SM331; AI 8 x 12 Bit
Getting Started
Part 1: 4-20mA
Safety-related Guidelines

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**Danger**
indicates that death, severe personal injury or substantial property damage will result if proper precautions are not taken.

**Warning**
indicates that death, severe personal injury, or substantial property damage can result if proper precautions are not taken.

**Caution**
indicates that minor personal injury or property damage can result if proper precautions are not taken.

**Note**
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We have checked the contents of this manual for agreement with the hardware and software described. Since deviations cannot be precluded entirely, we cannot guarantee full agreement. However, the data in this manual are reviewed regularly and any necessary corrections included in subsequent editions. Suggestions for improvement are welcomed.
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1 Preface

Purpose of the Getting Started

The Getting Started gives you a complete overview of the commissioning of the analog module SM331. It assists you in the installation and parameterization of the hardware of a 4-20mA sensor and the configuration with SIMATIC S7 Manager.

The target audience of the Getting Started is a beginner with only basic experience in configuration, commissioning and servicing of automation systems.

What to expect

Step by step the procedures from mounting the module to storing analog values in the STEP7 user program are explained in detail by means of an example. In the following sections you will be introduced to:

- Problem analysis
- Mechanical setup of the sample station
- Electrical connection of the sample station
- Configure hardware with SIMATIC Manager using HW Config
- Creating a small user program with STEP7 which stores the read analog values in a data block
- Triggering and interpreting diagnostic and hardware interrupts
2 Requirements

2.1 Required basic knowledge

No special knowledge in the area of automation technique is required to understand this description. As the configuration of the analog module is done with the software STEP7, proficiency in STEP7 would be advantageous.

Further information on STEP7 can be found in the electronic manuals that were delivered with STEP7.

Knowledge of PC or similar computer devices (e.g. programming devices) using the operating system Windows 95/98/2000/NT or XP is assumed.

2.2 Required Hardware and Software

The scope of delivery of the analog module consists of two parts: The module itself and a front connector, which enables it to comfortably connect the power supply and the data connections.

Table 2-1 Components of the analog module

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Article</th>
<th>Order number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SM 331, Electrically ISOLATED 8 AI, ALARM DIAGNOSTICS</td>
<td>6ES7331-7KF02-0AB0</td>
</tr>
<tr>
<td>1</td>
<td>20-pin FRONT CONNECTOR with spring contacts</td>
<td>6ES7392-1BJ00-0AA0</td>
</tr>
</tbody>
</table>

The general SIMATIC components required for the example are as follows:

Table 2-2 SIMATIC components of the sample station

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Article</th>
<th>Order number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PS 307 Power Supply AC 120/230V, DC 24V, 5A</td>
<td>6ES7307-1EA00-0AA0</td>
</tr>
<tr>
<td>1</td>
<td>CPU 315-2DP</td>
<td>6ES7315-2AG10-0AB0</td>
</tr>
<tr>
<td>1</td>
<td>MICRO MEMORY CARD, NFLASH, 4 MBYTE</td>
<td>6ES7953-8LM00-0AA0</td>
</tr>
<tr>
<td>1</td>
<td>SIMATIC S7-300, RAIL L=530MM</td>
<td>6ES7390-1AF30-0AA0</td>
</tr>
<tr>
<td>1</td>
<td>Programming device (PD) with MPI-interface and MPI cable PC</td>
<td>Depending on the configuration</td>
</tr>
</tbody>
</table>

Table 2-3 Software STEP7

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Article</th>
<th>Order number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>STEP7 Software version 5.2 or later, installed on the programming device.</td>
<td>6ES7810-4CC06-0YX0</td>
</tr>
</tbody>
</table>
The following current transducers can be used for the acquisition of analog signals:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Article</th>
<th>Order number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2-Wire current transducer</td>
<td>Depending on the manufacturer</td>
</tr>
<tr>
<td>1</td>
<td>4-Wire current transducer</td>
<td>Depending on the producer</td>
</tr>
</tbody>
</table>

**Note**

This „Getting Started“ describes only the application of 4 – 20 mA current transducers in the 2-Wire or 4-Wire model. If you want to use other transducers, then you have to wire and parameterize the SM331 differently.

Furthermore, the following tools and materials are necessary:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Article</th>
<th>Order number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple</td>
<td>M6-bolts and nuts (Length depending on the mounting place)</td>
<td>standard</td>
</tr>
<tr>
<td>1</td>
<td>Screwdriver with blade width 3,5 mm</td>
<td>standard</td>
</tr>
<tr>
<td>1</td>
<td>Screwdriver with blade width 4,5 mm</td>
<td>standard</td>
</tr>
<tr>
<td>1</td>
<td>Wire cutting pliers and tools for stripping</td>
<td>standard</td>
</tr>
<tr>
<td>1</td>
<td>Tools to mount the cable end sleeve</td>
<td>standard</td>
</tr>
<tr>
<td>X m</td>
<td>Wire for grounding the rail, 10 mm² diameter. Ring terminal with 6,5 mm hole, length according to local conditions.</td>
<td>standard</td>
</tr>
<tr>
<td>X m</td>
<td>Flexible wire with 1 mm² diameter with fitting wire end sleeves, Form A in 3 different colors – blue, red and green</td>
<td>standard</td>
</tr>
<tr>
<td>X m</td>
<td>3-wire power cord (AC 230/120V) with protective contact socket, length according to local conditions.</td>
<td>standard</td>
</tr>
<tr>
<td>1</td>
<td>Calibration device (Measuring instrument for commissioning, that can measure and supply current)</td>
<td>Depending on the manufacturer</td>
</tr>
</tbody>
</table>
3 Task

You want to connect three analog inputs to your station. One of them should have a 2-wire current transducer and the other two share a 4-wire current transducer.

You need failure diagnostic capabilities and want two sensors to be able to trigger hardware interrupts.

You have the analog input module SM331, AI8x12 Bit (order number 6ES7 331-7KF02-0AB0) available. The module is diagnostic and hardware interrupt capable and can process up to 8 analog inputs. Different measuring modes can be configured for each module (e.g. 4- 20 mA; PT 100; Thermocouple).

Figure 3-1 Sample station components
You will be guided through these steps

- Mechanical setup of the sample station (see chapter 4)
  - General mounting instructions for S7-300 modules
  - Configuration of the SM331 for the two selected measurement transducer types
- Electrical wiring of the sample station (see chapter 5)
  - Wiring of the power supply and the CPU
  - Wiring of the analog module
  - Standard pin layout of two measurement transducer types
  - Wiring of unused inputs
- Configuration with SIMATIC Manager (see chapter 6)
  - Use of project wizard
  - Completing the automatically generated hardware configuration
  - Integration of the supplied user program source
- User program testing (see chapter 7)
  - Interpreting the read values
  - Converting the measured values into readable analog values
- Utilizing the diagnostic capabilities of the SM331 module (see chapter 8)
  - Triggering a diagnostic interrupts
  - Analyzing the diagnostics
- Application of hardware interrupts (see chapter 8)
  - Parameterization of hardware interrupts
  - Configuration and analysis of hardware interrupts
4 Mechanical setup of the sample station

The setup of the sample station is divided into two steps. First, the setup of the power supply and the CPU is explained. After becoming acquainted with the analog module SM331 the mounting of it is described.

4.1 Mounting the sample station

Before you can use the analog input module SM331, you need a basic setup of general SIMATIC S7-300 components.

The order of the mounting takes place from left to right:

- Power supply PS307
- CPU 315-2DP
- SM331

<table>
<thead>
<tr>
<th>Graphics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image.png" alt="Image" /></td>
<td>Bolt together the rail to the ground or underground (screw size: M6) so that at least 40 mm space remains above and below the rail. If the base is a grounded sheet metal or a grounded mounting plate, ensure that the rail and the base are connected together with low resistance. Connect the rail with the protective ground wire. A M6 bolt is available for this purpose.</td>
</tr>
</tbody>
</table>

Mounting the power supply

- Hang the power supply to the top end of the rail
- and tighten it to the rail underneath
<table>
<thead>
<tr>
<th>Graphics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>Connect the bus connector (delivered with the SM331) to the left connector on the back of the CPU</td>
</tr>
</tbody>
</table>
| ![Image](image2.png) | Mounting the CPU:  
  - Hang the CPU to the top end of the rail  
  - Push it all the way left to the power supply  
  - Push it down  
  - and tighten the screw to the rail underneath |
4.2 Mounting the analog module

Before the actual mounting of the SM331 the module has to be completed with a front connector and the desired measurement mode of the inputs is set.

In this section you will learn

- Which components you need
- What are the properties of the analog input module
- What a measuring range module is and how it is set up
- How you mount the already setup module

4.2.1 Components of the SM331

A functional analog module consists of the following components:

- Module SM331 (in our example 6ES7331-7KF02-0AB0)
- 20-pin front connector. There are two different types of front connectors:
  - With spring contacts (Order number 6ES7392-1BJ00-0AA0)
  - With screw contacts (Order number 6ES7392-1AJ00-0AA0)

![Components of the SM331](image-url)
Table 4-2 The scope of delivery of SM331

<table>
<thead>
<tr>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module</td>
</tr>
<tr>
<td>Labeling strips</td>
</tr>
<tr>
<td>Bus connector</td>
</tr>
<tr>
<td>2 cable ties (not in the picture) to tie the external wiring</td>
</tr>
</tbody>
</table>

4.2.2 Properties of the analog module

- 8 inputs in 4 channel groups (each group with two inputs of same type)
- Measurement resolution adjustable for each channel group
- User defined measuring mode per channel group:
  - Voltage
  - Current
  - Resistance
  - Temperature
- Configurable diagnostic interrupt
- Two channels with limit value interrupt (Only channel 0 and channel 2 are configurable)
- Electrically isolated against backplane bus
- Electrically isolated against load voltage (exception: At least one module is set to position D)

The module is a universal analog module designed for the most commonly used applications.

The desired measuring mode should be set up directly on the module with the measuring range modules (see chapter 4.2.3).
4.2.3 Measuring range modules

The module SM331 has four measuring range modules (one per channel group). The measuring range modules can be set to 4 different positions (A, B, C or D). With the set position you determine which transducer can be connected to the respective channel group.

Figure 4-2  4 measuring range modules with default setting B (Voltage)

<table>
<thead>
<tr>
<th>Position</th>
<th>Measurement type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Thermocouple / Resistance measurement</td>
</tr>
<tr>
<td>B</td>
<td>Voltage (default setting)</td>
</tr>
<tr>
<td>C</td>
<td>Current (2-wire transducer)</td>
</tr>
<tr>
<td>D</td>
<td>Current (4-wire transducer)</td>
</tr>
</tbody>
</table>
In our example, a sensor with a 4 to 20mA 2-wire transducer is connected to channel group 1 at input 0.

A 4-wire transducer is connected to channel group 2 at inputs 2 and 3.

Therefore, the first measuring range module should have Position D and the second should have Position C

Table 4-4  Positioning of the measuring range modules

<table>
<thead>
<tr>
<th>Graphics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>With a screwdriver, pull out the two measuring range modules</td>
</tr>
<tr>
<td><img src="image2.png" alt="Image" /></td>
<td>Turn the measuring range module to the desired position:</td>
</tr>
<tr>
<td><img src="image3.png" alt="Image" /></td>
<td>Plug the measuring range module back into the module</td>
</tr>
<tr>
<td></td>
<td>In our example, the module should have the following positions:</td>
</tr>
<tr>
<td></td>
<td>CH0,1: D</td>
</tr>
<tr>
<td></td>
<td>CH2,3: C</td>
</tr>
</tbody>
</table>

**Note**

When you use a 2-wire transducer, the electrical isolation against the load voltage is lost for all the channels in the module (at least one measuring range module is set to position D).
4.2.4 Mounting the SM331 module

After you have prepared the analog module accordingly, mount it to the rail as well.

Table 4-5 Mounting the SM331 module

<table>
<thead>
<tr>
<th>Graphics</th>
<th>Description</th>
</tr>
</thead>
</table>
| ![Mounting the SM331](image1.png) | Mounting the SM331:  
- Insert the SM331 to the top part of the rail  
- Push it all the way left to the CPU  
- Push down  
- and tighten the screw at the bottom to the rail |
| ![Mounting of the front connectors](image2.png) | Mounting of the front connectors:  
- Press the upper release button of the front terminal block  
- Insert the front connector into the module until it snaps in |

Mechanically the sample station is now completely mounted.
5 Electrical connection

This chapter shows you how the various parts of the sample station are electrically wired from the power supply to the analog module.

Warning
You might get an electrical shock if the power supply PS307 is turned on or the power cord is connected to the line.
Wire the S7-300 only in power-off state.

5.1 Wiring the power supply and the CPU

Figure 5-1 Wiring the power supply and the CPU
The sample station requires a power supply. The wiring is done as follows:

### Table 5-1  Wiring the power supply and the CPU

<table>
<thead>
<tr>
<th>Step</th>
<th>Graphics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Open the front flaps of the power supply and the CPU</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Unscrew the pull relief bracket on the power supply</td>
</tr>
<tr>
<td>3</td>
<td><img src="image1.png" alt="Image" /></td>
<td>Remove the insulation from the power cord, attach the cable end sleeves (for multi-wire cords) and connect it to the power supply</td>
</tr>
<tr>
<td>4</td>
<td><img src="image2.png" alt="Image" /></td>
<td>Tighten the pull relief bracket</td>
</tr>
<tr>
<td>5</td>
<td><img src="image3.png" alt="Image" /></td>
<td>Insert two connecting cables between the power supply and the CPU and tighten them</td>
</tr>
<tr>
<td>6</td>
<td><img src="image4.png" alt="Image" /></td>
<td>Confirm that the setting of the voltage selector is set to your local line voltage. The power supply’s default setting is AC 230 V. If you have to change this setting, do the following: Remove the protective cap with a screwdriver, adjust the switch according to your line voltage and put the protective cap back.</td>
</tr>
</tbody>
</table>
5.2 Wiring the analog module

The wiring of an analog measurement transducer is dependant on its type and not on the SM331 module.

5.2.1 Current transducer wiring - Principle

Depending on the current transducer you use, you have to modify the wiring of the power supply. We differentiate between the wiring of a 2-wire current transducer and a 4-wire current transducer.

Wiring principles of a 2-wire current transducer

This transducer type is supplied with power from the analog input module.

Wiring principles of a 4-wire current transducer

Unlike a 2-wire transducer, this transducer has its own power supply.
5.2.2 **Wiring of the analog module**

The wiring of the analog module consists of the following tasks:

- Connection of the power supply (Red cable)
- Connection of the 2-wire current transducer (Green cables)
- Terminate unused channels with a resistor
- Connection of the first 4-wire current transducer (Green cables)
- Connection of the second 4-wire current transducer (Green cables)
- Connection to zero potential and short-circuit the other unused channels (blue wires)

---

![SM331 Front connector wiring](image)

**Figure 5-4** SM331 Front connector wiring

---

**Warning**

Possible destruction of the module!

If you connect a defective 4-wire current transducer to an input, which is configured for a 2-wire transducer, the module might get destroyed.
Step by step the tasks necessary for wiring are explained below:

<table>
<thead>
<tr>
<th>Graphics</th>
<th>Wiring</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open the front flap of the SM331</td>
<td>The connection diagram is printed on the front flap</td>
</tr>
<tr>
<td></td>
<td>Remove 6 mm of the insulation from the ends of the wires that go into the front connector. Attach cable end sleeves to these ends.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wire the front connector as follows: Terminal 1: L+</td>
<td>Power supply of the module</td>
</tr>
<tr>
<td></td>
<td>Terminal 2: M+ Sensor 1 Terminal 3: M- Sensor 1</td>
<td>Standard wiring for 2-wire current transducer</td>
</tr>
<tr>
<td></td>
<td>Connect Terminal 4 and 5 with a 1.5 to 3.3 kΩ resistor</td>
<td>In order to maintain the diagnostic capability of channel group 0, the second unused input must be connected to a resistor</td>
</tr>
<tr>
<td></td>
<td>Terminal 6: M+ Sensor 2 Terminal 7: M- Sensor 2</td>
<td>Standard wiring for 4-wire current transducer</td>
</tr>
<tr>
<td></td>
<td>Terminal 8: M+ Sensor 3 Terminal 9: M- Sensor 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Connect Terminal 10 (Comp) and terminal 11 (M_{\text{ana}}) with M Short-circuit terminals 12 to 19 and connect with M_{\text{ana}} Terminal 20: M</td>
<td>For measuring current Comp is not used Mandatory for 2-wire current transducers Unused channel groups should be short-circuit with M_{\text{ana}} in order to achieve a maximum interference resistance</td>
</tr>
</tbody>
</table>
5.2.3 Switch on now

If you want to test the wiring, you may now switch the power supply on. Do not forget to set the CPU to STOP (see the red circle).

Figure 5-5 Successful wiring, CPU in position STOP

If a red LED is lit, then there is an error in the wiring. Verify your wiring.
6 Configuration with SIMATIC Manager

In this chapter the following tasks are executed:

- Creating a new STEP7 project
- Parameterization of the hardware configuration

6.1 Create a new STEP7 Project

Use STEP7 V5.2 or later version for configuring the new CPU 315-2 DP. Start SIMATIC Manager by clicking the symbol „SIMATIC Manager“ on your windows desktop and create a new project with the STEP7 wizard „New Project“.

![Figure 6-1 Execute STEP7 wizard „New Project”](image_url)
An introduction window pops up. The wizard will guide you through the creation of a new project.

Figure 6-2  STEP7 wizard „New Project“, start

During the creation the following inputs are necessary:

- Selection of the CPU
- Define the basic user program
- Selection of organization blocks
- Project name

Click „Next“
6.1.1 CPU Selection

Choose the CPU 315-2DP for the sample project. (You can also use our example for a different CPU). Then choose your CPU.

![STEP7 wizard „New Project”, CPU selection](image)

Click „Next“

6.1.2 Define the basic user program

Choose the SIMATIC language STL and select the following organization blocks (OBs):

- OB1  Program Cycle Organization Block
- OB40  Hardware interrupt
- OB82  Diagnostic interrupt

OB1 is required in every project and is called cyclically. OB40 is called when a hardware interrupt occurs. OB 82 is called when a diagnostic interrupt occurs.

In case you use a module with diagnostic capabilities and OB82 is not inserted, the CPU changes to STOP mode when a diagnostic alarm occurs.

![STEP7 wizard „New Project”: Insert organization blocks](image)

Click „Next“
### 6.1.3 Specify the project name

Select the edit field “Project name” and overwrite the name in it with “Getting Started S7 SM331”

![STEP7 wizard „New Project“: Specify project name](image)

Click „Finish“. The basic STEP7 project is created automatically.

### 6.1.4 Resulting S7 project is created

The wizard has created the project “Getting Started S7-SM331”. In the right pane you can find the inserted organization blocks.

![STEP7 wizard „New Project“: Result](image)
6.2 Hardware configuration

The STEP7 wizard has created a basic S7 project. You also need a complete hardware configuration in order to create the system data for the CPU.

6.2.1 Create the hardware configuration

You can create the hardware configuration of the sample station with SIMATIC Manager.

In order to do this, select the folder „SIMATIC 300 Station“ on the left hand pane. Start the hardware configuration by double clicking the folder "Hardware" on the right hand pane.

![Starting the hardware configuration](image)

Figure 6-7 Starting the hardware configuration
6.2.2 Insert SIMATIC components

First select a power supply module from the hardware catalog. If the hardware catalog is not visible, open it with the shortcut key Ctrl+K or by clicking the catalog symbol (blue arrow). In the hardware catalog you can browse through the folder SIMATIC 300 to the folder PS-300.

Select the PS307 5A and drag it into slot 1 (see red arrow).

Result: PS 307 5A appears in the configuration of your rack.
Insert analog module

There are many SM331 analog modules. For this project we use an SM331, AI8x12 Bit with the order number 6ES7 331-7KF02-0AB0.

The order number is displayed at the bottom of the hardware catalog (blue arrow).

![Hardware configuration: Insert SM331](image)

Order number of the module

Drag the module into the first available field at slot 4 of your rack (see red arrow).

You have inserted all the modules into the hardware configuration. In the next step you parameterize the modules.
6.2.3 Parameterization of the analog module

SIMATIC Manager inserts the analog module with its standard settings. You can modify the parameters to change the sensor types, diagnostics and interrupt capabilities.

Functionality of the sample station

The table shows, which parameters have to be set for our sample station.

<table>
<thead>
<tr>
<th>Functionalities</th>
<th>Description</th>
</tr>
</thead>
</table>
| Process reactions | • Diagnostic interrupt - active  
                    • Hardware interrupt when limit exceeded |
| Sensor 1        | • 2-wire current transducer  
                    • Group diagnostics  
                    • Check for wire break  
                    • Measuring range 6 mA and 18 mA |
| Sensor 2 & 3    | • 4-wire current transducer  
                    • Group diagnostics  
                    • Check for wire break  
                    • Measuring range 6 mA and 18 mA |

Open the parameterization

Double click slot 4 that has the SM331 in it
Select the tab Inputs
Parameterize as follows:
- Diagnostic interrupt - checked
- Hardware interrupt when … - checked
- Input 0-1:
  - Measuring type: 2DMU
  - Group diagnostics - checked
  - With check for wire break - checked
- Input 2-3:
  - Measuring type: 2DMU
  - Group diagnostics - checked
  - With check for wire break – checked
- Input 4-5 and 6-7
  - Measuring type: Deactivated (---)
• Interference frequency:
  o Select your power frequency (50 Hz or 60 Hz)

• Trigger for Hardware Interrupt
  o High limit 18 mA
  o Low limit 6 mA

Figure 6-10  SM331: Parameterization

Explanation of the individual settings

Measuring type:
2DMU and 4DMU stand for 2-wire and 4-wire current transducers
--- means that the channels are deactivated. If you deactivate channels
then the remaining channels are processed faster.

Measuring range modules
The required setting of the measuring range module (chapter 4.2.3) is dis-
played.
Interference frequency (Interference frequency suppression)

The frequency of the AC power supply network can interfere with the measurement values, especially in low voltage ranges and when thermocouples are used. With this parameter you specify the frequency of your power supply on site.

This parameter also influences the granularity, integration time and the basic execution period of the channel group.

Resolution (Accuracy)

The analog value is stored in a 16-bit word.

Integration time

The module requires a certain amount of time to measure the analog voltage. This time is called integration time. The higher the required accuracy is, the longer the module needs for measuring the voltage.

Basic execution period

Besides the integration time, the module also needs a certain amount of time to provide the measurement value.

Table 6-2 Relationship between accuracy, interference frequency and integration period

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Interference frequency</th>
<th>Integration time</th>
<th>Basic execution time</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Bit</td>
<td>400 Hz</td>
<td>2,5 ms</td>
<td>24 ms</td>
</tr>
<tr>
<td>12 Bit</td>
<td>60 Hz</td>
<td>16,6 ms</td>
<td>136 ms</td>
</tr>
<tr>
<td>12 Bit</td>
<td>50 Hz</td>
<td>20 ms</td>
<td>176 ms</td>
</tr>
<tr>
<td>14 Bit</td>
<td>10 Hz</td>
<td>100 ms</td>
<td>816 ms</td>
</tr>
</tbody>
</table>

Hardware alarm

Only the channels 0 and 2 have hardware interrupt capabilities. You can use hardware interrupts to trigger an alarm when the analog signal exceeds its high or low limit.

Complete the hardware configuration

Close the parameter window.

Compile and save the project via Station → Save and Compile (Ctrl+S)

With this the hardware configuration of the project is completed.
### 6.2.4 Power up test

For testing, do a power up test and download the system data.

#### Power up

<table>
<thead>
<tr>
<th>#</th>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1.jpg" alt="Image" /></td>
<td>Erase your Micro Memory Card with a Power PG or a PC with external programming device: In SIMATIC Manager click “File → S7 Memory Card → Delete …”</td>
</tr>
<tr>
<td>2</td>
<td><img src="image2.jpg" alt="Image" /></td>
<td>Turn off the CPU’s power supply. Insert the MMC into the CPU. Turn on the power supply.</td>
</tr>
<tr>
<td>3</td>
<td><img src="image3.jpg" alt="Image" /></td>
<td>If the CPU is in RUN mode, set it to STOP mode.</td>
</tr>
<tr>
<td>4</td>
<td><img src="image4.jpg" alt="Image" /></td>
<td>Turn on the power supply again. If the STOP LED blinks, the CPU requests for a reset. Acknowledge this by turning the mode switch to MRES for a quick second.</td>
</tr>
<tr>
<td>5</td>
<td><img src="image5.jpg" alt="Image" /></td>
<td>Connect the CPU to the PG with an MPI cable. To do this, connect the MPI cable with the CPU’s MPI port. Connect the other end to the PG interface of your programming device.</td>
</tr>
</tbody>
</table>
Download hardware configuration

Download the hardware configuration into the CPU with HW Config.

Click the symbol „Load to module“ (shown in the red circle).

When the dialog window „Select target module“ pops up, click ok.

The dialog window „Select target address“ is shown. The system data are now transferred into the CPU.
Start CPU

Set the CPU to RUN mode.

If the hardware configuration was done correctly, two red LEDs (RUN and DC5V) should be lit at the CPU.

Figure 6-13  CPU in error free state
6.3 **STEP7 user program**

6.3.1 **Function of the user program**

In our example the input values are stored in a data block. Also, the hardware interrupt status should be stored in a marker word. It should be possible to acknowledge the status information by means of a bit.

Furthermore the channel values (values of the input words) should be stored in another data block.

In the user program the following tasks have to be performed:

1. Cyclical storage of the analog input values in a data block (DB1)
2. Cyclical conversion of the analog input values in floating point values (FC1) and storage in a data block (DB2)
3. Acknowledgement of the hardware interrupt status when the acknowledge marker (M200.0) is TRUE.
4. Store the status in a marker word (MW100) when a hardware interrupt occurs.

<table>
<thead>
<tr>
<th>Execution mode</th>
<th>Responsible Organisation block</th>
<th>Programming task</th>
<th>Used block or marker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclic execution</td>
<td>OB1</td>
<td>Store analog input values</td>
<td>DB1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Convert and store the sensor signals</td>
<td>FC1, DB2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acknowledge hardware interrupt</td>
<td>M200.0</td>
</tr>
<tr>
<td>Execution triggered by hardware interrupt</td>
<td>OB40</td>
<td>Store status</td>
<td>MW100</td>
</tr>
<tr>
<td>Execution triggered by diagnostic interrupt</td>
<td>OB82</td>
<td>Has to be implemented because a module with diagnostic capabilities is used</td>
<td>---</td>
</tr>
</tbody>
</table>

**About OB82**

OB82 is used for modules with diagnostic capabilities. If the diagnostic alarm is enabled for such modules, OB82 requests for diagnoses when a failure is detected (coming and going events). As a reaction to this the operating system calls OB82.

In our example we use OB82 in order to prevent the CPU from changing to STOP mode. You can program the output on hardware interrupts.
6.3.2 Create user program

There are two ways to create a user program.

- If you know how to program STEP7 SCL, then you can create and program the necessary blocks and the function blocks in the Blocks folder of STEP7.
- You can insert the user program from an SCL source into the project. In this "Getting started" we describe this way.

Creating a user program in STEP7 requires three steps:
1. Download of the source file directly from the web page
2. Import source file
3. Compile source file

Download of the source file

You can download the source file directly from the web page from which you loaded this "Getting Started".

The German version of the source file has the name „GSSM331T1DE.AWL“.

Save the source file to your hard drive.
Import source file

You can import the source file into SIMATIC Manager as follows:

- Right click the folder „Sources“
- Select „Insert new Object“ → External Source...

In the dialog window „Insert external source“ browse for the source file GSSM331T1DE.AWL, which you have already downloaded and saved on your hard drive.

Select the source file GSSM331T1DE.AWL (red arrow).

Click „Open“. 
SIMATIC Manager has opened the source file. On the right pane you can see the source file inserted.

![Image of SIMATIC Manager window showing the source file]

**Figure 6-16 Storing the source file**

**Compile source code**

In order to create an executable STEP7 program, the STL source has to be compiled.

Double click the source file GSSM331T1DE in the Sources folder. The source code editor is called.

In the window of the source code editor you can view the source code (code from Chapter 10).

```plaintext
DATA_BLOCK DB 1

TP11X analog modules channels values
VERSION : 1.0

STMOD
CH_0 : WO00 ; //Channel 0
CH_1 : WO00 ; //Channel 1
CH_2 : WO00 ; //Channel 2
```

![Image of source code editor window]

**Figure 6-17 Source code editor**
After the source code is loaded, start the compilation.

Press the shortcut key Ctrl+B or select File → Compile. The compilation starts immediately.

Figure 6-18 Translation of the STL source

In case of warning or error messages, check the source code.

Figure 6-19 Source code editor, messages after compilation

Close the source code editor.
After compiling the STL source without errors the following blocks should appear in the Blocks folder:

OB1, OB40, OB82, FC1, DB1 and DB2

Figure 6-20  Generated blocks
7 Test the user program

7.1 Download system data and user program

Hardware and software are ready now. The next step is to download the system data and the user program into the automation system. To do this, execute the following steps:

Table 7-1 Download user program and system data

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Download the user program and the system data (containing the hardware configuration) into the CPU.</td>
</tr>
<tr>
<td>2</td>
<td>Follow the instructions on the screen. If all sensors are properly connected, the CPU and the SM331 do not show any error light. The state of the CPU is displayed by the green „RUN“ light.</td>
</tr>
</tbody>
</table>
The labeling strips for the modules were created with Siemens S7-SmartLabel (Order no.: 2XV9 450-1SL01-0YX0).

The original size of the is displayed in Figure 7-1.
7.2 Visualization of the sensor signals

In order to visualize the sensor signals, insert a variable table as follows into the project. To do this, select from the context menu of the Blocks folder:

Insert new object → Variable Table

![Figure 7-2 Insert Variable Table](image)

Figure 7-2 Insert Variable Table

Fill the new variable table as follows:

![Variable table Control_Display](image)

Figure 7-3 Variable table Control_Display

- In this area you can monitor the channel values
- In this area you can see the analog values
- In this area you can monitor and control the status signals
Table 7-2 Description of the variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB1.DBW 0</td>
<td>Channel 0 Display of analog value</td>
</tr>
<tr>
<td>DB1.DBW 2</td>
<td>Channel 1 Display of analog value</td>
</tr>
<tr>
<td>DB1.DBW 4</td>
<td>Channel 2 Display of analog value</td>
</tr>
<tr>
<td>DB1.DBW 6</td>
<td>Channel 3 Display of analog value</td>
</tr>
<tr>
<td>DB1.DBW 8</td>
<td>Channel 4 Display of analog value</td>
</tr>
<tr>
<td>DB1.DBW 10</td>
<td>Channel 5 Display of analog value</td>
</tr>
<tr>
<td>DB1.DBW 12</td>
<td>Channel 6 Display of analog value</td>
</tr>
<tr>
<td>DB1.DBW 14</td>
<td>Channel 7 Display of analog value</td>
</tr>
<tr>
<td>DB2.DBD 0</td>
<td>Transducer1 current (mA)</td>
</tr>
<tr>
<td>DB2.DBD 4</td>
<td>Transducer2 current (mA)</td>
</tr>
<tr>
<td>DB2.DBD 8</td>
<td>Transducer3 current (mA)</td>
</tr>
<tr>
<td>MW 100</td>
<td>Status hardware interrupt</td>
</tr>
<tr>
<td>MW 200.0</td>
<td>Acknowledge hardware interrupt</td>
</tr>
<tr>
<td>M101.0</td>
<td>Channel 0 exceeded low limit</td>
</tr>
<tr>
<td>M101.1</td>
<td>Channel 0 exceeded high limit</td>
</tr>
<tr>
<td>M101.2</td>
<td>Channel 2 exceeded low limit</td>
</tr>
<tr>
<td>M101.3</td>
<td>Channel 0 exceeded high limit</td>
</tr>
</tbody>
</table>

**Monitoring of variables**

In order to monitor variables, open the online view of the controller by clicking the Eye Glasses symbol. Now you can monitor the values in the data blocks and markers.

![Online view of the variable table](image)

- **Channel values in hex format**
- **Converted analog value**
- **Status information**
Modification of variables

For modifying the Process Control Acknowledgement enter the desired value (TRUE or FALSE) into the column „Modify Value“. The value depends on whether you want to activate or deactivate the acknowledgement. Click the symbol with the two arrows.

![Modification of variables](image)

Figure 7-5 Modification of variables

Specifics for monitoring the variables

While monitoring the values you will notice that the channel values are different from the analog values. The reason for this is that the analog module only supports the binary format “Word” (16 bits). Therefore the values of the analog module have to be converted.
7.3 Display of analog values

The CPU can only process analog values in binary format. Analog input modules convert the analog process signal into a digital format (16 bit word).

Five ranges have to be taken into account when converting from digital to analog values:

Table 7-3 Display of analog value in the current range 4 to 20 mA

<table>
<thead>
<tr>
<th>Hex value</th>
<th>Current range</th>
<th>Comment</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>7FFF</td>
<td>22.96 mA</td>
<td></td>
<td>From hex value 16#F700 on, the sensor value is above the configured measurement value range and is no more valid.</td>
</tr>
<tr>
<td>7F00</td>
<td></td>
<td>Overflow</td>
<td></td>
</tr>
<tr>
<td>7EFF</td>
<td>22.81 mA</td>
<td>Oversteering range</td>
<td>This range corresponds to a tolerance band before the overflow range is reached. Within this range the resolution is not optimal though.</td>
</tr>
<tr>
<td>6C01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6C00</td>
<td>20 mA</td>
<td>Nominal range</td>
<td>The nominal range is the normal range for recording measurement values. This range guarantees optimal resolution.</td>
</tr>
<tr>
<td>5100</td>
<td>15 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4 mA + 578.7 nA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>4 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFFF</td>
<td></td>
<td>Understeering range</td>
<td>Range according to the oversteering range but for low values.</td>
</tr>
<tr>
<td>ED00</td>
<td>1,1185 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECFF</td>
<td></td>
<td>Underflow</td>
<td>From hex value 16#ECFF on, the sensor signal is below the configured measurement value range and is no more valid.</td>
</tr>
<tr>
<td>8000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is necessary to convert the binary format of the values in order to display analog process values. In our example mA are displayed. This is done by converting the display of analog values in mA in a programmed function (FC1).

In our example we look at the values from the output of the transducer.

With the aid of a current meter you can now compare the values on the meter with the values of the analog values display. The values will be identical.
8 Diagnostic interrupt

Diagnostic interrupts enable the user program to react on hardware failures.

Modules must have diagnostic capabilities in order to be able to generate diagnostic interrupts.

In OB82 you program the reaction on diagnostic interrupts.

8.1 Read diagnostic data from a PG

The analog input module SM331 AI8x12 has diagnostic capabilities.

Diagnostic interrupts that occur are signaled by the red „SF“ LED on the SM331 and on the CPU.

![Hardware failure](image)

Figure 8-1 Hardware failure

The cause of the failure can be determined online by requesting the hardware status.
In order to determine this, do the following:

Select the SM331 in the hardware configuration. Click the menu item CPU → Module Information... in order to perform a hardware diagnosis.

**8.2 General hardware interrupt**

On the Hardware Interrupt tab you find information for the failure reported. The interrupts are not channel dependent and apply to the entire module.
8.3 Channel dependent diagnostic interrupts

There are five channel dependent diagnostic interrupts:

- Configuration or parameterization errors
- Common mode error
- Wire break
- Underflow
- Overflow

---

**Note**

Here we show you only the channel specific diagnosis for the measuring modes 2- or 4-wire current transducers. Other measuring modes are similar but not described here.

---

8.3.1 Configuration / parameterization errors

The position of the measuring range modules does not match the measuring mode set in the hardware configuration.

8.3.2 Common mode errors

The voltage difference $U_{cm}$ between the inputs (M-) and the common voltage potential of the measuring circuit ($M_{ana}$) is too high.

In our example this failure cannot occur, because $M_{ana}$ is connected to M for a 2-wire transducer (fixed potential).
8.3.3 Wire break

If wire break detection is activated for 2-wire transducers, there will be no direct check for a wire break. The diagnostics rather reacts on the shortfall of the low limit current value.

For a 4 to 20 mA current transducer a diagnostic message “Analog input wire break” will be shown in the Module Information when the current goes below 3.6 mA.

The display of the analog values shows an underflow (Hex 8000) immediately even if the current measured is clearly above 1.1185 mA (see chapter 7.3).

Underflowing 3.6 mA is only possible if wire break detection was deactivated.

8.3.4 Underflow

The underflow notification is only triggered if the wire break detection is deactivated and the current is below 1.185 mA.

8.3.5 Overflow

If the current exceeds 22.81 mA, an overflow message stating „Analog input measuring range / High limit exceeded“ is displayed.

The display of the analog value (HEX 7FFF) is in the overflow range.
Figure 8-5  Left: Diagnostic message with overflow / Right: Variable table

Note
Disabled channels also have 7FFF hex as the analog display value.
9 Hardware interrupt

A special feature of the SM331 AI8x12bit is its capability to trigger hardware interrupts. Two channels (0 and 2) can be configured that way.

Hardware interrupts generally trigger alarm organization blocks. In our example OB40 is called.

The limit values for hardware interrupts have to be specified in mA.

Example:
You have connected a pressure sensor with a 4-20mA transducer to channel 0. Here the limit values should be specified in mA and not in Pascal (Pa).

In order to trigger a hardware interrupt, the limit values have to be within the nominal values of the measuring mode.

Example:
If wire break detection (3.6 mA) is enabled, and you choose 3.5 mA for the low limit value, this setting is accepted by the system. A hardware interrupt will not be triggered, because the diagnostic alarm is always triggered first.

In our example, 2 channels (sensor 1 and 2) are configured with the following limits:

- Low limit value: 6 mA
- High limit value: 18 mA

If a hardware interrupt occurs, OB40 is called. In the user program of OB40 you can program the reaction of the automation system on hardware interrupts.

In the sample user program, OB40 reads the cause of the hardware interrupt. This can be found in the temporary variable structure OB40_POINT_ADDR (Local words 8 to 11).

Figure 9-1 Startup information of OB40: Which event has triggered the hardware interrupt for which limit value

In the example OB40 only transfers LD8 and LD9 into a marker word (MW100). The marker word is monitored in the existing variable table. You can quit the marker word in OB1 by setting marker bit M200.0 or by setting it to TRUE in the variable table.

If you supply 5.71 mA with a calibration device to channel 0, you will get the value 0001 hex for MW100 in the variable table. That means that OB40 has been called and channel 0 exceeded its low limit value (6 mA).
Figure 9-2 Hardware interrupt: Channel 0 exceeded low limit value
10 Source code of the user program

In this chapter you find the source code of the user program from the example.

You can also download the source as an STL file directly from the HTML page from which you have loaded this “Getting started” (see chapter 6.3.2).

STL source code

DATA_BLOCK DB 1
TITLE = Analog module channel values
VERSION : 1.0

STRUCT
CH_0 : WORD ; // Channel 0
CH_1 : WORD ; // Channel 1
CH_2 : WORD ; // Channel 2
CH_3 : WORD ; // Channel 3
CH_4 : WORD ; // Channel 4
CH_5 : WORD ; // Channel 5
CH_6 : WORD ; // Channel 6
CH_7 : WORD ; // Channel 7
END_STRUCT ;
BEGIN
CH_0 := W#16#0;
CH_1 := W#16#0;
CH_2 := W#16#0;
CH_3 := W#16#0;
CH_4 := W#16#0;
CH_5 := W#16#0;
CH_6 := W#16#0;
CH_7 := W#16#0;
END_DATA_BLOCK

DATA_BLOCK DB 2
TITLE = Transducer value (in mA)
VERSION : 1.0

STRUCT
SE_1 : REAL ; // Sensor 1 current value (mA)
SE_2 : REAL ; // Sensor 2 current value (mA)
SE_3 : REAL ; // Sensor 3 current value (mA)
END_STRUCT ;
BEGIN
SE_1 := 0.000000e+000;
SE_2 := 0.000000e+000;
FUNCTION FC 1 : VOID
TITLE = Conversion of a channel’s raw values
VERSION : 1.0

VAR_INPUT
    Raw : WORD ;  // Analog value display
END_VAR

VAR_OUTPUT
    Current : REAL ;  // Current in mA
END_VAR

VAR_TEMP
    TDoubleInt : DINT ;
    TInt : INT ;
END_VAR

BEGIN

NETWORK

TITLE = Conversion of raw values in mA

L #Raw;
T #TInt;
// Only long integers can be converted into REAL format
L #TInt;
ITD ;
T #TDoubleInt;

L #TDoubleInt; // HEX value
DTR ; // Current = ---------------------
T #Current; // 1728

L 1.728000e+003; // ! /
/R ; // ! /
T #Current; // ! /
    // +-----/-------------
    // 4 20
L 4.000000e+000; // Offset adjustment
+R ;
T #Current;

END_FUNCTION
ORGANIZATION_BLOCK OB 1
TITLE = "Main Program Sweep (Cycle)"
VERSION : 1.0

VAR_TEMP
  OB1_EV_CLASS : BYTE ; //Bits 0-3 = 1 (Coming event), Bits 4-7 = 1 (Event class 1)
  OB1_SCAN_1 : BYTE ; //1 (Cold restart scan 1 of OB 1), 3 (Scan 2-n of OB 1)
  OB1_PRIORITY : BYTE ; //Priority of OB Execution
  OB1_OB_NUMBR : BYTE ; //1 (Organization block 1, OB1)
  OB1_RESERVED_1 : BYTE ; //Reserved for system
  OB1_RESERVED_2 : BYTE ; //Reserved for system
  OB1_PREV_CYCLE : INT ; //Cycle time of previous OB1 scan (milliseconds)
  OB1_MIN_CYCLE : INT ; //Minimum cycle time of OB1 (milliseconds)
  OB1_MAX_CYCLE : INT ; //Maximum cycle time of OB1 (milliseconds)
  OB1_DATE_TIME : DATE_AND_TIME ; //Date and time OB1 started

END_VAR
BEGIN
NETWORK
TITLE = Read channels
  // Channel values 0 to 7 are loaded and stored in DB1 (channel values)
  L PEW 256; // Channel 0
  T DB1.DBW 0;

  L PEW 258; // Channel 1
  T DB1.DBW 2;

  L PEW 260; // Channel 2
  T DB1.DBW 4;

  L PEW 262; // Channel 3
  T DB1.DBW 6;

  L PEW 264; // Channel 4
  T DB1.DBW 8;

  L PEW 266; // Channel 5
  T DB1.DBW 10;

  L PEW 268; // Channel 6
  T DB1.DBW 12;

  L PEW 270; // Channel 7
  T DB1.DBW 14;
NETWORK
TITLE = Conversion
// Conversion of the channel’s raw data into current values (mA)
CALL FC 1 (  
    Raw := DB1.DBW 0,  
    Current := DB2.DBD 0);

CALL FC 1 (  
    Raw := DB1.DBW 4,  
    Current := DB2.DBD 4);

CALL FC 1 (  
    Raw := DB1.DBW 6,  
    Current := DB2.DBD 8);

NETWORK
TITLE = Reset hardware interrupt
// Even though the hardware interrupt was reset by the hardware upon termi-
// nating OB40,
// the value of the hardware interrupt must be reset manually
  U M 200.0;
  SPBN lb10;
  L MW 100;
  SSI 4;
  T MW 100;
  lb10: NOP 0;
NETWORK
TITLE = The End

BE ;

END_ORGANIZATION_BLOCK

ORGANIZATION_BLOCK OB 40
TITLE = "Hardware Interrupt"
// Processing OB40_POINT_ADDR (L8 to L11)
//
//L8 High limit value exceeded
//L9 Low limit value exceeded
VERSION : 1.0

VAR_TEMP
  OB40_EV_CLASS : BYTE ;  //Bits 0-3 = 1 (Coming event), Bits 4-7 = 1 (Event class 1)
OB40_START_INF : BYTE ;  //16#41 (OB 40 has started)
OB40_PRIORITY : BYTE ;  //Priority of OB Execution
OB40_OB_NUMBR : BYTE ;  //40 (Organization block 40, OB40)
OB40_RESERVED_1 : BYTE ;  //Reserved for system
OB40_IO_FLAG : BYTE ;  //16#54 (input module), 16#55 (output module)
OB40_MDL_ADDR : WORD ;  //Base address of module initiating interrupt
OB40_POINT_ADDR : DWORD ; //Interrupt status of the module
OB40_DATE_TIME : DATE_AND_TIME ; //Date and time OB40 started

END_VAR

BEGIN

NETWORK

TITLE = Sensor 1 (Channel 0): Low limit

U   L   9.0; // Channel 0 low limit
SPBNB L001;
L  W#16#1;
L  MW  100;
OW  ;
T  MW  100;
L001: NOP  0;

NETWORK

TITLE = Sensor 1 (Channel 0): High limit

U   L   8.0; // Channel 0 high limit
SPBNB L002;
L  W#16#2;
L  MW  100;
OW  ;
T  MW  100;
L002: NOP  0;

NETWORK

TITLE = Sensor 2 (Channel 2): Low limit

U   L   9.2; // Channel 2 low limit
SPBNB L003;
L  W#16#4;
L  MW  100;
OW  ;
T  MW  100;
L003: NOP  0;

NETWORK

TITLE = Sensor 2 (Channel 2): High limit
NETWORK
TITLE = Sensor 3 (Channel 3): Low limit
// Only for demonstration purposes; Channel 3 has now hardware interrupt ca-
pabilities.
U   L   9.3; // Channel 3 low limit
SPBNB L005;
L   W#16#10;
L   MW   100;
OW   ;
T   MW   100;
L005: NOP   0;

NETWORK
TITLE = Sensor 3 (Channel 3): High limit
//Only for demonstration purposes; Channel 3 has now hardware interrupt ca-
pabilities.
U   L   8.3; // Channel 3 high limit
SPBNB L006;
L   W#16#20;
L   MW   100;
OW   ;
T   MW   100;
L006: NOP   0;