PC technology through the ages

25 years of PC history at Beckhoff

The personal computer (PC), as the "locomotive of automation technology," has been used at Beckhoff for a quarter of a century and is a global standard today. At the same time in 2011, the world is celebrating (only) 30 years of the existence of the PC, which has forever changed the technical, commercial and private worlds and will continue to do so.

Of course, 25 or 30 years represent a very long period of time in the field of technology. On reflection, however, the advantage of that is that many generations have experienced the development first hand and can relate from their own personal point of view. I am certain that the readers of this article will nod in many places and will find confirmation of their own experiences. The development of PC-based controllers at Beckhoff went hand in hand with the general progress of PC technology and was expressed in a multitude of devices, which made the flexibility and general validity of this platform available to the industrial world.

PC "Big Bang" 30 years ago

The computer landscape blossomed at the end of the 1970s/beginning of the 1980s and produced a set of computers that all seemed to lay claim to the designation "personal computer" because that was also how it was actually meant: one owned an affordable electronic computing machine that turned a formerly "normal" person into a technology enthusiast. These "private" computers included, for example:

1979 | Atari 400 (with MOS 6502 CPU, 1.77 MHz)
1980 | Sinclair Z80 (with Z80 CPU, 3.25 MHz)
1981 | Commodore VC 20 (with MOS 6502 CPU, 1.10 MHz)
1982 | Commodore 64 (with MOS 6510 CPU, 985 kHz)

The birth year of the PC as we know it today, however, is considered to be 1981. That was the year in which IBM delivered the first PC with an x86 CPU to the market: The IBM PC type 5150 had an 8088 processor that clocked at 4.77 MHz. IBM decided on this processor for reasons of cost since, unlike the already existing and more powerful 8086, it allowed the connection of inexpensive 8 Bit peripheral devices. Besides that, the company sought to provide some opposition to the increasing market successes of the Z80 and Motorola 68000 processors. The IBM PC with x86 processor co-existed in the 1980s with competitors in the private and office sectors (e.g. Atari, Apple Macintosh and Commodore Amiga); however, the x86 architecture became increasingly accepted.

I can remember vividly to this day how our Z80 computer club suddenly disintegrated, because all of the members jumped ship in hordes to the IBM PC-XT. The reasons at that time (in 1984) were more or less those which are taken for granted today: The PC promised a deeply interconnected community with compatible and simple to use hardware and software, including a then-gigantic 10 MB hard disk as the mass storage device. That finally put an end to the laborious saving of programs on audio cassettes.

The new DOS operating system from Microsoft, which allegedly only found its way onto the IBM PC because IBM and Digital Research (the manufacturer of CP/M) could not agree on the signing of a so-called NDA (Non-Disclosure Agreement), certainly also contributed to this success.

Andreas Thome,
PC Control Product Manager,
Beckhoff Automation

Intel: the PC clock generator

In addition to IBM there is one more name that occurs to one immediately in connection with the PC: It is the Intel company, founded in 1968 by Gordon Moore and Robert Noyce. The two original founders were joined a little later by Andy Grove, who was CEO of Intel until 1998 and acted as Chairman of the Board until 2004. Grove initiated Intel's decisive change of direction from a manufacturer of memory chips to the development and manufacturing of processors. The name of the company, by the way, is derived from "INTegrated ELectronics."

Today Intel has 93,000 employees, distributed over 151 locations in 62 countries and has an annual turnover of $43.6 billion (US dollars). Intel has come a long way to get where it is now: beginning with the first processor, the 4004 (4 Bits, 1971), then its 8 Bit successor, the 8008 (1972), up to the first PC processor, the 8080 (1974). The first x86 processor is considered to be

the 8086 16 Bit processor, which came out in 1978, but which – for reasons of cost – first found its way into the PC mass market in 1979 in the form of the 8088 processor with a stripped-down 8 Bit format (the 16 Bit peripheral devices were still too expensive at that time).

Table 1 shows the milestones in the development of the processors that were, or still are, also used by Beckhoff from 1985 onwards. If one looks at the structural widths and the number of transistors in the individual processors, then one can perceive the validity of the theory postulated by Gordon Moore according to which the number of transistors in a chip doubles approximately every 18 months. Precise proof is, however, made difficult by the multitude of derivatives of individual processor families that have been brought onto the market. A detailed overview of the processors manufactured by Intel since the beginning can be found in 1) by the way. Intel makes a quick reference to the technical data of processors and chipsets available in 2).

Intel was and is also significantly involved in the invention and specification of important PC technologies such as ISA, PCI, PCI-express and USB. However, there are also important interfaces that are attributed to other companies, such as DIE, ATA, ATAPI (Western Digital) and SATA (SATA International Org.). Although numerous companies manufactured x86-compatible processors in the past (e.g. IDT, Texas Instruments, SGS Thomson, Cyrix, National Semiconductor, Transmeta and UMC), only AMD and VIA remain today as serious competitors to Intel.

Andreas Thome: "My 'PC' in 1983 was a Casio FP1100 with Z80 CPU, 3.9936 MHz, C82-Basic in the ROM and CP/M2.2 on 5¼-inch disks – and it still runs without any trouble today."


A fully functional IBM PC 5150

Beckhoff: the Industrial PC turns 25

Beckhoff began in 1986 with the manufacturing and implementation of Industrial PCs (IPCs). Today that is taken for granted, but at the time it was a ground-breaking idea for industrial control technology. This marked a turning point in the Beckhoff story: away from the controllers that had been manufactured up to that point, based on the 8 Bit Motorola 6809 processor, towards x86-based IPC controllers. This development was also closely connected with the question of data acquisition and signal output between PC and machine. Therefore, the development of some salient I/O technologies and subassemblies will also be considered in the following chronological list.

1986 | First Beckhoff PC-XT-based controllers for woodworking machines. These were, on the one hand, controllers for double miter saws (i.e. the saw blades were driven to the desired length on both sides of a profile strip and angle cuts were made) and, on the other, for edge processing machines. The PCs were initially used as operating, computing and memory units; the actual real-time control still took place by means of the Motorola hardware. It was quickly recognized, however, that the PC could take over the complete function of a controller. As a result, the separate 6809 hardware became redundant and the idea of the multi-functional, real-time-capable PC controller was born.

1987 | B5000 – PC plug-in card for the reading in and output of electrical signals for the machine controller. The card was configurable on memory or port addresses and offered the PC direct access to the process image of the signals as driver-decoupled parallel I/O.

1989 | C1210 – Lightbus interface card and first M1000 Lightbus modules. Interestingly enough, the C1210 card was equipped with a Motorola 6809 processor; however, this was responsible only for the operation of the optical fiber fieldbus. The PC processor assumed the master controller role.

1990 | C2000 – All-in-one PC Motherboard with Intel® 386SX, Cirrus chipset and Lightbus interface onboard

| C1100 – Single-board PC core with interface to Siemens S5 (technology: 80386SX, 82370SX, 8255 port component, Xilinx XC3030 as Lightbus interface, DPR to the S5). This PC was known internally as the "Press PC," since its field of use was in metal presses.

| C1200, C1220 – ISA master cards for Lightbus. The C1200 was a passive card (with no processor of its own), while the C1220 had its own CPU for the processing of the Lightbus telegrams.

1992 | C1600 – Lightbus interface card for Mitsubishi PLC

1993 | C1110 – Single-board PC with interface to Siemens S5 (complete PC with 80486DX, video controller, hard disk + disk, Lightbus interface, DPR to the S5)

1994 | C1120 – Lightbus interface card for Siemens S5 with Infineon 80C166 processor and single overall width

2002 | Development of a motherboard for the CX1000 Embedded PC with Pentium MMX-compatible National Semiconductor (later AMD) SC2200 processor. The motherboard development for this device marked Beckhoff's return to the development of its own motherboards and BIOS, following a break of several years, and the start of an Embedded PC series for DIN rail mounting and with the direct connection of I/O Bus Terminals.

2003 | EtherCAT, the real-time Ethernet fieldbus, is born.

2004 | Development of motherboards in the formats CX, 3½", Slot, ATX and PC/104 with 855 chipset and Intel® Celeron® M /Pentium® M processors.

2006 | Development of motherboards in the formats 3½", Slot, ATX and PC/104 with 945 chipset and Intel® Core™ Duo /Core™2 Duo processors.

2009 | Development of motherboards in the formats 3½", ATX and PC/104 with GS45 chipset and Intel® Core™2 Duo processors. The Slot form factor was dropped. Intel® Atom™ with US15W chipset was used in the form factors CX, 3½" and PC/104.

Year	Processor	Register	Frequency	Transistors	Process	Note
1974	Intel® 8080	8 bit	2 MHz	6,000	6 μm	used in traffic lights, cash registers and first PCs, e.g. Altair 8800
1976	Intel® 8085	8 bit	5 MHz	6,500	6 μm	used e.g. in gaming machines, otherwise not particularly successful
1978	Intel® 8086	16 bit	4.77 – 10 MHz	29,000	3 μm	first "x86" processor, used e.g. in the Schneider PC 1640
1979	Intel® 8088	16 bit	4.77 – 8 MHz	29,000	3 μm	less expensive than 8086, used in the IBM PC 5150, coined the abbreviation "PC" from 1981 with 4.77 MHz
1982	Intel® 80286	16 bit	6 – 12.5 MHz	134,000	1.5 μm	used in the IBM PC/AT (5170) from 1984 with 6 MHz
1985	Intel® 80386	32 bit	16 – 33 MHz	275,000	1 μm	DX had 32-bit data bus, SX only 16-bit
1989	Intel® 80486	32 bit	25 – 100 MHz	1,200,000	1 – 0.8 μm	at last: a CPU with integrated hardware floating point unit (FPU)
1993	Intel® Pentium®	32 bit	30 – 233 MHz	3,100,000	0.8 – 0.35 μm	80586 could not be registered as a trademark, therefore transition to textual processor names
1996	Intel® Pentium® MMX	32 bit	166 – 233 Mhz	4,500,000	0.35 μm	first Pentium with MMX instructions (MultiMedia eXtension)
1997	Intel® Pentium® II	32 bit	233 – 450 MHz	7,500,000	0.35 – 0.25 μm	P6 architecture, not used by Beckhoff, listed only for completeness
1998	Intel® Celeron®	32 bit	300 – 533 MHz	19,000,000	0.25 μm	"Celeron" = simpler, less expensive CPU variants
1999	Intel® Pentium® III	32 bit	550 – 1.4 GHz	28,000,000	0.18 μm – 0.13 μm	first Pentium with SIMD instructions (Single Instruction/Multiple Data)
2000	Intel® Pentium® 4	32/64 bit	1.3 GHz – 2 GHz	42,000,000	0.18 μm	Netburst architecture, "130 W," first processors with Intel® 64
2002	Intel® Pentium® 4-M	32 bit	1.6 GHz – 2.4 GHz	55,000,000	0.13 μm	Netburst architecture, "35 W" instead of "130 W" notebook processor
2004	Intel® Pentium® M / Celeron® M	32 bit	600 MHz – 2.26 GHz	144,000,000	0.13 – 0.065 μm	turning away from Netburst, return to the P6 architecture such as Pentium® Pro/II
2006	Intel® Core™ Duo	32 bit	1.5 GHz – 2.33 GHz	151,000,000	0.065 μm	introduction of the "Core" trademark, changed P6 architecture, no Intel® 64
2006	Intel® Core™2 Duo	32/64 bit	3 GHz	291,000,000	0.065 μm	core micro-architecture, first generation
2007	Intel® Core™2 Quad	32/64 bit	3 GHz	582,000,000	0.065 – 0.045 μm	core micro-architecture, first generation
2008	Intel® Core™ Z510/Z530	32 bit	1.1 – 1.6 GHz	47,000,000	0.045 μm	low power "2.5 W" CPUs, in-order-architecture such as Pentium®, no Intel® 64
2011	Intel® Core™ i3,5,7 (Sandy Bridge)	32/64 bit	1.1 – 3.46 GHz	995,000,000	0.032 μm	core micro-architecture, second generation
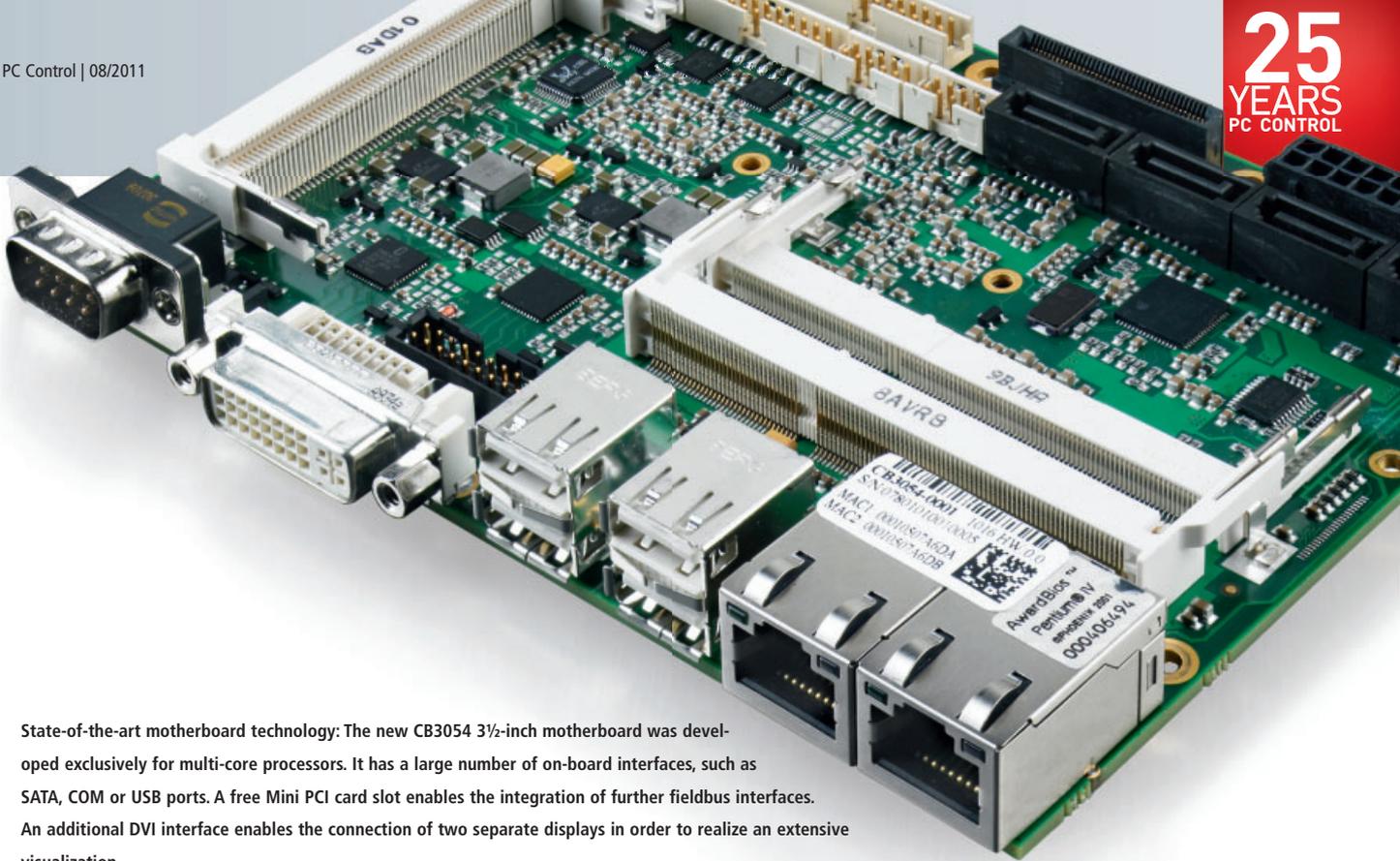
State-of-the-art motherboard technology: The new CB3054 3½-inch motherboard was developed exclusively for multi-core processors. It has a large number of on-board interfaces, such as SATA, COM or USB ports. A free Mini PCI card slot enables the integration of further fieldbus interfaces. An additional DVI interface enables the connection of two separate displays in order to realize an extensive visualization.

2011 | Further motherboard developments are pending here in the formats 3½", ATX and PC/104, with newer CPUs and chipsets of the "Sandy Bridge" generation. Where the Atom™ CPUs are concerned, the "Pineview D" and "Cedarview" will find their way into Beckhoff products.

What about the future of PCs?
It remains exciting!

The field of Industrial PCs is without any doubt technologically bound to the development of the PC systems in the commercial market. The past shows that new physicochemical processes are constantly being found to reduce the size of the transistor structures. Intel is presently setting a milestone along this road with 22 nm structures (Ivy Bridge processors). If we extrapolate the temporal progress of the reduction in Intel® processor size (fig. 4) on the basis an exponential function, then we can assume a structural size of around 15 nm for 2015 and around 8 nm for 2020. Other estimates are less conservative and expect 11 nm as early as 2015.

This development will favor the employment of complex processors in smaller, ultra-compact Industrial PCs, while at the other end of the complexity scale it will also fuel the development of many-core and multi-core processors (see Intel article on page 56). The integration of the entire functionality of a PC into a single chip will also be possible. The first approaches to a System-on-Chip (SoC) have already been realized with the fusion of CPU and Northbridge in current Intel® processors.

Also, the speed of internal and external bus systems is increasing: whereas USB 3.0 with 5 Gbit/s is already finding its way into products today, the PCI-express generation 4 is currently being specified. This exhibits a theoretical data rate of 16 GT/s (Gigatransfer per second, equivalent to a raw data rate of 16 Gbit/s) and is expected to be used in CPUs and chipsets in 2015. For Industrial PCs this means that process data can be transmitted and processed even faster. That, coupled with fast multi-core processors and fast fieldbus

systems such as EtherCAT, is paving the way in automation to scientific engineering methods, on the basis of precise and fast measured values. Beckhoff has coined the phrase "Scientific Automation" for this.

Microsoft's announcement that the company's next operating system, Windows 8, will also be made available for ARM processors has generated genuine shock waves. Further details about this are expected at the end of 2011. This announcement could decouple today's PC concept from the x86 architecture – and then we are back to the question that we asked ourselves once before in 1980: Is that now a PC? Of course it is.

[1] Source: Intel Corporate Overview June 2011
[2] http://www.intel.com/pressroom/kits/quickreffam.htm
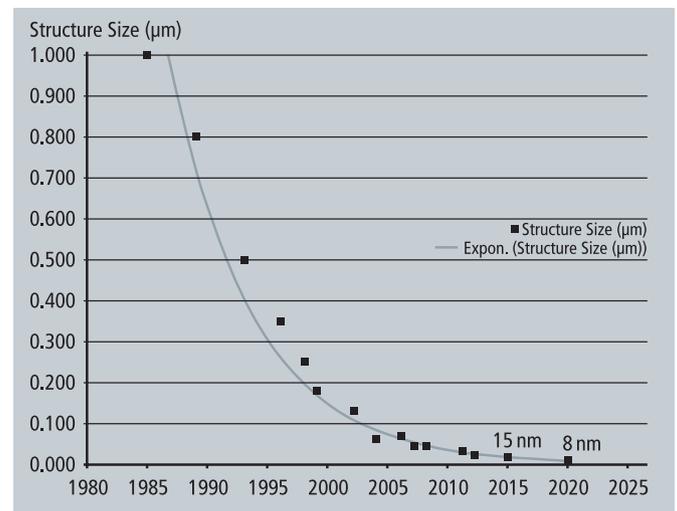[3] http://ark.intel.com

Fig. 4: Estimation of the future sizes of chip structures