Emerson Industrial Automation

A Guide to
Popular Fieldbus Systems
for use with
Variable Speed Drives

Control Techniques

This guide is one of a series covering subjects such as harmonics, safety features, EMC, feedback devices, industrial communications and motion control.

These can be accessed via www.controltechniques.com/guides.

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1 Introduction to fieldbus systems

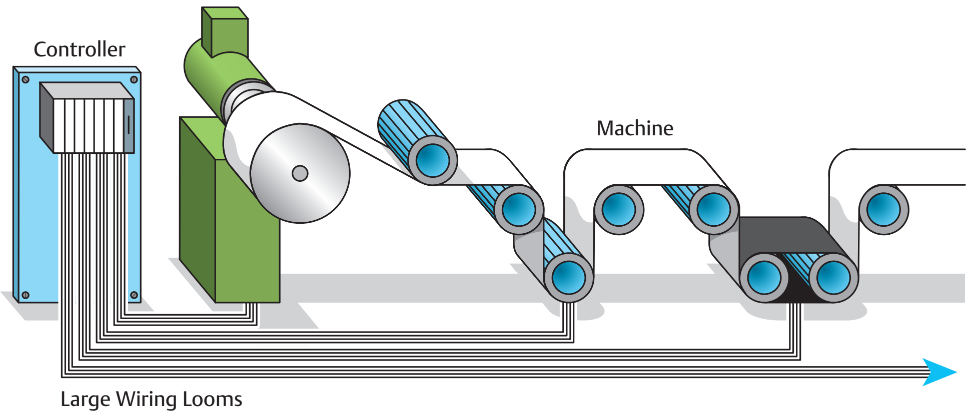
Fieldbus is the name given to a digital communications network that is used for automation and control. These networks have special properties that offer advantages over other technologies making them more suitable for use in industrial environments.

In the past, control systems were implemented using point-to-point wiring. Every switch, lamp, solenoid and variable speed drive required an individual connection to a centralised controller. With a fieldbus system the complex point-to-point wiring for machine control can be greatly reduced using a single communications cable.

Fieldbus networks typically offer the following features:

- A high degree of electrical noise immunity, when compared to conventional analogue wiring systems
- Lower lifetime costs through reduced installation, maintenance and diagnostic overheads
- Enhanced error handling and reporting
- Ability to operate within specified response times (high speed determinism)
- Excellent update rate, ensuring precise machine control and monitoring
- Can offer multiple device synchronisation for high performance motion systems

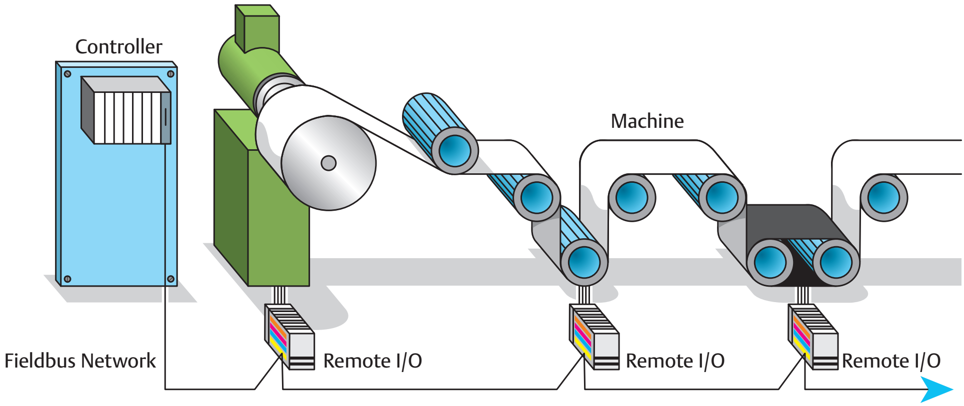
Figure 1 Traditional control system without fieldbus



Many applications require drives to be connected to input/output devices and master controllers. This philosophy traditionally resulted in large looms of wiring that are expensive to install, maintain and repair. Figure 1 shows a typical example of the cabling requirements for this type of system.

Fieldbus technology has revolutionised automation system design by reducing complex wiring to a manageable level. Figure 2 shows a practical example demonstrating the dramatic improvement when using fieldbus as opposed to a conventional wiring system. The overall reduction in complexity allows for more standardised machine design, thus reducing engineering costs and time to market.

Figure 2 Modern fieldbus network control system

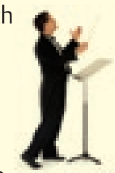


2 Centralised and decentralised control

Traditionally most complex machine designs relied on centralised control with one controller (PLC) coordinating the function of the entire machine. With increasing machine complexity some designs are now being implemented with a distributed control scheme allowing complex functions in the machine to be managed at a local level.

Using the example of "performing a concert", the centralised control strategy can be considered as a "one man band", where all instruments are played by one person. This can put considerable demands on the musician, trying to play all instruments in perfect tune and coordinating the timing of the piece.

With a distributed control approach each instrument is played by an individual musician with only a single task to perform in a similar way to an orchestra. The system can then be coordinated using the fieldbus.



Using a distributed control strategy can offer advantages for design and fault finding as a very specific function is done by each distributed element in the system.

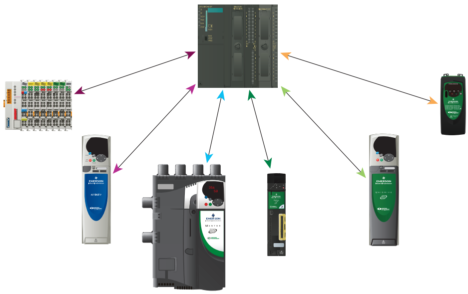
2.1 Centralised control

Centralised control usually requires a powerful controller to coordinate the machine and to perform all of the individual functions of the machine concurrently.

Typical features of centralised control are:

- Control is orchestrated from a single central controller
- Programming is executed from a central point
- Can result in complex programs as all functionality is contained in one program
- The controller can become a commissioning bottleneck as all testing must be performed centrally
- Processing delays can affect system performance as all functions run on a single controller

Figure 3 Information flow in centralised control data flow



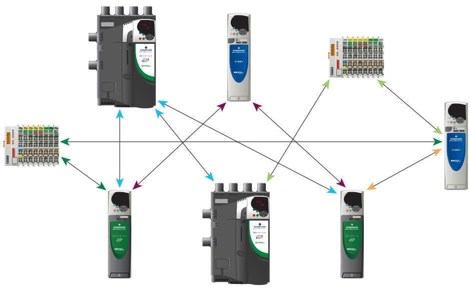
2.2 Decentralised networks

Decentralised networks require local intelligence in each device. Some co-ordination is required within the machine, however no specific node has overall control.

Typical features of decentralised control are:

- Peer-to-peer communications (devices exchange information)
- "Automation Intelligence" in some devices
- Good programming tools required to manage distributed control
- Typically lower cost as a dedicated PLC is not always required
- Modular software means easier development and maintenance of code
- Opportunity for faster response times and tighter machine control when compared to centralised control
- Reduced network traffic
- Inherent system redundancy possible as individual functional blocks of the machine can operate independently of central control

Figure 4 Decentralised network data flow



3 Physical network topology

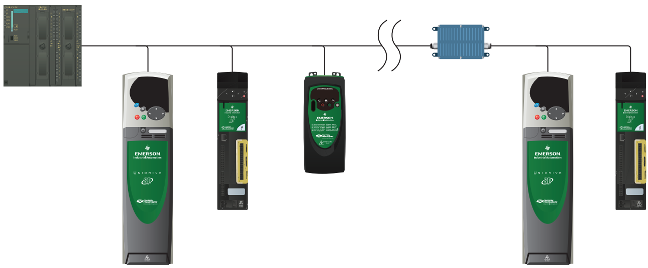
When designing a network, the "network topology" or physical hardware connections must be considered. Typically for a given fieldbus type the network topology is dictated by the specification. Guidelines for each fieldbus type must be adhered to.

There are various types of network topology; here we consider those associated with fieldbus.

3.1 Bus topology

With bus topology all network devices are usually connected to the same physical wire. Some fieldbuses allow the use of repeaters to increase the number of devices on the same physical network.

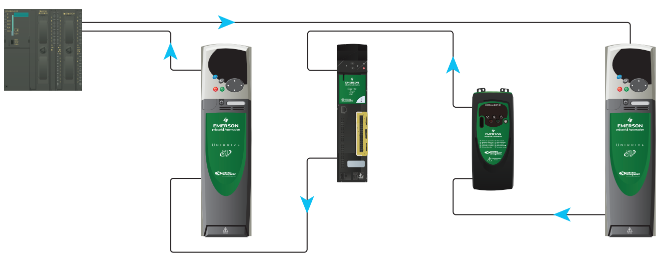
Figure 5 Bus topology



3.2 Repeated bus topology (daisy chain)

This is similar to the bus topology but each node actively repeats the electrical signal, this has the benefit of regenerating the electrical or optical signal, acting in a similar way to a repeater.

Figure 6 Repeated bus topology

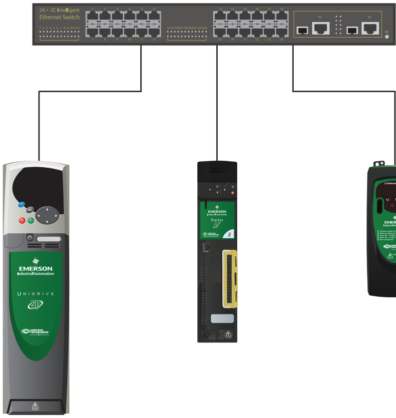


Depending on the fieldbus type the data from the network is either returned to the master with a dedicated connection, or returned using spare cores in the original cabling.

3.3 Star topology

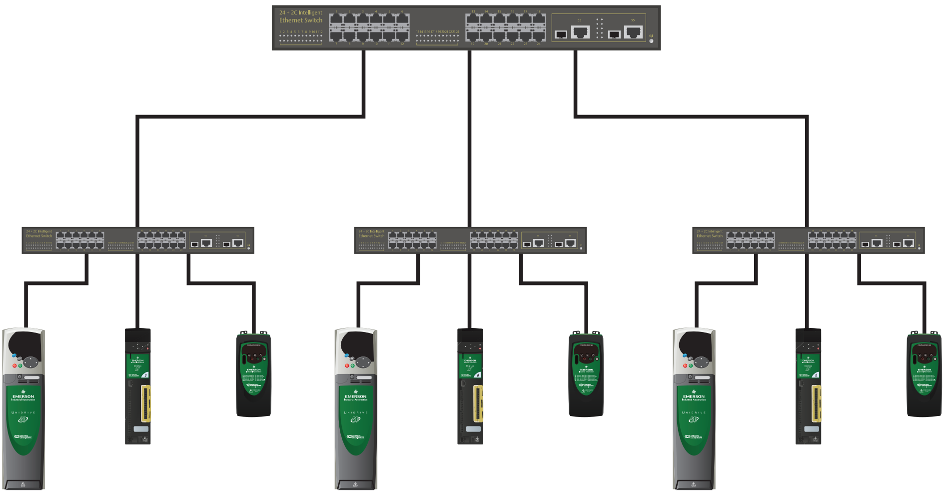
With a star network, devices are connected together at a single central point such as a switch.

Figure 7 Basic star topology



The logical extension of this is "root" topology where this is repeated using multiple switches to give a layout similar to the one below.

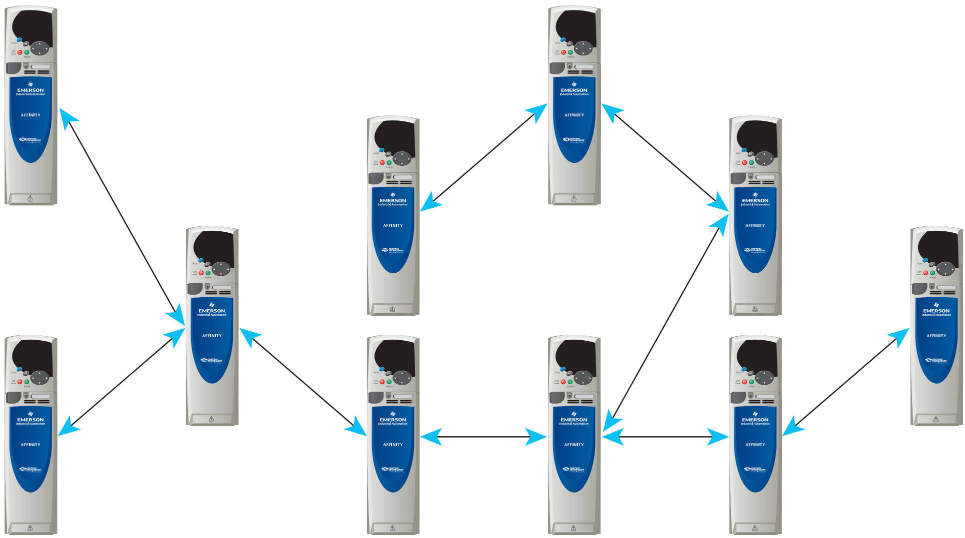
Figure 8 Logical extension of star (root) topology



3.4 Free topology

Devices are connected with few rules; spurs and branches are all allowed. Free topology offers the maximum flexibility to the installer, but can result in a limitation in network performance. An example of a free topology network is LonWorks.

Figure 9 Free topology with the Affinity drive



3.5 Redundant ring topology

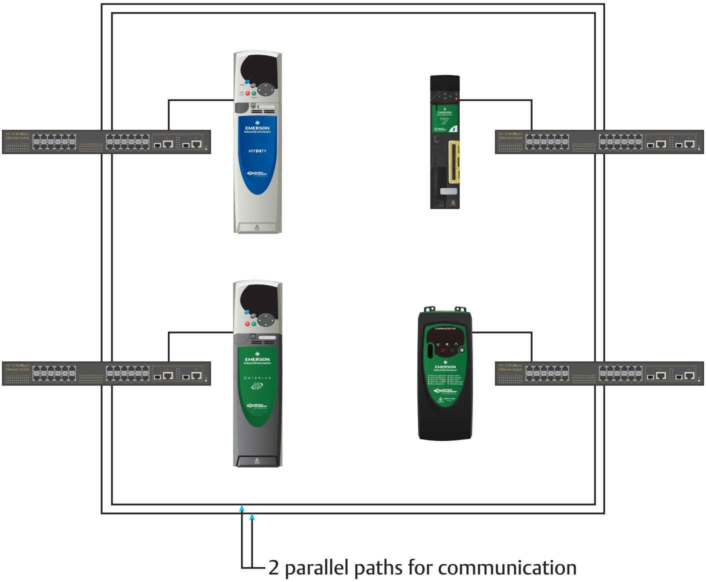
Redundant ring topology provides an additional route for signals in the event of a hardware fault.

A failure at any point on the cabling will not stop the network from running, however a fault would be detected, allowing for scheduled maintenance.

It is important with redundancy to ensure cables are routed separately to avoid both physical cables becoming damaged at the same time.

Most ring topologies will allow for multiple faults without causing network failure.

Figure 10 Redundant ring topology



4 Network design

4.1 Overview

The design and installation of the network is a vital part of the machine design process which should not be underestimated. Each fieldbus has its own set of rules that are described within the specifications. This guide contains advice on installation and recommendations for each fieldbus type.

The following sections should be considered for all network design projects, although it should be noted that each fieldbus has different requirements.

4.2 Cabling

Most fieldbus networks use approved cables and this is key to the success of any good installation. The use of approved connectors and best wiring practices help to ensure reliable operation of the network.

On some networks fibre optic cable can be used to reduce electrical noise and ground loops. If the fieldbus supports fibre optic cabling, such as Ethernet, then this can often solve installation problems on sites with excessive electrical noise or grounding problems.

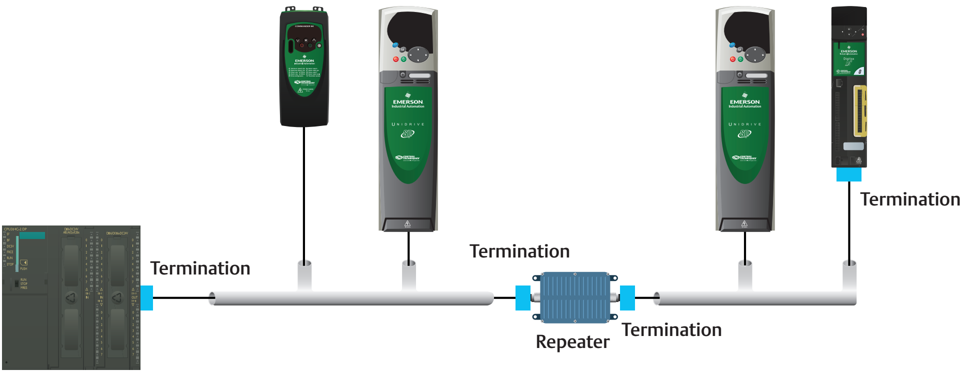
Each fieldbus type has a maximum cable length that is recommended and must not be exceeded.

4.3 Termination

Many fieldbus networks require electrical termination; this is usually achieved with resistors fitted in the network connectors. Termination is applied to the physical ends of a cable run, helping to prevent reflections and increase noise immunity. If repeaters are used, each segment either side of the repeater requires termination.

Figure 11 Termination of networks

Single network segment termination



Multiple network segment termination

4.4 Grounding

Grounding is important to ensure electrical safety as well as to maintain good noise immunity. Each fieldbus has slightly different recommendations which must be adhered to. It is vital that this is not omitted for safety and network stability to be ensured.

4.5 Number of nodes

When designing networks it is important to consider the maximum number of nodes that are supported. This is usually an electrical limitation (such as 32 nodes per electrical segment); this electrical limitation also needs to allow for any repeaters on the network that also contribute to the electrical loading on each segment.

The maximum number of nodes on a network can also be limited by the fieldbus type; some networks may only support a limited number of devices in order to maintain a specified update rate. Even when using networks such as Ethernet, with theoretically an infinite number of nodes, it is important to consider the traffic flow on the network to ensure reliable and consistent network performance.

As a general rule the more nodes that are present on the network and the more data transferred, the slower the update rate on the network will be. For any given network protocol, the available network bandwidth will be limited to a maximum level.

4.6 Machine safety over fieldbus systems

In recent years, changes in the way that machine safety issues are approached and solved have resulted in the integration of safety features into a wide range of automation equipment. The following points highlight why these changes have come about:

1. Machine safety standards are becoming stricter, meaning that previously acceptable approaches now must be certified as safe, e.g. permitting a machine to operate at a slow speed while a guard is open.
2. Machine designers wishing to use machines in new ways by enabling human interaction while equipment is still active, e.g. entering a car production robot cell without halting the equipment.

In both of the above cases, safe PLC functionality is required to control the sequence of events and some safe behaviour has to be guaranteed by the actuator (e.g. drive and motor). As a fieldbus communication link almost certainly already exists between the PLC and the drive, it makes sense to also use this link to transmit safety related data/commands. This requirement has led to the specification of a number of protocols that transmit safety related data over existing fieldbusses e.g.

- Profisafe
- Safety over EtherCAT (FSoE)
- CIP Safety

Typically these protocols rely on a ‘black channel’ approach, meaning that the intermediate network equipment does not have to be certified/approved. Instead the devices that construct and interpret the messages are responsible for providing the safe functionality and monitoring data integrity. This approach means that any network can be used to transmit safety related data. For example, a wireless network can be used to transmit safety related message because, although it may be susceptible to interference, if the message is lost or corrupted the protocol will ensure that the message is re-transmitted and that either the receiving and/or transmitting device perform their safe action.

4.7 Tools

The maintenance and support of a network can be greatly enhanced with the use of tools such as network analysers and cable testers. Analysers allow issues with data flow and timing to be quickly identified.

Each specific fieldbus type requires specific tools, which vary considerably in cost. An oscilloscope should be considered as a fundamental tool for diagnosing network issues for electrical noise and signal quality issues. When the network is initially installed benchmark waveforms should be stored for future reference, clearly showing the location where the waveforms were taken.

Figure 12 Analyser screen shot

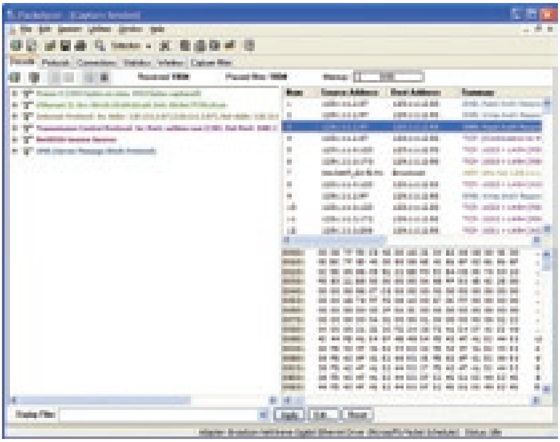


Figure 13 Cable tester

5 Gateways

5.1 Using the drive to link different fieldbus types

In certain circumstances it is advantageous to connect various fieldbus types together to integrate different systems from various suppliers. This removes barriers between different system architectures and allows the user a wider range of hardware and software. As an example this could be where a production machine uses Profibus, but a packaging machine uses DeviceNet. For these two units to work together the buses must be linked. A device that links different types of fieldbus is called a gateway.

A gateway consists of a device with two or more network interfaces, sharing common memory.

Control Techniques AC, DC and servo drives share the same control programming system and connectivity option modules. These provide the capability to gateway up to three fieldbus technologies through the use of plug-in Solutions Modules within the product envelope as demonstrated in Figure 14. This feature allows machine builders to standardise on their bus system, while still allowing their customers to connect to the machine through their own fieldbus of choice.

Figure 14 Typical Solutions Module layout inside a Control Techniques drive

Figure 15 Gateway dataflow

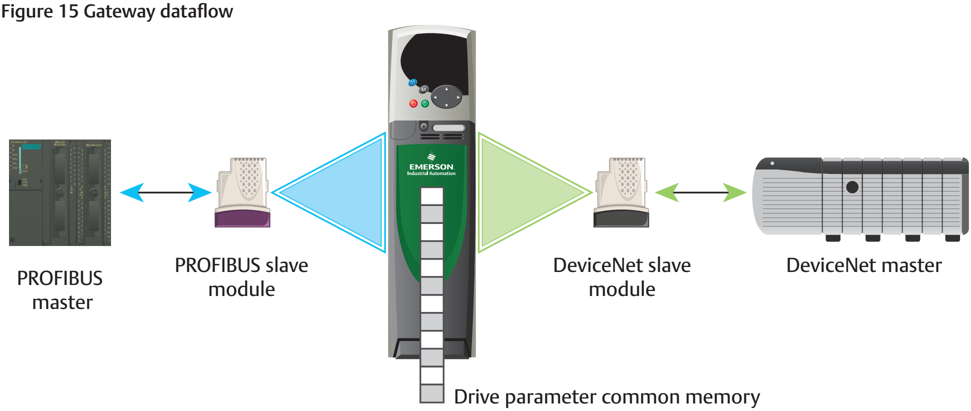
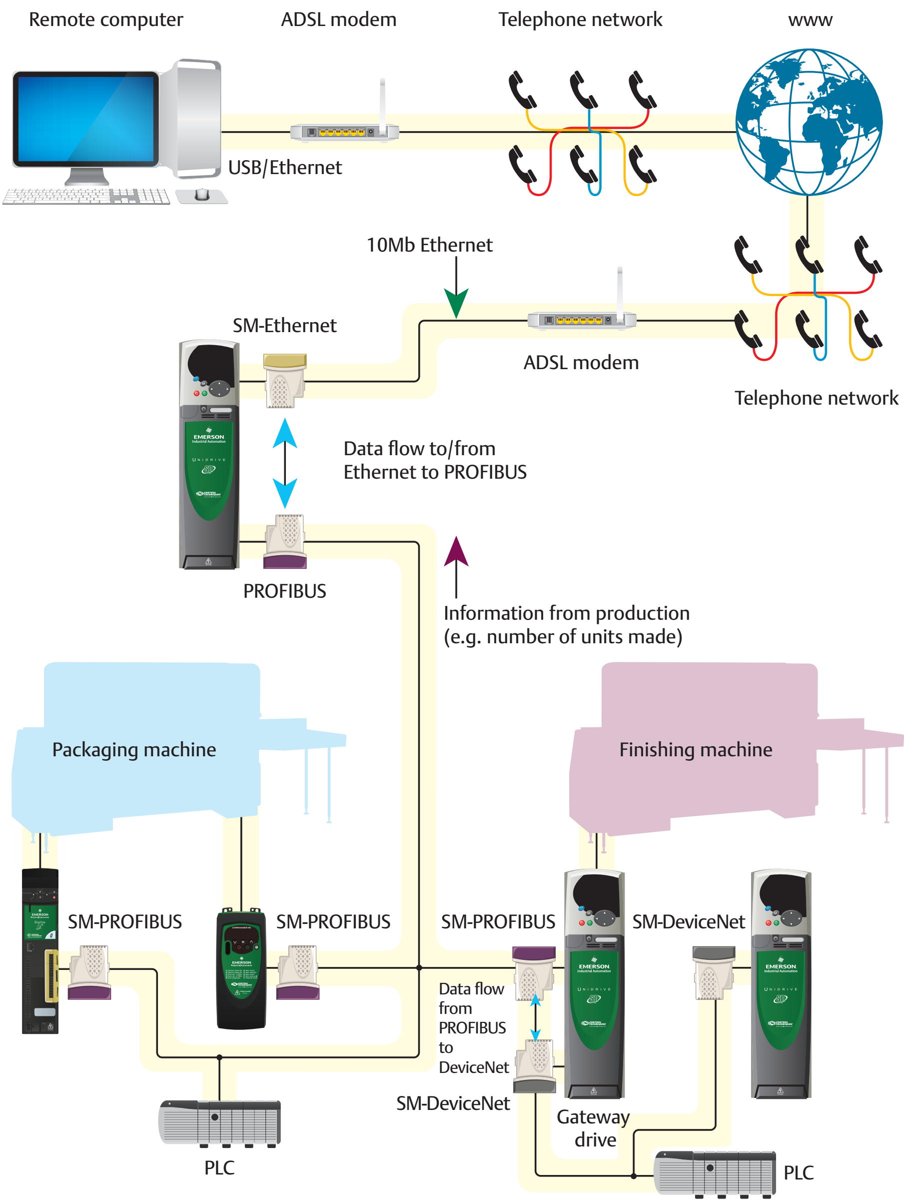


Figure 16 shows a typical real world example using the Internet for remote data flow to both DeviceNet and PROFIBUS.

Figure 16 Using Control Techniques drives as gateways: a practical example



6 Open and proprietary networks

6.1 Open networks

The term "Open" when used in the context of fieldbus systems means that control of the specification and standards has been adopted by, or transitioned to, an independent organisation that's membership is open to multiple vendors. The advantage of open networks is that in theory, devices can be purchased from multiple manufacturers and should be able to interoperate. Most fieldbus organisations provide a conformance certification programme to give end users the confidence that the devices are able to interoperate reliably.

It is good practice to always ensure that the devices are certified by the relevant organisation.

6.2 Proprietary networks

Proprietary networks are usually controlled and maintained by a single company or a small group of companies. The networks specifications are often tightly coupled to the features required for a particular company and their products.

The result is often a focused efficient solution to a particular problem or customer requirement, interoperability is not an issue as all devices are purchased from the same vendor group.

Communication standards such as OPC are able to provide a simple mechanism to get access to many proprietary networks.

7 OPC Technology

OPC (OLE* for Process Control) is an open technology that allows PCs to connect to industrial devices and networks for monitoring, configuration and data acquisition.

*Object Linking and Embedding

OPC has become the industry standard for connecting industrial automation components to higher level information systems, such as SCADA (Supervisory Control And Data Acquisition), MRP (Material Requirements Planning), ERP (Enterprise Resource Planning) and other manufacturing solutions. It is very common for higher level information systems to include an OPC client in their software.

The Control Techniques OPC server provides access to data within Control Techniques drives and associated products for Windows® based PCs. The server is configured to periodically collect data from the required drives and make this data available to Windows® applications.

Figure 17 shows a typical SCADA screen connected via OPC.

Figure 17 Typical process control screen

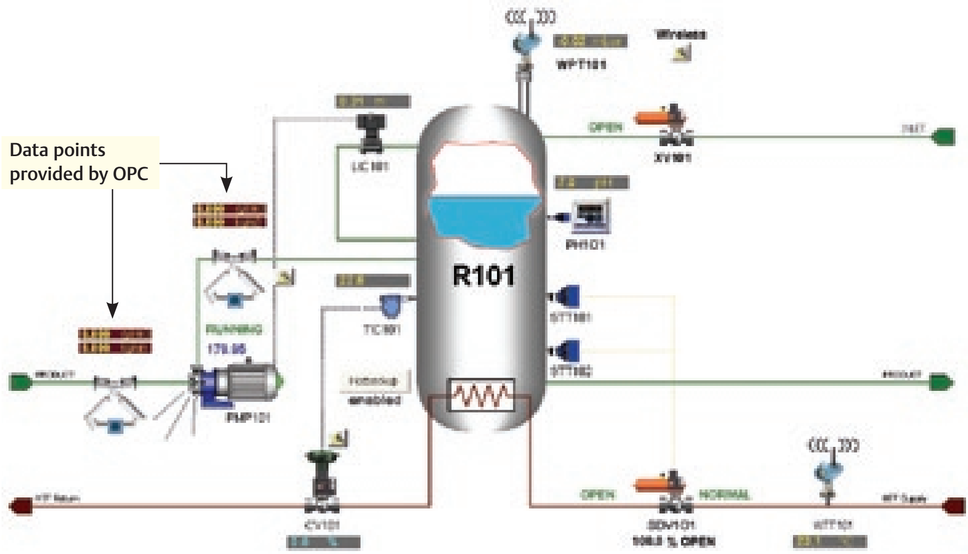


Figure 18 Typical OPC server implimentation
[1] SCADA, Visual Basic, other client, etc

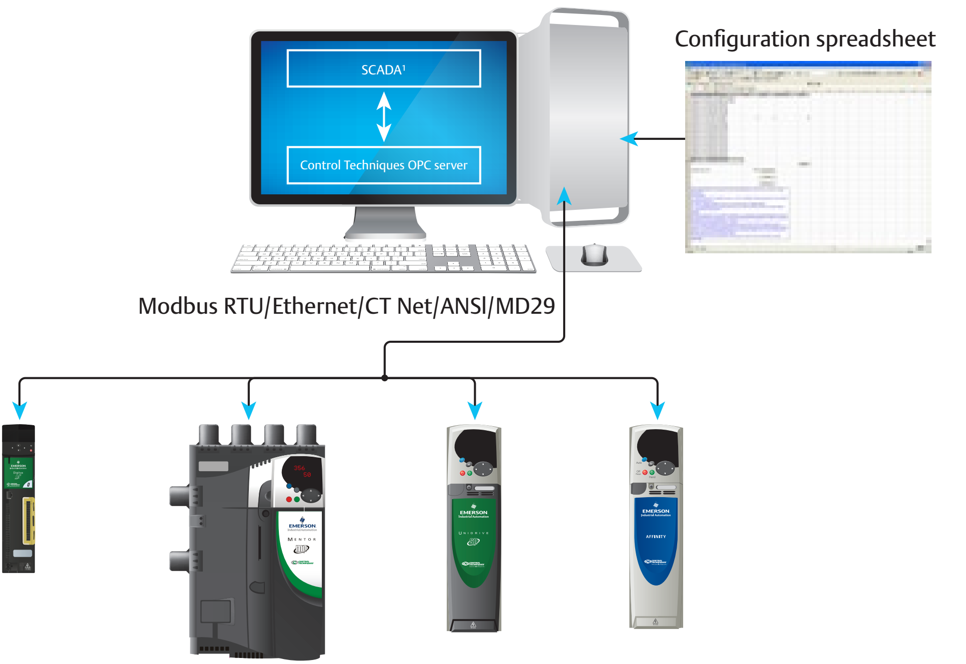


Figure 18 shows data flow from/to the drives through the physical network, the OPC server and finally the SCADA.

The Control Techniques OPC server is configured using an Excel® spreadsheet that defines which data is polled from the various components on the network. The OPC client is configured to connect to the Control Techniques OPC server. Once achieved, the OPC client can then browse and select data from the Control Techniques OPC server.

8 What to consider when choosing a fieldbus

There are many aspects to consider when choosing a suitable fieldbus for your machine or process. Picking an unsuitable fieldbus can have implications for performance, machine accuracy and future expansion.

When considering capital investment in new technology, an evaluation of the initial purchase costs (hardware and software) and reoccurring costs, such as engineering (programming and design), on-going maintenance and future expansion should be made.

An important part of the decision making process is to have a suitable network infrastructure for your requirements without the cost penalty of an overly high performance for your application; in essence, the best cost/performance ratio for your needs.

How many nodes?

Each fieldbus system will have a limitation on the maximum number of nodes, not only from an electrical point of view but also from a system point of view. The number of nodes will also affect how quickly each node can be updated on a system.

What equipment or systems are currently being used?

Considering what equipment is already present on a site is a key factor, as this may also determine what experience your staff have with a particular fieldbus or PLC. This also has implications for spares, as you only need to support a single system, although gateways can help aleviate this issue.

It should be noted that to move your system design forward, it is sometimes necessary to compromise on legacy support.

Future proofing

When choosing a fieldbus, consideration should be given to ensure the system covers your current and future needs, both in terms of expandability and additional functionality you may need thereafter.

Do you need a synchronous network?

For motion control, a synchronous network is recommended to ensure there is no skewing (i.e. delay in the coordinated movement of axes), thus maximising the quality of finished product. For a simple control system synchronisation may not be required.

Update speed

How fast do you need the data to be updated? On a building management system update rates of 30 seconds may be acceptable, but on a CNC machine 250µs (or better) may be required to ensure accuracy of the finished part.

Ease of implementation

Different networks require different skill sets to implement; some networks have very simple set-up tools while others have complex setup that needs programming in the controller to allow the network to function.

Connectivity to the business network

A machine that forms part of a large manufacturing plant, for example, may need to pass data to central engineering and management, for maintenance/production statistics. Higher level information flow is typically achieved using Ethernet based networks or OPC. To ensure separation of the plant and business IT systems, managed firewalls can be used to control visibility and flow of data.

9 Types of fieldbus

There are many different types of fieldbus, each with distinct features, some specific to various industries and geographical regions.

9.1 Traditional fieldbus

9.1.1 Modbus RTU

MODBUS RTU

Background Information

One of the most widely used and accepted fieldbus standards since the late 1970s, Modbus RTU is an EIA(RS)-485 based master/slave system running at baud rates of up to 115kbit/s. Developed by Modicon for PLC communication, but is also used for basic parameter control on drives.

Key statistics

Speed:	Dependant on serial link baud rate
Physical topology:	One-to-one or bus
Logical topology:	Centralised master / slave
Maximum number of devices:	247
Network length:	Modbus RTU maximum length is based on EIA(RS)-485 standards 1200m (dependent on speed). Longer length can be achieved with repeaters. Maximum number of nodes is 247 on a single network.
Transmission method:	Typically EIA(RS)-485

Industry biases

Used widely in all industries.

Geographical biases

Worldwide acceptance.

Website

www.modbus.org

Control Techniques products

All current Control Techniques variable speed drives support Modbus RTU as standard.

9.1.2 PROFIBUS DP–V0 and DP–V1

Background Information

PROFIBUS started life in the 1980s, developed by academic institutions within Germany and was quickly adopted as a German national standard. Now PROFIBUS is by far the most widespread fieldbus and is especially dominant throughout Europe. The DP version of PROFIBUS is for communication between automation and control systems and distributed I/O at the device level.

Key statistics

Speed:	Up to 12Mbit/s
Physical topology:	Bus
Logical topology:	Centralised, master/slave
Maximum number of devices:	32 without repeaters, 125 with repeaters
Network length:	Limted to 1000m without repeaters
Transmission method:	Typically twisted pair EIA(RS)-485 based

Industry biases

PROFIBUS is widely used throughout many industries, such as automotive, production machinery and metals processing.

Geographical biases

Widely accepted throughout Europe and a growing acceptance worldwide.

Control Techniques membership

Control Techniques is a member of PROFIBUS International, the standards organisation responsible for maintaining and developing the specification for PROFIBUS. All current Control Techniques PROFIBUS products are certified for conformance.

Website

www.profibus.org

Control Techniques products

SM-PROFIBUS-DP

9.1.3 DeviceNet

Background Information

In early 1994, Allen-Bradley turned the DeviceNet specification over to the 'Open DeviceNet Vendor Association' (ODVA), which boosted the popularity of DeviceNet. DeviceNet was developed especially for factory automation and therefore presents itself as a direct opponent to protocols like PROFIBUS-DP and Interbus.

DeviceNet uses a protocol called CIP – Common Industrial Protocol. Other fieldbuses that use this protocol include ControlNet and Ethernet IP.

Key statistics

Speed:	Typically 500kbit/s
Physical topology:	Bus
Logical topology:	Centralised, master/slave
Maximum number of devices:	64
Network length:	5000m data rate dependant (without repeaters)
Transmission method:	CAN bus, twisted pair with network power

Industry biases

DeviceNet is widely used in a large range of industries, such as general production machinery, automotive, etc.

Geographical biases

DeviceNet is well established throughout the Americas and continuing to grow worldwide.

Control Techniques membership

Control Techniques is a member of the ODVA the standards organisation responsible for maintaining and developing the specification for the CIP family of protocols. All Control Techniques DeviceNet products are certified for conformance.

Website

www.odva.org

Control Techniques products


SM-DeviceNet

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9.1.4 CAN

Background Information

CAN was originally developed by Robert Bosch GmbH, and released in 1986. It was intended for use in vehicles to network various electrical devices (engine management, central locking, etc). It provides a simple and standard means to connect sensors and actuators. Subsequently, it has found some use in industrial automation.

CAN specifies the data link layer, however higher-level protocols have been defined which operate over the CAN data link layer, such as CANopen and DeviceNet (defined by the ODVA).

Key statistics

Speed:	Up to 1Mbit/s
Topology:	Bus
Logical topology:	Distributed
Number of devices:	127 (limited by node address) on the same physical network.
Network length:	5000m subject to data rate.
Transmission method:	CAN bus, twisted pair

Industry biases

Automotive, elevators, test rigs, etc

Geographical biases

Worldwide

Control Techniques membership

Control Techniques is a member of CiA (Can in Automation), the standards organisation responsible for maintaining and developing the specification for CAN. All Control Techniques CAN products are certified for conformance.

Website

www.can-cia.org

Control Techniques products

SM-CAN

SM-CAN allows users to implement their own CAN protocols for integration with proprietary equipment in combination with SM-Applications.

9.1.5 CANopen

Background Information

In 1993, a European consortium lead by Bosch had been developing a prototype of what eventually became CANopen. After the completion of the project, the CANopen specification was handed over to the CiA for further development and maintenance.

In 1995, the completely revised CANopen communications profile was released and within five years became an important standardised embedded network in Europe. CANopen does not only define the application layer and a communication profile, but also a framework for programmable systems as well as different device, interface and application profiles. This is an important reason why whole industry segments (e.g. printing machines, maritime applications, medical systems) decided to use CANopen during the late 1990s.

An important feature of CANopen is its ability to close a position loop with reasonable (1ms) update times despite a relatively modest bus speed.

Key statistics

Speed:	1Mbit/s
Physical topology:	Bus
Logical topology:	Centralised, master/slave
Maximum number of devices:	127 (limited by node address) on the same physical network
Network length:	5000m subject to data rate
Transmission method:	CAN bus, twisted pair

Industry biases

CANopen has gained widespread acceptance with OEMs who manufacture their own custom controllers, due to the low cost and simplicity of implementation.

Geographical biases

CANopen is popular in Europe.

Control Techniques membership

Control Techniques is a member of CiA (Can in Automation), the standards organisation responsible for maintaining and developing the specification for CANopen. All Control Techniques CANopen products are certified for conformance.

Website

www.canopen.org

Control Techniques products


SM-CANopen

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9.1.6 Interbus

Background Information

Interbus, or Interbus-S, protocol was developed in the mid eighties by Phoenix Contact and several German technical institutions. The goal of the project was to simplify signal wiring in industrial applications. In 1990 Phoenix Contact decided to disclose the specifications of Interbus and as such this protocol became the first manufacturer independent fieldbus system.

The Interbus protocol has continued to develop since that time and is now controlled by the Interbus Club, an organisation run by users of the protocol.

Interbus has been adopted as a German standard (1994) and European standard (1998) according to DIN 19 258.

Key statistics

Speed:	500kbit/s and 2Mbit/s
Physical topology:	Repeated bus
Logical topology:	Centralised
Maximum number of devices:	512, 4096 I/O points
Network length:	400m between devices, up to 13km network length
Transmission method:	Twisted-pair or fibre optic

Industry biases

Widely adopted by automotive manufacturers.

Geographical biases

Popular within Europe.

Control Techniques conformance

All Control Techniques Interbus products are certified for conformance.

Website

www.interbusclub.org

Control Techniques products

SM-INTERBUS

9.1.7 SERCOS

Background Information

SERCOS is an acronym for SErial Real-time COmmunications System. It defines an open, standardised digital interface for communication between digital controls, drives, I/O, sensors and actuators for numerically controlled machines and systems. It is designed for high speed serial communication of standardised closed-loop data in real-time over a noise-immune, fibre-optic cable.

SERCOS interface takes full advantage of today's intelligent digital drive capabilities by not only replacing the de-facto ±10V analogue interface standard, but also by allowing powerful two way communications between controller and drive.

Key statistics

Speed:	Up to 16Mbit/s
Physical topology:	Repeated bus
Logical topology:	Centralised, master/slave
Maximum number of devices:	Up to 254, but update rate is affected as the device count increases.
Network length:	254 nodes per network, effectively limited by required update rate.
Transmission method:	Fibre optic

Industry biases

Motion, CNC applications, packaging etc.

Geographical biases

Worldwide.

Control Techniques membership

All Control Techniques SERCOS products are certified for conformance.

Website

www.sercos.de

Control Techniques products

SM-SERCOS

9.2 Fieldbus dedicated for HVAC/R and building automation

HVAC/R stands for Heating, Ventilation, Air Conditioning and Refrigeration. Typically building automation systems differ from machine control as the response times are significantly slower and not as critical. Response times are usually in the region of many seconds as opposed to machine control where milliseconds or microseconds are required.

9.2.1 LonWorks

LonMark® Partner

Background Information

LonWorks is a flexible, distributed peer-to-peer networking architecture. The technology has been developed by Echelon who have handed control over the specification to an open body called LonMark. As virtually every LonWorks device uses the same Neuron chips, and the LonMark certification process is fairly rigorous, LonWorks interoperability is generally very good.

Key statistics

Speed:	Typically 78kbit/s
Physical topology:	Bus or free
Logical topology:	Decentralised, peer to peer
Maximum number of devices:	2^{48} domains x 255 subnets x 127 (limited to 127 on the same physical cable)
Network length:	2200m bus topology, 500m free topology (Maybe extended with repeaters or hubs)
Transmission method:	Various but typically twisted pair; power line transmission is also possible

Industry biases

LonWorks had originally aimed to provide a network solution to a wide spectrum of industries, however, it has found its home in the HVAC/R building automation. In this industry simplicity of installation is essential and by providing free topology this is easily achieved.

LonWorks distributed topology removes the requirement for a centralised controller, for this reason their main opposition has come from manufacturers of building management systems.

Geographical biases

Global.

Control Techniques membership

Control Techniques is a member of LonMark, the standards organisation responsible for maintaining and developing the specification for LonWorks and the LonTalk protocol. All Control Techniques LonWorks products are certified for conformance.

Website

www.lonmark.org

Control Techniques products

SM-LON

9.2.2 BACnet

Background Information

BACnet stands for Building Automation Control network. This is a data communication protocol developed by ASHRAE, with the purpose of standardising communications between building automation devices from different manufacturers, allowing data to be shared and equipment to work together easily.

Key statistics

Speed:	Various
Physical topology:	Typically bus
Logical topology:	Centralised
Maximum number of devices:	127 (per network)
Network length:	1200m (speed dependent) on EIA(RS)-485, effectively unlimited on Ethernet
Transmission method:	Commonly EIA(RS)-485, Ethernet, LonTalk & ARCNET are also available

Industry biases

Building automation.

Geographical biases

Worldwide.

Website

www.ashrae.com

Control Techniques products

Affinity is Control Techniques' dedicated HVAC/R drive and has BACnet as standard.

9.2.3 Metasys N2

Background Information

This protocol was developed by Johnson Controls. Metasys provides connections via "point lists" with each device having a list of available points detailed in its documentation. For example, a drive may have points for speed references and control data.

Key statistics

Speed:	9,600 bit/s
Physical topology:	Bus topology
Logical topology:	Centralised
Maximum number of devices:	Limited to 32 unit loads per segment, up to 255 addresses per physical network, can be extended using additional networks.
Transmission method:	EIA(RS)-485, 2 wire half duplex

Industry biases

Building automation.

Geographical biases

Mainly America, although other regions use this.

Control Techniques products

Affinity is Control Techniques' dedicated HVAC/R drive and has Metasys as standard.

9.3 Ethernet based fieldbus

For many years Ethernet has been considered for industrial applications, but nondeterministic performance has largely excluded it from widespread use on the factory floor. Ethernet has now evolved into variants specifically targeted at addressing early issues with performance.

Ethernet can offer a huge number of advantages to users, such as board room to shop floor connectivity, wireless connectivity, and remote access. This is a mature technology providing familiarity to many industrial and IT engineers.

Most end users expected Ethernet to be the answer for standardisation and interoperability between different vendors' products. However, standard Ethernet was designed for IT networking and is generally not suitable for accurate real-time control such as motion and position control. Fieldbus organisations have met the challenge of making Ethernet suitable for industrial applications by incorporating a version of their standard protocol in an Ethernet frame.

Ethernet enabled devices are able to provide easy to access web page interfaces, e-mail generation and make use of standard Ethernet network features, such as obtaining time and date information, network addressing, etc.

Ethernet has now evolved to a point where it can be controlled in a way that allows deterministic delivery and distributed real time control systems to be realised. This has been done by taking the original Ethernet specification and adding protocols/transmission controls that effectively mean that this is no longer 'standard' Ethernet. Interoperability with standard Ethernet is still relatively easy to achieve thus removing restrictions whilst maintaining the benefits of the original Ethernet platform.

Figure 19 Web page interface on SM-Ethernet

Figure 19 shows a web page interface on Control Techniques' SM-Ethernet. The web page interface allows the user to configure items, such as setting up the drive parameters and configuring e-mail alerts.

9.3.1 Modbus TCP/IP

MODBUS TCP/IP

Background Information

MODBUS TCP/IP specification was developed in 1999 encapsulating the standard MODBUS packet within the TCP/IP messaging structure.

Modbus TCP/IP is currently the most popular industrial Ethernet protocol due to the simplicity of implementation using standard Ethernet.

Key statistics

Speed:	10Mbit/s, 100Mbit/s, 1Gbit/s
Physical topology:	Generally star based; can be bus, ring, tree or mesh
Logical topology:	Centralised, master/slave
Network length:	Theoretically unlimited number of nodes and distance, although realistically limited by the update rate
Transmission method:	Modbus IP utilises standard Ethernet

Industry biases

General.

Geographical biases

Worldwide.

Website

www.modbus.org

Control Techniques products

 SM-Ethernet

9.3.2 Ethernet/IP

Background Information

Ethernet/IP is an Ethernet based protocol for industrial automation applications using the standard Ethernet TCP/UDP/IP protocol suite.

Ethernet/IP has also been developed to offer safety features and real time motion functionality, called CIPSafe and CIPSync.

Ethernet/IP has a large and growing installed base due to the simplicity of implementation using standard Ethernet, its compatibility with previous CIP standards and its longevity in the market.

Key statistics

Speed:	10Mbit/s, 100Mbit/s, 1Gbit/s
Physical topology:	Generally star; can be bus, tree or mesh
Logical topology:	Centralised, master/slave
Network length:	Theoretically unlimited, however cycle times and network performance will be a limiting factor
Transmission method:	Utilises standard Ethernet

Industry biases

General machinery, car industry and production machines.

Geographical biases

The Americas.

Control Techniques membership

Control Techniques is a member of the ODVA, the standards organisation responsible for maintaining and developing the specification for Ethernet IP. All Control Techniques Ethernet IP products are certified for conformance.

Website

www.odva.org

Control Techniques products

SM-Ethernet

9.3.3 CIP Sync

Background Information

CIP Sync is an extension to the Common Industrial Protocol (CIP). It provides synchronisation functionality to networks based on CIP, such as Ethernet/IP, and is an implementation of IEEE1588. The CIP standard was originally developed by Rockwell Automation, but it is now maintained by ODVA (Open DeviceNet Vendors Association). The CIP Sync standard appears to be a very recent addition.

The IEEE1588 standard provides a means to synchronise a number of device clocks present on a network. Rather than ensuring that process data is transmitted by a master with a small message jitter, CIP Motion provides a means to timestamp process data, in order to compensate for variations in transmission time.

Key statistics

Speed:	Ethernet speed – currently 100Mbit/s
Physical topology:	Generally star; can be bus, tree or mesh
Logical topology:	Distributed (IEEE1588 provides a means for slaves to pick the best master clock on the network)
Maximum number of devices:	Theoretically unlimited, although cycle times will ultimately limit this
Network length:	Theoretically unlimited, however network performance and cycle times will be limiting factors
Transmission method:	Standard Ethernet

Typical time jitter between clocks on synchronised devices - ±100ns (with hardware time stamping, etc), ±100μs (with no special hardware).

Industry biases

This is currently unknown; there appears to be very little information regarding actual applications or products using CIP Sync or CIP Motion.

Geographical biases

Currently unknown; however, given the history of the Rockwell/ODVA network standards, it may be more popular in the US than in Europe.

Control Techniques membership

Control Techniques is a member of the ODVA, the standards organisation responsible for maintaining and developing the specification for Ethernet IP. All Control Techniques Ethernet IP products are certified for conformance.

Website

www.odva.org

9.3.4 EtherCAT

Background Information

EtherCAT is a real time industrial Ethernet fieldbus that has been developed by Beckhoff and subsequently handed over to the open EtherCAT Technology Group to maintain and develop the standard. The bus system modifies the standard Ethernet hardware and uses a repeated bus type structure to pass the data from device to device. Protocol efficiencies are gained by embedding the data for many devices within one Ethernet frame obtaining 90% efficiency from the available bandwidth. EtherCAT is able to service 100 drive axes in 100µs.

Key statistics

Speed:	100 Mbit/s
Physical topology:	Repeated bus
Logical topology:	Standard Ethernet based, typically repeated bus
Maximum number of devices:	65536, however network update rate will be affected
Network length:	Theoretically unlimited, however update rate will ultimately restrict this
Transmission method:	Standard Ethernet technology, with time management

Industry biases

High and general performance motion control.

Geographical biases

Predominantly Europe, with a growing interest in US markets

Website

www.ethercat.org

Control Techniques membership

Control Techniques is a member of the EtherCAT Technology Group (ETG), the standards organisation responsible for maintaining and developing the specification for EtherCAT.
All Control Techniques EtherCAT products are certified for conformance.

Control Techniques products


SM-EtherCAT

9.3.5 PROFINET

Background Information

PROFINET is an industrial Ethernet standard for automation that includes plant-wide fieldbus communication and shop floor to board room communication. PROFINET can handle standard Ethernet transmissions and real-time transmissions at sub millisecond speeds.

PROFINET communication is scalable in three levels. Component-based communication uses TCP/IP and enables cycle times in the order of 100 ms. It is preferred for communication between controllers. Real-time (RT) communication enables cycle times in the order of 10 ms and is well suited for use with distributed I/O. Isochronous real-time (IRT) communication enables cycle times less than 1 ms and is thus well suited for use in motion control applications. All these communication levels can co-exist on the same bus line together with IT communications.

PROFINET is somewhat behind Modbus TCP/IP and Ethernet IP in terms of installed base, as it has not been on the market for nearly as long, however, the popularity of PROFIBUS will ensure that this installed base grows rapidly as products are launched onto the market.

Key statistics

Speed:	100Mbit/s and higher
Physical topology:	Generally star; can be bus, tree or mesh
Logical topology:	Centralised
Maximum number of devices:	200 I/O points are possible on a PROFINET network. One of the main advantages of PROFINET compared to PROFIBUS is that you can have more nodes on the network.
Network length:	The length, speed and topology depend on the network components you choose for your network. With external components fibre optic distances of up to 26km are possible depending on the type of fibre optic being used and the vendors. In an electrical network the maximum distance between any two devices is 100m.
Transmission method:	Ethernet based with VLAN

Industry biases

Automotive.

Geographical biases

Predominently Europe.

Control Techniques membership

Control Techniques is a member of PROFIBUS international, the standards organisation responsible for maintaining and developing the specification for PROFINET.

Website

www.profibus.org/pn

9.4 Proprietary fieldbus

Proprietary fieldbus are predominantly developed by a single manufacturer, or in rare occasions may be shared among other parties.

9.4.1 CTNet

Background Information

Developed by Control Techniques, CTNet is a highly deterministic network based on ARCNET that provides the features required for drive control networks. CTNet is standard on SM-Applications modules and some integrated motion processors that fit within Control Techniques drives. CTNet provides connectivity to drives, I/O and HMIs.

This topology can be PLC free, allowing machine builders to offer a standard off-the-shelf solutions, and still provide a gateway between their machine and the customer's fieldbus of choice. A CTNet OPC server is available free of charge.

Key statistics

Protocol:	CTNet
Speed:	Typical speed 2.5Mbit/s (maximum 5Mbit/s)
Physical topology:	Bus
Logical topology:	Decentralised, peer to peer
Maximum number of devices:	255, (dependant on network length, baud rate and use of hubs)
Network length:	Up to 250m (maybe extended through hubs and repeaters)
Transmission method:	Twisted pair or fibre

Industry biases

Machine control industry.

Website

www.controltechniques.com

Control Techniques products


SM-Applications Plus

9.4.2 CTSync

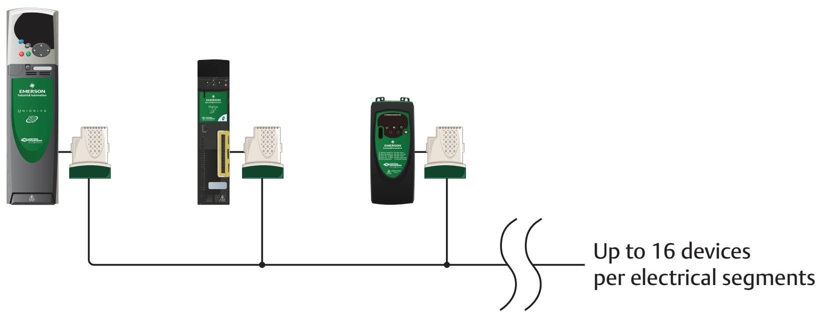
CTSync

Background Information

Developed by Control Techniques, CTSync is a unique protocol designed to address a specific problem of distributing master position information within a drives network.

Many applications require multiple drives to synchronise to a master reference, in the past this has resulted in unwieldy wiring and low reliability. CTSync addresses this by utilising a low cost EIA(RS)-485 network running at high-speed. The network uses hardware synchronisation to provide update information on an accurate time base of 250µs and to synchronise the speed, position and torque loop across multiple drives to maximise performance.

Figure 20 Typical CTSync application



Key statistics

Protocol:	CTSync
Speed:	897kbit/s
Physical topology:	Bus
Logical topology:	Master/slave, simplex communications
Maximum number of devices:	16 in 4 wire mode (can be extended with repeaters)
Transmission method:	EIA(RS)-485
Network length:	200m (single segment), repeaters may be used to extend the segment.

Industry biases

Printing, master-slave motion application such as flying shear, rotary knife, packaging, etc.

Website

www.controltechniques.com

Control Techniques products


SM-Applications Plus

9.5 Summary of protocols supported by Control Techniques products

Protocol	Control Techniques Option Module	Unidrive SP	Commander SK	Affinity	Mentor MP	Digitax ST
Modbus RTU	Not required	✔	✔	✔	✔	✔
BACnet	Not required			✔		
Metasys N2	Not required			✔		
CTNet	SM-Applications	✔		✔	✔	*
CTSync	SM-Applications	✔		✔	✔	*
SERCOS	SM-SERCOS	✔		✔		✔
Modbus TCP/IP	SM-Ethernet	✔	✔	✔	✔	✔
Ethernet/IP	SM-Ethernet	✔	✔	✔	✔	✔
EtherCAT	SM-EtherCAT	✔	✔	✔	✔	✔
INTERBUS	SM-INTERBUS	✔	✔	✔	✔	✔
CAN	SM-CAN**	✔		✔		✔
CANopen	SM-CANopen	✔	✔	✔	✔	✔
DeviceNet	SM-DeviceNet	✔	✔	✔	✔	✔
LonWorks	SM-LON	✔	✔	✔		✔
PROFIBUS-DP	SM-PROFIBUS-DP	✔	✔	✔	✔	✔

*Standard embedded motion processor on Digitax ST Plus

** Offers the ability to develop custom protocols for CAN

10 Vision of the future

Since the early 1970s various networking topologies have evolved, some of these systems have survived on their technical merits alone while others have persisted with effective marketing. Industry acceptance and geographical preferences have been a key driving force behind various fieldbus systems in industry.

Early fieldbus systems were predominantly used to replace large cable looms for input, output and control. Initially used to reduce production and maintenance costs, the technology evolved to encompass control loop synchronisation and higher level programming of devices using a single network.

The next generation of fieldbus utilises Ethernet to expand on the previous features adding a more coherent shop floor to board room communication flow. Modern Ethernet based systems allow high speed determinism, clock sharing and control loop synchronisation while simultaneously allowing information flow from the cell level to manufacturing/order processing systems and beyond.

This leaves the route open for effective process and production control, allowing management to effectively control production, optimise processes and reduce down-time through preventative maintenance. The future will see truly efficient and proactive manufacturing processes, not only within single companies but also extending to group companies and effective supply chain integration.

11 Glossary of industrial fieldbus terminology

10BASE-T	10Mbit/s Ethernet system based on Manchester signal encoding transmitted over Category 3 or better twisted-pair cable.
100BASE-FL	Popular 100Mbit/s link fibre optic solution which replaces the older FOIRL implementation.
100BASE-FX	100Mbit/s Fast Ethernet system based on 4B/5B signal encoding transmitted over fibre optic cable.
100BASE-TX	100Mbit/s Fast Ethernet system based on 4B/5B signal encoding transmitted over two copper pairs.
Address	Unique designation of a station in a fieldbus system.
ARCNET	Attached Resource Computer Net. Communication network using the token-passing method. ARCNET typically operates at a transmission speed of 2.5Mbit/s. A maximum of 255 stations may be connected. A coaxial cable is normally used as the transmission medium. This is the basis of CTNet.
Auto-negotiation	A protocol defined in the Ethernet standard that allows devices at either end of a link segment to advertise and negotiate modes of operation such as the speed of the link, half or full-duplex operation, and full-duplex flow control.
BACnet	A protocol used for building automation.
Bandwidth	The maximum capacity of a network channel. Usually expressed in bits per second (bit/s). Ethernet channels have bandwidths of 10, 100, and 1000 bit/s.
Baud	A baud is a unit of signaling speed representing the number of discrete signal events per second and, depending upon the encoding, can differ from the bit rate.
Bit	A binary digit. The smallest unit of data, either a zero or a one.
Bridge	A device that connects two or more networks at the data link layer (layer 2 of the OSI model).
Broadcast	Method by which messages are distributed to all stations.
Bus	A shared connection for multiple devices over a cable or backplane.
CAN	The Controller Area Network is a bus system developed jointly by Daimler-Benz, Bosch and Intel that was intended initially for installation in automobiles. In the meantime, the system is now also in use in the field of automation. CAN is a multimaster system with priority-controlled bus access.
CANopen	Expands on the CAN protocol by adding higher level features such as profiles and defined messages. Allows for synchronisation of control loops.
Category 5	Twisted-pair cable with electrical characteristics suitable for all twisted-pair Ethernet media systems, including 10BASE-T and 100BASE-TX Category 5 and Category 5e cable are preferred cable types for structured cabling systems.

EMERSON
Industrial Automation

Category 5e	An enhanced version of Category 5 cable developed to improve certain cable characteristics important to the Gigabit Ethernet operation. It is recommended that all new structured cabling systems be based on at least Category 5e cable.
CIP	The Common Industrial Protocol is an open industrial protocol for industrial automation applications.
CIP Sync	A method of distributing timing information and clock/position synchronisation.
Collision	The result of having two or more simultaneous transmissions on a common communications channel.
Collision domain	Part of a network where collisions are possible.
CRC	Cyclic Redundancy Check. An error-checking technique used to verify the accuracy of received data.
Crossover cable	A twisted-pair patch cable wired in such a way as to route the transmit signals from one piece of equipment to the receive port of another piece of equipment, and vice-versa. This allows communication between two peer devices. The opposite of crossover is a straight-through or patch cable.
CSMA/CD	Carrier Sense Multiple Access/Collision Detect. The medium access control (MAC) protocol used on Ethernet to provide collision detection and avoidance.
CTNet	Control Techniques' own communication protocol based on ARCNET which offers high speed cyclic data access.
CTSync	Control Techniques' own method of sharing references and synchronising drive loops.
Data rate	The data rate can be given in bit/s or in baud. Bit/s counts the number of individual bits per unit of time. Baud theoretically defines the signalling rate, which may consist of one or more bits per second.
Deterministic	Deterministic data transfer guarantees that data will be delivered within a specified time. This is normally used with quantifiers such as "real time" and "synchronous". When comparing systems always look for an actual timings to get real world performance figures. The term "real time" implies high speed (almost instantaneous), but again requires quantifying with actual timings, "synchronous" means that the data is used at the same time by devices on the network or in synchronisation with the drive's control loops for more accurate and co-ordinated machine control
DeviceNet	DeviceNet is a CAN based protocol that extends the basic operation by adding higher level functionality. DeviceNet provides both cyclic and non-cyclic access to a slave.

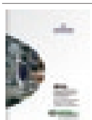
EIA(RS)-485	The EIA(RS)-485 is the most commonly used hardware layer for fieldbus systems. It defines a line with a maximum of 32 stations, terminated at both ends by bus-terminating resistors. It originally defined data rates of up to 500 kbit/s. The maximum distances can be up to 5km (hardware and data rate dependent). EIA(RS)-485 employs shielded twisted-conductor data-transmission lines. This ensures a relatively high degree of noise immunity.
EtherCAT	A high speed Ethernet based protocol allowing synchronisation of drive control loops.
Ethernet	Ethernet is a LAN (Local Area Network) standard that was developed jointly by Xerox, Intel and DEC in the seventies.The transmission rate is 10Mbit/s to 1000Mbit/s. In 1983 Ethernet was standardised by IEEE 802.3.
Ethernet/IP	Ethernet based protocol allowing cyclic data transfer.
Fast Ethernet	A version of Ethernet that operates at 100Mbit/s. Although 100Mbit/s is no longer the fastest data rate, this term is still used.
Fibre optic cable	A cable with a glass or plastic filament which transmits digital signals in the form of light pulses.
Fieldbus	A fieldbus is a system for serial data transmission at the sensor-actuator control levels and possibly extending as far as the cell level. This further extends to the boardroom with Ethernet based protocols.
Flow control	The process of controlling data transmission at the sender to avoid overfilling buffers and loss of data at the receiver.
Forwarding	The process of moving frames from one port to another in a switching hub.
Full-duplex operation	A communications method that allows for the simultaneous transmission and reception of data.
Gateway	A gateway acts as an interface between data-transmission systems of different types.
Gigabit Ethernet	A version of Ethernet that operates at 1000Mbit/s.
Half-duplex operation	A communication method in which transmission and reception can occur in either direction but not at the same time.
Hub	See 'Repeating hub'
Interbus	A fieldbus system for sensor-actuator applications. Developed in 1985 by Phoenix Contact, the system has since been standardised (DIN 19 258) or presented for standardisation (Europe/Internationally).
IP	See 'TCP/IP'.
LAN	Local Area Network. A network in a geographically limited area, usually also associated with a single company / system.

LON	A LON (Local Operating Network) is a fieldbus system from the American company Echelon. Echelon developed the Neuron chip as the basis for this communication system. Typically used in building automation.
LSB	Least Significant Bit.
MAC address	A unique address assigned to a station interface, identifying that station on the network.With Ethernet, this is the unique 48-bit station address.
Master	A master is a station that is able to transfer data on the bus. This is in contrast to a slave, which can send data only when requested to do so by a master.
Master/slave system	In a master/slave system, only one station, the master, has control over the bus. All other stations must constantly scan the bus and may send data on the bus only when requested to do so by the master.
Metasys N2	A protocol typically used in building automation.
Modbus RTU	One of the most common industrial protocols used in automation.
Modbus TCP/IP	Modbus over Ethernet.
Multi-master	A multi-master system may consist of two or more masters which are all able to directly access the bus.
Multicast	A transmission initiated by one station to many stations on the network.
OPC	Originally, OLE (Object Linking and Embedding) for Process Control. A process control communications standard for accessing process data from multi-vendor systems.
Open systems	Open systems allow the formation of multivendor system, i.e. systems that use components from different manufacturers on the same bus.
Optical fibre	Optical fibre has a high degree of immunity to interference. It requires more complex installation techniques.
OSI	Open systems Interconnection. A seven-layer reference model for networks, developed by the International Organization for Standardization (ISO).The OSI reference model is a formal method for describing the interlocking sets of networking hardware and software used to deliver network services.
Packet	A unit of data exchanged at the network layer.
Patch cable	A twisted-pair cable used to make a connection between a network interface (on a station or network port in a hub) and a media segment, or to directly connect station and hub ports together.
Parity bit	A parity bit is added to the bits of a byte in order to form an even (even parity) or odd (odd parity) number of ‘1’ bits.The receiving station does likewise and then compares the result with the bit it has received.
Physical layer	The bottom layer in the OSI seven-layer reference model. This layer is responsible for physical signaling - including connectors, timing, voltages, and related issues.

Polling	Polling means a cyclic data transmission between a master and it's slaves. The master cyclically checks input and output signals of all slaves. Polling is not event controlled data transmission.
Port mirroring	Port mirroring allows a switch port to monitor packets from any or all of its ports so that traffic can be analysed.
PROFIBUS	A fieldbus standard developed in 1987 as part of a government sponsored collaborative project in Germany. In 1991, DIN 19 245 was passed, making PROFIBUS one of the first fieldbus systems to be standardised. PROFIBUS is a hybrid bus system permitting multi-master and master-slave structures in one system.
PROFINET	An Ethernet based system offering different variants with different performance levels.
Propagation delay	The signal transit time through a cable, network segment, or device.
Protocol	A set of agreed-upon rules and message formats for exchanging information among devices on a network.
Reaction / response time	The reaction time of an automation system is the time that elapses between a signal being applied at an input terminal and a signal appearing at an output terminal.
Repeater	Bus amplifier. A repeater is a device used to amplify and regenerate signals in a system for serial data transmission. A repeater is used to extend an existing system beyond given limits, e.g. distance or number of stations.
Repeating hub	A repeater with more than two ports. This name is frequently shortened to simply "hub".
Ring	A ring is basically a topology in which a point-to-point connection is made from one station to the next. This means that each station in the ring must pass on without changing any data not intended for that station itself. Fieldbus systems employ optical-fibre systems (e.g. SERCOS) as a ring.
RJ-45	An 8-pin modular connector used on twisted-pair links.
Segment	A cable made up of one or more cable sections and connections joined together to produce the equivalent of a continuous cable.
SERCOS	The SERCOS interface (Serial Realtime Communication System) was introduced in 1989 as a digital interface between servo drives and numerical controls. Owing to its particular area of application in numerically controlled machine tools, the SERCOS bus has been specially designed for high-speed control processes. This is accomplished by high data rates over an optical fibre ring and through the definition of time slots for each station.
Server	A server is a station that provides a service for a client. A typical server is an input / output module that supplies input data and receives output data from the client (e.g. the PLC).

Slave	A device controlled by another device such as a PLC.
SNMP	Simple Network Management Protocol. The de facto standard for switch management.
Star	A star topology is one in which all stations are each connected by their own cables to a central station. The advantage of a star configuration is its ease of maintenance. If a cable breaks, for example, just one station goes down, with the result that the fault is simple to locate. The disadvantage of a star configuration is the large amount of cabling required.
TCP/IP	The Internet Protocol Suite (commonly known as TCP/IP) is the set of communications protocols used for the Internet and other similar networks. It is named from two of the most important protocols in it: the Transmission Control Protocol (TCP) and the Internet Protocol (IP), which were the first two networking protocols defined in this standard.
Token	A token is a means by which bus access is granted to a device. Only the device owning the token may transmit.
Topology	Structure of a communication system, e.g. star, line, ring, tree or network.
Transceiver	A combination of the words transmitter and receiver. A transceiver is the set of electronics that sends and receives signals.
Twisted-pair cable	A multiple-conductor cable whose component wires are paired together, twisted, and enclosed in a single jacket. Each pair consists of two insulated copper wires that are twisted together.
UDP	The User Datagram Protocol (UDP) is one of the core members of the Internet Protocol Suite. With UDP, computer applications can send messages, referred to as datagrams, to other hosts on an Internet Protocol (IP) network without requiring prior communications to set-up special transmission channels or data paths. UDP is sometimes called the Universal Datagram Protocol.
VLAN	Virtual Local Area Network. A LAN maps stations on a basis other than location such as by department, user type or application. Managing traffic, workstations and bandwidth can be easier with a VLAN.

Our simple, flexible product lines make choosing the right drive very easy. For more demanding solutions our engineers, located within our Drive Centre and Reseller network, are available to discuss your needs and provide advice. For further details, please refer to the brochures below.

	Control Techniques Company Profile	Company overview		
	Drives, Drive Systems and Servos	Product Overview	100V / 200V / 400V / 575V/ 690V	0.25kW to 1.9MW
	Commander SK	General purpose AC drive	100V / 200V / 400V / 575V/ 690V	0.25kW to 132kW
	Unidrive SP panel mounting	High performance AC and servo drive	200V / 400V / 575V / 690V	0.37kW to 132kW
	Unidrive SP Free Standing	Higher power performance AC drive	400V / 575V / 690V	90kW to 675kW
	Unidrive SP Modular	High power modular AC drive	200V / 400V / 575V / 690V	45kW to 1.9MW
	Mentor MP	High performance DC drive	400V / 575V / 690V	25A to 7400A
	Digitax ST	Intelligent, compact and dynamic servo drive	200V / 400V	0.72Nm to 19.3Nm (57.7Nm Peak)
	Affinity	Dedicated HVAC/R drive for building automation and refrigeration	200V / 400V / 575V / 690V	0.75kW to 132kW
	Unimotor fm	Performance AC brushless servo motor	0.72Nm to 136Nm (408Nm Peak)	

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