IEEE 802.3dg Task Force

Hazardous Area Requirements including 2-WISE

Steffen Graber, Pepperl+Fuchs

PEPPERL+FUCHS

Goal of this Presentation

This presentation provides a summary of 2-WISE (IEC TS 60079-47) safety specifications to assist the IEEE P802.3dg Task Force in meeting their objective to “Do not preclude working within an Intrinsically Safe device and system as defined in IEC 60079.”

Hazardous Area Requirements

- There are different hazardous area requirements, depending on the level of protection (e.g. supported hazardous area zone), if a segment is a trunk or a spur and if a segment is powered or not.
- The following table summarizes the relevant standards (the IEC TS 60079-47 references the base standard IEC 60079-11):

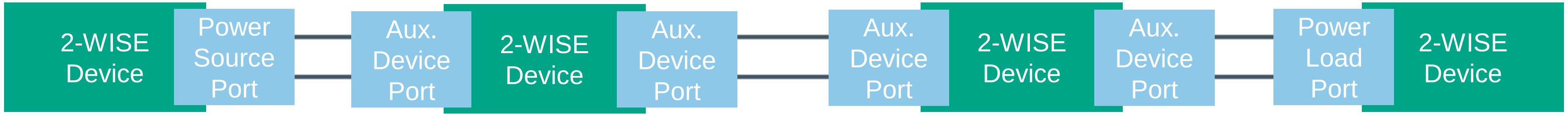
	Zone 2	**Zone 1**	**Zone 0**
Powered trunk	Ex ec (IEC 60079-7)	Ex eb (IEC 60079-7)	Not allowed
Communication only trunk	Ex ic (IEC TS 60079-47)	Ex ib (IEC TS 60079-47)	Ex ia (IEC TS 60079-47)
Powered spur	Ex ic (IEC TS 60079-47)	Ex ib (IEC TS 60079-47)	Ex ia (IEC TS 60079-47)
Communication only spur	Ex ic (IEC TS 60079-47)	Ex ib (IEC TS 60079-47)	Ex ia (IEC TS 60079-47)

- For **Ex i (intrinsic safety)** focus is on **limiting the maximum energy** to levels below the ignition energy of the gas atmosphere.
- Ex ic requires good industrial quality and design practices, Ex ib requires one component failure tolerance (2-times redundant electronics), Ex ia requires two component failure tolerance (3-times redundant electronics).
- For **Ex e (increased safety)** focus is on protection and ruggedness of the installation to **prevent the occurrence of a short or opening arc** using larger separation distances, specifically constructed contacts, and a rugged installation practice.
- Ex ec requires good industrial quality and smaller separation distances, Ex eb requires failure tolerance (e.g. related to contact failures inside a connector) and larger separation distances (e.g. 3.4 mm creepage for 63 VDC for a CTI value ≥ 175, 2.1 mm clearance), for Ex eb the connectors must be separately certified and are (pretty large) screw/spring type terminals.

2-WISE System

- Ethernet-APL spurs provide intrinsically safe powering and communication to a field device.
- Intrinsically safe Ethernet-APL is standardized in the **IEC TS 60079-47** and called **2-WISE** (2-wire intrinsically safe Ethernet).
- 2-WISE system with auxiliary device ports (e.g. surge protection) connected with short wires (stubs, ≤ 10 cm) to the cable:

- 2-WISE system with auxiliary device ports (e.g. surge protection) connected via a series connection in the cable:



- For the series connection the auxiliary device port is physically split into two terminals, but electrically connected through and therefore counted as one 2-WISE auxiliary device port per 2-WISE device.

2-WISE Power Source Ports

- A 2-WISE power source port can have a linear (resistively limited) or a non-linear (electronically limited) output characteristic.
- The maximum output voltage U_o shall be in the range of 14 V to 17.5 V.
- The maximum U_o is the sum of the DC supply voltage and the communication voltage.
- The maximum internal capacitance C_i of a 2-WISE power source port shall be ≤ 5nF.
- The maximum internal inductance L_i of a 2-WISE power source port shall be ≤ 10 µH.
- The capacitance and inductance values are the maximum allowed safety critical values, function wise the values need to be significantly lower, as otherwise the communication signal would be shorted or isolated.
- The maximum output current I_o for any 2-WISE power source port shall be determined in accordance with IEC 60079-11 and shall not exceed 380 mA.
- The maximum output power P_o shall not exceed 5.32 W (this is the theoretical maximum output power in case of failure conditions).
- The nominal output power is much less (e.g. for Ethernet-APL ≤ 0.54 W for power class A and ≤ 1.1 W for power class C).

2-WISE Power Load Ports

- 2-WISE specifies the following safety relevant input parameters for **powered 2-WISE load ports and auxiliary device ports**:

		2-WISE power load port	2-WISE auxiliary device port
Maximum input voltage	U_i	17.5 V	17.5 V
Maximum input current	I_i	380 mA	380 mA
Maximum input power	P_i	5.32 W	5.32 W
Maximum internal capacitance	C_i	5 nF	5 nF
Maximum internal inductance	L_i	10 µH	200 nH
Maximum leakage current		1 mA	50 µA

- The output parameters U_o, I_o and P_o of the 2-WISE power source port must be below or at maximum equal to the input parameters U_i, I_i and P_i of the 2-WISE load ports.
- The power load port and auxiliary device port must always be passive and are only allowed to feed back the leakage current to the segment; the internal capacitance and inductance values are the maximum values being visible at the port connector.
- The U_o, U_i values are the sum of the DC supply voltage and the clamped communication signal on top of the supply voltage.

2-WISE Communication Only Ports

- Additionally to the powered ports 2-WISE also supports intrinsically safe communication only ports with the following parameters:

Parameter		Value
Maximum output voltage	U_o	9 V
Maximum output current	I_o	112.5 mA
Maximum output power	P_o	254 mW
Maximum input voltage	U_i	17.5 V
Maximum input current	I_i	380 mA
Maximum input power	P_i	5.32 W
Maximum internal capacitance	C_i	5 nF
Maximum internal inductance	L_i	10 µH

- The U_o, I_o and P_o values are chosen so that a parallel or series connection of two communication only ports does not lead to critical energies in the 2-WISE system.
- As both communication only ports can provide energy, the output parameters are significantly lower than for a powered port.

2-WISE Cable Parameters, Isolation and Shield Grounding

- The cable used in a 2-WISE system must comply with the following parameters:
  - Cable resistance per unit length R_C: 15 Ω/km to 150 Ω/km
  - Cable inductance per unit length L_C: 0.4 mH/km to 1 mH/km
  - Cable capacitance per unit length C_C: 45 nF/km to 200 nF/km
- These parameters are the limiting factors related to intrinsic safety, the functional parameters typically have a smaller tolerance range.
- The cable isolation voltage must be at least 500 V AC between the wires and the cable shield (see IEC 60079-11:2011, chapter 6.3.13).
- The cable shield is either directly grounded on both sides (if there is a good potential equalization available) or on one side directly grounded and on the other side capacitively grounded using a 3 to 10 nF capacitor between the shield and ground (see Ethernet-APL Port Profile Specification, https://www.fieldcommgroup.org/technologies/ethernet-apl/apl-specifications).

Communication Signal Requirements – Unpowered Ports

- For unpowered **communication only ports**, there is pretty **much headroom for the communication signal**.

- The maximum allowed output voltage U_o is **±9 V** including all BLW/droop effects.
- As the BLW/droop can double the peak-to-peak communication voltage in the worst case, the **supply voltage** of the PHY/communication circuit (and all I/O signals to/from other circuit parts) can be **limited to less than e.g. 4 V to 4.5 V** and the output voltage will stay below the maximum allowed 9 V peak.

- The **current limitation can be done resistively** as the termination resistors are in series with the PHY driver circuit.

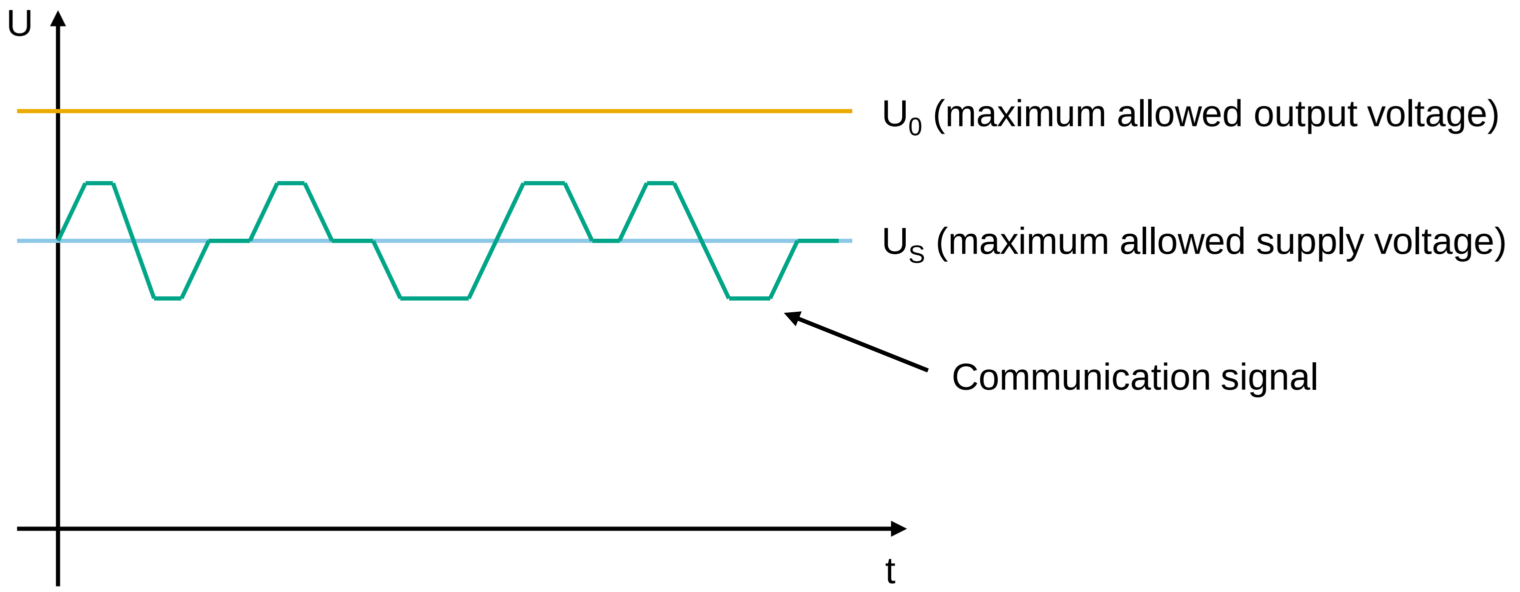
- As there is also no power coupling circuit, limiting the **BLW/droop is not one of the main targets**.

Communication Signal Requirements – Powered Trunk (Ex e)

- **For Ex e trunks no tight voltage limitation is required**, as installation measures prevent opening or closing arcs.
- Thus from **hazardous area** point of view **no specific measures** related to signal amplitude limitation as well as BLW/droop limitation are required.
- Nevertheless, due to the inductive power coupling there are boundaries for the low frequency content of the communication signal as for non-hazardous area applications, too.

Communication Signal Requirements – Power Spur (Ex i)

- For **powered spur ports** using protection method Ex i (intrinsic safety) there are **additional requirements** related to **BLW/droop limitation**.
- The maximum output voltage U_o of 17.5 V is the **sum of the DC supply voltage and the communication signal**.
- Therefore the communication signal needs to be **tightly limited** to allow to maximize the DC supply voltage and thus to **maximize the possible energy supply** for a field device.



- The requirements related to signal amplitude and BLW/droop limitation are very similar as those for 10BASE-T1L (reduced transmit amplitude and a tightly controlled BLW/droop).

Communication Signal Requirements – Power Spur (Ex i)

- Supporting intrinsically safe 200 m spurs by clamping the communication signal would mean for a 100BASE-T1L PHY that:
  - The signal amplitude will need to be limited to approx. 1.0 V_{pp} with low tolerance (e.g. 1.05 V_{pp} max).
  - The droop will need to be limited to low values (e.g. 10 %).
  - To limit the droop we likely need a controlled disparity or something similar in combination with relatively large inductance values.
  - External termination/hybrid resistors will be necessary to limit the current to/from the PHY IC.
  - As for 10BASE-T1L all these measures depend on how the clamping of the communication signal is done to limit the maximum output voltage U_o to less than 17.5 V.
- Alternatively to a strict clamping of the communication signal, as done for 10BASE-T1L intrinsically safe implementations, the overshoot energy would need to be safely limited:
  - This would allow for short times a larger than average output amplitude, e.g. if specific data patterns would lead in rare conditions to a larger BLW/droop and the overall signal amplitude could also be higher, as there would be no need to stay away from the clamping voltage of the diodes to reduce the non-linear signal distortion.
  - The inductance value of the power coupling circuit must be such small that the stored energy is low enough (e.g. 2-WISE allows a maximum unclamped internal inductance of 10 µH, which could be used for the power coupling inductor, but is still relatively small).
  - As hydrogen gas, which is most critical, e.g. has an ignition energy of about 40 µJ, likely larger inductors in the range of 100 µH @ 100 mA (0.5 µJ << 40 µJ) should be possible to get into a reasonable range, but this would require an adaption of the 2-WISE standard.

Communication Signal Requirements – Power Spur (Ex i)

- The IEC 60079-11 standard (see annex E) allows a maximum overshoot energy (single event) of 20 µJ (gas group IIC) for crowbar voltage limiting circuits.
- Depending on discussions with the notified body, which certifies the device, it can be possible to also assign this overshoot energy to other implementations, but there might be a different view from different notified bodies.
- From these 20 µJ typically a larger part is already used up by the reaction times (typ. 2 - 3 µs) of the electronic voltage and current limitation circuits.
- Therefore an overshoot energy of about 1 - 5 µJ could in principle be used for the communication signal exceeding its steady state limits, as long as these are single/rare events (the influence on the average signal energy must be negligible, which means that the duration between such events must be significantly longer than the overshoot event duration, a spark typically needs about 10 µs to fully evolve, so the pause in between the events should be >> 10 µs to be able to view the overshoots as single events).
- Going into this field needs a liaison or more likely cooperation with the IEC 60079-11 and IEC 60079-47 maintenance teams and interested notified bodies as especially going into dynamic arc behavior is still a field of research and not expressed in the actual standards.

- One important thing to mention is that the clamping circuit in the current intrinsically safe 10BASE-T1L applications limits the output voltage independent from internal failures of the PHY IC.
- Therefore in current Ex ia/ib implementations the 10BASE-T1L PHY IC itself is not safety relevant in the sense of limiting the output voltage.

Communication Signal Requirements – Power Spur (Ex i)

- This is different, if we cannot rely on an external (diode) clamping circuit.
- As for Ex ia/ib implementations component failures have to be assumed, in such a case the PHY IC must be able to guarantee under the failure assumptions of IEC 60079-11, that in no case a larger energy/voltage as expected is provided.
- This would mean:
  - The overshoot energy of a single rare event must be limited to the stated values also in case of internal device failures happening.
  - There may be no failures, where the single events happen in a faster than stated repetition rate, if this would increase the output energy above the stated limit.
  - As internal distances in a chip are very small, a short between signals inside the IC could not be avoided from a safety point of view.
  - Therefore very likely additional redundant components for external supervisory/limiting of the transmit signal amplitude and energy in case of a PHY IC failure would be required.

Thank you!