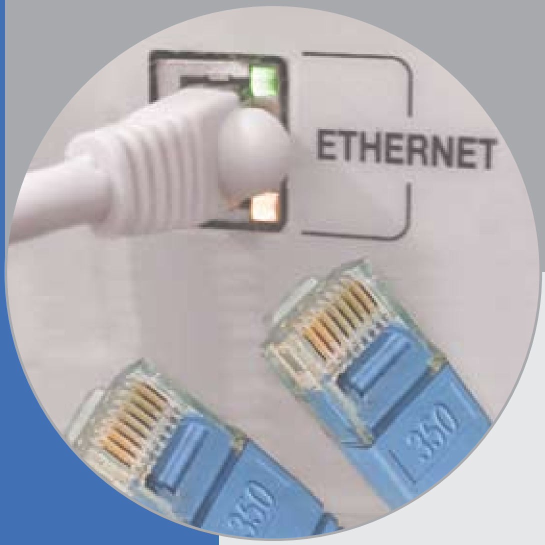
Control Networks



EtherCAT & CANopen
Servo & Stepper Drives
Control Software

Copley Controls

Control Archi

Introduction

EtherCAT and CANopen are international open standards for networked motion control. Key driving forces behind networking are simplified cabling, reduced cost and improved diagnostics. CANopen is targeted at distributed control systems whereas EtherCAT can be used in both centralized and distributed architectures.

Each network has its advantages and Copley offers a complete range of servo and stepper drives for both solutions. Copley also provides comprehensive software tools for simple system commissioning and easy migration from CANopen to EtherCAT.

Centralized and Distributed Control

The hierarchy and assignment of system tasks are shown below. Gray represents the controller, blue the drive. In a centralized architecture, all tasks except the current loop are performed by the controller. Current loops should be updated at least every 100 microseconds. This places a high computational burden on the controller and necessitates a high speed communications link.

In distributed control, all servo loops are closed by the drive. In profile mode (download move parameters and GO) the drive also performs path planning. The drive incurs no additional cost and the motion control card can be eliminated. As the required position loop update rate is much less than the current loop, a lower speed network can be employed.

CENTRALIZED	DISTRIBUTED
OPERATOR INTERFACE	OPERATOR INTERFACE
STATE SEQUENCING	STATE SEQUENCING
PATH PLANNING	PATH PLANNING
POSITION LOOP	POSITION LOOP
VELOCITY LOOP	VELOCITY LOOP
CURRENT LOOP	CURRENT LOOP

- Best for tightly coupled axes (robot arm)
- Most efficient real-time servo loop adjustment
- Requires high bandwidth network

- Ideal for point-to-point and most contouring
- Lowest cost solution, smallest drive size
- Requires low bandwidth network
- Easily expandable with no burden on controller

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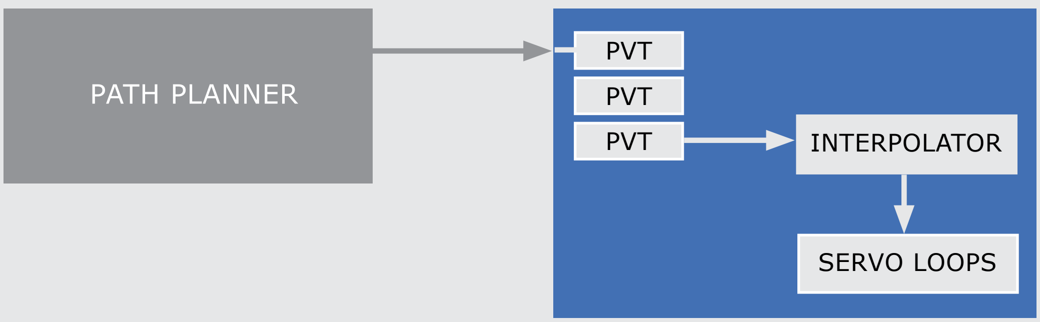
PVT Path Planning

For coordinated motion in distributed control systems, both EtherCAT and CANopen employ PVT path planning. The controller generates a stream of points defining the Position and Velocity of each axis at specific Times. PVT path planning is a very efficient way to define a motion trajectory.

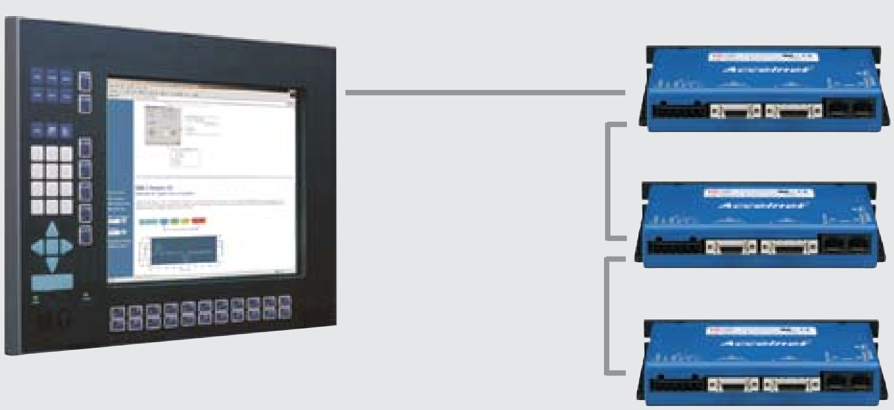
Trajectory points are typically sent every 10 msecs and buffered in the drive. The drives perform a cubic polynomial interpolation to generate a best-fit curve. After interpolation the position loop is synchronously updated on each drive at a rate of several kilohertz.



Network Speed and Efficiency

For motion control systems network efficiency, determinism and synchronization are far more important than raw speed. Standard Ethernet is 100 times faster than CANopen but was designed to transfer large files asynchronously. Collisions are destructive, requiring message resending. CANopen was created to transfer small real-time data packets at the lowest cost. For distributed control, it is as fast as it needs to be.

EtherCAT brings synchronization and determinism to Ethernet. Of the many real-time modifications to standard Ethernet, EtherCAT is clearly the most efficient. It has the speed to update a drive current loop and the flexibility to transfer PVT points for distributed control. An EtherCAT drive does, however, carry a price premium and is larger than a comparable CANopen drive.



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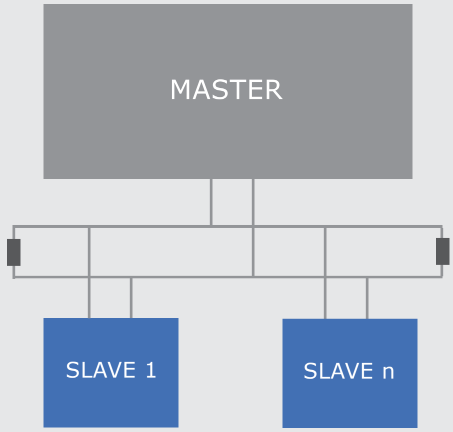
CANopen Introduction

CANopen is an open standard application layer built on the CAN data link layer. CAN was originally developed for automotive applications and is proven to be rugged, reliable and cost-effective. Master/slave and peer-to-peer communication is possible. Collisions are non-destructive.

Slaves are synchronized via distributed clocks locked by time-stamping. Parameters and real-time data are handled by separate messaging schemes (SDOs and PDOs) for optimal efficiency. Third party I/O and control software are available for a complete system solution.

Network Topology and Bus Arbitration

CAN is a multi-drop network employing a simple twisted pair. At the maximum bit rate, 1Mb/s, cable lengths up to 40m are possible. The network must be terminated at each end and care should be taken to minimize stub length. Up to 127 nodes can be connected to the network.



Any node can transmit data when it sees the bus is free. A message begins with an active-low start bit followed by a message identifier. The lower the identifier, the higher the priority. If two devices transmit at the same time, the higher priority identifier forces the bus low. This condition is recognized by the lower priority node and it relinquishes the bus.

Synchronization

CANopen slaves can be synchronized to within several microseconds. At startup, an assigned slave broadcasts a Sync Message establishing the network time base. Periodically, the actual time of the latest Sync Message (defined by the slave's internal clock) is broadcast. The time-stamp is used by each node to continually adjust its own clock to maintain synchronization lock.

SDOs and PDOs

SDOs are primarily employed for the asynchronous transmission of slave configuration parameters. Part of the 8 bytes in the CAN data field defines the parameter location in the slave. If the data packet is 4 bytes, only one CAN frame is required although the slave must acknowledge the SDO. Longer data packets can be sent in 7 byte chunks in subsequent multiple frames.

PDOs provide an efficient way to transfer real-time data packets of 8 bytes or less. All 8 bytes of the data field can be used since the PDO is mapped ahead of time to the relevant slave function. A PVT vector can be transmitted in one CAN frame. PDOs can also be initiated by a slave, acting as an interrupt to the master.

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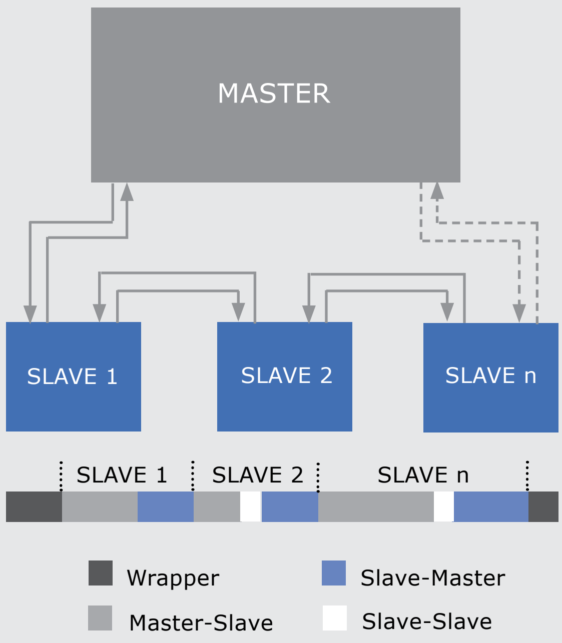
EtherCAT Introduction

EtherCAT is an open standard for real-time control. Fast and deterministic, EtherCAT can update 100 slaves with 8 bytes of data in 100 microseconds. All network topologies are supported, employing both copper and fiber optic cables. EtherCAT leverages CANopen and SERCOS device profiles, facilitating simple migration. The EtherCAT master uses standard hardware without the need for an additional communication processor. The slave employs a custom ASIC or FPGA, but the cost premium is negligible compared to a standard Ethernet node.

Messaging and Network Topology

EtherCAT makes optimal use of network bandwidth by assigning slaves a unique time slice within one standard Ethernet telegram. Each slave reads the master data and inserts its own data as the telegram passes through. This data can be for the master as well as downstream peers.



The most common EtherCAT topology is a line. As EtherCAT is full-duplex, connecting the last node back to the master (ring) provides cable redundancy. 65,535 nodes can be addressed with cable lengths between nodes up to 100m.

EtherCAT accommodates star topologies but this requires the slave to operate in Open Mode. Open Mode is not available in the current ASIC implementation. Star topologies are possible, however with the more flexible FPGA based design of Copley drives.

Synchronization

Similar to CANopen, EtherCAT employs distributed clocks to synchronize network nodes. The master uses time-stamp information from each slave to adjust the distributed clocks. Network jitter significantly less than 1 microsecond is possible even with hundreds of nodes.

CANopen over EtherCAT (CoE)

CANopen over EtherCAT implements standard SDO and PDO communication mechanisms. Even network management is very similar. Application code can be reused, faciliating EtherCAT migration. The CANopen device profile can also be expanded to capitalize on the high bandwidth of EtherCAT.

Using CANop

Control Software

Copley distributed control software makes system commissioning fast and simple. The development of low-level code to control a CANopen or EtherCAT network is eliminated. All network management is taken care of by a few simple commands linked into the application program.

Copley supports two development environments. Copley Motion Libraries (CML) link into a C++ application program. Copley Motion Objects (CMO) are COM objects that can be used by Visual Basic®, .NET®, LabVIEW® or any COM compliant software.

Application code interfaces with servo or stepper drive objects in CML/CMO. These objects can be linked to a CANopen or EtherCAT communications object. The basic application code remains unchanged in either implementation, simplifying migration from CANopen to EtherCAT. It is also possible to run a combination of EtherCAT and CANopen on the same PC.

Network Management

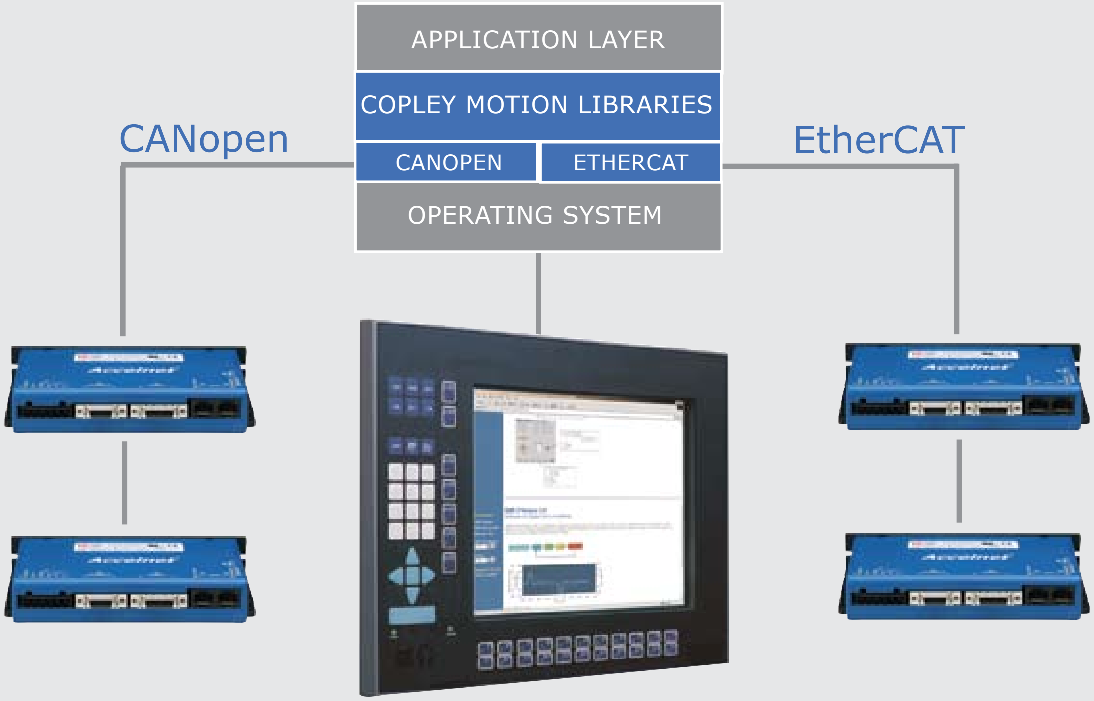
- Configuration and startup
- Synchronization
- Message generation
- Error management

Motion Control

- Path planning
- PVT generation
- Execute profiles
- PVT buffer management

General

- Set/get parameters
- Download setup files
- Drive fault handling
- I/O interfacing



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Network Solutions

For CANopen networks, Copley provides a dual-channel PCI card with on-board microcontroller. The card is supported with CANView for network diagnostics, message display and bus loading analysis.

Copley drives feature comprehensive local I/O, reducing the need for third-party devices. EtherCAT PCB-mounted drive modules also incorporate a high speed SPI interface for more extensive I/O expansion.

The Copley I/O Processor Module, with 72 discrete I/O and 12 analog inputs, enables OEMs to design optimal system interfaces and integrate them seamlessly into the control system.

CAN PCI Card

I/O Module

EtherCAT Masters

In a distributed control architecture with servo loops closed in the drive, CML and CMO make a custom master very accessible to OEMs. There are also a range of third party EtherCAT masters available from a variety of vendors. These products are primarily software tasks which require a PC with a real-time multi-tasking operating system.

Suppliers of EtherCAT masters include:

- Beckhoff (TwinCAT)
- Acontis Technologies
- Soft Servo
- ACS Motion Control
- 3S (CoDeSys)
- Koenig Process Automation

CANopen to EtherCAT Migration

CANopen is a proven and cost-effective solution for distributed control and meets the needs of most applications. For tightly coupled axes requiring centralized real-time adjustment of servo loops, EtherCAT is preferred. Network topology, number of nodes and cabling also factor into the selection of EtherCAT. The pros and cons of migrating from CANopen to EtherCAT are summarized below.

PROS

- Centralized control for tightly coupled axes
- Flexible wiring topology with redundancy
- Longer cable lengths (100m)
- Essentially unlimited number of nodes
- Fast slave-to-slave communication
- CAN card eliminated - standard Ethernet port

CONS

- Incremental drive cost
- Physical size of drive increases
- PCB board layout for drive modules must consider transmission line effects

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