آموزش
Analogue Signal Processing

۱-۲ سیستم‌های کنترل فرآیند

در یک فرآیند صنعتی، مواد اولیه به عنوان ورودی وارد شده و محصول یا محصولات نهایی از آن خارج می‌گردد. به آنچه در داخل فرآیند رخ می‌دهد می‌توان از جنبه‌های مختلف نگاه کرد:

- فرآیندهایی که با تغییرات شیمیایی ماهیت مواد اولیه را تغییر داده و آن‌ها را به مواد جدیدی تبدیل می‌کنند. صنایع شیمیایی از این دسته‌اند.
- فرآیندهایی که صرفاً تغییراتشان فیزیکی است و فقط ابعاد یا ظاهر محصول را تغییر می‌دهند، به عنوان مثال موادی با ضخامت زیاد به آن‌ها وارد شده و بدون این که در ماهیت آن‌ها تغییر داده شود صرفاً ضخامت آن‌ها کم می‌شود. برخی از بخش‌های صنایعی مانند فولاد و آلومینیوم و مس از این دسته‌اند.
- فرآیندهایی که مواد اولیه بدون هیچ تغییر فیزیکی یا شیمیایی به یکدیگر متصل شده و دستگاه یا ماشینی را شکل می‌دهند. خودروسازی از این دسته فرآیندهاست.
- فرآیندهایی که تنوع مواد اولیه آن‌ها محدود ولی محصولات خروجی آن‌ها بسیار متنوع است. به عنوان مثال صنایع لبنی که از ماده اولیه‌ای مانند شیر محصولات مختلفی را تولید می‌کنند.
- فرآیندهایی که الگوی تولید در آن‌ها همیشه ثابت است یا تغییرات جزئی دارد. این فرآیندها معمولاً محصول مشخصی را تولید می‌کنند که شرایط دما و فشار و سایر پارامترها برای آن همواره طبق یک الگوی واحد کنترل می‌شود.
- فرآیندهایی که الگوی تولید در آن‌ها متغیر است بسته به این که چه محصولی باید تولید شود، لازم است پارامترها و شرایط جدیدی برای فرآیند تنظیم گردد. برخی از بخش‌های صنایع داروسازی را می‌توان در این دسته جای داد.

سیستم کنترل و اتوماسیون بسته به نوع فرآیند متفاوت است.

به عبارت دیگر هر فرآیند سیستم خاص خود را نیاز دارد این گونه نیست که به عنوان مثال PLC را به عنوان سیستم کنترل برای همه‌ی فرآیندها پیشنهاد دهیم.

اگر به طور دقیق‌تر و به ویژه از جنبه‌ی کنترل و اتوماسیون به فرآیندها نگاه کنیم می‌توانیم آن‌ها را در سه تقسیم‌بندی زیر جای دهیم:

- Discrete Process
- Continuos Process
- Hybrid Process

۱-۲-۱ Discrete Process

در این فرآیندها دستگاه‌ها عمدتاً دارای وضعیت On/Off هستند و لوپ کنترلی برای پردازش و کنترل مقادیرآنالوگ ندارند. از نمونه این فرآیندها می‌توان به خطوط مونتاژ و صنایع خودروسازی اشاره کرد. در اتوماسیون، این دسته از فرآیندها Factory Automation نامیده می‌شوند و برای کنترل آن‌ها از PLC استفاده می‌گردد.

PLC مناسب ترین سیستم کنترل برای Factory Automation است.

۱-۲-۲ Continuous Process

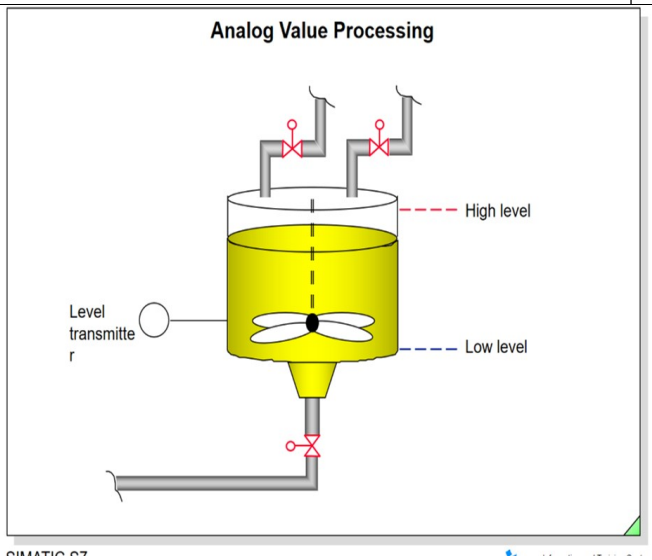
این فرآیندها نیاز به کنترل مداوم پارامترهای فرآیندی مانند فشار و دما و دبی و امثال آن‌ها دارند. به عبارت دیگر پردازش آنالوگ و لوپ‌های کنترلی در آن‌ها زیاد است. از نمونه این فرآیندها می‌توان صنایع شیمیایی، پالایشگاه‌ها، نیروگاه‌ها، صنایع نفت و گاز و پتروشیمی را نام برد. از دیدگاه اتوماسیون به این دسته از فرآیندها Process Automation اطلاق می‌شود. بهترین سیستم کنترل برای آن‌ها سیستم کنترل غیرمتمرکز یعنی DCS است که لوپ‌های کنترلی در CPU های مستقلی پردازش می‌شوند.

DCS مناسب‌ترین سیستم کنترل در Process Automation است.

۱-۲-۳ Hybrid Process

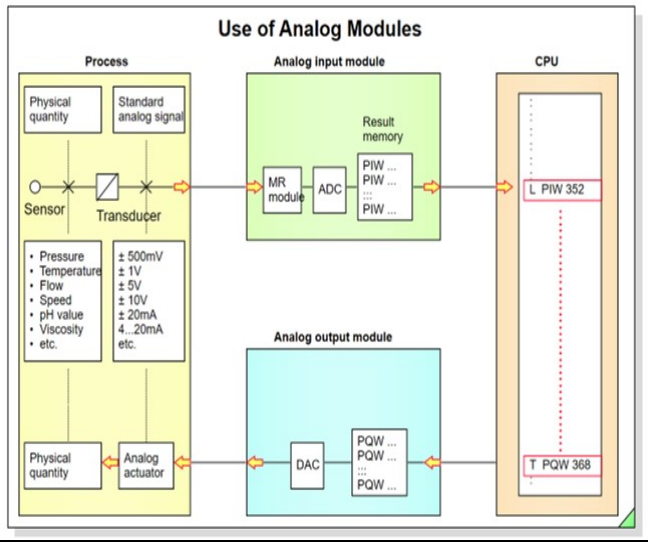
این فرآیندها مختلط هستند یعنی سیگنال‌های دیجیتال و آنالوگ و لوپ‌های کنترلی هر دو در آن‌ها به وفور یافت می‌شوند. صنایع سیمان و فولاد از این دسته‌اند. بسته به فراوانی این سیگنال‌ها و کاربرد مورد نظر معمولاً هر دو سیستم کنترل فوق‌الذکر در این صنایع یافت می‌شوند.

در سیستم‌های مختلط PLC و DCS هر دو بکار می روند.



SIMATIC S7

Contents Page



Principle In a production process, there are a variety of physical quantities (pressure, temperature, speed, rotational speed, pH value, viscosity, etc.) that need to be processed in the PLC for automation purposes.

Sensor Measuring sensors respond to changes in the quantity to be measured by linear expansion, angular ductability, alteration of electrical conductivity, etc.

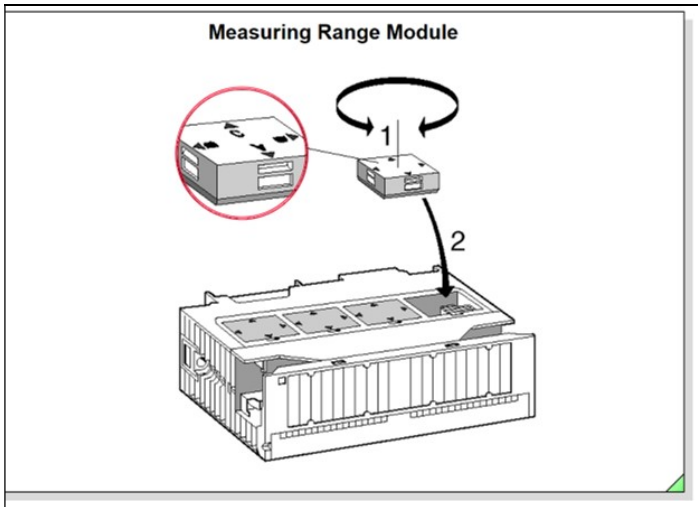
Transducer Measuring transducers convert these above-mentioned changes into standard analog signals, such as: ± 500mV, ± 10V, ± 20mA, 4...20mA.
These signals are supplied to the analog input modules.

ADC Before these analog values can be processed in the CPU, they must be converted to digital form. This is done by the ADC (Analog-to-Digital Converter) on the analog input module.
The analog-to-digital conversion is performed sequentially, that is, the signals are converted for each analog input channel in turn.

Result Memory The result of the conversion is stored in the result memory and remains there until it is overwritten by a new value.
The converted analog value can be read with the Load instruction "L PIW...".

Analog Output The Transfer instruction "T PQW..." is used to write the analog values calculated by the user program to an analog output module, where a DAC (Digital-to-Analog Converter) converts them to standard analog signals.

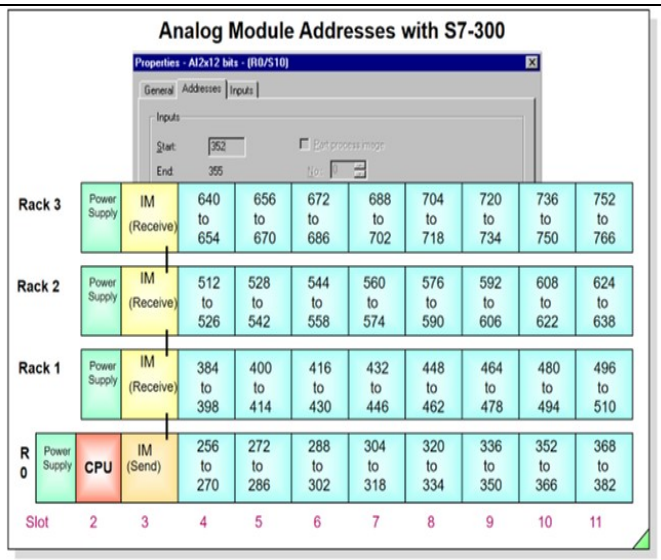
Analog Actuators with standard analog input signals can be connected to the analog output modules direct.



Type of Measurement You set the type of measurement and the measuring range by setting coding keys on the measuring range module.
Special modules without coding keys have different terminals for voltage and current measurement. Thus, the type of measurement can be set by wiring the appropriate terminal.

Measuring Range Module The measuring range modules with their coding keys are located on the left-hand side of the module. You must set them correctly before installing the module.
The possible settings are "A", "B", "C" and "D".
The settings for the various types of measurement and measuring ranges are printed on the module.

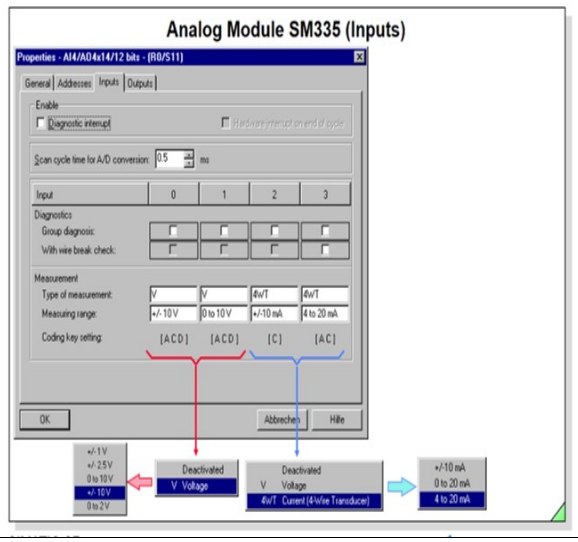
Channel Groups On some modules, several channels are grouped together to form a channel group. In this case, the coding key setting applies to the whole channel group.



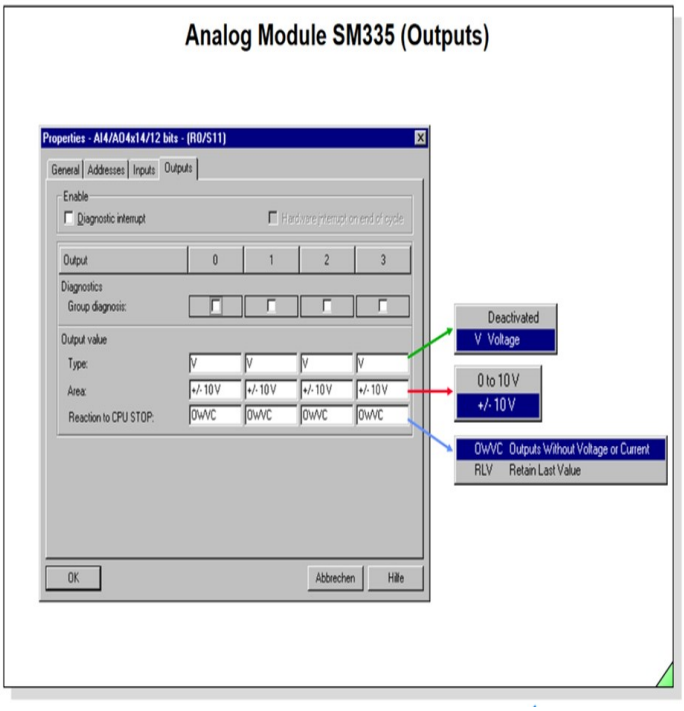
Address Area The S7-300 has a special address area for analog inputs and outputs, which is separate from the process image input and output tables for the digital modules (PII/PIQ).
This address area extends from byte 256 to byte 767. Each analog channel occupies 2 bytes.

Access You access the analog modules by means of Load and Transfer instructions.
Example: The statement "L PIW256" reads the first channel of the first module in rack 0.

S7-400 On the S7-400, the address area for the analog modules starts at byte 512.

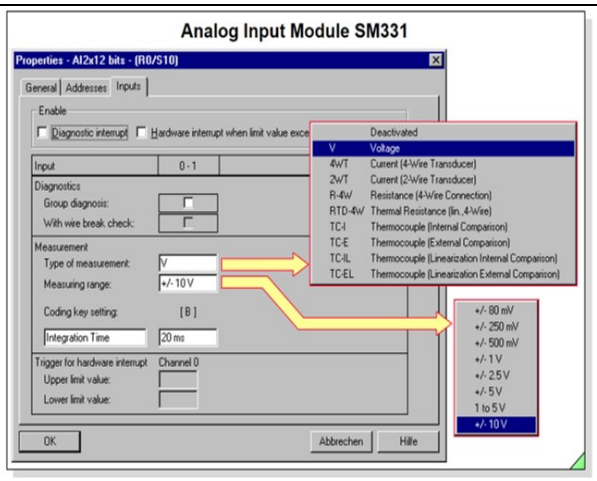


Diagnostic Interrupt	When the diagnostic interrupt is activated and a hardware fault occurs, such as a power supply failure, a diagnostic interrupt (OB 81) is triggered. As well, you must specify in the "Diagnostics" field which inputs are to be monitored. A wire break check is only possible with 4 to 20 mA power inputs.
Scan Cycle Time	The scan cycle time is the time it takes for the module to process ("convert") all the activated analog inputs once. The setting for the scan cycle time for A/D conversion can be between 0.5ms and 16ms. When it has processed all the analog inputs, the module can trigger a hardware interrupt (= End of Cycle interrupt) (only if a scan cycle time for conversion longer than 1ms has been selected).
Note	Unused inputs must be short-circuited on the hardware and "Deactivated" in the software. Deactivated analog inputs reduce the scan cycle time!
Measuring Range Module	When the type of measurement and the measuring range have been selected, the necessary coding key setting on the measuring range module is displayed. Example: For the measuring ranges selected in the slide above, the measuring range module must be inserted in position "C".
Resolution	The analog inputs of the SM 335 have a resolution of 13 bits + sign, the analog outputs 11 bits + sign.



Note Unused output channels must remain open on the hardware (not be short-circuited like the analog inputs) and be "deactivated" in the software.

Analog Input Module SM331



Parameters You can set two groups of parameters for analog input modules with the "HW Config" tool:

Module as a Whole

- Diagnostic Interrupt:
  If the "Group Diagnosis" checkbox has been activated and a diagnostic event occurs, the relevant information is entered in the diagnostics data area of the module and the diagnostic interrupt (OB82) is triggered.
  The analog module can detect the following diagnostic events:
  - Configuration/ parameter assignment errors
  - Wire break (if "With Wire Break Check" is activated)
  - Above measuring range
  - Below measuring range
  - No load voltage L+
- Hardware Interrupt when Limit Value Exceeded
  If the input value exceeds the range set by the entries for "Upper Limit Value" and "Lower Limit Value", the module triggers a hardware interrupt.
  Note: Only the first channel in a group can monitor the input value for violation of the selected limit values!

Individual Inputs

- Type of Measurement: When you click this box, the possible types of measurement (voltage, current...) are displayed. For unused channels or channel groups you select the "deactivated" option. You must connect these channels to chassis ground on the module
- Measuring Range: When you click this box, the possible measuring ranges for the type of measurement selected are displayed.
- Coding Key Setting: A very specific setting of the measuring range module becomes necessary when you select the type of measurement and the measuring range. This is displayed here.
- The integration time and interference frequency suppression are interdependent (see next page).

Analog Value Representation and Measured Value Resolution

Bit no.		Units		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit value		Dec.	Hex.	VZ	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
Reso-lution in bits + sign	8	128	80	*	*	*	*	*	*	*	*	1	0	0	0	0	0	0	0
	9	64	40	*	*	*	*	*	*	*	*	*	1	0	0	0	0	0	0
	10	32	20	*	*	*	*	*	*	*	*	*	*	1	0	0	0	0	0
	11	16	10	*	*	*	*	*	*	*	*	*	*	*	1	0	0	0	0
	12	8	8	*	*	*	*	*	*	*	*	*	*	*	*	1	0	0	0
	13	4	4	*	*	*	*	*	*	*	*	*	*	*	*	*	1	0	0
	14	2	2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1	0
	15	1	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1

* = **0** or **1**

Representation Analog values are represented as the two's complement.
The value is positive if bit No. 15=0 and negative if bit No.15=1.

Resolution If the resolution of an analog module is less than 15 bits, the analog value is written into the accumulator left-justified. The unused less significant bit positions are filled with "0"s.

Integration Time The resolution is specified indirectly by selecting an integration time with the "HW Config" tool.
The following table for the SM331 illustrates the relationship between integration time, resolution and interference frequency suppression:

Integration time (ms)	Resolution (in bits)	Interference frequency suppression (Hz)
2.5	9 + sign bit	400
16.6	12 + sign bit	60
20	12 + sign bit	50
100	14 + sign bit.	10

Accuracy Resolutions of between 8 and 15 bits are possible, depending on the type of module.

Conversion Time The conversion time depends on the conversion procedure used in the module (integrating procedure, successive approximation).
The conversion times of the different modules are given in the S7-300 manual.
Example: The SM344 has a conversion time of only 5 ms for all 4 input channels.

Analog Value Representation of Different Measuring Ranges

Range	Voltage e.g.:		Current e.g.:		Resistance e.g.:		Temperature e.g. Pt100	
	Meas.range ± 10V	Units	Meas.range 4 .. 20mA	Units	Meas.range 0...300Ohm	Units	Meas.range -200...+850°C	Units
Overflow	>= 11.759	32767	>= 22.815	32767	>=352.778	32767	>= 1000.1	32767
Overrange	11.7589 : 10.0004	32511 : 27649	22.810 : 20.0005	32511 : 27649	352.767 : 300.011	32511 : 27649	1000.0 : 850.1	10000 : 8501
Rated range	10.00 7.50 : -7.5 -10.00	27648 20736 : -20736 -27648	20.000 16.000 : 4.000	27648 20736 : 0	300.000 225.000 : 0.000	27648 20736 : 0	850.0 : -200.0	8500 : -2000
Underrange	- 10.0004 : - 11.759	- 27649 : - 32512	3.9995 : 1.1852	- 1 : - 4864	Negative values not possible	- 1 : - 4864	- 200.1 : - 243.0	- 2001 : - 2430
Underflow	<= - 11.76	- 32768	<= 1.1845	- 32768		- 32768	<= - 243.1	- 32768

Voltage, Current (Symmetrical) Encoding the symmetrical voltage or current ranges

- ± 80mV
- ± 250 mV
- ± 500 mV
- ± 1 V
- ± 2.5 V
- ± 5V
- ± 10V
- ± 3.2 mA
- ± 10 mA
- ± 20 mA

results in a rated range of -27648 to +27648.

Voltage, Current (Asymmetrical) Encoding the asymmetrical voltage or current ranges

- 0 to 2 V
- 1 to 5 V
- 0 to 20 mA
- 4 to 20 mA

results in a rated range of 0 to +27648.

Resistance Encoding the resistance ranges

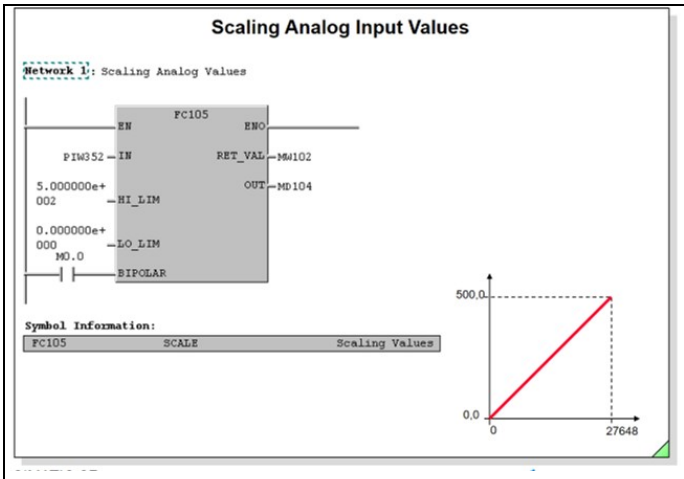
- 0 to 150 Ohm
- 0 to 300 Ohm
- 0 to 600 Ohm

results in a rated range of 0 to +27648.

Temperature Temperatures are measured with resistance thermometers or thermocouples.
Encoding results in a rated range of ten times the temperature range:

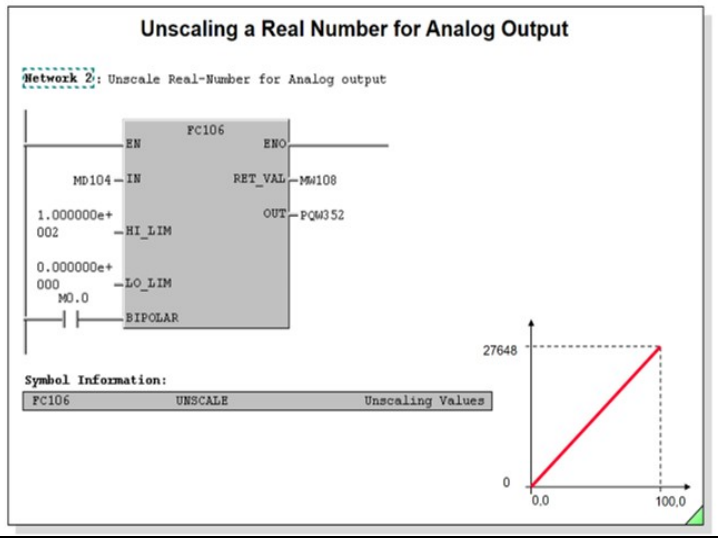
Sensor:	Temperature range:	Rated range when encoded:
• Pt 100	-200 to + 850 °C	-2000 to + 8500
• Ni 100	-60 to + 250 °C	-600 to + 2500
• Thermocouple type K	-270 to + 1372 °C	-2700 to + 13720
• Thermocouple type N	-270 to + 1300 °C	-2700 to + 13000
• Thermocouple type J	-210 to + 1200 °C	-2100 to + 12000
• Thermocouple type E	-270 to + 1000 °C	-2700 to + 10000.

Scaling Analog Input Values



Example	The level in a tank is to be measured in liters. The measuring transformer was chosen in such a way that 500 liters have an analog value of 10 V.
Scaling	The analog module encodes the analog value 10 V as the integer value 27 648. This value now has to be converted to the physical quantity "liters". This is known as "scaling" the analog value.
Program	Standard block FC 105 is used for scaling analog values. FC 105 is supplied with the STEP 7 software in the library "Standard Library" in the S7 Program "TI-S7 Converting Blocks".
IN	The analog value at input IN can be read in from the module direct or read from a data interface in INTEGER format.
LO_LIM, HI_LIM	Inputs LO_LIM (low limit) and HI_LIM (high limit) are used for specifying the limits for conversion to physical quantity. In the example the reading is scaled to the range 0 to 500 liters.
OUT	The scaled value (physical quantity) is stored as a real number at output OUT.
BIPOLAR	The input BIPOLAR determines whether negative values are also to be converted. In the above example, memory bit M0.0 has a signal "0" and thus indicates that the input value is unipolar.
RET_VAL	The output RET_VAL has the value 0 if execution is free of errors.

Unscaling a Real Number for Analog Output

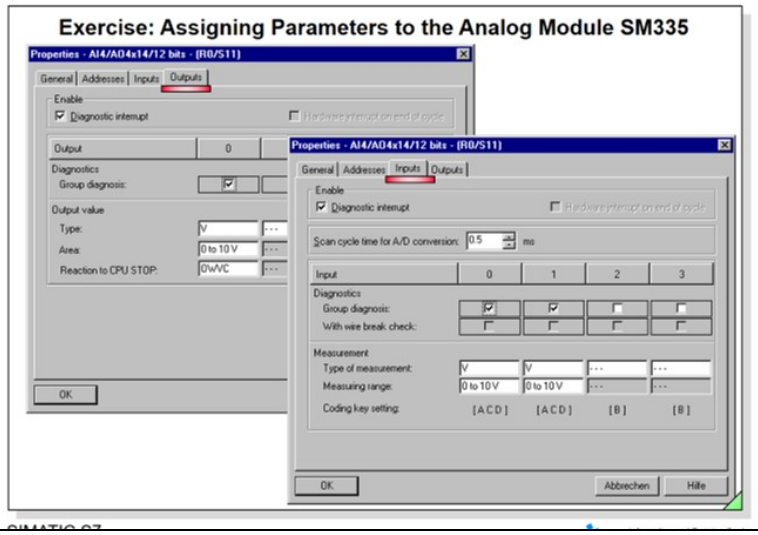


Example	The user program calculates an anaolg value in the range 0 to 100.0%. This value is to be output via an analog output module.
Unscaling	Standard block FC106 is used for unscaling (conversion of a real number from 0 to 100.0% to a 16-bit integer between 0 and 27648).
OUT	The unscaled analog value at output OUT can be transferred in the form of a 16-bit integer to a data interface or to the module direct.
Program	FC 106 is supplied with the STEP 7 software in the library "Standard Library" in the S7 Program "TI-S7 Converting Blocks".

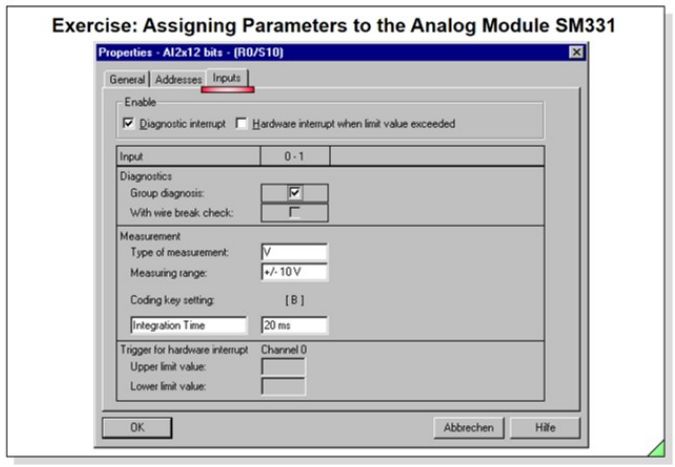
Analog Value Representation for the Analog Outputs

Range	Units	Voltage			Current		
		Output ranges:			Output ranges:		
		0 to 10V	1 to 5V	± 10V	0 to 20mA	4 to 20mA	± 20mA
Overflow	>=32767	0	0	0	0	0	0
Overrange	32511 ⋮ 27649	11.7589 ⋮ 10.0004	5.8794 ⋮ 5.0002	11.7589 ⋮ 10.0004	23.515 ⋮ 20.0007	22.81 ⋮ 20.005	23.515 ⋮ 20.0007
Rated range	27648 ⋮ 0 ⋮ - 6912 - 6913 ⋮ ⋮ - 27648	10.0000 ⋮ 0	5.0000 ⋮ 1.0000	10.0000 ⋮ 0 ⋮ ⋮ -10.0000	20.000 ⋮ 0	20.000 ⋮ 4.000	20.000 ⋮ 0 ⋮ ⋮ -20.000
		0	0.9999 ⋮ 0		0	3.9995 ⋮ 0	
			0			0	
Underrange	- 27649 ⋮ - 32512			- 10.0004 ⋮ - 11.7589			- 20.007 ⋮ - 23.515
Underflow	<=- 32513			0			0

Voltage, Current Symmetrical	For symmetrical voltage or current ranges a rated range of -27648 to +27648 is converted to: • ± 10V • ± 20mA.
Voltage, Current Asymmetrical	For asymmetrical voltage or current ranges a rated range of 0 to +27648 is converted to: • 0 to 10V • 1 to 5V • 0 to 20mA • 4 to 20mA.
Overflow	If the value to be converted reaches the overflow range, the analog output module is disabled (0V, 0mA).



Note	Depending on which analog module is in your training unit, you are to do either this exercise or the one on the following page.
Goal	To get to know how to change the settings and parameters of analog modules.
What to Do	Change the settings of your analog module to correspond to those in the slide.



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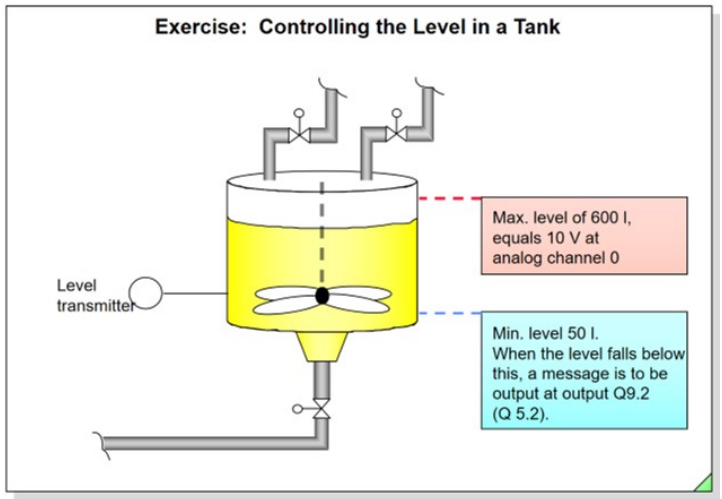
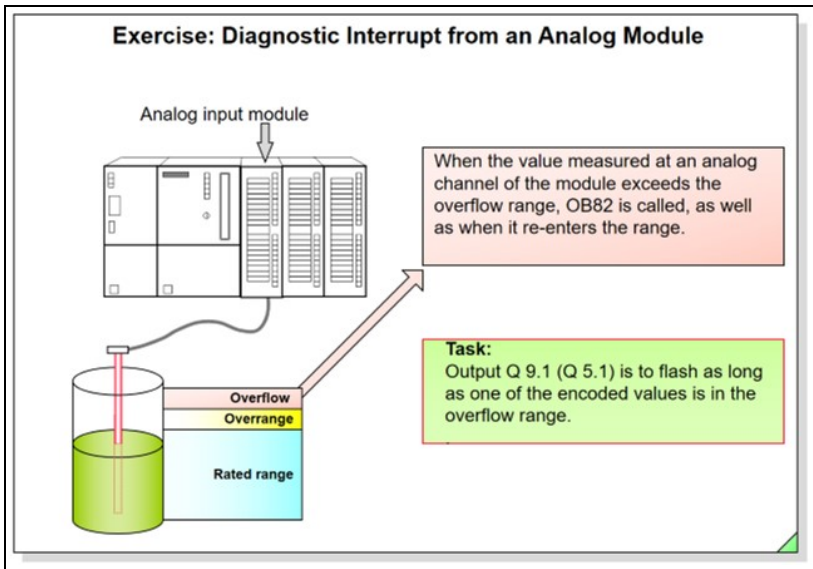


Task	The tank has a maximum capacity of 600 liters. The level is measured using a measuring transducer. It has an analog value of 10 V when the maximum level is reached. This analog value is to be converted to a physical quantity (number of liters) using the FC 105 block. If the level goes below the minimum 50 liters, the output Q 9.2 (Q 5.2) is to flash until the level is once more 50 liters or more. The first potentiometer on the simulator specifies the level.
What to Do	1. Create an FC 20 block in the S7 program "FILL" according to the task. 2. Call FC 20 in OB 1 as well. 3. Download the FC 20, FC 105 blocks and the OB1. 3. Test your program.



Task	Solve the problem shown above using the diagnostic interrupt OB82 and the diagnostics capability of the analog input module.
Note	If you want to specifically evaluate which channel is in the overflow range, you have to use a system function here.
What to Do	1. Write a program for OB82 in the S7 program "FILL" according to the task. 2. Supplement the program in OB 1 to control the output Q 9.1 or Q 5.1. 3. Test your program.