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POSITION PAPER CB 24 I

CLASSIFICATION OF BINARY 24 V INTERFACES

FUNCTIONAL SAFETY ASPECTS COVERED BY DYNAMIC TESTING

Die Elektroindustrie

Inhalt

1 SCOPE AND PURPOSE

This document describes characteristic features of binary 24V interfaces that use dynamic test pulses.

The purpose of this document is to:

- describe terms;
- define characteristics of interface types;
- specify product information (technical data) per interface type to be supplied by the manufacturer.

This document provides a technical description for all interface types. There is no safety assessment. For a complete assessment of the functional safety of a safety function, all relevant requirements of the applicable standards (e.g., ISO 13849, IEC 62061, IEC 61508) must be applied to the entire safety function.

2 NORMATIVE REFERENCES

The following cited documents are required for the application of this document. For dated references, only the referenced edition applies. For undated references, the latest edition of the referenced document (including all amendments) shall apply.

The general requirements set out in IEC 61131-2:2017 shall apply with respect to the present document where reference is made to them.

3 NOTES

Section 3 of IEC 61131-2:2017 applies with the following additions:

3.1 Information source (source)

The information source (hereafter referred to as source) transmits information to the information sink. The source output is connected to the input of the sink. A source can meet requirements of several interface types at the same time.

Note: For example, the source could be a sensor and the sink a control system. The term refers to the generation of the information and not to the generation of the test pulses. Generation of test pulses can be located in different parts of the system, depending on the interface type.

3.2 Information sink (sink)

The information sink (hereafter referred to as sink) receives information from the information source. The sink input is connected to the output of the source. A sink can meet requirements of several interface types at the same time.

Note: For example, the sink could be a control system. The term refers to the analysis of the information and not to the analysis of the test pulses. Analysis of test pulses can be located in different parts of the system, depending on the interface type.

3.3 Test pulse generation (TG)

Part of the system that generates test pulses used for system diagnosis.

3.4 Test pulse evaluation (TE)

Part of the system that evaluates test pulses for system diagnosis.

3.5 Supply voltage

Supply voltage is the voltage continuously supplied to a device.

3.6 Test pulse

A test pulse is a temporary change of a signal voltage level used to verify the proper operation of the output or device or the transmission path.

3.7 Test pulse duration t_i

The test pulse duration t_i is the time from the start of the test pulse (e.g. falling edge) until the end of the test pulse (e.g. rising edge).

3.8 Test pulse interval *T*

The test pulse interval *T* is the time between the start of a test pulse and the start of the next test pulse on the same output.

3.9 Test pulse delay Δt_i

The test pulse delay Δt_i is a pulse delay introduced by the source, between the input and the output of the information source.

3.10 Test pulse phase shift Δt_c

Time shift of test pulses between different test generation channels (interface type C and interface type D).

3.11 Discrepancy time Δt_{dis}

Simultaneity of the test pulse edges using OSSD outputs (interface type C).

3.12 ON state

The ON state of a source is the state in which the source output supplies energy.

3.13 OFF state

The OFF state of a source is the de-energized state.

3.14 Interface type

The interface type is a standardized interface for transmitters of signals (sources) and receivers of signals (sinks). Generation and analysis of test pulses is specified per interface type.

3.15 Class

The class is a group of sources and sinks with compatible technical data within an interface type based on the test pulses in use.

3.16 Output current I_n

The output current In is the nominal ON state current of an output.

3.17 Leakage current $I_{Leakage}$

The leakage current $I_{Leakage}$ is the output current of a source or sink in the OFF state.

3.18 Load capacitance C_L

The load capacitance C_L is the capacitance connected to an electrical output.

3.19 Inductive load L_L

The inductive load L_L is the inductance connected to an electrical output.

4 MINIMUM COMPATIBILITY SPECIFICATIONS IN THE MANUFACTURER'S DOCUMENTATION

4.1 Purpose

To simplify the compatibility check of device interfaces, additional information shall be provided in the manufacturers' device documentation.

4.2 Basic electrical parameters

These parameters are the basis for the information provided in the manufacturer's documentation.

Interface type	Maximum electrical resistance of the connecting cable	Maximum capacitive load of the test pulse generation TG (cable*1 + input capacitance)
A	15 Ohm*1	20 nF *2
B	15 Ohm*1	20 nF *2
C	15 Ohm*1	20 nF
D	15 Ohm*1	20 nF

Table 4-1: Basic electrical parameters

*1 Such a resistance and capacitance results, for example, from a cable with 0.25 mm^2, 5-pole: approx. 80 Ω/km per single conductor and 120 nF/km. These figures represent a typical cabling length of about 30 m.

*2 Serial connection should also be taken into account if applied.

4.3 Structure of the identification key

The identification key has the following structure:

Source / Sink	Interface type incl. class if applicable	Additional measures "M"	Sink / Source	Suitable interface type incl. class if applicable	Suitable interface type incl. class if applicable	Suitable Interface type incl. class if applicable

Table 4-2: Structure of the identification key

1. First position is the classification of the product.
2. Next, the interface types suitable for this product are specified. Up to three interface types can be indicated.
3. If additional measures are required, this is indicated by the letter "M" in the field "Additional measures". Definition of additional measures shall be provided in the manufacturer's documentation.
4. A row can only contain interface types of the same kind.
5. For products with multiple possible interface types, all possible combinations shall be indicated using several identification keys.
6. The number of cells and the structure of the identification key are fixed.

Examples:

1) Manufacturer information for a source of interface type C class 2 (e.g., sensor etc.):

Source:	C2		**Sink:**	C1	C2	

Explanation: In this case, a source of type C2 is compatible with a sink of type C1 and also with a sink of type C2.

2) Manufacturer information for a sink of interface type C class 2 (e.g., safety PLC etc.):

Sink:	C2		**Source:**		C2	C3

Explanation: In this case, a sink of type C2 is compatible with a source of type C2 and also with a source of type C3.

3) Manufacturer information for a sink of interface type A (e.g., safety evaluation unit etc.):

Sink:	A	M	**Source:**	A		

Explanation: In this case, a sink of type A is compatible with a source of type A subject to the additional measures "M".

Note: For the free classes C0 and D0, the identifying key is not used. These interface types require an individual compatibility test.

5 CHARACTERISTICS OF THE INTERFACE TYPES

5.1 Interface type A

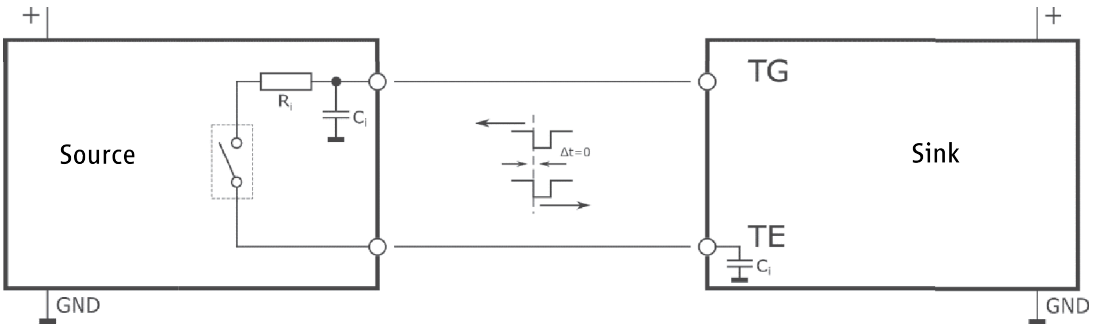

Figure 5-1: Interface type A

Description:

A sink sends test pulses to a source. The test pulses are returned to the sink without any change. If the sink does not receive test pulses the sink will enter a safe state. Cascading (series connection) of several sources is supported by this interface type. Internal resistances R_i of sources connected in series are additive. This needs to be taken into account when determining the expected value for the input voltage at the sink.

Examples:

Magnetically actuated position sensors and limit switches (reed switches) on hydraulic and pneumatic cylinders. Typical sinks of this type are e.g., electronic controls.

5.1.1 Static characteristics of the interface type A

1) A sink implementing interface type A has an output for test pulse generation (TG). In addition, the sink has an input for test pulse evaluation (TE).

2) A source implementing interface type A has a signal input for a test pulse and a signal output for the instantaneous output of the test pulse.

3) The electrical data shall be based on IEC 61131-2:2017 and will not be further addressed here. Sources of type A can be connected in series and allow potential-free operation.

5.1.2 Dynamic characteristics of the interface type A

1) The test pulse is not delayed by a source of interface type A that provides information.

2) A source implementing interface type A does not impose any requirement to timing characteristics of the test pulse. The source does not initiate a test pulse at the output on its own. In the OFF state of the source, test pulses are not passed on.

5.1.3 Product information of the manufacturer

The user manual of a source implementing interface type A shall provide additional data as follows:

Parameter source	min.	typ.	max.
Switching current I_i	*Minimum current $I_{i\ min}$*	-	*Maximum current $I_{i\ max}$*
Switching voltage U_i	*Minimum voltage $U_{i\ min}$*	-	-
Internal resistance R_i (in the switched state)	*Minimum internal resistance $R_{i\ min}$*	-	*Maximum internal resistance $R_{i\ max}$*
Load capacitance C_i	-	-	*Maximum capacitance at output $C_{i\ max}$*
Load inductance $L_{i(*)}$	-	-	*Maximum inductance at output $L_{i\ max}$*
Potential-free	*yes/no*		

(*) = optional indication of the manufacturer

Table 5-1: Manufacturer information interface type A – source

The user manual of a sink implementing interface type A shall provide additional data as follows:

Parameter sink	min.	typ.	max.
Input current I_i (in ON state)	*Minimum current $I_{i\ min}$*	-	*Maximum current $I_{i\ max}$*
Output voltage U_i	*Minimum voltage $U_{i\ min}$*	-	*Maximum voltage $U_{i\ max}$*
Input capacitance C_i	-	-	*Maximum capacitance in input $C_{i\ max}$*

Table 5-2: Manufacturer information interface type A – sink

5.1.4 Application notes

If several sources implementing interface type A are connected in series, the total voltage drop has to be considered.

Note 1: The input of a sink may not exceed the maximum load capacitanc and inductanc specified in the source and vice versa. The parasitic capacitance and inductance of cables should be taken into account here.

5.2 Interface type B

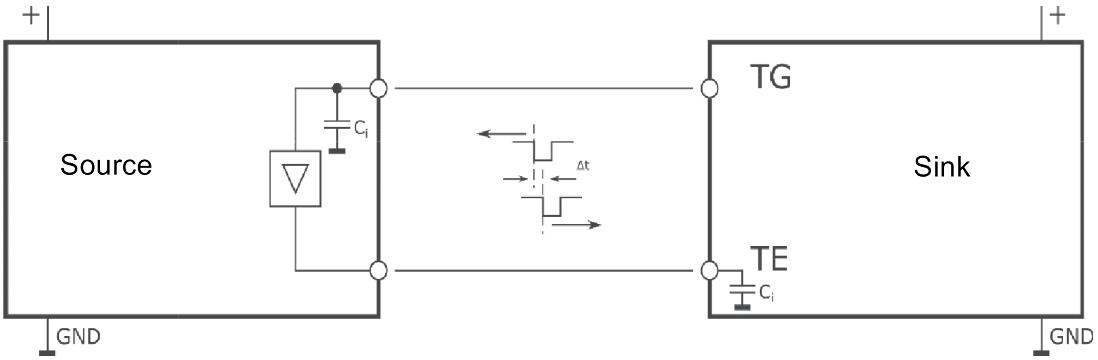

Figure 5-2: Interface type B

Description:

A sink generates periodic test pulses with a test pulse interval T. The periodic test pulses are delayed by the source by the time Δt_i and returned to the sink without other modification. If the test signals are not passed on to the sink by the source, or if the expected time value of the sink is outside the permissible tolerance limits, the sink will enter a safe state. This interface type allows cascading (series connection) of sources. Test pulse delays Δt_i of sources connected in series are additive. This needs to be taken into account when determining the expected time delay for the sink.

Examples:

Interface type B is often used for position monitoring by sensors (source) of different technologies (inductive / RFID / magnetic / optical / etc.), as it enables series connection. Examples of sinks specific to this interface type are electronic evaluation units and electronic control systems.

5.2.1 Static characteristics of the interface type B

1) A sink implementing interface type B has an output for test pulse generation (TG). In addition, the sink has an input for test pulse evaluation (TE).
2) A source implementing interface B has an input for the signal of the test pulse generation (TG) and an output for the delayed test signal.
3) The electrical data shall be based on IEC 61131-2:2017 and will not be further addressed here. All signals of this interface type are referenced to the signal ground (GND).

5.2.2 Dynamic characteristics of the interface type B

Two versions of interface type B exist:

1) The test pulse delay Δt_i is much smaller than the test pulse duration t_i (see Figure 5-3).

2) The test pulse delay Δt_i is greater than the pulse duration t_i (see Fig. 5-4).

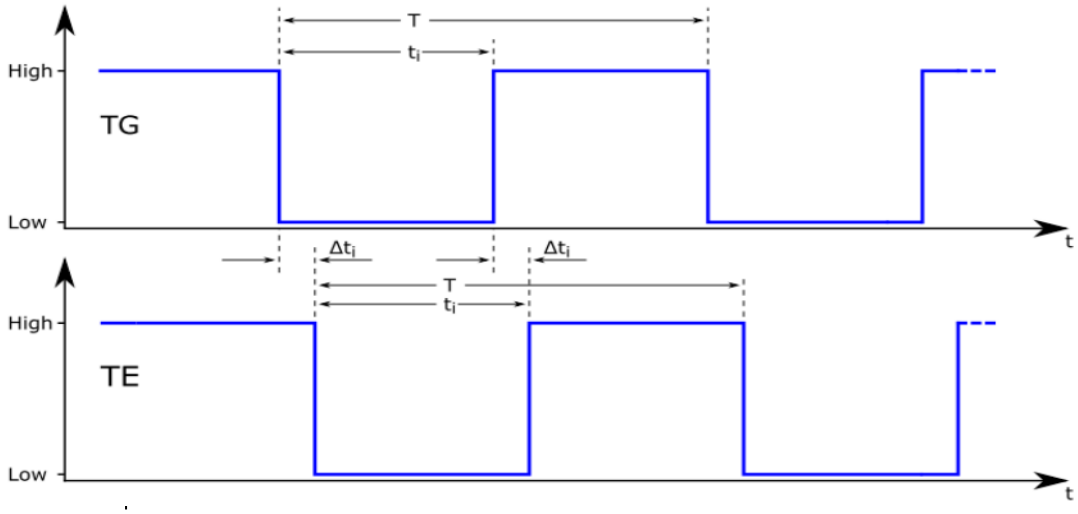

Figure 5-3: Test pulse delay Δt_i much smaller than test pulse duration t_i

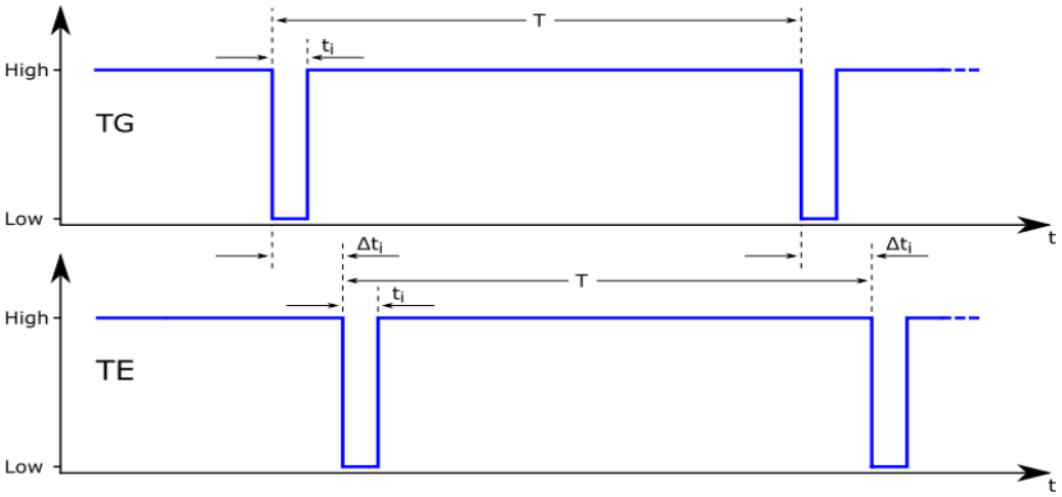

Figure 5-4: Test pulse delay Δt_i greater than test pulse delay $t_{i\ i}$

The test pulse duration t_i is determined by the sink. If the signal shape (pulse/pause ratio, delay) at the input of the sink is in the expected range, the sink can adopt a release state with regard to the source. If the signal shape is not as expected or if no signal is present, no release occurs in the sink. If the source refuses the release no signal is transmitted to the sink.

The falling edge and the rising edge of the test pulse input signal of the sink both occur with a test pulse delay of Δt_i at the output of the source. The test pulse delay Δt_i is a deliberately introduced delay time, which clearly differs from parasitic delay times. Typically, the switch-on and switch-off times of the test pulses including their tolerances are much smaller than the test pulse duration t_i. The timing characteristics of the test pulse generation (TG) are influenced by the capacitive load of the source (C_i) and have an effect on the total time. Furthermore, the input capacitance (C_i) of the sink influences the timing aspects of the test pulse analysis. Knowing the size of this capacitance (C_i) is essential for users of interface type B.

It is recommended that the capacitive, inductive and resistive parts of the cables between the sink and the source are taken into account. They have an influence on the signal quality, but this will not be further taken into account in this publication.

Product information of the manufacturer

The user manual of a source implementing interface type B shall provide additional data as follows:

Parameter	**min.**	**typ.**	**max.**
Test pulse delay Δt_i	*Minimum test pulse delay* $\Delta t_{i\,min}$	-	*Maximum test pulse delay* $\Delta t_{i\,max}$
Test pulse duration t_i	*Minimum test pulse duration* $t_{i\,min}$	-	*Maximum test pulse duration* $t_{i\,max}$
Test pulse interval T	*Minimum test pulse interval* T_{min}	-	*Maximum test pulse interval* T_{max}
Input capacitance C_i	-	-	*Maximum input capacitance* $C_{i\,max}$

Table 5-3: Manufacturer information interface type B – source

The user manual of a sink implementing interface type B shall provide additional data as follows:

Parameter	**min.**	**typ.**	**max.**
Test pulse delay Δt_i	*Minimum test pulse delay* $\Delta t_{i\,min}$	-	*Maximum test pulse delay* $\Delta t_{i\,max}$
Test pulse duration t_i	*Minimum test pulse duration* $t_{i\,min}$	-	*Maximum test pulse duration* $t_{i\,max}$
Test pulse interval T	*Minimum test pulse interval* T_{min}	-	*Maximum test pulse interval* T_{max}
Input capacitance C_i	-	-	*Maximum input capacitance* $C_{i\,max}$

Table 5-4: Manufacturer information interface type B – sink

Application notes

To verify the correct combination of signal sources (e.g., sensors in an application) and signal sinks (e.g., secondary control system), proceed as follows:

- Verification of interface types:
  - Source and sink shall be of interface type B.
- Verification of time parameters:
  - Comparison of the test pulse interval T (min. / max.) of the sink with that of the source. The permissible test pulse interval T of the source shall be in the specified range of the sink.
    - Comparison of the permissible (min. / max.) test pulse duration t_i of the source with that of the sink. Ideally, the test pulse duration t_i of the sink should be slightly smaller than the max. permissible test pulse duration of the source. The minimum required test pulse duration t_i of the source shall be considered.
    - The test pulse delay Δt_i of the source shall correspond to the permissible test pulse delay Δt_i of the sink.

Test pulse delays Δt_i of sources connected in series are additive. The test pulse delay Δt_i monitoring allows e.g., detection of incorrect wiring.

5.3 Interface type C

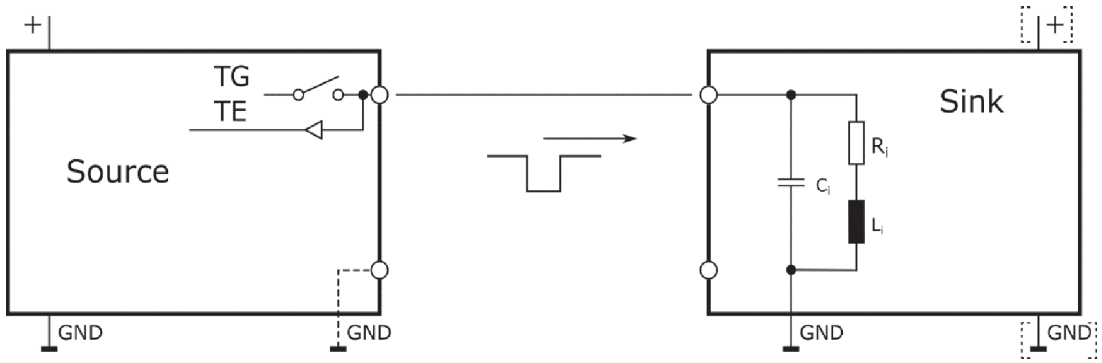

Figure 5-5: Interface type C

Description:

In the ON state, the source connects the supply voltage to the output. In the OFF state, the output is disconnected from the supply voltage.

In the ON state, the source transmits test pulses to the output. The correct function of the output is monitored in the source itself.

The sink shall suppress the test pulses of the source to prevent unintentional switching operations. The test pulse generation in the source, the test pulse transmission on the cable and the input circuit of the sink shall be matched to avoid an unintended fault reaction.

A source implementing interface type C itself detects failures of the output switching unit (e.g., in case of a stuck-at-fault).

Examples:

Interface type C is used as an "OSSD" output (Output Signal Switching Device) – e.g., safety outputs for light grids and proximity switches with defined behaviour under fault conditions as per EN 60947-5-3 etc. Source devices verify the function of their outputs with test pulses. Sink devices, e.g., control systems, relays or valves, shall not react to these test pulses. If devices have a sink and a source, series connections of devices are possible. Therefore, interface type C is often used for position monitoring.

5.3.1 Classes

Sources of interface type C are subdivided into classes according to the timing characteristics of the test pulses. When combining a source and a sink, it shall be ensured that the source always has the same or a higher class (i.e., shorter test pulses) than the sink.

Note 1: Verification of electric parameters: The limit values of the sink/source shall not be exceeded.

Note 2: The maximum load capacitances and inductances in the input of the sink shall not exceed the maximum values specified in the source. The parasitic capacitance and inductance per unit length of the cable should be taken into account.

5.3.2 Static characteristics of the interface type C

- The positive-switching output (P switch) of the source determines the switching status of the system.
- All signals of this interface type are referenced to the signal ground (GND).
- The electrical data for interface type C shall be based on IEC 61131-2:2017 and will not be further addressed here.

5.3.3 Dynamic characteristics of the interface type C

Test pulse duration t_i

The duration of the test pulses t_i transmitted by a source of a certain class shall not exceed the test pulse duration t_i specified in Table 5.5. Sinks of a certain class of interface type C shall not react functionally to the test pulses defined for this class as per Table 5.5.

- An interruption of the test pulses by the source due to further signal edges (e.g., for data transmission) is permissible. The time from the first switch-off until the last switch-on of the output is considered the test pulse length. A sink shall ignore any such interruptions within a defined test pulse duration.

Note 1: The test pulses shall be filtered out or suppressed in the sink to ensure that no functional influences occur. Flashing or dimming of an illuminated display indicating the input status is tolerated.

Note 2: The timing characteristics of the source's test pulses are influenced by the inductive and capacitive load of the cable and the sink. Knowing the size of these values in the sink and the maximum permissible values for a source is essential for users of type C.

It is recommended that the capacitive and inductive parts of the lines between the sink and the source are taken into account as they influence the signal quality. This is not topic of this paper.

Test pulse interval T

- Die Testimpulsdauer t_i sollte nicht mehr als 1 % des Testimpulsintervalls T betragen. Ist die Testimpulsdauer größer als 1 % des Testimpulsintervalls, so ist das Verhältnis t_i/T im Datenblatt explizit anzugeben.

Note: Sinks of a certain class of interface type C shall be designed so that the repeated test pulses in the intervals defined in Table 5.5 will not cause an impermissible drop of the energy level in the input (e.g., coils such as relays and valves).

5.3.4 Classification for interface type C (and D)

Parameter	Designation	Unit	Value		
			minimal	Nominal value	maximum
Class 0 (generic)					
Test pulse duration	$t_{i,0}$	µs	-		free*
Class 1					
Test pulse duration	$t_{i,1}$	µs	-		1000
Class 2					
Test pulse duration	$t_{i,2}$	µs	-		500
Class 3					
Test pulse duration	$t_{i,3}$	µs	-		100

*) to be specified individually for the individual device.

Table 5-5: Classification for interface type C (and type D)

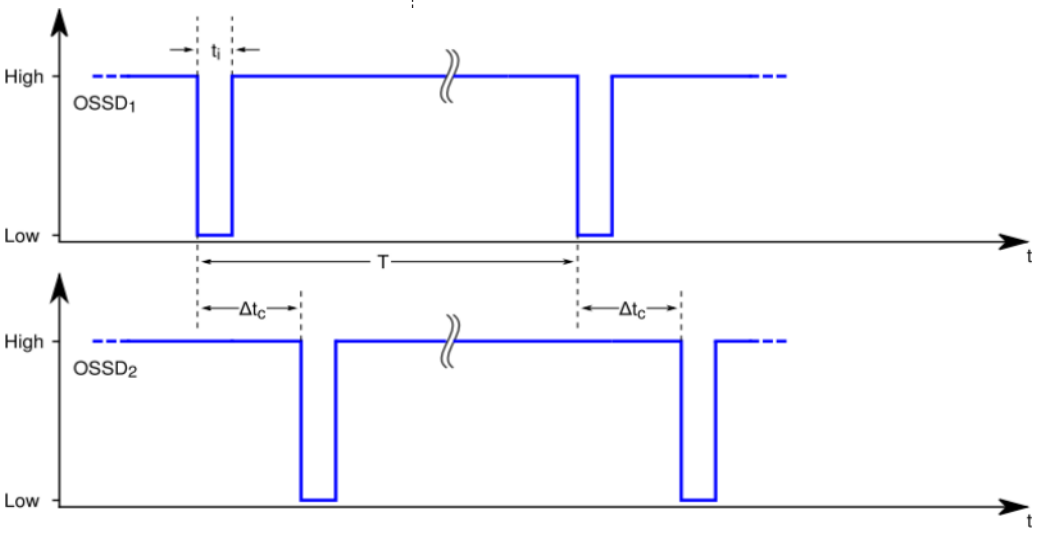

Figure 5-6: Dynamic behaviour interface type C

5.3.5 Application in the field of functional safety

In a safety application, a type C interface is designed with two channels and two separate OSSD outputs $OSSD_1$ and $OSSD_2$. For successful evaluation of the signals transmitted by the source in the sink, there are requirements for the interaction of the two OSSD outputs:

- Sequence of test pulses on the OSSD outputs
- Discrepancy time

5.3.5.1 Sequence of the test pulses

The test pulses are used for the detection of shortcuts between the OSSD outputs.

In addition, the test pulses can also be used to diagnose faults in the OSSD outputs themselves and to detect extraneous potentials on the outputs.

The following two approaches are recommended for the implementation of a two-channel system:

- Sources with test pulses occurring simultaneously
  - In these sources, test pulses occasionally occur simultaneously. The phase shift Δt_c is not defined. The maximum time until a cross-circuit is detected depends on how often test pulses occur simultaneously or overlap in time.
  - Simultaneous test pulses are initially indistinguishable from a switch-off for the sink. The sink must therefore tolerate simultaneous shutdowns at least for the class-specific test pulse duration t_i without recognizing a shutdown.
- Sources with test pulses occurring non-simultaneously
  - Test pulses must not occur simultaneously in these sources. A shortcut can be detected during the next test pulse.

- The phase shift Δtc should be at least twice as large as the test pulse duration ti defined for the class in order to enable a clear distinction in the sink.

Note: The sink can recognize a simultaneous switch-off of both OSSDs as a demand of the safety function even before the test pulse duration ti has expired and react on its own. In order to avoid entering a safe state by the sink, this property of the source must be explicitly specified. With this property of a source, the reaction time to a switch-off of the OSSD in the sink can theoretically be reduced below the test pulse duration t_i. In the event of an error, however, a single-channel switch-off will initially be interpreted as a test pulse, which increases the reaction time.

5.3.5.2 Discrepancy time Δt_{dis}

In a two-channel system, the sink must check the switching processes of the two OSSDs for simultaneity in order to detect errors. An excessive time offset between the switching times of the two OSSD outputs when switching on or off is detected by the sink as an error.

To ensure reliable operation, the maximum discrepancy time Δt_{dis} of a source must be specified as well as the maximum permitted discrepancy time in the sink. The discrepancy time tolerated by the sink must be higher than that of the source.

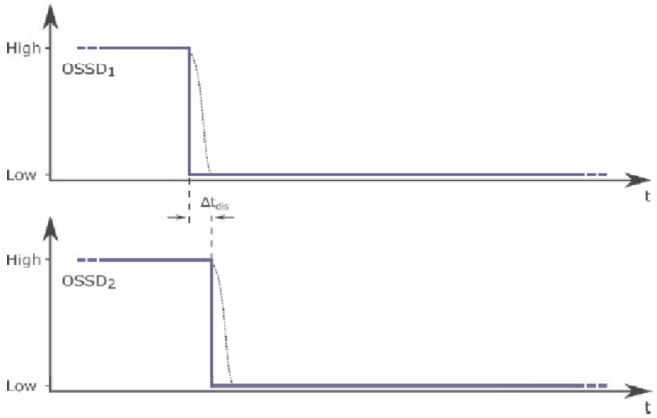

Figure 5-7: Discrepancy time Δtdis for interface type C – falling edge

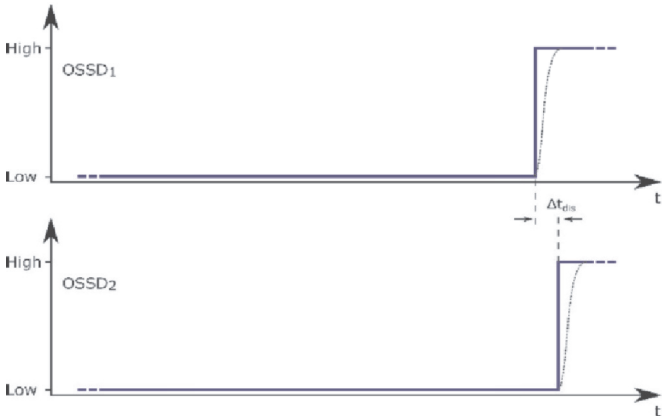

Figure 5-8: Discrepancy time Δtdis for interface type-C – rising edge

5.3.6 Product information of the manufacturer

The user manual of a source implementing interface type C shall provide additional data as follows (see also under 5.3.3):

Parameter	min.	typ.	max.
Class	*Indication of the class according to Table 5-5*		
Test pulse duration t_i	*Minimum test pulse duration t_{i_min} (*)*	-	*Maximum test pulse duration t_{i_max}*
Test pulse interval T	*Minimum test pulse interval T_{min} (**)*	-	
Rated current I_N	-	-	*Output current I_N*
Capacitive load C_L	-	-	*Maximum capacitive load C_{L_max}*
Inductive load L_L (*)	-	-	*Maximum inductive load L_{L_max}*

(*) = optional supplementary information provided by the manufacturer.

(**) = to be indicated by the manufacturer if t_i/T ratio is greater than 1%.

Table 5-6: Manufacturer information interface type C – source

The user manual of a sink implementing interface type C shall provide additional data as follows:

Parameter	min.	typ.	max.
Class	*Indication of the class according to Table 5-5*		
Test pulse duration t_i	-	-	*Maximum test pulse duration $t_{i\ max}$*
Test pulse interval T	*Minimum test pulse interval T_{min}*	-	
Input resistance R	*Minimum input resistance $R_{L\ min}$*	-	-
Input capacitance C_L	-	-	*Maximum input capacitance $C_{L\ max}$*
Inductance L_L (*)	-	-	*Maximum input inductance $L_{L\ max}$*

(*) = optional supplementary information provided by the manufacturer.

Table 5-7: Manufacturer information interface type C – sink

5.3.7 Application notes

To verify the correct combination of signal sources (e.g., sensors in an application) and signal sinks (e.g., control systems), proceed as follows:

1) Verify the interface types: Source and sink must both be an interface type C.

2) Verification of the class: The class of the sink shall correspond to the class of the source.

Note 1: The source shall have the same or a higher class than the sink. For example, a source of class 2 is compatible with a sink of class 1 or 2, but not with a sink of class 3.

Note 2: In the case of a generic source or sink, the manufacturer's specifications shall be compared. The maximum test pulse duration of the source shall not exceed the maximum test pulse duration of the sink.

Note 3: The guaranteed minimum test pulse interval of the source must be greater than the required minimum test pulse interval of the sink.

3) Verification of electric parameters: The load imposed by the sink shall not exceed the limits of the source.

Note 4: The maximum load capacitanc and inductanc for the input of the sink are those specified in the source. The parasitic capacitance and inductance per unit length of the cable should be taken into account.

5.4 Interface-Typ D

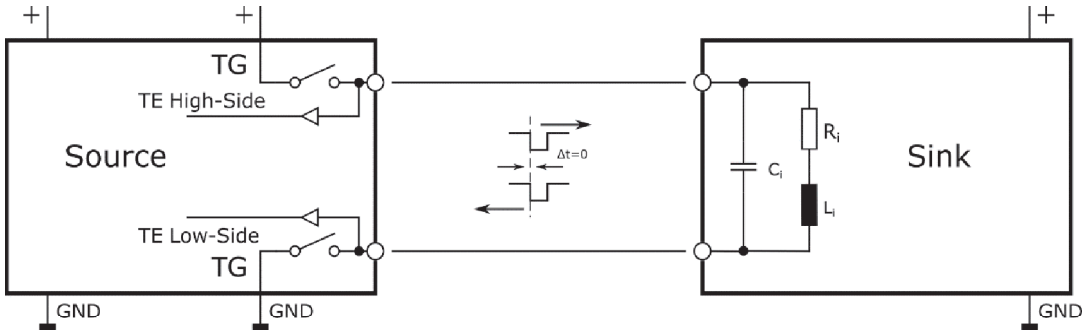

Figure 5-9: Interface type D

Interface type D is primarily used for the safe switching of actuators such as contactors, motors and valves, or for complete shut-down of the operating voltage of electric/electronic assemblies and devices. The major difference to the positive-switching output (P switch, see interface type C) is that the returning wire is also switched and tested, so that errors in the returning wire, such as short circuits to 0 V, can be detected. Vagabond voltages due to a shared but floating 0 V connection point will be prevented with this type of connection.

In addition, dual-channel switch-off is possible with 2 wires, preventing impermissible switching of the actuator due to a short circuit on one of the wires. For this purpose, the source transmits test pulses to the sink. The test pulses are analyzed by the source. The test pulses are neither distorted nor delayed by the sink.

The sink can have inductive, capacitive and resistive components, e.g. actuators such as valves, contactors, drives, but also complete devices. The source is typically a safety controller or a safety switching device with bipolar output.

5.4.1 Static characteristics of the source implementing interface type D

1) Die Quelle besitzt eine definierte Impedanz, die Teil der technischen Angaben sein muss. Sie schaltet eine Last in einem definierten Ausgangsstrombereich zweipolig (P, N) EIN bzw. AUS.

2) EIN-Zustand bedeutet, dass spätestens bei I_{max} der Quelle der Ausgangspegel für den EIN-Zustand der Senke erreicht werden muss. AUS-Zustand bedeutet, dass spätestens bei I_{min} der Quelle der Ausgangspegel für den AUS-Zustand der Senke erreicht werden muss.

5.4.2 Dynamic characteristics of the source implementing interface type D

1) Zur Quer- und Kurzschlusserkennung werden definierte Testimpulse generiert. Das Testimpulsintervall und die Testimpulsdauer sind anzugeben.

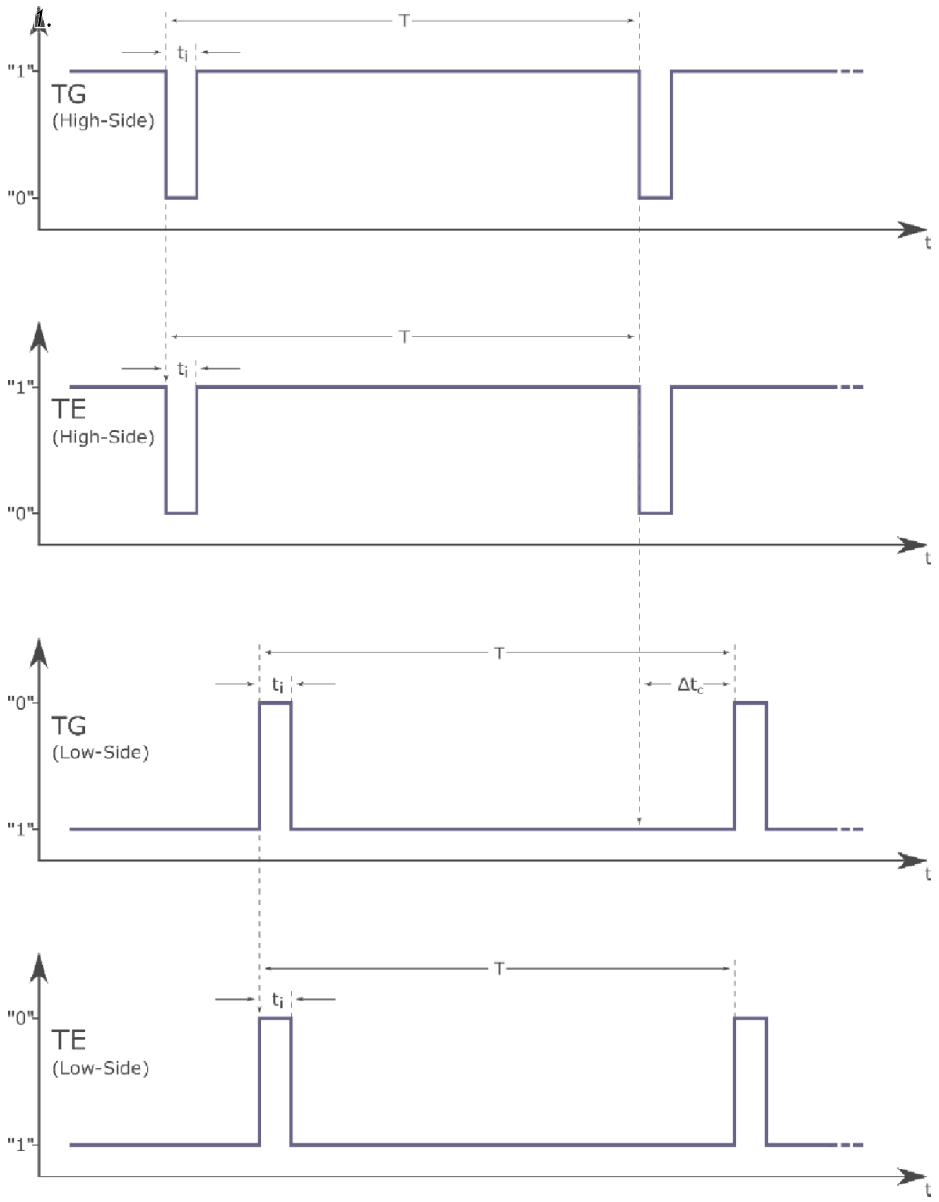

Figure 5-10: Dynamic behaviour interface type D

2) Cyclic testing causes additional power loss in the source and in the sink due to the dynamic charging and discharging of capacitances and inductances. Those parameters need to be defined for this interface type.

5.4.3 Product information provided by the manufacturer

The user manual of a source implementing interface type D shall provide additional data as follows:

Parameter	min.	typ.	max.
Class	*Indication of the class according to Table 5-5*		
Test pulse duration t_i	*Minimum test pulse duration t_i*	-	*Maximum test pulse duration t_i*
Test pulse interval T	*Minimum test pulse interval T_{min}*	-	-
Leakage current $I_{Leakage}$ of the output in OFF state	-	-	*Maximum output current $I_{Leakage}$*
Rated current I_N of the output in the ON state	-	-	*Rated current I_N*
Capacitive load C_L	-	-	*Maximum capacitive load C_L*
Inductive load L_L	-	-	*Maximum inductive load L_L*

Table 5-8: Manufacturer information interface type D – source

5.4.4 Classes

Devices implementing interface type D are subdivided into classes according to the timing characteristics of the test pulses. When combining a source and a sink, it shall be ensured that the source always has the same or a higher class (i.e., shorter test pulses) than the sink (see Table 5 5).

5.4.4.1 Static characteristics of a sink implementing interface type D

1) The sink has a defined impedance which shall be included in the technical data.

2) Special attention shall be payed on the required minimum current for the ON state and the maximum permissible leakage current for the OFF state. These parameters must be met by the source.

3) The sink shall provide the operating mode "bipolar disconnectable".

4) The sink must be able to be switched off utilizing two poles (e.g., no common 0 V connection to other sinks).

5.4.4.2 Dynamic characteristics of the sink of interface type D

1) If the sink allows defined test pulses from the source, the limit values for test pulse interval and test pulse duration shall be specified for the sink.

2) The inductive or also capacitive energies that are then recharged by the regular testing must be taken into account with regard to the permissible power loss of the source, but also of the sink, and shall therefore be defined for this interface type.

5.4.5 Product information provided by the manufacturer

The user manual of a sink implementing interface type D shall provide additional data as follows:

Parameter	**min.**	**typ.**	**max.**
Class	*Indication of the class according to Table 5-5*		
Test pulse duration t_i	-	-	*Maximum test pulse duration t_i at the input*
Test pulse interval T	*Minimum test pulse interval T_{min} at the input*	-	-
Input resistance R	*Minimum input resistance R_L*	-	-
Input current I_{ON} in ON state	*Minimum input current I_{ONmin}*	-	-
Input current I_{OFF} in OFF state	-	-	*Maximum input current I_{OFFmax}*
Input capacitance C_L	-	-	*Maximum input capacitance C_L*
Input inductance L_L	-	-	*Maximum input inductance L_L*

Table 5-9: Manufacturer information interface type D – sink

5.4.5.1 Classes

Devices implementing interface type D are subdivided into classes according to the timing characteristics of the test pulses. When combining a source and a sink, it shall be ensured that the source always has the same or a higher class (i.e., shorter test pulses) than the sink (see Table 5-5).

5.4.5.2 Application note

In order to ensure the OFF state of the sink, the maximum input current of the sink for the OFF state shall be greater than the maximum leakage current of the source.

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