SIEMENS

SIMATIC

High-precision input/output with Time-based IO

Function Manual

11/2019

A5E33454822-AC

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

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⚠ WARNING

indicates that death or severe personal injury **may** result if proper precautions are not taken.

⚠ CAUTION

indicates that minor personal injury can result if proper precautions are not taken.

NOTICE

indicates that property damage can result if proper precautions are not taken.

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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Ⓟ 11/2019 Subject to change

Preface

Purpose of the documentation

This function manual will support you when you use "Time-based IO" technology with the S7-1500, ET 200MP, and ET 200SP systems.

The documentation deals with the following topics:

- Using "Time-based IO" technology
- Functions of the "Time-based IO" technology
- Hardware and software requirements for "Time-based IO"
- Configuring the "Time-based IO" function with STEP 7 (TIA Portal)

Basic knowledge required

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

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Proficiency with STEP 7 (TIA Portal)
- Knowledge about isochronous mode

Scope of the documentation

The following documentation is valid for all components of the S7-1500, ET 200MP and ET 200SP systems that support the "Time-based IO" technology.

Conventions

The following terms are used as synonyms in this documentation:

- **TIO module**: This term is used as synonym for I/O modules of the type:
  - ET 200MP TM Timer DIDQ 16x24V
  - ET 200SP TM Timer DIDQ 10x24V
- **TIO_Time**: This term is used as synonym for the shared time base (relative time) of the TIO modules.
- **Jitter**: This is a general term that includes various time influences affecting accuracy. This means that:
  - for input data: Deviation of the measured time from the actual event.
  - for output data: Deviation of the actual switching time from the specified time.

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

Note

The notes contain important information on the product, handling the product or on part of the documentation to which particular attention should be paid.

Additional support

The range of technical documentation for the individual SIMATIC products and systems can be found on the Internet (http://www.siemens.com/simatic-tech-doku-portal).

For more information about configuration of Time-based IO, see the following FAQs in the Siemens Industry Online Support:

- Entry ID 109738186 (https://support.industry.siemens.com/cs/ww/en/view/109738186)
- Entry ID 109736374 (https://support.industry.siemens.com/cs/ww/en/view/109736374)

Additional information on isochronous mode is available in the Isochronous mode (http://support.automation.siemens.com/WW/view/en/49948856) and PROFINET with STEP 7 (https://support.industry.siemens.com/cs/ww/en/view/109755401) manuals.

Siemens Industry Online Support

You can find current information on the following topics quickly and easily here:

- **Product support**

  All the information and extensive know-how on your product, technical specifications, FAQs, certificates, downloads, and manuals.

- **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) and in the Information and Download Center (https://www.siemens.com/automation/infocenter).

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

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To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed under (http://www.siemens.com/industrialsecurity).

Table of contents

Documentation guide

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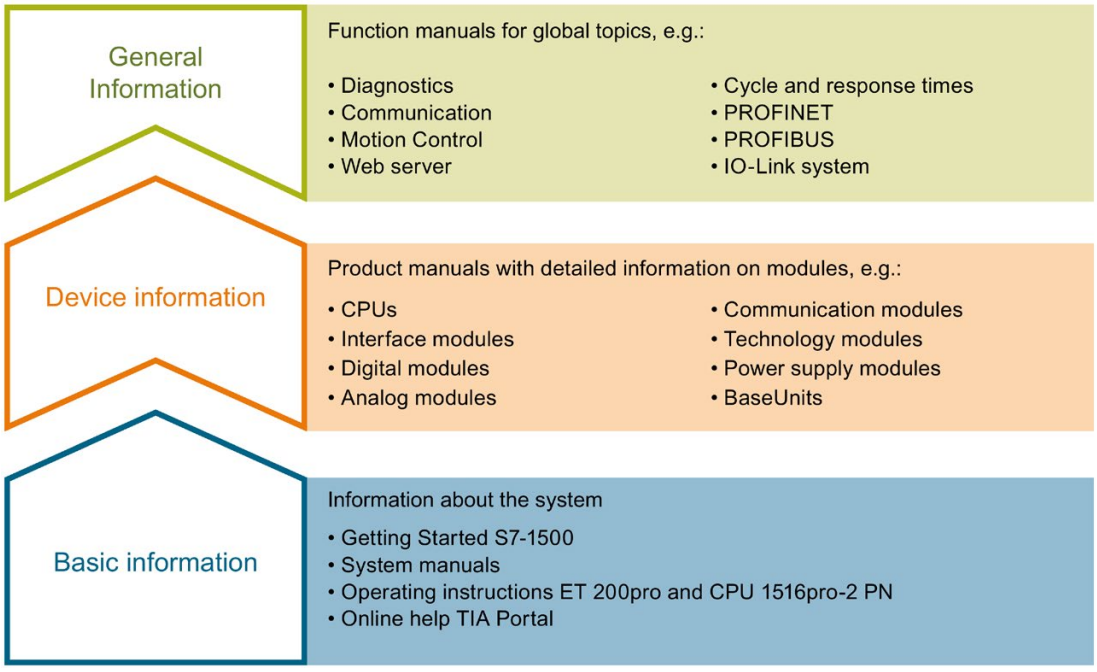
1.1 Guide to documentation function manuals

The documentation for the SIMATIC S7-1500 automation system, the CPUs 1513/1516pro-2 PN based on SIMATIC S7-1500, and 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 the CPUs 1513/1516pro-2 PN. The STEP 7 online help supports you in the 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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In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

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

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"mySupport" - CAx data

In the CAx data area of "mySupport", you can access the latest 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 (http://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 (http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool).

SIMATIC Automation Tool

You can use the SIMATIC Automation Tool to perform commissioning and maintenance activities simultaneously on various SIMATIC S7 stations as a bulk operation independent of TIA Portal.

The SIMATIC Automation Tool provides a multitude of functions:

- Scanning of a PROFINET/Ethernet system 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 the programming device/PC time converted to UTC time to the module
- Program download to CPU

- RUN/STOP mode switchover
- CPU localization by means of LED flashing
- Reading out of CPU error information
- Reading of the CPU diagnostics buffer
- Reset to factory settings
- Firmware update 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

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

- The topology overview automatically scans the 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 the optimal use of resources

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

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.
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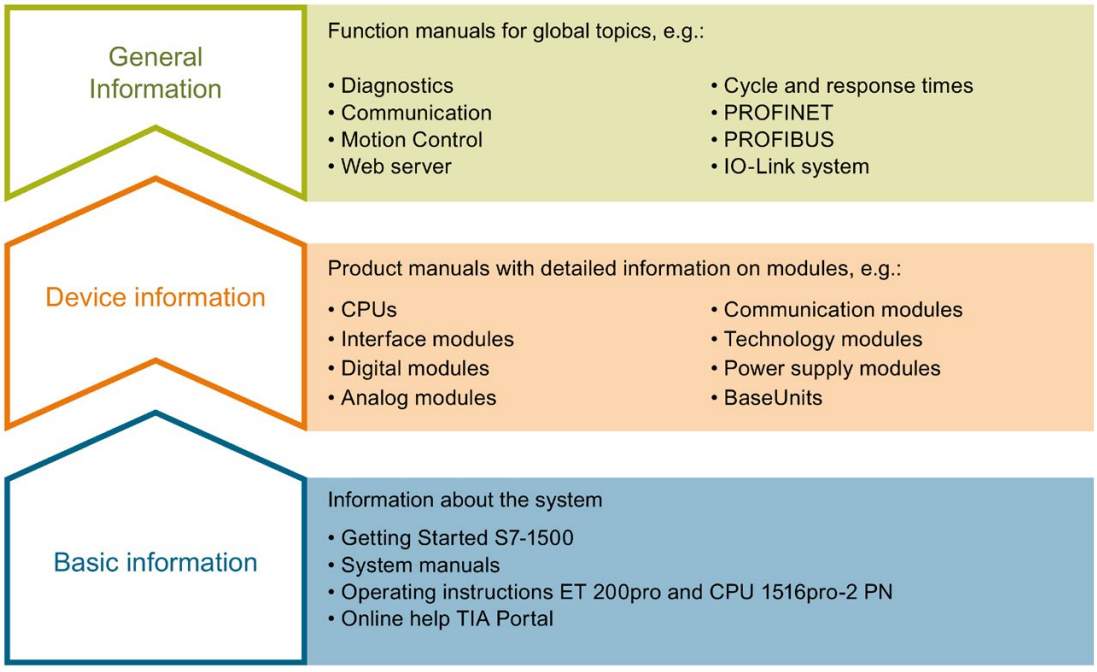

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Time-based IO basics

2

2.1 Using Time-based IO

Many processes in a plant require a relatively precise reproducibility as far as time is concerned. The reproducibility can be optimized to a limited extent by shorter CPU cycle times. The use of high-precision input/output with Time-based IO provides a more accurate reproducibility than the one that can be achieved by optimizing the CPU cycle time. An additional advantage of Time-based IO is the independence from the time scale of the application cycle.

Below is a selection of typical areas of application that can benefit from this technology.

Defined response times

An output signal that responds with a precise delay time that is independent of the application cycle can be output by adding a specified time to the time stamp of an edge at the digital input.

Length measurement

The length of a product passing by can be determined by the difference between two input time stamps and an associated travel speed.

Cam controller

The ongoing movement can be extrapolated from a synchronous position information (for example, from a counter module or an axis). Based on this result, the time of a switching position (cam position) is calculated and transferred to the TIO module (output). This way the switch event takes place at the required position.

Dosing

By specifying a switch-on and a switch-off edge to a time-controlled digital output, a valve can be opened for a specific time and the amount of liquid can be dosed accordingly.

2.2 Time behavior of Time-based IO

2.2.1 Time behavior of standard technology

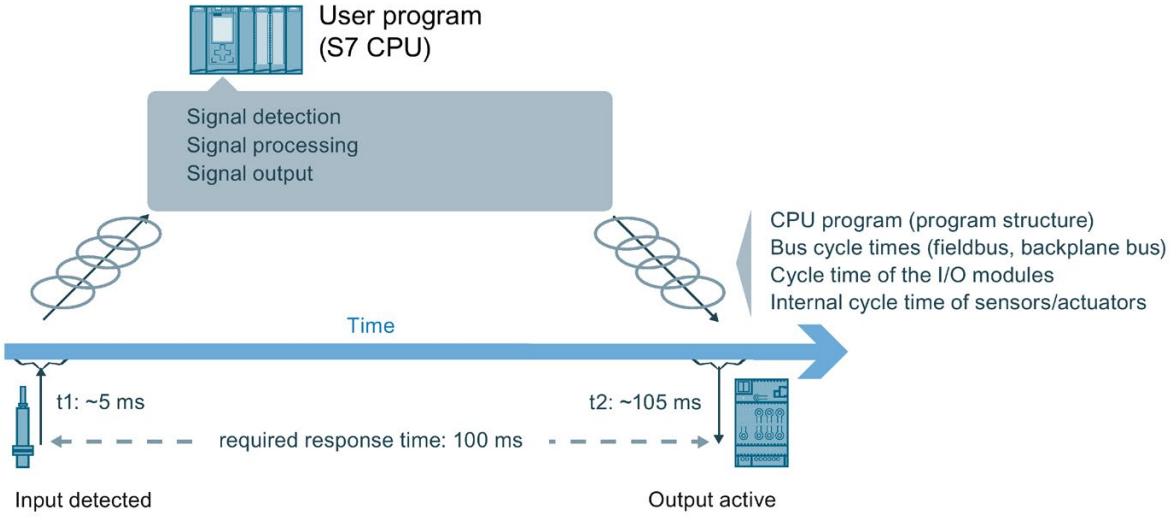
The time behavior of the inputs/outputs depends on the following factors for standard technology:

- CPU program (program structure)
- Bus cycle times (fieldbus, backplane bus)
- Cycle time of the I/O modules
- Internal cycle time of sensors/actuators

A deterministic statement as to

- when an input event (e.g., sensor signal) has taken place
- when the output event has an effect on the input event (e.g., output switches)

will become inaccurate due to the time factors listed above.

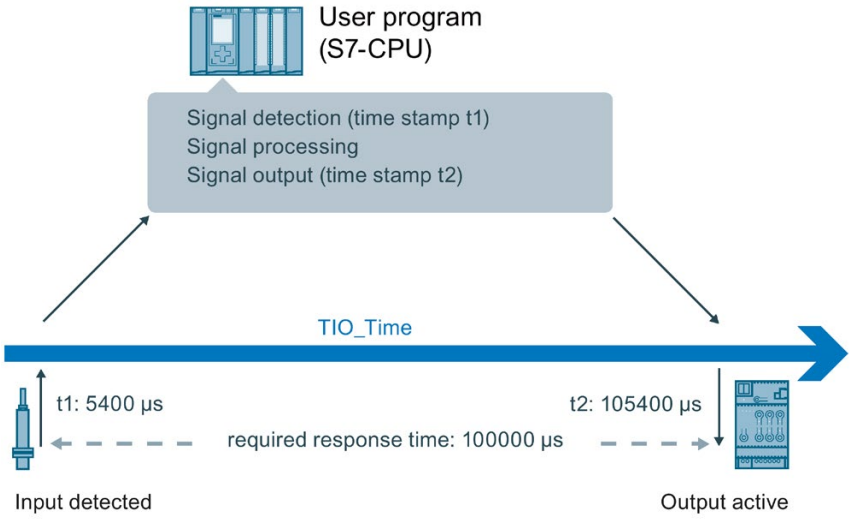


2.2.2 Time-based IO properties

Time-controlled I/O functionality

Time-based IO stands for time-based processing of I/O signals. All input signals are referred to one time (TIO_Time). The input signals receive the time stamp t1. After signal processing, the output event can also be linked with the TIO_Time and output at the required time. Output takes place at time t2.

Here an example for Time-based IO:



Independence and focus of Time-based IO

The shared time basis (TIO_Time) of all components involved is the basis for Time-based IO. By using TIO_Time, the accuracy of the output with Time-based IO does not depend on:

- CPU program (program structure)
- Bus cycle times (fieldbus, backplane bus)
- Cycle time of the I/O modules

The focus of Time-based IO is not on the I/O response time but on the predictability (determinism) of I/O signals. With Time-based IO, it is possible to respond to an input signal with an output signal within a defined time. Keep in mind the system-dependent minimum response time when using Time-based IO.

Time-based IO stands for:

- I/O functionalities executed with high precision
- I/O processes with time stamp

Accuracy

Accuracy is crucial for the performance capability of Time-based IO.

The accuracy is a property of the TIO modules and indicates the deviation with which the required response is achieved. For Time-based IO, the accuracy and reproducibility of the response is in the millisecond range.

Response time

In addition to a very high accuracy, a minimum response time to an input event can result depending on the configuration.

The response time is the time between the input event and the required output event.

For the minimum response time:

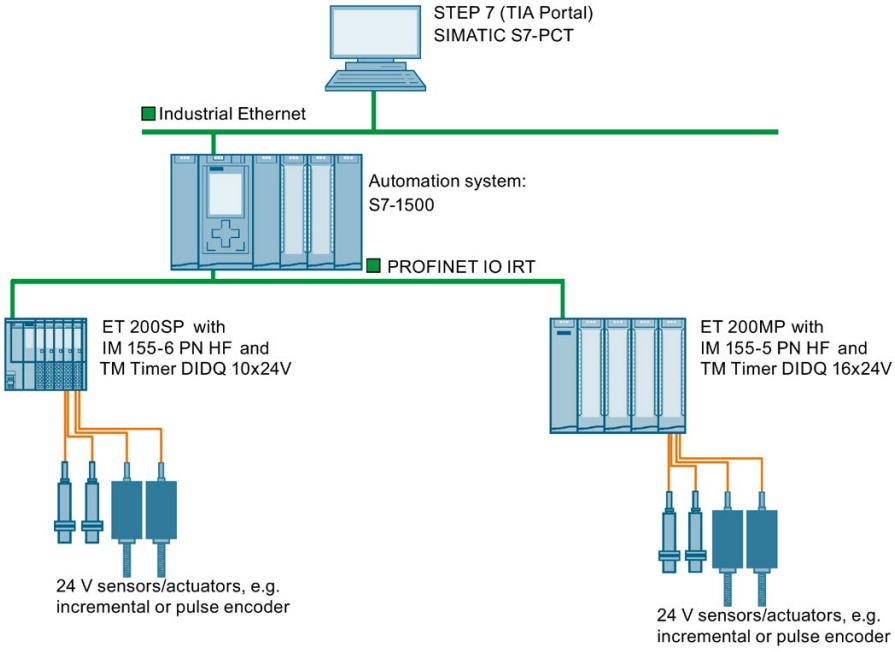
3 × application cycle T_{APP}

2.3 System environment

Introduction

Possible system configurations with PROFINET for the use of Time-based IO are shown below.

Use with STEP 7 (TIA Portal)



2.4 Hardware requirements

Introduction

The properties of the hardware components required for Time-based IO are listed below. You will also find specific modules as an example.

Requirements

Component	Properties	Examples
CPU	Isochronous mode/ PROFINET IO IRT: provides defines response time and high-precision plant behavior.	• CPU 1511-1 PN
ET 200 interface module	Supports isochronous mode	• ET 200SP with IM 155-6 PN HF (as of firmware V2.1) • ET 200MP with IM 155-5 PN HF
I/O module	TIO module	• ET 200SP: TM Timer DIDQ 10x24V • ET 200MP: TM Timer DIDQ 16x24V (as of firmware V1.0.1)

2.5 Configuration software requirements

Introduction

Below is a list of the software versions which support the "Time-based IO" function.

Requirements

Configuration software	Requirements	Supported hardware components	Additional information
STEP 7 (TIA Portal) V16 and above	PROFINET IO IRT or isochronous mode on the backplane bus	• S7-1500 automation system • ET 200SP and ET 200MP distributed I/O systems • TM Timer DIDQ 16x24V • TM Timer DIDQ 10x24V	STEP 7 (TIA Portal) online help

Additional information on isochronous mode is available in the Isochronous mode (http://support.automation.siemens.com/WW/view/en/49948856) and PROFINET with STEP 7 (https://support.industry.siemens.com/cs/ww/en/view/109755401) manuals.

TIO instructions

The TIO instructions are specific function blocks for use of Time-based IO. The following TIO instructions (Page 27) are available:

- TIO_SYNC
- TIO_DI
- TIO_DI_ONCE
- TIO_DQ

2.6 Technical implementation

Introduction

The information below will help you better understand the core aspects of Time-based IO and find out which SIMATIC functions are used to implement the described aspects.

Synchronization of involved modules (shared time basis)

The Time-based IO technology uses isochronous mode for all involved stations.

Isochronous mode enables multiple TIO modules to be synchronized to a shared time basis. The basis of the shared time basis for the TIO modules is the relative time TIO_Time.

Additional information on isochronous mode is available in the Isochronous mode (http://support.automation.siemens.com/WW/view/en/49948856) and PROFINET with STEP 7 (https://support.industry.siemens.com/cs/ww/en/view/109755401) manuals.

TIO_Time

The TIO_Time is the central time basis to which all time stamps refer.

TIO_Time has the following properties:

- Shared time basis for all TIO modules which are synchronized with the TIO instruction TIO_SYNC.
- The time starts counting again with each CPU startup.
- The TIO_Time has data type LTime (e.g. LT#14s830ms652us315ns).
- All valid time stamps refer to TIO_Time:
  - Input time stamps of the TIO modules are converted to the TIO_Time in the TIO instructions TIO_DI and TIO_DI_ONCE.
  - In the TIO instruction TIO_DQ, output time stamps are converted to the output time stamp of the TIO modules.
- The value of TIO_TIME corresponds to the current time with respect to TIO instructions and is updated with the call of TIO_SYNC. If you want an output to relate not to a previous input time stamp but to the current time, you can use the value of TIO_TIME as basis for the output time stamp. Example: Output of an edge in 20 ms: TIO_DQ.TimeStampRE=TIO_SYNC_DATA.TIO_TIME+LT#20ms)

TIO instructions in the isochronous OB

The TIO instructions must be called in a "Synchronous Cycle" or "MC-PostServo" OB.

You can find additional information in the chapter Programming (Page 27).

Note

The TIO instructions also support geared down isochronous mode. With a clock reduction ratio, the application cycle is longer than the send clock.

Note

The TIO instructions must be called in an "MC-PreServo" OB.

If you use an OB of the "MC-PostServo" type, you can decide separately for each TIO model whether it is used with Motion Control technology objects or with TIO instructions.

If you call the TIO instructions in an "MC-PostServo" type OB, you need to use the IPO model and also cannot use any reduction ratio.

Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.

Modes for updating the process image

In isochronous mode, you can influence the order of the update of the process image partition of the input and output data. In doing so, you can select the following program execution models:

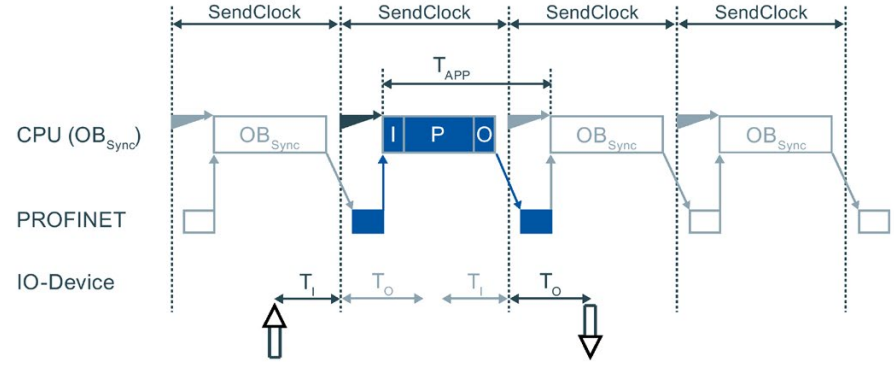
- IPO model (application cycle factor = 1)
- OIP model (application cycle factor >= 1)

The abbreviations I, P, O stand for the following processes: I = Input, P= Processing, O = Output.

Additional information on the application cycle factor is available in the PROFINET with STEP 7 (http://support.automation.siemens.com/WW/view/en/49948856) Manual.

IPO model (application cycle factor = 1)

The user program is started after the delay time. Start by updating the corresponding process image partition of the inputs in the user program by calling the SYNC_PI system instruction. Processing is started next (for example, calculation of the time stamps). The corresponding process image partition of the outputs is updated at the end of the user program in the CPU by SYNC_PO.



Transfer of inputs/outputs

T_{APP} Application cycle

Delay time

SYNC_PI SYNC_PO

SendClock Send clock

T_I Time for reading the input data

T_O Time until output of the output data

Time of read-in of the input data

Time of output of the output data

OB_{Sync} OB of type "Synchronous Cycle", "MC-PreServo" or "MC-PostServo"

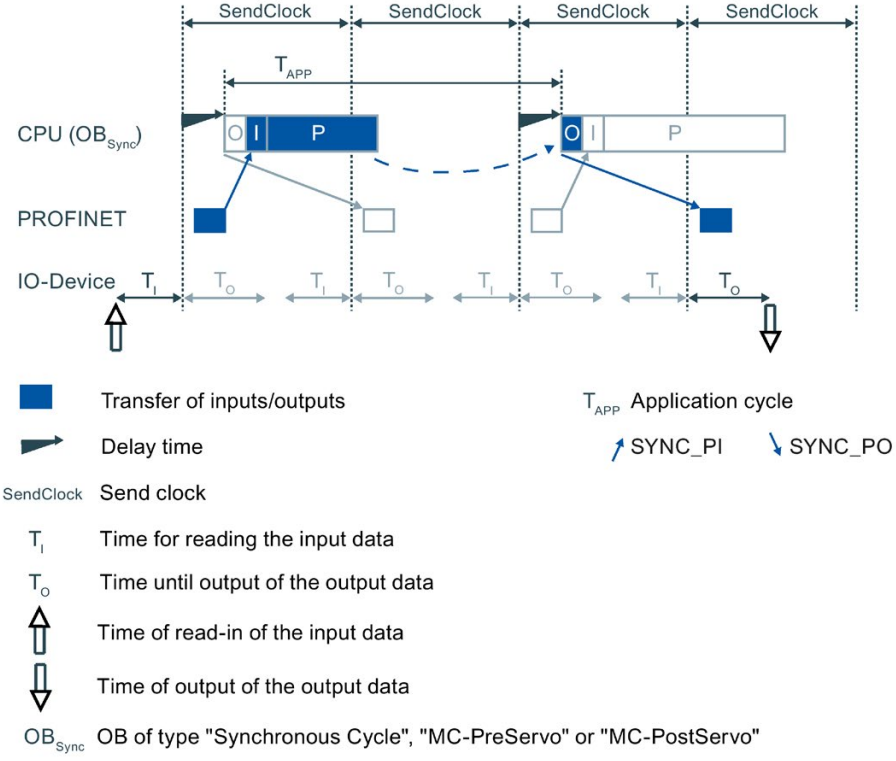
Properties of the IPO model:

- Supports shorter response times
- The application cycle must not be greater than the send clock.

  This gives the application less time than with the OIP model.

OIP model (application cycle factor >= 1)

The user program is started after the delay time. In PIP_Mode 0, the TIO_SYNC instruction updates the process image. In the other modes, you start by updating the corresponding process image partition of the outputs in the user program by calling the SYNC_PO system instruction. As a result, the output data that was calculated in the previous network cycle will become active during the next network cycle (T_O). Next the corresponding process image partition of the inputs is updated in the CPU by SYNC_PI. Processing starts after the data is transmitted (for example, calculation of the time stamps).



Properties of the OIP model:

- The response time is longer than with the IPO model.
- It is one application cycle longer than permitted by the send clock.
  This gives the application more time than with the IPO model.

Influence of accuracy

To estimate the accuracy you need the accuracy of

- TIO module
- Sensor/ actuator

Consult the data sheets of the respective module regarding the accuracy value.
You have to add the individual jitters of the TIO modules and the sensors/actuators. You can neglect any other influencing factors.

See also

Programming of Time-based IO (Page 28)

Configuring and parameter assignment 3

3.1 Requirements

Introduction

You need additional software components to use Time-based IO. You must also have created the standard configuration for your project.

Below you will learn more about the standard configuration for Time-based IO.

Requirements

In STEP 7 (TIA Portal):

- The project has been created.
- The CPU has been created and the parameters are assigned.
- Automation system and modules have been created and the parameters have been assigned.
- When using an ET 200 station: The connection has been created and the parameters are assigned via PROFINET.
- A "Synchronous Cycle" or "MC-PostServo" type OB has been created.

See also

System environment (Page 17)

Configuration software requirements (Page 19)

3.2 Settings for Time-based IO

Below you will find an overview of which settings have to be made for which components of Time-based IO.

Table 3- 1 Overview of settings for Time-based IO

Component	Where adjustable[1]	Properties to be set	Additional information
When using an ET 200 station: PROFINET subnet	Properties of the PROFINET subnet > sync domain	Create sync domain or edit properties of sync domain	• PROFINET function manual (http://support.automation.siemens.com/WW/view/en/49948856) • Online help in the STEP 7 (TIA Portal) information system
		Specify devices of the sync domain: • Specify CPU as sync master. • Specify ET 200 interface module as sync slave with RT class "IRT".	
S7-1500 station	Properties of the PROFINET interface > isochronous communication	Enable isochronous mode	• Function Manual Isochronous Mode (https://support.industry.siemens.com/cs/ww/en/view/109755401) • PROFINET function manual (http://support.automation.siemens.com/WW/view/en/49948856) • Manual Technology Module TM Timer DIDQ 16x24V (http://support.automation.siemens.com/WW/view/en/95153313) • Manual Technology Module TM Timer DIDQ 10x24V (http://support.automation.siemens.com/WW/view/en/95153951) • Online help in the STEP 7 (TIA Portal) information system
ET 200 station			
TIO module	Properties of the TIO module > I/O addresses	Enable isochronous mode	
	Properties of the TIO module > I/O addresses	Assign or create a "Synchronous Cycle" or "MC-PostServo" type OB	
	Properties of the TIO module > I/O addresses	Assignment of I/O addresses to the process image partition (e.g., PIP1)	
	Properties of the TIO module > Basic parameters	Configure "Module use from the user program"	
	Properties of the TIO module > Basic parameters/Channel parameters	For TM Timer DIDQ 10x24V: If required, assign parameters for Configuration "Use input/output individually"	
		Parameter assignment for use of Timer DI and Timer DQ	
Isochronous OB (Synchronous Cycle or MC-PostServo)	Properties of the Isochronous OB > Isochronous mode	Adjust application cycle, if necessary	

[1] Describes the topic area in the configuration software.

Setting for Time-based IO

If you have no special response time requirements, the following setting is suitable as a starting point:

- Send clock: 2 ms
- Application cycle: 4 ms
- Assignment to the process image partition: PIP1
- PIP_Mode: 0 (OIP model)

FAQ

For more information, see the following FAQs in the Siemens Industry Online Support:

- Entry ID 109738186 (https://support.industry.siemens.com/cs/ww/en/view/109738186)
- Entry ID 109736374 (https://support.industry.siemens.com/cs/ww/en/view/109736374)

See also

Programming of Time-based IO (Page 28)

Programming

4

4.1 Overview of instructions

Introduction

Time-based IO is used with special instructions (TIO instructions). The TIO_SYNC TIO instruction is responsible for synchronizing all involved TIO modules and creates a unique time basis (TIO_Time) to which all actions are referenced.

Additional instructions undertake the reading in of process input signals with associated time stamps and/or the time-controlled output of process output signals.

Note

The TIO instructions are helpful for general time-based IO applications. For special applications, such as cam controllers, there are also separate technology objects, for example, TO_CamOutput.

Note

The TIO instructions use the time stamp functions of the TIO modules. The other functions of the TIO modules can be used independently of the TIO instructions in applications.

TIO instructions

Instruction	Short description
TIO_SYNC	Synchronizes the TIO modules and provides the time basis for Time-based IO
TIO_DI	Detects the edges at the digital input (Timer DI) and supplies the associated time stamp
TIO_DI_ONCE	• Detects the edges at the digital input (timer DI) once and provides the associated time stamp • Controls a timer DI channel which is configured as an edge-triggered enable for another channel.
TIO_DQ	Outputs time-controlled edges at the digital output (Timer DQ)

4.2 Programming of Time-based IO

Introduction

To use Time-based IO, the TIO instructions must be called in an isochronous OB. The application can also run in another OB. This allows you to shorten the runtime of the isochronous OB.

You need the following TIO instructions according to the required task:

TIO module	TIO instructions
• TM Timer DIDQ 16x24V • TM Timer DIDQ 10x24V	• Per digital input, one TIO_DI or TIO_DI_ONCE for read-in • Per digital output, one TIO_DQ for output • One TIO_SYNC (for up to eight TIO modules)

This section below describes the programming of the CPU for Time-based IO.

Requirements

Hardware configuration in STEP 7 (TIA Portal):

- The TIO modules are assigned to an isochronous network.
- The TIO modules are assigned to a shared process image partition.
- The process image partition is assigned to an isochronous OB.
- The TIO modules are configured for use with instructions from the "Time-based IO" library.

Additional information on configuration of Time-based IO is available in the section Settings for Time-based IO (Page 25).

Procedure

1. Create a TIO instruction, TIO_SYNC, in the isochronous OB.
2. Connect all TIO modules to be synchronized at the TIO_SYNC TIO instruction using parameters HWID_1 to HWID_8.

   The HWID can be found in the hardware configuration under "Properties > System constants".

   Note

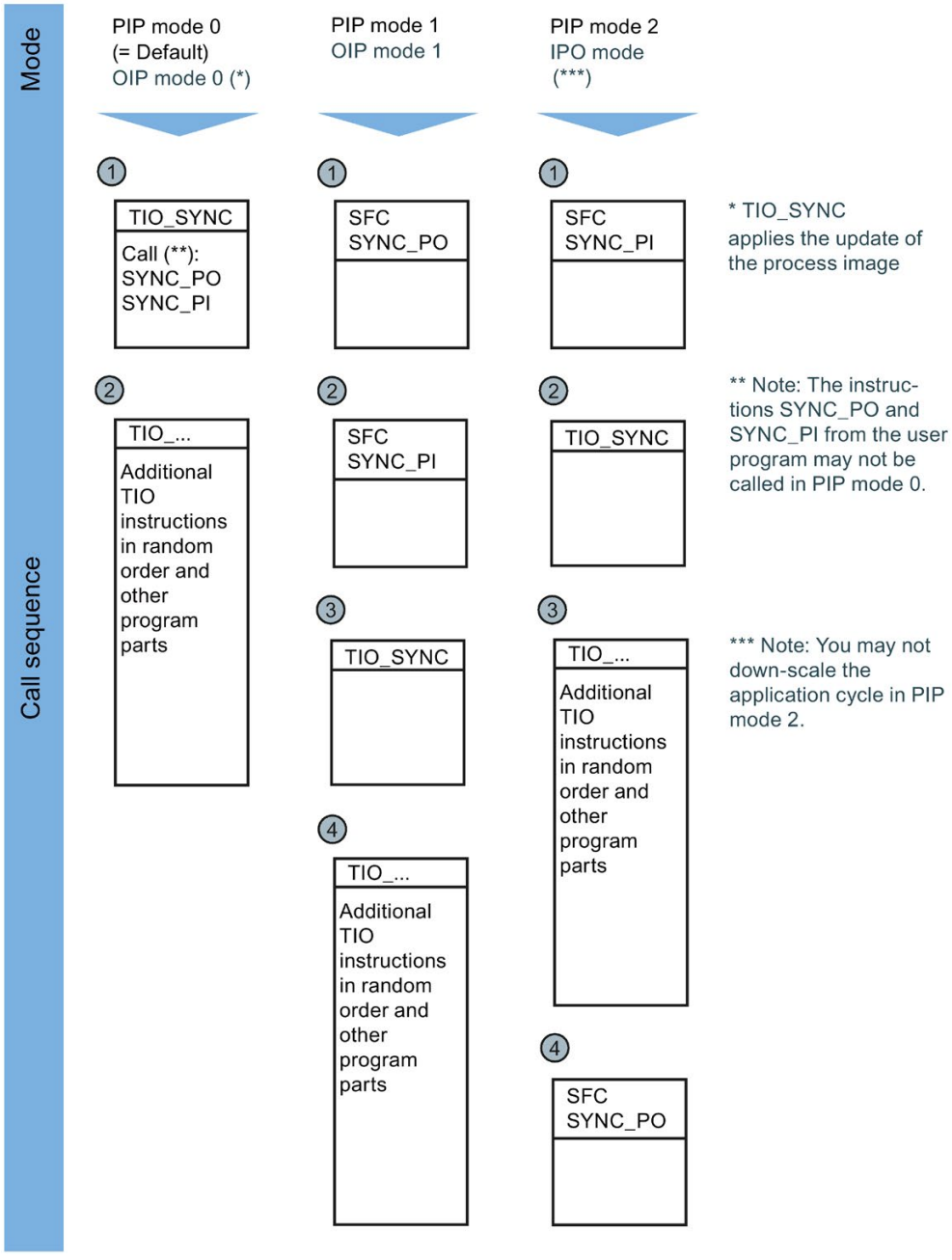
   Use of symbolic constants is generally preferred instead of absolute numerical values when interconnecting.

3. Set the data update mode at the TIO_SYNC instruction at the PIP_Mode input parameter.

   The description of the modes is available in the chapter Technical implementation (Page 20).

   The parameter assignment of the TIO_SYNC TIO instruction is complete.

4. For the following instructions, note the call sequence depending on the selected value for PIP_Mode:



5. Add the TIO instructions for read-in/output required for your application in the isochronous OB.
6. At the TIO instructions for read-in/output, interconnect in each case the input/output TIO_SYNC_Data with the same name output at the TIO_SYNC.
7. At the TIO instructions for read-in/output, assign parameters for the input parameters HWID (see "Properties > System constants" in hardware configuration) and Channel. The Time-based IO functionality is successfully programmed.

8. Interconnect the Time-based IO functionality with your application, such as evaluating the read-in time stamp in a step sequencer in another OB.
9. If TIO_SYNC does not automatically read out the send clock: Define the send clock manually, e.g. in OB100.
10. Compile and download the entire project to the CPU.

Result

You have completed programming the use of Time-based IO.

FAQ

For more information, see the following FAQs in the Siemens Industry Online Support:

- Entry ID 109738186 (https://support.industry.siemens.com/cs/ww/en/view/109738186)
- Entry ID 109736374 (https://support.industry.siemens.com/cs/ww/en/view/109736374)

4.3 Time-based IO

4.3.1 TIO_SYNC: Synchronizing TIO modules

Description

TIO_SYNC is the basis for all other TIO instructions. TIO_SYNC synchronizes TIO modules to a shared time basis TIO_Time.

You can synchronize up to 8 TIO modules with TIO_SYNC. All TIO modules must be assigned to the same process image partition (PIP). If you select "0" for the input parameter PIP_Mode, you assign the number of the process image partition at the PIP_PART input parameter.

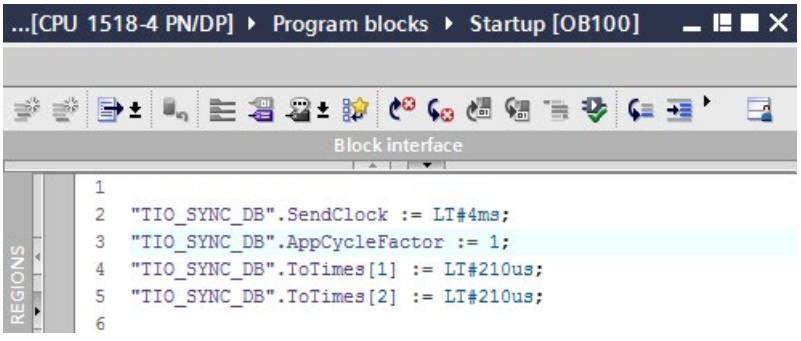
Additional information on configuration of Time-based IO is available in the Configuration and parameter assignment section.

Startup characteristics

At the startup of the CPU, the TIO_SYNC instruction receives and checks the input parameters once and initializes the TIO_Time.

You have several options for handling the optional parameters SendClock, AppCycleFactor and ToTimes:

- SendClock, AppCycleFactor and ToTimes can be read in automatically each time the system is started. This results in a time delay during startup, but the values are always consistent.
- Automatically read in SendClock, AppCycleFactor and ToTimes at each startup and apply the read-in values as set values during commissioning. This results in fast subsequent startups, but is inconsistent after changes in the hardware configuration (repeat commissioning necessary).
- Manually define SendClock, AppCycleFactor and ToTimes before the first call of the instruction, for example, in OB100:



This results in a fast startup, but you need to manually update the values after changes to the hardware configuration.

You will find information about the parameters in the table below.

If startup takes place without errors, the instruction changes to normal operation. In the event of an error, the instruction does not change to normal operation and generates an error message.

Functional description

In normal operation, the instruction ensures synchronization of all TIO modules configured at the HWID input.

The calculated TIO_Time for the instructions of the TIO modules is provided at the TIO_SYNC_Data output.

Reaction to error

The Error output indicates if the instruction was processed correctly. In the event of an error, the cause of the error is displayed at the Status output.

Parameter

The table below shows the parameters of the TIO_SYNC instruction.

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0	S7-1500		
HWID_1 ... HWID_8*	Input		HW_IO	65535	Hardware identifier for TIO module from hardware configuration
PIP_Mode*	Input		PIP	0	Mode for the data update**: • 0: OIP model with internal update of the process image by SYNC_PO and SYNC_PI. • 1: OIP model without internal update of the process image • 2: IPO model without internal update of the process image
PIP_PART*	Input		USInt	1	Only relevant if PIP_Mode = 0 Number of the process image partition which is to be updated isochronously.
TIO_SYNC_ Data	Output		"TIO_ SYNC_ Data"		Calculated system time for the TIO instructions of the TIO modules and internal data used for synchronization. See UDT TIO_SYNC_Data (Page 58).
Status	Output		DWord	16#0	Status of the instruction: see description of Status parameter
Error	Output		Bool	False	Error = True: An error has occurred. For detailed information see Status parameter. Error is reset as soon as the error is corrected.

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0	S7-1500		
OperatingState		Static	Int	0	Internal operating state of the instruction: • 0: Input parameters are checked • 1: Optional parameters are read out • 2: Read-out parameters are checked • 3: Normal operation (all parameters OK, TIO modules synchronized) As soon as operating state 3 is reached, time stamps can be read in and edges can be output. If you want to repeat the synchronization of the TIO modules and the readout of the optional parameters, you can set the operating state to 0.
SendClock	Input	Static	LTime	LT#0ns	Send clock of the sync domain. Apply the send clock from the PROFINET configuration.
AppCycle-Factor		Static	UInt	0	Application cycle factor: • Range of values: 0 <= AppCycleFactor <= 85 • 0: SendClock, AppCycleFactor and ToTimes are read in automatically The application cycle T_{APP} is calculated as follows: T_{APP} = AppCycleFactor × SendClock
ToTimes		Static	LTime array [1...8]	LT#0ns	T_o for each TIO module: Time for output of isochronous output data.

* Checked once at startup of the CPU

** The IPO model (PIP_Mode = 2) provides the shortest response times, but it also places the highest demands on system performance. Processing of all TIO instructions and other program sections must be completed within one send clock. Select the OIP model (PIP_Mode = 0) only if you use only *one* instance of the TIO_SYNC instruction per process image partition so that the SYNC_PI and SYNC_PO instructions are not called more than once in the isochronous OB. In addition, do not call SYNC_PI and SYNC_PO in the other program sections in the OIP model.

Note

The TIO instructions must be called in an "MC-PreServo" OB.

If you use an OB of the "MC-PostServo" type, you can decide separately for each TIO model whether it is used with Motion Control technology objects or with TIO instructions.

If you call TIO_SYNC in an "MC-PostServo" type OB, you need to use PIP_Mode = 2 and also cannot use any reduction ratio.

Status parameter

Error codes or status information is output as double word at the Status output.

The double word is divided as follows:

Error code (DW#16#...)	Meaning
z0yywwww	Error of a system function: • during startup (z = 1) • during normal operation (z = 0) System functions with subordinate use are coded in yy: See table with error codes. wwww specifies the RET_VAL of the system function. The error information is available in the help for the system function.
z0yy0000	An error that does not originate in a system function. This error receives a consecutive error number yy. The error can occur: • during startup (z = 1) • during normal operation (z = 0)

Table with error codes

Error code (DW#16#...)	Meaning	Solution
00000000	No error.	—
1001xxxx	An error has occurred with system function RD_SINFO. The low word xxxx displays the error information of the RET_VAL return value from RD_SINFO.	• Read the description of the RD_SINFO in the STEP 7 (TIA Portal) information system. • Make sure that TIO_SYNC is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10020000	The read cycle time of the isochronous OB is invalid (LT#0ms or negative). The instruction can only be used without errors in an isochronous OB.	• Correct the value of the cycle time. • Make sure that TIO_SYNC is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10030000	The TIO_SYNC instruction is not called in an isochronous OB. The instruction can only be used without errors in an isochronous OB.	Make sure that TIO_SYNC is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10040000	The assigned value at the PIP_Mode input parameter is outside the valid range of 0 to 2.	Correct the value at the PIP_Mode input parameter.
10050000	The configured send clock is outside the permitted range of 0 < SendClock <= 4 ms.	Correct the value of the send clock.
0006xxxx*	An error has occurred during execution of the SYNC_PI system function. The low word xxxx displays the error information of the RET_VAL return value from SYNC_PI.	Read the description of the SYNC_PI in the STEP 7 (TIA Portal) information system.
0007xxxx*	An error has occurred during execution of the SYNC_PO system function. The low word xxxx displays the error information of the return value RET_VAL from SYNC_PO.	Read the description of the SYNC_PO in the STEP 7 (TIA Portal) information system.

Error code (DW#16#...)	Meaning	Solution
10080000	At least one of the hardware identifiers does not belong to a TIO module.	Check the values of input parameters HWID_1 to HWID_8. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration.
10090000	HWID_1 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	Check the value of the respective input parameter. In each case, specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
100A0000	HWID_2 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100B0000	HWID_3 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100C0000	HWID_4 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100D0000	HWID_5 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100E0000	HWID_6 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100F0000	HWID_7 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
10100000	HWID_8 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
10110000	The value at input parameter PIP_PART is outside the valid range of 1 ... 31.	Correct the value at the PIP_PART input parameter.
10120000	The value "2" is configured at the input parameter PIP_Mode, while the value > 1 (reduction ratio) is configured at the static parameter AppCycleFactor.	Correct the value at the PIP_Mode input parameter. PIP_Mode with the value "2" does not allow a reduction ratio.
x0130000	MC-Servo (OB91) is not isochronous to the bus cycle time.	Correct the value of the cycle time of the MC-Servo to the value of the bus cycle time. Note: Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.
x014xxxx	An error has occurred when reading the data record. The low word xxxx indicates the error information of the instruction RDREC.	Read the description of the instruction RDREC in the STEP 7 (TIA Portal) information system.
x0FF0000	General internal error.	—

* Available only when "0" is selected for the input parameter PIP_Mode.

4.3.2 TIO_DI: Reading in edges at digital input and associated time stamps

Description

TIO_DI continuously detects the edges at a digital input of a TIO module and returns the associated time stamps.

Startup characteristics

During startup of the CPU, the instruction TIO_DI applies the input parameters once and checks the following:

- Checking HWID
- Checking to see if the number of the digital input (Channel) is in the permitted range (depending on addressed module and channel configuration)
- Checking TIO_SYNC_Data.ERROR: Is an error present at TIO_SYNC?
- Checking TIO_SYNC_Data.TO_TIMES for plausibility (0 ms to 4 ms)
- Checking to see whether the OB is isochronous

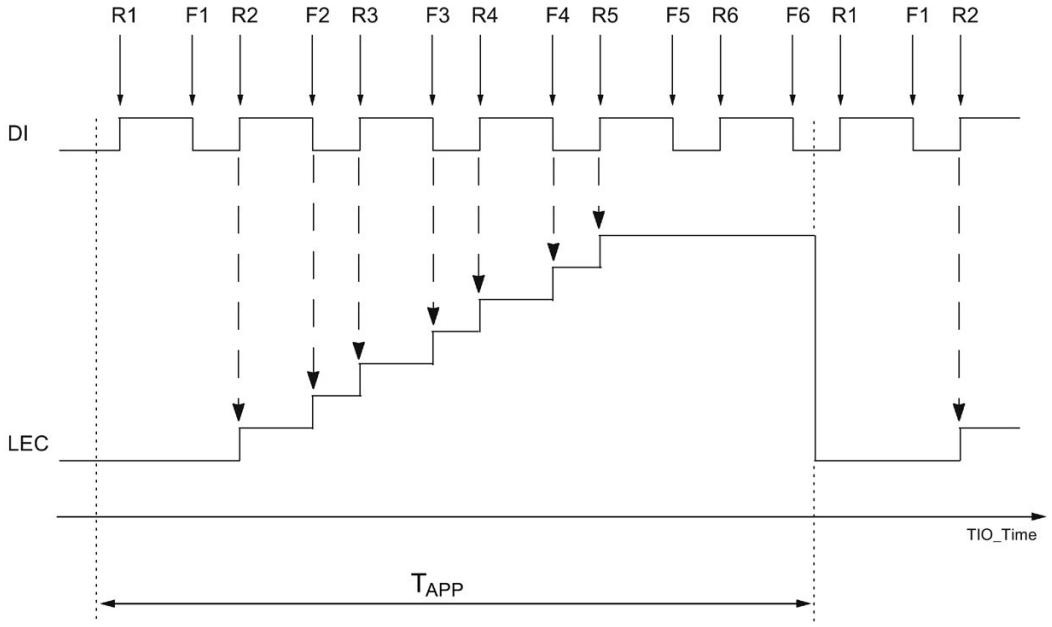
If startup takes place without errors, the instruction changes to normal operation. In the event of an error, the instruction does not change to normal operation and generates an error message.

Functional description

In normal operation, the instruction detects the edges at a digital input and the associated time stamps of the last valid, defined edge pair from the preceding isochronous cycle. Use the input parameter EdgeSel to determine the edges for which time stamps are detected.

You connect the input TIO_SYNC_Data with the output of the same name of the TIO_SYNC instruction. This ensures a shared time basis.

The following figure shows an example of the behavior of LEC when a read-in job is started with EdgeSel = 3 (rising and falling edge, order depending on occurrence).



T_{APP} Application cycle

Rn Specified times of a positive DI edge

Fn Specified times of a falling DI edge

The module can count a maximum of seven edges per application cycle. LEC = 7 means therefore that seven or more edges have been counted.

Reaction to error

The Error output indicates if the instruction was processed correctly. In the event of an error, the cause of the error is displayed at the Status output.

Parameter

The table below shows the parameters of the TIO_DI instruction.

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0	S7-1500		
HWID*	Input		HW_IO	0	Hardware identifier for TIO module from hardware configuration
Channel*	Input		UInt	0	Number (0 ... m) of the digital input of the connected TIO module
EdgeSel	Input		UInt	3	Specify the edges for which time stamps are detected: 0_D: Invalid 1: Two rising edges 2: Two falling edges 3: Rising and falling edge (order depending on occurrence) 4: First rising, then falling edge 5: First falling, then rising edge 6 to 255: Invalid EdgeSel can be changed during normal operation.
DI	Output		Bool	False	Status of digital input. If an inversion of the digital input is configured, this parameter is inverted as well.
TimeStampRE	Output		LTime	LT#0ns	Time stamp: Time at which a positive edge was detected. Exception: EdgeSel = 2: Time at which a falling edge has been detected (if *multiple* falling edges have occurred during the application cycle).
TimeStampFE	Output		LTime	LT#0ns	Time stamp: Time at which a falling edge was detected. Exception: EdgeSel = 1: Time at which a rising edge has been detected (if *multiple* rising edges have occurred during the application cycle).
EventCountRE	Output		UInt	0	Counter: Is incremented with each new, valid time stamp at a positive edge. The counter is reset with each CPU startup.
EventCountFE	Output		UInt	0	Counter: Is incremented with each new, valid time stamp at a falling edge. The counter is reset with each CPU startup.
LEC	Output		UInt	0	Counter: Number of edges for which no time stamp could be saved. The module can count a maximum of seven edges per application cycle. The counter is reset with each new application cycle.
Status	Output		DWord	16#0	Status of the instruction: see description of Status parameter

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0	S7-1500		
Error	Output		Bool	False	Error = True: An error has occurred. For detailed information see Status parameter. Error is reset as soon as the error is corrected.
TIO_SYNC_Data*	Input	InOut	"TIO_SYNC_Data"		System time provided for the TIO instructions of the TIO modules by the TIO_SYNC instruction. See UDT TIO_SYNC_Data (Page 58). Connect this input parameter with the "TIO_SYNC_Data" output parameter of the TIO_SYNC instruction.

* Checked once at startup of the CPU

Status parameter

Error codes or status information is output as double word at the Status output.

The double word is divided as follows:

Error code (DW#16#...)	Meaning
z0yywwww	Error of a system function: • during startup (z = 1) • during normal operation (z = 0) System functions with subordinate use are coded in yy: See table with error codes. wwww specifies the RET_VAL of the system function. The error information is available in the help for the system function.
z0yy0000	An error that does not originate in a system function. This error receives a consecutive error number yy. The error can occur: • during startup (z = 1) • during normal operation (z = 0)

Table with error codes

Error code (DW#16#...)	Meaning	Solution
00000000	No error.	—
10010000	The assigned number of the digital input at the Channel input parameter is outside the permitted range (depending on addressed module and channel configuration).	Correct the value at the Channel input parameter.
10020000	The TIO_DI instruction is not called in an isochronous OB. The instruction can only be used without errors in an isochronous OB.	Make sure that TIO_DI is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10030000	An error occurred when reading the HWID input parameter.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
x0040000	The data in TIO_SYNC_Data is invalid/incorrect.	Check the TIO_SYNC instruction and the interconnection of its TIO_SYNC_Data output.
1005xxxx	An error has occurred during execution of the RD_SINFO system function. The low word xxxx displays the error information of the RET_VAL return value from RD_SINFO.	• Read the description of the RD_SINFO in the STEP 7 (TIA Portal) information system. • Make sure that TIO_DI is called in a "Synchronous Cycle" or "MC-PostServo" OB.

Error code (DW#16#...)	Meaning	Solution
10060000	No TIO module found. Possible cause: The module configured using the hardware identifier is not a TIO module.	• Make sure that the configured module is a TIO module. • Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration.
10070000	An internal error occurred during the address calculation.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
00080000	TIO module is not synchronized using the TIO_SYNC instruction. The error code can also indicate that: • A job was already present before the first run of the instruction. • The assigned number at the Channel input parameter is not a digital input.	Check the instruction TIO_SYNC.
10090000	The read cycle time of the isochronous OB is outside the permitted range of 0 < T_{APP} <= 16 ms and is therefore invalid. The instruction can only be used without errors in an isochronous OB.	• Correct the cycle time. • Make sure that TIO_DI is called in a "Synchronous Cycle" or "MC-PostServo" OB.
100A0000	The time T_O of the TIO model stored in TIO_SYNC_Data is outside the permissible range of 0 < T_o <= 4 ms.	Check the instruction TIO_SYNC.
100Bxxxx	An error has occurred during execution of the RD_ADDR system function. The low word xxxx displays the error information of the RET_VAL return value from RD_ADDR.	Read the description of the RD_ADDR in the STEP 7 (TIA Portal) information system.
000C0000	The converted time stamp is invalid. Possible cause: Communication error	Check the communication with the TIO module.
000D0000	The Quality Information of the digital input indicates that an error has occurred at the digital input.	Check the supply voltage L+/1L+/2L+.
000E0000	The assigned number at the Channel input parameter is not a digital input configured as Timer DI.	• Check the channel configuration (only for TM Timer DIDQ 16x24V). • Check the operating mode of the digital input.
000F0000	The assigned value at the EdgeSel input parameter is outside the valid range of 1 to 5.	Correct the value at the EdgeSel input parameter.

Error code (DW#16#...)	Meaning	Solution
10100000	The send clock is outside the permitted range of 0 < SendClock <= 4 ms and is therefore invalid. The error code can also indicate that • The data in TIO_SYNC_Data is invalid or does not exist. • The TIO_DI instruction is not called in an isochronous OB.	Correct the send clock.
x0130000	MC-Servo (OB91) is not isochronous to the bus cycle time.	Correct the value of the cycle time of the MC-Servo to the value of the bus cycle time. Note: Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.
10140000	The configured value at the HWID input parameter is not present in the structure at the TIO_SYNC_Data parameter. The HWID and TIO_SYNC_Data parameters are not consistent.	Correct the value at the HWID input parameter or the structure at the TIO_SYNC_Data parameter.
x0FF0000	General internal error.	—

4.3.3 TIO_DI_ONCE: Reading in edges once at the digital input and associated time stamps

Description

TIO_DI_ONCE detects the edges at a digital input of a TIO module **once** and returns the associated time stamps. Alternatively, you can use this instruction to control a timer DI channel that is configured as an edge-triggered enable for another channel.

Startup characteristics

During startup of the CPU, the instruction TIO_DI_ONCE applies the input parameters once and checks the following:

- Checking HWID
- Checking to see if the number of the digital input (Channel) is in the permitted range (depending on addressed module and channel configuration)
- Checking TIO_SYNC_Data.ERROR: Is an error present at TIO_SYNC?
- Checking TIO_SYNC_Data.TO_TIMES for plausibility (0 ms to 4 ms)
- Checking to see whether the OB is isochronous

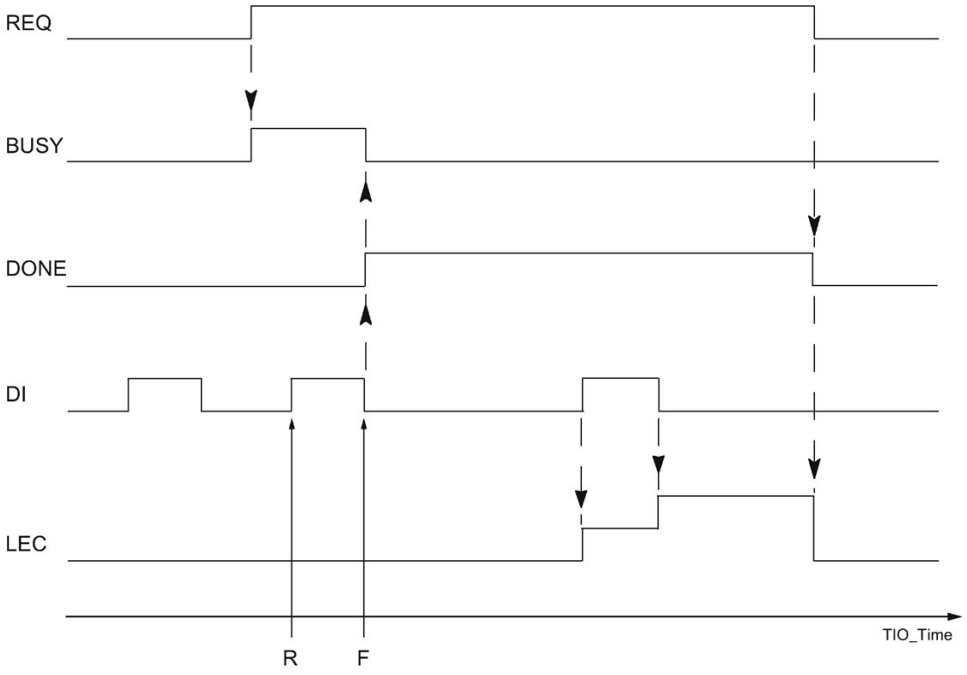
If startup takes place without errors, the instruction changes to normal operation. In the event of an error, the instruction does not change to normal operation and generates an error message.

Functional description: Time stamp detection

In normal operation, the instruction detects the edges at a digital input and the associated time stamps of the **first** valid, defined edge pair after the start of a read-in job. Use the input parameter EdgeSel to determine the edges for which time stamps are detected. To detect a new edge pair, a new positive edge is required at the REQ input parameter of the instruction.

You connect the input TIO_SYNC_Data with the output of the same name of the TIO_SYNC instruction. This ensures a shared time basis.

The figure below shows an example for the reaction of the bits DONE and BUSY at the start of a read-in job (EdgeSel = 4).



R Read-in time of the positive DI edge

F Read-in time of the falling DI edge

Functional description: edge-triggered enable

You can use this instruction to control a timer DI channel that is configured as an edge-triggered enable for another channel.

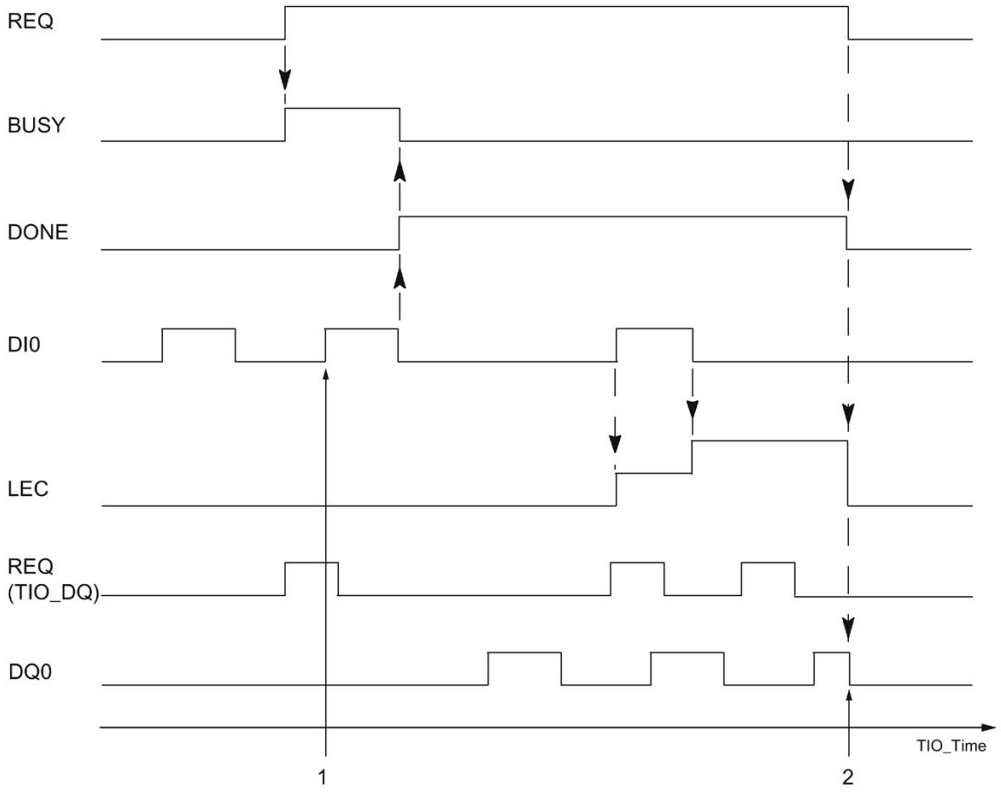
Example:

For a TIO module TM Timer DIDQ 10x24V, the following is configured in the hardware configuration for DQ0/DI0:

- Configuration DQ/DI group = timer DQ with enable
- HW enable by DI0 = edge-triggered
- DQ0 is not inverted

In this case, use the instruction TIO_DQ for DQ0 and the instruction TIO_DI_ONCE for DI0. You can control the enable by means of the input parameters REQ and EdgeSel of TIO_DI_ONCE. As soon as TIO_DI_ONCE has recorded a time stamp according to the value of EdgeSel, the enable is considered granted. You take the enable back by resetting REQ.

The following figure shows an example with EdgeSel = 4n (first positive, then falling edge). In this case the first valid positive edge at DI0 grants the enable for DQ0 after the start of a read-in job.



1 Start of enable at positive edge of enable input

2 End of enable when falling edge at REQ

If required, you can use the time stamps detected by the instruction for your application.

Reaction to error

The Error output indicates if the instruction was processed correctly. In the event of an error, the cause of the error is displayed at the Status output.

Parameter

The table below shows the parameters of the TIO_DI_ONCE instruction.

Parameter	Declaration	Data type S7-1500	Default	Description
REQ	Input	Bool	False	Starts the job at a positive edge.
HWID*	Input	HW_IO	0	Hardware identifier for TIO module from hardware configuration
Channel*	Input	UInt	0	Number (0 ... m) of the digital input of the connected TIO module
EdgeSel	Input	UInt	3	Specify the edges for which time stamps are detected: 0_D: Invalid 1: Two rising edges 2: Two falling edges 3: Rising and falling edge (order depending on occurrence) 4: First rising, then falling edge 5: First falling, then rising edge 6 to 255: Invalid If edge-triggered enable is used, the following also applies: 1: Enable at first positive DI edge 2: Enable at first falling DI edge 3: Enable at first DI edge 4: Enable at first positive DI edge 5: Enable at first falling DI edge EdgeSel can be changed during normal operation.
DONE	Output	Bool	False	DONE = True: The job was completed without errors.
BUSY	Output	Bool	False	BUSY = True: The job has not yet been completed.
Error	Output	Bool	False	Error = True: An error has occurred. For detailed information see Status parameter. Error is reset as soon as the error is corrected.
Status	Output	DWord	16#0	Status of the instruction: see description of Status parameter
DI	Output	Bool	False	Status of digital input. If an inversion of the digital input is configured, this parameter is inverted as well.
Time-StampRE	Output	LTime	LT#0ns	Time stamp: EdgeSel = 1: The last but one read-in time at which a positive edge was detected (if *multiple* positive edges have occurred). EdgeSel = 2: The last read-in time at which a falling edge was detected (if *multiple* falling edges have occurred). EdgeSel = 3; 4; 5: The last read-in time at which a falling edge was detected.

Parameter	Declaration	Data type S7-1500	Default	Description
Time-StampFE	Output	LTime	LT#0ns	Time stamp: EdgeSel = 1: The last read-in time at which a positive edge was detected (if *multiple* positive edges have occurred). EdgeSel = 2: The last but one read-in time at which a falling edge was detected (if *multiple* falling edges have occurred). EdgeSel = 3; 4; 5: The last read-in time at which a positive edge was detected.
LEC	Output	UInt	0	Counter: Number of edges for which no time stamp could be saved. The module can count a maximum of seven edges during REQ. The counter is reset with the falling edge at REQ.
TIO_SYNC_Data*	InOut	"TIO_SYNC_Data"		System time provided for the TIO instructions of the TIO modules by the TIO_SYNC instruction. See UDT TIO_SYNC_Data (Page 58). Connect this input parameter with the "TIO_SYNC_Data" output parameter of the TIO_SYNC instruction.
Initialized	Static	Bool	False	Instruction is initialized and ready

* Checked once at startup of the CPU

Status parameter

Error codes or status information is output as double word at the Status output.

The double word is divided as follows:

Error code (DW#16#...)	Meaning
z0yywwww	Error of a system function: • during startup (z = 1) • during normal operation (z = 0) System functions with subordinate use are coded in yy: See table with error codes. wwww specifies the RET_VAL of the system function. The error information is available in the help for the system function.
z0yy0000	An error that does not originate in a system function. This error receives a consecutive error number yy. The error can occur: • during startup (z = 1) • during normal operation (z = 0)

Table with error codes

Error code (DW#16#...)	Meaning	Solution
00000000	No error.	—
10010000	The assigned number of the digital input at the Channel input parameter is outside the permitted range (depending on addressed module and channel configuration).	Correct the value at the Channel input parameter.
10020000	The TIO_DI_ONCE instruction is not called in an isochronous OB. The instruction can only be used without errors in an isochronous OB.	Make sure that TIO_DI_ONCE is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10030000	An error occurred when reading the HWID input parameter.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
x0040000	The data in TIO_SYNC_Data is invalid/incorrect.	Check the TIO_SYNC instruction and the interconnection of its TIO_SYNC_Data output.
1005xxxx	An error has occurred during execution of the RD_SINFO system function. The low word xxxx displays the error information of the RET_VAL return value from RD_SINFO.	• Read the description of the RD_SINFO in the STEP 7 (TIA Portal) information system. • Make sure that TIO_DI_ONCE is called in a "Synchronous Cycle" or "MC-PostServo" OB.

Error code (DW#16#...)	Meaning	Solution
10060000	No TIO module found. Possible cause: The module configured using the hardware identifier is not a TIO module.	• Make sure that the configured module is a TIO module. • Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration.
10070000	An internal error occurred during the address calculation.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
00080000	TIO module is not synchronized using the TIO_SYNC instruction. The error code can also indicate that: • A job was already present before the first run of the instruction. • The assigned number at the Channel input parameter is not a digital input.	Check the instruction TIO_SYNC.
10090000	The read cycle time of the isochronous OB is outside the permitted range of $0 < T_{APP} <= 16$ ms and is therefore invalid. The instruction can only be used without errors in an isochronous OB.	• Correct the cycle time. • Make sure that TIO_DI_ONCE is called in a "Synchronous Cycle" or "MC-PostServo" OB.
100A0000	The time T_O of the TIO model stored in TIO_SYNC_Data is outside the permissible range of $0 < T_o <= 4$ ms.	Check the instruction TIO_SYNC.
100Bxxxx	An error has occurred during execution of the RD_ADDR system function. The low word xxxx displays the error information of the RET_VAL return value from RD_ADDR.	Read the description of the RD_ADDR in the STEP 7 (TIA Portal) information system.
000C0000	The converted time stamp is invalid. Possible cause: Communication error	Check the communication with the TIO module.
000D0000	The Quality Information of the digital input indicates that an error has occurred at the digital input.	Check the supply voltage L+/1L+/2L+.
000E0000	The assigned number at the Channel input parameter is not a digital input configured as Timer DI.	• Check the channel configuration (only for TM Timer DIDQ 16x24V). • Check the operating mode of the digital input.
000F0000	The assigned value at the EdgeSel input parameter is outside the valid range of 1 to 5.	Correct the value at the EdgeSel input parameter.

Error code (DW#16#...)	Meaning	Solution
10100000	The send clock is outside the permitted range of 0 < SendClock <= 4 ms and is therefore invalid. The error code can also indicate that • The data in TIO_SYNC_Data is invalid or does not exist. • The TIO_DI instruction is not called in an isochronous OB.	Correct the send clock.
x0130000	MC-Servo (OB91) is not isochronous to the bus cycle time.	Correct the value of the cycle time of the MC-Servo to the value of the bus cycle time. Note: Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.
10140000	The configured value at the HWID input parameter is not present in the structure at the TIO_SYNC_Data parameter. The HWID and TIO_SYNC_Data parameters are not consistent.	Correct the value at the HWID input parameter or the structure at the TIO_SYNC_Data parameter.
x0FF0000	General internal error.	—

4.3.4 TIO_DQ: Output edges time-controlled at the digital output

Description

TIO_DQ enables a digital output of a TIO module to be switched at specified times.

Startup characteristics

During startup of the CPU, the instruction TIO_DQ applies the input parameters once and checks the following:

- Checking HWID
- Checking to see if the number of the digital input (Channel) is in the permitted range (depending on addressed module and channel configuration)
- Checking TIO_SYNC_Data.Error: Is an error present at TIO_SYNC?
- Checking TIO_SYNC_Data.TO_TIMES for plausibility (0 ms to 4 ms)
- Checking to see whether the OB is isochronous

If startup takes place without errors, the instruction changes to normal operation. The input parameters REQ, Out_Mode, TimeStampRE and TimeStampFE can be changed during normal operation. In the event of an error, the instruction does not change to normal operation and generates an error message.

Functional description

The instruction outputs edges time-controlled at a digital output during normal operation.

- At the time defined at the TimeStampRE input parameter, a positive edge is output at the digital output.
- At the time defined at the TimeStampFE input parameter, a falling edge is output at the digital output.

Depending on the program execution model, a time stamp must exceed the following value:

Program execution model	TimeStampRE> ... TimeStampFE > ...
IPO model	TIO_Time + T_{APP} + T_O
OIP model	TIO_Time + T_{APP} + SendClock + T_O

Use the input parameter Out_Mode to determine if only one edge or both edges are output.

You connect the input TIO_SYNC_Data with the output of the same name of the TIO_SYNC instruction. This ensures a shared time basis.

You start an output job with a positive edge at the REQ parameter. You can only start a new job when there is no error pending and no job is active. When the output job is started, the digital output is switched at the times defined with TimeStampRE and TimeStampFE.

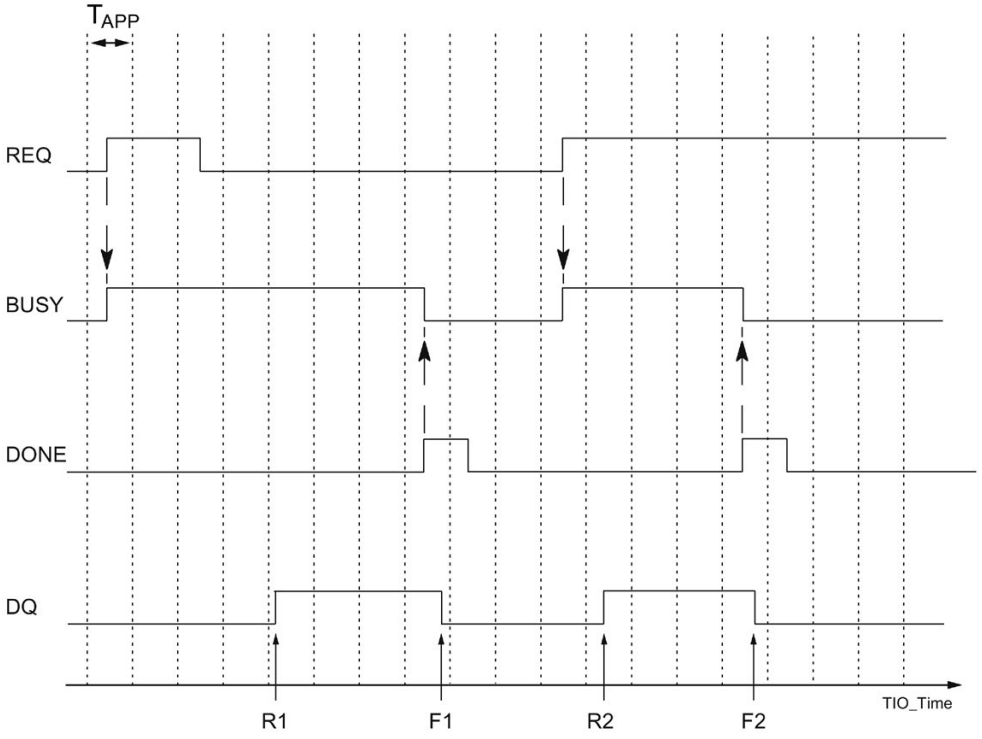
- If the digital output is already set at time TimeStampRE, the output job is not transferred to the module for the positive edge.
- If the digital output is not set at time TimeStampFE, the output job is not transferred to the module for the negative edge.

This means the digital output is not switched in both cases.

The job is done when the last application cycle is executed before the second output time is reached (DONE). Status and Error are constantly being updated during the job runtime. You can cancel an active output job by changing TimeStampRE or TimeStampFE to an invalid time stamp, e.g. LT#5µs.

The figure below shows an example for the reaction of the bits DONE and BUSY at the start of an output job under the following conditions:

- Out_Mode = 2 (both edges are output)
- The two time stamps are not changed between the start of the job and the output.



T_{APP}	Application cycle
R1, R2	Specified times of a positive DQ edge
F1, F2	Specified times of a falling DQ edge

Note

Once the job has been started with a positive edge at REQ, you can change the output times with a new input of TimeStampRE and TimeStampFE without having to restart the job.

Constraint:

If a changed time stamp is less than two application cycles before the output time (TimeStampRE - TIO_Time < 2*T_{APP} or TimeStampFE - TIO_Time < 2*T_{APP}), it is not taken into consideration. In this case, the last valid time stamp is used because it was already transferred to the TIO module.

Note

If you specify the same value for TimeStampRE and TimeStampFE, the instruction ignores the job and does not output an edge.

If you specify the value 0 for TimeStampRE or TimeStampFE, you can output the respective edge directly at the digital output with the input parameter Out_Mode = 3. This gives you the option to implement a direct control from the TIO module without time stamp in manual mode. You can use the direct control to interrupt an ongoing job.

Reaction to error

The Error output indicates if the instruction was processed correctly. In the event of an error, the cause of the error is displayed at the Status output.

Parameter

The table below shows the parameters of the TIO_DQ instruction.

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0	S7-1500		
REQ	Input		Bool	False	Starts the job at a positive edge.
HWID*	Input		HW_IO	0	Hardware identifier for TIO module from hardware configuration
Channel*	Input		UInt	0	Number (0 ... m) of the digital output of the connected TIO module
Out_Mode	Input		UInt	2	Specify the output mode for the edges at the digital output: 0: Only rising edge is output (TimeStampRE). 1: Only falling edge is output (TimeStampFE). 2: Both edges are output (TimeStampRE and TimeStampFE). 3: Each edge is output directly if TimeStampRE = 0 or TimeStampFE = 0 If both time stamps have the value "0" or if no time stamp has the value "0", no edge is output. 4 to 255: Invalid
TimeStampRE	Input		LTime	LT#0ns	Time stamp: Time when a positive edge is to be output.
TimeStampFE	Input		LTime	LT#0ns	Time stamp: Time when a falling edge is to be output.
StatusDQ	Output		Bool	False	Actual status of the digital output. If an inversion of the digital output is configured, StatusDQ is inverted as well. StatusDQ shows the internal state of the digital output independent of the effect of any configured HW enable.
DONE	Output		Bool	False	DONE = True is displayed for one cycle: The job was completed without errors.
BUSY	Output		Bool	False	BUSY = True: The job has not yet been completed.
Error	Output		Bool	False	Error = True: An error has occurred. In this case, BUSY and DONE are set to False. For detailed information see Status parameter. Error is reset as soon as the error is corrected.
Status	Output		DWord	16#0	Status of the instruction: see description of Status parameter
TIO_SYNC_Data*	Input	InOut	"TIO_SYNC_Data"		System time provided for the TIO instructions of the TIO modules by the TIO_SYNC instruction. See UDT TIO_SYNC_Data (Page 58). Connect this parameter with the TIO_SYNC_Data output parameter of the TIO_SYNC instruction.

* Checked once at startup of the CPU

Status parameter

Error codes or status information is output as double word at the Status output.

The double word is divided as follows:

Error code (DW#16#...)	Meaning
z0yywwww	Error of a system function: • during startup (z = 1) • during normal operation (z = 0) System functions with subordinate use are coded in yy: See table with error codes. wwww specifies the RET_VAL of the system function. The error information is available in the help for the system function.
z0yy0000	An error that does not originate in a system function. This error receives a consecutive error number yy. The error can occur: • during startup (z = 1) • during normal operation (z = 0)

Table with error codes

Error code (DW#16#...)	Meaning	Solution
00000000	No error.	—
10010000	The assigned number of the digital output at the Channel input parameter is outside the permitted range (depending on addressed module and channel configuration).	Correct the value at the Channel input parameter.
10020000	The TIO_DQ instruction is not called in an isochronous OB. The instruction can only be used without errors in an isochronous OB.	Make sure that TIO_DQ is called in an OB of the type "Synchronous Cycle" or "MC-PostServo".
10030000	An error occurred when reading the HWID input parameter.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
x0040000	The data in TIO_SYNC_Data is invalid/incorrect.	Check the TIO_SYNC instruction and the interconnection of its TIO_SYNC_Data output.
1005xxxx	An error has occurred during execution of the RD_SINFO system function. The low word xxxx displays the error information of the RET_VAL return value from RD_SINFO.	• Read the description of the RD_SINFO in the STEP 7 (TIA Portal) information system. • Make sure that TIO_DQ is called in a "Synchronous Cycle" or "MC-PostServo" OB.

Error code (DW#16#...)	Meaning	Solution
10060000	No TIO module found. Possible cause: The module configured using the hardware identifier is not a TIO module.	• Make sure that the configured module is a TIO module. • Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration.
10070000	An internal error occurred during the address calculation.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
x0080000	TIO module is not synchronized using the TIO_SYNC instruction. The error code can also indicate that: • A job was already present before the first run of the instruction. • The assigned number at the Channel input parameter is not a digital output.	Check the instruction TIO_SYNC.
10090000	The read cycle time of the isochronous OB is LT#0ms or has as negative value and is therefore invalid. Correct the value. The instruction can only be used without errors in an isochronous OB.	• Correct the cycle time. • Make sure that TIO_DQ is called in a "Synchronous Cycle" or "MC-PostServo" OB.
100A0000	The time T_O of the TIO model stored in TIO_SYNC_Data is outside the permissible range of $0 < T_o <= 4$ ms.	Check the instruction TIO_SYNC.
100Bxxxx	An error has occurred during execution of the RD_ADDR system function. The low word xxxx displays the error information of the RET_VAL return value from RD_ADDR.	Read the description of the RD_ADDR in the STEP 7 (TIA Portal) information system.
000C0000	One or both time stamps at the TimeStampRE and TimeStampFE input parameters are invalid. The error is only signaled for the duration of one application cycle.	Check the TimeStampRE and TimeStampFE input parameters.
000D0000	The Quality Information of the digital output indicates that an error has occurred at the digital output.	• Check the parameter assignment of the digital output. • Check the supply voltage L+/1L+/2L+. • Check the wiring of the digital output for short-circuit, overload, and overtemperature.
000E0000	The number configured at the Channel input parameter is not a digital output configured as Timer DQ.	• Check the channel configuration (only for TM Timer DIDQ 16x24V). • Check the operating mode of the digital output.
100F0000	The read cycle time of the OB of type "Synchronous Cycle" is too long: $T_{APP} > 16$ ms.	Configure a smaller multiple of the send clock as the cycle time.

Error code (DW#16#...)	Meaning	Solution
10100000	The send clock is outside the permitted range of 0 < SEND_CLOCK <= 4 ms and is therefore invalid. The error code can also indicate that • The data in TIO_SYNC_Data is invalid or does not exist. • The TIO_DQ instruction is not called in an isochronous OB.	Correct the send clock.
00110000	The assigned value at the Out_Mode input parameter is outside the valid range of 0 to 3.	Correct the value at the Out_Mode input parameter.
x0130000	MC-Servo (OB91) is not isochronous to the bus cycle time.	Correct the value of the cycle time of the MC-Servo to the value of the bus cycle time. Note: Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.
10140000	The configured value at the HWID input parameter is not present in the structure at the TIO_SYNC_Data parameter. The HWID and TIO_SYNC_Data parameters are not consistent.	Correct the value at the HWID input parameter or the structure at the TIO_SYNC_Data parameter.
x0FF0000	General internal error.	—

4.3.5 UDT TIO_SYNC_Data

Description

The data type UDT TIO_SYNC_Data contains the central structure and data for synchronization of the modules and passing of the TIO_Time.

Parameter

Parameter	Data type S7-1500	Description
TIO_TIME	LTime	Shared time basis (relative time) of the TIO modules
PIP_MODE	USInt	Mode for data update (is forwarded by the PIP_Mode input parameter of the TIO_SYNC instruction)
APP_CYC	LTime	Application cycle of the "MC-PostServo" or "Synchronous Cycle", "MC-PreServo" OB
SEND_CLOCK	LTime	Send clock of sync domain (is forwarded by the SendClock parameter of the TIO_SYNC instruction)
SYNC_MODULES	HW_IO array [1...8]	Hardware identifiers of the TIO modules from hardware configuration
TO_TIMES	UDInt-Array [1...8]	T_O for each TIO module:
TIO_TIME_BASE	LTime	Internal use
TBASE	LTime	
ERROR	Bool	

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