

Monitoring of Machine Vibration Variables with a SIPLUS SM 1281 Condition Monitoring System

SIPLUS SM 1281, SIMATIC S7-1200

<https://support.industry.siemens.com/cs/ww/en/view/109480750>

Siemens
Industry
Online
Support



Warranty and liability

Note

The Application Examples are not binding and do not claim to be complete regarding the circuits shown, equipping and any eventuality. The Application Examples do not represent customer-specific solutions. They are only intended to provide support for typical applications. You are responsible for ensuring that the described products are used correctly. These Application Examples do not relieve you of the responsibility to use safe practices in application, installation, operation and maintenance. When using these Application Examples, you recognize that we cannot be made liable for any damage/claims beyond the liability clause described. We reserve the right to make changes to these Application Examples at any time without prior notice.

If there are any deviations between the recommendations provided in these Application Examples and other Siemens publications – e.g. Catalogs – the contents of the other documents have priority.

We do not accept any liability for the information contained in this document. Any claims against us – based on whatever legal reason – resulting from the use of the examples, information, programs, engineering and performance data etc., described in this Application Example shall be excluded. Such an exclusion shall not apply in the case of mandatory liability, e.g. under the German Product Liability Act (“Produkthaftungsgesetz”), in case of intent, gross negligence, or injury of life, body or health, guarantee for the quality of a product, fraudulent concealment of a deficiency or breach of a condition which goes to the root of the contract (“wesentliche Vertragspflichten”). The damages for a breach of a substantial contractual obligation are, however, limited to the foreseeable damage, typical for the type of contract, except in the event of intent or gross negligence or injury to life, body or health. The above provisions do not imply a change of the burden of proof to your detriment.

Any form of duplication or distribution of these Application Examples or excerpts hereof is prohibited without the expressed consent of the Siemens AG.

Security information

Siemens provides products and solutions with industrial security 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 security concept. Siemens' products and solutions only form one element of such a concept.

Customer is responsible to prevent unauthorized access to its plants, systems, machines and networks. Systems, machines and components should only be connected to the enterprise network or the internet if and to the extent necessary and with appropriate security measures (e.g. use of firewalls and network segmentation) in place.

Additionally, Siemens' guidance on appropriate security measures should be taken into account. For more information about industrial security, please visit <http://www.siemens.com/industrialsecurity>.

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

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

Table of Contents

Warranty and liability.....	2
1 Introduction.....	4
1.1 Overview.....	4
1.2 Mode of operation	5
1.2.1 Configuration	5
1.2.2 Monitoring mode.....	6
1.2.3 Program overview	8
1.3 Components used	11
2 Engineering	12
2.1 Hardware setup	12
2.2 Configuration	13
2.2.1 Preparation	13
2.2.2 Installing the HSP	14
2.2.3 Downloading the STEP 7 project into the CPU.....	15
2.2.4 Downloading the WinCC project into the HMI	17
2.3 Commissioning	18
2.3.1 Measuring the normal operating condition of the machine	18
2.3.2 Determining the warning and alarm limits	18
2.4 Operation.....	21
2.4.1 Notes on setting parameters	21
2.4.2 Setting the static parameters	22
2.4.3 Setting dynamic parameters	23
2.4.4 Changing the operating mode.....	23
2.4.5 Reading measured values.....	24
2.4.6 Restoring parameters from the backup.....	25
3 Valuable Information	26
3.1 Basic terms.....	26
3.2 Mechanical vibrations.....	27
3.2.1 Meaning and significance of vibrations	27
3.2.2 Causes of mechanical vibrations	28
3.3 Monitoring and diagnosing vibrations.....	29
3.3.1 Measuring vibrations	29
3.3.2 Overview of diagnostic procedures	32
3.3.3 Vibration diagnosis by measuring characteristic values in the time domain.....	33
3.3.4 Vibration diagnosis through frequency analysis	35
3.3.5 Standards	36
3.4 SIPLUS SM 1281	36
3.5 Library "SM1281_Library"	37
3.5.1 Overview.....	38
3.5.2 Function block "SM1281_Module"	38
3.5.3 Function "SM1281_Channel"	39
3.5.4 Data block "SM1281_Status"	39
3.5.5 Data block "SM1281_Backup"	39
3.5.6 Data types	39
4 Appendix	40
4.1 Service & support	40
4.2 Links and literature	41
4.3 Change documentation	41

1 Introduction

1.1 Overview

To protect a machine efficiently against mechanical damage during operation and detect such damages at an early stage, the machine has to be monitored permanently.

Mechanical vibrations are crucial in this context. Vibrations are caused mainly by centrifugal forces at rotating machine parts.

This can be due to:

- Unbalance
- Improper alignment of machine trains
- Bearing-related damage
- Transmission faults
- Magnetic, hydraulic and other function-related changing forces

In order to monitor mechanical components, SIEMENS provides the SIPLUS CMS Condition Monitoring Systems. This monitoring system gives a permanent overview of all machines and of the entire system. In line with preventive maintenance, servicing activities can thus be planned more efficiently and carried out on schedule.

After a prolonged period of uninterrupted operation, the documented trend curves enable early detection of significant changes as a result of wear or other damage-related causes.

Topics not covered by this application

This application example covers the configuration of the SIPLUS SM 1281 Condition Monitoring Systems and the monitoring and visualization of characteristic values (RMS). This documentation does not cover the evaluation of the frequency spectrum using the integrated web server.

This application example does not include any description of the following topics:

- Configuring the drive
- Vibration diagnosis through frequency analysis
- Operating the integrated web server
- Data exchange via FTP

Assumed knowledge

The following basic knowledge is assumed:

- SIMATIC controllers
- STEP 7 programming
- WinCC

1.2 Mode of operation

1.2.1 Configuration

Monitoring is done via the SIPLUS CMS1200 Condition Monitoring System with the SM 1281 module. Specifically developed for connection to the SIMATIC S7-1200, the monitoring thus can be seamlessly integrated into the automation process.

The figure below shows a schematic overview of the most important components of the solution:

Figure 1-1: Overview of components

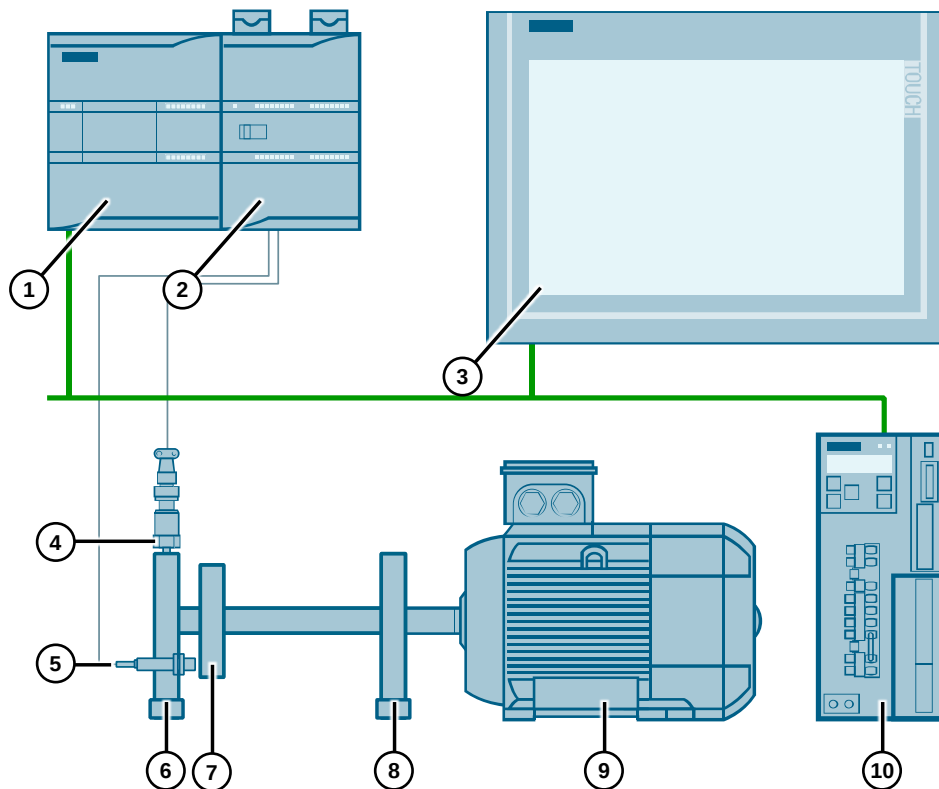


Table 1-1: Legend for Figure 1-1

	Designation
1.	S7-1200 automation system
2.	CMS module SM 1281
3.	HMI to visualize and operate the CMS
4.	Vibration sensor to acquire the vibration acceleration
5.	Retro-reflective photoelectric sensor for speed sensing
6.	Bearing at the shaft end
7.	Load
8.	Bearing at the shaft coupling
9.	Motor
10.	SINAMICS V90 drive

Vibration sensor

The SM 1281 uses a vibration sensor to monitor the vibrations at the shaft end bearing.

When commissioning the machine, the status under normal operating conditions is determined. From the characteristic values measured, the user defines the warning and alarm limits and stores them in the SM 1281.

Figure 1-2: Vibration sensor



During operation, the vibrations at the machine are monitored permanently and the status is reported to the user via an HMI. Warnings and alarms are generated if the set limit values are exceeded.

1.2.2 Monitoring mode

In monitoring mode, all variables to be monitored are measured, calculated and checked for the configured limits. When limits are violated, the corresponding messages are generated and the parameterized response is executed. A function block enables the control program to access the messages.

The measured variables are cyclically transmitted to the controller and recorded as a trend curve in the SM 1281. The trend curves can be displayed via the integrated web server.

Note

This application example focuses on starting up the SM 1281 and its monitoring mode. Additional operating modes can be found in the SM 1281 operating instructions:

<https://support.industry.siemens.com/cs/ww/en/view/109481490>

Threshold monitoring

To monitor RMS characteristic values, you can define threshold and hysteresis values. Threshold values are only applicable for warning and alarm limits per characteristic value.

RMS monitoring

The SM 1281 enables the calculation of the characteristic values aRMS and vRMS:

- vRMS is calculated based on the RMS value of vibration velocity.
- aRMS is calculated based on the RMS value of vibration acceleration.

Hysteresis

For the monitoring of vRMS and aRMS, three successive values that exceed the threshold must be present to trigger a warning or alarm. Accordingly, three

successive values that fall below the threshold (including the absolute value hysteresis) must be present for the warning or alarm to disappear again.

1.2.3 Program overview

PLC

The library "SM1281_Library" of the SM 1281 signal module was used for this application example. It contains program blocks and HMI text lists. The library enables the functions of the SM 1281 to be integrated easily into the user's control program. Blocks and data types which are part of the library carry the prefix "SM1281" in their name. Further information on the library "SM1281_Library" can be found in chapter 3.5.

The user program in this application example has a modular structure so that further modules can be added easily.

Figure 1-3: Program overview

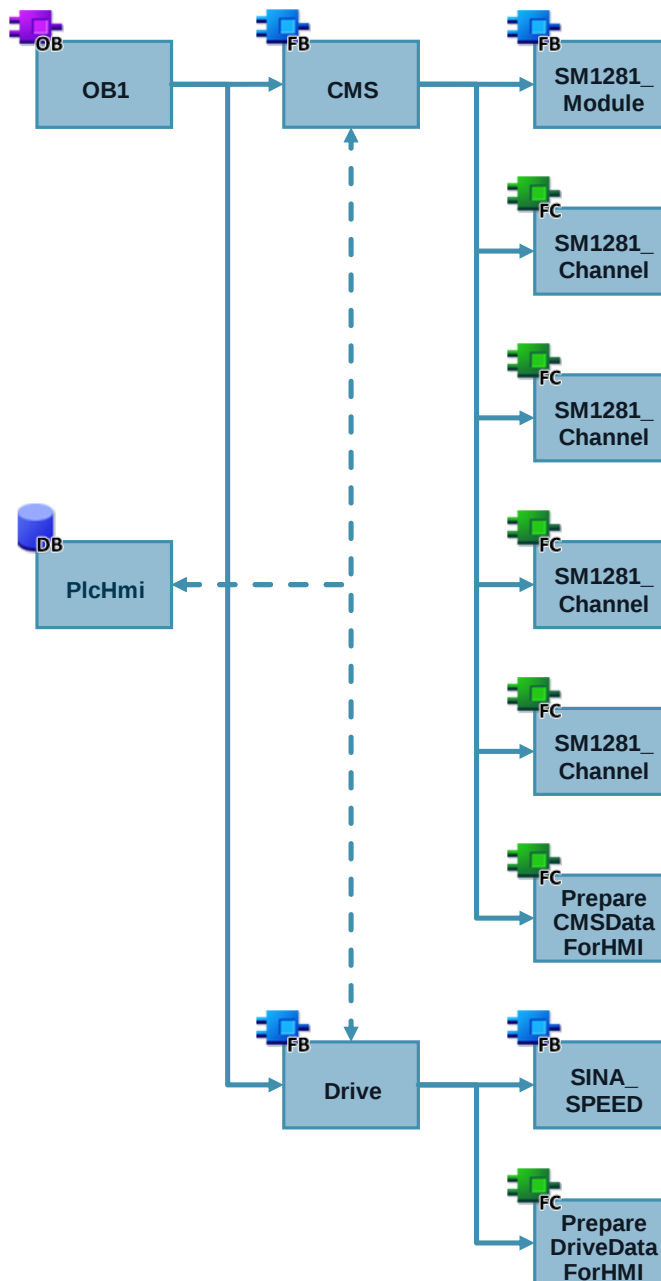


Table 1-2: Explanation of the blocks

Block	Explanation
CMS	This function block calls all required blocks for a specific SM 1281 module. If you are using several modules, create further instances of this function block.
SM1281_Module	This function block is part of the "SM1281_Library" and is intended for configuring, controlling and monitoring the SM 1281 module.
SM1281_Channel	This function block is part of the "SM1281_Library" and is intended for configuring, controlling and monitoring a channel of the SM 1281. For each channel (vibration sensor) used, the function "SM1281_Channel" is called. The example project is prepared for the maximum number of channels for an SM 1281 module, even if only one channel is enabled and evaluated.
PrepareCMSDataForHMI	This function prepares the data of the SM 1281 for visualization.
Drive	This function block controls the SINAMICS V90 drive. If you are using several drives, create further instances of this function block.
PrepareDriveDataForHMI	This function prepares the data of the drive for visualization.
PlcHmi	This data block is used for data exchange between PLC and HMI.

HMI

The SM 1281 is configured, operated and monitored via an HMI. Visualization consists of the following screens:

Table 1-3: Explanation of the screens

Screen	Explanation
Overview	This start screen shows the monitoring status of the SM 1281 and controls the drive.
Actual Values	On this screen, you can view the actual values of the channels and start the recording of raw data or fingerprints.
Backup	On this screen, you can view and restore the parameters of the module that have been stored as backup.
Maintenance	On this screen, you can exchange data with the module via FTP. This function is not discussed in this application example.
Parameters	On this screen, you can define the parameters of the module and its channels.

To make sure that further modules can be added to the application example, the following faceplates have been created in the project:

Table 1-4: Explanation of the faceplates

Faceplate	Explanation
ChannelBackup	This faceplate shows the parameters of a channel that have been stored as backup.
ChannelParameters	With this faceplate, you can define the parameters of a channel.
ChannelStatus	This faceplate shows the monitoring status of a channel.
ModuleBackup	This faceplate shows the parameters of the module that have been stored as backup.
ModuleOverview	This faceplate shows an overview of the monitoring states of a module.
ModuleParameters	With this faceplate, you can define the parameters of the module.

1.3 Components used

Validity

This application is valid for

- STEP 7 as of V13 SP1 Upd6
- WinCC as of V13 SP1 Upd6
- S7-1200 as of FW 4.1
- SM 1281 as of FW 2.0

Components used

This application example has been created with the following hardware and software components:

Table 1-5: Components used

Component	Qty.	Article number	Note
Power supply	1	6EP1332-4BA00	PM 190 W
SIMATIC S7 CPU	1	6ES7212-1AE40-0XB0	CPU 1212C DC/DC/DC
SIPLUS SM 1281	1	6AT8007-1AA10-0AA0	FW 2.0
Retro-reflective photoelectric sensor	1	GLV18-55-G/73/120	Pepperl + Fuchs
Vibration sensor	1	6AT8002-4AB00	Sensitivity: 100.08 mV/g
SIMATIC HMI TP1200 Comfort	1	6AV2124-0MC01-0AX0	12"
SINAMICS V90 PN	1	6SL3210-5FB10-2UF0	Single-phase operation at 240 V
STEP 7 Basic	1	6ES7822-0AA03-0YA5	TIA Portal V13 SP1 Upd 6 or higher
WinCC Advanced	1	6AV2102-0AA03-0AA5	TIA Portal V13 SP1 Upd 6 or higher
HSP 0113 for the SM 1281	1	--	V2.0 For the download link, refer to [5] .

Note

The functionality was tested with the hardware components specified. Similar products that are not included in the above list can also be used. In this case, please note that changes to the example code (e. g. different addresses) may become necessary.

This application example consists of the following components:

Table 1-6: Components of the application example

Component	Note
109480750_CMS_S7-1200_RMS_DOC_V20_en.pdf	This document
109480750_CMS_S7-1200_RMS_PROJ_TIIV13_V20.zip	This zip file contains the project for TIA Portal V13 SP1.
109480750_CMS_S7-1200_RMS_PROJ_TIIV14_V20.zip	This zip file contains the project for TIA Portal V14 SP1.

2 Engineering

2.1 Hardware setup

The figure below shows the hardware setup of the application.

Figure 2-1: Hardware setup

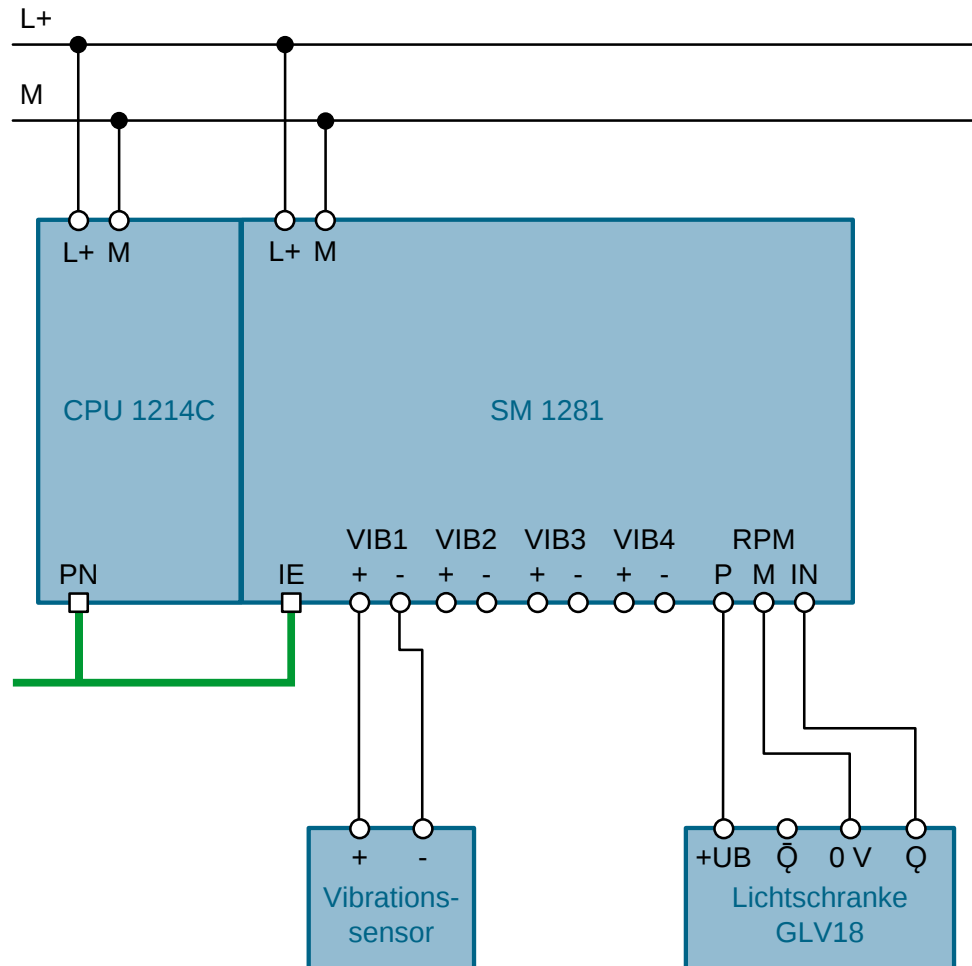


Table 2-1: Installation

No.	Action	Remark
1.	Place the CPU and the SM 1281 side by side on a top hat rail.	
2.	Connect the two components using the integrated bus.	
3.	Install the vibration sensor to the bearing pedestal of the shaft end.	Chapter 3.3.1 Measuring vibrations shows ways how to mount the sensor.

No.	Action	Remark
4.	Install the retro-reflective photoelectric sensor.	Using a separate speed sensor is not mandatory. You can also provide the speed to the SM 1281 via the user program. The function block "SM1281_Module" provides the "SpeedSource" and "Speed" parameters for this purpose.
5.	Wire the components as shown in the illustration above.	
6.	Switch on the power supply.	

For this application example, the following IP addresses were used:

Table 2-2: IP addresses used

Component	IP address	Subnet mask
CPU 1212C	192.168.0.1	255.255.255.0
HMI TP1200	192.168.0.2	255.255.255.0
Web server SM 1281	192.168.0.200	255.255.255.0
SINAMICS V90 PN	192.168.0.3	255.255.255.0

Note

You can specify the IP address of the web server of the SM 1281 at the parameter "IPAddress" of the FB "SM1281_Module" or via the HMI (see chapter 2.4.2).

2.2 Configuration

The following instructions describe the procedure for TIA Portal V13 SP1, but also applies to TIA Portal V14 and higher.

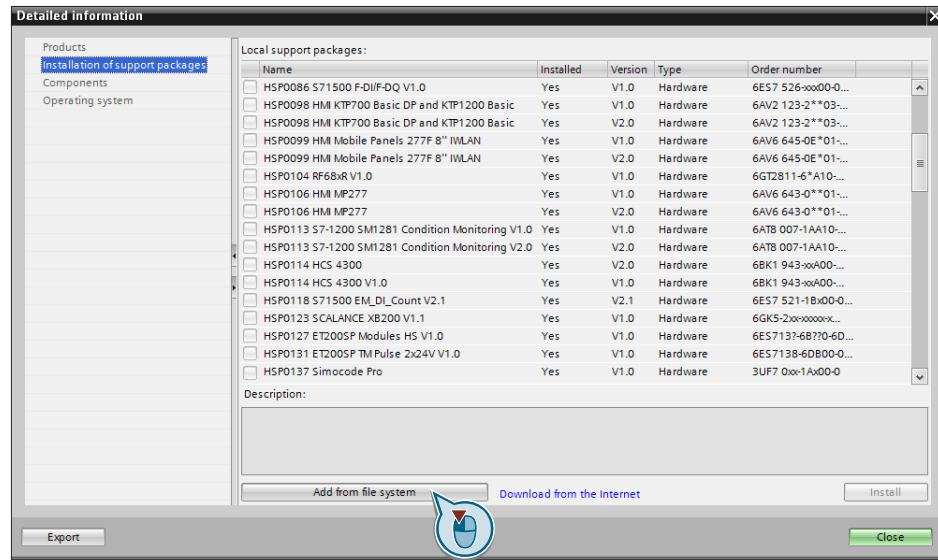
2.2.1 Preparation

1. Download the project file "109480750_CMS_S7-1200_RMS_PROJ_TIAV13_V20.zip" at: <https://support.industry.siemens.com/cs/ww/en/view/109480750>
2. Save the zip file in any directory on your computer and extract it.
3. Download the HSP 0113 for the SM 1281. It is included in the HSP collection for TIA Portal: <https://support.industry.siemens.com/cs/de/en/view/72341852>
4. Save the zip file in any directory on your computer and extract it.
5. Set the IP address of the PG/PC in such a way that the PG/PC is located in the same subnet as the CPU.
6. Use an Ethernet cable to connect the PG/PC with the Ethernet interface of the CPU.

2.2.2 Installing the HSP

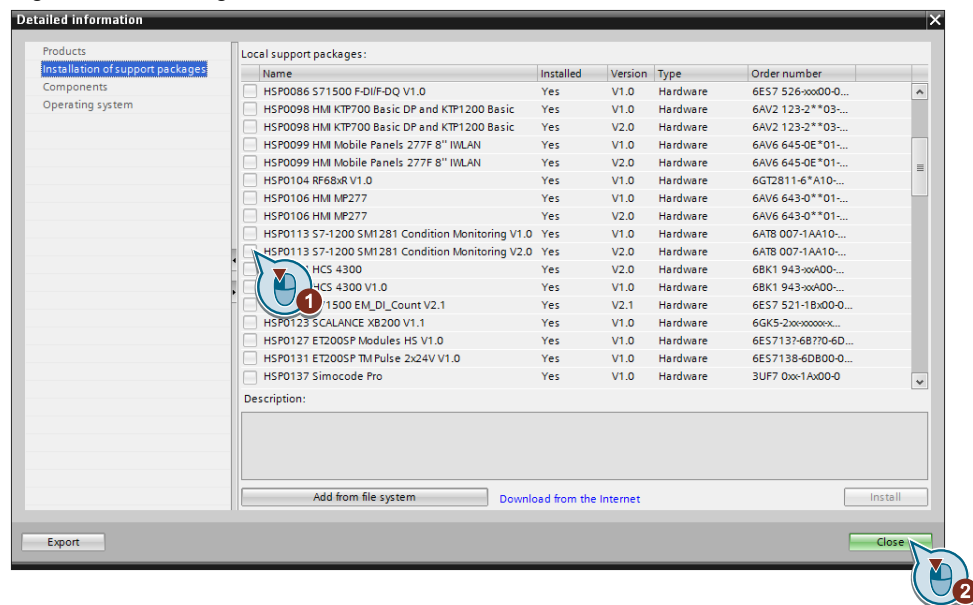
1. Open "TIA Portal V13".
2. Go to the project view.
3. In the menu bar, click "Options" > "Support Packages".
4. Click "Add from file system" and select the HSP 0113 from the downloaded HSP collection.

Figure 2-2: Adding an HSP



5. Select the HSP from the list and then click "Install".

Figure 2-3: Installing the HSP

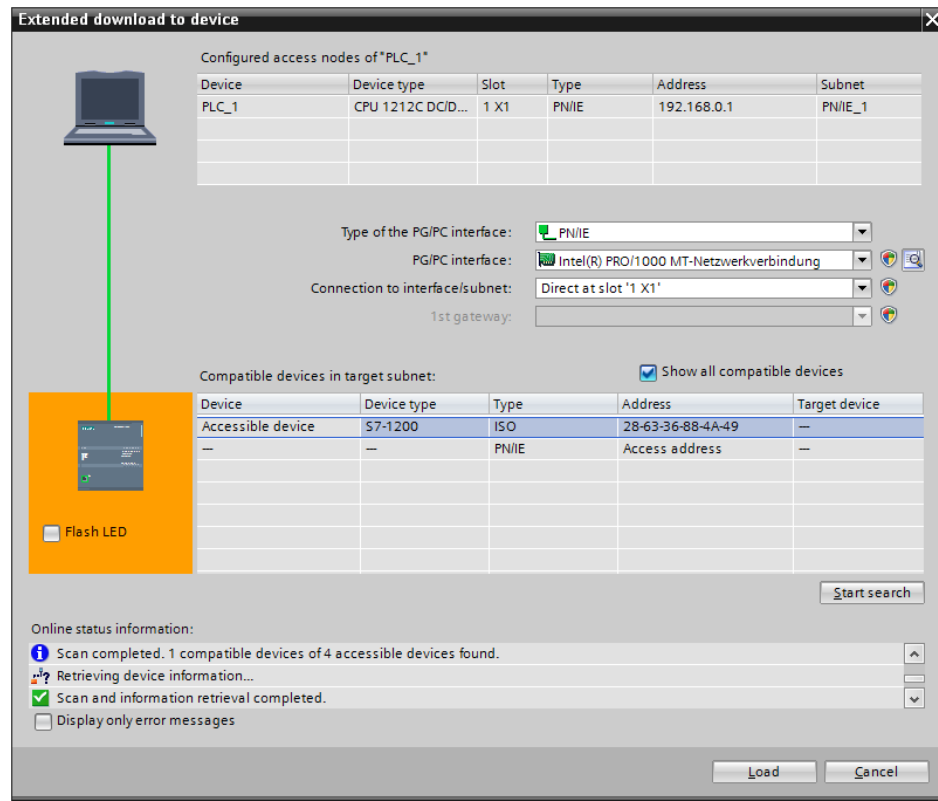


6. Follow the further instructions.

2.2.3 Downloading the STEP 7 project into the CPU

1. In the menu bar in TIA Portal, click "Project > Open".
2. Click "Browse" and open the extracted project.
3. Right-click "PLC_1 [CPU1212C DC/DC/DC]" in the project tree and then "Download to device > Hardware and Software (only changes)".
4. Select the corresponding interface and click "Start search".

Figure 2-4

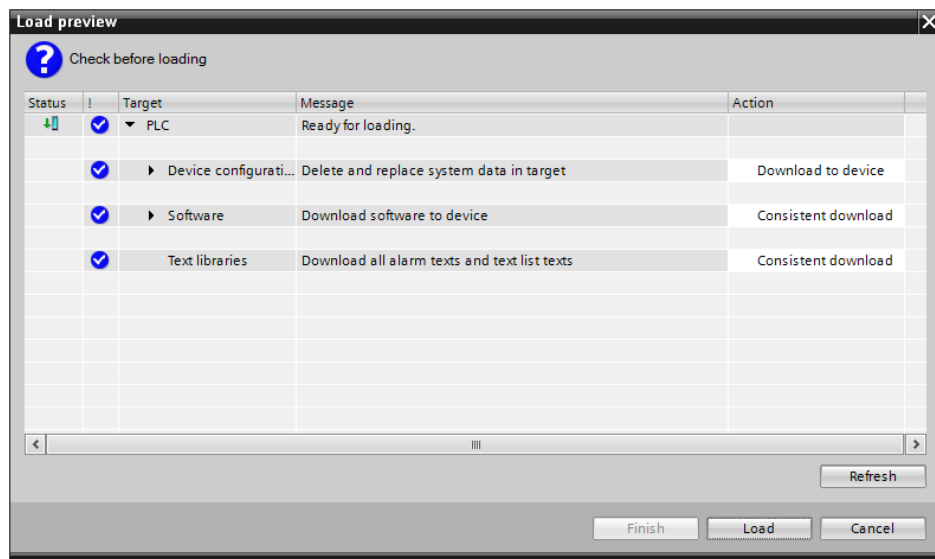


5. Select the CPU based on the IP or MAC address and then click "Load".

Note

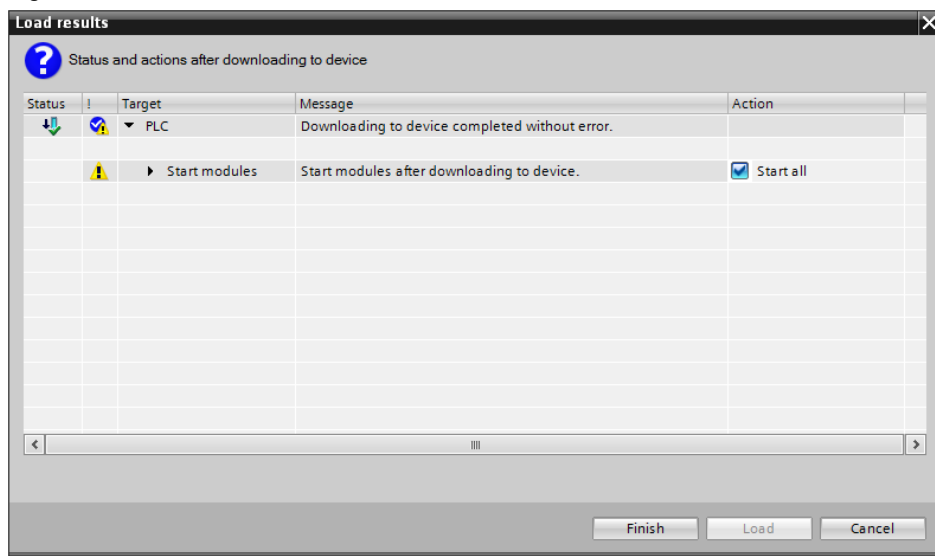
The IP address and the device name are automatically assigned when downloading the project into the CPU.

Figure 2-5



- Confirm the dialog by clicking “Load”. If the CPU is presently not in STOP, it has to be stopped.

Figure 2-6

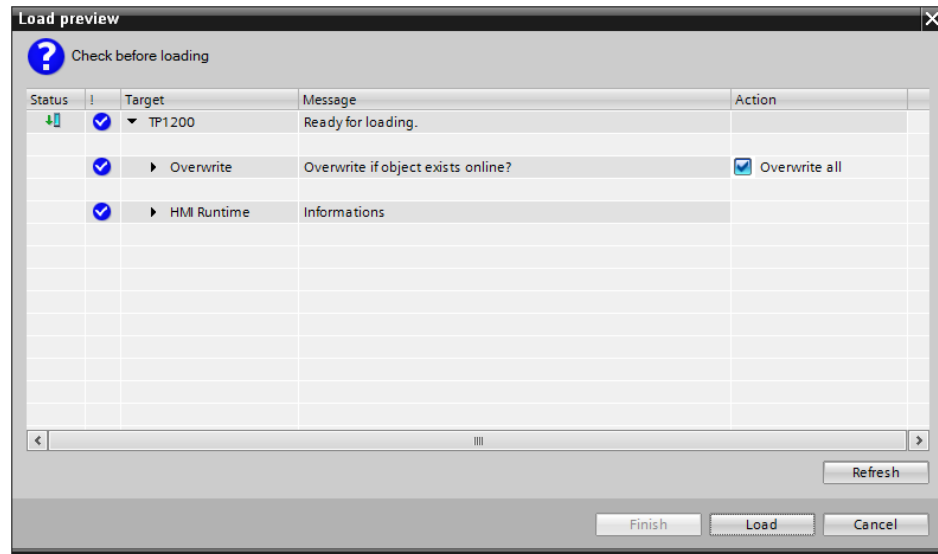


- Tick the “Start all” check box and click “Finish”.

2.2.4 Downloading the WinCC project into the HMI

1. Make sure that the HMI is in transfer mode or automatic transfer is allowed.
2. Right-click "TP1200 [TP1200 Comfort]" in the project tree and then "Download to device > Hardware and Software (only changes)".
3. Select the corresponding interface and click "Start search".
4. Select the HMI based on the IP or MAC address and click "Load".

Figure 2-7



8. Tick the "Overwrite all" check box and click "Load".

2.3 Commissioning

Below we will explain how you can determine limits for warnings and alarms for your machine.

2.3.1 Measuring the normal operating condition of the machine

To detect wear and damages at the machine, we need to know the vibration variables in the normal operating state. Therefore, the vibration variables are measured during commissioning and are used as the basic values to calculate warning and alarm limits.

Therefore, measure the vibration variables during commissioning and adjust the warning and alarm limits correspondingly. A detailed instruction is given in chapter [2.4 Operation](#).

ATTENTION

If a bearing damage already exists during commissioning, this is not automatically detected by the CMS. Please observe the guide values given in Table 2-3 to assess the condition of your machine during commissioning.

2.3.2 Determining the warning and alarm limits

We will show how to determine the warning and alarm limits using an example. The machine in our example has the following properties:

- The motor capacity is 20 kW.
- The motor is mounted on a soft foundation.

The following guide values apply for this type of machines according to DIN ISO 10816-3:

Table 2-3: Guide values according to DIN ISO 10816-3

Assessed zones		Vibration velocity
A	Newly started up machine	< 2.3 mm/s
B	Machine in unlimited long-term operation	< 4.5 mm/s
C	Machine in short-term operation	< 7.1 mm/s
D	Vibrations cause damages	> 7.1 mm/s

Warning limit v_{RMS}

The warning limit indicates that a significant change has occurred, but operation can generally be continued. The reasons for the changed vibration condition should be investigated and eliminated if necessary.

Recommendations from DIN ISO 10816-3:

If the increase (or decrease) of the vibration quantity exceeds 25 % of the upper limit value of the corresponding zone B, the changes have to be considered essential, in particular when they occur suddenly.

We therefore recommend setting the warning limit 25 % of the upper limit value of the corresponding zone B higher than the basic value (the basic value is obtained from past operational experiences at this measuring point). The limit should generally not be higher than 1.25 times the upper limit of zone B.

As no experience values are available at the beginning, the value measured when determining the normal operating state is used as the basic value. A basic value of 0.8 mm/s is measured for the machine in the example.

In this example, the warning limit is defined as follows:

$$\text{Warning limit } v_{RMS} = \text{basic value} + 0.25 * \text{upper limit zone B}$$

$$\text{Warning limit } v_{RMS} = 0.8 \frac{\text{mm}}{\text{s}} + \left(0.25 * 4.5 \frac{\text{mm}}{\text{s}} \right)$$

$$\text{Warning limit } v_{RMS} = 1.925 \frac{\text{mm}}{\text{s}}$$

Alarm limit v_{RMS}

The intention of the alarm limit is to indicate that further operation may cause machine damage. If this limit is exceeded, immediate measures should be taken to reduce vibrations or the machine should be shut down.

Recommendations from DIN ISO 10816-3:

In general, the limit is located within the zones C or D. Generally, the limit should not exceed 1.25 times the upper limit of zone C.

In this example, the upper limit of zone C is used as alarm limit:

$$\text{Alarm limit } v_{RMS} = 7.1 \frac{\text{mm}}{\text{s}}$$

Warning limit aRMS

You can use the value of the aRMS vibration acceleration averaged over a frequency range between 1 kHz and 10 kHz as bearing status monitoring.

The suggested warning and alarm limits are based on practical experiences. There is no normative specification for limits.

To determine the warning limit, add 1 m/s² to the measured basic value in normal operating condition of the machine.

A basic value of 0.8 m/s² is measured for the machine in the example.

$$\text{Warning limit aRMS} = \text{basic value} + 1 \frac{\text{m}}{\text{s}^2}$$

$$\text{Warning limit aRMS} = 1.8 \frac{\text{m}}{\text{s}^2}$$

Alarm limit aRMS

To determine the alarm limit, add 2 m/s² to the measured basic value in normal operating condition of the machine.

$$\text{Alarm limit aRMS} = \text{basic value} + 2 \frac{\text{m}}{\text{s}^2}$$

$$\text{Alarm limit aRMS} = 2.8 \frac{\text{m}}{\text{s}^2}$$

Now adjust the determined warning and alarm limits as shown in chapter [2.4.3](#).

Note

In a real application, fixed warning and alarm limits are not sufficient for all operating modes of a machine. For this, create e. g. an operating mode table containing the warning and alarm limits depending on the speed and load in a data block of the CPU.

Note

Over time, the machine will undergo transient oscillations and the warning and alarm limits should be adjusted.

2.4 Operation

2.4.1 Notes on setting parameters

Static parameters

The parameters at the block interfaces are generally transmitted to the SM 1281 upon request only. All parameters at the input parameters of the blocks "SM1281_Module" and "SM1281_Channel" are transmitted to the SM 1281 by a positive edge at the input parameter "SetAllParameters".

Depending on the current operating mode of the SM 1281, the operating mode is changed automatically in the process. This is necessary, because some parameters cannot be transferred into the SM 1281 in a RUN state. Following successful transfer of the parameters to the SM 1281, the operating mode that was active prior to the parameter transfer is restored.

If the parameters were not transferred successfully, an error message is generated at the output parameter "OpModeChangeStatus" of the "SM1281_Module" block as for a failed change of the operating mode and is displayed on the top right of each screen.

Dynamic parameters

Besides the option to transmit all parameters to the SM 1281, you can also transfer just the so-called dynamic parameters. The dynamic parameters at the input parameters of the functions "SM1281_Channel" are transmitted to the SM 1281 by a positive edge at the input parameter "SetDynParameters".

These parameters can also be transmitted in the status "RUN: Monitoring" and "RUN: INHIBITED" without the SM 1281 having to switch the operating mode into stop mode.

The following are dynamic parameters:

Table 2-4: Dynamic parameters of the SM 1281

Parameter	Description
AlarmLevel_vRMS	Alarm limit of vibration velocity in mm/s
WarningLevel_vRMS	Warning limit of vibration velocity in mm/s
AlarmLevel_aRMS	Alarm limit of vibration acceleration in m/s ²
WarningLevel_aRMS	Warning limit of vibration acceleration in m/s ²

2.4.2 Setting the static parameters

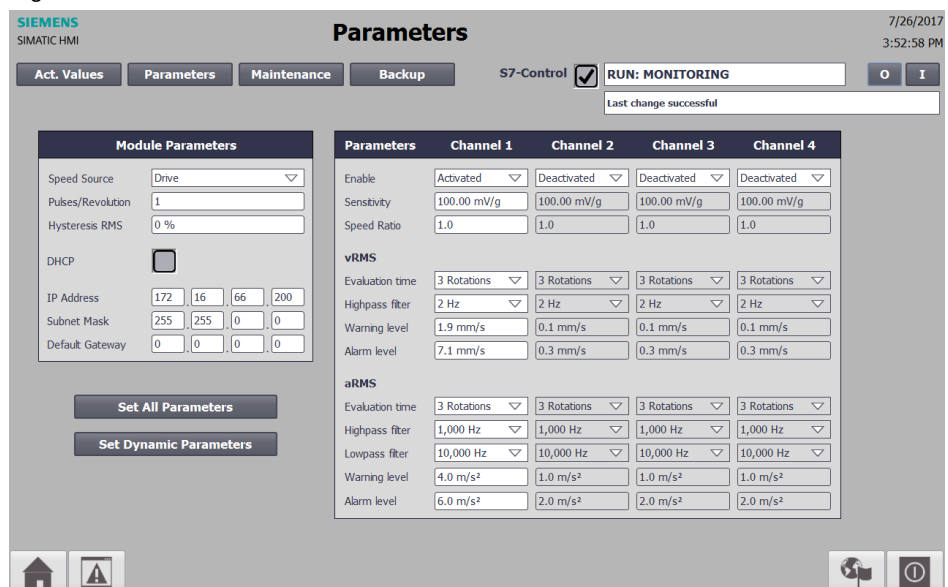
1. On the start screen, tap the SM 1281 overview.

Figure 2-8: Overview



2. Tap the "Parameters" button.
3. Set the desired parameters.

Figure 2-9: "Parameters" screen



4. Tap the "Set All Parameters" button.

The SM 1281 switches to the "STOP: CONFIGURATION" mode and sets the parameters. Subsequently, it changes back to the last operating mode.

2.4.3 Setting dynamic parameters

1. Tap the "Parameters" button.
2. Set the desired parameters.
3. Tap the "Set Dynamic Parameters" button.

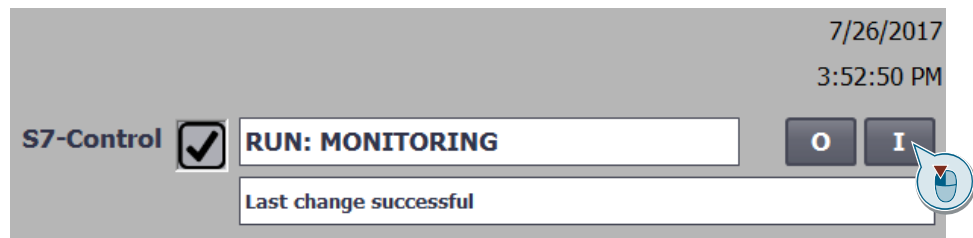
The SM 1281 switches to the "RUN: INHIBITED" mode and sets the parameters. Subsequently, it changes back to the last operating mode.

2.4.4 Changing the operating mode

The operating mode can be changed from any screen:

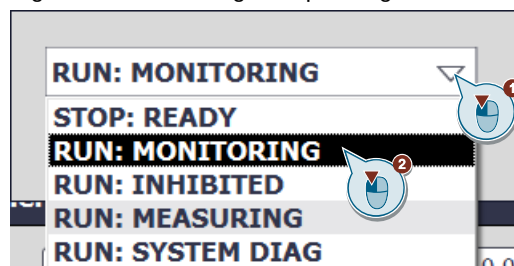
1. Tap the "ON" button.

Figure 2-10: Changing the operating mode



2. Select the desired operating mode from the drop-down list.

Figure 2-11: Selecting the operating mode



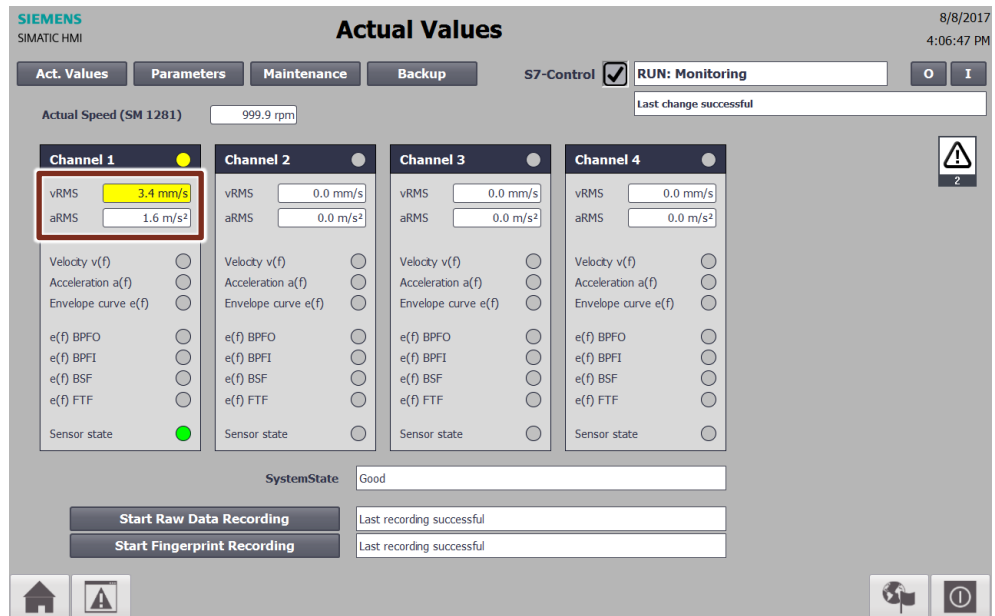
3. Tap "OK".

The operating mode is changed. The status is displayed in the text box below.

2.4.5 Reading measured values

Tap the “Act. Values” button and read the measured values for the corresponding channel.

Figure 2-12: Measured values vRMS and aRMS in case of the vRMS warning limit being exceeded



Note

The indicators of the spectra only show a status if frequency-selective monitoring is activated in the SM 1281.

2.4.6 Restoring parameters from the backup

With each successful transition to the “RUN: MONITORING” operating mode, the parameters last sent to the SM 1281 are automatically checked for validity. If the parameters are valid, they are backed up in the remanent data block “SM1281_Backup”. If the parameters are invalid, an error message occurs in the HMI and in the message system of the SM 1281 and the SM 1281 remains in the operating mode “STOP: READY”.

After a restart of the CPU or faulty parameterization, you can restore the saved parameters.

1. Tap the “Backup” button.
2. Tap the “Restore Parameters” button.

Figure 2-13

The screenshot shows the SIMATIC HMI Backup screen. At the top, there are tabs for 'Act. Values', 'Parameters', 'Maintenance', and 'Backup'. The 'Backup' tab is selected. Below the tabs, there is a status bar showing 'S7-Control' and 'RUN: MONITORING'. A message 'Last change successful' is displayed. The main area is divided into two sections: 'Backup Module' and 'Backup'.

Backup Module:

- Speed Source: Drive
- Pulses/Revolution: 1
- Hysteresis RMS: 0 %
- DHCP: ☐
- IP Address: 172, 16, 66, 200
- Subnet Mask: 255, 255, 0, 0
- Default Gateway: 0, 0, 0, 0
- Restore Parameters button

Backup:

	Channel 1	Channel 2	Channel 3	Channel 4
Enable	Activated	Deactivated	Deactivated	Deactivated
Sensitivity	100.00 mV/g	100.00 mV/g	100.00 mV/g	100.00 mV/g
Speed Ratio	1.0	1.0	1.0	1.0
vRMS				
Evaluation time	3 Rotations	3 Rotations	3 Rotations	3 Rotations
Highpass filter	2 Hz	2 Hz	2 Hz	2 Hz
Warning level	1.9 mm/s	0.1 mm/s	0.1 mm/s	0.1 mm/s
Alarm level	7.1 mm/s	0.3 mm/s	0.3 mm/s	0.3 mm/s
aRMS				
Evaluation time	3 Rotations	3 Rotations	3 Rotations	3 Rotations
Highpass filter	1,000 Hz	1,000 Hz	1,000 Hz	1,000 Hz
Lowpass filter	10,000 Hz	10,000 Hz	10,000 Hz	10,000 Hz
Warning level	4.0 m/s²	1.0 m/s²	1.0 m/s²	1.0 m/s²
Alarm level	6.0 m/s²	2.0 m/s²	2.0 m/s²	2.0 m/s²

The SM 1281 switches to the “STOP: CONFIGURATION” mode and sets the parameters. Subsequently, it changes back to the last operating mode.

3 Valuable Information

3.1 Basic terms

CMS

CMS stands for Condition Monitoring System.

IEPE

IEPE stands for Integrated Electronics Piezo Electric. It is an industry standard for piezoelectric sensors with built-in impedance converter electronics. They can be sensors for acceleration, force and pressure.

RMS

RMS stands for Root Mean Square. In the quadratic mean, bigger values usually have more impact than smaller ones in contrast to the geometric mean.

vRMS

Mean of the vibration velocity

aRMS

Mean of the vibration acceleration

3.2 Mechanical vibrations

3.2.1 Meaning and significance of vibrations

Term

Mechanical vibrations can be felt and measured at the surface of bodies. When monitoring machines, these are mainly machine surfaces, components and foundations.

Mechanical vibrations are also referred to as structure-borne sound, as they propagate in solid bodies only. The audible air-borne sound, in contrast, propagates through gaseous media, e. g. air.

Generation of mechanical vibrations

Whenever masses move, mechanically vibrations occur, too. These masses can be rotating or oscillating machine parts. However, these masses also include gases or liquids that hit solid bodies.

The significance of vibrations

When monitoring machines, mechanical vibrations provide excellent information as:

- Indicators of the machine condition
- Indicators of dynamic stress of machines, foundations and adjacent machine parts
- Indicators of the operational safety, service life and operating efficiency of machines
- Basis of machine diagnosis and vibration damping

Running machines exhibit various symptoms that allow drawing conclusions to the machine condition, e. g. looming machine damage.

These condition-relevant fault symptoms include:

- Changes in air-borne noise
- Displacement of machine parts
- Increased bearing temperatures
- Changed mechanical vibration behavior

3.2.2 Causes of mechanical vibrations

Generation of vibrations

Vibrations are caused mainly by centrifugal forces at rotating machine parts.

This is caused, for example, by:

- Unbalance
- Improper alignment of machine trains
- Bearing-related damage
- Transmission faults
- Magnetic, hydraulic and/or other function-related changing forces

Transmission and intensity of vibrations

Dynamic forces cause the rotor and rotor shaft to oscillate. These oscillations are transmitted through the bearings, for example. Transmission takes the following route:

1. From moving to fixed machine components
2. From fixed machine components to the foundation

The intensity of the transmitted oscillations depends on these parameters among others:

- Stiffness and dampening of the:
 - Machine construction
 - Bearing construction
 - Foundation
- Condition of the bearing lubricant
- Decoupling of the foundation
- Ratio of the masses of machine and foundation

3.3 Monitoring and diagnosing vibrations

To monitor a machine effectively during operation, specific variables have to be recorded. Mechanical oscillations are crucial in this context, because they are highly significant.

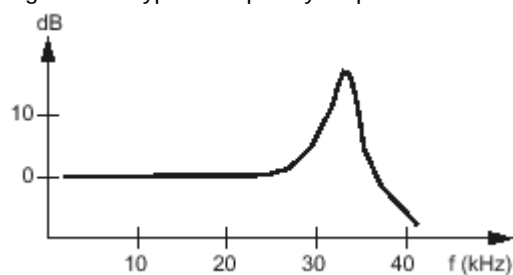
3.3.1 Measuring vibrations

Vibration sensor

Piezoelectric vibration sensors are used for the frequencies and frequency ranges to be covered in the vibration monitoring solution with SM 1281. These sensors generate an analog voltage signal in the presence of dynamic pressure and traction forces that can be processed. Static acceleration forces such as the gravitational acceleration are not detected by these sensors. IEPE (Integrated Electronics Piezo-Electric) is an industry standard for piezoelectric sensors.

The figure below shows the frequency response of a vibration sensor.

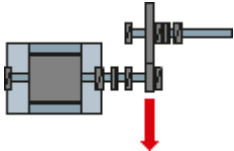
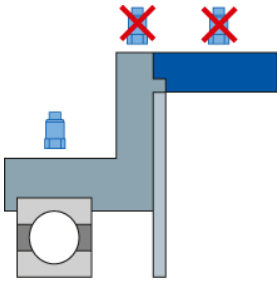
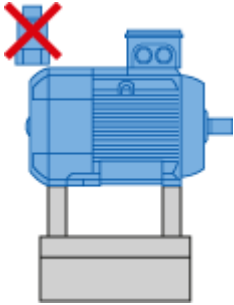
Figure 3-1: Typical frequency response



Selecting the measuring point

Below, you will find some general notes on positioning the vibration sensor:

Table 3-1: Measuring points

	Description	Display
1.	For an optimum measuring result, the sensor's measuring axis should be aligned in load direction if possible.	
2.	The measuring distance between machine bearing and measuring point should be as short and straightforward as possible. Observe the following notes in this context: - Vibration signals decrease with increasing signal path. - Transitions between materials dampen and/or reflect the signal to be measured.	
3.	Freely vibrating or elastically deformable housing or cladding parts (e. g. fan lid) are no suitable measuring points.	

Attachment to the object being measured

How the sensor is attached will considerably influence the measuring accuracy. Good signal quality requires smooth and clean coupling faces. Paint on coupling faces will also impair the result.

Below we will describe some common types of fasteners for vibration sensors:

Table 3-2: Attachment types

Attachment type		Suitability	Upper frequency limit
	Direct screwed connection using threaded bolts	For even and smooth surfaces	10 kHz to 20 kHz
	Screwed connection using an intermediate adapter	For uneven and/or painted areas	10 kHz to 20 kHz
	Glued connection using e. g. instant glue or epoxy resin	Depends on the temperature properties of the glue used	10 kHz to 18 kHz
	Attachment using permanent magnets	For fast and flexible attachment Suitability depends on the adhesive force, decreases at higher frequencies	5 kHz to 15 kHz

Measured variables, frequencies and energy

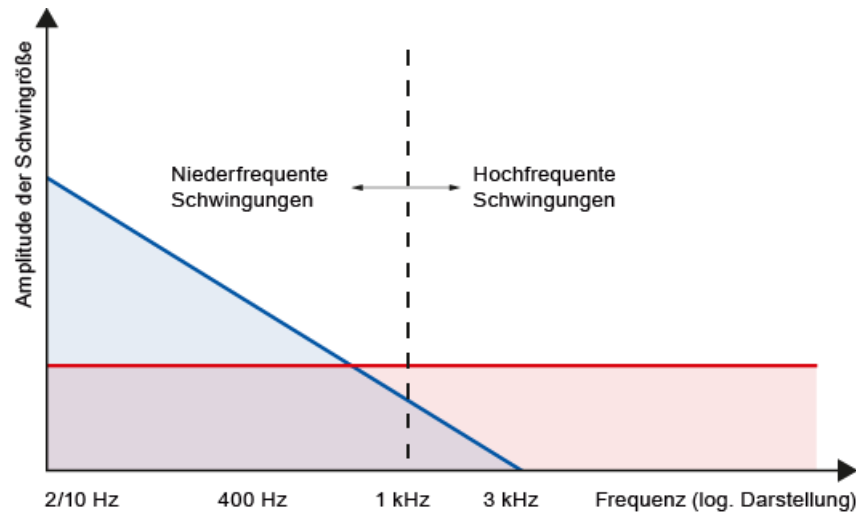
Vibration sensors provide a continuous vibration acceleration time signal (red line in Figure 3-2).

Low-frequency vibrations, i. e. vibrations associated with rotation, are the most energy-rich.

Now, if we take into account that the area below the red line corresponds to the vibration's energy content, it becomes clear that the evaluation of the vibration velocity is preferable for low-frequency oscillations.

For this purpose, the sensor signal is integrated which – depending on the energy content of the vibrations – results in the blue line shown in Figure 3-2.

Figure 3-2: Vibration velocity and acceleration



Further information

Further information on appropriate sensors and on selecting the measuring point can be found in this FAQ:

<https://support.industry.siemens.com/cs/ww/en/view/109740202>

3.3.2 Overview of diagnostic procedures

There are different methods and procedures to monitor and diagnose the condition of machines.

The procedures for signal processing of vibration data for machine and bearing diagnosis are divided into two main groups:

1. Characteristic values: summation of vibration data
2. Frequency-selective: evaluation of vibration data in the frequency spectrum

3.3.3 Vibration diagnosis by measuring characteristic values in the time domain

Application scope of vibration measurement in the time domain

Broadband vibration measurements in the time domain allow conclusions to be drawn as to the overall machine condition and the effectiveness of measures to suppress vibration.

The development of the machine condition can be verified by comparing actual measurements with previous vibration levels or with published guiding values or manufacturer specifications. This trend analysis enables degradations of the machine condition to be detected at an early stage and the corresponding countermeasures to be planned and implemented.

Note Detailed fault diagnosis is not possible or subject to restrictions for wideband vibration measurement based on characteristic values.

Features of vibration measurements in the time domain

- The measurement methods and the assessment of wideband vibration measurements are laid down and standardized in national and international guidelines and standards.
- The values of the RMS vibration velocity are measured and averaged over a defined frequency range.
- The range includes the frequencies from 2 Hz or 10 Hz to 1 kHz. Based on the velocity, the measuring range according to ISO 10816 starts either at 2 Hz (speeds from 120 to 600 rpm) or at 10 Hz (speeds greater than or equal to 600 rpm).

Fault types and diagnosis

The following table gives an overview of the most common fault types with the suitable measuring variables (marked with an x) in order to recognize these.

Table 3-3: Fault types

Fault type	Vibration measurement in the time domain	
	Vibration velocity v_{RMS}	Vibration acceleration a_{RMS}
Unbalance	x	--
Alignment fault, coupling fault	x	--
Incorrect setup	x	--
Blade pass frequency	$f_{BP} \leq 1 \text{ kHz}$	$f_{BP} > 1 \text{ kHz}$
Meshing fault	$f_M \leq 1 \text{ kHz}$	$f_M > 1 \text{ kHz}$
Belt fault	$f_b \leq 1 \text{ kHz}$	$f_b > 1 \text{ kHz}$
Resonances	x	--
Electric stator fault	x	--
Electric rotor fault	x	--
Bearing-related damage	--	x

Trend monitoring of the measured variables

The following chart depicts the typical shape of a trend curve by measuring/determining characteristic values. Signs of a looming fault usually manifest themselves long before the actual failure, e. g. by the increase of a vibration quantity.

Figure 3-3: Trend monitoring

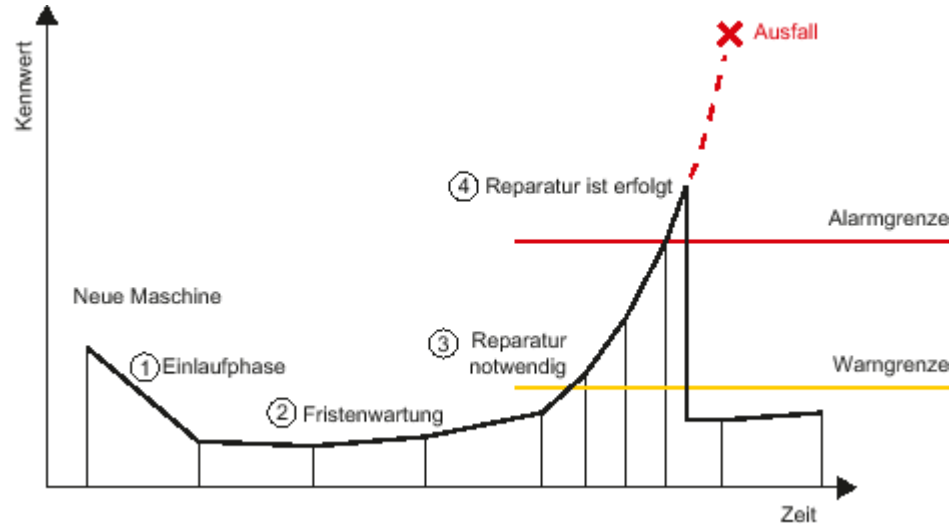


Table 3-4: Explanation of the trend monitoring

	Explanations on the chart
1.	During the run-in period of a new machine, the characteristic values are slightly elevated at first. Afterwards, they decline to values that correspond to the machine's normal operating state. DIN ISO 10816-3 provides guide values for different types of machines.
2.	The maintenance strategy may provide for scheduled maintenance. Regular condition monitoring allows a looming damage to be detected in its early stage.
3.	The characteristic value has exceeded a warning limit. The machine has to be repaired. But the machine can still be used. Additional measurements show a sharp increase of the characteristic values. Based on the trend it can be extrapolated when a capital damage with machine outage would occur.
4.	The defined alarm limit is exceeded. The machine is now repaired. Characteristic value measurements show that the machine is back in its normal operating condition.

Evaluating the machine condition using RMS values

The RMS value of the vibration velocity is a wideband vibration value. It is calculated by arithmetic averaging of all vibration events in a defined frequency range (e. g. 10 Hz to 1 kHz at RMS vibration velocity).

Table 3-5: RMS values

Characteristic value	Frequency range	Monitoring possible
vRMS Root Mean Square (velocity)	2 or 10 Hz to 1 kHz	Speed-related damages
aRMS Root Mean Square (acceleration)	> 1 kHz	Bearing-related damage

In the vibration frequency between 2 Hz or 10 Hz and 1 kHz, the RMS value of the vibration velocity is the most meaningful analysis value. This frequency range accommodates the typical rotation frequency excitations.

3.3.4 Vibration diagnosis through frequency analysis

Measuring the parameters is insufficient to pinpoint the fault. For this purpose, the machine's vibration profile needs to be analyzed in more detail. Most types of damages can be recognized in the frequency spectrum due to the occurrence of typical damage frequencies or typical patterns of damage frequencies. The SM 1281 allows the following spectra to be calculated and used for vibration diagnosis and monitoring:

- Frequency spectrum of vibration velocity
- Frequency spectrum of vibration acceleration
- Envelope spectrum

As this application example covers the diagnosis by measuring characteristic values in the time domain, we will not cover the diagnosis based on frequency analysis in further detail. For more information on vibration diagnosis through frequency analysis, refer to the SM 1281 manual at:

<https://support.industry.siemens.com/cs/de/en/view/109481490>

3.3.5 Standards

As a rule, the following standards and guidelines are used for machine monitoring using wideband characteristic values:

Table 3-6: Standards

Title	Content	Notes
EN 60034-14	Vibration measurement, acceptance measurements in the manufacturing factory	Axle height ≥ 56 mm, rated output ≤ 50 MW, n rated: 120 to 15,000 1/min)
DIN ISO 10816-1 and -3	Vibration measurement, assessment at the installation site	Parameter: RMS vibration velocity (referred to as vRMS for SIPLUS SM 1281)

3.4 SIPLUS SM 1281

The following chapter gives a brief overview of the SM 1281 with regard to the functions used in this application example.

For the operating manual of the SIPLUS SM 1281, refer to the Industry Online Support:

<https://support.industry.siemens.com/cs/de/en/view/109481490>

Overview

The SIPLUS SM 1281 is a module designed for use with the SIMATIC S7-1200 automation system.

SIPLUS SM 1281 allows the condition of components liable to wear (e. g. motors, bearings) and of critical machine components to be monitored permanently.

Together with an S7-1200, it can be used as an autonomous monitoring system.

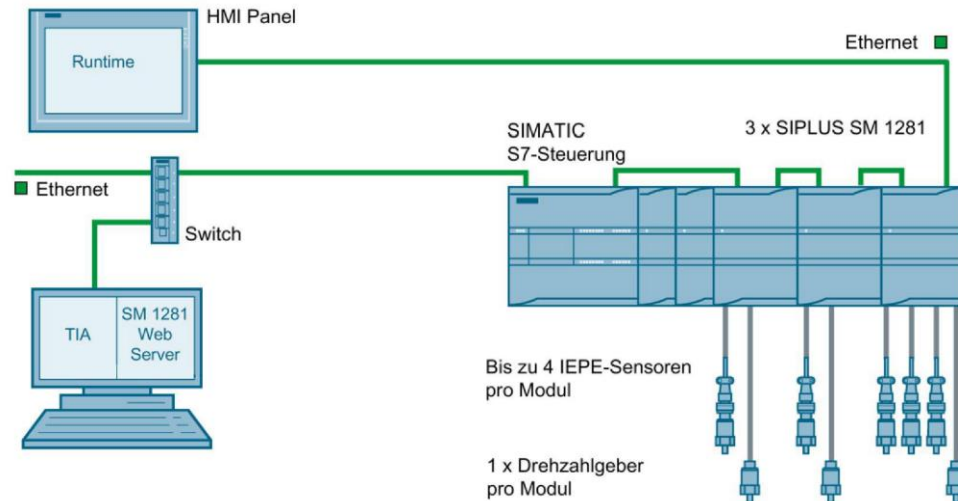
Technical features

- 4 vibration sensor channels for vibration signal monitoring
- 1 digital input for speed measurement
- Direct integration into existing SIMATIC S7-1200 automation systems
- Easy integration into existing and new machines
- High sampling rates
- Vibration analysis within the SM 1281. The result of the analysis is transmitted to the S7-1200 CPU for processing via the backplane bus in the form of status signals.
- Processing the results of the vibration analysis in the user's control program
- Configuration of SM 1281 functions directly from the TIA Portal

Configuration

The figure below shows an example configuration using an SM 1281 together with a SIMATIC S7-1200 automation system.

Figure 3-4: Exemplary setup



3.5 Library "SM1281_Library"

The library "SM1281_Library" of the SM 1281 signal module was used for this application example. It contains STEP 7 blocks and HMI text lists. The library enables the functions of the SM 1281 module to be integrated easily into the user's control program.

The STEP 7 blocks from the "SM1281_Library" enable the SM 1281 modules configured in the TIA Portal device configuration to be parameterized, controlled and diagnosed.

The library blocks provide the following functions:

- Parameterization of the SM 1281 modules
- Output of status and traffic light information
- Switching of operating modes
- Requesting fingerprint and raw data recording
- Output of status information on the recording
- Automatic backup of valid parameter records

Depending on which CPU is used, the blocks allow integrating up to seven SM 1281 modules into the control program.

3.5.1 Overview

The SM 1281 module features module- and channel-specific settings and diagnostic information. The module-specific settings and diagnostic information include e. g. the IP configuration and the selection of and feedback on the current operating mode. The channel-specific settings and diagnostic information refer to the four vibration channels of the SM 1281 module to which vibration sensors for machine monitoring can be connected.

Table 3-7: Components of the library

Type	Symbolic name
Function block	SM1281_Module
Function	SM1281_Channel
Global data block	SM1281_Status
Global data block	SM1281_Backup

Note

The blocks “SM1281_Module” and “SM1281_Channel” contained in the library are mandatory to operate the SM 1281 module. Without these blocks, parameterization and status monitoring is not possible. The parameters that can be set using the blocks cannot be changed using the web server of the SM 1281 module.

The following chapters give an overview of the blocks' functionality. You will find the library in SIOS:

<https://support.industry.siemens.com/cs/de/en/view/109482016>

For a detailed description of the parameters, see the SM 1281 operating instructions:

<https://support.industry.siemens.com/cs/de/en/view/109481490>

3.5.2 Function block "SM1281_Module"

The function block “SM1281_Module” from the library enables all general module settings to be entered and module status messages to be monitored.

The “SM1281_Module” block offers the following functions:

- IP configuration of the SM 1281 module
- Speed configuration
- Transmitting module and channel parameters to the SM 1281 module
- Requesting fingerprint and raw data recording
- Restoring the parameter record
- Selecting the operating mode of the SM 1281 module
- Output of module status and error information

3.5.3 Function "SM1281_Channel"

The function "SM1281_Channel" can be assigned to a channel of the SM 1281 module and enables the parameterization and monitoring of the corresponding vibration channel.

"SM1281_Channel" offers the following functions:

- Making channel-specific parameter settings
- Output of channel-specific status and error information

Basically, the function "SM1281_Channel" needs to be invoked for each used channel of the SM 1281 module. The assignment to the corresponding channel is made using the "ChannelNR" input parameter.

3.5.4 Data block "SM1281_Status"

The global data block "SM1281_Status" contains all information with regard to status, traffic light and faults of the SM 1281 module. The data are organized by module and channel. The data for an SM 1281 module are preset in the data block.

When using more than one SM 1281 module, the parameter "Module1" (PLC data type "SM1281_ModuleStatus") can be copied and inserted e. g. as "Module2". Moreover, you can rename the parameters "Module", "Channel_1", "Channel_2", "Channel_3" and "Channel_4" as desired.

3.5.5 Data block "SM1281_Backup"

The global data block "SM1281_Backup" stores the automatic backup of valid parameter records.

With each successful transition to the "RUN: MONITORING" operating mode, the parameters last sent to the SM 1281 are automatically checked for validity. If the parameters are valid, they are backed up in the remanent data block "SM1281_Backup". If the parameters are invalid, an error message occurs in the message system of the SM 1281 and the SM 1281 remains in the operating mode "STOP: READY".

The last valid and transferred parameter record can be restored using the input parameter "RestoreParameters" of the block "SM1281_Module".

3.5.6 Data types

Data types which are part of the block library carry the prefix "SM1281" in their name.

ATTENTION

If you change these data types, it may no longer be possible to compile your project due to the know-how protection of the library blocks. Therefore, leave these data types unchanged.

4 Appendix

4.1 Service & support

Industry Online Support

Do you have any questions or need support?

Siemens Industry Online Support offers access to our entire service and support know-how as well as to our services.

Siemens Industry Online Support is the central address for information on our products, solutions and services.

Product information, manuals, downloads, FAQs and application examples – all information is accessible with just a few mouse clicks at

<https://support.industry.siemens.com>

Technical Support

Siemens Industry's Technical Support offers quick and competent support regarding all technical queries with numerous tailor-made offers – from basic support right up to individual support contracts.

Please address your requests to the Technical Support via the web form:

www.siemens.com/industry/supportrequest

Service offer

Our service offer comprises, among other things, the following services:

- Product Training
- Plant Data Services
- Spare Parts Services
- Repair Services
- Field & Maintenance Services
- Retrofit & Modernization Services
- Service Programs & Agreements

Detailed information on our service offer is available in the Service Catalog:

<https://support.industry.siemens.com/cs/sc>

Industry Online Support app

Thanks to the "Siemens Industry Online Support" app, you will get optimum support even when you are on the move. The app is available for Apple iOS, Android and Windows Phone.

<https://support.industry.siemens.com/cs/ww/en/sc/2067>

4.2 Links and literature

Table 4-1: Links and literature

	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Download page of this entry https://support.industry.siemens.com/cs/ww/en/view/109480750
\3\	Operating instructions SM 1281 https://support.industry.siemens.com/cs/ww/en/view/109481490
\4\	STEP 7 Library SM 1281 https://support.industry.siemens.com/cs/ww/en/view/109482016
\5\	Support packages for the hardware catalog in TIA Portal https://support.industry.siemens.com/cs/ww/en/view/72341852

4.3 Change documentation

Table 4-2: Change documentation

Version	Date	Modifications
V1.0	02/2016	First version
V2.0	10/2017	Adaptation of application example SM 1281 FW 2.0