Designing intrinsically safe circuits

Safe and effective measurement technology for potentially explosive areas (Ex areas)

The intrinsic safety (Ex i) type of protection has established itself worldwide in the field of measurement and control technology in systems with potentially explosive areas. For one thing, it is much more cost-effective when it comes to construction when compared to other types of protection. For another, it allows for maintenance work and modifications during operation. Moreover, it is also possible to use simple electrical equipment without special approval (lead image).

Lead Image

The protection principle behind the Ex i type of protection is based on limiting the energy that is being conducted in the potentially explosive area and that can be stored there. This means that the energy from any potential spark is always less than the minimum ignition energy of the surrounding potentially explosive atmosphere. In addition, it prevents the creation of any

impermissible hot surfaces that could cause an ignition, such as electronic components. As opposed to all the other types of protection, Ex i refers not only to a single item of equipment but to the entire intrinsically safe circuit, in accordance with EN/IEC 60079-11.

Special significance of the Ex i isolators

Intrinsically safe circuits are generally composed of the following elements:

- the intrinsically safe equipment, that is, a consumer installed in the Ex i area (e.g., an Ex i temperature transmitter)
- the associated equipment, which involves a source in the non-Ex i area (Ex i isolator)
- the connecting line (cable).

The Ex i isolators are especially important here. In accordance with EN/IEC 60079-0 and -11, they provide the intrinsically safe circuit with galvanically safe isolation from all other non-intrinsically safe circuits and are therefore an absolute necessity in every Ex i MCR circuit. Moreover, they limit the energy conducted to the Ex area, i.e., the maximum off-load voltage U_o, the maximum short-circuit current I_o, and the maximum power P_o, to a non-incendive level. At the same time, via C_o und L_o, they determine which maximum additional energy storage elements – concentrated capacitance C_i and concentrated inductance L_i in the field device, line capacitances C_c and line inductances L_c – can be connected without jeopardising the intrinsic safety of the circuit.

Another important aspect of the Ex i type of protection is the reliability of the energy limitation itself under the assumption that certain faults will occur. For that reason, intrinsically safe electrical equipment and the Ex i-related switching parts of the associated equipment are designed in accordance with the required reliability and divided into different protection levels, which in turn are aligned with different zones in the Ex area. The Ex ia level of protection (double-fault tolerance) is suitable for use in Zone 0 (and therefore in Zones 1 and 2 as well), the Ex ib level of protection (single-fault tolerance) for use in Zone 1 (and therefore in Zone 2 as well), and the Ex ic level of protection (zero-fault tolerance) only for use in Zone 2.

Combining Ex i field devices and isolators from different manufacturers

To ensure that the respective connection cannot produce incendive sparks and hot surfaces, the user or system operator has to demonstrate and document “proof of intrinsic safety.” This is laid out in the ATEX Directive RL 1999/92/EC and the BetrSichV or the new GefStoffV and

described in the standardisation requirements for electrical explosion protection (e.g., EN/IEC 60079-14). This process offers the user the advantage of being able to select and combine Ex i field devices and isolators from different manufacturers in accordance with the specific requirements.

Figure 1 shows an intrinsically safe circuit marked in blue consisting of an associated item of equipment (source) with a linear or ohmic source characteristic curve, an intrinsically safe item of equipment, and the connecting cables (Figure 1). The figure also shows the safety technology parameters necessary for demonstrating intrinsic safety, along with the criteria that must be met to ensure the circuit is actually intrinsically safe. The parameters can be found in the EU examination certificates and user guides or data sheets.

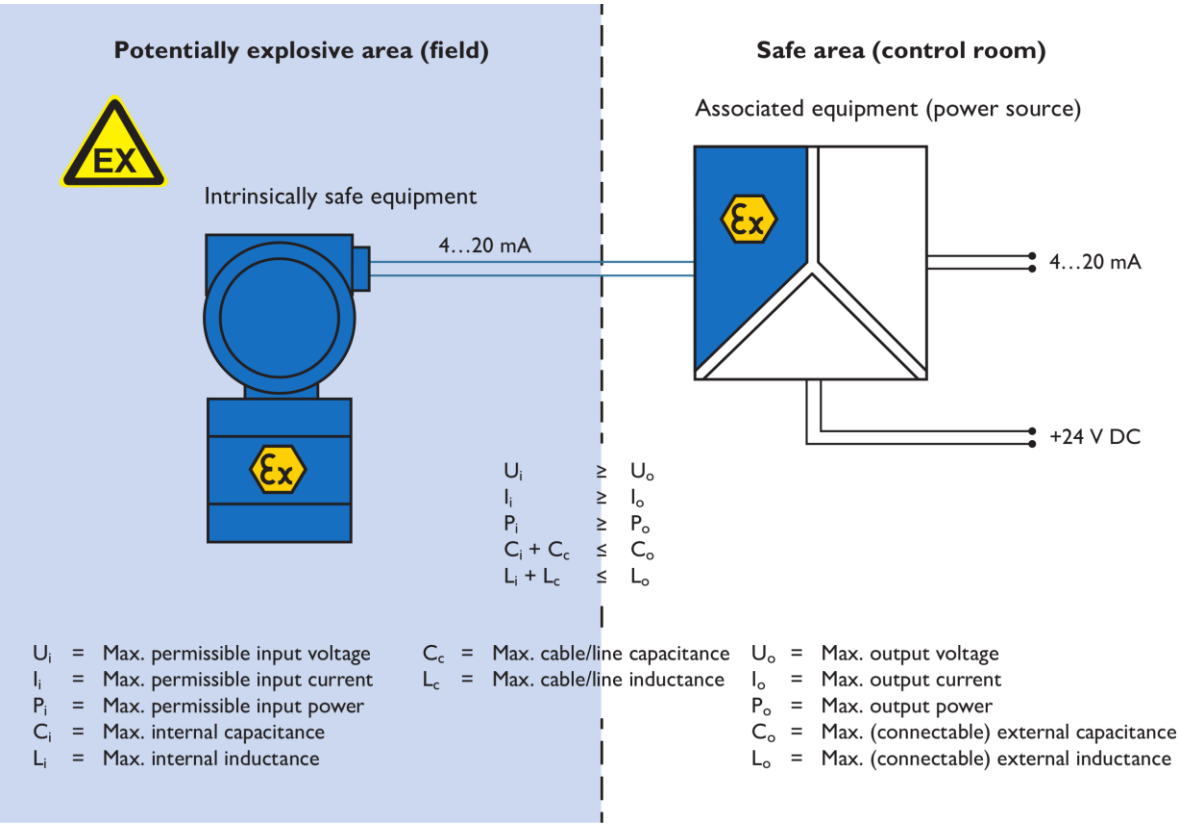

Figure 1 - Parameters and criteria of an intrinsically safe circuit

In accordance with the current versions of DIN EN 60079-11 and the DIN EN 60079-14 construction standard (VDE 0165-1), an evaluation must also be carried out to determine whether the 50-percent rule must be used. This is because the certified C_o and L_o values for the associated equipment may only be fully utilised in the following cases:

- in simple intrinsically safe circuits with no concentrated capacitances (= C_i) and no concentrated inductances (= L_i)
- in a mixed intrinsically safe circuit with concentrated capacitances and/or concentrated inductances on condition that L_i < 1% of L_o or C_i < 1% of C_o.

If $L_i \geq 1\%$ of L_o and $C_i \geq 1\%$ of C_o in a mixed intrinsically safe circuit, the certified C_o and L_o values must be reduced by 50 percent. In this case, the following applies:

$$C_i + C_C \leq 0.5\ C_o$$

$$L_i + L_C \leq 0.5\ L_o.$$

For this situation, there are in some cases – such as with the MACX MCR-EX product line – C_o and L_o value pairs available that have been specially derived from the testing sites that are greater than the half-value by up to a factor of 1.5.

Example of proof of the intrinsic safety of a temperature measurement circuit

In process engineering applications, process variables such as temperature, pressure, flow rate, moisture, or pH value in the Ex area are collected by intrinsically safe measuring transducers (transmitters) and converted into a 4…20 mA standard electrical signal. Of these, temperature is certainly one of the most frequently measured physical variables. For that reason, we have provided an example below showing how to verify the intrinsic safety of an intrinsically safe temperature measurement circuit up to Ex Zone 0 for a potentially explosive atmosphere resulting from a hydrogen/air mixture. The Ex i measurement circuit consists of an interconnection between a MACX MCR-EX-RPSSI-I repeater power supply as the active associated equipment item with a linear source characteristic curve and two passive intrinsically safe items of equipment: an FA MCR EX-HT-TS-I-OLP temperature transmitter and an FA MCR-EX-DS-I-I process indicator (Figure 2).

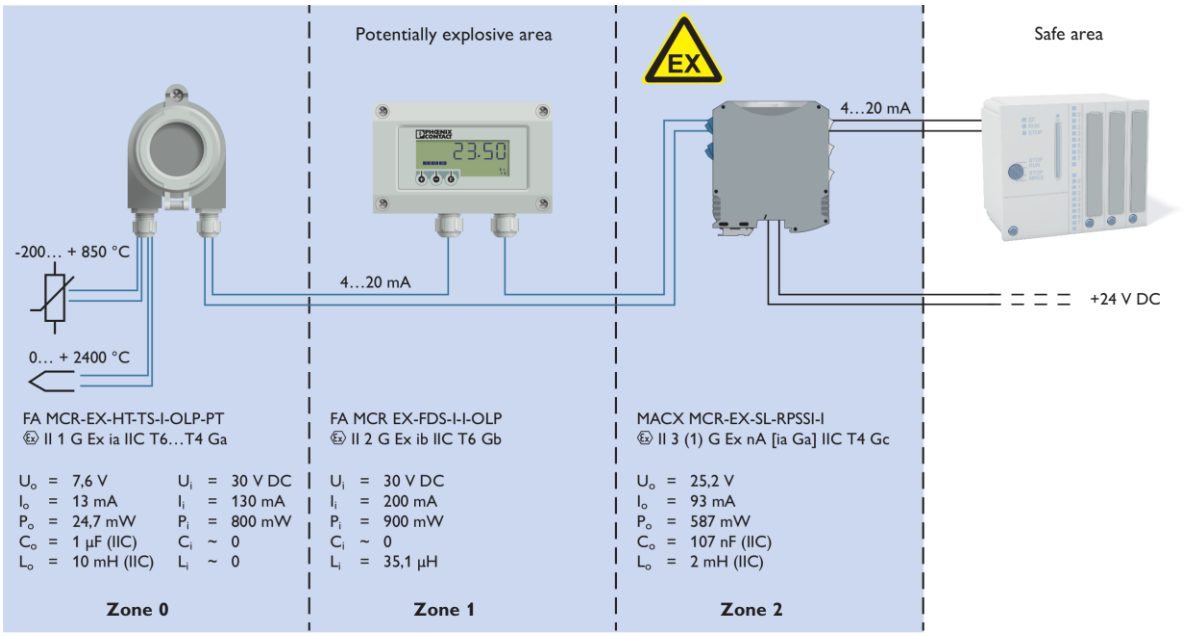

Figure 2 - Example of an intrinsically safe temperature measurement circuit

The following criteria must be met to demonstrate intrinsic safety:

- The Ex ia levels of protection for Zone 0 and the categories must match the zones. This criterion is met by the indication in the EU examination certificate for the field display that the device can be used within an Ex i circuit with level of protection ia without this affecting its level of protection.
- The material groups match.
- All Ex i devices are approved for a hydrogen/air mix Ex atmosphere in accordance with the IIC marking. The same applies for temperature class T4, so that this demand has also been met.
- The five criteria listed in Figure 1 for comparing Ex i criteria have been met. This precondition is met according to the Ex i parameters shown in Figure 2. In addition, we are dealing with a mixed Ex i circuit for which there is no need to use the 50-percent rule. Only the process indicator has a concentrated inductance of 35.1 µH. Therefore, based on calculations, a cable length of 750 meters is possible with a specific cable capacitance C_c of 140 nF/km and a cable inductance L_c of 1 mH/km with a C_o value of 107 nF, and a cable length of 1964.9 meters is possible with an L_o value of 2 mH and a C_i value of 35.1 µH.

This interconnection is therefore intrinsically safe with a cable length of up to 750 meters.

The proof of intrinsic safety described above must be implemented separately for the interconnection of the field-side connections of the head-mounted transducer with the thermocouple and the resistance temperature detector (RTD).

Simple electrical equipment

Thermocouples and RTDs are considered “simple electrical equipment” according to EN 60079-11. This means that, as an alternative, temperature sensors can also be used without approval. In this case, however, the user must ensure that the thermocouples and RTDs meet the characteristics specified in EN 60079-11 regarding energy storage and construction specifications. Moreover, the user must determine the surface heating of the devices via the P_o value in order to assign them a temperature class.

Additional consideration of functional data

When choosing devices, the dimensioning of the functional data must be taken into consideration along with the proof of intrinsic safety. For example, the MACX MCR-EX-SL-

RPSSI-I repeater power supply provides the FA MCR EX-HAT-TS-I-OLP temperature transmitter with a supply voltage of 16 V at 20 mA. The temperature transmitter in turn requires a feed voltage of at least 11 V DC. The slight voltage drop for the FA MCR EX-DS-I-I process indicator of < 1 V (< 1.9 V with HART) proves beneficial, because the feed voltage for Ex i sources is smaller than for non-Ex i devices. Consequently, 3.1 V are still available for a line-related voltage drop and as a reserve.

Multiple approvals for maximum flexibility

Innovative Ex i isolator ranges such as the 12.4 mm narrow MACX MCR Ex stand out, thanks to their ideally coordinated I_o, U_o, and P_o values, making them compatible with a large number of Ex i field devices. While developing the product range, importance was also placed on the highest possible C_o values, given that this is an essential parameter for determining the maximum viable cable length (Figure 3).

Figure 3 - MACX Analog Ex: comprehensive product range with 12.5 mm overall width

The Ex i isolators of the MACX MCR Ex series are approved according to the current ATEX directive 2014/34/EU and the corresponding harmonised standards for explosion protection with Ex II(1)G [Ex ia Ga]IIC and Ex II(1)D [Ex ia Da]IIIC marking for Ex i circuits up to Ex zone 0 (gas) and Ex zone 20 (dust). They can therefore also be used in all Ex zones for all material groups, giving them a high degree of flexibility. Furthermore, MACX devices can be installed in Ex zone 2 according to the Ex n type of protection, which makes them easier to use in decentralised automation concepts. Other international approvals such as IECEx, EAC, and UL are prerequisites for their use in applications across the globe.

Functional safety up to SIL 2 or SIL 3

If an MCR signal within the Ex system structure is part of the protection level, the system operator must, in addition to the proof of intrinsic safety, carry out a qualification of signal transmission with regard to availability and quality. This is why the MACX MCR-… Ex i series of isolators and the FA MCR… process indicators and field devices have been developed for use in safety-oriented circuits in accordance with EN 61508. Independent testing sites have certified them for use in applications up to SIL 2 or SIL 3.

Narrow overall width of only 12.5 mm

In addition to the Ex i repeater power supplies described above, the portfolio also includes the Ex i MACX MCR-EX-SL series of isolators for analogue input signals in versions with two galvanically isolated 4…20 mA outputs (signal duplicator) and two-channel designs. In the case of the signal duplicators, users can choose between versions where either both 4…20 mA outputs forward the HART signal or the second output filters out the HART signal. This turns out to be important for inputs with high sensitivity. For processing all of the other signals relevant for MCR technology - such as thermocouples, RTDs, analog output signals (e.g., for controlling proportional valves), binary input signals from NAMUR sensors or switching contacts and binary outputs for actuating On/Off valves and alarm transmitters - the MACX MCR-EX-SL series of Ex i isolators offers a comprehensive and thorough functional spectrum of Ex i isolators, signal duplicators, measuring transducers, and limit switches.

These devices are ideal for all single- and two-channel designs, thanks to, among other things, their overall width of only 12.5 millimetres. This saves users up to 45 percent more space compared to the sizes generally available on the market. The compact design is made possible, thanks to a patented transducer and circuit design with low power dissipation. At the same time, the lack of electrolytic capacitors in the circuit design contributes to a longer service life with consistently good transmission accuracy of typically 0.05 percent of the final value.

Loop-powered temperature transmitters with extended diagnostic functions

Figure 4 - Devices from the MCR Field Analog product range

With its continually expanding Field Analog product range, Phoenix Contact also provides field devices such as transmitters for temperature sensors and process indicators. The new loop-powered temperature transmitters can be used to process two thermocouples or RTDs and to convert them to a scalable 4…20 mA or HART signal. Functions available as options include mean-value generation, comparison, subtraction, or sensor backup. In addition, up to four values that can be freely adjusted can be forwarded to the downstream peripherals via the HART protocol. The temperature transmitter delivers a convincing level of high accuracy, reliability, and long-term

stability, along with enhanced diagnostic functions via HART or the programming interface. This device comes in two different designs: a housing for DIN rail mounting and for installation in a form B connecting head according to DIN 50446 (Figure 4).

Multifunctional process indicators in different degrees of protection

These loop-powered, HART-compatible process indicators enable flexible display of the measured values so that the data can be scaled and visualised in the required units. Because the devices have been designed as HART masters, users can now benefit from previously unused HART functionality. Now, up to four additional measurement values can be shown on the display using the HART protocol.

Multifunctional process indicators combine the features of classical signal conditioners with the advantages of flexible display devices. The multifunctional input can be used to capture different analogue values, such as current, voltage, thermocouples or RTDs. The input additionally supplies voltage to the sensor, if required. The two relay outputs can be used for different limit value switching functions, while the signal is transmitted to downstream systems via the analogue output. Thanks to flexible setting options, the display can also be adjusted to meet all the requirements of the user. Indication of the measured values can be scaled as desired, and the signal can be transmitted together with the desired unit or the measuring point designation. Both the multifunctional process indicators and the HART-compatible process indicators are available with IP20 and IP66 degree of protection.

Summary

Whether a painting system or a refinery, plastics processing or the chemical industry: thanks to their features, the MACX isolators and Field Analog devices are proven cost-effective solutions when it comes to explosion protection and system safety. They offer planners and system operators a high degree of long-term flexibility, efficiency, and availability.
Figure 4:

More information:www.phoenixcontact.co.uk

If you are interested in publishing this article, please contact Becky Smith: marketing@phoenixcontact.co.uk or telephone 0845 881 2222.