***Analog signal processing with PLC***

**Introduction**

The controller of a PLC has the task of leading single operations of a machine or a machine plant as per a given function sequence. The functioning depends on sensor signals. The electrical signals which are applied at the inputs and outputs of a PLC can, in principle, be divided into two different groups: Binary signals and analog signals.

**Tasks**

1. Read the introduction carefully and match the English to the German expressions in the table below. Work on your own and do it without the aid of a dictionary.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | English |  | Nr. | German |
| 1 | controller |  | 2 | weiterleiten |
| 2 | (to) lead |  | 4 | anstehen |
| 3 | function sequence |  | 1 | Steuereinheit |
| 4 | (to) apply |  | 4 | Funktionsablauf |

1. Work in pairs and translate the introduction into German. **Goal: You understand every detail of the text.**
2. Label the time charts below using the following terms:

Bianry

V

t

V

t

Analog

* analog signal
* binary signal

1. Complete the following statements:

Binary signals can take the value of 2 possible states.

Analog signals can take any values within a certain range.

Learning objectives

By the end of this learning sequence you will be …

* … more familiar with binary and analog signals.
* … able to understand the function of an analog-to-digital converter.
* … able to calculate an application of an ADC.

**Homework**

Make your own vocab cards and learn the new vocabulary!

**Binary digits**

A binary signal can only take the two values "0" or "1". Such a binary signal is also designated as a binary digit and receives the designation "bit". Several binary signals result in a digital signal (code). While a binary signal only provides a grouping of a bivalent size (e.g. door open/door closed), one can form for example a number or digit as digital information by the bundling of binary digits.

The summarization of *n* binary digits allows the representation of 2n different combinations. One can show four different types of information with two binary digits:

|  |  |  |
| --- | --- | --- |
| combination of the binary digits | | type of information (e.g.) |
| switch 2 | switch 1 |
| 0 | 0 | both switches open |
| 0 | 1 | switch 1 closed / switch 2 open |
| 1 | 0 | switch 1 open / switch 2 closed |
| 1 | 1 | both switches closed |

**Tasks**

1. Work in pairs and translate the sequence about binary digits into German. **Goal: You understand every detail of the text.**
2. Complete the table below. Refer to an online dictionary if necessary.

|  |  |
| --- | --- |
| English | German |
| binary digit | Binär ziffer |
| designation | Bezeichnung |
| bivalent | Zweiwertig |

1. How many different types of information can one show with four binary digits?

16

1. What is the abbreviation for binary digit?

Bit

**Analog signal**

Contrary to a binary signal that can accept only signal statuses "voltage available (e.g. +24 VDC)" and "voltage not available (e.g. 0 VDC)", there are

analog signals that can take many values within a certain range. A typical example of an analog sensor is a potentiometer. Depending on the position of the rotary button, any resistance can be adjusted up to a maximum value.

Examples of analog values in control systems are:

* Temperature, e.g. -50 to +150 °C
* Flow, e.g. 0 to 200 l/min
* Number of revolutions, e.g. 500 to 1500 R/min

With the help of a transducer these physical values are converted to electrical voltages, currents or resistances. For example, if a number of revolutions are collected, the speed range can be converted over a transducer from 500 to 1500 R/min into a voltage range from 0 to +10 VDC.

**Tasks**

1. Read the sequence about analog signals carefully and match the English to the German expressions in the table below. Work on your own and do it without the aid of a dictionary.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | English |  | Nr. | German |
| 1 | range |  | 5 | erfassen |
| 2 | rotary button |  | 3 | Messumformer |
| 3 | transducer |  | 2 | Drehknopf |
| 4 | (to) convert |  | 1 | Bereich |
| 5 | (to) collect |  | 4 | umwandeln |

1. Work in pairs and translate the sequence about analog signals into German. **Goal: You understand every detail of the text.**
2. An analog sensor collects the number of revolutions of a motor and converts the speed range from 300 to 3’000 R/min into a voltage range from 0 to +10 VDC using a transducer. Calculate the **output voltage level of the transducer** if the measured number of revolutions is 1’675 R/min.

Note: Write down the procedure for the solution exactly. Give the result in volts and round it to two decimal places.

**Processing of analog signals with a PLC**

When analog signals are inputted to a PLC, the input channel needs to convert the signal to a digital signal using an **analog-to-digital converter (ADC)**. With a rack-mounted system this may be achieved by mounting a suitable analog input card in the rack.

*Fig.: Analog input card*

The figure below illustrates the function of an analog-to-digital converter (ADC). A single analog input signal gives rise to on/off output signals along eight separate wires. The eight signals then constitute the so-termed digital *code* corresponding to the analog input signal level. With such an **8-bit converter** there are 28 = 256 different digital values possible; these are 0000 0000 to 1111 1111, that is 0 to 255. The digital output goes up in steps and the analog voltages required to produce each digital output are termed quantization levels.

If the binary output needs to be changed, the analog voltage has to change according to the difference in the analog voltage between the successive levels. The term **resolution** is used for the smallest change in analog voltage that will give rise to a change in 1 bit in the digital output. With an 8-bit ADC, if, say, the full-scale analog input signal varies between 0 and 10 V, a step of one digital bit involves an analog input change of about 0,04 V (= 10 V/256). This means that a change of 0,03 V in the input will produce no change in the digital output. The number of bits in the output from an analog-to-digital converter thus determines the resolution, and hence, the **accuracy** that is possible.

|  |  |
| --- | --- |
| analog input | digital output |
| 0,00 V | 0000 0000 |
| 0,04 V | 0000 0001 |
| 0,08 V | 0000 0010 |
| 0,12 V | 0000 0011 |
| 0,16 V | 0000 0100 |
| 0,20 V | 0000 0101 |
| 0,24 V | 0000 0110 |
| 0,28 V | 0000 0111 |
| 0,32 V | 0000 1000 |
| etc. |  |

Digital output

Bit

7

6

5

4

3

2

1

0

analog-to-

digital converter

0000 0010

Digital output

0000 0001

0 1 2

analog input

0000 0000

The following illustrates the analog-to-digital conversion for an 8-bit converter when the analog input is in the range of 0 to 10 V:

**Tasks**

1. Read the text above carefully using the vocabulary word bank given below.

|  |  |
| --- | --- |
| English | German |
| (to) give rise to sth. | führen zu |
| (to) constitute | darstellen |
| successive | aufeinander folgend |
| hence | folglich |

1. Work in pairs and translate the sequence about processing of analog signals into German. **Goal: You understand what it is about.**
2. Illustrate in the following table an analog-to-digital conversion for a **2-bit converter** when the analog input is in the range of 0 to 10 V?

|  |  |
| --- | --- |
| analog input | digital output |
| 0 V | 00 |
| 2.5 V | 01 |
| 5 V | 10 |
| 7.5 V | 11 |

1. Consider a PT100 used as a sensor with a PLC and giving an output of 0,5 mV per °C. What will be the **accuracy** with which the PLC activates the output device if the PT100 is connected to an analog input with a range of 0 to 10 VDC and using a 10-bit analog-to digital converter?

*Step 1:* How many digital codes are covering the 0 to 10 VDC range with a 10-bit converter?

1024

*Step 2:* A change of 1 bit corresponds to how many mV?

9,765625V

*Step 3:* Complete the following sentence:

The accuracy with which the PLC recognizes the input from the PT 100 is ± 9,765625 mV or ± 0,0977 °C.

1. A 12-bit ADC can be used to represent analog voltages within its input range with …

* … 12 different binary numbers.

\_

\_

* … 24 different binary numbers.
* … 144 different binary numbers.

\_

* … 4096 different binary numbers.

X

1. For an analog input range of 0 to 10 V, the minimum size ADC needed to register a change of 0,1 V is …

* … 4-bit

\_

\_

* … 6-bit
* … 8-bit

X

* … 12-bit

\_

1. Complete the table below. Refer to an online dictionary if necessary.

|  |  |
| --- | --- |
| English | German |
| 8-bit converter | 8-Bit Umwandler |
| resolution | Auflösung |
| accuracy | Genauigkeit |