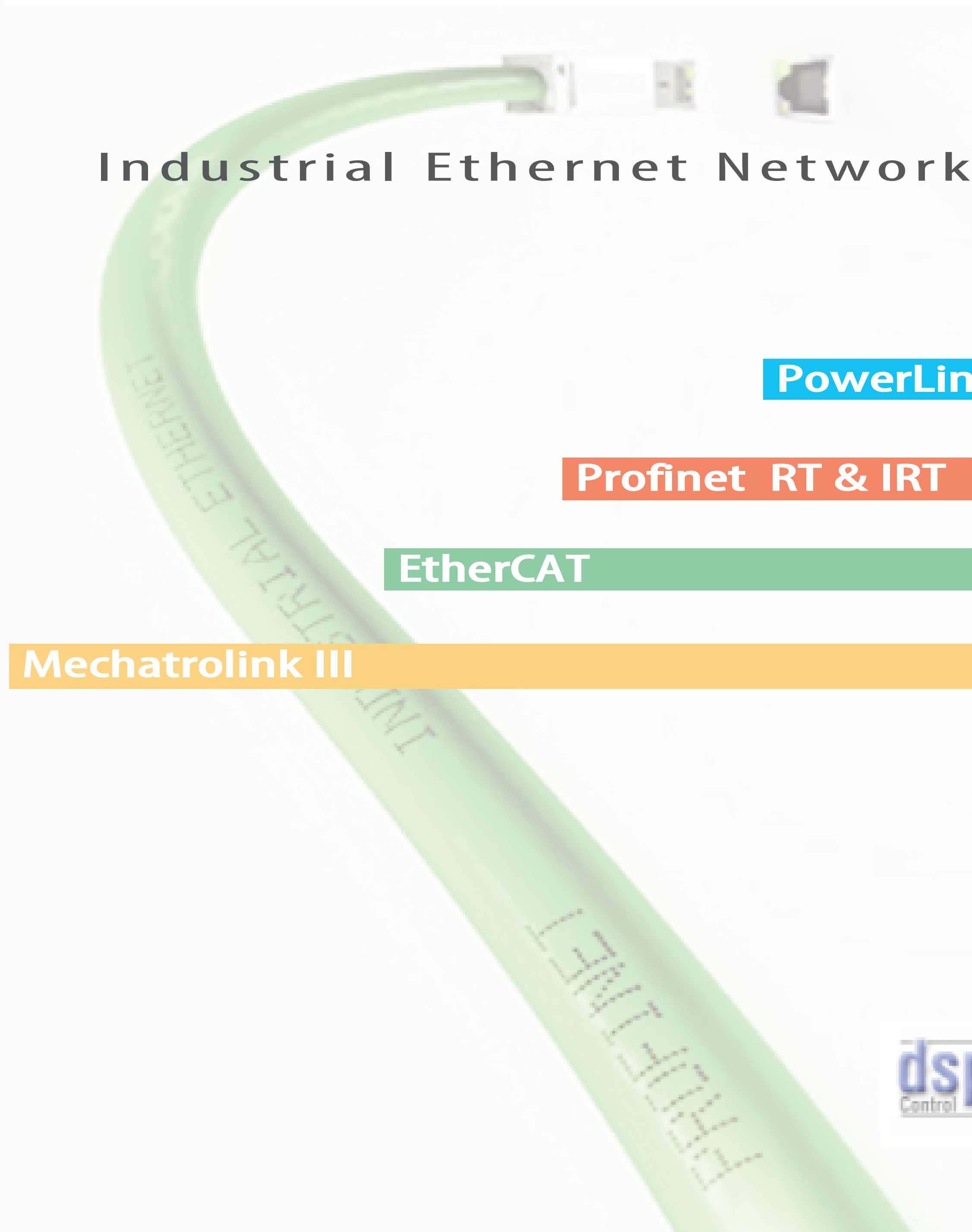
System Automation Masters

on

Industrial Ethernet Networks



PowerLink

Profinet RT & IRT

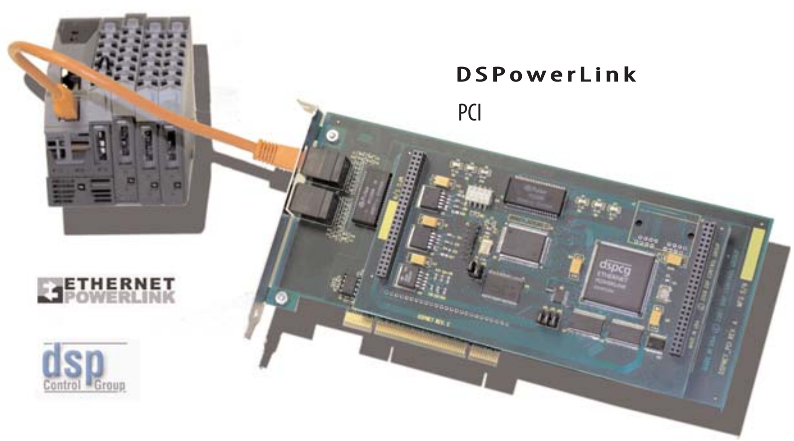
EtherCAT

Mechatrolink III

dsp Control Group

DSPowerLink

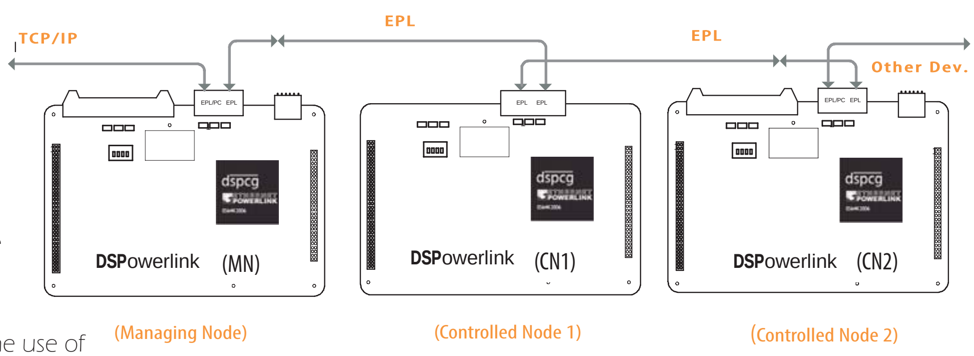
Ethernet PowerLink Master Motion Controller and Network Manager



Features

- Fully compliant with EPL standard
- Fully compliant with IEEE 802.3 standard
- Simultanous use of EPL and Ethernet
- Maps EPL I/O onto DPRAM
- 100 Mbps of Isochronous speed
- Maps motion commands onto network
- Includes Ethernet gateway
- Offered in PCI and Stand-alone forms

DSPowerlink, a single Ethernet cable is sufficient to configure and program all elements of a network. Whether the network is inclusive of a single I/O or multiple I/Os and drive amplifiers, **DSPowerlink** as the managing node is capable of transmitting the asynchronous and isochronous real-time information through the same cable. The DSPL (motion controller language) provided an instruction set that makes the use of peripheral network components such as remote I/Os simple. For example, variables EPL_INP1_REG and EPL_INP2_REG, in DSPL each contains 16 inputs connected to the remote I/O unit (e.g. B&R x20 remote I/O units). These variables may be used in conjunction with a PLC or a motion control program residing in a PC (as a soft motion controller) or a DSP based motion controller provided by DSPCG. Similarly, EPL_OUTP_ON and EPL_DRIVE_COMMAND instructions enable the PC or motion controller to assert its command on the network. While these instructions take advantage of EPL network, they make network information available on an ordinary Ethernet connection which is also available on a DSPowerlink card.



DSPowerLink

Ethernet PowerLink Master Motion Controller and Network Manager

Industrial ethenet for automation of Motion, PLC and other Powerlink Network Devices

ETHERNET Powerlink (EPL) is a deterministic real-time protocol for standard Ethernet. EPL expands Ethernet with a mixed polling and time-slicing mechanism. That brings:

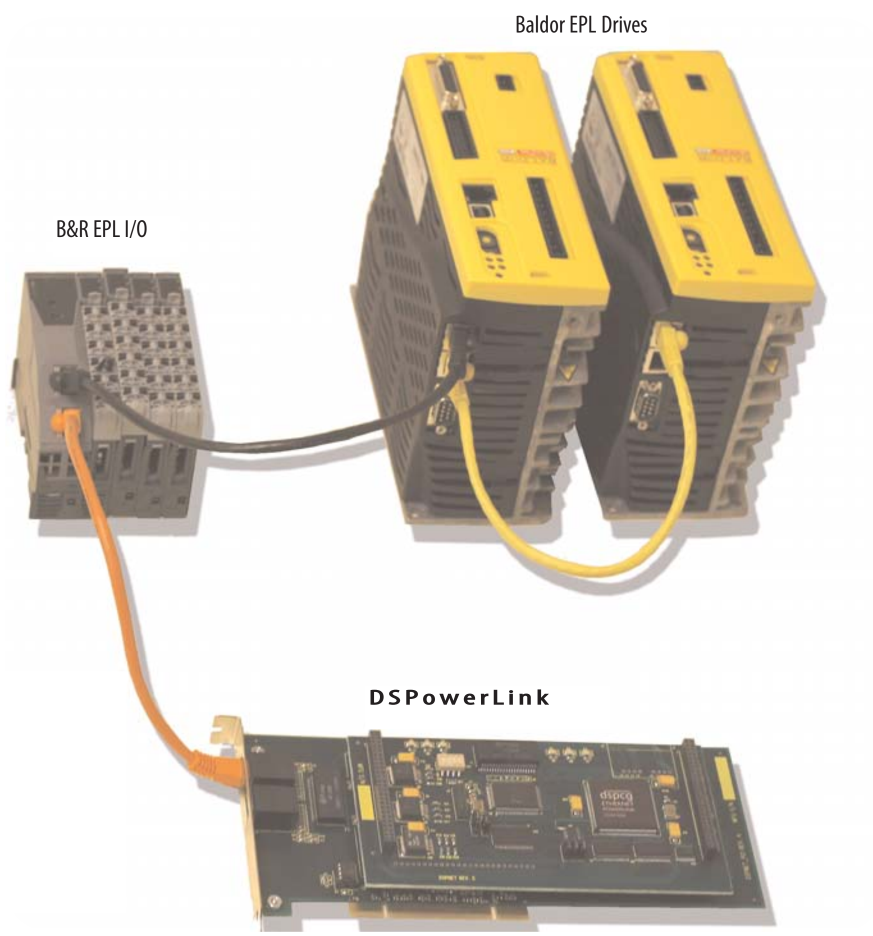
(a) Guaranteed transfer of time-critical data in very short isochronous cycles with configurable response time

(b) Time-synchronization of all nodes in the network with a very high precision of sub-microseconds

(c) Transmission of less time-critical data in a reserved asynchronous channel

DSPCG implementation, DSPowerlink reaches cycle-times of 200µs and a time-precision (jitter) of less than 1µs.

This communication profile meets timing demands typical for high-performance automation and motion applications without changing basic principles of the Fast Ethernet Standard IEEE 802.3; it also extends it towards Real Time Ethernet (RTE). EPL is a cyclic communications network.



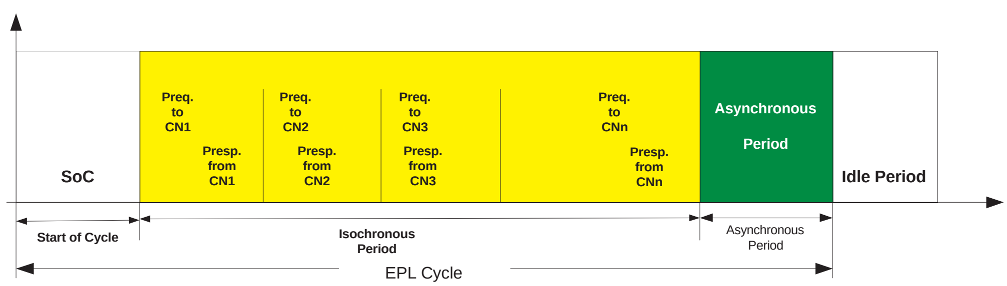
The diagram next page represents one EPL cycle.

DSPowerLink

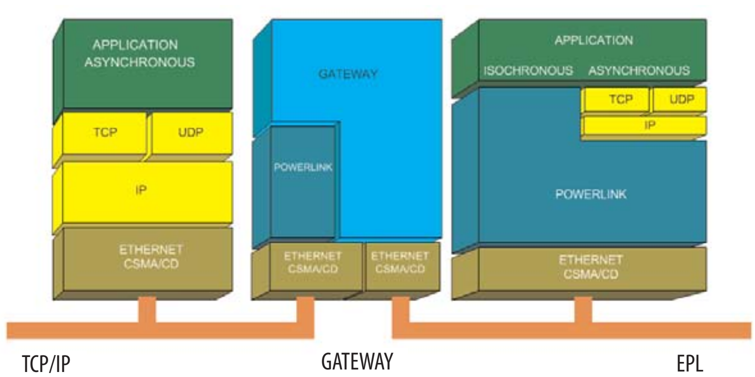
Ethernet PowerLink Cyclic Communication

To avoid collisions and to make maximum use of the bandwidth, data exchange between the devices is time slot-based. One device on the EPL network takes on the function of the Managing Node, which controls the communication, defines the clock pulse for synchronization of all nodes, and assigns the right of transmission to the individual devices. The Controlled Nodes only transmit when requested to by the manager. An EPL cycle is divided into three periods:

a) Start of Cycle (SOC): Here the manager transmits a "Start of Cycle" frame (SoC) as a broadcast message to all controllers. All devices in the EPL network synchronize on the SoC. b) Isochronous Period: Cyclic data exchange takes place in this time period. According to a preset (configurable) schedule, the manager transmits a Poll Request frame (PReq) sequentially to each controller. The addressed controller responds with a Poll Response frame (PRes). All nodes involved with these data can receive them, whereby a real producer (or consumer) communication between the nodes is achieved similar to CAN.



c) Asynchronous Period: This time interval is available for asynchronous, non-time-critical data exchange. The Master Node grants access to one of the Controlled Nodes based on a priority which the request contains.

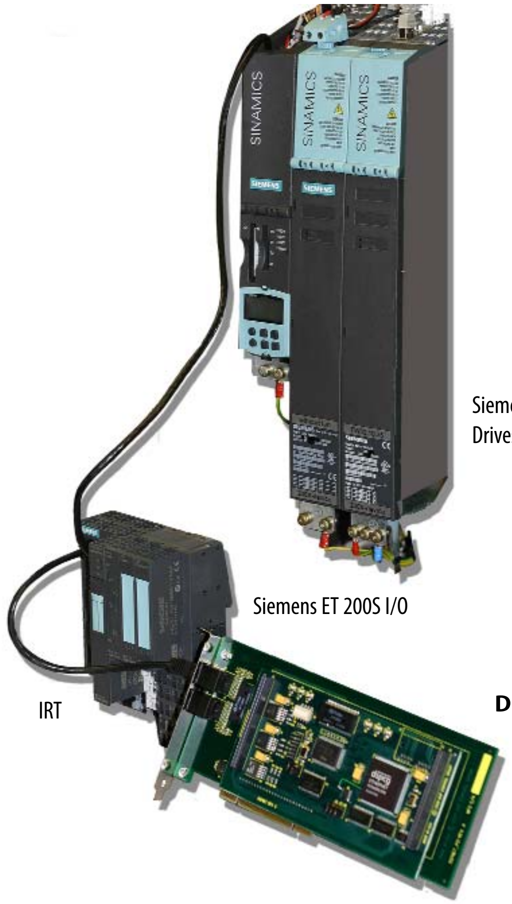


Internal Data Communication Flow of **DSPowerlink**

DSPowerlink superior implementation allows for simple communication between an ordinary Ethernet and the EPL network. That is, information on the EPL network is made available to a generic Ethernet card that may be part of any PC computer. The figure above illustrates the hardware and communication protocol provided by **DSPowerlink**.

DSProfinet

Profinet IRT Master Motion Controller and Network Manager



Features

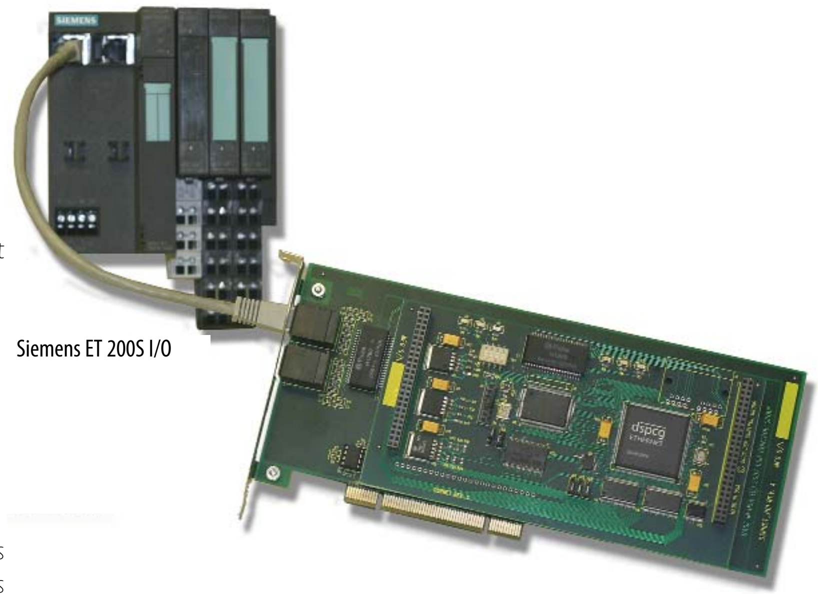
- Fully compliant with Profinet IRT standard
- Fully compliant with IEEE 802.3 standard
- Simultanous use of Profinet and Ethernet
- Maps Profinet I/O onto DPRAM
- 100 Mbps of Isochronous speed
- Maps motion commands onto network
- Includes Ethernet gateway
- Offered in PCI and Stand-alone forms
- Offered with a DSP Motion Control Based HW or Soft Motion (where PC generates motion commands.)

DSProfinet IRT: a single line industrial ethernet for real-time applications

DSProfinet IRT offers a simple digital alternative to traditional analog systems that functions over the Profinet IRT interface. By combining the power of Profinet IRT with the power of either DSP-based motion controller hardware or a software motion commands generated insider a PC, a powerful master IRT solution has been created. Of all the digital networking standards that have been created over the years, one of the oldest, most flexible, and most reliable is Industrial Ethernet. The robustness of Ethernet's design is attested to by the fact that it continues to be adapted to new applications, and is constantly being upgraded to provide new capabilities. **DSProfinet IRT** is offered in three platforms of **1)** PCI-based DSP motion control ler **2)** Stand-alone DSP motion controller and **3)** Soft motion controller (meaning commands are generated inside a PC by the user program.)

DSProfinet

Profinet IRT Master Motion Controller and Network Manager



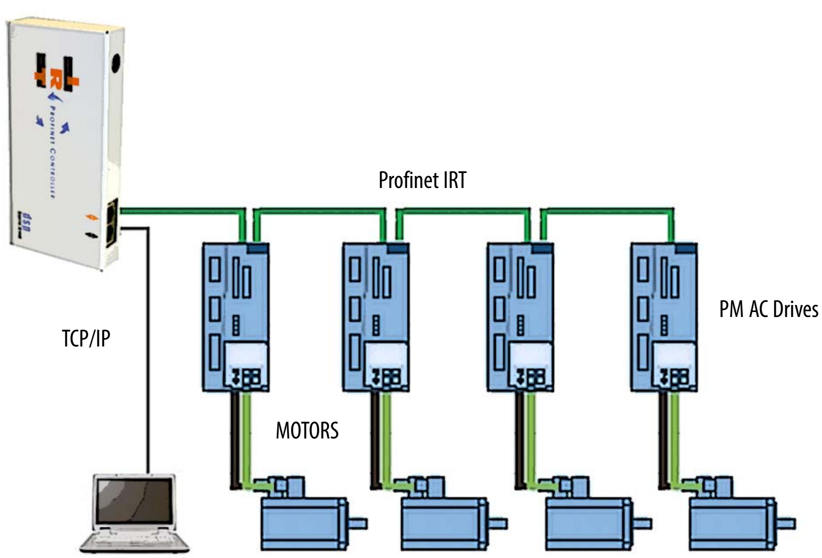
DSProfinet

when programming with DSProfinet IRT Controller, a single Ethernet cable is sufficient to configure and program all your SINAMICS S120 drives on the Profinet IRT network.

Whether the Profinet network is inclusive of a single or multiple SINAMICS S120 drives, DSProfinet as the IRT Controller is capable of transmitting the isochronous real-time information through an Ethernet cable in a daisy chained fashion. The PROFIdrive commands on DSProfinet links your PC program to multiple SINAMICS S120 units in a coordinated system.

Determinism of the IRT Profinet Controller

For high performance motion control applications such as precise coordination of hundreds of axes with microsecond precision, Profinet includes an isochronous real-time channel. As indicated by the word "isochronous" in its acronym, Profinet IRT (Profinet Isochronous Real-Time) is used for closed-loop control of a system, where the control (both the set-point and feedback) for multiple devices occurs during the same sample period. This sample period can be as strict as 250 microseconds, meaning that the controller in a Profinet IRT network issues its command to all devices every 250 microseconds. Similarly, each device in the Profinet IRT will respond with its data (for example, the actual position and/or speed in a motion system) during the same period.



Operational Principle of DSProfinet IRT Motion Master

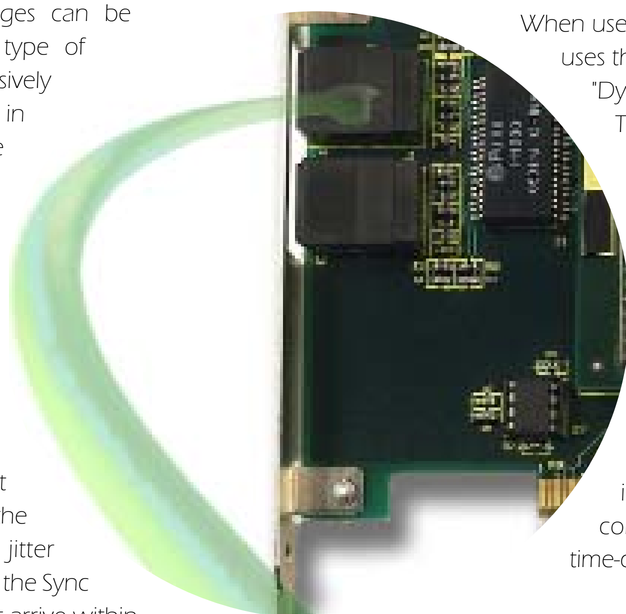
After an initial communication period between the controller and the device(s), Profinet IRT begins to start taking place. (Note that this initial communication period is just used to establish the parameters of the ensuing Profinet IRT communication, such as how much and what type of data will be exchanged during each interval, etc. It only needs to take place once and will last less than 30 seconds.)

There are two important classes of messages that get exchanged during each interval. (Occasionally there will be additional network management-type messages appearing in the network, but these are not related to control nor are they periodic. Also, they would certainly occur after the IRT messages for the current interval have been sent and received.) One of these classes of messages is synchronization messages, commonly referred to as "Sync" messages. These messages can be thought of as the "keep-alive" type of message. They are sent exclusively from the controller to the devices in the network and no response from the devices is necessary. Also, they do not contain any control data, but instead serve to ensure that the controller is keeping up with the strict timing constraints of Profinet IRT. Namely, that it is starting the interval precisely one millisecond (or two milliseconds, as the case may be) from the last interval. This is the message that the devices will use to base the jitter calculations off of. In other words, the Sync message is the message that must arrive within one microsecond of when it is supposed to, for every interval.

Also during the interval, messages carrying data from the device to the controller and the controller to the device will be exchanged. These messages are named Real-Time Class 3 (RTC) messages. (Don't let the lack of the word "isochronous" from this name mislead you - Real-Time Class 1 messages are for Profinet RT (non-IRT) communications.)

For each interval, the controller will send out one RTC message for each device that it is controlling. This RTC message will contain the data, such as speed set points or position information that the device needs to have. In return, at the same time each device in the network is sending an RTC message to the controller. This RTC message will correspond with the RTC message it received. For example, if speed control is being performed, the controller's RTC to the device will have a desired speed (speed set point) and the device's RTC to the controller will have the actual speed. Finally, one may wonder what exactly connects the Profinet IRT controller to its devices. The answer is standard Ethernet cable. Profinet IRT will function with a CAT 5 Ethernet cable, with an Ethernet interface operating at 100 MB/s.

Information exchange between DSProfinet and SINAMICS



When used with SINAMICS S120, DSProfinet uses the PROFIdrive profile that contains "Dynamics Servo Control" (DSC) concept. This can be used to significantly increase the dynamic stability of the position control loop in what Siemens refers to as application class 4 with simple means. The telegrams used by DSProfinet are 5 & 6 (for DSC 1 position encoder and DSC 2 position encoder respectively), 390, 391 and 392 (telegrams for control unit Drive Object 1, DO1, digital inputs/outputs). Cyclic communication is used to exchange time-critical process data.

Telegrams 5 & 6 (motion parameters)

From the DSProfinet IRT Controller to the SINAMICS S120 Telegram 5 (application class 4 DSC) delivers:

CTW1	control word 1
NSOLL_B....	32-bit speed set point
CTW2	control word 2
G1_CTW.......	encoder 1 control word
XERR	position deviation
KPC	position control gain factor

Using the same telegram, S120 returns (to DSProfinet) the following data:

STW1 .... control word 1
NIST_B .... 32 bit actual speed
STW2 .... status word 2
G1_STW ...... encoder 1 status word
G1_XIST1 ..... encoder 1 actual position value 1
G1_XIST2 ..... encoder 1 actual position value 2

Telegram 390 (I/O parameters)

From the DSProfinet IRT Profinet Controller to the SINAMICS S120 Telegram 390 delivers:

CU_CTW ....control unit control word
O_DIGITAL ......16 bit digital output control word

Using the same telegrams S120 returns the following data to the DSProfinet:

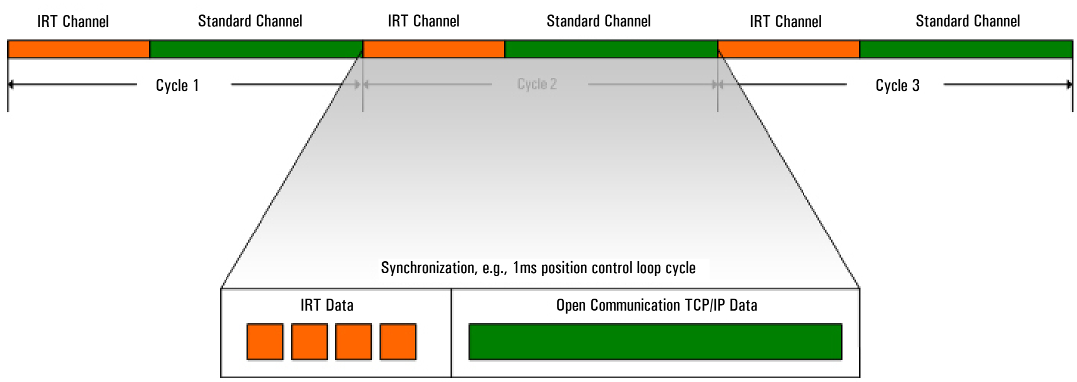
CU_STW ....control unit status word
I_DIGITAL ......16 bit digital input control word

In addition, telegrams 391 and 392 also send and return (to DSProfinet) probe status:

PR_CTW ....from DSProfinet to SINAMICS and
PR_STW ....from SINAMICS to DSProfinet

DSProfinet

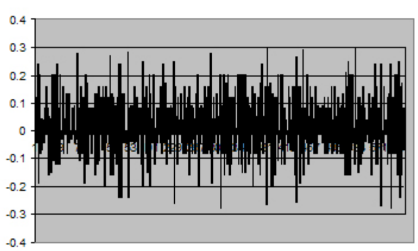
Profinet IRT Master Motion Controller and Network Manager



Critical data for motion applications are transmitted on Profinet via the IRT Channel ensuring a precise and deterministic response.

What is unique about the Profinet IRT Controller?

Certainly other Ethernet protocols in motion control today operate on a regularly occurring interval basis. So one may ask, what is special about Profinet IRT Controller? The guiding factor that sets Profinet IRT apart from other real-time, cyclic protocols is the concept of "jitter". The jitter is defined as a time fluctuation in the start of the interval. For example, in a one-millisecond interval, if the controller started the next interval 100 nanoseconds after the termination of previous interval, the system could be described as having a jitter of 100 nanoseconds at this point in time.



DSProfinet Jitter (in fraction of a microsecond) vs. sample time

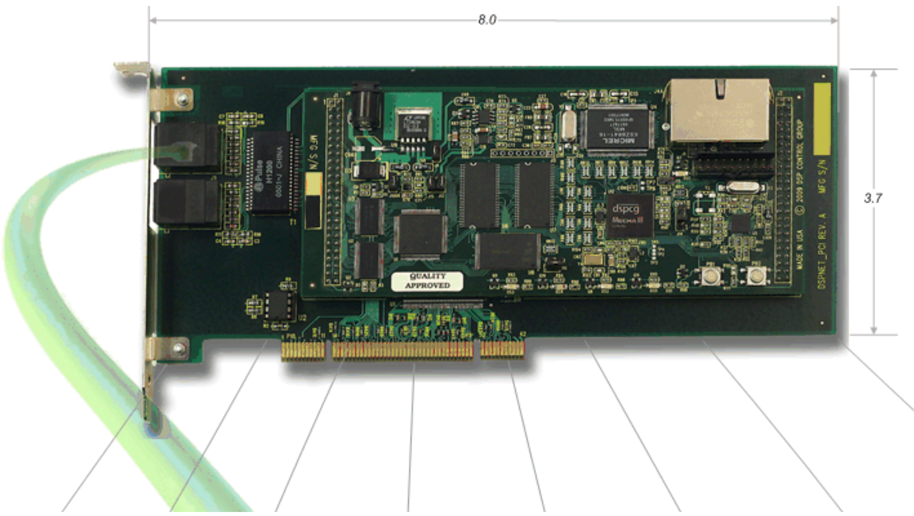
Other cyclic protocols may (EtherCat) or may not (Profinet RT, Ethernet PowerLink) be concerned with whether there is jitter at the start of each interval.

In the case of Profinet IRT, both devices and controller are very concerned with jitter. The threshold for jitter allowed by the Profinet IRT protocol is defined to be one microsecond. Hence, an entity that wishes to serve as a controller in a Profinet IRT network must be able to start each cycle very precisely on the aforementioned millisecond boundary. The devices in a Profinet IRT network are designed to be made aware of when a controller is not adhering to the jitter requirement. Upon recognition of this situation, the devices will stop operating with the controller. It would then be up to the controller to essentially "start over" and show the devices that it is capable of operating within the jitter specification. (For example, maybe the controller wasn't able to start a series of cycles due to a bad cable. Once the cable is replaced, the controller will be able to attempt Profinet IRT with the devices from the beginning.)

The operation of cyclic control at these extremely precise intervals (such as one or two-millisecond interval times occurring within one microsecond of jitter) is what allows for extremely precise coordinated motion control applications to occur across multiple axes.

DSPEtherCAT

EtherCAT Master Motion Controller and Network Manager



Features

- Fully compliant with EtherCAT standard
- Fully compliant with IEEE 802.3 standard
- Simultanous use of EtherCAT and TCP/IP
- Full Motion Controller & PLC on Network
- 100 Mbps of Isochronous speed
- Maps motion commands onto network
- Includes Ethernet Gateway
- Offered in PCI and Stand-Alone forms
- Offered with DSP Motion Control Base Brd. HW or Soft Motion (where PC generates motion commands

DSPEtherCAT: Master Motion Controller, Linking Servo Amplifiers, I/Os and Managing Network

DSPEtherCAT Motion Master

DSPEtherCAT uses real-time industrial EtherCAT protovol and supports both the line or star topologies. EtherCAT is also very fast - 100 servos can each be updated with 8 bytes of data every 100 microseconds. EtherCAT protocol has a unique feature that distinguishes it from other industrial networking protocols. With EtherCAT there is only one packet per cycle; each slave's data is in a specified part of that packet.. Of all the digital networking standards that have been created over the years, one of the oldest, most flexible, and most reliable is industrial Ethernet. **DSPEtherCAT** is offered in three platforms of

1) PCI-based DSP motion control hardware,
2) S tand-alone DSP motion controller and
3) Soft Motion controller (meaning,using a real-time operating system, commands are generated inside the PC by the user program.)

Other protocols can require one packet per slave, with each slave also sending one packet back to the master. Hence when there are many slaves, EtherCAT's approach does not put much of a load on the master's CPU. This can allow for faster cycle times.

Network Delay

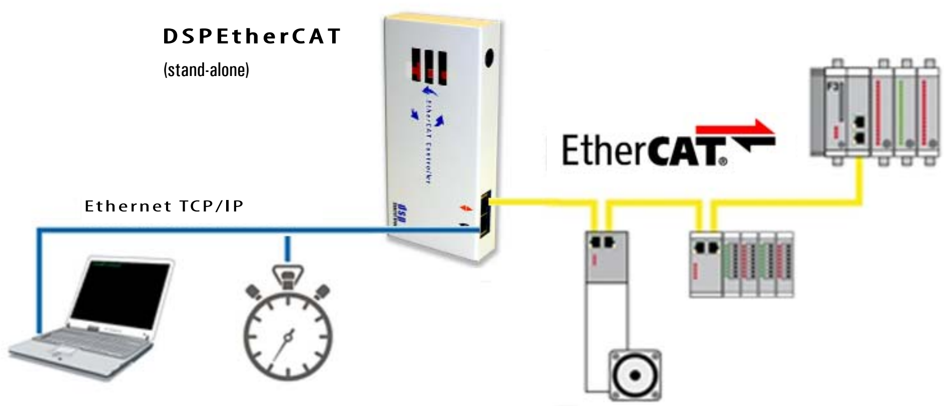
The EtherCAT packet leaves the master and then traverses the network. The delay introduced by processing (forwarding) at each slave is bounded by approximately 500 nanoseconds. (The reason that the delay from each slave is so low is because of special hardware that each EtherCAT slave must have. This hardware allows for data to be read or written while the packet passes through the slave.) Taking into account the PHY delay and cable delay, the addition of a slave can add 1 microsecond of delay into the system.

DSPEtherCAT

EtherCAT Master Motion Controller and Network Manager

The EtherCAT solution

The EtherCAT protocol is a real-time industrial Ethernet protocol. As a matter of fact, it was one of the first, and is supported well and widely used. The protocol is completely open. Most people are now familiar with the term "Ethernet". This technology is very prevalent in home and office networks as the mechanism for PCs to be a part of a network, which usually involves access to the Internet and internal networked servers. However, because this technology has been so developed and tested, it now presents itself as a solution for industrial networking as well. The components, such as Ethernet cabling and PHY interfaces, are well-tested and widely available. These components are used in an EtherCAT solution.

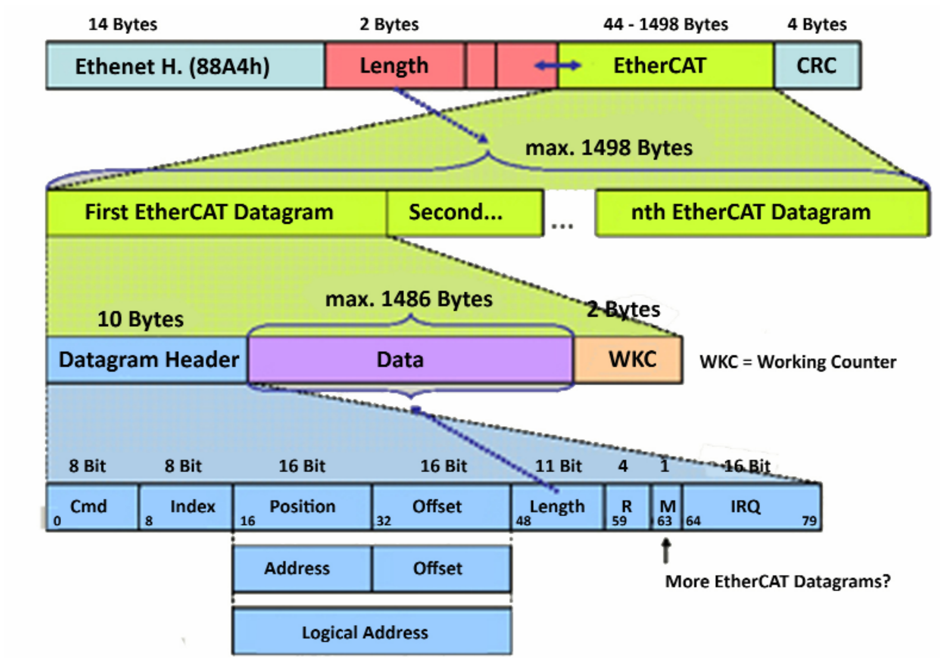


EtherCAT Timing Cycle

With EtherCAT there is only one packet per cycle; each slave's data is in a specified part of that packet. Since Ethernet allows for a maximum packet size of 1518 bytes, subtracting the 18 bytes for Ethernet overhead leaves 1500 bytes for EtherCAT to work with (also there will be 14 bytes of EtherCAT header, leaving 1486 bytes for data). This lends itself to optimal bandwidth utilization. When you incorporate the 32 bytes of overhead per packet, one large packet is certainly more optimal than many small packets.

DSPEtherCAT

EtherCAT Master Motion Controller and Network Manager



Ethernet Frame Structure / EtherCAT Datagrams

Contact Information

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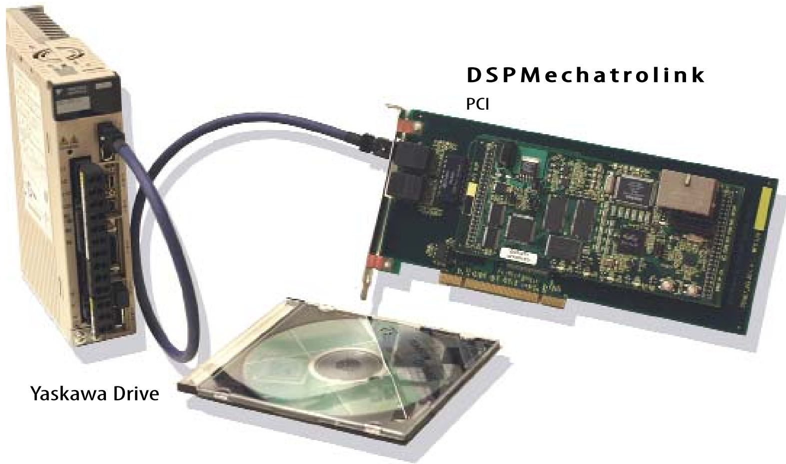
DSPMechatrolink

Mechatrolink III Master Motion Controller and Network Manager



Features

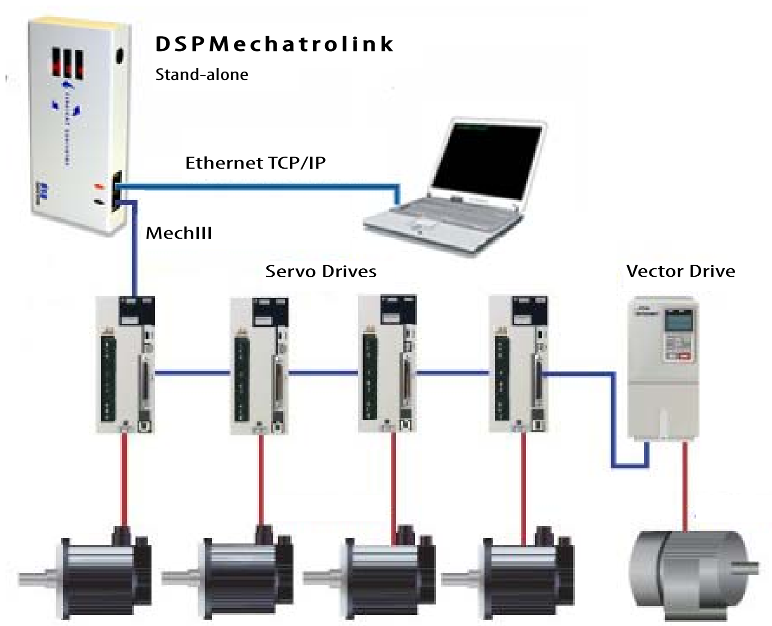
- Fully compliant with MIII standard
- Fully compliant with IEEE 802.3 standard
- Simultanous use of MIII and TCP/IP
- Maps Mechatrolink III I/O onto DPRAM
- 100 Mbps of Isochronous speed
- Maps automation commands onto network
- Includes Ethernet Gateway
- Offered in PCI and Stand-alone forms
- Offered with a DSP Motion Control Based HW or Soft Motion (where PC generates motion commands.)

Industrial ethernet for automation of Motion, PLC and other MIII Network Nodes

DSPMechatroLink offers a simple, low-cost digital alternative to a cumbersom noise prone analog system. By combining the power of Ethernet with Yaskawa's MIII protocol that is both simple and reliable, a complete network solution has been created. Of all the digital networking standards that have been created over the years, one of the oldest, most flexible, and most reliable is Industrial Ethernet. This product is avaliable on PCI and stand-alone forms and is accompanied by an application software that runs on Windows 7. The robustness of MIII Ethernet is attested to by the fact that it continues to be adapted to new applications, and is constantly being upgraded to provide new capabilities. **DSPMechatrolink** is offerered in three platforms of

1) PCI-based DSP motion controller
2) Stand-alone DSP motion controller
3) Soft motion controller (meaning, motion commands are generated inside a PC by the user program.)

Transmission Cycle (ms)	Maximum Nodes
0.25	8
0.5	14
1	20
2	32



DSPMechatrolink

Mechatrolink III Master Motion Controller and Network Manager

Any interface between a high-speed motion controller and its motor drives must meet two basic criteria. It must be fast, and it must be reliable. Conceptually, a serial digital interface would seem to be a natural fit for this application, but technology has been slow to catch up with the particular requirements of the motion control industry. Most motor drives still operate with an analog voltage command input and parallel encoder feedback. While it is hard to imagine a faster interface over copper, data corruption and cable complexity are ubiquitous problems.

Real-time Industrial Ethernet

The Mechatrolink III protocol, developed by Yaskawa, is a real-time industrial Ethernet protocol. Most people are now familiar with the term "Ethernet". This technology is very prevalent in home and office networks as the mechanism for PCs to be a part of a network, which usually involves access to the Internet and internal networked servers. However, because this technology has been so developed and tested, it now presents itself as a solution for industrial networking as well. The components, such as Ethernet cabling and PHY interfaces, are well-tested and widely available.

No concrete definition for "Real-time" among vendors

While there is no concrete definition across the industry for "Real-time", the concept is universally known. What is desired is for communication to happen "when scheduled". The controller in your industrial network will be what schedules the communication. Since the communication occurs over and over, repeatedly, this is termed a "cycle". A typical cycle might be 1 millisecond. Communication from a controller to a slave(s) will start at the beginning of a cycle, and then the controller will wait until the next cycle to begin the next round of communication.

Jitter can be thought of as the difference between when an event (such as updating of data) occurred and when the event should have occurred.

The Mechatrolink III protocol can be operated in either synchronous (real-time) or asynchronous mode. With synchronous mode, data is sent from the master to the slave(s) every cycle with very low jitter. At the same time, data is being sent from the slave(s) to the master (again, with very low jitter). Certainly, if you have an application which requires adherence to strict timing requirements, synchronous mode is the way to go.

Mechatrolink III offers a range of servo commands that Mechatrolink III devices must support. These allow for Torque Control, Speed Control, and Position Control. The commands are 32 bytes in length. An additional 16 bytes can be used for sending a subcommand. Similarly, the response from the slave can be either 32 or 48 bytes in length. With a 32 byte response, three 4-byte monitoring fields can be given to the master. With the addition of a subcommand, an additional three fields of 4 bytes each can be returned from the slave.

Mechatrolink III also has the following properties:

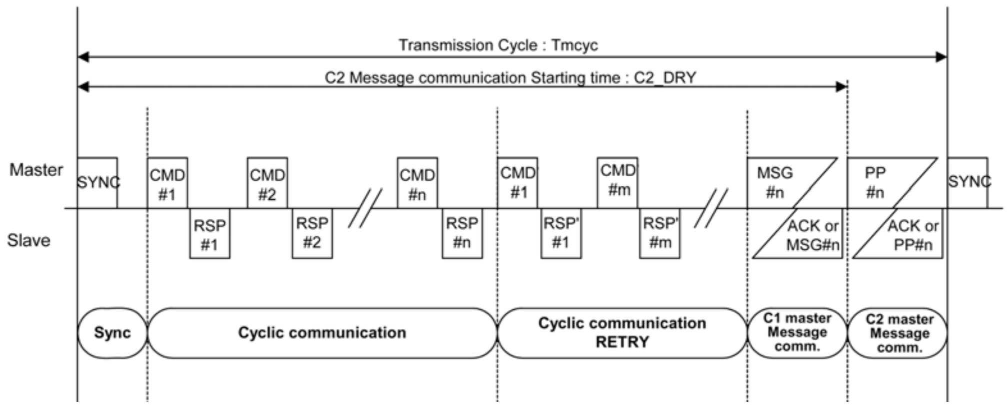
- One controller can be responsible for up to 62 slaves.
- Cycle times as low as 31.25 microseconds, or as high as 64 milliseconds can be achieved. (However, note that not all slaves are guaranteed to support these times.)
- Slaves can be configured in a line or star topology.
- Since it is Ethernet-based, the transmission rate is 100 Mbps.

DSPMechatrolink

Mechatrolink III Master Motion Controller Transmission Cycle

Here is how the transmission cycle works. After broad casting the synchronous frame at the start of the transmission cycle, the C1 master **DSPMechatroLink**, monitors the response from the slaves and determines the slaves to be retry targets. Slaves from which data reception was abnormal or slaves from which the response data was not received within the response monitoring time are taken as retry targets.

Cyclic communication



After finishing the exchange of command data and response data for all slaves, the C1 master re-sends the command data to the retry target slaves to receive the response data. After finishing the retry, the C1 master performs C1 message communication if sufficient time is available before the scheduled start of C2 (e.g., monitoring laptop computer) message communications.

If the C1 master completes cyclic communication and C1 message communication before the time to start sending C2 message, it sends a message token to the C2 master to prompt C2 message communication.

The C2 master performs C2 message communication at the C2 message communication start time or when it receives the message token from the C1 master. C2 message communication continues until the end of the transmission cycle.

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