REAL TIME AUTOMATION

EtherCAT

Leopard-like Speed and Efficiency

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Overview

EtherCAT is a highly flexible network protocol that, frankly, is achieving deployments and design wins at an astounding rate. A unique principle called "processing on the fly" gives EtherCAT a handful of unique advantages. EtherCAT is designed for new, dual port device implementations with embedded switch technology. Messages are processed by a node and passed to the next. A single message can update all nodes on an entire subnet giving EtherCAT incredible speed and efficiency. The process also creates flexibility in topology and synchronization.

Outside of the advantages gained from unique processing, EtherCAT benefits from superb development. EtherCAT includes, among other things, a safety protocol and multiple device profiles. EtherCAT also benefits from a strong users group. The combination of benefits means EtherCAT is poised for continued growth.

History

In the early part of the new millennium, Beckhoff, a German automation company, was working on a new fieldbus system called Fast Lightbus. This protocol would lead to a newer protocol, EtherCAT. Beckhoff released the initial version of EtherCAT in 2003. The company continued to promote EtherCAT, but also began to work on other new protocols.

EtherCAT Technology Group

BECKHOFF

The German company Beckhoff created EtherCAT.

In 2004, Beckhoff helped to create a new group to promote the EtherCAT protocol. Their efforts led to the EtherCAT Technology Group, or ETG. Beckhoff donated the rights to EtherCAT to the ETG. Like similar groups for Ethernet/IP, DeviceNET, and PROFINET protocols, the ETG became a high-powered coalition.

The advantages of a capable alliance are numerous. The ETG is able to provide research and advancement of the EtherCAT protocol. The ETG also publishes specifications and papers that allow member organizations greater success in using EtherCAT.

The ETG is headquartered in Nuremberg, Germany, but also has offices in Japan, China, Korea, and Austin, TX.

International Standards

The ETG works with the International Electrotechnical Commission (IEC), specifically serving as a liaison for the digital communications working group. The partnership has led to standardization throughout the EtherCAT protocol's history.

In 2005, EtherCAT was standardized as IEC/PAS 62407. This standard is now obsolete, though not due to any fault in EtherCAT. Instead, EtherCAT has been integrated into a number of other standards, a sign of its versatility. The IEC fieldbus standards IEC 61158 and IEC 61784-2 both include EtherCAT as of 2007. EtherCAT is also included in the ISO 15745-4 published standard.

Fundamental Principle

The fundamental principle of EtherCAT is pass-through reading. Because frames are not accepted, read, modified, and passed, EtherCAT networks can achieve greater speed. To understand the process, imagine an office mail clerk carrying a set of important messages.

The clerk could travel to each office and deliver applicable messages to the people in those office. Upon delivering the message to that office, the clerk could stand in the doorway waiting for the recipient to read the message, write a reply, place the reply in an envelope, and hand that envelope back to the clerk with a stack of other outgoing messages.

After stopping at each office, checking for messages for the person in the office, and waiting for responses, the clerk would have spent a lot of time completing the pass. There are advantages. All replies would be sent right away, the messages would be reasonably sure to reach all recipients, and a thorough message system would result.

The process efficiency and speed can be improved, though. In the improved system, the mail clerk would have the messages sorted before leaving. The clerk would drop off messages to each office, giving the person in the office a chance to read any messages meant for everyone. They would then continue down the hall until each person in each office had received their messages. Then, the clerk would work back, picking up any replies.

EtherCAT works like the second scenario. Each node receives the message and, before processing and responding, transmits the message to the next node. The message continues through each node before looping back. Another way to imagine this principle would compare the message to a train. The train continues to move through each node without stopping. The nodes empty the train cars meant for them and load the empty cars back up while the train continues to move. The train turns around after the last node and speeds through each node to ensure all cars are reloaded as necessary.

EtherCAT Frame

For the EtherCAT train to keep rolling without stopping at each node, the train must contain specific cars. Looking at the EtherCAT frame, its analogy to a train is quite apparent. The header acts like a locomotive. The cars, plus their content, are PDO Data. The caboose, complete with shipping information, is the working counter.

All of these parts fit into the EtherCAT frame and that frame fits simply into an Ethernet frame. The Ethernet is the transmission media that allows EtherCAT to operate. The EtherCAT frame simply replaces the IP frame of a standard Ethernet message. Thus, the Ethernet frame does not need modification, again contributing to flexibility for EtherCAT.

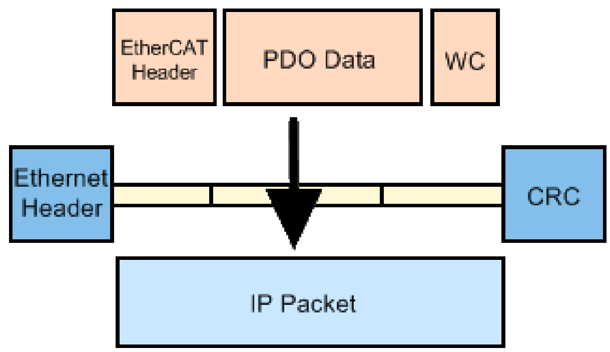

Figure 1 — The EtherCAT Frame replaces the Ethernet Data portion of an Ethernet Packet, often IP data.

EtherCAT Header

The EtherCAT frame starts with a standard header. The first integer is a length identifier. This bit tells the nodes how long the EtherCAT portion of the frame will be. Length is especially important in an EtherCAT frame; the length varies with the number of message bytes and nodes just like more train cars of product makes the train longer.

The second portion of the EtherCAT header is a reserved bit, which is followed by a type integer. The type integer defines the type of message, ensuring correct interpretation.

PDO Data

After the header, the Ether CAT frame contains Process Data Objects, or PDOs. The PDOs correspond to the number of nodes and messages within the frame. Each PDO contains data for a node, the product inside the boxcar. The PDOs are also individually addressed, telling the nodes which PDOs to take. For those of you with CANopen experience, PDOs are the same Process Data Objects used in CANopen.

Working Counter

The final portion of an EtherCAT frame is the working counter. This number works much the same way a frame check sequence works. The working counter is dependant on the content of the EtherCAT frame. By ensuring the working counter is correct, each node can ensure it receives the entirety of the frame.

Advantage: Speed

The fundamental principle behind EtherCAT provides a clear advantage. The delay a message would experience over a standard Ethernet network is much larger than the minute delay in an EtherCAT network. There are two important things to note, however. First, there is a delay. The EtherCAT frame cannot move continuously, so each node introduces a small delay.

Second, EtherCAT networks can be slowed if necessary. Some computers may have difficulty handling the increased quantity of cycles and decreased cycle times optimized EtherCAT can offer. The network can be configured for the computer, however, to allow the greatest speed these computers can operate under.

Flexible Topology

The “processing on the fly” principle of EtherCAT has another advantage in addition to speed. EtherCAT networks can be configured in many types of topology. Just like Ethernet, a star topology is quite simple. EtherCAT can extend well beyond a star topology, though.

EtherCAT creates the possibility of a fieldbus system using Ethernet hardware. Combing the fieldbus, or trunk, topology with the start topology creates an incredibly useful new style. The combination of trunk lines and individual branches give flexibility in programming for an Ether CAT network.

EtherCAT has built-in redundancy that compensates for potential breaks in wiring. When a line is broken, the network can detect a break. The EtherCAT frame can travel to the end of the network and, because messages travel back over the same path in reverse, the frame reverses and travels back to the master. In this way, all EtherCAT networks can act as though they’re in a ring topology. Configuring an EtherCAT network in a ring topology, then, adds another level of redundancy.

Synchronization

EtherCAT provides synchronization.

As made clear through the publishing of the IEEE 1588 Precision Time Protocol standard, synchronization has gained importance in the Industrial Networking industry. Synchronization is another advantage of EtherCAT systems. EtherCAT includes a distributed clock mechanism, giving it a low jitter that meets the specifications of IEEE 1588 without additional hardware.

The mechanism is possible because of, once again, the fundamental principle. Each node attaches a time stamp to the EtherCAT frame twice. First, the slave node adds a timestamp when receiving the message as it is sent through the network. Then, when the frame returns back through the nodes, each slave adds another time stamp. The master receives the frame with two time stamps per slave.

With the time information, the master can calculate the delay for each node. The master repeats the calculation for every frame it sends. As the network operates, the enormous sample size means the master has incredibly accurate data. The inherent ring topology creates an incredibly efficient clock mechanism that increased in accuracy with every message.

Other Features

Synchronization, flexible topology, and speed are advantages EtherCAT has due to its unique operating principle. Through the work of the ETG, though, EtherCAT has some other distinct features worth mentioning.

Device Profiles

EtherCAT uses device profiles much like Ethernet/IP and other CIP protocols use objects. Many fieldbus devices used in EtherCAT networks are already defined in CAN. EtherCAT supports the entire CANopen family, another IEC standard EtherCAT fits within. In addition to CANopen, EtherCAT supports the Sercos drive profile.

Safety Protocol

One more IEC standard among the many that describe portions of EtherCAT is IEC 61508. This standard describes Safety over EtherCAT (SoE). The SoE version of the EtherCAT protocol meets the requirements of Safety Integrity Level 3. To achieve higher safety, SoE adds in safety information to the standard EtherCAT frame.

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