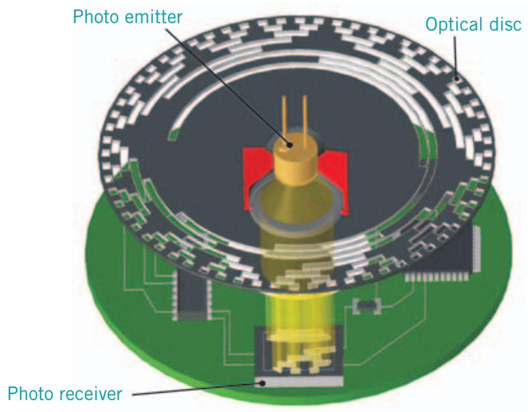
ABSOLUTE ENCODERS
GENERAL DESCRIPTION

ISO 9001:2000

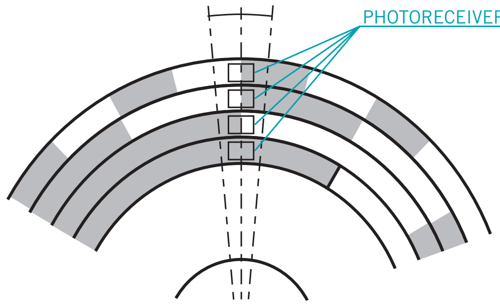
Working principle

The working principle of an absolute encoder is very similar to the incremental one: a rotating disk, with transparent and opaque windows, interrupts a light beam acquired by photo receivers. Consequently, light pulses are converted into electric ones and then they are processed and transmitted by the output electronic.



Absolute coding

The main difference between an incremental and an absolute is how they determine the position: the incremental determines the position from the zero index while the absolute bases its position on the output code, which is unique for each position inside the turn. Consequently, an absolute encoder never looses the real position neither if the power goes out nor in case of shifting.
Nonetheless, with an absolute encoder as soon as the power is restored the position is updated and immediately available instead, with an incremental encoder, the zero set would be required.

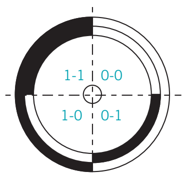


The output code is used to specify the absolute position. The first natural choice would be the binary code because it can be easily processed by external devices but the issue is that it is extracted directly from the rotating disc: acquiring the position synchronized with the output data can be difficult due to the simultaneous change of more than one bit.
For example, if two consecutive binary codes as 7 (0111) and 8 (1000) are considered, it can be noticed that the status of all bits changes. So, if the attempt to read the code in a specific time is made, it could be difficult to assure the correctness of the read data because there is more than one bit change in the same time. Therefore, a Gray code is used where only the status of one bit changes during two consecutive codes (even from the last to the first).

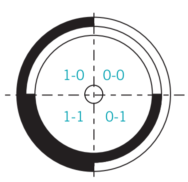
The Gray code can be easily converted to the binary by using a simple combinatory circuit (see tables above).

DECIMAL	BINARY	GRAY
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111
11	1011	1110
12	1100	1010
13	1101	1011
14	1110	1001
15	1111	1000

2 Bit optical disc with binary code



2 Bit optical disc with grey code



The Gray excess code

However, when the number of defined position is not a power of 2, even with the Gray code more than one bit can change simultaneously between the last and the first code value.
For instance, in a hypothetical 12 ppr absolute encoder, the code should be as the one shown in the aside. It is clear that between the positions 11 and 0 a 3 bit status simultaneous change may involve reading errors so that's not acceptable. The Gray excess code is used to maintain the typical one-bit variation specificity by making the 0 position corresponding to the N value. The N is a number that subtracted from the Gray code converted into binary provides the exact position value.

The formula to calculate the N value is:

$$N = \frac{2^n - IMP}{2}$$

Where: *IMP* IMP is the number of PPR
2^n is the power of 2 multiple immediately higher than IMP

In our example N will be:

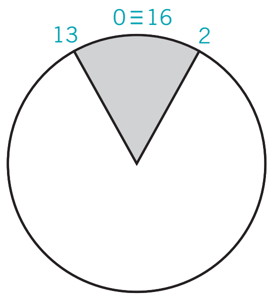
$$N = \frac{2^4 - 12}{2} = \frac{16 - 12}{2} = 2$$

POSITION	GRAY	
0	0000	
1	0001	
2	0011	
3	0010	
4	0110	
5	0111	
6	0101	
7	0100	
8	1100	
9	1101	
10	1111	
11	1110	Error
0	0000	

POSITION	GRAY
0	0011
1	0010
2	0110
3	0111
4	0101
5	0100
6	1100
7	1101
8	1111
9	1110
10	1010
11	1011

Example: conversion of the position number 5

The Gray code of the position number 5 is 0100 which - converted into binary - is 0111 (7 in decimal). Subtracting from 7 the N value the real position value which is 7-2=5) will be obtained.



Singleturn Absolute Encoders

A singleturn absolute encoder allows a precise acquisition of the angular position of the shaft to which the encoder is coupled to even if power goes out. Therefore, each single degree position is converted into a specific code (gray or binary) proportionally to the bit position. Eltra single-turn encoders can reach a resolution up to 8.192 ppr. (13 bit).

Multiturn Absolute Encoders

The multiturn absolute encoder series is identified by the EAM prefix. This device allows a higher number of application representing such an interesting extension of the single turn encoder. This type of encoder presents a high single turn resolution (8192 ppr) and in the meantime it keeps count of the number of turns (up to 4096) representing so a significant linear extension maintaining flexibility according to customer specifications.
The encoder uses a main shaft to which one or more mechanical reducers are mounted in 'cascade' allowing a precise code reading even after a mechanical movement when the device is not powered.
Eltra's encoders are currently available up to 25 bit resolution equal to 33.554.432 positions. Safety and performances are among the highest in the market. Eltra's multiturn encoders are available with several electronic and mechanical output.

SV001IT0705A

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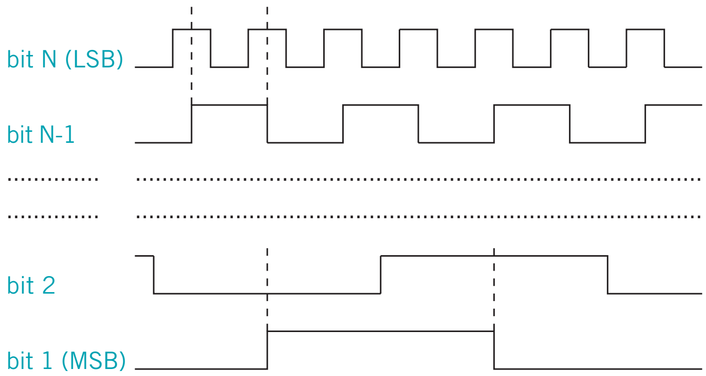
PARALLEL INTERFACE
GENERAL DESCRIPTION

ISO 9001:2000

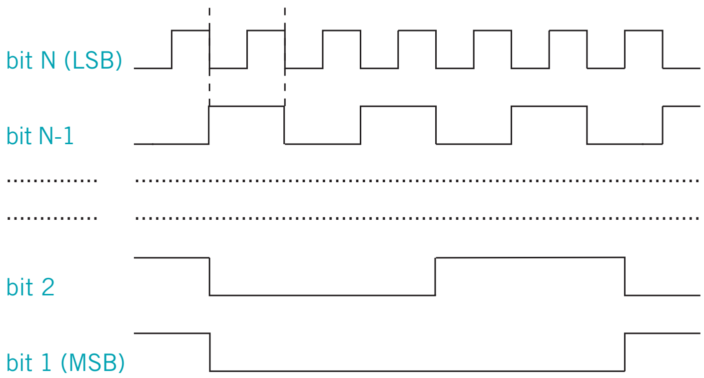
Parallel Interface

Parallel output is the standard one for singleturn absolute encoders mainly because it provides the data output in a 'bit by bit' way so there is basically a pin for each bit. However, this type of output is more burdensome for multiturn encoders when the bit number becomes high. Simply, just consider that a single turn encoder can have a resolution up to 13 bit while a multiturn can reach up to 25 bit. Moreover, in these bit numbers additional signals as count inversion and data output block (LATCH) have not been taken in consideration. So, the high number of signal outputs is the main reason for been introduced alternative transmission protocol as Serial Synchronized Interface (SSI) or field buses (PROFIBUS, CANBUS, etc.).

Output data in Gray format:



Output data can be available, depending on models, in both Gray and binary standard. In the latest encoder generation, the binary output is obtained by ASIC devices processing the Gray code signals coming from the photo-receiver circuit.
However, in the binary code the correct output data issue is still intrinsically present due to the multiple bit status transitions between contiguous positions. In order to avoid this problem, in the past an output sync signal (STROBE) was used while the adoption of programmable logic overcame this limitation. Output data in binary format:



There are several output configurations to satisfy different electronic specifications requested from the controllers. Standard outpus are: NPN, NPN OPEN-COLLECTOR, PNP OPEN COLLECTOR, PUSH-PULL.

Command inputs and optional outputs

As previously mentioned, external signals can control and command encoder output as reported below.

STANDARD SIGNAL

- U/D: the encoder will increase the counting while the shaft rotates clock-wise. It is equivalent to rotate the encoder shaft in the opposite direction.

INPUT	HIGH STATE	LOW STATE
U / D	Inverts the code	No effect
LATCH	Blocks the code	No effect
RESET	Output reset	No effect

OPTIONAL SIGNALS
(directly contact our offices for availability):

- LATCH: when connected, it maintains the current data as output. In this way, while the encoder shaft continues to turn, the output data doesn't change.
- RESET: it sets the zero position.
- STROBE: this signal is available only with binary code and indicates when it is possible to read the data. In fact, the logical status of the STROBE changes when the data is available (all bits have been updated).

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SSI INTERFACE
GENERAL DESCRIPTION

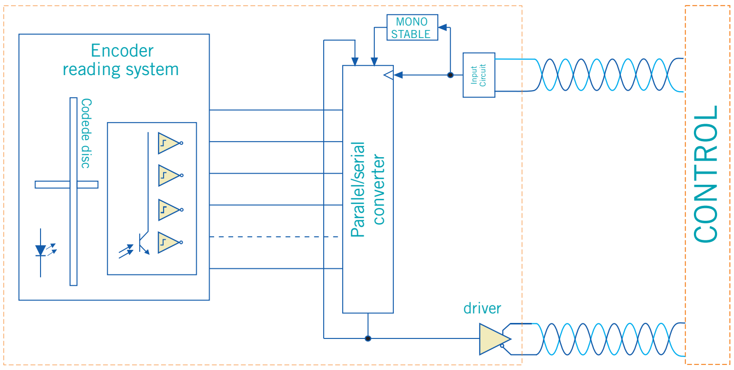
ISO 9001:2000

Introduction

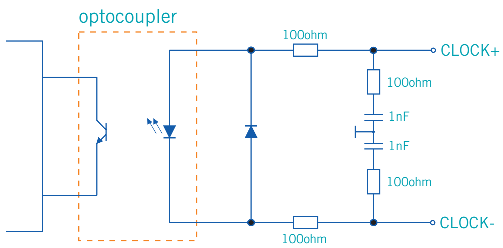
Evolution in automation is continuously growing and so its request for precision in measurement devices and consequentially also in absolute encoder. To satisfy these demands, absolute encoders have been designed with higher and higher resolutions. However, higher precision means an increasing number of bits and consequently a growing need of wires. SSI interface was created in order to contain installation costs and to simplify wiring. This interface transmits data in a serial mode by using only two signals (CLOCK and DATA), independently from the precision of the encoder.

Description

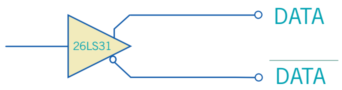
The SSI interface allows the transmission of the absolute encoder position data by a serial line synchronized by a clock. The following figure shows the block diagram of an encoder featuring an SSI interface:



The working principle of an encoder with an SSI interface is very similar to a standard one. Main parts are: a light source, a disc with transparent and opaque windows, photo-electric receivers, comparison/trigger circuits, a parallel/serial converter, a mono-stable circuit, an input circuit for the clock signal and an output driver for the data signal.
The position data is obtained by the encoder reading system and continuously transmitted to a parallel/serial converter (based by a “shift register” with parallel loading). When the mono-stable circuit is activated by a clock signal transition, the data is stored and transmitted to the output synchronized with the clock signal. CLOCK and DATA signals are transmitted differentially (RS422) to enhance immunity from interference and to allow longer transmission distances.



CLOCK signal circuit input

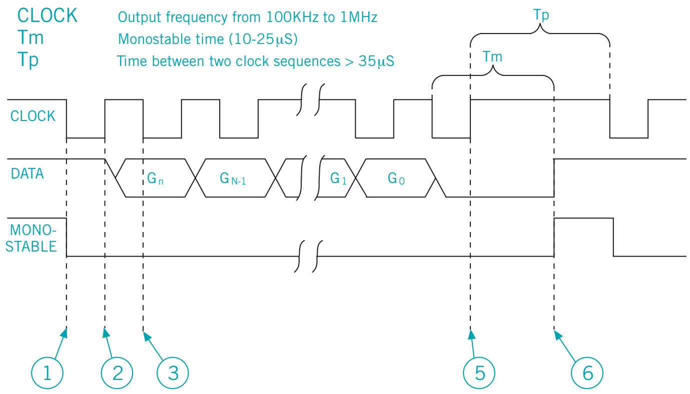


DATA signal circuit output

Working Principle

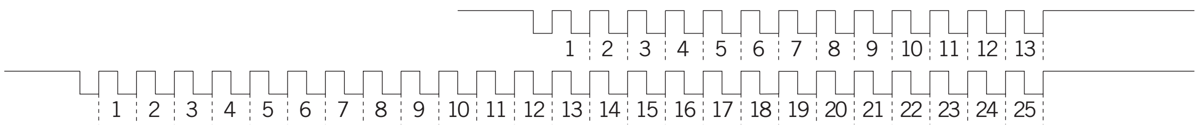
When quiescent, CLOCK and DATA signals have a high logical status and the mono-stable circuit is disabled.

1. On the first CLOCK signal descent front, the mono-stable is activated and the parallel value at the P/S converter input is stored into the shift register.
2. On the CLOCK signal ascent front, the Most Significant Bit (MSB) is copied into the DATA signal output.
3. On the CLOCK descent front (when the signal is stable) the controller acquires the level value from the DATA signal and the mono-stable is re-activated.
4. On each further ascent front of the CLOCK pulse sequence, following bits up to the least significant one are copied in the DATA signal output and then acquired by the control on the descent front.
5. At the end of the CLOCK pulse sequence, when the external control has also acquired the value of the Least Significant Bit (LSB), the CLOCK pulse sequence stops and therefore the mono-stable is no longer re-activated.
6. Once the mono-stable time (Tm) has elapsed, the DATA signal returns to a high logical status and the mono-stable disables itself.



Transmission Protocol

The frame length of the transmitted data depends only on the encoder type (singleturn or multiturn) and not on the resolution. In fact, the standard frame length for a singleturn encoder is 13 bits, whilst for a multiturn one it is 25 bit. The MSB is in the center of the data, as shown by the below reported table:



T	2^T																												Ta		2^n	n
12	4096	1	1	G_{n+11}	G_{n+10}	G_{n+9}	G_{n+8}	G_{n+7}	G_{n+6}	G_{n+5}	G_{n+4}	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	G_{n-6}	G_{n-7}	G_{n-8}	G_{n-9}	G_{n-10}	G_{n-11}	G_{n-12}	G_{n-13}	0	1	8192	13
11	2048	1	1	0	G_{n+10}	G_{n+9}	G_{n+8}	G_{n+7}	G_{n+6}	G_{n+5}	G_{n+4}	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	G_{n-6}	G_{n-7}	G_{n-8}	G_{n-9}	G_{n-10}	G_{n-11}	G_{n-12}	0	0	1	4096	12
10	1024	1	1	0	0	G_{n+9}	G_{n+8}	G_{n+7}	G_{n+6}	G_{n+5}	G_{n+4}	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	G_{n-6}	G_{n-7}	G_{n-8}	G_{n-9}	G_{n-10}	G_{n-11}	0	0	0	1	2048	11
9	512	1	1	0	0	0	G_{n+8}	G_{n+7}	G_{n+6}	G_{n+5}	G_{n+4}	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	G_{n-6}	G_{n-7}	G_{n-8}	G_{n-9}	G_{n-10}	0	0	0	0	1	1024	10
8	256	1	1	0	0	0	0	G_{n+7}	G_{n+6}	G_{n+5}	G_{n+4}	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	G_{n-6}	G_{n-7}	G_{n-8}	G_{n-9}	0	0	0	0	0	1	512	9
7	128	1	1	0	0	0	0	0	G_{n+6}	G_{n+5}	G_{n+4}	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	G_{n-6}	G_{n-7}	G_{n-8}	0	0	0	0	0	0	1	256	8
6	64	1	1	0	0	0	0	0	0	G_{n+5}	G_{n+4}	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	G_{n-6}	G_{n-7}	0	0	0	0	0	0	0	1	128	7
5	32	1	1	0	0	0	0	0	0	0	G_{n+4}	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	G_{n-6}	0	0	0	0	0	0	0	0	1	64	6
4	16	1	1	0	0	0	0	0	0	0	0	G_{n+3}	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	G_{n-5}	0	0	0	0	0	0	0	0	0	1	32	5
3	8	1	1	0	0	0	0	0	0	0	0	0	G_{n+2}	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	G_{n-4}	0	0	0	0	0	0	0	0	0	0	1	16	4
2	4	1	1	0	0	0	0	0	0	0	0	0	0	G_{n+1}	G_n	G_{n-1}	G_{n-2}	G_{n-3}	0	0	0	0	0	0	0	0	0	0	0	1	8	3
1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	G_n	G_{n-1}	G_{n-2}	0	0	0	0	0	0	0	0	0	0	0	0	1	4	2

Singleturn

Multiturn

Number of turns

ppr

The transmitted frame format depends on the bit per turn and bit for turns encoder configuration.

N = number of bits per revolution

T = number of bits for turns

Ta = $\frac{Tm - Tc}{2}$

Tc = clock period

Tm = monoflop time

SV003IT0705A

SSI INTERFACE

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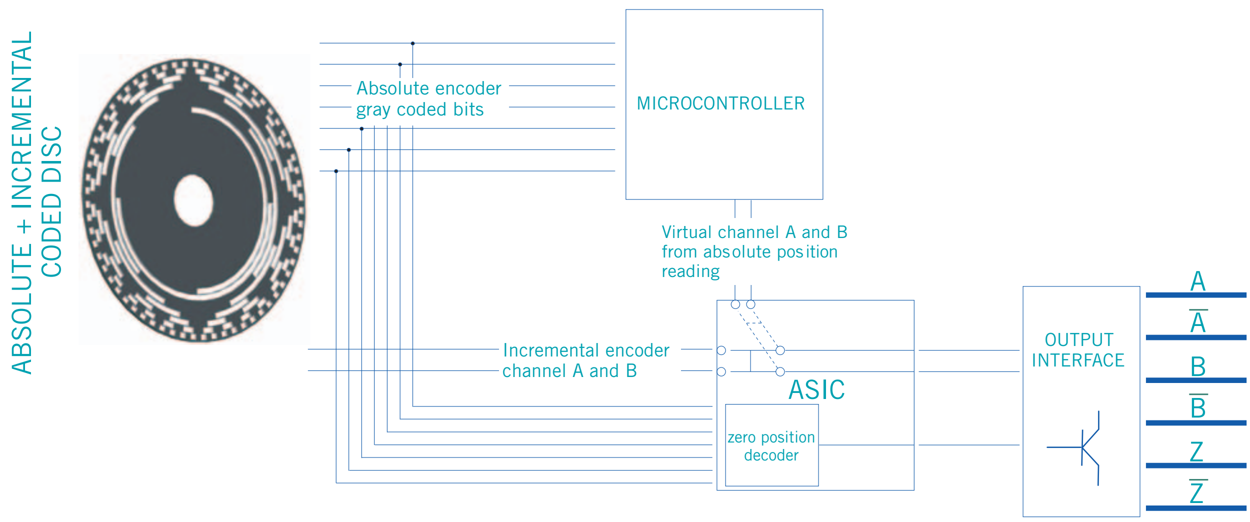
ISO 9001:2000

Introduction

Absolute encoders with Incremental Code Output (ICO) combine, in a single product, advantages of both absolute and incremental encoders. ICOs are absolute encoders (they provide the absolute position within the single revolution) using the same output signals as incremental encoders. Main advantage of ICO encoders is – specially with high resolution – the number of wires because it is the same as an incremental encoder so substantially reduced compared to a standard absolute encoder. Moreover, as with incremental encoders, a simple counter is sufficient for reading the position instead of dedicated boards or multi I/O instruments.

Description

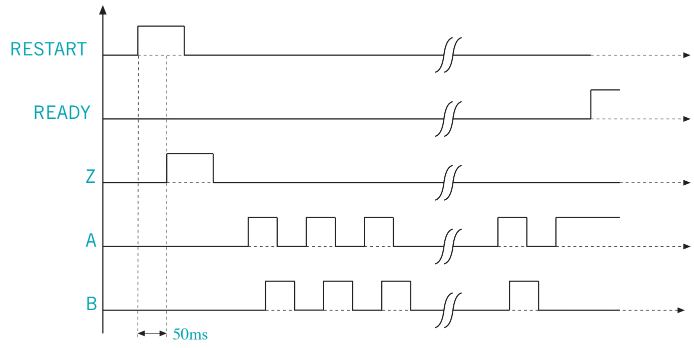
From the reading system point of view, an ICO encoder is exactly made as a standard absolute one. Essentially the light beam is detected by photo-receivers and interrupted by a rotating disc with transparent and opaque windows. However, ICO encoders have a disc etched both with tracks for the absolute bit code and with tracks of an incremental encoder. Incremental output signals are out of 90 electrical grades one from the other and phased with the absolute code. The following figure shows the encoder block diagram:



Please note that a micro-controller handles encoder operations and initialization sequences. It also reads the absolute position and controls the ASIC device. The ASIC integrates a switch for A and B channels and a position decoder for the Z signal generation. Finally, the output interface converts the signals from the ASIC to the final electronic output signals.

Working Principle

When the encoder is powered up, it goes into a stand-by state where A, B and Z channels are at a low logical level and the READ output is disabled. In this state the encoder does not work and any shaft rotation does not produce any effect on the output channel status.
To make the encoder working, it is necessary to activate the RESTART input for at least 50 ms. In this way the microcontroller managing the encoder reads the absolute position and then transmits a number of pulses equal to the absolute position detected by the A and B output channels. A pulse on the Z channel is transmuted before the position pulse sequence allowing in such way a zero setting of the counter.



When that pulse sequence is completed, the READY signal commutes to a high logical level and the counter has the absolute encoder position. Then, the micro-controller releases the control of A, B and Z channel outputs and the system managing the incremental encoder starts working. The described steps are called 'START-UP' sequence: when completed, the encoder is effectively ready to work.

U / D

The U/D (Up-Down) input allows the inversion of the detected rotation direction represented by the increasing or decreasing the output data. By connecting this input to the power supply voltage, the count increases rotating the shaft clockwise. Vice versa, connecting U/D to the 0 V (or not connected), the output data value increases when the shaft rotates counterclockwise.

READY

The READY output indicates the encoder working status. When it has a low logical level, it means that the encoder is not functioning and so the RESTART input has to be activated. When the 'START-UP' is completed, the READY signal has a high logical level meaning the encoder is ready to work. The READY output also indicates any encoder malfunctioning due, for instance, to power supply interruptions or to internal faults. If it is continuously monitored, it can be used as a real alarm signal.

Resolution levels

ICO absolute encoders are available with a resolution up to a maximum of 1.024 ppr. The resolution is referred to the incremental output. In fact, a 1.024 ppr ICO encoder has a resolution equal to a 4.096 ppr of a standard absolute encoder. This is thanks to a x4 multiplication factor in the encoder reading device.

RESTART

When the RESTART input is activated for at least 50ms the encoder executes the start-up sequence. It can be automatically executed when the power goes on, by permanently connecting the RESTART input to the power supply voltage.

SIGNAL TRACKING

If the encoder is moving at the beginning of the 'START-UP' procedure, i.e. due to vibrations or drive offset, the initial read position can be different when the transmission of the data as pulse sequence is completed. In order to avoid this situations, the encoder checks the absolute position value after the pulse sequence has been transmitted. If there is any difference, the encoder transmits again the absolute position until no difference is detected. Then the 'START-UP' stops and the READY output is activated. If variations in the position are quicker than transmissions, READY will not be activated.

Output configurations

Push-Pull and Line Driver output electronics are available. READY output is available only with Push-Pull electronic.

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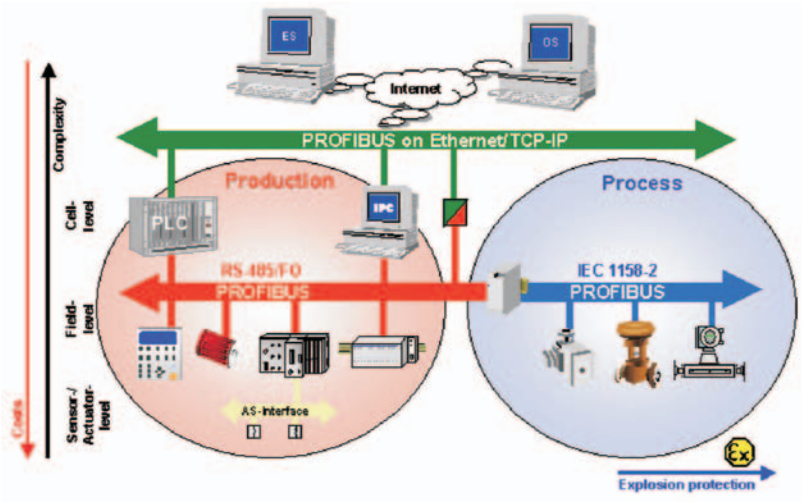
PROFIBUS General Information

PROFIBUS (Process Field Bus) is a serial communications standard for devices connected to automation networks (field bus). It is an open protocol defined by the DIN 19245 that became European standard as EN 50170 volume 2. Profibus is promoted by Siemens and is widely diffused all over Europe. Thanks to the definition of three different communication profiles DP, FMS and PA, this field bus is suitable for many requirements in automation system. Starting with applications requiring a high cyclical exchange speed of a reduced number of bit (Profibus DP), up to the management of complex communications between "intelligent" devices (Profibus FMS) or tasks strictly related to automation process (Profibus PA).
Hereinafter the attention will be focused on the DP version (decentralized periphery), which is the standard solution to manage devices by a bus. These devices usually are: I/O modules, sensors/transducers or actuators on a low level in automation systems.

INDUSTRIAL
PROFIBUS
NETWORK



PROFIBUS DP characteristics

NETWORK TOPOLOGY: It is a common bus structure (closed on both sides) where up to 126 devices can be connected at the same time. If the physical support is an RS485 interface, up to 32 nodes can be inserted without using signal repeaters/re-generators.
HARDWARE LEVEL: In addition to the RS485 differential serial technology transmission, an optical fiber connection can be used. In any event, DP and FMS devices can co-exist in the same network. They share the same harware interface communication (they are the same levels 1 and 2 of the ISO/OSI stack). The established standard requires an extremely accurate communication speed between 9.6 kBaud (min) and 12 kBaud (max).
DEVICES PRESENT IN THE NETWORK: It is possible to divide the devices into three classes: class 1 Master DP(DPM1), class 2 Master DP (DPM2) and Slave. The class 1 includes all the devices periodically exchanging information with distributed peripheral (they can directly manage the I/O network data with the other nodes, mainly slaves). The class 2 masters are designated to configure and to monitor network status and devices connected to it. Slaves have the task of directly exchanging information with the external word in both directions (in and out). Typical examples of slaves are: digital I/O, encoders, drivers, valves, different types of transducers, etc.
BUS ACCESS METHODS: Two configurations are available in a bus with single or multi master operating ways: the 'Token Passing' one, for exchanging information about network management among possible available masters, and the well known 'polling interrogation' for the master-slave communication.

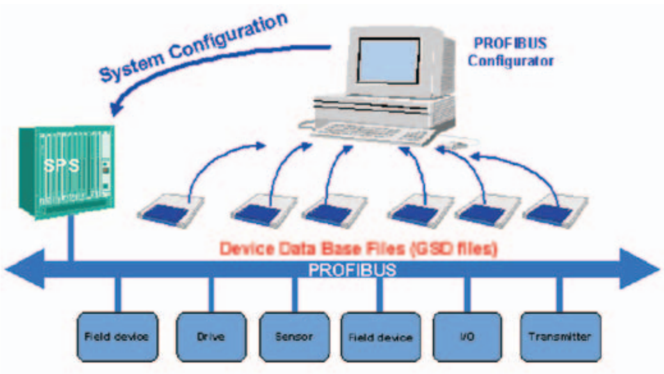
Main Functions:

The main characteristics implemented in the Profibus DP protocol are as follows:
Periodic data exchange: After the slave initialization step, every master is configured in order to exchange a maximum of 244 input bytes and 244 output bytes with every slave. The effective data exchange rate is based on the selected BaudRate, on the nodes present in the network and on the specific bus settings. Considering the maximum data exchange rate of 12 Mbaud, the Profibus DP is one of the fastest field buses.
Synchronization: Command controls are available (they are sent by the master in multicast). This gives the possibility to create a synchronous acquisitions through a slave, a group or all the slaves (Freeze Mode). Outputs sent to the slave have similar behavior. (Sync Mode).
Parameterization and configuration security: After a preset period of time - if the communication between the master/s and the slave/s is not repeated - the system goes into a safe status.
Diagnostic functions: Each slave can require to the master to be set up for reading its own diagnostic. In such way any possible problem occouring in the slave can be easily localized. The diagnostic can contain up to 244 bytes of information. Among them, the first six are mandatory for each DP slave.
Dynamic slave management: There is the possibility to activate or disactivate slaves present in the network. Moreover, it is possible to change by the bus slaves addresses that make possible this function.
Easy network configuration: Main characteristics of each device present in the network are listed in the form of a GSD file complying to Profibus specifications. This simplify the set up and the configuration of the device by a graphic tools suitable for the purpose, such as the Siemens COM PROFIBUS software. As mentioned, the master-slave exchange data takes place periodically depending on the topology of the network and on the number of nodes present. However, before this step the slave has to be successfully parameterized and configured.
Parameter setting: The master sends to the slave a series of parameters necessary to specify its operation. The standard requires 7 bytes containing the mandatory information for the slave. Additional data can start from the eighth byte in the DU field (Data Unit, for more information see the Profibus DP) up to a maximum of 244 bytes for the communication frame.
Configuration: This step starts when the master has successfully set slave's parameters. During this step the master specifies the number and type of data, or better, the number of bytes to be exchanged with the slave both for incoming and outgoing information. This data is also present in the DU field of the communication frame: if the slave accepts the configuration, it can periodically exchange with the master.
Periodic exchange: The master specifies within the DU field frame the necessary information and the slave sends requested data within the reply frame. During periodic exchange, the slave may advise the master that a new diagnostic data is ready and then it asks to the master if it prefers reading this information in the next polling instead of the input data coming from the peripheral.

Master-Slave Communication

As already mentioned, the master-slave data exchange is periodic and essentially depends on the network topology and on the present node number. However, before starting the data exchange, it is necessary that slave parameter settings and slave configuration have been successfully completed. More details are as follows:
PARAMETER SETTING: During this step the master sends to the slave a series of operating parameters necessary for specifying its operation. The standard requires 7 bytes containing the mandatory information for the slave. Additional data can start from the eighth byte in the DU field (Data Unit, for more information see the Profibus DP) up to a maximum up to a maximum of 224 bytes.
CONFIGURATION: When the master successfully set slave parameters, the configuration process starts. Then, the master specifies the number and type of data represented from the incoming and outgoing bytes number which has to be exchanged with the slave. This data is also present in DU field; if the slave accepts the configuration, it will begin to periodically exchange data with the master.
PERIODIC EXCHANGE: The master specifies within the DU field frame the needed information and the slave will send requested data in the reply frame. During periodic data exchange the slave may advise the master that a new diagnostic data is ready and then it asks to the master if it prefers reading this information in the next polling instead of the input data coming from the peripheral.

NETWORK
CONFIGURATION
BETWEEN THE GDS
FILES



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