bar{t}) \quad \forall \bar{t} \in [t, t-T] \\ y(t-\Delta t) & \text{otherwise} \end{cases}$$

where y is the digital output, x_1 and x_2 are the analog inputs, B is the comparison dead-band, T is the switching dead-time, and Δt is the loop sampling time.

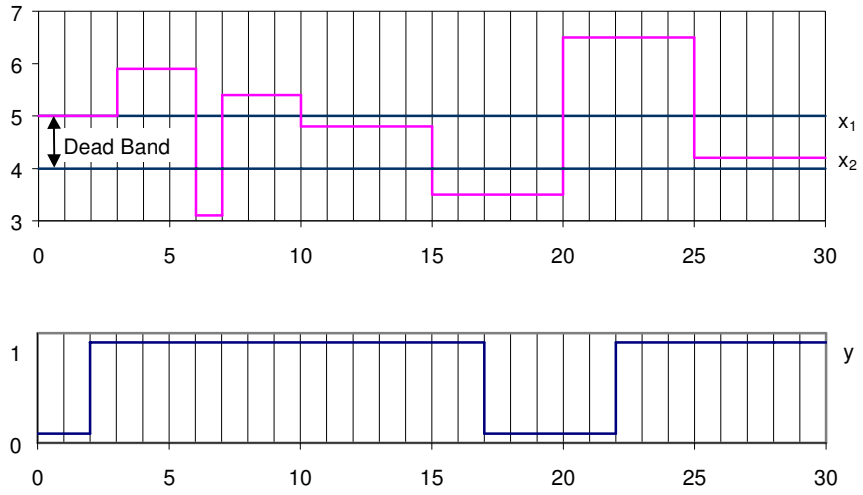
For example, suppose that the initial output is $y(0)=0$, input signal x_1 is fixed $(x_1 \equiv 5.0)$, the dead-band is set to $B=1.0$, the switching dead-time is set to $T=2$ seconds, and signal x_2 has the following profile:

$$x_2(t) = \begin{cases} 5.0 & 0 \le t < 3 \\ 5.9 & 3 \le t < 6 \\ 3.1 & 6 \le t < 7 \\ 5.4 & 7 \le t < 10 \\ 4.8 & 10 \le t < 15 \\ 3.5 & 15 \le t < 20 \\ 6.5 & 20 \le t < 25 \\ 4.2 & t \ge 25 \end{cases}$$

Under these conditions, the output of the *Less-or-Equal Comparator* will be

$$y(t) = \begin{cases} \text{LOW} & 0 \le t < 2 \\ \text{HIGH} & 2 \le t < 17 \\ \text{LOW} & 17 \le t < 22 \\ \text{HIGH} & t \ge 22 \end{cases}$$

A plot of the input signals and a plot of the operator output are shown next.



Initially, the output is $y(0)$=*LOW* (as specified by the initial condition property). The output remains LOW for the first two seconds (the switching dead-time). It goes HIGH after two seconds because the less-or-equal condition is satisfied. It remains HIGH while $x_2(t) = 5.9$ and even while $x_2(t) = 3.1$ because the greater-than condition is not maintained for at least two seconds. And, the output remains HIGH while $x_2(t) = 4.8$ because the input signals satisfy the less-or-equal condition (within the dead-band, *i.e.*, 5.0+1.0≤4.8). The output goes LOW at t=17 seconds since $x_1(t) + B > x_2(t)$ for two consecutive seconds. It switches back to HIGH (and remains HIGH thereafter) at t=22, when $x_1(t) \le x_2(t)$ for two consecutive seconds.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time t=0)

Dead Band. The dead-band, B

Switching Dead-Time. The length of time a signal must satisfy the comparison condition, for the output to switch from LOW to HIGH (from HIGH to LOW). The switching dead-time is denoted by T in the equation above, and is expressed in seconds.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The dead-band must be greater than or equal to zero, $B \geq 0$
- The switching dead-time must be greater than or equal to zero, $T \geq 0$

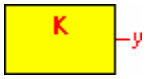
See Also:

=, ≠, >, <, and ≤ Comparators; High/Low Alarm; Thresholding

CONSTANT (ANALOG)

Operator Menu Location: *Signal Reference*

Operator Bitmap:



Functional Description:

The output of the *Constant* operator is the fixed value

$$y = K$$

where y is the output, and K is the user-defined constant value.

User-Defined Properties:

Object Name. A string label that identifies the operator

Constant Value. The constant value, K

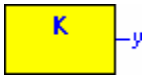
Comments: None.

See Also: Variable (Analog or Digital)

CONSTANT (DIGITAL)

Operator Menu Location: *Signal Reference*

Operator Bitmap:



Functional Description:

The output of the *Constant* operator is the fixed value

$$y = K$$

where y is the output, and K is the user-defined constant value.

User-Defined Properties:

Object Name. A string label that identifies the operator

Constant Value. The constant value, K

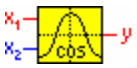
Comments: None.

See Also: Variable (Analog or Digital)

COSINE WAVE GENERATOR

Operator Menu Location: *Generators*

Operator Bitmap:



Functional Description:

The output of the *Cosine Wave Generator* is

$$y(t) = A\cos 2\pi x_1(t)t$$

where y is the output, x_1 is the input frequency in hertz, and A is the amplitude.

The operator has an enable input pin, x_2 which can be optionally connected to turn off the generator. That is, when x_2 is LOW, the output is $y(t)$=0.

If the generator frequency does not need to change over time, input $x_1(t)$ need not be connected. Instead, the frequency can be defined by the operator property f and the generator output will be

$$y(t) = A\cos 2\pi ft$$

User-Defined Properties:

Object Name. A string label that identifies the operator

Amplitude. The cosine wave amplitude, A

Frequency. The cosine wave frequency in hertz. This parameter is ignored if the frequency input x_1 is connected.

Display Frequency Input. This property determines if the frequency input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Enable Input. This property determines if the enable input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema

when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments: None.

See Also: Sine Wave Generator

D FLIP-FLOP

Operator Menu Location: *Logic Functions*

Operator Bitmap:

Functional Description:

The *D Flip-Flop* or “Delay" Flip-Flop is a logic gate with one-bit memory. It toggles its output whenever its input value switches from LOW to HIGH; otherwise, the output value remains unchanged. The operator has the following truth-table:

$x(t)$	$x(t\text{-}\Delta t)$	$y(t)$
LOW	LOW	$y(t-\Delta t)$
LOW	HIGH	$\overline{y(t-\Delta t)}$
HIGH	LOW	$y(t-\Delta t)$
HIGH	HIGH	$y(t-\Delta t)$

In the table, y is the output, x is the input, and Δt is the loop sampling time.

Design Pad G3 will issue an error on processing if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) on startup (at time t=0)

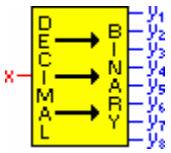
Comments: None.

See Also: RS Flip-Flop

DECIMAL TO BINARY CONVERSION

Operator Menu Location: *Data Conversion*

Operator Bitmap:



Functional Description:

The *Decimal to Binary Conversion* block accepts an analog input x, and computes its binary representation y_i (i=1,2,...,8). Two of the operator properties, $x_{\min}$ and $x_{\max}$, define the range of the input signal. They are used to map the input signal into an integer value between 0 and 255. The mapping is

$$Y_{10} = \begin{cases} 0 & \text{if} \quad x < x_{\min} \\ \text{round}\left[\dfrac{255(x - x_{\min})}{x_{\max} - x_{\min}}\right] & \text{if} \quad x_{\min} \le x \le x_{\max} \\ 255 & \text{if} \quad x > x_{\max} \end{cases}$$

where Y_{10} is the base-10 output value to be mapped into the eight digital signals, y_i (i=1,...,8). The round[] function above rounds its argument to the nearest integer.

User-Defined Properties:

Object Name. A string label that identifies the operator

Minimum (0) Value. The output value corresponding to a base-10 output value of 0 ($y_{\min}$).

Maximum (255) Value. The output value corresponding to a base-10 output value of 255 ($y_{\max}$).

Comments: None.

See Also:

Decimal To Binary Conversion, Multiplexer, Demultiplexer, A/D Conversion, D/A Conversion

DELAY ELEMENT (ANALOG OR DIGITAL) (ANALOG or DIGITAL)

Operator Menu Location: *Signal Conditioning*

Operator Bitmap:

Functional Description:

The output of the *Delay Element* operator is the time-shifted value of its input

$$y(t + M\Delta t) = x(t)$$

where y is the output, x is the input, Δt is the loop sampling time, and M is the number of samples to delay the signal by. Time multiple M must be an integer in the range [1,100].

Design Pad G3 will issue an error if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Time Delay Multiple. An integer multiple of the loop sampling time Δt. It indicates the number of time steps to delay the input signal. It must be an integer in the range [1,100].

Initial Condition. The output value on startup (*i.e.*, $y(0) = y_0$). If $M > 1$, the same initial condition is applied to all initial outputs (*i.e.*, $y(t) = y_0 \ \forall t < M\Delta t$

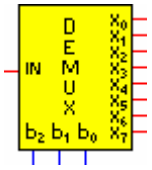
Comments:
The default time delay multiple is M=1.

See Also:
Moving Average, Timer, PID Controller with External Feedback

DEMULTIPLEXER (ANALOG)

Operator Menu Location: *Signal Switching*

Operator Bitmap:



Functional Description:

The *Demultiplexer* operator passes its analog input signal to one of its eight analog outputs. The analog output that passes the analog input is determined by the state of the three digital inputs, as shown in the table below:

b_2	b_1	b_0	Selected Output
LOW	LOW	LOW	$x_0 = IN$
LOW	LOW	HIGH	$x_1 = IN$
LOW	HIGH	LOW	$x_2 = IN$
LOW	HIGH	HIGH	$x_3 = IN$
HIGH	LOW	LOW	$x_4 = IN$
HIGH	LOW	HIGH	$x_5 = IN$
HIGH	HIGH	LOW	$x_6 = IN$
HIGH	HIGH	HIGH	$x_7 = IN$

In the table, $x_i (i = 0,1,...,7)$ represent the analog output signals, *IN* represents the analog input signal, and $b_i (i = 0,1,2)$ are the digital selector inputs. The outputs that are not selected are set to zero, *i.e.*, $x_i = 0 \ \forall i \neq \hat{\imath}$, where î is the index of the selected signal.

Design Pad G3 will issue an error if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

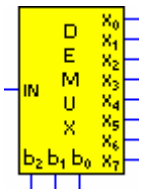
Comments: None.

See Also:
Multiplexer (Analog), Demultiplexer (Digital), Multiplexer (Digital)

DEMULTIPLEXER (DIGITAL)

Operator Menu Location: *Signal Switching*

Operator Bitmap:



Functional Description:

The *Demultiplexer* operator passes its digital input signal to one of its eight digital outputs. The digital output that passes the digital input is determined by the state of the three digital inputs, as shown in the table below:

b_2	b_1	b_0	Selected Output
LOW	LOW	LOW	$x_0 = IN$
LOW	LOW	HIGH	$x_1 = IN$
LOW	HIGH	LOW	$x_2 = IN$
LOW	HIGH	HIGH	$x_3 = IN$
HIGH	LOW	LOW	$x_4 = IN$
HIGH	LOW	HIGH	$x_5 = IN$
HIGH	HIGH	LOW	$x_6 = IN$
HIGH	HIGH	HIGH	$x_7 = IN$

In the table, $x_i (i = 0,1,...,7)$ represent the digital output signals, *IN* represents the digital input signal, and $b_i (i = 0,1,2)$ are the digital selector inputs. The outputs that are not selected are set to LOW, *i.e.*, $x_i = \text{LOW} \ \forall i \neq \hat{\imath}$, where î is the index of the selected signal.

Design Pad G3 will issue an error if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also:

Multiplexer (Digital), Demultiplexer (Analog), Multiplexer (Analog)

DIGITAL HYSTERESIS

Operator Menu Location: *Signal Conditioning*

Operator Bitmap:

Functional Description:

The *Digital Hysteresis* operator filters spurious switching on its a boolean input signal. Its output generally tracks its input signal value, but will delay changing state in response to an input signal change until the input stabilizes. For the output to change from LOW to HIGH, the input must must change from LOW to HIGH and remain HIGH for a user-specified length of time—the *Switch to HIGH Delay* time. Likewise, for the output to switch from HIGH to LOW, the input signal must switch from HIGH to LOW and remain LOW for a user-specified length of time—the *Switch to LOW Delay* time.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time t=0)

Switch to LOW Delay. The length of time (in seconds) that the input signal must remain LOW for the output to switch from HIGH to LOW.

Switch to HIGH Delay. The length of time (in seconds) that the input signal must remain HIGH for the output to switch from LOW to HIGH.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The *Switch to LOW Delay* time must be greater than or equal to zero
- The *Switch to HIGH Delay* time must be greater than or equal to zero

See Also:
Timer Delay

DIGITAL INPUT (EVENT TIMER)

Operator Menu Location: *Generic Hardware Operators* → *Digital Inputs*

Operator Bitmap:

Functional Description:

The *Event Digital Input* generic hardware operator provides access to a pair of high-speed digital input channel resources in the physical hardware capable of measuring the time delay between digital events. When the generic operator is linked to a specific hardware resource, its output value will correspond to the time duration between successive digital pulses between the two channels (measured from the rising edge of the pulse on the first channel to the rising edge of the pulse on the second channel).

Operator output y_1 represents the time duration between pulses, expressed in seconds or milliseconds (the output format is a property of the operator). Output y_2 indicates when a new event time measurement becomes available. The output is HIGH for one schema compute cycle each time a new event is measured; otherwise the output is LOW. Output y_1 remains unchanged between event measurements.

The operator has a reset input *x* which clears its outputs (sets $y_1 = 0$ and $y_2 = \text{LOW}$).

User-Defined Properties:

Object Name. A string label that identifies the operator.

Display Reset Input. This property determines if reset input pin *x* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Output Format. Determines the time unit of measure (seconds or milliseconds) that the event duration should be expressed in.

Comments: None.

See Also:
Digital Input (Standard), Digital Input (Event Timer), Digital Input (Pulse Counter), Digital Input (Pulse Width), Digital Input (Quadrature Decoder)

DIGITAL INPUT (FREQUENCY)

Operator Menu Location: *Generic Hardware Operators* → *Digital Inputs*

Operator Bitmap:

Functional Description:

The *Frequency Digital Input* generic hardware operator provides access to a digital input channel resource in the physical hardware capable of providing frequency measurements. When the generic operator is linked to a specific hardware resource, its output values will correspond to the physical signal connected to that resource. Its output y_1 is the signal frequency (in Hertz), and its output y_2 is the signal duty cycle.

User-Defined Properties:

Object Name. A string label that identifies the operator

Display Duty Cycle Output. This property determines if output pin y_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

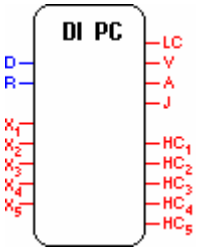
Comments: None.

See Also:
Digital Input (Standard), Digital Input (Event Timer), Digital Input (Pulse Counter), Digital Input (Pulse Width), Digital Input (Quadrature Decoder)

DIGITAL INPUT (PULSE COUNTER)

Operator Menu Location: *Generic Hardware Operators* → *Digital Inputs*

Operator Bitmap:



Functional Description:

The *Pulse Counter Digital Input* generic hardware operator provides access to a digital input channel resource in the physical hardware capable of digital counting pulses. When the generic operator is linked to a specific hardware resource, its output value will correspond to the number of pulses accumulated since it was last reset. Input pin x_1 serves to reset the operator count. Input pin x_2 determines if the count is to increment ($x_2 = \text{HIGH}$) or decrement ($x_2 = \text{LOW}$) when a pulse is detected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Display Reset Count Input. This property determines if output pin x_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Up/Down Count Input. This property determines if output pin x_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Units. Engineering units label used for readability

Comments: None.

See Also:
Digital Input (Standard), Digital Input (Event Timer), Digital Input (Frequency), Digital Input (Pulse Width), Digital Input (Quadrature Decoder)

DIGITAL INPUT (PULSE WIDTH)

Operator Menu Location: *Generic Hardware Operators* → *Digital Inputs*

Operator Bitmap:

Functional Description:

The *Pulse Width Digital Input* generic hardware operator provides access to a digital input channel resource in the physical hardware capable of measuring digital pulse widths. When the generic operator is linked to a specific hardware resource, its output value will correspond to the time duration of a digital pulse (from rising edge to falling edge).
Operator output y_1 represents the pulse width, expressed in seconds or milliseconds (the output format is a property of the operator). Output y_2 indicates when a new pulse width measurement becomes available. The output is HIGH for one schema compute cycle each time a new pulse is measured; otherwise the output is LOW. Output y_1 remains unchanged between pulse readings.

The operator has a reset input *x* which clears its outputs (sets $y_1 = 0$ and $y_2 = \text{LOW}$).

User-Defined Properties:

Object Name. A string label that identifies the operator.

Display Reset Input. This property determines if reset input pin *x* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Output Format. Determines the time unit of measure (seconds or milliseconds) that the pulse duration should be expressed in.

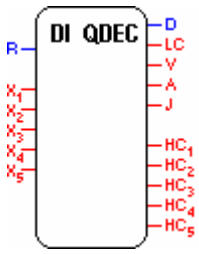
Comments: None.

See Also:
Digital Input (Standard), Digital Input (Event Timer), Digital Input (Frequency), Digital Input (Pulse Counter), Digital Input (Quadrature Decoder)

DIGITAL INPUT (QUADRATURE DECODER)

Operator Menu Location: *Generic Hardware Operators* → *Digital Inputs*

Operator Bitmap:



Functional Description:

The *Quadrature Decoder Digital Input* generic hardware operator provides access to a pair of high-speed digital input channel resources in the physical hardware capable of decoding quadrature encoders. When the generic operator is linked to a specific hardware resource, its output values will correspond to the physical signals attached to the hardware.

A quadrature encoder is a device that translates rotational motion into two digital signals that can be processed to determine position and direction of rotation. Quadrature decoding is the process of taking the encoder output signals and determining position (and any derivatives of interest) and direction of rotation. In its most basic form, a quadrature decoder produces count pulses that indicate a fixed unit of rotational motion and a direction signal that indicates either clockwise or counter-clockwise rotation.

There are three different resolutions that quadrature decoders can operate at—1x, 2x, and 4x. A 1x decoder produces a count pulse and updates the direction signal only on the rising edge of one of the channels. A 2x decoder produces a count pulse and updates the direction signal on each edge of one of the channels. A 4x decoder produces a count pulse and updates the direction signal on each edge of both channels. The *Quadrature Decoder* operator in *Design Pad G3* is a 4x decoder.

The *Quadrature Decoder* operator maintains scaled position, velocity, acceleration and jerk information for the associated digital inputs. Initial values can be provided for all of these quantities.

As some quadrature encoder applications require more than the 7 digits of precision for position information that the analog signal types used in *Design Pad G3* provide, the operator provides a set of 5 position outputs that together provide much greater precision. Each one of these outputs provides 4 decimal digits of precision, except the most

significant one, which provides 3. A corresponding set of inputs is also provided for setting a high-precision initial position.

The *Quadrature Decoder* operator inputs are listed below.

Input	Name	Description	Range
R	Reset/Load	Sets the position outputs to the value given on the load inputs (0 if not connected), and sets the other outputs to their initial values	[LOW, HIGH]
x_1	Load 5	Digits 16-18 of the scaled high-precision position	[-922, 922] with same sign as others
x_2	Load 4	Digits 12-15 of the scaled high-precision position	[-9999, 9999] with same sign as others
x_3	Load 3	Digits 8-11 of the scaled high-precision position	Same as above
x_4	Load 2	Digits 4-7 of the scaled high-precision position	Same as above
x_5	Load 1	Digits 0-3 of the scaled high-precision position	Same as above

And the operator outputs are:

Output	Name	Description	Range
D	Direction	Indicates direction of rotation	[LOW, HIGH]
LC	Low-precision position	Scaled position output as a single number, but limited to 7 decimal digits of precision	Approximately [-3.402823E+38, 3.401823E+38] with 7 digits of precision
V	Velocity	Scaled velocity (counts/sec when scale factor is 1)	Same as above
A	Acceleration	Scaled acceleration (counts/sec/sec when scale factor is 1)	Same as above
J	Jerk	Scaled jerk (counts/sec/sec/sec when scale factor is 1)	Same as above
HC_1	High-precision position 5	Digits 16-18 of the scaled high-precision position	[-922, 922] with same sign as others

HC_2	High-precision position 4	Digits 12-15 of the scaled high-precision position	[-9999, 9999] with same sign as others
HC_3	High-precision position 3	Digits 8-11 of the scaled high-precision position	Same as above
HC_4	High-precision position 2	Digits 4-7 of the scaled high-precision position	Same as above
HC_5	High-precision position 1	Digits 0-3 of the scaled high-precision position	Same as above

If the quadrature encoder being used has E_{cpr} counts per revolution, then the value of the position output after one revolution, P_{rev} will be as follows:

$$P_{rev} = \frac{4 \times E_{cpr}}{SF}$$

where *SF* is a scaling factor.

The factor of 4 in the numerator of the above expression is there because we have a 4x quadrature decoder, meaning we count two events for each pulse on each of the two phases of the quadrature encoder output.

If $E_{cpr} = 300$, *SF* = 1, and the decimal point position is 0, then the values on the high-precision outputs would be as follows:

Output	5				4				3				2				1		
Digit	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0

If the decimal point position is changed to 2, then the values on the high-precision outputs would be as follows, since we have requested that two decimal places be shown in the high-precision outputs:

Output	5				4				3				2				1		
Digit	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0

User-Defined Properties:

Object Name. A string label that identifies the operator

Display Reset/Load Input. This property determines if reset input pin *R* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Units. Engineering units label used for readability.

Odometer Mode. If checked, all pulses increase position independent of direction, just like an odometer. If unchecked, pulses in one direction will increase position and pulses in the other direction will decrease position.

Invert Direction. Swap which direction of rotation is considered positive. Not relevant if odometer mode is used.

Scaling Factor. Raw counts will be divided by this value

Decimal Point Position. Location of decimal point in high-precision output. If *n* is the decimal point position, then the high precision output is multiplied by 10^n.

Initial Velocity. Velocity at reset

Initial Acceleration. Acceleration at reset

Initial Jerk. Jerk at reset

Comments:

Consider the following example usage. Suppose you have a piece of rotating machinery with a main shaft, and you wish to know the RPM of that shaft, the direction of rotation, and also maintain a count of the total number of revolutions. You have a quadrature encoder that provides 600 counts per revolution, and it is connected to the shaft of interest with 1:2 gearing (one revolution of the main shaft yields two revolutions of the quadrature encoder shaft).

Because this is a 4x quadrature decoder, one revolution of the encoder shaft will yield 2400 counts. Because of the 1:2 gearing, one revolution of the main shaft will yield two revolutions of the encoder shaft, and thus 4800 counts.

If we create a quadrature decoder operator and set its scale factor to 4800, the position output would give revolutions of the main shaft, and the velocity output would give revolutions per second, which could then be multiplied by 60 external to the operator to

yield RPM. The direction output will indicate the direction of rotation. We want to check *Odometer Mode* in the property settings so that we keep track of total revolutions. Otherwise, the revolutions count would increase or decrease depending on direction. Note that when *Odometer Mode* is checked, the velocity output is really the speed, as it will always be positive.

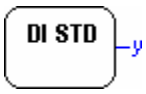
If an odometer type function is desired, along with a velocity output whose sign depends on direction of rotation, then two quadrature decoder operators could be used, with each one configured accordingly.

See Also:
Digital Input (Event Timer), Digital Input (Frequency), Digital Input (Pulse Counter), Digital Input (Pulse Width)

DIGITAL INPUT (STANDARD)

Operator Menu Location: *Generic Hardware Operators* → *Digital Inputs*

Operator Bitmap:



Functional Description:

The *Standard Digital Input* generic hardware operator provides access to a digital input channel resource in the physical hardware. When the generic operator is linked to a specific hardware resource, its output value will correspond to the physical signal connected to that resource. When the physical input signal is below the activation threshold (see the hardware specification), the operator state is LOW. When the input signal is above the threshold, the operator state is HIGH. The operator state will change only if the input signal remains above/below the activation threshold for at least the hysteresis time.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (LOW or HIGH at startup (at time t=0). This parameter is ignored when the *Hysteresis* value is zero.

Hysteresis. The minimum length of time (in seconds) that the input voltage level must remain above the activation threshold (or below the deactivation threshold) for the operator state to switch from HIGH to LOW (or from LOW to HIGH). This parameter serves to filter out noisy measurements.

Comments:
The hysteresis time must be greater or equal to zero.

See Also:
Digital Input (Event Timer), Digital Input (Frequency), Digital Input (Pulse Counter), Digital Input (Pulse Width), Digital Input (Quadrature Decoder)

DIGITAL OUTPUT (RELAY STANDARD)

Operator Menu Location: *Generic Hardware Operators* → *Digital Outputs*

Operator Bitmap:

Functional Description:

The *Standard Relay Digital Output* generic hardware operator provides access to a relay output channel resource in the physical hardware. When the generic operator is linked to a specific hardware resource, it causes that hardware resource to generate a physical signal corresponding to its input pin value. If the input is LOW, the relay will open; if the input is HIGH, the relay will close.

User-Defined Properties:

Object Name. A string label that identifies the operator

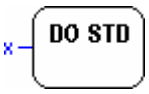
Comments: None.

See Also: Digital Output (Standard), Digital Output (Waveform)

DIGITAL OUTPUT (STANDARD)

Operator Menu Location: *Generic Hardware Operators* → *Digital Outputs*

Operator Bitmap:



Functional Description:

The *Standard Digital Output* generic hardware operator provides access to a digital output channel resource in the physical hardware. When the generic operator is linked to a specific hardware resource, it causes that hardware resource to generate a physical signal corresponding to its input pin value. If the input is LOW, the hardware resource will generate a logic low voltage; if the input is HIGH, the hardware will generate a logic high voltage.

User-Defined Properties:

Object Name. A string label that identifies the operator

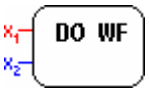
Comments: None.

See Also:
Digital Output (Relay Standard), Digital Output (Waveform)

DIGITAL OUTPUT (WAVEFORM)

Operator Menu Location: *Generic Hardware Operators* → *Digital Outputs*

Operator Bitmap:



Functional Description:

The *Waveform Digital Output* generic hardware operator provides access to a digital output channel resource in the physical hardware capable of generating signal waveforms. When the generic operator is linked to a specific hardware resource, it causes that hardware resource to generate a physical signal corresponding to its x_1 input value whenever the operator is enabled (x_2 = HIGH).

User-Defined Properties:

Object Name. A string label that identifies the operator

Output Mode.

Profile.

Maximum Velocity.

Maximum Acceleration.

Maximum Jerk.

Display Enable Input. Determines if input pin x_2 is displayed on the screen. The pin must be displayed if a virtual signal wire is connected to it.

Comments: None.

See Also:
Digital Output (Standard), Digital Output (Relay Standard)

D/A CONVERSION

Operator Menu Location: *Data Conversion*

Operator Bitmap:

Functional Description:

Design Pad G3 supports two signal types—analog signals (floating point values) drawn in red, and digital signals (boolean values, *i.e.*, true/false or high/low) drawn in blue. These signal types cannot be directly mixed—analog signals may not be directly connected to digital ones. But, analog signals may be converted into digital ones (and vice-versa). The *D/A Conversion* operator converts a HIGH/LOW boolean value into an analog floating point value. The analog output *y* of the *D/A Conversion* operator is

$$y = \begin{cases} 0.0 & \text{if} \quad x = \text{LOW} \\ 1.0 & \text{if} \quad x = \text{HIGH} \end{cases}$$

where *x* is the digital input value.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also:
A/D Conversion, Decimal To Binary Conversion, Binary To Decimal Conversion

DIVISION

Operator Menu Location: *Math Functions*

Operator Bitmap:

Functional Description:

The output of the *Division* operator is the quotient of its inputs,

$$y = \frac{x_1}{x_2}$$

where y is the output, x_1 is the numerator input, and x_2 is the denominator input. *Design Pad G3* will issue an error on processing if an input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments:

If $x_2 = 0$, output y is set to the maximum floating-point value, 3.38×10^{38}

See Also:

Multiplication, Power, Addition, Subtraction, Unit Conversion

EDGE TRIGGER

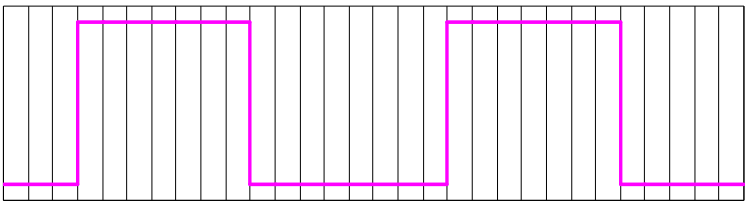
Operator Menu Location: *Logic Functions*

Operator Bitmap:

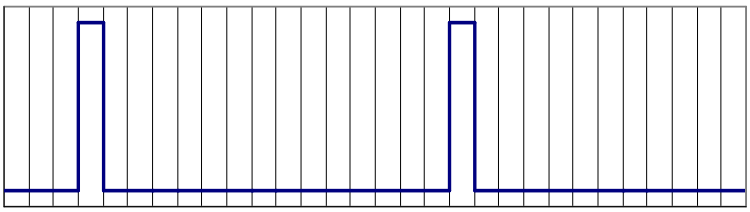
Functional Description:

The *Edge Trigger* operator generates a pulse when it detects a change in the logic state of its input. It can be configured to generate the pulse on a rising edge (when the input state switches from LOW to HIGH) or on a falling edge (when the input state switches from HIGH to LOW) or on *both* the falling edge and rising edge.

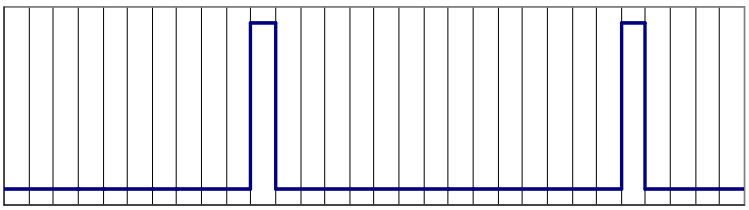
The operator output is HIGH only for one schema compute cycle, immediately following the edge detection. Otherwise the output is LOW. (The width of the HIGH pulse is equal to the schema loop time.) For example, for the input signal shown in figure (a) below, the *Edge Trigger* operator output will be as shown in figure (b) when configured for rising edge detection only, as shown in figure (c) when configured for falling edge detection only, and as shown in figure (d) when configured for both rising edge and falling edge detection.



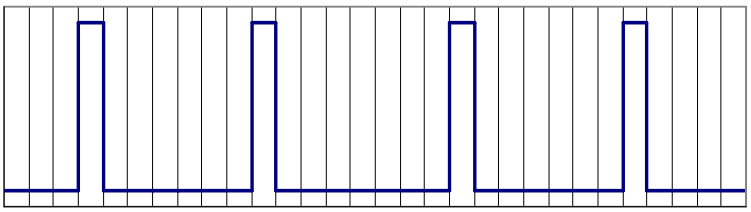
(a) Input signal



(b) Output signal when configured for *Rising Edge* Detection



(c) Output signal when configured for *Falling Edge* Detection



(d) Output signal with both *Rising Edge* and *Falling Edge* Detection

The *Edge Trigger* operator is useful for example, when multiple transition events in a state-transition diagram are triggered by the same signal source, but only one transition is desired whenever the signal source is active. For example, consider the schema diagram in the figure below containing a state-transition diagram with a start state and a stop state. The controller is to switch state whenever the same start/stop push button is pressed. Suppose a push-button operator were connected directly to the boolean variable that triggers the event transitions between the start and stop states (as shown in figure (b)). With this implementation, the controller will bounce back and forth between the start and stop states, as long as the push button is held down. This is generally not desirable behavior. A preferable outcome would be a single event transition each time the start/stop button is depressed, regardless of how long it is held down. This can be accomplished by inserting an edge-trigger operator (configured for rising-edge activation) between the push-button and boolean event trigger. In this way, the boolean variable is only set to TRUE for one schema compute cycle, rather than as long as the button is depressed.

Design Pad G3 will issue an error upon processing if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Trigger On. Determines the edge condition on the input that results in an output pulse. If set to *Rising Edge*, output pulse occurs when input value switches from LOW to HIGH. If set to *Falling Edge*, output pulse occurs when input value switches from HIGH to LOW. If set to *Both Edges*, output pulse occurs whenever input value changes.

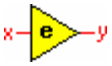
Comments: None.

See Also: Snapshot Recorder, Strip-Chart Recorder

EXPONENTIAL

Operator Menu Location: *Math Functions*

Operator Bitmap:



Functional Description:

The output of the *Exponential* operator is

$$y = e^x$$

where y is the output and x is the input. *Design Pad G3* will issue an error upon processing if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

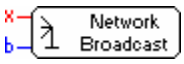
Comments: None.

See Also: Natural Logarithm, Power

FAIRNET BROADCAST

Operator Menu Location: *Generic Hardware Operators* → *Networking* → *FairNET*

Operator Bitmap:



Functional Description:

The *FairNET Broadcast* generic hardware operator provides access to a networking channel resource in the physical hardware. When the generic operator is linked to a specific networking hardware resource, it will broadcast a message over that channel resource using the *FairNET* protocol.

FairNET Broadcast operators encode their input signal *x* into a communication message that they broadcast over a controller network. All devices connected to the network will receive the broadcasted message. But, only those controllers with a receiver operator "tuned" to that broadcast will actually decode the message.

Design Pad G3 supports two types of broadcast operators: analog and digital.

Analog FairNET Broadcast operators transmit encoded floating-point signals. They have two inputs—one analog and one digital. Analog input *x* is the signal that the operator is to broadcast. Digital input *b* disables (HIGH) or enables broadcasting (LOW). If the digital input is not connected, broadcasting is always enabled.

Analog broadcast operators use a 16-bit integer to encode the analog input signal. A 16-bit integer can assume $2^{16} = 65536$ distinct values (0-65535). The communication message *m*—the 16-bit integer that the analog broadcast operator transmits is determined from:

$$m = \begin{cases} 0 & \text{if} \quad x < x_{0\%} \\ \dfrac{65535(x - x_{0\%})}{x_{100\%} - x_{0\%}} & \text{if} \quad x_{0\%} \le x \le x_{100\%} \\ 65535 & \text{if} \quad x > x_{100\%} \end{cases}$$

where $x_{0\%}$ is the minimum value that *x* is expected to assume and $x_{100\%}$ is the maximum value that *x* is expected to assume. The signal mappings $x_{0\%}$ and $x_{100\%}$ are properties of the broadcast operator.

Digital FairNET Broadcast operators transmit boolean signals. They have two digital inputs. Digital input *x* is the broadcast signal and digital input *b* is the disable pin. To minimize bandwidth utilization, the FairNET protocol packages multiple digital messages (bits) originating from the same device into a single message.

User-Defined Properties:

Signal Name. A string label that identifies the broadcast signal. It is used to associate this *FairNET Broadcast* operator in one schema with *FairNET Receiver* operator(s) in other schemas.

Initial Broadcast Value. The signal value transmitted initially.

Broadcast Priority. This parameter indicates if the network signal is critical or non-critical. Critical signals are deterministic; a FairNET network guarantees that consecutive critical broadcasts occur within a specified time interval (the critical broadcast interval is a property of the FairNET network that the operator is part of). Non-critical signals are non-deterministic; consecutive broadcasts generally occur within a specified time-interval but may occasionally take more time (the non-critical broadcast interval is a property of the hardware module that the operator is linked to).

0% Mapping. The lower limit of the *x* input signal range, $x_{0\%}$

100% Mapping. The upper limit of the *x* input signal range, $x_{100\%}$.

Display Enable Input. This property determines if the enable input pin *b* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

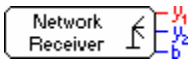
Comments: None.

See Also: FairNET Receiver

FAIRNET RECEIVER

Operator Menu Location: *Generic Hardware Operators* → *Networking* → *FairNET*

Operator Bitmap:



Functional Description:

The *FairNET Receiver* generic hardware operator provides access to a networking channel resource in the physical hardware. When the generic operator is linked to a specific networking hardware resource, it will receive messages broadcast over that channel resource using the *FairNET* protocol.

FairNET Receiver operators decode *FairNET* messages broadcasted over a network. The operator has three outputs:

- Output y_1 is the value of the broadcast signal obtained from the network. It is analog or digital depending on the receiver type (analog or digital).

- Output y_2 indicates if the value has changed since the last transmission. For an analog signal, the value change must exceed a user-defined dead-band parameter to be declared as having changed. The output is HIGH during the single schema compute cycle in which the signal value change was detected; otherwise it is LOW.

- Output y_3 indicates if the broadcast transmissions are being received regularly (i.e., indicates if the network link is good). It is LOW while transmissions are regularly received, and the output is HIGH if the operator has not received a broadcast in a user-specified time interval (the *Broadcast Dead-Time* property of the receiver).

Analog broadcast signals are encoded into a 16-bit integer that can assume $2^{16} = 65536$ distinct values (0-65535). The receiver operator decodes the 16-bit integer into an analog value in the range $y \in [y_{0\%}, y_{100\%}]$ as follows:

$$y = y_{0\%} + \frac{m(x_{100\%} - x_{0\%})}{65535}$$

where m the 16-bit integer. The signal mappings $y_{0\%}$ and $y_{100\%}$ are properties of the receiver operator. The broadcast operator uses its own signal mapping properties ($x_{0\%}$ and $x_{100\%}$) to encode the broadcast signal. If the receiver mapping properties are not the

same as the broadcast mapping properties, the output of the receiver operator will not be the same as the input to the broadcast operator.

In order to associate a receiver operator to a particular network broadcast, the generic operator must be linked to a specific network channel in the physical hardware, and its signal name property must match the broadcast signal name exactly. Signal names are case sensitive—*Design Pad G3* considers the names "*OilPressure*", "*oilPressure*", and "*OILPRESSURE*" to refer to different signals.

User-Defined Properties:

Signal Name. A string label that identifies the broadcast signal that the receiver is "tuned" to. *Design Pad G3* associates this receiver operator in one schema with a broadcast operator in another schema that has the same signal name.

Maximum Broadcast Dead-Time. The period of time (in milliseconds) that may elapse before the receiver operator indicates that it has not received a broadcast signal (switches output y_3 to HIGH). Output y_3 remains LOW while the operator actively receives the broadcasted signal.

0% Mapping. The lower limit of the y_1 output signal range, $y_{0\%}$

100% Mapping. The upper limit of the y_1 output signal range, $y_{100\%}$.

Display Value Change of Value Output. This property determines if the error output pin y_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Error Output. This property determines if the error output pin y_3 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Change of Value Dead-Band. This parameter is applicable only to analog receivers. It determines the magnitude of the signal change that must be detected in order for output y_2 to declare that the signal has changed value. For example, if this property is set to 0.1, and the broadcast value changes from 39.50 to 39.58, the operator will declare that the value has not changed. If the value next changes to 39.62, the operator will declare that the value has changed (relative to 39.50). The next value change indication will not occur until the received broadcast signal is ≤39.52 or ≥39.72.

Comments: None.

See Also: FairNET Broadcast

FLASH SAVE

Operator Menu Location: *Signal Reference*

Operator Bitmap:

Functional Description:

The *Flash Save* operator commits to non-volatile flash memory all *Variable* operator signal values that have been designated for persistent storage (such that they are retained when the device is powered off).

Variable operators are designated for persistent storage in the *Variable Settings* dialog. Three flash save options are available: *None*, *On Command* and *On Command + Power Loss*. *On Command* refers to a variable record action triggered by the *Flash Save* operator. *Power Loss* refers to a variable record action trigger by loss of power. Only variable values that are *critical* to the given application should be designated for saving *On Command + Power Loss*. When a device loses power, it has precious little time to perform clean-up operations, such as saving critical variables to non-volatile memory. The quantity of variables that can be designated as critical is limited and depends on the target hardware.

The *Flash Save* operator will initiate a write-to-flash action when an edge is detected on its input pin. The operator may be configured to trigger on a rising edge (when the input switches from LOW to HIGH) or on a falling edge (when the input switches from HIGH to LOW).

User-Defined Properties:

Object Name. A string label that identifies the operator

Enable On. The input condition that triggers the flash save action. Maybe be either *Rising Edge* (*i.e.*, input switches from LOW to HIGH) or *Falling Edge* (*i.e.*, input switches from HIGH to LOW).

Comments:
Flash memory has a limited number of write-cycles. Care should be taken to ensure that the operator does not trigger a flash-write action with too high a frequency.

See Also:
Variable (Float), Variable (Boolean)

GAIN

Operator Menu Location: *Signal Conditioning*

Operator Bitmap:

Functional Description:

The *Gain* operator multiplies its input value by a constant factor. The output of the operator is

$$y = Gx$$

where y is the output, x is the input, and G is the gain factor.

Design Pad G3 will issue an error on processing if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Gain. The gain factor G

Comments: None.

See Also: Bias, Unit Conversion, Multiplication, Division

HIGH/LOW ALARM

Operator Menu Location: *Signal Comparators*

Operator Bitmap:

Functional Description:

The *High/Low Alarm* operator compares an analog input signal to high and low alarm levels. The operator's digital output is set LOW if the input signal is between the alarm levels, and is set HIGH otherwise. The output will change only if the alarm condition is maintained for a user-specified length of time-the hysteresis time. That is, the output y is defined by

$$y(t)=\begin{cases} 0 & \text{if} \quad x_{\min} < x(\bar{t}) < x_{\max} \ \forall \bar{t} \in [t, t-H] \\ 1 & \text{if} \ x(\bar{t}) \le x_{\min} \ or \ x(\bar{t}) \ge x_{\max} \ \forall \bar{t} \in [t, t-H] \\ y(t-\Delta t) & \text{otherwise} \end{cases}$$

where x is the input, $x_{\max}$ is the high alarm level, $x_{\min}$ is the low alarm level, H is the hysteresis time, and Δt is the loop sampling time.

For example, suppose that the initial output is $y(0) = 0$, the high alarm level is $x_{\max} = 80$, the low alarm level is $x_{\min} = 20$, the hysteresis time is $H = 2$ seconds, and the input signal has the following profile:

$$x_2(t)=\begin{cases} 50 & 0 \le t < 3 \\ 90 & 3 \le t < 4 \\ 70 & 4 \le t < 7 \\ 85 & 7 \le t < 10 \\ 75 & 10 \le t < 11 \\ 85 & 11 \le t < 20 \\ 25 & 20 \le t < 25 \\ 10 & t \ge 25 \end{cases}$$

Under these conditions, the output of the *High/Low Alarm* operator will be

$$y(t) = \begin{cases} LOW & 0 \le t < 9 \\ HIGH & 9 \le t < 22 \\ LOW & 22 \le t < 27 \\ HIGH & t \ge 27 \end{cases}$$

Initially, the output is $y(0)=LOW$ (as specified by the initial condition property). The output remains LOW while $x(t)=50$ since an alarm condition is not met. Although an alarm condition exists while $x(t)=90$, the output remains LOW because the condition is not sustained for two seconds (the hysteresis time). The output switches to HIGH at $t=9$ seconds because an alarm condition is maintained for at least two seconds. It remains HIGH even while $x(t)=75$ (within alarm levels) because the condition $x_{\min} < x < x_{\max}$ is not sustained for two seconds. At $t=20$ seconds, the input signal satisfies the no-alarm condition, but the output does not switch to LOW until $t=22$ seconds. (when the input signal has remained within the alarm levels for at least two seconds.) Likewise, the output will go HIGH (and remain HIGH thereafter) at $t=27$ seconds (because the low alarm condition is sustained).

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time $t=0$)

Low Alarm. The low alarm level, $x_{\min}$

High Alarm. The high alarm level, $x_{\max}$

Hysteresis. The length of time a signal must satisfy the alarm condition, for the output to switch state. The hysteresis time is denoted by H in the equation above, and is expressed in seconds.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The high alarm level must exceed the low alarm level, $x_{\max} > x_{\min}$
- The hysteresis time must be greater than or equal to zero, $H \ge 0$

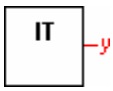
See Also:

=, ≠, >, ≥, <, and ≤ Comparators; Thresholding

INTERNAL TEMPERATURE

Operator Menu Location: *Generic Hardware Operators* → *Misc*

Operator Bitmap:



Functional Description:

The *Internal Temperature* generic hardware operator provides access to a system information resource in a physical module. When the generic operator is linked to a specific module, it will report the internal temperature of that module.

The operator has a single analog output that provides the current temperature of the linked module. The temperature reading can be provided in degrees Celsius or degrees Farenheit.

User-Defined Properties:

Object Name. A string label that identifies the operator

Scale. The scale to report the temperature in: *Celsius* or *Farenheit*.

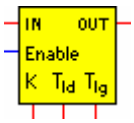
Comments: None.

See Also:
Self-Diagnostics, Loop-Time, Module Hardware Information, Module Active

LEAD-LAG CONTROLLER

Operator Menu Location: *Controller Blocks*

Operator Bitmap:



Functional Description:

The *Lead-Lag Controller* block implements a lead-lag compensator with transfer function:

$$K\frac{T_{ld}s+1}{T_{\lg}s+1}$$

where T_{ld} and $T_{\lg}$ are compensator time constants, and K is the compensator gain. The corresponding discrete-time implementation is

$$y(t)=y(t-\Delta t)+\left[1-e^{-\Delta t/T_{\lg}}\right]\left[Kx(t)-y(t-\Delta t)\right]+K\frac{T_{ld}}{T_{\lg}}\left[x(t)-x(t-\Delta t)\right]$$

where y is the compensator output (*OUT*), x is the compensator input (*IN*), and Δt is the schema loop sampling time.

In addition to the analog signal input (*IN*) and compensator coefficient inputs (K, T_{ld}, and $T_{\lg}$), the lead-lag controller block has an *Enable* input. When the *Enable* input is HIGH, the output is computed as indicated above; when the *Enable* input is LOW, the compensator is disabled and the output simply passes the input, *i.e.*, $y(t) = x(t)$.

The value of output y is limited by user-defined parameters, $y_{\min}$ and $y_{\max}$. Even if the input value is outside of the range $[y_{\min}, y_{\max}]$, the output will never fall outside of that range.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial Condition. The output value at startup (at time t=0)

Minimum Output. The minimum output value

Maximum Output. The maximum output value

Comments:

- *Design Pad G3* will issue an error on processing if the *IN* input pin is not connected
- The coefficients T_{ld} and $T_{\lg}$ are expressed in minutes
- The lag coefficient must be at least 60 milliseconds, *i.e.*, $T_{\lg} \geq 0.001$ min

See Also: PID Controller, PID Controller with External Feedback

LED DISPLAY

Operator Menu Location: *Generic Hardware Operators* → *Displays*

Operator Bitmap:

Functional Description:

The *LED Display* generic hardware operator provides access to an LED indicator resource in the physical hardware. When the generic operator is linked to a specific hardware resource, it will command that LED resource to turn on or off. If the hardware resource is so capable, the operator may drive it to assume one of three different colors as follows:

x_1	x_2	LED State
LOW	LOW	OFF
LOW	HIGH	RED
HIGH	LOW	GREEN
HIGH	HIGH	YELLOW

If the hardware resource is only capable of ON/OFF indication, it will turn ON whenever either input x_1 or x_2 are HIGH and will turn OFF whenever both inputs are LOW.

Digital input x_3 determines if the indicator will flash (when lit). If $x_3 = \text{HIGH}$ then the LED will flash.

User-Defined Properties:

Object Name. A string label that identifies the operator

Display Blinking Input. This property determines if input pin x_3 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Green Input. This property determines if input pin x_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Red Input. This property determines if input pin x_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments:

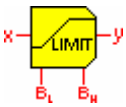
- If the *LED Display* operator is in a sub-schema that is not currently active, its state (ON/OFF) will not be displayed. If no other operators are linked to that resource, the display is turned off and remains off until the sub-schema is activated.

See Also: Numeric Display, Bargraph Display

LIMITER

Operator Menu Location: *Signal Conditioning*

Operator Bitmap:



Functional Description:

The *Limiter* operator confines its input signal *x* within an operating band. The output *y* is defined by

$$y(t) = \begin{cases} B_L(t) & \text{if} \quad x(t) \le B_L(t) \\ B_H(t) & \text{if} \quad x(t) \ge B_H(t) \\ x(t) & \text{otherwise} \end{cases}$$

where limiting inputs $B_L(t)$ and $B_H(t)$ define the lower and upper boundaries of the operating band.

If the signal boundaries do not change over time, inputs $B_L(t)$ and $B_H(t)$ need not be connected. Instead, the signal limits can be defined by the operator properties $x_{\min}$ and $x_{\max}$.

User-Defined Properties:

Object Name. A string label that identifies the operator

Low Limit. The lower limit of the operating band, $x_{\min}$. This parameter is ignored if input $B_L(t)$ is connected.

High Limit. The upper limit of the operating band, $x_{\max}$. This parameter is ignored if input $B_H(t)$ is connected.

Display Low Limit Input. This property determines if the input pin B_L is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema

when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display High Limit Input. This property determines if the input pin B_H is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

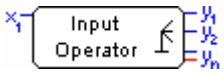
Comments: None.

See Also: Rate Limiter, High/Low Alarm

LONTALK INPUT VARIABLE

Operator Menu Location: *Generic Hardware Operators* → *Networking* → *Lontalk*

Operator Bitmap:



Functional Description:

The *LonTalk Input Operator* generic hardware operator provides access to a networking channel resource in the physical hardware. When the generic operator is linked to a specific networking hardware resource, it will receive data from the Application running on the Neuron.

This data is application dependent and can include network variable values, configuration property values, or program variables. A Library and demo programs are provided for use with NodeBuilder.

The *LonTalk Input Operator* has three fixed pins:

- Disable Input x_1. A HIGH input will stop updates from propagating from the application through the operator to the Schema

- Output y_1 indicates if the operator is linked with the application running on the Neuron. It is LOW if the "Link Key" was matched with a corresponding link key on the Neuron application. The output is HIGH if the operator key could not be matched with one on the Neuron.
- Output y_2 indicates if the value has changed from the last value received from the neuron. The output is HIGH during the single schema compute cycle in which the signal value change was detected; otherwise it is LOW.
- Value Outputs y_n. Depending on the type selected for the Input Operator, there can be 1 or more input digital or analog signals.

In Addition to the fixed pins, there can be multiple output pins based on the "Type" selection in the properties dialog. Numerous SNVTs are supported, as well as basic Neuron C types [boolean, char, int, long, s32, float, uchar, uint, ulong]

When configured for a type of SNVT, values received from the application will be scaled based on the standard Echelon scaling for that SNVT. {Note the inverse is true for the LonTalk Output Operator}

Refer to the Echelon document "**LONMARK® SNVT Master List**" for information on scaling factors and structures of SNVTs.

User-Defined Properties:

Signal Name. Name of the operator.

Type. This property lets you select a SNVT, or a basic Neuron C type which determines the size and scaling (if any) to be applied to this operator data.

Neuron Link Key. This property sets the key used by the Neuron application and the Schema to dynamically link operators with the Neuron application.

Display Disable Input. This property determines if the disable input pin x_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Error Output. This property determines if the error output pin y_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Value Change of Value Output. This property determines if the error output pin y_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

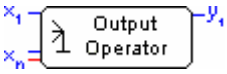
Comments: None.

See Also:
LonTalk Output Operator

LONTALK OUTPUT VARIABLE

Operator Menu Location: *Generic Hardware Operators* → *Networking* → *Lontalk*

Operator Bitmap:



Functional Description:

The *LonTalk Output Operator* generic hardware operator provides access to a networking channel resource in the physical hardware. When the generic operator is linked to a specific networking hardware resource, it will send data to the Application running on the Neuron.

This data is application dependent and can include network variable values, configuration property values, or program variables. A Library and demo programs are provided for use with NodeBuilder.

The *LonTalk Output Operator* has two fixed pins:

- Disable Input x_1. A HIGH input will stop updates from propagating through the operator to the Neuron application
- Value Inputs x_n. Depending on the type selected for the Output Operator, there can be 1 or more input digital or analog signals.
- Output y_1 indicates if the operator is linked with the application running on the Neuron. It is LOW if the "Link Key" was matched with a corresponding link key on the Neuron application. The output is HIGH if the operator key could not be matched with one on the Neuron.

In Addition to the fixed pins, there can be multiple input pins based on the "Type" selection in the properties dialog. Numerous SNVTs are supported, as well as basic Neuron C types [boolean, char, int, long, s32, float, uchar, uint, ulong]

When configured for a type of SNVT, values sent from the schema to the application will be scaled based on the standard Echelon scaling for that SNVT. {Note the inverse is true for the LonTalk Input Operator}

Refer to the Echelon document "**LONMARK® SNVT Master List**" for information on scaling factors and structures of SNVTs.

User-Defined Properties:

Signal Name. Name of the operator.

Type. This property lets you select a SNVT, or a basic Neuron C type which determines the size and scaling (if any) to be applied to this operator data.

Neuron Link Key. This property sets the key used by the Neuron application and the Schema to dynamically link operators with the Neuron application.

Display Disable Input. This property determines if the disable input pin x_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Error Output. This property determines if the error output pin y_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

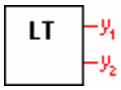
Comments: None.

See Also:
LonTalk Input Operator

LOOP TIME

Operator Menu Location: *Generic Hardware Operators → Misc*

Operator Bitmap:



Functional Description:

The *Loop Time* generic hardware operator provides access to a system information resource in a physical module. When the generic operator is linked to a specific module, it will report on the computational performance of that module.

The operator has two analog outputs. Output y_2 is the user-defined target loop-time performance for the top-level schema executing in the module that the operator is linked to. Output y_1 is the actual loop-time performance reported by that module during its last compute cycle. (Actual loop-time performance refers to how much time actually elapsed while the controller executed the last complete scan of all operators. Ideally, the actual loop-time performance should be less than the target performance at every scan. While this condition holds, the controller remains idle for that fraction of time necessary to match the target performance.)

Both outputs are expressed in seconds.

User-Defined Properties:

Object Name. A string label that identifies the operator

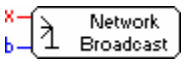
Comments: None.

See Also:
Self-Diagnostics, Module Hardware Information, Module Active

MODBUS COIL BROADCAST

Operator Menu Location: *Generic Hardware Operators* → *Networking* → *Modbus*

Operator Bitmap:



Functional Description:

The *Modbus Coil Broadcast* generic hardware operator provides access to a networking channel resource in the physical hardware. When the generic operator is linked to a specific networking hardware resource, it will broadcast a message over that channel resource using the *Modbus* protocol.

The *Modbus Coil Broadcast* operator encodes boolean input signal *x* into a communication message that it broadcasts over an industrial network. All devices connected to the network will receive the broadcasted message. But, only those controllers with a *Modbus Coil Receiver* operator "tuned" to that broadcast will actually decode the message.

The operator has a second digital input *b* that disables transmissions. When *b* = LOW, the operator broadcasts input *x* onto the network. When *b* = HIGH, the operator doesn't do anything.

User-Defined Properties:

Signal Name. A string label that identifies the broadcast signal. It is used to associate this *Modbus Coil Broadcast* operator in one schema with *Modbus Coil Receiver* operator(s) in other schemas.

Initial Broadcast Value. The signal value transmitted initially.

Display Disable Input. This property determines if the disable input pin *b* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

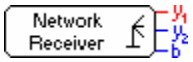
Comments: None.

See Also:
Modbus Coil Receiver, Modbus Register Broadcast, Modbus Register Receiver

MODBUS COIL RECEIVER

Operator Menu Location: *Generic Hardware Operators* → *Networking* → *Modbus*

Operator Bitmap:



Functional Description:

The *Modbus Coil Receiver* generic hardware operator provides access to a networking channel resource in the physical hardware. When the generic operator is linked to a specific networking hardware resource, it will receive messages broadcast over that channel resource using the *Modbus* protocol.

The *Modbus Coil Receiver* operator decodes *Modbus* messages broadcasted over a network. The operator has three outputs:

- Digital output y_1 is the value of the broadcast signal obtained from the network.
- Digital output y_2 indicates if the value has changed since the last transmission. The output is HIGH during the single schema compute cycle in which the signal value change was detected; otherwise it is LOW.
- Digital output y_3 indicates if the broadcast transmissions are being received regularly (i.e., indicates if the network link is good). It is LOW while transmissions are regularly received, and the output is HIGH if the operator has not received a broadcast in a user-specified time interval (the *Broadcast Dead-Time* property of the receiver).

In order to associate a receiver operator to a particular network broadcast, the generic operator must be linked to a specific network channel in the physical hardware, and its signal name property must match the broadcast signal name exactly. Signal names are case sensitive—*Design Pad G3* considers the names "*OilPressureAlarm*", "*oilPressureaLarm*", and "*OILPRESSUREALARM*" to refer to different signals.

User-Defined Properties:

Signal Name. A string label that identifies the broadcast signal that the receiver is "tuned" to. *Design Pad G3* associates this receiver operator in one schema with a broadcast operator in another schema that has the same signal name.

Maximum Broadcast Dead-Time. The period of time (in milliseconds) that may elapse before the receiver operator indicates that it has not received a broadcast signal (switches output y_3 to HIGH). Output y_3 remains LOW while the operator actively receives the broadcasted signal.

Display Value Change of Value Output. This property determines if the error output pin y_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Error Output. This property determines if the error output pin y_3 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

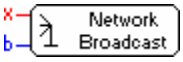
Comments: None.

See Also:
Modbus Coil Broadcast, Modbus Register Receiver, Modbus Register Broadcast

MODBUS REGISTER BROADCAST

Operator Menu Location: *Generic Hardware Operators* → *Networking* → *Modbus*

Operator Bitmap:



Functional Description:

The *Modbus Register Broadcast* generic hardware operator provides access to a networking channel resource in the physical hardware. When the generic operator is linked to a specific networking hardware resource, it will broadcast a message over that channel resource using the *Modbus* protocol.

Modbus Register Broadcast operators encode their input signal *x* into a communication message that they broadcast over an industrial network. All devices connected to the network will receive the broadcasted message. But, only those controllers with a receiver operator "tuned" to that broadcast will actually decode the message.

The *Modbus Register Broadcast* operator has two inputs—one analog and one digital. Analog input *x* is the signal that the operator is to broadcast. Digital input *b* disables (HIGH) or enables broadcasting (LOW). If the digital input is not connected, broadcasting is always enabled.

The operator transmits 16-bit messages that can represent: a floating-point value, an unsigned integer value in the range [0,65535], or a signed integer value in the range [-32768,32767].

When configured to transmit a floating-point value, the operator maps input *x* into a 16-bit representation: transmits is determined from:

$$m = \begin{cases} 0 & if \quad x < x_{0\%} \\ \dfrac{65535(x - x_{0\%})}{x_{100\%} - x_{0\%}} & if \quad x_{0\%} \le x \le x_{100\%} \\ 65535 & if \quad x > x_{100\%} \end{cases}$$

where $x_{0\%}$ is the minimum value that *x* is expected to assume and $x_{100\%}$ is the maximum value that *x* is expected to assume. The signal mappings $x_{0\%}$ and $x_{100\%}$ are properties of

the operator. The narrower the band defined by $x_{0\%}$ and $x_{100\%}$ the better resolution the broadcasted message retains.

When configured to transmit an unsigned integer value, the operator first rounds input x to the nearest integer, then broadcasts the value. If the input is outside of the unsigned integer range, the value is clipped. In other words the broadcast message, m is

$$m = \begin{cases} 0 & \text{if} \quad x \le 0 \\ \lfloor x + 0.5 \rfloor & \text{if} \quad 0 < x \le 65535 \\ 65535 & \text{if} \quad x > 65535 \end{cases}$$

Similarly, when configured to transmit a signed integer value, the broadcast message is

$$m = \begin{cases} 0 & \text{if} \quad x \le -32768 \\ \lfloor x + 0.5 \rfloor & \text{if} \quad -32768 < x \le 32767 \\ 32767 & \text{if} \quad x > 32767 \end{cases}$$

User-Defined Properties:

Signal Name. A string label that identifies the broadcast signal. It is used to associate this *Modbus Register Broadcast* operator in one schema with *Modbus Register Receiver* operator(s) in other schemas.

Initial Broadcast Value. The signal value transmitted initially.

Network Data Format. Determines the format of the transmitted message: *Analog Range*, *Unsigned Integer*, or *Signed Integer*. The *Analog Range* setting is used to transmit floating-point values, according to the mapping formula above.

0% Mapping. The lower limit of the x input signal range, $x_{0\%}$

100% Mapping. The upper limit of the x input signal range, $x_{100\%}$.

Display Disable Input. This property determines if the disable input pin b is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

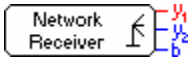
Comments: None.

See Also:
Modbus Register Receiver, Modbus Coil Broadcast, Modbus Coil Receiver

MODBUS REGISTER RECEIVER

Operator Menu Location: *Generic Hardware Operators* → *Networking* → *Modbus*

Operator Bitmap:



Functional Description:

The *Modbus Register Receiver* generic hardware operator provides access to a networking channel resource in the physical hardware. When the generic operator is linked to a specific networking hardware resource, it will receive messages broadcast over that channel resource using the *Modbus* protocol.

The *Modbus Register Receiver* operator decodes *Modbus* messages broadcasted over a network. The operator has three outputs:

- Analog output y_1 is the value of the broadcast signal obtained from the network.
- Output y_2 indicates if the value has changed since the last transmission. In order for the operator to declare a change in value, the magnitude of the value change must exceed a user-defined dead-band parameter. The output is HIGH during the single schema compute cycle in which the signal value change was detected; otherwise it is LOW.
- Output y_3 indicates if the broadcast transmissions are being received regularly (i.e., indicates if the network link is good). It is LOW while transmissions are regularly received, and the output is HIGH if the operator has not received a broadcast in a user-specified time interval (the *Broadcast Dead-Time* property of the receiver).

Analog broadcast signals are encoded into 16-bit integer messages that can assume $2^{16} = 65536$ distinct values. The broadcasted message can represent a floating-point value, an unsigned integer in the range [0,65535], or a signed integer in the range [-32768,32767].

When configured to decode floating-point values, the receiver operator maps the 16-bit message *m* into an analog value in the range $y \in [y_{0\%}, y_{100\%}]$ as follows:

$$y = y_{0\%} + \frac{m(x_{100} - x_{0\%})}{65535}$$

The signal mappings $y_{0\%}$ and $y_{100\%}$ are properties of the receiver operator. The broadcast operator uses its own signal mapping properties ($x_{0\%}$ and $x_{100\%}$) to encode the broadcast signal. If the receiver mapping properties are not the same as the broadcast mapping properties, the output of the receiver operator will not be the same as the input to the broadcast operator.

When configured to decode an unsigned integer message, the receiver output is simply the raw transmitted value in the range [0,65535]. The same is true for decoding signed integer messages, with the exception that the output range is [-32768,32767].

In order to associate a receiver operator to a particular network broadcast, the generic operator must be linked to a specific network channel in the physical hardware, and its signal name property must match the broadcast signal name exactly. Signal names are case sensitive—*Design Pad G3* considers the names "*OilPressure*", "*oilPressure*", and "*OILPRESSURE*" to refer to different signals.

User-Defined Properties:

Signal Name. A string label that identifies the broadcast signal that the receiver is "tuned" to. *Design Pad G3* associates this receiver operator in one schema with a broadcast operator in another schema that has the same signal name.

Maximum Broadcast Dead-Time. The period of time (in milliseconds) that may elapse before the receiver operator indicates that it has not received a broadcast signal (switches output y_3 to HIGH). Output y_3 remains LOW while the operator actively receives the broadcasted signal.

Network Data Format. Determines the format of the transmitted message: *Analog Range*, *Unsigned Integer*, or *Signed Integer*. The *Analog Range* setting is used to transmit floating-point values linerarly mapped between $y_{0\%}$ and $y_{100\%}$—see *0% Mapping* and *100% Mapping* properties below.

0% Mapping. The lower limit of the y_1 output signal range, $y_{0\%}$

100% Mapping. The upper limit of the y_1 output signal range, $y_{100\%}$.

Display Value Change of Value Output. This property determines if the error output pin y_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Error Output. This property determines if the error output pin y_3 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema

when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Change of Value Dead-Band. This parameter determines the magnitude of the signal change that must be detected in order for output y_2 to declare that the signal has changed value. For example, if this property is set to 0.1, and the broadcast value changes from 39.50 to 39.58, the operator will declare that the value has not changed. If the value next changes to 39.62, the operator will declare that the value has changed (relative to 39.50). The next value change indication will not occur until the received broadcast signal is ≤39.52 or ≥39.72.

Comments: None.

See Also:
Modbus Register Broadcast, Modbus Coil Receiver, Modbus Coil Broadcast

MODULE ACTIVE

Operator Menu Location: *Diagnostic*

Operator Bitmap:

Functional Description:

In *Design Pad G3* a control node is formed by joining one or more modules together. Most modules are assumed to be "intelligent"—that is, they have processing and memory resources. The *Module Active* operator indicates if the module in the specified node position is responsive. The position of a module is relative to the *leftmost* module in the node. The leftmost module is in position 1, the module to its right is in position 2, and so on.

The operator output is HIGH if the module in the specified position is *alive*. This means that the module is responding to communication requests from neighboring modules. It does not necessarily imply that the module is executing a *schema* program or that no error conditions have been reported by that module.

The operator output is LOW if the module fails to respond to communication requests. This will occur when the module is removed from the node, if the module is not "intelligent", or if the module has sustained a hard failure (will not power up).

The operator has a single analog input that defines the module position that the operator is to report on. The module position can also be set as an operator property. If the input is connected, the property setting is ignored.

User-Defined Properties:

Object Name. A string label that identifies the operator

Display Module Position. This property determines if input pin *x* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Module Position. The position in the node of the module of interest (the module whose health the operator reports on). This parameter is ignored when the module position input is connected.

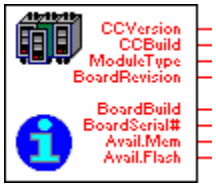
Comments: None.

See Also:
Module Position, Module Hardware Information, Self-Diagnostic

MODULE HARDWARE INFO

Operator Menu Location: *Diagnostic*

Operator Bitmap:



Functional Description:

The *Module Hardware Information* generic hardware operator provides access to a system information resource in a physical module. When the generic operator is linked to a specific module, it will acquire system information from that module and populate its output values with that information.

The operator has eight outputs which provide the following information:

***Control Code Version*.** The version number of the embedded firmware executing in the module

***Control Code Build*.** The build number of the embedded firmware executing in the module

***Module Type*.** A numeric value corresponding to the module part number (see table below)

***Board Revision*.** The revision code for the primary electronic PC board in the embedded hardware target. For *Chameleon* modules, this is the PC board that is mounted in the module faceplate cover. The output value is a number corresponding to the revision code letter: 1 = A, 2 = B, 3 = C, ...

***Board Build*.** The build code for the primary electronic PC board in the embedded hardware target. For *Chameleon* modules, this is the PC board that is mounted in the module faceplate cover.

***Board Serial Number*.** The product serial number

Available Memory. The amount of available volatile memory (RAM) in the embedded hardware target

Available Flash. The amount of available non-volatile memory in the embedded hardware target

The *Module Type* output values correspond to the following Fairmount Automation part numbers:

Fairmount Automation Part Number	Description	Module Type
PCM-1	Chameleon Process Control Module, Type 1	2
PCM-2	Chameleon Process Control Module, Type 2	14
DAM-1	Chameleon Discrete Automation Module, Type 1	7
DAM-2	Chameleon Discrete Automation Module, Type 2	15
DAM-3	Chameleon Discrete Automation Module, Type 3	19
DAM-4	Chameleon Discrete Automation Module, Type 4	20
NIM-1	Chameleon RS-485 Network Interface Module	3
NIM-2	Chameleon Ethernet Network Interface Module with 5-Port Switch	12
NIM-3	Chameleon RS-422 Network Interface Module	13
NIM-4	Chameleon RS-232 Network Interface Module	16
NIM-5	Chameleon Ethernet Network Interface Module	17
NIM-6	Chameleon LonTalk TP/FT-10 Network Interface Module	18
FAC2000-DC-28-C	Multi-Loop Process Controller	0
FAC2000-DC-28-C-RAAA	Multi-Loop Process Controller with Solid-State Relays	1

User-Defined Properties:

Object Name. A string label that identifies the operator

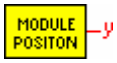
Comments: None.

See Also: Module Active, Module Position, Self-Diagnostic

MODULE POSITION

Operator Menu Location: *Diagnostic*

Operator Bitmap:



Functional Description:

In *Design Pad G3* a control node is formed by joining one or more modules together. The *Module Position* operator indicates the position of the module within the node. The module position is relative to the *leftmost* module in the node. The leftmost module is in position 1, the module to its right is in position 2, and so on.

The operator has a single analog output that reports the position of the module executing the schema that contains the operator.

User-Defined Properties:

Object Name. A string label that identifies the operator

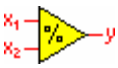
Comments: None.

See Also:
Module Active, Module Hardware Information, Self-Diagnostic

MODULO

Operator Menu Location: *Math Functions*

Operator Bitmap:



Functional Description:

The output of the *Modulo* operator is the remainder of integer division of input x_1 by x_2:

$$y = x_1 \% x_2$$

where *y* is the output. The operator first rounds the *float* inputs x_1 and x_2 to their nearest integer values, then performs the modulo calculation. If $x_2 = 0$, then the remainder output is defined to be $y = x_1$.

Design Pad G3 will issue an error on processing if an input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also: Division

MOVING AVERAGE

Operator Menu Location: *Math Functions*

Operator Bitmap:

Functional Description:

The *Moving Average* operator computes the average of the past N_s input values

$$y(t) = \frac{1}{N_s} \sum_{i=0}^{N_s-1} x(t - i\Delta t)$$

where $y(t)$ is the output at time t, Δt is the loop sampling time, N_s are the number of samples, and $x(t - i\Delta t), i \in [0, N_s - 1]$ are the past N_s input samples.

Design Pad G3 will issue an error upon processing if an input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Samples. The number of samples, N_s

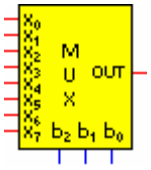
Comments: None.

See Also: Delay Element, Addition, Division, Multiplication

MULTIPLEXER (ANALOG)

Operator Menu Location: *Signal Switching*

Operator Bitmap:



Functional Description:

The output of the *Multiplexer* operator is equal to one of its eight analog inputs. The analog input that is passed through to the output is determined by the state of the three digital inputs, as shown in the table below:

b_2	b_1	b_0	OUT
LOW	LOW	LOW	x_0
LOW	LOW	HIGH	x_1
LOW	HIGH	LOW	x_2
LOW	HIGH	HIGH	x_3
HIGH	LOW	LOW	x_4
HIGH	LOW	HIGH	x_5
HIGH	HIGH	LOW	x_6
HIGH	HIGH	HIGH	x_7

In the table, OUT represents the output signal, $x_i (i = 0,1,...,7)$ are the analog input signals, and $b_i (i = 0,1,2)$ are the digital selector inputs.

User-Defined Properties:

Object Name. A string label that identifies the operator

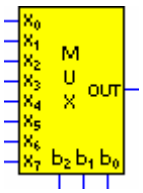
Comments: None.

See Also:
Multiplexer (Digital), Demultiplexer (Analog), Demultiplexer (Digital), A/B Switch

MULTIPLEXER (DIGITAL)

Operator Menu Location: *Signal Switching*

Operator Bitmap:



Functional Description:

The output of the *Multiplexer* operator is equal to one of its eight digital inputs. The digital input that is passed through to the output is determined by the state of the three selector inputs, as shown in the table below:

b_2	b_1	b_0	*OUT*
LOW	LOW	LOW	x_0
LOW	LOW	HIGH	x_1
LOW	HIGH	LOW	x_2
LOW	HIGH	HIGH	x_3
HIGH	LOW	LOW	x_4
HIGH	LOW	HIGH	x_5
HIGH	HIGH	LOW	x_6
HIGH	HIGH	HIGH	x_7

In the table, *OUT* represents the output signal, $x_i (i = 0,1,...,7)$ are the digital input signals, and $b_i (i = 0,1,2)$ are the digital selector inputs.

User-Defined Properties:

Object Name. A string label that identifies the operator

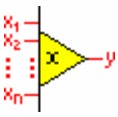
Comments: None.

See Also:
Multiplexer (Analog), Demultiplexer (Digital), Demultiplexer (Analog), A/B Switch

MULTIPLICATION

Operator Menu Location: *Math Functions*

Operator Bitmap:



Functional Description:

The output of the *Multiplication* operator is the product of its inputs,

$$y = \prod_{i=1}^{n} x_i$$

where y is the output, $x_i (i = 1,...,n)$ are the inputs, and n is the number of inputs. *Design Pad G3* assumes that $x_1 \equiv 1$ if input pin i is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Inputs. The number of input pins n, where $2 \leq n \leq 6$

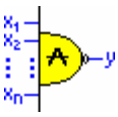
Comments: None.

See Also: Division, Power, Addition, Subtraction, Unit Conversion

NAND-GATE

Operator Menu Location: *Logic Functions*

Operator Bitmap:



Functional Description:

The output of the *NAND Gate* operator is the logical *NAND* of its inputs,

$$y = \overline{x_1 \wedge x_2 \wedge \ldots \wedge x_n}$$

where y is the output, $x_i (i = 1,\ldots,n)$ are the inputs, and n is the number of inputs. In other words, the output state is LOW if all inputs are HIGH. If any input is LOW, the output is HIGH. Below is the truth table for a 3-input NAND-gate:

x_1	x_2	x_3	y
LOW	LOW	LOW	HIGH
LOW	LOW	HIGH	HIGH
LOW	HIGH	LOW	HIGH
LOW	HIGH	HIGH	HIGH
HIGH	LOW	LOW	HIGH
HIGH	LOW	HIGH	HIGH
HIGH	HIGH	LOW	HIGH
HIGH	HIGH	HIGH	LOW

Design Pad G3 assumes that $x_i \equiv \text{HIGH}$, if input pin i is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Inputs. The number of input pins n, where $2 \le n \le 6$

Comments: None.

See Also:
AND Gate, OR Gate, NOR Gate, NOT Gate, XOR Gate, XNOR Gate

NATURAL LOGARITHM

Operator Menu Location: *Math Functions*

Operator Bitmap:

Functional Description:

The output of the *Natural Log* operator is

$$y(t) = \ln x(t)$$

where y is the output and x is the input. *Design Pad G3* will issue an error upon processing if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments:

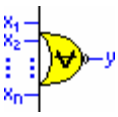
If the input is less than zero, $x(t) < 0$, then the output is set to the minimum 4-byte floating point value: $y = -3.37 \times 10^{38}$.

See Also: Exponential, Power

NOR-GATE

Operator Menu Location: *Logic Functions*

Operator Bitmap:



Functional Description:

The output of the *NOR Gate* operator is the logical *NOR* of its inputs,

$$y = x_1 \vee x_2 \vee ... \vee x_i$$

where y is the output, $x_i (i = 1,...,n)$ are the inputs, and n is the number of inputs. In other words, the output state is LOW if all inputs are HIGH. If any input is LOW, the output is HIGH. Below is the truth table for a 3-input NOR-gate:

x_1	x_2	x_3	y
LOW	LOW	LOW	HIGH
LOW	LOW	HIGH	LOW
LOW	HIGH	LOW	LOW
LOW	HIGH	HIGH	LOW
HIGH	LOW	LOW	LOW
HIGH	LOW	HIGH	LOW
HIGH	HIGH	LOW	LOW
HIGH	HIGH	HIGH	LOW

Design Pad G3 assumes that $x_i \equiv 0$, if input pin i is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Inputs. The number of input pins n, where $2 \le n \le 6$

Comments: None.

NOT-GATE

Operator Menu Location: *Logic Functions*

Operator Bitmap:

Functional Description:

The output of the *NOT Gate* operator is the logical negation of its input,

$$y = \overline{x}$$

where y is the output and x is the input. In other words, the output state is LOW if the input is HIGH, and the output state is HIGH, if the input is LOW.

Design Pad G3 will issue an error on processing if the input is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also:
AND Gate, NAND Gate, OR Gate, NOR Gate, XOR Gate, XNOR Gate

NUMERIC DISPLAY

Operator Menu Location: *Generic Hardware Operators* → *Displays*

Operator Bitmap:

Functional Description:

The *Numeric Display* generic hardware operator provides access to a numeric display resource in the physical hardware. When the generic operator is linked to a specific hardware resource, it will command that resource to display the value of its input x_1.

Digital input x_2 controls the presentation of signal x_1 on the display. If $x_2 = \text{HIGH}$, the x_1 value will flash on the numeric display; otherwise, if $x_2 = \text{LOW}$, the value will be shown continuously. Flashing the contents of the numeric display may be useful to indicate particular operating states. For instance, it could be used to indicate that the controller is in *Manual* mode, or that some alarm condition has arisen.

When multiple generic *Numeric Display* operators are linked to the same specific hardware resource (*e.g.*, the same physical display), the display will cycle between each operator input value. The digital output y of the operator is HIGH while the physical hardware is currently displaying its input value x_1 (*e.g.*, while the operator is active). Digital output y is LOW while the operator is inactive. When a resource is shared between multiple operators, it is a good idea to indicate what value is currently being displayed. This can be done by connecting output y to an *LED Display* operator. For example, the same physical display can be used to indicate both a process variable and a process setpoint. In the schema diagram below, both process and setpoint values are displayed on the Chameleon PCM-1 top numeric display. The top LED is lit while the process variable is displayed and the second LED is lit when the process setpoint is displayed.

User-Defined Properties:

Object Name. A string label that identifies the operator

Decimal Point Position. The position of the decimal point on the numeric display. The decimal point position can be floating, or it can be fixed after any digit position. It can also indicate that no decimal point is to be displayed. When in floating mode, the decimal point position will depend on the value of input signal x_1. It will display the signal at the maximum resolution possible (using all the available digits).

Brightness. A brightness setting for the LED digits in the range [0-15], with 15 indicating maximum brightness.

Active Period. The period of time (in milliseconds) that the physical display will show input x_1 of this operator if the resource is shared. This parameter has no effect if the resource is not shared.

Refresh Rate. The period of time (in milliseconds) between successive display updates while this operator is active.

Display Blinking Input. This property determines if input pin x_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Active Output. This property determines if output pin *y* is visible in the schema diagram.

Pad Leading Zeros. If checked, pads input x_1 with leading zeros so that every digit in the display is used. For instance, suppose the linked display has four digits, the operator is configured to not display a decimal point, and the input value $x_1 = 10$. If this property is checked, the display will indicate "`0010`"; otherwise it will indicate "`10`" and the first two digits will be turned off. In this example, if the decimal point position were configured to float, the display would indicate "`10.00`".

Comments:

- If the numeric display operator is in a sub-schema that is not currently active, its value will not be displayed. If no other operators are linked to that resource, the display is turned off and remains off until the sub-schema is activated.

- If the value of input signal x_1 exceeds the capacity of the display (*e.g.*, 9999 for a four-digit numeric displays when the decimal point is floating, or 9.99 for a three-digit display when the decimal point position is set to 'After First Digit'), the displays will show an 'H' in each digit (*i.e.*, "`HHHH`" on a four-digit display, "`HHH`" on a three-digit display, *etc*.).

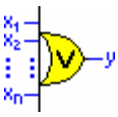
- If x_1 is less than the minimum value for the chosen setting (*e.g.*, -99.9 for a four-digit display with a 'After Second Digit' decimal point position, or -99 for a three-digit display with a floating decimal point), the displays will show an 'L' in each digit (*i.e.*, "`LLLL`" on a four-digit display, "`LLL`" on a three-digit display, *etc*.)

See Also:
LED Display, Bargraph Display

OR-GATE

Operator Menu Location: *Logic Functions*

Operator Bitmap:



Functional Description:

The output of the *OR Gate* operator is the logical *OR* of its inputs,

$$y = x_1 \vee x_2 \vee \ldots \vee x_i,$$

where y is the output, $x_i (i = 1,\ldots,n)$ are the inputs, and n is the number of inputs. In other words, the output state is LOW if all inputs are LOW. If any input is HIGH, the output is HIGH. Below is the truth table for a 3-input OR-gate:

x_1	x_2	x_3	y
LOW	LOW	LOW	LOW
LOW	LOW	HIGH	HIGH
LOW	HIGH	LOW	HIGH
LOW	HIGH	HIGH	HIGH
HIGH	LOW	LOW	HIGH
HIGH	LOW	HIGH	HIGH
HIGH	HIGH	LOW	HIGH
HIGH	HIGH	HIGH	HIGH

Design Pad G3 assumes that $x_i \equiv 0$, if input pin i is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Inputs. The number of input pins n, where $2 \le n \le 6$

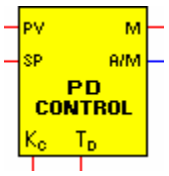
Comments: None.

See Also:
NOR Gate, AND Gate, NAND Gate, NOT Gate, XOR Gate, XNOR Gate

PD CONTROLLER

Operator Menu Location: *Controller Blocks*

Operator Bitmap:



Functional Description:

The *PD Controller* block implements the position form of a Proportional-Derivative control algorithm [2] . It computes a control signal *M*, as the sum of proportional, integral (reset), and derivative (rate) control modes:

$$M(t) = B_P(t) + B_D(t).$$

Each mode is based on measurements (samples) of an error signal *E*. For direct-acting control, this error signal is defined as

$$E = PV - SP,$$

where *PV* is the process variable and *SP* is the set-point. For reverse-acting control, the error is defined as

$$E = SP - PV.$$

The direct/reverse acting attribute of a PD controller refers to the relative direction of movement of the process variable and controller output. Under a direct acting configuration, an increase in the process variable results in an increase in the controller output. Under a reverse acting configuration, an increase in the process variable results in a decrease in controller output. The proper setting depends upon the process itself. In most processes, the controller should be set to reverse acting. (Hence, the operator defaults to reverse acting.)

The proportional mode term, B_P, is calculated as the product of the proportional gain, K_c, and the error term $E(t)$,

[2]See Corripio, A.B., Tuning of Industrial Control Systems (Research Triangle Park, NC: ISA, 1990).

$$B_P(t) = K_C E(t).$$

The derivative mode term, B_D, is obtained from

$$B_D(t) = \begin{cases} K_c \left[\dfrac{60\ T_D}{\Delta t} \right] \left[E(t) - E(t - \Delta t) \right] & \text{if} \quad T_D > 0 \\ 0 & \text{if} \quad T_D \le 0 \end{cases}$$

where T_D is the derivative time, expressed in minutes. With this definition, a change in the process set-point can cause undesirable pulses in the derivative mode term. These undesirable pulses, known as derivative kick, can also result from discretization effects and from the noise-amplification effect of differentiation. Derivative kick can be avoided by having the derivative mode act on the process variable, rather than on the error. To avoid derivative kick B_D is calculated from

$$B_D(t) = \begin{cases} K_c \left[\dfrac{60\,T_D}{\Delta t + \alpha\ 60\,T_D} \right] \left[\alpha\, B_D(t - \Delta t) + \Delta PV(t) \right] & \text{if} \quad T_D > 0 \\ 0 & \text{if} \quad T_D \le 0 \end{cases}$$

where ΔPV is the process variable change from one sample to the next. For direct acting processes, we have

$$\Delta PV(t) = PV(t) - PV(t-\Delta t)$$

and for reverse acting processes, we have

$$\Delta PV(t) = -PV(t) + PV(t-\Delta t)$$

The parameter α in the equations above acts as a noise filter. Its reciprocal, $1/\alpha$, is called the "dynamic gain limit" and corresponds to the maximum amplification of the error signal. By default, the operator is configured to avoid derivative kick. And, the default value of the filter parameter is set to $\alpha=1$.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial Condition. The output value at startup, *i.e.*, $M(0)$

Minimum Output. The minimum output value

Maximum Output. The maximum output value

Direct Acting. A boolean property that governs the relative direction of movement of the process variable and controller output. When the property is checked, an increase in the process variable results in an increase in the controller output. When it is not checked, an increase in the process variable results in a decrease in controller output. By default, this property is left unchecked (in most applications, a PD controller should be reverse acting.)

Derivative on Measure. A boolean property that governs the computation of the derivative-mode term. When this property is checked, the derivative mode term is based on the process variable; when it is not checked, it is based on the error. The latter case may result in derivative kick when the set-point is modified, or when the operator switches between automatic and manual modes. By default, this property is checked to eliminate derivative kick and to limit the noise amplification effect of differentiation.

Filter Parameter, α. A scalar parameter used when the 'Derivative on Measure' property is checked. It serves to limit the effects of noise and discretization on the derivative-mode term.

Comments:

- The rate time (T_D) input is measured in minutes

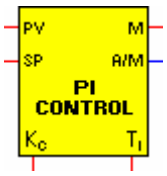
- The minimum proportional gain (K_c) input is 0.001 (if a smaller value is present, 0.001 will be used as the gain in the computation of the output signal.)

See Also:
PID Controller, PI Controller, PID Controller with External Feedback, Lead-Lag Controller

PI CONTROLLER

Operator Menu Location: *Controller Blocks*

Operator Bitmap:



Functional Description:

The *PI Controller* block implements the position form of a Proportional-Integral control algorithm [3] . It computes a control signal *M*, as the sum of proportional, integral (reset), and derivative (rate) control modes:

$$M(t) = B_P(t) + B_I(t).$$

Each mode is based on measurements (samples) of an error signal *E*. For direct-acting control, this error signal is defined as

$$E = PV - SP,$$

where *PV* is the process variable and *SP* is the set-point. For reverse-acting control, the error is defined as

$$E = SP - PV.$$

The direct/reverse acting attribute of a PI controller refers to the relative direction of movement of the process variable and controller output. Under a direct acting configuration, an increase in the process variable results in an increase in the controller output. Under a reverse acting configuration, an increase in the process variable results in a decrease in controller output. The proper setting depends upon the process itself. In most processes, the controller should be set to reverse acting. (Hence, the operator defaults to reverse acting.)

The proportional mode term, B_P, is calculated as the product of the proportional gain, K_c, and the error term $E(t)$,

$$B_P(t) = K_C E(t).$$

[3]See Corripio, A.B., Tuning of Industrial Control Systems (Research Triangle Park, NC: ISA, 1990).

The integral mode term B_I is obtained from

$$B_I(t) = \begin{cases} K_c \left[\dfrac{\Delta t}{60\ T_I} \right] S(t) & \text{if} \quad T_I > 0 \\ 0 & \text{if} \quad T_I \le 0 \end{cases}$$

where T_I is the integral or reset time expressed in minutes, Δt is the loop sampling time expressed in seconds, and $S(t)$ is the sum of all past errors, computed from

$$S(t) = S(t-\Delta t) + E(t), \quad S(0)=0$$

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial Condition. The output value at startup, *i.e.*, $M(0)$

Minimum Output. The minimum output value

Maximum Output. The maximum output value

Direct Acting. A boolean property that governs the relative direction of movement of the process variable and controller output. When the property is checked, an increase in the process variable results in an increase in the controller output. When it is not checked, an increase in the process variable results in a decrease in controller output. By default, this property is left unchecked (in most applications, a PI controller should be reverse acting.)

Comments:

- The reset time (T_I) input is measured in minutes
- The minimum proportional gain (K_c) input is 0.001 (if a smaller value is present, 0.001 will be used as the gain in the computation of the output signal.)

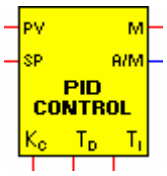
See Also:

PID Controller, PI Controller, PID Controller with External Feedback, Lead-Lag Controller

PID CONTROLLER

Operator Menu Location: *Controller Blocks*

Operator Bitmap:



Functional Description:

The *PID Controller* block implements the position form of a Proportional-Integral-Derivative control algorithm[4] . It computes a control signal *M*, as the sum of proportional, integral (reset), and derivative (rate) control modes:

$$M(t) = B_P(t) + B_I(t) + B_D(t).$$

Each mode is based on measurements (samples) of an error signal *E*. For direct-acting control, this error signal is defined as

$$E = PV - SP,$$

where *PV* is the process variable and *SP* is the set-point. For reverse-acting control, the error is defined as

$$E = SP - PV.$$

The direct/reverse acting attribute of a PID controller refers to the relative direction of movement of the process variable and controller output. Under a direct acting configuration, an increase in the process variable results in an increase in the controller output. Under a reverse acting configuration, an increase in the process variable results in a decrease in controller output. The proper setting depends upon the process itself. In most processes, the controller should be set to reverse acting. (Hence, the operator defaults to reverse acting.)

The proportional mode term, B_P, is calculated as the product of the proportional gain, K_c, and the error term $E(t)$,

$$B_P(t) = K_C E(t).$$

[4]See Corripio, A.B., Tuning of Industrial Control Systems (Research Triangle Park, NC: ISA, 1990).

The integral mode term B_I is obtained from

$$B_I(t) = \begin{cases} K_c \left[\dfrac{\Delta t}{60\ T_I} \right] S(t) & \text{if} \quad T_I > 0 \\ 0 & \text{if} \quad T_I \le 0 \end{cases}$$

where T_I is the integral or reset time expressed in minutes, Δt is the loop sampling time expressed in seconds, and $S(t)$ is the sum of all past errors, computed from

$$S(t) = S(t-\Delta t) + E(t), \quad S(0)=0$$

Finally, the derivative mode term, B_D, is obtained from

$$B_D(t) = \begin{cases} K_c \left[\dfrac{60\ T_D}{\Delta t} \right] \left[E(t) - E(t-\Delta t) \right] & \text{if} \quad T_D > 0 \\ 0 & \text{if} \quad T_D \le 0 \end{cases}$$

where T_D is the derivative time, expressed in minutes. With this definition, a change in the process set-point can cause undesirable pulses in the derivative mode term. These undesirable pulses, known as derivative kick, can also result from discretization effects and from the noise-amplification effect of differentiation. Derivative kick can be avoided by having the derivative mode act on the process variable, rather than on the error. To avoid derivative kick B_D is calculated from

$$B_D(t) = \begin{cases} K_c \left[\dfrac{60\,T_D}{\Delta t + \alpha\ 60\,T_D} \right] \left[\alpha\, B_D(t-\Delta t) + \Delta PV(t) \right] & \text{if} \quad T_D > 0 \\ 0 & \text{if} \quad T_D \le 0 \end{cases}$$

where ΔPV is the process variable change from one sample to the next. For direct acting processes, we have

$$\Delta PV(t) = PV(t) - PV(t-\Delta t)$$

and for reverse acting processes, we have

$$\Delta PV(t) = -PV(t) + PV(t-\Delta t)$$

The parameter α in the equations above acts as a noise filter. Its reciprocal, $1/\alpha$, is called the "dynamic gain limit" and corresponds to the maximum amplification of the error signal. By default, the operator is configured to avoid derivative kick. And, the default value of the filter parameter is set to α=1.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial Condition. The output value at startup, *i.e.*, $M(0)$

Minimum Output. The minimum output value

Maximum Output. The maximum output value

Direct Acting. A boolean property that governs the relative direction of movement of the process variable and controller output. When the property is checked, an increase in the process variable results in an increase in the controller output. When it is not checked, an increase in the process variable results in a decrease in controller output. By default, this property is left unchecked (in most applications, a PID controller should be reverse acting.)

Derivative on Measure. A boolean property that governs the computation of the derivative-mode term. When this property is checked, the derivative mode term is based on the process variable; when it is not checked, it is based on the error. The latter case may result in derivative kick when the set-point is modified, or when the operator switches between automatic and manual modes. By default, this property is checked to eliminate derivative kick and to limit the noise amplification effect of differentiation.

Filter Parameter, α. A scalar parameter used when the 'Derivative on Measure' property is checked. It serves to limit the effects of noise and discretization on the derivative-mode term.

Comments:

- The reset time (T_I) and rate time (T_D) inputs are measured in minutes
- The minimum proportional gain (K_c) input is 0.001 (if a smaller value is present, 0.001 will be used as the gain in the computation of the output signal.)

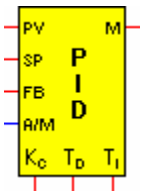
See Also:

PID Controller with External Feedback, Lead-Lag Controller

PID with EXTERNAL FEEDBACK

Operator Menu Location: *Controller Blocks*

Operator Bitmap:



Functional Description:

The *PID Controller with External Feedback* block implements the position form of a Proportional-Integral-Derivative control algorithm[5] . Like the *PID Controller* block, it computes a control signal *M*, as the sum of proportional, integral (reset), and derivative (rate) control modes:

$$M(t) = B_P(t) + B_I(t) + B_D(t).$$

Unlike the *PID Controller* block, it computes the reset mode B_I from an external feedback signal *FB*

$$B_I(t) = B_I(t - \Delta t) + \left[FB(t) - B_I(t - \Delta t)\right]\frac{60\Delta T}{T_I}$$

where T_I is the integral or reset time, expressed in minutes, and where Δt is the loop sampling time. If the signal that is fed back is simply the output signal *M*, *i.e.*,

$$FB(t) = M(t\text{-}\Delta t),$$

then, the *PID Controller* operator and the *PID with External Feedback* operator will function identically. The external feedback version is useful if you intend to do additional processing between the output signal *M* and the end actuator (as shown in the schema below). The *PID Controller* block should be used when output *M* drives an actuator directly.

The proportional and rate modes are based on measurements (samples) of an error signal *E*. For direct-acting control, this error signal is defined as

[5]See Corripio, A.B., Tuning of Industrial Control Systems (Research Triangle Park, NC: ISA, 1990).

$$E = PV - SP,$$

where *PV* is the process variable and *SP* is the set-point. For reverse-acting control, the error is defined as

$$E = SP - PV.$$

The direct/reverse acting attribute of a PID controller refers to the relative direction of movement of the process variable and controller output. Under a direct acting configuration, an increase in the process variable results in an increase in the controller output. Under a reverse acting configuration, an increase in the process variable results in a decrease in controller output. The proper setting depends upon the process itself. In most processes, the controller should be set to reverse acting. (Hence, the operator defaults to reverse acting.)

The proportional mode term, B_P, is calculated as the product of the proportional gain, K_c, and the error term $E(t)$,

$$B_P(t) = K_C E(t).$$

The derivative mode term, B_D, is obtained from

$$B_D(t) = \begin{cases} K_c \left[\dfrac{60\ T_D}{\Delta t} \right] \left[E(t) - E(t - \Delta t) \right] & \text{if} \quad T_D > 0 \\ 0 & \text{if} \quad T_D \le 0 \end{cases}$$

where T_D is the derivative time, expressed in minutes. With this definition, a change in the process set-point can cause undesirable pulses in the derivative mode term. These undesirable pulses, known as derivative kick, can also result from discretization effects and from the noise-amplification effect of differentiation. Derivative kick can be avoided by having the derivative mode act on the process variable, rather than on the error. To avoid derivative kick B_D is calculated from

$$B_D(t) = \begin{cases} K_c \left[\dfrac{60 T_D}{\Delta t + \alpha\ 60 T_D} \right] \left[\alpha\, B_D(t - \Delta t) + \Delta PV(t) \right] & \text{if} \quad T_D > 0 \\ 0 & \text{if} \quad T_D \le 0 \end{cases}$$

where ΔPV is the process variable change from one sample to the next. For direct acting processes, we have

$$\Delta PV(t) = PV(t) - PV(t-\Delta t)$$

and for reverse acting processes, we have

$$\Delta PV(t) = -PV(t) + PV(t-\Delta t)$$

The parameter α in the equations above acts as a noise filter. Its reciprocal, $1/\alpha$, is called the "dynamic gain limit" and corresponds to the maximum amplification of the error signal. By default, the operator is configured to avoid derivative kick. And, the default value of the filter parameter is set to α=1.

The *PID with External Feedback* block provides a boolean input labeled *A/M* that indicates the operating mode: *automatic* or *manual*. If input *A/M*=LOW, the operator is in *automatic* mode and the output is computed as explained above. If input *A/M*=HIGH, the operator is in *manual* mode; the output is tied directly to the feedback signal, *i.e.*,

$$M(t)=FB(t) \quad \text{if} \quad A/M=\text{HIGH}.$$

And, the integral term is matched to the difference between the feedback signal and the automatic output:

$$B_I(t) = FB(t) - B_P(t) - B_D(t).$$

With this arrangement, the transition between *automatic* and *manual* modes will be bumpless.

A sample schema demonstrating the use of this *PID with External Feedback* block is shown in the figure below.

In the figure, the *PID with External Feedback* block is used in conjunction with an external *A/M Button* block. Note that the Bumpless Transfer property of the *A/M block* should not be selected, since bumpless transfer between automatic and manual modes is built-into the controller block.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial Condition. The output value at startup, *i.e.*, $M(0)$

Minimum Output. The minimum output value

Maximum Output. The maximum output value

Direct Acting. A boolean property that governs the relative direction of movement of the process variable and controller output. When the property is checked, an increase in the process variable results in an increase in the controller output. When it is not checked, an increase in the process variable results in a decrease in controller output. By default, this property is left unchecked (in most applications, a PID controller should be reverse acting.)

Derivative on Measure. A boolean property that governs the computation of the derivative-mode term. When this property is checked, the derivative mode term is based on the process variable; when it is not checked, it is based on the error. The latter case may result in derivative kick when the set-point is modified, or when the operator switches between automatic and manual modes. By default, this property is checked to eliminate derivative kick and to limit the noise amplification effect of differentiation.

Filter Parameter, α. A scalar parameter used when the 'Derivative on Measure' property is checked. It serves to limit the effects of noise and discretization on the derivative-mode term.

Comments:

- The reset time (T_I) and rate time (T_D) inputs are measured in minutes
- The minimum reset time (T_I) input is 0.001 minutes (if a smaller value is applied, 0.001 will be used as the reset time in the computation of the integral term)
- The minimum proportional gain (K_c) input is 0.001 (if a smaller value is applied, 0.001 will be used as the gain in the computation of the output signal)

See Also:
PID Controller, A/M Button, Lead-Lag Controller

POWER

Operator Menu Location: *Math Functions*

Operator Bitmap:

Functional Description:

The output of the *Power* operator is

$$y = (x_1)^{x_2}$$

where y is the output and x_1 and x_2 are the inputs. *Design Pad G3* will issue an error upon processing if an input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments:

The *Power* operator can be used to implement a square root operation; simply set x_2=0.5.

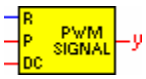
See Also:

Exponential, Multiplication

PULSE WIDTH MODULATION

Operator Menu Location: *Generators*

Operator Bitmap:



Functional Description:

The *Pulse-Width Modulation* operator generates a pulse-train waveform (alternating between LOW and HIGH) output with variable period and duty-cycle. One *period* or *cycle* of the waveform consists of a single interval of HIGH output followed by a single interval of LOW output. The period input *P*, determines the duration (in seconds) of one output cycle. The duty cycle input *DC* determines the percentage of the period that the output remains HIGH. For example, if the inputs are fixed at *P*=10 seconds and *DC*=30%, the output waveform will be HIGH for three seconds and LOW for seven seconds.

Reset input *R* restarts the waveform cycle.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments:

- If the duty cycle input is set to 0%, the output will be LOW throughout the entire cycle.

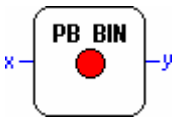
- If the duty cycle input is set to 100%, the output will be HIGH throughout the entire cycle.

See Also:
Square Wave Generator, Sine Wave Generator, Cosine Wave Generator

PUSH BUTTON (BINARY)

Operator Menu Location: *Generic Hardware Operators* → *Push Buttons*

Operator Bitmap:



Functional Description:

The *Binary Push Button* generic hardware operator provides access to a pushbutton resource in the physical hardware. When the generic operator is linked to a specific hardware resource, its output value will relate to the physical state of that resource.

The *Binary Push Button* can be configured in one of three modes: *momentary*, *toggling*, or *latching*. In *momentary* mode, the operator output will directly correspond to the current state of the physical button, such that output $y_1 = \text{HIGH}$ while the button is depressed and $y_1 = \text{LOW}$ otherwise.

In *toggling* mode, the operator output will switch between $y_1 = \text{LOW}$ and $y_1 = \text{HIGH}$ each time the physical button is depressed. Assuming the operator initial state is LOW, its output will toggle HIGH when the button is depressed. It will remain HIGH while the button remains depressed and after it is released. If it is depressed again, it will then toggle back to LOW.

In *latching* mode, the operator output will latch HIGH when the physical button is depressed. When the button is subsequently released/depressed, the output will remain HIGH. The output will reset to LOW, if reset input x = HIGH.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output of the operator at startup.

Button Type. The operator mode: *momentary*, *toggling*, or *latching*.

Display Reset Input. This property determines if the reset input pin x is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

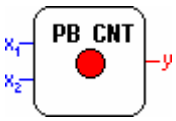
Comments: None.

See Also: Push Button (Counting)

PUSH BUTTON (COUNTING)

Operator Menu Location: *Generic Hardware Operators* → *Push Buttons*

Operator Bitmap:



Functional Description:

The *Counting Push Button* generic hardware operator provides access to a pushbutton resource in the physical hardware. When the generic operator is linked to a specific hardware resource, its output value will relate to the physical state of that resource.

The *Counting Push Button* maintains a count of the number of times the corresponding physical button has been depressed. When the direction input is $x_2 = \text{HIGH}$, the operator output will increment by r where r is a user-defined *Increment Magnitude* parameter. When the direction input is $x_2 = \text{LOW}$, the operator output will decrement by r.

The output count is limited by user-defined parameters *Minimum Count* and *Maximum Count*. The output count can be arranged to automatically rollover when these limits are exceeded.

User-Defined Properties:

Object Name. A string label that identifies the operator

Minimum Count. The minimum output of the operator. A decrement action will not result in the output being lower than this value.

Maximum Count. The maximum output of the operator. An increment action will not result in the output being higher than this value.

Initial Count. The operator output at startup, $y(0)$.

Increment Magnitude. The magnitude of the adjustment made to the operator output while the physical pushbutton is depressed.

Delay Before Key Repeat.

Key Repeat Time.

Automatic Rollower.

Display Reset Input. This property determines if the reset input pin x_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Up/Down Count Input. This property determines if the direction input pin x_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

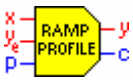
Comments: None.

See Also: Push Button (Binary)

RAMP PROFILE

Operator Menu Location: *Generators*

Operator Bitmap:



Functional Description:

The *Ramp Profile* operator produces a sequence of linear ramps defined by an eleven-point (time, output value) data set:

$$\{(t_i, y_i) | 0 \le t_i \le t_{i+1}\}$$

The operator has two analog inputs x and y_e, one digital input p, one analog output y, and one digital output c. Digital input p activates the ramp sequence. While p is LOW, the operator tracks the input, *i.e.*, $y(t)=x(t)$. While p is HIGH, the operator executes the ramp sequence, beginning with the ramp segment where the output value matches the input y_e. That is, the output y of the ramp profile operator is

$$y(t) = \begin{cases} x(t) & \text{if} \quad p = \text{LOW} \\ y_0 & \text{if} \quad p = \text{HIGH AND } t - t_p < t_0 \\ t_i + (y_{i+1} - y_i)\dfrac{t - t_p - t_i}{t_{i+1} - t_i} & \text{if} \quad p = \text{HIGH AND } t_i \le t - t_p < t_{i+1} \quad (i = 0,1,...,9) \\ y_{10} & \text{if} \quad p = \text{HIGH AND } t - t_p \ge t_{10} \end{cases}$$

where t_p is a time reference indicating when the ramp sequence begins. If input y_e is not connected, then t_p is equal to the instant that digital input p switches to high (*i.e.*, $t_p = t_{sp}$). Otherwise, if input y_e is connected, then the time reference t_p is determined from:

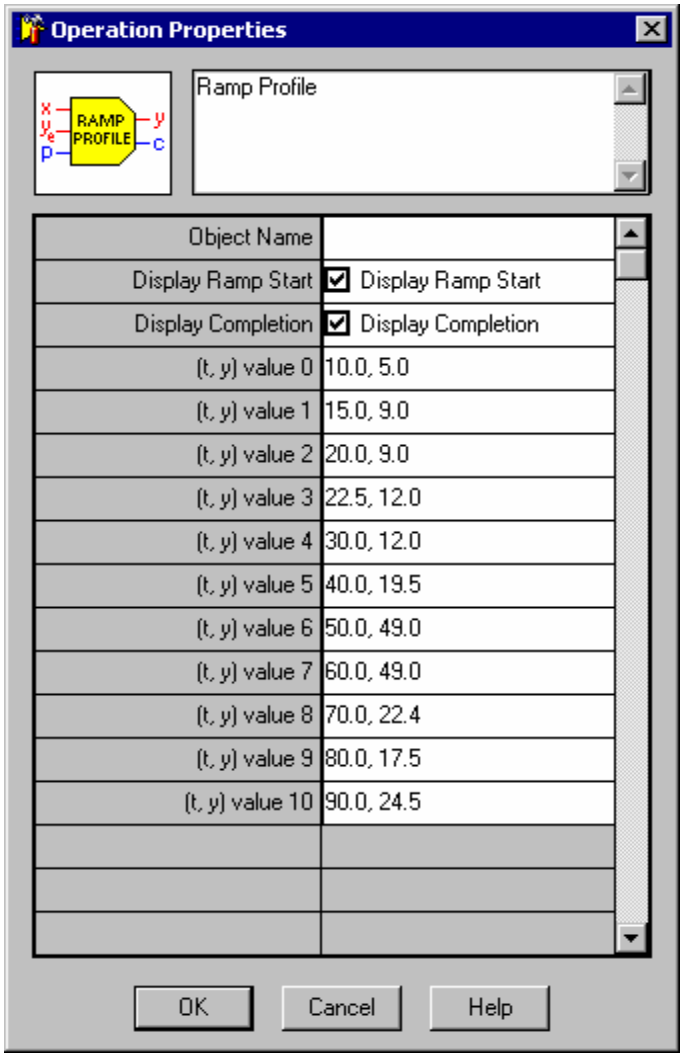
$$t_p = t_{sp} + \frac{(t_{i+1} - t_i)(y_e - y_i)}{y_{i+1} - y_i}$$

for the smallest index $i \in [0,9]$ that satisfies either $y_i \le y_e \le y_{i+1}$ or $y_i \ge y_e \ge y_{i+1}$. If no such index exists (*i.e.*, if $y_e > \max y_i$ and $y_e < \min y_i$) then the entire ramp sequence is executed (*i.e.*, $t_p = t_{sp}$).

Digital output *c* indicates when the ramp sequence is complete. It is defined by

$$c = \begin{cases} \text{HIGH} & \text{if} \quad p = \text{HIGH} \ \text{AND} \ t - t_p \ge t_{10} \\ \text{LOW} & \text{if} \quad \text{otherwise} \end{cases}$$

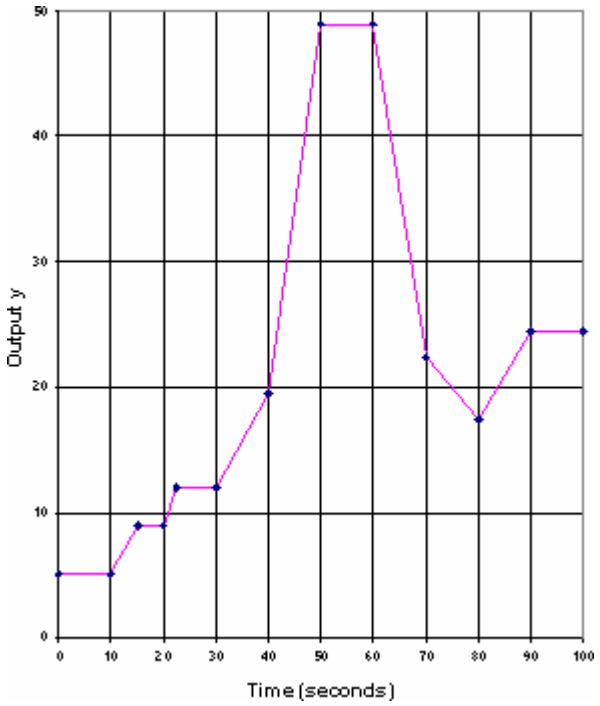
Consider the property sheet shown below for a sample ramp profile operator. When input *p* activates the operator, the portion of the ramp sequence that will be executed will depend on the value of input y_e at the activation time.

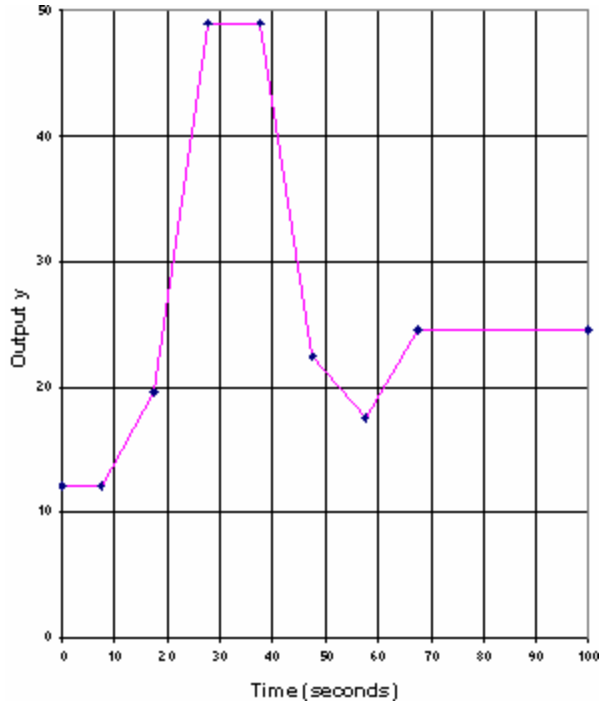


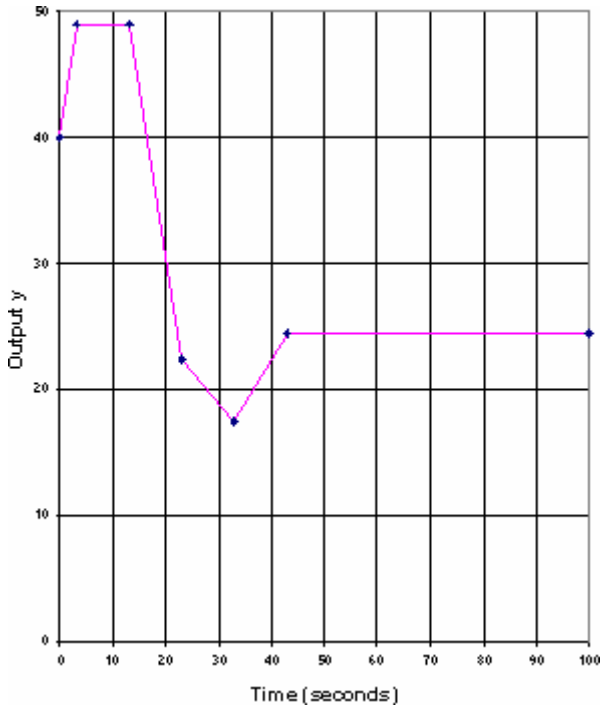
If input y_e is not connected then the entire ramp sequence will be executed, as shown in the figure below. The entire sequence will also be executed if input y_e is outside of the ramp range (*i.e.*, if $y_e < 5.0$ or $y_e > 49.0$).

When input y_e is connected, the operator will begin the ramp sequence with the first output value matching y_e. For instance, when $y_e = 12.0$, the ramp output will begin with the fourth segment of the ramp sequence (skipping the first 22.5 seconds).

And when $y_e = 40.0$, the output will begin with the seventh segment of the ramp sequence (skipping the first 46.77 seconds).







User-Defined Properties:

Object Name. A string label that identifies the operator

Initial Condition. The output value on startup (at time *t*=0)

$(\mathbf{t}_0, \mathbf{y}_0)$**.** First (time, output value) data pair in ramp sequence

$(\mathbf{t_1}, \mathbf{y_1})$**.** Second (time, output value) data pair in ramp sequence

…

$(\mathbf{t_{10}}, \mathbf{y_{10}})$**.** Last (time, output value) data pair in ramp sequence

Comments:

- The time coordinates must be non-negative and may not exceed 8,388 seconds (139.8 minutes), *i.e.*, $0 \le t_i \le 8388, i = 0,1,...,10$

- The time coordinates of the ramp sequence must be monotonically increasing, *i.e.*, $t_i \le t_{i+1}, i = 0,1,...,9$

- Output *y* will be discontinuous if $y_0 \neq x(t_p)$

See Also: Characterizer

RANDOM NUMBER GENERATOR (UNIFORM)

Operator Menu Location: *Generators*

Operator Bitmap:

Functional Description:

The *Uniform Random Number* generator produces a pseudo-random number with uniform distribution in the range [*A*,*B*].

Computer generated pseudo-random numbers are deterministic sequences with statistical properties that make them appear to be truly random. The sequence is typically "seeded" with a starting number. The same seed will yield the same sequence.

The operator has an enable input pin which can be optionally connected to turn off random number generation. When the generator is disabled, it's output is set to zero.

User-Defined Properties:

Object Name. A string label that identifies the operator

Minimum Value. The minimum output value, *A*

Maximum Value. The maximum output value, *B*

Seed (0 - use clock). The seed for the random sequence. If set to 0, the seed will be initialized according to the internal clock state. Using the clock to seed the random number generator, will generally yield a different random number sequence.

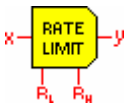
Display Enable Input. This property determines if the enable input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments: None.

RATE LIMITER

Operator Menu Location: *Signal Conditioning*

Operator Bitmap:



Functional Description:

The *Rate Limiter* operator restricts a signal's rate of change to a specified operating band: It prevents a signal from growing faster than the rising rate limit, input $R^+(t)$. And, it prevents a signal from decreasing in value faster than the fall rate limit, $R^-(t)$.

In mathematical terms, the rate limiter output is defined by

$$y(t) = \begin{cases} y(t-\Delta t) + R^+(t)\Delta t & \text{if} \quad x(t) \geq x(t-\Delta t) \quad \text{and} \quad \Delta x \geq R^+(t)\Delta t \\ y(t-\Delta t) + \Delta x \Delta t & \text{if} \quad x(t) \geq x(t-\Delta t) \quad \text{and} \quad \Delta x < R^+(t)\Delta t \\ y(t-\Delta t) - R^-(t)\Delta t & \text{if} \quad x(t) < x(t-\Delta t) \quad \text{and} \quad \Delta x \geq R^-(t)\Delta t \\ y(t-\Delta t) - \Delta x \Delta t & \text{if} \quad x(t) < x(t-\Delta t) \quad \text{and} \quad \Delta x < R^-(t)\Delta t \end{cases}$$

where y is the output, $\Delta x = |x(t) - x(t-\Delta t)|$ is the change in the input value, Δt is the loop sampling time, input $R^+(t) \geq 0$ is the maximum positive rate of change, and input $R^-(t) \geq 0$ is the maximum negative rate of change.

If the rate limits will not change over time then inputs $R^+(t)$ and $R^-(t)$ need not be connected. Instead, the rate limits can be defined by the operator properties $\Delta x^+_{\max}$ and $\Delta x^-_{\max}$.

User-Defined Properties:

Object Name. A string label that identifies the operator

Rise Rate Limit. The maximum positive rate of change in the input signal, $\Delta x^+_{\max}$. Ignored if $R^+(t)$ input is connected.

Fall Rate Limit. The maximum negative rate of change in the input signal, $\Delta x^-_{\max}$. Ignored if $R^-(t)$ input is connected.

Display Rise Rate Limit Input. Determines if the input pin R^+ is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Fall Rate Limit Input. Determines if the input pin R^- is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

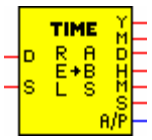
Comments: None.

See Also: Limiter, Delay Element

RELATIVE TO ABSOLUTE TIME

Operator Menu Location: *Time*

Operator Bitmap:



Functional Description:

The *Relative to Absolute Time* operator converts a relative representation of a date/time—consisting of the number of days and seconds since the epoch (midnight on December 31, 1999)—into an absolute representation, fully defined with MM/DD/YYYY and HH:MM:SS.

The operator has two inputs: the number of days (x_1) and seconds (x_2) since the epoch representing the date/time to be converted. The number of seconds input refers to the fractional part of a day and can range from 0 to 60×60×24-1=86,399.

The operator has three outputs for the date, including the year (y_1), month (y_2), and day (y_3). And three outputs for the time, including the hour (y_4), minutes (y_5), seconds (y_6). If the time is to be represented in 12-hour mode, a seventh output y_7 is used to indicate if the time is before noon (AM) or after noon (PM). A LOW value represents AM and a HIGH value represents PM.

Using a relative representation for a date/time is convenient for performing date arithmetic (*e.g.*, finding the difference between two dates). An *inverse* operator is available to convert an absolute date/time representation into an relative one—see the *Absolute To Relative Time* operator.

User-Defined Properties:

Object Name. A string label that identifies the operator

Absolute Time Format. The time format represented by outputs $y_4,..., y_7$; either 12-hour or 24-hour.

Comments: None.

See Also:
Relative To Absolute Time, Calendar, Time-of-Day Clock, Alarm Clock

RESET COUNTER

Operator Menu Location: *Generic Hardware Operators* → *Miscellaneous*

Operator Bitmap:

Functional Description:

The *Reset Counter* generic hardware operator provides access to module statistics. When the generic operator is linked to a specific module, the operator reports the number of times that the module power has been cycled since the schema containing the operator was last downloaded into the device.

Output *y* represents the reset count.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also: Self-Diagnostics

ROUNDING

Operator Menu Location: *Math Functions*

Operator Bitmap:

Functional Description:

The *Rounding* operator determines the integer component of a floating-point value. It can be configured to round to the *floor* of the input value:

$$y = \lfloor x \rfloor$$

such that the floating-point input x is rounded to the largest integer less than x. For example, $\lfloor 4.9 \rfloor = 4$, $\lfloor -5 \rfloor = -5$, and $\lfloor -3.1 \rfloor = -4$. It can also be configured to round to the *ceiling* of the input value:

$$y = \lceil x \rceil$$

such that the floating-point input x is rounded to the smallest integer no less than x. For example, $\lceil 4.4 \rceil = 5$, $\lceil -5 \rceil = -5$, and $\lceil -3.6 \rceil = -3$.

The *Rounding* operator can also be configured to round towards zero, or

$$y = \begin{cases} \lfloor x \rfloor & \text{if} \quad x \geq 0 \\ \lceil x \rceil & \text{if} \quad x < 0 \end{cases}$$

Alternatively, the operator can be configured to round to the nearest integer. Mathematically, the relationship can be expressed as:

$$y = \lfloor x + 0.5 \rfloor$$

Design Pad G3 will issue an error upon processing if the input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Rounding. The rounding behavior of the operator: *floor*, *ceiling*, *towards zero*, or *towards nearest*.

Comments: None.

See Also: Modulo

RS FLIP-FLOP

Operator Menu Location: *Logic Functions*

Operator Bitmap:

Functional Description:

The *RS Flip-Flop* is a logic gate that *sets* its output HIGH if both the *S* ("set") input is HIGH and the *R* ("reset") input is LOW. The flip-flop *resets* its output to LOW if input *R* is HIGH and input *S* is LOW. If both *S* and *R* are LOW, the output does not change. If, both *S* and *R* are HIGH, the output will switch state. The truth table for the operator is:

R	*S*	$y(t)$
LOW	LOW	$y(t-\Delta t)$
LOW	HIGH	HIGH
HIGH	LOW	LOW
HIGH	HIGH	$\overline{y(t-\Delta t)}$

In the table, *y* represents the output, *R* is the reset input, *S* is the set input, and Δt is the loop sampling time.

Design Pad G3 will issue an error on processing if an input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) on startup (at time t=0)

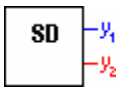
Comments: None.

See Also: D Flip-Flop

SELF-DIAGNOSTICS

Operator Menu Location: *Generic Hardware Operators* → *Miscellaneous*

Operator Bitmap:



Functional Description:

The *Self-Diagnostic* generic hardware operator provides access to a system information resource in a physical module. When the generic operator is linked to a specific module, it will trap error codes from that module.

The operator can be configured to signal when a specific error condition (*i.e.*, a specific error code) has arisen or when *any* error condition has arisen. When trapping a specific error condition, its corresponding error code number is defined in the operator property window.

Operator digital output y_1 signals when an error condition has been detected in the physical hardware. If configured to trap a specific error, the output will be HIGH only while that specific error condition is present; otherwise it remains LOW. If configured to trap all errors, the output will be HIGH when any error condition arises, and LOW when no error condition is present.

Operator analog output y_2 reports the code value of the error condition that has been detected. If no error condition is present, the output is $y_2 = 0$.

The table below provides a list of error codes and descriptions:

Error Code	Description
79	Real-Time Clock was improperly configured: invalid time setting
81	Real-Time Clock was improperly configured: invalid date setting
82-89	Analog Input 1-8 RTD sensor failure detected
91	Adjacent left-side power source failure detected
92	Adjacent right-side power source failure detected
93	Battery voltage is low
94	Maximum recommended operating temperature has been exceeded
95-113	Analog Output 1-8 wiring error detected (check for short-circuit)

114	Unit has not been calibrated
115-123	Analog Input 1-8 current too high
124	Backplane error—second master detected in node
125-133	Analog Input 1-8 current too low
134	The node configuration file has been corrupted
135	Failed to set the Real-Time Clock
136	Backplane initilization timeout
137	Invalid node position detected
138	Compute time exceeds module loop sampling time
139	File System corruption detected
141	File System does not have sufficient space
142	Could not load new node configuration
143	The new schema ID does not match the active schema
144	File System format conversion failed
145	Digital Input 'Event Timer' mode not supported

User-Defined Properties:

Object Name. A string label that identifies the operator

Filter Options. Determines if the operator is to trap a specific error or signal when any error condition is present.

Error Code to Filter On. This property only applies when the operator is configured to trap a specific error. It specifies the number of the error to be detected.

Display Error Output. This property determines if the error code output pin y_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

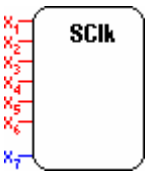
Comments: None.

See Also:
Module Hardware Information, Module Active, Module Position

SET CLOCK

Operator Menu Location: *Generic Hardware Operators* → *Time*

Operator Bitmap:



Functional Description:

The *Set Clock* generic hardware operator provides access to a real-time clock (RTC) resource in the physical hardware. When the generic operator is linked to a specific module's hardware resource, it enables updating of that module's RTC.

The operator has six analog inputs ($x_1,...,x_6$) and two digital inputs (x_7, x_8). If the operator is configured for a rising-edge trigger, it will update the RTC when digital input x_8 switches from LOW to HIGH. If it is configured for a falling-edge trigger, it will update the RTC when x_8 switches from HIGH to LOW.

Upon triggering, the operator will set the RTC with input values $x_1,...,x_7$ representing the desired date/time. The time to be set can be represented in 24-hour or 12-hour format. The inputs are:

Input Label	Signal	Range
x_1	Year	
x_2	Month	1-12
x_3	Day	1-31
x_4	Hour	0-23 (24-hour format) or 1-12 (12-hour format)
x_5	Minutes	0-59
x_6	Seconds	0-59
x_7	AM/PM	

Input x_7 is only applicable in 12-hour format (the input pin will not be visible in the schema when the operator is configured for 24-hour format). In 12-hour format, a LOW input value corresponds to an *Ante Meridiem* time (*before noon*). A HIGH input value represents a *Post Meridiem* time (*after noon*).

User-Defined Properties:

Object Name. A string label that identifies the operator

Time Format. The format that the time is expressed in; either 24-hour or 12-hour (with AM/PM designation)

Enable On. Indicates when the RTC update should occur. If enabled on *Rising Edge*, the RTC will be updated when input x_8 switches from LOW to HIGH. If enabled on *Falling Edge*, the RTC will be updated when input x_8 switches from HIGH to LOW.

Comments:

- If the input values do not adhere to the ranges in the table above, or if they do not represent a valid date/time, the RTC setting will not be modified.

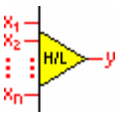
See Also:

Time-of-Day Clock, Calendar, Alarm Clock, Stopwatch

SIGNAL SELECTOR

Operator Menu Location: *Signal Switching*

Operator Bitmap:



Functional Description:

The *Signal Selector* accepts *n* input signals and produces one output signal. The output signal value is equal to the minimum or maximum input signal value. The selection of the minimum or maximum value is a property of the operator (see below). The operator ignores any input pin that is not connected when computing the minimum or maximum value.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Inputs. The number of input pins *n*, where $2 \leq n \leq 6$

Signal Select. Determines if the operator should select the minimum input signal value, or the maximum input signal value

Comments: None.

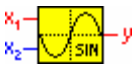
See Also:

=, ≠, >, ≥, <, and ≤ Comparators; Multiplexer; Demultiplexer

SINE WAVE GENERATOR

Operator Menu Location: *Generators*

Operator Bitmap:



Functional Description:

The output of the *Sine Wave Generator* is

$$y(t) = A\sin 2\pi x_1(t)t$$

where y is the output, x_1 is the input frequency in hertz, and A is the amplitude.

The operator has an enable input pin, x_2 which can be optionally connected to turn off the generator. That is, when x_2 is LOW, the output is $y(t)=0$.

If the generator frequency does not need to change over time, input $x_1(t)$ need not be connected. Instead, the frequency can be defined by the operator property f and the generator output will be

$$y(t)=A\sin 2\pi ft$$

User-Defined Properties:

Object Name. A string label that identifies the operator

Amplitude. The sine wave amplitude, A

Frequency. The sine wave frequency in hertz. This parameter is ignored if the frequency input x_1 is connected.

Display Frequency Input. This property determines if the frequency input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Enable Input. This property determines if the enable input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

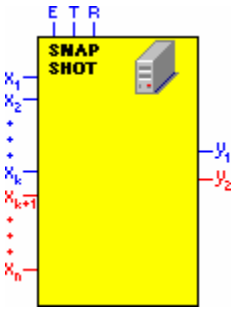
Comments: None.

See Also: Cosine Wave Generator

SNAPSHOT RECORDER

Operator Menu Location: *Data Logging and Recording*

Operator Bitmap:



Functional Description:

The *Snapshot Recorder* logs signal data to non-volatile memory for long-term storage. It records event-triggered signal "snapshots" of defined durations. When triggered, the operator will record signal samples for a user-defined time-period following the trigger event as well as signal samples that preceded the event.

The operator records data only while its enable input *E* is HIGH. If *E* is LOW the operator ignores its signal inputs. The operator begins logging data to non-volatile memory when trigger input *T* switches from LOW to HIGH. Once triggered, the operator records an entire snapshot (even if trigger input *T* switches back to LOW). After snapshot recording completes, input *T* must switch to LOW and then back to HIGH to trigger another snapshot recording (*i.e.*, input is edge-triggered).

While the operator is enabled but not triggered, it records all signal data in RAM. The number of samples it maintains in RAM is determined by the operator property *Number of Samples Before Trigger*. When the operator is triggered these signal samples stored in RAM are copied to non-volatile memory. Post trigger event samples are then appended to complete the snapshot.

Reset input *R* clears all recorded information in the data log (non-volatile memory) as well as any recent samples stored in RAM.

The operator can record a number of signals in each sample—the user defines how many signals are to be recorded. The sampling frequency and total number of samples to store in each snapshot are also properties of the operator.

The operator time-stamps every signal sample within a snapshot that it records. The time-stamp is based on the underlying hardware's real-time clock and includes the date (MM/DD/YYY) and time (HH:MM:SS.MMM).

The operator can record multiple snapshot events (the number of snapshots to record is a property of the operator). Once the operator has recorded all of the required snapshots (*i.e.*, has filled up its memory buffer) it sets its output pin y_1 HIGH. Output y_1 remains LOW until all snapshots are recorded. The operator can be configured to overwrite the oldest snapshots if triggered while full.

Operator output y_2 indicates the number of snapshots that have been recorded, including a snapshot recording that may be in progress. If the operator is reset (*e.g.*, *R* = HIGH), the snapshot count output will be reset to 0.

To retrieve the data set recorded by the operator, select the *Query Data Recorder Resources* item from the *Communications* menu in *Design Pad G3* or *Schema Viewer G3* (while establishing a wired or wireless connection with the hardware). The application will retrieve all data sets stored in the target hardware and identify each set with the name assigned to the operator. Once the data set is selected, the application will retrieve the log file from the hardware and prompt the user to save to disk on the PC. The format of the file is tab-delimited text, permitting import to data analysis and charting programs such as Microsoft Excel.

User-Defined Properties:

Data Set Name. The name used to identify the data set recorded by this operator.

Number of Digital Inputs. The quantity of *boolean* type input signals to be recorded.

Number of Analog Inputs. The quantity of *float* type input signals to be recorded.

Number of Snapshots to Store. The quantity of signal data sets (snapshots) to be recorded.

Overwrite Old Snapshots When Full? . When the data recorder has stored all of the requested snapshots, it can either discard the oldest snapshot to record a new one, or stop recording any new snapshots.

Record Interval. The time (in milliseconds) that must elapse between consecutive recorded samples. The default value is 60,000 milliseconds, specifying that signals are to be recorded once every minute.

Number of Samples per Snapshot. The total number of samples to be recorded in a single snapshot data set. The default value is 1,440; with a *Record Interval* value of one minute (60,000 milliseconds), this setting specifies that the operator is to maintain one day (60×24=1,440) of data per snapshot.

Number of Samples Before Trigger Event. The number of signal samples temporally preceding the trigger event that are to be recorded in the snapshot. This value must be less than the total number of samples to store in the snapshot (previous property).

Display Enable Input. This property determines if input pin *E* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Analog Input. This property determines if input pin *R* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Memory Full Output. This property determines if output pin y_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Snapshot Count Output. This property determines if input pin y_2 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments:

- The amount of non-volatile memory consumed by each sample is

$$M_{Sample} = 4 \times N_{AI} + \left\lceil \frac{N_{DI}}{8} \right\rceil + 6$$

  where N_{AI} is the number of analog inputs, N_{DI} is the number of digital inputs, and where $\lceil \cdot \rceil$ denotes the *ceiling* operation (meaning round up to the nearest whole number). The elements of the formula suggest that each analog input sample requires 4 bytes, digital input samples are packaged into single 8-bit byte chunks, and the time stamp requires 6 bytes.

- The total amount of non-volatile memory consumed by the operator is

$$M = \left\lceil M_{Sample} \times N_{SC} \times N_{SS} \times \frac{M_S}{M_S - 3} \right\rceil$$

where N_{SC} is the number of snapshots, N_{SS} is the total number of samples per snapshot, and M_S is the sector-size of the non-volatile memory medium (typically $M_S = 512$ bytes for Chameleon modules). The last element of the formula above includes a 3-byte sector stamp used for internal file management purposes. The result of the computation above should be rounded up to the nearest M_S bytes. For example, if $N_{AI} = 4$, $N_{DI} = 6$, $N_{SC} = 4$, $N_{SS} = 1000$, and $M_S = 512$, then

$$M = \left\lceil \left(4 \times 4 + \left\lceil \frac{6}{8} \right\rceil + 6 \right) \times 4 \times 1000 \times \frac{512}{509} \right\rceil = 92543$$

The total memory consumed is obtained by rounding up 92543 to the nearest integer divisible by 512; the result is 92672.

- If the operator is triggered shortly after it was reset, it may not have all samples preceding the trigger event that the user indicated must be recorded.

- If enable input *E* switches to LOW after the operator is triggered but before a snapshot has been fully captured, the operator will cease recording data until re-enabled. When it is re-enabled it will record any remaining samples it did not store prior to disabling.

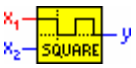
- Multiple data recorders can be included in the same schema / hardware module. The limiting factor is the amount of non-volatile memory (*e.g.*, flash memory) available in the target hardware module.

See Also: Snapshot Recorder

SQUARE WAVE GENERATOR

Operator Menu Location: *Generators*

Operator Bitmap:



Functional Description:

The *Square Wave Generator* produces a periodic output alternating between LOW and HIGH; LOW is output over half of the period and HIGH during the other half.

The wave frequency (the inverse of the wave period) is determined by input x_1. Mathematically, the operator output *y* can be expressed as

$$y(t) = \begin{cases} \text{LOW} & \text{if} \quad t_0 \le t < t_0 + \dfrac{1}{2x_1(t)} \\ \text{HIGH} & \text{if} \quad t_0 + \dfrac{1}{2x_1(t)} \le t < t_0 + \dfrac{1}{x_1(t)} \end{cases}$$

where t_0 denotes the start of a wave cycle.

The operator has an enable input pin x_2 which can be optionally connected to turn off the generator. That is, when x_2 is LOW, the output is $y(t)$ = LOW.

If the generator frequency does not need to change over time, input $x_1(t)$ need not be connected. Instead, the frequency can be defined by the operator property *f*.

User-Defined Properties:

Object Name. A string label that identifies the operator

Frequency. The square wave frequency in hertz. This parameter is ignored if the frequency input x_1 is connected.

Display Frequency Input. This property determines if the frequency input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Enable Input. This property determines if the enable input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

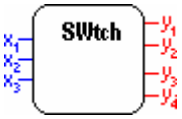
Comments: None.

See Also: Pulse Width Modulation, Timer

STOP WATCH

Operator Menu Location: *Generic Hardware Operators* → *Time*

Operator Bitmap:



Functional Description:

The *Stopwatch* generic hardware operator provides access to a real-time clock resource in the physical hardware. When the generic operator is linked to a specific hardware resource, the operator performs event-timing functions. The *Stopwatch* measures long-duration events (*e.g.*, years) with a one-second resolution.

The operator has three digital inputs and four analog outputs. The outputs indicate the cumulative duration of timed events since the stopwatch was last reset, measured in days (y_0), hours (y_1), minutes (y_2), and seconds (y_3). The output ranges are:

$$y_0 \geq 0$$
$$0 \leq y_1 \leq 23$$
$$0 \leq y_2 \leq 59$$
$$0 \leq y_3 \leq 59$$

Start/stop input x_0 enables the timer. When $x_0 = \text{HIGH}$, the stopwatch is activated (*e.g.*, the clock is running); when $x_0 = \text{LOW}$, the stopwatch is stopped. If the stopwatch is started, then stopped, and then started again, the timer is not cleared—it maintains the cumulative duration of time that the stopwatch has been active.

Reset input x_2 clears the timer (*i.e.*, sets $y_i = 0$ for *i*=1,2,3,4).

Track & hold input x_1 can freeze the output values while the timer remains activated. When $x_1 = \text{LOW}$, the outputs follow the internal clock count. When $x_1 = \text{HIGH}$, the output values are fixed even while the stopwatch continues to run (while $x_0 = \text{HIGH}$). When x_1 switches from HIGH to LOW while the stopwatch remains active, the outputs will be discontinuous (*i.e.*, they will jump from their frozen values to the current internal timer duration).

User-Defined Properties:

Object Name. A string label that identifies the operator

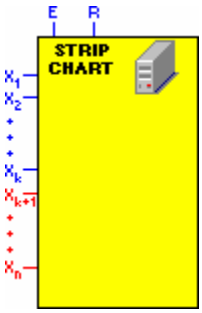
Comments: None.

See Also:
Time-of-Day Clock, Set Clock, Alarm Clock, Timer, Event Timer Digital Input

STRIPCHART RECORDER

Operator Menu Location: *Data Logging and Recording*

Operator Bitmap:



Functional Description:

The *Strip-Chart Recorder* logs signal data to non-volatile memory for long-term storage. The operator time-stamps every sample set it records. The time-stamp is based on the underlying hardware's real-time clock and includes the date (MM/DD/YYY) and time (HH:MM:SS.MMM). When the operator's memory buffer fills up, it discards the oldest records in the log to make room for new samples.

The *Strip-Chart Recorder* has a variable number of inputs—the user defines how many signals are to be recorded. The sampling frequency and total number of samples to store are also properties of the operator.
The operator records data only while enable input *E* is HIGH. If *E* is LOW the operator ignores its signal inputs. Reset input *R* clears all recorded information in the data log.

To retrieve the data set recorded by the operator, select the *Query Data Recorder Resources* item from the *Communications* menu in *Design Pad G3* or *Schema Viewer G3* (while establishing a wired or wireless connection with the hardware). The application will retrieve all data sets stored in the target hardware and identify each set with the name assigned to the operator. Once the data set is selected, the application will retrieve the log file from the hardware and prompt the user to save to disk on the PC. The format of the file is tab-delimited text, permitting import to data analysis and charting programs such as Microsoft Excel.

User-Defined Properties:

Data Set Name. The name used to identify the data set recorded by this operator.

Number of Digital Inputs. The quantity of *boolean* type input signals to be recorded.

Number of Analog Inputs. The quantity of *float* type input signals to be recorded.

Record Interval. The time that must elapse between consecutive recorded samples in milliseconds. The default value is 60,000 milliseconds, specifying that signals are to be recorded once every minute.

Number of Samples to Store. The total number of samples to be recorded in the data set. Once all samples are recorded, the oldest samples will be discarded to make room for new samples. The default value is 1,440; with a *Record Interval* value of one minute (60,000 milliseconds), this setting specifies that the operator is to maintain one day (60×24=1,440) of data.

Display Enable Input. This property determines if input pin *E* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Display Analog Input. This property determines if input pin *R* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments:

- The amount of non-volatile memory consumed by each sample is

$$M_{Sample} = 4 \times N_{AI} + \left\lceil \frac{N_{DI}}{8} \right\rceil + 6$$

where N_{AI} is the number of analog inputs, N_{DI} is the number of digital inputs, and where $\lceil \cdot \rceil$ denotes the *ceiling* operation (meaning round up to the nearest whole number). The elements of the formula suggest that each analog input sample requires 4 bytes, digital input samples are packaged into single 8-bit byte chunks, and the time stamp requires 6 bytes.

- The total amount of non-volatile memory consumed by the operator is

$$M = \left\lceil M_{Sample} \times N_{SS} \times \frac{M_S}{M_S - 3} \right\rceil$$

where N_{SS} is the total number of samples per snapshot, and M_S is the sector-size of the non-volatile memory medium (typically $M_S = 512$ bytes for Chameleon modules). The last element of the formula above includes a 3-byte sector stamp used for internal file management purposes. The result of the computation above

should be rounded up to the nearest M_S bytes. For example, if $N_{AI} = 4$, $N_{DI} = 6$, $N_{SS} = 1000$, and $M_S = 512$, then

$$M = \left\lceil \left(4 \times 4 + \left\lceil \frac{6}{8} \right\rceil + 6 \right) \times 1000 \times \frac{512}{509} \right\rceil = 23136$$

The total memory consumed is obtained by rounding up 23136 to the nearest integer divisible by 512; the result is 23552.

- Multiple data recorders can be included in the same schema / hardware module. The limiting factor is the amount of non-volatile memory (*e.g.*, flash memory) available in the target hardware module.

See Also: Snapshot Recorder

SUB-SCHEMA (FUNCTION BLOCK)

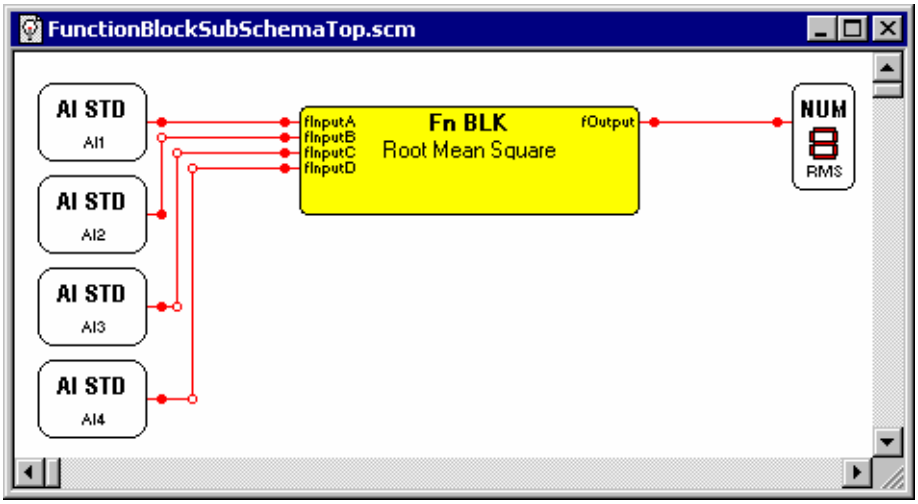
Operator Menu Location: *Sub-Schemas*

Operator Bitmap:

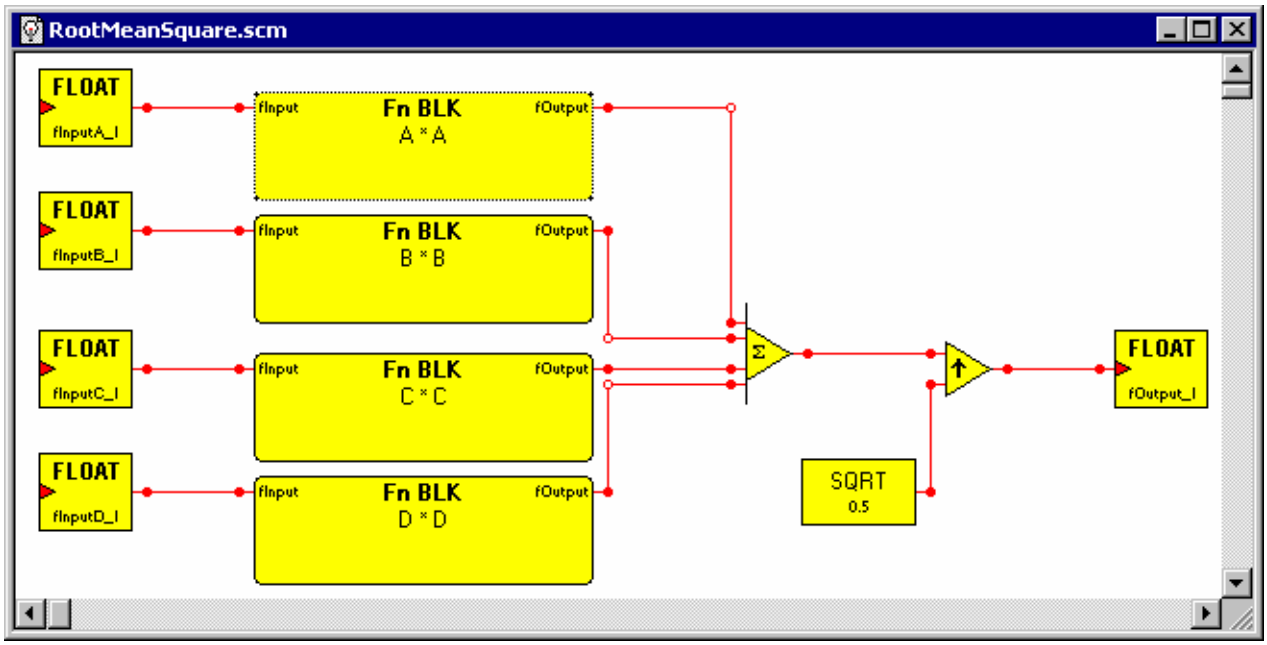
Functional Description:

The *Function Block Sub-Schema* operator is a user-defined custom operator. Its input/output definition (quantity/type) and its functional behavior (I/O mapping) are defined by a collection of interconnected graphical operators (a sub-schema).

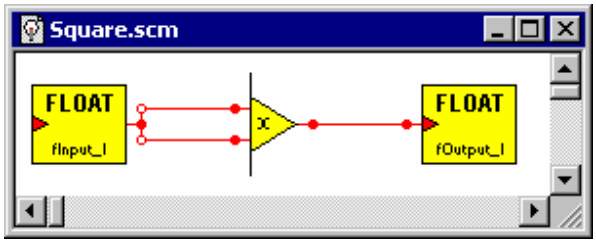
A *Function Block Sub-Schema* can itself contain other *Function Block Sub-Schema* operators which themselves contain yet other *Function Block Sub-Schema* operators. The example schemas below illustrate this point. The schema diagram below contains a single *Function Block Sub-Schema* operator with four analog inputs and one analog output.



The underlying schema for the function block is shown below. It computes the root mean square (RMS) of its inputs and applies the result to its output (*i.e.*, it computes the square root of the sum of the squares of the inputs).



Each input pin in the parent schema's *Function Block Sub-Schema* operator graphic corresponds to a like-named *Float Variable* operator in the subschema. For instance, the input labeled "fInputA" in the sub-schema graphic corresponds to the variable named "fInputA". That is, the variable named "fInputA" takes on the value applied to the sub-schema input pin labeled "fInputA".



The RMS sub-schema itself contains four *Function Block Sub-Schema* operators. Each sub-schema operator computes the square of its input signal as shown below:

Each function block diagram shown above represents an independent schema (.scm) file. The example above includes three schema files: `FunctionBlockExample.scm` (Figure A), `RootMeanSquare.scm` (Figure B), and `Square.scm` (Figure C).

A *Function Block Sub-Schema* must be *linked to* or associated with a schema (.scm) file that contains the desired functional behavior. In the example above, the sub-schema operator labeled "Root Mean Square" in Figure (A) is linked to the `RootMeanSquare.scm` schema of Figure B, and the four sub-schema operators in Figure (B) are individually linked to the `Square.scm` schema of Figure (C). Each sub-schema operator in Figure (B) represents a distinct instance of the `Square.scm` schema.

Unlike most operators, the *Function Block Sub-Schema* is not configured thru a property sheet. Instead, its configuration is defined by attributes of the linked schema file (e.g., quantity and type of I/O) and thru a drop-down menu. This drop-down menu is accessed by right-clicking on the operator icon graphic. It contains commands to manage the operator's link to a schema file. For instance, to link an existing schema file to the operator, select the *Link Existing Schema* item, and use the *File Open* dialog to select the desired file.

The schema link is stored as a relative file path to the parent schema. The link can be manually edited by selecting the *Edit Schema Link* item from the drop-down menu. This command is useful if the schema file is renamed or moved to a different directory outside of the *Design Pad G3*environment. The schema link can be removed altogether by selecting the *Unlink Schema* item from the drop-down menu.

Once a schema file is associated with a *Function Block Sub-Schema* operator, the file can be opened by double-clicking the left mouse button on the sub-schema graphic. The file can also be opened by selecting the *Open Linked Schema* item from the drop-down menu.

As indicated above, the operator's input and output pins correspond to like-named *Variable* operators in the linked sub-schema file. The input-pin type (*e.g.*, analog or digital) must also correspond to the *Variable* operator type (*e.g.*, Float or Boolean). Variables in the sub-schema file that are to serve as sub-schema inputs or sub-schema outputs must be explicitly identified as such. This is done within the *Sub-Schema Setup* dialog—to view the dialog select the *Sub-Schema Setup* item from the *Schema* menu. The dialog box (as pictured below) contains a list control (top left quadrant) and two list-boxes (top right quadrant) that identify sub-schema inputs and outputs. The list control on the left contains all sub-schema file *Variable* operators of *Local* scope (only variables with local scope can serve as sub-schema I/O). The two list-boxes on the right contain the subset of variables that are to serve as I/O. The ordering of the variables in the list-boxes correspond to the ordering of the I/O pins in the sub-schema operator graphic. To change the pin order, simply drag the variable name from one position in the list-box to another. To identify a variable as a sub-schema input or output, select "YES" in the combo-box in the appropriate column and then click the *Update* button. (The changes are then reflected in the list-boxes on the right.)

Function Block Sub-Schema operators can be configured to execute conditionally or periodically. (This is defined in the *When to Compute* group control located in the lower left quadrant of the *Sub-Schema Setup* dialog). The *Enable On* combo determines when the underlying sub-schema file is to execute. If set to *Always Enabled*, the sub-schema will execute periodically, with a user-defined updated rate (the *Periodic Compute Time*). The sub-schema can be configured to execute at the same frequency as its parent schema executes or at a different user-specified frequency.

When the *Enable On* property is set for conditional execution the operator will include a digital input pin that dictates when the underlying sub-schema file is to execute. If set to

Rising Edge, the sub-schema will execute at the instant that the digital input switches from LOW to HIGH. If set to *Falling Edge*, the sub-schema will execute at the instant that the digital input switches from HIGH to LOW. If set to *Active High* or *Active Low*, the sub-schema will execute whenever the input is HIGH or LOW, respectively.

Drop-Down Menu Commands:

Namespace. This property is used to uniquely identify multiple instances of the same *Variable* operator. When *Namespace* is activated, this operator's name (see *Set Label* command below) is pre-pended to *Variable* operators in the sub-schema file (or its associated sub-schemas) that have their *Pre-Pend Name* property also set to *Namespace*. A more complete description of variable namespaces can be found in the operator reference section for *Variable* operators.

Link Existing Schema. Associates an existing schema file (`.scm`) with the operator.

Link New Schema. Creates a new schema file and associates it with the operator.

Edit Schema Link. Permits manual editing of the link to the associated schema file. This is useful when the file name or path is modified outside of the *Design Pad G3*environment.

Unlink Schema. Deletes the association between the operator and schema file.

Set Label. A string label that identifies the operator. This name may be pre-pended to other operator names (*e.g.*, *FairNET Networking* operators, *Variable* operators, *etc.*) to uniquely identify them. The name is also used in a module's *Hardware Connection Window* to specify the location of generic hardware operators that have been linked to that module.

Update Operator Pins. Updates the operator graphic to reflect the input/output definition of the linked schema file. The linked schema file contains *Variable* operators of *Local* scope that have been designated as a sub-schema input or output.

Open Linked Schema. Opens the linked schema document in a new window. If the document is already open, activates the window.

Process Linked Schema. Executes the *Process Schema* command on the linked schema file. As usual, processing results (*e.g.*, errors, warnings, and other information) is displayed in the *Message Window*.

Comments:

- Only *Variable* operators with *Local* scope can be identified as sub-schema inputs or outputs.

- Sub-schemas cannot execute more frequently than their parent schemas. If the user-defined periodic compute time for the sub-schema is less than the periodic compute time of the parent schema, the sub-schema will execute whenever the parent schema executes.

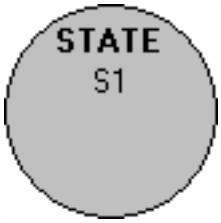
- The *Activation Behavior* setting(s) in the lower right quadrant of the *Sub-Schema Setup* dialog do not apply to *Function Block Sub-Schema* operators.

See Also:
State Sub-Schema

SUB-SCHEMA (STATE)

Operator Menu Location: *Sub-Schemas*

Operator Bitmap:



Functional Description:

The *State Sub-Schema* operator enables the creation of state-transition diagrams to represent *finite state machines* or *directed graphs*. They can be used to implement flowcharts and/or sequential function charts.

A state-transition diagram consists of a set of *State Sub-Schema* operators interconnected by directed arcs (transitions). Each *State Sub-Schema* operator is associated with a sub-schema file that executes while the operator is *active*. Only a single state within a connected state-transition diagram may be active at any instant of time. The system will *transition* from the active state to another state when a logical condition associated with the transition arc that connects the two states is met. For example, consider a state-transition diagram having two states, *A* and *B,* and a transition arc *T* that connects state *A* to state *B*. The system will exit active state *A* to enter state *B* when transition *T* is true.

As indicated above, only a single *State Sub-Schema* operator within a state-transition diagram may be active at a given time instant. However, a schema may contain multiple disjoint state-transition diagrams that execute concurrently. (A schema may then contain multiple *State Sub-Schema* operators that are active at the same time, provided that they belong to disjoint state-transition diagrams.)

Each *State Sub-Schema* operator must be *linked to* or associated with a schema (`.scm`) file that contains the desired functional behavior to be executed while the operator is active. The sub-schema file is itself a collection of interconnected graphical operators that may include other *State Sub-Schema* operators and/or *Function Block Sub-Schema* operators (which may themselves contain sub-schema operators).

Unlike most operators, the *State Sub-Schema* operator is not configured thru a property sheet. Instead, its configuration is defined by attributes of the linked schema file and thru a drop-down menu. This drop-down menu is accessed by right-clicking on the operator

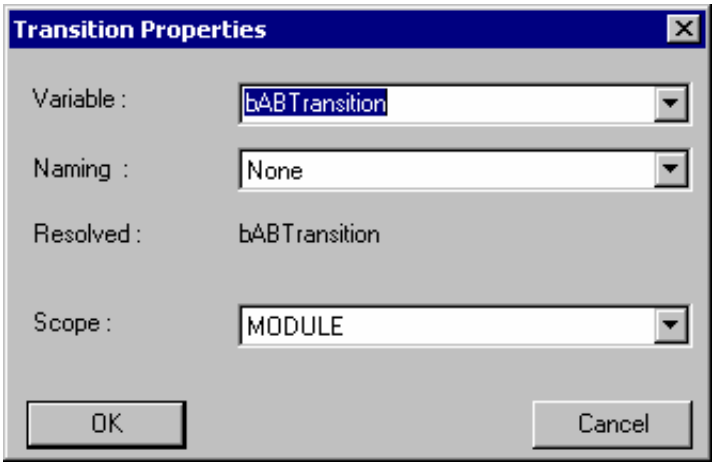
icon graphic (*i.e.*, the circle). It contains various commands to manage the operator's link to a schema file. For instance, to link an existing schema file to the operator, select the *Link Existing Schema* item, and use the *File Open* dialog to select the desired file.

The schema link is stored as a relative file path to the parent schema. The link can be manually edited by selecting the *Edit Schema Link* item from the drop-down menu. This command is useful if the schema file is renamed or moved to a different directory outside of the *Design Pad G3*environment. The schema link can be removed altogether by selecting the *Unlink Schema* item from the drop-down menu.

Once a schema file is associated with a *State Sub-Schema* operator, the file can be opened by double-clicking the left mouse button on the sub-schema graphic. The file can also be opened by selecting the *Open Linked Schema* item from the drop-down menu.

Every connected state-transition diagram must define a single state to serve as its *Initial State*. This state will be the active state when the schema first begins executing. When a *State Sub-Schema* operator is designated as the *Initial State* its graphic (gray circle) is stamped with a dark green dot.

Each transition arc must be associated with a *Boolean Variable* operator. The transition takes effect when the associated variable's value is HIGH. To associate a transition with a *Boolean Variable* operator, double-click on the arc to view the *Transition Properties* dialog shown below.



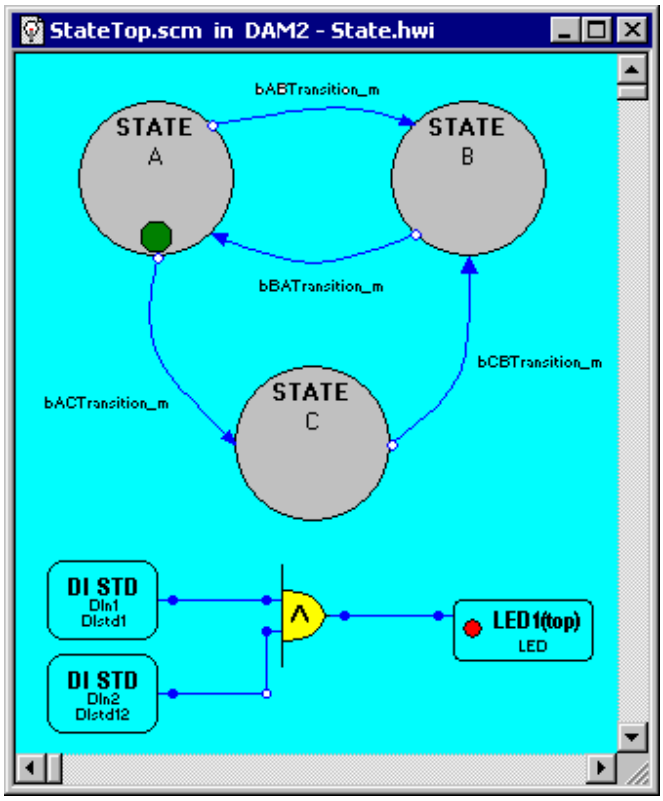
To make the link, first select the *Scope* of the *Boolean Variable* to populate the *Variable* drop-down combo. If the *Scope* is set to *Local*, then the drop-down combo will contain only *Boolean Variable* operators of *Local* scope found in the schema containing the transition arc. If the *Scope* is set to *Module*, then the drop-down combo will contain all *Boolean Variable* operators of *Module* scope found in any schema related to the module that includes the schema that contains the transition arc (including the parent schema linked to the module and any of its descendent sub-schemas). If the *Scope* is set to *Global*, then the drop-down combo will contain all *Boolean Variable* operators of *Global*

scope found in any schema related to the node that includes the schema that contains the transition arc (including the parent schema linked to each module in the node as well as any of their descendent sub-schemas).

When a state is activated (*i.e.*, when the system transitions into that state) the operators in the underlying sub-schema file can be configured to re-initialize or to continue executing where they left off when the state was last active. This distinction applies only to operators that have *memory*, meaning that the computation of their output value depends on information from the past. The *Addition* operator for instance has no memory since its output at time *t* is simply the sum of its inputs at time *t*. The *Delay Element* operator however does have memory since its current output value is equal to a past input value. For example, consider a sub-schema that contains a *Delay Element* operator that has its *Time Delay Multiple* property set to 1. If the sub-schema is configured to re-initialize upon activation, then the *Delay* operator's initial output will be equal to its user-defined initial condition. If the sub-schema is configured to retain its state upon activation, then the *Delay* operator's initial output will be equal to the input value it sampled just before the state last became inactive.

The activation behavior of a sub-schema is defined in its *Sub-Schema Setup* dialog—to view the dialog select the *Sub-Schema Setup* item from the *Schema* menu. The dialog contains a check-box control in its bottom left quadrant to set the initialization behavior. The other settings in the dialog box do not affect the behavior of the schema when linked to a *State Sub-Schema* operator.

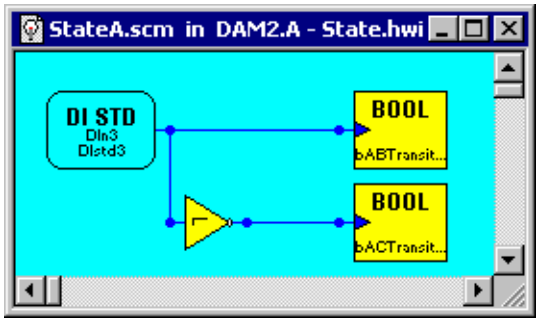
The concepts described above are best illustrated by example. Consider a hardware interface file consisting of a Chameleon node with one ACP-1 AC Power Module and one DAM-2 Discrete Automation Module linked to the schema shown in Figure (a). The schema contains a single state transition diagram with three *State Sub-Schema* operators, labeled *A*, *B*, and *C*. State *A* is designated as the initial state as indicated by the dark-green stamp in its graphic. The system can transition from state *A* to state *B*, from *B* to *A*, from *A* to *C*, and from *C* to *B*, as indicated by the directed arcs that connect the states. The transition arcs are labeled with the name of a *Boolean Variable* operator that they are associated with (for instance, the arc from *A* to *B* is associated with the *Boolean Variable* named *bABTransition*). The transition occurs when the associated *Variable* operator value is HIGH.



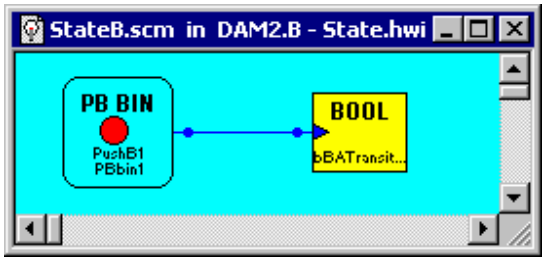
(a)

The schema diagram of Figure (a) contains a state transition diagram as well as other operators to execute digital logic (two *Digital Input* operators feed an *AND Gate* block which feeds an *LED Display* operator). At each computation interval, the schema of Figure (b) executes these digital logic functions as well as all of the operators contained in the sub-schema file linked to the currently active *State Sub-Schema* operator.

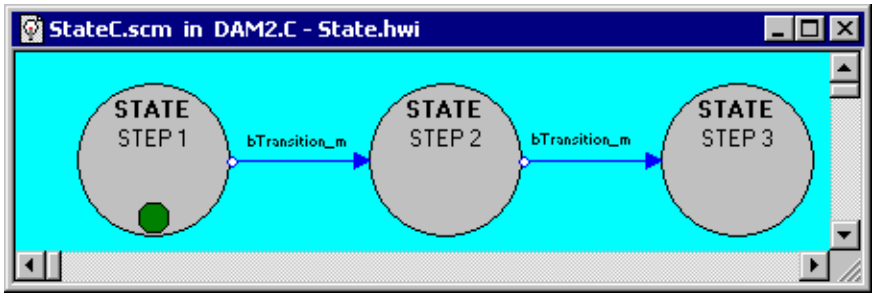
Each of the states in the Figure (a) schema is linked to the sub-schema files shown in the figures below. State *A* is linked to `StateA.scm` (Figure b); state *B* is linked to `StateB.scm` (Figure c); and state *C* is linked to `StateC.scm` (Figure d).



(b)



(c)

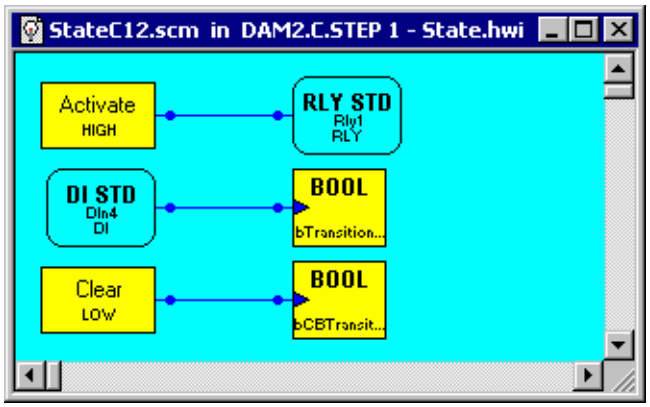


(d)

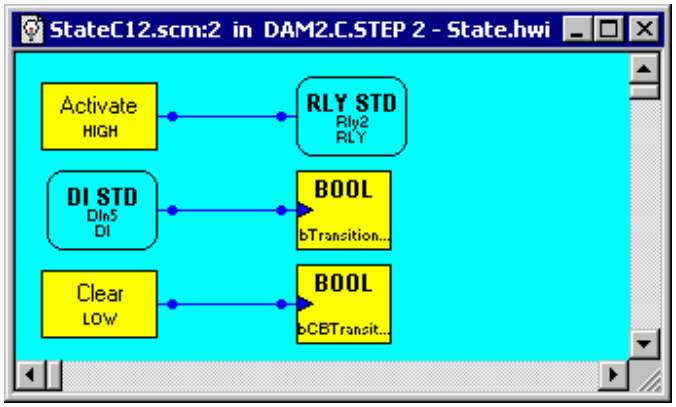
When the schema of Figure ab) first executes (*i.e.*, when the hardware powers up), state *A* is active. In the underlying sub-schema for state *A*, a *Digital Input* operator associated with the DAM-2 module's DI Channel 3 drives two *Boolean Variable* operators. These variables, named *bABTransition* and *bACTransition* are associated with transitions from state *A* to state *B* and state *A* to state *C*, respectively. When DI Channel 3 in the DAM-2 module is ON, the output of the *Digital Input* operator is HIGH, thereby setting variables *bABTransition* HIGH, and *bACTransition* LOW. With *bABTransition* HIGH the system transitions from state *A* to state *B*. (State *A* as implemented can be thought of as an *IF...THEN* statement: if DI Channel 3 is OFF, execute state *C*, otherwise execute state *B*.)

The sub-schema associated with state *B* and shown in Figure (c) simply monitors the DAM-2 module's top push-button and initiates a transition back to state *A* when the button is pressed.

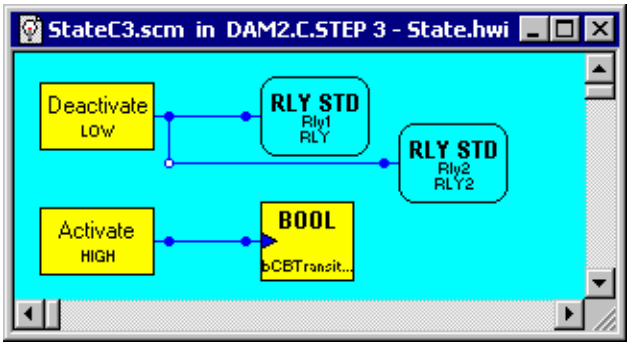
The sub-schema associated with state *C* and shown in Figure (d) itself contains another state-transition diagram that executes a three-step command sequence. The sub-schema files associated with each state (labeled *Step 1*, *Step 2*, and *Step 3*) are shown below.



(e)



(f)



(g)

Note that the same schema file (`StateC12.scm`) is associated with states *Step 1* and *Step 2*. The schema activates a relay and monitors a digital input to initiate a transition. When the schema is associated with state *Step 1*—Figure (e)—the *Relay* operator is linked to the DAM-2 module's DO Channel 1 and the *Digital Input* operator is linked to the DAM-2 module's DI Channel 4. When the schema is associated with state *Step 2*—Figure (f)—the *Relay* operator is linked to the DAM-2 module's DO Channel 2 and the *Digital Input* operator is linked to the DAM-2 module's DI Channel 5.

The schema file associated with State *Step 3* (`StateC3.scm`) is shown in Figure (g). It de-activates the two relay outputs activated during the earlier steps in the sequence, and sets the *Boolean Variable* operator named *bCBTransition* to HIGH. The latter action causes the state-transition diagram in its parent schema to switch from executing state *C* to executing state *B*.

The schema file `StateC3.scm` is configured to re-initialize its operators upon activation. As a result, each time the system enters state *C* in Figure (a), the entire sequence executes (first state *Step 1*, then state *Step 2*, and then state *Step 3*). If the schema file were not configured to re-initialize upon activation, then the system would immediately resume executing *Step 3*.

Drop-Down Menu Commands:

Namespace. This property is used to uniquely identify multiple instances of the same *Variable* operator. When *Namespace* is activated, this operator's name (see *Set Label* command below) is pre-pended to *Variable* operators in the sub-schema file (or its associated sub-schemas) that have their *Pre-Pend Name* property also set to *Namespace*. A more complete description of variable namespaces can be found in the operator reference section for *Variable* operators.

Link Existing Schema. Associates an existing schema file (`.scm`) with the operator.

Link New Schema. Creates a new schema file and associates it with the operator.

Edit Schema Link. Permits manual editing of the link to the associated schema file. This is useful when the file name or path is modified outside of the *Design Pad G3*environment.

Unlink Schema. Deletes the association between the operator and schema file

Initial State. Indicates if the state will be the active state when the system initializes.

Set State Label. A string label that identifies the operator. This name may be pre-pended to other operator names (*e.g.*, *FairNET Networking* operators, *Variable* operators, *etc*.) to uniquely identify them. The name is also used in a module's *Hardware Connection Window* to specify the location of generic hardware operators that have been linked to that module.

Open Linked Schema. Opens the linked schema document in a new window. If the document is already open, activates the window.

Process Linked Schema. Executes the *Process Schema* command on the linked schema file. As usual, processing results (*e.g.*, errors, warnings, and other information) is displayed in the *Message Window*.

Comments:

- *Design Pad G3*will issue an error on processing of a connected state-transition diagram does not contain a *State Sub-Schema* operator that is designated as the *Initial State*. That is, *Design Pad G3*will issue an error if no state has been designated as the initial state or if more than one state have been designated as such.

- If the active state contains two or more outgoing transition arcs with associated *Boolean Variable* operator outputs that are HIGH, the system may execute any one of the enabled transitions (generally the first it encounters in its search).

- The currently active *State Sub-Schema* operator in a state-transition diagram executes with the same periodicity as the rest of the operators in the schema. The *Periodic Compute Time* setting in the lower left quadrant of the *Sub-Schema Setup* dialog does not apply to the *State Sub-Schema* operator.

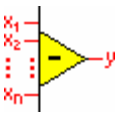
- The input and output variable definitions in the upper half of the *Sub-Schema Setup* dialog do not apply to the *State Sub-Schema* operator.

See Also:
Function Block Sub-Schema

SUBTRACTION

Operator Menu Location: *Math Functions*

Operator Bitmap:



Functional Description:

The output of the *Subtraction* operator is the difference,

$$y = x_1 - x_2 - \ldots - x_n$$

where y is the output, $x_i (i = 1,\ldots,n)$ are the inputs, and n is the number of inputs. *Design Pad G3* assumes that $x_i \equiv 0$ if input pin i is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Number of Inputs. The number of input pins n, where $2 \le n \le 6$

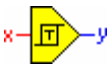
Comments: None.

See Also: Addition, Multiplication, Division, Unit Conversion

THRESHOLDING

Operator Menu Location: *Signal Comparators*

Operator Bitmap:



Functional Description:

The *Thresholding* operator compares an analog input signal to high and low threshold levels. The operator's digital output is set HIGH if the input signal is greater than the upper limit; it is set LOW if the input signal is less than the lower limit; and it remains unchanged while the input signal is between the threshold levels. For the output to change from LOW to HIGH, the input must exceed the threshold level for a user-specified length of time—the rising dead-time. Likewise, for the output to switch from HIGH to LOW, the input signal must be less than the threshold level for a user-specified length of time—the falling dead-time. That is, the output y is defined by

$$y(t) = \begin{cases} \text{HIGH} & \text{if} \quad x(t) \geq x_{\max} \ \forall t \in [t, t-R] \\ y(t-\Delta t) & \text{if} \quad x_{\min} < x < x_{\max} \\ \text{LOW} & \text{if} \quad x(t) \leq x_{\min} \ \forall t \in [t, t-F] \end{cases}$$

where x is the input, $x_{\max}$ is the high threshold level, $x_{\min}$ is the low threshold level, R is the rising dead-time, F is the falling dead-time, and Δt is the loop sampling time.

User-Defined Properties:

Object Name. A string label that identifies the operator

Initial State. The output state (HIGH or LOW) at startup (at time t=0)

Low Threshold. The low threshold level, $x_{\min}$

High Threshold. The high threshold level, x_{max}

Falling Dead-Time. The length of time a signal must satisfy the low threshold condition, for the output to switch from HIGH to LOW. The falling dead-time is denoted by F in the equation above, and is expressed in seconds.

Rising Dead-Time. The length of time a signal must satisfy the high threshold condition, for the output to switch from LOW to HIGH. The rising dead-time is denoted by *R* in the equation above, and is expressed in seconds.

Comments:

- *Design Pad G3* will issue an error on processing if the input pin is not connected
- The high threshold level must exceed the low threshold level, $x_{max} > x_{min}$
- The falling dead-time must be greater than or equal to zero, $F \geq 0$
- The rising dead-time must be greater than or equal to zero, $R \geq 0$

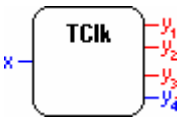
See Also:

=, ≠, >, ≥, <, and ≤ Comparators; High/Low Alarm

TIME CLOCK

Operator Menu Location: *Generic Hardware Operators* → *Time*

Operator Bitmap:



Functional Description:

The *Time-of-Day Clock* generic hardware operator provides access to a real-time clock resource in the physical hardware. When the generic operator is linked to a specific hardware resource, the operator outputs report the current time in hours (y_1), minutes (y_2), and seconds (y_3).

The operator can be configured for 12-hour (AM/PM) or 24-hour reporting. In 12-hour format, digital output y_4 indicates if time is AM (LOW) or PM (HIGH).

The operator has a track & hold input which freezes its outputs while HIGH; while the input is LOW, the outputs track the real-time clock. The hold feature is useful to maintain the time that an event occurred.

User-Defined Properties:

Object Name. A string label that identifies the operator

Time Format. The format that the time is to be reported in: 12-hour or 24-hour.

Display Track & Hold Input. This property determines if the track & hold input pin is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Comments: None.

See Also: Time-of-Day Clock, Set Clock, Alarm Clock, Stop Watch

TIMER

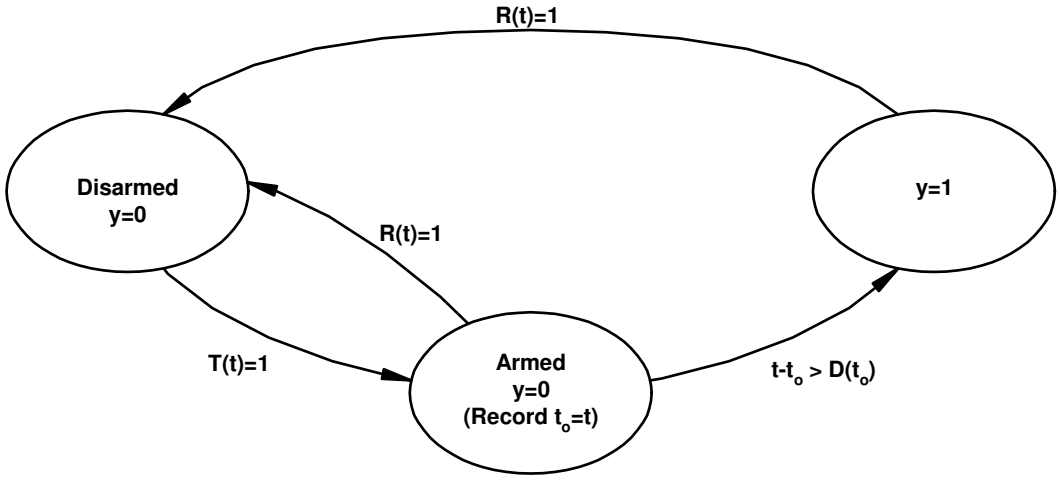
Operator Menu Location: *Time*

Operator Bitmap:

Functional Description:

The *Timer* operator measures elapsed time. It is activated when the *Trigger* (*T*) input is HIGH. After the *Timer* is activated, the output remains LOW until the time specified by the *Delay* (*D*) input (in seconds) elapses. After the *Delay* time elapses, the output will go HIGH, and remain HIGH until the *Reset* (*R*) input goes HIGH. After a *Reset* pulse is applied, the timer can be triggered again.

The state transition diagram shown below illustrates the functional behavior of the *Timer* operator.

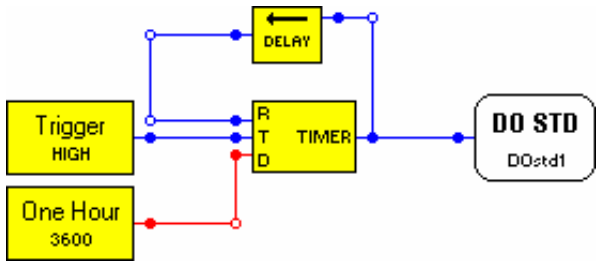


It consists of three states: (i) a disarmed state with the output LOW—the initial state; (ii) an armed state with the output LOW; and (iii) a HIGH output state. The operator transitions from the disarmed state to the armed state when input $T(t)$=*HIGH*. The time instant when the *Timer* is armed or triggered is recorded as t_0=t. Once armed, the *Timer* will begin to record the elapsed time. It will transition from the armed state to the HIGH output state when

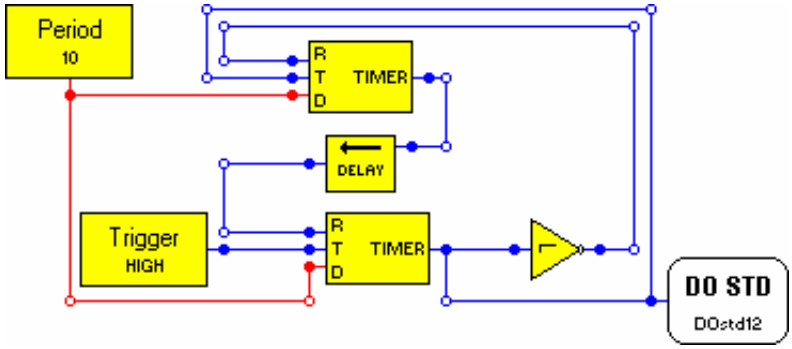
$$t - t_0 \geq D(t_0)$$

The operator transitions to the disarmed state whenever input $R(t)$ = HIGH.

The *Timer* operator can be configured to issue a pulse at regular intervals. For example, the simple schema shown in the figure below will produce a short pulse every hour.



The *Timer* operator can also be configured to function as a square-wave generator. For example, in the schema shown below, two *Timer* operators continually activate and deactivate a *Relay Output* operator in alternating 10 second periods. (The same result can be obtained with the *PWM Signal* operator.)



User-Defined Properties:

Object Name. A string label that identifies the operator

Comments:

The *Timer* operator cannot measure events greater than 139.8 minutes (8,388 seconds). Therefore, input *D* may not exceed 8,388 when the timer is activated.

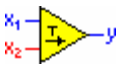
See Also:

PWM Signal, Square Wave Generator, Delay Element

TIMER DELAY

Operator Menu Location: *Logic Functions*

Operator Bitmap:



Functional Description:

The *Timer Delay* operator triggers its output upon expiration of a user-defined delay period. The operator can be configured to function as either an "ON Timer" or an "OFF Timer".

When configured as an "ON Timer", the output y will switch from LOW to HIGH d seconds after input x_2 switches from LOW to HIGH and remains HIGH for at least d seconds:

$$y(t) = \begin{cases} \text{LOW} & \text{if} \quad x_2(t) = \text{LOW} \\ \text{HIGH} & \text{if} \quad x_2(\bar{t}) = \text{HIGH} \;\; \forall t \geq \bar{t} \geq t - d \\ \text{LOW} & \text{otherwise} \end{cases}$$

When configured as an "OFF Timer", the output y will switch from HIGH to LOW d seconds after input x_2 switches from HIGH to LOW and remains LOW for at least d seconds:

$$y(t) = \begin{cases} \text{HIGH} & \text{if} \quad x_2(t) = \text{HIGH} \\ \text{LOW} & \text{if} \quad x_2(\bar{t}) = \text{LOW} \;\; \forall t \geq \bar{t} \geq t - d \\ \text{HIGH} & \text{otherwise} \end{cases}$$

The delay time d can be dynamically adjusted via input x_1 or fixed by operator property *Delay Value*. If input x_1 is connected the operator property value is ignored.

User-Defined Properties:

Object Name. A string label that identifies the operator

Delay Type. Logic state to trigger on; either "ON Timer" or "OFF Timer"

Display Delay Value Input. This property determines if input pin x_1 is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when

the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Delay Value. The time period *d* that must elapse for output to trigger (in seconds).

Comments: None.

See Also: Delay Element, Timer

TRACK & HOLD

Operator Menu Location: *Signal Conditioning*

Operator Bitmap:

Functional Description:

The *Track & Hold* operator has an analog input x, a digital input b, and an analog output y. While input b is LOW, output y tracks input x (*i.e.*, $y(t)=x(t)$). When input b switches to HIGH, y will thereafter *hold* the value of x at that instant. In other words, the operator output is defined by

$$y(t) = \begin{cases} x(t) & \text{if} \quad b(t) = \text{LOW} \\ \\ x(\bar{t}) & \text{if} \quad b(t) = \text{HIGH} \end{cases}$$

where $\bar{t}$ is the time instant that b switched to the hold state (b=*HIGH*).

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments:
The operator output may be discontinuous when switching from the hold condition to the track condition.

See Also:
A/B Switch

TRIGONOMETRIC COSINE

Operator Menu Location: *Math Functions*

Operator Bitmap:

Functional Description:

The output of the *Trigonometric Cosine* operator is simply,

$$y(t) = \cos x(t)$$

where y is the output and x is the input in radians. Output y is in the range [-1,1].

Design Pad G3 will issue an error on processing if input pin x is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also: Trigonometric Sine

TRIGONOMETRIC SINE

Operator Menu Location: *Math Functions*

Operator Bitmap:

Functional Description:

The output of the *Trigonometric Sine* operator is simply,

$$y(t) = \sin x(t)$$

where y is the output and x is the input in radians. Output y is in the range [-1,1].

Design Pad G3 will issue an error on processing if input pin x is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also: Trigonometric Cosine

UNIT CONVERSION

Operator Menu Location: *Data Conversion*

Operator Bitmap:

Functional Description:

The *Unit Conversion* operator should be used to map between units of measurement. For example, to convert a 4-20mA signal to a pressure reading of 1100-1400Psi. The output of the unit conversion operator is

$$y = \begin{cases} x_{\min} & \text{if} \quad Mx + S < x_{\min} \\ x_{\max} & \text{if} \quad Mx + S > x_{\max} \\ Mx + S & \text{otherwise} \end{cases}$$

where y is the output, x is the input, M is the conversion multiplier, S is the conversion offset, $x_{\min}$ is the minimum operator output value, and $x_{\max}$ is the maximum operator output value.

User-Defined Properties:

Object Name. A string label that identifies the operator

Multiplier. The conversion multiplier, M

Offset. The conversion offset, S

Min. Output Value. The minimum conversion value, x_{min}

Max. Output Value. The maximum conversion value, x_{max}

Input Signal Unit. The unit of measurement of the input signal (serves as label only)

Output Signal Unit. The unit of measurement of the output signal (serves as label only)

Comments: None.

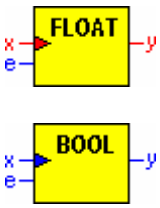
See Also:

Gain, Bias, Addition, Multiplication, Subtraction, Division, Power

VARIABLE (BOOLEAN OR FLOAT)

Operator Menu Location: *Signal Reference*

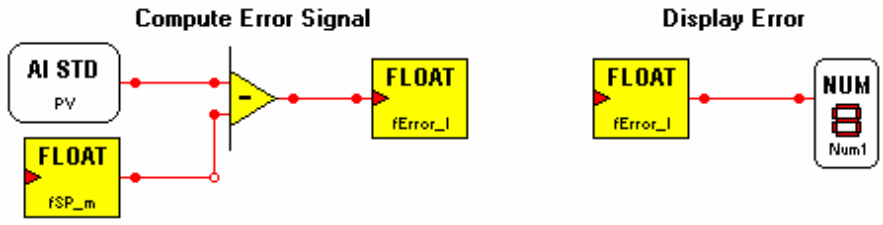
Operator Bitmap:



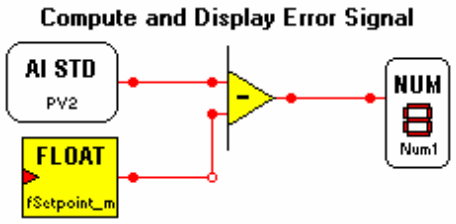
Functional Description:

The *Variable* operator stores a signal value that can change during schema execution. For instance, it may store a system set-point or tuning parameter that a plant operator or design engineer may wish to modify at runtime.

Multiple *Variable* operators can reference the same signal value provided they have the same *name* and *scope*. In the sample schema pictured below an error signal is computed and stored in a *Float Variable* named `fError_l`. Another *Float Variable* operator elsewhere in the schema has the same name, `fError_l`, and sources a *Numeric Display* operator. While the two *Variable* operators are distinct objects in the schema, they reference the very same error signal—namely the difference between process (PV) and setpoint (SP) signals, so that the value computed by the *Subtraction* operator is shown on the *Numeric Display*.



In other words, the two instances of the `fError_l` variable are akin to explicitly connecting a signal wire between the output of the *Subtraction* operator and the input of the *Numeric Display* operator as shown below.



The use of *Variable* operators as virtual signal connections is a good technique for making schemas more readable. It offers an alternative to direct connections, thereby avoiding situations where signals must cross over each other or where long connections must be used to zigzag around other objects.

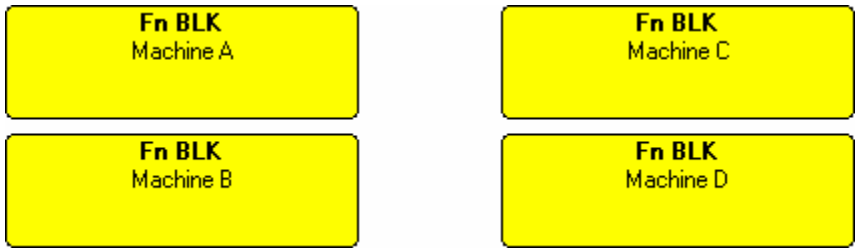
Variable operators not only serve to bind signals within the same schema, they can also bind signals across schemas and/or across modules in a node. In other words, they allow a signal computed in one schema or module, to be referenced in another schema or module. *Variable* operators have a *scope* attribute that determines their access range—*Local*, *Module*, or *Global*. A variable with *Local* scope may only be referenced within the same schema document. A variable with *Module* scope may be referenced within any schema executing in the same module (*i.e.*, the *parent* schema linked to the module, any of its sub-schemas, or any of its sub-schemas' sub-schemas.). A variable with *Global* scope may be referenced within any schema executing within any module in the same node.

Design Pad G3 automatically appends the characters "`_l`", "`_m`", or "`_g`" to the *Variable* signal name according to its scope, *Local*, *Module*, or *Global*, respectively.

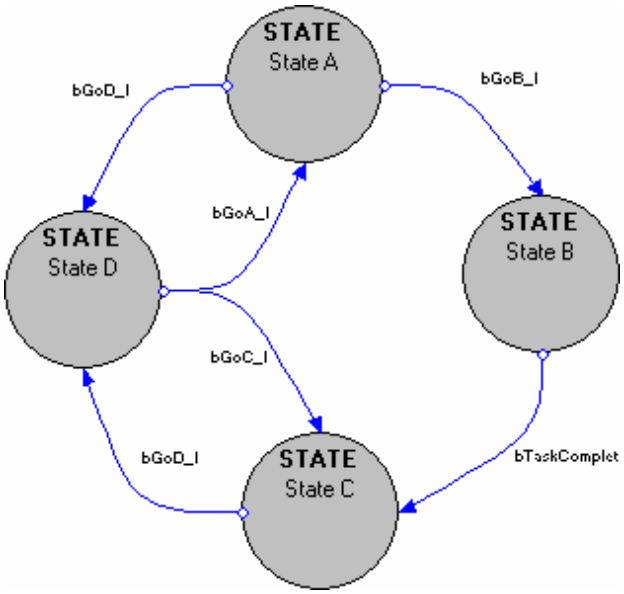
In addition to binding signals from disparate schemas, *Boolean Variable* operators also serve as the triggering mechanism to initiate a transition in a state-transition diagram. In this context, a *Boolean Variable* is bound to a transition arc in the diagram. The transition is activated when the variable value is HIGH. Please see the help reference for the *Sub-Schema State* operator for more information and examples. Also refer to the help reference for the *Sub-Schema Function Block* operator for examples on the use of *Variable* operators to bind signals between a schema and its sub-schema(s).

A key motivation behind the use of sub-schemas is that they promote program re-use. The idea is that re-using *code* can drastically reduce development and testing time. Moreover, if a bug is ever found within a sub-schema it only needs to be corrected in one place, thereby simplifying code management. Because *Variable* operators serve as the glue that bind sub-schemas together, they also play an important role in program re-use. Proper selection of variable scope is an critical factor in maintaining re-usable code. The operator scope should have the minimum range required to achieve the desired objective. If a variable is not needed outside of the schema in which it resides, it should be assigned *Local* scope. This avoids the possibility that when a sub-schema is re-used in a different application, a variable with *Module* or *Global* scope is not inadvertently bound to another variable with the same name and scope in the other application.

The available scope settings on their own are sometimes not sufficient to achieve re-use. For instance, consider an application where four identical machines are to be controlled. The ideal approach from a re-usability standpoint is to implement the algorithm in a sub-schema and to reference that same sub-schema four times.



Suppose the algorithm were best implemented as a state diagram, as shown below, with a transition bound to a *Boolean Variable* named `bTaskComplete_m` having *module* scope.

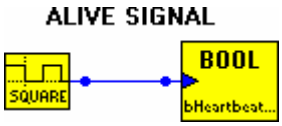


Suppose the variable `bTaskComplete_m` necessarily had to have *module* scope because its state (LOW or HIGH) could only be determined within the sub-schema file associated within state *State B*. But the assignment of *module* scope to `bTaskComplete_m` creates a problem. Remember that the same state-diagram is to be referenced by the four sub-schemas, meaning that four distinct instances of this same state diagram are to execute concurrently and independently. However, because `bTaskComplete_m` has *module* scope, every appearance of that variable is interpreted as a reference to the very same signal. As a result, *Design Pad G3*will bind together each and every instance of the `bTaskComplete_m` transition, such that machine operation will be incorrectly coupled and the schemas will not execute as expected.

This problem can be solved by using the *Prepend Name* property of *Variable* operators and (optionally) enabling the *namespace* feature of sub-schema operators. As its label implies, the *Prepend Name* property prefixes the variable name with the node name, module name, sub-schema namespace, or a combination of these. The resolved name (i.e., the combination of the *Prepend Name* and *Signal Name* properties) can then be used to uniquely identify a variable reference.

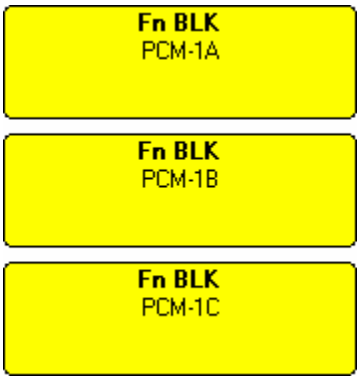
The problem in the example described above can be rectified by activating the *Namespace* property of the *Function Block Sub-Schema* operators, setting the *Prepend Name* property of the `bTaskComplete_m` to *Namespace*, and setting the *Naming* drop-down combo in the *Transition Properties* dialog box to *Namespace*. Then, the resolved names for the problematic operators would be unique: `Machine A.bTaskComplete_m`, `Machine B.bTaskComplete_m`, `Machine C.bTaskComplete_m`, and `Machine D.bTaskComplete_m`.

Another example usage of the *Prepend Name* property to promote program re-use is shown below. Consider a hardware interface file consisting of three PCM-1 modules, one NIM-1 module, and one ACP-1. The NIM-1 module is to monitor the health of the three PCM-1 modules that are to control identical machines. Since each of the PCM-1 modules perform an identical function, it is desirable to associate them all to the same schema file. This schema file generates a heartbeat signal to be monitored by the NIM-1 module, as shown below:

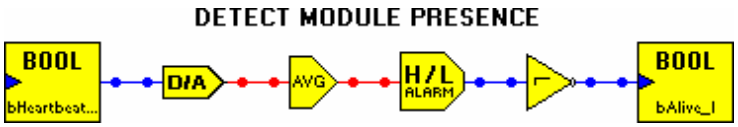


The heartbeat signal, named `bHeartbeat_g` is assigned *Global* scope so that it is accessible from the NIM-1 module. But if the same schema is assigned to the three PCM-1 modules, each module would attempt to set the value of the same global variable named `bHeartbeat_g`. In order for the heartbeat signal variable to be unique to the module that sources it, the *Prepend Name* property of the variable must be set to *Module* so that the module name is used as a prefix to the signal name. The fully resolved name will be `PCM-1A.bHeartbeat_g`, `PCM-1B.bHeartbeat_g`, or `PCM-1C.bHeartbeat_g`.

Then, the schema linked to the NIM-1 module should contain three namespace-enabled *Function Block Sub-Schema* operators with names to match the module names as follows:



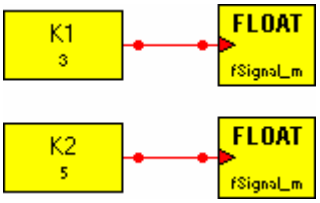
Each of these *Function Block Sub-Schema* operators can then be linked to the same schema file that contains a circuit used to monitor the heartbeat signal:



Note that in this case, the *Prepend Name* property of the `bHeartbeat_g` operator is set to Namespace, such that its name is prefixed with the name of the sub-schema. The fully resolved name will be `PCM-1A.bHeartbeat_g`, `PCM-1B.bHeartbeat_g`, or `PCM-1C.bHeartbeat_g`, to match the source signal names.

In the preceding examples, there were instances of *Variable* operators where the input pin *x* was visible but the output pin *y* was not, and vice-versa. A *Variable* operator may be of type *Input-Only*, *Output-Only*, *Input-Output*, or *None*. The type determines if input pin *x* and output pin *y* are visible in the schema and serve a purpose. When input pin *x* is connected, the internal variable value is set equal to the value of *x* as dictated by enable input *e*. If input *e* is not connected, the internal variable value is set to *x* every time the operator computes. If input *e* is connected, the internal variable value is updated according to the *Enable On* property—see the operator properties section below. Obviously, when output *y* is visible, it can be used to feed the input pin(s) of other operators with the signal value the variable represents.

Great care must be taken when connecting input *x* of two or more distinct *Variable* operators that represent the same signal (*i.e.*, they have the same fully-resolved name). Consider the schema below in which two distinct operators representing the same signal—`fSignal_m`—are fed by different constant values.



If a device were to execute this schema, what value (3 or 5) would `fSignal_m` assume? The answer is not definitive—it depends on which operator executes last. In fact, if the schema contained several other operators, the result would be even more unpredictable as it is possible that the execution order could have one *Variable* first, then other operators, then the second *Variable*, then other operators. So the signal value could be 3 during part of the computation cycle that some operators compute and 5 during part of the cycle that other operators compute.

Design Pad G3 explicitly disallows the same variable signal from being set in multiple locations within the same schema. That is, an error is issued at compile-time when the schema above is processed. However, the ability to set the same signal from different sub-schemas is quite desirable so *Design Pad G3* allows it. For example, it may be desirable to set the same signal to a different value depending on which state sub-schema is currently active.

Like most operators, *Variable* operators have various attributes that may be specified in the properties dialog—a list of such properties is enumerated below. In addition, to these operator-specific properties, there are several settings that related apply to the set of operators that reference the same signal. These attributes are specified in the *Variable Settings* and are also enumerated below. There are actually three distinct *Variable Settings* dialogs, one for each type of variable scope. For variables of *Local* scope, the dialog is accessed from the *Schema* menu (select the *Local Variable Settings* item). For variables of *Module*, and *Global* scope, the dialog is accessed from the module drop-down menu in the hardware interface file view,

User-Defined Properties:

Signal Name. A string label that identifies the operator. Multiple *Variable* operators with the same signal name are treated as the same object–subject to the *Scope* and *Prepend Name* property settings below.

Variable Type. Indicates if the *Variable* is to serve as a signal source (*Output Only*), signal sink (*Input Only*), both (*Input-Output*) or neither (*None*). Operator input *x* is visible if this property is set to *Input Only* or *Input-Output*. Operator output *y* is visible if this property is set to *Input Only* or *Input-Output*.

Scope Access. Determines the operator's access range, *Local*, *Module*, or *Global*. A variable with *Local* scope may only be referenced within the same schema document. A variable with *Module* scope may be referenced within any schema executing in the same module (*i.e.*,the *parent* schema linked to the module, any of its sub-schemas, and any of its sub-schemas' sub-schemas.). A variable with *Global* scope may be referenced within any schema executing within any module in the same node. *Design Pad G3*automatically appends the characters "`_l`", "`_m`", or "`_g`" to the *Signal Name* according to its scope.

Display Enable Input. Determines if input pin *e* is visible in the schema diagram. *Design Pad G3* issues a warning upon processing the schema when the pin is visible but not connected. The warning message is not issued when the pin is not visible (when this property is not checked).

Enable On. Enable input *e* may be optionally used to manage updates to the parameter value. The operator can be configured to update its stored value on an edge-trigger (rising edge or falling edge) or logic state (active LOW or active HIGH). For instance, if *Enable On* is set to *Rising Edge*, then the variable value will only be updated with the value of input *x*, during the instant that input *e* switches from LOW to HIGH.

Initialization Behavior. Determines if the initial variable value is set by the User-Defined *Initial Value* property (specified in the Local/Module/Global Variable Settings Dialog—see below) or by input *x* (valid only if *x* is connected.

Instance Note. Text used to document the application. This text is displayed as hover help when the mouse-cursor is placed over the operator graphic.

Prepend Name. Indicates if the *Signal Name* is to be prefixed by the module name, node name, sub-schema namespace, or a combination thereof. When *Namepace* is selected, the *Signal Name* is prefixed with the name of each namespace-enabled sub-schema (state or function-block) along the path from the schema that contains the *Variable* operator to the topmost parent schema. In the four-machine example described in the text above, only the name of the *Function Block Sub-Schema* operator is prepended to the signal name: `Machine A.bTaskComplete_m`. If the *State Sub-Schema* operator were also namespace-enabled, then its name would also be prepended to the signal name: `Machine A.State B.bTaskComplete_m`.

Resolved Name. Displays the full name of the signal, formed prefixing the *Signal Name* property with the *Prepend Name* property.

Variable Settings Dialog:

Data Type. The variable's data type, *Boolean* or *Float*. This is a read-only column in the dialog.

Signal Name. The fully resolved signal-name (see *Signal Name*, *Prepend Name*, and *Resolved Name* properties of operator. This is a read-only column in the dialog.

Initial Value. The value the variable should be set to when the schema it is in first executes.

Link Access. Future expansion.

Browse Access. Indicates if the variable value can be accessed when using an ad-hoc HMI.

Update in Flash. Indicates if the variable value is to be stored in non-volatile memory such that it is retained when the device is powered off. Three setting are available: *None* indicates that the variable is not to be saved in flash; *On Command* indicates that the variable is to be recorded on *Flash Save* operator command; *On Command + Power Loss* indicates that the variable value will be store in flash when explicitly commanded by the *Flash Save* operator or when the device is powered off (intentionally or unintentionally). When the device loses power, it has precious little time to perform clean-up operations, such as saving critical variables to non-volatile memory. The quantity of variables that can be designated as critical is limited and depends on the target hardware.

Merge Behavior. When downloading a node configuration file into the target hardware, the user can elect to first erase the configuration being replaced, or to merge the old configuration with the new. The latter option is useful if software updates must be made "on the fly"—while maintaining control over the machinery it is connected to. This property indicates what should be done with the variable value if the node configuration files are to be merged. There are two options: *Leave Existing* and *Reset to Default*. This first option is the default and maintains the variable value stored in the device (useful for setpoint settings, etc). The second option resets the variable to the value stored in the new configuration.

Access Level. Node configuration files may contain a password to prevent unauthorized access to modify certain parameters. When this property is set to *Operator*, anybody is free to modify the variable value. When this property is set to *Engineer*, a password is required to modify the variable value.

Instance Note. User notes that serve as documentation. The notes are incorporated into the hover help box that is displayed when the user positions the mouse over the operator graphic. This note applies to all instances of a *Variable* operator with the same *Signal Name*. (As opposed to an *Instance Note* property associated with a specific instance of an operator.)

Comments:
None.

See Also:
Sub-Schema Function Block, Sub-Schema State

XNOR-GATE

Operator Menu Location: *Logic Functions*

Operator Bitmap:

Functional Description:

The output of the *XNOR Gate* operator is the negated exclusive logical *OR* of its inputs,

$$y = \overline{x_1 \veebar x_2}$$

where y is the output, and x_1 and x_2 are the inputs. In other words, the output state is HIGH if the input states are equal, and the output is LOW, if the input states differ. Below is the truth table for the XOR-gate:

x_1	x_2	y
LOW	LOW	LOW
LOW	HIGH	HIGH
HIGH	LOW	HIGH
HIGH	HIGH	LOW

Design Pad G3 will issue an error on processing if an input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also:
XOR Gate, OR Gate, NOR Gate, NOT Gate, AND Gate, NAND Gate

XOR-GATE

Operator Menu Location: *Logic Functions*

Operator Bitmap:

Functional Description:

The output of the *XOR Gate* operator is the exclusive logical *OR* of its inputs,

$$y = x_1 \forall x_2 ,$$

where y is the output, and x_1 and x_2 are the inputs. In other words, the output state is LOW if the input states are equal, and the output is HIGH, if the input states differ. Below is the truth table for the XOR-gate:

x_1	x_2	y
LOW	LOW	HIGH
LOW	HIGH	LOW
HIGH	LOW	LOW
HIGH	HIGH	HIGH

Design Pad G3 will issue an error on processing if an input pin is not connected.

User-Defined Properties:

Object Name. A string label that identifies the operator

Comments: None.

See Also:
XNOR Gate, OR Gate, NOR Gate, NOT Gate, AND Gate, NAND Gate

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