SIEMENS

EQUIPMENT MANUAL

SIMATIC

S7-1500

Technology Module TM MFP
6ES7558-1AA00-0AB0

support.industry.siemens.com

SIEMENS

SIMATIC

S7-1500
Technology Module TM MFP

Equipment Manual

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.

> ### ⚠ DANGER
>
> indicates that death or severe personal injury **will** result if proper precautions are not taken.

> ### ⚠ 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.

Proper use of Siemens products

Note the following:

> ### ⚠ WARNING
>
> Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

All names identified by ® are registered trademarks of Siemens Aktiengesellschaft. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Table of contents

Introduction 1

1.1 Purpose of the documentation

This equipment manual supplements the system manual of the S7-1500 Automation System/ET 200MP Distributed I/O System as well as the function manuals. The equipment manual contains a concise description of module-specific information. System-related functions are described in the system manual. Cross-system functions are described in the function manuals.

The information provided in this equipment manual and the system manual enables you to commission the TM MFP.

Basic knowledge required

To understand this documentation, knowledge of the following is required:

- Basics of software and automation engineering
- SIMATIC industrial automation system
- Working with STEP 7
- Working with Linux systems

Conventions

- STEP 7: To designate the configuration and programming software, this documentation uses "STEP 7" as a synonym for all versions of "STEP 7 (TIA Portal)".
- TM MFP: Multifunctional Platform technology module, or technology module for short

Also pay attention to the notes labeled as follows:

NOTE

A note contains important information on the product described in the documentation, on the handling of the product or on the section of the documentation to which particular attention should be paid.

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).

Recycling and disposal

For environmentally sustainable recycling and disposal of your old equipment, contact a certified electronic waste disposal service and dispose of the equipment according to the applicable regulations in your country.

1.2   Open Source Software

Open-source software is used in the firmware of the product described. Open Source Software is provided free of charge. We are liable for the product described, including the open-source software contained in it, pursuant to the conditions applicable to the product. Siemens accepts no liability for the use of the open source software over and above the intended program sequence, or for any faults caused by modifications to the software.
For legal reasons, we are obliged to publish the original text of the license conditions and copyright notices. Please read the information relating to this on the Internet.

1.3   Documentation guide

The documentation for the SIMATIC S7-1500 automation system and the ET 200MP distributed I/O system is arranged into three areas.
This arrangement enables you to access the specific content you require. Changes and supplements to the manuals are documented in a Product Information.
You can download the documentation free of charge from the Internet (https://support.industry.siemens.com/cs/ww/en/view/109742691).

Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC S7-1500 and ET 200MP systems.
The STEP 7 online help supports you in the configuration and programming.
Examples:
- Getting Started S7-1500
- S7-1500/ET 200MP System Manual
- Online help TIA Portal

Device information

Equipment manuals contain a compact description of the module-specific information, such as properties, wiring diagrams, characteristics and technical specifications.
Examples:
- Equipment Manuals CPUs
- Equipment Manuals Interface Modules
- Equipment Manuals Digital Modules
- Equipment Manuals Analog Modules
- Equipment Manuals Communications Modules
- Equipment Manuals Technology Modules
- Equipment Manuals Power Supply Modules

General information

The function manuals contain detailed descriptions on general topics relating to the SIMATIC S7-1500 and ET 200MPsystems.
Examples:

- Function Manual Diagnostics
- Function Manual Communication
- Function Manual Motion Control
- Function Manual Web Server
- Function Manual Cycle and Response Times
- PROFINET Function Manual
- PROFIBUS Function Manual

Product Information

Changes and supplements to the manuals are documented in a Product Information. The Product Information takes precedence over the device and system manuals.
You can find the latest Product Information on the S7-1500 and ET 200MP systems on the Internet (https://support.industry.siemens.com/cs/de/en/view/68052815).

Manual Collection S7-1500/ET 200MP

The Manual Collection contains the complete documentation on the SIMATIC S7-1500 automation system and the ET 200MP distributed I/O system gathered together in one file.
You can find the Manual Collection on the Internet.
(https://support.industry.siemens.com/cs/ww/en/view/86140384)

Manual Collection fail-safe modules

The Manual Collection contains the complete documentation on the fail-safe SIMATIC modules, gathered together in one file.
You can find the Manual Collection on the Internet.

SIMATIC S7-1500 comparison list for programming languages

The comparison list contains an overview of which instructions and functions you can use for which controller families.
You can find the comparison list on the Internet
(https://support.industry.siemens.com/cs/ww/en/view/86630375).

1.4 SIMATIC technical documentation

Additional SIMATIC documents will complete your information. You can find these documents and their use at the following links and QR codes.

The Industry Online Support gives you the option to get information on all topics. Application examples support you in solving your automation tasks.

Overview of the SIMATIC Technical Documentation

Here you will find an overview of the SIMATIC documentation available in Siemens Industry Online Support:

Industry Online Support International (https://support.industry.siemens.com/cs/ww/en/view/109742705)

Watch this short video to find out where you can find the overview directly in Siemens Industry Online Support and how to use Siemens Industry Online Support on your mobile device:

Quick introduction to the technical documentation of automation products per video (https://support.industry.siemens.com/cs/us/en/view/109780491)

YouTube video: Siemens Automation Products - Technical Documentation at a Glance (https://youtu.be/TwLSxxRQQsA)

Retention of the documentation

Retain the documentation for later use.

For documentation provided in digital form:

1. Download the associated documentation after receiving your product and before initial installation/commissioning. Use the following download options:
   – Industry Online Support International:
     The article number is used to assign the documentation to the product. The article number is specified on the product and on the packaging label. Products with new, non-compatible functions are provided with a new article number and documentation.
   – ID link:
     Your product may have an ID link. The ID link is a QR code with a frame and a black frame corner at the bottom right. The ID link takes you to the digital nameplate of your product. Scan the QR code on the product or on the packaging label with a smartphone camera, barcode scanner, or reader app. Call up the ID link.

2. Retain this version of the documentation.

Updating the documentation

The documentation of the product is updated in digital form. In particular in the case of function extensions, the new performance features are provided in an updated version.

1. Download the current version as described above via the Industry Online Support or the ID link.
2. Also retain this version of the documentation.

mySupport

With "mySupport" you can get the most out of your Industry Online Support.

Registration	You must register once to use the full functionality of "mySupport". After registration, you can create filters, favorites and tabs in your personal workspace.
Support requests	Your data is already filled out in support requests, and you can get an overview of your current requests at any time.
Documentation	In the Documentation area you can build your personal library.
Favorites	You can use the "Add to mySupport favorites" to flag especially interesting or frequently needed content. Under "Favorites", you will find a list of your flagged entries.
Recently viewed articles	The most recently viewed pages in mySupport are available under "Recently viewed articles".
CAx data	The CAx data area gives you access to the latest product data for your CAx or CAe system. You configure your own download package with a few clicks: • 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" on the Internet. (https://support.industry.siemens.com/My/ww/en)

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 can find the application examples on the Internet.
(https://support.industry.siemens.com/cs/ww/en/ps/ae)

Industrial Cybersecurity

2

2.1 Introduction to industrial cybersecurity

Due to the digitalization and increasing networking of machines and industrial plants, the risk of cyber attacks is also growing. Appropriate protective measures are therefore mandatory, particularly in the case of critical infrastructure facilities.

Refer to the System Manual (https://support.industry.siemens.com/cs/us/en/view/59191792) for general information and measures regarding industrial cybersecurity.

This section provides an overview of security-related information pertaining to your SIMATIC device.

NOTE

Security-relevant changes to software or devices are documented in the section "New functions (Page 14)".

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

In order to protect plants, systems, machines, and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial cybersecurity concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For more information on protective industrial cybersecurity measures for implementation, please visit (https://www.siemens.com/industrialsecurity).

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customers' exposure to cyber threats.

To stay informed about product updates at all times, subscribe to the Siemens Industrial Cybersecurity RSS Feed under (https://www.siemens.com/cert).

2.2 Cybersecurity-relevant information

Note all cybersecurity-relevant information.

Topics with cybersecurity-relevant information	Reference
Operational application environment and security assumptions	
Requirements for the operational application environment of the system and security assumptions	This section is found in the System Manual (https://support.industry.siemens.com/cs/us/en/view/59191792).
Area of application	You can find the section Area of application (Page 15) in this Equipment Manual.
Security properties of the product	
Access protection Physical protection: • You can protect the CPU against unauthorized access by locking the front flap. Password protection	Information on locking and on password protection can be found in this Equipment Manual in the section Operator controls and display elements (Page 19). Also note the information on the topic of access protection in the Protection section of the System Manual (https://support.industry.siemens.com/cs/us/en/view/59191792).
Secure operation	
Corrective measures for known risks	Corrective measures for known risks are announced on the Siemens ProductCERT web page (https://www.siemens.com/cert). For more information on SIEMENS ProductCERT, refer to the System Manual (https://support.industry.siemens.com/cs/us/en/view/59191792).
Security checks	Application-specific security measures such as cyclic checks of the configuration via checksums are described in the System Manual (https://support.industry.siemens.com/cs/us/en/view/59191792).
Recording Security events	Information on recording security events can be found in the "Safe operation of CPUs" section of the System Manual (https://support.industry.siemens.com/cs/us/en/view/59191792).
Secure decommissioning Products that contain security-relevant data must be securely decommissioned before disposal or resale.	You can find information on safe decommissioning in the "Secure operation of the system" section of the System Manual (https://support.industry.siemens.com/cs/us/en/view/59191792).

Module-specific security information

The TM MFP is equipped with two Ethernet ports and is intended for use within an intranet or in networks without direct Internet access. Use the device behind a firewall.

With the default setting, the ufw firewall has been enabled and only port 22 is open. We recommend only opening ports that are necessary for system operation. Use of an ufw firewall is described in section Uncomplicated Firewall (Page 41) (ufw).

It is recommended that the need-to-know principle be applied and that the number of persons that have access to the device and are able to connect directly or via SSH be limited. For the SSH connection, authentication with public key and a password-protected SSH key is preferred.

The root user is disabled by default. MFP users can use temporary administrator rights with the sudo command.

The user password, including the root password, must be long enough and complex enough to minimize security risks. Passwords must be handled carefully and should not be divulged.

Follow the principle of least privilege in order to minimize security risks.

The system has been configured to receive security patches from the Debian community over the Internet. Updates can be performed manually and should be done regularly. For more information, refer to the section Installing and updating software (Page 23).

The operating system has been equipped with a clamAV virus scanner. The database can be updated online (via the Internet) or offline by copying the database file. We recommend that the virus database be kept up-to-date and that a virus scan be run regularly.

The umask default value has been set to 077. This means that files can be read, written and executed by their owner (the person who created them). Other users or groups cannot read, write or execute these files.

TM MFP has been equipped with PTT (Platform Trust Technology). It is recommended that PTT be used for secure storage of customer certificates. You can use PTT from the operating system via tmp2 tools.

The user has full control over the internal SSD memory. The user is responsible for maintaining free capacity for system purposes, i.e. logging.

Ensure that all connected I/O devices comply with standards (USB3, Ethernet, DisplayPort).

Use of Ethernet interfaces

The TM MFP Ethernet interfaces and the services contained therein are designed exclusively for communication in an access-protected area of your system.

Connecting the TM MFP Ethernet to a cloud or a device outside of this access-protected area poses a security risk. Establish communication with external cloud services or devices using security mechanisms, e.g. a firewall.

Reference

Also observe the information on running security updates in section Installing updates (Page 31).

Product overview

<div style="text-align:right; font-size:3em; font-weight:bold;">3</div>

3.1 New functions

This section contains an overview of the most important new functions as compared to the previous version.

New functions of the TM MFP

New functions	Contents	More information
Network settings	e.g. information on the Network Manager system service	More information is available here (Page 37).
Time synchronization	e.g. information on the automatic time synchronization of the TM MFP with the CPU S7-1500 via backplane bus	More information is available here (Page 41).
Backplane bus	Improved performance of backplane bus communication: TM MFP establishes a communication channel between the user area of the operating system and the backplane bus of the CPU S7-1500. For TM MFP V1.0, the D-Bus service of the Linux environment was used to connect the user program with the backplane bus endpoint supplied by Siemens. The new function replaces D-Bus with a shared memory-based approach.	More information is available here (Page 43).
Diagnostics and alarms	Introduction of diagnostics and alarm functions for TM MFP V1.1: With the diagnostics function, TM MFP system data, e.g. hard disk usage and system temperatures, is collected and the messages are evaluated based on the preset threshold values. When the threshold value is exceeded, diagnostics events are sent to the CPU: Incoming events to set the error and outgoing events to reset it. The diagnostic events are indicated by the status LEDs of the TM MFP. Hardware interrupts can be triggered within the user program on the TM MFP. If a hardware interrupt is triggered in the TM MFP user program, it is forwarded to the master CPU via the backplane bus. The hardware interrupt is processed there by a specific interrupt OB according to the user requirements.	More information is available here (Page 56).

3.2 Area of application

The TM MFP (Multifunctional Platform technology module) is a module for IT applications in automation engineering, meaning for applications that directly evaluate and further process data and information from the CPU but are not directly integrated into the actual control task.

The technology module enables processing of data of connected sensors, e.g. of cameras and robot systems, and data from the user program of the CPU. The Linux-based operating system SIMATIC Industrial OS (IndOS) has been pre-installed on the TM MFP.

Die Graphics Processing Unit (GPU) of the built-in processor is able to run and accelerate AI routines. This enables fast and efficient processing of large amounts of data and optimization of processes.

The technology module supports Docker software (not pre-installed by default) for loading software and algorithms, for example, into the TM MFP in the form of bins

For configuring the technology module, use:

- TIA Portal as of V19
- Hardware Support Package HSP TM MFP

The TM MFP supports applications programmed in high-level languages C, C++ and Python for protocol converters, database connections, complex algorithms and integration of optical systems.

3.3 Hardware properties

Article number

6ES7558-1AA00-0AB0

View of the module

The figure below shows the TM MFP.

Figure 3-1 TM MFP

Properties

The TM MFP has the following technical properties:

- Connection to the CPU via the backplane bus or Ethernet for processing data from the CPU and the CPU user program
- Compatibility with S7-1500 CPUs (standard CPUs, compact CPUs, F-CPUs and T-CPUs) as of version V2.5
- Industrial Ethernet interface interfaces (X1 PN/IE and X2 PN/IE)
- USB 3.0 interfaces (X60 and X61)
- DisplayPort DPP (X70)
- Power supplied over the backplane bus from the system power supply
  The nominal power consumption of the TM MFP is 25 W. We recommend using the TM MFP with a Siemens power supply that supplies power to all modules on the rack.

NOTICE

Ensure that the TM MFP does not consume more than 25 W and that the supply of the other modules on the rack is not adversely affected.

- 4-core processor (Intel Atom® E3940; 1.6 GHz)
- Mass storage (128 GB SSD)

NOTE

To increase performance, the TM MFP operating system can write files to the SSD memory with a delay. To ensure that data is written to the memory, you should synchronize all cache areas to persistent memory before switching the module off and back on or rebooting.

- Work memory (8 GB RAM)

Supported cameras

The TM MFP currently supports the following camera systems:

- IDS Ensenso N35 and uEye color image camera for productive use
- Intel RealSense L515/D415/D435 for development and test purposes

You can find manufacturer documentation for the recommended camera systems here:

- Ensenso (https://www.ensenso.com/manual/3.4/about/index.html)
- Intel RealSense (https://www.intel.com/content/www/us/en/homepage.html)

Accessories

The following accessories are supplied with the technology module and can also be ordered as replacement parts:

- U-connector (6ES7590-0AA00-0AA0)
- Front flap (6ES7528-0AA60-7AA0)

You can find more information on the accessories and their article numbers in the system manual (http://support.automation.siemens.com/WW/view/en/59191792).

3.4 Firmware functions

Functions

The TM MFP has the following integrated functions:

- Pre-installed and configured Linux-based operating system SIMATIC Industrial OS
- Communication between the TM MFP and CPU via I/O communication on the backplane bus, TCP, UDP, Web API, OPC UA API (Web API/OPC UA API not included in the scope of delivery)

In addition, the TM MFP allows applications for connection and implementation of:

- Cloud systems
- Robot systems
- Optical systems
- Artificial intelligence (AI)
- High-level languages C, C++ and Python
- MathWorks MATLAB

3.5 Operator controls and display elements

3.5.1 Front view without front flap

The following figure shows the front view of the TM MFP without the front flap.
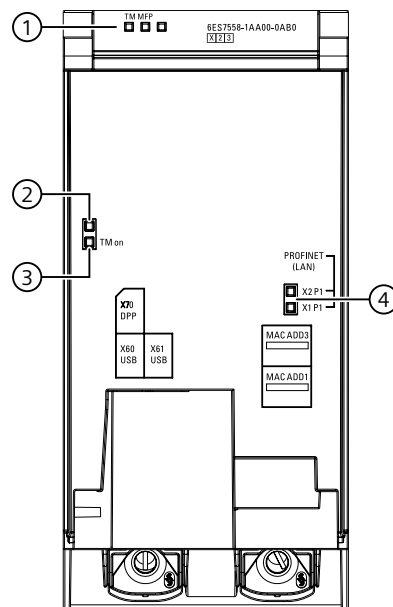
  ①   LED displays for the current operating state and diagnostics status of the TM MFP
  ②   LED has no function
  ③   LED display of the operating voltage
  ④   LED displays for Industrial Ethernet interfaces X1 and X2

Figure 3-2 Front view

Mounting and connecting

<div align="right">

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4.1 Mounting and connecting the TM MFP

Mounting and connecting the TM MFP

In order to operate a centrally-configured TM MFP within the S7-1500 system, you need at least the following components:

- System power supply
  The system power supply (PS) has a connection to the backplane bus and supplies the connected modules with the internal supply voltage.
- S7-1500 CPU (standard CPU, compact CPU, F-CPU or T-CPU) as of version V2.5
  The CPU establishes the communication connection to the TM MFP over the backplane bus.

You can find information regarding installation of the mounting rail, the order in which modules are mounted and connection of the individual modules in the system manual (http://support.automation.siemens.com/WW/view/en/59191792).

Interfaces

The figure below shows the position of the interfaces on the underside of the TM MFP.
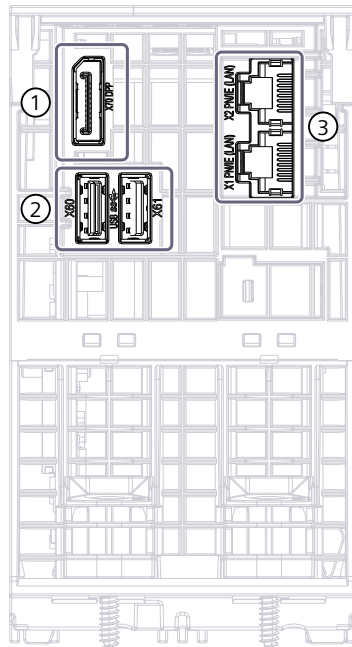
① DisplayPort DPP X70
② USB 3.0 interfaces X60 and X61
③ Industrial Ethernet interfaces X1 and X2

Figure 4-1   Bottom view

Industrial Ethernet interfaces X1 and X2

You can use the X1 and X2 interfaces to connect other devices to the TM MFP via Industrial Ethernet with a maximum data transfer rate of 1 Gbps full-duplex.

USB 3.0 interfaces X60 and X61

You can use the USB interfaces to connect other devices, such as a USB keyboard or USB camera, to the TM MFP.

The USB 3.0 interface has been implemented with a Type A port. The plug connector is not equipped with a strain relief. Provide strain relief for the USB cable using a 2.5 mm-wide cable tie.

Connect only sensors and cables in which shield and ground signal are galvanically isolated to the USB interface.

4.2 Schematic circuit diagram

The figure below shows the schematic circuit diagram of the TM MFP.
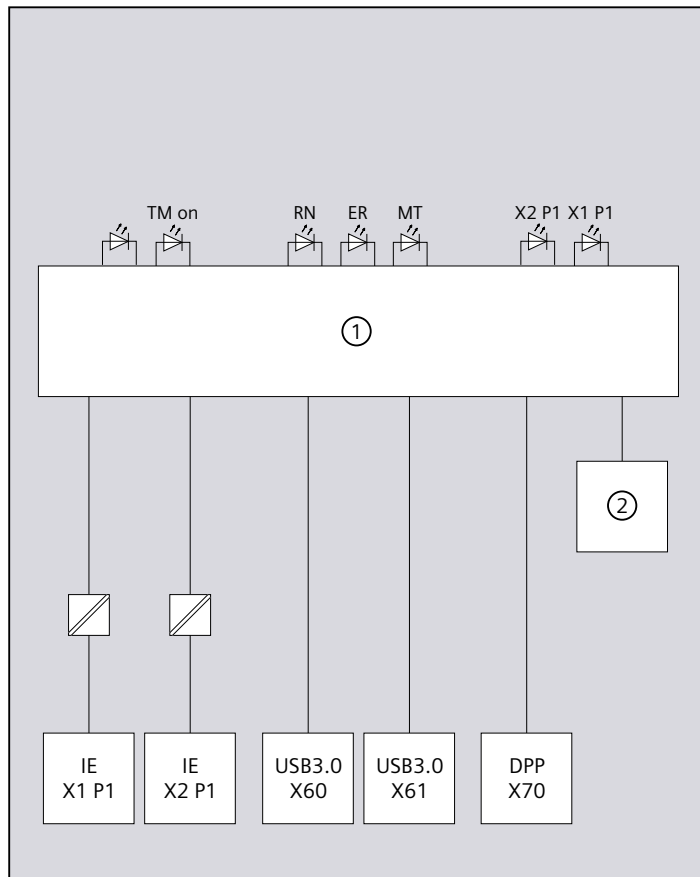
①	Processor unit	TM On	LED display of the operating voltage
②	Backplane bus interface	RN	RUN LED (green)
IE X1 P1	Ethernet interface	ER	ERROR LED (red)
IE X2 P1	Ethernet interface	MT	MAINT LED (yellow)
USB 3.0 X60	USB 3.0 interface	X2 P1	Ethernet interface LED
USB 3.0 X61	USB 3.0 interface	X1 P1	Ethernet interface LED
DPP X70	DisplayPort DPP		

Figure 4-2   Schematic circuit diagram

NOTE

Galvanic isolation

There is no galvanic isolation between the processor unit of the TM MFP and the USB ports and DisplayPort. Therefore, ensure that there are no potential differences between the supply and the utilized devices at the USB ports and DisplayPort. Avoid different sources of supply/potential references for the devices at the USB ports and DisplayPort.

Installing and updating software

<div align="right">

5

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5.1 Industrial OS Service Stick

You obtain the Service Stick image via an OSD download (Online Software Delivery) from the Siemens Industry Mall. You need a bootable USB mass storage device (flash drive or hard disk) when you download the image.

Hardware setup

For Siemens Industrial OS installation/backup/restore actions, you must connect a monitor via DisplayPort, a standard USB keyboard and the prepared Service Stick to the TM MFP. Do not use USB hubs.

Required components:
- Technology Module TM MFP
- USB mass storage device (e.g. USB flash drive) with at least 16 GB
- Service Stick image file (*.img.gz)

Procedure:
1. Transfer the Service Stick image file to the TM MFP (into directory /home/mfp/ in this example)
2. Connect the USB mass storage device to the TM MFP.
3. Establish a connection to the TM MFP and run the following command:
   ```
   gunzip -c /home/mfp/<name-of-image-archive-file> | sudo dd
   of=/dev/sdb status=progress
   ```

   NOTE

   To avoid overwriting a connected USB flash drive, replace "sdb" with the device name of the connected USB flash drive, e.g. "sdc".

   ---

4. This process takes approximately one hour for a USB 3.0 mass storage device.
5. The Service Stick is ready to use.

To prepare a bootable USB mass storage device on a Windows system, you can use third-party tools, such as USB Imager (https://bztsrc.gitlab.io/usbimager/) or Rufus (https://rufus.ie/en/).

Booting from the Service Stick

If the hardware setup requirements have been met, you can boot from the Service Stick. To do this, carry out the following steps:

1. Call the reboot command of the running operating system or switch the CPU off and on again.

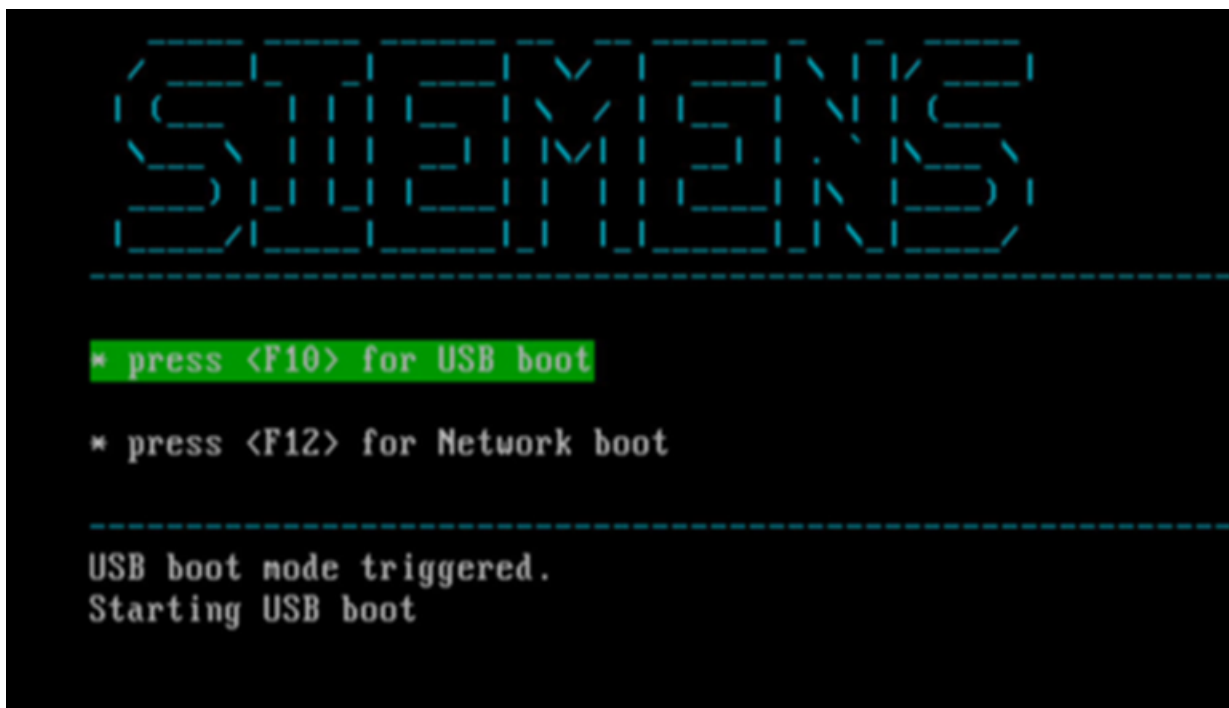2. Press the F10 key for USB boot. The following start screen appears.

Figure 5-1 Start screen

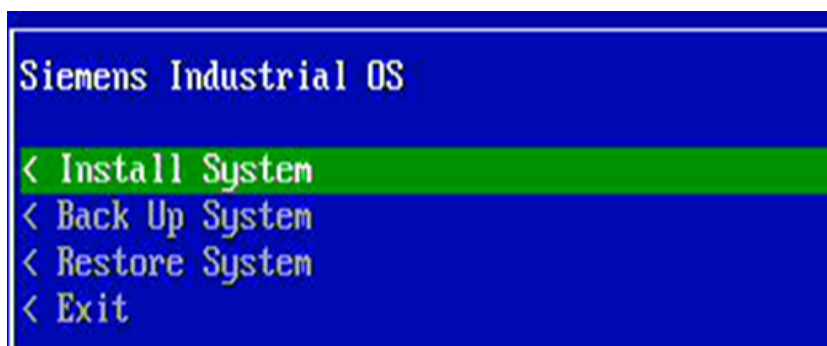3. The main menu appears once the boot has finished.

Figure 5-2 Main menu

5.2   Installing the Siemens Industrial OS

To install the Siemens Industrial OS, follow these steps:

1. Boot the TM MFP from the Service Stick.
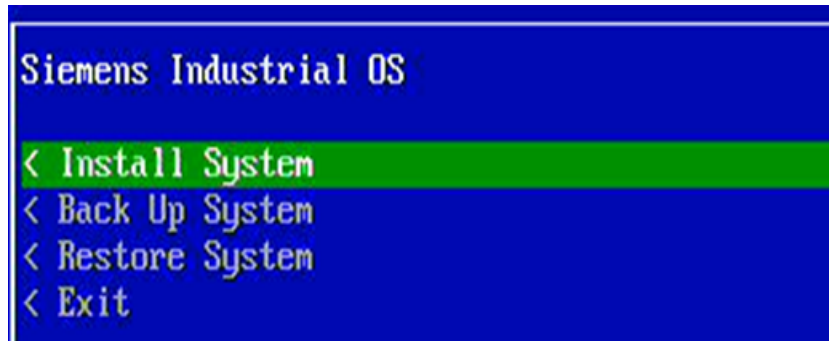2. Select "Install System" in the main menu and confirm with the Enter key.

Figure 5-3 Install System

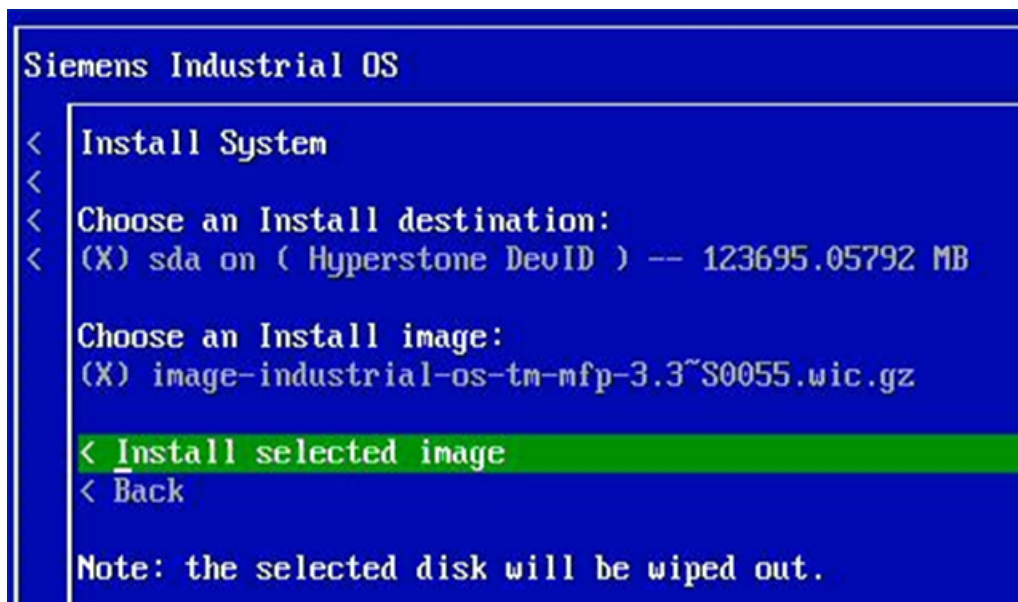3. Choose "Install selected image" in the "Install System" dialog and confirm with the Enter key.

Figure 5-4 Install selected system

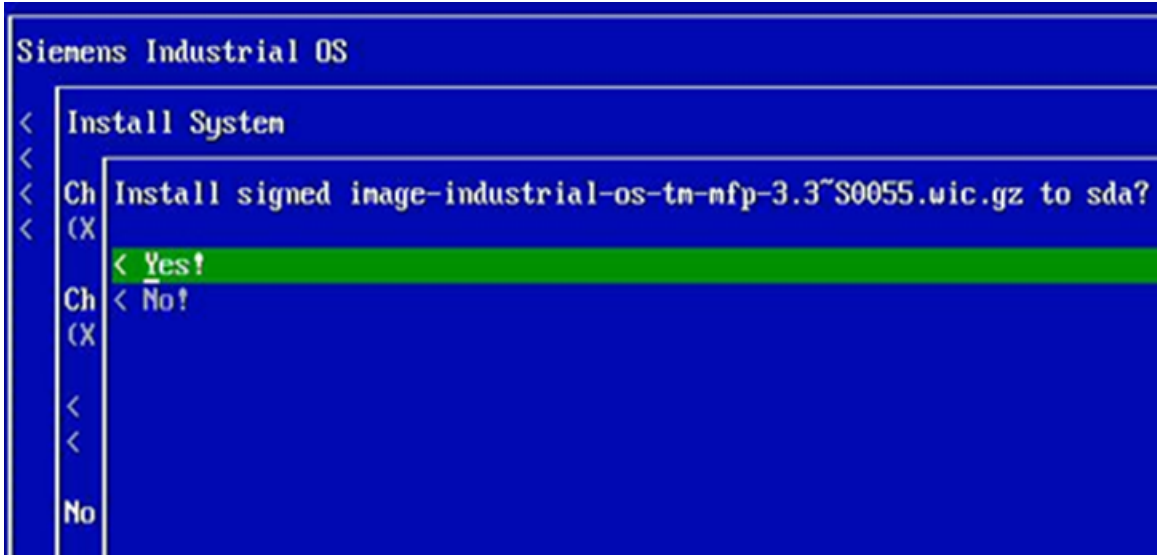4. After the image validation, confirm the installation.

Figure 5-5 Confirm installation

5. Perform a reboot in this step. It is not necessary to restore a backup configuration. Do not remove the Service Stick.
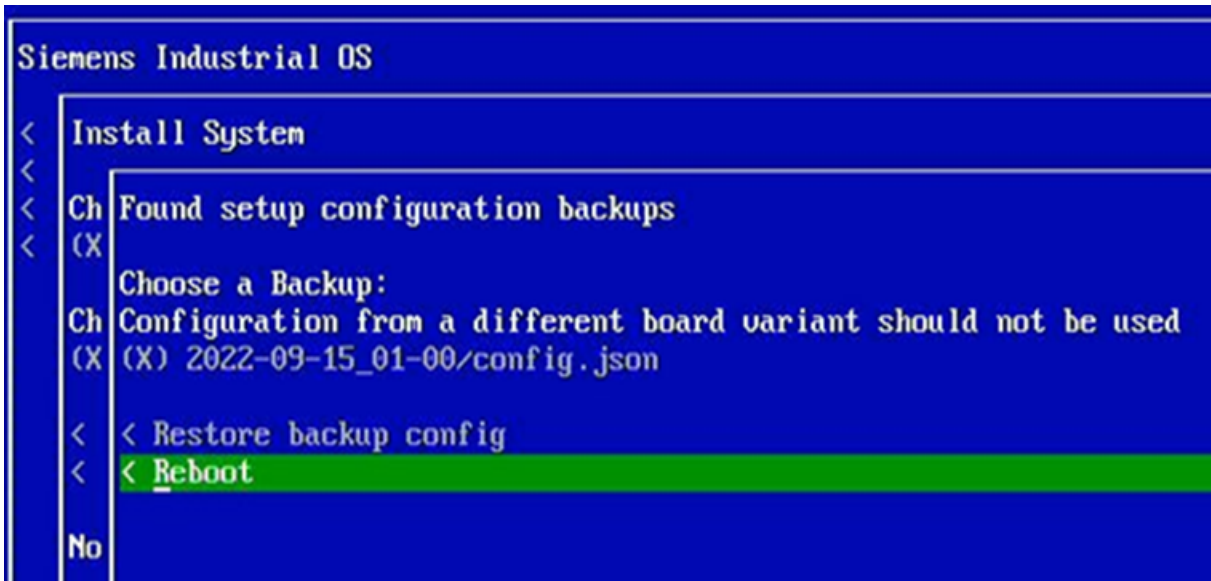

Figure 5-6 Reboot

6. After the reboot, the installed system configures itself and performs another reboot. The new Siemens Industrial OS is then ready to use.

5.3 Backing up the configuration and files

Backing up the configuration and files

The Service Stick offers the option of backing up all user files and the system configuration on the TM MFP. To do so, follow these steps:

1. Boot the TM MFP from the Service Stick.
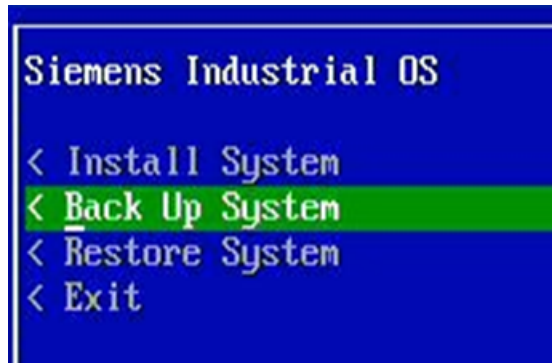2. Choose "Back Up System" in the main menu.

Figure 5-7 Back Up System

3. Make sure there is enough storage space available on the Service Stick for the new backup. Chose "Continue" to start the backup.
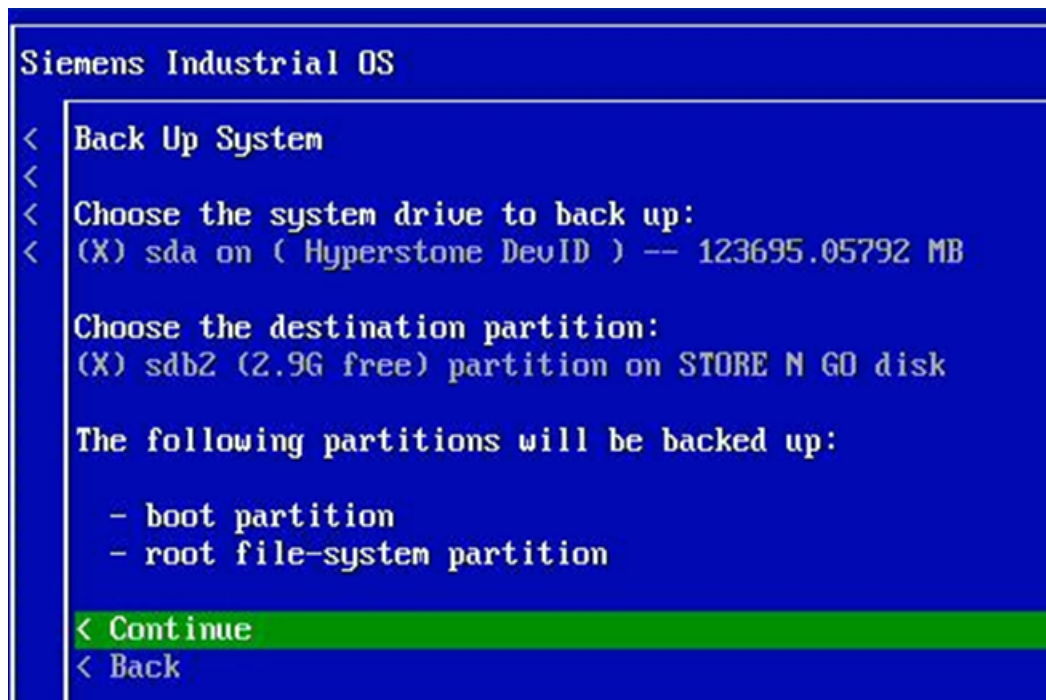

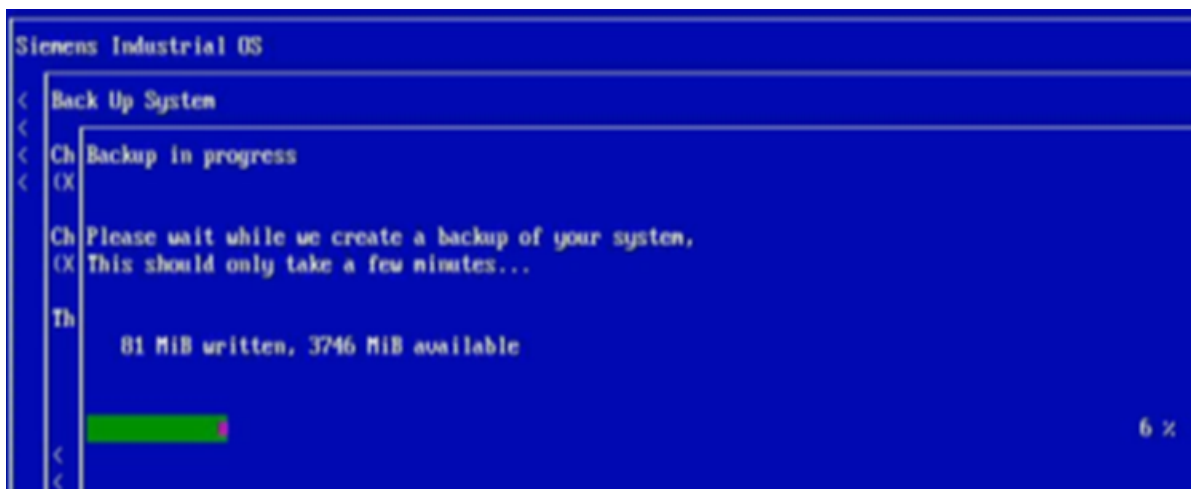Figure 5-8 Continue

4. The progress of the backup is displayed.

Figure 5-9 Backup progress

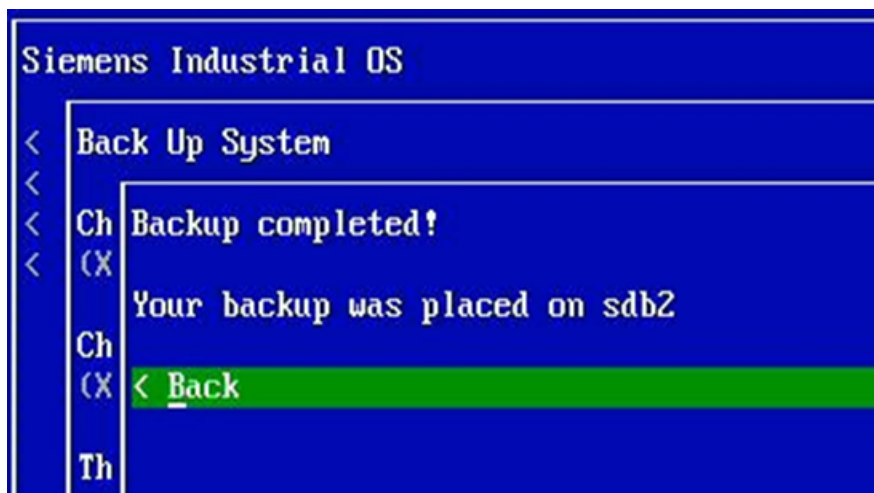5. When the backup has finished, you can return to the main menu.

Figure 5-10 Back to main menu

5.4 Restoring the configuration and files

To restore backed up files, follow these steps:

1. Boot the TM MFP from the Service Stick.
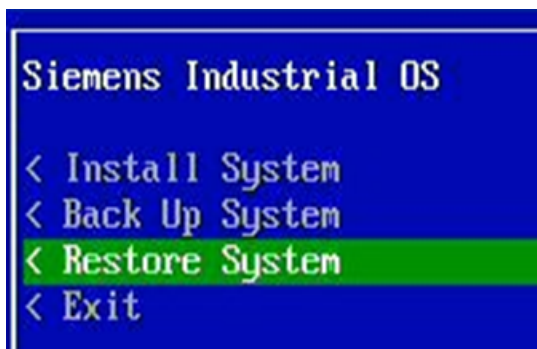2. Choose "Restore System" in the main menu.

Figure 5-11 Restore system

3. Choose one of the existing backups and continue with "Restore backup".
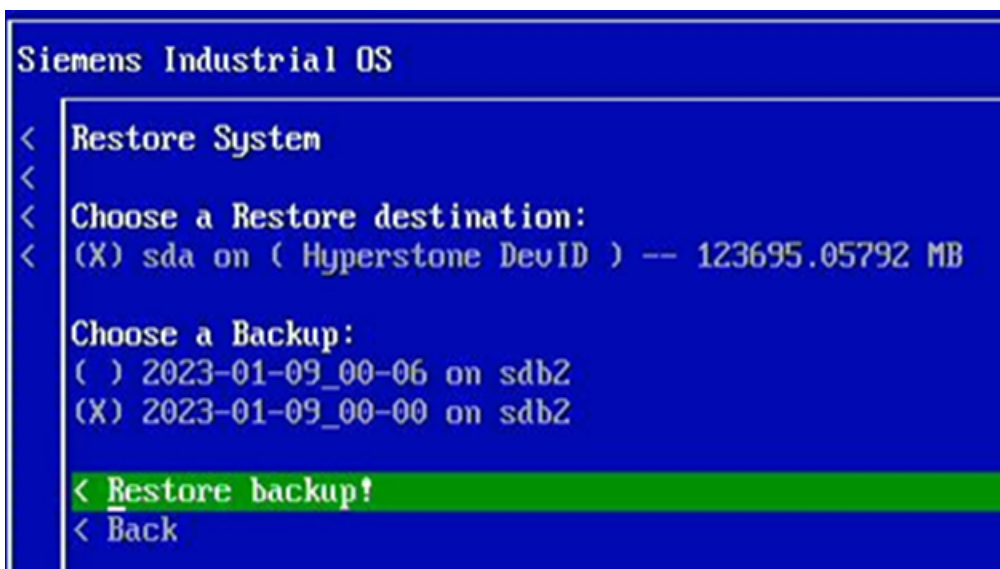

Figure 5-12 Restore backup
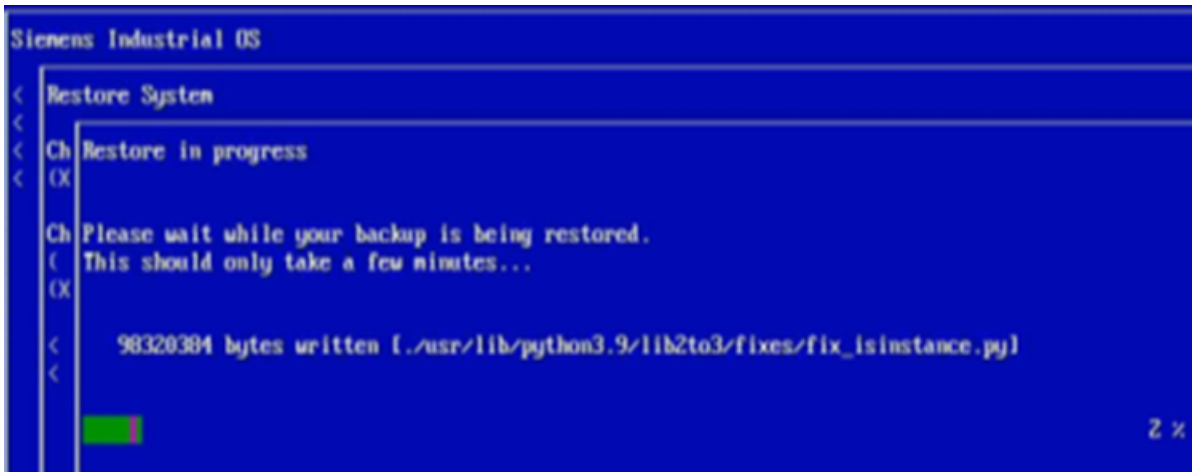
4. The status of the restore operation is displayed.

Figure 5-13   Status of restore operation

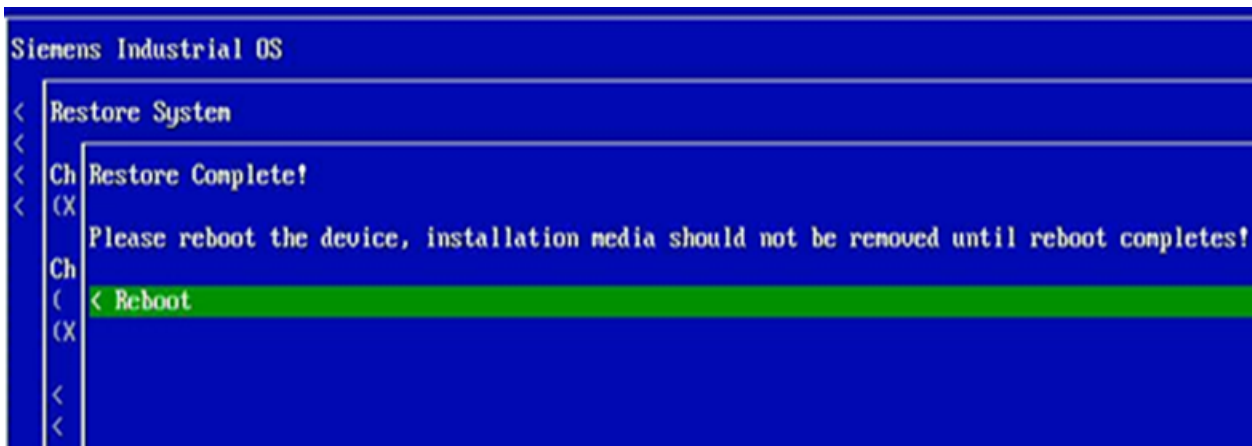5. Perform a reboot after the restore operation has finished.

Figure 5-14   Reboot

5.5 Installing updates

Security updates

Perform security updates of the TM MFP software via the network on a regular basis. Use the same procedure for updates as for Debian Linux distributions. To install new software and updates, you use the `apt` package manager, which has been installed in the TM MFP. Before you update the system, you must adapt the configuration.

NOTICE
Installation and update during operation
Do not perform updates or install new software during productive operation of the plant. Ensure that the plant is in a safe state when performing updates and installing new software.

Installing security updates

To obtain an up-to-date list of all available security updates, use the `apt` tool. Use the following command for this:

```
sudo apt update
```

You then use the following command to install security patches:

```
sudo apt upgrade
```

NOTE

Linux kernel and OpenSSL library

You cannot update the Linux kernel and the OpenSSL library using `sudo apt`. Linux kernel updates and OpenSSL updates are issued by Siemens.

Installing software

Use the `apt` tool to install new software. By default, only the Debian repository has been configured for security updates. You can create you own `/etc/apt/sources.list.d/sources.list` file that contains the configuration of your software package repository.

Below are some examples of repositories:

```
deb http://deb.debian.org/debian bullseye main
deb-src http://deb.debian.org/debian bullseye main
deb http://deb.debian.org/debian bullseye-updates main
deb-src http://deb.debian.org/debian bullseye-updates main
```

NOTE

If you create a new `/etc/apt/sources.list` file as root user, you have the option of changing the rights so that all users can read this file.

The `/etc/apt/sources.list.d/security-updates.list` file already contains a configuration for the security repository.

After adding the new package repository, you must update the package list with the following command:

```
sudo apt update
```

You can then install the new software, e.g. "tree":

```
sudo apt install tree
```

If you are use a pre-configured Industrial OS Service Stick, you can connect it to the TM MFP and use the offline repository. The repository is mounted automatically. The repository on the Service Stick contains an extract of the Debian packages.

5.6 BIOS update

To update the TM MFP to the latest BIOS version, you need:

- A TM MFP technology module that has been connected to the CPU and switched on
- BIOS tar.gz package for download from SIOS (https://support.industry.siemens.com/cs/us/en/view/109945851)
- SSH connection to the TM MFP or a direct connection via monitor and keyboard
- User with `sudo` privileges (`mfp` by default)

NOTICE
Reboot after BIOS update
Note that when the BIOS update has finished, the TM MFP module is automatically rebooted and the CPU changes to STOP mode.

Performing an update

To perform a BIOS update, follow these steps:

1. Log into the TM MFP.
2. Transfer the BIOS tar.gz package to the TM MFP. Use an SCP file transfer (Secure Copy Protocol) or a USB flash drive.
3. To start the BIOS update, run the following command.
   ```
   sudo bios-update <path-to-bios-package>
   ```
4. Enter your sudo user password.
5. Confirm the prompt to continue.
6. Wait for the installation to finish and the module to reboot.

NOTE

The BIOS update is sensitive to power supply interruptions. If the BIOS update is interrupted, e.g. due to a power failure or for other reasons, the interruption can lead to a state that cannot be restored. TM MFP can no longer be started. Do not switch off the device during the BIOS update.

NOTE

If you have multiple TM MFPs in a rack, perform the BIOS updates one after the other.

Configuring 6

6.1 Booting the TM MFP

By default the TM MFP boots the operating system, which is located on the internal SSD. You can modify this behavior during the boot operation. You have the following options:

- While the boot operation is in progress, press F10 on the keyboard to boot from USB.
- While the boot operation is in progress, press F12 on the keyboard to boot from the HTTP server (netboot).
- Change the configuration file on the internal SSD under `/boot/boot.conf`.

Booting from USB

If USB boot is active, the system uses the ext14 partition with label "root" in the connected USB mass storage devices.

The `/boot/boot.conf` file must be located in this partition and contain information about the location of the kernel, ramdisk and root partitions, e.g.:

```
KERNEL=../vmlinuz
INITRD=../initrd.img
CMDLINE=root=UUID=2a91bde9-d891-412f-a6f5-4a25c4813761 rootwait
quiet nohz=off
```

The specified UUID (Universally Unique Identifier) must match the UUID of the partition.

NOTE

The USB mass storage device should already be available before the TM MFP is powered on. However, you can also add the USB mass storage device during the USB waiting phase (approximately 30 seconds). The device initiates a USB boot from the first valid ext14 root partition. If a USB mass storage device is not found, the CPU changes to STOP mode. To start a new boot, the CPU must be switched off and on again.

Booting from the HTTP server (netboot)

If you boot from the HTTP server (netboot), the system contacts the HTTP server at the specified web address and port. The system downloads the netboot-conf file from the server to determine where the Linux kernel and ramdisk are located. The kernel command line parameters should also be specified here:

```
KERNEL=vmlinuz
INITRD=initrd.img
CMDLINE=boot=live iomem=relaxed console=ttyS1,115200n8 console=tty0
```

The system retrieves the Linux kernel and ramdisk and loads them into the web root directory of the HTTP server.

NOTE

Siemens does not supply an HTTP server. However, you may use any HTTP server.

The preset IP address of the HTTP server is 192.168.15.249/24, port 8090.
The preset IP address of the TM MFP during the netboot is 192.168.15.19/24.

If you want to use a user-specific IP address, modify the file in the internal SSD memory under /boot/boot.conf as follows:

```
BOOT=NETBOOT
KERNEL=../vmlinuz
INITRD=../initrd.img
CMDLINE=root=UUID=2a91bde9-d891-412f-a6f5-4a25c4813761  rootwait
rootwait quiet nohz=off
IP0=192.168.15.61/24
SERVER=192.168.15.63:8090
```

The BOOT=NETBOOT instruction causes the system to perform a netboot the next time the TM MFP is switched off and on again. The KERNEL, INITRD AND CMDLINE instructions are ignored in this case. IP0 is the IP address of the X1 interface. SERVER specifies the IP address of the HTTP server and the port.

6.2   Logging into the operating system of the TM MFP

Logon via keyboard and monitor

After the TM MFP has booted, a logon dialog with the following preset logon data appears on the monitor:

- user: **mfp**
- password: **mfp**

After the first logon, you are prompted to change the preset password as follows:

```
You are required to change your password immediately (administrator
enforced).
Changing password for mfp.
Current password:
```

1. Enter the current password and confirm with the Enter key.
   The password is not displayed on the monitor but is recorded internally.
2. Enter your new password and then enter it again for confirmation.

Logon via the network

By default, only the X1 interface is active, and the assigned IP address is 192.168.15.19. You can also use the following command to log into the TM MFP remotely via an SSH connection:
```
$ ssh mfp@192.168.15.19
```

Use the SSH client of Windows or the SSH client of a third-party provider, e.g. PuTTY. You can find information regarding correct use of the SSH client on the provider's website.

When you log in for the first time, you are prompted to confirm the authenticity of the device with IP address 192.168.15.19 as follows:
```
The authenticity of host '192.168.15.19 (192.168.15.19)' can't be
established.
ECDSA key fingerprint is
SHA256:AesI/wiBEzhFOgZWM5nFWmr3jhE7P0Tq4/WPlLO6p9c.
Are you sure you want to continue connecting (yes/no/[fingerprint])?
```

Enter `yes` to confirm this connection.

After the first logon, the system prompts you to change the default password by displaying the following information:
```
You are required to change your password immediately (administrator
enforced).
You are required to change your password immediately (administrator
enforced).
Linux mfp 5.10.104-cip3-rt3+ind14 #1 SMP PREEMPT_RT Mon Jan 9
09:43:00 UTC 2023 x86_64


The programs included with the Debian GNU/Linux system are free
software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.


Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
WARNING: Your password has expired.
You must change your password now and logon again!
Changing password for mfp.
Current password:
New password:
Retype new password:
```

Immediately after entry of the password, you are logged out and must log in again via SSH with the new password.

If you have already connected to another device using IP address 192.168.15.19, the following warning appears. If this happens, remove the fingerprint from the device with IP address 192.168.15.19.
```
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!    @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle
attack)!
It is also possible that a host key has just been changed.
The fingerprint for the ECDSA key sent by the remote host is
...
```

For Linux you remove the fingerprint from `known_hosts` as follows:
`ssh-keygen -f "/home/${USER}/.ssh/known_hosts" -R "192.168.15.19"`
For Windows you remove the fingerprint from `known_hosts` as follows:
Remove the lines containing the IP address `192.168.15.19` in the `.ssh/known_hosts` file.

6.3 Network settings

The TM MFP network is managed by the Network Manager system service. This service manages the devices and connections within the network and ensures the network connectivity. You can make changes to the network using the command-line client nmcli (https://networkmanager.dev/docs/api/latest/nmcli.html) or the interactive text configuration tool nmtui (https://networkmanager.dev/docs/api/latest/nmtui.html). You can find the Network Manager manual on the following website (https://manpages.debian.org/unstable/network-manager/NetworkManager.conf.5.en.html).

Displaying a list of all connections with nmcli

To display a list of all currently defined connections, use the command:
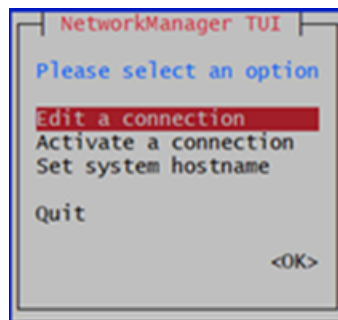`$ nmcli connection show`
Only one Ethernet connection (Ethernet interface X1) is enabled for the `enp1s0` device by default. To display more information about this connection, use the command:
`$ nmcli device show enp1s0`

Using the text configuration tool nmtui

To start the tool and open the main menu, use the command:
`$ sudo nmtui`

To display a list of the currently defined connections, use the option "Edit a connection".

By default, there is the Ethernet connection enp1s0 (X1 Ethernet interface) with fixed IP address and enp2s0 (X2 Ethernet interface) which is preconfigured for DHCP. To show more detailed information or change parameters of this connection, use the option "Edit":
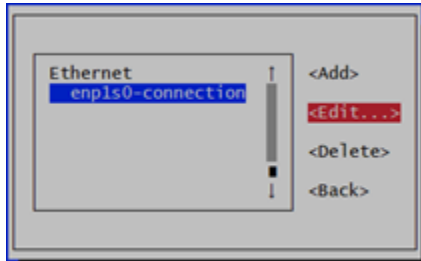

Setting up a static IP address

NOTICE
Remote connection via SSH
If you have connected remotely via SSH, a change to the Ethernet interface settings may result in disconnection.

The enp1s0 interface has been assigned the following static IP address `192.168.15.19`. You can modify the interface from the Network Manager with the following command:

```
$ sudo nmcli connection modify enp1s0-connection ipv4.address
"192.168.15.10/24"
```
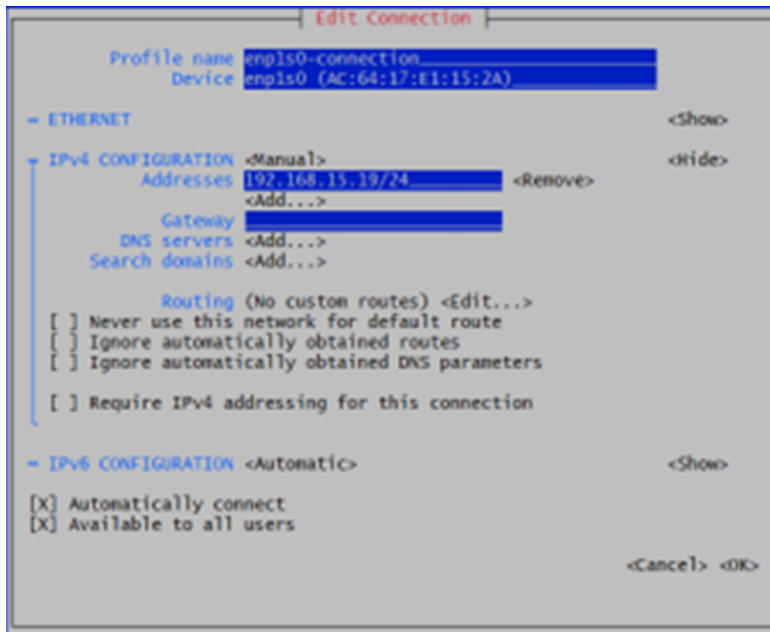

After modifying the IP address, you must reload the configuration with the following command:
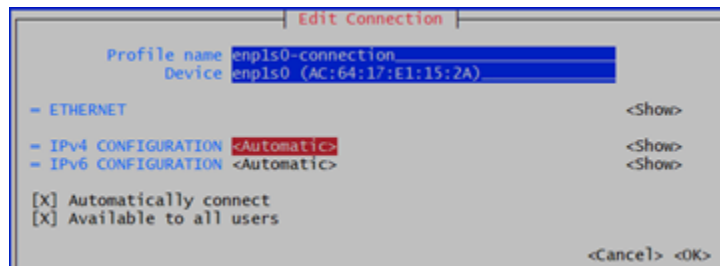
```
$ sudo nmcli device reapply enp1s0
```
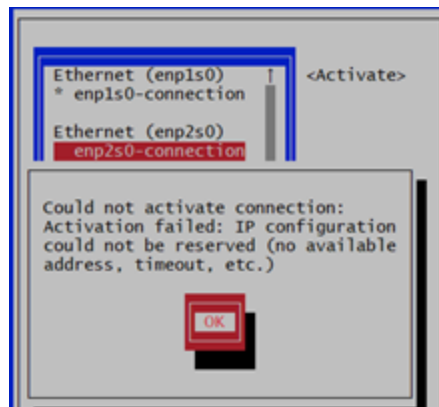
NOTE

Remote connection

Note that a remote connection will be interrupted after running the command.

Enabling a DHCP client

The X1 interface enp1s0 uses a static IP address by default. To enable `dhcp client` for this interface, edit the "enp1s0-connection" and set the IPv4 configuration to "automatic".


After this change, disable and enable the connection again via nmtui. To be able to make this change successfully, you require an active DHCP server in your network. Otherwise, the process fails with the following error message. The connection retains its static IP address until the next restart:

Configuring DNS for a remote server

In order to work with remote servers, you must configure a DNS (Domain Name System). When you edit a connection, you can configure one or more DNS servers.
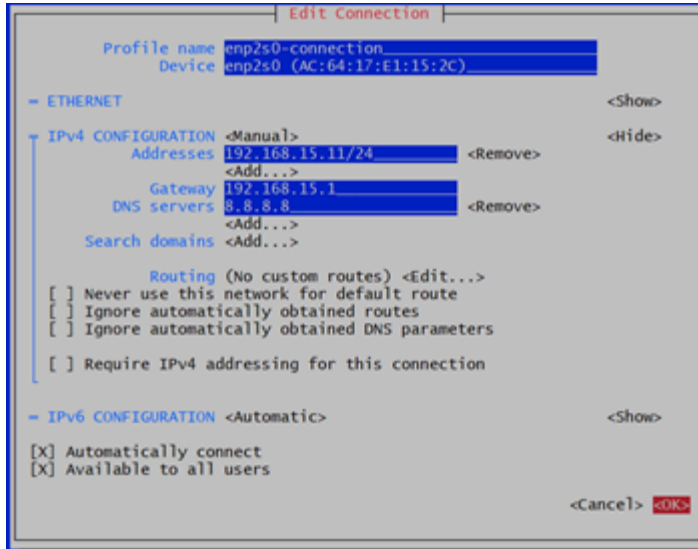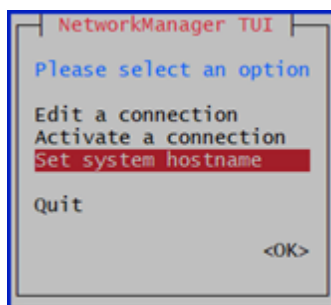

NOTE

Example address of the DNS server

The IP address 8.8.8.8 of the DNS server is only an example. Use a suitable DNS address instead.

The Network Manager has now generated the `/etc/resolv.conf` file with DNS value 8.8.8.8.

Set hostname

You can define the host name with the last option "Set system hostname" in the nmtui main menu. This change is applied immediately.

6.4 Uncomplicated Firewall (ufw)

The TM MFP has an active Uncomplicated Firewall (ufw) by default. Only `port 22` is open for SSH by default. You can check this setting with the following status query:
```
$ sudo ufw status
```

You can add your own rules, for example, that incoming TCP packets are accepted at port 80:
```
$ sudo ufw allow 80/tcp
```

As an alternative to specifying a port number, you can use the name of the service with the known default port. This command leads to the same result as the previous command:
```
$ sudo ufw allow http/tcp
```

You can also specify which network traffic you want to block. In the following example, we block the incoming network traffic at port 8090:
```
$ sudo ufw deny 8090
```

To check the current settings, use firewall rules with a rule ID:
```
$ sudo ufw status numbered
```

If you want to remove the ufw rule, delete this rule using the rule number. In the following example, this is the rule with number 2:
```
$ sudo ufw delete 2
```

6.5 Time-of-day synchronization via backplane bus

By default, TM MFP is configured in such a way that it retrieves the time from the backplane bus.

You can check the active time synchronization via the backplane bus. Use the following command for this purpose:
```
sudo journalctl -u bbus-agent
```
The time synchronization is confirmed in the output:
```
BBus MFP Agent Version: 1.1.1
Config: Time synchronization with PLC active
TmMfpModule: Module configured
TmMfpModule: Application Ready State
TmMfpModule: System time was synchronized with master PLC
```

Deactivating time synchronization

If time synchronization is not desired, check the configuration file /etc/bbus/bbus-agent.conf:
```
# Synchronize system time with master PLC
# Valid values (0|1), Default value = 1
SyncTimeWithPLC=1
```
Set `SyncTimeWithPLC=0`. Restart the `bbus-agent`:
```
$ sudo systemctl restart bbus-agent.service
```

Time zone and daylight saving time

Information on time zones or daylight saving time settings in the CPU are not automatically applied to the TM MFP.

In the TM MFP, you set the time zone with the following command:

```
$ sudo timedatectl set-timezone <your_time_zone>
```

This command contains the information on daylight saving time in the time zone.

Time jumps

The time of the TM MFP is synchronized exactly with the time of the CPU.

When you change the time of the CPU, this change also has an effect on the TM MFP. A time change can lead to time jumps into the future or into the past. In settled state, no time jumps are to be expected because the time information is updated in the TM MFP every 10 seconds.

6.6 Time-of-day synchronization via NTP

If time synchronization via the backplane bus is disabled, set up a pre-installed NTP client.

To synchronize the time via the Ethernet network, you must adapt the configuration.

The configuration of the NTP client is stored in the `/etc/ntp.conf` file. Configure your NTP server in this file. You can specify the server with its host name or IP address.

```
#You do need to talk to an NTP server or two (or three).
#server ntp.your-provider.example
server 192.168.15.59 iburst
```

Then restart the NTP service as follows:

```
$ sudo systemctl restart ntp.service
```

The server `192.168.15.59` is used to synchronize the network time. You can check correct functioning with the ntpq tool:

```
$ ntpq -pn
```

There should now be a connection to your NTP server. The value increases every 64 seconds. Non-zero values are displayed for delay, offset and jitter.

If your device has no access to publicly available NTP servers, you can disable the `debian.pool.ntp.org` server under etc/ntp.conf or enter the addresses of the available NTP servers:

```
# pool.ntp.org maps to about 1000 low-stratum NTP servers.  Your
server will
# pick a different set every time it starts up.  Please consider
joining the
# pool: <http://www.pool.ntp.org/join.html>
#pool 0.debian.pool.ntp.org iburst
#pool 1.debian.pool.ntp.org iburst
#pool 2.debian.pool.ntp.org iburst
#pool 3.debian.pool.ntp.org iburst
```

NOTE

Using multiple time sources at the same time for the TM MFP is not permitted. Synchronize the time, e.g. via NTP or the backplane bus.

6.7 Backplane bus

6.7.1 Communication over the backplane bus

In order to read and write values for the inputs and outputs (256 bytes in each direction), the CPU communicates with the TM MFP over the backplane bus.

You will find example code in C++ and Python for the I/O communication in this section. You can compile C++ directly in the TM MFP.

The source codes establish a connection to the I/O data of the CPU via a shared memory device and the supplied shared library `libbbus.so`.

To be able to access the backplane bus, use bbus-agent. bbus-agent runs by default on the operating system and requires no additional interaction with the user.

Reboot and startup of the TM MFP

The TM MFP is powered via the backplane bus and is automatically switched on as soon as it is supplied with power.

It is not recommended to restart, hibernate or shut down the operating system of the TM MFP. This could disrupt the communication over the backplane bus.

NOTE

Do not reboot the TM MFP operating system in the production environment. This may cause the CPU to change from RUN to STOP mode.

6.7.2 Details on the TM MFP backplane bus

bbus-agent

The `bbus-agent` application is crucial for communication over the backplane bus. Without this application, data exchange between the CPU and the TM MFP is not possible.

By default, the `bbus-agent` starts when the TM MFP boots. The `bbus-agent` must be running for an error-free changeover of the CPU to RUN mode.

The application does not require user interaction. Do not close or restart the application.

The binary file of the application is located at the following path:

`/usr/bin/bbus-agent`

You can see by the `top` output that this process is currently running:

`mfp@mfp:~$ top`

The output should look similar to the following:

```
top - 23:44:20 up 15 days, 22:44, 3 users, load average: 0.12, 0.14,
0.16
Tasks: 144 total, 2 running, 142 sleeping, 0 stopped, 0 zombie
%Cpu(s): 1.5 us, 5.9 sy, 0.0 ni, 91.2 id, 0.0 wa, 0.0 hi, 1.5 si,
0.0 st
MiB Mem : 7841.7 total, 7204.2 free, 202.1 used, 435.4 buff/cache
MiB Swap: 0.0 total, 0.0 free, 0.0 used. 7468.7 avail Mem
PID USER PR NI VIRT RES SHR S %CPU %MEM TIME+ COMMAND
85190 bbus 20 0 314272 51124 15048 S 18.8 0.6 17:30.75 bbus-agent
85817 mfp 20 0 10500 3832 3284 R 12.5 0.0 0:00.03 top
85800 mfp 20 0 10464 3812 3204 S 6.2 0.0 0:00.54 top
1 root 20 0 167060 10552 7812 S 0.0 0.1 0:52.17 systemd
```

```
2 root 20 0 0 0 0 S 0.0 0.0 0:00.16 kthreadd
```

bbus-agent service

The `bbus-agent` application runs automatically as systemd service. The service has been defined in:

`/lib/systemd/system/bbus-agent.service`

To check the status of the `bbus-agent`, use the systemctl command:

`mfp@mfp:~$ sudo systemctl status bbus-agent.service`

The expected status is: `active (running)`:

```
bbus-agent.service - BBus communication service application
(/usr/bin/bbus-agent process)
Loaded: loaded (/lib/systemd/system/bbus-agent.service; enabled;
vendor preset: enabled)
Active: active (running) since Thu 2022-06-16 18:39:24 UTC; 6s ago
Main PID: 7953 (bbus-agent)
Tasks: 9 (limit: 9378)
Memory: 36.3M
CPU: 1.412s
CGroup: /system.slice/bbus-agent.service
└─7953 /usr/bin/bbus-agent

Jun 16 18:39:24 mfp systemd[1]: Started BBus communication service
application (/usr/bin/bbus-agent proc>
Jun 16 18:39:24 mfp bbus-agent[7953]: BBus MFP Agent Version: 1.0.0
Jun 16 18:39:24 mfp bbus-agent[7953]: TmMfpModule: Module configured
Jun 16 18:39:24 mfp bbus-agent[7953]: TmMfpModule: Application Ready
State
```

The service starts the `bbus-agent` application. The status of the service should be: `active (running)`, since the TM MFP cannot communicate with the CPU otherwise.

Logs

Because the `bbus-agent` application runs as systemd service, you can access the log via the `journalctl` subsystem. To display the log, use:

`sudo journalctl -u bbus-agent`

NOTE

Time stamp

The clock of the TM MFP is interrupted when the module is switched off and on again. If this happens, the log files could contain incorrect time stamps. To avoid this situation, read the Time synchronization section.

Configuration

The configuration is available as a text file at the following path:

`/etc/bbus/bbus-agent.conf`

I/O data is queried at fixed time intervals. You can change the query times. However, if you change the times, this can affect the speed of the I/O communication and the performance of the `bbus-agent`.

The configuration values depend on the CPU load and the I/O data throughput. Shorter cycles allow faster communication with the CPU but simultaneously increase the CPU load.

Owners and rights

The `bbus-agent` application runs under the bbus user.

Shared memory device and shared library

`bbus-agent` creates a shared memory device: `/dev/shm/bbus-io-data`. The shared memory device is a connection point between your application and the I/O data of the CPU.

The shared memory device is used by the shared library libbbus.so, which provides all functions required to handle I/O data of the CPU. These functions are declared in the header file bbuslib.h.

Both the library and the header file are contained in the TM MFP OS.

These functions are declared in bbuslib.h:

```
extern int init_io_data();
extern int release_io_data();
extern int read_all_plc_output(uint8_t outputs[]);
extern int read_one_plc_output(uint8_t idx, uint8_t *value);
extern int write_all_plc_input(uint8_t inputs[]);
extern int write_one_plc_input(uint8_t idx, uint8_t value);
extern int sync_all(uint8_t inputs[], uint8_t outputs[]);
extern int read_plc_data_valid();
extern int trigger_hw_interrupt(uint8_t eventId);
```

6.8 Example application for the backplane bus

6.8.1 Example overview

The provided C++ and Python source codes include a simple example for the periodic exchange of I/O data between the CPU and TM MFP.

To enable exchange of I/O data between the CPU and the TM MFP, you need to download a hardware configuration to the CPU in RUN mode.

You can find components of the example applications in the folder `/usr/share/doc/bbus-agent/`:

- `cpp/`: Source files of the C++ example application
- `python/`: Source files of the Python 3 example application
- `doc/`: Documentation files
- `README.md:` bbus-agent and manual for the example application

The C++ application is suitable for real-time applications, provided that all real-time requirements recommended by Linux are met.

NOTE

Applications based on Python do not guarantee real-time behavior.

Requirements

The following requirements must be met for the application examples:

- The supply power of 25 W required for the TM MFP is available.
- You have downloaded a correct hardware configuration to the CPU.
- You have put the CPU into RUN mode.

The bbus application examples have been implemented as an infinite loop with the following steps:

- Reading all CPU output data
- Processing of the CPU output data and preparation of the CPU input data
- Writing the CPU input data

Infinite loop example

The application examples have been implemented as an infinite loop with the following steps:

1. Check the CPU RUN state. This check is a precondition for valid I/O data values.

2. Read the data from the CPU outputs.

3. Business logic of the application: Process the CPU output data and prepare the CPU input data.

4. Write data into CPU inputs.
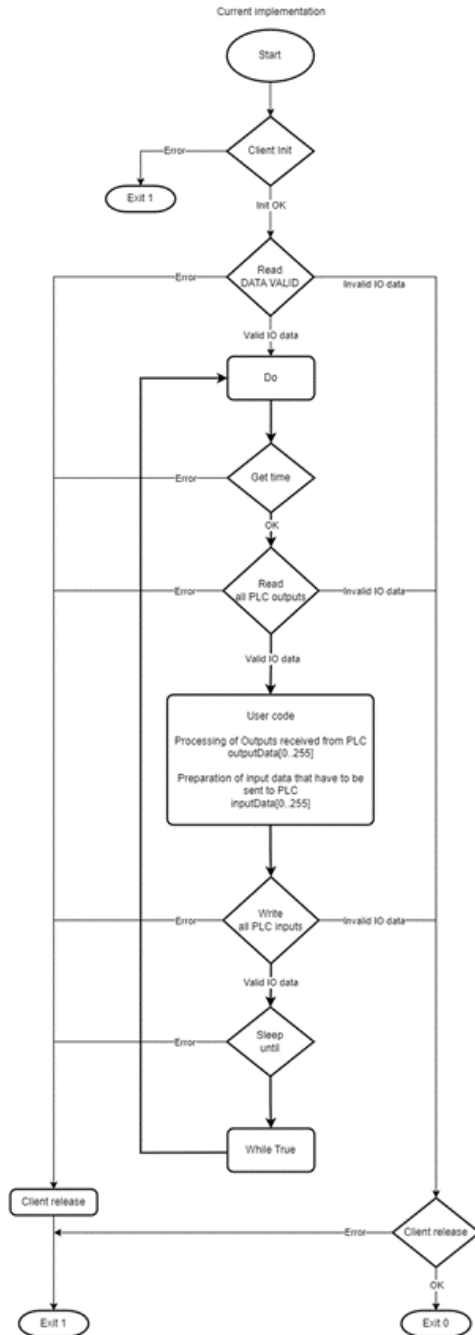
6.8.2 Example C++ application

Required development tools

You need the following tools for the example project:

- Linux operating system
- Compiler gcc 8.3.0 or higher
- Build system CMake 3.12 or higher
- Shared backplane bus library libbbus.so

NOTE

All the required development tools are already integrated in the pre-installed Linux operating system.

The project with the example application is configured with the `build.sh` script and generated with CMake.

NOTE

Storage of example code in a root folder

The example source code is stored by default in a path that requires root privileges.

If you want to make your own changes, create a local copy of the project files. Generate the project locally as a user without root privileges.

Copying, generating and executing the project

This section lists commands with which you can perform various actions.

- Create a local copy with the following command:
  ```
  cp -r /usr/share/doc/bbus-agent ~/bbus-example
  ```
- Generate a project with the following command:
  ```
  cd ~/bbus-example/cpp/
  ./build.sh
  ```
- Execute the example application. You can find the executable applications in the folder `~/bbus-example/cpp/build`
- Start the application with the following command:
  ```
  ./build/bbus_example
  ```

6.8.2.1 C++ client interface

Initializing I/O data access

The following paragraph contains the program for initializing the I/O data client:

```cpp
// Initialize IO data access
retVal = init_io_data();
if (retVal != CLIENT_OK) {
    cerr << "Error: Initialization of IO data access failed" <<
endl;
    exit(1);
}
```

Reading CPU output data

The following paragraph contains the program for reading CPU output data.

```cpp
// Read one PLC output
uint8_t output_index = 10;
uint8_t output_value;
retVal = read_one_plc_output(output_index, &output_value);
if (retVal != CLIENT_OK_DATA_VALID) {
    // invalid data or reading failed
    if (retVal == CLIENT_OK_DATA_INVALID) {
        cerr << "IO data are not valid. Verify PLC state!" << endl;
        break;
    }
    cerr << "Error: read one PLC output failed" << endl;
    exit(1);
}
// Read all PLC outputs
uint8_t outputData[256];
retVal = read_all_plc_output(outputData);
if (retVal != CLIENT_OK_DATA_VALID) {
    // invalid data or reading failed
    if (retVal == CLIENT_OK_DATA_INVALID) {
        cerr << "IO data are not valid. Verify PLC state!" << endl;
        break;
    }
    cerr << "Error: reading of all PLC outputs failed" << endl;
    release_io_data();
    exit(1);
}
```

Writing CPU input data

The following paragraph contains the program for writing CPU input data.

```
// Write one PLC input
uint8_t input_index = 10;
uint8_t input_value = output_value;
retVal = write_one_plc_input(input_index, input_value);
if (retVal != CLIENT_OK_DATA_VALID) {
    // invalid data or writing failed
    if (retVal == CLIENT_OK_DATA_INVALID) {
        cerr << "IO data are not valid. Verify PLC state!" << endl;
        break;
    }
    cerr << "Error: write one PLC input failed" << endl;
    exit(1);
}
// Write all PLC inputs
uint8_t inputData[256];
retVal = write_all_plc_input(inputData);
if (retVal != CLIENT_OK_DATA_VALID) {
    // invalid data or writing failed
    if (retVal == CLIENT_OK_DATA_INVALID) {
        cerr << "IO data are not valid. Verify PLC state!" << endl;
        break;
    }
    cerr << "Error: writing of all PLC inputs failed" << endl;
    release_io_data();
    exit(1);
}
```

Synchronizing I/O data (reading and writing)

The following paragraph contains the program for synchronizing the I/O data, reading and writing in one step.

```
// Sync all
uint8_t inputData[256];
uint8_t outputData[256];
retVal = sync_all(inputData, outputData);
if (retVal != CLIENT_OK_DATA_VALID) {
    // invalid data or writing failed
    if (retVal == CLIENT_OK_DATA_INVALID) {
        cerr << "IO data are not valid. Verify PLC state!" << endl;
        break;
    }
    cerr << "Error: sync all failed" << endl;
    exit(1);
}
```

Determining the validity status of data

The following paragraph contains the program for determining the validity status of data.

```
// Verify IO data validity
retVal = read_plc_data_valid();
if (retVal == CLIENT_OK_DATA_VALID) {
    // code ...
}
else {
    if (retVal == CLIENT_OK_DATA_INVALID) {
        // Process IO data invalid state here ...
        cerr << "IO data are not valid. Verify PLC state!" << endl;
        release_io_data();
        exit(0);
    }
    else {
        // Process error state here ...
        cerr << "Error: reading of data status failed" << endl;
        release_io_data();
        exit(1);
    }
}
```

Releasing I/O data sources

The following paragraph contains the program for releasing I/O data client sources.

```
// Release IO data resources
retVal = release_io_data();
if (retVal != CLIENT_OK) {
    cout << "Error: Releasing of IO data resources failed" << endl;
}
```

Triggering a hardware interrupt

Use the following code to trigger a hardware interrupt for the CPU user program. You can find more information on hardware interrupts in the Diagnostics section.

```
// trigger_hw_interrupt
uint8_t eventType = 0;
retVal = trigger_hw_interrupt(eventType);
if (retVal != HWINT_SEND_OK) {
    cout << "Error: Process event cannot be sent" << endl;
}
```

6.8.2.2 Recommendations for real-time applications

The PREEMPR_RT patch is contained in the operating system of the TM MFP. The patch enables client applications to be run with real-time priority, especially with multiple threads.

Real-time applications with multiple threads

Below is a recommended procedure for handling real-time applications with multiple threads.

1. Add Memory-Locking.
   The memory that is to be used for the real-time section of a program must be locked in page tables so that memory is neither swapped nor reorganized:
   ```
   int ret = mlockall(MCL_CURRENT | MCL_FUTURE);
   ```
2. The following three scheduling policies are available for real-time threads: SCHED_FIFO, SCHED_RR and SCHED_DEADLINE.
3. For mutexes, use POSIX mutexes.
   If priority inheritance is active, set the attribute PTHREAD_PRIO_INHERIT:
   ```
   int ret = pthread_mutexattr_setprotocol(&mattr,
   PTHREAD_PRIO_INHERIT);
   ```

Absolute times in real-time threads

Use absolute times in real-time threads. For example, use the C-Style clock_* functions with the CLOCK_MONOTONIC argument for this:
```
int ret = clock_nanosleep(CLOCK_MONOTONIC, TIMER_ABSTIME,
&timespec_sleep_until, NULL);
```

NOTE

High-resolution clock

Do not use high_resolution_clock.

By default, Linux boots without real-time behavior enabled. You must explicitly set the real-time behavior with the chrt command. This command requires root privileges.
```
sudo chrt 60 ./bbus_example
```
Another option is to set real-time priority in the thread of the source code. In this case, the binary needs the authorization.
```
setcap "cap_sys_nice,cap_ipc_lock=eip" ./bbus_example
```
The user group that runs the binary must have a defined maximum permissible real-time priority rtprio in the /etc/security/limits.conf file.

NOTE

Real time priority

For the best performance and stability, the real time priority must be 60 or higher.

NOTE

Testing programs and settings

Test your programs and settings carefully. Monitor the bbus-agent log for error, warning and information messages during the test phase.

6.8.3 Python application example

Like in the C++ example, this application periodically exchanges I/O data between the CPU and the TM MFP. In addition, the shared library libbbus.so is required. This is already installed in the TM MFP operating system.

Copying and executing the example

If you want to edit the Python example, copy the scripts to a local folder. Execute the example application. Proceed as follows for this:

1. Create a local copy.
   ```
   cp -r /usr/share/doc/bbus-agent ~/bbus-example
   ```
2. Execute the Python example application. You can find the executable Python script in the `~/bbus-example/python/` folder.
3. Execute the application as follows:
   ```
   cd ~/bbus-example/python/
   ./bbus_example.py
   ```

NOTE
Testing programs and settings
Test your programs and settings carefully. Monitor the bbus-agent log for error, warning and information messages during the test phase.

6.9 Using systemd services

On the TM MFP, `systemd` runs as the initialization and service manager system. The tool that controls `systemd` is `systemctl`. For example, you display a list of all units that have `systemd` in the memory:
```
$ sudo systemctl list-units
```
To display more information about a specific service, use the following command:
```
$ systemctl status ssh
```
This command displays information about the SSH service, for example.

To stop, start or restart a specific service, use:
```
$ systemctl stop ntp.service
```
To restart the service, use:
```
$ systemctl start ntp.service
```

Creating and starting your own systemd service

To create your own systemd service, you need to configure and start this service. A service typically runs binary applications or a script. Under `~/bin/my-uptime.sh`, we have created the following script example in the mfp Home directory named `~/bin/my-uptime.sh`:
```
#!/bin/bash
while :
do
        echo "TM MFP uptime: $(uptime)"
        sleep 3
done
```

Change the access privileges of the script in order to run it:

```
$ chmod a+x ~/bin/my-uptime.sh
```
You can now create a new systemd service that starts, stops or restarts your application. To do this, create a new `systemd` configuration file `my-uptime.service` in the `/etc/systemd/system/` folder with the following content (root privileges required):
```
[Unit]
Description=An example of service which prints uptime each 3 seconds
After=network.target
[Service]
ExecStart=/home/mfp/bin/my-uptime.sh
Type=simple
User=mfp
[Install]
WantedBy=multi-user.target
```
Notify the systemd daemon about the new service:
```
$ sudo systemctl daemon-reload
```
Now start the new service:
```
$ sudo systemctl start my-uptime.service
```
See the status of the service:
```
$ sudo systemctl status my-uptime.service
```
To stop the service, use:
```
$ sudo systemctl stop my-uptime.service
```
To start the service automatically after a system start, use:
```
$ sudo systemctl enable my-uptime.service
```
To not start the service automatically after a system start, use:
```
$ sudo systemctl disable my-uptime.service
```
The log files of systemd services are controlled by the journald daemon, see sectionSystem logs .

6.10 System logs

System logs are created by the `journald` daemon and managed by `journalctl`. If no parameters were defined, `journalctl` displays all logs that were collected by `journald`:
```
$ sudo journalctl
```

If you want to have messages displayed by only one service, specify the name of the service:
```
$ sudo journalctl -u my-uptime.service
```

Setting up persistent logs

By default, the log files of the TM MFP are deleted during a reboot cycle. You see only the log files since the last reboot. If log files are to be retained when the module is switched off and on again, edit the `journalctl` config file under `/etc/systemd/journald.conf.d/mel.conf`.
Edit the `Storage` configuration as follows:
```
Storage=persistent
```
Then load the new configuration of the `journald` service:
```
$ sudo systemctl restart systemd-journald.service
```
The logs are now retained when the module is switched off and on again.

Backplane bus logs

The `bbus-agent` service enables communication with the CPU over the backplane bus. You display log messages of this service as follows:

```
$ sudo journalctl -u bbus-agent
```

A minimum log level is set by default. You can increase the number of messages by increasing the log level. A total of four log levels are available. The default level is 0. To change the log level, specify the desired log level in the configuration file under `/etc/bbus/bbus-agent.conf`, e.g.:

```
LogLevel=1
```

The different log levels have the following properties:

Log level	Description
0	Minimum log level set by default
1	Extended log level for IO communication
2	Log level for troubleshooting by the user
3	Extended log level for troubleshooting by the user

NOTE

Log levels 2 and 3 are for troubleshooting faults and errors and should not be used in a production environment.

Once you have specified the log level, restart `bbus-agent`.

```
$ sudo systemctl restart bbus-agent
```

NOTE

A restart of `bbus-agent` causes the CPU to change to STOP mode.

Diagnostics

7

7.1 Status and error displays

You have several possibilities to identify an error in more detail:

- Evaluate the display of the CPU.
- Evaluate the display of the module information in STEP 7.
- Evaluate the diagnostic buffer of the CPU.
  In the diagnostic buffer, you can find plain text information about the error that occurred and the number of the matching error OBs.

The status LEDs are not supported in firmware V1.0 of the TM MFP.

Meaning of the LEDs RUN/ERROR/MAINT

| LEDs			Meaning	Solution
RUN	ERROR	MAINT		
□ Off	□ Off	□ Off	No or too little supply voltage. The module is switched off.	Check the supply voltage on the CPU.
■ On	■ On	■ On	The module is starting. Early boot phase.	Wait until the module has started.
■ On	Not relevant	Not relevant	The module is starting. Later boot phase.	Wait until the module has started.
■ On	□ Off	■ On	The module is starting. Start of SIMATIC Industrial OS.	Wait until the module has started.
☀ Flashes	□ Off	□ Off	The module is starting. Waiting for configuration from the CPU.	Configure the module with the configuration software.
■ On	□ Off	□ Off	The module is configured and is exchanging data with the CPU.	---
■ On	☀ Flashes	□ Off	Diagnostic interrupt is active.	Check the diagnostics buffer. Check the log files.
■ On	■ On	□ Off	Communication error in backplane bus.	Check the status of the bbus-agent service.

7.2　Interrupts

Interruptions/diagnostic interrupts

TM MFP can trigger up to eight different hardware interrupts in the user program. This function is configurable in the TIA Portal. More information is available here (Page 48).

The status of the TM MFP is evaluated periodically. The status can be checked in TM MFP logs visually via status LEDs or in the diagnostics buffer of the CPU.

Hardware interrupts

If an event is triggered by a Linux user program, the module generates a hardware interrupt in the PLC.

The total number of available interrupts is 8. The type numbers are in the range 0...7.

The module slot and the interrupt type are entered in the status information of the organization block (`IChannel, EventType`). Because the module only has one interrupt channel, the value of `IChannel` is always 0. The `EventType` can have a value within the specified range. This value is set by the Linux user program while the alarm is triggered.

Enabling/disabling hardware interrupts

You can enable or disable hardware interrupts within the CPU hardware configuration.

Select hardware interrupts in the device configuration. Select the "Enable interrupts raised by Linux application" option. As hardware interrupt parameter, select an existing hardware interrupt OB or create one. Now the type 0 interrupt is released and linked to the OB. Proceed as described for the other interrupts also, if necessary.

To complete the configuration, compile the project and load it into the CPU.
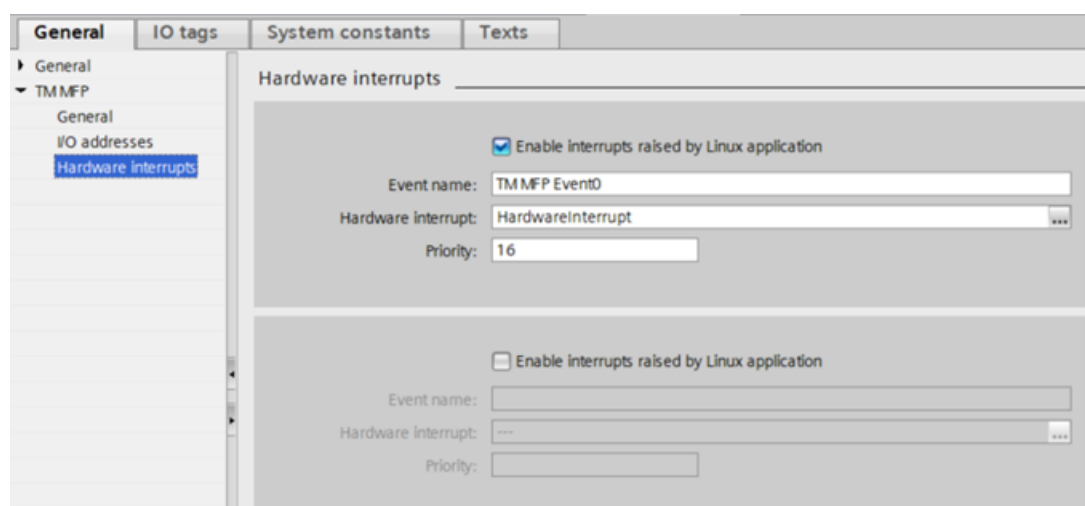
Triggering hardware interrupts

You can trigger a hardware interrupt from a Linux user program via the `trigger_hw_interrupt` interface. Use of the interface is described in the Backplane bus (Page 43) section.

The hardware interrupt cannot be processed by the CPU in the following cases:

- TM MFP is not configured.
- Hardware interrupts are not enabled in the CPU configuration.
- No organization block is attached to the hardware interrupt.
- CPU is not in RUN state.

Use hardware interrupts only to react to sporadically occurring events. The use of hardware interrupts to react to events recurring often or very often is not recommended. Hardware interrupts extend the cycle time of program execution on the CPU. Too many hardware interrupts occurring in quick succession and their execution can lead to the cycle time being exceeded in the CPU.

Parameter data record

The hardware interrupts of the TM MFP module are configured by means of a parameter data record.

- Parameter assignment in the user program:

You can reconfigure the TM MFP in RUN state. The WRREC instruction is used to transfer the parameters to the module using data record 128. With this action, the parameters set in the CPU hardware configuration are changed temporarily. They are valid again after a CPU restart. The parameters are only checked by the module for plausibility after the transfer.

- STATUS output parameter of the WRREC instruction:

The module ignores errors that occurred during parameter transfer with the WRREC instruction. The module continues operation with the previous parameter assignment. A corresponding error code is written to the STATUS output parameter. The description of the WRREC instruction and the error codes is available in the STEP 7 online help.

Structure of the parameter data record

The example in the table below shows the structure of the data record 128. The values in byte 0 and byte 1 are fixed and cannot be changed. You enable the parameter by setting the corresponding bit to "1".

Header	Byte 0	7	6	5	4	3	2	1	0	Version
		0	0	0	1	0	0	0	0	
		Major version				Minor version				
	Byte 1	7	6	5	4	3	2	1	0	Data length 6 bytes
		0	0	0	0	0	1	1	0	
Data	Byte 2	7	6	5	4	3	2	1	0	Enable

Data	Byte 2	0	0	0	1	1	1	1	1	hardware interrupts (bit 0...7 for interrupt 0...7)
	Byte 3...7	7	6	5	4	3	2	1	0	Reserved
		0	0	0	0	0	0	0	0	

Diagnostic interrupts

Diagnostic interrupts are generated and the ERROR LED lights up on each diagnostic event on the TM MFP. The events are generated by the `bbus-diag` diagnostics service, which is run in the Linux user program of the TM MFP. The service is run by default and does not require additional interaction with the user.

You will find the diagnostic interrupts in the following table.

Diagnostic interrupts	Error code	Meaning	Solution
Overtemperature	418$_H$	One of the following temperature limits is reached: CPU: 100 ^{o}C SSD: 95 ^{o}C	Check the environmental conditions for use of the module.
General error	1 B$_H$	SSD is using memory space ≥ 95% of the maximum size.	Free up more SSD memory space in the Linux user program.

Application example

<div style="text-align: right; font-size: 2em;">8</div>

8.1 Bin picking

The following section describes a real-world example.

Automation task

The automation task to be implemented consists of the removal of unsorted objects from a bin and the organized placement of these objects in a target bin (bin picking).

Hardware overview

To coordinate this complex operation, the following hardware components are used.
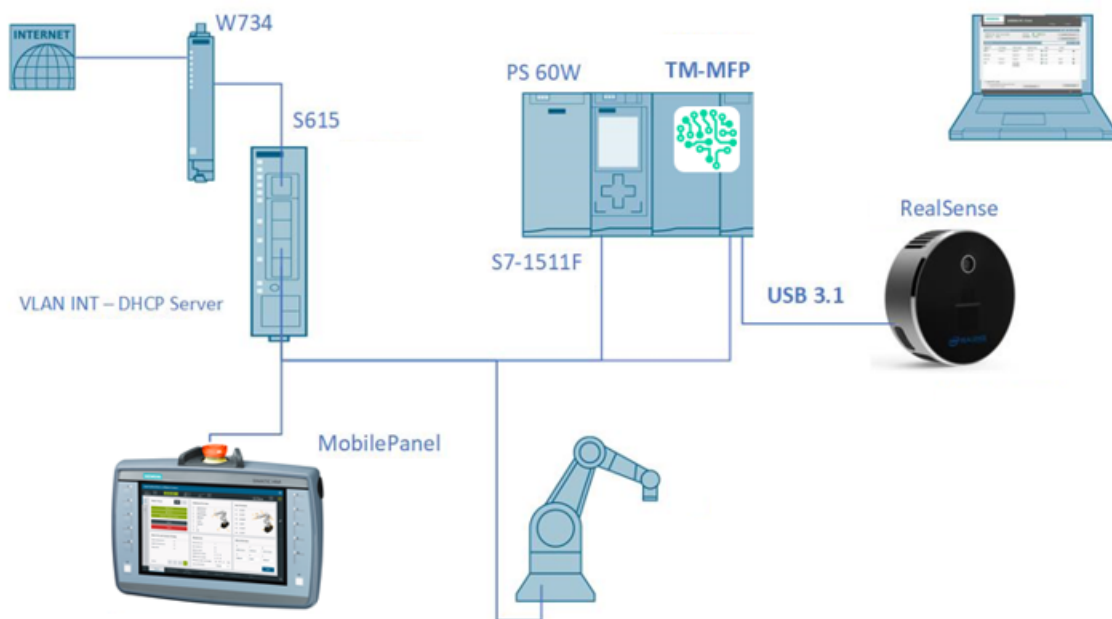

Figure 8-1 Overview of the devices involved

Within this automation task, the TM MFP processes the data of the connected RealSense USB camera and the data from the user program of the CPU.

Process sequence

The process steps for this automation task are summarized below.

1. A 3D image of the bin and its contents is created with the camera.
2. The recorded images pass through a trained neural network.
3. Using an AI algorithm, the software calculates possible pick positions for the object.
4. The optimal pick point of the existing objects in the bin is selected.
5. Data of the optimal pick points is transferred to the CPU.
6. The CPU passes the data to the robot controller and coordinates the robot movements.
7. The robot system then executes the picking movement and removes the object from the bin.
8. The object is placed in the target bin.

Reference

This section describes the application example in a highly condensed form.

You can find a detailed description of the application example in the manual for the Machine Vision Software for AI-based Universal Picking "SIMATIC Robot Pick AI".

Technical specifications

<div style="text-align: right; font-size: 3em; font-weight: bold;">9</div>

Technical specifications

Article number	6ES7558-1AA00-0AB0
General information	
Product type designation	TM MFP
Firmware version	V1.1
• FW update possible	Yes
Product function	
• I&M data	Yes; I&M0 to I&M4
Engineering with	
• STEP 7 configurable/integrated from version	- / -
• PROFIBUS from GSD version/GSD revision	- / -
• PROFINET from GSD version/GSD revision	- / -
Installation type/mounting	
Mounting position	Horizontal, vertical
Rail mounting	Yes
Control cabinet installation	Yes
Power	
Power available from the backplane bus	25 W
Power loss	
Power loss, typ.	10.5 W
Drives	
SSD	Yes; 128 GB
Address area	
Address space per module	
• Inputs	256 byte
• Outputs	256 byte
Interfaces	
Number of Ethernet interfaces	2
Number of USB interfaces	2
Ethernet interface	Yes
USB port	Yes
SD card slot	No
Connection for keyboard/mouse	USB / USB
Video interfaces	
• Graphics interface	1x DisplayPort

Article number	6ES7558-1AA00-0AB0
Interface types	
RJ 45 (Ethernet)	
• 1000 Mbps	Yes
USB port	
• USB specification	USB 3.0
• Design of the USB ports	USB type A socket
Protocols	
Protocols (Ethernet)	
• GigE Vision	No
Web server	
• supported	No
Interrupts/diagnostics/status information	
Status indicator	Yes
Alarms	Yes
Diagnostics function	Yes
Diagnostics indication LED	
• RUN LED	Yes
• ERROR LED	Yes
• MAINT LED	Yes
• LINK LED	Yes
• ACT LED	Yes
• Monitoring of the supply voltage (PWR-LED)	Yes
Ambient conditions	
Ambient temperature during operation	
• horizontal installation, min.	0 °C
• horizontal installation, max.	60 °C
• vertical installation, min.	0 °C
• vertical installation, max.	40 °C
Ambient temperature during storage/transportation	
• min.	-40 °C
• max.	70 °C
Altitude during operation relating to sea level	
• Installation altitude above sea level, max.	5 000 m; Restrictions for installation altitudes > 2 000 m, see manual
Operating systems	
pre-installed operating system	
• Industrial OS	Yes

Article number	6ES7558-1AA00-0AB0
Decentralized operation	
to SIMATIC S7-300	No
to SIMATIC S7-400	No
to SIMATIC S7-1200	No
to SIMATIC S7-1500	No
to standard PROFIBUS master	No
to standard PROFINET controller	No
Dimensions	
Width	70 mm
Height	147 mm
Depth	129 mm
Weights	
Weight, approx.	645 g

Dimension drawing A

A.1 Dimension drawing TM MFP

This appendix contains the dimension drawing of the technology module installed on a mounting rail. You must take into account the dimensions when installing the module in cabinets, control rooms, etc.
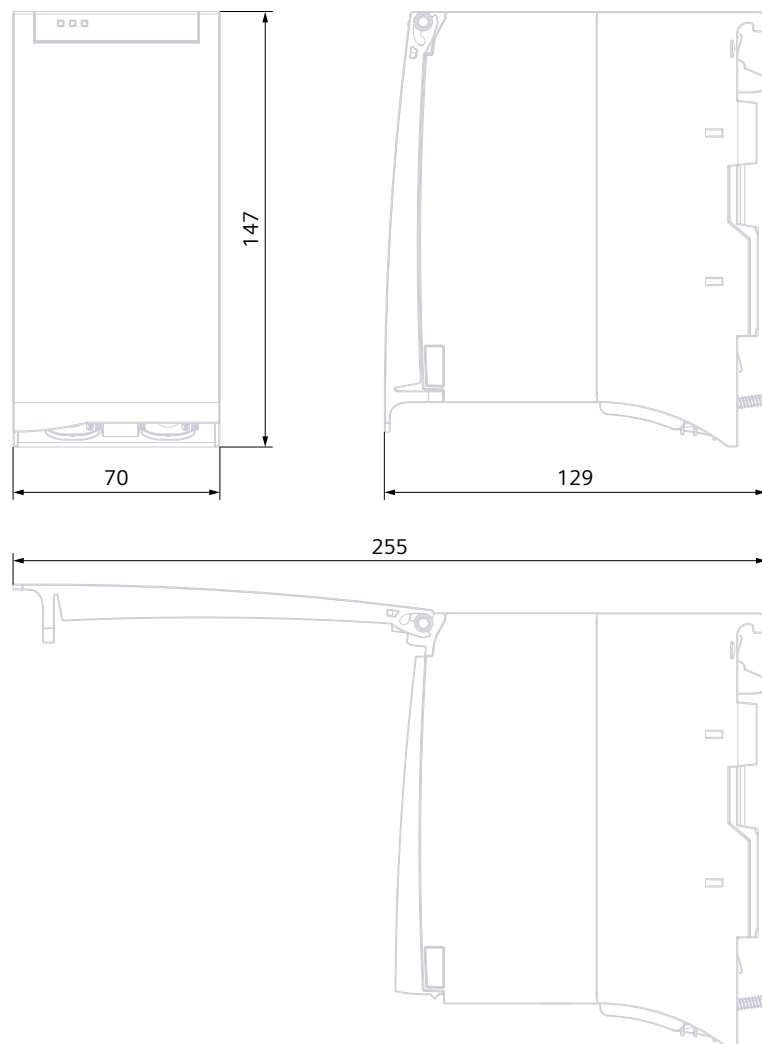
Dimension drawings of the TM MFP technology module

Figure A-1 Dimension drawing TM MFP