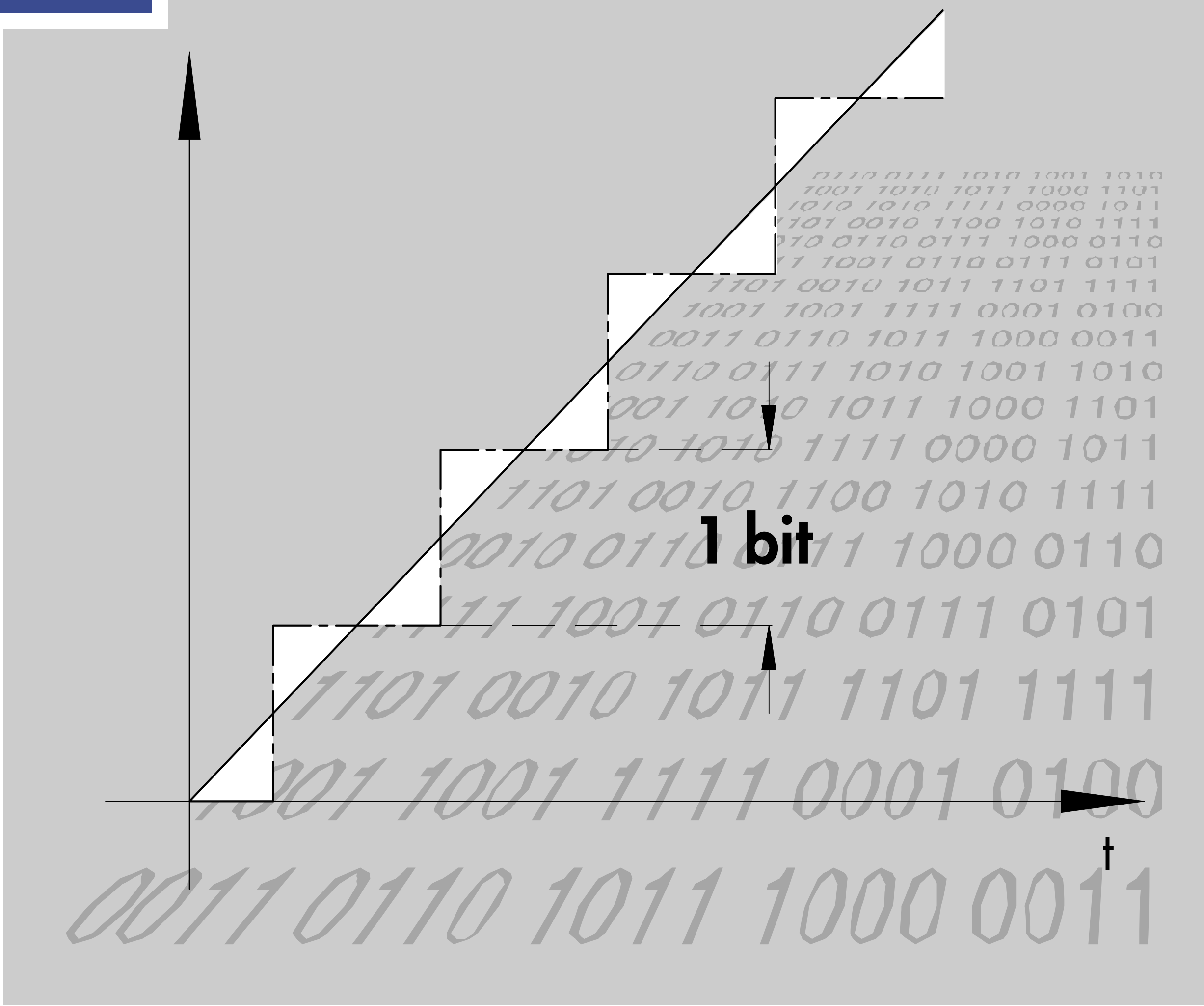
Technical Information

Digital Signals

1



Part 1 Fundamentals

Technical Information

Should you have any further questions or suggestions, please do not hesitate to contact us:

SAMSON AG
V74 / Schulung
Weismüllerstraße 3
D-60314 Frankfurt

Phone (+49 69) 4 00 94 67
Telefax (+49 69) 4 00 97 16
E-Mail: schulung@samson.de
Internet: http://www.samson.de

Digital Signals

CONTENTS

Digital Signals

In electronic signal and information processing and transmission, digital technology is increasingly being used because, in various applications, digital signal transmission has many advantages over analog signal transmission. Numerous and very successful applications of digital technology include the continuously growing number of PC's, the communication network ISDN as well as the increasing use of digital control stations (Direct Digital Control: DDC).

continuous or discrete signals

Unlike analog technology which uses continuous signals, digital technology encodes the information into discrete signal states (Fig. 1). When only two states are assigned per digital signal, these signals are termed binary signals. One single binary digit is termed a bit – a contraction for binary digit.

Range of values and discretization

digital data are composed of several bits (binary digits)

A binary signal representing only two states contains very little information compared to an analog signal. If a quantitiy to be represented digitally requires a wider range of values, it must be described by several bits. As you can see in the table in Fig. 2., the range of values increases rapidly with the number of bits used.

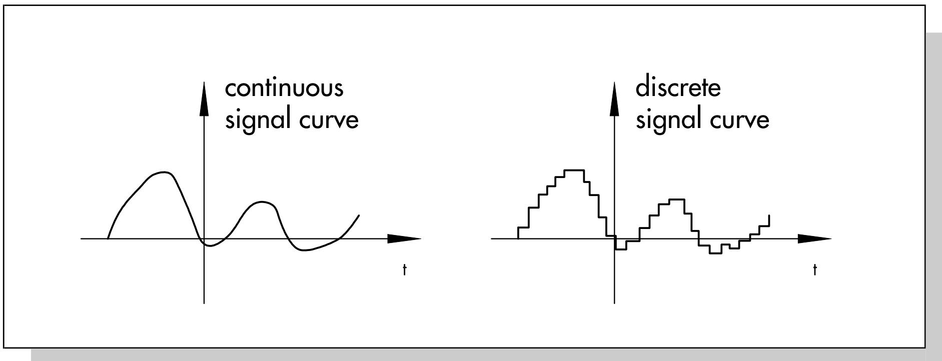


Fig. 1: Analog and discrete signal curves

1 bit	=>	2^1	states =	2 values
2 bits	=>	2^2	–„– =	4 values
3 bits	=>	2^3	–„– =	8 values
4 bits	=>	2^4	–„– =	16 values
8 bits	=>	2^8	–„ =	256 values
12 bits	=>	2^{12}	–„– =	4096 values
16 bits	=>	2^{16}	–„– =	65536 values
20 bits	=>	2^{20}	–„– =	1048576 values
etc.				

Fig. 2: Range of values of digital quantities

conversion of analog signals

quantization error caused by A/D conversion

To be able to process analog quantities digitally, they have to be converted into digital values first. Since an analog quantity can assume an infinite number of intermediate values and a digital quantity, on the other hand, can only assume a limited number of values, quantization errors occur when analog signals are converted into discretized, digital signals (Fig. 3). Increasing the number of bits used for digital representation and the sampling rate of the analog signal reduces quantization errors.

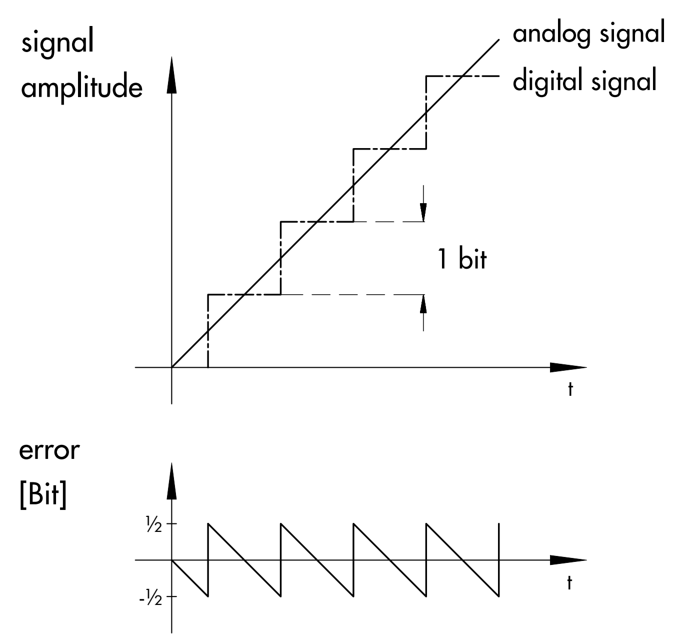


Fig. 3: Quantization error caused by reduced discretization and sampling rate

Analog measuring range:	0 to 30 cm
Range of values of an 8-bit unit:	256
Quantization error:	(30/256) cm = 1.2 mm
Range of values of a 12-bit unit:	4096
Quantization error:	(30/4096) cm = 0.073 mm

Fig. 4: Determining the quantization error for displacement measurement

discretization versus increased complexity of processing

An increasing number of bits also increases the complexity of data processing and transmission. To keep the loss of information during conversion as low as possible while choosing a binary representation that is not too extensive, the range of values must be adapted to the particular task.

calculation example

The example in Fig. 4 calculates the discretization of the measured displacement data using 8- and 12-bit representation. A discretization of 1.2 mm would be perfectly alright for sorting piece goods, whereas it is absolutely insufficient for positioning a machine tool. To be able to work accurately in the tenth millimeter range, a minimum range of values of 12 bits is necessary.

- Bits and bytes in hexadecimal notation

8 bits = 1 byte

Digital technology rarely operates with the smallest possible digital quantity, but often groups 8 bits together to form a byte. So 8, 16 or 32 bit units are termed accordingly 1, 2 or 4 byte units.

The binary system with its 0's and 1's soon becomes unclear when it comes to larger range of values, as you can see from this 2-byte variable: 01101001 00001101.

16 characters for hexadecimal notation

More clarity can be achieved when using the hexadecimal system. In this numbering system, each character can assume 16 different values: 0 to 9 and A to F.

<u>**NOTE:**</u> In the decimal numbering system, a character can assume 10 different values, these are 0 to 9.

Binary	Hex	Binary	Hex	Binary	Hex	Binary	Hex
0000	0	0100	4	1000	8	1100	C
0001	1	0101	5	1001	9	1101	D
0010	2	0110	6	1010	A	1110	E
0011	3	0111	7	1011	B	1111	F

Fig. 5: Binary and hexadecimal representation of a 4-bit unit

hexadecimal notation improves clarity

Fig. 5 shows that each hexadecimal number is assigned to a value of a 4-bit unit. Using this shorter and clearer type of representation, the 2-byte variable (4 * 4 bits) shown above is now the hexadecimal number '690D':

Binary notation:	0110	1001	0000	1101
Hexadecimal notation:	6	9	0	D

- Digital encoding of information

code schemes for information encoding

To be able to process data and messages digitally, they have to be encoded into binary digits. Whether letters, texts, numbers or states (e.g. properties of a body) are involved, each piece of information must be converted into a binary unit using an unambiguous code scheme. This process is also called

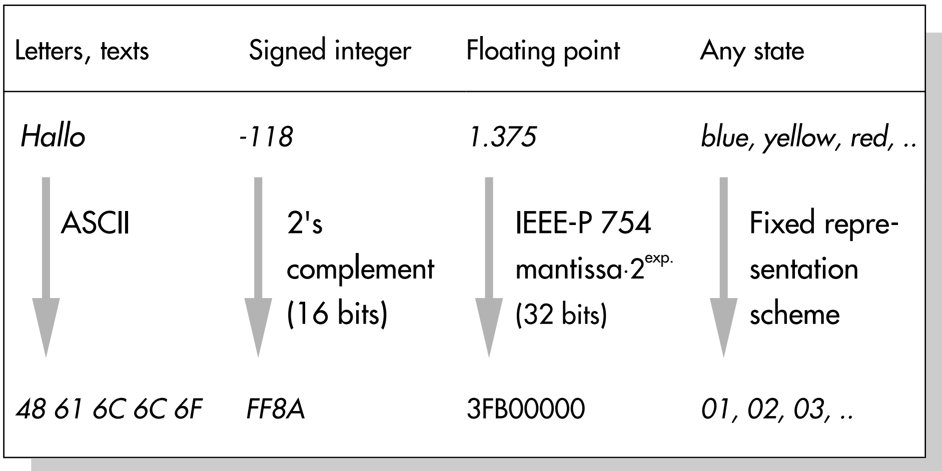


Fig. 6: Examples for binary encoding of information

data encoding. Effective data processing is only possible if cooperating computers and programs all use the same codes.

many codes have proven successful in practice

In practice, there are many different, largely standardized types of codes for letters, texts, numbers and states. Fig. 6 gives some of the most common code schemes. Such codes for characters and numbers exist, of course, also for other – smaller as well as wider – ranges of values.

Advantages of digital signal processing

At first glance, digital representation and processing of (analog) information seems extremely complex compared to analog representation. Each analog quantity must be encoded according to a code scheme to be then described by several binary signals. This disadvantage, however, is more than compensated for by the numerous advantages digital technology offers for a broad range of applications:

- high interference immunity,
- easy data storage,
- flexible processing,
- various transmission options.

• High interference immunity

high interference immunity

Analog information is highly liable to interference, i.e. errors are caused by – even the smallest – disturbance signals, whereas digitally encoded information will be distorted only when the disturbance signal is larger than the signal-to-noise ratio of the digital level used. The signal-to-noise ratio results from the difference between the transmitting and the receiving level (Fig. 7). It determines how strong capacitive or inductive interferences (system hum,

Signal level of a TTL-LS circuit

LOW level:

Guaranteed transmitter level:	max.	0.5 volt
Guaranteed receiver level:	max.	0.8 volt
Static signal-to-noise ratio:		0.3 volt

HIGH level:

Guaranteed transmitter level:	min.	2.7 volt
Guaranteed receiver level:	min.	2.0 volt
Static signal-to-noise ratio:		0.7 volt

Fig. 7: Signal-to-noise ratio of a digital signal

noise, switching peaks) or voltage fluctuations can be without distorting the digital signal. By selecting the binary information representation (see L153e) the signal-to-noise ratio can be adjusted within broad limits to the environmental conditions.

- Short-time and permanent storage

good storage properties

Digital data can be stored very easily on a variety of often very cost-effective data carriers. There is the option of storing in volatile semiconductor memories (Random Access Memory: RAM), or permanently on magnetic and optical data carriers.

- Flexible processing

flexible processing

Microprocessor-based and software-controlled data processing enables even complex algorithms to be computed in almost no time with a high degree of flexibility.

- Various transmission options

electrical, optical or acoustical transmission

The two states of a binary signal can be encoded in many different ways, thus offering a broad spectrum of application. For data transmission over long distances, for example, optical fiber cables are used because of their low energy consumption and high interference immunity. Binary signals can be assigned directly to the ON/OFF states of a light signal, while analog signals can only be transmitted optically after expensive and time-consuming linearization and intensity analysis which is liable to errors.

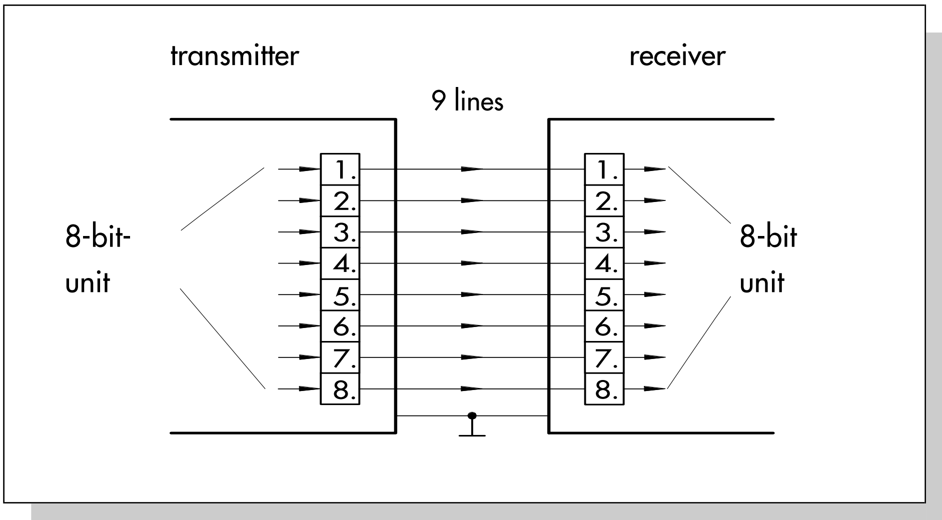


Fig. 8: Parallel data transmission

Transmission of digital signals

There are two ways to transmit digital data between one or several devices or communication participants, either parallel or serial transmission.

- Bit-parallel transmission

transmission via several signal lines

With parallel transmission, all bits of a piece of information are transmitted at the same time – bit-parallel – via an appropriate number of signal lines. The installation costs are high and only acceptable for short distances. The transmission of one byte alone requires a minimum of nine lines – 8 bits and a reference potential (Fig. 8). Therefore, this technique is presently almost only used for device busses. This application – over short distances – requires high transmission rates while doing without conversion methods that need a large number of components.

- Bit-serial transmission

transmission via one signal line

For long distances, serial transmission is a good solution. Here, only one signal line transmits the bits one after the other. As a result, the transmission of information takes more time, which is nevertheless acceptable because, on the other hand, the installation effort and the costs are considerably reduced (Fig. 9). Since all the information is mostly generated and processed in bit-parallel mode, the transmitter must convert the data from parallel to serial, and the receiver must reconvert it from serial to parallel. This function is

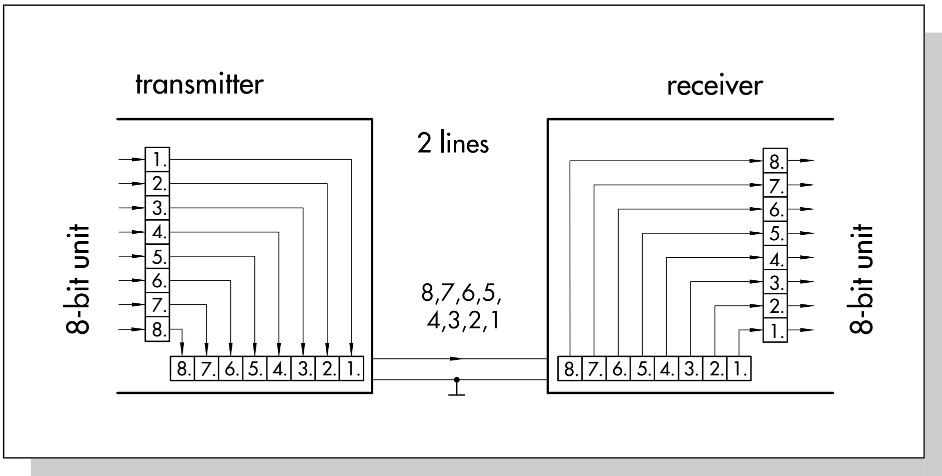


Fig. 9: Serial data transmission

performed by specially operated shift registers which are already integrated in communication modules available on the market.

Appendix A1: Additional Literature

[1] L153EN: Serial Data Transmission
Technical Information; SAMSON AG

[2] L155EN: Networked Communications
Technical Information; SAMSON AG

[3] L450EN: Communication in the Field
Technical Information; SAMSON AG

[4] L452EN: HART-Communication
Technical Information; SAMSON AG

[6] L453EN: PROFIBUS PA
Technical Information; SAMSON AG

[7] L454EN: FOUNDATION Fieldbus
Technical Information; SAMSON AG

Figures

FIGURES

SAMSON AG · MESS- UND REGELTECHNIK · Weismüllerstraße 3 · D-60314 Frankfurt am Main
Phone (+49 69) 4 00 90 · Telefax (+49 69) 4 00 95 07 · Internet: http://www.samson.de

1999/12 · L150EN