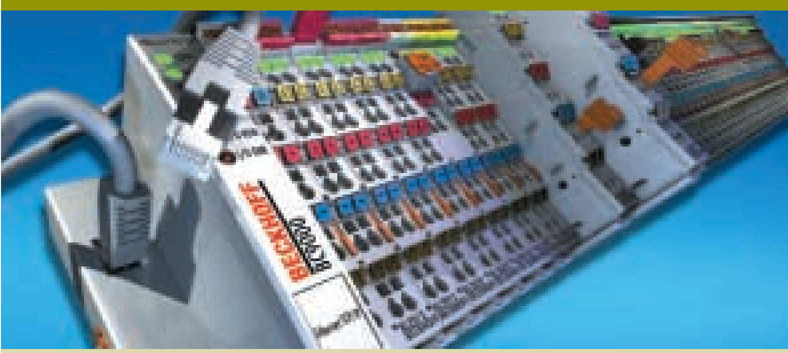
Beckhoff Controller Categories

Customized Automation

What has boxing got to do with automation technology? Not a lot, at first sight, but wouldn't it be nice if there were classifications in automation technology as clear as there are in boxing? – onto the scales before the fight, check the weight, and from that get a fair idea of what sort of performance can be expected. – Choosing a controller appropriate for a particular task often calls for a balancing act between the computing performance, complexity and the cost. Clear performance categories that would make the "painful choice" easier are absent even from the most clearly structured catalogs.



Bus Terminal Controller BC

Bus Terminal Controller BX

It would be possible, in analogy to boxing, to make the clock rate of the CPU used into an indicator of the "weight class". The hardware properties listed in the table on page 7 allow the controllers in the Beckhoff range to be allocated to four basic categories:

- Bus Terminal Controller BC (lightweight)
- Bus Terminal Controller BX (middleweight)
- Embedded PC CX (light-heavyweight)
- Industrial PC (heavyweight)

Bus Terminal Controller BC

The devices in the BC series of Bus Terminal Controllers have been on the market for some years now. They are aimed at the small automation applications sector, where either an autonomous automation task, or a distributed task, configured as a subsidiary controller in a fieldbus topology, is to be implemented. Put simply, a BC is a mini PLC with a slave connection to the associated bus system. It is either programmed over the fieldbus from a central PC, or by means of the serial programming interface with which all such devices are fitted. The full range of Bus Terminals is available in modular form as the I/O level. Although no other communication interface is available immediately at the BC, facilities are available in the Bus Terminal program for the exchange of data with other devices using, for instance, RS232/RS484. Only the BC9000, however, is capable of being connected to Ethernet. The BC family is used for all applications in which it is necessary for a program to be executed autonomously, such as when controlling relatively independent machine aggregates like conveyors or sorters, the regulation of critical processes (temperature, pressure, tension control) or in building automation (room temperature, shade, lighting). The size of the user program is restricted by the amount of memory installed.

Bus Terminal Controller BX

New on the outside, new on the inside, new all-over – Beckhoff's BX device family will be introduced for the first time at the end of November, 2002 at the SPS/IPC/DRIVES exhibition in Nuremberg, Germany. The level of its fittings and its performance place it between the BC and the CX. Similarly to the BC, it is a microcontroller-based device that can operate as an autonomous controller or as a fieldbus slave. The housing design is based on that of the CX1000, and allows any BX controller to be given a Compact Flash card for mass storage. The principal feature distinguishing the BC from the BX is the greater amount of memory fitted to the BX (see table), and what is expected to be the somewhat higher computing capacity. The BX devices also have two serial interfaces – one for programming, and the other one free – as well as the Beckhoff Smart System Bus (SSB) with which other peripheral devices such as displays can be connected. The device itself includes an illuminated 2 line x 16 character FSTN LCD display and an RTC (real-time clock). The Bus Terminals can be connected directly in the usual way. This series will find similar applications to that of the BC series, with the difference that the larger memory of the BX will allow significantly more complex, larger programs to be executed, and more data to be managed locally (recording history and trend data, for example), which can then later be fetched over the fieldbus or Ethernet.

Embedded-PC CX1000

The CX1000 system represents a transition in Beckhoff's range of products between controllers based on microcontrollers and those based on PCs, and has some features of both a hardware controller and of an Industrial PC. The housing can be mounted on 30 mm DIN rail; the I/O modules can be aligned adjacently; no moving components are used, and the system can be operated

Embedded PC CX

Industrial PC

without a screen or mouse; all the connections usual on a PC (DVI, USB, Ethernet, COM1/2/3, Audio, Video, Compact Flash) are available as options. The Windows CE.NET and Windows XP Embedded operating systems also rather suggest a PC. In terms of the fieldbus connection, the CX, like all Beckhoff Industrial PCs, can act as either master or slave, and supports the simultaneous operation of multiple fieldbusses.

The CX is the "light-heavyweight" amongst Beckhoff controllers, and has been equipped with medium to large tasks in mind, where the properties of Microsoft operating systems may also be required: a graphical Human-Machine Interface, networking, database access, a web server and so forth. The CX, which has a hardware floating point unit, is better equipped than the BC/BX Bus Terminal Controllers, particularly for tasks requiring heavy computation using floating point values or trigonometric functions. PC-based controllers are universal controllers – it is difficult to indicate typical applications, because the variety of possible uses is so large. In some cases the price/performance ratio is crucial, and the CX family here offers an effective entry to Embedded Industrial PC control.

The high end controller: Industrial PC

The Industrial PC family represents the most powerful class of devices. All the same, the performance is scalable to a high degree within this range of products through the selection of particular components (CPU and memory). It begins at 266 MHz with 64 Mbyte RAM and ends, presently, at 2.8 GHz with 1 Gbyte RAM. In between we find the typical "workhorses", such as a Pentium III 850 MHz with 128 Mbyte RAM, a configuration that is quite sufficient for a large number of demanding and extensive control tasks, and yet which represents a reasonable price/performance ratio. The available mechanical constructions are very flexible: the housing design permits components to be accessed from different sides, and the PCs can be mounted as built-in or add-on variations in a control cabinet or on support arms systems. The PCs may have a TFT display attached directly, or may be attached via CP-Link technology to the Beckhoff Control Panel, which may be up to 100 m away. The trend here is clearly moving in the direction of increased performance density in a smaller space, as illustrated by the new, compact C6300 series. Generally speaking the I/O level is connected via PC fieldbus cards, although onboard interfaces such as RS 232, USB or Ethernet can also be "abused" to implement a low price fieldbus.

Beckhoff Controller	CPU	Frequency	Memory Flash	Memory RAM	Compact Flash Card	FPU	RTC	NOVRAM	Supported Fieldbus Systems	Fieldbus Master/ Slave	Other Interfaces
BC2000 **BC3100** **BC4000** **BC7300** **BC8000** **BC8100**	µC	16 MHz	256 kB (max. 96 k available)	64 kB	-	Emulation	-	512 Byte	Lightbus Profibus Interbus Modbus RS232 RS485	Slave	RS232
BC9000		20 MHz		128 kB				4 kByte	Ethernet		
BX3100 **BX5120** **BX5200** **BX8000** **BX9000**	µC	25 MHz	1 MB (max. 256 k available)	1 MB	optional	Emulation	yes	2 kByte	Profibus CANopen DeviceNet RS232 Ethernet	Slave	SSB RS232/485
CX1000	x86 Pentium MMX compatible	266 MHz	16 MB (64 MB)	32 MB (128 MB)	yes	yes	yes	8 kByte	Lightbus Profibus CANopen DeviceNet Sercos	Master/ Slave	Ethernet USB, DVI, 2xRS232 1xRS485 Audio, Video
Industrial PC	Intel Pentium	850 MHz (e.g.)	40 GB hard disk	256 MB (e.g.)	optional	yes	yes	32 kByte optional	Lightbus Profibus Interbus CANopen DeviceNet Sercos USB, RS232	Master/ Slave	all standard PC interfaces

Many controllers – one programming software

All Beckhoff controllers, regardless of the performance class to which they belong, have one thing in common: they are all parameterized and programmed with one and the same software – TwinCAT. This gives the customer the freedom to make last-minute decisions: If the planned controller is no longer adequate, the next most powerful device can be used instead. Normally it is not necessary to make any changes in the user program for this purpose. The user continues to work with the same, familiar TwinCAT tools (e.g. the PLC programming interface, System Manager and TwinCAT scope), and only when the program is downloaded does he decide which device will execute it. Not every TwinCAT component, however, is supported by every platform. The Motion Control functionality, for instance, is only possible on devices at the CX level and above.

Consistent interconnection with ADS

A second important aspect is the possibility of programming centrally in plants where Beckhoff devices are networked. Segments where the physical transmission layer takes different forms may be bridged with the Beckhoff ADS protocol. It is possible, for instance, to use a programming station (PC) that communicates over Ethernet in order to program a BC3100, but for this to be connected via Profibus to a second PC in the Ethernet network.

The following table summarizes which TwinCAT functionalities are available on particular devices. TwinCAT PLC here refers to the execution of a IEC 61131-3 program, while TwinCAT NC handles Motion Control (i.e. point to point movement of axes), including special functions such as camshafts/flying saw. TwinCAT NC I includes interpolating 3-D movements; TwinCAT CNC is the quintuple interpolation package for machine tools and other machining centers.

Beckhoff Controller	Operating System	TwinCAT					
		I/O	PLC	PTP	NC I	CNC	OPC Server
BCxx00	Beckhoff BCOS	direct	R	-	-	-	R (via ADS)
BXxx00	Beckhoff BCOS	direct	R	-	-	-	R (via ADS)
CX1000	Windows CE.NET, XP Embedded	R	R	R	R	-	R
Industrial PC	Windows CE.NET, NT, NT Embedded, 2000, XP XP Embedded	R+T	R+T	R+T	R+T	R+T	R+T

The table illustrates whether only the runtime components can be executed on the destination device (R=Runtime), or whether the programming tool can also execute (T=Tool).

Scalable computing capacity

For historical reasons, the computing time required for 1024 PLC commands is often used as a reference for a controller's performance. This is a very imprecise measure, because the commands to be measured and the operand types differ from one manufacturer to another. It does, however, at least give some guide to the running time to be expected for a PLC program, and allows different controllers from one manufacturer to be compared, provided the same test programs are used in every case. A set of three programs is used here for the test:

Test program 1:

A test program with BOOL, INT, WORD; assignment, arithmetic, limiting, bit-string logic, shift/rotate, bitwise logic and comparisons

Test program 2:

A test program with BOOL, INT, DINT, WORD, DWORD; assignment, arithmetic, limiting, bit-string logic, shift/rotate, bitwise logic and comparisons

Test program 3:

A test program with 32 bit floating point values and including types BOOL, INT, WORD, DWORD, REAL; assignment, arithmetic, limiting, bit-string logic, shift/rotate, bitwise logic and comparisons

IL (Instruction List) is used as the test language, because it allows the number of instructions to be most effectively quantified. The instructions used and their proportion of the total program is illustrated in Figure 1.

The running times measured for the execution of 1000 IL lines on the different CPUs are recorded in Figure 2. A BC9000 Ethernet Bus Terminal Controller was tested as a representative of the BCs, a CX1000 represented the Embedded PCs, while an Industrial PC C6140 with an 850 MHz PIII and a Pentium 4 running at 2.8 GHz with a 533 MHz frontside bus represented what is technically possible nowadays. At the time of going to press, there were still no reliable values for the new generation of BX controllers. It is, however, expected that they will be 20% faster than a BC9000 in normal operating mode.

For the sake of clarity, let us repeat that the values indicated in Figure 2 represent the time required to execute the PLC test code, and not the controllers' cycle times. Effective cycle times are generally longer, because I/O times, system administration time and time slices for the operating system will have to be added.

Diagram 1

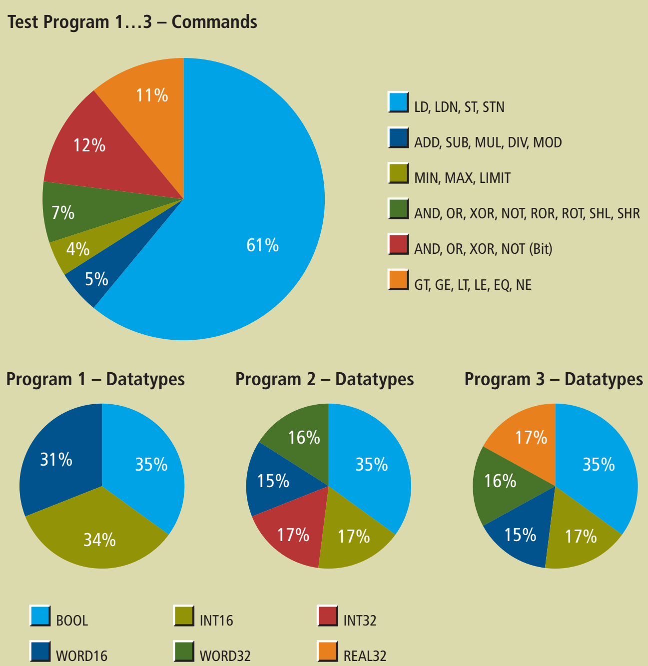
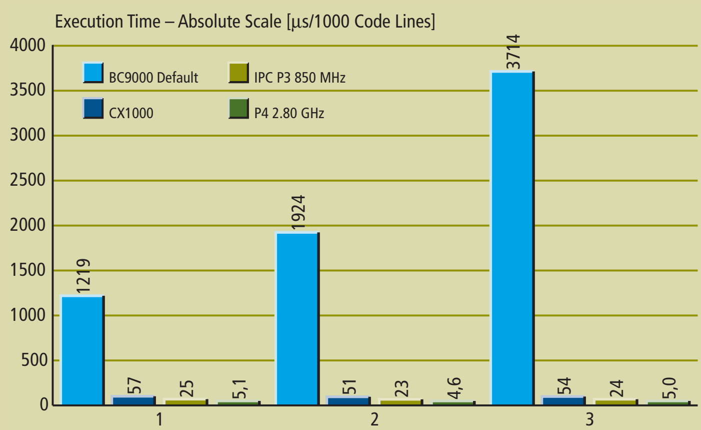


Diagram 2 | PLC Code Execution Time Benchmark



- Even within the range of Beckhoff products, PC technology is increasingly gaining ground at the expense of microcontrollers. This is a powerful endorsement of the correctness of the direction Beckhoff have been taking: Flexible and innovative PC technology instead of rigid hardware solutions.
- The bottleneck for automation is again found amongst the peripherals: automation technology does not need new controllers, but does have a use for faster fieldbusses and faster signal acquisition.
- Even automation engineers will soon have to become used to quoting times in nanoseconds.

For those device series that are capable of motion control, the measurements for floating point processing can be used to indicate the computing time for each axis. On the PIII 850 MHz device, a basis time of 40 µs was measured for the motion control functionality, as was a computing time (for positioning with the generation of set values and subsidiary position control) of about 13 µs. For the CX controller the values are about six times as great, giving a basis time of 250 µs and a computing time of 80 µs for each axis. In practice it has been found that for a CX1000 controller an effective general rule of thumb is "1 ms for each controlled axis". This means that the sampling time for the axis control in TwinCAT should be set for a CX1000 with two axes to two milliseconds, with three axes to three milliseconds and so forth. These values are, of course, heavily dependent on the overall configuration and also on the extent to which TwinCAT may monopolize the device: If no visualization displays are to be generated, and if the operating system is rarely used, it is quite possible for a system to devote well over 70% of its capacity to the real-time tasks. This in turn will mean that more ambitious sampling times can be used for Motion Control, such as, for instance, 2 axes in 1 millisecond on the CX1000. The much greater capacity of the Industrial PCs means that quite different figures apply to them: Depending on the CPU type, 10 or more axes within one millisecond are not a problem.

Conclusion and outlook

BC, BX, CX, IPC – Beckhoff's range of controllers is comprehensive. TwinCAT provides consistent programming and parameterization of all devices – both for PLCs and for Motion Control.

What has been mentioned above, of course, is just a snapshot of Beckhoff's controllers at the end of 2002. The next generation of microcontrollers and x86-compatible CPUs, some of which have already been announced, make it clear that the performance of Beckhoff controllers will continue to rise next year, and that new series of devices will emerge: It is quite conceivable, for instance, that the Beckhoff Control Panel, so far only used as a display device, could also take over control functions, so that the PC in the control cabinet would become unnecessary. The monitor screen would become a controller, although only 30 mm thick! In addition to increased performance, a second trend can be recognized for 2003: The PC (or whatever serves that purpose) is extending its range of applications in the direction of medium-sized to small controllers – the motto is "embedded PC control". Once again, industrial automation is profiting here from the consumer sector and its efforts to implement high computing capacity with low-power consumption in the smallest possible space. And there's nothing wrong with that.

→ Andreas Thome, Product Manager PC Control