Beckhoff Training Series

Module 1: Introduction to TwinCAT

Beckhoff Automation LLC
12150 Nicollet Avenue South
Burnsville, MN 55337

877 894-6228
beckhoff.usa@beckhoff.com

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Introduction

Beckhoff Automation

Beckhoff Automation provides advanced and open automation products based upon proven industrial technologies. Beckhoff customers can implement high performance control systems faster and at a lower overall cost than traditional PLC and motion control systems. Beckhoff's "New Automation Technology" product range includes PC based control software, industrial PCs, automation controllers, operator interface hardware, distributed I/O, industrial Ethernet products, servo drives and motors. Sales and service are handled directly, with no intermediaries involved to provide faster response and improved technical support.

The TwinCAT suite was put together by Beckhoff Automation to be a complete development environment for writing, editing and debugging PLC programs. TwinCAT includes support for five industry standard programming languages plus a new variant of FBD. Any of these languages (or combination thereof) may be employed to complete your program.

TwinCAT empowers beginner and advanced programmers alike through the use of libraries. Libraries contain support code that save the programmer research time. Code that normally would have been written from scratch now becomes a call to a specific library.

TwinCAT has a built-in software PLC so programs can be tested without connecting to the actual hardware. Furthermore, another program called TwinCAT Scope View is included that offers a graphical analysis of the program's variables which can help with troubleshooting and fine-tuning a program, as well as aid in tuning servo systems.

TwinCAT also allows for integration through the use of an interface system that makes it possible to interact with the PLC from other programming environments such as Microsoft Visual Studio .net using standard DLL and OCX architecture. TwinCAT can also be used to exchange data with other systems for example, values in an Oracle database can be called by TwinCAT and the resulting instruction sent over the network to yet another system for processing.

NOTE: This manual assumes basic to intermediate knowledge of Windows based computers and basic programming knowledge. Though someone with any level of knowledge will benefit from the instruction in this manual, users are encourage to take classes in the two disciplines mentioned above to better grasp the concepts presented here.

I/O

I/O, or Input/Output, refers to communication between a computer and its users, its storage devices, other computers (via a network) or attached hardware. Generally speaking, a device receives Input and delivers Output. But keep in mind that what is defined as Input or Output can change depending on what is being discussed and the particulars of the interaction, for example a printer receives Input from a computer (what to print) but the computer can also receive Input from the printer (e.g. low ink alert).

In the Beckhoff world, we usually are referring to fieldbus components when we talk about I/O. Fieldbus components basically describe how the controller connects to what is being controlled. In simplistic terms, the program to control an assembly activity uses fieldbus components to “talk” to the assembly machinery.

I/O components include **Bus Couplers** (Ethernet, fiber optic, PROFIBUS, RS232/RS485, etc.) and **Bus Terminals** (digital and analog input/output). These devices and more act as liaisons between the computing device (computer or embedded CPU) and the machines, systems (database, etc.) and other computing devices in your facility.

Important aspects of I/O that will be discussed later are: throughput, latency, and whether the communications are synchronous or asynchronous. This will be important in determining what I/O components and infrastructure will provide the best results given the infrastructure budget.

You can use the catalog (described in the next section) to explore the different components available.

Unit

A unit consists of a Bus Coupler, Some number of Bus Terminals (dependent on the model of Bus Coupler and available extension hardware) and one end terminal. The terminals handle the individual inputs and outputs while the Bus Coupler handles communication between the terminals and between the Unit and the fieldbus.

Bus Couplers

There are a number of different Bus Couplers, supporting different types of communication and other specifics. Model numbers are a two-letter code followed by a two-digit type code followed by a two-digit form code. BK9100 would describe a standard Ethernet Bus Coupler without onboard processor.

Letter codes:
BC – onboard processor; can run in isolation.
BK – no onboard processor; needs a PC to function.
BX – eXtended, has extra communication ports.
LC – Low Cost

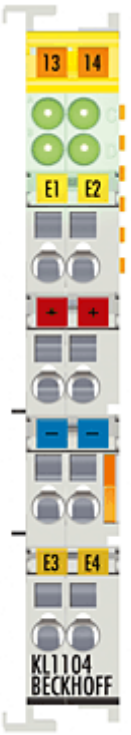
Type codes:
11 – EtherCAT
2x – Lightbus
3x – PROFIBUS
4x – Interbus
51 – CANopen
52 – DeviceNet
70 – ControlNet
71 – CC-Link
73 – Modbus
74 – Fipio
75 – SERCOS
80 – RS485
81 – RS232
90, 91 – Ethernet TCP/IP
95 – USB

Form codes:
00 – Standard
10 – Economy
20 – Economy Plus
5x – Compact

(BC and BK only; LC and BX always ends with 00

Example of a Low Cost PROFIBUS Bus Coupler.

Bus Terminals



Terminals come in a number of varieties as well depending on the needs of the system. Model numbers are a two-letter series code followed by a single-digit type code followed by a two-digit sub-model code and ending with a single-digit channel code.

One place to begin thinking about appropriate components is the difference between KLxxxx (standard) Bus Terminals and ELxxxx (ultra high-speed) EtherCat Bus Terminals.

So a standard, four channel, digital input will have the model number of: KL1xx4. ⇨

Regardless of the model, terminals are color coded for quick identification:
Yellow (XX1xxx) – Digital Input
Red (XX2xxx) – Digital Output
Green (XX3xxx) – Analog Input
Blue (XX4xxx) – Analog Output
Clear (XX5xxx) – Sensor
Clear (XX6xxx) – Communication
Clear (XX7xxx) – Power Terminal
Clear (XX9xxx) – Power Terminal

Two important Power Terminals are the KL9510 which breaks the power loop, separating digital from analog I/O slices, and the KL9010 Bus Terminal which closes the electrical loop and must be the very last slice (or the last slice of the last chained box).

Installation of the TwinCAT Suite

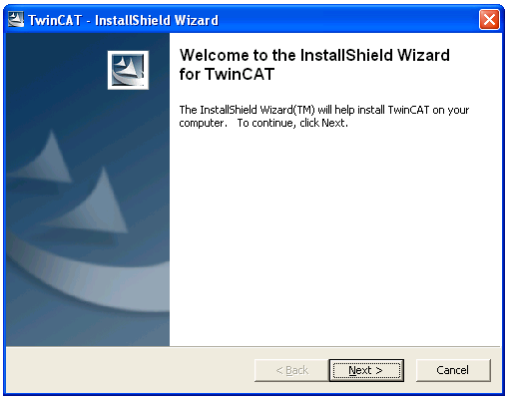
The TwinCAT Suite is free to download but requires a serial number after 30 days. This will help guarantee that your organization does not experience downtime, even during a holiday.

Download and Install

To download TwinCAT:

- Go to www.beckhoff.com (enter this URL exactly).
- Click on Download on the left hand side of the screen.
- Click on TwinCAT (30 days version).
- Enter all the fields with a red arrow with real data and click the Register button.
- You will receive an email from Beckhoff with a link. Click the link to download TwinCAT.
- Find where the installer was saved (probably the desktop). The file should start with "tcat_" followed by the version number.
- Double click on the file…

Welcome – Click the Next button and then follow the instructions on the next page.

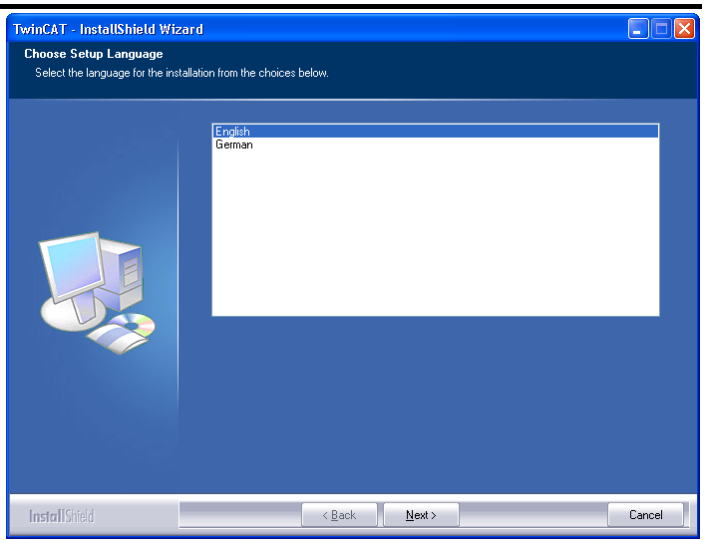


CD Install

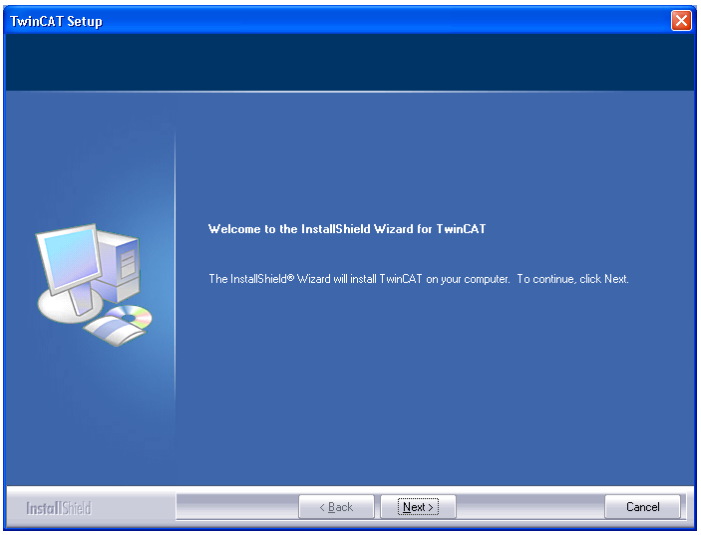
To install from the CD:

- Insert the Beckhoff Software Products CD.
- Close the browser which will automatically launch.
- Go into My Computer, right click on the CD drive (it might be titled BECKHOFF) and select Explore.
- Go into the TwinCAT folder and double click on Setup.exe.

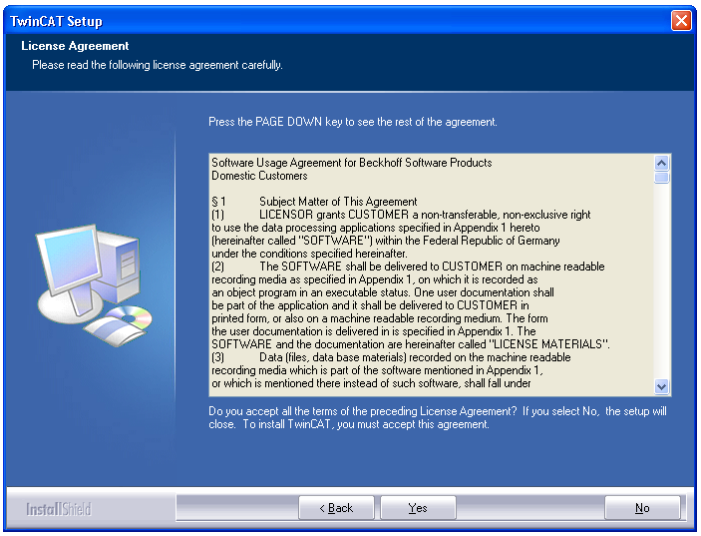
Choose Setup Language – make sure English is highlighted and click the Next button.



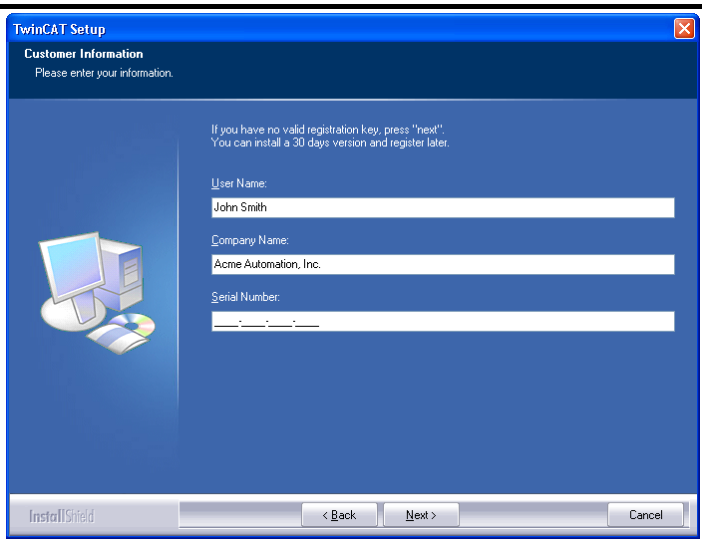
Welcome – press the Next button.



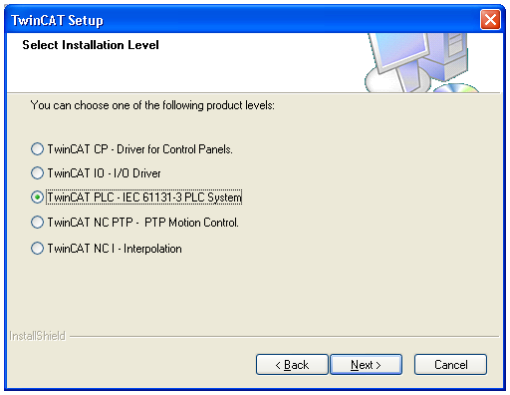
License Agreement – after reading the entire agreement, click the Yes button.



Customer Information – verify your information. If you have the serial number enter it here, otherwise just click the Next button; you will be able to enter the serial number later.



Select Installation Level – select the TwinCAT PLC radial button and click the Next button.



CP – Contains the necessary components for the special functions (S-Keys, etc.) of the Beckhoff Control Panels.

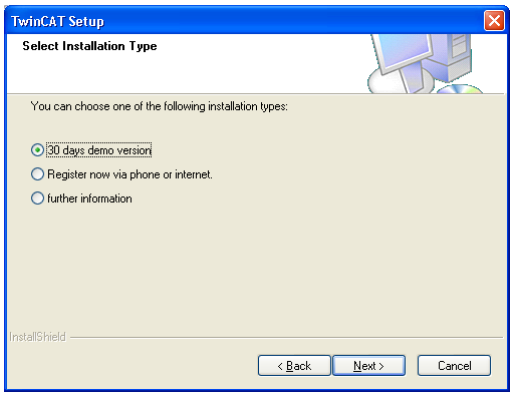
IO – The (User Mode-) Program can directly access the IO Devices. This Level does not include the PLC.

PLC – includes the IEC61131-3 Software Development kit.

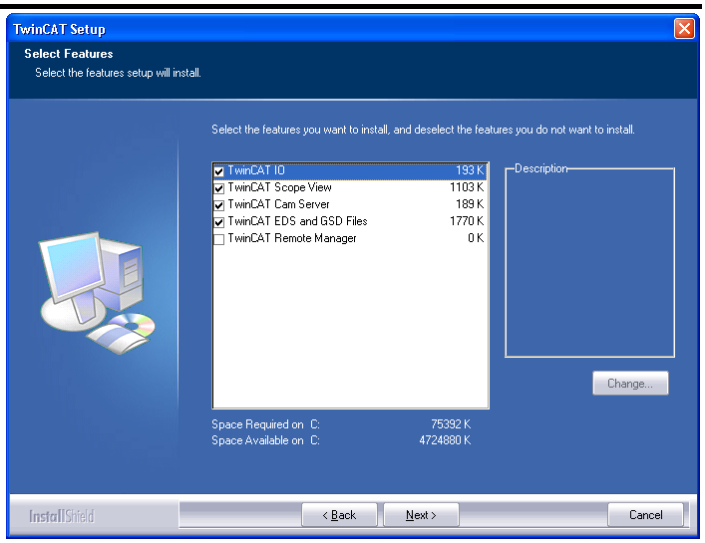
NC PTP – Enhances PLC with the NC/CNC functionality to control the PTP-Axis.

NC I – Enhances PLC with the NC functionality for interpolated drives in 3D.

Select Installation Type – for now, select 30 days demo version (you can register later) and click the Next button.



Select Features – select the first four components as shown, and click the Next button.



TwinCAT IO – Allows the direct access to IO via a DLL. Can be installed with TwinCAT PLC or TwinCAT NC PTP (see Installation Levels above).

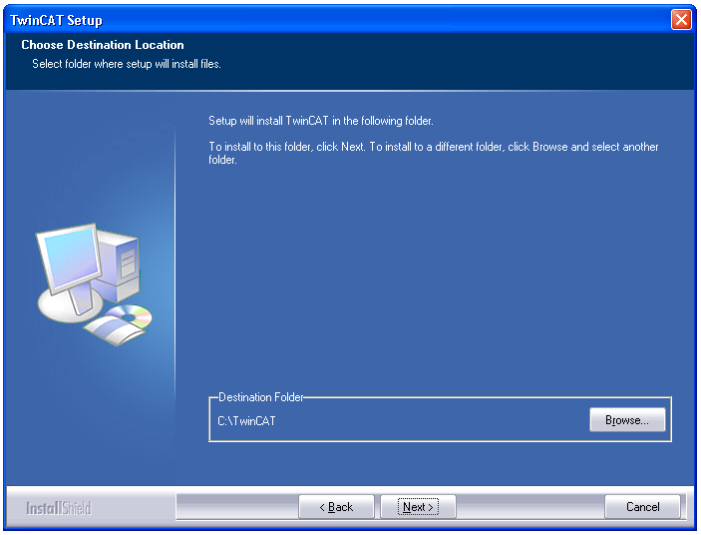
TwinCAT Scope View – Diagnostic tool (see Scope View section near the end of this manual).

TwinCAT Cam Server – Fast Cam Server.

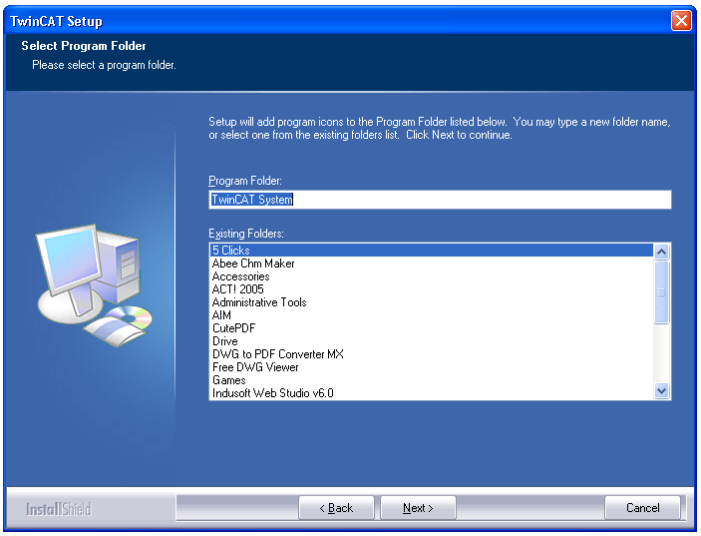
TwinCAT EDS and GSD Files – The EDS (DeviceNet) and GSD (characteristic master device file, Profibus) makes all the settings available to the user for the configuration of the system.

TwinCAT Remote Manager – Support for managing several different versions of the TwinCAT system manager and of TwinCAT PLC control.

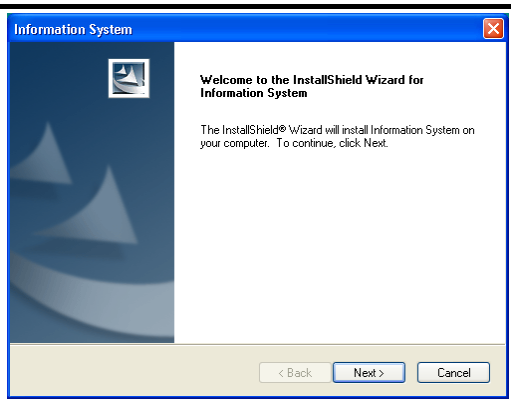
Choose Destination Location – click the Next button.



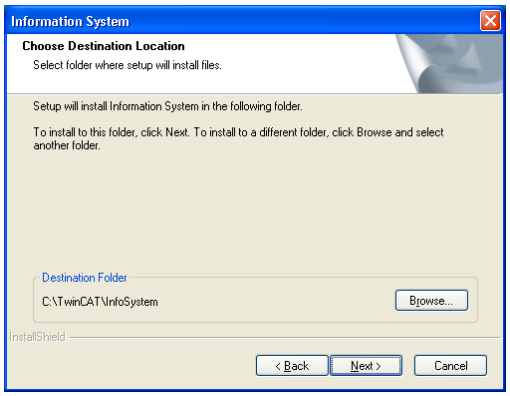
Select Program Folder – click the Next button.



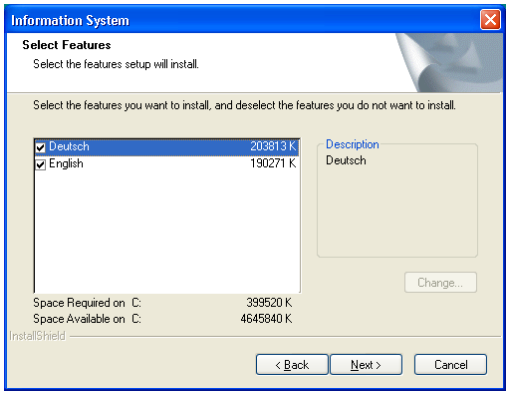
Information System – after the installation of TwinCAT, the TwinCAT Information System is automatically installed. Click the Next button.



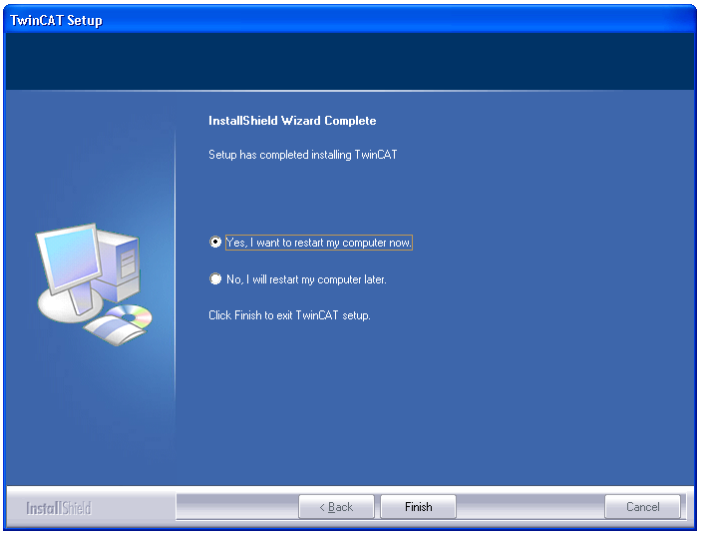
Choose Destination Location – click the Next button.



Select Features – deselect Deutsch if you want to save space and click the Next button.



InstallShield Wizard Complete – it is recommended that you select Yes and click the Finish button to restart the computer and complete the installation.



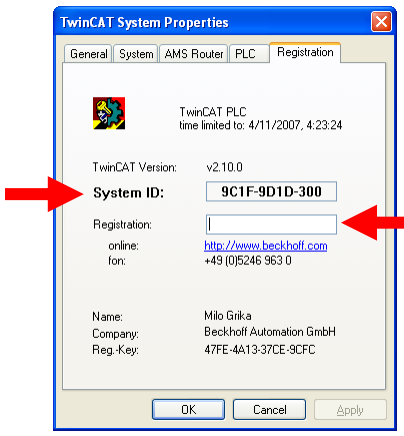
Licensing

TwinCAT must be licensed by entering a Registration Key or it will expire and cease to run 30 days after installation.

First, find and record your System ID. To find your System ID, click on the TwinCAT icon in the system tray and select Properties.

Select the Registration tab.

The System ID should be in the System ID field. Select the ID, copy it and paste it into an email. Add your P.O. number from purchasing the software (if you have it) and send it to your Inside Sales representative.



Within 24 hours (not necessarily including weekends and holidays) you should receive back a new Registration Key. This can be copied and pasted in the Registration field.

If you have any questions, feel free to call 877 TWIN-CAT (877 894-6228) for assistance.

Tour of the TwinCAT Environment

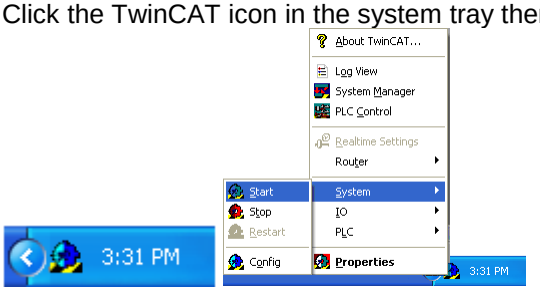
Components

There two main components to creating a PLC program in TwinCAT: TwinCAT PLC Control and TwinCAT System Manager. TwinCAT PLC Control is where the program is written and TwinCAT System Manager is where the hardware connections are configured.

A third component, the TwinCAT System Service acts as the liaison between the program and the connected hardware on a PC that is being used as the controller. It is also used to connect to a training/test station so that programmers can practice and test how the program interacts with inputs and outputs.

The TwinCAT programs can be launched in a number of ways:

1. Click the TwinCAT icon in the system tray then select the application needed.

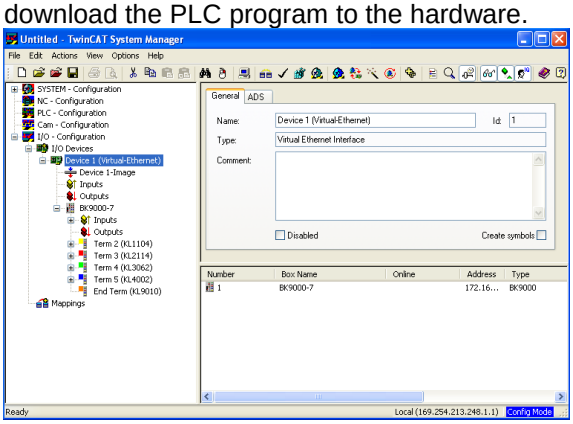


2. Click the Start button, select Programs (or All Programs), select TwinCAT System and select the program needed.

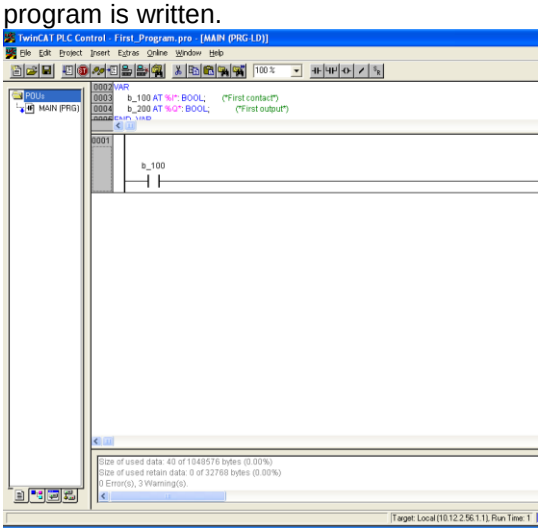
3. Double click on My Computer on the desktop (sometimes found by clicking the Start button), double click on the C: drive (might be different if a different drive was specified during installation), Double click on TwinCAT:
    a. TwinCAT PLC Control is found in the PLC folder and is called: TCatPlcCtrl.exe
    b. TwinCAT System Manager is found in the Io folder and is called: TCatSysManager.exe

As mentioned in number 3 above, TwinCAT System Manager and TwinCAT PLC Control are the two programs that will be used the most.

TwinCAT System Manager is used to configure the hardware and ultimately to attach or download the PLC program to the hardware.



TwinCAT PLC Control is the programming environment. This is where the actual PLC program is written.



TwinCAT, making Windows a Real-Time Operating System

The importance of precise timing can not be stressed enough in automation. Almost every automation application has at least a safety aspect and many have the potential for very expensive mistakes.

Leaving the control of a system up to the unpredictability of Windows could be catastrophic. TwinCAT effectively turns a Windows computer into a real-time computer.

Real-Time Computing

Real-time computing basically means that there is a deadline to when the system responds after a request. Normally, PCs respond when they get around to it. Conversely, in a real-time system, the system must process the request in a given timeframe.

Another concept that is related here is *deterministic computing*. This can be described as always getting the expected result given the exact same input.

For this to happen, the initial state of the system must always be exactly predictable. Next we will look at what is required of a computer system to achieve this and TwinCAT's role.

Kernel

The kernel is the part of a computer's operating system that links hardware to software. In other words, whenever you do anything on a computer, no matter what the program, at minimum, the RAM and the processor are accessed; the kernel handles these access requests.

When TwinCAT is installed, Microsoft's kernel is taken over by TwinCAT. This is because Microsoft's kernel is built for compatibility and TwinCAT is built for perfect timing.

Within each tick (see below), TwinCAT regulates how system resources are allocated. This allows the PC to operate in a deterministic, real-time way. Furthermore, Beckhoff's patented RT (real-time) kernel is capable of surviving crashes and "blue screens" since it runs outside of the Windows operating system.

Tick

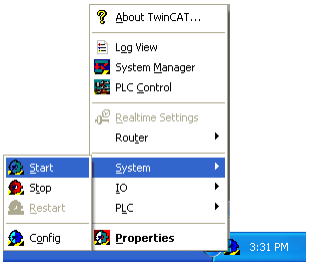
The smallest clock unit considered by a computer is called a tick (sometimes referred to as a runtime). The actual length of the tick is dependent on processor speed, RAM and other variables, but is usually described in milliseconds.

Normally the Windows OS decides what to do in each tick. When TwinCAT is installed, it takes over control, allocating space within each tick for TwinCAT operations before handing control back to Windows. By default, TwinCAT reserves 80% of each tick but this can be configured up to 90% in the Realtime Settings.

Within each portion of each tick governed by TwinCAT, up to four runtimes can be run in order. Within each runtime, four tasks can be run in order. And within each task, a number of Projects (determined by the processor) can be run in alphabetical order.

TwinCAT always gives control back to Windows at the end of the tick. If the task isn't done, it is resumed at the beginning of the next tick from where it had stopped. If more than one task is running but one task does not finish or does not even start, it runs first at the beginning of the next tick.

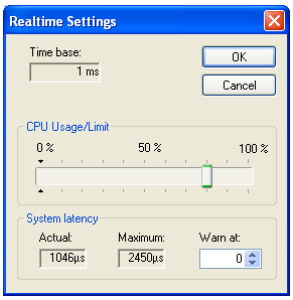
To change the settings the Realtime System must be running. Click on the TwinCAT icon in the system tray and select Start. Then click on the TwinCAT icon again and select Realtime Settings.



Latency

Latency describes the time it takes the system to respond to a request. Even though every attempt is made to control the behavior of the system, some latency is unavoidable.

The actual latency is displayed dynamically in the Realtime Setup (see Tick above). In the lower left-hand corner is the Actual System latency field that continuously updates as it monitors the computer processor. This is showing how late the central system tick arrived.



Configuring Hardware with TwinCAT System Manager

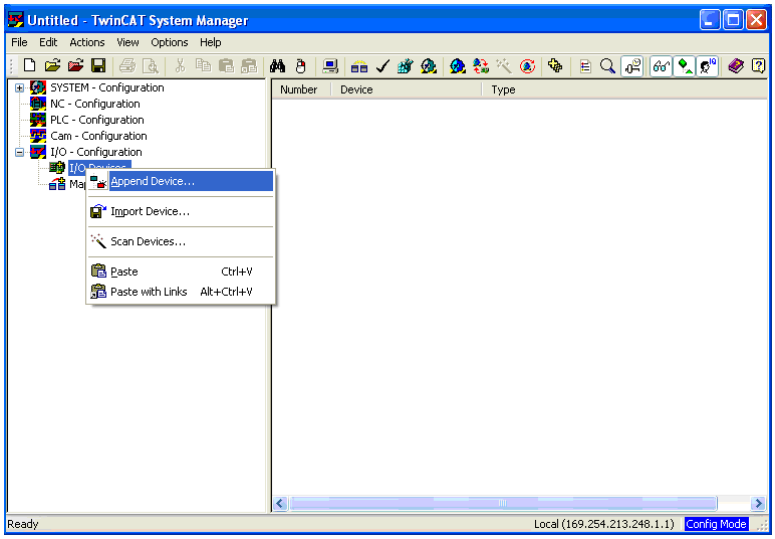
Two operations are performed when attempting to identify and configure hardware connected to the computer being used for programming and/or acting as the PLC: Append and Scan.

Append is used when no hardware is attached. Scan is used to find hardware that is attached.

When looking at the left pane of the System Manager window, Everything from I/O - Configuration on down is hardware related. Everything above I/O - Configuration is software related. Different options will be listed depending on what was installed, but the common configurations are:

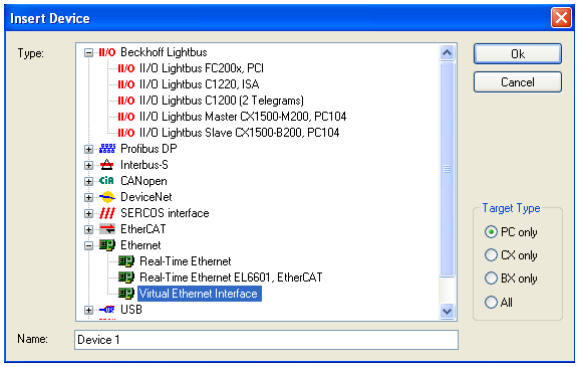
SYSTEM - Configuration – Describes how the system will run, especially run-time settings.
PLC - Configuration – Describes how the PLC program will run, particularly how it will run autonomously.
I/O - Configuration – Describes what hardware is attached and specifies communication parameters.

Since hardware constitutes I/O, appending and scanning is dealt with using the I/O - Configuration portion of TwinCAT System Manager and specifically with the I/O Devices subcategory. Also, since this is a configuration activity, the system must be in Config Mode before an interface can be appended.



When System Manager is told to append a device, a list of devices that can be inserted appears. This is a generic list and does not necessarily reflect what interfaces might actually exist.

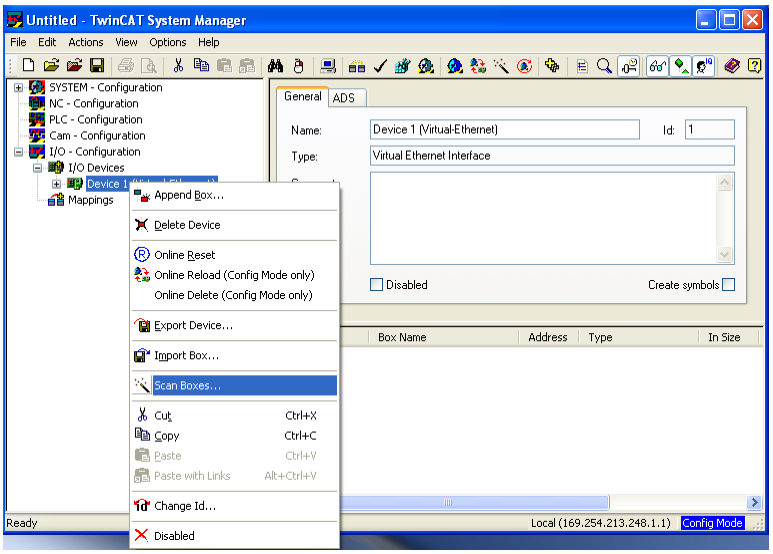
Devices are grouped by type which can be expanded to show specific devices. Though there may be multiple interfaces attached to the computer, only one device can be selected at a time.



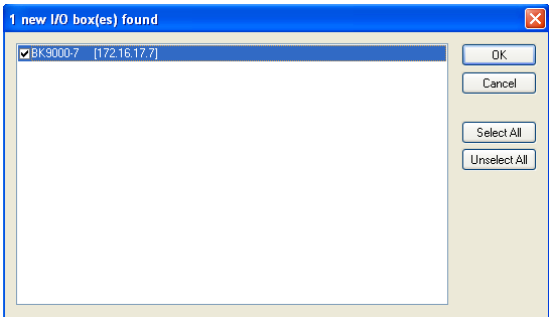
Each interface has to be added separately and will be listed under I/O Devices under I/O - Configuration.

These instructions are for version 2.8 and up. If using an older version, please contact your support person for help.

Once the interface is added to the list of I/O Devices, then that interface can be scanned to discover what hardware is attached.



If an actual existing and functioning interface is scanned, a list of boxes will be displayed. This list is specific and shows only the hardware detected via that interface.



The selected box can then be added to System Manager. System Manager then displays the selected box(es) under the device that was appended under I/O Devices under I/O - Configuration.

I/O - Configuration is really only concerned with I/O, that is, input and output. For this reason, some Bus Terminals also called “slices”, such as those that deal with electrical termination, are not generally displayed.

It’s critical to know what mode TwinCAT is in during development. The mode can always be identified by the icon in the system tray and sometimes in the message in the lower right corner of the application:

	Config Mode	**Run Mode**	**Stopped**	**Changing**	***Free Run***
	This is the mode that is required for development.	This is the mode that is required for running the PLC.	Neither development nor operations can be performed.	This should only be visible for an instant between state changes.	This is a special mode for testing connections in System Manager.
TwinCAT System Tray icon					
TwinCAT System Manager	Config Mode	RTime 0%	Stopped		Flashes between Config Mode and Free Run
TwinCAT PLC Control	TwinCAT Config Mode	RUN			

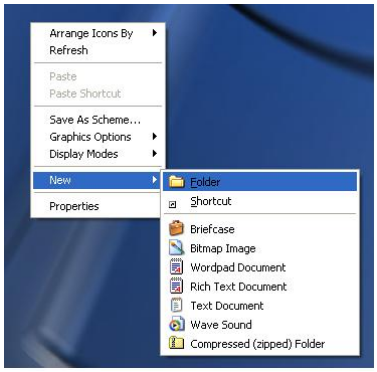
Lab 1: Append and Scan

Purpose: In this lab, you will be using TwinCAT System Manager to identify the hardware attached to the computer. You will also see the representation of the attached hardware in System Manager and how it is different from the physical hardware as described above.

Working Directory

Here you will make a folder on the Desktop in which you will save all the files from the subsequent labs:

1. Close any applications, clicking the No button if asked to save. Right click on the desktop, bring your mouse down to New and select Folder.

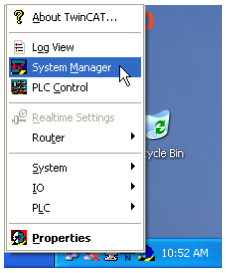


2. Type your name and hit the Enter key on the keyboard.

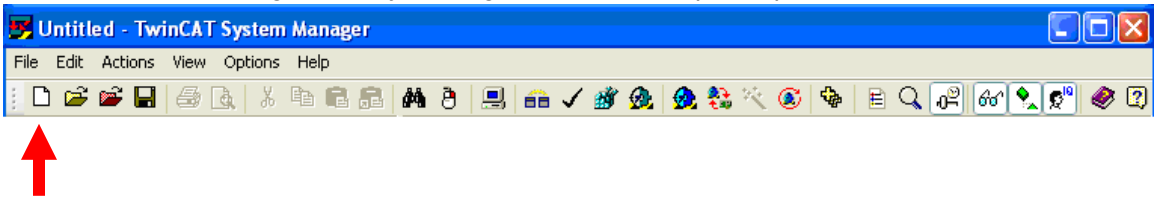
Hardware Configuration

3. Click on the TwinCAT icon in the system tray.

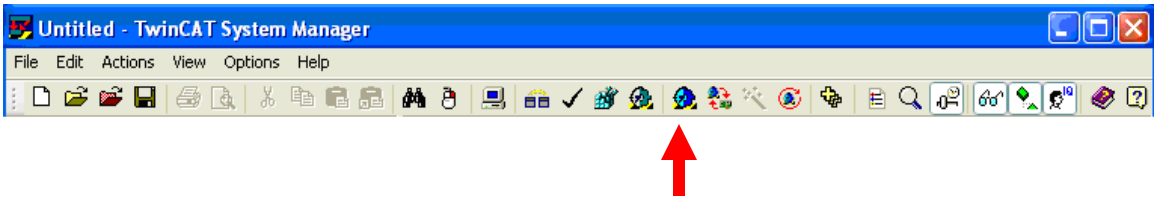
3a. Select System Manager.



3b. Start a new configuration by clicking the New button (Ctrl+N).

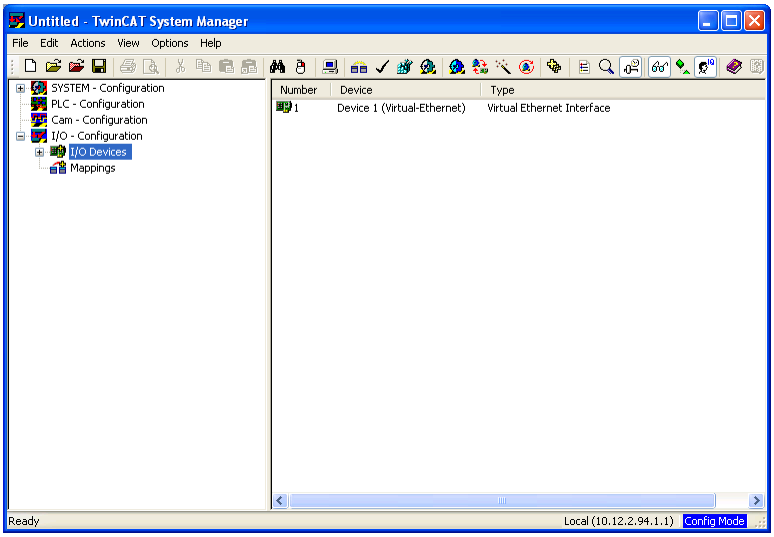


4. Enter Config mode by clicking the Set/Reset TwinCAT to Config Mode button (Shift+F4).

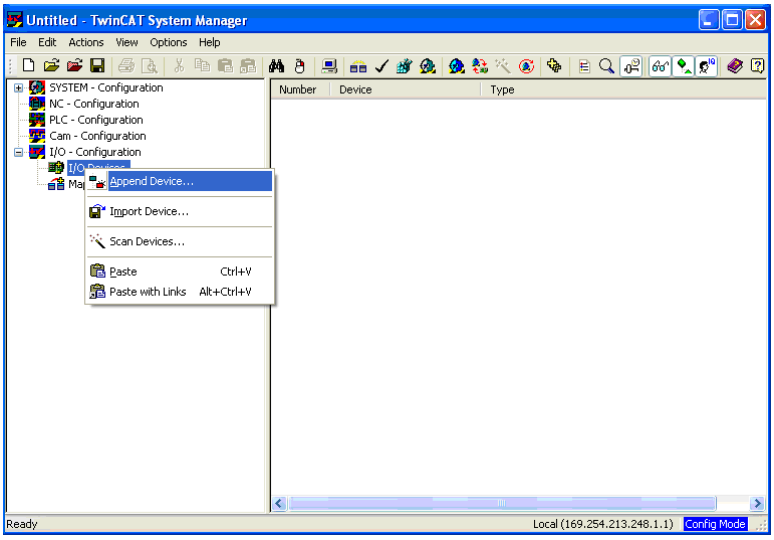


4a. Click on the OK button to Restart TwinCAT System in Config Mode.

5. If necessary, click on the ⊞ next to I/O - Configuration



6. Right-click on I/O Devices and select Append Device

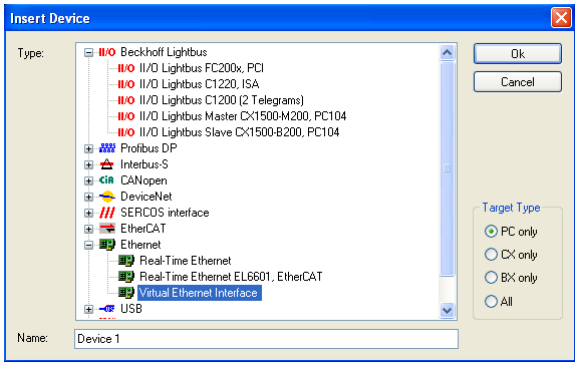


? Why

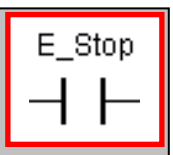
The purpose of appending is to be able to configure hardware when offline or if the Fieldbus being configured is unavailable.

7. Click on the ⊞ next to Ethernet then select Virtual Ethernet Interface.

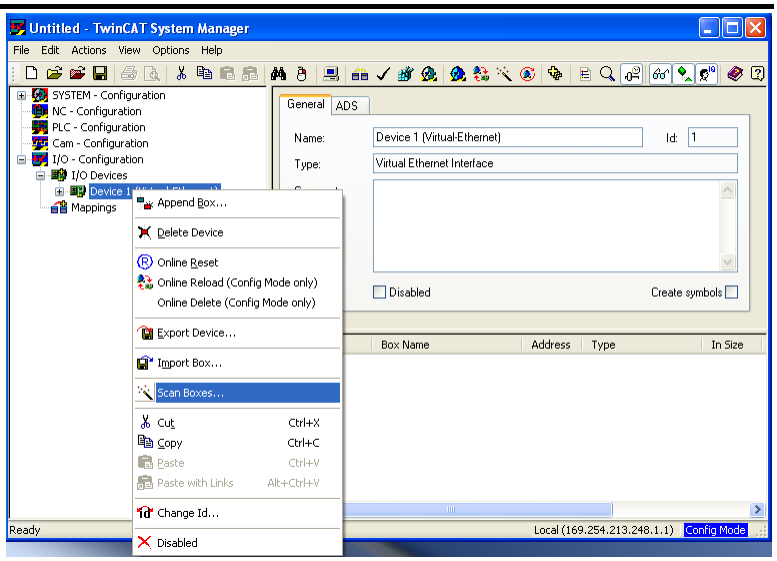
7a. Click the Ok button.



If Append Device is grayed out, then the system is not in config mode. Click the Config Mode button (see step 2 above) or (shift-F4).

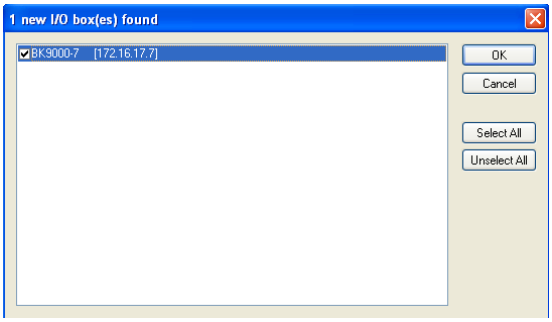


8. Right click on Device 1 (Virtual-Ethernet) and select Scan Boxes.



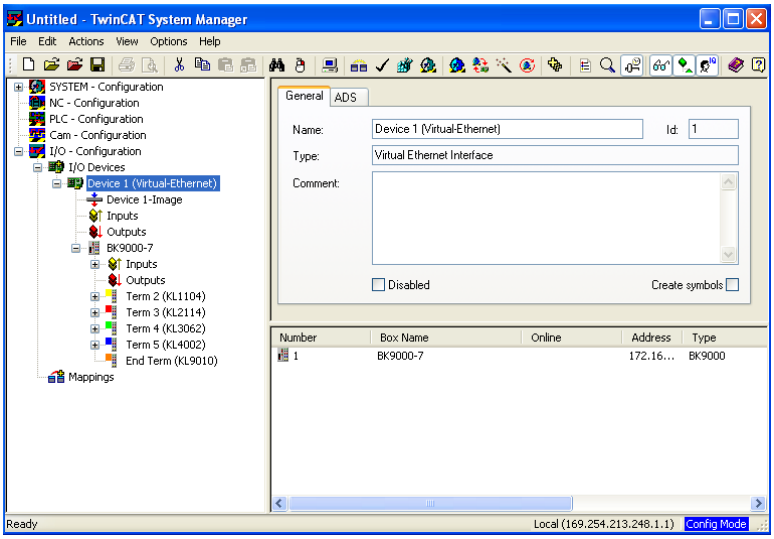
9. Click on the check box next to BK9000-7 (exact number might be different) to select.

9a. Click the OK button.

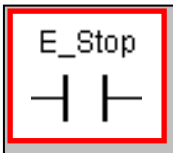


10. Click on the ⊞ next to BK9000-7 (will be the same device name as discovered in step 7 above).

Notice that all the input and output slices are listed but not all the other types of slices existing in the box.



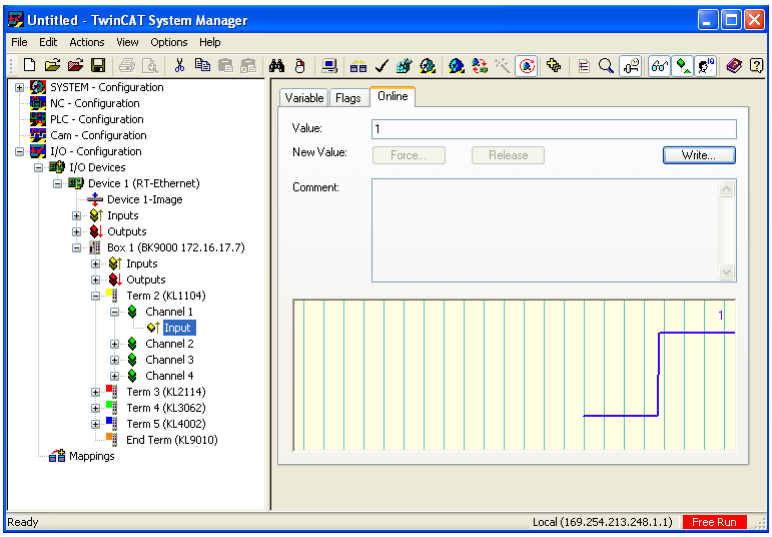
Only controllable elements need be displayed. Other elements, such as power terminators are unprogrammable so there is no need having them clutter up the System Manager.



For System Manager to find attached devices, you may have to either turn off Windows Firewall or open ports bf02 and bf03. Contact support help if necessary.

Testing Configured Hardware

TwinCAT System Manager can also be used to test the attached hardware to ensure that everything is configured correctly and functioning. Basically, inputs will be captured and outputs will be forced.



Once the hardware is “seen” by TwinCAT System Manger by way of appending and scanning, individual slices can then be queried and acted upon. This process mimics how the box will react when connected to a PLC.

The terminals are separated into the different channels that are available for communication. The channels contain the direction of communication available to that terminal.

It has already been discussed how System Manager is configured in Config Mode, a sub-mode of Config Mode is Free Run Mode which allows for checking inputs and outputs. This mode empowers System Manager to operate like a real-time PLC where inputs and outputs are controlled manually instead of via a PLC program.

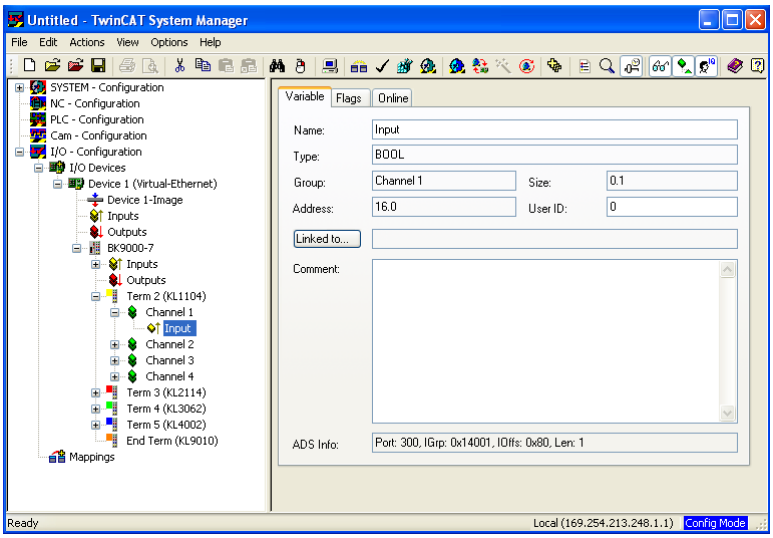
Watching an input on a particular slice while its associated, physical input is tripped will result in an on-screen response. This is displayed in a built-in scope within System Manager. Likewise, simulating an output using System Manager will result in a response in the physical hardware.

Lab 2: Testing I/O

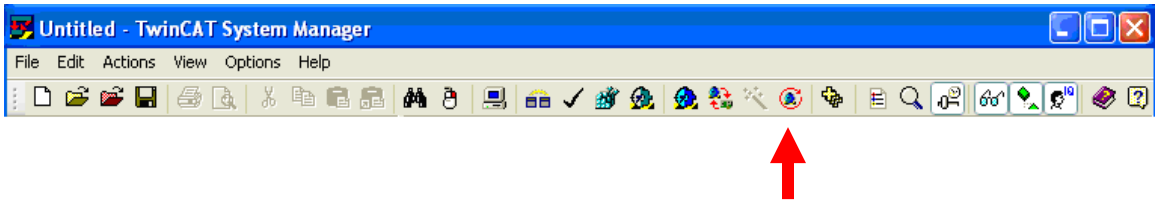
Purpose: In this lab you will learn to manually check the hardware connections. Besides ensuring that the hardware is functioning before applying a program, this can be one of the steps in troubleshooting a system.

1. Returning to your previous lab bench, start by clicking on the ⊞ next to Term 2 then click on the ⊞ next to Channel 1.

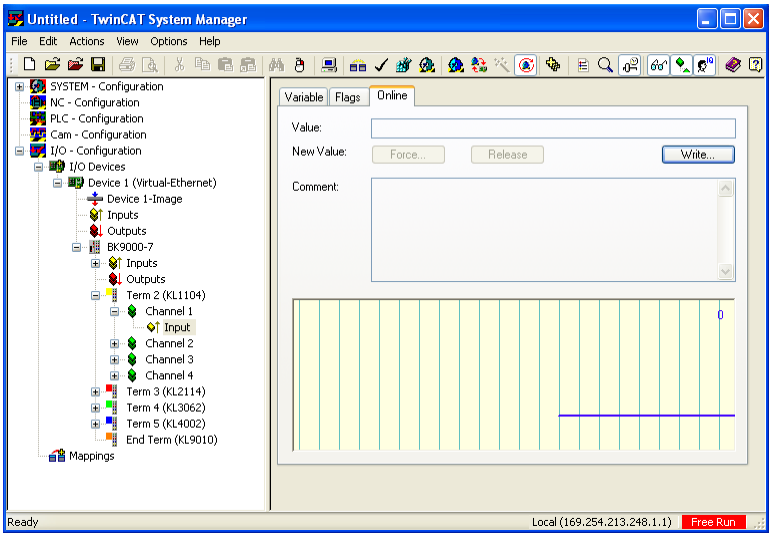
1a. Select Input.



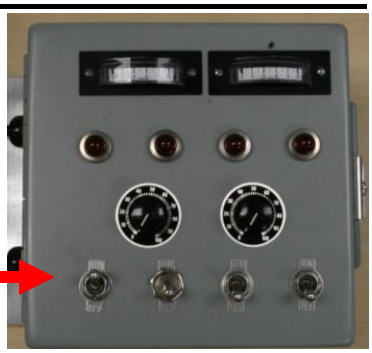
2. Enter Free Run mode by clicking the Toggle Free Run State button (Ctrl+F5).



3. Click on the Online tab.



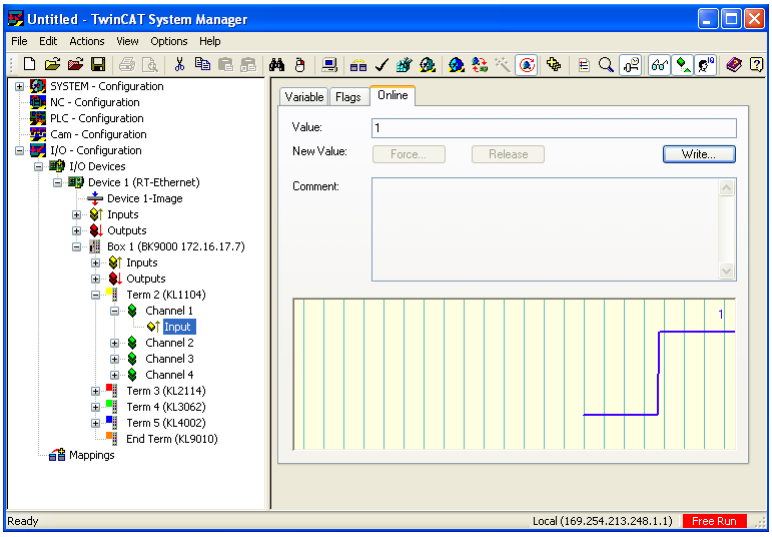
3a. Flip the first switch on the demo box to On (your demo box might look somewhat different).



3b. The scope in TwinCAT System Manager should respond.

3c. Also notice that a LED on the Digital Input slice (yellow) has illuminated.

3d. Flip the first switch on the demo box to Off.

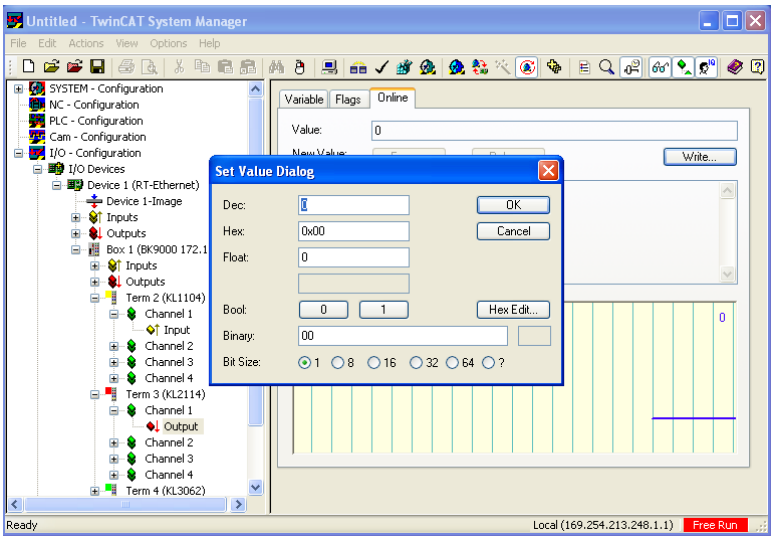


4. Click on the ⊞ next to Term 3 then click on the ⊞ next to Channel 1.

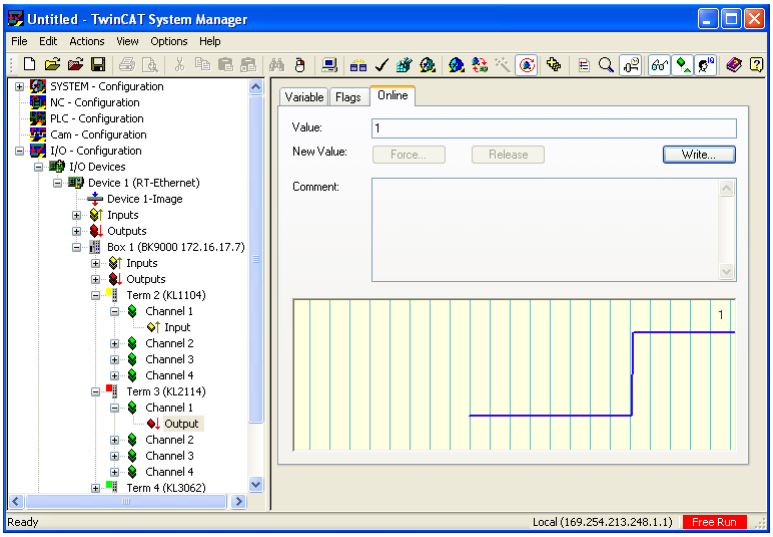
4a. Select Output

5. Click the Write button.

5a. Click the 1 button.



5b. Notice the scope in TwinCAT System Manager.

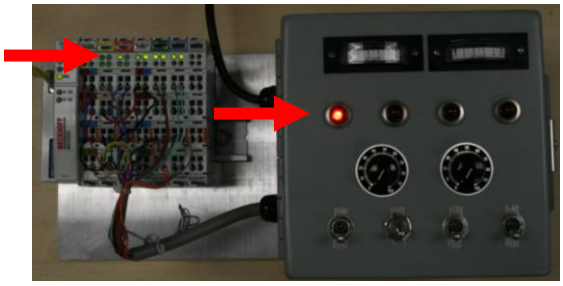


6. Check the demo box for light 1.

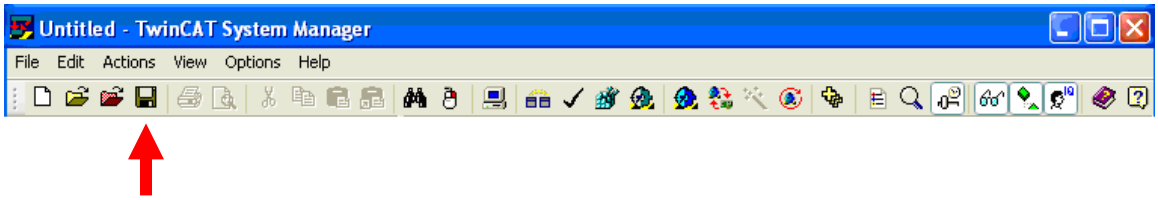
6a. Also notice that a LED on the Digital Output slice (red) has illuminated.

6b. Click the Write button again.

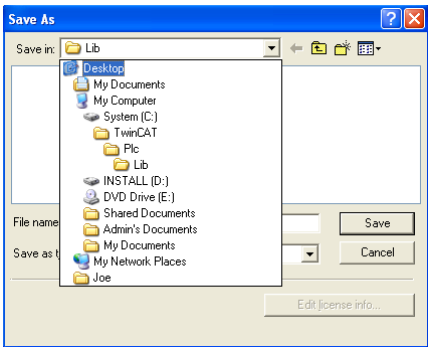
6c. Click the 0 (zero) button.



7. Click the Save button.



8. Select the folder you made in the beginning of Lab 1. Click on the Save in field, it should be at the bottom of the pull down menu. Otherwise, click on Desktop and it should be listed there.



9. Type First_Project in the File name field.

9a. Click the Save button.

PLC programming with TwinCAT PLC Control

As part of the Beckhoff's commitment to providing one solution for all of your PLC needs, TwinCAT PLC Control offers a programming environment with all the features and support necessary to meet the requirements of any PLC application. This includes five IEC standard programming languages plus a new variation on FBD called CFC which is not yet a standard:

IL (Instruction List) – is a low level language with a structure similar to a simple machine assembler. Though it can be used to write tight code for simple yet critical operations, it is the least documented language of the IEC standard, because of this, it might not be the best choice for beginner programmers. There is a proposal to improve IL so a future version might make it a better choice.

LD (Ladder Diagram) – aka RLL (Relay Ladder Logic) is representative of electrical wiring diagrams, specifically ones used in the car industry. Subsequently it is easy for people familiar with simple electrical systems and is well accepted by electricians and plant technicians.
-Its main deficiencies are its lack of scalability and the variation of symbols used throughout the industry.

FBD (Function Block Diagram) – is a graphical language which effectively depicts a system in terms of the flow of signals between processing elements and is very similar to signal flows illustrated in electronic circuit diagrams.

SFC (Sequential Function Chart) – is a graphical language developed largely by a French standards group called Grafcet. It is structured as a series of steps which intuitively describe sequences of operations.

ST (Structured Text) – is a high level language with some similarities to PASCAL and BASIC.

CFC (Continuous Function Chart) – is a variation of FBD not yet a part of the IEC standard. In addition to the display of FBD, CFC also shows the resource and task assignments.

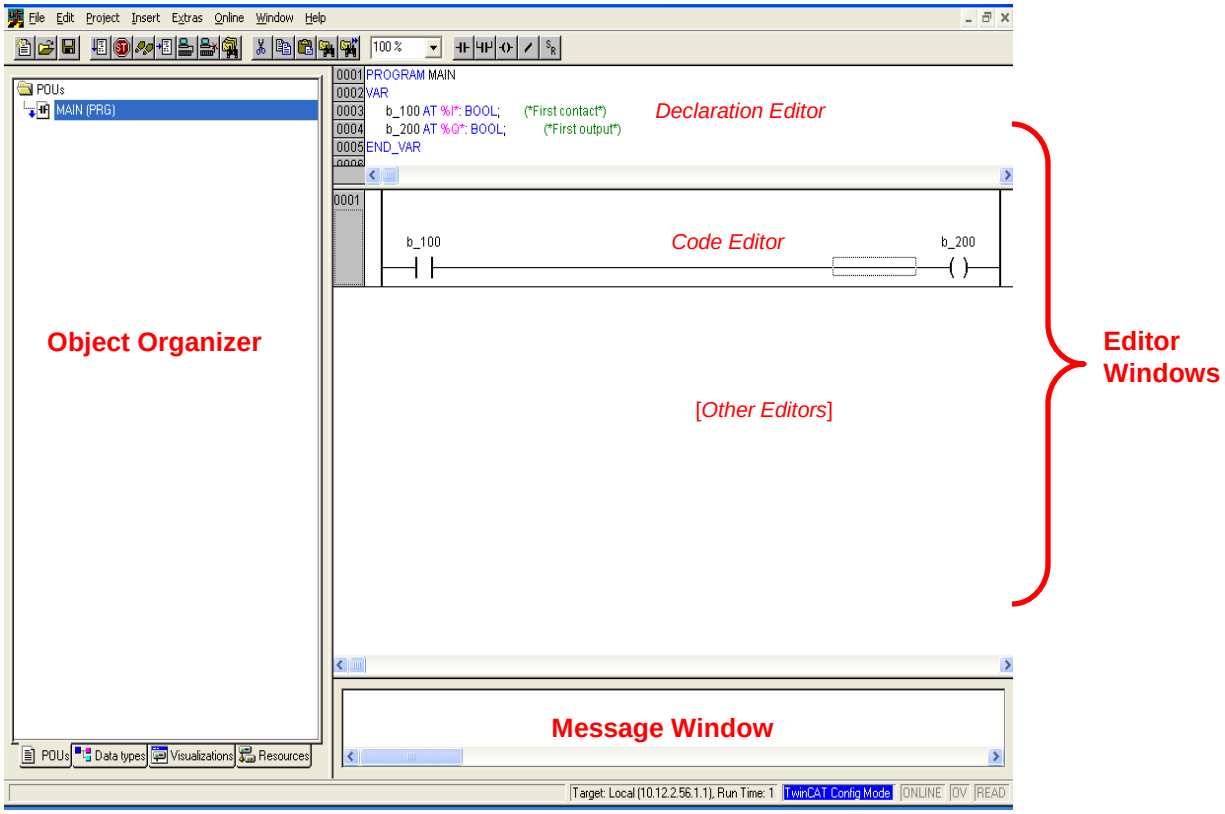
PLC Control allows for any number of the languages to be used in the completion of a Project. This not only allows the programmer to select the best method to design a system, but allows that programmer to switch between tools as the specific operations within that system demand.

A complete TwinCAT program is called a Project. A Project can contain three kinds of objects: Program Organizational Units (POUs), data types and resources, plus libraries which are collections of the afore mentioned objects which can speed the writing of new code and give the Project added power such as connecting to third party hardware.

A POU basically contains variables and the use of those variables. Data types are additional types of information that the variables designated in the POU(s) can be declared to contain. And resources are elements that multiple POUs may work with; most common are global variables, but also include hardware configuration tools, logging tools and the Library Manager (which lists available objects in any attached libraries).

Understanding the specifics of how TwinCAT programs are structured is not necessary to complete this training course. As one begins creating more complex programs, the above description will become clearer and more useful.

TwinCAT PLC Control is separated into four frames:



Editor Windows – This where the code is written. There will be an Editor Window for each object in your Project and each Editor Window will conform to the language used for that object. In the LD example above, there is a Code Editor that also includes a Declaration Editor:

> Declaration Editor – This is where the variables can be manually assigned though generally coding is done in the Code Editor where auto declaration does the work which is displayed in the Declaration Editor. In Run mode, this pane will also show the states of the variables.
>
> Code Editor – This is the main area for writing the code. Variables such as inputs and outputs can be added with a point and click methodology. In the LD example shown, the ladder rungs are displayed. As assignments are made, the Declaration Editor automatically updates to show the change.

Messages – As the program is compiled (built) and run, feedback is displayed here. Detected problems with the program will be identified here.

Object Organizer – This is where all the objects of the Project are listed. There is a tab for each of the three types of objects: POUs, Data types, and Resources. There may also be a tab for Visualizations where interactive graphic representations of inputs and outputs can be made.

Lab 3: TwinCAT PLC Control Familiarization

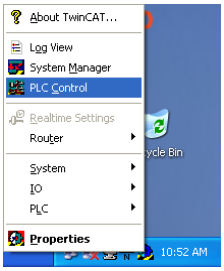
Purpose: In this lab, you will be creating a simple PLC program. This section is not intended to be even an introductory programming course; it is merely to acquaint you with the functionality of TwinCAT and basic procedure to start a project.

1. Click on the TwinCAT icon in the system tray.

1a. Select PLC Control.

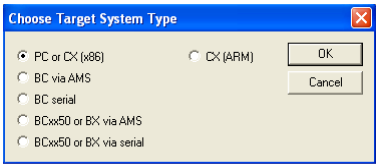
1b. Click the OK button when presented with the Could not open project/library alert.

1c. Go under the File menu to New.



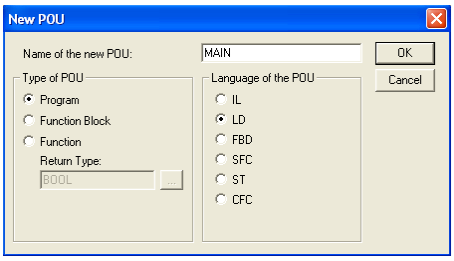
2. Select PC.

2a. Click on the OK button.

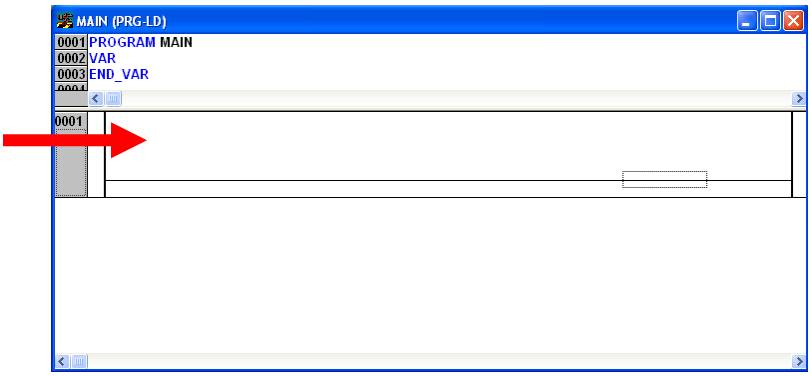


3. Select LD under Language of the POU.

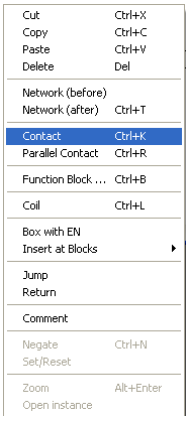
3a. Click the OK button.



4. Right click in the Code section of the programming window.

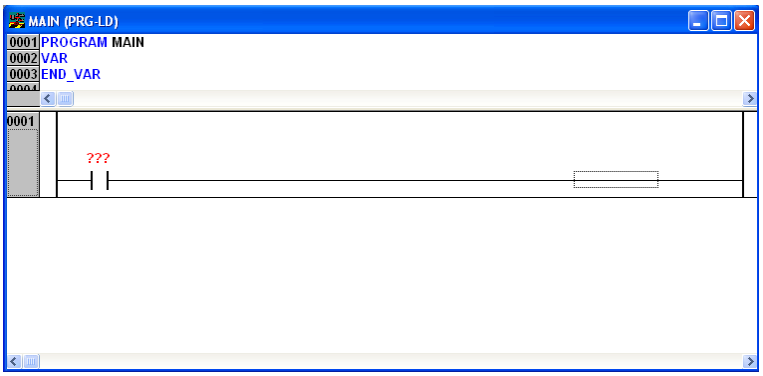


5. Select Contact (Ctrl+K).



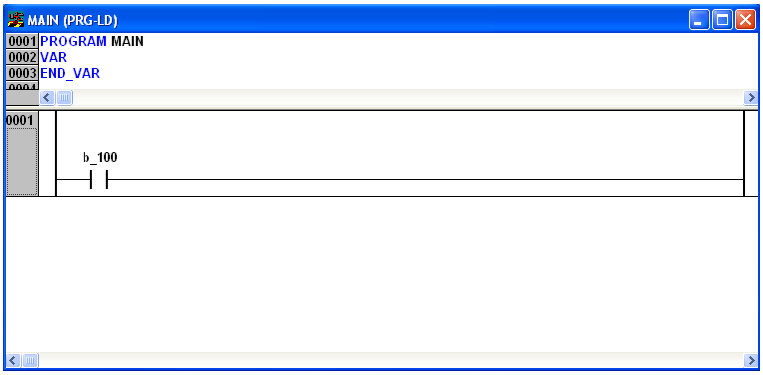
6. Click the red ???.

6a. The ??? should highlight. If instead you see a blinking line between ?s, than double click the ???.



7. Type b_100.

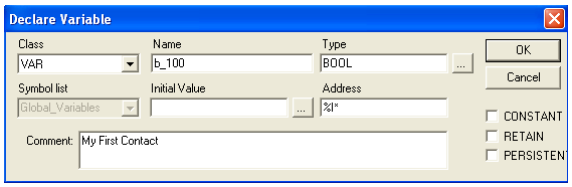
7a. Hit the Enter key on the keyboard.



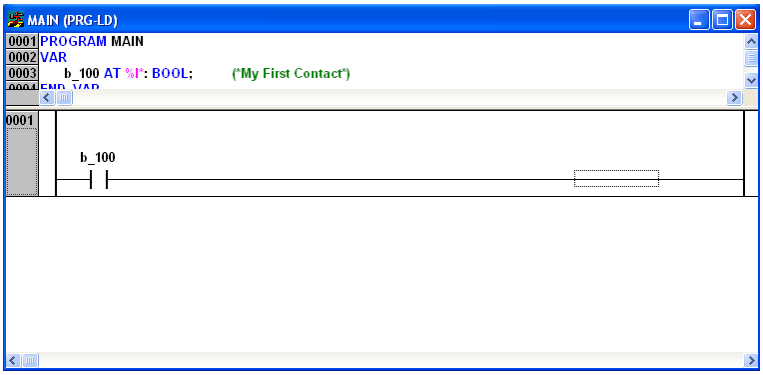
8. Type %I* (percent sign, capital “I”, asterisk) in the Address field.

8a. Type My First Contact in the Comment field.

8b. Click the OK button.

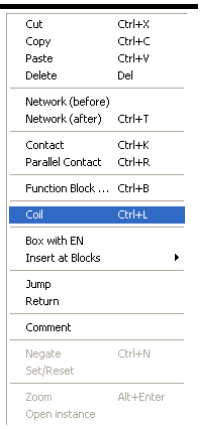


9. The Declaration area should update to reflect the changes.



10. Right click in the Code section again.

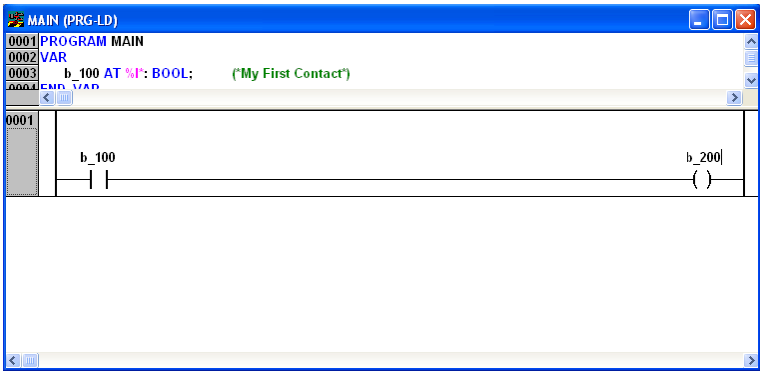
10a. Select Coil (Ctrl+L).



11. The ??? should already be selected, that is, they should be blue. If not, click on the red ??? to select it

11a. Type b_200.

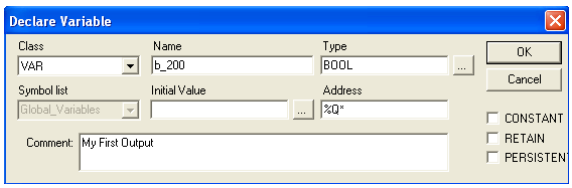
11b. Hit the Enter key on the keyboard.



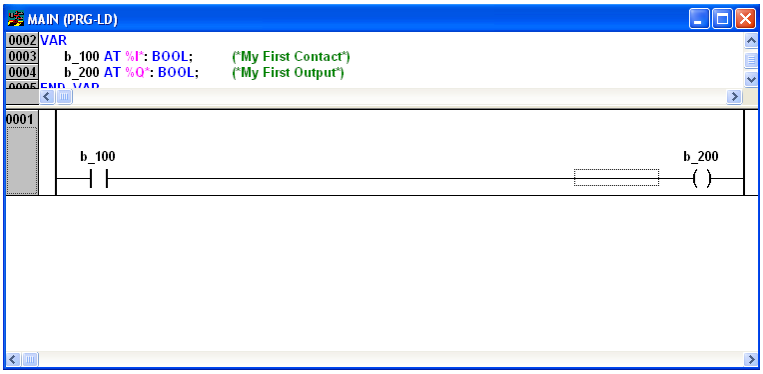
12. Type %Q* in the Address field. (“Q” is used as “O” might be misread as a zero.)

12a. Type My First Output in the Comment field.

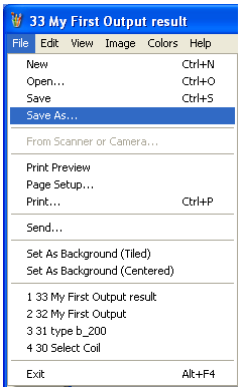
12b. Click the OK button.



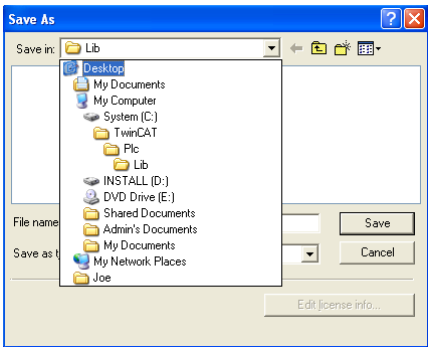
13. The Declaration area should update to reflect the changes.



14. Go under the File menu to Save As.

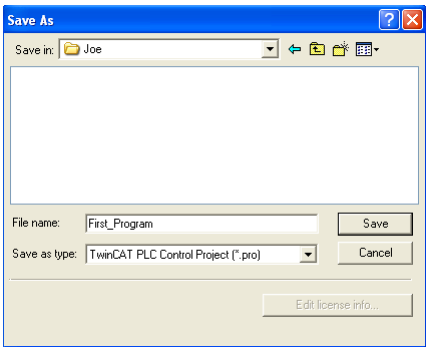


15. Select the folder you made in steps 1 and 2.
Click on the Save in field, it should be at the bottom of the pull down menu. Otherwise, click on Desktop and it should be listed there.



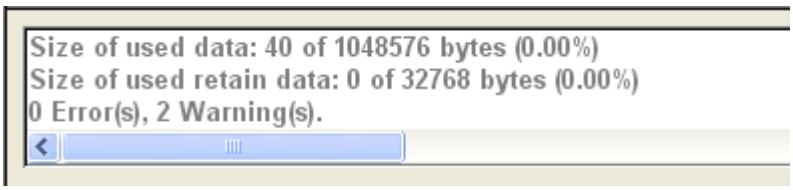
16. Type First_Program in the File name field.

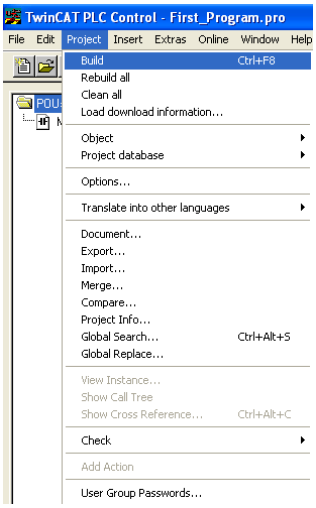
16a. Click the Save button.



17. Go under the Project menu to Build (Ctrl+F8).

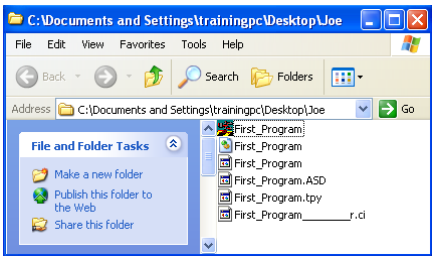
17a. There should be 0 (zero) errors reported at the bottom of the screen. It's OK to have any number of warnings.



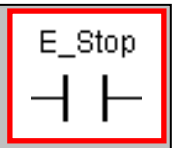


18. Go under the File menu to Save.

18a. The folder on the desktop should contain the following files.



If the .tpy file did not get created, there was probably an Error in the program when building. Remember that while there can be warnings, there must be NO errors.



Connecting the PLC Program to the Hardware

The System Manger is the bridge between a PLC program and the hardware being controlled. It assigns which hardware input is controlled by which software input. It also connects the hardware outputs to software outputs so the PLC programs can monitor and react to the changes in the hardware states.

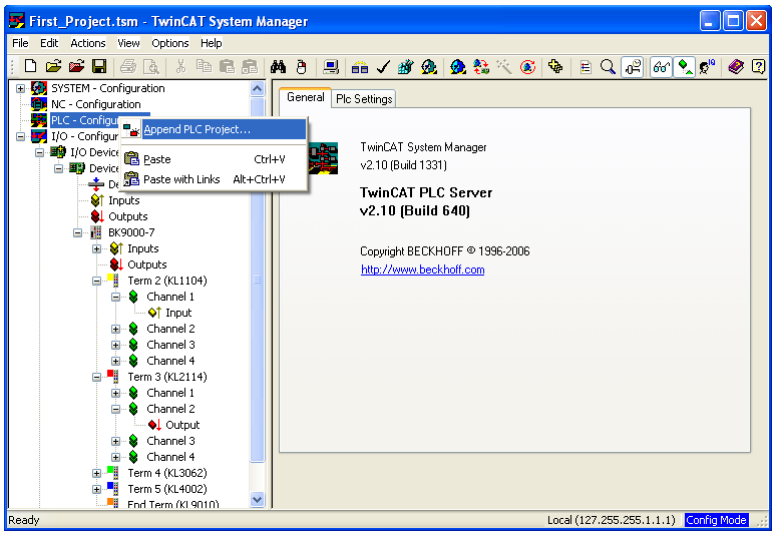
Lab 4: Putting it all together

Purpose: In this lab, you will be building on the knowledge gained in the previous labs to take the program you wrote and the hardware you configured and get them to communicate together.

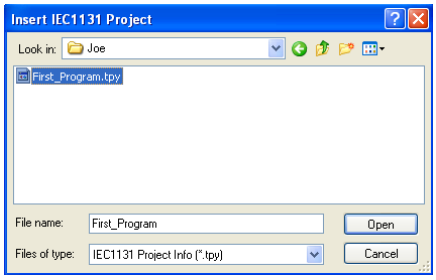
Hardware Configuration

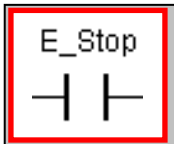
1. Switch to Untitled - TwinCAT System Manager using the Task Bar.

2. Right click on PLC - Configuration (scroll up in the left pane if necessary) and select Append PLC Project.



3. Find the folder you made in steps 1 and 2. Select First_Program.tpy and click the Open button.

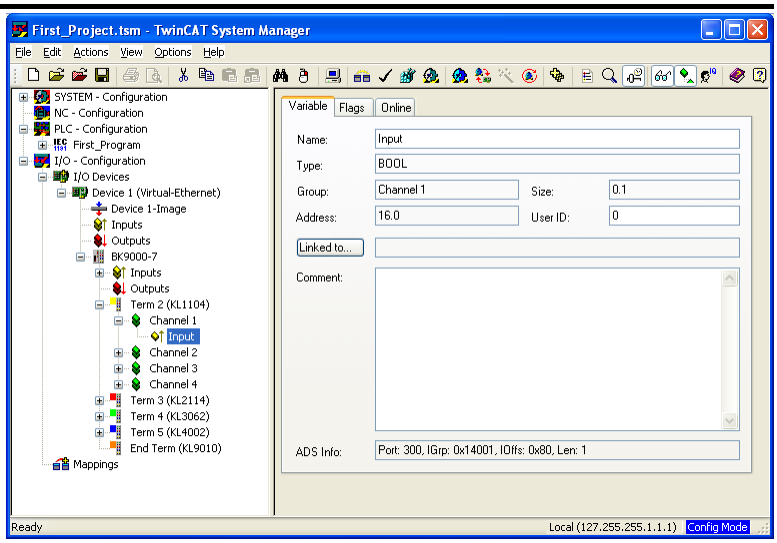




If input(s) are not showing up, the wrong program was probably Appended. Go under the File menu in PLC Control and select Save as to see where that version of the program was saved.

3a. If necessary, click on the ⊞s next to Term 2 and Channel 1.

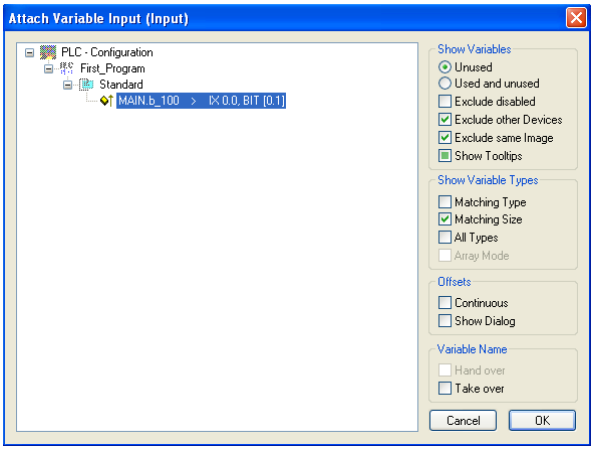
3b. Double click on Input.



4. Select MAIN.b_100.

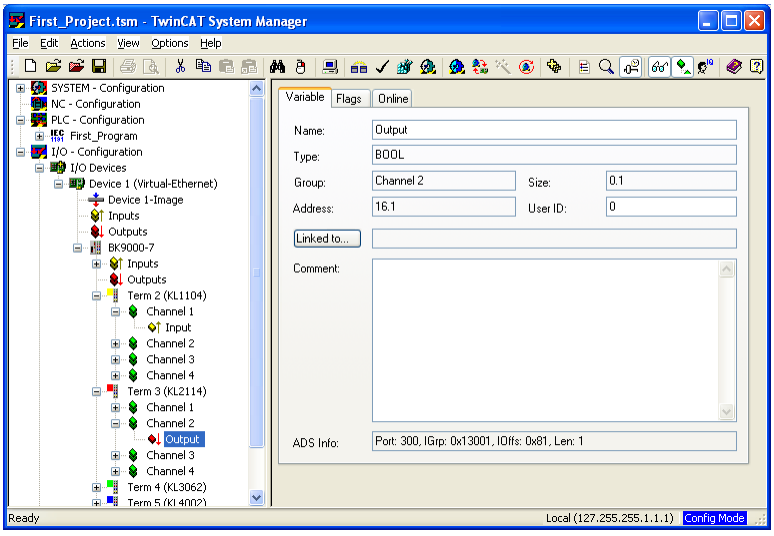
4a. Click the OK button.

-The Input icon now has a little arrow on it indicating that it is linked to a control.

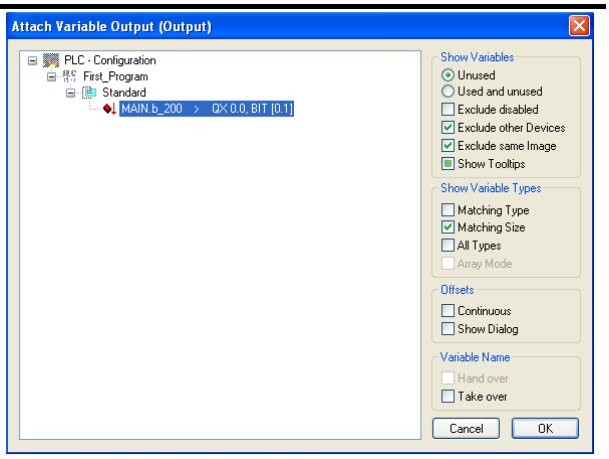


5. If necessary, click on the ⊞s next to Term 3 and Channel 1.

5a. Double click on Output.



6. Select MAIN.b_200.



6a. Click the OK button.

6b. Click the Save button (Ctrl+S).

7. Click on the Activate configuration button.

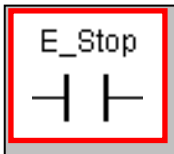
7a. Click on the Yes button that Document is modified!

7b. Click on the OK button to Activate Configuration.

7c. Click on the OK button to Restart TwinCAT System in Run Mode.

-The system should now be in run mode and both System Manager and the TwinCAT icon in the system tray should reflect this. See page 18.

-Notice that the WDG LED on the Bus Coupler is lit solid and the ACT LED is flashing quickly.



There are three ways to activate a configuration:

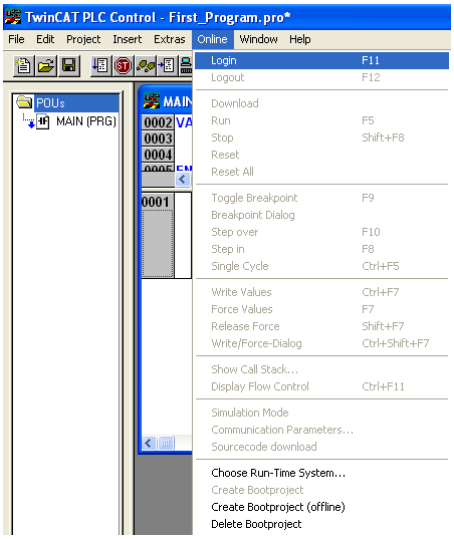
- **The Activate button**
- **Under the Actions menu and selecting Activate Configurations**
- **Ctrl+Shift+F4**

Launching the PLC

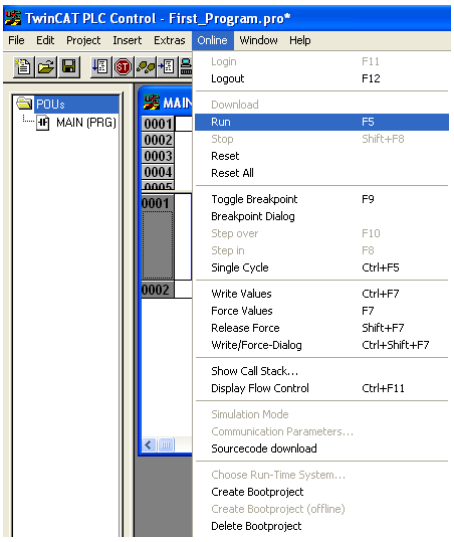
8. Switch to TwinCAT PLC Control using the Task Bar.

9. Go under the Online menu and select Login (F11).

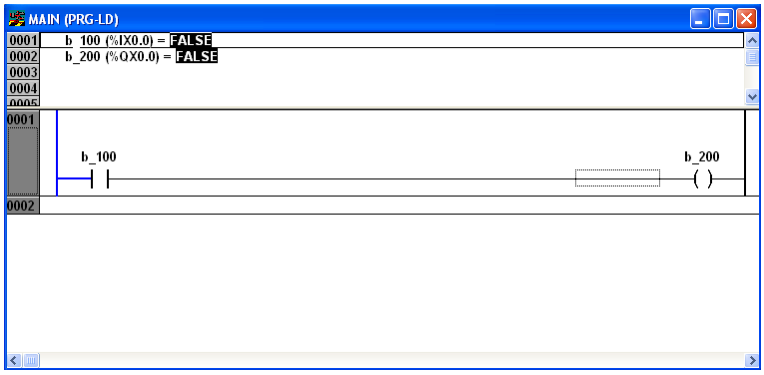
9a. When notified that The program has changed, click on the Yes button to Download the new program.



10. Go under the Online menu and select Run (F5).

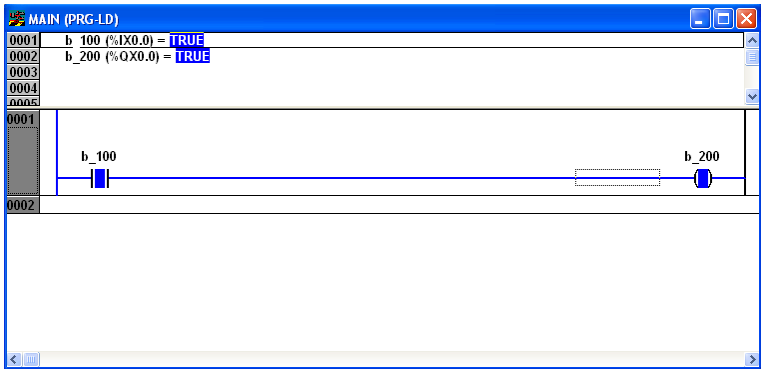


10a. The response should be FALSE for both the input and the output.



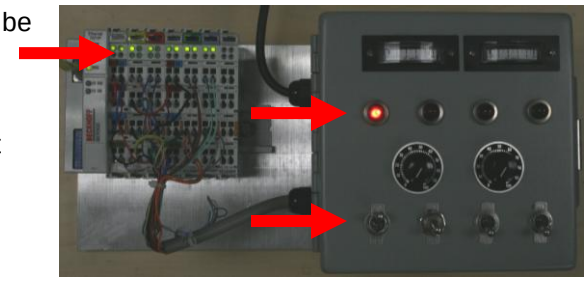
11. Flip the first switch on the demo box.

11a. The response for both input and output should now be TRUE and the contact and the coil should now be blue.



11b. The first light on the demo box should also be lit.

11c. Also notice that LEDs are lit on both the Digital Input slice (yellow) and the Digital Output slice (red).



12. Exit out of both PLC Control and System Manager, clicking the Yes button if asked to save.

Boot Project

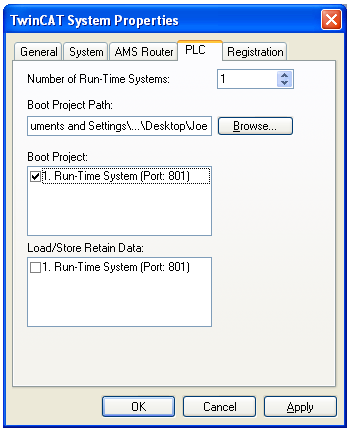
Most if not all system critical operations require the ability to automatically restart a system after a power-failure. As part of the previous labs, the PLC program was downloaded to the Bus Coupler, but that program is erased when power is cycled to the Bus Coupler.

Besides the system critical nature mentioned above, another way to help decide if a Boot Project is something to consider is to think about what would happen after a long shutdown. If this PLC is to control a conveyor belt of rocks, upon restoring power, there is no reason not to start up the belt again and deliver the rocks. On the other hand, if it is conveying cabbages instead, it would make sense to wait until the potentially rotted product is inspected and perhaps removed before manually restarting the belt.

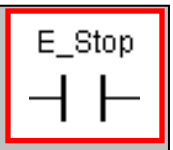
TwinCAT can be used to save a PLC program to the Bus Coupler so that it will be present and can initialize after a power cycle. This is accomplished by creating a Boot Project.

The Boot Project must be configured in three steps:
1. Setting the PLC program as a Boot Project
2. Setting the TwinCAT system to Auto Boot
3. Telling the TwinCAT system which Boot Project to load

Step 1 is done in PLC Control and steps 2 and 3 are done in TwinCAT System Properties. There is a secondary choice when configuring the second step above: Load/Store Retain Data. This is only checked if there is information that might have been written to a variable that needs to be referenced when restarting the system. If unsure whether you need this or not, please contact your Beckhoff representative.



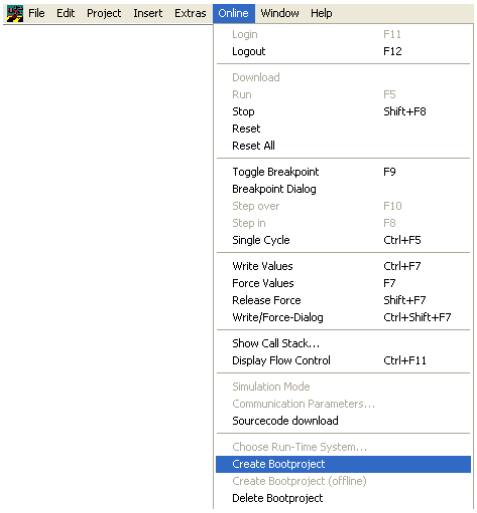
Make sure to save all changes to the PLC program. Not only is this a good habit in general, but more importantly, at auto restart, only the last SAVED version will be loaded.



Lab 5: Creating a Boot Project.

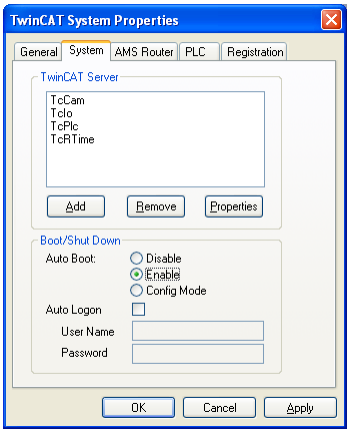
Purpose: In this lab you will learn to configure a Project as a Boot Project and how to configure the System Properties to automatically launch the project.

1. In PLC Control, go under the Online menu and select Login (F11) then again to select Create Boot Project.



2. Double click on the TwinCAT icon in the system tray.

3. Select the System tab and select the Enable radial button.



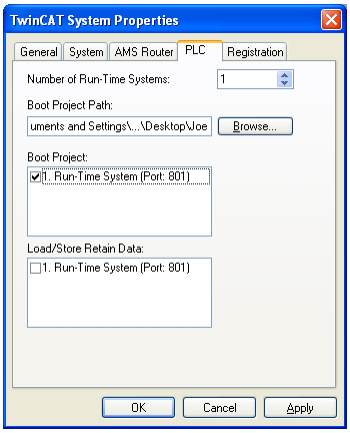
4. Select the PLC tab.

4a. Click the Browse button and find your folder on the desktop.

4b. Put a checkmark in Run-Time System in both the Boot Project and Lead/Store Retain Data fields.

4c. Click the Apply button.

4d. Click the OK button.



Scope View

Also installed with TwinCAT is a diagnostic tool called TwinCAT Scope View. Scope View is something of a virtual oscilloscope and works with System Manager and PLC Control together to not only offer another method of visualizing results, but will aid in tweaking the system, especially in motion applications.

Both System Manager and PLC Control need to be running for Scope View to be configured. Once configured however, as long as the program has been downloaded to the hardware and is running, Scope View can be used by itself to monitor the box.

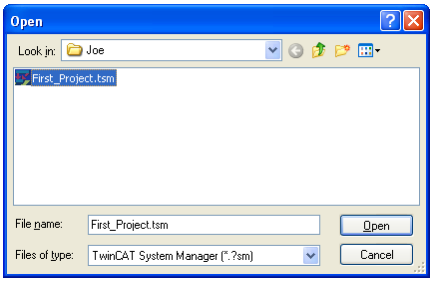
Lab 6: Configuring and Using Scope View.

Purpose: In this lab you will learn to configure Scope View to monitor your project (both the PLC program and the hardware being controlled).

1. Launch System Manager.

2. Go under the File menu and select Open (Crtl+O).

3. Find your folder on the desktop and, select First_Project.tsm and click the Open button.



4. Click on the Activate configuration button.

4a. Click on the Yes button that Document is modified!

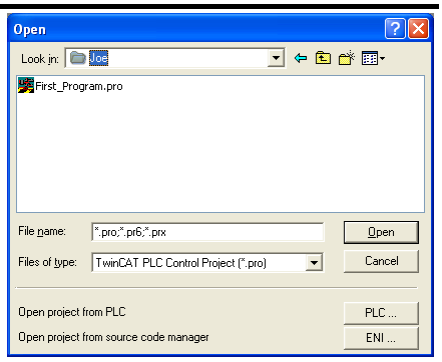
4b. Click on the OK button to Activate Configuration.

4c. Click on the OK button to Restart TwinCAT System in Run Mode.

5. Launch PLC Control.

6. Go under the File menu and select Open (Ctrl+O).

7. Go to your folder on the Desktop, select First_Program.pro and click the Open button.

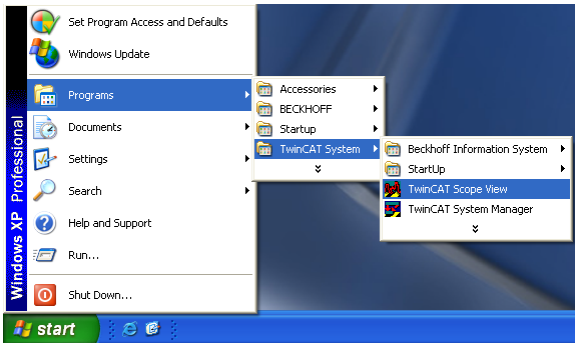


8. Go under the Online menu and select Login (F11).

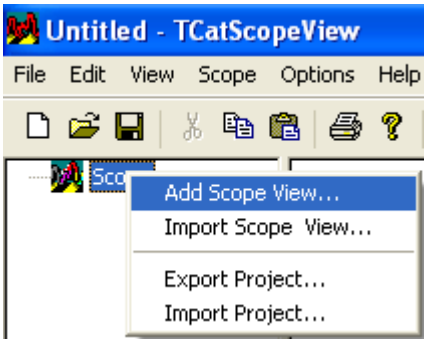
8a. When notified that The program has changed, click on the Yes button to Download the new program.

9. Click the Run button  (F5).

10. Click the Start button, then go to Programs (or All Programs) then TwinCAT System then TwinCAT Scope View.

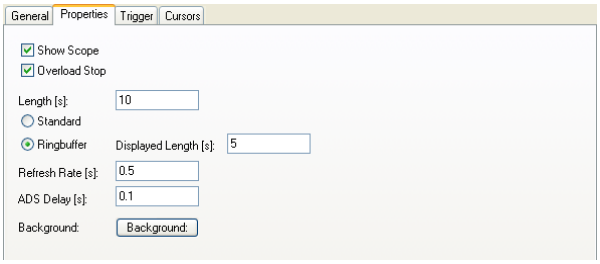


11. Right click on Scope and select Add Scope View.

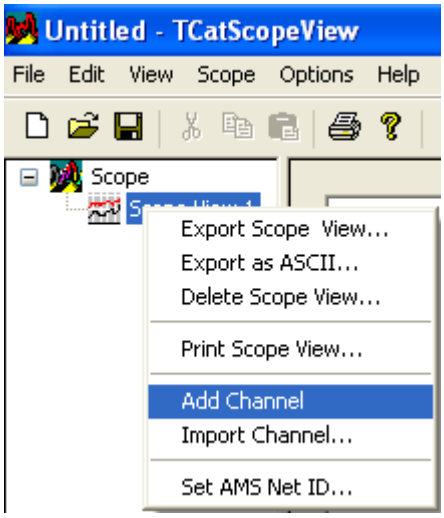


12. Click on the Properties tab in the bottom section of the screen.

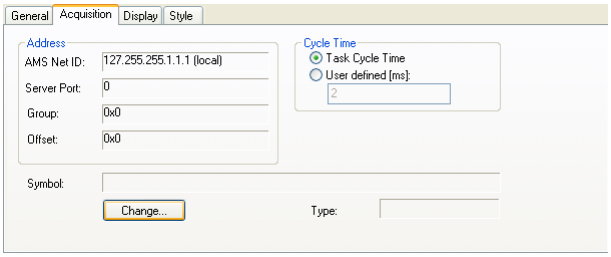
12a. Click on the Ringbuffer radial button.



13. Right Click on Scope View 1 and select Add Channel.



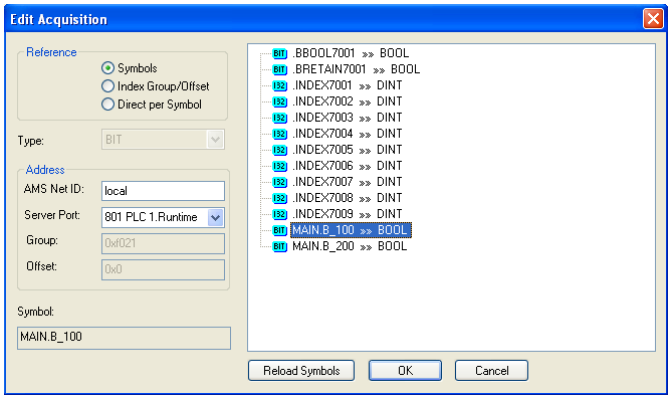
14. Click on the Acquisition tab and click on the Change button.



15. Click on the Reload Symbols button.

15a. Select MAIN.B_100.

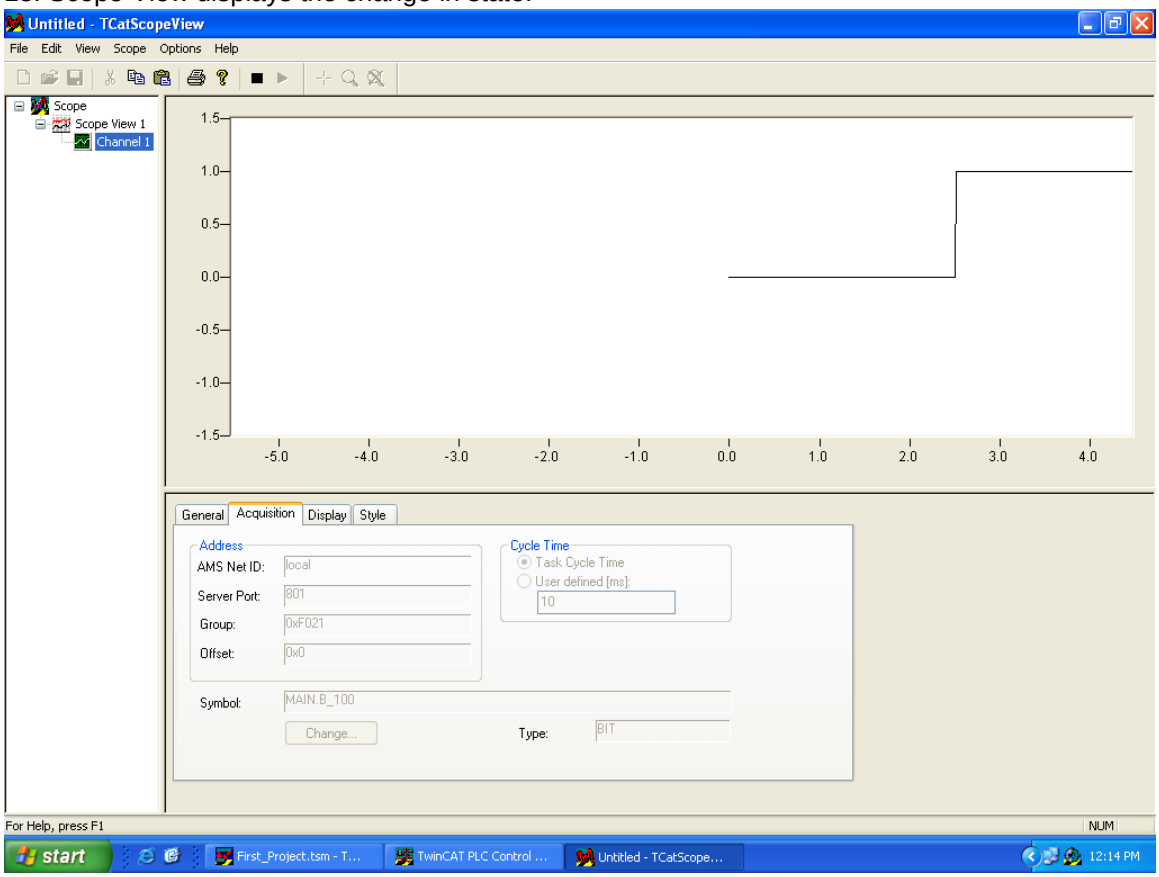
15b. Click the OK button.



16. Click on the Start button  (F5).

17. Flip the first switch on the demo box to On.

18. Scope View displays the change in state.



Documentation

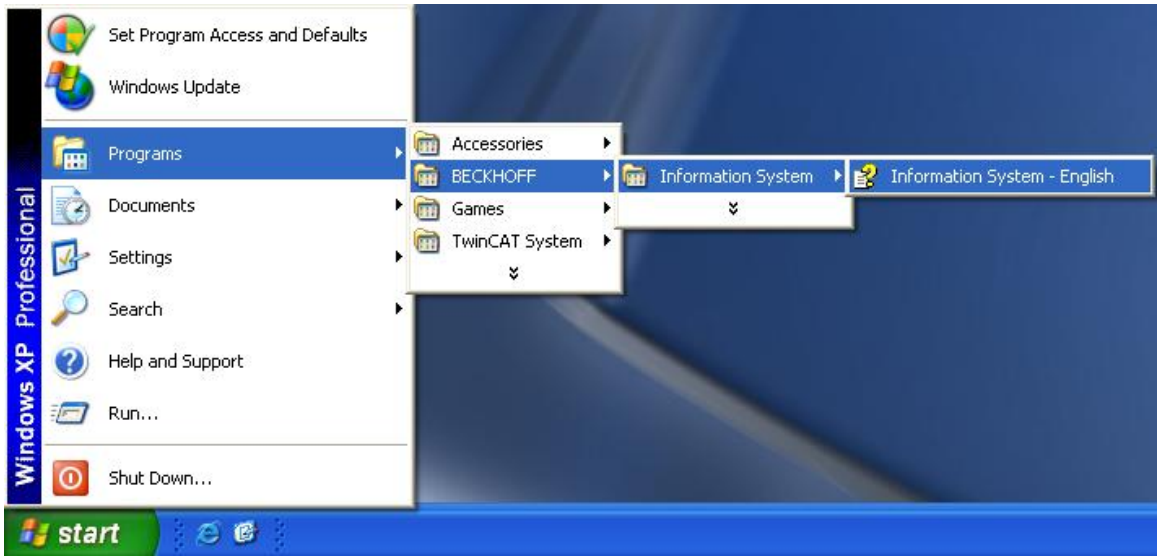
A number of sources of information are available when learning about, using specific Beckhoff tools, Beckhoff products and services and company information. As a customer of Beckhoff, all of this information will be at your disposal.

Beckhoff Information System

By far, the most complete source of information is the Beckhoff Information System. It includes information about every Beckhoff product, its use and interoperability. When TwinCAT is installed from the CD, the complete Information System is automatically installed. If TwinCAT was installed from a download, a slimmed-down version may have been installed to save download time. The full version can also be downloaded from the Beckhoff site.

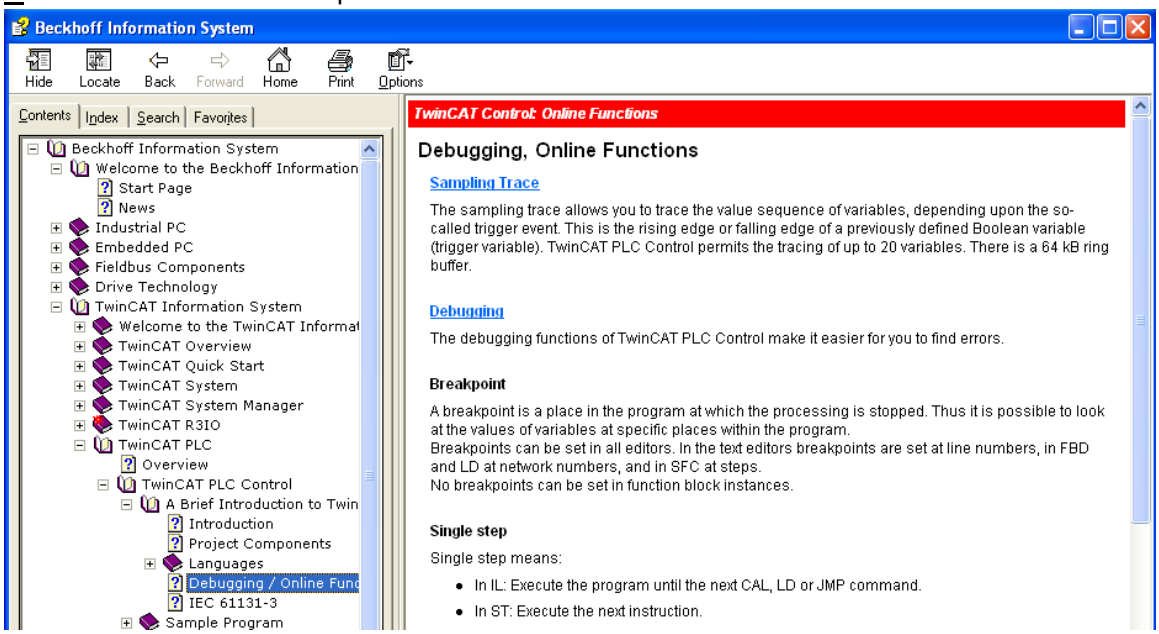
Arguably, Information System's greatest asset is in its help with troubleshooting. Information System includes explicit details of programming and hardware elements. This includes error codes plus their causes and potential remedies.

To access Information System, click the Start button, then Programs (or All Programs) then BECKHOFF, then Information System and finally the language of your choice.

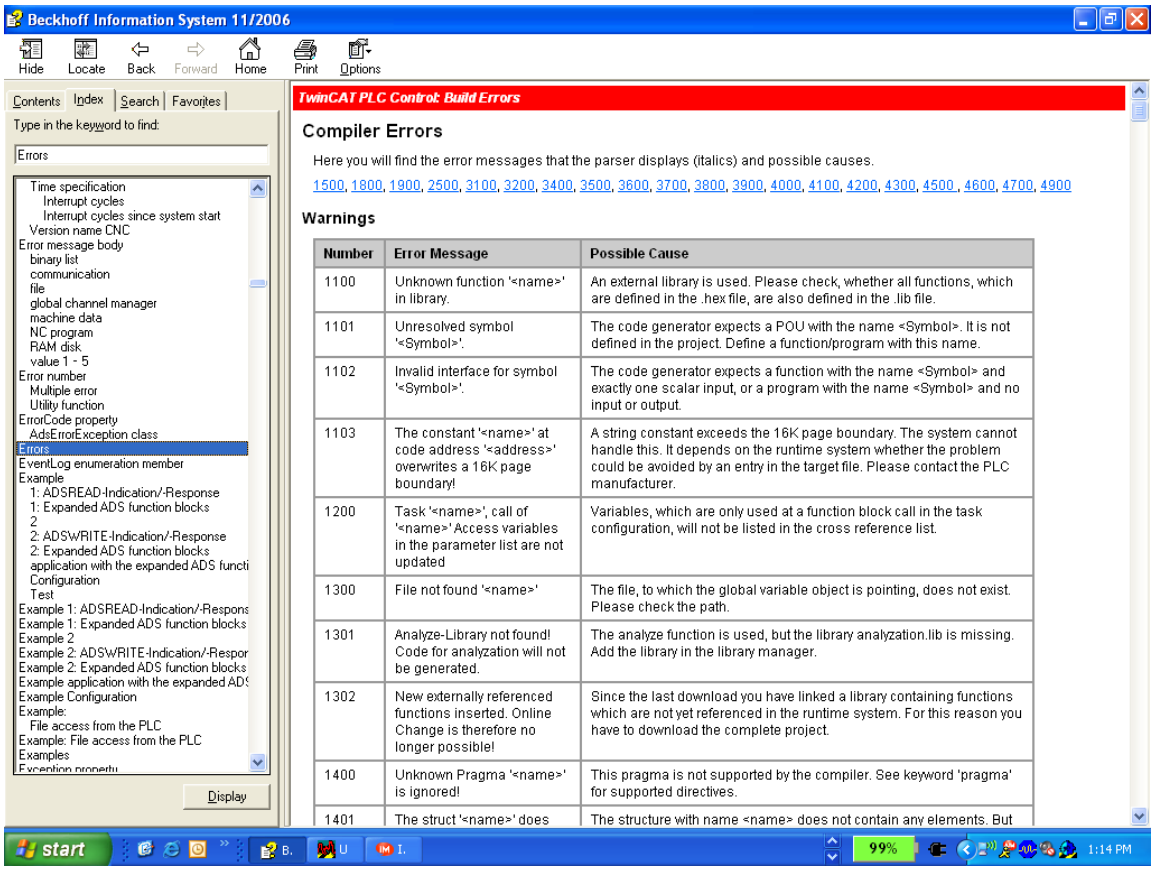


There are three main ways to find information in the Information System:

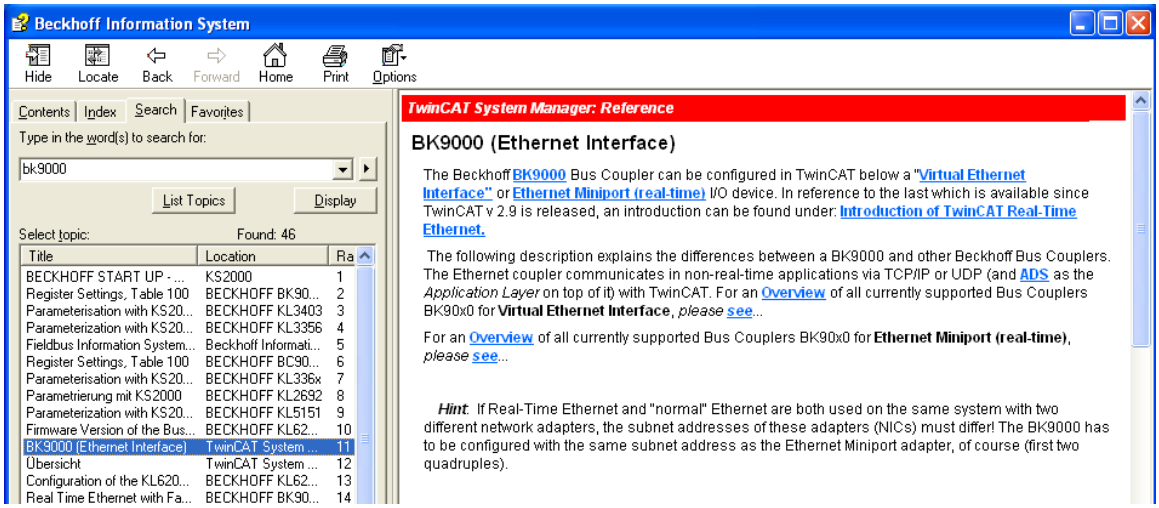
Contents shows a tree of topics that can be browsed.



Index takes a keyword and shows items specified as being related to that keyword.



Search returns every page that contains the entered search term.



If you find something close to what you are looking for in a search, try clicking on the Contents tab to see where the selected page falls in the tree. You can then browse from there to pinpoint the information you require.

Other resources

www.beckhoff.com

This is the official website of Beckhoff Automation. At this site you will have access to company information, including news, training locations, contact information, products and services.

PC Control

This printed, monthly magazine, published by Beckhoff offers stories about companies that are benefiting from the incorporation of Beckhoff products plus tips, new product announcements and general news. It can also be read online at www.pc-control.net/english.

Main Catalog

This printed document contains all of Beckhoff's products and services and also includes some company information. See the **I/O** section in this manual for a description of model numbering and color scheme.

Products & Solutions

This CD set includes a CD with the entire website, Main Catalog, documentation, all of the publications of PC Control available at the time plus a second, installation CD of Beckhoff software products.

General PLC Information

For non-company specific information on the PLC standards, programming and more, visit www.plcopen.org.

Glossary

ADS (Automation Device Specification), an interface that utilizes a Message router to communicate between ADS devices over TCP/IP.

Box, a Bus Coupler, Bus Controller or a Fieldbus Box. It can also refer to the lab device used in training.

Bus Terminal (aka slice), the part of the box that handles I/O and sometimes added communication and specific electrical requirements.

CFC (Continuous Function Chart), a version of FBD that is not yet an IEC standard PLC programming language.

CNC (Computer Numerical Control), connected to a machine to repeatedly make items and whose program can be updated or replaced to change production.

Deterministic computation, given an initial state of a system, the system will always produce the same final state when given the same input.

DIN (Deutsches Institut für Normung), normally used in reference to DIN rails (also called top-hat rails) which are used to mount control equipment, specifically Bus Couplers and Bus Terminals, inside equipment racks.

DLL (dynamic-link library), a block of code that is called by a program but remains separate, generally written in higher-level languages.

FBD (Function Block Diagram), an IEC standard, graphical, PLC programming language.

Fieldbus, an industrial network system for real-time distributed control.

Force, the act of manually changing the state of an input or output. Can be performed programmatically in PLC Control, virtually in System Manager or physically on the box.

IEC (International Electrotechnical Commission), the world standards organization for electrical and electronic international standards.

IEC 61131-3, the global standard for common industrial control programming.

IL (Instruction List), an IEC standard, text based, PLC programming language.

I/O (Input/Output), communication between a computer and its users, its storage devices, other computers (via a network) or attached hardware.

Jitter, very small timing fluctuations. Used when discussing deterministic timings and usually described in microseconds. Can also be considered a component of task time when figuring response times.

K-Bus, internal bus for communication and power between the coupler and Bus Terminals.

Kernel, the part of a computer operating system that manages the system's resources and the communication between hardware and software components.

LD (Ladder Diagram), an IEC standard, graphical, PLC programming language.

Library, a collection of POUs (generally Functions and Function Blocks) often grouped together by task, that aids in development.

Link, the means by which the hardware information is connected to the software information.

Millisecond, 1000th (0.001) of a second.

NC (Numerical Control), predecessor of CNC, connected directly to a machine to repeatedly make a single item.

OCX, a DLL that contains one or more ActiveX controls. Mainly used when linking a program to code written in Microsoft Visual Basic or .net.

Online, Beckhoff uses this term to describe connecting to the box in real time.

OS (Operating System), the software that runs a computer or is embedded in and runs Fieldbuses.

PLC (Programmable Logic Controller), a small special-purpose computer used to automate machines.

PLC Control (TwinCAT PLC Control), the Beckhoff PLC programming environment.

POU (Program Organization Unit), functional elements within a PLC program as described by IEC 1131-1.

Real Time, a live connection to hardware.

Real-time system, a computer system that is forced to respond to an input in an explicitly allotted time.
SFC (Structured Function Chart), an IEC standard PLC programming language that is both graphical and textual.

Slice, alternate name for Bus Terminal.

ST (Structured Text), an IEC standard, text based, PLC programming language.

System Manager (TwinCAT System Manager), the Beckhoff hardware configuration tool.

Tick, The smallest increment of time as measured by a computer system, usually measured in milliseconds.

TwinCAT (**T**he **Win**dows **C**ontrol and **A**utomation **T**echnology), all the PLC tools and system modification components offered by Beckhoff Automation.

Index