Embedded PC as EtherCAT master

Addition to the family: Embedded PC CX1020

Three years ago Beckhoff launched the CX1000 Embedded PC, thus integrating PC technology and modular I/O level as a top hat rail unit in the control cabinet. With the CX1020 Beckhoff presents a new member of this product family, offering higher CPU performance and direct connection of EtherCAT I/O terminals.

High performance with very compact design: Embedded-PC CX1020

Product announcement

Product announcement: estimated market release 3rd quarter 2005

Intel CPU number	Processor	Clock frequency	FSB	L2 Cache	TDP	Technology
760	Pentium M	2.0 GHz	533 MHz	2 MB	27 W	Dothan
745	Pentium M	1.8 GHz	400 MHz	2 MB	21 W	Dothan
738	Pentium M LV	1.4 GHz	400 MHz	2 MB	10 W	Dothan
713	Pentium M ULV	1.1 GHz	400 MHz	1 MB	11 W	Banias
370	Celeron M	1.5 GHz	400 MHz	1 MB	21 W	Dothan
320	Celeron M	1.3 GHz	400 MHz	512 kB	24.5 W	Banias
373	Celeron M ULV	1.0 GHz	400 MHz	512 kB	5 W	Dothan
–	Celeron M ULV	0.6 GHz	400 MHz	512 kB	7 W	Banias

Embedded roadmap for Pentium M processors

A closer look at the general interaction of control and fieldbus technology over the last twenty years reveals a clear correlation between the respective processing speeds, particularly in the case of PC controllers. In the early days PC controllers were still relatively slow, since their signal acquisition cards provided more data than the PCs could process. Then fieldbus systems arrived. They actually made data acquisition slower compared with discrete circuits, but they offered distributed I/O signals and enabled collection of larger data quantities. Over time, the PC managed to gain the upper hand in terms of processing speed, since the development of processors was – and still is – more continuous and more dynamic than that of fieldbus systems. Classic fieldbus systems frequently became a bottleneck, since PCs could now offer real-time processing in the millisecond range, while it was not possible to refresh the process image within this timeframe. Today, the pendulum is swinging back again and it is once again the PC that has some catching up to do: In theory, advanced fieldbus systems such as EtherCAT can scan in the process periphery within less than 10 µs, but currently no PC offers this kind of cycle time.

These considerations show that the fieldbus is no longer the bottleneck, and the reaction time of a PC-based controller is determined by the performance of its processor. Accordingly, faster response times offer higher parts output from production machines, better production tolerance & repeatability etc. In short: the faster, the better. Based on these considerations Beckhoff presents the CX1020 Embedded PC, a new, faster member of the CX family.

Step change in CPU performance

While the CX1000 featured an AMD Geode processor with 266 MHz, the CX1020 is equipped with an Intel Celeron M CPU offering 600 MHz. It is an energy-saving device that operates with ultra-low core voltage and features low thermal power dissipation of only 7 W TDP (thermal design power). As a result, no fan is required despite the compact design of the CX1020 Embedded PC. Since compact flash is used as boot and memory medium, no rotating media are required in the controller. This is an important aspect for increasing the MTBF (mean time between failures) of the overall system.

In combination with the proven Intel 855GME chipset, the graphics hardware is also implemented in a cost-saving manner, since it is already included in the chipset. As usual for Pentium M, DDR RAM is used as the main memory. The basic configuration comes with 256 MB. Since it is internally configured as SO DIMM, the RAM memory can be expanded up to 1 GB by using different memory modules.

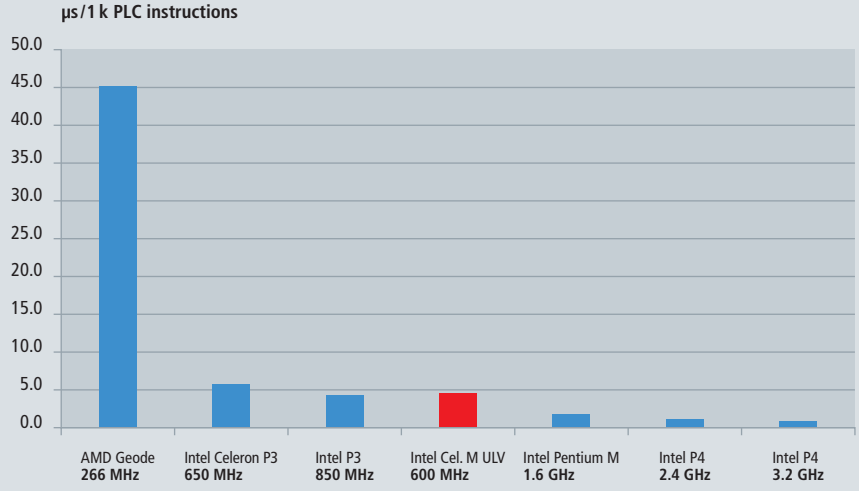
The CPU was chosen based on the fact that it is part of the embedded roadmap (overview on the top) for Intel Pentium M processors, which means that they are likely to be available for several years. Intel mentions five years, although the actual figure may be higher or lower.

In general, the Intel Pentium M processor family and its "slimmed-down" Celeron M variants are interesting for controller applications, since their performance is comparable to that of P4 processors with higher clock speeds (a 2 GHz Pentium M, for example, does not have to shy away from a comparison with a 2.4 GHz P4), but they are characterized by significantly lower thermal output.

In an industrial environment, the yardstick for performance is the time a CPU requires for processing 1000 PLC commands. While this test has not yet been standardized (although first attempts for defining a standard have been made), it does provide a guide for classifying processors. Measurements undertaken by Beckhoff indicated that a 600 MHz Celeron M is indeed comparable with an 850 MHz Intel PIII. The comparative measurements were carried out with 5000 rows of PLC instructions combining a wide range of operations (LD, ST, ADD, SUB, string, bit and compare operations) with different data types. What the diagram does not show is the fact that, for larger programs with more than approximately 25,000 rows, the Celeron M is always faster than the PIII 850. This can mainly be attributed to the larger second level Advanced Transfer Cache of the Celeron M (512 kB).

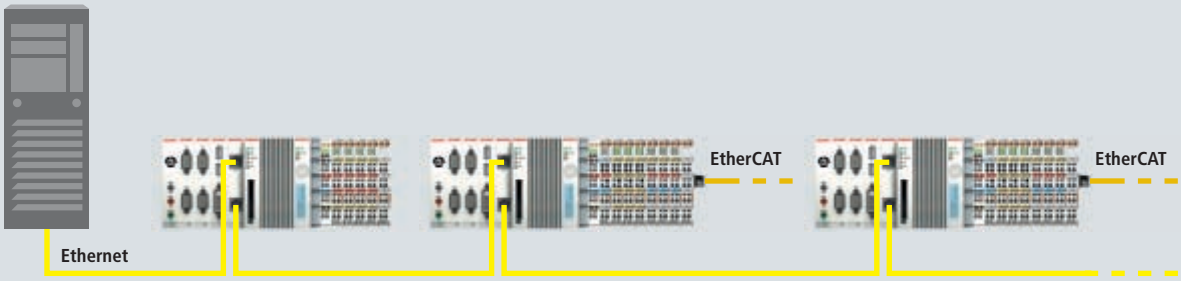
Similar features

The case and assembly concept of the CX1020 is similar to that of its smaller brother, the CX1000: Both Embedded PCs consist of several components that can be assembled by the user – in their simplest form they consist of a CPU module and a multi-functional power supply unit. The PC104 bus is used for the connection between these and all other CX components, although in the CX1020 this was extended with EtherCAT signals. The basic CPU module is equipped with two RJ45 sockets and an integrated 3-port switch as standard. In practice, this often means that no separate switch is required, since a line topology can be configured conveniently. This saves costs, for example in building installations, where



Comparative measurements with 5000 rows of PLC instructions

Structure of an IT line topology with subordinate EtherCAT islands



several room controls can be distributed across each floor, which otherwise would have to be networked via a star topology. Like the CX1000, the CX1020 can be expanded with optional system interfaces. A DVI-I (=DVI-D + VGA) output, two USB-2.0 interfaces, up to four RS232 interfaces and audio are available. The four RS232 interfaces feature opto-decoupling and can optionally be implemented as RS422/RS485.

The CX1020 is not fussy when it comes to selecting a suitable fieldbus system: In addition to EtherCAT, it supports all main classic fieldbuses. The same PROFIBUS, CANopen, DeviceNet, Lightbus and Sercos fieldbus master and slave components are used as for the CX1000.

The same reusability also applies to the multi-functional power supply units of the CX1000, which are available as different versions without I/O terminal connection, with K-Bus connection, with K-Bus and IP-Link connection for IP 67 protected Fieldbus Box modules and a new power supply unit with direct connection facility for the Beckhoff EtherCAT terminals.

All power supply units share the integrated NOVRAM, the illuminated 2 x 16-character FSTN display and the navigation key.

EtherCAT as a fast I/O system

The CX1020 Embedded PC was developed for optimum interaction with EtherCAT. The two Ethernet interfaces of the CPU module are not primarily intended for EtherCAT operation, although technically this would be feasible. These two "IT" interfaces are internally connected with a MAC (Media Access Controller).

For EtherCAT the CX1020 offers a second MAC, i.e. an internal Ethernet interface that is also 100-Mbit-capable. Its physical signal level is transformed to the E-bus in the CX1100-0004 power supply unit, enabling direct connection of EtherCAT terminals with the Embedded PC. The E-bus runs through each individual terminal as a physical LVDS signal with a maximum delay of 10 ns per terminal. Due to the EtherCAT protocol definition it is able to accept and issue data from and to each device (terminal) during telegram execution. The physical communication bandwidth is thus utilized twice, leading to a substantial increase in the usable data rate. Since the Ethernet controller of the CX1020 takes the process data directly from the RAM and stores them again in the RAM, the usual delays for copying data between a dual-ported RAM of a PCI or ISA (PC104) fieldbus card are a thing of the past. In practice this means shorter cycle times and therefore shorter response times. In combination with the fast CPU processing time this offers new opportunities: A PLC task with a cycle time of 100 µs can always process an updated process image, for example.

Interestingly, EtherCAT offers several options for connecting classic fieldbus systems with the CX1020, either as a CX1500-xxxx module directly with the CPU or as an EtherCAT device in terminal form. The PROFIBUS master is available either as a CX1500-M310 or as an EL6731 EtherCAT terminal. Both types offer the same performance characteristics – e. g. both support PROFIBUS DP-V2. In practice, this means that the PROFIBUS master can be positioned exactly where it is required within a machine. It no longer has to be implemented as a plug-in card in the IPC or a master controller in the control cabinet.

PLC, Motion Control, interpolation and HMI

As a top hat rail IPC and in conjunction with the TwinCAT software from Beckhoff, the CX1020 offers the same functionality as large Industrial PCs. In terms of PLC, up to four virtual IEC 61131 CPUs can be programmed with up to four tasks each, with a minimum cycle time of 50 microseconds. All IEC 61131-3 languages can be used.

Moreover, all TwinCAT functionalities are available for Motion Control applications: In theory, up to 256 axes can be controlled. In addition to simple point-to-point movements, more complex multi-axis functions such as electronic gearbox, cam plates and flying saw can be implemented. In contrast to the CX1000, due to its higher CPU performance the CX1020 can now also execute interpolating 3D path movements and DIN66025 programs.

In addition to real-time execution of control tasks, the TwinCAT real-time kernel ensures that enough time remains for the user interface (HMI), to communicate with the real-time components via software interfaces such as ADS or OPC.

For the CX1020 the same basic principle applies: It is a programming tool for all controllers. The complete programming of PLC, Motion Control and visualization is transferable to all PC controls from Beckhoff, which is reassuring in cases where it becomes apparent during a project that a P4 with 3.4 GHz and hyperthreading has to be used after all.

Suitable operating systems for the CX1020 are Microsoft Windows CE, Windows XP Embedded or Windows XP Professional. The latter is made possible through the development of the compact flash storage media that are now available in sizes between 2 GB and a maximum of 8 GB.

Conclusions

Performance with very compact design: The CX1020 is a new member of the Embedded PC family from Beckhoff. In combination with EtherCAT as the fieldbus it offers response times of less than one millisecond, thereby opening up new application options and scope for process improvement. The only downside affects automation literature typography: the "µ" sign will have to be used more often.