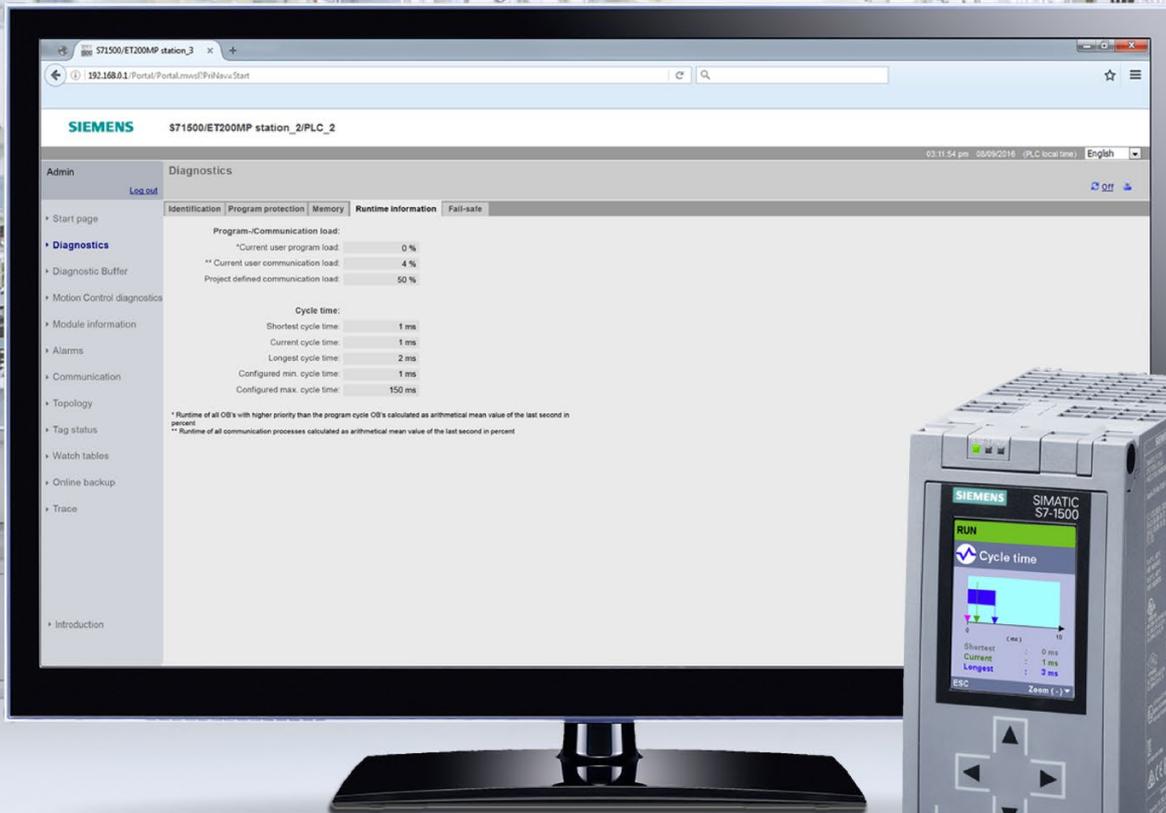


# SIEMENS



Function manual

# SIMATIC

## S7-1500, S7-1500R/H, ET 200SP, ET 200pro

Cycle and response times

Edition

07/2018

[support.industry.siemens.com](http://support.industry.siemens.com)

# SIEMENS

## SIMATIC

### S7-1500 Isochronous mode

#### Function Manual

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## Legal information

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indicates that death or severe personal injury <b>may</b> result if proper precautions are not taken.
 <b>CAUTION</b>
indicates that minor personal injury can result if proper precautions are not taken.
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# Preface

## Purpose of the documentation

This function manual provides an overview of the isochronous mode function for I/O modules that you operate isochronously:

- As central I/O in a SIMATIC S7-1500
- In distributed I/O systems on PROFINET IO
- In distributed I/O systems on PROFIBUS DP
- Jointly as central and distributed I/O on PROFINET IO

The documentation supports you in the configuring and programming of isochronous mode.

## Basic knowledge required

The following knowledge is required in order to understand the manual:

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Knowledge about the use of Windows-based computers
- Knowledge about how to use STEP 7 (TIA Portal)

## Scope

This documentation is the basic documentation for the SIMATIC S7-1500 automation system and all SIMATIC products from the PROFINET and PROFIBUS environments. The product documentation is based on this documentation.

The manual applies to the SIMATIC S7-1500 automation system with CPUs Firmware Version V2.6 or higher (except S7-1500 Compact CPUs and S7-1500R/H CPUs). SIMATIC STEP 7 Professional V15.1 or higher is also required.

## Conventions

**STEP 7:** We refer to "STEP 7" in this documentation as a synonym for the configuration and programming software "STEP 7 as of V15.1 (TIA Portal)" and subsequent versions.

This documentation contains pictures of the devices described. The figures may differ slightly from the device supplied.

You should also pay particular attention to notes such as the one shown below:

---

### Note

A note contains important information on the product, on handling of the product and on the section of the documentation to which you should pay particular attention.

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## Security information

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- **Product support**

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- **Application examples**

Tools and examples to solve your automation tasks – as well as function blocks, performance information and videos.

- **Services**

Information about Industry Services, Field Services, Technical Support, spare parts and training offers.

- **Forums**

For answers and solutions concerning automation technology.

- **mySupport**

Your personal working area in Industry Online Support for messages, support queries, and configurable documents.

This information is provided by the Siemens Industry Online Support in the Internet (<https://support.industry.siemens.com>).

## Industry Mall

The Industry Mall is the catalog and order system of Siemens AG for automation and drive solutions on the basis of Totally Integrated Automation (TIA) and Totally Integrated Power (TIP).

You can find catalogs for all automation and drive products on the Internet (<https://mall.industry.siemens.com>).

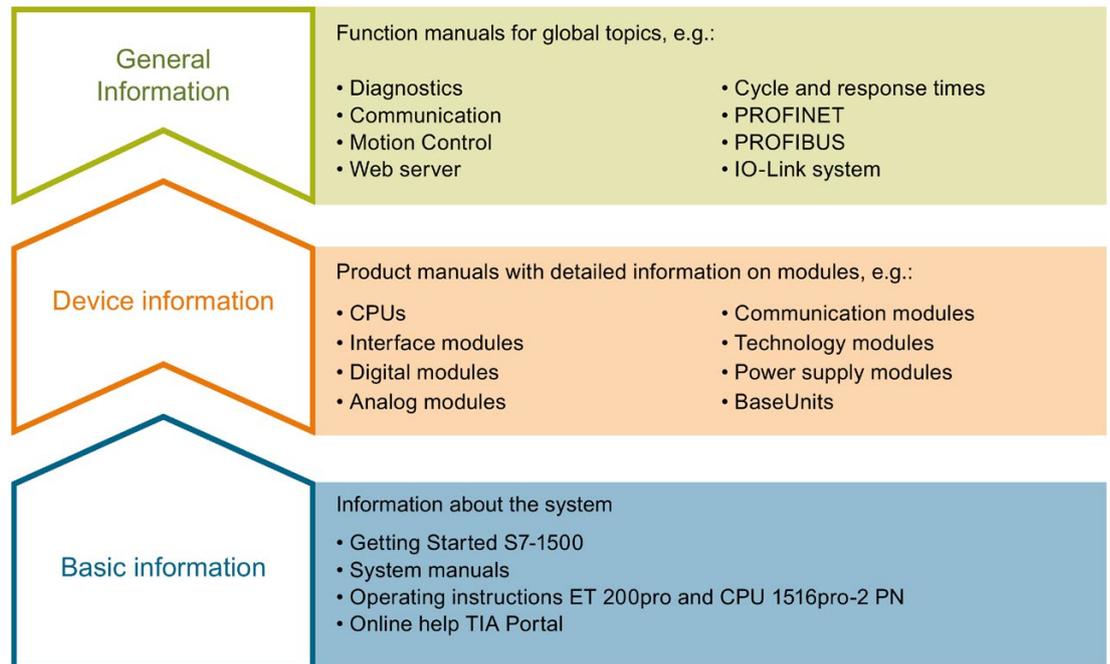
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## Documentation guide

The documentation for the SIMATIC S7-1500 automation system, for CPU 1516pro-2 PN based on SIMATIC S7-1500, and for the distributed I/O systems SIMATIC ET 200MP, ET 200SP and ET 200AL is divided into three areas.

This division allows you easier access to the specific information you require.



### Basic information

System manuals and Getting Started manuals describe in detail the configuration, installation, wiring and commissioning of the SIMATIC S7-1500, ET 200MP, ET 200SP and ET 200AL systems; use the corresponding operating instructions for CPU 1516pro-2 PN. The STEP 7 online help supports you in configuration and programming.

### Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

### General information

The function manuals contain detailed descriptions on general topics such as diagnostics, communication, Motion Control, Web server, OPC UA.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742705>).

Changes and additions to the manuals are documented in product information sheets.

You will find the product information on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/us/en/view/68052815>)
- ET 200SP (<https://support.industry.siemens.com/cs/us/en/view/73021864>)
- ET 200AL (<https://support.industry.siemens.com/cs/us/en/view/99494757>)

### Manual Collections

The Manual Collections contain the complete documentation of the systems put together in one file.

You will find the Manual Collections on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/ww/en/view/86140384>)
- ET 200SP (<https://support.industry.siemens.com/cs/ww/en/view/84133942>)
- ET 200AL (<https://support.industry.siemens.com/cs/ww/en/view/95242965>)

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You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

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You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<https://support.industry.siemens.com/My/ww/en/documentation>).

## "mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<https://support.industry.siemens.com/my/ww/en/CAxOnline>).

## Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

## TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet (<https://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

## SIMATIC Automation Tool

You can use the SIMATIC Automation Tool to run commissioning and maintenance activities simultaneously on different SIMATIC S7 stations as a bulk operation, independently of the TIA Portal.

The SIMATIC automation tool provides a variety of functions:

- Scanning of a PROFINET/Ethernet plant network and identification of all connected CPUs
- Address assignment (IP, subnet, gateway) and station name (PROFINET device) to a CPU
- Transfer of the date and programming device/PC time converted to UTC time to the module
- Program download to CPU
- Operating mode switchover RUN/STOP
- CPU localization by means of LED flashing
- Reading out CPU error information
- Reading of CPU diagnostic buffer
- Reset to factory settings
- Updating the firmware of the CPU and connected modules

You can find the SIMATIC Automation Tool on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/98161300>).

## PRONETA

With SIEMENS PRONETA (PROFINET network analysis), you analyze the plant network during commissioning. PRONETA features two core functions:

- The topology overview independently scans PROFINET and all connected components.
- The IO check is a fast test of the wiring and the module configuration of a plant.

You can find SIEMENS PRONETA on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/67460624>).

## SINETPLAN

SINETPLAN, the Siemens Network Planner, supports you in planning automation systems and networks based on PROFINET. The tool facilitates professional and predictive dimensioning of your PROFINET installation as early as in the planning stage. In addition, SINETPLAN supports you during network optimization and helps you to exploit network resources optimally and to plan reserves. This helps to prevent problems in commissioning or failures during productive operation even in advance of a planned operation. This increases the availability of the production plant and helps improve operational safety.

The advantages at a glance

- Network optimization thanks to port-specific calculation of the network load
- Increased production availability thanks to online scan and verification of existing systems
- Transparency before commissioning through importing and simulation of existing STEP 7 projects
- Efficiency through securing existing investments in the long term and optimal exploitation of resources

You can find SINETPLAN on the Internet (<https://www.siemens.com/sinetplan>).

## What is isochronous mode?

### Objectives of isochronous operation

The advantages of the isochronous mode function in automation engineering can be seen in an example from everyday life.

The transmission of data corresponds to the transport of people on public transport. Assuming public transport were to operate at maximum speed while reducing stop times at the passenger terminals to absolute minimum, the last thing many potential passengers would notice of the departing contraption are its red tail lights. The overall travel time is, however, decided by the train, bus or underground-railway clock, because well adjusted timing is essential to a good service. This also applies in automation engineering. Not only fast cycles but also the coordination and synchronization of the individual cycles result in optimum throughput.

## Just-In-Time

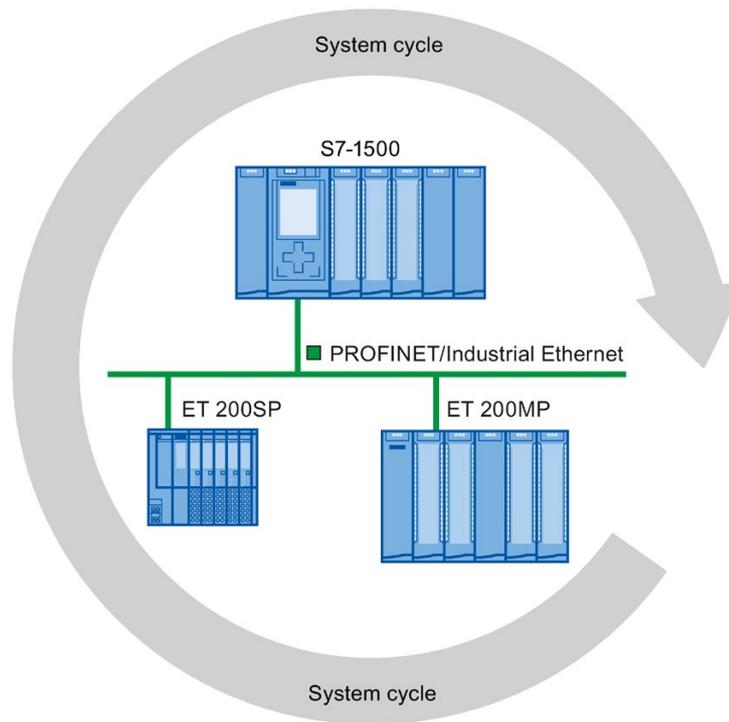


Figure 2-1 System cycle

The fast and reliable reaction time of a system operating in isochronous mode is based on the fact that all data are provided just-in-time. The basis for this is a constant bus cycle.

The isochronous mode function guarantees synchronization of the following at constant time intervals:

- Signal acquisition and output by the central and distributed I/O
- Signal transmission via backplane bus, PROFINET IO or PROFIBUS DP
- Program execution in the CPU in local time, in time with the constant bus cycle time PROFINET IO or PROFIBUS DP

The result is a system that acquires its input signals, processes them and outputs the output signals at constant time intervals. Isochronous mode guarantees precisely reproducible and defined process reaction times as well as constant bus cycle and synchronous signal processing for central and distributed I/O.

### **Advantages of isochronous mode**

The use of isochronous mode enables high-precision control loops.

- Optimized control loops through constant, calculable dead times
- Determinism, reliable reproducibility of reaction times
- Consistent (simultaneous) reading in of input data
- Consistent (simultaneous) output of output data
- Oversampling for processing of fast processes thanks to higher sampling rates than the send clock permits

## Use of isochronous mode

An isochronous system acquires measured values and process data within a fixed system cycle, processes the signals and outputs them synchronously to the process. Isochronous mode contributes to a high control quality and increased production accuracy. With isochronous mode, the possible fluctuations of process reaction times are drastically reduced. You make use of the time-assured processing to improve machine cycle times. Even fast processes can be reliably controlled thanks to the precise time reproducibility of all sequences. Shorter cycle times increase the processing speed and help to lower production costs.

In principle, isochronous mode lends itself to being used whenever measured values must be acquired synchronously, movements must be coordinated, and process responses must be defined and carried out simultaneously. There are thus numerous applications for isochronous mode.

### Example: Measuring at multiple measurement points with isochronous mode

#### Automation task

A camshaft production process requires precise measurement of the camshafts for quality assurance purposes.

#### Feature

For this purpose, a component is needed that can synchronously measure the positions and displacements of the cam during a rotation of the camshaft.

#### Solution

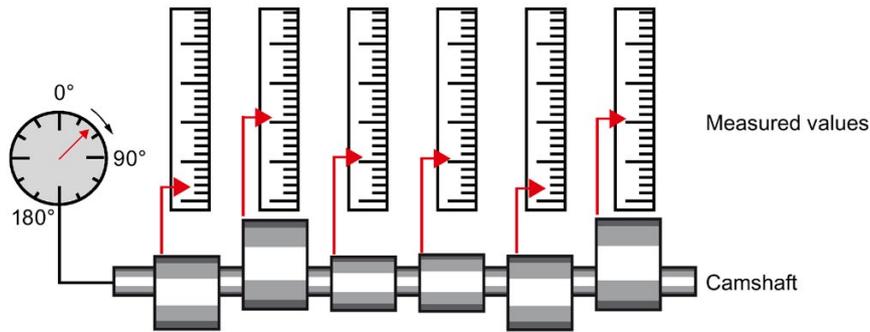


Figure 3-1 Measuring of camshafts

With use of isochronous mode, the measured values are simultaneously acquired at the various measuring points at fixed times. This yields the following sequence of operations:

- Continuously rotate the camshaft
- During the continuous rotation, synchronously measure the positions and cam displacements
- Process the next cam shaft

Thus, during a single rotation of the camshaft, all the positions of the camshaft and the associated measured values (red) are measured synchronously. The machine cycle time improves with the same or better measuring accuracy.

#### Advantage and benefits

The time required for measurement is reduced.

# Time sequence of synchronization

## Introduction

The basic time sequence of all components involved in the synchronization is explained in the following sections: The synchronization is differentiated according to distributed configuration and central configuration in an S7-1500. You can combine isochronous I/O with non-isochronous I/O in the configuration.

## 4.1 Time sequence of synchronization on PROFINET IO and PROFIBUS DP

### Introduction

You can operate I/O modules in distributed I/O systems isochronously on a CPU:

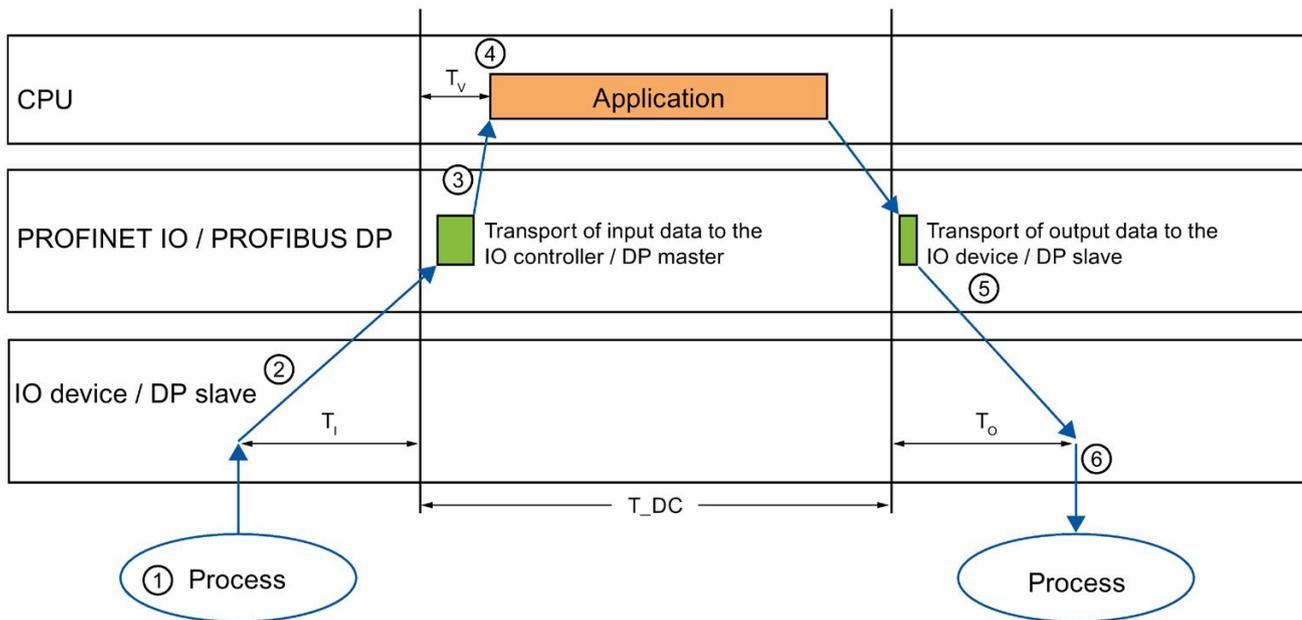
- On PROFINET IO, e.g. in distributed I/O systems ET 200SP, ET 200MP
- On PROFIBUS DP, e.g. in distributed I/O systems ET 200S, ET 200M.

Like the I/O modules, the interface modules of the I/O systems must support isochronous mode.

**From reading-in of input data to outputting of output data**

The basic time sequence of all components involved in synchronization is explained in the following:

- ① Measured value acquisition in the process
- ② Isochronous read-in of input data
- ③ Transport of input data to the IO controller/DP master (CPU) via the subnet
- ④ Further processing in the isochronous application of the CPU
- ⑤ Transport of output data to the outputting IO device/DP slave via the subnet
- ⑥ Isochronous output of output data



- $T_{DC}$  Data cycle (Time\_DataCycle)
- $T_i$  Time for reading in the input data
- $T_o$  Time for outputting the output data
- $T_v$  Configured delay time

Figure 4-1 Time sequence of synchronization on PROFINET IO/PROFIBUS DP

So that all input data is ready for transport via the subnet at the next start of the PROFINET IO-/PROFIBUS DP cycle, the start of the I/O read-in cycle is advanced by the amount of lead time  $T_i$ .  $T_i$  is the "flashbulb" for the inputs. All synchronized inputs are read in at this time.  $T_i$  is necessary in order to compensate for analog-to-digital conversion, backplane bus times and the like. The lead time  $T_i$  can be configured by STEP 7 or by you. Let the lead time  $T_i$  be assigned automatically by STEP 7. With the default setting, STEP 7 ensures that a common, minimum  $T_i$  is set.

The subnet transports the input data to the IO controller/DP master. The application is started synchronized to the cycle. That is, the isochronous mode interrupt OB is called after a configurable delay time  $T_v$ . The user program in the isochronous mode interrupt OB defines the process response and provides the output data in time for the start of the next data cycle. The length of the data cycle (send clock/DP cycle time) is always configured by you.

$T_o$  is the time for the compensation arising from the backplane bus and the digital-to-analog conversion within the IO device/DP slave.  $T_o$  is the "flashbulb" for the outputs. The synchronized outputs are output at this time. Time  $T_o$  can be configured by STEP 7 or by you. Let time  $T_o$  be assigned automatically by STEP 7. STEP 7 automatically calculates a common, minimum  $T_o$ .

## 4.2 Time sequence of synchronization in the central configuration

### Introduction

You can operate I/O modules isochronously downstream of an S7-1500 CPU starting with Firmware Version 2.6.

Exception: Isochronous operation of I/O modules in the central configuration is generally **not** possible:

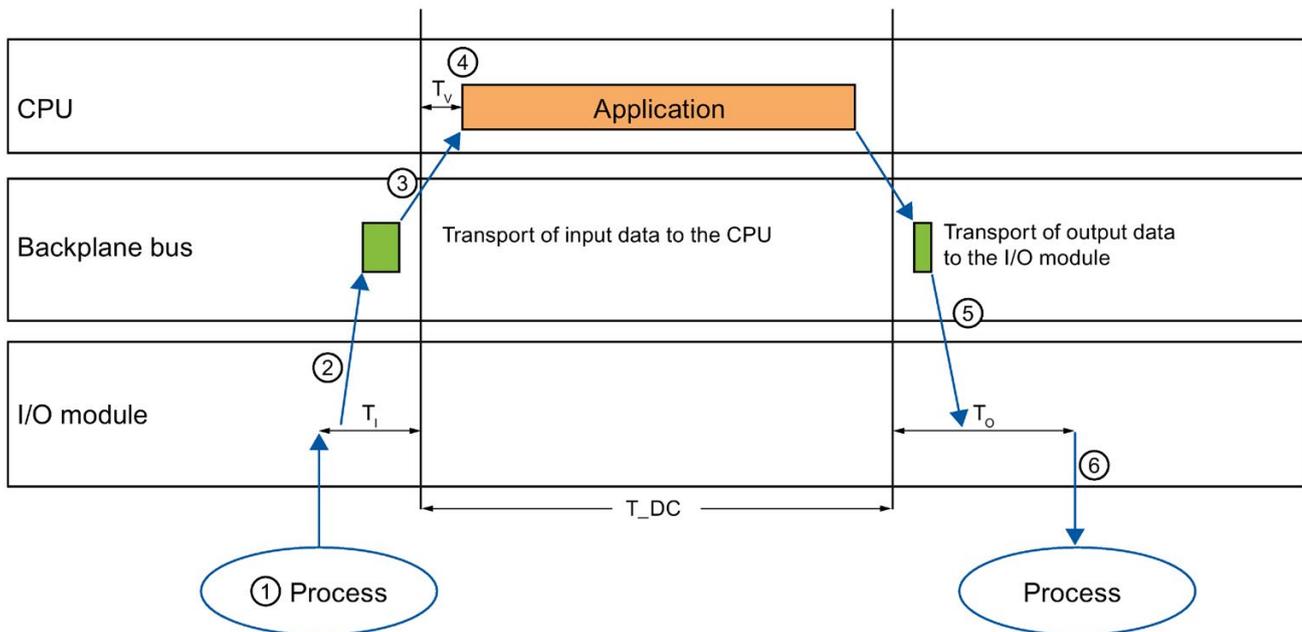
- With compact CPUs of S7-1500
- With CPUs of S7-1500R/H
- With PROFINET IO and PROFIBUS DP systems on centrally configured communications processors (CPs) or communication modules (CMs)
- With communications processors (CPs) or communication modules (CMs) as I-devices or I-slaves in the central configuration

When using isochronous I/O in the central configuration, you cannot make use of the configuration control (option handling) function.

**From reading-in of input data to outputting of output data**

The basic time sequence of all components involved in synchronization is explained in the following:

- ① Measured value acquisition in the process
- ② Isochronous read-in of input data from the central I/O
- ③ Transport of input data to the CPU
- ④ Further processing in the isochronous application of the CPU
- ⑤ Transport of output data to the central I/O
- ⑥ Isochronous output of output data



T\_DC Data cycle (Time\_DataCycle)  
 T<sub>i</sub> Time for reading in the input data  
 T<sub>o</sub> Time for outputting the output data  
 T<sub>v</sub> Configured delay time

Figure 4-2 Time sequence of synchronization in the central configuration

So that all input data is ready for transport to the CPU at the next start of the cycle, the start of the I/O read-in cycle is advanced by the amount of lead time T<sub>i</sub>. T<sub>i</sub> is the "flashbulb" for the inputs. After that, all synchronized inputs are read in. T<sub>i</sub> is necessary in order to compensate for analog-to-digital conversion and the like. The lead time T<sub>i</sub> can be configured by STEP 7 or by you. Let the lead time T<sub>i</sub> be assigned automatically by STEP 7. With the default setting, STEP 7 ensures that a common, minimum T<sub>i</sub> is set.

The backplane bus transports the input data to the CPU. The application is started synchronized to the cycle. That is, the isochronous mode interrupt OB is called after a configurable delay time  $T_v$ . The user program in the isochronous mode interrupt OB defines the process response and provides the output data in time for the start of the next data cycle. The length of the data cycle (send clock) is always configured by you.

Within time  $T_o$ , the data is:

- Transported to the I/O module over the backplane bus
- Processed in the I/O module, e.g. converted to an analog value

After expiration of time  $T_o$ , the data is output to the process.

Time  $T_o$  can be configured by STEP 7 or by you. Let time  $T_o$  be assigned automatically by STEP 7. STEP 7 automatically calculates a common, minimum  $T_o$ .

# Configuring isochronous mode

You can operate I/O modules isochronously both as central I/O in SIMATIC S7-1500 and as distributed I/O in a distributed I/O system.

You can also jointly operate central and distributed I/O on PROFINET IO isochronously.

The following sections describe the procedure for configuring this using examples.

## Configuring at a glance

### Setting parameters for isochronous operation of the I/O module

You use the properties of the I/O addresses of the corresponding I/O module to:

- Set isochronous mode for the module
- Assign the inputs and outputs of the module to a process image partition and an isochronous mode interrupt OB

The data of the process image partition is updated synchronously to the assigned OB. Isochronous mode interrupts give you the option of starting programs isochronously with the backplane bus, with the PROFIBUS DP cycle or PROFINET send clock. Isochronous mode interrupts are processed with high priority.

### Setting the send clock or DP cycle time

The send clock/DP cycle time is the shortest possible transmission interval for the data exchange. In isochronous mode, the send clock/DP cycle time corresponds to data cycle T<sub>DC</sub>.

For distributed I/O in S7-1500, you set the send clock in the properties of the CPU. For PROFINET IO, you set the send clock in the properties of the PROFINET interface of the CPU or in the sync domain. For PROFIBUS DP, you set the DP cycle time in the properties of the DP master system.

### Setting the application cycle

The application cycle is a multiple of data cycle T<sub>DC</sub>. If the runtime of the isochronous mode interrupt OB is short, the application cycle can be identical to the data cycle (= send clock/DP cycle time).

You can reduce the application cycle of the isochronous mode interrupt OB relative to the send clock of an isochronous system. Set an integer multiple of the send clock as the reducing factor.

You use the factor to reduce the CPU utilization by executing the isochronous mode interrupt OB less frequently. You set the application cycle in the properties of the isochronous mode interrupt OB.

You can find more information in the section Programming isochronous mode (Page 43).

### Setting the delay time

The delay time is the time between the start of the send clock and the start of the isochronous mode interrupt OB. During this time, the IO controller/DP master performs the cyclic data exchange with the IO devices/DP slaves.

STEP 7 sets the default delay time in such a way that the isochronous update of the process image partition automatically falls within the execution window of the application cycle.

You set the delay time in the properties of the isochronous mode interrupt OB. A shorter delay time enables you to increase the processing time for your user program in the isochronous mode interrupt OB.

### Additional configurations for isochronous mode on PROFINET IO:

- **Setting IRT as the RT class for the interconnected PROFINET interfaces**

A precondition for isochronous operation on PROFINET IO is IRT communication (Isochronous Real Time Communication). IRT means synchronized data exchange at reserved time intervals.

- **Configuring the topology of the configuration**

A precondition for IRT communication is the topology configuration. In addition to the reserved bandwidth, the exchange of frames on defined transmission paths is used for further optimization of data communication. For this, the topological information of the configuration is used for planning the communication.

- **Using a sync domain** you assign the IO devices (sync slaves) to an IO controller (sync master) for the isochronous data exchange.

A precondition for IRT communication is a synchronization cycle for all PROFINET devices in a sync domain, for distribution of a common time base. With this base synchronization, a synchronous operation of the transmission cycle of the PROFINET devices within a sync domain is achieved.

## 5.1 Configuring isochronous mode for distributed I/O on PROFINET IO

### Introduction

The configuring of isochronous mode for a module is described in the following for an IO device based on the ET 200MP distributed I/O system. The procedure described also applies to other distributed I/O systems (e.g., ET 200S or ET 200SP).

The IO controller is an S7-1500 CPU.

### Requirements

- The network view of STEP 7 is open.
- An S7-1500 CPU has been placed (e.g. CPU 1516-3 PN/DP).
- An IM 155-5 PN HF interface module (ET 200MP) has been placed and networked with the CPU via PROFINET IO.
- All requirements for an IRT configuration are met:
  - The ports of the networked PROFINET interfaces of the CPU and interface module are interconnected (topology configuration).
  - The RT class of the PROFINET interface of the interface module is set to "IRT" (area "Advanced options > Real time settings > Synchronization").
  - The "sync master" and "sync slave" roles are assigned for the PROFINET interfaces of the CPU and interface module (in the properties of a PROFINET interface: area "Advanced options" > "Real time settings" > "Synchronization").

## Procedure

To create an isochronous connection between the I/O and user program, follow these steps:

1. Select the "IM 155-5 PN HF" in the network view of STEP 7. Change to the device view.
2. Insert an I/O module that can be operated isochronously (e.g. DI 16 x 24VDC HF).
3. Go to the "I/O addresses" area in the Inspector window of the selected I/O module.

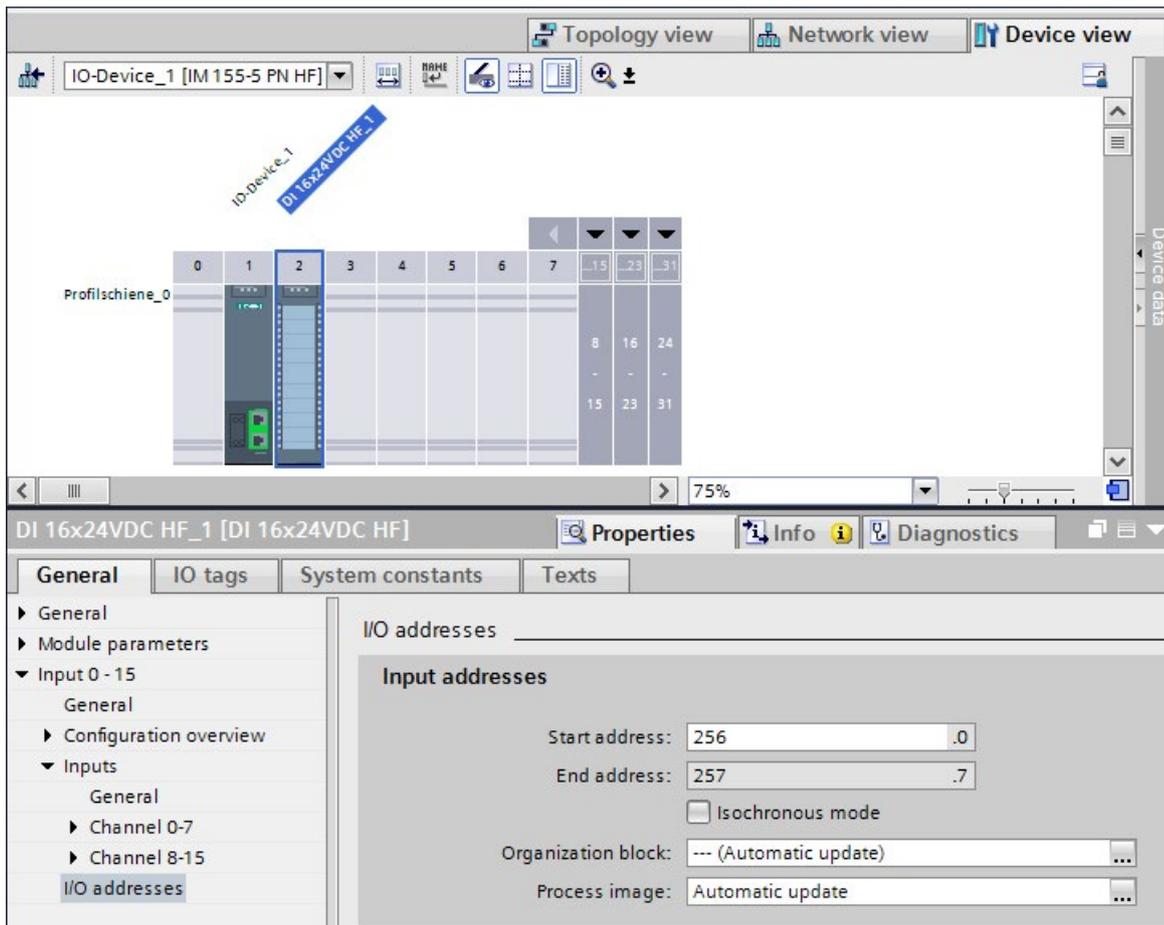


Figure 5-1 Configuring isochronous mode on PROFINET IO

4. Make the following settings in the I/O addresses area:

- Select the "Isochronous mode" option.
- Select a process image partition, e.g., process image partition 1.
- Click the "Organization block" drop-down list. Click the "Add" button or select an already existing OB. A dialog box for selecting organization blocks opens.
- Select the "Synchronous Cycle" OB. Confirm the selection with "OK".

In the case of automatic number assignment, OB 61 will be generated and opened.

In the Inspector window, you can continue directly with the setting of the application cycle and delay time (Page 41) in the "Isochronous mode" area and start the programming of the OB in the instruction section.

5. If required, add additional I/O modules in the central configuration and IO devices in the hardware configuration. Adapt the configuration and the settings for the isochronous mode.
6. You want to retrieve information about calculated bandwidths or for adapting the send clock. Select the PROFINET interface in the network view and navigate to the area "Advanced options" > "Real time settings" > "Synchronization" > "Domain settings".

## Reference

You can find more information on PROFINET functions, such as IRT, in the PROFINET (<http://support.automation.siemens.com/WW/view/en/49948856>) function manual.

You can find examples of parameter assignment and possible settings of isochronous mode for distributed I/O and drives in STEP 7 as FAQs on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109480489>).

## 5.2 Configuring isochronous mode for central I/O in S7-1500

### Introduction

The configuring of isochronous mode for a module is described in the following based on an analog input module in S7-1500. The procedure is also valid for other I/O modules that support isochronous mode.

### Requirements

- The network view of STEP 7 is open.
- An S7-1500 CPU has been placed (e.g. CPU 1516-3 PN/DP).

## Procedure

To create an isochronous connection between the I/O and user program, follow these steps:

1. Select the CPU 1516-3 PN/DP in the network view of STEP 7. Change to the device view.
2. Insert an I/O module that can be operated isochronously (e.g. AI 8 x U/I HS).
3. Go to the "I/O addresses" area in the Inspector window of the selected I/O module.

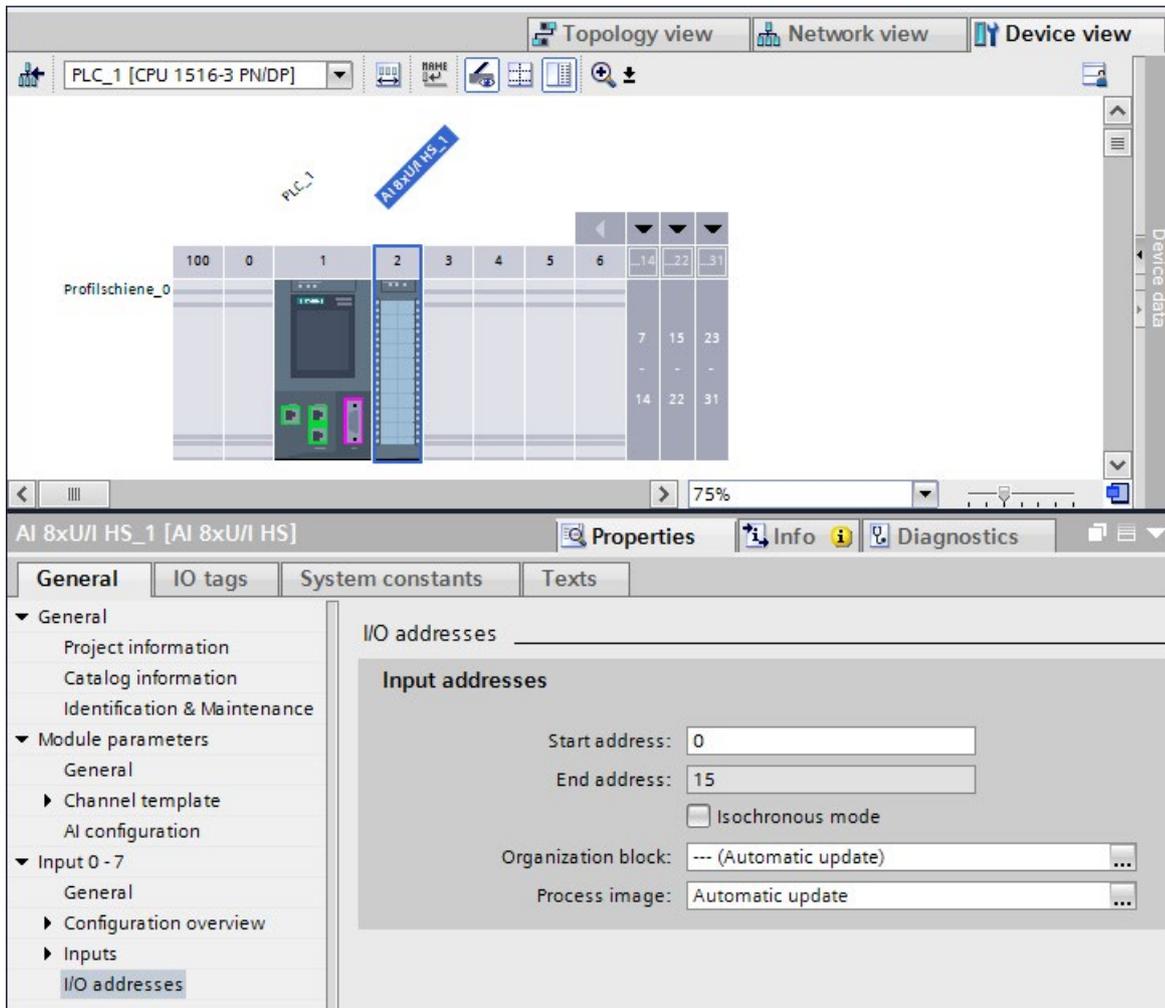


Figure 5-2 Configuring isochronous mode centrally on the AI module

4. Make the following settings in the I/O addresses area:
  - Select the "Isochronous mode" option.
  - Select a process image partition, e.g., process image partition 1.
  - Click on the "Organization block" drop-down list and click the "Add new" button or select an already existing OB. A dialog box for selecting organization blocks opens.
  - Select the "Synchronous Cycle" OB. Confirm the selection with "OK".

In the case of automatic number assignment, OB 61 will be generated and opened. The "Isochronous mode" area is selected in the Inspector window, and you can continue directly with the setting of the application cycle and delay time (Page 41) and start the programming of the OB in the instruction section.

5. If, due to the utilized modules, the isochronous system only operates with a certain send clock (e.g. 1 ms) but the process values must be sampled faster, use the oversampling function. In the example, you minimize the send clock into 4 sub-clocks using the sampling rate. In this way you sample the process values for the channels of the analog input module every 250 µs.

In the properties of the analog input module in the "Module parameters" > "AI configuration" area, set a sampling rate of 4 samples per cycle under "Oversampling".

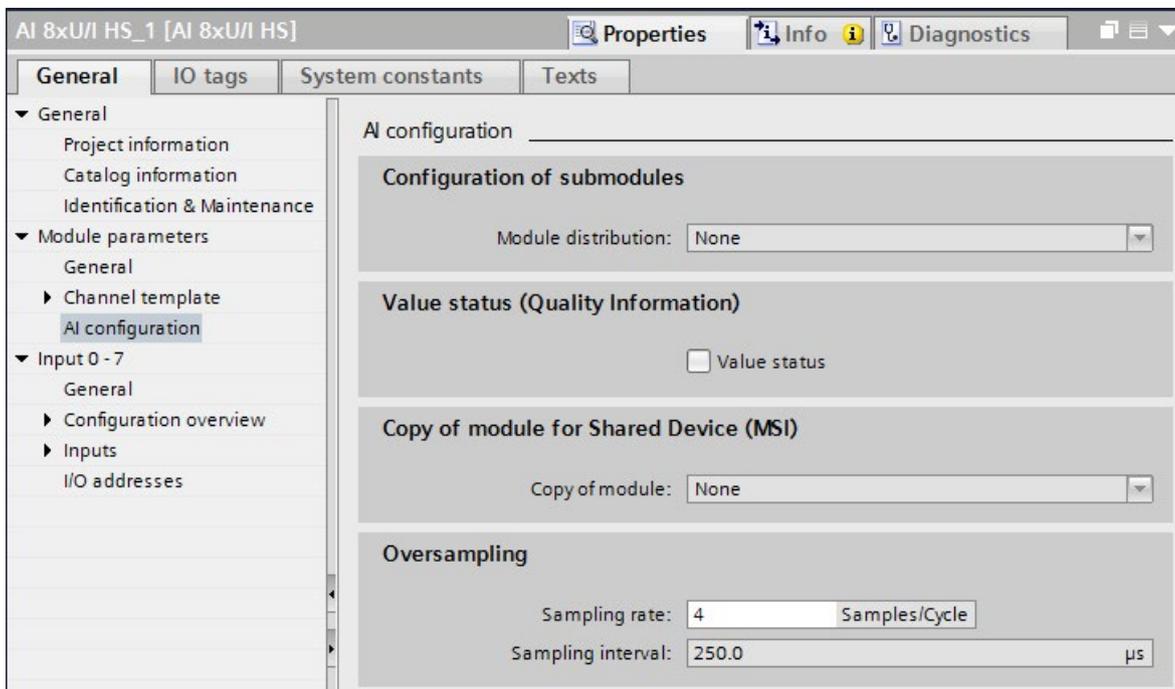


Figure 5-3 Configuring oversampling on the AI module

6. If required, insert additional I/O modules in the device view. Adapt the configuration and the settings for isochronous mode.
7. Select the CPU 1516-3 PN/DP in the device view of STEP 7 in order to check the settings for isochronous mode.
8. Navigate to the "Isochronous mode" area in the Inspector window of the selected CPU

9. In the "Isochronous mode for local modules" area, check to determine if:

- Isochronous mode is selected
- "Local send clock" is selected as the synchronization type

If necessary, you can adapt the send clock and times  $T_i/T_o$  for the isochronous read-in/output of data.

10. In the "Detail overview" area, you see all modules of the configuration you can operate isochronously. Select or deselect isochronous mode for the desired modules as appropriate.

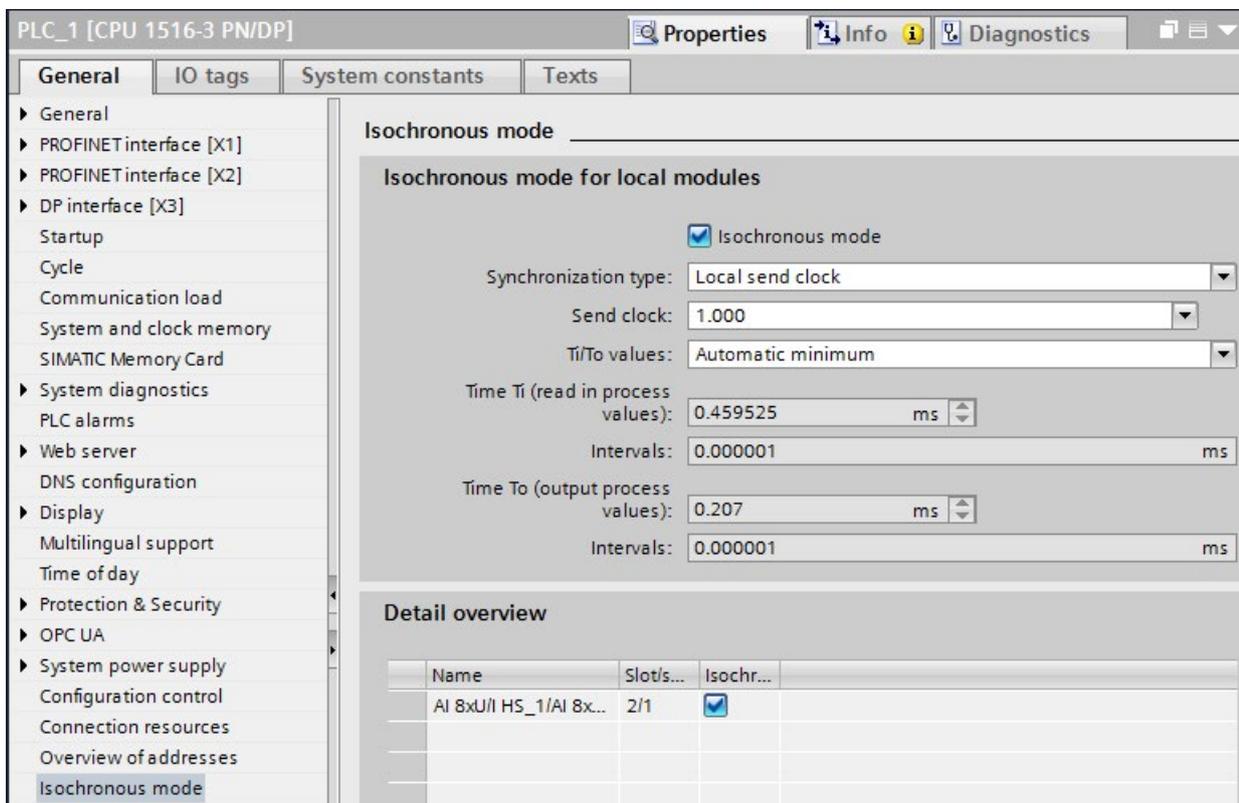


Figure 5-4 Configuring isochronous mode centrally on the CPU

## 5.3 Configuring joint isochronous operation of central and distributed I/O

### Introduction

You can jointly operate central I/O in S7-1500 and distributed I/O on PROFINET IO isochronously.

For the coordination and synchronization of the processing cycles of the central and distributed I/O, you set the same send clock and isochronous mode interrupt OB in STEP 7.

The system clock results from the values for the central and distributed configurations. Foremost here is the PROFINET send clock to which the central configuration is synchronized. If necessary, you must set a higher send clock for PROFINET IO, which takes the overall system into account.

### Setting the same send clock for central and distributed I/O

You want to operate modules configured as central I/O in S7-1500 and modules configured as distributed I/O in ET 200MP isochronously with the same send clock.

#### Requirements

- You have connected distributed I/O in an ET 200MP as isochronous I/O to PROFINET IO (see section Configuring isochronous mode for distributed I/O on PROFINET IO (Page 24)).
- The IO controller is an S7-1500 CPU.
- You have connected central I/O of the S7-1500 as isochronous I/O (see section Configuring isochronous mode for central I/O in S7-1500 (Page 26)).
- You have configured the same isochronous mode interrupt OB and the same process image partition for central and distributed I/O.

### Procedure

1. Navigate to the "Isochronous mode" area in the properties of the CPU.
2. In the "Isochronous mode for local modules" area, use "Use send clock of PROFINET interface [X1]" in the "Synchronization type" drop-down list.

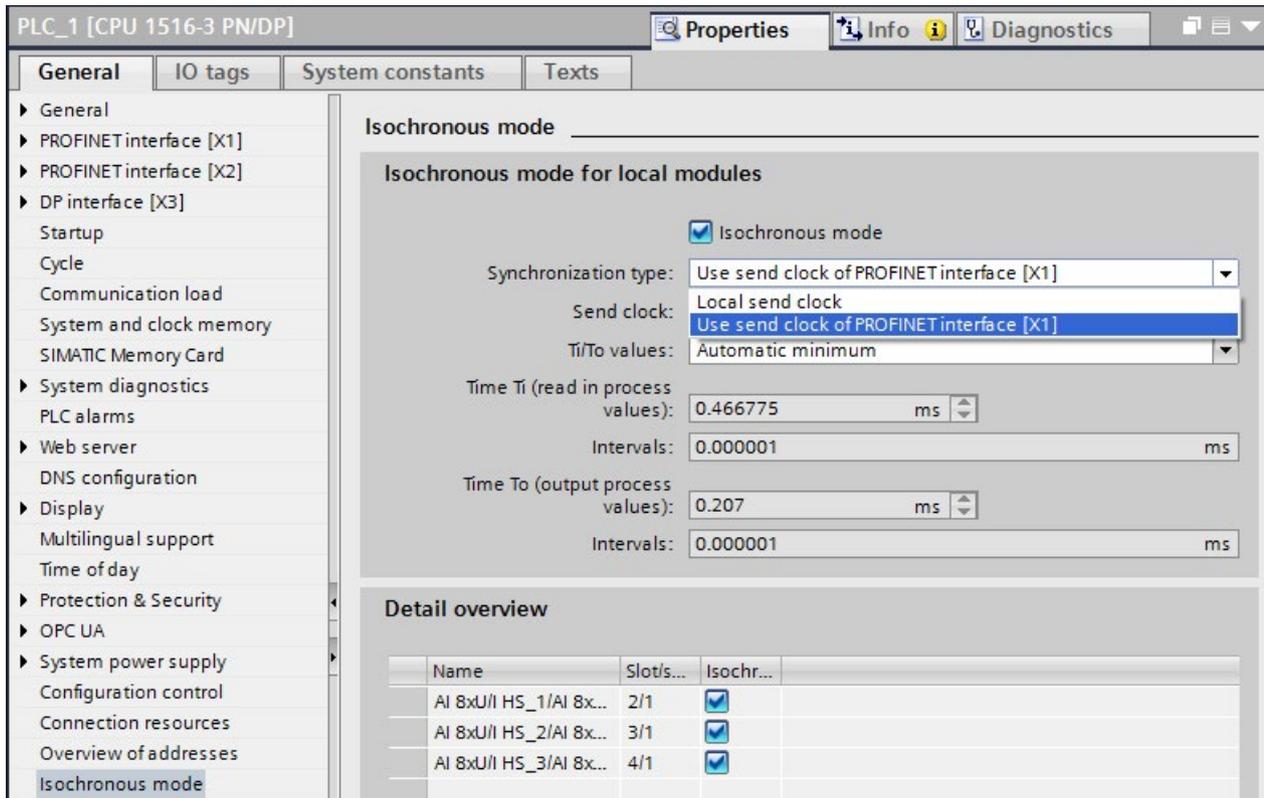


Figure 5-5 Setting the same send clock for central and distributed I/O

**Result:** The modules in the central configuration have adopted the send clock and the  $T_i/T_o$  values from the PROFINET interface X1.

### Isochronous mode interrupt OB and process image partition

For joint isochronous operation of central and distributed I/O in a project, the following condition must be met:

#### Note

Ensure that you have configured the same isochronous mode interrupt OB and the same process image partition for the central and distributed I/O you want to jointly operate isochronously.

## 5.4 Configuring isochronous mode for distributed I/O on PROFIBUS DP

### Introduction

The configuring of isochronous mode is described in the following for a DP slave based on the ET 200S distributed I/O system. The procedure described also applies to other distributed I/O systems, e.g. for ET 200M.

The IO controller is an S7-1500 CPU.

### Requirements

- The network view of STEP 7 is open.
- A CPU has been placed (e.g., CPU 1516-3 PN/DP).
- An interface module which supports isochronous mode has been placed and networked with the CPU (e.g., IM 151-1 HF).
- I/O modules have been placed (e.g. 2DI x DC24V HF and 2DO x DC24V/0,5A HF).
- Only the constant bus cycle time master is permitted as active station on the isochronous PROFIBUS DP.
- Assignment of a SYNC/FREEZE group to the DP slave is not permitted.

### Procedure for configuring isochronous mode on the DP slave

1. Select the DP slave in the network view. Navigate to the "Isochronous mode" area in the Inspector window.
2. Enable the option for synchronization to the DP cycle for the DP slave.  
Default: The DP slaves get the Ti/To values from the subnet. Therefore, the values are automatically the same for all DP slaves of the DP master system.
3. In the "Detail overview", select the "Isochronous mode" option for all I/O modules you want to operate isochronously.
4. Repeat steps 1 and 3 for all DP slaves that you want to operate in isochronous mode.

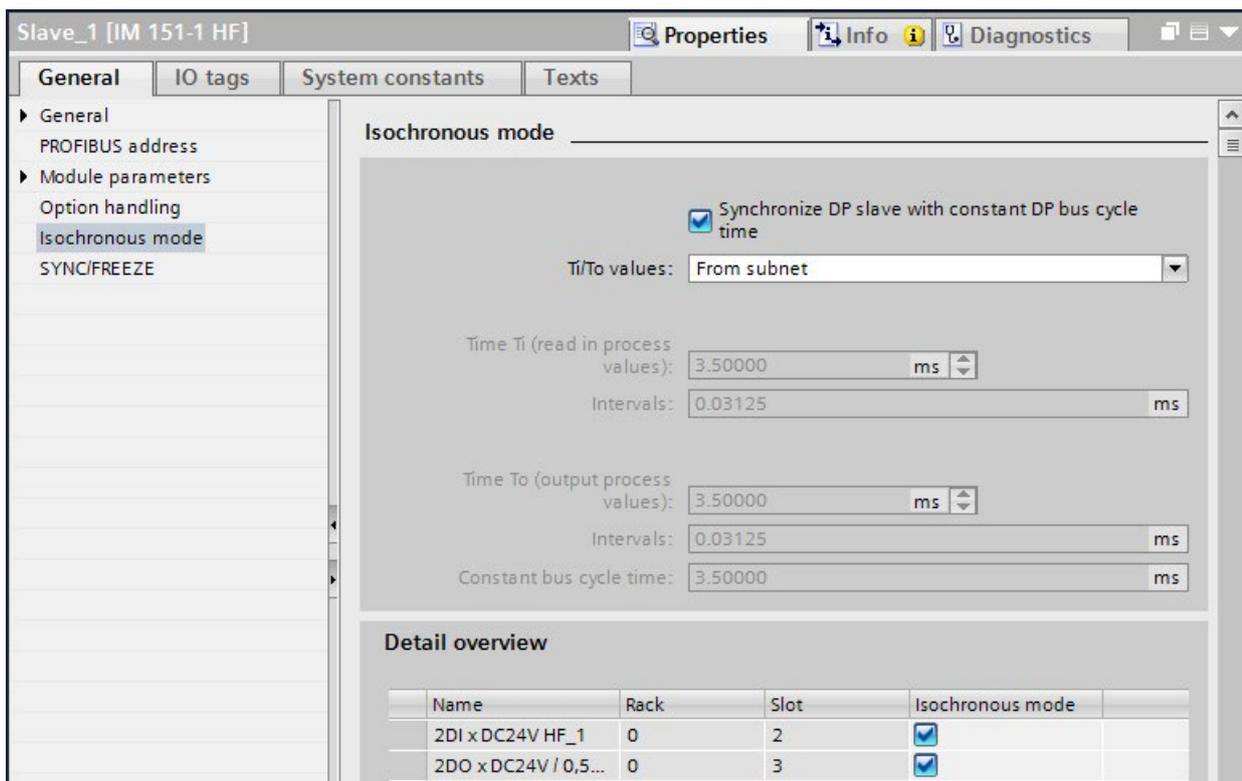


Figure 5-6 Configuring isochronous mode on the DP slave

### Procedure for configuring the I/O module

1. Select an I/O module in the device view. Navigate to the "I/O addresses" area in the Inspector window.
  - The option for isochronous mode is selected.

Assign the process image partition and OB to the I/O modules as described in section Configuring isochronous mode for distributed I/O on PROFINET IO (Page 24).

## 5.5 Configuring isochronous mode for a Motion Control application

### Introduction

The configuring of isochronous mode for a Motion Control application with cam output is described in the following.

You connect a SINAMICS V90 drive with a positioning axis to an S7-1500 CPU as isochronous distributed I/O.

The drive is controlled using the CPU-internal Motion Control functions.

You connect the cam output to the CPU as an isochronous cam output using technology module TM Timer DIDQ 16 x 24V.

### Requirements

- The network view of STEP 7 is open.
- An S7-1500 CPU has been placed (e.g. CPU 1516-3 PN/DP).

### Procedure for configuring isochronous mode for a drive

For isochronous operation of a drive, you configure the drive frame as an isochronous frame. So that the CPU can control the drive, you then assign the drive to a Motion Control technology object of the CPU.

Follow these configuration steps:

1. Insert a SINAMICS V90 drive from the hardware catalog in the network view (Additional Field Devices > PROFINET IO > Drives > SIEMENS AG > SINAMICS > SINAMICS V90 PN).
2. Connect the PROFINET interface of the V90 to the PROFINET interface X1 of the CPU in the network view.
3. Change to the topology view. Interconnect the corresponding ports of the PROFINET interfaces of the devices.
4. Select the V90 and change to the device view.
5. In the properties of the V90, navigate via General > PROFINET interface > Advanced options to the "Isochronous mode" area.
6. Select the "Isochronous mode" option.

7. In the hardware catalog, double-click on Standard Frame 3, ...

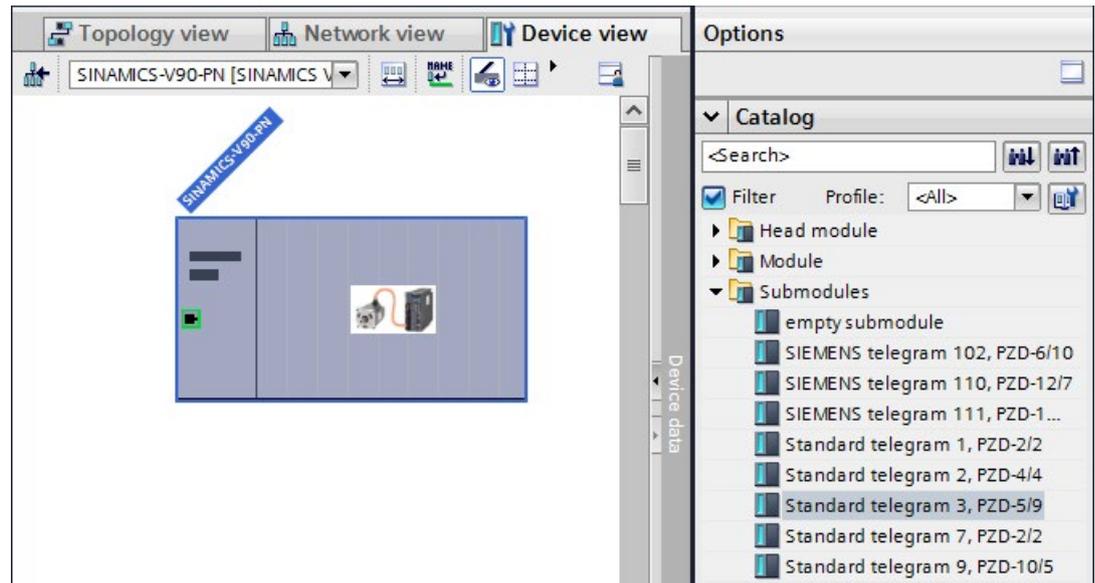


Figure 5-7 Assigning Standard Frame 3 to the V90

- 8. In the properties of the V90, select the "Isochronous mode" option for Standard Frame 3 in the detail overview.

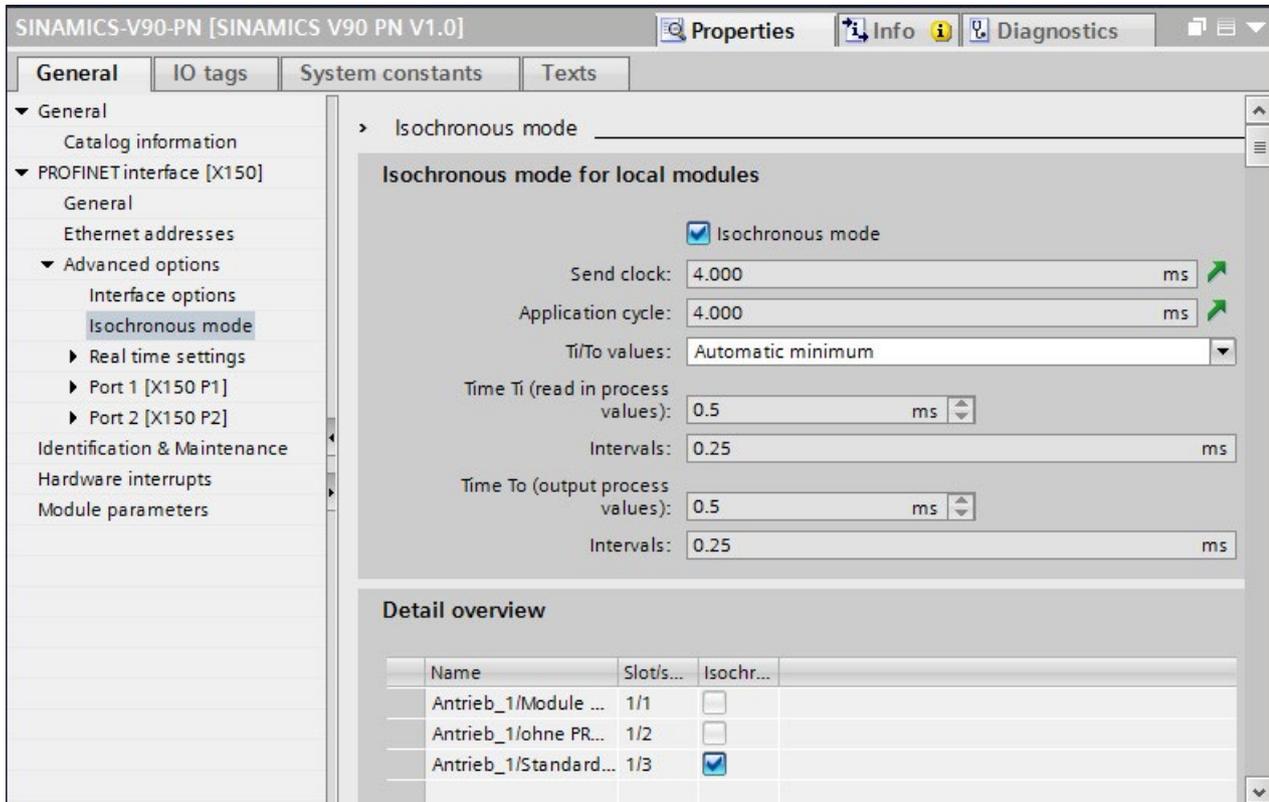


Figure 5-8 Assigning isochronous mode to Standard Frame 3

9. In the project tree, navigate in the folder of the CPU to "Technology objects".
10. Insert a "Positioning axis" technology object.

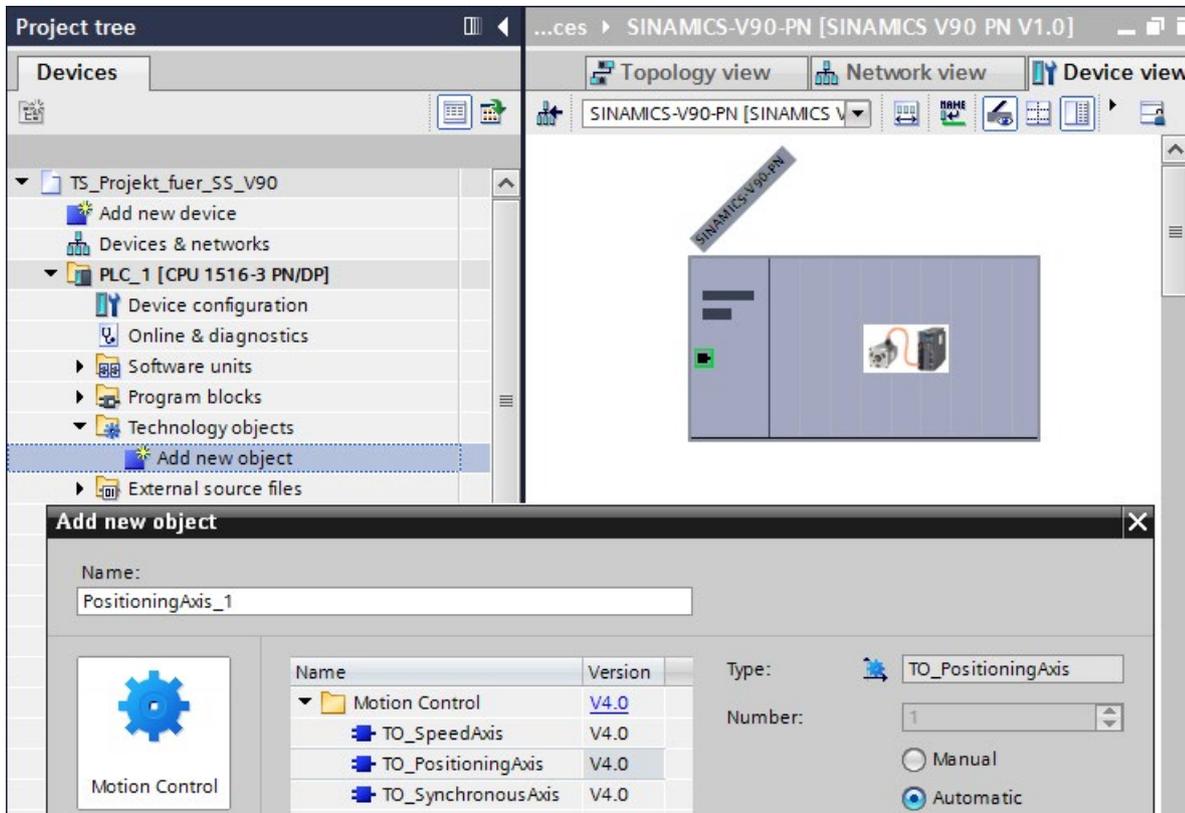


Figure 5-9 Creating a positioning axis technology object

11. Assign the drive V90 to the positioning axis.

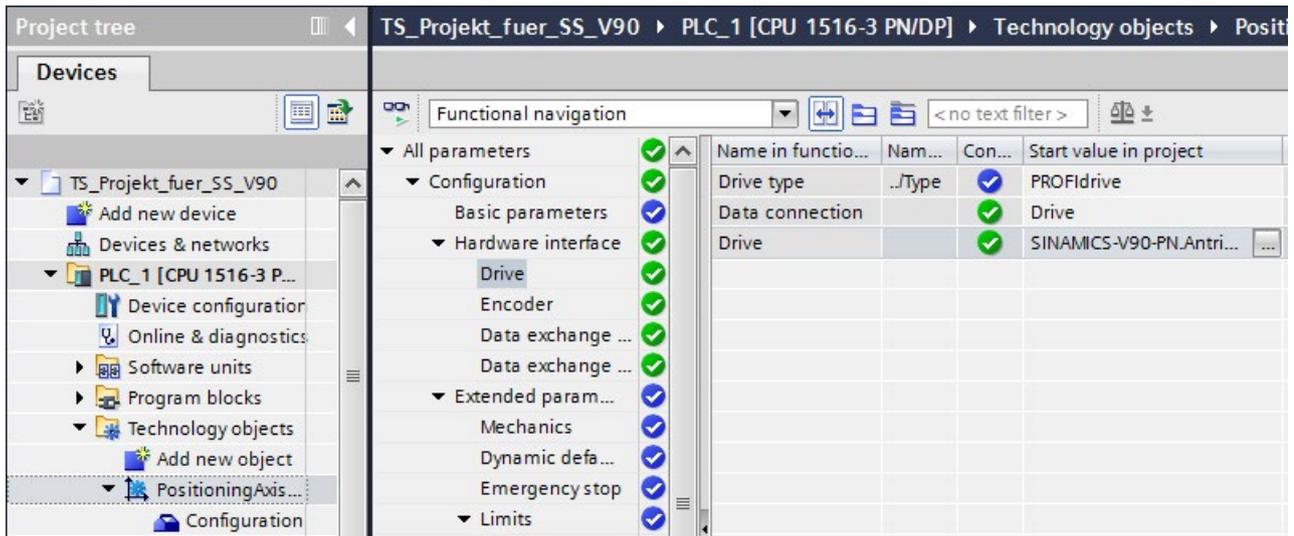


Figure 5-10 Assigning the drive to the positioning axis

**Results:**

- As soon as an axis was created for the CPU, the MC Servo OB is automatically created and set synchronous to the PROFINET IO.
- The drive is automatically assigned to the MC Servo OB and the TPA OB Servo process image partition when the axis is created.
- The drive is connected as an isochronous drive.

## Procedure for configuring isochronous mode for a cam controller using a Timer technology module

For isochronous operation of a cam controller on a CPU, you configure a TM Timer technology module as an isochronous technology module. So that the CPU can control an output cam of the axis isochronously, you assign an output cam to the TM Timer technology module.

Follow these configuration steps:

1. Switch to the device view of the CPU.
2. Select technology module TM Timer DIDQ 16 x 24V from the hardware catalog. Place the technology module in a slot to the right of the CPU.
3. The channel configuration "0 inputs, 16 outputs" and operating mode "Timer DQ" are preset in the properties of the technology module for the individual outputs.
4. In the properties of the technology module, "I/O addresses", select the "Isochronous mode" option.
5. Set the same send clock for central and distributed I/O. You can find more information in the section Configuring joint isochronous operation of central and distributed I/O (Page 30).
6. In the project tree for the positioning axis, add a new output cam under "Output cams".

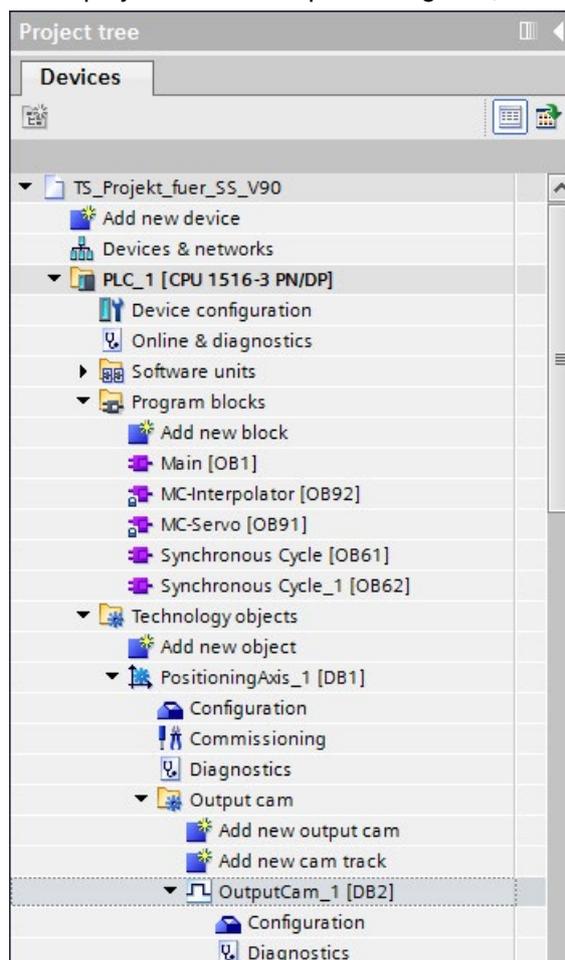


Figure 5-11 Assigning the output cam to the positioning axis

7. In the "Output cam output" area of the configuration, enable output by the technology module for the output cam. Assign a cam output.

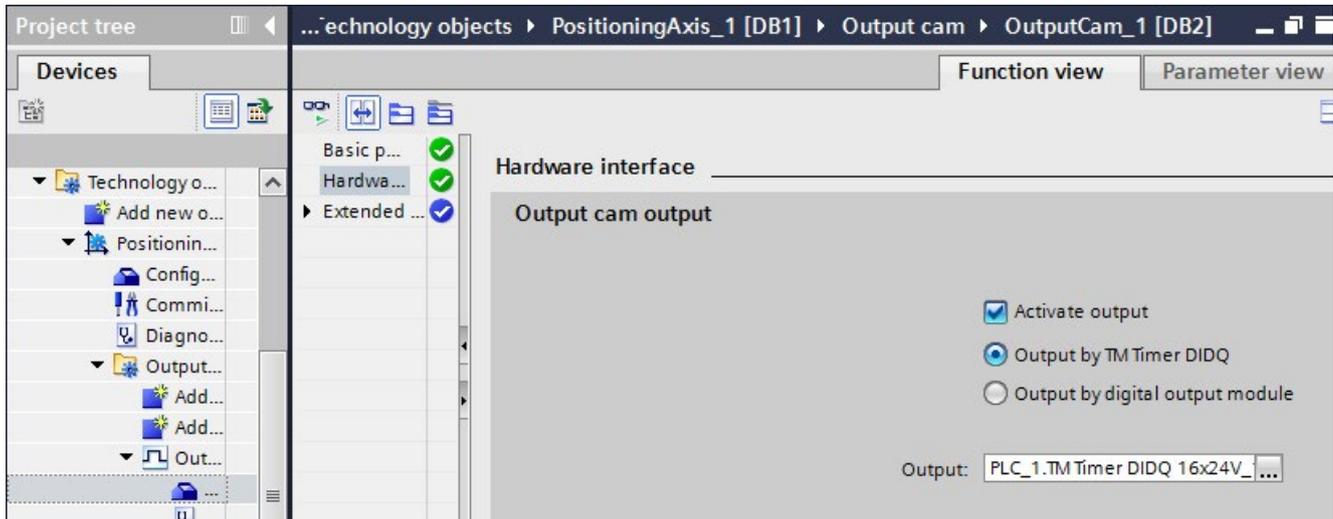


Figure 5-12 Assigning output of the technology module to the output cam

The addresses and TPA OB Servo process image partition are automatically assigned to the technology module.

**Result:** The cam output is configured as isochronous cam output.

## Reference

You can find information on programming isochronous mode for Motion Control applications in section Programming isochronous mode.

You can find additional information on the above-mentioned OBs and their use in the STEP 7 online help.

You can find examples of parameter assignment and possible settings of isochronous mode for distributed I/O and drives in STEP 7 as FAQs on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109480489>).

## 5.6 Setting the application cycle and delay time

### Requirements

- You have created an isochronous mode configuration in STEP 7.
- You have created an isochronous mode interrupt OB Synchronous Cycle (OB 6x).
- The isochronous mode interrupt OB is open.

### Setting the application cycle

The application cycle is a multiple of data cycle T\_DC (send clock). You use the application cycle setting to reduce the CPU utilization caused by execution of the isochronous mode interrupt OB. In the following example, the OB is called only after every 2nd data cycle T\_DC in the CPU.

To set the application cycle for your isochronous mode application, follow these steps:

1. Open the "Properties" dialog of the isochronous mode interrupt OB under consideration.
2. In the area navigation, click the "Isochronous mode" group .
3. Set the application cycle in "Application cycle (ms)". Open the drop-down list box and select the application cycle. The drop-down list offers multiples of data cycle T\_DC as possible values for the application cycle. Data cycle T\_DC is set to 2 ms in the following figure.

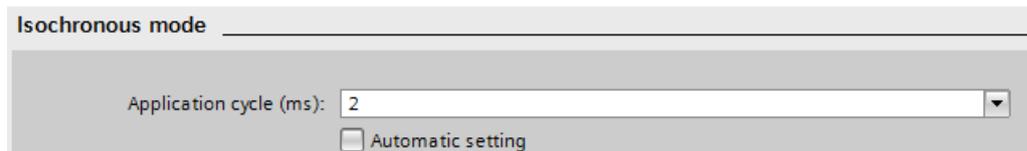


Figure 5-13 Setting the application cycle

### Setting the delay time

The delay time is the time between the start of the send clock and the start of the isochronous mode interrupt OB. STEP 7 sets the delay time automatically to the start of the execution window by default. As a result, the isochronous mode update of the process image partition automatically falls within the execution window of the application cycle. Note that you must call the "SYNC\_PI" and "SYNC\_PO" instructions in the execution window of the application cycle.

You can also set the delay time manually. A shorter delay time enables you to increase the processing time for your user program in the isochronous mode interrupt OB.

To set the delay time for your isochronous mode application, follow these steps:

1. Open the "Properties" dialog of the isochronous mode interrupt OB under consideration.
2. In the area navigation, click the "Isochronous mode" group .
3. Clear the "Automatic setting" check box.
4. Enter your desired delay time in "Delay time (ms)".



Figure 5-14 Setting the delay time

# Programming isochronous mode

## Programming in the isochronous mode interrupt OBs

You program the isochronous section of the program exclusively in the isochronous mode interrupt OBs Synchronous Cycle (OB 6x) and, for Motion Control applications, in the OBs MC-PreServo and MC-PostServo.

The isochronous mode interrupt OBs Synchronous Cycle (OB 6x) apply to the isochronous operation of modules centrally in S7-1500 and in the assigned distributed I/O systems.

Because the isochronous mode interrupts are processed with high priority, only the time-critical sections of the program should be processed in the isochronous mode interrupt OB. The isochronous mode interrupt is called with a configured delay time.

## Access to isochronous I/O through call of instructions

You access the isochronous I/O via a process image partition. That is, the addresses of the isochronous modules must be within one process image partition.

The CPU updates the process image partitions of the isochronous I/O in the central and distributed configurations by calling the instructions SYNC\_PI and SYNC\_PO .

These instructions are not necessary for Motion Control applications. OB MC-Servo automatically updates the process image partitions.

---

### Note

Recommendation: To prevent inconsistent data from being returned to OB 6x, do not use the "DPRD\_DAT" and "DPWR\_DAT" instructions (direct data access) in the isochronous mode interrupt OB.

---

The "SYNC\_PI" and "SYNC\_PO" instructions update the process image partition only within the permitted execution window. The execution window stretches from the end of the cyclical data exchange to the point in time before the end of T\_DC at which the outputs can still be copied in time. The data exchange must be started within this time window. If the execution window is violated by the processing of the "SYNC\_PI" and "SYNC\_PO" instructions, the instructions indicate a corresponding error message.

## Program execution models

Depending on your requirements regarding reaction time and execution time of the isochronous mode interrupt OB, there are two basic models for processing the program:

- **IPO** model (read **I**nputs - **P**rocessing - write **O**utputs)
- **OIP** model (write **O**utputs - read **I**nputs - **P**rocessing)

You implement the respective model through the different call sequence of SYNC\_PI and SYNC\_PO in the user program.

## 6.1 Program execution according to the IPO model

If the execution time of the isochronous mode interrupt OB is significantly shorter than one data cycle T\_DC, use the IPO model. In the IPO model, you do not reduce the data cycle. That is, the application cycle of the isochronous mode interrupt OB is equal to data cycle T\_DC.

The IPO model enables the shortest reaction times.

### Programming according to the IPO model in the isochronous mode interrupt OB

For programming according to the IPO model:

1. Call the SYNC\_PI instruction at the start of the isochronous mode interrupt OB.
2. Then, call the actual user program.
3. Call the "SYNC\_PO" instruction at the end of the isochronous mode interrupt OB.

Table 6- 1 Sequence according to the IPO model

Step	Action	Explanation
1	Read in (I)	The SYNC_PI instruction reads in the inputs of the process image partition and provides them to the isochronous mode interrupt OB.
2	Process (P)	The user program in the isochronous mode interrupt OB is executed.
3	Output (O)	The SYNC_PO instruction outputs the data changed by the user program via the process image partition.

## Signal sequence in the IPO model

The following figure shows the signal sequence in the IPO model from the acquisition and the processing in the CPU to the output of the process values:

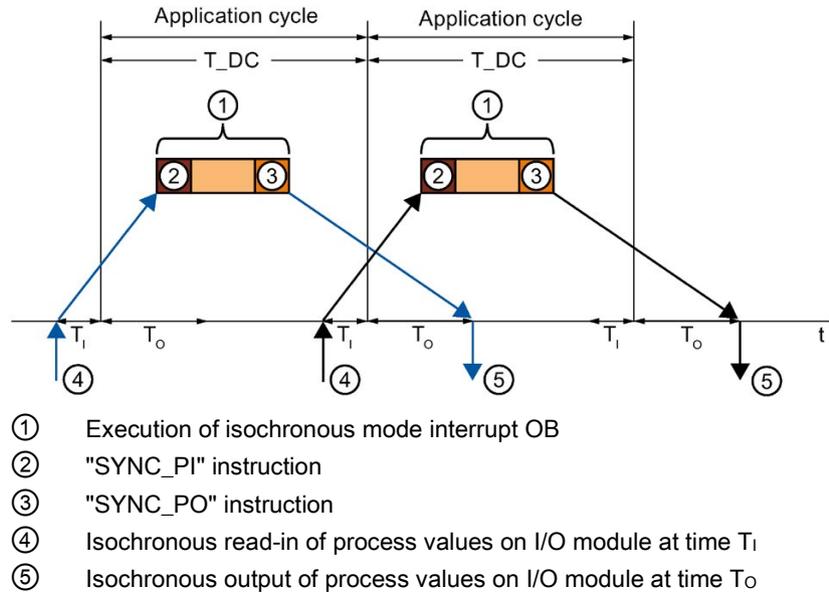


Figure 6-1 Signal sequence in the IPO model

At time  $T_I$  the process values are read in isochronously on the I/O. The processing of the data in the IPO model is completed within one data cycle  $T_{DC}$ . The output data is always available on the I/O in the next data cycle  $T_{DC}$  at time  $T_O$ .

With the IPO model, there is a constant execution time from the "input terminal" to the "output terminal" of  $T_I + T_{DC} + T_O$ .

$T_I + 2 \times T_{DC} + T_O$  can be guaranteed for the process response time for asynchronous events.

## 6.2 Program execution according to the OIP model

Use the OIP model in the case of execution cycles of the isochronous mode interrupt OB of different lengths, if the application cycle is greater than data cycle T\_DC.

The data exchange with the process is always deterministic also in the OIP model, which means it takes place at a precisely specified time.

### Programming according to the OIP model in the isochronous mode interrupt OB

For programming according to the OIP model:

1. Call the SYNC\_PO instruction at the start of the isochronous mode interrupt OB.
2. Then call the SYNC\_PI instruction:
3. Then, call the actual user program.

Table 6- 2 Sequence according to the OIP model

Step	Action	Explanation
1	Output (O)	The SYNC_PO instruction outputs the data that was changed by the user program in the previous cycle via the outputs of the process image partition.
2	Read in (I)	The SYNC_PI instruction reads in the inputs of the process image partition of the current cycle and provides the inputs to the isochronous mode interrupt OB.
3	Process (P)	The user program in the isochronous mode interrupt OB is executed.

### Signal sequence in the OIP model

The following figure shows the signal sequence in the OIP model from the acquisition of process values and the processing in the CPU to the output of the process values: The application cycle is twice as long as data cycle  $T_{DC}$  in this example.

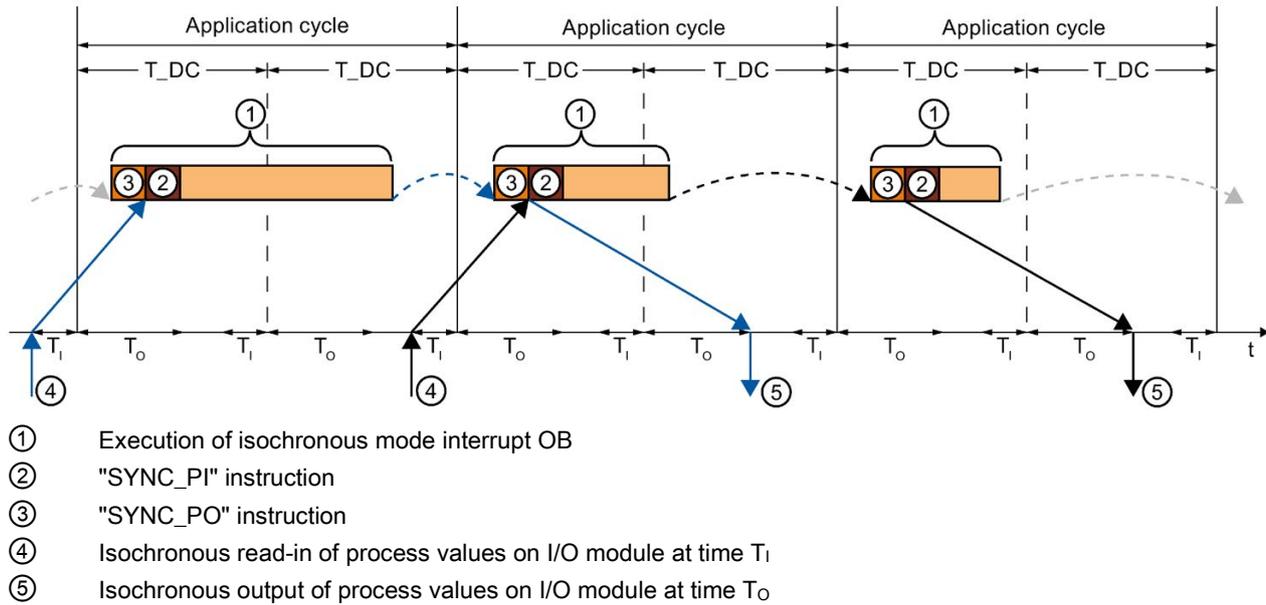


Figure 6-2 Signal sequence in the OIP model

At time  $T_i$  the process values are read in isochronously on the I/O. The data is processed over 2 application cycles in the OIP model. The output data is always available on the I/O in the following application cycle at time  $T_{DC} + T_o$ .

With the IPO model, there is a constant execution time from the "input terminal" to the "output terminal" of  $T_i + \text{application cycle} + T_{DC} + T_o$ .

$T_i + 2 \times \text{application cycle} + T_{DC} + T_o$  can be ensured as the process reaction time.

## 6.3 Programming of isochronous mode for Motion Control applications

### MC-Servo, MC-PreServo and MC-PostServo OBs

The CPU-internal Motion Control functions are to control a drive. When an axis is created in the CPU, the MC Servo OB is automatically created in the user program. This OB contains an automatic update of the process image partitions.

If user programs are to be processed synchronized to the MC-Servo OB, integrate the user programs in the MC PreServo or MC PostServo OBs. The SNYC\_PI and SYNC\_PO instructions are not necessary.

The process image partitions are always updated as follows:

- The inputs are read prior to processing the MC-PreServo OB.
- The outputs are output after processing the MC-PostServo OB.

The runtime of the MC Servo OB must never be longer than the send clock of the isochronous PROFINET IO system. When the runtime of the MC-Servo OB reaches the length of the send clock, you must:

- reduce the application cycle in the properties of the MC-Servo OB  
and
- extend the send clock in the properties of the PROFINET interface of the CPU

---

#### Note

The reduction ratio of the MC-Servo OB also influences the axis control of the Axis technology object.

Interferences at the axis may not be compensated for satisfactorily by a reduction ratio that is set too high.

---

### Reference

You can find additional information on the above-mentioned OBs and their use in the STEP 7 online help.

You can find examples of parameter assignment and possible settings of isochronous mode for distributed I/O and drives in STEP 7 as FAQs on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109480489>).

# Glossary

## Analog-to-digital conversion

Conversion of analog input signals into digital signals for processing in the CPU.

## Application, isochronous

User program in the isochronous mode interrupt OB. The user program in the isochronous mode interrupt OB ensures the isochronous and consistent updating of the assigned process image participation.

## Automation system

Programmable logic controller for the open-loop and closed-loop control of process chains in process and production engineering. The automation system consists of different components and integrated system functions depending on the automation task.

## Backplane bus

The backplane bus is a serial data bus for module intercommunication and the distribution of the necessary power to the modules.

## Bus

A bus is a transmission medium that interconnects several devices. Data transmission can take place electrically or via optical fiber, both in series and in parallel.

## CPU

**Central Processing Unit** - Central module of the S7 automation system with a control and arithmetic unit, memory, operating system and interface for programming device.

## Delay time

In isochronous mode, the delay time is the time between the send clock and the start of the isochronous mode interrupt OB. During this time, the IO controller/DP master performs the cyclic data exchange with the IO devices/DP slaves.

## Determinism

Determinism means that a system responds in a predictable (deterministic) manner.

### Direct access, direct data access

As an alternative to access via the process image, you also have direct read and write access to the I/O, if this is necessary for programming reasons. A direct (write) I/O access also writes to the process image. This prevents a subsequent output of the process image from overwriting the value written by direct access.

### Distributed I/O system

System with I/O modules at a distance from the CPU controlling them.

### DP master

A master that behaves in accordance with EN 50170, Part 3, is called a DP master.

→ *See also Master*

### DP slave

A slave operated on PROFIBUS with the PROFIBUS DP protocol and in accordance with EN 50170, Part 3 is called a DP slave.

→ *See also Slave*

### Execution window

The "SYNC\_PI" and "SYNC\_PO" instructions can update the process image partition only within the permitted execution window in isochronous mode. The execution window refers to the time period during which a call of the SYNC\_PI and SYNC\_PO instructions is possible, i.e. from the end of the cyclic data exchange until the point in time before the end of data cycle T\_DC at which the outputs can still be transferred to the I/O in time. In STEP 7 the delay time is preset to the start of the execution window. A violation of the execution window is signaled by an error message at the block call.

### I/O modules

All modules that can be operated with a CPU or an interface module.

### I-device

The "I-device" (intelligent IO device) functionality of a CPU allows it to exchange data with an IO controller and thus to be used as an intelligent preprocessing unit of sub-processes. In its role as an IO device, the I-device is connected to a "higher-level" IO controller.

### Interface module

Module in the distributed I/O system. The interface module connects the distributed I/O system to the CPU (IO controller) via a fieldbus and processes the data for and from I/O modules.

**IO controller, PROFINET IO controller**

Central device in a PROFINET system, usually a classic programmable logic controller or PC. The IO controller sets up connections to the IO devices, exchanges data with them and thus controls and monitors the system.

**IO device, PROFINET IO device**

Distributed I/O device of a PROFINET system that is monitored and controlled by an IO controller (e.g. distributed inputs/outputs, valve blocks, frequency converters, switches).

**IRT**

IRT is a synchronized transmission method for the cyclic exchange of IRT data between PROFINET devices. A reserved bandwidth within the send clock is available for the IRT data. The reserved bandwidth guarantees that the IRT data can be transferred at reserved, synchronized intervals without being affected by other higher network loads (e.g. TCP/IP communication or additional real-time communication).

**I-slave**

The "I-slave" functionality of a CPU allows it to exchange data with a DP master and thus to be used, for example, as an intelligent preprocessing unit of sub-processes. In its role as a DP slave, the I-slave is connected to a "higher-level" DP master.

**Master**

Higher-level, active device on the communication network/PROFIBUS subnet. It has bus access rights (token), sends data and requests data.

**Network**

A network consists of one or more linked subnets with any number of devices. Several networks can exist alongside each other.

**Organization block**

Organization blocks (OBs) form the interface between the operating system of the CPU and the user program. The organization blocks determine the order in which the user program is executed.

**Parameter**

1. Variable of a STEP 7 code block:
2. Variable for setting the behavior of a module (one or more per module)

In its delivery state, each module has an appropriate basic setting that can be changed by configuring in STEP 7.

There are static and dynamic parameters

### **Parameter assignment**

Parameter assignment is the transfer of parameters from the IO controller/DP master to the IO device/DP slave.

### **Process image (I/O)**

The CPU transfers the values from the input and output modules to this memory area. At the start of the cyclic program, the CPU transfers the process image output as a signal state to the output modules. The CPU then reads the signal states of the input modules to the process image inputs. Next the CPU executes the user program.

### **Process image partition**

In a process image partition, you group input and output data according to its use in the program and assign the data to an OB.

### **PROFIBUS**

**Process Field Bus** - European Fieldbus standard.

### **PROFIBUS DP**

A PROFIBUS with DP protocol that acts in conformance with EN 50170. DP stands for decentralized peripherals (fast, real-time capable, cyclic data exchange). From the perspective of the user program, the distributed I/O is addressed in exactly the same way as the central I/O.

### **PROFINET**

Open component-based industrial communication system based on Ethernet for distributed automation systems. Communication technology promoted by the PROFIBUS User Organization.

### **PROFINET IO**

Communication concept for the realization of modular, decentralized applications within the scope of PROFINET.

PROFINET IO is based on switched Ethernet with full-duplex operation and a transmission bandwidth of 100 Mbps.

### **PROFINET IO system**

PROFINET IO controller with assigned PROFINET IO devices.

**Reaction time**

The reaction time in the case of cyclic or time-controlled program execution is the time between the detection of an input signal and the change of a connected output signal.

**RT**

PROFINET IO with **Real Time** communication (RT) is the optimal transmission method for time-critical applications in factory automation. PROFINET IO frames are prioritized over standard frames in accordance with IEEE802.1Q. This ensures the required determinism in the automation technology.

**Send clock**

Period between two consecutive intervals for IRT or RT communication. The send clock is the shortest possible transmission interval for the data exchange. If IRT is activated for an IO device, T\_DC is equal to the send clock.

**Slave**

A slave can only exchange data with a master after a request by the master.

→ *See also DP slave*

**STEP 7**

STEP 7 is an engineering system and includes programming languages for the creation of user programs for SIMATIC S7 controllers.

**Subnet**

Part of a network whose parameters must be coordinated for the devices (e.g. for PROFINET). A subnet includes the bus components and all connected devices. Subnets can be connected, for example, using gateways or routers, to form a network.

**T\_DC**

→ *See Send clock*

**User program**

SIMATIC differentiates between the operating system of the CPU and user programs. The user program contains all instructions and declarations as well as data for the signal processing that enable a plant or process to be controlled. The user program is assigned to a programmable module (e.g. CPU) and can be structured in smaller units.

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