



► About guard locking devices

Whitepaper
February 2024

PILZ
THE SPIRIT OF SAFETY

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1st edition

At a glance

Guard locking devices can be found in the most diverse range of applications in production plants and manufacturing machinery. They are often indispensable in order to minimise risk on plant and machinery. That's why they are often also referred to as safety locking devices. The characteristics of a guard locking device on the market vary greatly, and not every product is the right one for an application.

EN ISO 14119:2013 is available to help you select your guard locking device. What EN ISO 14119:2013 only addresses in basic terms and in principle is described in this paper in detail with reference to actual guard locking devices. Description is based on different technical applications in order to demonstrate their practical implementation.

This white paper does not include all normative aspects in their entirety. For example, manipulation protection in EN ISO 14119:2013 is not considered in detail in this white paper. For this reason, the standard itself must be consulted for a plant's conformity declarations, for example.

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1. Guard locking safety function and structures of interlocking devices with guard locking

Guard locking is a safety function in plant and machinery, which is understood to be a chain of sensor, logic and actuator technology.

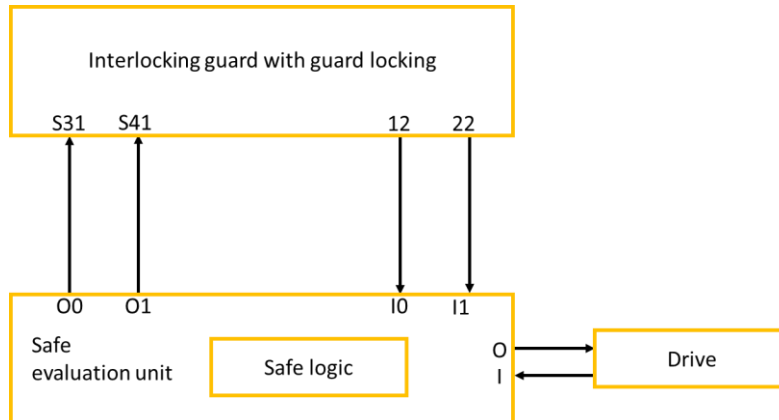


Figure 1: Guard locking safety function

It is quickly apparent that the “guard locking” safety function consists of several connected installations or devices. To avoid misunderstandings, the standard uses the term “interlocking device with guard locking” for the device.

In the information below, the term here is limited to guard locking, so you can tell from the context whether it concerns a device, the safety function or a subsystem of the safety function.

As the standard term suggests, guard locking devices are part of the interlocking and guard locking functions. The different subfunctions and their technical principles are described in detail in the sections that follow.

1.1. Interlocking and guard locking functions

Interlocking and guard locking are two different functions and should be understood as follows:

- ▶ Interlocking prevents the operation of hazardous machine functions under specified conditions. For example, this means that the machine will not restart if a gate, and therefore also the interlocking device on the gate, is not closed.
- ▶ The job of a guard locking device is to lock a guard, e.g. a gate, in position. The guard locking device is activated and evaluated by the machine control system.

Put simply, the functions for guard locking devices mean the following:

- ▶ An interlocking device detects whether or not a gate or flap is closed.
- ▶ A guard locking device locks a gate or flap in the closed position.

Both functions are typically features of one device, but do not have to be: For example, a valve can perform the guard locking function, and the interlock is implemented using a magnetic safety switch.

Even when both functions are accommodated in one device, interlocking and guard locking are shown separately in the block diagram for guard locking devices:

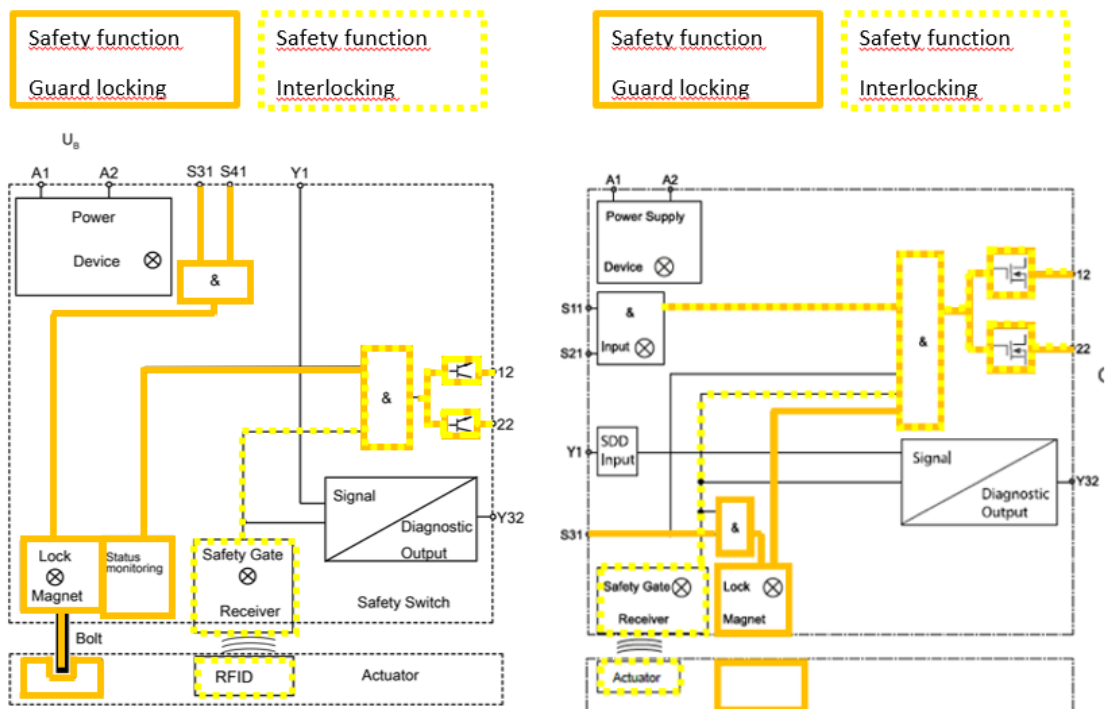


Figure 2: Interlocking and guard locking, using as an example a block diagram for the guard locking device PSEN mlm ba (left) and PSEN sl2-G (right)

You can see in Figure 2 that both functions affect outputs 12 and 22. However, the inputs and logic within this device are different, so that both functions must be considered as separate from each other.

1.2. Interlocking with guard locking devices

Mechanical contacts or RFID transponders are generally used for the interlocking.

1.2.1. Mechanical approach to interlocking

Interlocks of this type have electromechanical contacts, which are operated via a single-channel, mechanical, direct-acting control element. The control element is moved by inserting the actuator and remains latched within the switch. As a result, the gate remains in position without using any other component, including where there is vibration.

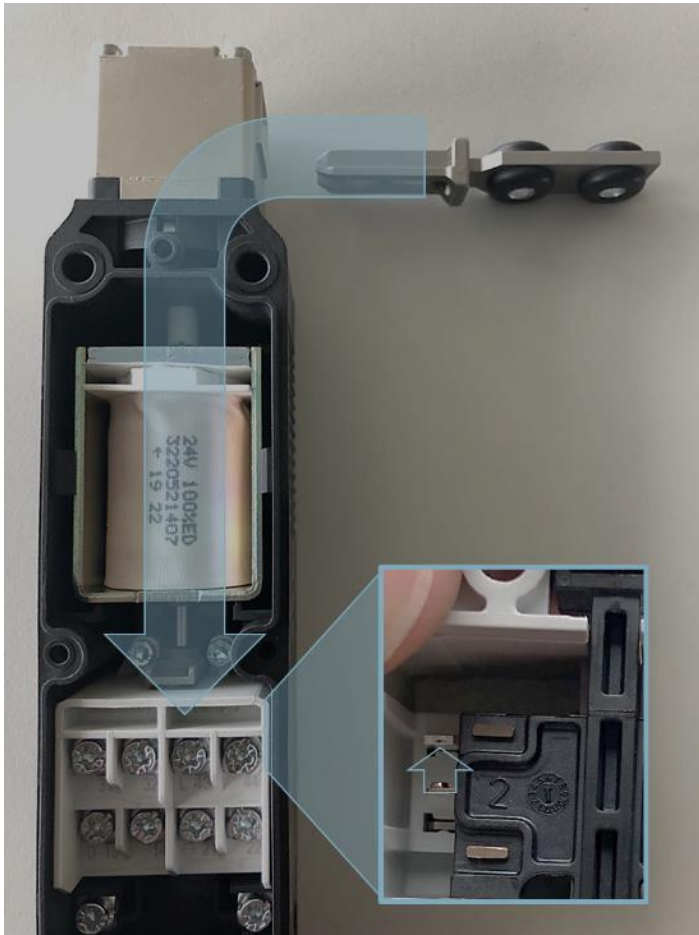


Figure 3: Contact block and contacts, plus control element of a mechanical switch, using the PSEN me5 from Pilz as an example

Different contacts are provided for both interlocking and guard locking. These should also be evaluated separately. This has the advantage that the machine can run in different speed modes. E.g. one operating mode for slow speed where only interlocking contacts are monitored and a high-speed mode, where also guard locking is active. The different status can be signalled to the operator via illuminated buttons, for example.

Mechanical switches generally have one connection chamber. Due to the narrow mounting area and many possible connection points, the mounting must be concentrated. Some manufacturers also offer M12 plug-in connectors to simplify and speed up the connection, although often at higher prices.

The advantage of the connection chamber also comes into play with series connection. In the field, switches can be connected in series without any additional wiring aids. However, it's precisely here that potential fault masking should also be taken into consideration. Fault masking means that a fault is not detected but remains concealed by operating another switching element in series, see ISO/TR 24119:2015.

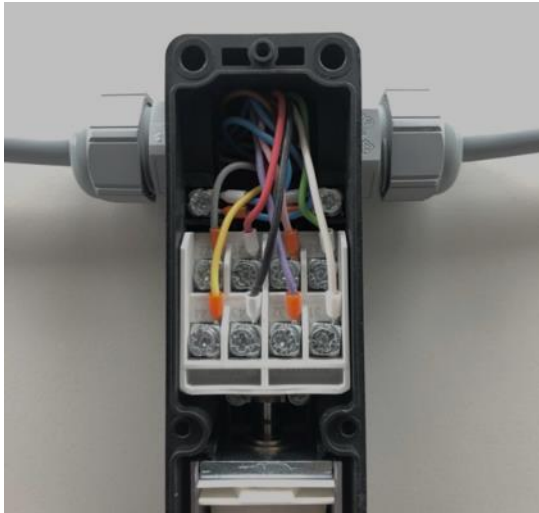


Figure 4: Series connection PSEN me5

Differences in the actuators are sometimes substantial. Simple actuators are lasered metal parts and have very low tolerances of 0.5mm horizontally and vertically. But actuators may be cast in 3D form and may also be fitted with compensation rings or even sprung mountings.



Figure 5: Tolerances on mechanical actuators

The coding level is usually low on mechanical interlocking devices. The protection against manipulation via a spare actuator is rather low, if switches are installed within direct reach, for example, and an actuator can be carried relatively easily on a key ring. A latching mechanism on the actuator makes manipulation even easier. To counter manipulation, the installation of switches can be concealed. Also, in accordance with the GS-ET-19 E principles of testing, it shall not be possible to use simple tools, such as two screwdrivers for example, for manipulation.

Benefits of mechanical interlocking devices

- Simple, cost-effective design
- Simple series connection in the field, possible through wiring
- EMC-immune
- Contacts can withstand a wide voltage and current range, i.e. 24V, as well as 110V or 230 VDC or VAC. The limiting thermal current at 24V is in the range of a few Amperes, typically 2...5A.

Note:

- Minimum contact current: Due to the high density of inputs on evaluation units, minimal currents are used in order to control the waste heat and work in an energy-efficient manner. On the switch side, low currents on mechanical contacts are a challenge for clean closing.
- Since mechanical contacts may vibrate during switching, an input filter can be required, particularly with fast control.
- Possible Fault masking
- Possible Performance level limited due to single-channel structure
- Low level of security against manipulation
- Usually really low tolerances. In the case of a larger gate offset, damage may occur, leading to the loss of safety.
- Susceptible to dirt, dust and gases
- Injury risk in the case of simple actuators
- It is not possible to determine the injury risk generally, but heavily worn actuators made of thin metal may present an injury risk.

1.2.2. RFID approach to interlocking

Electronic guard locking devices generally use RFID for interlocking. This means that an electric coil in the switch transmits energy, and an electric coil in the actuator captures this energy and sends back a signal with information.

125kHz RFID signals are generally used. 13.56 MHz RFID systems enable faster and more comprehensive data exchange in comparison with 125kHz systems. However, 125kHz systems have a more robust switching characteristic with different mounting positions and assembly materials.

Electronic inputs and outputs, as well as RFID for interlocking, have the following benefits:

- Non-wearing
- Very low probability of faults
- Series connection capability, also in interlocking, up to PLe in accordance with EN ISO 13849-1:2015, free from fault masking in the series connection
- No partial operation in the sensor section – partial operation only through inputs and outputs, and wiring errors
- It is possible to achieve a very high level of manipulation protection
- Higher mechanical offset possible, typically +/- 2..5mm on guard locking devices

Note:

- Design not so cost-effective
- Voltage drop in the event of long cables and series connection
- EMC disturbances can limit availability

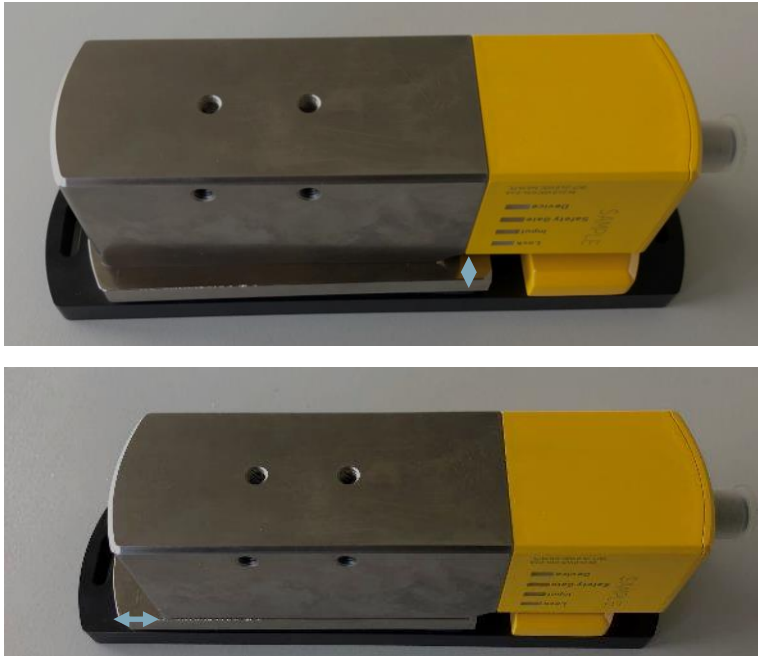


Figure 6: Actuator: Offset with RFID actuators, electromagnetic guard locking

1.3. Guard locking devices

Guard locking is another function alongside interlocking. Guard locking means that the switch can hold an actuator in the closed position.

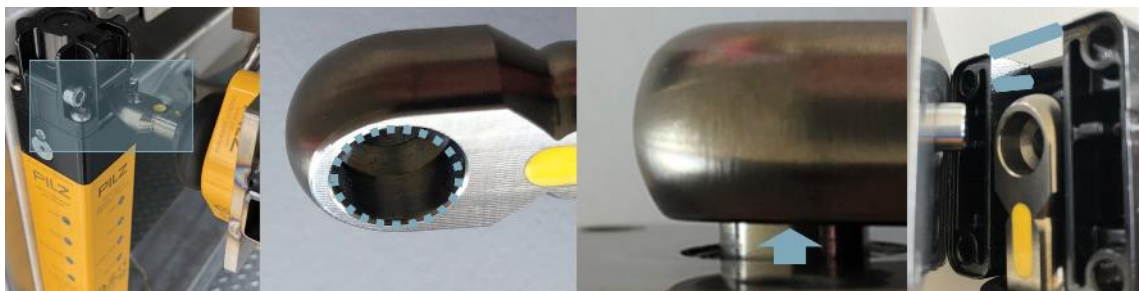


Figure 7: Mechanical guard locking: tongue, pin, insertion shaft

In addition to mechanical guard locking devices, which work electronically or electrically, there are also electromagnetic guard locking devices.

As interlocking and guard locking are two different functions, the result after the risk assessment will be two different required performance levels PLr. For this reason, different safety-related values per function should be listed in the details for the guard locking device.

However, guard locking may only be activated when the switch is interlocked. This condition is called failsafe locking: it is guaranteed that guard locking can only occur when the actuator is inserted and the gate is therefore actually locked.

The technical design of guard locking devices widely in use today is based on an internal magnet, which

- a) acts against a spring and blocks or releases a pin. Depending on the design and position of the spring, they are indicated as spring type interlocking / power to unlock / closed circuit current principle or magnet type interlocking / power to lock / open circuit current principle.
- b) remains in 2 end positions and is therefore called bistable. It also drives a pin.

The pin is therefore the key element in the safety architecture. Electromagnetic guard locking devices are an exception, where the magnet itself is the key element.

Characteristic values for a guard locking device

1. Force F_{1max} , up to which a guard locking device remains closed.
2. Force F_{ZH} is force F_{1max} reduced by a safety factor, which must correspond to the design of the gate.
3. Actuation force needed to close a gate
4. Retention force needed to open a gate that is latched, in other words closed, but no longer guard locked.
5. Number of mechanical switching cycles before a fault occurs and specified guard locking values are still achieved.
6. Minimum gate radius
7. Current requirement in the open state, in the closed state and when the state changes

1.3.1. Safety factor for forces and benefits of maintenance

In accordance with EN ISO 14119:2013, safety factors of at least 1.3 should be accepted. Some guard locking devices consider a safety factor of 2.0. In this case, the regular check of the switch's function, in respect to the switch's intact appearance and intact mounting, is omitted.

1.3.2. Forces

The holding force of a guard locking device, including the lever and material tolerances on the guard locking product, should be dimensioned in such a way that one person cannot deliberately overcome it. There may be great leverage forces, particularly on swing gates. EN ISO 14119:2013, Annex I, provides reference values for the forces that one person can apply: For example, one-handed grip pulling vertically 700N, and two-handed grip pulling vertically

1100N. The maximum force stated is 1400N. The size and position of the gate handles play a role here, as do the support points for the person.



Figure 8: Leverage on a guard locking device on gates

Most guard locking devices on the market operate with a single tongue and make a fault exclusion for PLd and PLe assessments in accordance with EN ISO 13849-1:2015. If necessary, manufacturers must list limitations in the operating manual.

There are differences in the way the RFID tag is positioned on actuators. If the RFID TAG is housed directly in the tongue, guard locking devices can generally be installed more closely together. In many cases, such a design subsequently offers a high degree of manipulation protection. The guard locking, and consequently the output signal switching devices, OSSDs, only become active when the actuator is actually in the target position, in other words engaged, and the guard locking is actually holding the gate closed.

1.3.3. Need for guard locking

EN ISO 14119:2013 regulates the need for guard locking (to be understood as a safety function) in clause 6.2.1: If the system's overall stopping performance is greater than the access time, then a safe guard locking device is required.

1.3.3.1. Stopping performance and access time on gates and flaps

Stopping performance

EN ISO 13855:2010 clause 5.1 defines the stopping performance: The reaction times of the safe interlocking device, safe evaluation and drive are taken into account.

$$T_{\text{StoppingPerformance}} = T_{\text{Interlocking device}} + T_{\text{Stopping time evaluation and drive}}$$

Formula for stopping performance

Access time

Clause 9 of EN ISO 13855:2010 explains the access time on gates and flaps in accordance with the usual formula: $S = (K \times T) + C$ where S is the minimum distance and $K = 1600 \text{ mm/s}$, C as additional safety distance and T as $T_{\text{StoppingPerformance}}$. C is zero if the gap dimensions of the gates are less than 4mm. Where the gap dimensions are larger, refer to EN ISO 13857:2019. Also, T may be extended by the time t_3 because gates and flaps can vary greatly. Ergonomic reasons have a key role to play here. For example, these could be: a forced movement when opening the gate, two-handed opening due to the size or weight of the gate or its handle, overcoming force due to latching device.

An example of a latching device is the integrated magnetic latching on the PSENslock 2, whose force of 30N, 110N or 200N must be overcome. The magnetic force decreases exponentially, and after a few millimetres distance, it is close to 0N. This sudden drop in the latching force when opening the gate is so abrupt that the operator needs coordination time before they can reach into the danger zone, see section 1.7.

1.3.4. Electromechanical guard locking devices

The structure of such a guard locking device looks as follows, for example:



Figure 9: Interior view of electromechanical guard locking device PSEN me5

A control element is moved due to the magnetic force of a coil against a spring. The currents flowing through the coil are between 2.5VA to 8VA. The coils are also optimised for different voltage ranges, so there are different versions of the switch. For example, there is a 24V version and another 230V version.

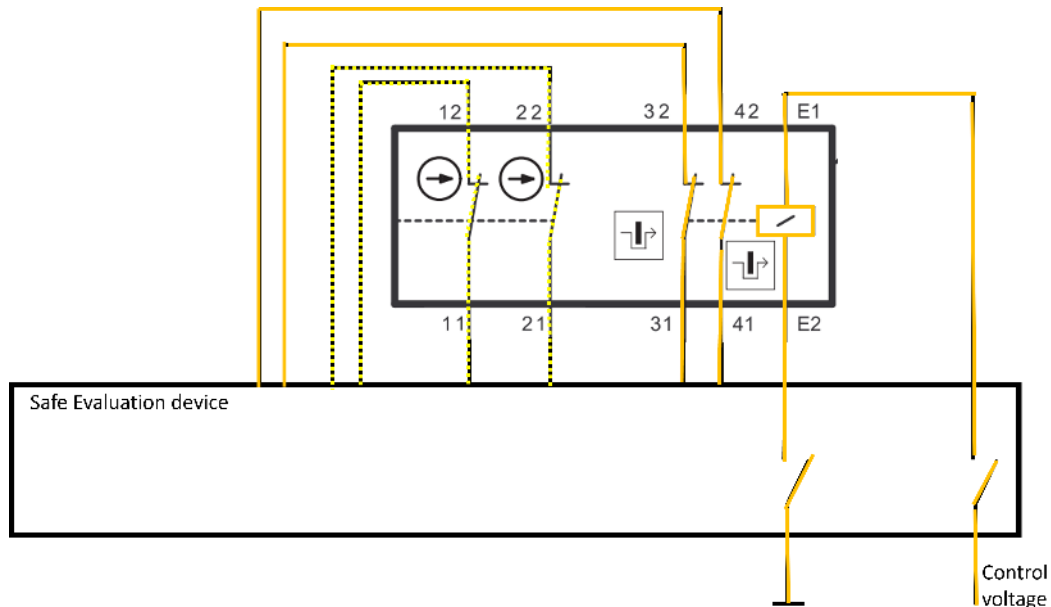


Figure 10: Block diagram for electromagnetic guard locking

Mechanical guard locking devices are made up of simple components. External, safe evaluation and control are required in order to form the safety functions. This means that a B10_D value is stated for these components. Often, the devices' operating manuals state the same value here for interlocking and guard locking.

For a partial safety function with regard to safe guard locking and safe monitoring of the guard locking position, correctly speaking, fault exclusion should be implemented via the locking system, so that it cannot assume the released state on its own, see GS-ET-19 E, clause 5.6.1.1.

For the partial guard locking function it is important that the contacts for monitoring guard locking have a form-fit connection to the position of the locking bolt. In order to correctly calculate the guard locking subsystem, the relevant B10_D value of the switch must be taken. This calculation takes wiring, common cause failures and environmental influences into account, among others. For this reason, manufacturers state B10_D values, despite partial fault exclusions.

As described in section 1.3 above, it is essential to check whether faulty closure protection is already implemented mechanically. Otherwise, this must be implemented via the controller as a safety function, if appropriate.

The performance level that can be achieved for electromechanical guard locking devices is limited by the single-channel structure of the control element. Fault exclusions can be made in certain applications through a leading bolt and an end stop. With 2-channel evaluation and further considerations of the application, a maximum PLd Category 3 in accordance with EN ISO 13849:2015 can be achieved. Pilz provides an application note for this, see References.



Figure 11: Fault exclusion due to leading bolt

Alongside the stated advantages and disadvantages for interlocking, you can add the following for guard locking separately:

- ▶ Advantages
 - 230V control possible
- ▶ Disadvantages
 - Risk of injury due to strong self-heating. Switch surface temperatures of 50°C clearly possible

1.3.5. Electronic guard locking devices

In this case, interlocking and guard locking are two separate systems by design.

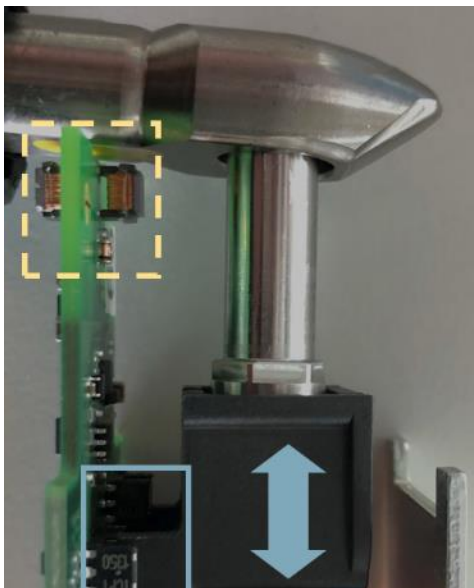


Figure 12: Yellow: RFID interlock / Blue Guard locking device with light barriers, using PSENmlock as an example

Interlocking is generally implemented with RFID. As shown previously, an antenna coil and an RFID tag are used. In this case, the RFID tag is in the yellow cast.

In contrast to electromechanical switches, guard locking is implemented separately from interlocking. Irrespective of the tag, a pin is securely positioned and safely monitored via light barriers, for example.

In the electronics, the logic connection between RFID and guard locking occurs in a microcontroller.

Due to the complex structure, a performance level and a PFHD value are stated for these devices in accordance with EN ISO 13849-1:2015.

Operating mode	EN ISO 13849-1: 2015 PL	EN ISO 13849-1: 2015 Category
1-ch. guard locking	PL d	Cat. 2
2-ch. guard locking	PL e	Cat. 4
2-ch. OSSD	PL e	Cat. 4
Escape release		Cat B

Figure 13: Statement of safety-related characteristic data, using PSEnMlock as an example

Alongside the stated advantages and disadvantages with RFID interlocking, you can add the following for guard locking separately:

- ▶ Particular advantages
 - Guard locking to PL e possible in accordance with EN ISO 13849-1:2015
 - Low current consumption and low surface temperature possible with bistable guard locking devices
 - Minimum dimensions possible
 - Long series connection chains possible through intelligent forwarding of the guard locking signals

1.3.6. Electromagnetic guard locking devices

With magnetic guard locking devices, interlocking and guard locking are also two separate systems.

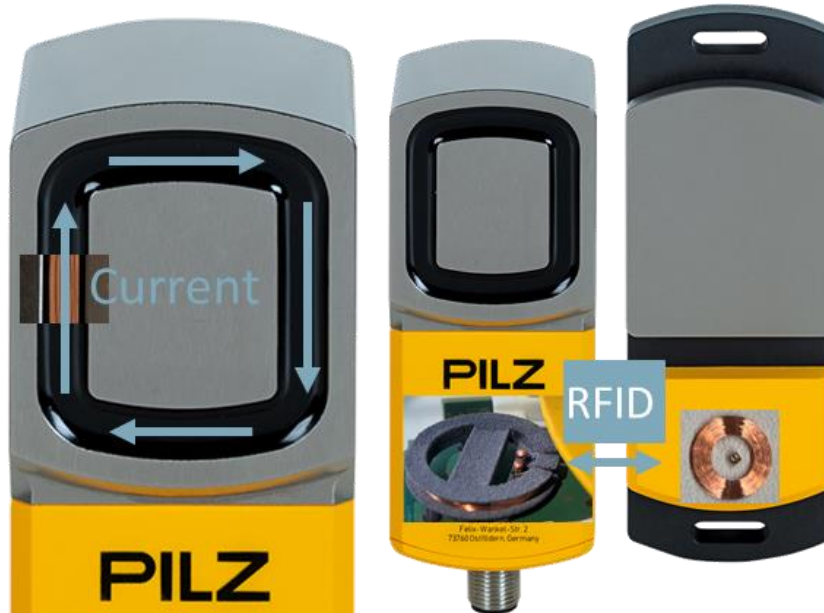


Figure 14: Example of PSENslock 2 with current loops for guard locking and RFID transmission for interlocking

Guard locking is achieved via electromagnetic forces. Due to the space requirement of the coils and the ferromagnetic body, the forces are rather lower in comparison with mechanical guard locking. For example, F1max is identified on the PSENslock 2 as electromagnetic guard locking with 2,000N, and on the PSENmlock with up to 15,000N. In this case, it is even more important to evaluate the necessary forces correctly, see Figure 8.

Cyclical measurements are required for safe, electromagnetic guard locking devices. A single measurement, as in the case of non-safety related guard locking devices, is not sufficient.

During the measurements, several current and voltage parameters are monitored and controlled.

► Particular advantages

- Low-wearing
- Wash-down best suited
- Mechanically robust guard locking devices
- Highest mechanical offsets in all directions
- Highest mechanical impact energy: mechanical stop
- No protruding moving parts (no tongue)

► Disadvantages

- Adhesive layers of dirt can reduce availability
- Typically, only power-to-lock guard locking principle

1.4. Control of guard locking devices

With mechanical guard locking devices, the control signals impact directly on the magnet, which activates or deactivates the guard locking. That means the control signals must be power signals, i.e. there are higher current flows, generally $\gg 100\text{mA}$.

Electronic guard locking devices allow the control signal to be isolated from the current that flows through the locking magnet. In other words, electronic guard locking devices mostly have a control signal, and the required energy comes via the voltage supply. You can also use quiescent current control signals, for example, and a bistable magnet to activate and deactivate the guard locking.

The advantage of control signals is that the evaluation device outputs can be low power and are therefore cheaper.

The advantage of power signals to sensor manufacturers is that the sensors can have smaller dimensions and less heat is generated.

1.5. Operating principles of guard locking devices

Most guard locking devices have a bistable or monostable magnet to activate and deactivate the guard locking. EN ISO 14119:2013 clause 5.7.1 requires energy to be fed in for the deactivation of the guard locking, see table below, prescribed normative approach, bistable magnet and monostable magnet with quiescent current control.

On some applications, however, it is necessary that access to plant and machinery in a de-energised state must be guaranteed, in order to avoid or contain damage. For example, this might be the case on plants in which the moving goods are highly flammable, or the process operates with high heat or fire. In this case, monostable magnets with operating current control are selected.

The need for a risk analysis for each individual machine is apparent, one which looks into the various states of a machine and the behaviour of the guard locking:

Magnet type	Bistable*		Monostable	
Product examples	PSENmlock	PSENmlock mini	PSENm5	PSENm5 M/ PSENslock 2
Prescribed normative application	Yes	Yes	Yes	Only with evidence through risk analysis
Control	Pulse	Quiescent current	Quiescent current	Operating current
Activation of guard locking	Can be defined through user program	When actuator is detected	When actuator is detected	After operating command
Deactivation of guard locking	After operating command			
Voltage drop	Last state		Closed	Open
Shutdown	Choice, open or closed		Closed	Open
Auxiliary release	Necessary			Can be implemented via power supply
Risk analysis de-energised state	If necessary Fire considered → emergency release			Open gate considered
Increased power requirement	Only in change of state		Opened gate	Closed gate
0V Machine run-up	Last state remains	Closed	Closed	Open
Series connection	More devices		Potential limitation due to circular connector	
Process guard locking / OSSD only on interlock	Possible			
Safe guard locking	Possible			
Safe monitoring of guard locking position	Possible			

* bistable means that guard locking cannot change its activated or deactivated state without power (fault exclusion on manufacturer's side).

Table 1: Operating principles of guard locking devices

This results in a variety of timing diagrams:

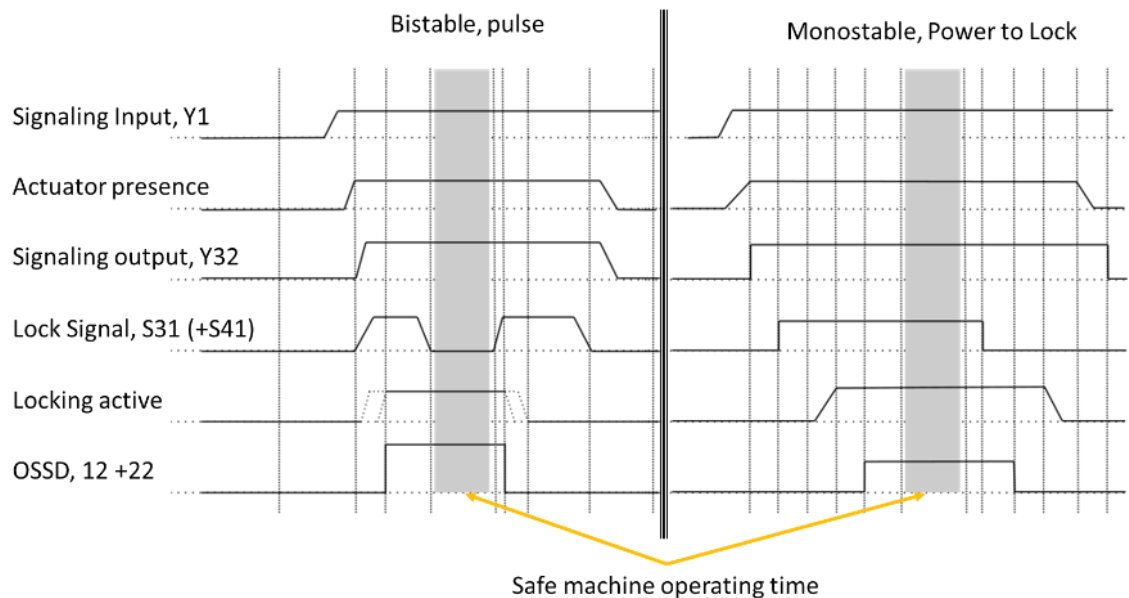


Figure 15: Timing diagram of bistable and monostable guard locking devices

You can see that, on both versions, the actuator rests when guard locking is active. There should be no dynamic forces through rebounding of the gate. These forces can place a substantial load on switches; even EN ISO 14119:2013 refers to it in clause 6.2.2 and see section 1.3.

In particular, pulse control has the additional feature that neither voltage loss nor a controller restart can cause the guard locking device to open. The assumption here is that when a controller is restarted, outputs are not briefly switched to “high” and correspond to an opening pulse.

With pulse control, in a series connection the problem could occur that guard locking devices do not activate or deactivate guard locking synchronously. The problem can be resolved by offsetting the pulses on both control signals, see PSEN ml sa types for example.

1.6. Limitations of the guard locking partial safety function

There are also a wide range of devices on the market on which the safe outputs only react to the presence of the actuator, irrespective of whether or not guard locking is active. So, we don't talk about safe guard locking. Hence, the safety function is reduced to only safe interlocking.

1.7. Latching

A latching device is not a guard locking device and so does not represent any minimisation of risk. However, latching devices are essential for the smooth-running process on the machines: The guard locking devices on several gates are opened, but the gates do not spring open immediately because they remain latched. Machine operators can make their way alongside the gates. That explains the requirement from EN ISO 14120:2015, clauses 5.3.12 and 5.3.13, that the opening of a gate must be a deliberate act and that a closed gate must be held in position, irrespective of whether or not a guard locking device is used.

Even when closing a gate, the gates should be held in the correct position for the specific insertion of the guard locking pin. Actuator detection is also maintained steadily through a good latching device.

Latching devices operate mechanically, against a spring for example, or they may be implemented magnetically. They usually have a force of between 10N and 200N; higher values are generally implemented through an additional supply.

To minimise strain and physical effort for the machine operator, EN ISO 14120:2015 clause 5.2.5.3 requires low operating forces. Reference is also made to EN ISO 12100:2010. Clause 6.2.8 of this standard says that account shall be taken of body sizes of the operator, strengths and postures, movement amplitudes, and the frequency of cyclic actions.

This means that, for frequent usage, unfavourable ergonomic conditions and high retention forces, other locking mechanisms may make more sense than latching via guard locking: a clamping lever, for example.



Figure 16: PSENslock 2 with adjustable latching force of 30Nm, 110Nm or 200Nm

2. Distinction between safe guard locking, safe position monitoring and process guarding

As explained previously, guard locking and interlocking are two different subfunctions. Now we have the function of guard locking for personnel protection in its different forms: Safe guard locking is a different safety function to that of safe monitoring of the guard locking position. In addition, there is also guard locking for process protection.

A safe guard locking device is understood to be an actuator, which is

- a) activated safely by an evaluation unit using safe outputs: guard locking as actuator.
- b) evaluated safely by an evaluation unit using safe inputs: guard locking and interlocking as sensor.

In the case of safe monitoring of the guard locking position, the device is understood as a sensor, which is

- a) evaluated safely by an evaluation unit using safe inputs: guard locking and interlocking as sensor.

2.1. Safe guard locking device

To implement a safe guard locking device as an overall safety function, the safe evaluation device and safe detection of unlocking condition (e.g. stand still of a drive) must also be added, EN ISO 14119:2013 clause 8.4:

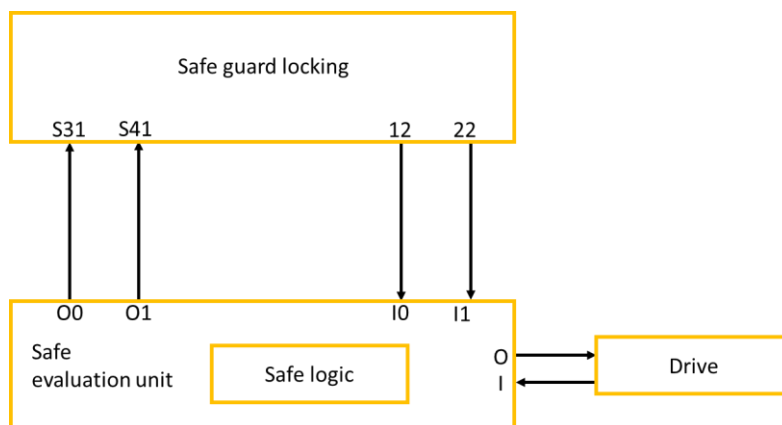


Figure 17: Safe guard locking safety function

Irrespective of the guard locking device, a safe evaluation unit controls the drive, to switch to a safe state. This is monitored by safe logic, for example through a timer or a direct signal exchange. The safe logic then controls the safe inputs on the guard locking device via safe outputs. The inputs and the internal processing within the guard locking device must also be designed to be safety-related.

This means that any faults in the logic, in the outputs or in the cable cores to the sensor will be managed by the evaluation device. Faults from the sensor to the safe logic will be managed in the sensor by the outputs, known as output signal switching devices, OSSD for short.

The different elements in a safe guard locking device are represented in the following diagrams:

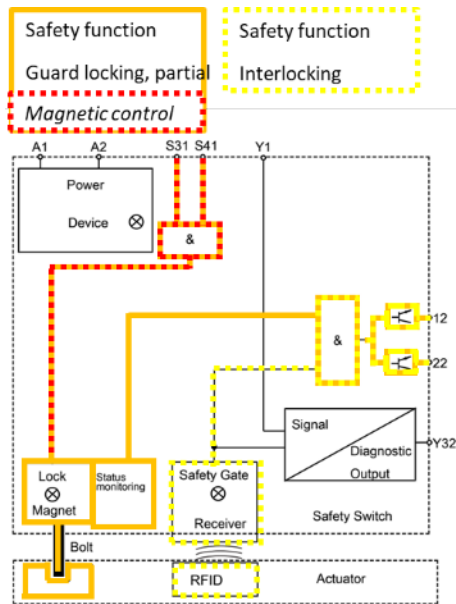


Figure 18: Safety functions: light yellow dotted line interlocking, dark yellow including red dotted line safe guard locking, using PSEN mIm ba as an example

Implementations of a safe guard locking device are independent of a performance level and independent of the technology. Safe guard locking is available as an overall function with electromechanical, electromagnetic and electronic guard locking devices in the application.

One potential implementation of the control, processing and evaluation of a safe guard locking device is shown below.

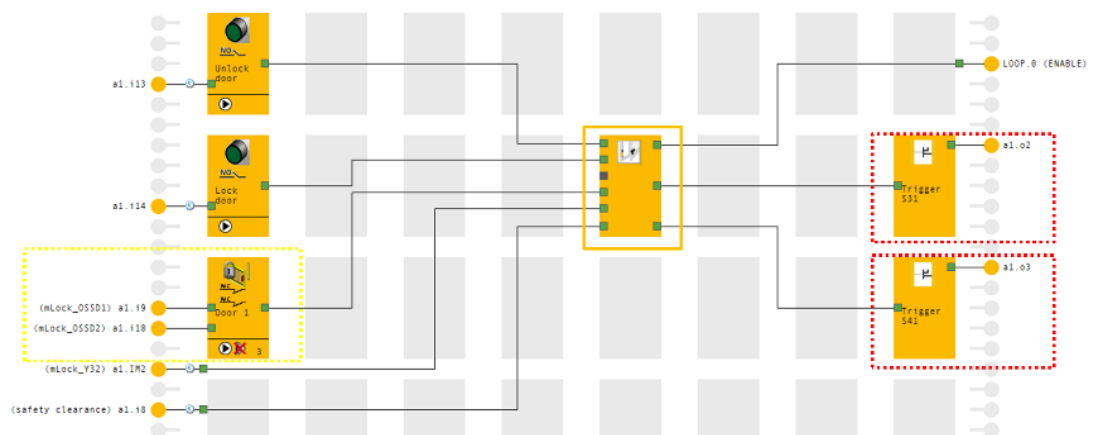


Figure 19: Implementation of safe guard locking at control level, using PNOZmulti Configurator with function block PSENmlock as an example

By way of example focussing on sensor and logic, therefore, this is how the calculations look for guard locking and interlocking:

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Safety function

Documentation PLr PL Subsystems

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Status	Name	Ref. des.:	PL	PL-Software	PFHD [1/h]
✓ SB	Türschalter		c	n.a.	1,1E-6
✓ SB	PNOZ m EF 8DI4DO		d	n.a.	2,1E-9
✓ SB	PNOZ m B1		e	n.a.	4,2E-10
✓ SB	PNOZ m EF 8DI4DO		e	n.a.	2,8E-10
✓ SB	PNOZ m EF 8DI4DO		e	n.a.	1,6E-10
✓ SB	Leistungsschütze		e	n.a.	2,5E-8

Context

Interlock (Stellungsabfrage)

PLr c

PL c

PFHD [1/h] 1,2E-6

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Safety function

Documentation PLr PL Subsystems

Library VDMA Library

New Edit Delete

Status	Name	Ref. des.:	PL	PL-Software	PFHD [1/h]
✓ SB	PNOZ m B1		e	n.a.	4,2E-10
✓ SB	PNOZ m EF 8DI4DO		e	n.a.	2,8E-10
✓ SB	PNOZ m EF 8DI4DO		e	n.a.	1,6E-10
✓ SB	PSEN ml b 1.1		e	n.a.	4,2E-9

Context

Guardlock (Zuhaltung)

PLr c

PL e

PFHD [1/h] 5,1E-9

SB -

PL -

PFHD [1/h] -

Cat. -

MTTFD [a] -

DCavg [%] -

CCF -

BE -

MTTFD [a] -

DC [%] -

EL -

MTTFD [a] -

DC [%] -

Figure 20: Extract, calculation of guard locking und interlocking using PSENmlock and PNOZmulti as an example, with the help of Sistema Version 2.0.8

You can see that it comes to different values. The guard locking device has different values for both functions. On the safe evaluation device page, different values, even different components, are used. This clearly illustrates again that a distinction must be made between interlocking and guard locking.

2.2. Safe monitoring of guard locking position

With safe monitoring of the guard locking position, guard locking can be controlled using a non-safety-related signal.

This means a residual risk: when fault and access coincide, a residual risk will be there! This is particularly hazardous because systematic faults can occur: in this case there is no mandatory, functionally safe fault reaction.

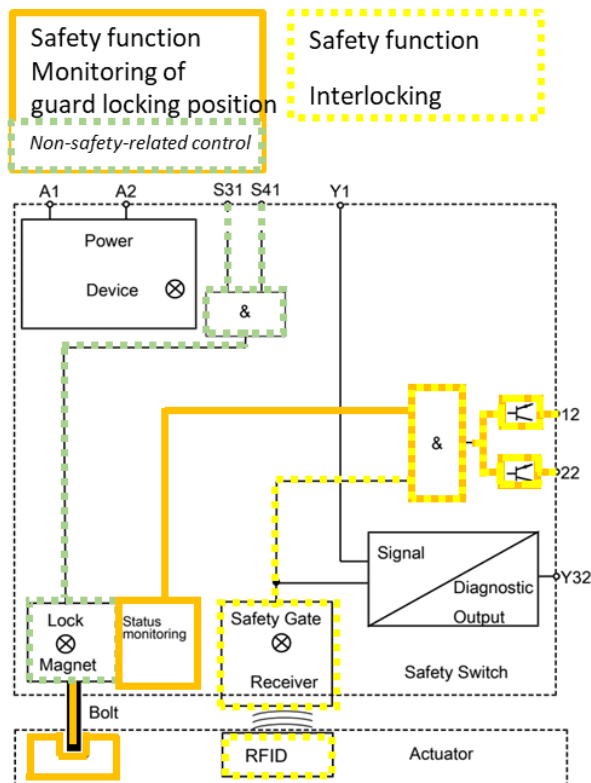


Figure 21: Safe monitoring of guard locking position, theoretical example

Initially this is irrespective of how guard locking itself is implemented. Where guard locking devices are designed purely for safe monitoring of guard locking, there are non-safety-related inputs for guard locking, and internally too, control of the guard locking magnet is not safety-related. However, monitoring of the position of the pin is safety-related and the reaction of the OSSDs to its position is safety-related. In turn, these must be processed by a safe evaluation device.

For some applications, safe monitoring of the guard locking position might be sufficient, see section 2.4.

Safe monitoring of the guard locking position is not always sufficient: faults can occur here sporadically or depending on the state, and these are not always apparent to the operator as faults. People will look for the fault, and therefore open the gate. An open, but not locked, gate can no longer protect the operator if the hazardous movement has not yet slowed down.

2.3. Process guarding

The corresponding block diagram for process guarding can look as follows:

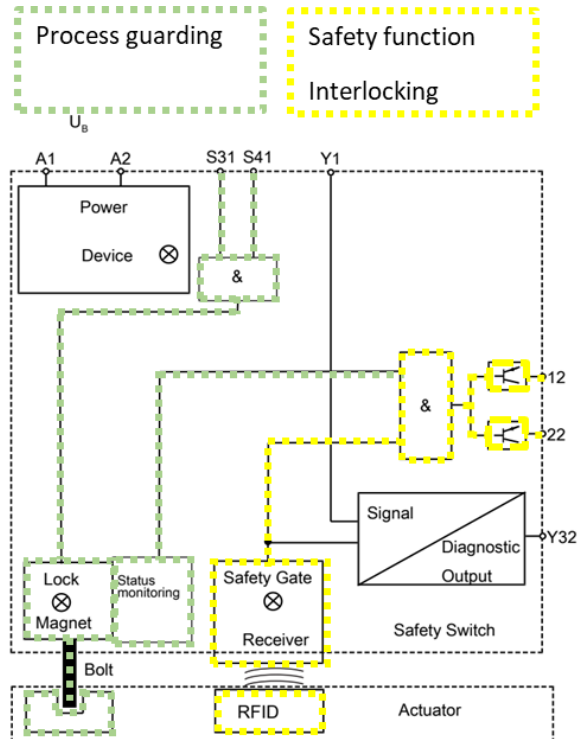


Figure 22: Process guarding with safe interlocking and non-safety related guard locking, theoretical example




Process guard locking devices are intended to protect the process from the operator. This means that interventions should not occur at just any time, as an uncontrolled stop means long setup times and therefore low availability of the machine.

So with process guarding, only the interlocking is safety-related. There are various versions on the market, on which the guard locking either does or does not affect the outputs on the sensor. From a safety-related perspective, there is no difference here: the access time to the hazardous movement must be greater than the time needed by the machine to achieve a safe state / standstill.

However, for the machine operation, it can be an advantage if gates are no longer locked, but the machine continues running and the process can be monitored. The operator can then intervene more quickly in the process, where this is necessary, or leave the machine running.

It can be sometimes difficult to see the difference between “process guard locking” and “safe monitoring of the guard locking position”, because I/O interfaces and appearance look similar. So, it is very important to check the intended use and its corresponding declared safety functions.

2.4. Overview of safe guard locking, safe monitoring of guard locking position and process guarding

	Safe guard locking	Safe monitoring of guard locking position	Process guarding
Product examples	PSENmlock, PSEN sl 2-G, PSENmlock mini, PSEN me5	***	***, PSEN sl 2-D
Safety-related control	Mandatory	Possible	Possible
Fault management	In accordance with performance level	<ul style="list-style-type: none"> a) Incorrect control possible in the event of non-safety-related control. b) Guard locking device opens at the wrong time due to internal sensor error. c) i.e. machine start-up when guard locking is defective is prevented by polling the guard locking device. 	<ul style="list-style-type: none"> a) Incorrect control possible in the event of non-safety-related control. b) Guard locking device opens at the wrong time due to internal sensor error. c) OSSDs do not react to the state of the guard locking device d) i.e. machine start-up is possible when guard locking device is defective.
Typical applications	Access to a danger zone in which a hazardous movement is not immediately apparent and manageable or on which the powertrain needs longer* to come to a standstill.**	Access to a danger zone. Hazard is not directly behind the gate, but is visible, and the powertrain can be brought to a standstill immediately*.	Powertrain can be brought to a standstill in a very short time*.
Examples			

* This relates to the access time and distances to the hazard, which must be determined individually.

** See Note 1 EN ISO 14119:2013 clause 8.4

*** Products capable of safe guard locking can also be used for safe monitoring of the locking position and process guarding

Table 2: Differences in the application of the various forms of a guard locking device

2.5. Summary

This means that only the left-hand column for personnel protection can be used on plants with a significant stopping time.

3. Installation considerations for flaps and for accessible gates

EN ISO 14120:2015 describes the general requirements for the design and construction of such guards. Typical movable guards are flaps and fully body access doors. They protect humans from a hazard by means of a safe guard locking device. Such devices for risk reduction must make no distinction performance level or safety integrity level. However, there are differences in selection, installation and also in additional necessary equipment.

	Flaps	Accessible gates
Height of the gate	Typically: 25...75cm	Typically: 230cm
Gate/flap radius on swing gates	Typically: 10...100cm	Typically: 60...150cm (sliding gates would be significantly larger)
Offset on swing gates	Typically: +/- 1 mm with each closing process	Typically: +/- 2 mm wear over its lifetime
Weight	Lighter, e.g. <50kg	Heavier, e.g. >50kg
Protection against unexpected restart	Not usually necessary	Mandatory, mechanical or electrical
Escape release	Not usually necessary	To be provided
Integrated buttons	Possibly on sliding flaps	Frequently on swing gates and sliding gates
End stop	Separate, or note values in the switch's technical details	

Table 3: Flaps and accessible gates

3.1. Load on flaps

Due to the lower weight, smaller flaps can be well managed with one hand. Hinges are smaller, and the offset can vary from one closing process to the next, depending on the ergonomic position of the operator. For this reason, it's necessary to be aware of an offset due to wear in the hinge or loosening of the fixing screws: If the offset is greater than that stated in the technical details for the guard locking device, the switch is being operated outside of the specification.

The smaller gate radius represents the particular challenge. If the actuator can no longer find its insertion shaft, the actuator, and possibly also the switch, may be damaged as a result.



Angle adapter and centering ring	Open insertion shaft
	
<p>Angle adapter: Optimisation of the insertion angle with small flap radiuses or larger parallel offset of switch and hinge</p> <p><u>Centering ring</u>: On small gate radiuses, limits the offset, to reach the insertion shaft</p>	<p>This open design enables very small radiuses in one, and only one, level.</p>

Table 4: Examples for solutions for small gate radiuses

3.2. Load on gates

In comparison with flaps, gates generally have a greater, freely swinging mass of larger dimensions. In other words, the operator generally has no direct influence on the offset and is also limited in their ability to absorb the gates rebounding at the mechanical end stop. In this case, the power to lock and bistable control have the advantage that the guard locking device only closes in the rest position and forces from the rest position can impact on the guard locking device.

Offsetable flexible actuator:

Actuator remains in the offset position and is barely retracted to the centre



Figure 23: Example of tolerance compensation for solutions on large gates

3.3. Protection against unexpected restart





Additional danger zone monitoring through radar or scanner	Mechanical lock in the actuator	Mechanical lock on the switch	Mechanical or electrical key
			
Irrespective of the switch enable, there is a wait for the enable from the radar, for example, before a machine restarts	Lock prevents the insertion of the actuator and the switch does not provide a safety enable	Lock prevents the detection of the actuator and the switch does not provide a safety enable	Irrespective of the switch enable, there is a wait for the enable from the key
≥1 gate solution	One-gate solution	One-gate solution	Mechanical: 1 gate solution Electrical: ≥1 gate solution
Device fuse protection	Administrative control	Administrative control	Device fuse protection and administrative control

Table 5: Options for protecting against unexpected restart

If operators enter a danger zone, they must protect themselves against the machine starting to move again while they are still in the danger zone, particularly in areas of the danger zone with no visibility.

Please note: A single one of the above options is generally not enough. Particularly with key options, a delayed start with warning signals is required, for example.

Errors in the work stages must often be assumed.

3.4. Auxiliary, emergency and escape releases

Against the background of failure of the protection against unexpected restart, risk analyses frequently show that accessible gates must be equipped with an escape release. These give operators the option to leave the danger zone via a manual action.

An auxiliary release and emergency unlocking device are also available as additional unlocking options on guard locking devices, in addition to the escape release. In general, all guard locking devices that have a bistable magnet or a monostable magnet with power to unlock control have an auxiliary release.

If access from outside is required in an emergency, these guard locking devices must also have an emergency release.

3.4.1. Emergency unlocking devices

An emergency unlocking device can be reset using a tool, a manual intervention or at control level. Misuse of the emergency unlocking device as a quick means of access should be prevented.

<p>Emergency unlocking with reset via tool</p>	
<p>Emergency unlocking with manual reset and manual intervention</p>	
<p>Emergency unlocking with manual reset and cancellation at control level. Display on the visualisation</p>	

Table 6: Implementations of emergency unlocking devices

Please note: The standard EN ISO 14119:2013 only requires that normal, continued operation is prevented. As a result, access to various machine functions is still possible, only normal continued operation is not.

There are guard locking devices on the market that behave differently in terms of electronic reset. Generally speaking, only devices with power reset may be used for emergency unlocking, to prevent normal, continued operation. Guard locking devices with automatic reset are not

equipped with an emergency unlocking device and may only be equipped with an auxiliary and escape release.

3.4.2. Escape release integrated in the actuator/handle



Figure 24: Escape release integrated in the handle, PSENmlock door handle module (red handle) as example

For accessible gates in particular, escape releases can be integrated directly in the actuator or in the handle unit. This has the benefit that there is no need to provide another hole in the gate frame and there is no need to create additional space for access on the gate frame.

On very light gates, a handle weight of over 1kg should be considered. The low holding forces are acceptable, as the handle only allows for one hand and cannot act as a lever. That's why most devices on the market are well above the required static minimum forces of 700N, as per EN ISO 14119:2013 Table I.1.

3.4.3. Escape release on the switch or remote

Escape releases on the switch are significantly cheaper to acquire than integrated escape releases in the handle.

Also, handles are not an option if the switch is to be mounted above 1.7m, see IEC 60204-1:2016. To satisfy the ease of operation referred to in EN ISO 14119:2013 clause 5.7.5.2, the escape release must be operated from a distance. In this case, most manufacturers offer an escape release that is connected to the switch via a mechanical cable or cord.



Figure 25: Escape release, using the remote escape release on the PSENmlock as an example

4. Summary and outlook

In order to implement guard locking devices in compliance with the standards, there are many aspects to consider. There are many possible solutions, each with advantages and disadvantages. This white paper explains the features and properties of guard locking devices, so that normative requirements are better understood and guard locking devices are selected and applied correctly in practice.

New editions of the standards and technological developments will require further editions of this white paper, in order to stay up to date. There will be a new edition of ISO 14119: In 2024, ISO/FDIS 14119:2024 will be published, which includes the subject of series connection from ISO/TR 24119:2015, for example.

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6. Documentation

6.1. Normative references

The following references to standards and application notes have been used:

No.	Description
1	EN ISO 13849:2015
2	EN ISO 14119:2013
3	EN ISO 13855:2010
4	EN ISO 13857:2019
5	EN ISO 14120:2015
6	EN ISO 12100:2010
7	ISO/TR 24119:2015
8	GS-ET-19 E
9	https://www.pilz.com/download/open/AN_PSEN_me5_Fault_Exclusion_1005752-EN-01.pdf
10	ISO/FDIS 14119:2023
11	EN IEC 60204-1:2016

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