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Monitoring of Machine Vibration Variables with a SIPLUS CMS1200 Condition Monitoring System

SIPLUS CMS1200 SM 1281, SIMATIC S7-1200

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

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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 CMS1200 SM 1281 Condition Monitoring Systems and the monitoring and visualization of characteristic values. 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 SM 1281 Condition Monitoring System. 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

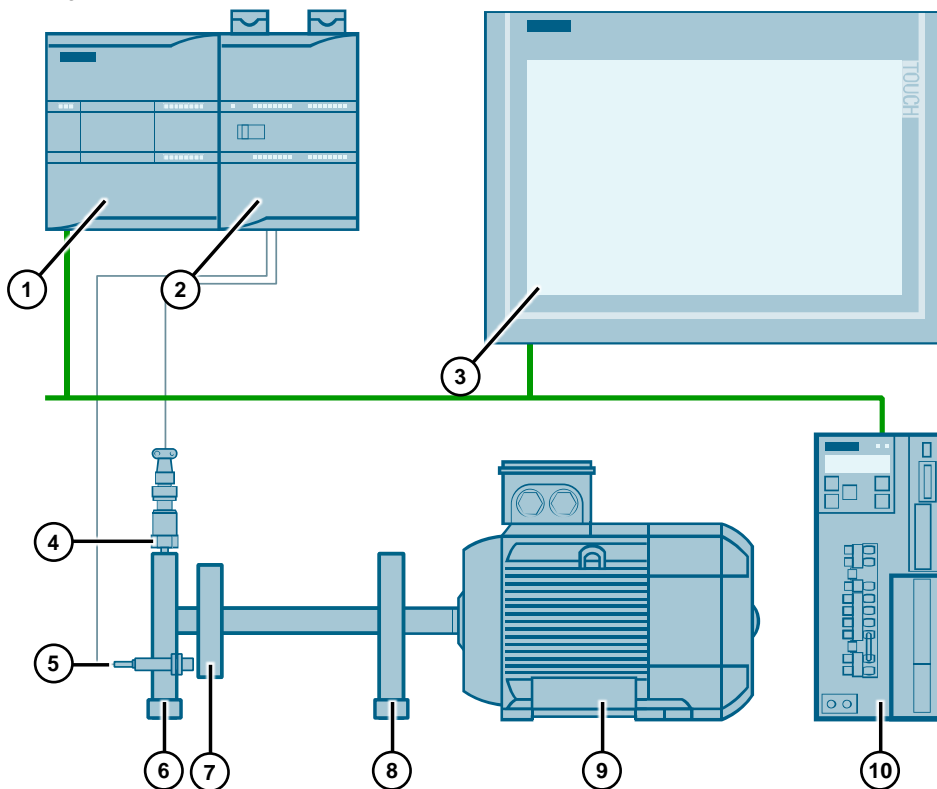


Table 1-1: Legend for Figure 1-1

	Designation
1.	SIMATIC S7-1200 automation system
2.	SIPLUS CMS1200 SM 1281 Condition Monitoring System
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/109757963>

RMS monitoring

The SM 1281 enables the calculation of the following characteristic values:

- vRMS (root mean square velocity) is calculated based on the interval rms value of vibration velocity.
- aRMS (root mean square acceleration) is calculated based on the interval rms value of vibration acceleration.
- DKW (diagnostic characteristic value) is calculated based on the interval rms value of the vibration acceleration.

For each vibration channel, warning and alarm limits and hysteresis can be set.

Hysteresis

For the monitoring of vRMS, aRMS, DKW and spectra, 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

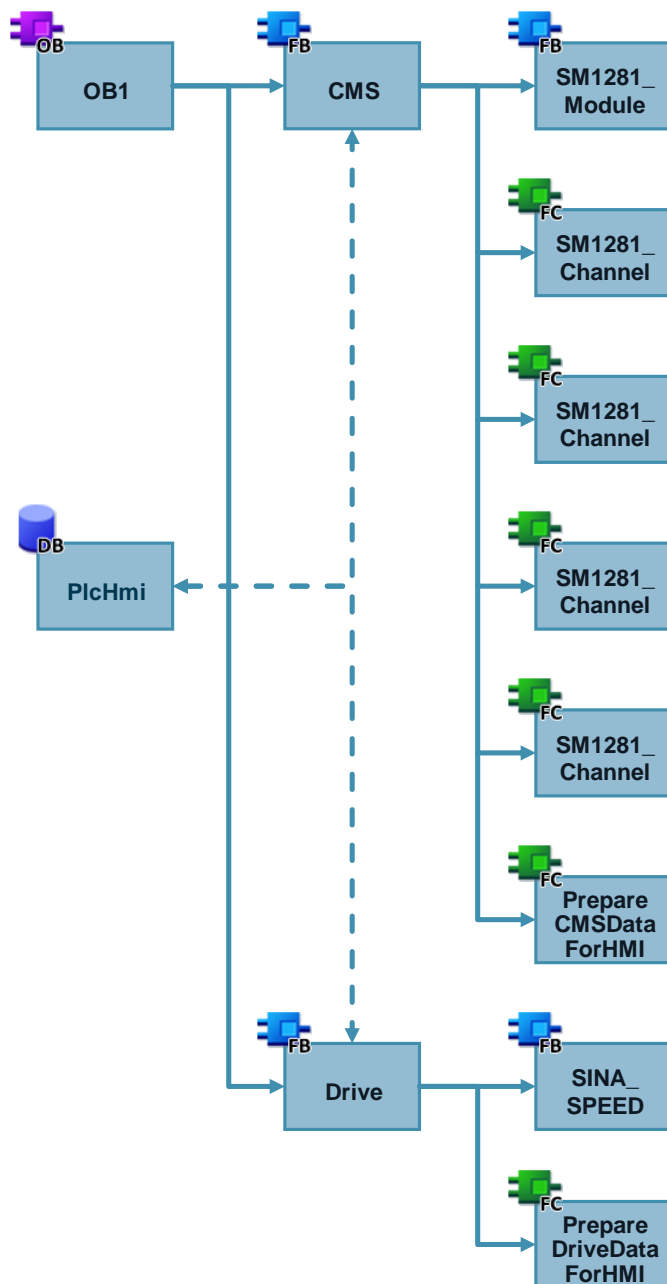


Table 1-2: Explanation of the blocks

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 on 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 V15 and higher
- WinCC V15 and higher
- S7-1200 FW 4.2 and higher
- SM 1281 FW 3.0

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 CMS1200 SM 1281	1	6AT8007-1AA10-0AA0	FW 3.1
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	6ES7822-0AE05-0YA5	
WinCC Advanced	1	6AV2102-0AA05-0AH5	

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

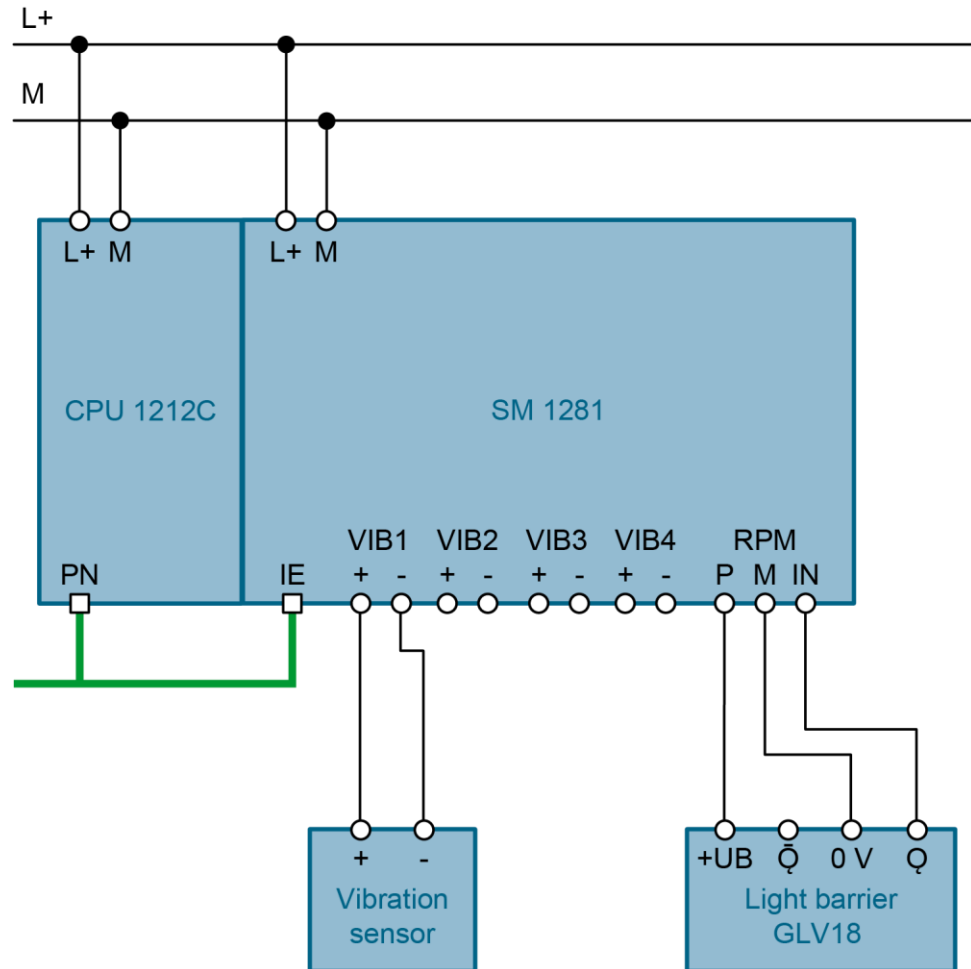
Component	Note
109480750_CMS_S7-1200_RMS_DOC_V31_en.pdf	This document.
109480750_CMS_S7-1200_RMS_PROJ_V31_TIAP_V15.1.zip	This zip file contains the project for TIA Portal V15.1.
109480750_CMS_S7-1200_RMS_PROJ_V31_TIAP_V15.zip	This zip file contains the project for TIA Portal V15.

2 Engineering

2.1 Hardware setup

The figure below shows the hardware setup of the application.

Figure 2-1: Hardware setup



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.
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 2-1: 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

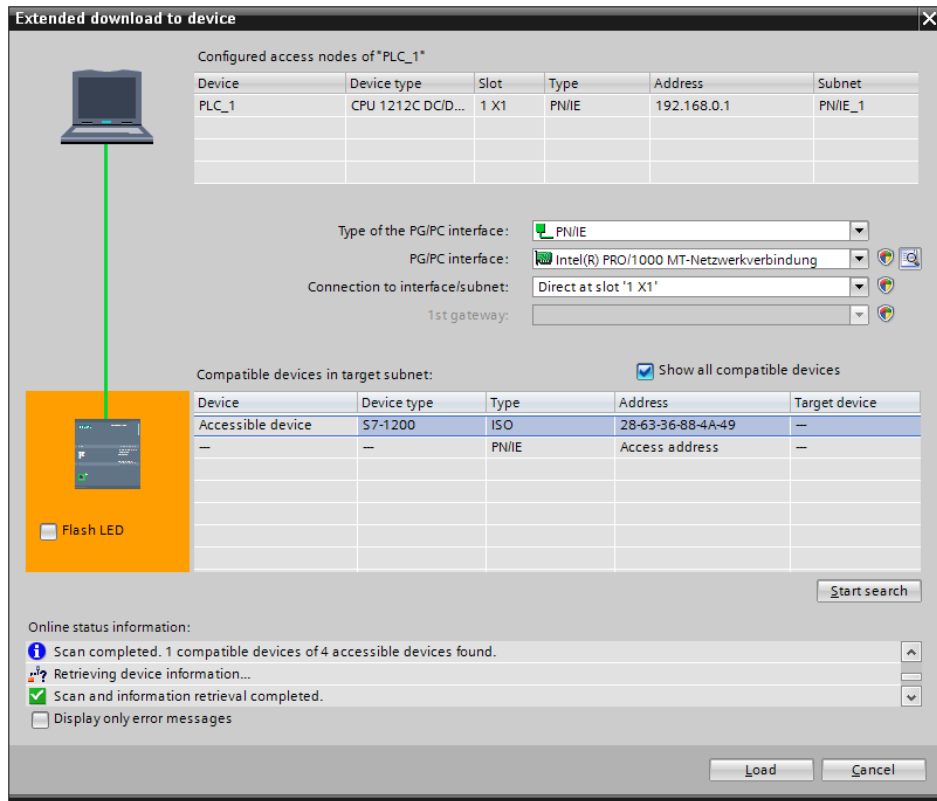
You can specify the IP address of the web server of the SM 1281 at the parameter "IP_Config" of the FB "SM1281_Module" or via the HMI (see chapter 2.3.1).

2.2 Configuration

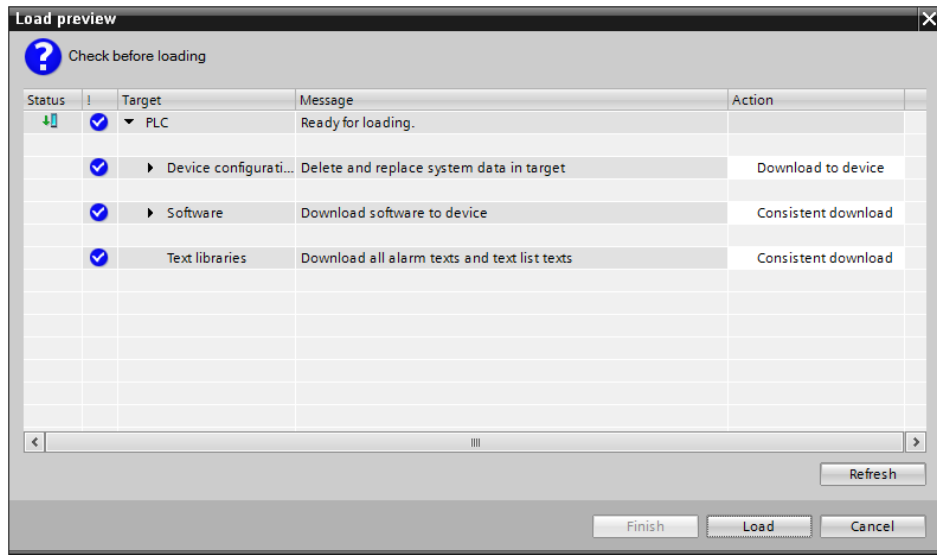
2.2.1 Downloading the STEP 7 project into the CPU

1. Download the project file "109480750_CMS_S7-1200_RMS_PROJ_V31_TIAP_V15.1.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. 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.
4. Use an Ethernet cable to connect the PG/PC with the Ethernet interface of the CPU.
5. Open the extracted project.
6. Right-click "PLC_1 [CPU1212C DC/DC/DC]" in the project tree and then "Download to device > Hardware and Software (only changes)".

7. Select the corresponding interface and click "Start search".

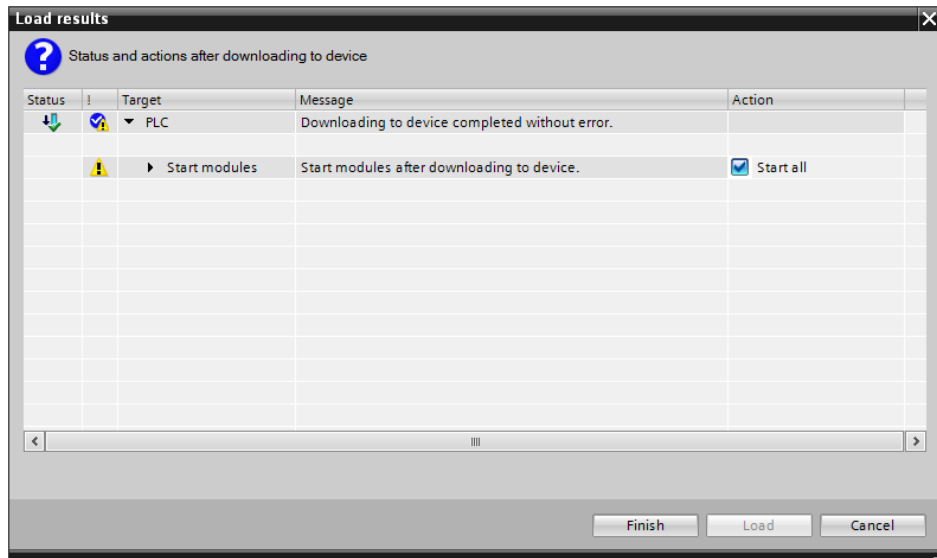


8. Select the CPU based on the IP or MAC address and then click "Load".



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

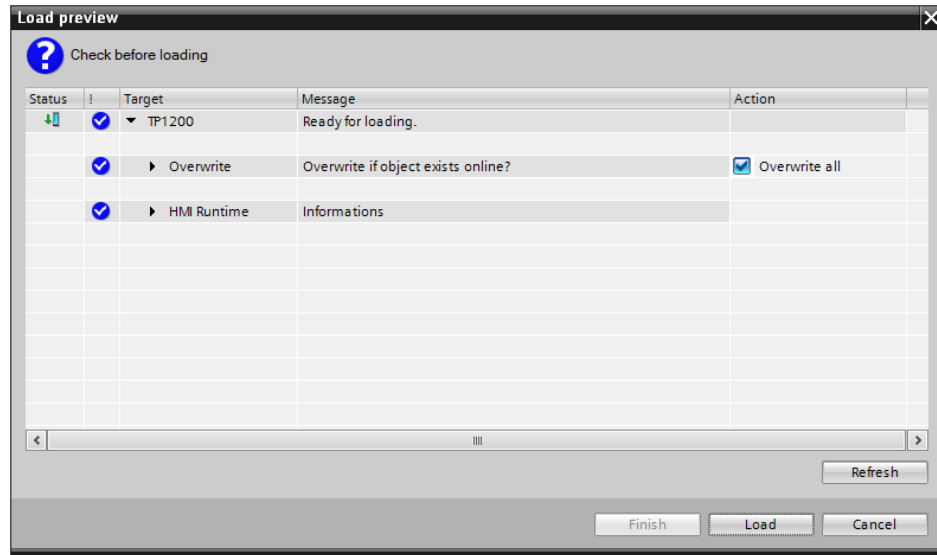
9. Confirm the dialog by clicking "Load". If the CPU is presently not in STOP, it has to be stopped.



10. Tick the "Start all" check box and click "Finish".

2.2.2 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 "HMI_1 [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".

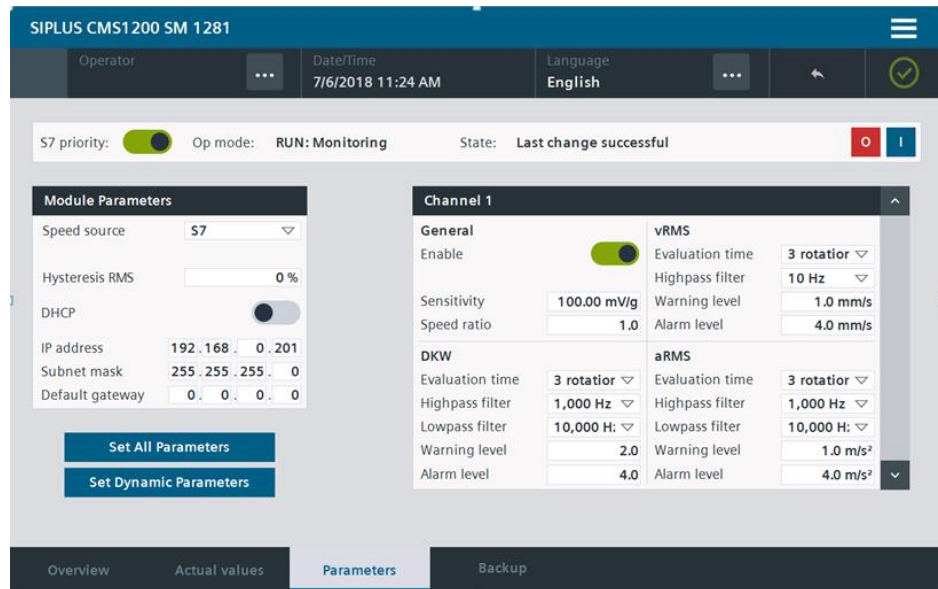


11. Tick the "Overwrite all" check box and click "Load".

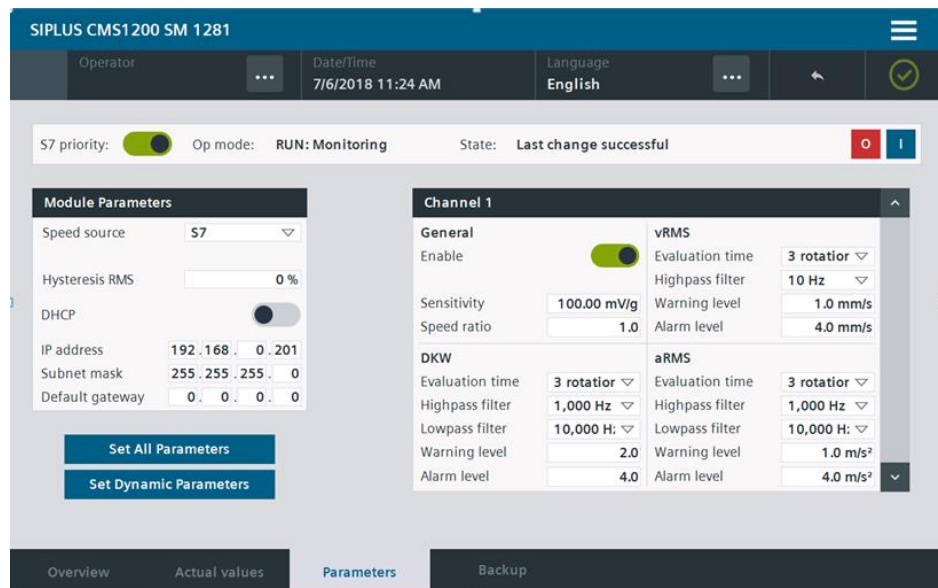
2.3 Commissioning

2.3.1 Setting parameters

1. On the start screen, tap the "Parameters" button.
2. Set the desired parameters for the module and channel 1.



3. In order to set parameters for the other channels, use the scroll bar to the right of the channel parameters.



4. Tap the "Set All Parameters" button.
The SM 1281 switches to the "STOP: Config/Param" mode and sets the parameters. Subsequently, it changes back to the last operating mode.

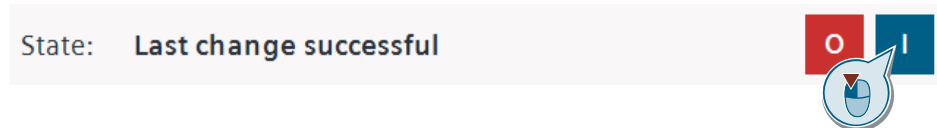
2.3.2 Measuring the normal operating condition of the machine

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 reference values to calculate warning and alarm limits.

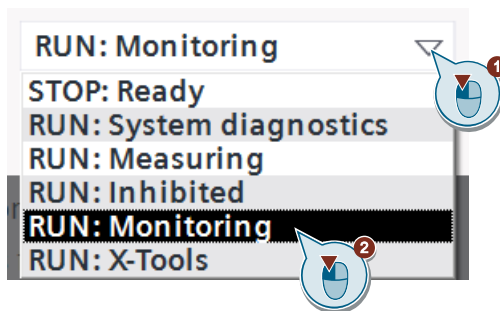
Proceed as follows:

Measuring reference values for vRMS and aRMS

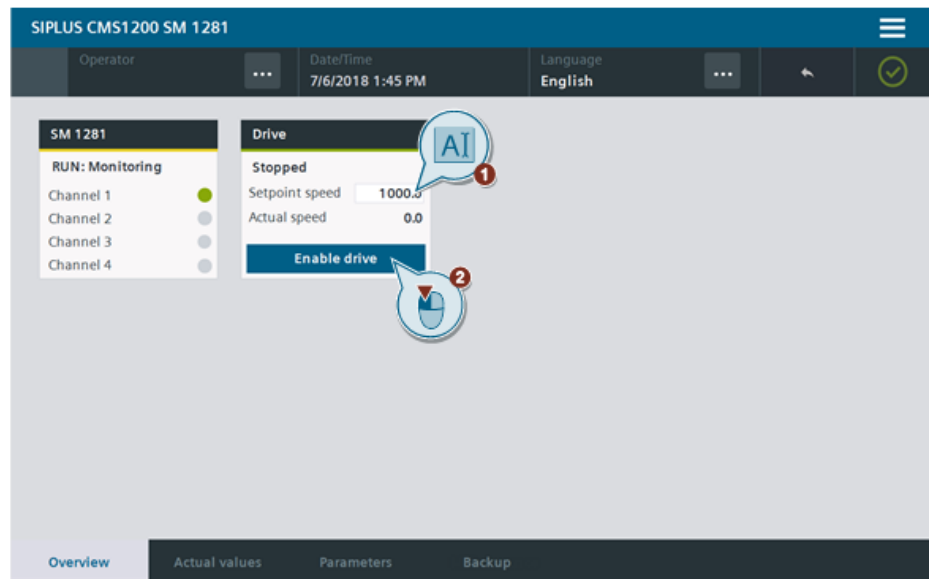
1. Tap the "ON" button.



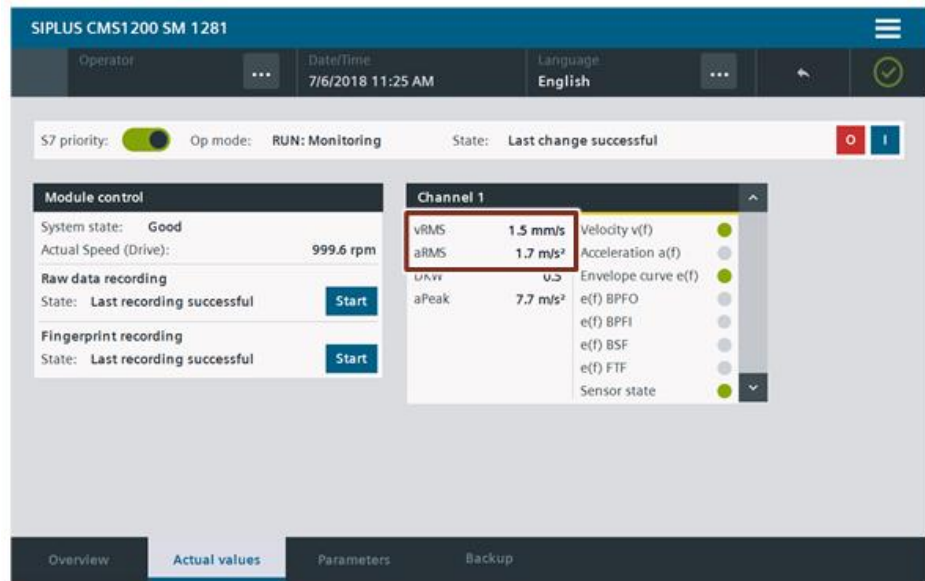
2. Select the operating mode "RUN: Monitoring" from the drop-down list and tap "OK".



3. Open the screen "Overview", enter a typical speed and enable the drive.



- Open the screen "Actual Values" and note the measured values for the corresponding channels.



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

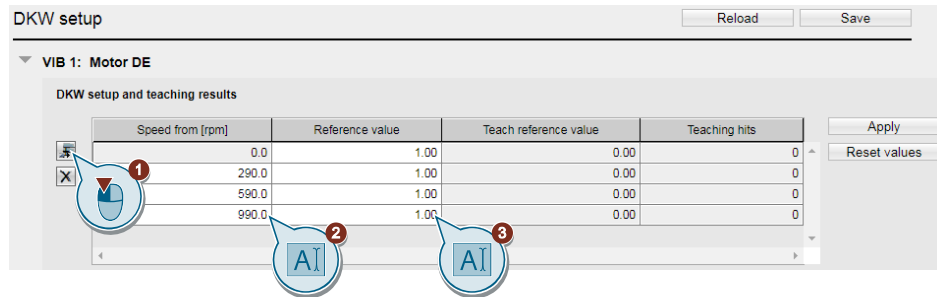
NOTICE If a bearing damage already exists during commissioning, this is not automatically detected by the CMS. Please observe the guide values given in [Table 2-2](#) to assess the condition of your machine during commissioning.

Measuring reference values for the DKW calculation

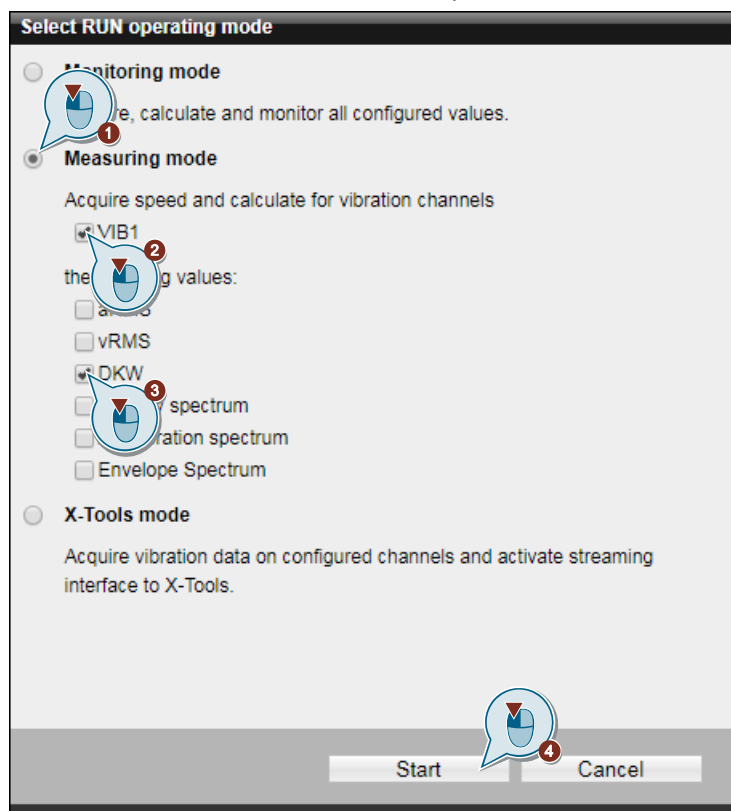
The reference values for the DKW calculation are measured through teaching through the web server of the SM 1281. Proceed as follows:

- Deactivate the "S7 priority" check box on the HMI, to give the control priority to the web server.
- Open the web server of the SM 1281 in a web browser.
- Log into the web server. If the password was not changed, the default password "0000" applies.
- Open "Monitoring settings > DKW-Setup".
- Change the operating mode of the SM 1281 to "STOP: System ready".

6. Add additional lines and create typical speed ranges each with the reference value "1.00".

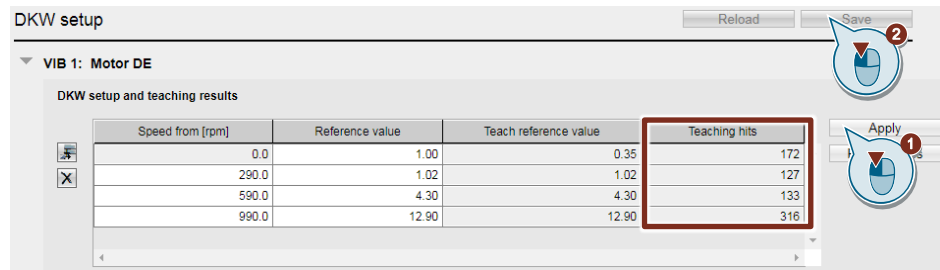


7. Click "Save".
8. Change the operating mode of the SM 1281 to "RUN: Measuring" and activate the calculation of the DKW for the respective channel.



9. Enable the drive via the HMI and let it run within the created speed ranges. The web server updates the teaching values cyclically.
10. Once you measured enough teaching values (the SM 1281 stores up to 1000 values per speed range), change the operating mode of the SM 1281 to "STOP: System ready".

11. In order to apply the measured teaching values as reference values, click "Apply" and "Save".



2.3.3 Setting 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 2-2: 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 vRMS

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 reference value measured when determining the normal operating state is used as the basic value. A reference value of 0.8 mm/s is measured for the machine in the example.

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

*Warning limit vRMS = basic value + 0.25 * upper limit zone B*

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

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

Alarm limit vRMS

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:

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

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 reference value in normal operating condition of the machine.

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

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

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

Alarm limit aRMS

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

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

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

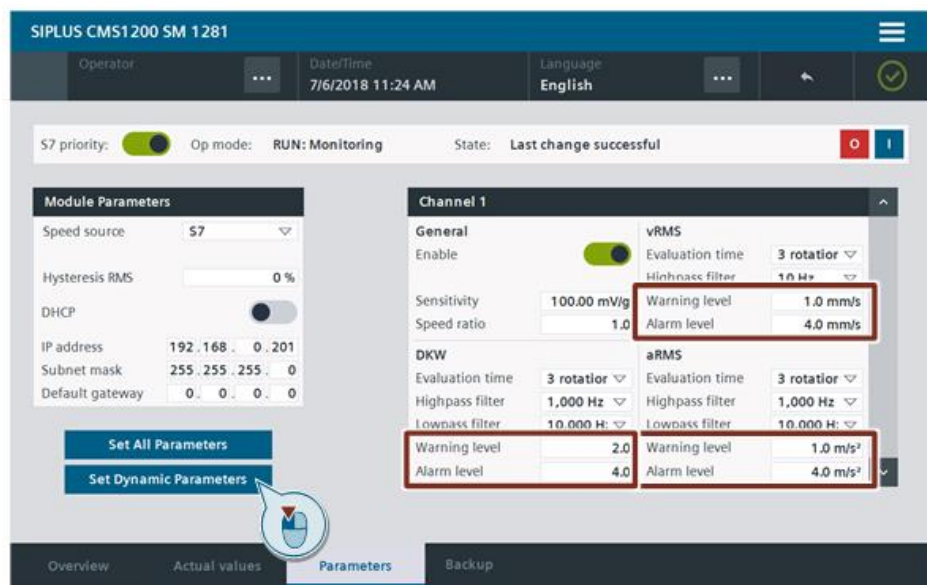
Warning and alarm limit DKW

According to [Table 3-7](#) it is recommended to set the warning limit of the DKW to 2 or higher.

Set the alarm limit of the DKW to a value between 5 and 50.

Setting the warning and alarm limits

1. Open the screen "Parameters".
2. Set the determined warning and alarm limits for vRMS, aRMS and DKW for the respective channels.



3. Tap the button "Set dynamic parameters".

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 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.

How to set dynamic parameters is shown in chapter [2.3.1](#).

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 parameters are dynamic:

Table 2-3: Dynamic parameters of the SM 1281

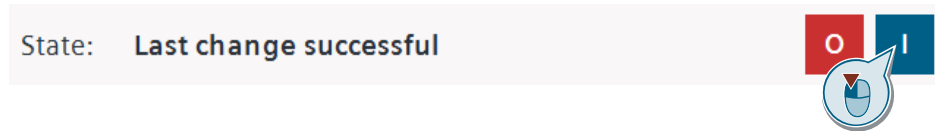
Parameter	Description
AlarmLevel_vRMS	Alarm limit of vibration velocity in mm/s
WarningLevel_vRMS	Warning limit of vibration velocity in mm/s
AlarmLevel_aRMS	Alarm limit of vibration acceleration in m/s ²
WarningLevel_aRMS	Warning limit of vibration acceleration in m/s ²
AlarmLevel_DKW	Alarm limit of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

How to set dynamic parameters is shown in chapter [2.3.3](#).

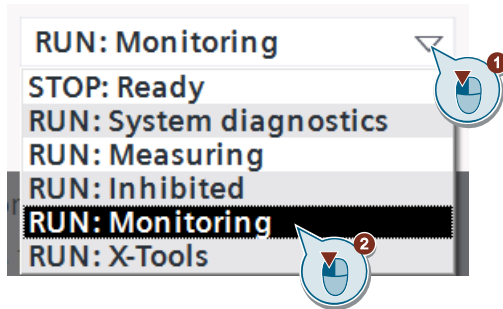
2.4.2 Changing the operating mode

The operating mode can be changed from any screen:

1. Tap the "ON" button.



2. Select the desired operating mode from the drop-down list and tap "OK".



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

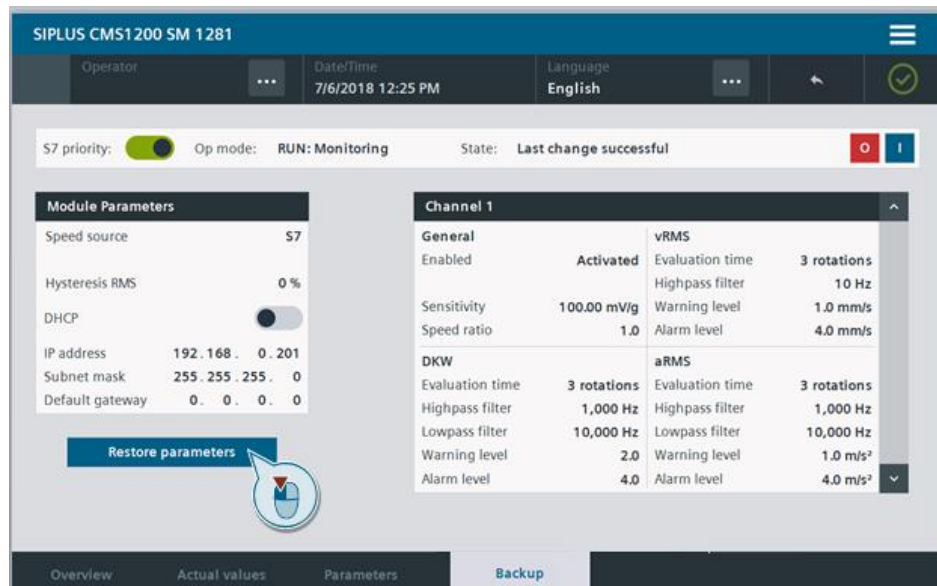
2.4.3 Restoring parameters from the backup

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 retentive data block "Backup". For an easy connection to the faceplates, the DB from the library "LSM1281" is not used. However the functionality of both DBs (DB "SM1281_Backup" and DB "Backup") are identical.

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.



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.

DKW

The diagnostic characteristic value allows for qualitative diagnosis of the overall state of rolling contact bearings.

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.

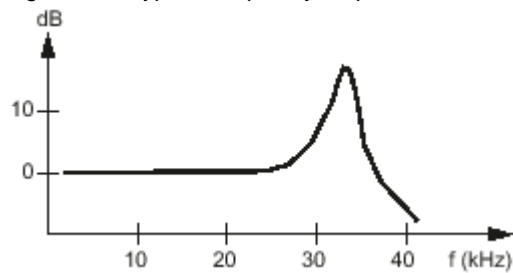
3.3.1 Measuring vibrations

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.

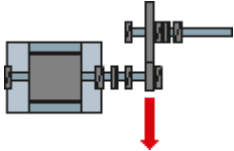
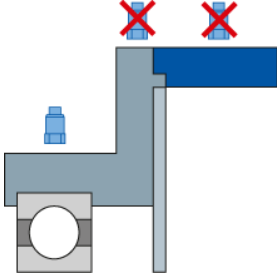
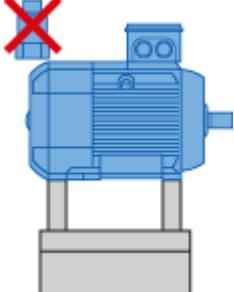
Figure 3-1: Typical frequency response



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: <ul style="list-style-type: none"> • 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

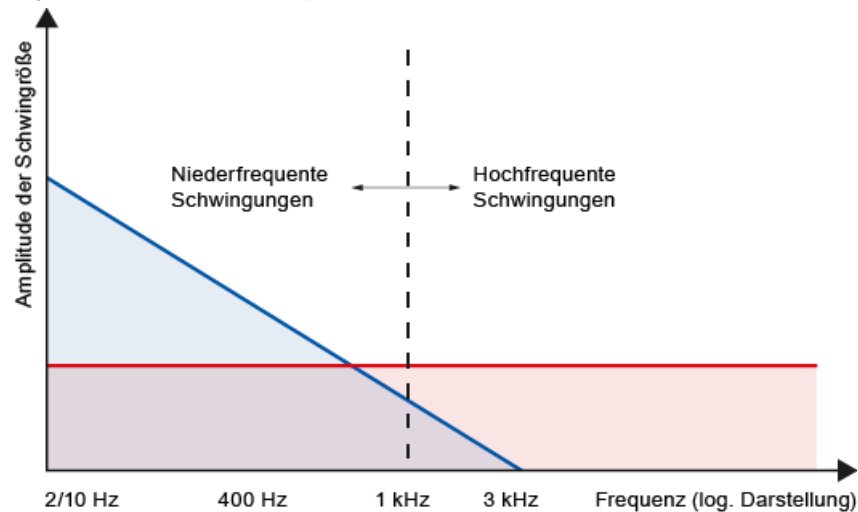
Vibration sensors provide a continuous vibration acceleration time signal (red line in Figure 3-2).

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



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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. Vibration diagnostics by characteristic value formation in the time range
2. Vibration diagnostics by frequency analysis

Fault types and diagnosis

The following table shows the most frequent types of errors, which are detected via the diagnostic procedure.

Table 3-3: Fault types and diagnostics

Fault type	Vibration measurement in the time range	Frequency analysis spectrum		
		Vibration velocity	Vibration acceleration	Envelope curve
Unbalance	RMS	Single rotation frequency f_n	--	--
Misalignment, coupling defect	RMS	Single rotation frequency f_n Double rotation frequency f_n	--	--
Mounting defect	RMS	Single rotation frequency f_n Double rotation frequency f_n Triple rotation frequency f_n	--	--
Blade pass frequency	RMS	$f_{SP} \leq 1 \text{ kHz}$	$f_{SP} > 1 \text{ kHz}$	--
Meshing defect	--	$f_z \leq 1 \text{ kHz}$	$f_z > 1 \text{ kHz}$	--
Belt defect	RMS	$f_R \leq 1 \text{ kHz}$	$f_R > 1 \text{ kHz}$	--
Resonance	RMS	Single rotation frequency f_n	--	--
Bearing wear	DKW	--	$3 \text{ kHz} \leq f_{LE} \leq 10 \text{ kHz}$	--
Bearing damage frequency	DKW	--	--	Geometry-dependent for outer ring, inner ring, cage and rolling element
Electrical stator faults	RMS	Double line frequency f_{line}	--	--
Electrical rotor faults	RMS	$f_{bar} \leq 1 \text{ kHz}$	$f_{bar} > 1 \text{ kHz}$	--
Rotor bar break	RMS	Double line frequency f_{line}	--	--

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).

Standards and guidelines

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

Table 3-4: 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 CMS1200 SM 1281)
VDI 3832	Rolling element bearing condition, various procedures	--

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

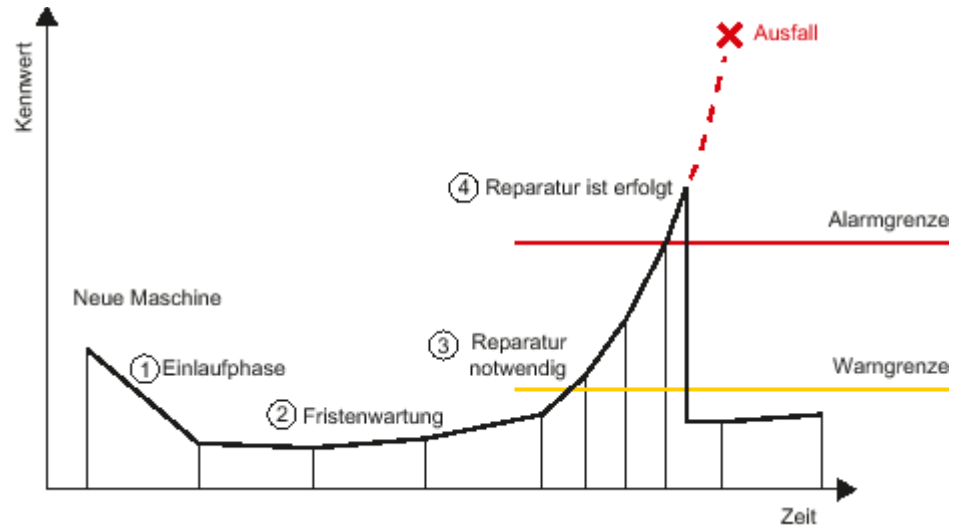


Table 3-5: Explanation of the trend monitoring

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.

Evaluation of machine condition on basis of RMS value for vibration level

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 3-6: RMS values

Characteristic value	Frequency range	Monitoring possible
vRMS	2 or 10 Hz to 1 kHz	Speed-related damages
aRMS	> 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.

Characteristic value formation through vibration acceleration (DKW)

The characteristic value formation through the diagnostic characteristic value (DKW) allows for qualitative diagnosis of the overall state of the rolling contact bearing.

The measured rms values and peak values of vibration acceleration at the initial condition of the bearing are compared relative to the current condition to calculate the DKW value.

The diagnostic characteristic value DKW exhibits a high correlation with the damage condition of rolling element bearings and is therefore very meaningful.

The diagnostic characteristic value (DKW) is calculated by following formula:

$$DKW(t) = \frac{a_{max}(t) \times a_{eff}(t)}{a_{max}(0) \times a_{eff}(0)}$$

The authors Prof. Dr. Sturm, Dr. Förster, Dr. Hippmann and Dr. Kinsky describe in their book "Diagnostics of rolling contact bearings in machines and plants" (16), only available in German) the relation between the DKW and the state of the rolling contact bearing as follows:

Table 3-7: Relation between the DKW and the bearing state

DKW	Bearing state
< 1	Improvement of the technical state (e.g. after start-up phase)
> 1 to 2	Good running characteristic
> 2 to 5	Effect of damage-accelerating influencing factors
> 5 to 50	Effect of the damaging process
> 50	Formation of a damage with the risk of a failure

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/ww/en/view/109757963>

3.4 SIPLUS CMS1200 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 CMS1200 SM 1281, refer to the Industry Online Support:

<https://support.industry.siemens.com/cs/ww/en/view/109757963>

Overview

The SIPLUS CMS1200 SM 1281 is a module designed for use with the SIMATIC S7-1200 automation system.

SIPLUS CMS1200 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.

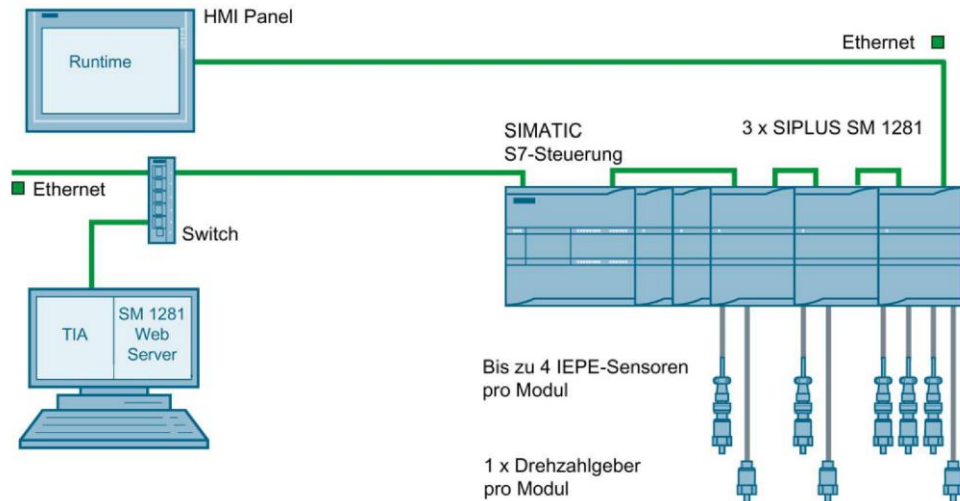
Technical features

- 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 3-8: 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/ww/en/view/109482016>

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

<https://support.industry.siemens.com/cs/ww/en/view/109757963>

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.

NOTICE	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 assistance?

Siemens Industry Online Support offers round the clock access to our entire service and support know-how and portfolio.

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

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<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/109757963
\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
\6\	Diagnostics of rolling contact bearings in machines and plants (only available in German) Prof. Dr. Sturm, Dr. Förster, Dr. Hippmann, Dr. Kinsky ISBN-10: 3885852616 ISBN-13: 978-3885852612

4.3 Change documentation

Table 4-2: Change documentation

Version	Date	Modifications
V1.0	02/2016	First version
V2.0	10/2017	Adapted for SM 1281 FW 2.0
V2.1	08/2018	Adapted for SM 1281 FW 3.0
V3.0	08/2018	Upgrade of the project to TIA Portal V15 Revision of the visualization on basis of the HMI Template Suite
V3.1	11/2018	Adapted for SM 1281 FW 3.1 Upgrade of the project to TIA Portal V15.1