SIEMENS

SIMATIC S5

Ex I/O: S5-100U

Manual

Part 1 / Part 2

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Part 1: General Notes on Explosion Protection

Contents

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Abbreviations

ANSI	American National Standards Institute
BAM	Federal Institute for Materials Testing
BVS	Mines Testing Station in Dortmund-Derne
CENELEC	European Committee for Electrotechnical Standardization
EC	European Community
ElexV	Regulations for electrical equipment in hazardous areas
EN	European standards
ET	Electronic terminator
EX-RL	Guidelines for avoiding the hazards of an explosive atmosphere, explosion-protection guideline
Ex Vo	Regulations for electrical equipment in hazardous areas
FM	Factory Mutual
IEC	International Electrotechnical Commission
MESG	Maximum experimental safety gap
MIC	Minimum igniting current
NFPA	National Fire Protection Association
PA	Equipotential bonding conductor
PE	Protecting earth (ground)
PII	Process input image
PIQ	Process output image
PLC	Programmable logic controller
PTB	Physikalisch-Technische Bundesanstalt in Braunschweig
SEV	Swiss Electrotechnical Association
TRbF	Technical rules for flammable liquids
TÜV	Technical Inspectorate
UL	Underwriters’ Laboratories
UVV	Accident prevention regulations
VbF	Regulations for flammable liquids
VDE	German Association of Electrical Engineers
VwV	Statutory rules

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Foreword

Summarized in this guide are instructions and information on the planning, installation and operation of SIMATIC Ex modules when setting up automation systems for the open and closed-loop control of equipment in hazardous areas.

> ## Note
>
> If you are not yet familiar with the **User Safety Instructions and the Guidelines for Handling Electrostatically Sensitive Components and Modules (ESDs)**, you should read them before referring to this guide. By carefully reading and observing the guidelines, you can avoid the risk of personal injury and damage to the system, before and during operation.

This guide consists of two parts:

- a general part (Chapters 1 - 8 and appendices)
- and a SIMATIC Ex module-related part (Chapters 9 - 12 and appendices).

The guide is intended for planners, installers, designers and users of SIMATIC S5 and TELEPERM M systems.

The following table shows which chapters relate to particular task areas, i.e. it informs the user of the chapters in Part 1 which are important for him.

Task Areas	**Chapters**							
	Chap.1	Chap.2	Chap.3	Chap.4	Chap.5	Chap.6	Chap.7	Chap.8
Planner/Designer	1	2.1 to 2.3	3.1 to 3.4	4	5	6	7	-
Installer	1	-	-	-	5	6	-	8.1 to 8.8
User	1	2.4	-	-	5	-	-	-

The trend today is for the increased use of electrical apparatus in systems for measurement, open and closed-loop control, particularly within the scope of automation and rationalization in the chemical, petrochemical and process engineering industry. For such areas, in which explosive gas/air or dust/air mixtures can occur, electrical apparatus with which sparks or dangerous temperatures can develop in normal operation or during a malfunction, forms a potential hazard, the result of which can be serious injury and damage.

Protective measures to avoid these hazards have therefore been developed in many countries. Their international convergence requires a standardized international harmonization of protective measures.

The first (general) part of the manual is intended for technicians and engineers who are involved in the planning, installation and operation of measurement and control systems in explosive atmospheres. However, sales engineers and other interested specialists are also offered a summary of the subject, starting with an introduction to the problems of explosion protection; it is therefore an overview of the status of explosion protection both nationally and internationally.

Defined in the first chapter is the scope of coverage of this documentation with regard to explosions and the use of electrical apparatus in potentially explosive atmospheres. Basic terms relating to explosion protection are explained. In general, this documentation only covers electrical apparatus for hazardous areas (explosion Group II). Apparatus for mines susceptible to firedamp (explosion Group I) is not discussed.

Chapter 2 contains the legal principles of explosion protection; the main features of nationally applicable regulations and guidelines are discussed, starting with a brief historical consideration of the development for the Federal Republic of Germany. Summaries of the currently valid standards and regulations as well as existing testing stations within and outside the EC are given.

The usual measures for primary explosion protection are explained in Chapter 3.

The following explanations relate to secondary explosion protection. The basic zone classification for hazardous areas are presented first, to allow the subsequent discussion of the required measures for explosion protection for installers and users.

Since the emphasis of this manual lies in the consideration of intrinsic safety "i" as the type of protection and therefore its application to measurement and control systems in hazardous areas, a detailed introduction to this type of protection and therefore to the design of an intrinsically safe electrical circuit is given.

The subsequent overview of safety characteristics represents the basis for the classification of electrical apparatus according to explosion groups and temperature classes.

Presented in Chapters 1 to 4 is the necessary knowledge to be able to understand the classification of explosion-protected electrical apparatus in Chapter 5.

The in-depth discussion of intrinsic safety "i" as the type of protection in Chapter 6 is the central point of this documentation. It serves as the basis for the classification and interconnection of electrical apparatus, right up to applications in the field. Segregation between intrinsically safe and non-intrinsically safe circuits plays an important part.

The wide-ranging exposition of the problems of explosion protection in previous chapters are then followed by Chapter 7, which explains the nationally applicable regulations and requirements for the installation and operation of electrical systems in hazardous areas.

Finally, it should be noted that the general part of the manual (Chapters 1 to 8) covering the problems of explosion protection is intended to provide an extensive introduction to the topic; there is no suggestion, however, that the reader dispense with a study of the original documents, particularly with regard to the legal principles, as well as more detailed literature.

1 Introduction to Explosion Protection

Figures

1 Introduction to Explosion Protection

1.1 Explanation of Terms

Explained in the following are the main terms used in this documentation. The official definition of these terms can be found in **ElexV /1/ (in German: Regulations for electrical systems in hazardous areas).**

Area

Within the scope of explosion protection, industrial premises in which the assessment of explosion hazard is made, are considered on the basis of

- the physical and chemical principles of explosion protection;
- the safety characteristics of an explosive atmosphere;
- the operational and local circumstances.

In the VDE regulations, **industrial premises** are considered to be an outdoor location or a room serving for any business operations and regularly accessible to untrained persons. "Outdoor locations" or the word "room" is intended to mean a generally limited volume which, in turn, can be subdivided into zones (see Section 4.1) of different levels of danger with respect to explosion protection. The word **area** is used in the following as a synonym for industrial premises, according to international and other German regulations.

Explosion

This covers **explosions** which, by definition, cause an exothermic reaction (i.e. with heat emission) in explosive mixtures or explosive atmospheres; this reaction takes place on account of the temperature rise caused by the released heat, with a high velocity (order of magnitude m/s) and sudden pressure and report.

In contrast, there is a **deflagration if the propagation rate of the reaction is in the cm/s region. If the reaction takes place with an extremely high pressure and report and with a velocity of some km/s it is known as a** detonation.

Hazardous area

This is an area in which there may be a risk of explosion or dangerous, explosive atmosphere on account of the local and operational circumstances.

Electrical apparatus

This is understood to mean all the system sections serving entirely or partly for the application of electrical power. It includes, amongst other items: system sections for generating, conducting, distributing, storing, measuring, regulating, converting/transforming and consuming electrical power. Electrical systems are formed by interconnecting electrical apparatus.

1.2 Explosive Atmosphere

An **explosive atmosphere is a mixture of air and flammable gases, vapors, mist or dusts which can ignite in a suitable concentration under atmospheric conditions, and with which a combustion is** self-propagating **after ignition from the ignition source. The atmospheric conditions applying are a total pressure of 0.8 bar to 1.1 bar and mixture temperatures of -20 ^{o}C to +60 ^{o}C.**

For an atmosphere to be potentially explosive and its ignition, the following aspects must be considered:

- Degree of dispersion of the flammable substances
- Concentration of the flammable substances
- Existence of a hazardous amount
- Effectiveness of the ignition source

Concentration of flammable substances

Liquids - gases / vapors:
Parts of a liquid turn into the gaseous aggregate state on account of **evaporation**. For this reason, a mixture of vapors and air develops above a free liquid surface; the mixture need not necessarily be flammable. If the temperature is sufficiently high, however, the liquid develops such great amounts of vapor by evaporation that these form with the air a flammable mixture above the liquid. This temperature is known as the **flash point** and is determined in a closed cup under specified conditions, by means of extraneous ignition. However, continuous combustion is not yet possible because insufficient vapors still develop at this liquid temperature. If the temperature is higher and just sufficient for the changed vapor/air mixture to continue burning above the liquid, the temperature is known as the **combustion point.**

The values of the flash point and combustion point are not physical constants but so-called substance-related characteristics of the gas-air mixtures. These are defined as **safety characteristics (see also Section 4.3) because other factors such as convection and diffusion also contribute to the determination of the above temperatures. The flash point can be affected by admixture to flammable liquids.**

The development of an explosive atmosphere depends on the mixture concentration forming over the liquid. When there is a mixture concentration with which the mixture is just barely explosive, the **lower explosion limit (also known as the lower ignition limit) has been reached; the corresponding temperature is known as the** lower explosion point.

If the mixture concentration is increased, the degree of concentration finally reached is such that the mixture contains insufficient oxygen on account of the higher content of gases and vapors, and is therefore no longer explosive; the **upper explosion limit** or ignition limit has been reached. Above this limit, the mixture is too rich but is still combustible in an oxidizing agent.

The region of concentration between the explosion limits (ignition limits) is known as the **explosion region (ignition region); see Figure 1.1.**

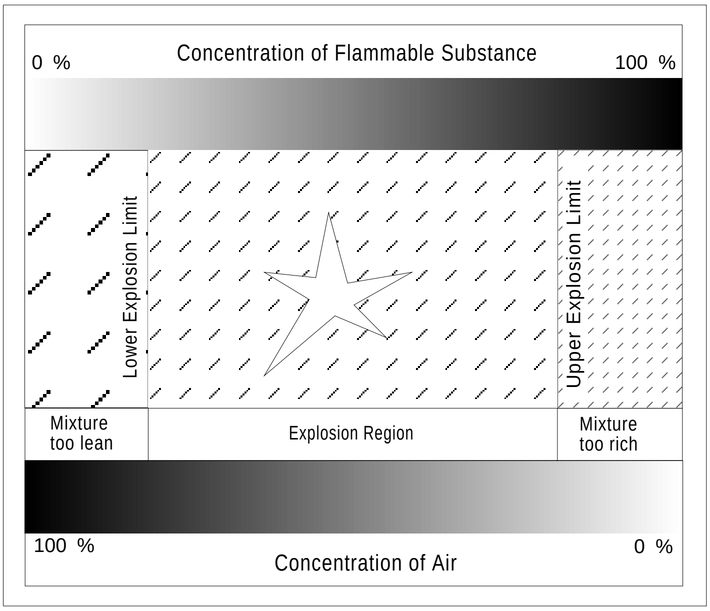

Figure 1.1 Concentration of a Flammable Substance in Air (Explosion Limits are Substance-Dependent)

For a mixture with oxygen, the upper explosion limit is considerably higher than for a mixture with air. If an **inert gas** is substituted for oxygen or air, an explosion is no longer possible.

The **ignition temperature of a flammable gas or liquid is the lowest temperature determined in a test device for a heated wall on which the flammable substance mixed with air just barely ignites (see also Table 4.6). The ignition temperatures of gases can be classified in various temperature classes (see Section 4.3.2).**

Dusts:
Solid substances are often in a comminuted form, such as dust. Dust deposits can be compared to a porous body and have a voidage of up to 90 %. When dusts of a small grain size are whirled, they can ignite more easily because the surface rises as the comminution increases. When the temperature of a dust deposit is increased, spontaneous ignition of the combustible substance in the form of dust occurs. A **smoldering or glowing fire** takes place; this always starts at temperatures lower than the explosion of the same dust as a dust/air mixture. Such a smoldering fire, particularly with whirling of the dust particles, can be the ignition source for a dust/air mixture. For this reason, the **smoldering temperature, determined for ignition of a 5 mm high dust layer, is an important safety characteristic for dusts. With greater layer thicknesses, smoldering can occur below this smoldering temperature.**

For dust/air mixtures, there are also explosion limits and regions as for the gases and vapors. Given in Table 4.3 is a summary of safety characteristics for dusts of the most common materials.

Unstable substances and gases

With certain chemically unstable substances and gases such as acetylene, an exothermic reaction can be initiated by ignition, even when no oxygen or air is present.

Existence of a hazardous amount

An explosive atmosphere in a hazardous amount is a **dangerous explosive atmosphere**, i.e. the amount is such that direct or indirect injury or damage can be expected in the event of an explosion.

As a rule, 10 litres of cohesive explosive atmosphere in a closed room can be considered as hazardous, irrespective of the room's size. Additionally, however, even lesser amounts can be considered dangerous, especially if they are in the vicinity of persons and can be ignited there.

A rule of thumb:

Room volume ≤ 10 000 x mixture volume
Example: This is reached with only 8 litres in a room of 80 m^3 volume.

Effectiveness of the ignition source

The effectiveness of an ignition source and therefore its ability to ignite an explosive atmosphere depend on the energy of the ignition source and the properties of the explosive atmosphere.

According to /1/ (from the explosion protection guidelines), the following are ignition sources:

- Hot surfaces
- Flames and hot gases
- Mechanically produced sparks
- Electrical equipment
- Electric circulating currents, cathodic protection
- Static electricity
- Lightning strikes
- Electromagnetic waves
- Optical radiation
- Ionizing radiation
- Ultrasound
- Adiabatic compression, shock waves of flowing gases
- Chemical reactions

In practice, electrical devices and systems represent a major share of possible ignition sources. Switching sparks and components overheated by excessively high currents (i.e. in the event of a short-circuit fault) can act as an ignition source.

1.3 Protective Measures

There are two basic measures for avoiding explosions:

1. Preventing the formation of a dangerous, explosive atmosphere, i.e. primary explosion protection

2. Preventing the ignition of a dangerous, explosive atmosphere, i.e. secondary explosion protection

According to ElexV, Paragraph 7, measures for preventing an explosive atmosphere are mandatory.

Primary explosion protection

Primary explosion protection is understood to mean all measures which prevent or restrict the development of a dangerous explosive atmosphere (see Chapter 3). For example, this can be achieved by:

- avoiding the use of flammable liquids;
- inertness;
- substituting non-combustible substances for combustible substances;
- limiting the concentration below the lower and above the upper explosion limit;
- suitable equipment design;
- natural and technical ventilation.

Detailed considerations for primary explosion protection can be found in Part E 1 "Measures which prevent or restrict the formation of a dangerous explosive atmosphere" (in German) of the Ex-RL /1/,/4/ (see also Chapter 3).

Secondary explosion protection

There are, however, many applications in which primary protective measures cannot be employed. Secondary explosion protection measures prevent ignition, thus ensuring the safety of personnel and equipment in hazardous areas.

Secondary explosion protection encompasses all measures which prevent ignition of an explosive atmosphere. There are different, standardized types of protection which are described in Section 4.2. With regard to electrical apparatus, secondary explosion protection relates to the observance of constructional requirements for electrical apparatus with explosion protection. By means of design and/or circuit-related measures, these are intended to prevent an explosion or, in the event of an explosion in the interior of apparatus, to prevent ignition of the ambient explosive atmosphere (see also Chapter 4).

2 Legal Principles of Explosion Protection

Figures

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2 Legal Principles of Explosion Protection

2.1 Development Within the Federal Republic of Germany

Since its establishment in 1893, the German Association of Electrical Engineers (VDE) has been involved in measures for protection against the hazards of electric current. The **regulations for electrical apparatus with protection against firedamp and explosion**, issued in 1943, formed the basis for the **police ordinance on electrical apparatus in hazardous areas and installations as well as in mining installations susceptible to firedamp**, dated October 13, 1943 and valid until 1963.

The police ordinance was replaced in 1963 by the **regulations for electrical systems in hazardous areas (ExVo)**. This legal basis for explosion protection did not represent detailed stipulations on the nature, operation and maintenance of electrical equipment in hazardous areas; in two annexed statutory regulations, it referred to the recognized technical rules of the Employers' Liability Insurance Association of the chemical industry and of the VDE.

The regulations introduced a requirement for approval of explosion-protected apparatus by the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig or the Mines Testing Station (BVS) in Dortmund-Derne, as well as the need for type approval by the competent authorities of the relevant German state.

Harmonization of the legal principles for explosion protection within the European Community (EC) began with the **EC Ex general guidelines** dated December 18, 1975; the European Committee for Electrotechnical Standardization (CENELEC) was responsible for drafting them.

The requirements for design and construction of electrical apparatus are governed in so-called **constructional requirements** by European Standards EN 50014 to EN 50020 and EN 50028 as well as EN 50039, which were incorporated in German standards as DIN EN 50014 to 50020 and DIN EN 50028 as well as DIN EN 50039, and which also apply as VDE regulations VDE 0170/0171/5.78 (VDE 0170 for protection against firedamp and VDE 0171 for explosion protection).

Adaptation of the legal principles for explosion protection in the Federal Republic of Germany to the EC guidelines took place in 1980 with the **regulations for electrical equipment in hazardous areas (ElexV)**. They were enacted by the Federal Government on February 27, 1980 within the meaning of Section 24 of the **Factory Act** /11/. The ElexV is the basis of so-called **installation specifications** because it governs the installation and operation of electrical equipment in hazardous areas.

General legal requirements according to Articles 24 and 25 of the German Factory Act

According to Art. 24 of the German Factory Act, which is valid in all states (Länder) in the Federal Republic of Germany, electrical systems in hazardous areas are subject to supervision. The text below quotes relevant passages from this article:

Art. 24, Systems Subject to Supervision

(1) In order to protect workers and third parties against dangers caused by systems which due to their hazardous character are subject to supervision, the Federal Government is authorized to decree the following by statutory order after having consulted the parties concerned:

1. If such a system is to be installed or put into operation, or if an already operating system is to be modified, this must be made known to the relevant authorities and certain documents must be supplied. This also applies to certain other conditions relevant for the system.

2. Installing, operating or modifying such a system requires the previous permission by an authority specified in the regulation or authorized by federal law or Art. 155 Paragraph 2.

2a. Such systems or parts of such systems can obtain general approval after a design test. A general approval can be made subject to certain conditions regarding operation and maintenance.

3. Such systems must meet certain requirements, in particular regarding installation, manufacturing, design, material, equipment, maintenance and operation.

4. Such systems are subject to a test before start-up, regular inspections during operation and tests ordered by the authorities.

5. ...

Systems subject to supervision according to Paragraph (1) are:

1. Steam boiler installations and pressure vessels;

2. Plants for decanting gases pressurized, liquefied or dissolved under pressure;

3. Pipelines under inner pressure for flammable, corrosive or poisonous gases, vapors or liquids;

4. Lifts;

5. Electrical systems in hazardous areas;

6. Acetylene installations and acetylith stocks;

7. Plants for storing, decanting or transporting flammable liquids.

Art. 24b, Duty to Tolerate Inspections

Owners of systems subject to supervision and persons manufacturing or operating such systems are obliged to open the system to the experts authorized to inspect it, to permit the inspection laid down in the regulations or ordered by the authorities, to provide the workpower and aids required for this purpose and to make available to experts any information or documents required for fulfilling their task. The basic right granted by Art. 13 of the German Basic Constitutional Law is restricted by these regulations.

Art. 24c, Inspections by Experts

The systems subject to supervision are inspected by officially approved experts or experts officially approved for this specific purpose unless the statutory orders decreed according to Art. 24, Paragraph 1 provide something else. These persons are to be organized in technical surveyance organizations.

Art. 24d, Supervisory Authority

Execution of the statutory order decreed according to Art. 24, Paragraph 1 is supervised by the trade supervisory authorities...

Art. 25, Closing Down of Systems and Preventing Operation

The authority in charge can order a system to be closed down or removed if the system has been installed, operated or modified without the permission or expert inspection required by a statutory order according to Art. 24, Paragraph 1, No. 2 or 4.

The **Factory Act** summarizes in general all systems requiring monitoring; these naturally include systems in hazardous areas. In parallel with ElexV, a new edition of the **regulations for systems for the storage, filling and conveying of flammable liquids on land (VbF)** /21/ was issued within the scope of the Factory Act.

The German Commission for Electrical Systems with Explosion Protection (DExA) is the permanent legislative advisory body according to Section 18 of ElexV.

Additional regulations for the construction and installation of apparatus are specified in a statutory regulation of ElexV:

- **Guidelines for avoiding the hazards of an explosive atmosphere**
  – explosion-protection guideline (EX-RL)

- VDE regulations
  DIN VDE 0170/0171 Part 1 to Part 7, Part 9 and Part 10 - EN 50014 to EN 50020, EN 50028, 50039 (constructional requirements)
  DIN VDE 0165 (installation specification)

2.2 Regulations for Electrical Equipment in Hazardous Areas (ElexV)

Briefly described in the following are the main points of these regulations; the aspects relating to the operation of electrical equipment are covered in Chapter 7.

Application

For hazardous areas, the installation and operation of electrical systems comprising individual or interconnected electrical apparatus are covered by ElexV. These regulations do not apply to electrical systems serving neither for industrial nor business purposes and in whose hazardous area no persons are employed. Also excluded is equipment in aircraft, on seagoing and inland shipping as well as equipment of the German Federal Railways, the German Defence Force and mining enterprises.

The nature of electrical equipment and systems

According to Section 3 of ElexV, the installation and operation of electrical equipment in hazardous areas must comply with and be handled according to generally recognized engineering practice. The nature of the equipment must therefore be such that, with proper operation, either

- no sparks, arcing or temperatures capable of causing ignition are produced;
- or an explosion when an ignition source is present is ruled out,
- or a resulting explosion cannot be propagated in the room.

These requirements can be met by one of the following measures, for example:

- Restricting the energy applied in the circuit so that no sparks or temperatures capable of causing ignition can occur
- Design measures which prevent the coincidence of an explosive atmosphere and an ignition source
- Design-related arrangement of the housing which prevents an internal explosion in the apparatus from continuing to the environment

A notable item in ElexV is the reference to primary explosion protection so that operationally expedient measures can be required from this aspect also, to prevent or restrict from the start the formation of an explosive atmosphere in a hazardous amount.

The use of Ex apparatus

With the introduction of ElexV, the previous test certificates (approvals of the testing stations) and type approvals are replaced by a **special test procedure**. A significant requirement of ElexV is that electrical apparatus in hazardous areas may only be placed in operation when it is covered by **special test certificates** and the electrical apparatus is marked accordingly.

The following are special test certificates as required by ElexV:

- National test certificate
- Certificate of conformity
- Inspection certificate

The **national test certificate** provides confirmation of compliance with the constructional requirements of VDE 0170/0171/2.61 to 1.69; this was possible until May 1, 1988.

A **certificate of conformity** confirms compliance with the constructional requirements of European Standards EN 50014 and subsequent standards.

An **inspection certificate** can be issued if explosion protection is achieved by other measures which are not yet standardized, with the same degree of safety.

A certificate of conformity or inspection certificate can be issued by every approved explosion-protection testing station of the EC member states. For the Federal Republic of Germany, the testing stations of the Physikalisch-Technische Bundesanstalt (PTB) and Mines Testing Station of the German mining technology (DMT/BVS) are currently approved.

Equipment with a certificate of conformity or inspection certificate is marked by the manufacturer with the standardized Ex sign:

All electrical apparatus with explosion protection tested after May 1, 1988 must be marked with this sign. Before that date, marking was at the discretion of the manufacturer.

By marking with the Ex sign, the manufacturer confirms that

- the apparatus thus marked conforms to the type for which a test certificate is held;
- a routine test has been carried out at the manufacturing plant;
- the manufacturer has met his obligations to the testing station.

Note

The certificate of conformity allows the unrestricted sales of goods within the EC. Outside the EC, additional tests at the national testing stations of the recipient country may be required.

Exceptions:

Exempt from the special test procedure is apparatus in which none of the electrical values **1.2 V, 0.1 A, 20 microjoules or 25 mW** is exceeded (e.g. with thermocouples, Pt 100, electrical displacement sensors). With such apparatus, therefore, a special test procedure and standard marking are dispensed with. The electrical data to be given by the manufacturer (such as temperature-rise behaviour, compliance with the constructional requirements of EN 50014, etc.) are sufficient to utilize such apparatus in hazardous areas.

Note

Although zones (see Section 4.1) have not yet been explained, it should already be noted that apparatus without a special test certificate can also be used in Zones 2, 11 and M if they meet certain requirements (see Sections 7.4 to 7.7).

In Zones 0, 10 and G, however, only apparatus specifically approved for the purpose may be used.

Responsibility of the installing party

Table 2.1 provides information on the demarcation of responsibility in planning, installation, placing in service, maintenance and repair.

Table 2.1 Responsibilities in the Installation and Operation of Electrical Systems in Hazardous Areas

Task	Responsible Party
System planning	Overall planner, project leader (consultation with factory inspectorate)
Prepare layout drawing for hazardous areas (define zones according to EX-RL)	User (preferably with support of supervisory authority)
Determine explosion classes for the existing gases and liquids	User

Table 2.1 continued

Task	Responsible Party
Selecting the apparatus for the hazardous areas	Overall planner, project leader
Assembly, installation according to ElexV, i.e. DIN VDE 0165 (in Germany)	Installation company
Installation of intrinsically safe circuits, interconnection	Computed or measured confirmation by the responsible planner or expert
Placing in service	Project leader
Testing, operation and maintenance of the system	Expert or specialist of the user
Special version	Expert
Repair	Manufacturer or expert
Modification	Expert

2.3 Regulations for Equipment for the Storage, Filling and Conveying of Flammable Liquids on Land (VbF)

Simultaneously with ElexV, within the scope of the regulations of **Section 24 of the Factory Act**, the VbF was re-enacted with effect from July 1, 1980. These regulations contain requirements for explosion protection because certain liquids can form an explosive atmosphere.

Certain requirements for electrical apparatus were made according to the subdivision of hazardous areas in zones (see Section 4.1). Wherever the explosion protection of a system depends on the functional reliability of devices, such as anti-overflow devices or certain limit sensors, they must additionally be certified as being functionally reliable by a testing station, such as the PTB or BVS. The test itself can be carried out by a suitably equipped technical supervisory body, such as the Technical Supervisory Board (TÜV).

For certain electrical apparatus or equipment, a design approval by the local inspection authority is required. For this, the authority must be presented with a report from the Physikalisch-Technische Bundesanstalt (PTB) or, depending on competence, the Federal Institution for Materials Testing (BAM) on the apparatus or equipment. This applies to, amongst other items, apparatus

- which is used in Zone 0 (e.g. devices for measurement such as liquid indicators, temperature, pressure and density measuring equipment);
- devices protecting against flame transmission;
- anti-overflow devices;
- leakage indicators.

Within the scope of the VbF, the equipment must be tested by experts before being placed in service and thereafter at regular intervals according to Section 15 of the VbF (normally every 5 years). In contrast to areas subject to the ElexV, continual monitoring by a responsible engineer does not provide an exemption from this mandatory testing.

It should also be noted that both regulations ElexV and VbF for hazardous areas make the same requirements for protection against ignition for the apparatus, with the exception of Zone 0.

2.4 Explosion-Protection Guidelines (EX-RL) of the Employers' Liability Insurance Association for the Chemical Industry

In the **guidelines for avoiding the dangers of an explosive atmosphere with a collection of examples - explosion-protection guidelines** (the full title) of the Employers' Liability Insurance Association for the Chemical Industry, specific information on the dangers in hazardous areas is given, and measures for avoiding or reducing them are shown. This is covered, in particular, by the **collection of examples** in which these measures on individual, potentially explosive process systems of widely differing industrial sectors are listed in detail. Useful ideas and suggestions or risk assessments are thus available for planners and users of such or similar process systems. The application of primary explosion-protection measures, in particular, can be taken from the examples (see Chapter 3) thus indicating the required, secondary explosion-protection measures (see Chapter 4).

The following subjects are covered in the **collection of examples of the EX-RL**:

- Flammable gases (gas-operated plants, gas works)
- Flammable liquids (e.g. manufacture, storage, filling, cleaning, degreasing)
- Manufacture and application of dyes, paints, floorcovering and leather cleaning agents
- Manufacture and processing of rubber and plastics
- Machining (comminution), processing and storage of dusts or solid substances with dust deposits

Table 2.2 Example from the Tables in the Collection of Examples in the Guidelines for Explosion Protection

Serial No. (column 1)	Example (column 2)	Characteristics/remarks/ requirements (column 3)	Protective measures according to E1 (column 4)	E3 (column 5)	E2 in (remaining) zones specified below (column 6)
2.3	CLEANING AND DEGREASING USING FLAMMABLE LIQUIDS	See also Accident Prevention Regulation "Chemischreinigung" (VBG 66)			
2.3.1	Removal of stains using benzine, acetone, etc., except stain removing in dry-cleaning	Solvents in sealable spraying bottles, no stocks. Small quantity of solvent in proportion to the space	E1.3.4.1		Zone 2 :1 m
2.3.2	Areas for storing and washing cleaning cloths containing liquids whose flash point is up to 100 °C		E1.3.4.2		Zone 1 : 5 m vertically 1 m
2.3.3	Areas for cleaning and degreasing metal parts in unheated plants	Max. ambient temperature 40 °C, spraying of the cleaning agent impossible. a) Flash point of cleaning agent below 40 °C b) Flash points of cleaning agent 40 °C or above See also "Richtlinie für Anlagen zum Reinigen von Werkstücken mit Lösemitteln" (ZH 1/562)	 E1.3.4.2 E1.3.4.1		 Zone 1 : 5 m vertically 1.5 m None
2.3.4	Cleaning individual machines	Manual work. No spraying of the cleaning agent. Use of small quantities of the cleaning agents. Temperatures of cleaning agent and machine parts below flash point. See also "Richtlinie für Anlagen zum Reinigen von Werkstücken mit Lösemitteln" (ZH 1/562)	E1.3.4.1		None

2.5 Overview of Specifications, Standards and Regulations

Summarized in Table 2.3 are the specifications, standards and regulations currently valid in the Federal Republic of Germany. Figure 2.1 shows the relationship between the legal principles for explosion protection.

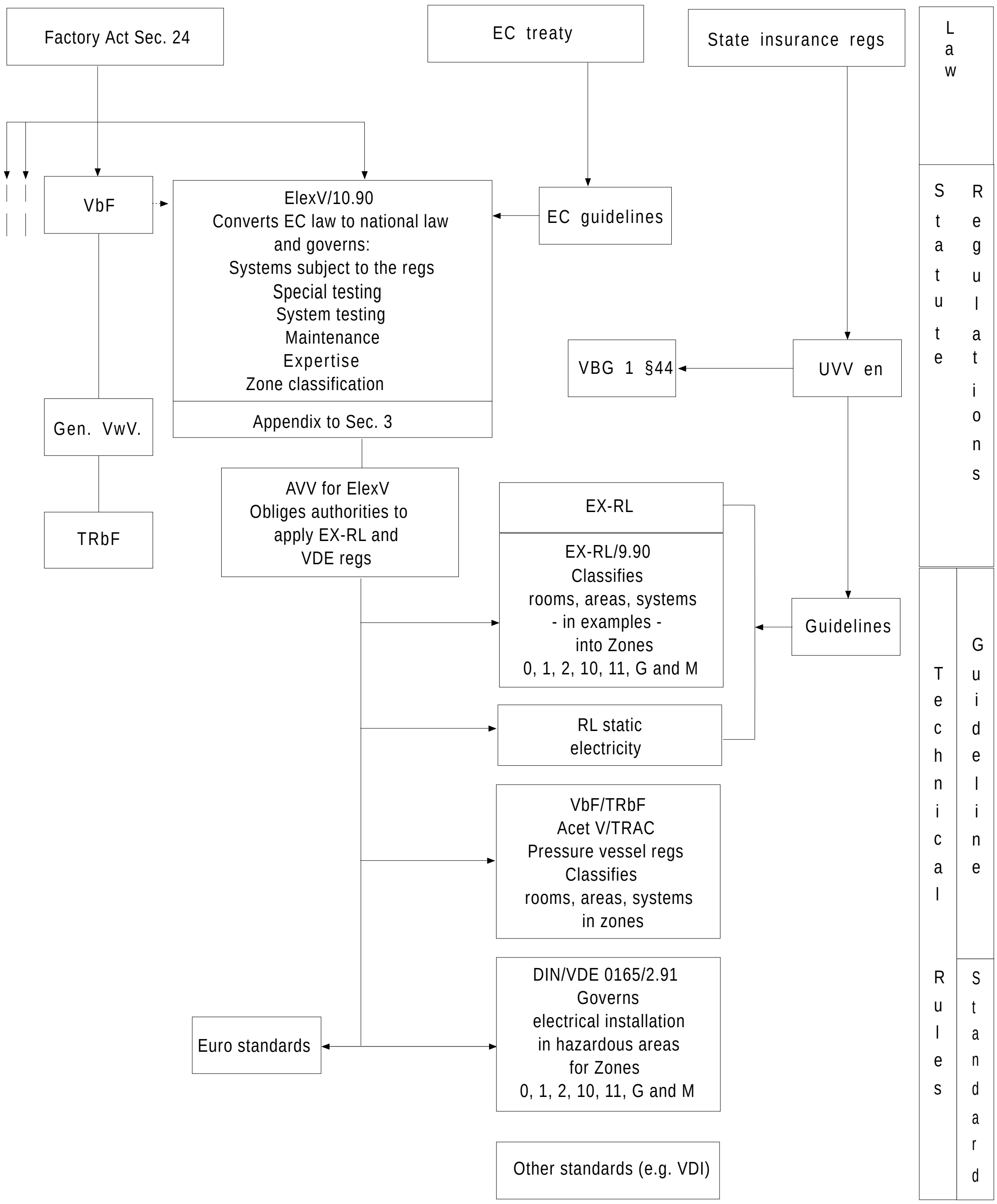
Constructional requirements

In 1980, the new, harmonized European Standards EN 50014 to EN 50039 replaced the previously valid VDE regulations. The European standards are published as DIN EN ... in the German language and are simultaneously identified as VDE regulations. Incorporation in German law takes place with an announcement by the Federal Employment Secretary in the Federal Gazette.

In the meantime, the existing standards DIN EN 50014 to DIN EN 50020 have been supplemented by some amendments marked as A1, etc. in Table 2.3.

Installation specifications

So far, the installation specifications for electrical systems in hazardous areas (see Table 2.2) have only been regulated at national level. DIN VDE 0165/2.91, in particular, applies to the Federal Republic of Germany. Consultations relating to a European and international installation specification are currently in progress.



ElexV	-	Regulations for electrical equipment in hazardous area
AVV	-	General statutory regulations
EX-RL	-	Explosion-protection guidelines with collection of examples of the Employers' Liability Insurance, Chemical Industry
VbF	-	Regulations for flammable liquids
TRbF	-	Technical rules for flammable liquids
Acet V	-	Acetylene regulations
TRAC	-	Technical rules for acetylene plants and calcium carbide stores
UVV	-	Accident prevention regulations

Figure 2.1 Relationship Between Legal Principles for Explosion-Protection in the Federal Republic of Germany

Table 2.3 Summary of the Standards and Regulations for the Federal Republic of Germany (as in December 1992)

Standard/Regulations	Remarks
Constructional requirements	
DIN EN 50014 / VDE 0170/0171 Part 1/5.78 and amend's: A1 to A5	Electrical apparatus for hazardous areas: General requirements
DIN EN 50015 / VDE 0170/0171 Part 2/5.78 and amend's: A1	Electrical apparatus for hazardous areas: Oil immersion "o"
DIN EN 50016 / VDE 0170/0171 Part 3/5.78 and amend's: A1	Electrical apparatus for hazardous areas: Pressurized enclosure "p"
DIN EN 50017 / VDE 0170/0171 Part 4/5.78 and amend's: A1	Electrical apparatus for hazardous areas: Powder filling "q"
DIN EN 50018 / VDE 0170/0171 Part 5/5.78 and amend's: A1 to A3	Electrical apparatus for hazardous areas: Flameproof enclosure "d"
DIN EN 50019 / VDE 0170/0171 Part 6/5.78 and amend's: A1 to A5	Electrical apparatus for hazardous areas: Increased safety "e"
DIN EN 50020 / VDE 0170/0171 Part 7/5.78 and amend's: A1 to A5	Electrical apparatus for hazardous areas: Intrinsic safety "i"
DIN EN 50028 / VDE 0170/0171 Part 9/7.88	Electrical apparatus for hazardous areas: Encapsulation "m"
DIN EN 50039 / VDE 0170/0171 Part 10/4.82	Electrical apparatus for hazardous areas: Intrinsically safe electrical systems "i"
DIN VDE 0171 Part 13/11.86	Requirements for apparatus of Zone 10
Installation specifications (including operation)	
DIN VDE 57105 Part 9/ VDE 0105 Part 9/5.86	Operation of power systems, additional stipulations for hazardous areas
DIN VDE 0165/2.91	Installation of electrical equipment in hazardous areas
DIN IEC 601 Part 1 / VDE 0750 Part 1/12.91	Electro-medical equipment
DIN VDE 0848 Part 3/3.85	Hazards caused by electro-magnetic fields (explosion-protection)
ElexV - Regs for electrical equipment in hazardous areas	(Subject to the Factory Act)
VbF - Regs for equipment for storing, filling and conveying flammable liquids on land /5.82	
TRbF - Technical rules for flammable liquids /1.76 - 11.90	120 individual standards
EX-RL - Guidelines for avoiding the dangers of an explosive atmosphere with collection of examples - Explosion-protection guideline - (EX-RL)/3.85	Explosion-protection guidelines of the Employers' Liability Insurance for the Chemical Industry with collection of examples

2.6 National Authorized Testing Stations

In the Federal Republic of Germany, there are two testing stations according to the field of application of the apparatus to be tested. The Mines Testing Station (DMT/BVS) in Dortmund-Derne tests electrical apparatus for operation in Group I (Zones 10 and 11) as well as Group II (Zone 1). The Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig is responsible for the electrical apparatus of Group II (Zones 0 and 1).

The task of the Technical Supervisory Board (TÜV) is the safety testing of entire systems. If the TUV employees are certified experts, the stipulations of ElexV apply to their tasks (special versions, individual testing, etc.).

The new German states

The Institute for Mining Safety (IfB) in Freiberg/Saxony was the approval center in Saxony, Saxony-Anhalt, Thueringen, Brandenburg and Mecklenburg-Vorpommern. The type test certificate issued by the IfB covers the equipment manufactured according to this certificate (Figure 2.2).

Equipment with certificates of other testing stations could also be approved in agreement with the IfB by the State Department for Technical Supervision (TÜ) in the form of a device approval.

At a time specified in the "Treaty of Union", the ElexV will apply to new equipment in the five new German states. For existing systems and those being installed, there will be transitional rules on the basis of the technical rules (TGL) applying so far. This will also apply to the introduction on the market of apparatus on the basis of TGL-55037 for the activity of experts in workshops for the repair of explosion-protected electrotechnical apparatus, etc.. The transitional regulations for ElexV in the five new German states are given in Figure 2.2.

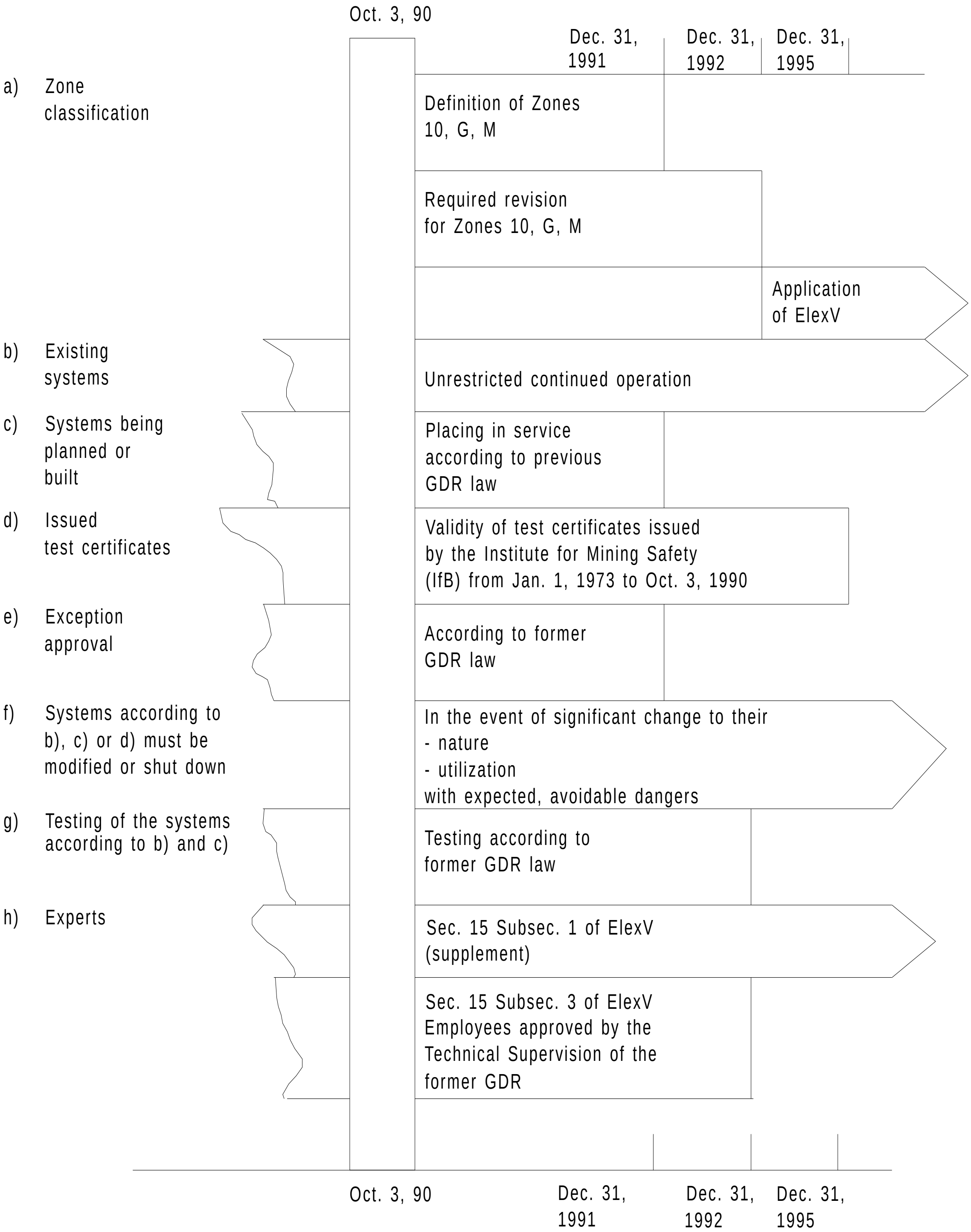


Figure 2.2 Transitional Regulations for ElexV in the Five New German States /1/

2.7 Testing Stations Within the EC

The EC commission has designated the testing stations listed in Table 2.4; these can issue the certificates of conformity or inspection according to the EC explosion-protection guidelines.

The obligation of mutual recognition of test certificates of the national testing stations currently exists only for the EC member states, but not for the remaining CENELEC states such as Austria, Switzerland, Finland, Norway, Sweden.

Table 2.4 Testing Stations Within the EC

Country Code	Explosion Group (see Section 4.3.1)	Testing Station / Location	
B (+ NL)	I + II	INIEX (ISSEP)	Institut National des Industries Extractives Rue Grande 60; B-7340 Colfontaine
DK	I + II	DEMKO	Danmarks elektriske materielkontrol Lyskaer 8, DK-2730 Herlev
D	I + II (No approval for Zone 0)	DMT/BVS	Mines Testing Station Specialist department for safety of electrical apparatus of the DMT Gesellschaft fuer Forschung und Pruefung mbH, Beylingstr. 65, D-44329 Dortmund
	II (No approval for Zone 10)	PTB	Physikalisch-Technische Bundesanstalt Bundesallee 100, D-38116 Braunschweig
F	I + II Name from 1991:	CERCHAR INERIS	Centre d' Etudes et Recherches des Charbonnages de France Institut National de l'Environnement et de Risques B. P. no 2, F-60550 Verneuil-en-Halatte
	I + II	LCIE	Laboratoire central des industries électriques PB833, Avenue du Général Leclerc, F-92260 Fontenay-aux-Roses
GB	I	HSE (M) (MECS)	Health & Safety Executive (MINING) Buxton (Mining Equipment Certification Service, Part of EECS, below)
	II	BASEEFA (EECS)	Health & Safety Executive British Approvals Service for Electrical Equipment in Flammable Atmospheres Harpur Hill, Buxton, Derbyshire SK17 9JN,
	II	SCS	Sira Certification Service Saighton Lane, Saighton, Chester CH3 6EG
E	I + II	LOM	Laboratorio Oficial Madariaga Alenza 2, E-28003 Madrid
I	I + II	CESI	Centro Elettrotecnico Sperimentale Italiano Via Rubattino 54, I-20134 Milano

For special information and questions, e.g. relating to the classification of mixtures with flammable gases, vapors or mists in temperature classes, the user can consult the testing stations.

2.8 Testing Stations Outside the EC

The following testing stations serve the European countries which are not in the EC:

Austria	-	ETVA, Bundesanstalt Arsenal, Wien,
	-	TÜV Wien
Switzerland	-	SEV, Schweizerischer Elektrotechnischer Verein, Zurich
Norway	-	NEMKO, Norges Elektriske Materiellkontroll, Oslo
Sweden	-	SP, Statens Provningsanstalt, Boras
Finland	-	Finnish Electrotechnical Inspectorate, Helsinki
Poland	-	Institute for Mining Safety in Mikolow

As a rule, East European countries recognize the certificates of the PTB.

Examples of testing stations of non-European countries:

Canada	-	CSA, Testing Laboratories, Toronto
	-	Canadian Explosive Atomspheres Laboratories, Fuels Research Centre, Ottawa
	-	ULC, Underwriters Laboratories, Canada
USA	-	UL, Underwriters Laboratories Inc., Chicago, New York, San Francisco
	-	FM, Factory Mutual Association
	-	MESE
Australia	-	SAA (Standard Association of Australia)
Japan	-	RIIS (The Research Institute of Industrial Safety of the Ministry of Labor)

2.9 Standardization Commissions

IEC (international)

The international standardization commission for electrical engineering is the International Electrotechnical Commission (IEC); it receives standardization proposals from the national committees, which then result in IEC publications and IEC standards.

The IEC has produced publications for the construction and installation of explosion-protected electrical apparatus, which have appeared in IEC Publications 79-0 to 79-16.

Table 2.5 Summary of Publications for Explosion-Protected Apparatus

IEC	CENELEC	GERMANY	
79-0	DIN EN 50 014	DIN EN 50 014	General specifications
79-6	DIN EN 50 015	DIN EN 50 015	Oil immersion o
79-2	DIN EN 50 016	DIN EN 50 016	Pressurized enclosure p
79-5	DIN EN 50 017	DIN EN 50 017	Power filling q
79-1	DIN EN 50 018	DIN EN 50 018	Ex-proof enclosure d
79-7	DIN EN 50 019	DIN EN 50 019	Increased safety e
79-11	DIN EN 50 020	DIN EN 50 020	Intrinsic safety i
79-18	DIN EN 50 028	DIN EN 50 028	Encapsulation m
79-3			Spark testing unit for intrinsically safe circuits
79-4			Method for determining ignition temperature

Table 2.5 continued

IEC	CENELEC	GERMANY	
79-10		ElexV	Zone classification
79-14 79-15 79-16 79-12 79-13		DIN VDE 0165	Installation requirements for Group II Electrical equipment with type of protection "n" Forced ventilation for the protection of analysis rooms Classification of gas and vapour/ air mixtures on the basis of experimental safe gap and min. ignition current Construction and operation of rooms and buildings with pressurized enclosure

On the basis of these IEC publications, an attempt is being made to harmonize the different European and national requirements.

CENELEC (European)

The European Committee for Electrotechnical Standardization (CENELEC) is responsible for producing European standards for the EC area. On the basis of IEC standard drafts in IEC working group TC 31 or on the basis of its own drafts, CENELEC produces European standards DIN EN 50... for explosion-protected electrical apparatus. Shown in Figure 2.3 is the interaction between various standardization commissions.

The CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

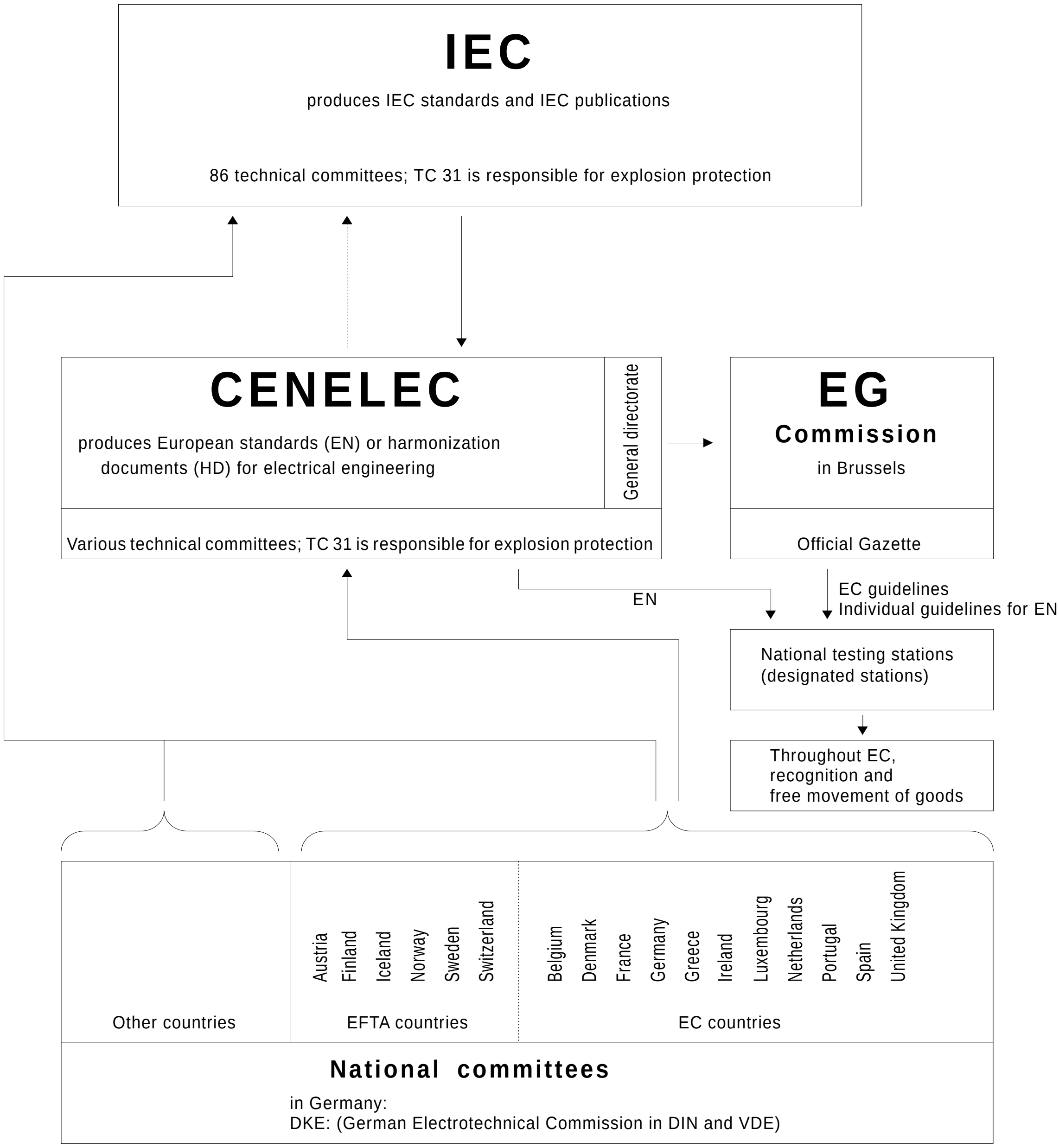


Figure 2.3 Interaction between Standardization Commissions

2.10 International Publication of European Standards for Explosion Protection

The member states of CENELEC have undertaken to adopt with the status of a national standard, and without any change, the European standards which are issued in three official versions (English, French, German). Table 2.6 shows how the European standards for explosion protection are published in the countries listed.

Table 2.6 Designations of European Standards for Explosion Protection in Selected Countries

Country	EN 50 014	EN 50 015	EN 50 016	EN 50 017	EN 50 018	EN 50 019	EN 50 020
Belgium	NBN C23-001	NBN C23-104	NBN C23-105	NBN C23-106	NBN C23-103	NBN C23-102	NBN C23-101
Denmark	FSNIT 50	AFSNIT 50-1	AFSNIT 50-2	AFSNIT 50-3	AFSNIT 50-4	AFSNIT 50-5	AFSNIT 50-6
Federal Republic of Germany	DIN EN 50 014 VDE 0170/ 0171 T. 1	DIN EN 50 015 VDE 0170/ 0171 T. 2	DIN EN 50 016 VDE 0170/ 0171 T. 3	DIN EN 50 017 VDE 0170/ 0171 T. 4	DIN EN 50 018 VDE 0170/ 0171 T. 5	DIN EN 50 019 VDE 0170/ 0171 T. 6	DIN EN 50 020 VDE 0170/ 0171 T. 7
Finland 1)	SFS 4094	SFS 4095	SFS 4096	SFS 4097	SFS 4098	SFS 4099	SFS 4100
France	NF C23-514	NF C23-515	NF C23-516	NF C23-517	NF C23-518	NF C23-519	NF C23-520
United Kingdom	BS 5501: Part 1	BS 5501: Part 2	BS 5501: Part 3	BS 5501: Part 4	BS 5501: Part 5	BS 5501: Part 6	BS 5501: Part 7
Italy	CEI 31-8	CEI 31-5	CEI 31-2	CEI 31-6	CEI 31-1	CEI 31-7	CEI 31-9
Netherlands	NEN-EN 50 014	NEN-EN 50 015	NEN-EN 50 016	NEN-EN 50 017	NEN-EN 50 018	NEN-EN 50 019	NEN-EN 50 020
Norway 1)	NEN 110	NEN 111	NEN 112	NEN 113	NEN 114	NEN 115	NEN 116
Austria 1)	EN 50 014	EN 50 015	EN 50 016	EN 50 017	EN 50 018	EN 50 019	EN 50 020
Sweden 1)	SS EN 50 014	SS EN 50 015	SS EN 50 016	SS EN 50 017	SS EN 50 018	SS EN 50 019	SS EN 50 020
Switzerland 1)	SEV 1068-EN 50 014	SEV 1069-EN 50 015	SEV 1070-EN 50 016	SEV 1071-EN 50 017	SEV 1072-EN 50 018	SEV 1073-EN 50 019	SEV 1074-EN 50 020
Spain	UNE 21 814	UNE 21 815	UNE 21 816	UNE 21 817	UNE 21 818	UNE 21 819	UNE 21 820

1) Not an EC member state

2.11 Test and Certification Procedures

The constructional requirements of DIN VDE 0170/0171/2.61 ended on May 1, 1988 after 20 years' validity. Since that time, only certificates of conformity are issued according to DIN EN 50014 / VDE 0170/0171 Part 1/5.78 to DIN EN 50020 / VDE 0170/171 Part 7/5.78.

The following rules currently apply to previously certified apparatus:

Test certificates to VDE 0171, old form

- Test certificates to VDE 0171 (editions 2.61, 2.65 and 1.69) are no longer issued since May 1, 1988.
- No further supplements to these test certificates can be issued.
- For electrical apparatus tested to the old VDE requirements, no transition period has yet been specified for their continued use and introduction on the market.

Certificates of conformity of the "A" generation

- These certificates of conformity to European standards of the first generation (Edition 1977/1978) were only issued until December 31, 1987.
- They are **valid until January 1, 2005.**
- Supplements will no longer be issued.

Certificates of conformity of the "B" generation

- The so-called "B" generation of certificates of conformity includes the amendments (A1 etc.) to the European standards drawn up in the course of time, and is identified by an additional "B" in the certificate number (e.g. PTB No. Ex-88.B.2149).
- The apparatus thus marked complies with valid CENELEC standards.
- Certificates of conformity for this generation will still be issued as supplements until December 31, 1992.
- They are **valid until December 31, 2009.**

Certificates of conformity of the "C" generation

- With the "C" generation of certificates of conformity issued since January 1, 1989, only slight changes were made with respect to the "B" generation; it is therefore often possible to simply reissue the "B" as "C" certificates (e.g. certificate number PTB No. Ex-91.C.2110).

3 Primary Explosion Protection

3 Primary Explosion Protection

Measures for primary explosion protection are mainly required and explained in the explosion protection guidelines of the Employers' Liability Insurance Association (BG) for the Chemical Industry (EX-RL) and in ElexV /1/. They must chiefly be applied by planners and users of equipment and are primarily intended to prevent or limit the development of an explosive atmosphere. Various methods for this primary explosion protection are given in the following.

3.1 Avoidance of Flammable Liquids

Action is taken here to establish whether flammable substances can be replaced by nonflammable ones. For example, flammable solvents or cleaning agents can be replaced by aqueous solutions, amongst other things.

3.2 Raising the Flash Point

The flash points of flammable liquids can be changed by admixture. In the case of nonflammable admixtures, the flash point is usually raised; this is quite possible by, for example, the addition of water to water-soluble flammable substances. A satisfactory level is achieved if the flash point is at least 5 K higher than the processing temperature or room temperature.

3.3 Limiting the Concentration

With this measure, an attempt is made to keep the concentration of flammable substances below the lower or above the upper explosion limit, to prevent the formation of an explosive atmosphere in a hazardous amount.

For liquids, it is preferable in practice to attempt to keep the concentration below the lower explosion limit, because the equipment overhead for maintaining saturated vapor concentrations is very high.

For gases, it is often possible in practice to keep the concentration outside the hazardous area. A problem that may occur, however, is that the hazardous area has to be travelled through during startup or shutdown of a system.

In the case of dusts, it is very difficult in practice to avoid an explosive atmosphere by limiting the concentration.

3.4 Inertness

The formation of an explosive atmosphere is prevented by adding gaseous nonflammable substances such as carbon dioxide, nitrogen, water vapor or inert substances in powder form.

Once the oxygen content is less than 10 % by volume there is generally no longer an explosive atmosphere.

For inertness, the minimum values of ratio of the contents by volume of inert gas to the particular flammable gas have been determined (see ElexV /1/), at which an explosive atmosphere is no longer formed irrespective of the addition of air. In practice, this is significant with leaky apparatus to prevent the development of ignitable mixtures.

3.5 Ventilation

In practice, ventilation also often serves to prevent or restrict the formation of an explosive atmosphere.

Natural ventilation is based on an air change in rooms every hour; in cellar rooms only about 40 % of the air is changed every hour, but this also depends on the specific circumstances relating to convection. To assess the concentration of the resultant mixture and the required air intake and removal measures, it is necessary to know the amount of flammable gases and vapors flowing out as well as the mixing conditions; if possible, ventilation specialists should be consulted.

Greater amounts of air and better air channelling are possible with **technical** ventilation. However, it requires continuous attention and necessary maintenance.

3.6 Design Related Measures

The measures taken here do not prevent an explosion but restrict its effects to a harmless degree.

An **explosion-proof design** is such that the system involved can withstand the maximum explosion or detonation pressure.

Within the scope of **explosion pressure relief**, when an explosion is initiated or has spread to some extent, the originally closed apparatus is briefly or permanently opened in a safe direction (pressure relief valve).

With **explosion suppression**, the flames are extinguished with suitable extinguishing agents immediately after the onset of ignition, so that at most a partial explosion occurs with the least possible pressure.

Devices protecting against flame transmission are used, for example, with non-gastight system sections, i.e. fittings are designed to be explosion-proof, continuous combustion or detonation-proof.

4 Secondary Explosion Protection

Figures

Tables

4 Secondary Explosion Protection

Although methods for primary explosion protection should be applied by preference within the scope of explosion protection, explosion hazards cannot be avoided in many areas. Measures for secondary explosion protection are then employed, and these are specified in the constructional requirements for the various types of protection for explosion-protected electrical apparatus.

The extent of secondary explosion protection measures depends on the probability of a dangerous explosive atmosphere occurring. This assessment is first based on a zone classification of hazardous areas.

4.1 Zone Classification

Hazardous areas are classified in different zones according to the time-related and local probability of the presence of a dangerous explosive atmosphere. The definition of these zones is given in ElexV and in installation specifications DIN VDE 0165/2.91.

The stipulations of the constructional requirements entitled "Electrical apparatus for hazardous areas" (DIN EN 50014 etc.) also differ according to the application in the various zones.

There are two main justifications for classification in zones: firstly there are the safety-related reasons. Secondly there are economic reasons because differentiation in the relevant area makes demands of differing degree on the devices provided, as a function of the degree of danger. This means that devices in areas continuously subjected to explosion hazard are subject to higher requirements, and those in less hazardous areas to lower requirements.

As a rule, 95 % of equipment is installed in Zone 1 and only 5 % of the devices in Zone 0. An expert should be consulted to specify the zones.

The zone definitions are described in Tables 4.1 and 4.2. An example is given in Figure 4.1.

Table 4.1 Zones for Flammable Gases, Vapors and Mists /1/

Zone	Area Covered	Examples
Zone 0	Covers areas in which there is a **continuous** or **long-term**, dangerous explosive atmosphere.	In the interior of vessels or apparatus (evaporators, reaction vessels, etc.)
Zone 1	Covers areas in which the **occasional** occurrence of a dangerous, explosive atmosphere can be expected.	Immediate vicinity of Zone 0; immediate vicinity of charging doors; in the area of filling and discharge equipment, in the area of fragile apparatus or lines made of glass, ceramic and the like; in the close vicinity of insufficiently tight packing glands, e.g. on pumps, gate valves within apparatus such as evaporators, reaction vessels.
Zone 2	Covers areas in which the occurrence of a dangerous, explosive atmosphere can be expected, but only **rarely** and for a **short time**.	Areas surrounding Zones 0 and 1; in the close vicinity of flange joints with flat gaskets of the usual design on piping in enclosed rooms.

Table 4.2 Zones for Combustible Dusts /1/

Zone	Area Covered	Examples
Zone 10	Covers areas in which there is a **long-term** or **frequent**, dangerous explosive atmosphere.	In the interior of apparatus such as mills, dryers, mixers, silos, delivery piping, etc. when a dangerous amount of dust can form.
Zone 11	Covers areas in which the **occasional** occurrence of a dangerous, explosive atmosphere for a **short time** can be expected on account of whirling, deposited dust.	In the immediate vicinity of apparatus containing dust, and from which dust can be emitted through leaks, and where dangerous amounts of dust can be deposited (e.g. in mill rooms).

Assessing the explosion hazards in Zones 10 and 11

Dust becomes deposited and can accumulate. In the event of an explosion resulting from merely a small amount of dust-laden atmosphere, the leading explosion pressure wave can cause this deposited dust to whirl, thus providing a large amount of combustible matter.

Given in Table 4.3 is an extract from the combustion and explosion characteristics of dusts together with, as a comparison, the minimum ignition energies for acetylene, methane and hydrogen. These suggest that the risk of explosion with dusts is much lower than with gases, vapors and mists. It should be noted, however, that gaseous substances released by a process or resulting from a malfunction, usually become rapidly diluted with the existing air; this is not the case with combustible dusts.

Table 4.3 Combustion and Explosion Characteristics in Dusts [1)]

Substance	Ignition Temperature [C°]	Smoldering Temperature [C°]	Min. Ignition Energy [mJ]
Lignite	410 - 430	230 - 250	150 - 400
Coal	460 - 850	240 - 450	-
Wood	470 - 520	290 - 320	7 - 100
Milk powder			50 - 490
Wheat flour	450 - 610	280 - 400	100 - 500
Methyl cellulose	390 - 430	320 - 450	> 2000
Aluminum	560 - 840	270 - 430	29
Acetylene	305 [2)]		0.019 [2)]
Methane	595 [2)]		0.28 [2)]
Hydrogen	560 [2)]		0.016 [2)]

1) Extract from combustion and explosion characteristics of dusts of the Employers' Liability Insurance Institute for Work Safety and the Mines Testing Station (1987 edition) /14/.

2) According to Redeker, Schoen: (in German) Safety characteristics of flammable gases and vapors /3/

Table 4.4 Zones for Rooms Used for Medical Purposes /1/

Zone	Area Covered
Zone G	Also known as "enclosed medical gas systems"; covers cavities, not necessarily enclosed on all sides, in which explosive mixtures (other than an explosive atmosphere) are produced, transferred or applied in small amounts either continuously or occasionally.
Zone M	Also known as a "medical environment"; covers the part of a room in which an explosive atmosphere can occur in in small amounts and only for a short time, because of the application of analgesic agents or medical skin cleansing or disinfection agents.

Notes on zone classification for Zone 0 and Zone 1

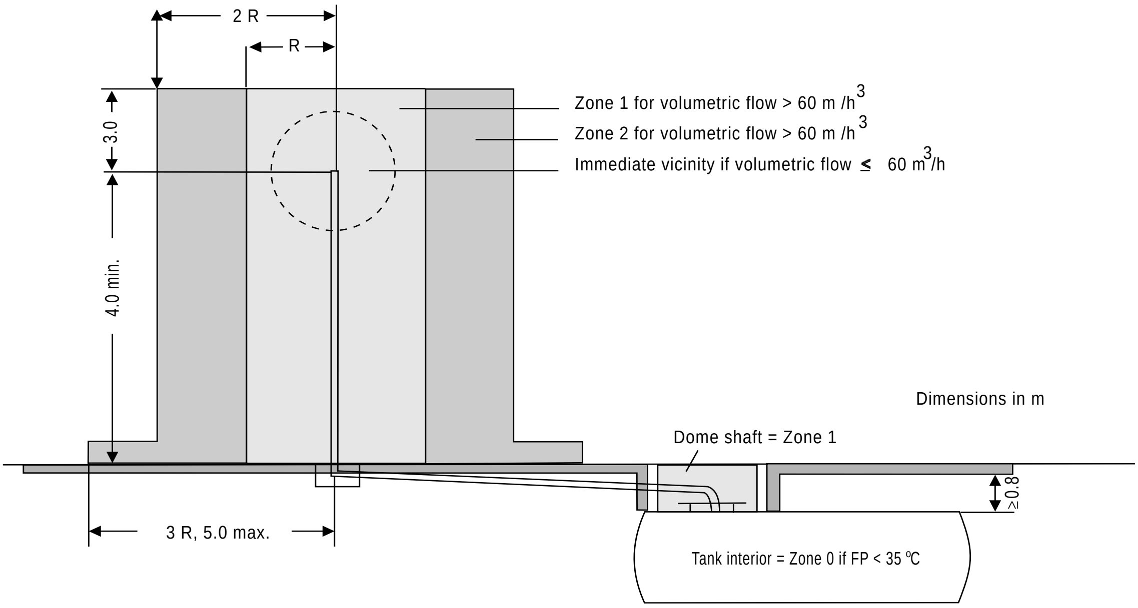


Figure 4.1 Example of Zone Classification, Tank Ventilation

Note

Where, in practice, the individual zones of a hazardous area and even the nonhazardous areas are to be defined in an **Ex zone plan** (see Appendix B "Configuring Aids", the collection of examples of EX-RL of the Employers' Liability Insurance for the Chemical Industry are helpful /4/. The assessment and therefore the zone classification of the hazardous area are defined by the user together with an expert or the competent supervisory authority (e.g. Factory Inspectorate, Technical Inspectorate).

In general, it should also be noted that only electrical apparatus for which a special test certificate from a recognized testing station exists may be installed in Zones 0 and 1.
Apparatus for Zone 0 must be specially certified for that zone.

The apparatus certified for Zones 0 and 1 may also be used in Zone 2. Furthermore, apparatus which complies with the requirements of DIN VDE 0165/2.91 Section 6.3 may also be used in Zone 2.

A detailed discussion of installation specifications for the individual zones can be found in Chapter 7.

4.2 Types of Protection

The individual types of protection for electrical apparatus are briefly described in the following. These types of protection encompass all the special design-related and circuit-related measures which prevent the ignition of an ambient explosive atmosphere by sparks or excessive temperature rise of electrical apparatus; i.e. the intention is to rule out the simultaneous occurrence of an ignition source and a hazardous amount of explosive mixture.

4.2.1 General Stipulations (DIN EN 50014 / VDE 0170/171 Part 1)

Defined in the general stipulations are requirements applying to the construction of explosion-protected electrical apparatus for all types of protection. These requirements relate to, for example, seals, connection elements, terminal compartments, cable routing and fuses; also given are the test requirements as well as apparatus markings.

4.2.2 Oil Immersion "o" (DIN EN 50015 / VDE 0170/0171 Part 2)

With this type of protection, electrical apparatus or parts of the electrical apparatus are immersed in oil, thus ensuring that an explosive atmosphere above the oil surface or outside the housing is not ignited (Figure 4.2). Transmission of the flame to the area above the oil surface is thus prevented.

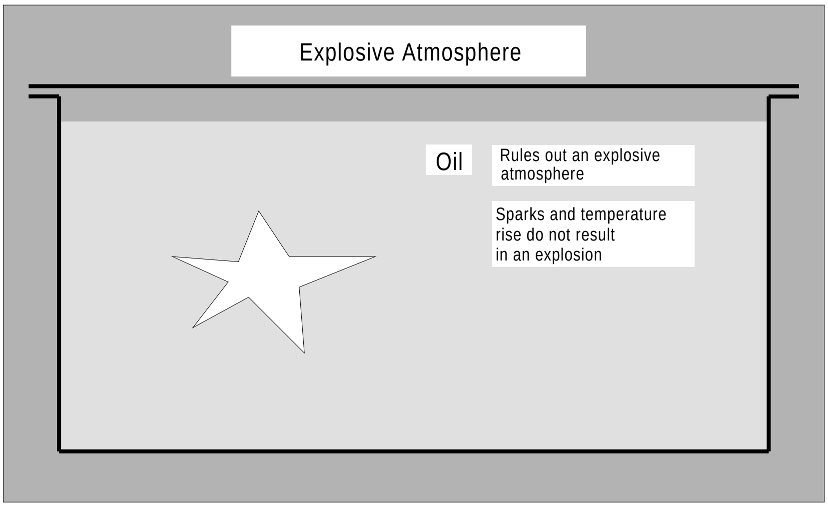


Figure 4.2 Oil Immersion "o" Type of Protection

This type of protection is mainly applied to electrical apparatus in power engineering which produces sparks and/or dangerous temperatures during operation or in a malfunction (e.g. motors, transformers, switchgear). This type of protection is rarely used for electrical apparatus in measurement and control systems.

4.2.3 Pressurized Enclosure "p" (DIN EN 50016 / VDE 0170/0171 Part 3)

With this type of protection, an explosive atmosphere is prevented from penetrating into the housing of electrical apparatus by keeping an inert gas, air, or the like in the housing at a pressure (≥ 0.5 mbar) with respect to the ambient atmosphere (Figure 4.3). The pressure is maintained with or without continuous flushing by means of inert gas or air.

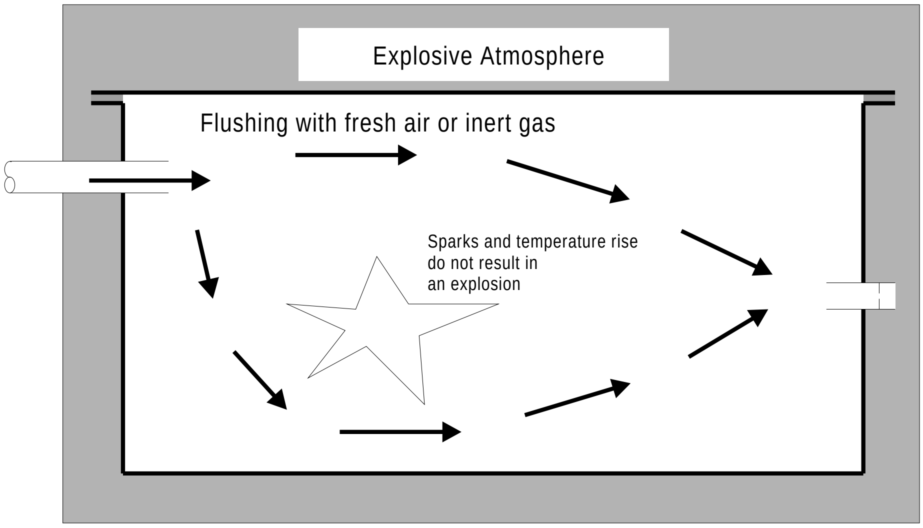


Figure 4.3 Pressurized Enclosure "p"

The pressure of the inert gas or air must be monitored with an independent device which immediately shuts down all non-intrinsically safe circuits in the event of pressure drop. When the pressure has been restored, these circuits may only be switched on again when the possibly explosive atmosphere in the housing has been diluted to less than the lower explosion limit by adequate flushing. The monitoring system must be certified with a suitable type of protection.

This type of protection is used for large non-explosion-protected electrical apparatus such as motors, transformers, units with high power, luminaires and programmable controllers operating in a hazardous area.

A distinction is made between the following types of pressurized enclosure:

- Pressurized enclosure with continuous flushing
- Pressurized enclosure with compensation for leakage losses

4.2.4 Sandfilled Apparatus "q" (DIN EN 50017 / VDE 0170/0171 Part 4)

Here, the housing of electrical apparatus is filled with fine-grained material to ensure that when it is used as specified, an arc created within the housing does not ignite an ambient explosive atmosphere. There must be no ignition by flames or by excessive temperatures on the housing surface (Figure 4.4).

This measure is often applied to capacitors, batteries, transformers and control circuits with hot or spark-emitting parts.

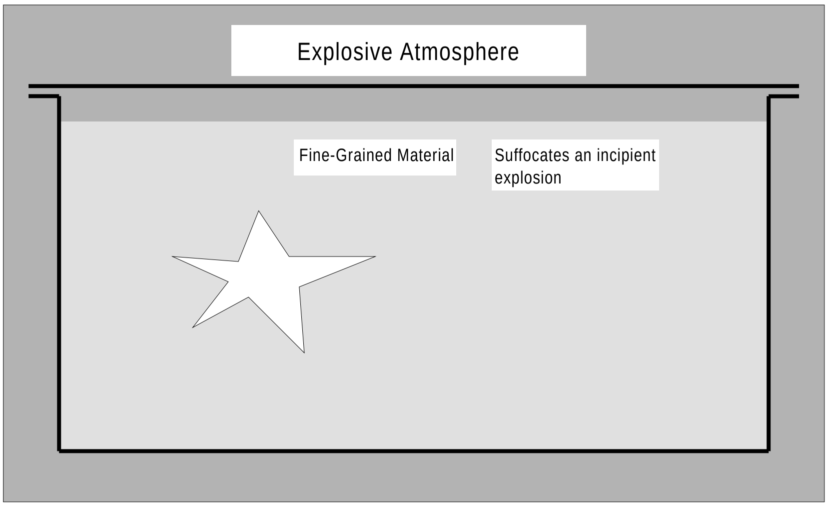


Figure 4.4 Sandfilled Apparatus "q"

4.2.5 Flameproof Enclosure "d" (DIN EN 50018 / VDE 0170/0171 Part 5)

With this type of protection, parts which could ignite an explosive atmosphere are enclosed in a housing. The design of this housing is such that in the event of ignition of an explosive mixture within the housing, it withstands the corresponding pressure and prevents a transfer of the explosion to the ambient explosive atmosphere (Figure 4.5).

In this case, therefore, an explosion in the housing is permissible; this is why the housing must be so designed that it withstands the explosion pressure and prevents a transfer of the explosion to the exterior with a so-called flameproof joint (e.g. gap). Defined in the stipulations for this type of protection are design guidelines for material, wall thickness, gap width, gap length, etc..

This type of protection is very common; it is used for electrical apparatus which emits sparks and/or considerable temperatures during operation, such as switches, motors, heaters, incandescent lamps and analyzers.

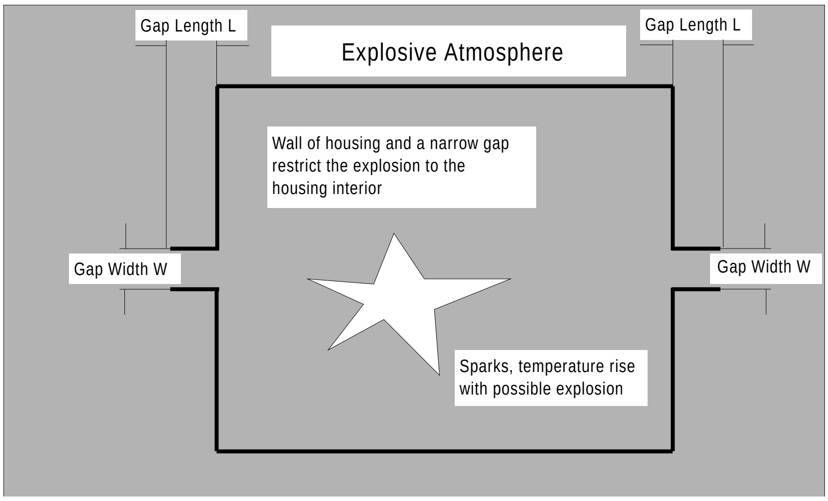


Figure 4.5 Flameproof Enclosure "d"

Note regarding "flameproof enclosure":

Figure 4.6 shows two different ways of routing cables into an "Ex d" area via an "EEx e" cable compartment.

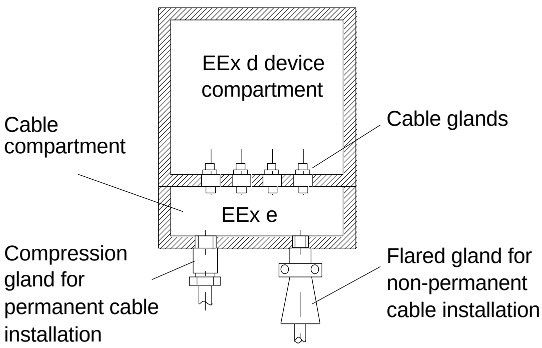


Figure 4.6 Cable Entry for Flameproof Enclosure

4.2.6 Increased Safety "e" (DIN EN 50019 / VDE 070/0171 Part 6)

In the scope of this type of protection, measures are taken which prevent with a high degree of reliability the risk of excessively high temperatures and the creation of sparks or arcing in the interior or at exterior parts of electrical apparatus, on which these do not occur in normal operation.

The purpose of these measures is to rule out fully the formation of ignition sources (Figure 4.7). It is particularly important that the maximum permissible surface temperature be met according to the intended temperature classes T1 to T6 (see Section 4.3.3), even at all surfaces within the housing. This type of protection can thus particularly be used for electrical apparatus, and parts of it which do not produce sparks or arcing or develop dangerous temperatures under normal conditions, and whose rated voltage does not exceed 11 kV.

This very common type of protection is used, for example, on induction motors with squirrel-cage rotors, brushless light-power and miniature motors for actuators in control systems and for transducers or transformers. However, connection elements in terminal boxes, such as terminal strips, may also be given this type of protection.

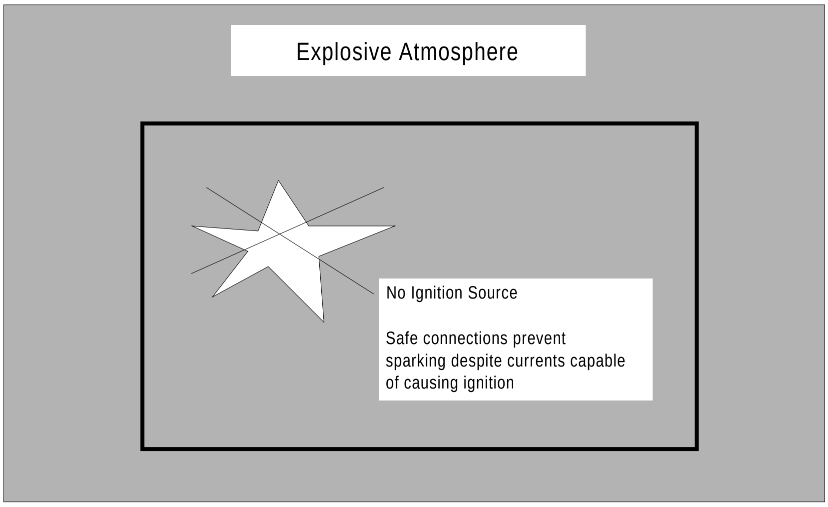


Figure 4.7 Increased Safety "e"

a) Notes regarding motors with "Increased Safety EEx e"

To prevent the permissible temperatures from being exceeded, additional protective elements such as motor circuit-breakers are often used. The following parameters play an important part with motor circuit-breakers:

- Starting current ratio I_a/I_n
- Locked rotor time T_E

Motor circuit-breakers are usually installed outside the Ex area.

b) Notes regarding terminal blocks with "Increased Safety EEx e":

Ex terminal blocks must be tested and certified according to the DIN EN 50014 or 50019 standard. They are classified as apparatus which does neither produce sparks or arcing nor develop dangerous surface temperatures. For these reasons, terminal blocks conform to temperature class T6. In normal operation a temperature limit (ambient temperature + self-heating) of 85 °C is not exceeded. The terminal blocks are

– protected against accidental loosening,

– designed in such a way that sufficient contact pressure is ensured.

Note

During operation, no work is permitted on circuits designed with "Increased Safety EEx e".

c) Note regarding cables with "Increased Safety EEx e":

Cables which are installed according to EEx e type of protection in hazardous areas must be specially protected at places particularly endangered by thermal, mechanical or chemical stress, for example by installing them in cable conduits, flexible tubes, etc.

d) Different cable entries:

Figure 4.8 shows different ways of leading cables into an EEx e compartment.

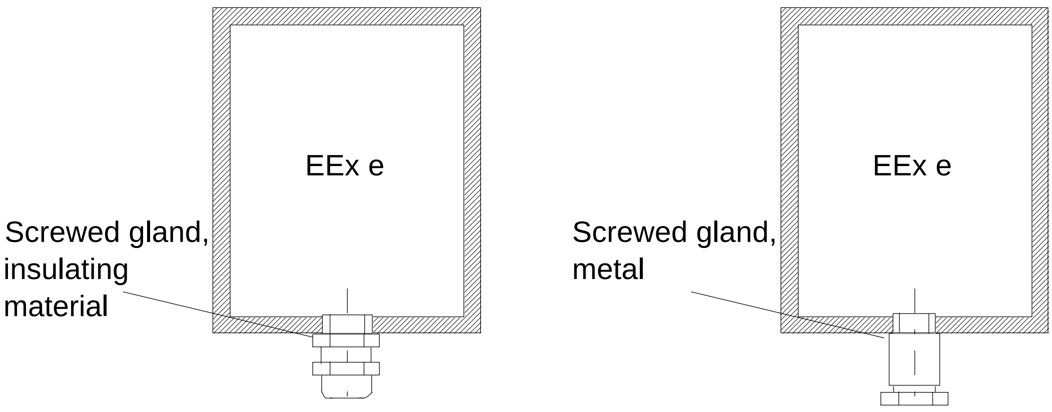


Figure 4.8 Cable Entries for Devices with Increased Safety

4.2.7 Intrinsic Safety "i" (DIN EN 50020 / VDE 0170/0171 Part 7)

Electrical apparatus is designated as **intrinsically safe** when all the circuits it contains are intrinsically safe. An **intrinsically safe circuit** is a circuit in which the short-circuit current and no-load current are limited so that sparks and thermal effects capable of causing ignition cannot occur in normal operation or during a malfunction (Figure 4.7). This means that the energy in an intrinsically safe circuit is less than the minimum ignition energy required for igniting an ignitable mixture.

Categories "ia" and "ib", safety factors

With the "intrinsically safe" type of protection, electrical apparatus and intrinsically safe circuits of the corresponding electrical apparatus are classified in two categories. During testing of the circuits for ignition due to sparks, safety factors apply either to the voltage or to the current or to a combination of both variables.

With the following safety factors:

1.5	:	in normal operation and with a fault
1.0	:	with a fault when the apparatus does not contain unprotected switching contacts

Category "ia"

No ignition must be caused by the following operational states:

- Normal operation
- A fault
- An arbitrary combination of two faults

Note

Intrinsically safe circuits of category "ia" are designed for operation in Zone 0. They must be specially certified by a testing station for operation in Zone 0.

The constructional requirements for electrical apparatus to be utilized in Zone 0 are in preparation (draft: DIN 57071, Part 12).

Category "ib"

No ignition must be caused by the following operational states:

- Normal operation
- The occurrence of a fault

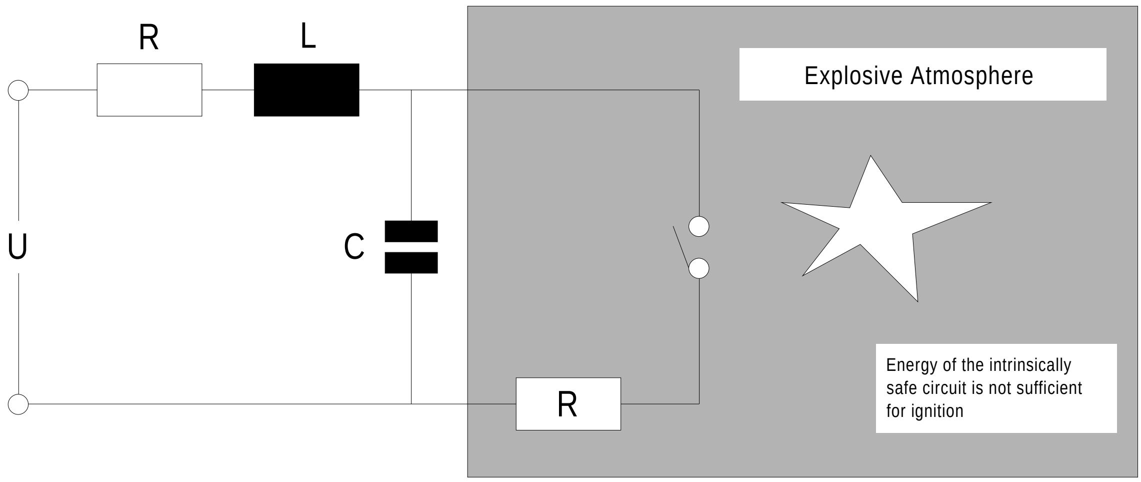


Figure 4.9 Intrinsic Safety "i"

> **Note**
>
> Circuits of category "ib" are intended for installation in Zones 1 and 2

Considered in the following is a **fully intrinsically safe circuit** comprising (see Figure 4.10):

- The associated electrical apparatus
- Cables
- Intrinsically safe electrical apparatus

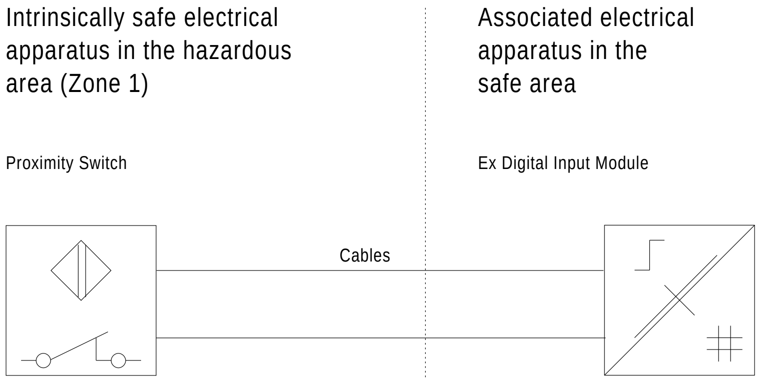


Figure 4.10 Intrinsically Safe Circuit (Example)

Intrinsically safe electrical apparatus

According to the above definition, all the circuits of such apparatus are intrinsically safe, i.e. the minimum ignition energy is reached by limiting the voltage and current values in the intrinsically safe electrical apparatus, and by tested characteristics relating to energy storage and temperature rise.

Intrinsically safe electrical apparatus may be installed in the hazardous area without an additional type of protection.

Intrinsically safe electrical apparatus is also distinguished as follows:

- Passive intrinsically safe apparatus without an energy store
- Passive intrinsically safe apparatus with an energy store
- Active intrinsically safe apparatus

Associated electrical apparatus

Designated as the associated electrical apparatus is apparatus in which not all circuits are intrinsically safe, but in which there is at least one intrinsically safe circuit leading into a hazardous area. In general, an intrinsically safe signal is converted to a non-intrinsically safe signal or vice versa, whereby the current can flow into or out of the hazardous area. Associated electrical apparatus thus has the task of signal separation (e.g. safety barriers), signal conversion (transducer, isolation amplifier) or supply (power supply unit). For example, SIMATIC Ex modules can be considered to be associated apparatus. They take on the characteristics of both signal conversion and supply.

With associated electrical apparatus, a distinction is made between:

- Electrical apparatus equipped with one or more other types of protection listed in European Standard EN 50014. **It may be installed in the hazardous area** if certified for the purpose, e.g. with the following marking: EEx deq [ib] IIC T5.

- Electrical apparatus which is **not** protected accordingly and may therefore **not** be installed in the hazardous area. It is identified by square brackets around the code for type of protection and by the lack of a temperature class (for example [EEx ib] IIC).

Cables

DIN VDE 0165/2.91 must be complied with when selecting and installing cables; particular attention must be paid to, for example, cable characteristics such as electric strength and minimum cross-section as well as, in the case of long cable lengths, the cable capacitance and inductance (see also Chapter 7). The connecting points and cables for intrinsically safe circuits must be identified (light-blue cables) and separated from the other connecting points and cables of non-intrinsically safe circuits.

Finally, circuits with the intrinsically safe type of protection are so designed that they cannot produce sparks capable of causing ignition during opening, closing, short-circuit and ground fault, even when a number of countable faults occurs.

Advantages of the intrinsically safe type of protection

This type of protection offers the user great **advantages**; it is particularly easy to handle because the nature of intrinsically safe circuits is such that they cannot produce sparks capable of causing ignition, and they can be opened and closed during operation. This grants the system user an important facility for component replacement, repair and system expansion without shutting it down. Handling during operation and maintenance is almost the same as for non-explosion-protected systems. Furthermore, the cables of intrinsically safe circuits are incorporated n the explosion protection. Additionally, the intrinsically safe type of protection offers considerably more economical problem solutions, because the electrical apparatus used in the field necessitates no complex special designs such as explosion-proof enclosures or embedding in sealing compounds.

A disadvantage of this type of protection, however, is that intrinsic safety makes higher demands on the planning and installation of a system than other types of protection. Not only must the constructional requirements for the individual apparatus be observed, but the interconnection of all apparatus in the intrinsically safe circuit must be planned with care and accuracy. Moreover, a correct installation is essential to prevent, in particular, external energy from being picked up by the intrinsically safe circuit.

The intrinsically safe type of protection has only been a separate type of protection in Germany since 1965 and has gained greatly in importance in recent years through its application to electronic modules for measurement, control and analysis as well as telecommunications and data processing. In these applications, the required low level of electrical variables can be met without problems in many cases.

4.2.8 Encapsulation "m" (DIN EN 50028 / VDE 0170/0171 Part 9)

With this type of protection, the parts which could ignite an explosive atmosphere are embedded in a sealing compound offering sufficient resistance to the effects of the environment. The explosive atmosphere around the apparatus cannot therefore be ignited by sparks or excessive temperature rise.

A distinction is made between two methods of encapsulating electrical components: either enveloping the components or sealing them in compound. Duromers, thermoplastics and elastomers serve as sealing compounds.

This type of protection is used, in particular, with electronic modules for measurement, control and analysis where the power and energy level is so great that the requirements of the intrinsically safe type of protection cannot be met. This is the case, for example, with small transformers, fuses, relays and line voltage rectifiers.

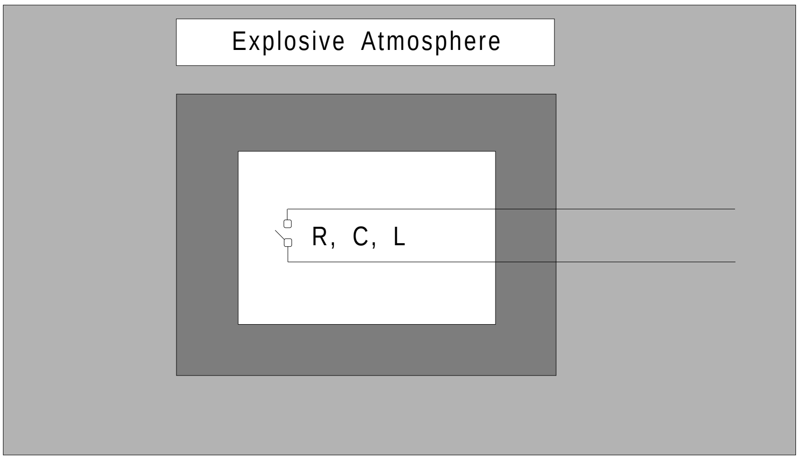


Figure 4.11 Encapsulation "m"

4.2.9 Intrinsically Safe Electrical Systems "i" (DIN EN 50039 / VDE 0170/0171 Part 10)

With this type of protection, the interconnection of two or more intrinsically safe circuits is certified, with the circuits fully or partly installed in hazardous areas. Such systems are documented with a system overview; they must be marked at a particularly conspicuous point with the letters "SYST", a reference to the testing station and to the system certificate.

A distinction is made between

- Certified intrinsically safe electrical systems
- Uncertified intrinsically safe electrical systems

With **certified intrinsically safe electrical systems**, the certificate confirms that the type of electrical system conforms to Standard EN 50039; a certificate is not required for each individual electrical apparatus of an intrinsically safe electrical system, as long as the relevant electrical apparatus can be clearly identified.

With **uncertified intrinsically safe electrical systems**, all components have their own certificate except for the simple apparatus.

For each intrinsically safe electrical system, the system planner drafts a **system overview** describing the electrical apparatus, its electrical characteristics and the characteristics of connecting lines. For the installer, this means that all equipment and its cabling pertaining to the system are precisely defined. The user must not make any changes and modifications.

In practice, intrinsically safe systems are used for measurement, open and closed-loop control systems as interconnected intrinsically safe and associated electrical apparatus, including accessories and cabling.

> **Note**
>
> The practice in the United Kingdom is to issue test certificates for "intrinsically safe systems". In the Federal Republic of Germany, interconnections of intrinsically safe circuits in hazardous areas are only assessed according to installation specification DIN VDE 0165/2.91 and do not require a system certificate.

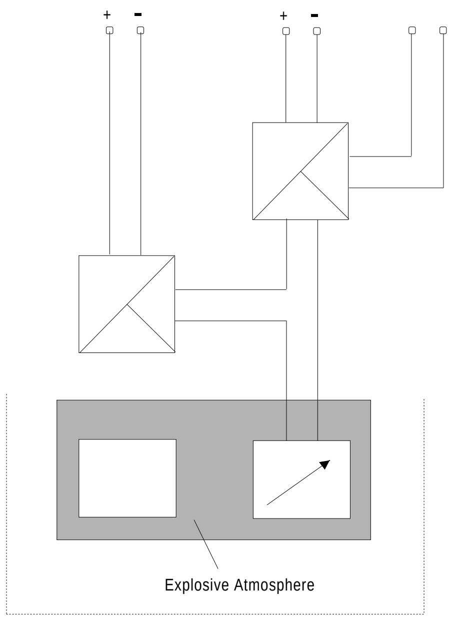


Figure 4.12 Intrinsically Safe Systems "i-SYST"

4.3 Safety Characteristics

The operating conditions of apparatus discussed here (apparatus for mining is not considered here) are characterized by a great number of the relevant flammable gases which differ, in some cases considerably, in their chemical and physical behavior. The gases are characterized and classified by means of so-called safety characteristics, of which the following ones are particularly important:

- Ignition temperature
- Minimum ignition energy
- Minimum ignition current (MIC)
- Safe gap (MESG)
- Explosion limits

The **ignition temperature** indicates that flammable gas/air mixtures can ignite on hot surfaces (cf. Section 1.2). It is therefore determined for flammable gases in a special test unit and extends from less than 100 ^{o}C to more than 600 ^{o}C.

The **minimum ignition energy** specifies the minimum energy (e.g. of an electric spark) required to ignite the relevant gas/air mixture under the most explosive, i.e. most critical, conditions.

The **minimum ignition current** (MIC) for a flammable gas/air mixture is the current which just barely ignites the test mixture in a circuit, in a spark testing unit.

Flammable gas/air mixtures exhibit a different flame transmission behavior through gaps in a housing. So-called flameproof joints suppress the propagation of the combustion reaction. In a test unit, the maximum width of a gap - the **safe gap** (MESG) - at which flame transmission can no longer occur, is determined as a function of the mixture concentration for the relevant gas/air mixture.

The **explosion limits** represent the lower and upper limit values of concentration of a flammable substance in a mixture of gases, vapors, mists and/or dusts, at which a flame independent of the ignition source can no longer be transmitted independently after ignition.

The typical substance-related characteristics such as susceptibility to ignition and flame transmission make different demands on the construction of explosion-protected electrical apparatus. However, a grading of requirements is also possible, depending on the intended application. The stipulations are described in the constructional requirements for the individual types of protection, and are expressed in the form of different limit values for surface temperatures, gap dimensions (for flameproof enclosure "d") and ignition curves (for intrinsic safety "i"). The safe gap MESG and minimum ignition current MIC therefore apply as classification criteria.

The safety characteristics (see Table 4.5 for a selection) have been experimentally determined for the most common substances with a specified test set-up, allowing classification into groups for the various substances.

Accordingly, explosion-protected electrical apparatus is classified in explosion groups (see Section 4.3.2) and temperature classes (see Section 4.3.3) according to the applications and requirements, to meet economic aspects, in particular.

Table 4.5 Safety Characteristics of Selected Flammable Gases

Substance	Ignition Temperature [°C] 1)	Min. Ignition Energy [μJ] 1)	Min. Ignition Current [mA] 3)	Safe Gap [mm] 2)	Explosion Limit [% by vol. in air] lower	upper1)
Acetone	540	550	-	1.02	2.5	13.0
Acetylene	305	19	24	0.37	2.3	100
Ethyl ether	170	190	75	0.87	1.7	36.0
Ethylene	425	82	45	0.65	2.3	32.4
Ammonia	630	14000	-	3.17	1.4	33.6
Butane	365	250	80	0.98	1.4	9.3
Hexane	240	240	75	0.93	1.0	8.1
Methane	595	280	85	1.14	4.4	16.5
Propane	470	250	70	0.92	1.7	10.6
Carbon bisulphide	95	9	-	0.34	0.6	60.0
Hydrogen	560	16	21	0.29	4.0	77.0

1) According to Nabert, Schoen: Sicherheitstechnische Kennzahlen brennbarer Gase und Daempfe
2) According to IEC 79-1A/1975
3) According to IEC/TC 31 (Secretariat) 165

4.3.1 Explosion Groups

A basic distinction is made between two groups of apparatus according to European standards:

Explosion group I:

- Relates to electrical apparatus **for mines susceptible to firedamp** and is not discussed in the following.

The DMT/BVS is responsible for testing and approval.

Explosion Groups	Test Gas
I	Methane

Explosion group II:

- Electrical apparatus **for all other hazardous areas**
- Owing to the great number of flammable gases, a further subdivision of this group into the following **explosion groups** is made (according to safe gap MESG for the flameproof enclosure "d" type of protection, and ratio between minimum ignition current MIC and minimum ignition current of methane for the intrinsic safety "i" type of protection):

Explosion Groups	Test Gas
II A	Propane
II B	Ethylene
II C	Hydrogen

The dangerous nature of the gases increases from explosion group II A to II C; the requirements of the electrical apparatus therefore also rise.

The electrical apparatus approved for explosion group II C can, of course, also be used for the other explosion groups.

Given in Table 4.6 is the classification in individual explosion groups for various gases and vapours. For unlisted substances, it is advisable to consult the PTB or another testing station.

Table 4.6 Safety Characteristics of Flammable Gases and Vapors [1)]

Designation	Ignition Temperature [°C]	Flash Point [°C]	Temperature Class	Explosion Group
Acetic aldehide	140	≤ 20	T4	II A
Acetone	540	≤ 20	T1	II A
Acetylene	305	(Gas)	T2	II C
Ethane	515	(Gas)	T1	II A
Ethyl acetate	460	-4	T1	II A
Ethyl ether	180 Peroxide formation	< -20	T4	II B
Ethyl alcohol	425	12	T2	II A /II B
Ethyl chloride	510	(Gas)	T1	II A
Ethylene	425	(Gas)	T2	II B
Ethylene oxide	440 Spont. decomp.	(Gas)	T2	II B
Ethyl glycol	235	40	T3	*)
Ammonia	630	(Gas)	T1	II A
i-amyl acetate	380	25	T2	II A

1) Extract from /1/ and extract from Appendix A, DIN VDE 0165/2.91

*) Not yet determined

Table 4.6 continued

Designation	Ignition Temperature [°C]	Flash Point [°C]	Temperature Class	Explosion Group
Gasoline (petrol) Initial boiling point < 135 °C	220 to 300	< 21	T3	II A
Petroleum spirit Initial boiling point > 135 °C	220 to 300	> 21	T3	II A
Benzene (pure)	555	- 11	T1	II A
n-butane	365	(Gas)	T2	II A
n-butyl alcohol	340	35	T2	II A
Cyclohexanon	430	43	T2	II A
1,2-dichlorethane	440	13	T2	II A
Diesel fuels DIN 51 601/04.78	220 to 300	> 55	T3	II A
Jet fuels	220 to 300	< -20 to 60	T3	II A
Acetic acid	485	40	T1	II A
Acetic anhydride	330	49	T2	II A
Heating oil EL DIN 51 603 Part 1/12.81	220 to 300	> 55	T3	II A
Heating oil L DIN 51 603 Part 2/10.76	220 to 300	> 55	T3	II A
Heating oils M and S DIN 51 603 Part 2/10.76	220 to 300	> 65	T3	II A
n-hexane	240	< -20	T3	II A
Carbon oxide	605	(Gas)	T1	II A
Methane	595 (650)	(Gas)	T1	II A
Methanol	455	11	T1	II A
Methyl chloride	625	(Gas)	T1	II A
Naphthalene	520	80	T1	II A
Oleic acid	360 Spont. decomp.	189	T2	*)
Phenol	595	82	T1	II A
Propane	470	(Gas)	T1	II A
n-propyl alcohol	405	15	T2	*)
Carbon bisulphide	95	< -20	T6	II C
Hydrogen sulphide	270	(Gas)	T3	II B
City gas	560	(Gas)	T1	II B
Tetraline (Tetrahydronaphthalene)	425	77	T2	*)
Toluene	535	6	T1	II A
Hydrogen	560	(Gas)	T1	II C

*) Not yet determined

These temperatures have been published in Publication 79-8 "Classification of the highest surface temperature". They are referred to an ambient temperature of 40 °C during operation and measurement of the apparatus.

4.3.2 Temperature Classes

With this type of classification, the ignition temperature determined experimentally with gases and vapors serves as a basis; this is the temperature at which thermal ignition, e.g. by a hot surface of apparatus, can take place. In practice, the maximum surface temperature of electrical apparatus must always be lower than the ignition temperature of the explosive mixture in which it is used.

Table 4.7 Classification of Substances by Percent in Temperature Classes and Substance Groups

<table>
<tr><th colspan="7">Temperature Class</th></tr>
<tr><td>T1</td><td>T2</td><td>T3</td><td>T4</td><td>T5</td><td>T6</td><td>Total</td></tr>
<tr><td>28 %</td><td>37.6 %</td><td>30.5 %</td><td rowspan="2">3.1 %</td><td rowspan="2">0 %</td><td rowspan="2">0.3 %</td><td rowspan="2">351</td></tr>
<tr><td colspan="3">96.5 %</td></tr>
<tr><th colspan="7">Explosion Group</th></tr>
<tr><td>IIA</td><td>IIB</td><td>IIC</td><td></td><td></td><td></td><td>Total</td></tr>
<tr><td>80.2 %</td><td>18.1 %</td><td>0.7%</td><td></td><td></td><td></td><td>436</td></tr>
</table>

For electrical apparatus of explosion group II, therefore, **Temperature classes T1 to T6** have been introduced; each apparatus is classified here according to its maximum surface temperature (see Table 4.8). However, the explosive mixtures can also be assigned to temperature classes according to their ignition temperature. The maximum surface temperature of the particular class must not reach the ignition temperature of the relevant explosive mixture, i.e. the ignition temperature of the explosive mixture must always be higher than the temperature class of the apparatus.

Note

Apparatus relating to a higher temperature class may also be used for applications requiring a lower temperature class.

The classification of various gases and vapors in individual temperature classes can be found in Table 4.5.

In practice, the maximum surface temperature of electrical apparatus taken as a basis results from the sum of maximum ambient temperature and the increase caused by temperature rise (including a malfunction).

Note

The lowest ignition temperature of the explosive atmosphere must be higher than the maximum surface temperature. Ethylene, for example, has an ignition temperature of 510 ^{o}C; apparatus of temperature classes T1 to T6 can therefore be used.

For intrinsically safe electrical apparatus, the certificate of conformity only specifies a permissible ambient temperature if it is likely to be **higher than 40 °C**. If, for example, higher ambient temperatures are expected in a switching cabinet, intrinsic safety within the meaning of the certificate is no longer ensured and a new test would be required. In practice, therefore, different temperature classes can be certified at various ambient temperatures in one certificate of conformity for electrical apparatus.

Table 4.8 Temperature Classes

Temperature Class	Max. Surface Temperature of Apparatus	Ignition Temperatures of Flammable Substances
T 1	450 °C	> 450 °C
T 2	300 °C	> 300 °C
T 3	200 °C	> 200 °C
T 4	135 °C	> 135 °C
T 5	100 °C	> 100 °C
T 6	85 °C	> 85 °C

4.4 Regulations for Explosion Protection Outside the CENELEC Member States

Outside the CENELEC member states, IEC Recommendations IEC 79-0 to 79-16 form the basis for explosion protection regulations. National institutions and standards in the individual countries specify the technical implementation of explosion protection measures.

The following, separate regulations apply to the **USA and Canada**. In contrast to European standards, there is a different classification of zones and explosion groups. Zones 0 and 1 are combined and designated as Division 1, whilst Zone 2 corresponds to Division 2 (Table 4.9).

For the explosion groups, there is finer subdivision than for European standards.
Temperature classes T1 to T6 are unchanged with respect to European standards.

Approval by the Factory Mutual (FM) or Underwriters' Laboratories (UL) is required for the application of apparatus in the USA. The apparatus is marked with the possible application according to Division 1 or 2 and the class/group classification.

The FM and UL testing stations work to their own standards. For example, intrinsically safe apparatus is tested by the Factory Mutual to FM 3610 which is based on national standard NFPA 493. Underwriters' Laboratories, in contrast, uses UL 913 which is based on ANSI/UL 913.

Table 4.9 Summary of the Intrinsic Safety "i" Type of Protection Outside the CENELEC Member States

	IEC	**USA and Canada**
Categories	**Category ia:** Ignition must not be caused by normal operation, a fault or arbitrary combination of two faults. Intended operation is in Zone 0, which also permits operation in Zones 1 and 2. **Category ib:** Ignition must not be caused by normal operation or a fault. Intrinsically safe apparatus is approved for Zones 1 and/or 2.	**Only one category:** Safety for up to two component or other faults. Intrinsically safe apparatus can be arranged in hazardous areas in Division 1 or 2 and may be connected to apparatus in other areas.
Area Classification	**Zone 0:** This covers areas in which a dangerous, explosive atmosphere exists **continuously** or for a **long time**. **Zone 1:** This covers areas in which the **occasional** occurrence of a dangerous, explosive atmosphere can be expected. **Zone 2:** This covers areas in which it can be expected that a dangerous, explosive atmosphere occurs only **rarely** and for a **short time**. **Zone 10:** (for dusts) This covers areas in which a dangerous, explosive atmosphere exists for a **long time** or **frequently** . **Zone 11:** (for dusts) This covers areas in which it can be expected that a dangerous, explosive atmosphere occurs **occasionally** for a **short time** on account of whirling of deposited dust.	**Division 1:** This covers areas in which dangerous concentrations of flammable gases or vapors or combustible dusts in the floating state are present continuously, from time to time or regularly under normal operating conditions. **Division 2:** This covers areas containing volatile, flammable liquids or flammable gases which are normally within closed vessels or systems from which they can only escape under abnormal operating or fault conditions. Combustible dusts which are not normally in the floating state and for which this state is not probable.
Gas Features	Details of the classification (C) and ignition temperature (T) of frequently used gases and vapors are contained in the following standards: IEC 79-12 (C)	Details of the classification (C) and ignition temperature (T) of frequently used gases and vapors are contained in the following standards: NFPA 325M: (T) NFPA 497M: (CT) (incl. dusts) CSA C22.1: (CT)

Table 4.9 continued

	IEC	USA and Canada
Classification of Gases	Flammable gases, vapors and mists are classed according to the spark energy required to ignite the most easily flammable mixture with air. Apparatus is grouped together with the gases with which it can be operated. - Other hazardous areas: Calibration gas **Group IIC:** acetylene (most easily flammable) **Group IIC:** hydrogen **Group IIB:** ethylene **Group IIA:** propane	Flammable gases, vapors and mists a well as combustible dusts, fibers and suspended matter are classed according to the spark energy required to ignite the most easily flammable mixture with air. Calibration gas Class I, Group A: acetylene (most easily flammable) **Class I, Group B:** hydrogen **Class I, Group C:** ethylene **Class I, Group D:** propane **Class II, Group E:** metal dust **Class II, Group F:** coal dust **Class II, Group G:** flour, starch, grain **Class III:** fibers and suspended matter
	- Mining: Calibration gas **Group I:** methane	Calibration gas **Not classed:** methane
Classification of Temp-eratures	Apparatus for hazardous areas is classed, allowing for the maximum surface temperature under fault conditions at an ambient temperature of 40 ^{o}C: **T1** 450 ^{o}C **T2** 300 ^{o}C **T3** 200 ^{o}C **T4** 135 ^{o}C **T5** 100 ^{o}C **T6** 85 ^{o}C	
Approval	With respect to approved apparatus, national approval authorities issue certificates indicating the permissible areas of application.	FM and UL (USA) as well as CSA (Canada) issue reports and publish lists of approved apparatus, specifying the permissible areas for application.
Standards	All countries in western Europe comply with Standards EN 50020 (apparatus) and EN 50039 (systems). The member states of CENELEC issue certificates based on these standards, and receive certified apparatus from other members. Other countries comply with their own standards based on IEC 79-11 (e.g. Australia, Brazil, CIS, Japan) or accept apparatus and systems certified according to European and/or US/Canadian standards.	FM and UL work to their own standards. FM 3610 is based on US national standard NFPA 493, and UL 913 is based on ANSI/UL 913. Canada complies with standard CSA C22.2, No. 157.
Procedural Specifica-tions	IEC 79-14: DIN VDE 0165:	ANSI/ISA-RP 12.6-1987

5 Marking of Explosion-Protected Electrical Apparatus

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5 Marking of Explosion-Protected Electrical Apparatus

5.1 Type and Method of Marking

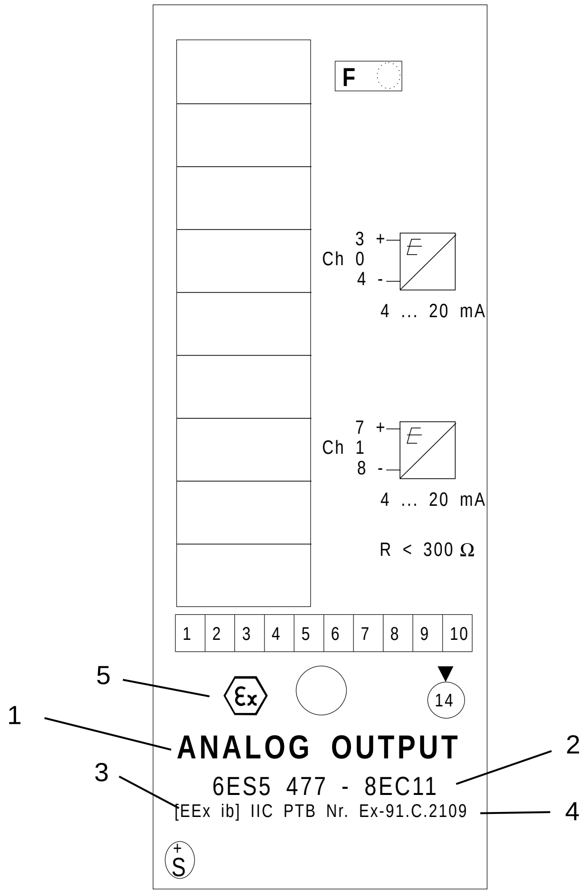
According to the general requirements of EN 50014, the marking of explosion-protected electrical apparatus is mandatory, irrespective of whether the apparatus is to be marketed within or outside the EC.

The following details must appear in brief form at a visible point on the main part of the apparatus:

- Name or trademark of the manufacturer
- Type designation and, if applicable, serial number of the apparatus
- The following symbol in the case of apparatus which is type and routine-tested to EN standards

- Classification according to type(s) of protection, explosion group and temperature class
- Testing station, year of issue and number of the special test certificate (certificate of conformity)
- For apparatus with intrinsic safety as the type of protection, the electrical limits including power ratings should be stated if possible.

Given in Figure 5.1 is an example of full marking of an item of electrical apparatus from Siemens. The code for marking explosion-protected electrical apparatus is shown as a summary in Figure 5.2.



1 Name or trademark of manufacturer

2 Type designation of apparatus

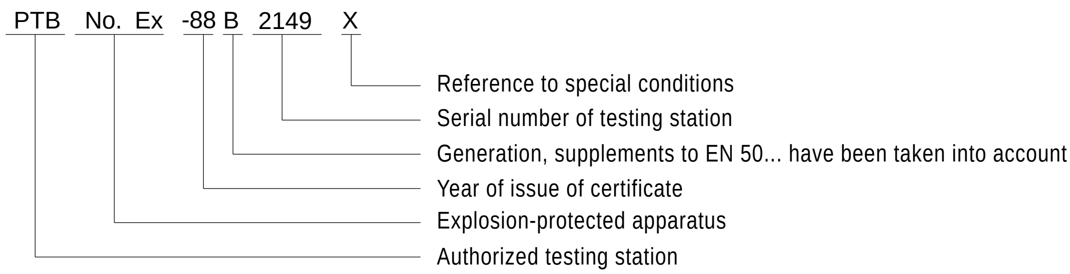
3 Classification of one of the types of protection

4 Testing station and certificate number

5 The symbol ⟨Ex⟩ must be displayed since May 1, 1988 if the apparatus has been type and routine-tested to EC standards and is the subject of a certificate of conformity.

Figure 5.1 Markings on a Siemens Analog Output Module for Connecting Actuators in a Hazardous Area

Example of a certificate number:



A suffix letter, such as x, may follow the test certificate number; its meaning is given in Table 5.1.

Table 5.1 Meaning of the Suffix Letter for Test Certificates

Regulation	Letter	Meaning
to VDE 0171/2.61 (old standard)	B	The test certificate contains special conditions. The apparatus must be additionally labelled: "Observe approval certificate".
	S	The apparatus contains intrinsically safe circuits which may lead into the hazardous area. However, the apparatus must be installed outside the hazardous area.
	U	Incomplete apparatus. No design approval has been issued (e.g. for lamp sockets, ballast, terminals, impregnating varnish, mechanical design of motors and the like). Instead there is an "auxiliary certificate". However, the letter U is also used to issue a partial certificate for incomplete apparatus, e.g. with intrinsic safety.
to EN 50014 ... EN 50020/ VDE 0171/5.78 (new standard)	X	Certificate of conformity for apparatus complying with the new European standards (EN) contains the identification letter X for special features instead of the previous letter B. The type of restrictions can be found on the certificate of conformity.
	U	Incomplete apparatus. No design approval has been issued (e.g. for lamp sockets, ballast, terminals, impregnating varnish, mechanical design of motors and the like). This will only be issued together with the complete apparatus. However, the letter U is also used to issue a partial certificate for incomplete apparatus, e.g. with intrinsic safety.

Listed in the following is the marking of explosion-protected electrical apparatus in Figure 5.2.

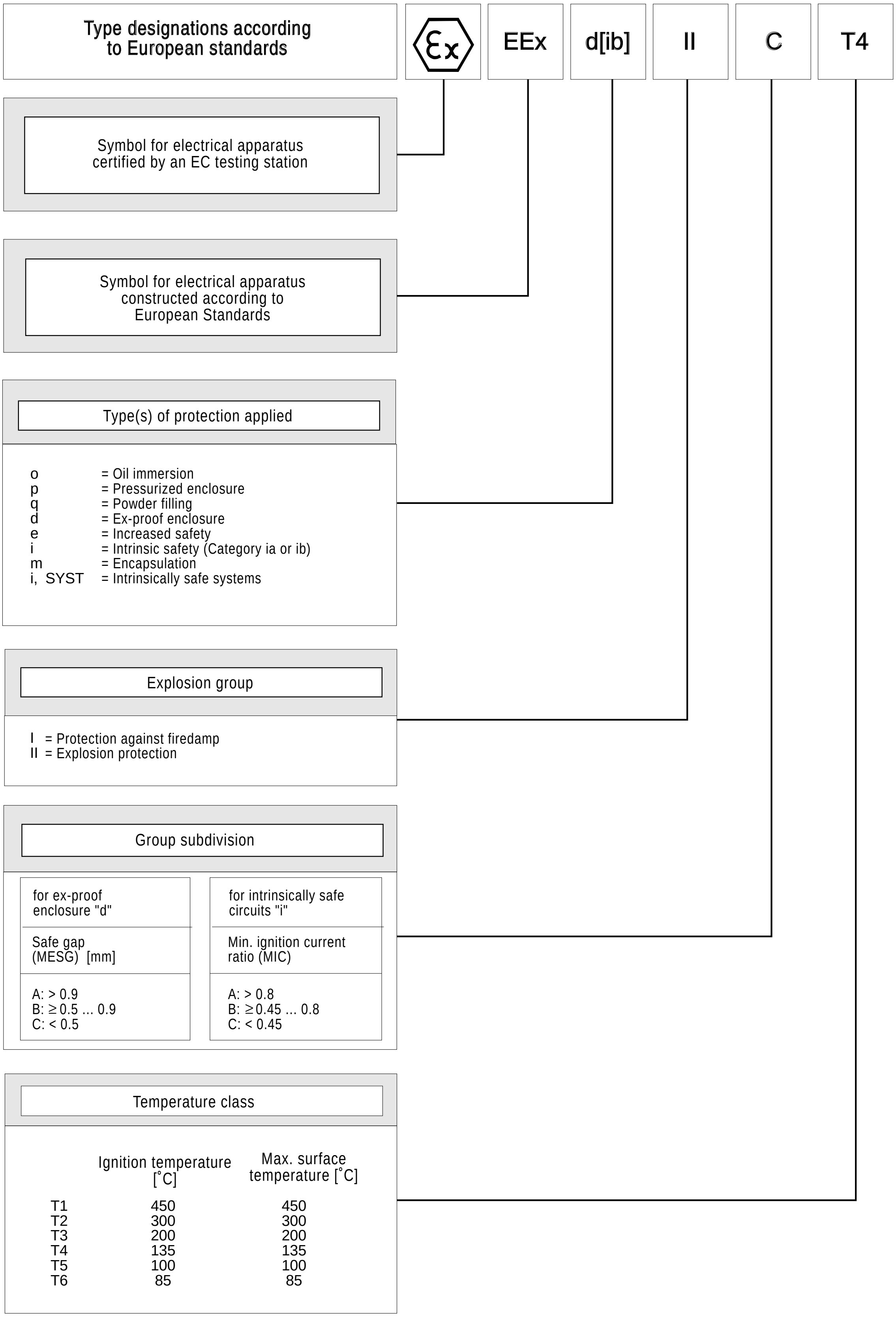


Figure 5.2 Example of Markings for Explosion-Protected Electrical Apparatus

5.2 Comparison Between Old and New Markings

Table 5.2 is a comparison of markings for apparatus according to the old requirements of VDE 0170/0171/2.62 and the new European standards EN 50014 to 50020.

Table 5.2 Markings for Electrical Apparatus According to the Old and New Standards

New Standard: DIN EN 50014 to DIN EN 50020/5.78		**Old Standard: VDE 0170/0171/2.61 2.65**		**Terms/Explanations**
				Identification
Ex		Ex		– Explosion-protected electrical apparatus, type tested and routine tested by the manufacturer
				General code
EEx...I		Sch		– Protection against firedamp
EEx...II		Ex		– Explosion protection
Ignition protection		Type of protection		Code for
o		ö		– Oil immersion
p		f		– Pressurized enclosure or separate ventilation
q		q		– Powder filling
d		d		– Ex-proof enclosure
e		e		– Increased safety
i		i		– Intrinsic safety
-		s		– Special protection (only to "old" VDE/2.61)
m		-		– Encapsulation (DIN EN 50028)
Explosion group		Explosion class		– Ignition transmission behavior (spark ignition), specifying the safe gap (MESG) at 25 mm gap length [mm]
A	(> 0.9)	1	(> 0.6)	Calibration gas: propane
B	(≥ 0.5 ... 0.9)	2	(≥ 0.4 ... 0.6)	ethylene
C [1]	(< 0.5)	3a	(< 0.4)	hydrogen
		3b		carbon bisulphide
		3c		acetylene
		3n		all gases of Group 3

[1] Explosion group C: calibration gas = hydrogen

Table 5.2 continued

New Standard: DIN EN 50014 to DIN EN 50020/5.78		**Old Standard: VDE 0170/0171/2.61 2.65**		**Terms/Explanations**
Temperature Class		Ignition Group		Ignition temperature of gases and vapors
Ignition Tempera-ture [°C]	Max. Surface Tempera-ture [°C]	Ignition Tempera-ture [°C]	Permissible Tempera-ture Limit [°C]	
T1 > 450	450	G1 > 450	360	
T2 > 300	300	G2 > 300 ... 450	240	
T3 > 200	200	G3 > 200 ... 300	160	
T4 > 135	135	G4 > 135 ... 200	110	
T5 > 100	100	G5 from 100 to 135	80	
T6 > 85	85			

5.3 Examples of Marking

Listed in Table 5.3 are some examples of the markings for explosion-protected electrical apparatus and intrinsically safe circuits.

Table 5.3 Examples of Markings for Explosion-Protected Electrical Apparatus

Marking (Example)	Explanation
EEx ia IIC T6	Intrinsically safe electrical apparatus of Category ia and approval for all explosive mixtures
[EEx ib] IIC	Associated electrical apparatus for installation **outside** the hazardous area, for connection of intrinsically safe. Note: **Specification of the temperature class is dispensed with**.
EEx deq [ib] IIB T4	Associated electrical apparatus for installation in Zone 1, because types of protection d, e and q additionally exist; approval for explosive mixtures of explosion groups IIA and IIB with an ignition temperature of > 135 ^{o}C
EEx e IIC T5	Explosion-protected electrical apparatus of the "increased safety" type of protection; approval for all explosive mixtures with an ignition temperature of > 200 ^{o}C

Note

The significance of the square brackets for the markings within the scope of intrinsic safety "i" should be pointed out again.

For associated electrical apparatus which must **not** be installed in the hazardous area, the square brackets are placed around the EEx symbol and the code for type of protection. The temperature class is not specified.

For associated electrical apparatus which is additionally certified for other types of protection and may therefore be installed in the hazardous area, the square brackets are placed around the symbol for the intrinsic safety type of protection according to the relevant category. The temperature class is additionally specified.

6 The Intrinsic Safety "i" Type of Protection

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6 The Intrinsic Safety "i" Type of Protection

Intrinsic safety as the type of protection has continued to grow in significance in recent years for the installation of electrical systems in hazardous areas. It is not the individual, intrinsically safe apparatus to DIN EN 50020, but the entirety of two or more items of apparatus including connecting cables in the intrinsically safe electrical system which are significant here and are discussed in the following.

6.1 Principles of Intrinsic Safety

6.1.1 Functional Principle

The basis for intrinsic safety as the type of protection is that a certain minimum ignition energy is required to ignite an explosive atmosphere. In an intrinsically safe circuit, this minimum ignition energy is not present in the hazardous area in normal operation or in a malfunction. The intrinsic safety of a circuit is achieved by limiting the current and voltage. The intrinsic safety "i" type of protection is therefore restricted to circuits with relatively low power levels.

In an intrinsically safe circuit, therefore, there are no

- sparks or
- thermal effects (temperature rise)

during operation or a malfunction which could cause ignition of an explosive atmosphere.

Ignition due to sparks is therefore also ruled out, i.e. there are no sparks capable of causing ignition during the operational opening and closing of the circuit or during a short-circuit or ground fault.

Nor is there any **thermal ignition** in normal operation or in a malfunction, because excessive temperature rise of the apparatus in the intrinsically safe circuit and cables is ruled out.

The principle of intrinsic safety as the type of protection is shown in Figure 6.1.

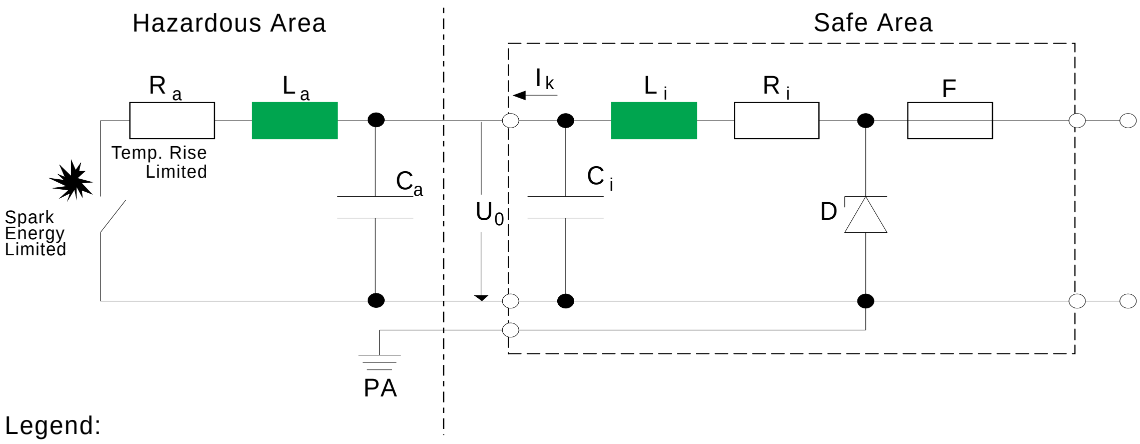
Zener diodes are normally used for **voltage limiting** in the event of a fault. Their characteristic is that they only start to conduct at a particular voltage, i.e. the current through the zener diode rises rapidly above the so-called zener voltage, resulting in voltage limiting.

Two cases of **current limiting** should be considered (Figure 6.2):

- **resistive** current limiting with a linear or trapezoidal basic characteristic, or
- **electronic** current limiting with a rectangular basic characteristic.

Furthermore, it should be noted that in mixed circuits containing both inductances and capacitances, the ignition values (combinations of current and voltage values) are lower than in circuits with only inductive or only capacitive energy stores.

In the case of **resistive current limiting**, this effect can be ignored for applications in Zone 1. For applications with mixed circuits in Zone 0, the values for Ca and La must be reduced. This is taken into account during approval of the apparatus. In the case of **electronic current limiting**, the effect of a mixed circuit has such a pronounced effect that complicated calculation algorithms are needed even for applications in Zone 1.



Legend:

U_0	= No-load voltage	D	= Zener diode
I_K	= Short-circuit current	PA	= Equipotential bonding
R_i	= Internal resistance	R_a	= External resistance
L_i	= Internal inductance	L_a	= External inductance
C_i	= Internal capacitance	C_a	= External capacitance
F	= Fuse		

Figure 6.1 Basic Circuit Diagram for Voltage/Current Limiting with the Intrinsic Safety "i" Type of Protection

Resistive current limiting is achieved by using series resistors R which are fed from a reliably limited voltage source. The trapezoidal characteristic is produced with the resistor and a voltage-limiting zener diode (Figure 6.2). Shown as a comparison is a characteristic with electronic current limiting.

The **intrinsic safety can be impaired** by energy stores in a circuit such as inductances or capacitances (e.g. moving-coil meter, long lines).

Where a **capacitor** is connected in an intrinsically safe circuit, it stores an **energy of 1/2 CU^2** in the charged state. In the event of a short in the circuit, the energy released at the point of the short-circuit results from that supplied by the apparatus and the energy stored in capacitor. Thus the capacitor must be in the circuit without fail for safety reasons, because the total energy in the spark must be less than the minimum ignition energy.

In the case of an **inductance** in the intrinsically safe circuit, the **stored energy is 1/2 LI^2** which is released when the circuit is opened; this must be taken into account when testing for intrinsic safety.

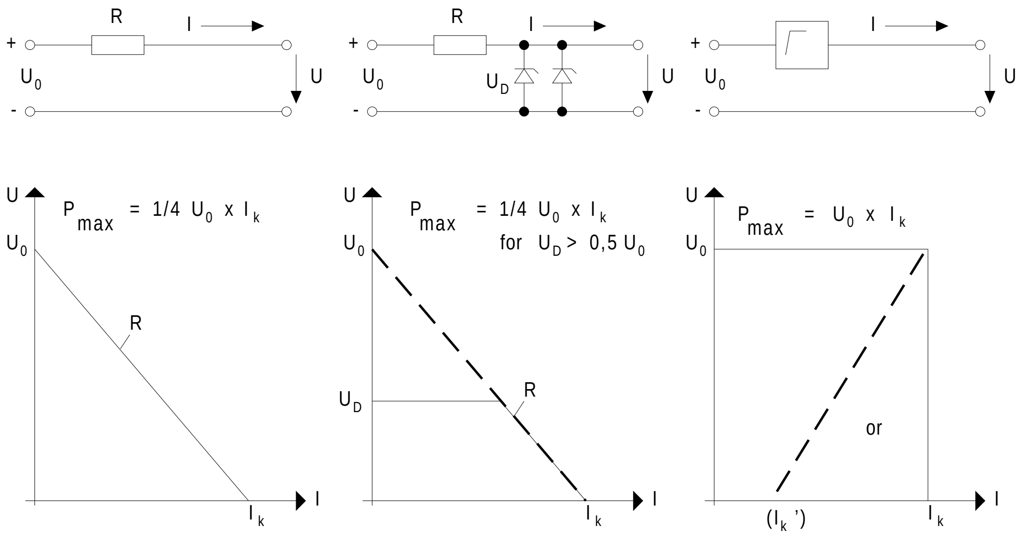


Figure 6.2 Basic Characteristics for Resistive and Electronic Current Limiting

> **Note**
>
> The test for intrinsic safety of a circuit must therefore take into account the resistive, capacitive and inductive characteristic values.

A **guarantee of intrinsic safety** is achieved in practice by protective design measures and suitable circuitry.

Measures for **avoiding ignition due to sparks** ensure that even in the event of a fault in the intrinsically safe circuits of the apparatus, the voltages, currents or power levels occurring are so low that during opening, closing and grounding of the circuits, ignition of the ambient explosive atmosphere by resultant sparks is prevented.

An experimental method is used to determine the current and voltage values at which the resultant sparks in the intrinsically safe circuit are not yet capable of causing ignition: the standard spark testing unit is employed and the method is documented in so-called **minimum igniting curves** (Appendix A of DIN EN 50020 / VDE 0170/0171 Part 7/5.78) for assessing (simple) intrinsically safe circuits. Spark ignition is reliably avoided in an intrinsically safe circuit by voltage and current limiting, and by restricting the maximum external capacitance Ca and inductance La to values below the minimum igniting curves to DIN EN 50020.

The minimum igniting curves have been plotted for an ignition probability of W ~10^3, i.e. statistically there is one ignition per 1000 sparks on average. When the **safety factor** is additionally taken into account, the ignition probability decreases by 2 to 3 decimal powers.

The minimum igniting curves given in EN 50020 relate to the linear basic characteristics produced with resistive current limiting. Circuits with electronic current limiting cannot be assessed with them. They ignite with a considerably lower combination of current and voltage values. The maximum power output P_{max} with electronic current limiting is higher.

To **rule out thermal ignition**, the apparatus to be interconnected should be selected and verified according to its temperature-rise behavior. The temperature class determined for apparatus governs its application.

Since the temperature rise of apparatus in the intrinsically safe circuit is mainly governed by the applied power, to ensure intrinsic safety of the tested electrical apparatus, it must not be supplied with more current, voltage or power than permissible according to the test certificate. This is a simple method for the user to assess the temperature-rise behavior of apparatus without having to take measurements.

Summary:

On the whole, the energy which can be stored by inductive, capacitive or thermal energy stores in the intrinsically safe circuit is limited, so that the total energy in the circuit is less than the minimum ignition energy.

Additionally, the purpose of protective measures is to ensure that when an intrinsically safe current or voltage is produced from the AC line or another source, intrinsic safety is not impaired by failure of the components which govern it, such as semiconductors, capacitors, zener diodes.

Note:

The minimum igniting curves given in the following have been taken from the currently valid edition of European Standard EN 50020. Meanwhile, however, there is a tentative new edition of this standard with revised minimum igniting curves in which only currents of up to 500 mA are permissible, in compliance with the present approval practice of the PTB.

6.1.2 Minimum Igniting Curves for a Resistive Circuit

Shown in Figure 6.3 are the minimum igniting curves for circuits with a negligible, low inductance and capacitance - also known as resistive circuits. The power of a short-circuit spark results from the product of current and voltage, so that low currents are allowed at high voltages, and high currents at low voltages.

The **current-voltage pairs of values on the minimum igniting curve** indicate the values at which there is no longer a spark capable of causing ignition when testing with the spark testing unit.

The minimum igniting current can then be determined from the minimum igniting curve at a given maximum voltage U_0, i.e. the no-load voltage. In order not to exceed the maximum permissible current I_k, i.e. the short-circuit current, for an intrinsically safe circuit, a safety factor must be taken into account. The short-circuit current I_k is obtained by dividing the minimum igniting current read off the minimum igniting curve by a safety factor of 1.5.

Example:

At a given maximum voltage U_o, the corresponding minimum igniting current can be determined from a minimum igniting curve. The maximum current I_k permissible for the intrinsically safe circuit is obtained by dividing the minimum igniting current by a safety factor of 1.5. U_0 is the no-load voltage of the intrinsically safe circuit, and I_k is the short-circuit current.

Example:

U_0 = 30 V

$$I_k = \frac{150}{1.5} \text{ mA} = 100 \text{ mA}$$

(using the minimum igniting curve for explosion group IIC, Figure 6.3).

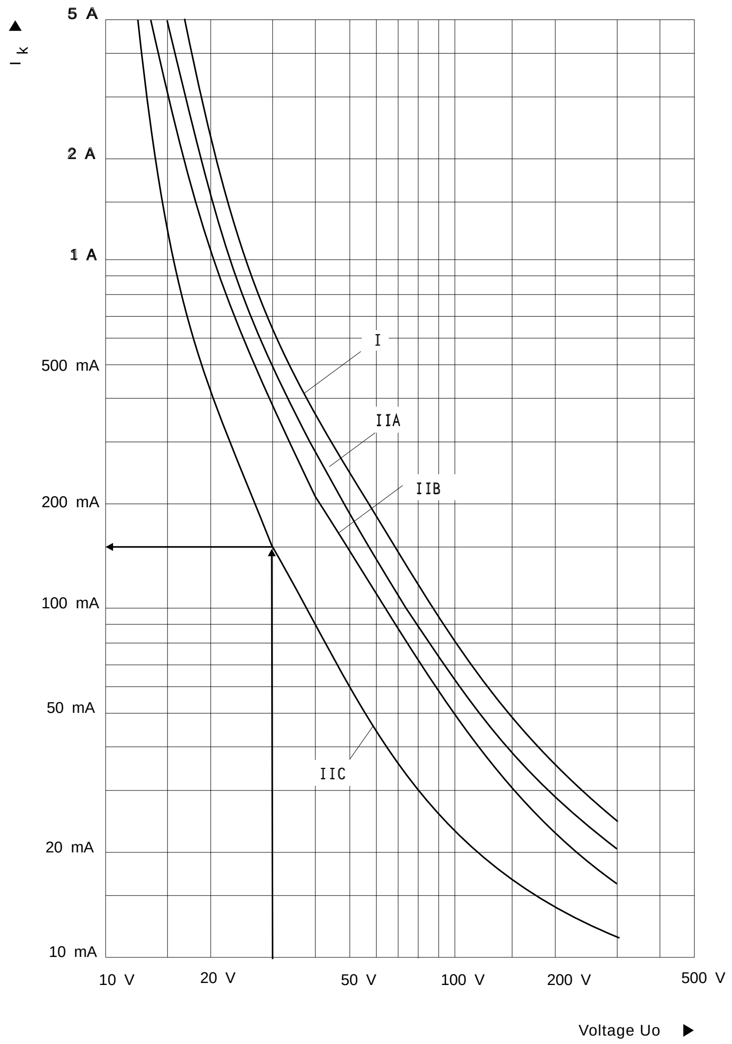


Figure 6.3 *Minimum Igniting Curves for Resistive Circuits of Explosion Groups I, IIA, IIB, IIC (to DIN EN 50020, 05.78, Appendix A)*

The minimum ignition energy on which spark ignition is based is very substance-dependent (cf. Table 4.5). The classification derived from this for explosion-protected electrical apparatus in explosion groups also results in different minimum igniting curves.

During plotting of the minimum igniting curves, the most dangerous gas of the group is tested in the most explosive mixture with air for each explosion group, using the spark testing unit. In practice, with applications of explosion groups IIB and IIA, a reduction of the requirements for intrinsically safe circuits can thus be achieved. Higher voltage and current values are therefore permissible according to the relevant minimum igniting curve.

6.1.3 Minimum Igniting Curves for Capacitive Circuits

Inductances or capacitances are capable of storing energy in a circuit which has a boosting effect on ignition. Additional energy is supplied to the resultant sparks during opening and closing of the circuit.

When a circuit is closed, **capacitances** provide the stored energy $W = 1/2\ CU^2$ very quickly. At the start of contact of the surfaces, a high current therefore flows immediately; this can cause melting or evaporation of the microscopically small peaks on the material surface, thus contributing to the formation of so-called crackle sparking.

The highest voltage occurring in the circuit, the no-load voltage U_0, is in relation to the value of a permissible capacitance C_a in an intrinsically safe circuit. This relationship has been experimentally determined with a testing unit and is documented as a minimum igniting curve for capacitive circuits in Appendix A of DIN EN 50020.

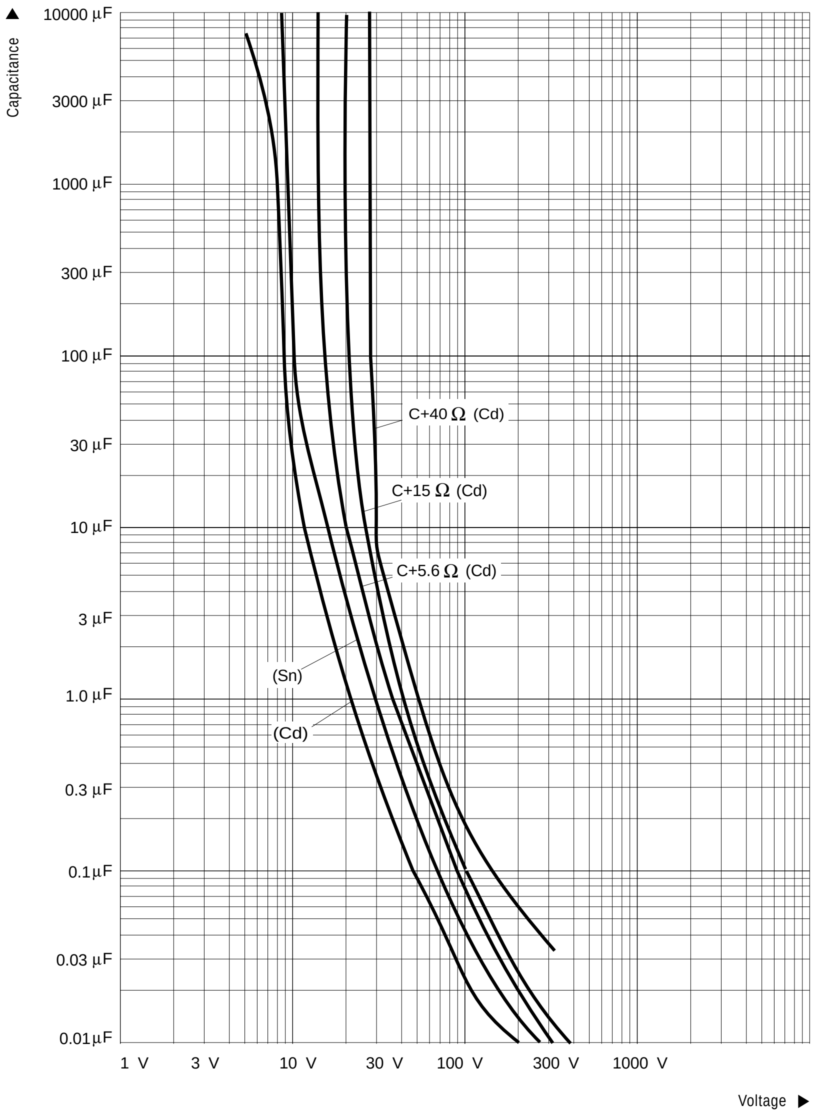
When the minimum igniting curves are used, a safety factor should be taken into account: the value for the no-load voltage U_0 should be multiplied by the safety factor of 1.5, and the permissible capacitance C_a for this value should then be determined from the minimum igniting curve.

Example for capacitive circuits

Shown in Figure 6.4 are the minimum igniting curves for capacitive circuits (Group IIC). The value of the permissible capacitance C_a in an intrinsically safe circuit depends on the maximum voltage occurring in a circuit (no-load voltage) U_0. This voltage should be multiplied by the safety factor 1.5. Example for explosion Group IIC:

U_0 = 24 V

$U_0 \times 1.5$ = 36 V, then C_a = 200 nF (from Cd curve)
C_a = 500 nF (from Sn curve)



Minimum igniting voltages to be used for electrical apparatus of Group IIC. The curve marked Sn should only be used for electrical apparatus without cadmium, zinc, magnesium or aluminum.

Figure 6.4 Minimum Igniting Voltages in Capacitive Circuits (EN 50020, Appendix A)

6.1.4 Minimum Igniting Curves for Inductive Circuits

Inductances cause sparking when a circuit is opened. The stored energy $W = 1/2\ LI^2$ results in a high voltage when contacts are opened, allowing a considerable clearance in air to be jumped by an electrical discharge in the form of an arc. Here too, the relationship between the maximum safety-related current during a short-circuit I_k and the permissible inductance L_a is represented on minimum igniting curves.

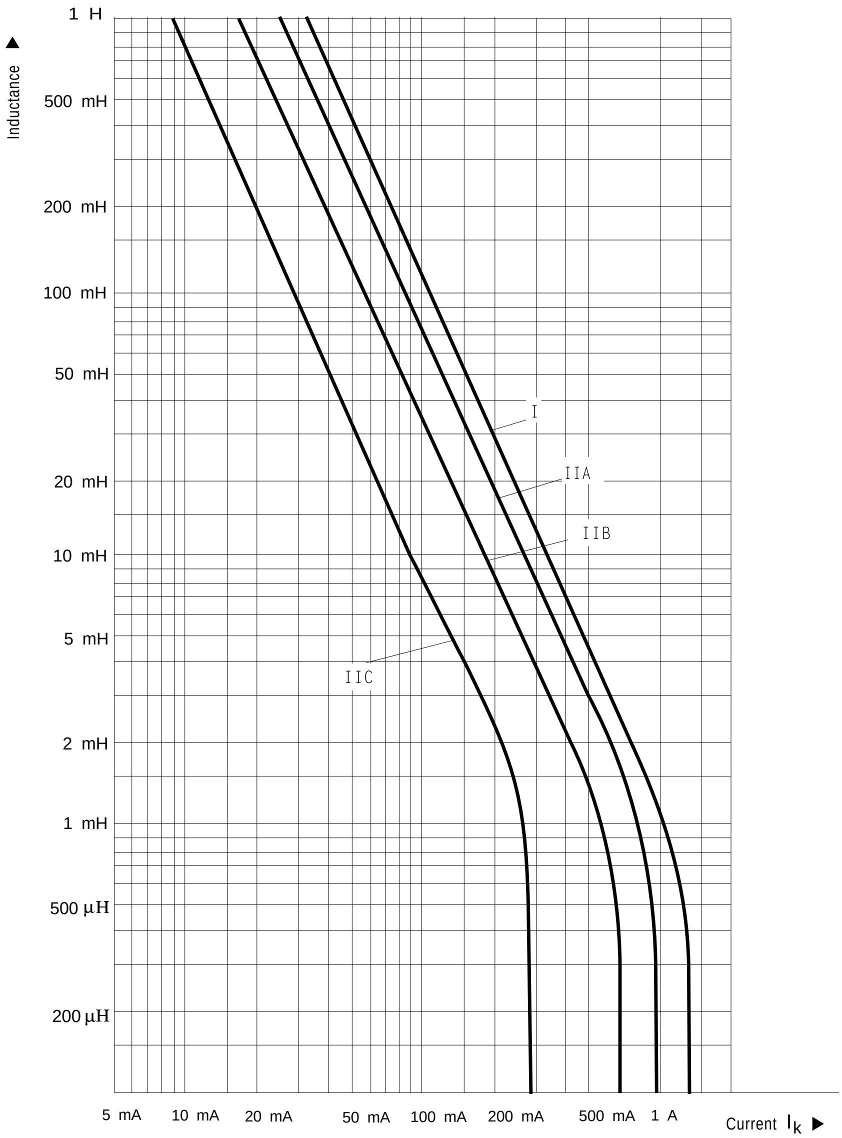
In this case also, a safety factor should be taken into account when using the minimum igniting curves; the short-circuit current I_k should be multiplied by the safety factor 1.5. With the resultant current value, the corresponding inductance La can be read off the minimum igniting curve (see example).

In general, when using minimum igniting curves, it should be noted that they are important not only for testing individual electrical apparatus but also for interconnections of associated apparatus in an intrinsically safe circuit. It should be pointed out that the values used for short-circuit current I_k and no-load voltage U_0 in the minimum igniting curves never occur simultaneously. In fact, the values in an intrinsically safe circuit are bound to be lower. Shown in Figure 6.5 is the minimum igniting curve for inductive circuits.

For circuits containing components with an inductive behavior, the opening spark is critical. The stored energy is governed here by the inductance value and by the magnitude of flowing current. When the contact is opened, the current results in a high voltage which is capable of jumping a considerable clearance in air with an electrical discharge (arc). The permissible inductance L_a depends on the maximum safety-related current Ik during a short-circuit. Here too, the safety factor of 1.5 should be taken into account.

Example for explosion group IIC:

I_k = 20 mA, I_k = 20 mA x 1.5 = 30 mA, then L_a = 85 mH



Minimum igniting currents to be used for electrical apparatus with cadmium, zinc, magnesium or aluminum at U = 24 V

Figure 6.5 Minimum Igniting Curves for Inductive Circuits to EN 50020, Appendix A

6.1.5 Using the Minimum Igniting Curves

PTB Report W39 expressly points out that the minimum igniting curves shown in EN 50020 are only to be used for electrical apparatus with linear current/voltage basic characteristics.

6.2 Apparatus in an Intrinsically Safe Circuit

6.2.1 Subdivision of Intrinsically Safe Apparatus

Shown in Figure 6.6 is the basic arrangement of an intrinsically safe system for measurement, open and closed-loop control in a hazardous area. The required automation and indicating equipment, which need not itself be explosion-protected, is situated outside the hazardous area, e.g. in an instrument room. All field circuits leading into the hazardous area must be of the intrinsically safe type. **Isolating stages** between the intrinsically safe field circuits and the non-intrinsically safe instrument room circuits provide the necessary voltage and current limiting for the intrinsically safe area. The installation specifications for intrinsically safe systems should therefore be applied especially to the field circuits and isolating stages.

The isolating stages may be in the form of separate apparatus, e.g. safety barriers and isolating transformers, or integrated in SIMATIC Ex modules.

The advantage of the SIMATIC Ex modules with integral isolating stages is that the space requirement and wiring costs are reduced. Furthermore, rewiring can be implemented by software.

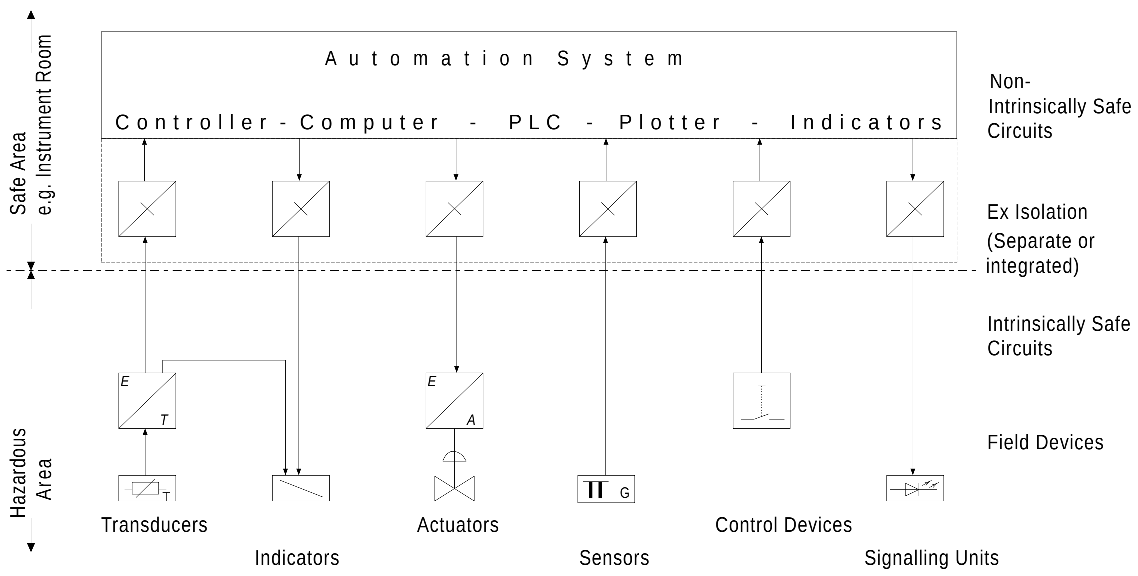


Figure 6.6 Typical Arrangement of an Intrinsically Safe Measurement and Control System

Section 4.2.7 covered the classification of apparatus in an intrinsically safe circuit into intrinsically safe and associated electrical apparatus. The **intrinsically safe apparatus** is further distinguished into:

- **Active intrinsically safe** apparatus
- **Passive intrinsically safe** apparatus

This distinction is important in the event that approval for Zone 1 is required. Intrinsically safe apparatus is subject to a mandatory special test procedure for Zone 0.

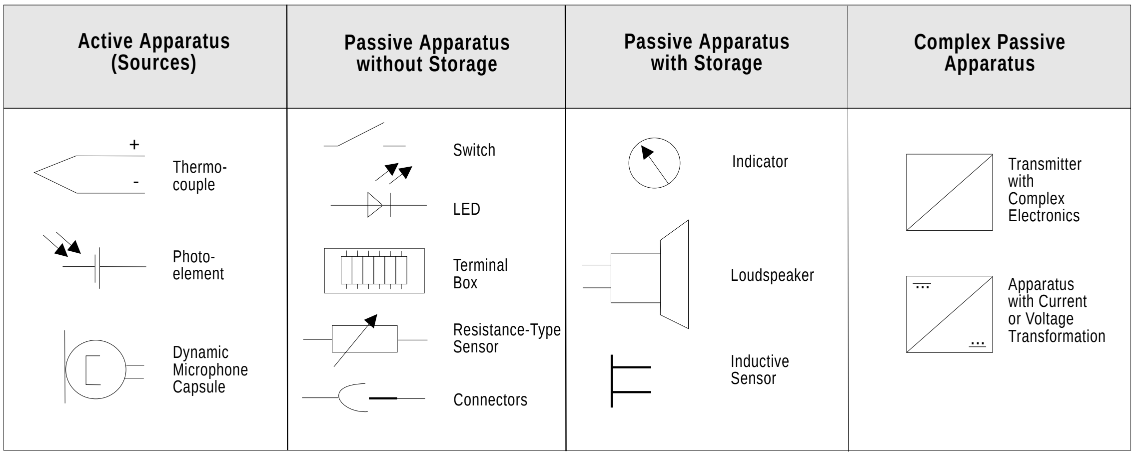


Figure 6.7 Overview of Intrinsically Safe Apparatus

Active intrinsically safe apparatus contains its own power supply; limiting of the voltage and current values must therefore be achieved with suitable circuitry. It must be type tested and approved unless the electrical values of 1.2 V, 0.1 A, 20 µJ or 25 mW (EN 50014) are not exceeded. Examples of this apparatus which need not be certified include thermocouples, photoelements and dynamic microphone capsules.

In the case of **passive intrinsically safe apparatus without** electrical, magnetic or thermal **energy storage**, no additional energy need be taken into account in the intrinsically safe circuit with regard to spark formation or excessive temperature rise. This apparatus includes, for example, switches, connectors, terminal boxes, LEDs, PTC thermistors and resistance-type sensors. It can be considered as intrinsically safe apparatus without special circuitry; according to DIN VDE 0165, it need not be certified or subjected to type testing.

Of course, the electrical characteristics and temperature-rise behavior of the apparatus must be known, and the constructional requirements to DIN EN 50020 / VDE 0170/0171, Part 7 must be observed. This particularly applies to the prevention of electrostatic charges, the observance of clearances in air and leakage paths and adequate clearances at the connection elements.

Constructional requirements to DIN EN 50020

- At least IP 20 for the housing

- At least 50 mm clearance between connection elements of intrinsically safe circuits and connection elements or bare conductors of non-intrinsically safe circuits

- Clearance in air between connection elements of intrinsically safe circuits and grounded metal parts:
  ≥ 3 mm
  between two different intrinsically safe circuits:
  ≥ 6 mm

- Isolation between conductive parts

Voltage	375 V	30 V
Leakage path in air, mm	10	2
Clearance in air, mm	6	2
Clearance in encapsulation, mm	2	0.7

- Insulation voltage between parts of intrinsically safe circuits and parts which may be grounded: double the voltage, but at least 500 V AC
  Insulation voltage between intrinsically safe circuits and parts of non-intrinsically safe circuits 2 x U + 1000 V AC, but at least 1500 V AC.

Where the electrical and thermal behavior of **passive intrinsically safe apparatus with energy storage** is clearly apparent, it need not be subjected to special testing because the installer or user is responsible.

Where the circumstances are not clearly apparent, however, the electrical and thermal behavior of the apparatus must be determined within the scope of a special test and therefore certified. This particularly applies to complex passive apparatus because its inner circuitry is difficult to assess. Examples of this include transmitters with complex electronics and apparatus with current or voltage transformation. With this apparatus, the characteristic limits (internal inductance, capacitance, etc.) must also be indicated on the equipment’s markings.

Associated electrical apparatus requires a construction which ensures reliable isolation between intrinsically safe and non-intrinsically safe circuits, as well as limiting of the current and voltage values for intrinsically safe circuits. Such apparatus must be subjected to special testing.

In associated electrical apparatus, the connection elements for external circuits must be so designed that damage to components during connection is ruled out. To rule out the interchanging of intrinsically safe and non-intrinsically safe lines during connection work, the connection elements of intrinsically safe and non-intrinsically safe circuits must be arranged at least **50 mm thread measure** from each other, and specially marked. However, this requirement applies only to external connection elements to which the user has access.

Type testing required?

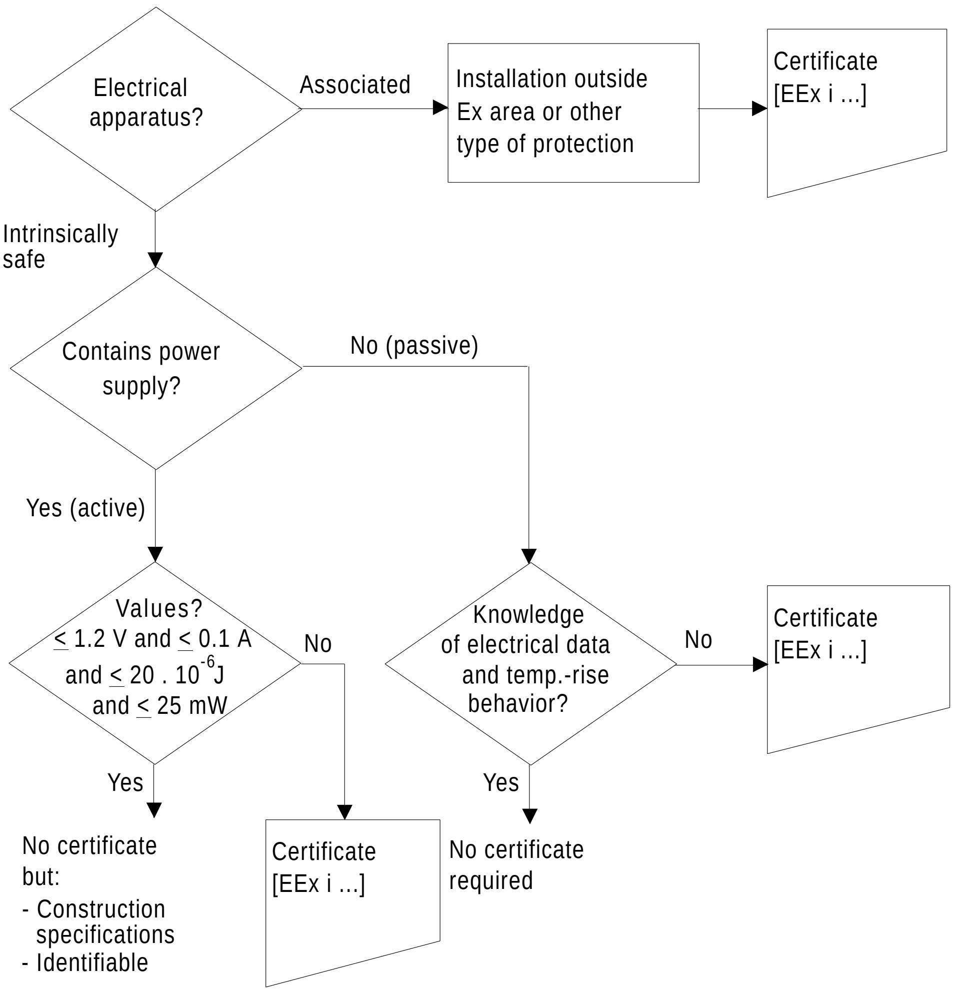


Figure 6.8 Flowchart for Selecting Apparatus for Zone 1

6.2.2 Principle of Operation of Safety Barriers

Safety barriers are isolating stages between the intrinsically safe and the non-intrinsically safe parts of a circuit; they provide voltage and current limiting but no metallic isolation when they are of the normal design.

Briefly explained in the following is the principle of operation of a safety barrier comprising a fuse, zener diode and resistor. It is therefore also known as a zener barrier (see Figure 6.9). For safety reasons, the zener diodes must be at least doubled.

The purpose of a safety barrier is to limit the current and voltage of the intrinsically safe circuit, even during a fault. Two conceivable faults should be considered:

- an excessively high voltage on the non-intrinsically safe side,
- and a short-circuit on the intrinsically safe side.

If the voltage U exceeds a permissible value on account of a fault on the non-intrinsically safe side of the safety barrier, the zener diodes limit the voltage for the intrinsically safe circuit to the value of the zener diode voltage. A fuse F is in circuit with the zener diodes to protect them; in the event of an excessive current, the fuse burns out before the zener diodes are overloaded or destroyed. The fuse and zener diode are matched according to their current-time characteristics.

In the event of a short-circuit on the intrinsically safe side, resistor R limits the short-circuit current to a permissible value.

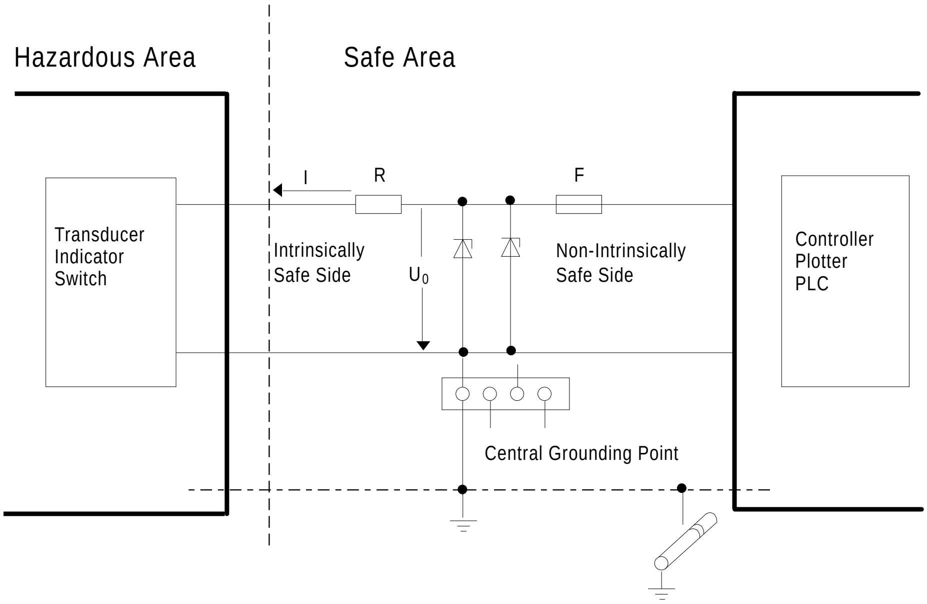


Figure 6.9 Basic Circuit Diagram of a Safety Barrier

Since all components of a safety barrier jointly ensure the protection of an intrinsically safe circuit, they are usually encapsulated together.

Note

Once more, it should be noted that safety barriers must be installed in the safe area.

Safety barriers can also cause problems because the internal fuse often burns out in the event of a terminal short-circuit which is not critical with respect to explosion protection, thus damaging the barrier beyond repair.

6.2.3 Apparatus without Metallic Isolation

An application for an intrinsically safe circuit without metallic isolation was given in Figure 6.1.

Despite voltage and current limiting, an excessively high potential with respect to ground can develop in the intrinsically safe circuit. Since there is no metallic isolation here between the intrinsically safe and non-intrinsically safe circuits, the following action must be taken:

- Equipotential bonding throughout the installation area of the intrinsically safe circuit which must be present for the hazardous area
- Short connection between ground terminal of the safety barrier and the equipotential bonding
- An appropriately great conductor cross-section (at least 1.5 mm^2 of copper)

Shown in Figure 6.10 is the principle of operation of equipotential bonding which prevents circulating currents from flowing through the intrinsically safe circuit in the event of a fault. Within a system, potential differences between the intrinsically safe circuit and conductive system parts are thus avoided.

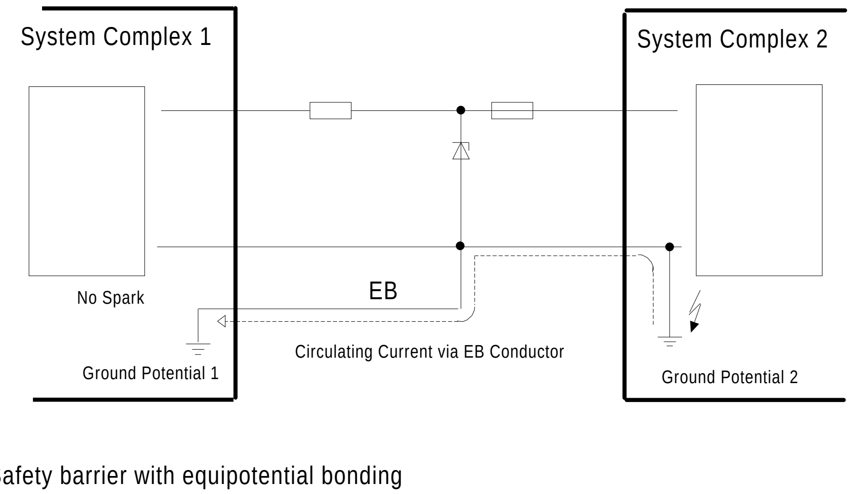


Figure 6.10 Principle of Operation of Equipotential Bonding

It should also be noted that an intrinsically safe circuit may only be grounded at one point. In an application using the grounded arrangement of Figure 6.1, grounding takes place at the safety barrier; additional grounding, e.g. in the hazardous area, is not allowed.

Disadvantages of safety barriers

The use of safety barriers with zener diodes also involves some disadvantages. For example, barriers have a high series resistance which is also temperature-dependent. Furthermore, zener diodes exhibit leakage currents at input voltages in the area. The use of safety barriers for voltage/current limiting without metallic isolation between the intrinsically safe and non-intrinsically safe circuits is not allowed for Zone 0, even if the arrangement otherwise complies with the requirements of Category "ia".

In measurement and control systems, there are some applications which do not always permit the direct grounding of an intrinsically safe circuit. Special safety barriers for an ungrounded configuration have been developed for these cases.

6.2.4 Apparatus with Metallic Isolation

It is often essential to provide metallic isolation between intrinsically safe and non-intrinsically safe circuits for reasons of measuring technique or for safety reasons (Figure 6.11).

With respect to measurement techniques, metallic isolation offers higher interference rejection in addition to greater flexibility for interconnection with other apparatus. Furthermore, the user can dispense with the connection of an additional equipotential bonding conductor.

Safety reasons apply, for example, when sensors in the intrinsically safe circuit are grounded or the 500 V test voltage with respect to ground cannot be observed. Metallic isolation is then mandatory because the intrinsically safe circuit may only be grounded at one point.

For apparatus whose intrinsically safe circuits are intended for Zone 0, metallic isolation is a prerequisite for approval in the Federal Republic of Germany.

Metallic isolation by transformer must comply with the constructional requirements of EN 50020, i.e. the specified creepage and clearance in air, the electric strength of 2500 V, etc. must be observed. These measures ensure metallic isolation even in the event of a fault, e.g. when the full line voltage is present at the transformer.

The principle of metallic isolation with safety barriers or SIMATIC S5 Ex modules is as follows: an applied DC voltage is converted by a chopper to an AC voltage signal which is isolated by the transformer and transferred to the output side, where it is rectified again. Current and voltage limiting which follows ensures intrinsic safety of the output circuit.

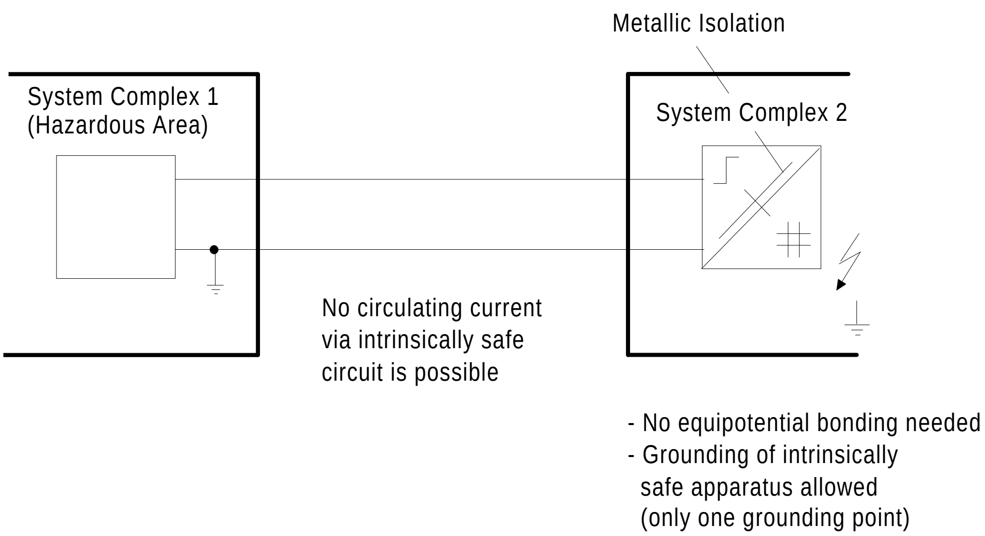


Figure 6.11 Application with Metallic Isolation

Advantages of Metallic Isolation

- Application in Zone 0 (Category "ia") is possible because the installation specifications require metallic isolation.
- The intrinsically safe field apparatus can have a functional ground so that no circulating current can flow with single-point grounding.
- For measurements, no errors can be caused by ground potentials.
- No additional equipotential bonding conductor is required; this reduces the installation overhead.
- The intrinsically safe circuit and evaluation circuit can be at different potentials.

6.3 Interconnection in the Intrinsically Safe Circuit

6.3.1 Intrinsically Safe Circuit with One Item of Associated Electrical Apparatus

To ensure intrinsic safety, maximum permissible values for inductances, capacitances and temperature apply to an intrinsically safe circuit; these values must be ensured when connecting intrinsically safe electrical apparatus in an intrinsically safe circuit.

Where there is only one item of associated apparatus in the intrinsically safe circuit, the procedure of Figure 6.12 can be followed. The maximum permissible values for the intrinsically safe circuit should be taken from the special test certificate; the permissible capacitance C_a depends on the maximum safety-related voltage U_0 (no-load voltage), and the inductance L_a depends on the short-circuit current I_k of the associated apparatus.

For apparatus and its cables intended for the hazardous area, the effective capacitance and inductance (C_i and L_i) must be determined. To ensure intrinsic safety, a check is made to establish that the values for effective capacitance C_i and inductance L_i do not exceed the maximum permissible values C_a and L_a.

To determine the effective capacitance of cables, they can usually be simplified as lumped capacitances. With standard commercial cables and lines, the rough figures serving as a basis are a cable capacitance of 200 nF/km and cable inductance of 1 mH/km.

Listed in Table 6.1 are the conditions to be observed when interconnecting intrinsically safe apparatus and an item of associated apparatus. U_{max}, I_{max}, P_{max}, C_{max} and L_{max} are the maximum values of the apparatus according to its certificate of conformity.

Table 6.1 Comparison of Safety-Related Limits

Field Device + Cable	Comparison	Associated Apparatus
U_{max}	≥	U_0
I_{max}	≥	I_k
P_{max}	≥	P
$C_{i\ field\ device}$ including + C_{cable}	≤	C_a
$L_{i\ field\ device}$ including + L_{cable}	≤	L_a

Observance of the maximum permissible temperature is initially ensured if the intrinsically safe apparatus complies with the required temperature class. Furthermore, maximum values for current I_{max} and voltage U_{max} and the maximum permissible power P_{max}, which the intrinsically safe apparatus must not exceed during operation, should be taken from the special test certificate. These are the basis for selecting the associated apparatus which must meet the safety-related values U_o, I_k and P_{max}, even in the event of a fault.

Field Device + Cable	Comparison	Associated Apparatus
$U_{max.}$ = 15.5 V	≥	U_0 = 10.1V
I_{max} = 52 mA	≥	I_k = 43 mA
P_{max} = 169 mW	≥	P = 97 mW
$C_{i\ field\ device}$ = 125 nF + $C_{cable=}$ 20 nF	≤	C_a = 3 µF
$L_{i\ field\ device}$ = 0.72 mH + $L_{cable\ =}$ 0.1 mH	≤	L_a = 20 mH

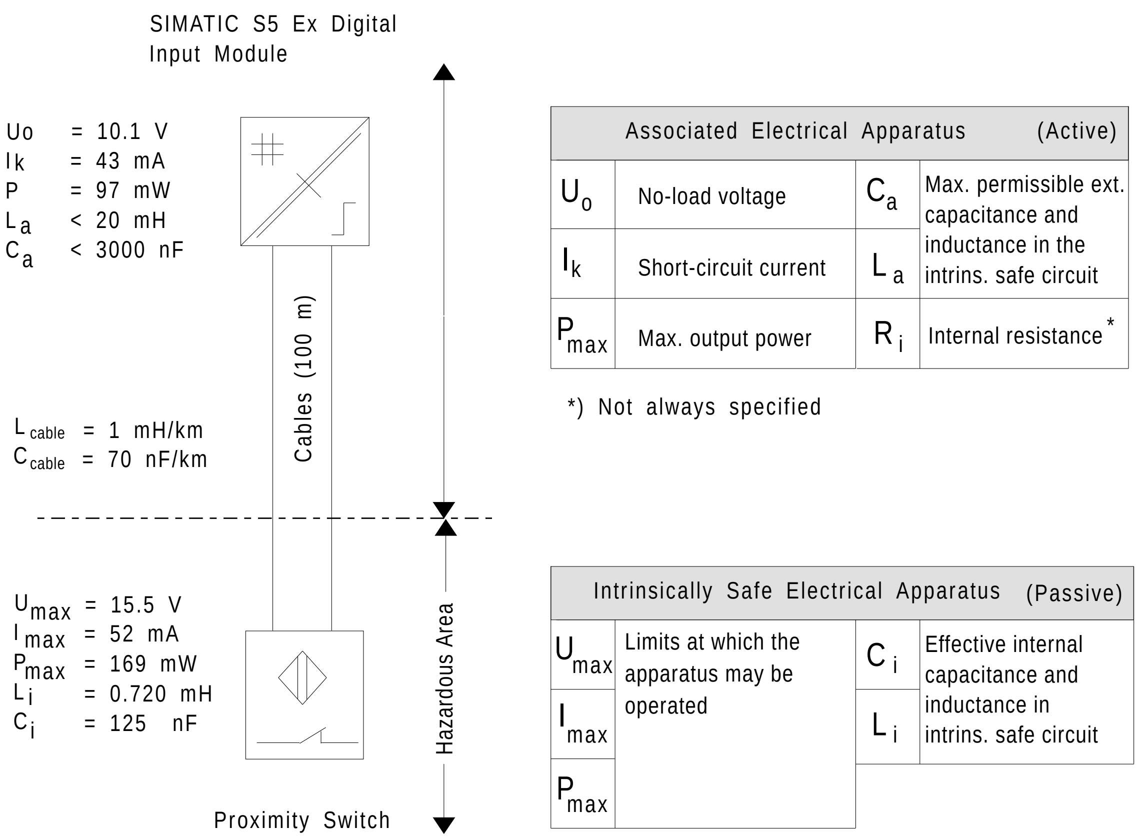


Figure 6.12 Permissible Interconnection Within an Intrinsically Safe Circuit

For many types of intrinsically safe apparatus, the special test certificate also specifies the maximum permissible power for which the apparatus is designed. In these cases the associated apparatus may not supply more power, in order to ensure intrinsic safety. For electrical apparatus with resistive current limiting, the power calculation is Pmax = 1/4 U_0 x I_k. Depending on the characteristic, in contrast, electrical apparatus with electronic current limiting may supply up to P_{max} = U_0 x I_k.

6.3.2 Intrinsically Safe Circuit with Two or More Items of Associated Electrical Apparatus (Requirements for Installation in Zones 0 and 1)

Interconnection of two or more items of apparatus

- **Calculation method according to DIN VDE 0165/2.91 and PTB Report W-39**

DIN VDE 0165/2.91 requires that a system overview be drawn up for systems with intrinsically safe circuits using two or more items of associated apparatus. For the interconnection of intrinsically safe circuits with more than one item of associated apparatus, the ensuring of intrinsic safety must be demonstrated by calculation or measurement.

The possibilities of current addition or voltage addition must be verified with care. The maximum permissible capacitance and inductance must be determined for the total current and total voltage. For Zone 0, however, demonstration by calculation is not sufficient. Only certified interconnections of two or more associated items of apparatus are allowed here.

The components of the interconnected apparatus used for current and voltage limiting must not be overloaded, even during a malfunction; this must be demonstrated by measurement or calculation. Given in DIN VDE 0165/2.91 is a calculation method for associated electrical apparatus with a linear current/voltage basic characteristic.

For interconnection with active apparatus which exhibits nonlinear current/voltage characteristics, DIN VDE 0165/2.91 refers to PTB Report W-39. This "apparatus" can be apparatus with active, intrinsically safe circuits in normal operation or only in the event of a fault.

Of the two calculation methods mentioned, the one to be chosen must be determined from the shape of the basic characteristic of all interconnected associated apparatus. The calculation method of PTB Report W-39 applies to linear, trapezoidal and rectangular current/voltage basic characteristics. Demonstration by measurement according to PTB Report W-39 is at present only carried out by one testing station.

- **Determining the current/voltage basic characteristic**

PTB Report W-39 distinguishes between linear, trapezoidal and rectangular current/voltage basic characteristics. All items of active apparatus and their equivalent circuits are referred to one of the three basic types shown.

Since, according to DIN VDE 0165/2.91, all apparatus with active intrinsically safe circuits must be certified, the following characteristic values should be taken from the relevant special test certificates for this apparatus:

No-load voltage	U_0
Short-circuit current	I_k
Internal resistance	R
Maximum output power	P_{max}

Conclusions as to the type of characteristic can be drawn on the basis of these values (Figure 6.2):

$P_{max} = 1/4\ U_0 \times I_k$	-	linear characteristic
$P_{max} = U_0 \times I_k$	-	rectangular characteristic

In order to facilitate determination of the overall basic characteristic by the planner or user, the PTB and BVS now specify the internal resistance R and, for nonlinear circuits, the shape of the characteristic. Where these electrical data are not available for older apparatus, they should be obtained from the manufacturer or from the testing station.

– Calculation method for linear current/voltage characteristics

The calculation method to DIN VDE 0165/2.91 applies only to intrinsically safe circuits with associated apparatus which exhibits a linear current/voltage characteristic. An interconnection of active apparatus should be considered as a single item of electrical apparatus and subjected to the fault case according to DIN EN 50020/VDE 0170/0171 Part 7/5.78, Section 4.

In a network of intrinsically safe circuits with two or more items of associated apparatus, the following conditions must be met at each point in the network:

1. The maximum possible voltage resulting from meshing of the entire network, or of a part of it, must not be greater than that resulting from DIN EN 50020/VDE 0170/0171 Part 7/5.78, Figures A 2.1 and A 2.2 for the maximum possible short-circuit current at the relevant point, multiplied by a safety factor of 1.5.

2. According to DIN EN 50020/VDE 0170/0171 Part 7/5.78, Figures A 1.1 and A 1.2, the maximum permissible inductance is obtained from the short-circuit current multiplied by a safety factor of 1.5. In the same way, the maximum permissible capacitance for the voltage is obtained from Figures A 3.1 and A 3.2 of the same standard.

The proposed procedure for interconnections is as follows:

1. The maximum values for voltage and/or current occurring in the interconnection (safety-related series or parallel connection) should be determined. These values serve to verify whether the interconnection is within intrinsically safe limits. U_{max} or I_{max} is multiplied by a safety factor of 1.5 for the purpose.

2. The maximum permissible inductance should be taken from the minimum igniting curve for inductive circuits; the maximum possible short-circuit current of the interconnection results from the sum of maximum current values for the associated apparatus multiplied by a safety factor of 1.5.

3. Similarly to 2., the maximum permissible capacitance should be taken from the minimum igniting curve for capacitive circuits. The possible sum of maximum voltage values must also be multiplied by a safety factor of 1.5.

4. The maximum length of connecting cable, for example, between the items of apparatus can be derived from the maximum permissible values thus determined for external capacitance and external inductance. In the case of standard commercial cables and lines, a first approximation can be based on a cable capacitance of 200 nF/km and a cable inductance of 1mH/km.

The maximum permissible short-circuit current is given by the minimum igniting curves in DIN EN 50020 from the maximum possible voltage resulting from meshing of the entire network, multiplied by a safety factor of 1.5 (Appendix D).

The safety-related characteristic values thus calculated have been determined under the precondition that the maximum values for no-load voltages and short-circuit currents of the individual items of apparatus, as given on the rating plate or special test certificate, are effective. This approach should be used for simple, clearly arranged interconnections. It is based on the least favorable conditions and thus results in a high degree of reliability.

Example of a SIMATIC S5 Ex module to demonstrate intrinsic safety with a parallel circuit

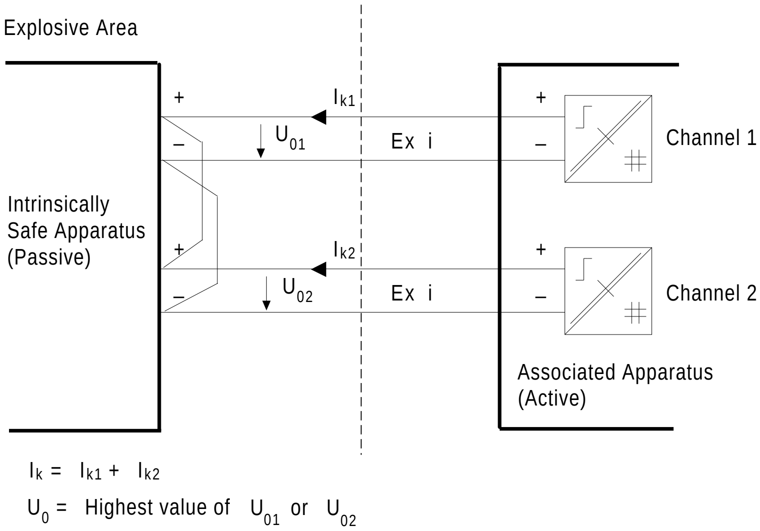


Figure 6.13 Parallel Connection of Two Outputs (Only Current Addition is Possible)

Where, for example, two outputs of the SIMATIC S5 Ex digital output module with linear characteristic are connected in parallel to intrinsically safe, passive electrical apparatus, the following must be verified on the basis of the characteristic data of the apparatus (I_k = 43 mA, U_0 = 10.1 V, P_{max} = 97.0 mW) using the minimum igniting curves:

I_k = $I_{k1} + I_{k2}$ = 86 mA
I_{ksafe} = I_k x safety factor 1.5 = 129 mA
U_0 = $U_{0max.}$ = 10.1 V (with 2 identical units, otherwise the higher voltage)
U_{0safe} = U_0 x safety factor 1.5 = 15.15 V

The current and voltage values calculated with allowance for the safety factors are the basis for determining the values ensuring intrinsic safety from the minimum igniting curves.

Inductive minimum igniting curve IIC (Figure 6.5) shows the relationship L = f(I). From the curve, it can be seen that for

I_{ksafe} = 129 mA an inductance of $L \leq 5$ mH

does not impair intrinsic safety.

The capacitive minimum igniting curve (Figure 6.4) shows the relationship C = f(U). From the curve, it can be seen that for

U_{0safe} = 15.15 V a capacitance of ≤ 3 µF

does not impair intrinsic safety.

The maximum permissible capacitance of the cable to be connected can be derived from this value, less the internal capacitance of the apparatus. Cable capacitances should be considered as lumped capacitances, taking as a basis a capacitance per unit length of 200 nF/km.

Example of a SIMATIC S5 Ex module to demonstrate intrinsic safety with a series circuit

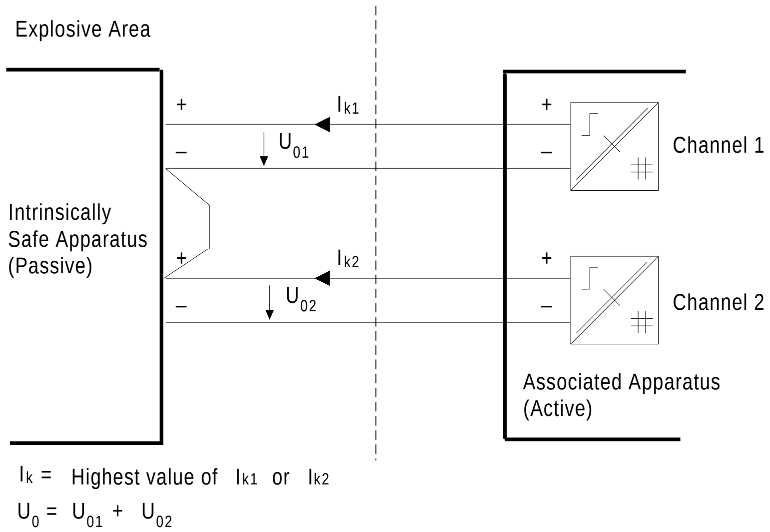


Figure 6.14 Series Connection of Two Outputs (Only Voltage Addition is Possible)

In the series connection of two outputs of the SIMATIC S5 Ex digital output module with linear characteristic and with inverse polarity, the voltage addition occurring here results in an increase of the safety-related maximum voltage in the intrinsically safe circuit. Current addition is not possible here because the currents (and voltages) are inverted. The higher of the two values I_{k1} and I_{k2} can serve as the maximum safety-related current.

The maximum permissible values for L_a and C_a should be read off the minimum igniting curves with these new current and voltage values.

Demonstrating intrinsic safety with a series or parallel circuit

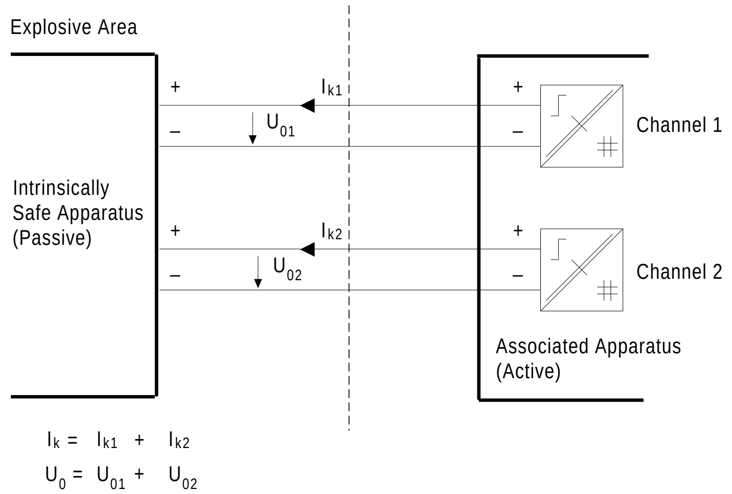


Figure 6.15 Series Connection of Two Outputs; Only Voltage Addition is Possible. With Parallel Connection, Only Current Addition is Possible.

> **Note**
>
> Where the associated electrical apparatus (safety barriers, isolation amplifiers) for SIMATIC Ex modules are not clearly interconnected with respect to potential (see Figure 6.20), or if the safety barriers are intended for a changing potential, there may be a series connection or parallel connection after the fault to be considered. In this case, voltage addition and current addition should be treated separately and the least favorable values taken as a basis.
>
> Since SIMATIC Ex modules do not have a clear connection with respect to potential, voltage and current addition must be carried out separately and the least favorable values taken as a basis.

Calculation method according to PTB Report W-39

The introduction to PTB Report W-39 refers to some basic stipulations:

1. The method presented in PTB Report W-39 should only be used at present for explosion groups IIB and IIC, but for all types of current/voltage characteristic according to Figure 6.2.

2. When intrinsically safe circuits are being planned, the meshing and number of interconnected items of apparatus should be kept as low as possible.

3. For the interconnection of intrinsically safe circuits with two or more sources for which at least one item of associated apparatus exhibits a nonlinear current/voltage basic characteristic, overall basic characteristics for current and/or voltage should be determined by graphical addition, according to the interconnection.

4. For Zone 0, all apparatus and its interconnection must be specially certified for operation in this area.

5. The limit curves in the minimum igniting curve diagrams were determined experimentally with the spark testing unit mentioned in EN 50020.

6. For safety considerations, functionally passive inputs of plotters, transducers and other apparatus can behave as active sources in the event of a fault. Their maximum values for no-load voltage and short-circuit current specified in the special test certificate must therefore be taken into account in the safety considerations.

PTB Report W-39 considers five different case of interconnection and the resultant overall basic characteristics.

In the following diagrams,

- the overall basic characteristic of the voltage for series connections 1 and 2 (Figures 6.16 and 6.17),
- the overall basic characteristic of the current for parallel connections 1 and 2 (Figures 6.18 and 6.19),
- and the overall basic characteristic of current and voltage for the series or parallel connection (Figure 6.20)

are shown separately according to the fault.

a) Series connection 1

With this circuit configuration, only voltage addition is possible irrespective of the polarity of the sources. The overall basic characteristic shown as a dashed line is obtained by graphical addition, by adding the corresponding voltage values for each current value I.

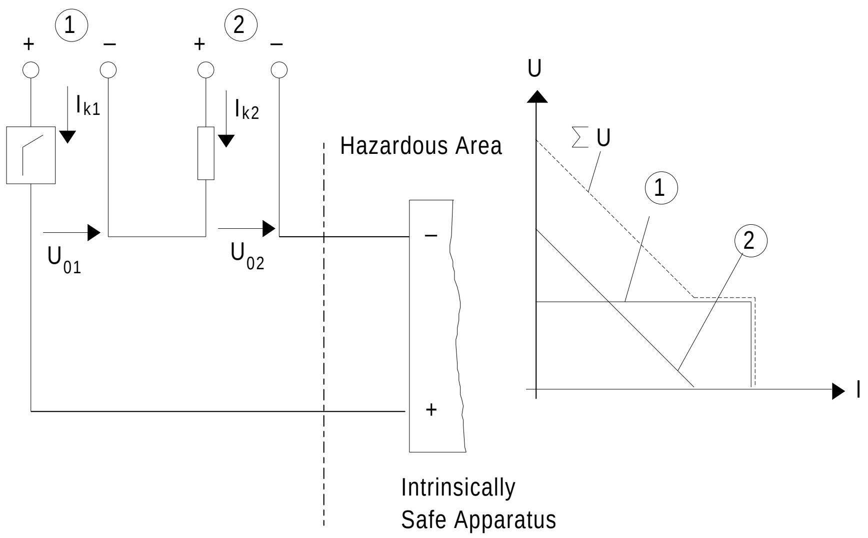


Figure 6.16 Series Connection 1

b) Series connection 2

Where the common terminal of both sources is routed to the load, current addition should only be ruled out if the polarity of the sources is established with respect to safety in the direction drawn here.

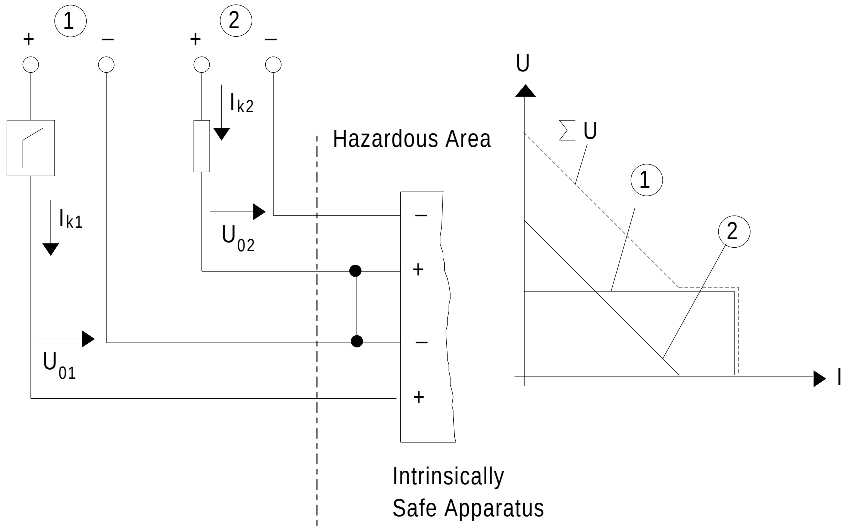


Figure 6.17 Series Connection 2

c) Parallel connection 1

With the circuit of sources shown here, current addition is only possible when two terminals are interconnected for each of the two-terminal sources. Voltage addition is not possible in this case, and the overall basic characteristic is obtained by graphical addition of the individual current values.

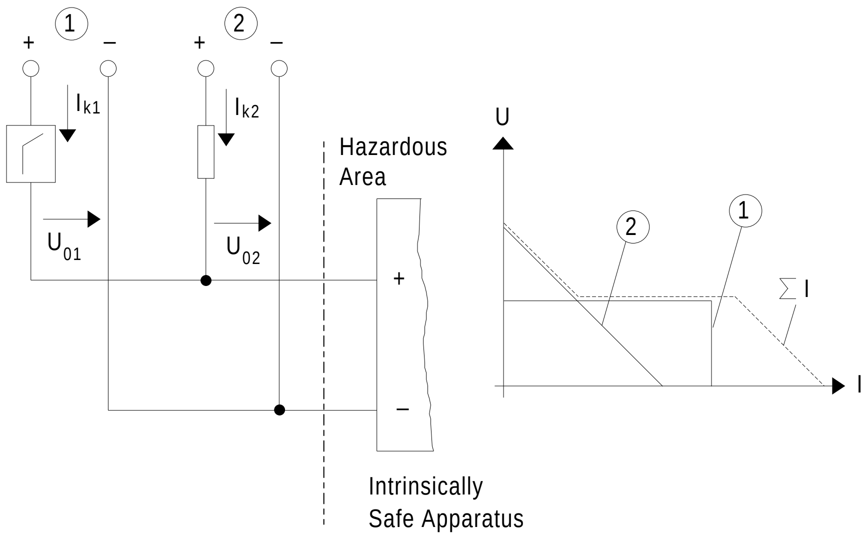


Figure 6.18 Parallel Connection 1

d) Parallel connection 2

If only one terminal of each source is connected to that of the other source, voltage addition should only be ruled out if the polarity of the sources is established with respect to safety, as shown here. Otherwise both voltage and current addition must be considered.

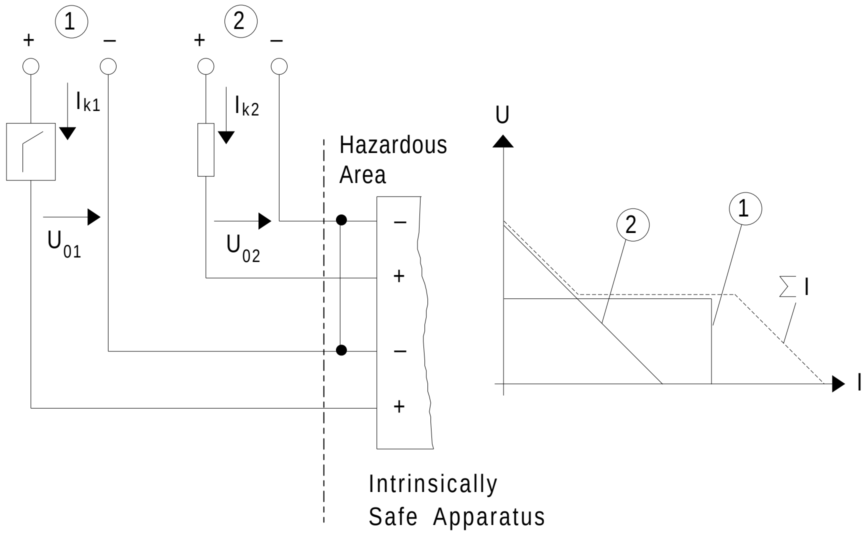


Figure 6.19 Parallel Connection 2

e) Series or parallel connection

Where arbitrary node connections can be made between two or more circuits, as shown here, both voltage and current addition must be expected. However, these cases cannot occur simultaneously and the overall basic characteristic for current and voltage addition must be plotted in two operations.

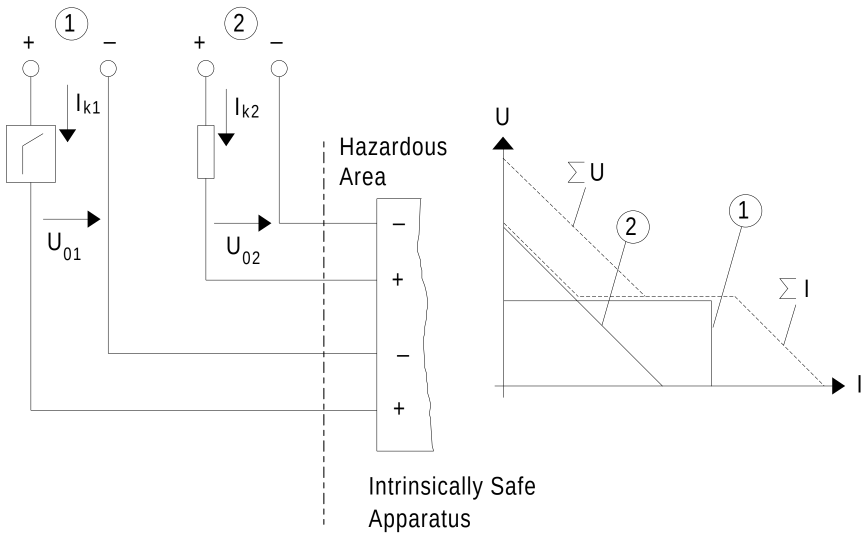


Figure 6.20 Series or Parallel Connection

This procedure is always necessary when the circumstances of the interconnection are not clear, or when there are circuits with more than two conductors. The result is then always on the safe side.

For each of explosion groups IIB and IIC, the PTB report offers five limit curve diagrams with different total inductances of the intrinsically safe circuit according to Table 6.2.

Table 6.2 Allocation of Minimum Igniting Curve Diagrams to Explosion Groups and Inductance

Explosion Group	Permissible External Inductance L_a
IIC	0.15 mH
	0.5 mH
	1 mH
	2 mH
	5 mH
IIB	0.5 mH
	1 mH
	5 mH
	10 mH
	25 mH

As an example, Figure 6.21 shows the minimum igniting curve diagram for explosion group IIC with a maximum inductance of 1 mH in the intrinsically safe circuit.

Note:
The remaining eight igniting curve diagrams are contained in the PTB-Bericht W-39 /7/.

Figure 6.24 shows the minimum igniting curve diagram for explosion group IIB with a maximum inductance of 1 mH in the intrinsically safe circuit.

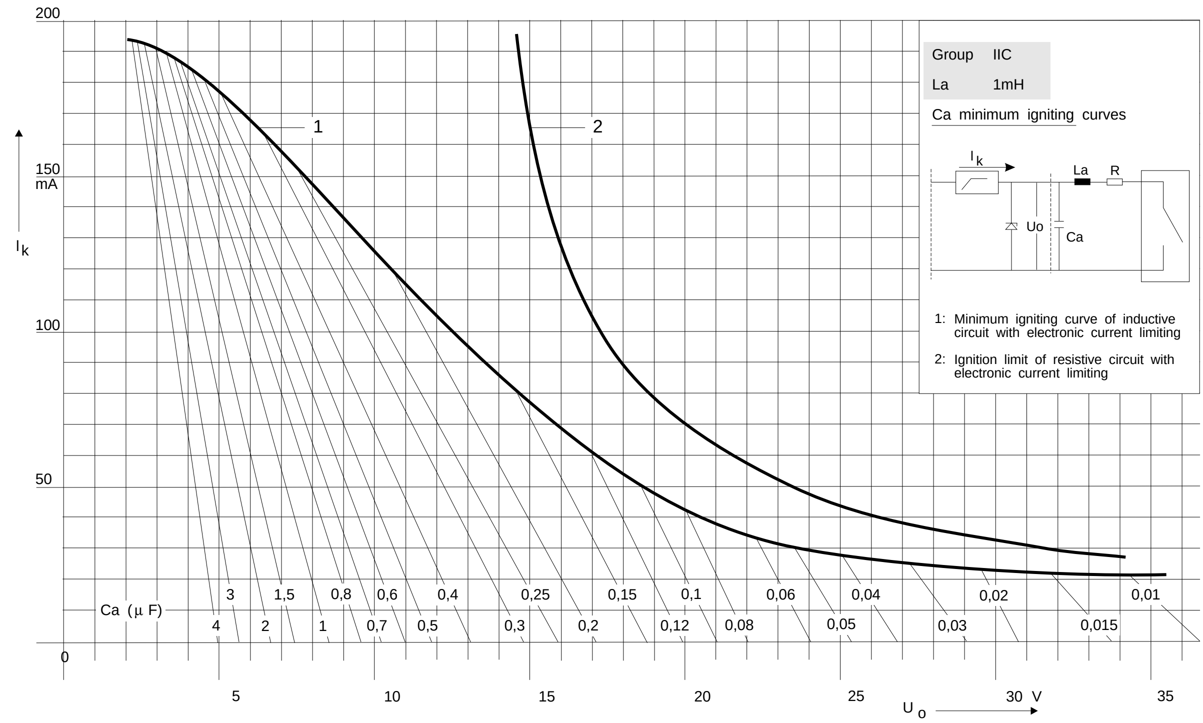


Figure 6.21 Minimum Igniting Curve Diagram for Interconnection with Electronic Current Limiting Circuitry (Safety Factor of 1.5 Taken into Account)

Each minimum igniting curve diagram comprises three components:

- Limit curve of the inductive circuit (Curve 1)
- Limit curve of the resistive circuit (Curve 2)
- Family of curves to determine the maximum permissible capacitance C_a

When the explosion group and the maximum total inductance of the intrinsically safe circuit have been established, the overall basic characteristic determined graphically for the particular interconnection is drawn onto the relevant minimum igniting curve diagram. Intrinsic safety is demonstrated in three stages:

1. Intrinsic safety of the resistive circuit

The overall basic characteristic must not intersect Curve 2. The higher the value given for maximum total inductance La of the circuit, the lower are the current and voltage values for the same explosion group. This means that if Curve 2 is intersected by the overall basic characteristic, the inductance must be reduced to maintain intrinsic safety for the resistive circuit.

2. Intrinsic safety of the inductive circuit

The overall basic characteristic must not intersect Curve 1. Where it is necessary to permit a greater inductance whilst maintaining intrinsic safety of the resistive circuit, a sacrifice is made in permissible capacitance in the intrinsically safe circuit.

3. Determining the maximum permissible capacitance

The maximum capacitance of the intrinsically safe circuit can be read off the C_a family of curves. The maximum permissible capacitance corresponds to the C_a limit curve with the highest C_a value which is still not intersected by the overall basic characteristic.

When demonstrating intrinsic safety, the supplementary explanations for the characteristic method (Item 3.3 of PTB Report W-39) must be observed. Thus, with purely resistive circuits (lumped inductance < 10 µH), Curve 1 may be exceeded but not Curve 2.

Using the calculation method according to PTB Report W-39

Shown in Figure 6.22 is the interconnection of three items of associated electrical apparatus (power supply unit, plotter and electronic indicator) with one item of intrinsically safe apparatus (analyzer) together with their safety-related characteristic values. In normal operation the power supply unit is the active source. In the safety considerations, the characteristic values of all three items of associated apparatus must be assessed for the fault condition.

Depending on the fault condition, the two overall basic characteristics shown in Figure 6.23 must be determined for current and voltage addition.

When the two overall basic characteristics are entered in the limit curve diagram of explosion group IIB for a total inductance of L_a = 1 mH, it is apparent that this circuit is intrinsically safe under the following maximum values:

U_0 = 28.7 V
I_k = 264 mA
P = 1.9 W
L_a = 1 mH
C_a = 120 nF.

These values should be taken from Figure 6.24.

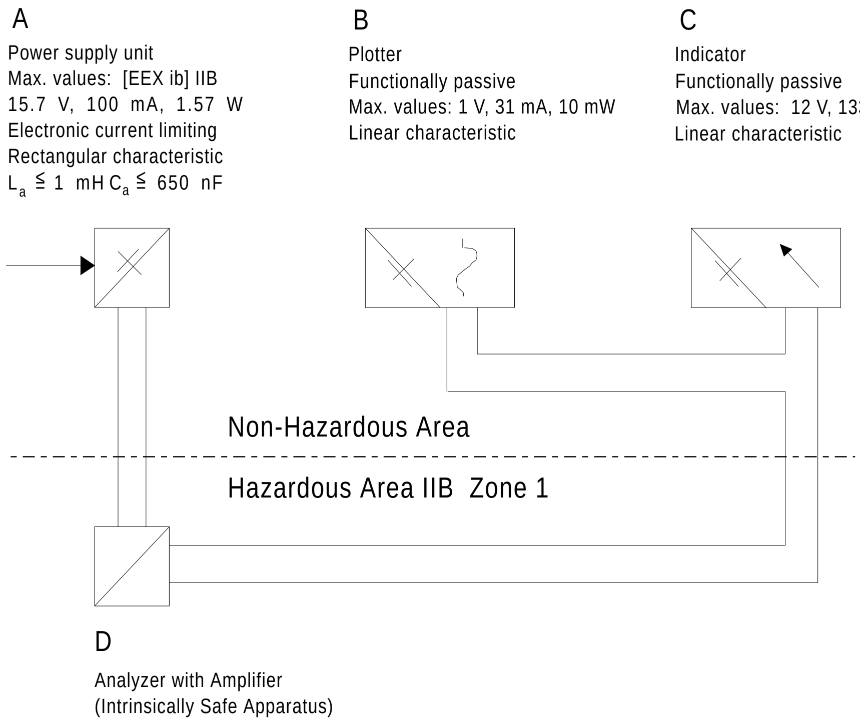


Figure 6.22 Example of Interconnection of Three Items of Associated Apparatus with One Item of Intrinsically Safe Apparatus

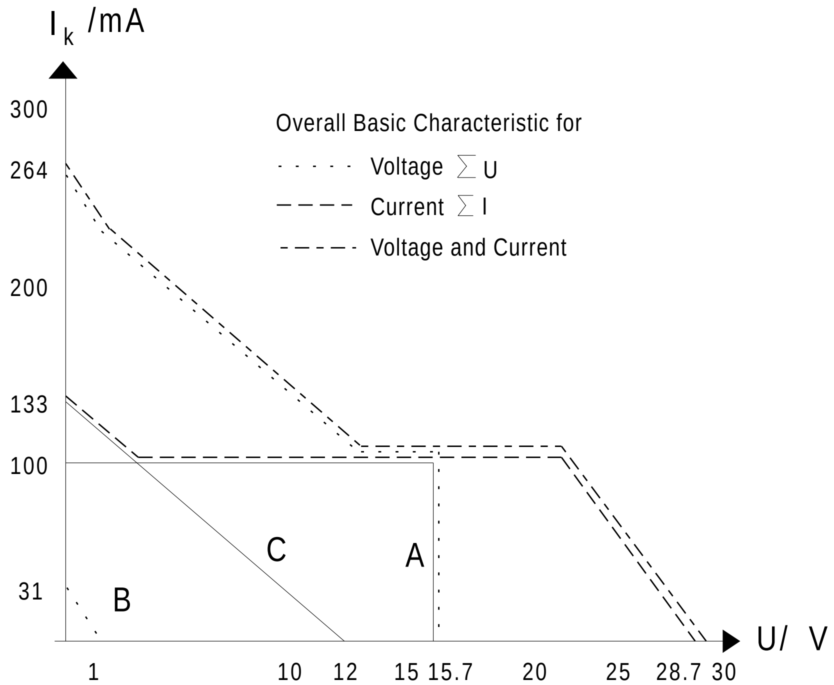


Figure 6.23 Overall Basic Characteristics of the Interconnection Circuit of Figure 6.19

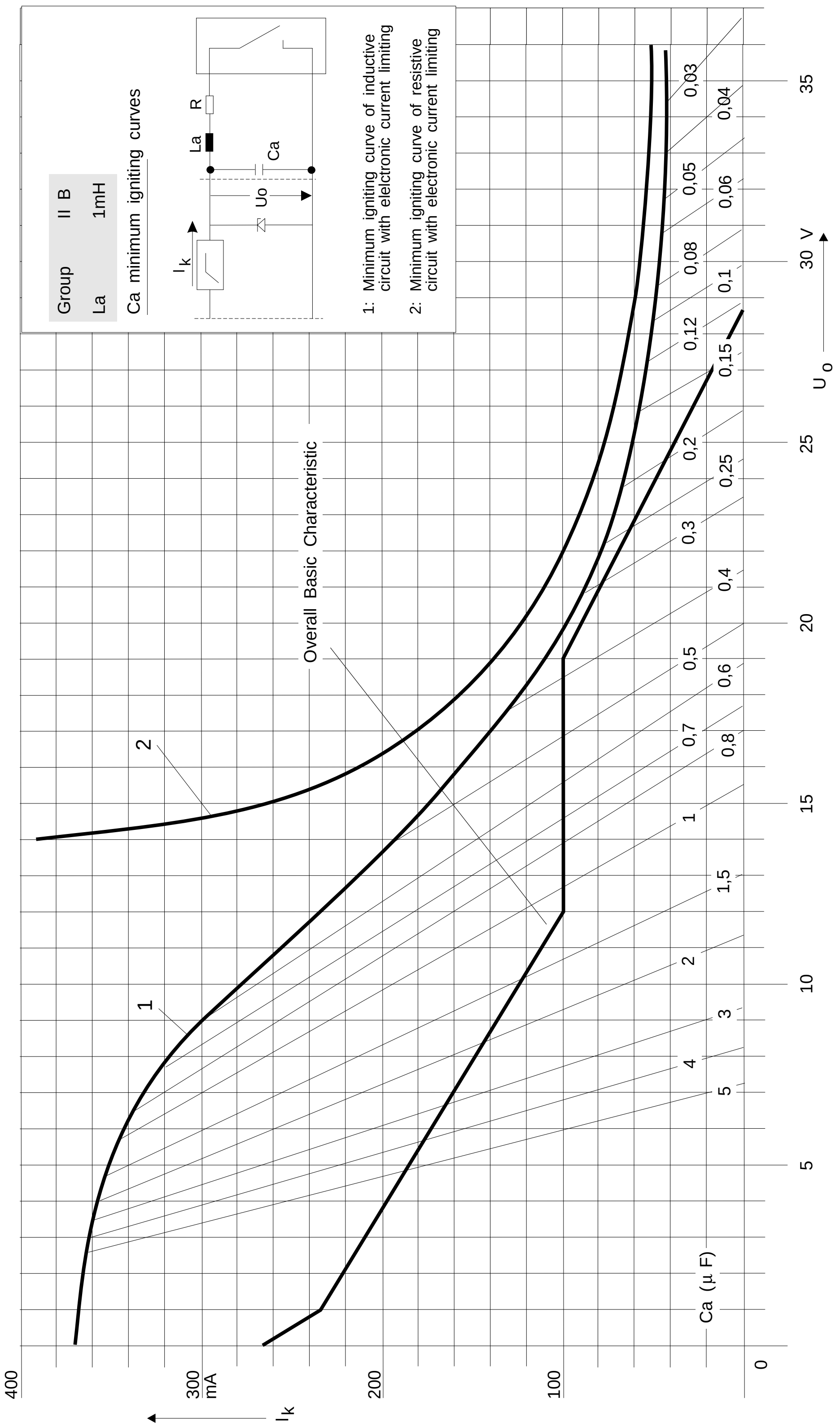


Figure 6.24 Limit Curve Diagram for Interconnection with Electronic Current Limiting Circuitry (Safety Factor of 1.5 Taken into Account)

7 Installation, Operation and Maintenance of Electrical Systems in Hazardous Areas

Figures

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7 Installation, Operation and Maintenance of Electrical Systems in Hazardous Areas

7.1 Installation Specifications

In contrast to the constructional requirements of electrical apparatus for which there is harmonization within the CENELEC member states, international standardization for installation specifications is not yet so advanced. Harmonization in the European CENELEC area is in preparation.

Given in Table 7.1 as an extract is an overview of the national and international installation specifications currently valid.

Table 7.1 Installation Specifications

Country		Installation Specifications
Europe		DIN EN 60 079 *)
Germany	(D)	DIN VDE 0165/2.91
Austria	(A)	ÖVE 165
Belgium	(B)	Regl. Gen. P:NBN 716
Canada	(CDN)	CSA Std. C22.1 (Industry) C22.5 (Mining)
Switzerland	(CH)	SEV 1015
France	(F)	NFC 12-300/320 C 20-061 23-210 (=S.A.)
United Kingdom	(GB)	BS 5345:Part4:1977
Sweden	(S)	SEN 2108.. ().69)
Russia	(SU)	PUE VII-3
USA	(USA)	ANS1/1SA-RP 12.6-1987 in clarification of NEC 504-1 ... NEC 504-50

*) in preparation

In the **Federal Republic of Germany**, various national specifications and regulations must be observed when installing electrical systems in hazardous areas (see Table 2.2). The basic regulations are the ElexV. Based on this is the installation specification DIN VDE 0165/2.91 which has a major place in this chapter because it describes not only the special features with regard to explosion protection, but must be observed particularly during the installation of intrinsically safe systems in hazardous areas.

Given here as an extract are the following, additional VDE specifications to be met for the installation of systems in hazardous areas:

- VDE 0100 Specifications for installing power systems with rated voltages of up to 1000 V
- VDE 0101 Specifications for installing power systems with rated voltages above 1 kV
- VDE 0800 Specifications for installing and operating telecommunications systems including data processing systems
- VDE 0801 Specifications for installation cables of telecommunications systems
- VDE 0105 Part 9 - Operation of power systems in hazardous areas
- VDE 0185 Lightning protection systems

It should be noted that the installation and operation of **intrinsically safe systems and circuits** according to German installation specifications are very flexible in comparison with the requirements of many other countries. Only a test and certificate for individual items of apparatus are required. In the Federal Republic, interconnection can be carried out by the installer under his sole responsibility, whilst observing DIN VDE 0165 (except for applications in Zone 0). Abroad, in contrast, only fully certified circuits within the scope of so-called system certificates are approved.

In Germany, the installer assumes responsibility for the activation of intrinsically safe apparatus in tested circuits, under observance of the maximum permissible inductance or capacitance values.

DIN VDE 0165/2.91 for the installation of electrical systems in hazardous areas covers the following main topics:

- Classification of hazardous areas in zones
- Selecting the apparatus
- Contact protection to avoid the risk of ignition
- Cables and lines, selection and laying
- Requirements for the individual zones
- Individual requirements for certain apparatus

Zone classification for hazardous areas has already been presented in Section 4.1 (zone plan -> Appendix B).

Apparatus for hazardous areas should be selected according to the existing zone, highest temperature class and explosion group of the combustible substances. If the safety characteristics of the substances (see Table 4.6) are not known, they must be obtained from a testing station.

Contact protection to avoid the risk of ignition plays an important part in hazardous areas. However, protective measures against indirect contact are also intended to prevent the risk of ignition during a malfunction or normal operation.

For selecting **cables and lines**, the requirements relating to the expected mechanical, chemical and thermal effects are given. The type and method of laying within the hazardous area and to the non-hazardous area are discussed.

The **requirements for the individual zones** are discussed very extensively in the installation specification and therefore make a significant contribution to this chapter. The **individual requirements for certain apparatus** are therefore not covered further.

7.2 Contact Protection and Equipotential Bonding

Direct contact

Protection against direct contact is basically a personnel safety measure. In hazardous areas, this protection has the additional function of avoiding sparks capable of causing ignition.

In practice, therefore, only apparatus with protection against direct contact with active parts may be used in all live voltage areas. However, direct contact with active parts can also be prevented by the method of installation; this is already achieved with type of protection IP 20, for example.

Equipotential bonding

ElexV and DIN VDE 0165 require equipotential bonding within hazardous areas of Zones 0 and 1, to prevent the occurrence of sparks capable of causing ignition, or temperature rise caused by potential differences. Implementation of the equipotential bonding must comply with the system configuration to DIN VDE 0100 Part 410 and design ratings to DIN VDE 0100 Part 540.

Full equipotential bonding is achieved by connecting not only the housings of electrical apparatus to the PE conductor by means of an equipotential bonding conductor, but also all other accessible, conductive structural parts such as constructions, metal containers, piping, etc. (see Figure 7.1). Extraneous conductive parts which do not pertain to the structure or installation of the system and with which no shifting of potential by fault currents must be expected (e.g. door frames, window frames), need not be incorporated in equipotential bonding. This also applies to housings if their method of fixing provides reliable contact with structural parts or piping already involved in equipotential bonding. The connections for equipotential bonding must be reliable, e.g. using secured screw terminals.

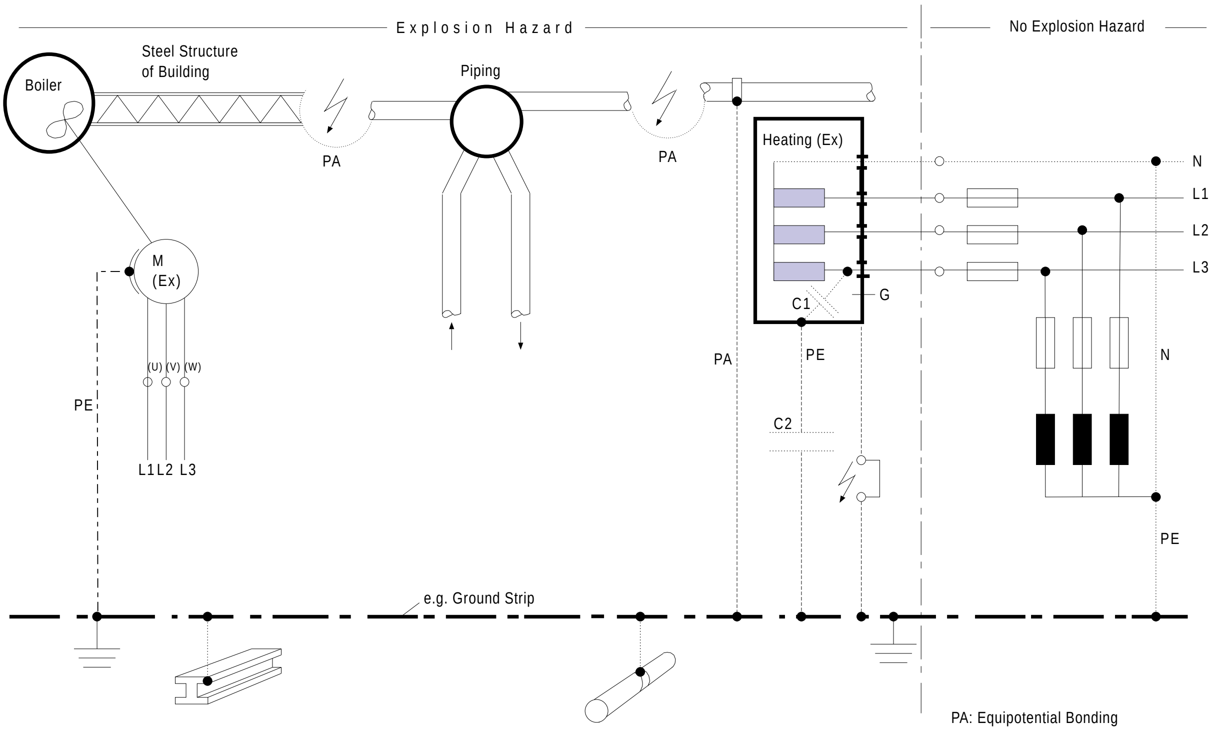

Figure 7.1 Equipotential Bonding in the Hazardous Area

7.3 Cables and Lines

There are special requirements for cables and lines in hazardous areas; additional requirements apply to intrinsically safe circuits (see Sections 7.4 and 7.5).

When cables and lines are being **selected** according to their type, only those which can withstand the expected mechanical, chemical and thermal effects should be used. With respect to the mechanical requirements, cross-sections used for copper conductor must not be less than those specified. Aluminum is also allowed as a conductor material with the appropriate connection elements and cross-sections. Where cables or lines are not laid in the ground or in sand-filled ducts, the outer jackets and sheaths must be flame-retardant, i.e. their burning behavior must be demonstrated according to DIN VDE 0472, Part 804, Test Type B.

When cables and lines are being **routed** through openings to non-hazardous areas, care must be taken to provide an adequate seal at the lead-in openings, e.g. sand filling, mortar. At particularly hazardous points, cables and lines must be protected from thermal, mechanical or chemical stress by, for example, conduits, tubing or covers.

Where stranded, fine or extra-fine conductors are used for the connections within an item of apparatus, the ends must be protected against separation of the individual conductors, e.g. with cable lugs or ferrules.

7.4 Installation in Zone 0

Only electrical apparatus which is specially certified and approved may be used in Zone 0.

Increased requirements also apply to **cables and lines**. For example, branches and connections are not allowed over the cable and line routes. Cables and lines must also be continuously monitored for the state of insulation of their conductors with respect to the metal sheath by means of measurement. If the insulation resistance drops below 100 ohms per volt of rated voltage, the affected circuit must shut down automatically and with all phases. These requirements do not apply to cables and lines of intrinsically safe circuits.

For **systems with intrinsically safe circuits**, there is also a requirement that the intrinsically safe and associated electrical apparatus be specially certified for Zone 0.

In contrast, there is no need for special certification of intrinsically safe apparatus which has no energy storage and is installed outside Zone 0 (e.g. terminal boxes, connectors, switches).

Lines of intrinsically safe circuits for Zone 0 must be laid so that mechanical damage is ruled out. In Zone 0, lines or non-sheathed cables of intrinsically safe and non-intrinsically safe circuits must not be routed together in cables, lines, conduit or conductor bundles.

The zener barriers without metallic isolation intended for voltage/current limiting in intrinsically safe circuits for Zone 1 are not allowed for Zone 0.

Summary of requirements for apparatus in Zone 0

– Apparatus which is specially certified for Zone 0

– Intrinsically safe apparatus complying with Category "ia". (In systems with intrinsically safe circuits for Zone 0, intrinsically safe and associated apparatus must be certified as components of the intrinsically safe system for Zone 0.)

– The apparatus must have reliable metallic isolation.

> **Note**
>
> The interior of containers and tanks (subject to the VbF) as well as the immediate vicinity of filling centers are classed as Zone 0.

7.5 Installation in Zone 1

The electrical apparatus for Zone 1, except for cables and lines, must comply with the requirements of individual types of protection to European standards (see Section 4.2), and must be certified by an approved testing station. This does not apply to equipment for which none of the values **1.2 V, 0.1 A, 20 µJ or 25 mW** is exceeded, according to the manufacturer's data; it requires neither certification nor marking.

A requirement for **selecting apparatus** for systems with intrinsically safe circuits is that the intrinsically safe and associated apparatus must comply with at least Category "ib" to EN 50020.

> **Note**
>
> Associated electrical apparatus of the intrinsically safe type of protection must be arranged outside the hazardous area, unless it additionally complies with another type of protection, such as a pressurized enclosure.

Where intrinsically safe electrical apparatus contains no voltage source, and the electrical characteristic data and temperature-rise behavior are known, this apparatus (such as switches, connectors, resistors) need not be type-tested to EN 50020 and marked. This apparatus must, however, comply with the constructional requirements of DIN EN 50020 VDE 0170/0171 Part 7.

It is a **requirement of cables and lines** in intrinsically safe circuits that the cables and lines must be insulated and withstand a test voltage of at least 500 V AC between conductors, and between a conductor and ground. The diameter of a single conductor within the hazardous area must be not less than **0.1 mm**. Cables and lines of intrinsically safe circuits must be marked, e.g. with a light-blue sheath. Similarly, connection elements of the intrinsically safe circuits must be marked as intrinsically safe, e.g. with a light-blue color. Where certain requirements are met, such as those for conductor insulation, test voltage and shielding, the routing of more than one intrinsically safe circuit in a cable or line is allowed.

Additional requirements apply to intrinsically safe circuits, e.g. with respect to grounding. On the one hand, intrinsically safe circuits should generally be floating, but on the other hand they are grounded for safety or functional reasons. Furthermore, in Zone 1, conductors for non-sheathed cables of intrinsically safe and non-intrinsically safe circuits must not be routed together in cables, lines, conduits or conductor bundles. Non-sheathed cables of intrinsically safe and non-intrinsically safe circuits must be laid separately in ducts, or they must be separated by an intermediate layer of insulating material. This additional separation can be dispensed with by using lines with suitable jacket insulation, for example.

Intrinsic safety must not be impaired by external electrical or magnetic fields; it is therefore advisable to use shielded and/or twisted lines.

Proof of intrinsic safety of a circuit is given by the electrical characteristic data on the rating plate of the apparatus and/or on the special test certificate; these must not be exceeded.

Lines can be represented as lumped capacitances. For intrinsically safe circuits, it is sufficient to determine the maximum capacitance between two adjacent cores. With standard commercial cables and lines, a rough capacitance of 200 nF/km can be taken as a basis.

Where intrinsically safe circuits are interconnected with more than one item of active apparatus, "intrinsic safety" must also be ensured under fault situations. This must be demonstrated by calculation or measurement. The new characteristic data of the interconnected intrinsically safe circuits must be summarized in a certificate, taking into account, where necessary, the current and voltage addition which may occur during a fault (see also Section 6.3).

For certain apparatus such as machines, transformers, capacitors and switchgear, special individual requirements for installation in Zone 1 are stipulated in DIN VDE 0165.

Summary of the requirements for apparatus in Zone 1

- Apparatus which is specially certified for Zone 1
- Intrinsically safe apparatus complying with Category "ib"
- The maximum surface temperature is lower than the ignition temperature of the gas/air mixture.
- The apparatus with its explosion group must correspond to that of the gas/air mixture.
- The overall characteristic data for the interconnection of the intrinsically safe and associated apparatus must be determined.

7.6 Installation in Zone 2

Electrical apparatus which is suitable for Zones 0 or 1 may be used in Zone 2; this is defined by ElexV as a low-risk hazardous area. Also allowed is electrical apparatus without a special test certificate if, in its operational state, it produces no ignition-capable sparks or arcing or does not develop excessive temperatures. A temperature is considered as excessive if it is at least as high as the ignition temperature of the particular combustible substance. The operational state is understood to mean the properly functioning operation of an item of apparatus permitted within limits specified by the manufacturer.

For certain apparatus such as machines, transformers, capacitors and heating equipment, special individual requirements for installation in Zone 2 are stipulated in DIN VDE 0165.

Also allowed in Zone 2 according to DIN VDE 0165 is measurement, control and telecommunications equipment which is not specially tested and which may or may not produce sparks in the operational state, if the voltages and currents in the operational state are not higher than the maximum permissible values for the intrinsic safety type of protection. However, the maximum permissible values for inductances and capacitances of this electrical apparatus must not be exceeded.

Summary of requirements for apparatus in Zone 2

- Apparatus which is suitable for Zones 0 or 1.
- Apparatus producing no sparks or arcing in the operational state
- Apparatus whose housing has restricted breathing (IP 54) or is a simplified pressurized enclosure
- Apparatus with bare, active parts operating outdoors (at least IP 54)
in rooms (at least IP 40)
- Apparatus using only insulated parts and operating outdoors (at least IP 44)
in rooms (at least IP 20)
- A manufacturer's declaration of suitability for Zone 2 must be provided.

7.7 Installation in Zones 10 and 11

Zones 10 and 11 are hazardous areas on account of combustible dusts. If these areas are simultaneously subjected to explosion hazard from flammable gases, vapors and mists, the requirements for Zone 0 or 1 additionally apply.

Only apparatus specially tested and certified for the purpose may be installed in **Zone 10**. For systems with intrinsically safe circuits, the requirements for Zone 0 apply analogously.

Electrical apparatus without a special test certificate may be used in **Zone 11**. It need only be adequately protected against dust. This means that neither explosive dust/air mixtures nor dangerous dust deposits may develop in the interior of such apparatus. These conditions are met if the apparatus complies with at least type of protection IP 54.

There must also be no excessive dust deposits on the surface, because heat accumulation or whirling dust can also result in an explosion. This requires that various conditions be met. For example, the surface temperature must not exceed 2/3 of the ignition temperature of the relevant dust/air mixture: $\mathbf{T_{surface} \leq 2/3 \times T_{ignition}}$ of the dust/air mixture. Additionally, in the case of surfaces which are not adequately protected against dust deposits capable of smoldering, the surface temperature must not be higher than the smoldering temperature of the relevant dust less 75 K: $\mathbf{T_{surface} \leq 2/3 \times T_{smolder} - 75\ K}$. The use of electrical apparatus of the intrinsic safety type of protection requires no protection against dust deposits. However, the requirements relating to surface temperature must be complied with. Furthermore, the apparatus must be labelled with the surface temperatures developed during continuous operation, e.g. $\mathbf{T_{surface} < 80\ ^\circ C}$.
For Zones 10 and 11 there are also special individual requirements in DIN VDE 0165 for certain apparatus such as machines and luminaires.

Associated electrical apparatus with intrinsic safety for use of sensors/actuators in Zone 10 or 11

1. Associated electrical apparatus, for example ib-certified SIMATIC S5-100U Ex modules, require no further certification for supplying power to electrical apparatus in Zone 11 or being connected to such apparatus. The electrical apparatus installed in Zone 11 must meet the requirements for Zone 11.

2. The regulations under 1. apply correspondingly for Zone 10: Associated ib-certified electrical apparatus may feed electrical apparatus in Zone 10 if the latter are certified to Zone 10.

Caution: When a system is installed, special attention is to be paid to the separation of zones, for example dust-proof cable entries into Zone 10.

7.8 Operation, Maintenance, Faults and Repairs

According to Paragraph 13 of the ElexV, **operation and maintenance** of electrical systems in hazardous areas are the sole responsibility of the user. This means that the user must keep the system in a properly functioning state, operate it correctly and supervise it continuously. Furthermore, the user must carry out necessary maintenance and repair work without delay, and implement any safety measures as may be required.

Before a system is started for the first time, the user must arrange for a test by an electrical specialist. This test may be dispensed with if the manufacturer or installer has confirmed proper installation of the system to the user.

Clearly, proper operation requires that generally accepted engineering practice, especially that of electrical engineering, be observed. The regulations for operating power systems with the additional stipulations for hazardous areas (DIN VDE 57105 Part 9 / VDE 0105 Part 9) must be complied with. Monitoring of the electrical apparatus of such systems for a proper operational state is a significant requirement.

Normal operation of a system also includes its servicing, **maintenance** and care to prevent shutdowns. The mechanical state of a system should be verified within a 12-month period. This extends from the state of screw terminals to ensuring the IP protection of housings.

With regard to the proper operating state of a system, ElexV requires **verification** of a system at intervals of at **least 3 years**, if it is not continuously monitored by a responsible engineer. For this verification, the explosive atmosphere should be removed because measuring instruments, for example, are generally not explosion-protected. All housings must also be opened and the mechanical and electrical state of all parts in their interior inspected, i.e. state of contacts and insulation values. For electrical apparatus of the intrinsic safety type of protection, this type of verification is dispensed with because this apparatus is maintenance-free.

Note

The supervisory authority can order any required supervisory measures in individual cases.

In the event of a **fault** on a system, the relevant apparatus must be disconnected from the AC system with all phases. This also applies to apparatus outside the hazardous area, if explosion protection depends on it (e.g. associated apparatus).

> **Note**
>
> In the event of an explosion which may be caused by operation of the electrical system, it must be reported by the user to the supervisory authority. This authority may require an examination of the cause of the explosion, of the state of the system in order to rule out a subsequent explosion, and further protective measures.

Repair work is only allowed if the specified protective measures for hazardous areas are observed. It is prohibited, for example, to work on live electrical apparatus in hazardous areas. Work on intrinsically safe circuits is an exception.

The work may only be carried out by electrical specialists or persons under the supervision of an electrical specialist. Notes on these tasks is given in Table 7.2.

Once the repair work is completed, normal operation may only resume when effectiveness of the required explosion protection measures has been ensured. An expert must issue a certificate to this effect, or apply his test symbol to the apparatus.

Table 7.2 Notes for Working on Explosion-Protected Electrical Apparatus

Type of Protection of Apparatus	Type of Work to be Carried Out	Work Within Hazardous Areas		
		Zone 0	Zone 1	Zone 2
EEx ia with approval for Zone 0	Opening the housing	Not allowed	Allowed	All work allowed except in event of sudden risk of explosion
	Connecting/ disconnecting lines			
	Current, voltage and resistance measurement	Allowed with measuring instruments certified for Zone 0; observe L and C.	Allowed with apparatus certified for Zone 1; observe certificates of intrinsic safety for Zone 0	Allowed
	Soldering	Prohibited	Prohibited	Prohibited
EEx ia/ EEx ib	Opening the housing	Not allowed	Allowed	All work allowed except in event of sudden risk of explosion
	Connecting/ disconnecting lines			
	Current, voltage and resistance measurement		Allowed with certified apparatus or devices without integral power supply	Allowed
	Soldering		Prohibited	Allowed if soldering temperature lower than ignition temperature

Table 7.2 continued

Type of Protection of Apparatus	**Type of Work to be Carried Out**	**Work Within Hazardous Areas**		
		Zone 0	**Zone 1**	**Zone 2**
EEx e	Opening the housing	Not allowed	Only allowed in de-energized state (see voltage measurement for exception)	All work allowed except in event of sudden risk of explosion
	Connecting/ disconnecting lines		Only allowed in de-energized state	
	Current, voltage and resistance measurement		Only voltage measure-ment allowed with certified instruments (short-time measurement); other measurements only after EEx e installation	
	Soldering		Prohibited	
EEx "p" previously (Ex)f	Opening the housing	Not allowed	Only allowed in deenergized state and for period of time indicated on apparatus	
	Connecting/ disconnecting lines		Only allowed in deenergized state	
	Current, voltage and resistance measurement		Only allowed if certified testing devices are used and EEx "p" protection is ensured	
	Soldering		Prohibited	
EEx "d"	Opening the housing	Not allowed	Only allowed in deenergized state and for period of time indicated on apparatus	
	Connecting/ disconnecting lines		Only allowed in deenergized state	
	Current, voltage and resistance measurement		No work possible due to encapsulation. Exception: separate terminal compartment in EEx "e"	
	Soldering		Prohibited	
Applies to all types of protection	Tools	Only allowed with tools which do not produce sparks in operation	Allowed with non-sparking tool (e.g. copper-beryllium)	All tools are allowed
	Mechanical work (drilling, hammering, grinding, parting)	Prohibited	Sparking and excessive temperature rise are prohibited	All work allowed except in event of sudden risk of explosion

8 Procedure for Installing an Explosion-Protected System, Based on an Example

8 Procedure for Installing an Explosion-Protected System, Based on an Example

An example is given for purposes of illustration only; the main procedure and some details of the installation requirements for explosion-protected electrical systems are given once again as a summary.

A control room for the entire plant and a small pumping station for flammable liquids are to be installed in an annex of an existing factory building. In the course of planning of the technological procedure, it is decided that a tank be set up as a preparation and storage vessel as well as an additional vessel with a stirrer, in the building to be constructed.

8.1 Assessing the Risk of Explosion (Example)

– Which flammable substances are to be processed?	Ethyl acetate
– What will be the quantity and throughput per unit of time?	250 m^3/h max.
– Maximum concentration in air?	Natural ventilation
– Type of processing and handling?	Pumping, mixing, stirring, filling
– Possible escape of vapors?	Open containers
– Method and efficiency of forced ventilation?	None

8.2 Determining the Safety Characteristics

– Density, density ratio (gaseous)	3.04
– Flash point	- 4 °C
– Lower explosion limit	2.1 % by volume
– Ignition temperature	460 °C

8.3 Assessing the Overall Process

– Will there be any explosive atmosphere in the building?	Yes
– At which points and in which quantities?	Not important in this case because there is no technical ventilation
– Will the explosive atmosphere occur in a hazardous amount?	Yes

8.4 Selecting the Explosion-Protection Measures

Since the use of primary explosion-protection measures is not planned, the occurrence of ignition sources must be avoided.

8.5 Zone Classification

EX-RL and TRbF will serve as a basis for zone classification.

– Rooms with systems for storing, filling and mixing	Zone 1
– Equipment which will be opened during operation for charging and emptying	Zone 1 up to 10 m
– Pumps in rooms (Ri = 250 m^3/h)	Zone 1 up to 3 m
– Piping with detachable connections in rooms	Zone 2 up to 3 m

The decision is made to consider the entire pump room as Zone 1.

8.6 Selecting the Electrical Apparatus

		Type of protection
– Which electrical apparatus must definitely be accommodated in the hazardous area?	Pump motor	e or d
	Stirrer motor	e or d
	Lighting	e or d
	Measurement and control systems	EEx ib
– Explosion group?	IIA	
– Temperature class?	T1	
– Type of zone?	Zone 1	

8.7 Interconnecting the Electrical Apparatus with Intrinsically Safe Circuits

- For the intrinsic safety type of protection, explosion protection is determined by the interaction between two or more items of apparatus including connecting cables.
- A high level of responsibility will be assumed by the installer or user for demonstrating intrinsic safety.
- A prerequisite for the installation of intrinsically safe circuits is that the permissible values for temperature, power and energy stores be not exceeded.
- For the interconnection of linear and nonlinear intrinsically safe circuits, the specifications of PTB Report W-39 must be observed.

8.8 Selecting the Cables and Lines

– Motor connection	NYY
– Stirrer motor	H07RN-F because portable
– Lighting	NYM
– Measurement and control system (temperature, level, flow rate)	H05RN-F

8.9 Laying the Cables and Lines

– Over a common cable route	Clearance
– Penetration into non-explosion protected area	Partitioning
– Marking of intrinsically safe lines	Blue color
– Lead-in and connection of lines	Ensure marking and avoid swapped connections

8.10 Special Features

– Type of protection "e" for pump motor	Fit motor protection
– Equipotential bonding	Additional equipotential bonding
– Lightning protection	Required
– Adjacent electrical premises	Separation by air

Part 2: SIMATIC S5 Ex Modules with Intrinsically Safe Circuits

Contents

Part 2: SIMATIC S5 Ex Modules with Intrinsically Safe Circuits

Appendices

9 Mechanical Arrangement of an Automation System with Ex Modules

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9 Mechanical Arrangement of an Automation System with Ex Modules

Note

Ex systems may only be installed by authorized personnel.

9.1 Assessing the Risk of Explosion (Examples)

Apart from the I/O modules, all parts of the PLC/ET are snapped onto standard sectional rails to DIN EN 50022-35x15. These parts of the PLC are, for example:

- Load power supply, e.g. PS 931
- S5-95U PLC, CPU 102/103 or IM 318-8M.. interface module (for ET 100U/ET 200 U), PS 935 auxiliary power supply
- Non-Ex bus units
- Ex bus units
- Partition

The I/O modules are plugged into the bus units as follows:

- Non-Ex I/O modules into the non-Ex bus units
- Ex I/O modules into the Ex bus units

The partition must be positioned between the Ex and non-Ex modules. The standard sectional rail should be fitted to a metal plate to ensure the same reference potential. There are different assembly heights for bus units in the SIGUT or crimp snap-in connection system.

Ensure that you follow the procedure in Table 9.1 when installing, dismantling or modifying the arrangement:

Table 9.1 Installing, Dismantling and Modifying the PLC/ET

Installation, Dismantling and Modifying:	POWER State PLC/ET	Mode PLC/ET	Load Voltage
Ex I/O modules	POWER OFF	STOP	X
Non-Ex I/O modules	POWER OFF	STOP	OFF
Ex bus units	POWER OFF	X	X
Non-Ex bus units Interface modules	POWER OFF	X	X
CPU PS 935 power supply	Supply voltage OFF	X	X

9.1.1 Assembling a Tier with Ex Modules

You will need the following parts to assemble an automation system with intrinsically safe and non-intrinsically safe I/O circuits:

- A load power supply module
- A PLC and a CPU/IM 318 interface module
- A PS 935 auxiliary power supply module (if required)
- Ex and non-Ex bus units
- Ex and non-Ex I/O modules

Start assembling at the left-hand end of the standard sectional rail and fit the other modules on the immediate right.

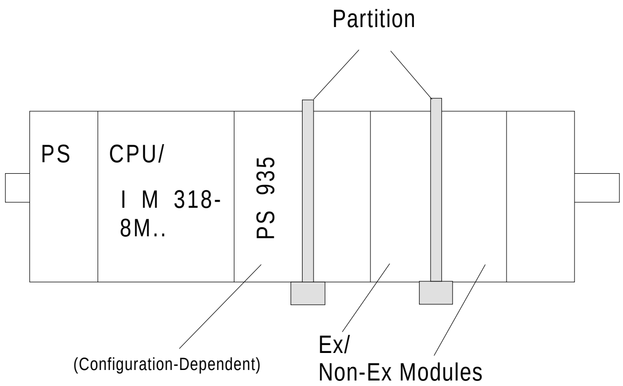


Figure 9.1 Tier with Ex Modules

Fitting the PS 931 power supply module

The design of the backplane also allows simple mounting on the standard sectional rail.

- Position the power supply module so that it catches in the standard sectional rail.
- Swivel it back until the slider engages.

Dismantling

Switch off the input voltage of the PS 931.

- Detach the connections between the CPU and power supply module or IM 318 interface module and power supply module.
- Use a screwdriver to press the slider on the bottom of the power supply module downwards.
- Swivel the module out of the standard sectional rail.

Fitting the PLC/CPU/IM 318 interface module

Proceed as for the power supply module.

- Position the PLC/CPU/IM 318 interface module on the right of the power supply module so that it catches in the standard sectional rail.
- Swivel it back until the slider engages.

Removing the PLC/CPU/IM 318 interface module

- Switch off the supply voltage of the PLC/CPU/IM 318 interface module.
- Remove the I/O module or PS 935 auxiliary power supply from Slot "0".
- Detach the connection (ribbon cable) between the PLC/CPU/IM 318 and the first bus unit or PS 935.
- Detach the connections between the PLC/CPU/IM 318 and power supply module.
- Use a screwdriver to press the slider at the bottom of the module downwards.
- Swivel the module out of the standard sectional rail.

Fitting the PS 935 power supply module

- Connect the plug of the ribbon cable to the male connector on the right-hand side of the PLC/CPU/IM 318 interface module.
- Position the power supply module so that it catches in the standard section rail and swivel it back until the slider engages.
- Connect the 24 V DC terminal (+) of the PLC/CPU/interface module to the 24 V DC terminal of the PS 935.

> **Note**
>
> Always fit PS 935 in the first slot.

Removing the PS 935

- Switch off the voltage of the 24 V DC supply.
- Detach the connections of the 24 V DC supply.
- Detach the connection (ribbon cable) to the bus unit.
- Remove the bus unit on the right of the PS 935.
- Use a screwdriver to press the slider of the module downwards and swivel the module out of the standard sectional rail.
- Disconnect the plug of the ribbon cable from the PLC/CPU/IM 318 interface module.

Fitting the Ex bus unit

Position the unit and swivel it in as for the power supply and CPU modules.

- Hooks on the side serve to connect the Ex bus units to each other and to
  - non-Ex bus units or
  - the PLC/CPU/IM 318 interface module.
- **A partition must always** be fitted between the Ex bus units and non-Ex parts of the PLC/IM 318 interface module, to ensure 50 mm thread measure between intrinsically safe and non-intrinsically safe terminals.

Connecting the Ex bus units to each other or to non-Ex parts of the PLC/IM 318 interface module

- Disconnect the plug of the ribbon cable - on the upper left of the bus unit - from the mount.
- Insert it over the partition (only needed for Ex and non-Ex bus units) in the female connector of the adjacent bus unit on the left,
- or in the female connector on the right-hand side of the PLC/CPU/IM 318 interface module.

Removing the intrinsically safe bus units

- Detach the connections to the adjacent Ex/Non-Ex bus units or to the PLC/CPU/IM 318 interface module.
- Use a screwdriver to press the slider downwards.
- Swivel the module out of the standard sectional rail.

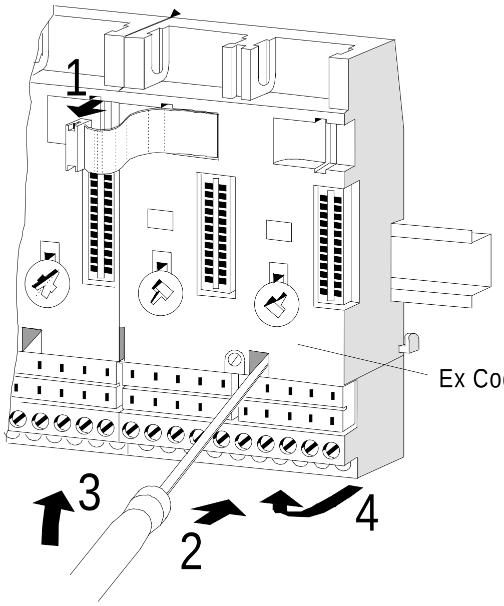


Figure 9.2 Removing the Bus Units

Fitting Ex I/O modules

Before fitting an Ex I/O module, you must set the coding key of the Ex bus unit to the module type. The module type must be entered on the labelling strip of the Ex bus unit.

Setting the coding key:
Printed on each Ex I/O module is an identification number from 9 to 16, according to the type of module. A blue coding key is fitted to the rear of each module. Depending on the type of module, it is in a different unchangeable position. The bus unit has the matching element for each slot: a blue rotatable coding element as the "lock" (Figure 9.2). Use a screwdriver to set the "lock" on the bus unit according to the module identification number (Table 9.2).

Danger

When you are replacing an Ex module, only a module of the same type may be inserted at this slot. If a different module is inserted at this slot, intrinsic safety of the circuits connected at the Ex bus unit can no longer be ensured.

Table 9.2 Slot Coding for Ex Modules

Module	Order No.	Module Key	Marking on Module Rear	To Be Set on Bus Unit
Ex digital input module (NAMUR)	6ES5 437-8EA12	12	F	12
Ex digital output module	6ES5 457-8EA12	13	E	13
Ex analog input module (4 to 20 mA)	6ES5 467-8EE11	14	D	14
Ex analog output module (4 to 20 mA)	6ES5 477-8EC11	14	D	14

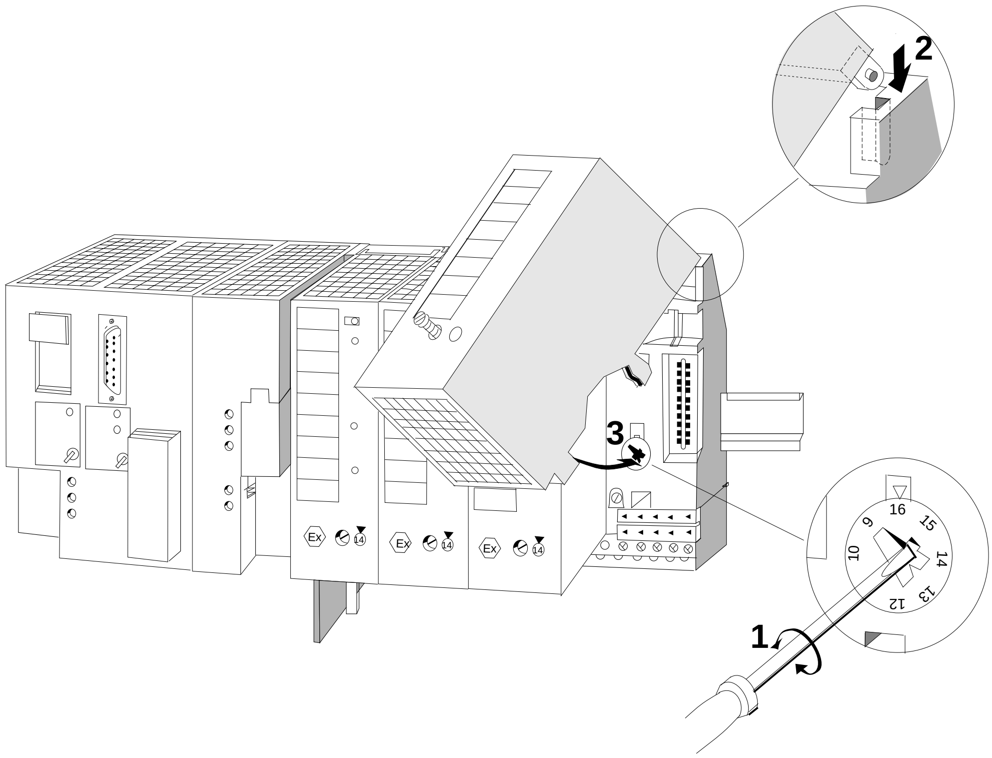


Figure 9.3 Setting the Coding Key on the Ex Bus Unit

Fitting an I/O module

- Position the module at the bus unit so that it catches.
- Swivel it towards the bus unit.
- Press it firmly and
- screw the module onto the bus unit.

Removing an I/O module

- Slacken the fitting screw and swivel the module forwards and up to remove it.

9.1.2 Expansion Over Two or More Tiers

If you cannot fit all the modules in one tier, expansion with up to four tiers is possible. You may use up to 16 bus units, and any number of units in one tier. You will need one IM 316 interface module per tier to connect the individual tiers.

Installation is the same as for the bus units. The IM 316 interface module must again be connected via the ribbon cable to the last bus unit. A partition must always be fitted between the IM 316 interface module and an Ex bus unit.

With a two-tier arrangement, use the IM 315 interface. It comprises two modules which are permanently interconnected via a 0.5 m long cable. For an arrangement with more than two tiers, use the IM 316 interface modules. The interfaces must be connected with the 712-8 cable (Order No. 6ES5 712-8...). The length of the cable depends on the current load on the connecting cable (see Section 11.4.2).

An arrangement in two or more cabinets requires a common reference potential for the standard sectional rail.

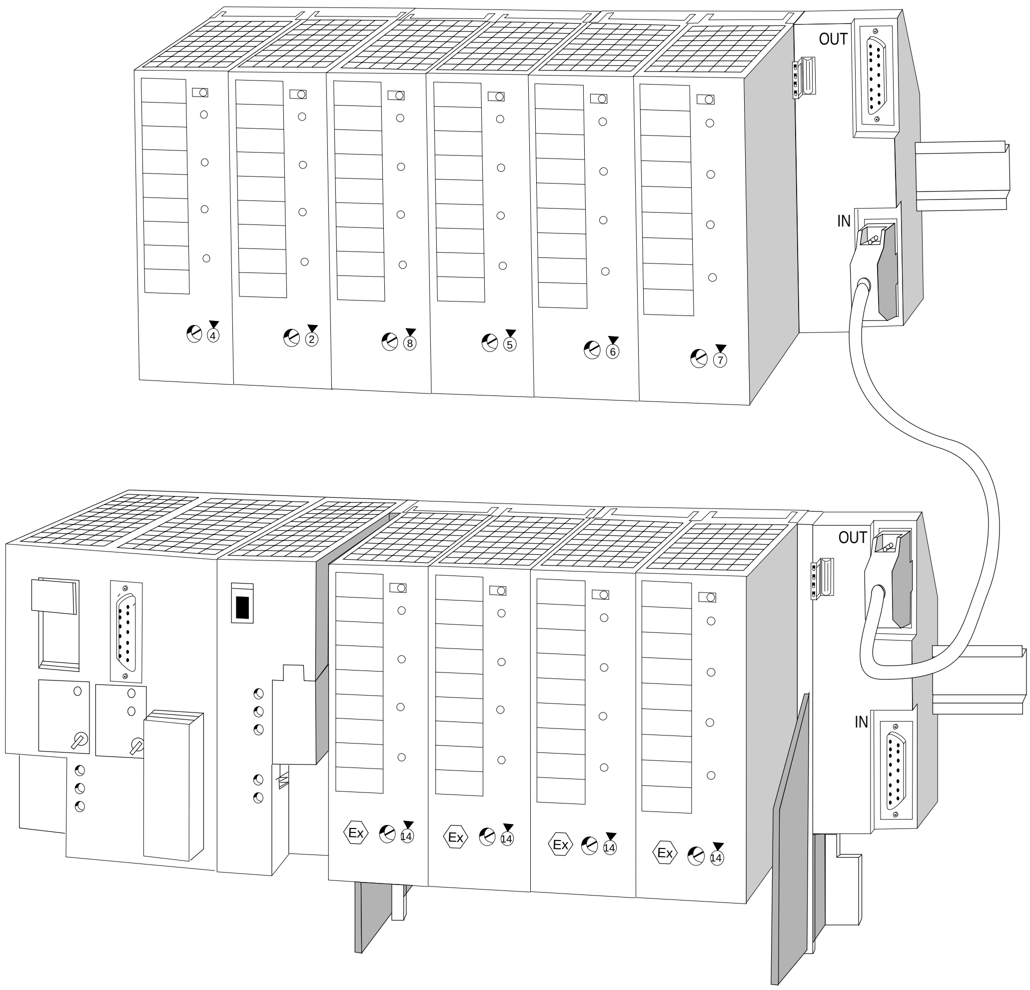


Figure 9.4 Connection by means of Interface Modules (6ES5 316-8MA12)

Fitting the IM 315/IM 316 interface module

- Position the interface module so that it catches in the standard sectional rail.
- Swivel the module back so that it engages.
- Use the ribbon cable to connect the module to the last bus unit. (If the last one is an Ex bus unit, do not forget the partition.)
- Connect the two interface modules with a 712-8 connecting cable.
- Plug the cable into the "OUT" connector on the PLC tier and into the "IN" connector on the expansion tier.
- Use the two screws to secure each plug of the connecting cable.

Removing the IM 315/IM 316 interface module

- For the IM 316 only: slacken the fixing screws of the plugs and detach the connecting cable.
- Detach the connection (ribbon cable) to the adjacent bus unit.
- Use a screwdriver to press the slider at the bottom of the interface module downwards and swivel the module out of the standard sectional rail.

9.1.3 Cabinet Installation

To improve interference rejection, the PLC/ET should be mounted on a metal plate; at the least, all standard sectional rails must be connected at a low resistance. Ensure a good electrical connection when assembling.

In addition to cabinets of the 8MF system, possibly fitted with the double swing frame for a higher packing density, you can use mounting plates of the 8LW or 8LX systems; see Figure 9.4 (Catalog NV 21). The distance between two standard sectional rails must be at least 210 mm. Use the dimension drawings in the appendix.

To improve the heat distribution,

- the PS 931 and PS 935 power supplies,
- the CPU/IM 318-8M.. interface module
- and the Ex analog modules

should always be arranged in the lowest tier in unventilated cabinets, and in the top tier in ventilated cabinets.

When designing the cabinet ventilation, use the sum of all typical power dissipations as the total power dissipation (Table 9.3).

Table 9.3 Power Dissipations of the PLC/ET and Ex Modules

Module	Typ. Power Dissipation	Max. Current Drawn from PLC Backplane Bus
S5-95 PLC (6ES5 095-8MA..)	12 W	-
CPU 102 (6ES5 102-8MA..)	11.4 W	-
CPU 103 (6ES5 103-8MA..)	11.6 W	-
IM 318-A (6ES5 318-8MA..) (for ET 100U)	6 W	-
IM 318-B (6ES5 318-8MB..) (for ET 200U)	6 W	-
PS 935 (6ES5 935-8ME11)	7.5 W	-
Ex digital input module (6ES5 437-8EA12) Ex digital input module (6ES5 437-8EA21)	0.45 W 0.45 W	50 mA 50 mA
Ex digital output module (6ES5 457-8EA12)	0.5 W	55 mA
Ex analog input module (6ES5 467-8EA11) Ex analog input module (6ES5 467-8EE11) Ex analog input module (6ES5 467-8EF11)	2.5 W 2.9 W 2.5 W	270 mA 320 mA 270 mA
Ex analog output module (6ES5 477-8EC11)	3.15 W	350 mA

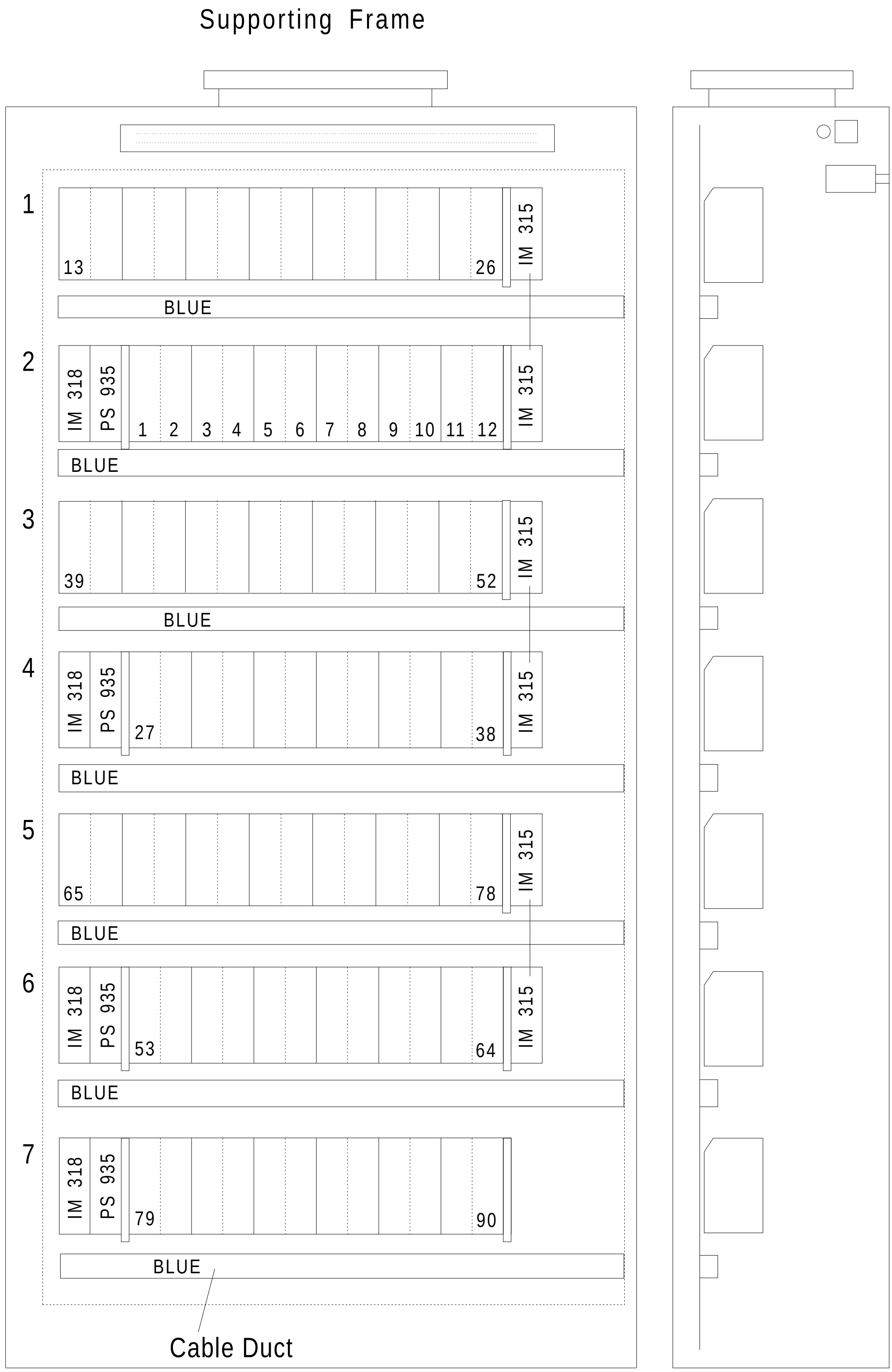


Figure 9.5 Multi-Tier Arrangement with Intrinically Safe Ex Modules in an 8MF Cabinet

Figure 9.6 Multi-Tier Arrangement in a Swing Frame (6XK3...)

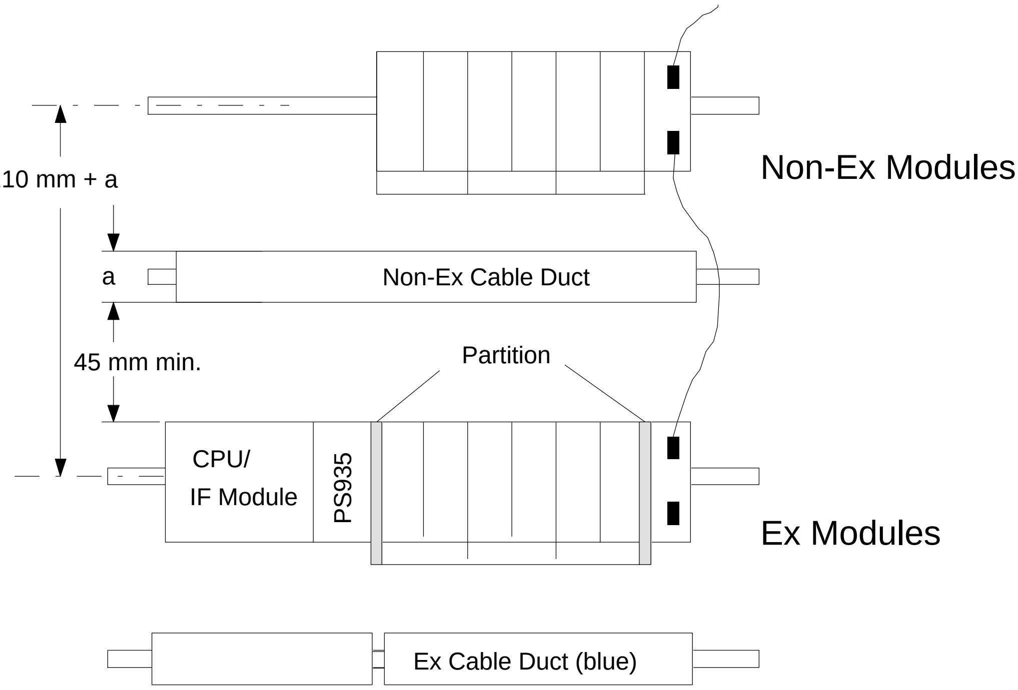


Figure 9.7 Cabinet Installation with One Ex and One Non-Ex Cable Duct

9.1.4 Vertical Arrangement

The standard sectional rails can also be fitted vertically so that the modules can be stack-mounted one above the other. Heat removal by convection is lower in this case, and the permissible ambient temperature is therefore limited to 40 °C max..

The minimum clearances for vertical arrangement must be the same as for a horizontal arrangement.

A grounding clip (6ES5 728-8AM11) must be fitted at the lower end of the PLC tier to secure the modules mechanically.

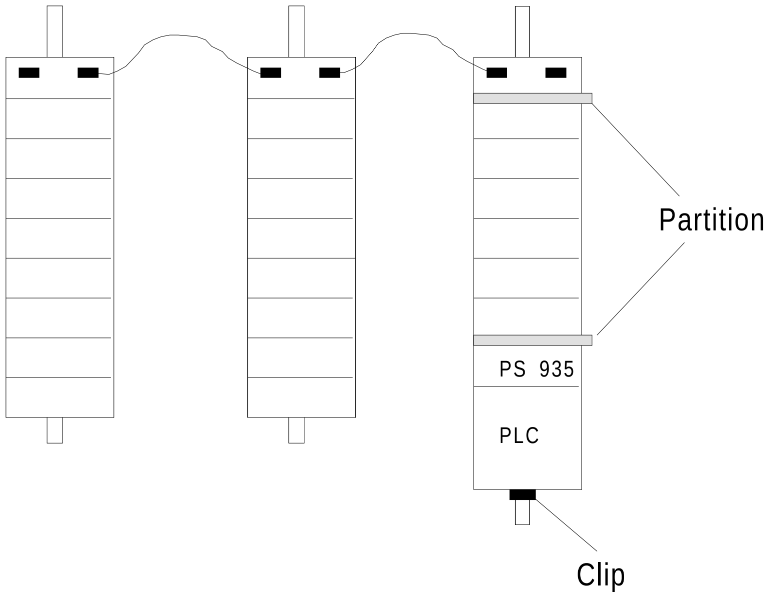


Figure 9.8 Vertical Arrangement of the PLC

9.2 Wiring an Automation System with SIMATIC Ex Modules

9.2.1 Connecting the Power Supply

Connecting the PS 931 power supply module

- Remove the cover from the voltage selector switch.
- Set the voltage selector switch to the AC line voltage.
- Raise the protective cover of the supply cable.
- Connect the AC power cable to terminals L1, N and ⏚.
- Close the protective cover.

Connecting the CPU/interface module

- Connect terminals L+ and M of the PS 931 power supply module to the corresponding terminals of the CPU/IM 318 interface module.
- Connect terminal ⏚ of the CPU/IM 318 interface module to the standard sectional rail.

Connecting the PS 935 auxiliary power supply module

Connect terminal L+ of the CPU/IM 318 interface module to the corresponding terminal of the PS 935 auxiliary power supply module.

9.2.2 Connecting Ex I/O Modules

The Ex I/O modules plug into Ex bus units. Ex I/O modules are powered via the backplane bus and not via the terminal blocks of the bus units. The Ex sensors and Ex actuators should be connected to the terminals of the individual Ex bus units. The sensors and actuators are powered via the Ex modules or via their own intrinsically safe power supplies (e.g. four-wire transducer).

Note

Before a sensor or actuator is connected to an Ex module, a safety assessment of this intrinsically safe circuit by an expert may be required. Forms for the approval of an interconnection can be found in Appendix D: "Safety assessment for the interconnection of intrinsically safe circuits".

9.3 Electrical Circuitry

Power supply

The entire control system consists of separate circuits:

- The supply circuit for the PLC/ET (24 V DC)
- The control circuit for the non-intrinsically safe sensors (24 V DC)
- The load circuit for the non-intrinsically safe actuators (24 V DC or 115/230 V AC)

The Ex sensors and Ex actuators are powered via the Ex I/O modules. The supply of power to the Ex sensors and Ex actuators, and that to the Ex modules via the backplane bus is metallically isolated.

Supply of power for the PLC/ET backplane bus

Power for the PLC/ET backplane bus is supplied via the CPU/IM 318 interface module, and a total current consumption of up to 1 A is ensured.

If the total current drawn from PLC/ET backplane bus is more than 1 A, you must use the PS 935 which ensures a current supply of up to 2.5 A.

The load circuit

The supply of power to the Ex sensors and Ex actuators for the process I/Os is ensured by the Ex I/O modules.

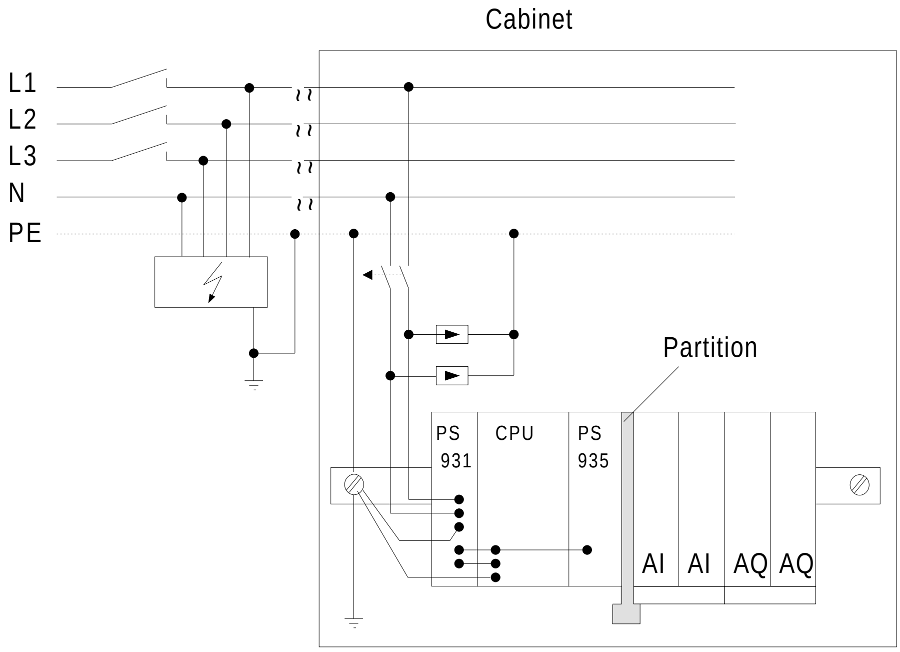


Figure 9.9 Configuration of an S5-100U with Intrinsically Safe Modules

9.4 Equipotential Bonding in Systems with Explosion Protection

Potential differences can develop between the elements of electrical apparatus connected with PE conductors, and conductive structural elements, piping, etc. which does not pertain to the electrical apparatus. During bridging of these potential differences, sparks capable of causing ignition can be produced. To equalize the potentials, conductive metal parts which can be touched must be connected to each other and to the PE conductor. Equipotential bonding with the PE conductor can be best implemented at the distribution board. The cross-section of the bonding conductor must be at least that of the PE conductor. In all other cases, the equipotential bonding conductor must have a cross-section of at least 10 mm^2 of copper.

The Ex modules have metallic isolation between the PLC/ET backplane bus and the I/O circuit; there is therefore no need for connection to the equipotential bonding conductor. An exception is when a connection to the EB conductor must be made for measurement purposes. Where lightning protection devices are required in the intrinsically safe circuit (Section 9.7), they must be connected to the EB conductor at the same point as the shield of the intrinsically safe circuits.

In systems with functional extra-low voltages of ≤ 50 V AC or ≤ 120 V DC, metallic conductive elements of apparatus must be connected to the PE conductor or EB conductor.

Cable racks must be incorporated in the grounding system throughout.

Equipotential bonding in a building

According to VDE 0100, Part 410 and Part 540 and DIN VDE 0185, equipotential bonding must be provided in every building and via the overall cabling of the automation system; if this is not the case, it must be installed.

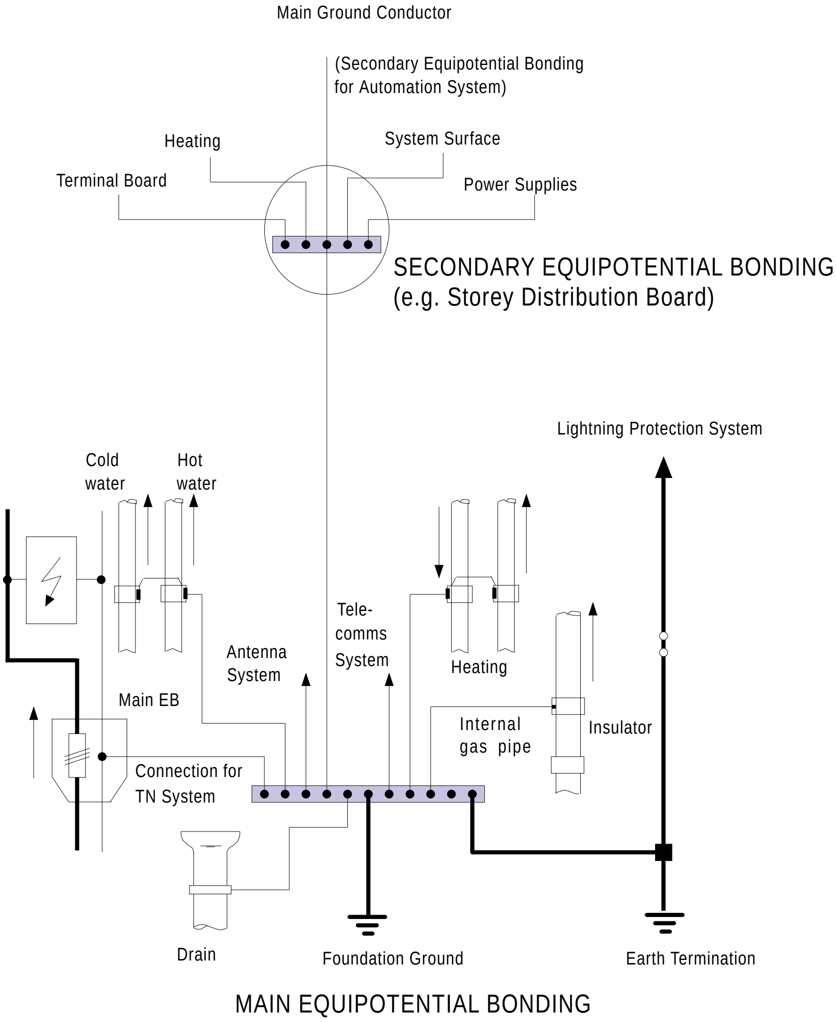


Figure 9.10 Main and Secondary Equipotential Bonding According to VDE

Main equipotential bonding

This interconnects the following conductive elements by the EB conductor at the EB bus:
$A_{PA} = 0.5 \times A_{PE\text{-}main}$

- Main PE conductor
- Main ground conductor
- Earth termination
- Main water pipe
- Main gas pipe
- Other metal piping systems
- Metal structural elements of the building (if possible)
- Power and information system cables extending beyond the building, via lightning conductor

Additional equipotential bonding

This interconnects the following conductive elements by the EB conductor at the EB bus:

- All "extraneous conductive elements" such as structural elements, supports, containers, piping (these themselves can form EB conductors), A_{PA} = 0.5 x A_{PEmax} (A = cable cross-section) from the distribution board.
- Elements of stationary electrical apparatus which is accessible to simultaneous contact, when it is connected to PEN (otherwise a PE connection is sufficient); A_{PA} = 0.5 x A_{PE} of both items of apparatus.

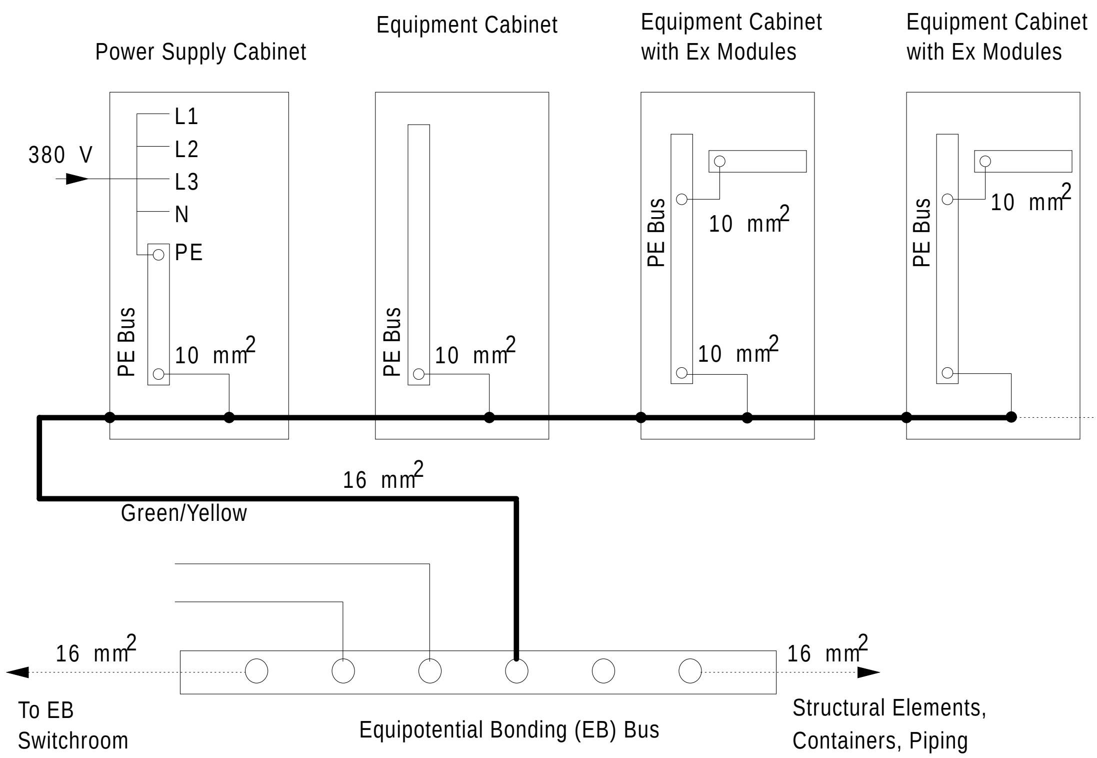


Figure 9.11 Example of Equipotential Bonding for Measurement and Control Systems

9.5 Wiring and Cabling in Ex Systems

Neither the electrical installation nor the required materials such as cables, lines and installation hardware are subject to the special test procedure of ElexV, with respect to their design. The responsibility of plant personnel or of an installation company for proper installation of an Ex system is particularly high, on account of the risk of explosion in the event of improper implementation.

General planning principles for cable routes are very similar to those for piping. At the drafting stage of installation plans and building layouts, areas with increased risk of fire and danger zones must be defined according to ElexV and VbF (see Appendix B: Ex Zone Plan). It is desirable for cable and piping routes to be arranged only in the **area of low risk**. Furthermore, accessibility and ease of maintenance must be ensured, also for subsequent expansion. With all types of switchroom, steps must be taken to ensure that the cable and line routes to the hazardous area are sealed so that they do not provide escape routes for hazardous gases or vapors into the switchroom.

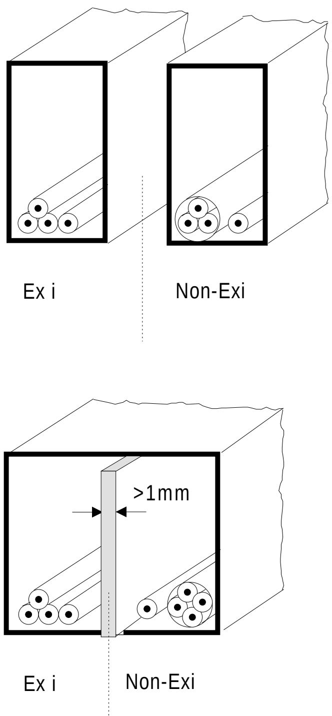
Note

The laying of cables in ducts in the floor should be avoided. There is a risk of
- the ingress or formation of explosive gas-air mixtures and their uncontrolled transmission;
- the ingress of corrosive liquids.

For the creation of intrinsically safe circuits, non-sheathed cables and single conductors in flexible cables need only have a diameter of ≥ 0.1 mm. For implementation in the Ex area, cables and lines must primarily withstand the expected mechanical, chemical and thermal effects. It is therefore always necessary to lay considerably larger cross-sections and use cables and lines which are flame-retardant and oil-resistant.

Intrinsically safe and non-intrinsically safe lines (conductors, non-sheathed cables) must be laid separately or with appropriate insulation. Common routing in cables, lines and conductor bundles is not permissible.

Special care must be taken to ensure full isolation in cable ducts. This can be achieved with a continuous intermediate 1 mm layer of insulating material or by laying sheathed cables (Figure 9.12).



Cables routed in separate, insulating cable ducts

Cables routed in a common cable duct with an insulating intermediate layer

(The solid insulating intermediate layer of > 1 mm provides reliable isolation of the intrinsically safe lines to EN 50020.)

Figure 9.12 Routing of Cables for Intrinsically Safe Circuits

Where sheathed cables of intrinsically safe and non-intrinsically safe circuits are routed together, the sheathed cable of the intrinsically safe circuit must withstand a minimum test voltage of 2000 V_{rms} AC.

The high test voltage of 1500 V AC can be dispensed with if the intrinsically safe or non-intrinsically safe circuits are enclosed in a grounded shield. However, the test voltage of the lines for intrinsically safe circuits must be at least 500 V AC (between conductor-conductor-ground).

Intrinsically safe lines must be clearly marked. If a color is used, it must be light-blue. An exception to this rule is the routing of lines within equipment, distribution panels and switchrooms. Cables and lines thus marked must not be used for other purposes.

In general, intrinsically safe circuits must be installed in a floating arrangement. A connection to ground via a 15 kohm resistor, e.g. to discharge electrostatic charges, does not qualify as a ground. Intrinsically safe circuits must be grounded when this is required for measurement or safety reasons. Grounding may only take place at one point by connection to the equipotential bonding conductor. Equipotential bonding must be provided throughout the entire area of installation of intrinsically safe circuits.

In systems with intrinsically safe and non-intrinsically safe circuits, such as measurement and control cabinets, the connection elements must comply with the specifications of DIN EN 50020/VDE 0170/0171 Part 7/05.78, 5.4.1. The terminals of the intrinsically safe circuits must be marked as intrinsically safe (light-blue).

9.5.1 Marking of Cables and Lines of Intrinsically Safe Circuits

Cables and lines of intrinsically safe circuits must be marked. Where jackets or sheaths are color-coded, light-blue must be chosen as the color. Cables and lines thus marked must not be used for other purposes. Equalizing conductors for thermocouples with a plastic sheath may be provided with colored longitudinal stripes as follows, according to the type of thermocouple:

- Copper/cupro-nickel (copper/constantan) brown
- Iron/cupro-nickel (iron/constantan) dark blue
- Nickel-chrome/nickel green
- Platinum-rhodium/platinum white

In the case of equalizing conductors for thermocouples with a mineral sheath or metal braid, a light-blue strip of sufficient width must be woven in as the color code for intrinsic safety.

Within measurement and control cabinets and in the interior of switching and distribution systems, special measures must be taken where there is a risk of interchanging the lines of intrinsically safe and non-intrinsically safe circuits, e.g. where there is a blue neutral conductor to DIN 47002.

The following measures are acceptable:

- Bunching of conductors in a common light-blue sheath
- Labelling
- Clear arrangement and physical separation

9.5.2 Wiring and Cabling in Cable Bedding Made of Metal or in Conduits

Cable bedding made of metal must be incorporated in the protective measures against indirect contact. This can be achieved by routing an existing ground conductor made of steel strip or with a good conductive connection between individual beds.

For single laying, conduits made of metal are now only usual where particular mechanical or thermal stress is developed. In general, PVC conduits of two different types are used, according to the expected mechanical stress. Remember, however, that PVC exhibits a linear expansion which is about eight times that of metal. The fixing points must therefore be such that the linear expansion is taken up.

9.5.3 Summary of the Requirements to DIN VDE 0165/02.91

The following table provides, once again, an overview of the most important stipulations of DIN VDE 165/02.91 for cables and lines.

Table 9.4 Contents of DIN VDE 0165/02.91

Application	Requirements of Cables and Lines
General requirements: Observe additional requirement for "i" and Zone 0	• Select according to mechanical, chemical and thermal effects (see DIN VDE 0298 and DIN VDE 0891) • Protect against fire spread (e.g. lay cables in sand; demonstrate burning behavior of lines to DIN VDE 0472, Part 804, Test Type B) • Copper or aluminum conductor material (Al only for multicore cables from 25 mm^2 or single-core cables from 35 mm^2; use suitable connection elements)
(Smaller cross-section permissible for multicore lines with more than 5 cores, and lines for measurement and control, for example)	• Min. cross-sections for copper conductor: Single-core cable: 1 mm fine 1.5 mm solid conductor Multicore cable: 0.75 mm fine, otherwise as above
Permissible types for portable/mobile apparatus (does not apply to intrinsically safe systems)	• U ≤ 750 V — TRS flexible cable H07RN or equivalent (e.g. NSHou) • U ≤ 250 V — TRS flexible cable H07RN or equivalent (see Sec. 9.5.5) • I ≤ 6 A — No severe mechanical stress • In measurement and control systems, telecomms and telecontrol systems — Plastic-sheathed flexible cable H05VV-F min. cross-section 1 mm^2 (not at ambient temp. below 5 °C)

Table 9.4 continued

Application	Requirements of Cables and Lines
Laying of cables and lines	• Penetrations from Ex areas to non-Ex areas tightly sealed, e.g. with sand, mortar, or the like • Unused inlets sealed with certified sealing plugs (certificate not required for Zone 2) • Where there is particular thermal, mechanical or chemical stress, protect cables and lines, e.g. by laying in conduit, sheaths, metal tubing (not in enclosed conduits) • Where routed into ex-proof enclosure, use certified cable entry elements
Connection of cables and lines	• Conductor connections on the exterior of apparatus should only be crimped • Conductor connections within apparatus should use suitable clamps, multicore or fine conductor ends should be secured against separation • Crimp connections can be protected with resin fittings or shrink sleeving if they are not mechanically stressed.

9.5.4 Selecting the Cables and Lines according to DIN VDE 0165

According to ElexV, cables and lines laid in hazardous areas do not require a test certificate. All types which are suitable for the purpose may be used if they comply with the standards stipulated in DIN VDE 0165, Item 5.6. The electrical characteristic data (e.g. capacitance 200 nF/km, inductance 1 mH/km) must be specified for cables used in intrinsically safe measurement and control circuits.

The following applies within a group cable:
The insulation between lines of intrinsically safe and non-intrinsically safe circuits must withstand an alternating voltage of 2U + 1000 V_{rms}, but at least 1500 V, where U is the sum of rms voltage values of the intrinsically safe and non-intrinsically safe circuits.

Table 9.5 Minimum Cross-Sections of Copper Conductors to DIN VDE 0165

Cable Type	No. of Cores	Flexible Stranded Conductor mm^2	Solid Conductor mm^2	Conductor Diameter mm
Power cables and lines to DIN VDE 0298, Parts 1, 3	1 2 - 5 > 5	1 0.75 0.5	1.5 1.5 1	-
Wiring cables and lines to DIN VDE 0891, Parts 1, 5, 6 for voltages	> 1	0.5	0.5	0.8
< 60 V AC or	2	0.5	0.5	0.8
< 120 V DC	> 2	0.28	0.28	0.6
	2 (Shielded)	0.28	0.28	0.6

9.5.5 Types of Cable

The cables suitable for process signals are wiring cables for industrial electronics (SIMATIC cables) with twisted pairs of color-coded bunched conductors. Cables with a solid conductor (0.5 mm^2 cross-section, 0.8 mm diameter) have a static shield. Cables with flexible conductors (J-LIYCY) have a braid shield (C) made of copper wires.

Table 9.6 Types of Cable

Cable Designation			Cable for	
A-Y(St) YY	nx2x0.8/1.4 BdSi		Outdoor cable (for burying in ground *)	
J-Y(St) Y	nx2x0.8/1.4 BdSi		Normal applications	
J-LiYY	nx2x0.5/1.6 BdSi		Compact control stations	
J-LiYCY	nx2x0.5/1.6 BdSi		Vibration and impact stress Connectors	
				Order No.
JE-Y(St) Y	2x2x0.8/BdSi	BL	M'ment & control lines	V45480-F25-C25
JE-LiYCY	2x2x0.5/BdSi	BL	M'ment & control lines	V45483-F25-C15

*) Direct burying in ground is not recommended.

Type designations for lines according to harmonized standards

1	2	3	4	5	-	6	7	8	9

1 Basic type	H	Harmonized type
	A	National type
2 Rated voltage	03	300/300 V
	05	300/500 V
	07	450/750 V
3 Insulating material	V	PVC
	R	Rubber
	S	Silicone rubber
4 Sheath material	V	PVC
	R	Rubber
	N	Chloroprene rubber
	J	Glass-filament braid
	T	Fabric braid
5 Special features	H	Ribbon cable, separable
	H2	Ribbon cable, not separable
6 Conductor types	U	Solid
	R	Stranded
	K	Fine wire (permanently laid)
	F	Flexible stranded
	H	Extra-fine
	Y	Tinsel
7 Number of cores	...	Number of cores
8 Protective conductor	X	Without protective conductor
	G	With protective conductor
9 Conductor cross-section	...	In mm^2

Type designations for telecommunications cables and lines

□□-□□□ □x□x□ □□
1 2 3 4 5 6 7 8 9 10

1 Basic type	A	Outdoor cable
	G	Mining cable
	J	Wiring cable
	L	Sheathed cable
	S	Switchboard cable
2 Type supplement	B	Lightning protection system
	J	Interference-protected
	E	Electronics
3 Insulating material	Y	PVC
	2Y	Polyethylene
	O2Y	Cellular PE
	5Y	PTFE
	6Y	FEP
	7Y	ETFE
	P	PAPER
4 Design features	F	Petrolatum filler
	L	Aluminum sheath
	LD	Corrugated aluminum sheath
	(L)	Aluminum tape
	(ST)	Metal foil shield
	(K)	Copper tape shield
	W	Corrugated steel sheath
	M	Lead sheath
	Mz	Special lead sheath
	B	Armoring
	C	Jute sheath + compound
	E	Compound layer + tape
5 Sheath material		(see 3. Insulation)
6 Number of elements	n	Number of stranding elements
7 Stranding element	1	Single Core
	2	Pair
8 Conductor diameter	...	in mm
9 Stranding element	F	Star quad (railway)
	St	Star quad (phantom)
	St I	Star quad (long-distance cable)
	St III	Star quad (local cable)
	TF	Star quad for CF
	S	Signal cable (railway)
	PiMF	Shielded pair
10 Type of stranding	Lg	Layer stranding
	Bd	Unit stranding
11 Sheath color	BL	Blue

Table 9.7 Siemens Cables for Measurement and Control to DIN VDE 0815

Cable Designation		Order No.
JE-LIYCY	2x2x0.5 BD SI BL	V45483-F25-C15
JE-LIYCY	16x2x0.5 BD SI BL	V45483-F165-C15
JE-LIYCY	32x2x0.5 BD SI BL	V45483-F325-C55
JE-Y(ST)Y	2x2x0.8 BD SI BL	V45480-F25-C25
JE-Y(ST)Y	16x2x0.8 BD SI BL	V45480-F165-C35
JE-Y(ST)Y	32x2x0.8 BD SI BL	V45480-F325-C25
JE-Y(ST)Y	100x2x0.8 BD SI BL	V45480-F1005-C15

Characteristic values of cables for intrinsically safe circuits

Example: Cable type JE-LiYCY

Coupling:	200 pF/100 m	at 800 Hz
Working capacitance:	approx. 200 nF/km	at 800 Hz
Working inductance:	approx. 1 mH/km	

Minimum bending radius for permanent installation:	6 x line dia.
Temperature range, perm. installation :	- 30 °C to 70 °C
for movable use:	- 5 °C to 50 °C
Test voltage:	Core/core 2000 V, core/shield 500 V
Loop resistance:	approx. 80 ohms/km

9.5.6 Requirements of Terminals for the Intrinsic Safety Type of Protection

These must be identifiable, for example by their type designation, and the following constructional requirements must be observed:

- Clearance in air and leakage path to EN 50014/EN 50020 between two connection elements of different intrinsically safe circuits must be at least 6 mm.
- Clearance in air and leakage path between connection elements of each intrinsically safe circuit and grounded metal parts must be not less than 3 mm.
- Marking of connection elements must be unambiguous and easily recognized. When a color is used for the purpose, it must be light blue.

The following must also be observed for the use of terminals:

Connection terminals of intrinsically safe circuits must be at a distance of at least 50 mm from connection elements or bare conductors of any non-intrinsically safe circuit, or must be isolated from it by an insulating partition or grounded metal partition. When such partitions are used, they must extend at least by up to 1.5 mm from the housing panels, or must ensure a minimum clearance of 50 mm between connection elements, measured around the partition in all directions.

The insulation between an intrinsically safe circuit and the chassis of the electrical apparatus or parts which may be grounded, must withstand an alternating rms voltage of twice the voltage value of the intrinsically safe circuit, but at least 500 V.

9.6 Shielding and Measures to Counteract Interference Voltage

Shielding

Shielding is a method for attenuating magnetic, electric or electromagnetic interference fields. Shielding can be subdivided into

- Equipment shielding
- Line shielding

9.6.1 Equipment Shielding

Where cabinets and housings are incorporated in control system shielding, please observe the following:

- Cabinet covers such as side panels, rear panels, top and bottom panels, must make contact in an overlapping arrangement at adequate distances (e.g. 50 mm).
- Doors must be given additional contact with the cabinet ground. Use several grounding strips.
- Lines exiting the shielded housing should either be shielded or routed via filters.
- Where the cabinet contains sources of severe interference (transformers, lines to motors, etc.), they must be partitioned from sensitive electronic areas with metal plates. The metal plates must have several low-impedance bolted joints to the cabinet ground.

Interference voltages picked up in the programmable controller via non-Ex signal and supply lines are diverted to the central ground point (standard sectional rail).

The central ground point should have a low-impedance connection to the PE conductor via a copper conductor of $\geq 10\ mm^2$ which is as short as possible.

9.6.2 Line Shielding

Non-Ex circuits

As a rule, shielded lines must always be given a good electrical connection to cabinet potential at each end. A satisfactory suppression of all frequencies picked up can only be achieved by shielding at both ends.

Ex circuits

Do not connect the shield at the PLC/ET to the shield bus but at the sensor or actuator.

> **Note**
>
> If a shield is connected at both ends, fluctuations in ground potential can cause a circulating current to flow, with the risk of explosion when the connection is opened.

With SIMATIC controllers, interference currents on cable shields are discharged to ground via the equipotential bonding conductor. To prevent these discharged currents themselves from becoming an interference source, a low-impedance path to ground must be provided for the interference currents:

- Firmly tighten the fixing screws of cable plugs and equipotential bonding conductors.
- Protect the supporting surfaces of equipotential bonding conductors from corrosion.

Shielding of lines

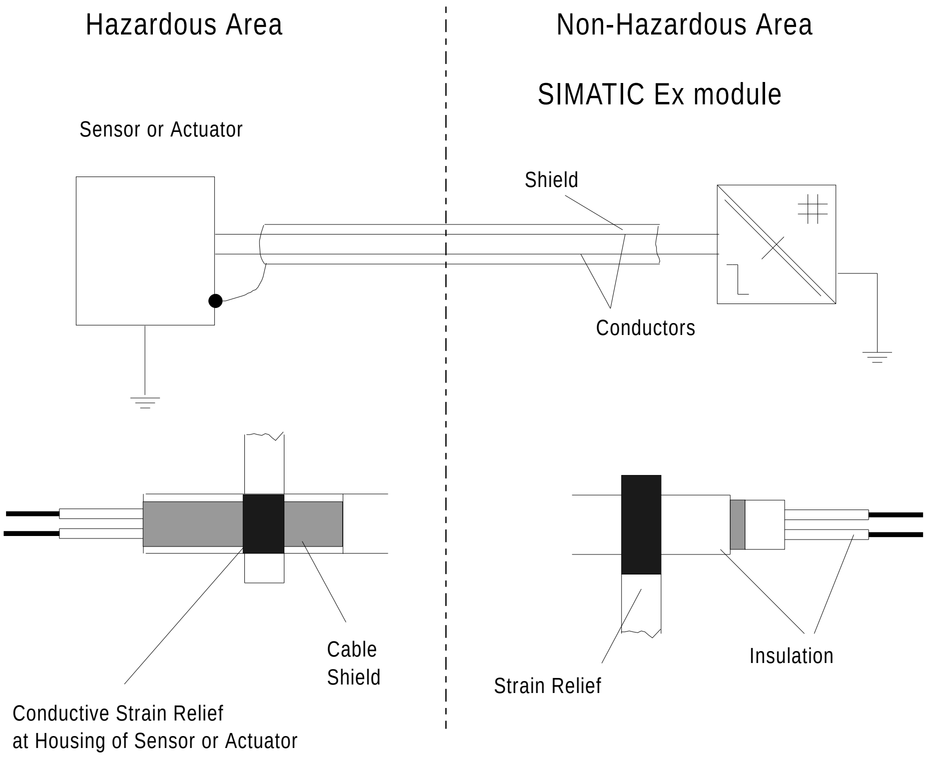


Figure 9.13 Shielding of Ex Lines

9.6.3 Measures to Counteract Interference Voltages

Measures to suppress interference voltages are often only implemented when the control system is already in operation and proper reception of a useful signal is impaired. The overhead for such measures, such as special contactors, can frequently be reduced considerably by observing the following points during configuration of your control system:

- Favorable arrangement of equipment and lines
- Grounding of all inactive metal elements
- Filtering of power cables and signal lines
- Shielding of equipment and lines
- Special interference-suppression measures

Arrangement of equipment and lines

Magnetic DC or AC fields of low frequency, such as 50 Hz, can only be sufficiently attenuated at great expense. In such a case, however, you can often solve the problem by providing the greatest possible distance between interference source and sink.

Note

The analog Ex modules operate with a method which suppresses faults caused by AC system ripple.

Grounding of inactive metal elements

Well implemented grounding is an important factor for interference-free assembly. Grounding is understood to mean a good electrical connection of all inactive metal elements (VDE 0160). The principle of surface grounding should be followed. All conductive, inactive metal elements should be grounded.

Observe the following when grounding:

- All ground connections must have a low impedance.
- All metal elements should have a large-area connection. Use particularly wide ground strips for the connection. The surface of the ground connection and not its cross-section is decisive.
- Screw connections should always have spring washers or lock washers.

Protection against electrostatic discharge

To protect equipment and modules from electrostatic discharge, metal housings or cabinets enclosed on all sides should be used; these should be given a good electrical connection to the grounding point on site, and also connected to the main equipotential bonding conductor.

If you install your controller in a terminal box, use a cast-metal or sheet-metal housing if possible. Plastic housings should always have a metallized surface.

Doors or covers of housings should be connected to the grounded body of the housing with ground strips or contact springs.

If you are working on the system with the cabinet open, please observe the guidelines for protective measures for electrostatically sensitive devices (ESDs).

Electrical systems must be so installed that the risk of ignition by electrostatic charges cannot be expected. See also the "Guidelines for avoiding the risk of ignition resulting from electrostatic charges" of the main association of industrial employers' liability insurance.

If electrostatic charges cannot be avoided, a charge should be kept as low as possible or safe discharge should be provided. The following measures, in particular, should be applied:

- Electrostatic grounding of all conductive elements. Solid materials can be considered as being electrostatically grounded if their leakage resistance at any point is not greater than 10^6 ohms. Under favourable conditions, 10^8 ohms is satisfactory, particularly for small equipment of low capacitance.
- Reducing the electrical resistance of the material moved or parts moved with respect to each other.
- Incorporation of grounded metal elements in material subject to electrostatic charging.
- Increasing the relative air humidity. By increasing the relative air humidity to about 65 % with air conditioning, sprays or by hanging moist cloths, the surface resistance of most non-conductive materials can be adequately reduced. However, if the surface of a plastic is water-repellant, this action will not succeed.
- Ionization of the air.

9.6.4 The Most Important Basic Rules for Ensuring EMC

To ensure EMC, it is often sufficient to observe some elementary rules. When assembling the control system, observe the five following basic rules.

When installing the programmable controllers, ensure high-quality surface grounding of the inactive metal elements.

- Connect all inactive metal elements over a large area and at low impedance.
- On painted and anodized metal elements, make screwed connections with special contact washers or remove the insulating protective layers.
- If possible, do not use aluminum elements. Aluminum oxidizes easily and is therefore less suitable for grounding.
- Provide a central connection between chassis ground and the ground/protective conductor system.

Follow the rules for line routing when wiring.

- Subdivide the cabling into line groups.
  (AC power cables, supply lines, Ex and non-Ex signal lines, data lines)
- Always install power cables and signal or data lines in separate ducts or bunches.
- Route the signal and data lines as closely as possible to grounded surfaces such as supporting bars, metal rails, cabinet sheet metal.
- Install Ex and non-Ex signal lines in separate ducts.

Ensure that line shields are properly secured.

- Data lines should be shielded when laid. The shield should be connected at both ends.
- Analog lines should be shielded when laid. When low-amplitude signals are transmitted, it may be advantageous if the shield is connected at only one end.
- For Ex signal lines, connect the line shields only at the sensor or actuator end. Ensure that the connected shield continues without interruption as far as the module, but do not connect it there.
- Ensure that the shield has a low-impedance connection to the equipotential bonding conductor.
- Use metal or metallized plug housings for shielded data lines.

Use special EMC measures for particular applications.

- For all inductances, fit quenching elements which are not controlled by SIMATIC S5 modules.
- Use incandescent bulbs for lighting the cabinets, and avoid fluorescent lamps.

Provide a standard reference potential, and ground all the electrical apparatus if possible.

- Ensure specific grounding measures. Grounding of the control system is a protective and functional measure.
- System elements and cabinets with central controllers and expansion units should be connected in star-configuration to the ground/protective conductor system. You can thus avoid the formation of ground loops.
- In the event of potential differences between system elements and cabinets, install adequately rated equipotential bonding conductors.

9.7 Lightning Protection

In systems with hazardous areas the most important task, not least for reasons of explosion protection, is to avoid overvoltages; where this is not possible, they must be reduced and safely discharged.

In addition to the provision of external lightning protection, these measures cover the internal lightning protection and overvoltage protection. The measures must be coordinated with the equipment-related EMC.

9.7.1 External Lightning Protection/Shielding of Buildings

External lightning protection is a measure for preventing damage to buildings and fire damage. For this task, a large-mesh wire cage comprising lightning conductor and down conductor is sufficient.

On buildings with sensitive electronic equipment such as control rooms, the external lightning protection must be supplemented by a building shield. For these purposes, where possible, metal facades and reinforcements of walls, floors and ceilings on or in the building are connected to form shield cages. Where this is not possible, the lightning conductor and down conductor should have a reduced mesh size and, where applicable, the supporting construction of the intermediate floor should be electrically interconnected.

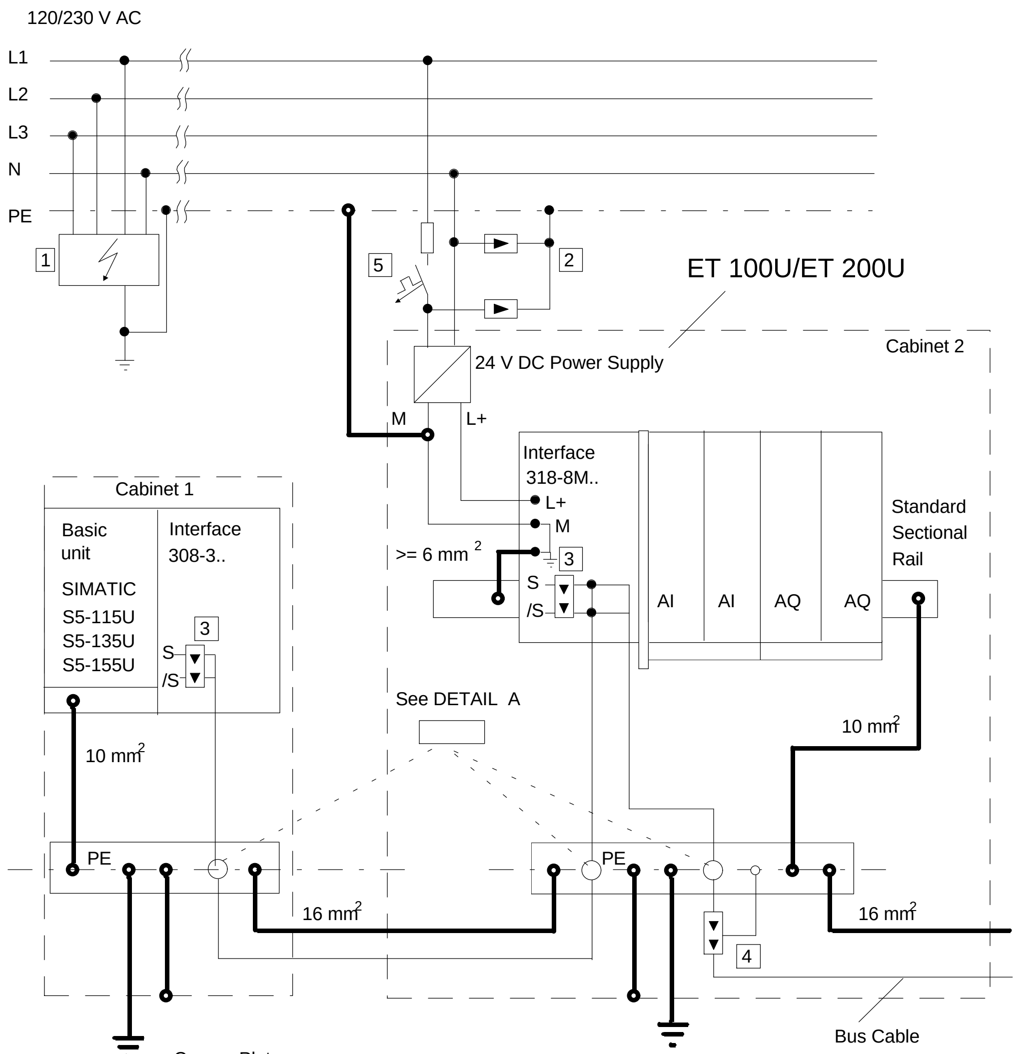
Electrical equipment protruding above roof level must be protected against direct lightning strikes. Where such equipment is metallically connected to the external lightning protection system, a partial current is picked up by the building in the event of a lightning strike; this can result in destruction of the equipment sensitive to overvoltages. The pick-up of partial lightning currents can be prevented by protecting the electrical equipment protruding above the roof from direct lightning strikes by means of rods insulated from the equipment (45-degree protective area), or by cage-type tensioned wires or cables.

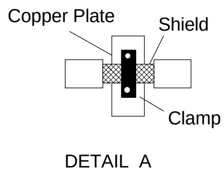
The down conductors for external lightning protection and, if applicable, the reinforcements and supporting constructions, should be connected to the ground system. Each individual building has its own functioning ground system. The ground systems are meshed to create a common grounding network. The voltage between the buildings is thus reduced.

9.7.2 Distributed Arrangement of Systems with SIMATIC S5 ET 100/ET 200 U

The process engineering of a plant, such as the gas supply, requires a wide-ranging exchange of information between the systems with the distributed Ex I/O devices and the central, electrical or electronic measurement and control system. This necessitates a great number of cable connections, sometimes extending over several hundred metres - in the case of gas storage systems, over several thousands of metres. In the event of a lightning strike, therefore, extensive voltage pick-up occurs.

A distributed arrangement of instrumentation and control equipment with relatively short cables to the plant, and the connecting of distributed I/O stations to each other and to the central controller via a bus (SINEC L2-DP) or fiber-optic cable, are an important measure for reducing overvoltages between sections of the plant.





		Order No.
1	Lightning Conductor, VGA 280/4	5 SD7 003
2	Surge Diverter, VM 280	2 x 5 SD7 004
3	Fine Protection	DSN: 924 017
4	Surge Protection Module KT (ET 100U), Type ARE 8 V	DSN: 919 232
	Surge Protection Module KT (ET 200U), Type AHFD	DSN: 919 270
5	Line Protection	

Figure 9.14 ET 100U / ET 200U Lightning Protection Concept

9.7.3 Shielding of Cables and Buildings

Overvoltages between separate plant sections or buildings cannot be avoided in practice by meshing. In the event of a lightning strike, a circulating current will flow over the path created by metal connections between the buildings or between a building and I/O device. Cable cores are ideal for the purpose. The lightning or partial lightning current must therefore be offered other conductive connections. Shielding which can be implemented in different ways, is particularly suitable. For example:

- A helical current-rated metal strip or metal braid as the cable shield, e.g. NYCY or A2Y(K)Y.
- By installing the cables in continuously connected metal conduits which are grounded at both ends.
- By installing the cables in reinforced concrete ducts with through-connected reinforcement or on closed cable racks made of metal.
- By laying conductors (shield conductors) in parallel with cables. This measure, however, only relieves the cables of partial lightning currents.
- By laying fiber-optic cables.

So that the currents at the cable ends cannot destroy overvoltage-sensitive equipment, it must also be shielded. This is achieved with metal housings or by installing the equipment in metal cabinets which are connected to the ground conductor.

9.7.4 Equipotential Bonding for Lightning Protection

"Internal lightning protection" covers all the additional measures which prevent the magnetic and electrical effects of the lightning current within the building to be protected. These include, in particular, the "equipotential bonding for lightning protection" which reduces the potential differences caused by the lightning current.

The principle of internal lightning protection is to incorporate in the equipotential bonding for lightning protection all the lines entering and exiting from a volume to be protected; these include, apart from all metal piping such as that for water, gas and heat, all power and information cables whose cores are connected via suitable protective devices. Since considerable, partial lightning currents can flow over such lines and must be discharged by the protective devices, they must be chosen for a suitable current carrying capacity (lightning current conductors).

9.7.5 Overvoltage Protection

The efficiency of overvoltage protection devices largely depends on the connection and cable routing. If the devices are used in hazardous areas or intrinsically safe circuits, DIN VDE 0165 must be complied with.

Since these overvoltage protection devices are passive modules to DIN VDE 0165, they require neither marking nor certificate of conformity in intrinsically safe circuits. However, the system installer must ensure observance of the minimum igniting curves given in DIN VDE 0170/0171, Part 7/05.78 EN 50020 and the maximum temperature rise.

Overvoltage protection in intrinsically safe circuits

Overvoltage protection devices can be used to protect intrinsically safe circuits against overvoltages. Since these overvoltage protection devices are considered as passive modules, they do not require a PTB certification.

Figure 9.15 shows how this overvoltage protection technology can be installed in an intrinsically safe circuit.

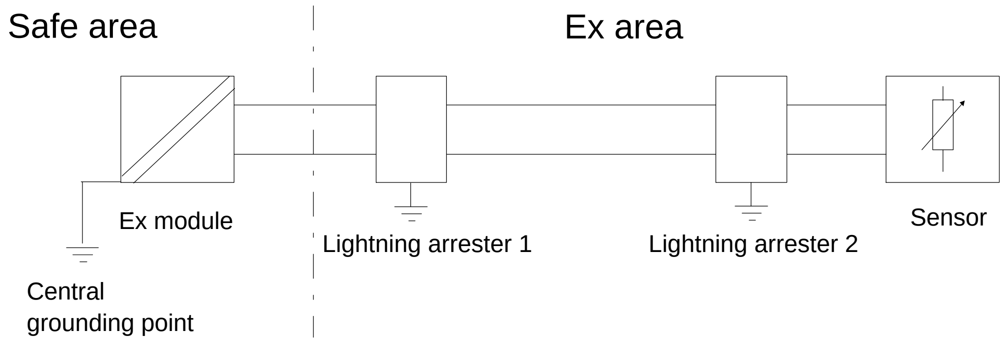


Figure 9.15 Overvoltage Protection in Intrinsically Safe Circuits

The discussion of safety-relevant aspects is limited to the direct comparison of the data for inductance and capacity.

Ex module	Comparison	Lightning arrester 1	Cable	Lightning arrester 2	Sensor/ Actuator
La Ca	≥ ≥	L_{BD1} C_{BD1}	$+L_{Ltg}$ $+C_{Ltg}$	$+L_{BD2}$ $+C_{BD2}$	+Li +Ci

Example:

Ex analog input	Comparison	Lightning arrester 1	Cable	Lightning arrester 2	Sensor/ actuator
La = 4 mH Ca = 270 nF	≥ ≥	< 0.5 µH < 1 nF	< 50 µH < 10 nF	< 0.5 mH < 6 nF	< 0.6 mH < 6 nF

The overvoltage protection elements described in this section are only effective if used together with external lightning protection. External lightning protection measures reduce the effects of a lightning stroke.

Table 9.8 Suitable Lightning Protection Elements for Ex Modules

Ex Module	Order No.	Lightning Arrester	Order No. (Siemens)
Ex digital input mod.	6ES5 437-8EA12	ARE 12 V	DSN 919233
Ex digital output mod.	6ES5 457-8EA12	ARE 12 V	DSN 919233
Ex analog input mod.	6ES5 467-8EE11	ARE 24 V	DSN 919230
Ex analog input mod.	6ES5 467-8EF11	ARE 24 V	DSN 919230
Ex analog input mod.	6ES5 467-8EA11	ARE 24 V	DSN 919230
Ex analog output mod.	6ES5 477-8EC11	ARE 24 V	DSN 919230

9.7.6 Devices for Overvoltage Protection, Even in the Event of Direct Lightning Strikes

The connection and cable routing of overvoltage protection devices is very important for their efficiency. DIN VDE 0165 must be observed when using the devices in hazardous areas or intrinsically safe circuits.

Since these overvoltage protection devices are passive modules to DIN VDE 0165, they require neither marking nor certificate of conformity in intrinsically safe circuits. However, the system installer must ensure observance of the minimum igniting curves given in DIN VDE 0170/0171, Part 7/05.78 EN 50020 and the maximum temperature rise.

An example of the use of protective devices is given in the "Lightning/overvoltage protection for a gas compressor station" (Figure 9.16).

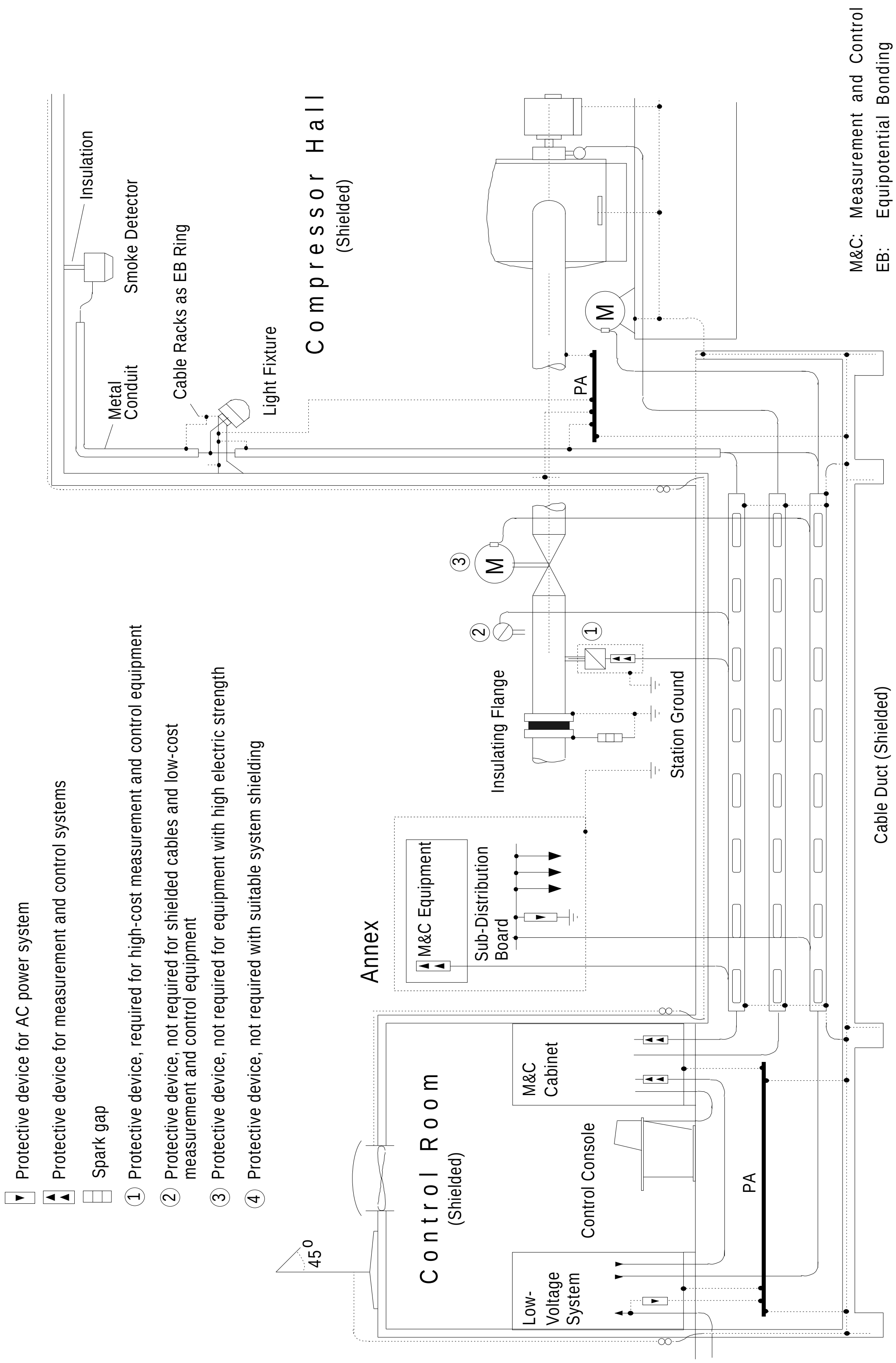


Figure 9.16 Lightning/Overvoltage Protection for a Gas Compressor Station

9.7.7 Lightning Strike

When lightning strikes an explosive atmosphere, it always ignites. There is also a risk of ignition by excessive temperature-rise of the lightning discharge paths. In order to prevent at Zones 0, 1 and 10 themselves the harmful effects of lightning strikes occurring outside these zones, surge diverters, for example, must be fitted at suitable points. Tank installations covered with earth and made of metal materials with electrical equipment or electrically conductive system sections, which are electrically insulated with respect to the tank, require equipotential bonding; for example, in the case of measurement and control systems and filling pipes.

Note

Lightning protection equipment and grounding systems must be tested by an expert after completion and at regular intervals. Based on ElexV, the testing interval for electrical systems and lightning protection systems for hazardous areas is three years.

Summary:

- Enhanced external lighting protection (reduced mesh size, increased number of down conductors) on all buildings and systems.
- Meshing of grounding systems in the building to create area grounding.
- Meshing of equipotential bonding.
- Fitting of lightning conductors and surge diverters in the power system.
- Fitting of overvoltage fine-protection devices at both ends of measurement and control cables.
- Shielding of measurement and control cables.
- Measurement and control cables with twisted pairs of cores.

9.8 Installation Work in Hazardous Areas

9.8.1 Safety Measures

Tools which tend to produce sparks must not be used for working in potentially explosive systems or system sections. Copper-beryllium is a suitable material for tools such as screwdrivers, pliers, wrenches, hammers and chisels. Since this material has low wear-resistance, the tools should be used with care.

For mechanical work, the risk of sparks capable of causing ignition is

low	- when bare steel elements strike each other;
possible	- when steel elements collide or drop;
great	- when striking rusty steel;
very great	- when striking rusty steel with an alloy coating, such as aluminum paint.

The creation of sparks capable of causing ignition is very greatly reduced by using non-sparking tools. An exception is when the tool is harder than the workpiece.

Measures for eliminating the risk of explosion:

- Safely closing-off the working area, e.g. with dummy panels.
- Good ventilation of the rooms.
- Flushing with inert gas. Testing the effectiveness of the flushing (gas tester, see EX-RL /1/). Then working with a normal tool.

If the risk of explosion at the workplace cannot be eliminated, the following measures must be taken:

- Avoidance of collision and dropping of steel elements.
- Wearing antistatic shoes, e.g. leather shoes or using shoe grounding strips.
- Avoidance of rust layers and aluminium coating at impact points. If this is not possible, eliminating the risk of explosion locally, e.g. with inert gas.
- Adequate intake and exhausting of air.
- Removing or enclosing readily flammable substances in the vicinity.
- Keeping the workplace and, possibly, floor moist.

Table 9.9 Safety Measures

Working Area	Safety Measures
Installations with readily flammable gas and vapor-air mixtures, e.g. hydrogen, city gas, acetylene and hydrogen sulphide	Working only allowed after implementation of special safety measures and with written permission of plant manager. Only non-sparking tools to be used (tool softer than workpiece).
Installations with gas and vapor-air mixtures such as methane, propane, butane and petrol (gasoline)	Sufficient to use non-sparking tools. Exception: For materials with rust formation and aluminum coating or similar, special protective measures required.
Installations with risk of explosion from readily flammable dust	Remove dust deposits. Keep working area wet and protect against dust formation. Normal tools may be used.

Note

Working on energized electrical installations and apparatus in hazardous industrial premises is prohibited. This also includes the disconnection of live control lines for test purposes.

As an exception, tasks on intrinsically safe circuits are permitted; also, in special cases, tasks on other electrical systems where the user has certified in writing that there is no risk of explosion for the duration of the work at the site.

If necessary, a fire permit must additionally be obtained.

Grounding and short-circuiting may only be carried out in hazardous industrial premises when there is no risk of explosion at the point of grounding and short-circuiting.

Use measuring instruments which are approved for the zones, to test for no voltages.

9.8.2 Ex Assemblies in Hazardous Areas

It is basically possible to install a SIMATIC assembly in a hazardous area, i.e. Zone 1 or 2. However, additional measures are required to protect the modules. Two types of protection are available:

- The Ex assembly is installed in a pressurized enclosure.
- The Ex assembly is installed in a flameproof enclosure.

The figure below shows a possible assembly in a flameproof enclosure with an increased-safety terminal compartment.

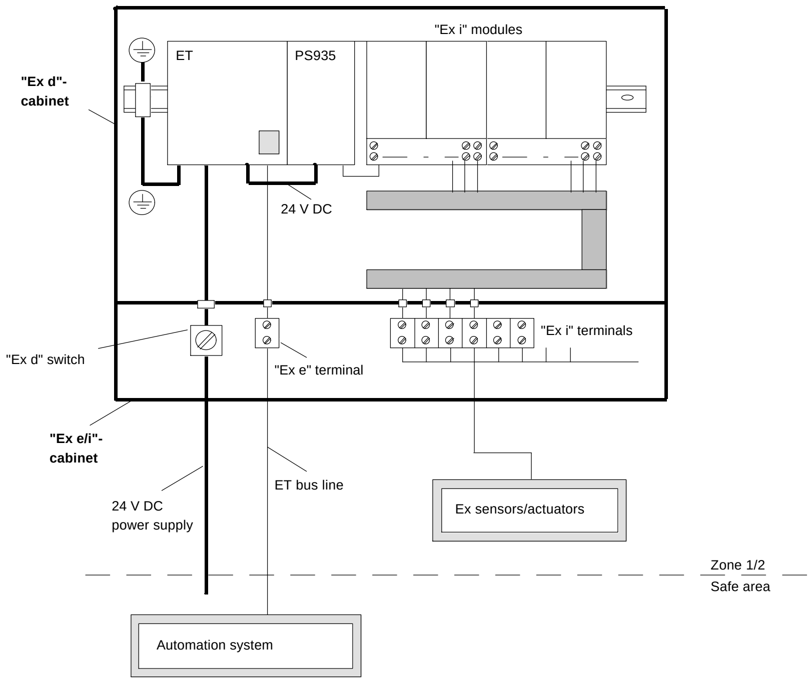


Figure 9.17 SIMATIC Ex Modules in Hazardous Area

Enclosure

The selected type of enclosure is characterized by the fact that it is able to withstand explosions occurring inside the enclosure and that an explosive gas/air mixture surrounding the enclosure is not ignited. In addition, the surface temperature does not exceed the limit values of the temperature classes. Cable glands that are protected against transmission of internal ignition and isolated against the enclosure wall must be used for leading the supply leads into the flameproof enclosure.

A housing with "increased safety" is used as terminal compartment. Special screwed glands are used for the cable entries.

The housing must be certified by a testing authority to comply with the EEx d type of protection and the relevant design requirements.

Explosion protection of the housing: EEx de II T5 .. T6.

Cables

The cables must comply with the DIN EN 50014 and DIN EN 50 020 standards for intrinsically safe circuits or with DIN EN 50 039 for circuits with "increased safety".

The cables for the assembly are to be installed in such a way that they are endangered neither by thermial, mechanical nor chemical strain.

> **Note**
>
> The cables should be installed in cable conduits if necessary.

Terminals

The terminal connectors for the power supply cable and the bus line should always meet the requirements of the "increased safety" type of protection. The clamping points of the intrinsically safe circuits should always be implemented according to the guidelines of "intrinsic safety".

Protective device

The assembly is connected to a 24 V DC supply circuit fed by a power supply with safe electrical isolation. The supply circuit must be protected by an appropriate circuit-breaker. This circuit-breaker is installed outside the Ex zone.

Switch

The switch for enabling the system should comply with "EEx de II T6" type of protection.

Table 9.10 Working on Systems to Type of Protection EEx de [ib] T5 .. T6

Type of Protection of Apparatus	Type of Work to be Carried Out	Work Within		Additional Requirements and Notes
EEx ib		Zone 1	Zone 2	
	Opening the housing, Ex i/e housing only	Allowed	Allowed	If no other apparatus is in the housing
	Connecting/ disconnecting lines	Allowed	Allowed	
	Current, voltage and resistance measurement	Allowed with certified apparatus	Allowed	
	Soldering	Prohibited	Allowed if soldering temperature lower than ignition temperature	

Table 9.10 continued

Type of Protection of Apparatus	Type of Work to be Carried Out	Work Within		Additional Requirements and Notes
EEx e		Zone 1	Zone 2	
	Opening the housing, Ex i/e housing only	Allowed	Allowed	If no other apparatus is in the housing
	Connecting/ disconnecting lines	Not allowed unless in deenergized state	Only in deenergized state and if no risk of explosion	
	Current, voltage and resistance measurement	Voltage measurement with certified apparatus only	Voltage measurement with certified apparatus only	
	Soldering	Prohibited	Allowed in deenergized state if soldering temperature lower than ignition temperature	
EEx d				
	Opening the housing, Ex d housing only	Prohibited	Allowed if no risk of explosion	Apparatus in flameproof are no longer pro-tected against explosion if housing is opened
	Connecting/ disconnecting lines	Not allowed unless in deenergized state	Allowed if no risk of explosion	
	Current, voltage and resistance measurement	Work not possible	Allowed if no risk of explosion	
	Soldering	Prohibited	Allowed in deenergized state if soldering temperature lower than ignition temperature	

See also Section 7.8 "Operation, Maintenance, Faults and Repairs", Table 7.2.

9.9 Maintenance of Electrical Apparatus

9.9.1 Replacing Apparatus

Work on electrical installations and apparatus may only be carried out when a "permit" has been obtained. When replacing electrical apparatus, ensure compliance with regulations relating to temperature class, explosion group and the relevant (Ex) zone. Certificates of conformity or PTB test certificates and design approval must have been obtained.

9.9.2 Repair of Apparatus

Repaired electrical apparatus may only be placed in operation again after testing by a recognized expert according to Paragraph 15 of ElexV, and the test has been certified, unless explosion protection has not been affected by the repair. If the repair affects explosion protection, only original spare parts may be used. Improvised repairs which no longer ensure the explosion protection of apparatus, are not allowed.

10 Methods of Linking and Interfacing SIMATIC S5 Ex Assemblies

Figures

Tables

10 Methods of Linking and Interfacing SIMATIC S5 Ex Assemblies

You can use the Ex analog and digital modules in the S5-95U/S5-100U PLC and in the ET 100U/ET 200U systems. Various SIMATIC interface facilities enable you to operate intrinsically safe assemblies, without restricting their functional features, with other programmable controllers. Assemblies with Ex modules can also be incorporated in the automation system of the TELEPERM M process control system.

Figure 10.1 provides an overview of possible networking and the number of ET 100Us/ET 200Us which can communicate with a central system. For the maximum number of Ex modules which can be connected to an S5-100U system, please consult Section 11.3.

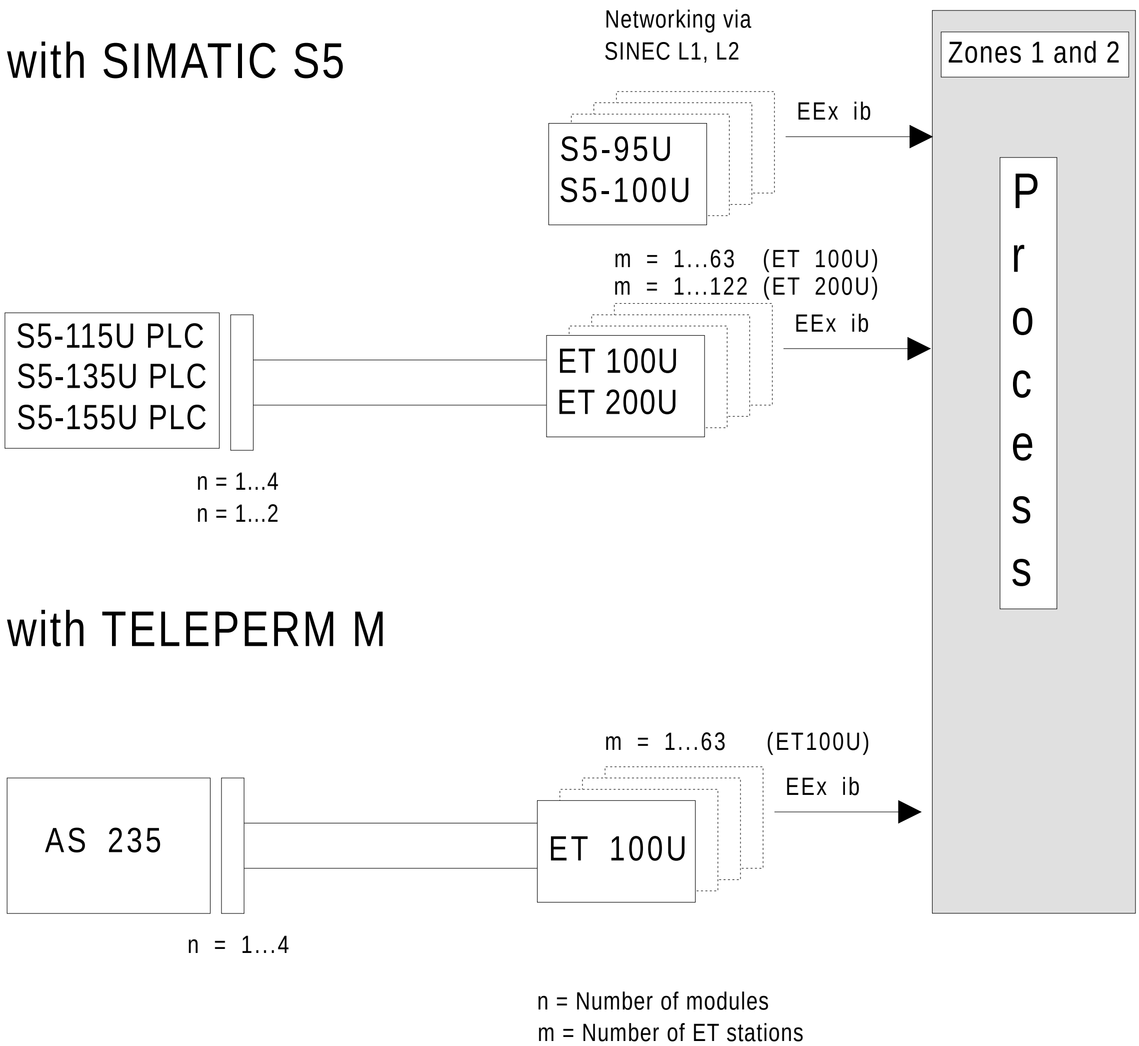


Figure 10.1 Using the SIMATIC Ex Modules in the SIMATIC/TELEPERM M Environment

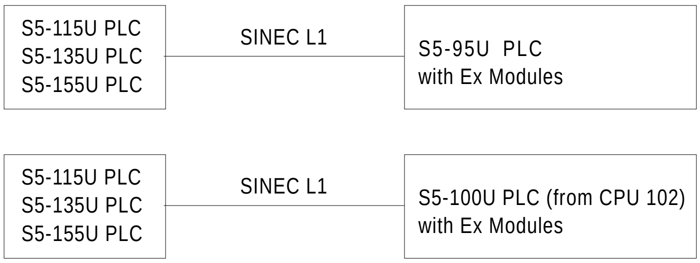
10.1 SIMATIC-to-SIMATIC Links

SIMATIC-to-SIMATIC links are those between SIMATIC S5 programmable controllers. You can implement the links with

- SINEC L1 (four-core cable)
- SINEC L2, SINEC L2-DP (two-core cable, fiber-optic cable)

Only the possible interfacing variants are listed here. The method of setting up and programming the links is described in the relevant manuals.

Linking via SINEC L1



Linking via SINEC L2

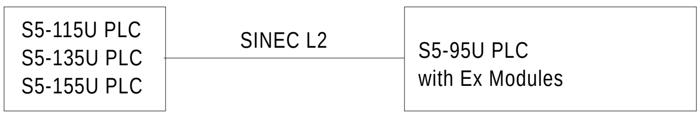
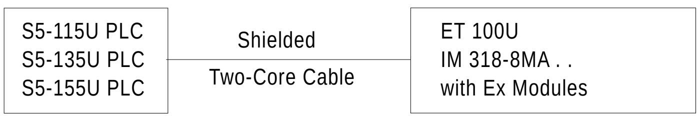


Figure 10.2 SIMATIC-to-SIMATIC Links (SINEC L1/L2)

Linking via ET 100U



Linking via ET 200U

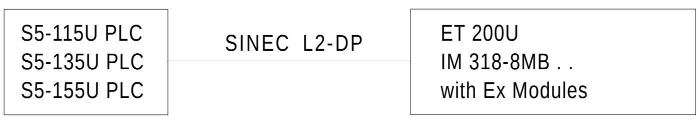


Figure 10.3 SIMATIC-to-SIMATIC Links (ET 100U/200U)

10.2 Overview of LANs available for the SIMATIC S5 Mini-PLCs

Table 10.1 provides you with an overview of LANs for the SIMATIC S5 mini-PLCs.

Table 10.1 Overview of LANs for the SIMATIC S5 Mini-PLCs

Topology	**SINEC L1 (S5-95U PLC, CPU 102, CPU 103)**	**SINEC L2 (S5-95U PLC with L2 interface)**
Interface	RS 485	RS 485
Bus cable	Four-core, shielded cable	Twisted, shielded two-core cable, optical fiber cable (glass or plastic fiber)
Connections of stations to bus via - RS 485 technology - Optical fiber technology - FSK technology	 BT 777 bus terminal Via N converter of RS 485 interface (ODCL module) No	 SINEC-L2 bus connector RS 485 bus terminal Via SINEC L2FO bus terminal No
Max. number of stations on bus - total - master - SLAVE	 31 1 30	Depending on type of link Stand. conn. / PLC/PLC / Cycl. I/O 32 / 32 / 127 31 / 31 / 31 0 / 0 / 126
Max. network size	RS 485: 50 km Optical fiber cable: 75 km	RS 485: up to 93.75 Kbaud 9.6 km 187.50 Kbaud 8.0 km 500.00 Kbaud 3.2 km 1500.00 Kbaud 1.0 km
Transmission rate		9.60 Kbaud 19.20 Kbaud 93.75 Kbaud 187.50 Kbaud 500.00 Kbaud 1500.00 Kbaud
Transmission protocol	AS 511 (Siemens)	Profibus protocol to DIN 19245, Part 1 (implemented protocol layers of the ISO 7-layer model: 1, 2 and 7)
Type of transmission	Bit serial	Bit serial
Access method	Master-slave	Token passing with subordinate master-slave (to DIN 19245, Part 1)

10.3 Overview of ET 100U and ET 200U Distributed I/O Systems

Table 10.2 provides you with an overview of technical specifications of the distributed I/O systems.

Table 10.2 Overview of ET 100U und ET 200U Distributed I/O Systems

	ET 100U	ET 200U
Field bus	ET 100 bus	SINEC L2-DP
Open bus system	No	Yes
Access method	Master-slave	Master-slave, token passing
Max. number of master interfaces in the central controller **- SIMATIC S5-115U** **- SIMATIC S5-115H** **- SIMATIC S5-135U** **- SIMATIC S5-155U** **- SIMATIC S5-155H**	 2 - 4 4 4	 2 2 4 4 4
- SIMATIC S5-115U/H **- SIMATIC S5-135U** **- SIMATIC S5-155U/H**	256 bytes inputs 256 bytes outputs 1 Kbyte inputs 1 Kbyte outputs 1 Kbyte inputs 1 Kbyte outputs	756 bytes inputs 756 bytes outputs 756 bytes inputs 756 bytes outputs 756 bytes inputs 756 bytes outputs
Max. number of stations on bus **- total** **- master** **- slave**	 64 1 63	 125 3 122
Address space per slave station	32 bytes for inputs and outputs digital or analog	64 bytes for inputs and outputs digital or analog
To be used with intelligent I/O (IPs) communications processor (CPs)	No	Yes
Max. number of Ex modules with PS 935 additional power supply		
- Ex digital input NAMUR 6ES5 437-8EA12	30 = 120 channels	30 = 120 channels
- Ex digital input NAMUR 6ES5 437-8EA21	30 = 120 channels	30 = 120 channels
- Ex digital output 7 V DC, 2 mA 6ES5 457-8EA12	30 = 120 channels	30 = 120 channels
- Ex analog input thermistors 6ES5 467-8EA11	3 = 12 channels	3 = 12 channels
- Ex analog input 4 ... 20 mA 6ES5 467-8EE11	7 = 14 channels	7 = 14 channels
- Ex analog input PT 100 6ES5 467-8EF11	7 = 14 channels	7 = 14 channels
- Ex analog output 4 ... 20 mA 6ES5 477-8EC11	3 = 6 channels	7 = 14 channels
Interface	Similar to RS 485	RS 485
Synchronism	asynchronous, half-duplex	asynchronous, half-duplex
Hamming distance	3 - 5	4

Table 10.2, continued

	ET 100U	**ET 200U**
Safety of data transmission	Error detection and correction using cyclic BCH code (BCH block check code)	Error detection and correction using FCS frame check sum SD start delimiter ED end delimiter
Transmission protocol	SIEMENS protocol	Profibus protocol to DIN 19 245, Part 1 Layer model: 1,2
Type of transmission	Bit serial	Bit serial
Transmission rate	31.25 Kbytes - 375 Kbytes	9.6 Kbytes - 1.5 Mbyte
Transmission medium	Two-core, shielded cable	Two-core, shielded cable Optical fiber cable
Max. length of network	up to 3 km	up to 9.6 km/93.75 Kbytes with RS 485 up to 23.8 km/187.5 Kbytes (with repeater and optical fiber cable)
Bus cycle time	typ. 30 - 60 ms	typ. 3 - 15 ms
Updating of signal values	Depends on system configuration type of CPU, user program, configuration and baud rate	Depends on system configuration type of CPU, user program, configuration and baud rate
Behavior in the case of bus fault	Message frames are repeated twice if a fault is detected! Outputs are automatically reset!	Message frames are repeated twice if a fault is detected! Outputs are automatically reset!
Redundancy	Yes via SIMATIC H systems (hot standby or 2 out of 3 operating)	Yes via SIMATIC H systems (hot standby or 2 out of 3 operating) in addition, cable and repeater redundancy
Diagnostics	Group diagnostics, station diagnostics	Station diagnostics, module diagnostics, I/O diagnostics
Acknowledgement delay	Yes (selectable)	Yes (selectable)
IP 65 compact station	No	Yes
IP 20 compact stations	No	Yes
Non-Siemens devices	Yes	No

10.4 Interfacing Between TELEPERM and SIMATIC

Extending beyond SIMATIC, it is possible to connect TELEPERM systems to intrinsically safe SIMATIC assemblies. The following can be linked via the 6DS1 327-8AA interface module:

- The ET 100U system (with Ex modules)
- Other SIMATIC S5 assemblies

Figure 10.4 Links Between TELEPERM M and SIMATIC

Description of the 6DS1 327-8AA interface module.

Table 10.3 Description of TELEPERM M-SIMATIC Link via AS 235 to ET 100U

Process Control System / Distributed I/Os	6DS1 327-8AA Interface Module
ET 100U	1 Kbyte inputs/outputs

Table 10.4 Description of TELEPERM M-SIMATIC Links

	Interface module **6DS1 327-8AA** **connected to ET 100U**	**6DS1 327-8AA** **connected to ET 200U**
Field bus	ET 100 bus	SINEC L2-DP
Open bus system	No	Yes
Access method	Master-slave	Token passing with subordinate Master-slave (to DIN 19 245)
Max. number of **master interfaces in the AS 235**	4	
Address space per interface	1 Kbyte	
Max. number of stations on bus **- total** **- master** **- slave**	 64 1 63	 125 3 122
Address space per slave station	32 bytes for inputs and outputs digital or analog	64 bytes for inputs and outputs digital or analog
- Ex digital input NAMUR 6ES5 437-8EA12	30 = 120 channels	30 = 120 channels
- Ex digital input NAMUR 6ES5 437-8EA21	30 = 120 channels	30 = 120 channels
- Ex digital output 7 V DC, 2 mA 6ES5 457-8EA12	30 = 120 channels	30 = 120 channels
- Ex analog input thermistors 6ES5 467-8EA11	3 = 12 channels	3 = 12 channels
- Ex analog input 4 ... 20 mA 6ES5 467-8EE11	7 = 14 channels	7 = 14 channels
- Ex analog input PT 100 6ES5 467-8EF11	7 = 14 channels	7 = 14 channels
- Ex analog output 4 ... 20 mA 6ES5 477-8EC11	3 = 6 channels	7 = 14 channels
Interface	Similar to RS 485	RS 485
Synchronism	asynchronous, half-duplex	asynchronous, half-duplex
Hamming distance	3 - 5	4
Safety of data transmission	Error detection and correction using cyclic BCH code (BCH block check code)	Error detection and correction using FCS frame check sum SD start delimiter ED end delimiter
Transmission protocol	Siemens protocol	
Type of transmission	Bit serial	Bit serial
Transmission rate	31.25 Kbytes - 375 Kbytes	9.6 Kbytes - 1.5 Mbytes
Transmission medium	Two-core, shielded cable	Two-core, shielded cable Optical fiber cable
Bus cycle time	typ. 30 - 60 ms	
Max. length of network	up to 3 km	up to 9.6 km/93 Kbytes with RS 485 up to 23.8 km/187.5 Kbytes (with repeater and optical fiber cable)

Table 10.4, continued

	Interface module **6DS1 327-8AA** **connected to ET 100U**	**6DS1 327-8AA** **connected to ET 200U**
Updating of signal values	Depends on system configuration type of CPU, user program, configuration and baud rate	
Behavior in the case of bus fault	Message frames are repeated twice if a fault is detected Output can be parameterized as 0 or to maintain last value	Message frames are repeated twice if a fault is detected (can be parameterized). Outputs can be parameterized
Redundancy	No	Yes
Diagnostics	Group diagnostics, station diagnostics	Station diagnostics, module diagnostics, I/O diagnostics
Acknowledgement delay	Yes (selectable)	Yes (selectable)

11 SIMATIC S5 Ex Modules

Figures

Tables

11 SIMATIC S5 Ex Modules

11.1 Ex Modules in the SIMATIC S5 System

The programmable (logic) controllers (PLCs) of the SIMATIC S5 family offer economical solutions for both simple and complex control tasks. For the installation of automation systems of the open and closed-loop control of plants in hazardous areas there are several I/O modules. These have been certified for type of protection [EEx ib] IIC to allow the direct connection of intrinsically safe process devices and apparatus with intrinsically safe circuits to the S5-95U and S5-100U PLCs, as well as a distributed configuration with the corresponding ET 100U and ET 200U expansion units.

These are the following I/O modules, including integral Ex isolation, which are certified as associated electrical apparatus for installation **outside** the hazardous area, for the connection of intrinsically safe electrical apparatus of Category ib (for Zones 1 and 2):

- Ex digital input module (for NAMUR sensors) 6ES5 437-8EA12
- Ex digital output module (for solenoid valves, LEDs) 6ES5 457-8EA12
- Ex analog input module (4 to 20 mA) 6ES5 467-8EE11
- Ex analog output module (4 to 20 mA) 6ES5 477-8EC11

To configure a PLC with Ex I/O modules, you will also need:

- Ex bus units, 6ES5 700-8EA11
- Partition 6ES5 497-8EA11 to isolate Ex and non-Ex modules
- If necessary, the PS 935 power supply module, 6ES5 935-8ME11

All Ex modules can be plugged into special bus units with blue terminal blocks, which are part of the S5-95U and S5-100U PLCs and of the ET 100U/200U expansion units. Ex modules are certified apparatus which must be installed outside the hazardous area and which have metallic isolation. There is therefore no need for equipotential bonding between the PLC/ET backplane bus and sensors/actuators.

Features of the Ex I/O modules

- Metallic isolation on the module
- No need for safety barriers, isolation amplifiers and transmitter devices
- Terminal boards are dispensed with
- Reduction in planning, installation and documentation costs
- Same system technology as non-Ex apparatus
- Keying to avoid insertion errors
- Advantages of a distributed configuration
- Measurements can be taken on an intrinsically safe, live circuit.

Programmable controllers and expansion units

The SIMATIC S5-95U/S5-100U programmable controllers are compact and amongst the smallest and lowest-cost controllers of the SIMATIC S5 family. They are particularly suitable for small and simple, central automation tasks whilst offering high performance and flexibility. Their implementation already becomes economical if five auxiliary contactors are replaced. These handy, rugged units operate without filters. The I/O modules plug into bus units and are securely screwed on. Bus units are snap-mounted onto a standard sectional rail.

- **S5-95U PLC**

This powerful controller solves tasks such as the processing of analog values. It can be connected via an interface to the SINEC L1/L2 bus system and can communicate with other PLCs. The basic version of the S5-95U PLC contains, apart from the processor and interface, 16 digital inputs, 16 digital outputs, 8 analog inputs and 1 analog output, 4 interrupt inputs and 2 count inputs. Modular expandability directly at the PLC enables the connection of modules of the S5-100U series with up to 256 digital inputs and outputs.

- **S5-100U PLC**

The modular design allows, depending on the CPU, a configuration with up to 256 digital I/Os. The S5-100U PLC is therefore also suitable for machine controllers as well as for the process automation and monitoring of plants of up to medium size. The fine stages of expansion and different module types give an S5-100U PLC optimum adaptability to the control task. The S5-100U can be assembled over one or two tiers, and either vertically or horizontally.

Figure 11.1 shows an S5-100U PLC configuration with

- CPU
- PS 935 power supply module
- 3 Ex modules
- 2 Ex bus units
- 2 partitions
- 1 non-Ex bus unit

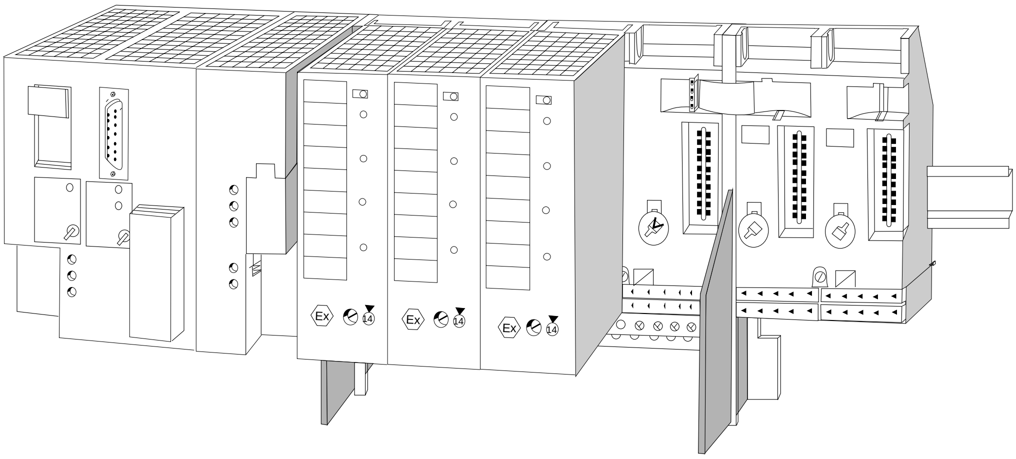


Figure 11.1 S5-100U PLC Configuration with PS 935 and Ex Modules

The programming language is STEP 5 with an extensive operation set. The methods of representation are the ladder diagram, control system flowchart and statement list; with the S5-100U PLC, upward of CPU 103, the GRAPH 5 method of representation is also available.

- **ET 100U /ET 200U expansion units**

The ET 100U and ET 200U (electronic terminal) expansion units are modular systems allowing the distributed connection of I/O modules over greater distances. They enable the direct local connection of sensors, actuators, valves and lamps. Cabling and installation costs can be considerably reduced by dispensing with terminal boards and by using a distributed bus (serial two-core connection to the PLC). Here too, the Ex I/O modules with intrinsically safe inputs and outputs are available for the connection of devices from hazardous areas.

The ET 100U offers modular expansion in fine stages. The modules comprise rugged blocks which are fitted onto a 35 mm standard sectional rail. A housing is not absolutely necessary. The central controller interface module (CC-IM 318), which must be fitted first at the left-hand end of the rail, serves for interfacing with a PLC or with TELEPERM M.

The ET 200U system is based on the PROFIBUS communications standard (DIN 19245, Part 1); SINEC L2 components can therefore also be used to configure the system. The field bus, on which the ET 200U system is based, is variant of SINEC L2 known as SINEC L2-DP. This variant is designed for extremely fast reaction times for communication with I/Os in a distributed arrangement.

11.2 Configuration with Intrinsically Safe Modules

You can incorporate Ex modules in the SIMATIC environment of the S5-100U PLC without mutual impairment of the functional features. Connection to TELEPERM M is also possible.

Communication between the systems takes place via

- Computer links
- Point-to-point links (CP 521 ->...)
- Teleservice (TK 858)
- SINEC L1
- SINEC L2
- SINEC L2-DP

11.3 Maximum Number of Analog and Digital Ex Modules in Individual Systems

11.3.1 Available Current in the Individual Systems

The number of usable slots depends on the consumption of the modules and on the current available at the backplane bus. The following table provides an overview of available current at the S5 backplane bus in the various systems

- without PS 935
- and with PS 935.

Table 11.1 Maximum Available Current of the S5 Systems at the Backplane Bus

System/ Station	Available Current at		Available Current with PS 935[1] at		Max. No. of Slots	Slot Assign-ment
	40 °C	60 °C	40 °C	60 °C		
S5-95U PLC		approx. 1.0 A		approx. 2.5 A	32	Fixed
S5-100 U PLC CPU 100 CPU 102 CPU 103		approx. 1.0 A		approx. 2.5 A	32	Fixed
per ET 100U	approx. 0.9 A	approx. 0.7 A		approx. 2.5 A	32	Variable
per ET 200U	approx. 0.9 A	approx. 0.7 A		approx. 2.5 A	32	Variable

1) The CPU 100 cannot be operated with the PS 935.

11.3.2 Addressing Range of the Individual Systems

Apart from the available current, the addressing range of the relevant system may limit the number of usable slots. The following table provides an overview of addressing ranges in the various systems.

Table 11.2 Addressing Ranges of the Individual Systems

System/ Station	**Slots (Digital Mod.)**	**Slots (Analog Mod.)**	**Addressing Range (Digital Mod.)**	**Addressing Range (Analog Mod.)**
S5-95U PLC	32 max.	8 I/O max.	32 byte max.	32 byte max.
S5-100U PLC				
CPU 100	32 max.	8 I/O max.	32 byte max.	32 byte max.
CPU 102	32 max.	8 I/O max.	32 byte max.	32 byte max.
CPU 103	32 max.	8 I/O max.	32 byte max.	64 byte max.
per ET 100U Station	32 max.	max. of 8 slots with 4 bytes per slot	Max. of 32 bytes inputs and outputs, digital/analog	
per ET 200U Station	32 max.	max. of 16 slots with 4 bytes per slot (of which 8 inputs and outputs)	Max. of 32 bytes inputs and 32 bytes outputs, digital/analog	

11.3.3 Maximum Number of Ex Analog/Digital Modules

The following table provides information on the maximum number of Ex analog/digital modules which can be plugged into the various systems.

Table 11.3 Max. Number of Ex Analog/Digital Modules

System/ Station	**Ex Digital Modules**					**Ex Analog Modules**			
	without PS 935			**with PS 935**		**without PS 935**		**with PS 935**	
	DI		**DQ**	**DI**	**DQ**	**AI**	**AQ**	**AI**	**AQ**
S5-95U PLC	20 max.		18 max.	30 max.	30 max.	3 max.	2 max.	6 max.	6 max.
S5-100U PLC CPU 100 CPU 102 CPU 103	20 max. 20 max. 20 max.		18 max. 18 max. 18 max.	- 30 max. 30 max.	- 30 max. 30 max.	3 max. 3 max. 3 max.	2 max. 2 max. 2 max.	- 6 max. 6 max.	- 6 max. 6 max.
per ET 100U	18 max. 14 max.	at 40 °C at 60 °C	16 max. 12 max.	30 max.	30 max.	2 at 40 °C max. 2 at 60 °C max.		7 max.	3 max.
per ET 200U	18 max. 14 max.	at 40 °C at 60 °C	16 max. 12 max.	30 max.	30 max.	2 at 40 °C max. 2 at 60 °C max.		7 max.	7 max.

A precise assessment of the situation for Ex modules requires verification of current availability and addressing capacity for the individual systems.

Example: Determining the maximum number of Ex analog modules which can still be plugged into an ET 200U station (with PS 935 and 8 digital Ex modules already inserted).

1. Current Calculation

Module	Current Drawn from S5-100U Backplane Bus	No. of Modules	Total
Ex 437 digital input	50 mA	2	100 mA
Ex 437 digital output	55 mA	6	330 mA

In an ET 200U station, 2500 mA is available to you at the backplane bus, i.e. a residual current of 2070 mA can still be used in the example. With a current requirement of 260 to 350 mA per analog module, the maximum expansion is given by the following equation:

2070 mA : 350 mA $\triangleq$ 6 Ex analog modules

2. Addressing Capacity

Within this ET 200U, you can use up to 32 bytes of inputs and 32 bytes of outputs for addressing.

Module	Addressing Requirement per Module	No. of Modules	Bytes Input	Bytes Output
Ex 437 digital input	1 byte * input	2	2	-
Ex 457 digital output	1 byte * output	6	-	6
935 aux. power supply	2 bytes inputs	1	2	-

Within this ET 200U station, after deducting the bytes already allocated, you still have 28 bytes of inputs and 26 bytes of outputs for Ex analog modules.

Module	Current Consumption (mA)	Addressing Requirement per Module	No. of Modules
Ex 467-8EE11 analog input	320	4 bytes inputs	7 max.
Ex 467-8EA11 analog input (thermistors)	260	8 bytes inputs	3 max.
Ex 467-8EF11 analog input (Pt100)	260	4 bytes inputs	7 max.
Ex 477-8EC11 analog output (4 ... 20 mA)	350	4 bytes inputs/ 4 bytes outputs	6 max.

11.4 PS 935-8ME11 Power Supply Module

You have to use a PS 935 power supply module when you are configuring a PLC/ET with Ex analog modules (4 to 20 mA) whose current consumption exceeds the maximum current available in the system (Table 11.1). The 2.5 A output current with the PS 935 at the PLC/ET backplane bus enables the operation of up to 7 analog Ex modules. You can use the PS 935 in the S5-95U/S5-100U (not CPU 100) and ET 100U/ET 200U systems. The PS 935 is always fitted on the standard sectional rail to the right of the PLC/CPU or to the right of the IM 318 interface module.

- **Controls and indicators on the PS 935**

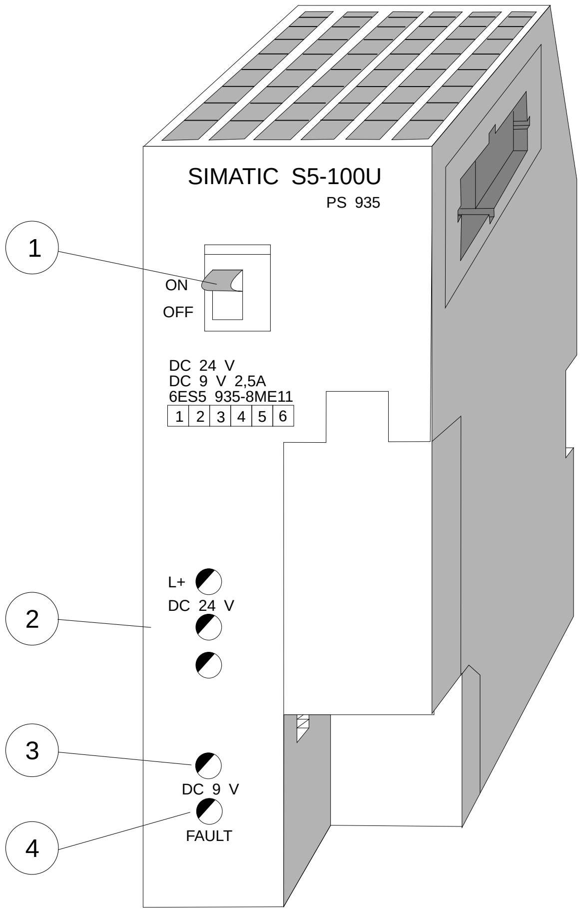


Figure 11.2 Controls and Indicators on the PS 935

(1) On/Off switch for the 9 V I/O bus supply
(2) Terminal for 24 V DC supply
(3) 9 V LED (indicates fault-free operation)
(4) Fault LED for fault messages

Fitting and removing the PS 935

Fitting the PS 935

- Insert the plug of the ribbon cable in the male connector on the right-hand side of the PLC/CPU/IM 318 interface module
- Position the power supply module on the standard section rail so that it catches.
- Connect the 24 V DC terminal (+) of the PLC/CPU/interface module to the 24 V DC terminal of the PS 935 (Figure 11.3).

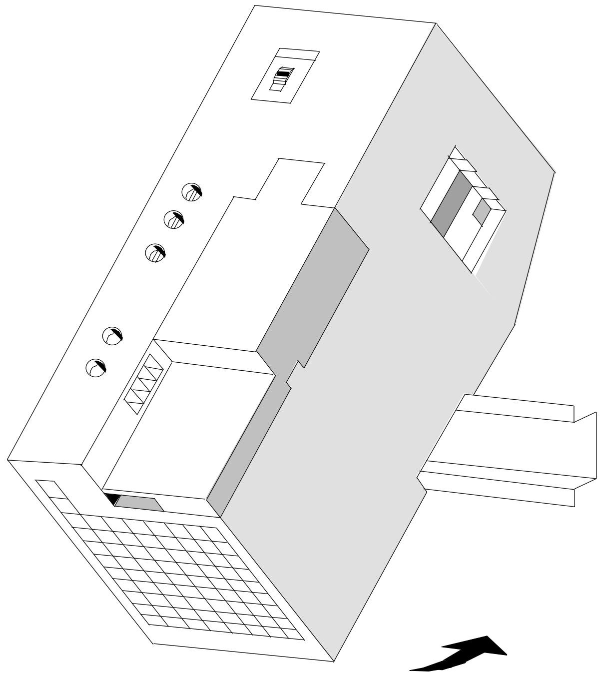


Figure 11.3 Fitting the PS 935 Power Supply Module

Removing the PS 935

- Switch off the 24 V DC supply.
- Detach the connections of the 24 V DC supply.
- Disconnect the ribbon cable to the bus unit.
- Use a screwdriver to press the slider of the module downwards and swivel the module out of the standard sectional rail.
- Disconnect the plug of the ribbon cable from the PLC/CPU/IM 318 interface module.

11.4.1 Electrical Connection of the PS 935

Swivel the protective cover upwards.

- Connect the cable from the 24 V DC supply to terminal L+ (Figure 11.4).
- Close the protective cover.

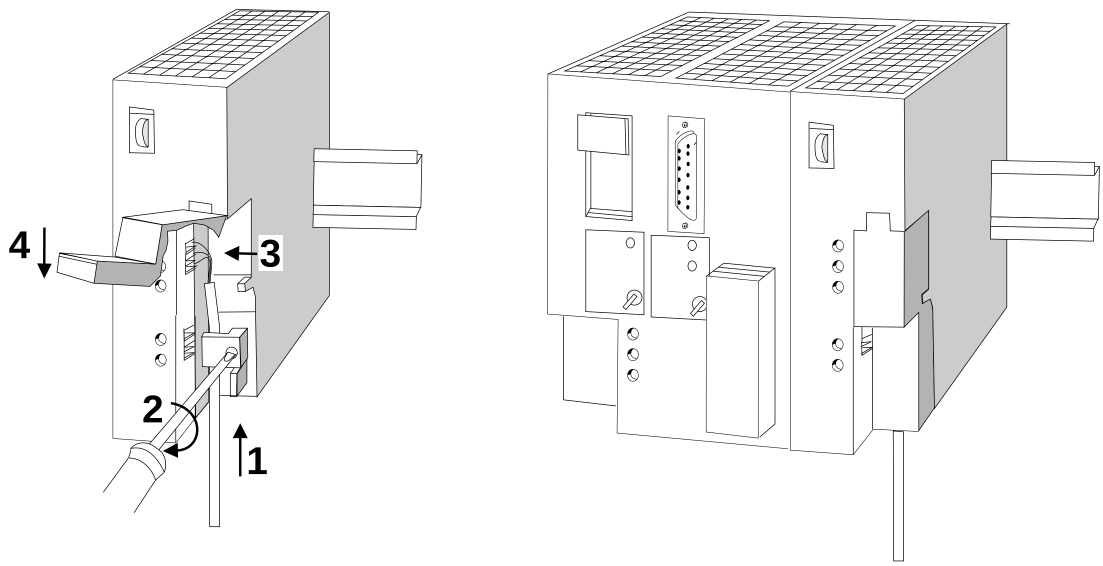


Figure 11.4 Connecting the Power Supply and CPU Module

11.4.2 Using the PS 935 in the S5-95U/S5-100U PLC Systems (Fixed Slot Addressing)

Slot assignments

The PS 935 power supply module is fitted to the standard sectional rail to the right of the S5-95U PLC or CPU 102/103. Although the PS 935 does not plug into a bus unit, it occupies two slots. Two bits of the slot address are reserved for diagnostic messages to the CPU. You can interpret these diagnostic bits in the user program (Section 11.4.4).

Single tier arrangement in the S5-95U/S5-100U PLC

Shown in the following figure is a possible configuration with a mixture of Ex and non-Ex modules.

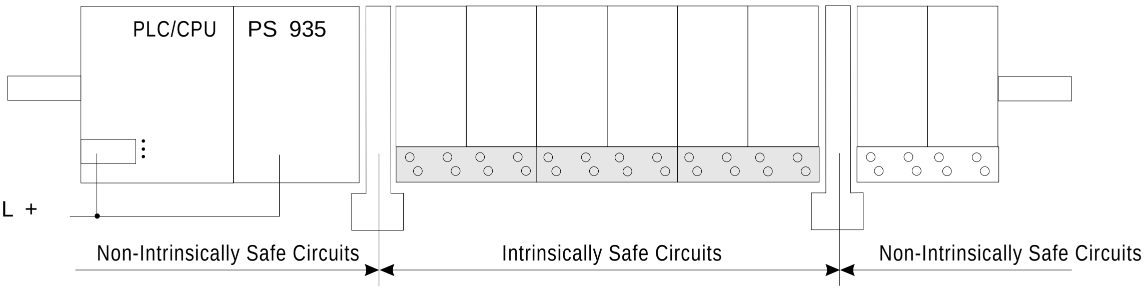


Figure 11.5 Single Tier Arrangement of an S5-95U/S5-100U PLC with Ex and Non-Ex Modules

You must segregate the modules allowing connection of intrinsically safe I/O circuits from the other modules. Insert a 497-8EA11 partition between the corresponding bus units on the standard sectional rail (Section 11.6).

Multi-tier arrangement in the S5-95U/S5-100U PLC

The distance between the IM 316 interface modules of the first and last tiers of a multi-tier arrangement must not exceed 30 m. A multi-tier arrangement can comprise up to 4 tiers. In Figure 11.6, the maximum current consumption in the expansion tier is plotted as a function of distance.

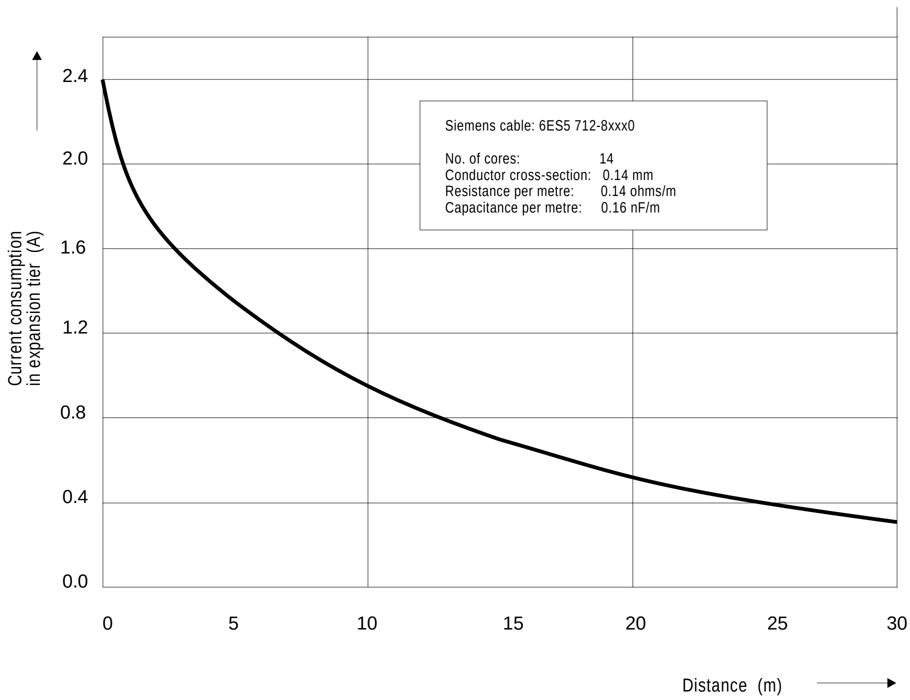


Figure 11.6 Current Consumption in the Expansion Tier

Example:

Determine the maximum consumption in the expansion tier for the following configuration.

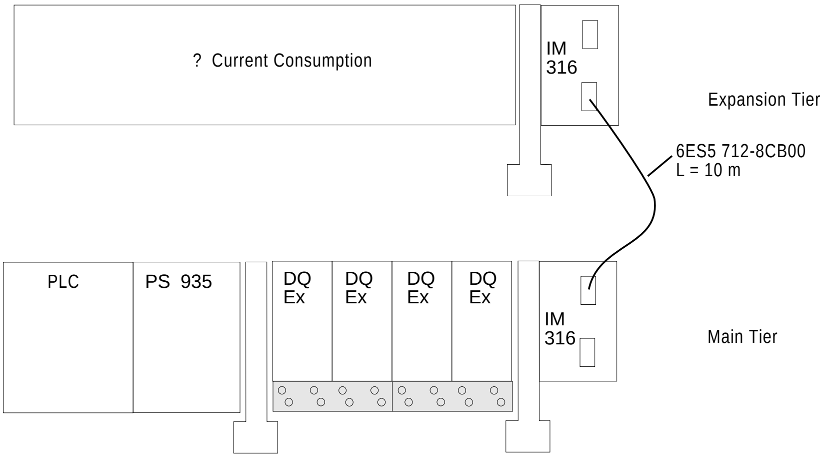


Figure 11.7 Determining the Maximum Current Consumption in the Expansion Tier

The PS 935 is capable of supplying up to 2.5 A to the PLC/ET backplane bus. The four digital Ex modules draw 4 x 55 mA = 220 mA from the backplane bus.

With a distance of 10 m between main and expansion tiers, the value of approx. 1 A can be read off the characteristic in Figure 11.6: for example, three analog Ex modules could be plugged into the expansion tier (3 x 320 mA).

What residual current is still available at the main tier?

Current calculation:

Total current	2500 mA
Main tier	220 mA
Expansion tier	1000 mA
Residual current	1280 mA

A residual current of 1280 mA is available at the main tier.

Note

Analog intrinsically safe modules should only be fitted to the first tier of the configuration.

Shown in the following figure is a possible configuration of a multi-tier arrangement with a mixture of intrinsically safe and non-intrinsically safe modules.

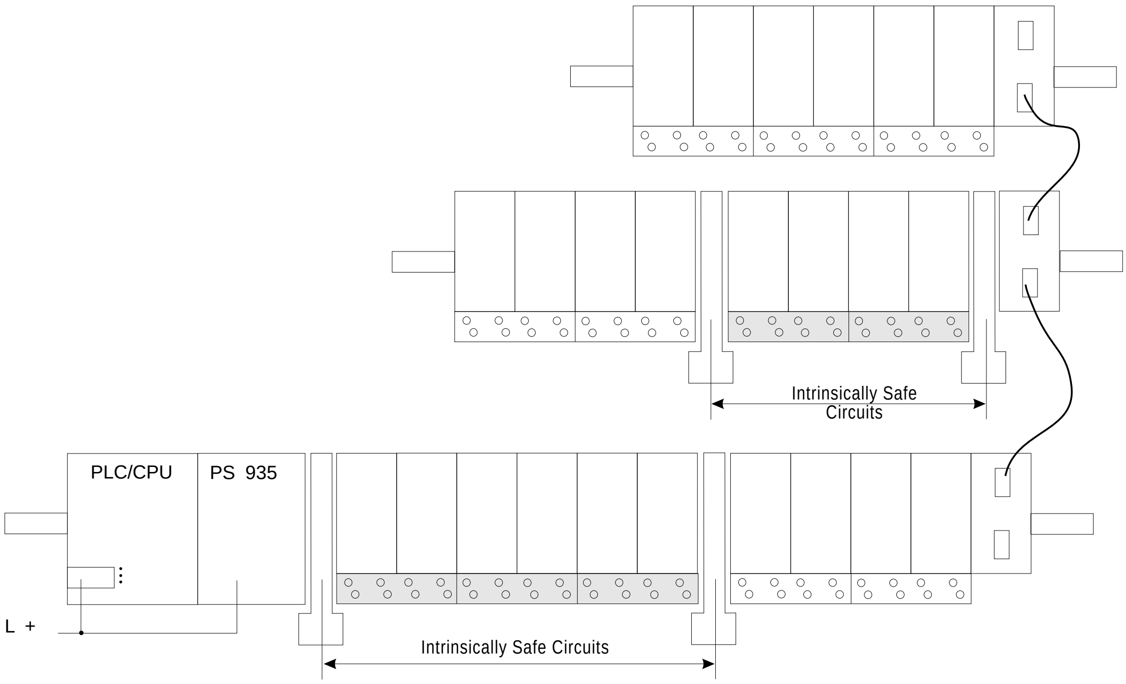


Figure 11.8 Multi-Tier Arrangement of an S5-95U/S5-100U PLC with Ex and Non-Ex Modules

You must segregate the modules allowing connection of intrinsically safe I/O circuits from the other modules. Insert a 6ES5 497-8EA11 partition between the corresponding bus units on the standard sectional rail (Section 11.6).

Addressing of the PS 935 in the S5-95U/S5-100U PLC

The PS 935 reserves input byte "0" and input byte "1". This results in the following addresses for the module to the right of the PS 935:

Digital module:	Byte address "2"
Analog module, CP/IP:	Byte address "80"

11.4.3 Using the PS 935 in the ET 100U/ET 200U Systems (Variable Slot Addressing)

Slot assignments

The PS 935 power supply module is fitted to the standard sectional rail to the right of the IM 318-8M.. interface module. Although the PS 935 does not plug into a bus unit, it occupies two slots. Two bits of the slot address are reserved for diagnostic messages. You can interpret these diagnostic bits in the user program (Section 11.4.4).

Single tier arrangement in the ET 100U/ET 200U systems

Shown in the following figure is a possible configuration with a mixture of Ex and non-Ex modules.

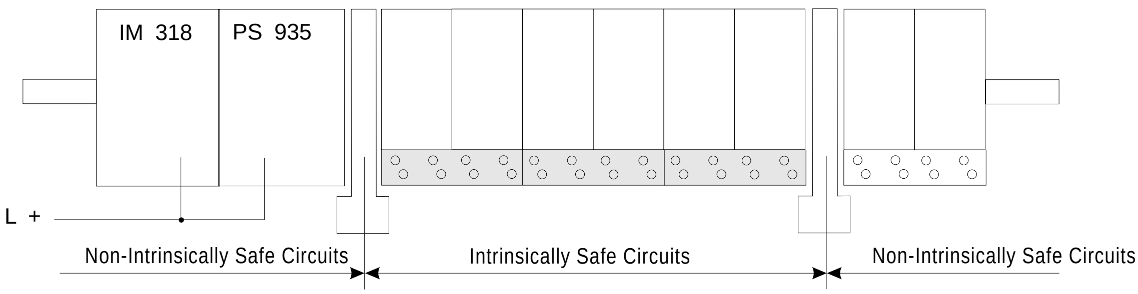


Figure 11.9 Single Tier Configuration with ET 100U/ ET200U using Ex and Non-Ex Modules

You must segregate the modules allowing connection of intrinsically safe I/O circuits from the other modules. Insert a 6ES5 497-8EA11 partition between the corresponding bus units on the standard sectional rail (Section 11.6).

Multi-tier arrangement in the ET 100U/ET 200U systems

The distance between IM 316 interface modules of the first and last tiers of a multi-tier arrangement must not exceed 30 m (Figure 11.6).

Analog intrinsically safe modules should only be fitted to the first tier of the arrangement. Shown in Figure 11.10 is a possible configuration of a multi-tier arrangement with a mixture of Ex and Non-Ex modules.

You must segregate the modules allowing connection of intrinsically safe I/O circuits from the other modules. Insert a 6ES5 497-8EA11 partition between the corresponding bus units on the standard sectional rail (Section 11.6).

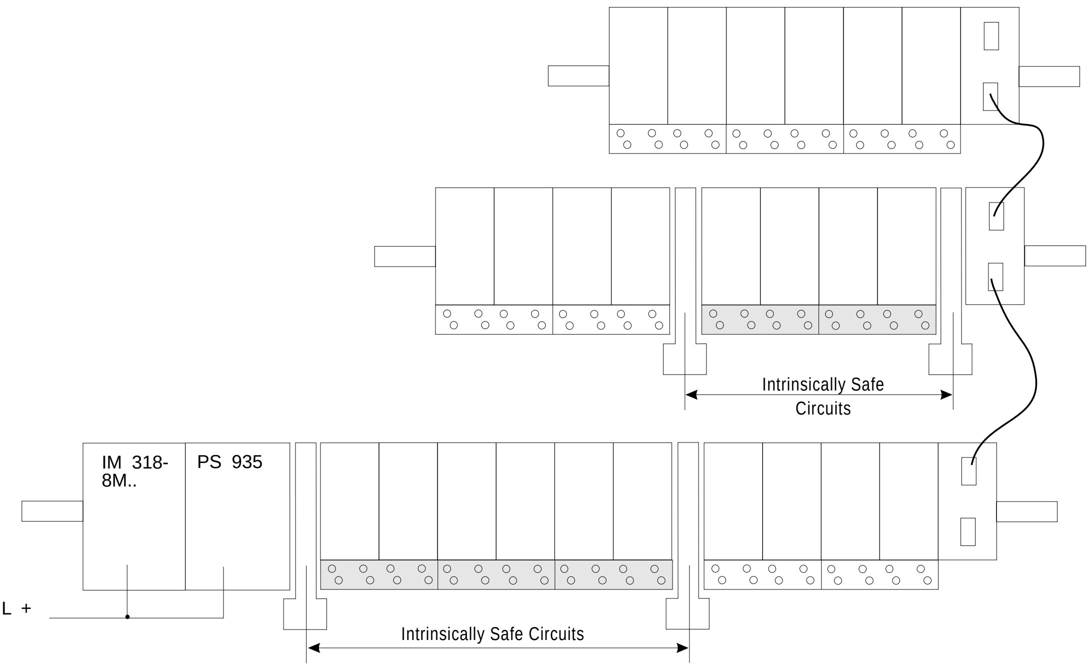


Figure 11.10 Multi-Tier Configuration with ET 100U/ET 200U Using Ex and Non-Ex Modules

Addressing in the ET 100U/ET 200U systems

In the ET 100U and ET 200U systems, there is no fixed slot addressing as with the S5-95U/S5-100U PLC. You must assign the module addresses with COM software. When assigning them, you must allow for the PS 935, i.e. the PS 935 must be configured as a 2 x 4-channel input module. The address identifier is 2 x 4 DE; with the ET 200U, 2 x 008 is also possible (see also Section 12.2).

Slots:

0/1		2	3	4	5
IM 318-8M..	PS 935	467-8	477-8	437-8	457-8

Address identifier:

COM software						
COM ET 100	4DE 4DE	2AE	2AX	4DE	4DA	
COM ET 200	4DE 4DE	2AE	2AX	4DE	4DA	
	008 008	013	029	008	016	

Figure 11.11 Example of Address Assignments when Using a PS 935

Note: In the ET 200U system, 4-bit (nibble) address assignment is not possible.

11.4.4 Monitoring and Diagnostics with the PS 935

Situated on the front of the PS 935 are two LED indicators, one 9 V LED and one FAULT LED.

- The green 9 V LED lights up to indicate that the power supply module is in order.
- The red FAULT LED lights up to indicate faulty operation.
- If the red FAULT LED lights up and the green 9 V LED flashes simultaneously, there is an overload at the output to the 9 V I/O bus.

The input byte of the PS 935 serves as a diagnostic byte; you can interpret it for fault-finding in the control program.

Figure 11.12 shows the bit assignments of the input byte.

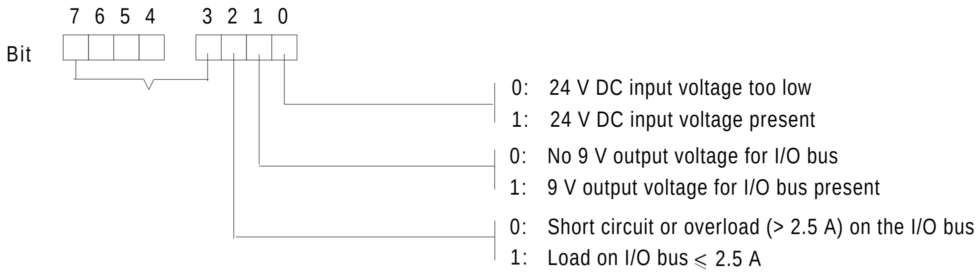


Figure 11.12 Structure of the Diagnostic Byte of the PS 935

As soon as at least one of bits 0 or 1 is reset, the red FAULT LED lights up. The 9 V LED also flashes in the event of overload at the 9 V PLC/ET backplane bus.

11.5 6ES5 700-8EA11 Ex Bus Unit

To use Ex analog or digital modules, you must fit them to Ex bus units. The differences between the Ex bus units and the 6ES5 700-8MA11 (SIGUT) non-Ex bus units are as follows:

- Terminal block and coding keys are marked blue.
- Coding keys are of a different type.

As with the non-Ex bus units,

- the 6ES5 700-8EA11 bus unit is fitted on the standard sectional rail;
- it is removed from the standard sectional rail;
- ribbon cable provides the connection between the bus units or from the bus unit to the PS 935, CPU or interface module.

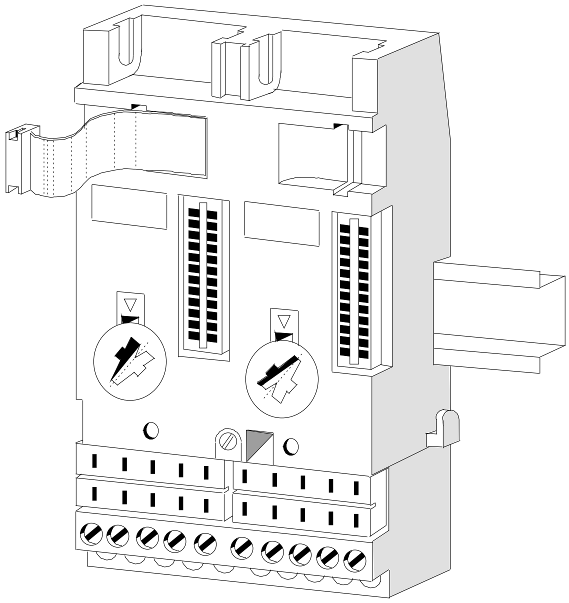


Figure 11.13 6ES5 700-8EA11 Ex Bus Unit

11.6 6ES5 497-8EA11 Partition

You must fit the 6ES5 497-8EA11 partition

- between Ex and non-Ex bus units,
- and between Ex bus units and devices with non-intrinsically safe circuits.

The partition ensures the required clearance of 50 mm thread measure between the terminals of the intrinsically safe I/O circuits and terminals of non-intrinsically safe I/O circuits.

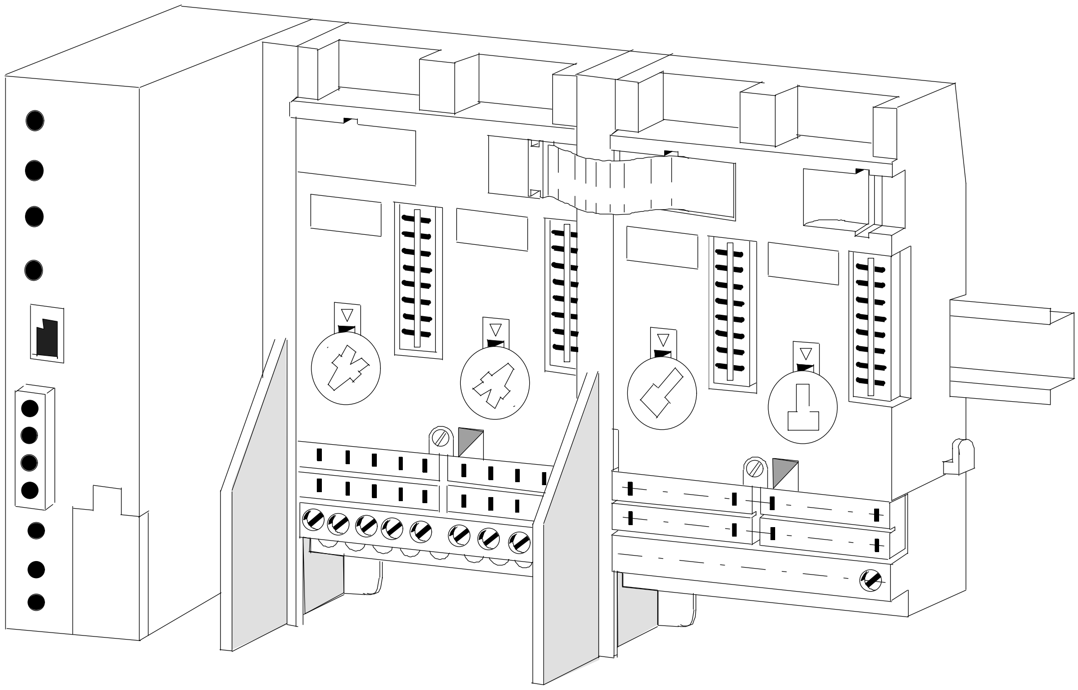


Figure 11.14 6ES5 497-8EA11 Partitions Between ET 100U and Ex Bus Unit, as well as Between Ex and Non-Ex Bus Units

11.7 Ex Digital Modules

Note

These modules may only be used **outside** the hazardous area.

In addition, you must segregate the Ex digital modules with a 6ES5 497-8EA11 partition from non-Ex modules (Section 11.6).

11.7.1 6ES5 437-8EA12 Ex Digital Input Module

The four-channel Ex digital modules process the digital input signals from the hazardous area and present them to the automation system via the S5 bus.

The Ex 437 digital input module is certified as associated apparatus under type of protection [EEx ib] IIC. This Ex digital input module must be used together with the 6ES5 700-8EA11 Ex bus unit (Section 11.5).

Connecting the 6ES5 437-8EA12 Ex digital input module

The DIN 19234 standard specifies the technical data for the interface between a NAMUR proximity switch and the digital Ex input module. The connection is provided by a two-core line which also powers the proximity switch. The Ex digital input module is controlled by the current consumption of the proximity switch, which varies according to external influences.

Interaction between a proximity switch and the module

To ensure reliable interaction between a proximity switch (Figure 11.15a) and the Ex digital input module, the following values are specified for the module:

1. Power supply for the control circuit

   No-load voltage U_0: approx. 7 V
   Short-circuit current I_k: approx. 7 mA

2. Current-dependent switching points and monitoring points

   a) Switching point

   The switching point of the Ex digital input module lies in the range of a 1.2 mA to 2.1 mA current consumption of the proximity switch.

   b) Open-circuit monitoring

   If the current consumption of the proximity switch drops below a certain value, it is assumed that there is an open-circuit or corresponding fault in the proximity switch. The open-circuit monitor responds in the current range from 0.05 mA to 0.15 mA.

   c) Line short-circuit monitoring

   If the current consumption of the proximity switch exceeds a value of 5.5 mA, it is assumed that there is a line short-circuit or corresponding fault in the proximity switch.

The four channels of the module are numbered Ch 0 to Ch 3. A pair of terminals on the terminal block is allocated to each channel. This allocation and the terminal diagram are printed on the front plate of the module. The inputs of the four channels are intrinsically safe. They are metallically isolated from each other and from the S5 bus.

Example: A sensor is to be connected to the input module at Slot 3, Channel 2 (Address I 3.2); Figure 11.15.

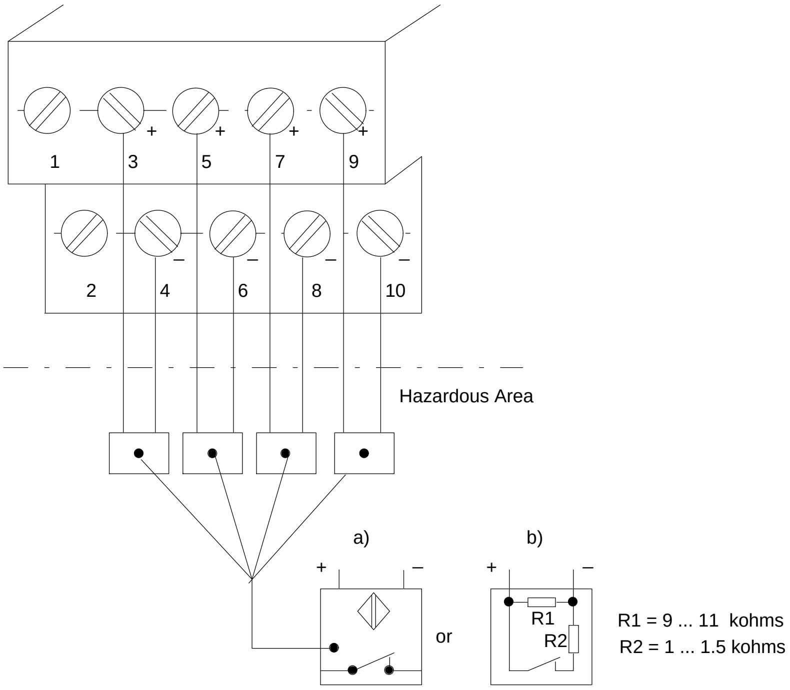


Figure 11.15 Two-Wire Connection of Sensors to the Ex 437 Digital Input Module

Interaction of a wired up contact and a module

A contact must be wired with an appropriate resistor to ensure interaction between the contact and the Ex digital output module (Figure 11.15a). This wiring simulates a NAMUR sensor.

Simulation of a NAMUR sensor

Wiring a contact with an appropriate resistor makes it possible to simulate a NAMUR sensor to DIN 19234.

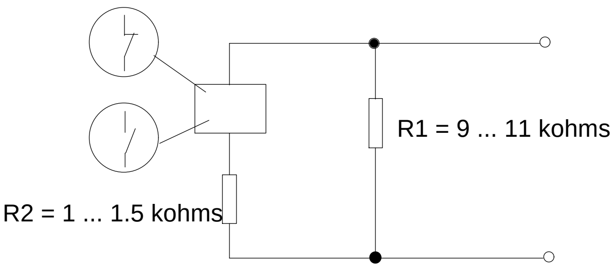


Figure 11.15a

Contact	Resistance [kohms]	Bus signal
Open	9 ... 11	1
Closed	0.9 ... 1.3	0

> **Note**
>
> These modules may only be used **outside** the hazardous area.
>
> If a contact without resistor wiring is connected to the module, the module signals a fault.

LED indicators on the front plate (diagnostic functions)

The green LEDs indicate that control states of the sensors. The red LED indicates a fault. The following are detected as a fault by the Ex 437 digital input module:

- Short-circuit
- Overload

Interconnected sensors at an Ex digital input module

Certain applications require sensors to be interconnected (Figure 11.16).

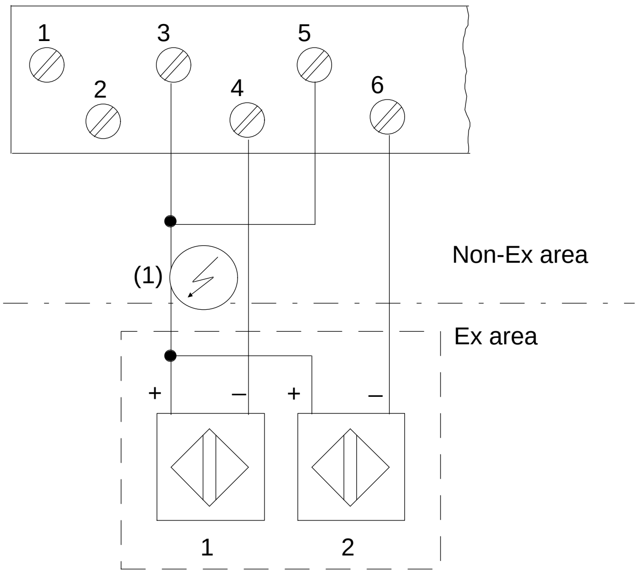


Bild 11.16 Interconnected NAMUR Sensors

In this application, a short-circuit might occur in the supply line (1) while signal 1 is applied to NAMUR sensor 2. This combination of a fault and a regular operating state can cause an addition of currents in the supply line. The following safety-relevant evaluations become necessary since applications used in Zone 1 must still be safely under control if a fault occurs (see also Section 6.3.2 "Intrinsically Safe Circuit with Two or More Items of Associated Electrical Apparatus").

Example: Procedure for electrical apparatus with linear current/voltage characteristic

1. Determine highest possible current in meshed system:

   $I_K = I_{K1} + I_{K2}$
   $I_{K1} = 43 \text{ mA} + 43 \text{ mA} = 86 \text{ mA}$

   I_K = new short-circuit
   I_K = short-circuit current of channel 1
   I_{K2} = short-circuit current of channel 2 from certificate of conformity PTB No. 88.B.2149X

2. Determine maximum current of interconnection:

   $I_{max} = I_K * 1.5$
   $= 86 \text{ mA} * 1.5 = 129 \text{ mA}$

   I_{max} = max. current
   1.5 = Safety factor to DIN VDE 0165

   The connected sensors must consequently withstand a current of 129 mA.

3. The maximum voltage of the interconnection must be determined. There is no voltage increase since inputs are connected in parallel in this interconnection.

   $U_0 = U_{01} = U_{02}$
   $U_0 = 10.1 \text{ V} = 10.1 \text{ V} = 10.1 \text{ V}$

   U_0 = new voltage
   U_{01} = no-load voltage of channel 1
   U_{02} = no-load voltage of channel 2 from certificate of conformity PTB No. 88.B.2149X

4. The maximum voltage of the interconnection is:

   $U_{max} = U_0 * 1.5$
   $= 10.1 \text{ V} * 1.5 = 15.15 \text{ V}$

   Consequently, the sensors connected must be designed for a voltage of 15.15 V.

5. The maximum permissible inductance of the circuit must be determined. It is derived from the characteristic in Figure 6.5 "Minimum Igniting Curves for Inductive Circuits to EN 50020".

   I_{max} = 129 mA (from charcteristic $L_a \approx 5$ mH)

6. The maximum permissible capacity of the circuit must be determined. It is derived from the characteristic in Figure 6.4 "Minimum Igniting Voltages in Capacitive Circuits (EN 50020)".

   U_{max} = 15.15 V (from characteristic $C_a \approx 2$ µF)

7. The interconnection of the electrical apparatus results in new safety-relevant values in the intrinsically safe circuit:

   U_{max} = 15.15 V
   I_{max} = 129 mA
   $L_{a\,max}$ = 5 mH
   $C_{a\,max}$ = 2 µF

Table 11.4 Functional Overview and Fault Indications of the Ex 437 Digital Input Module

Input Current mA	Sensor Status	Bus Signal	LED green	LED red
0.15 to 1.2	Open/attenuated	0	Off	Off
1.2 to 2.1	Closed/not attenuated	1	On	Off
> 5	Short-circuit	1		On

Note

If these resistors R1 and R2 are fitted in the hazardous area, their temperature rise must be taken into account.

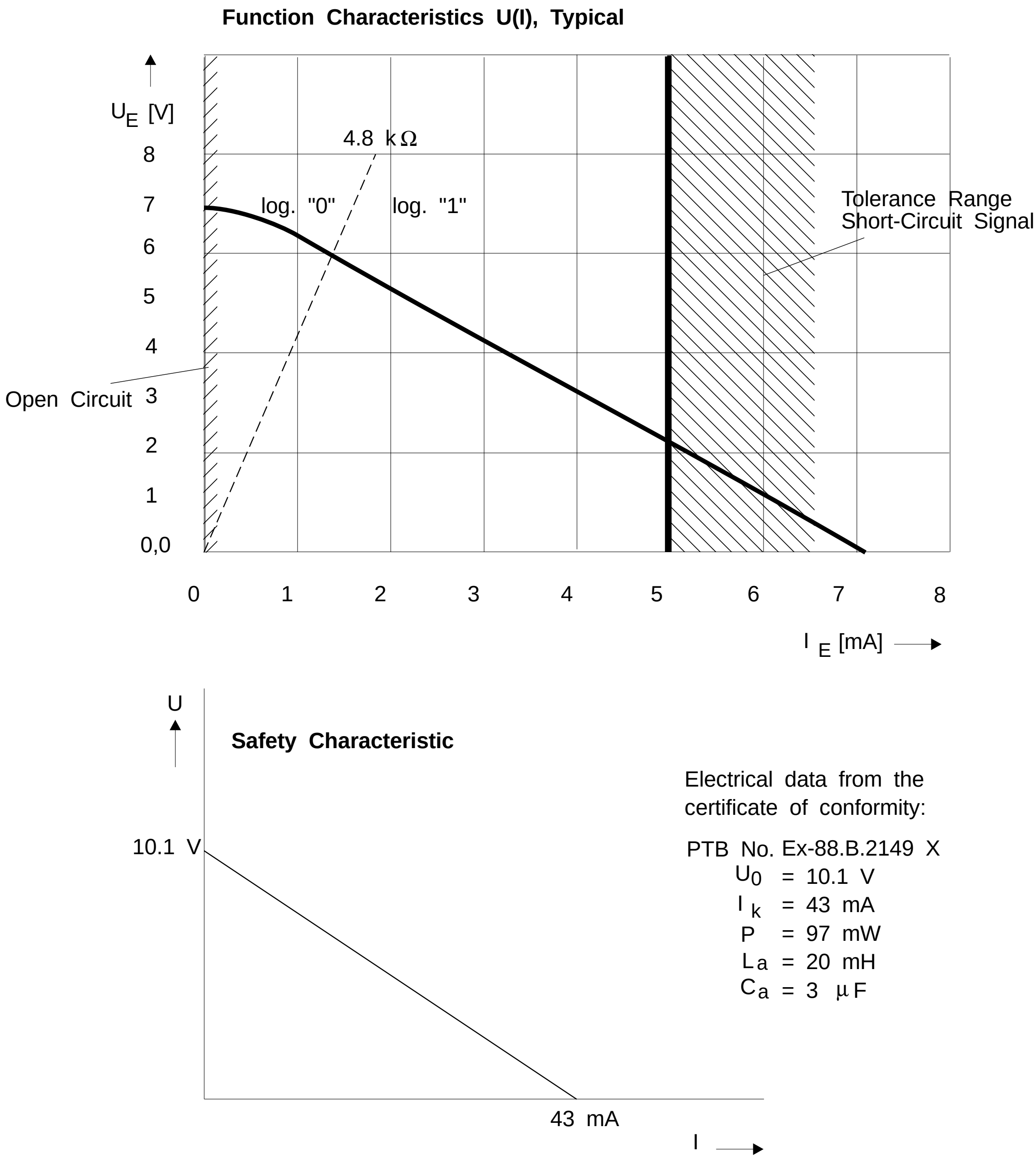


Figure 11.17 Input Characteristics of the Ex 437 Digital Input Module

11.7.2 6ES5 457-8EA12 Ex Digital Output Module

The Ex 457 digital output module converts digital Ex output signals from the automation system to scaled, intrinsically safe process signals which are permissible for the hazardous area.

The Ex digital output module is certified as associated apparatus under type of protection [EEx ib] IIC. This Ex digital output module must be used together with the 6ES5 700-8EA11 Ex bus unit (Section 11.5). Additionally, the Ex digital output module must be segregated from non-Ex modules with a 6ES5 457-8EA11 partition (Section 11.6).

Connecting the Ex digital output module

The four channels of the module are numbered Ch0 to Ch3. A pair of terminals on the terminal block is allocated to each channel. This allocation and the terminal diagram are printed on the front plate of the module. The intrinsically safe outputs of the four channels are metallically isolated from each other and from the S5 bus.

Example: An intrinsically safe solenoid valve is to be connected to the output module at Slot 1 Channel 3 (Address Q 1.3); see Figure 11.18.

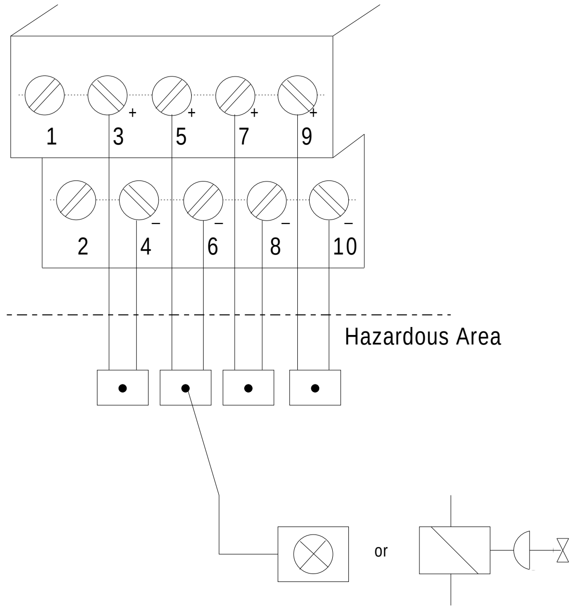


Figure 11.18 Two-Wire Connection of an Indicator Lamp to Channel 1 of the Ex 457 Digital Output Module

Interaction between the module and a connected solenoid valve

A two-core cable provides the connection. The intrinsically safe solenoid valve, for example, is driven via this cable. To ensure reliable interaction between the intrinsically safe solenoid valve and the Ex module, the following values are specified:

1. Characteristic values of the control circuit

   No-load voltage U_0: 9 V

   Rated current: 3.5 mA max.

   Short-circuit current I_k: 10 mA

2. Current-dependent operating point and monitoring point

   a) Operating point

   The operating point of the Ex module is at approx. 7.0 V DC/2 mA

   b) Line short-circuit monitoring

   If the current consumption exceeds a certain value, it is assumed that there is a line short-circuit or corresponding fault in the solenoid valve. The short-circuit monitor responds in a current range of > 3.5 mA, which corresponds to an equivalent resistance of the solenoid valve of < 1.65 kilohms.

LED indicators on the front plate (diagnostic function)

The green LEDs indicate the control state of the channels. The red group fault LED indicates a fault. The Ex digital output module recognizes an overload as a fault. As long as the overload persists, the red LED remains lit.

Table 11.5 Functional Overview and Fault Indications of the Ex 457 Digital Output Module

Output Current mA	Actuator Status	Bus Signal	LED green	LED red
0	-	0	Off	Off
2 - 3.5	Actuated	1	On	Off
> 5	Short-circuit	1	On	On

Fault messages **of the 6ES5 457-8EA12 Ex digital output module**

In addition to the fault indication (red LED), the Ex digital output module can signal faults to the PLC/ET.

S5-95/100U PLC

Input channel I X.0 can be scanned for a fault message (not CPU 100).

Address	Type of fault
I X.0	Short-circuit on an output channel

ET 100U

The fault message can be interpreted via the diagnostic word of group diagnostics of the slave station; the corresponding bit is then at logic 1.

F1: Output short-circuit to 0 V ground
The Ex module signals that at least one output exhibits a short-circuit to 0 V ground.

ET 200U

The fault message can be interpreted via the diagnostic word of group diagnostics of the slave station; the corresponding bit is then at logic "1".

Bit 3: Output short-circuit to 0 V ground

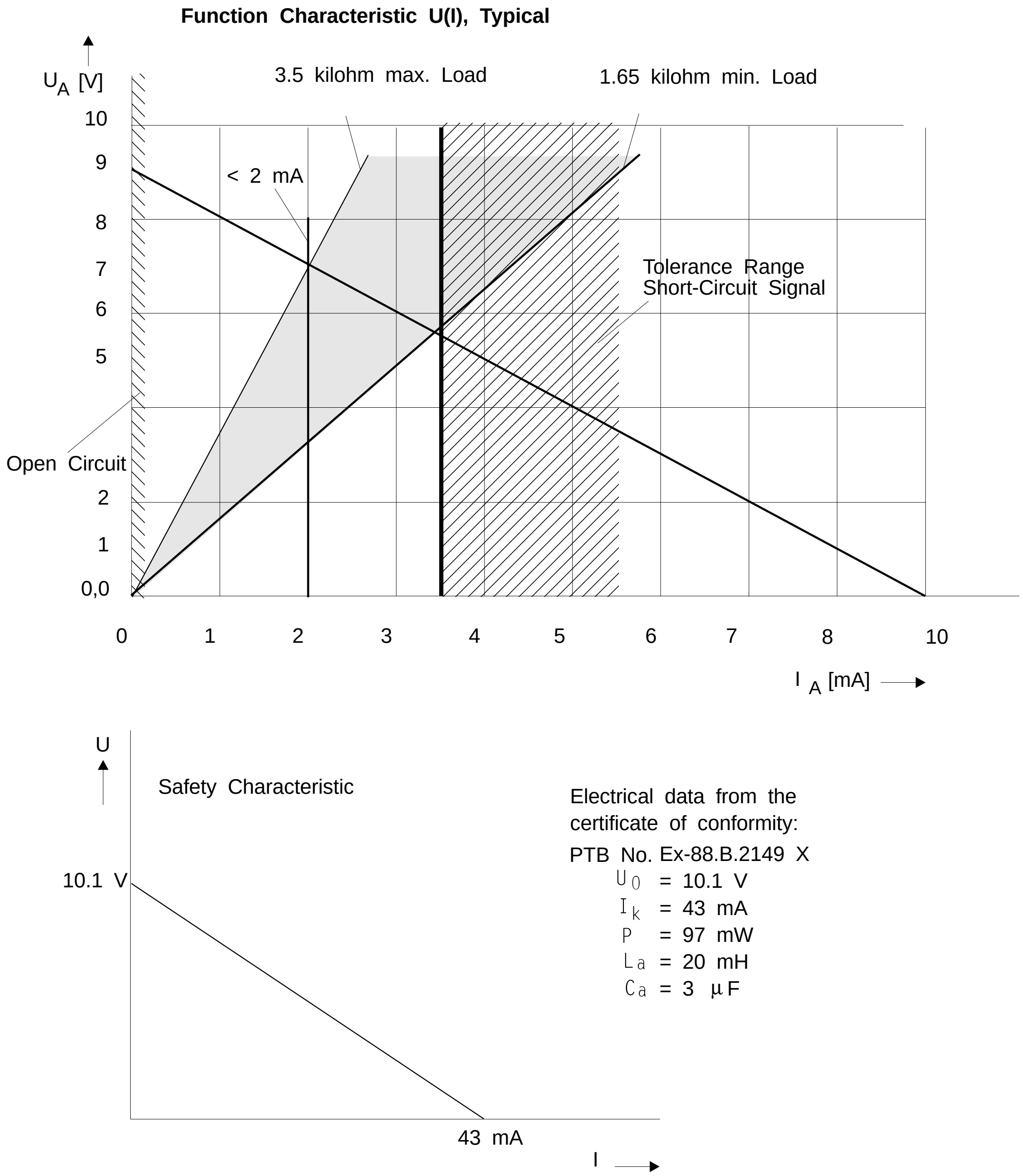


Figure 11.19 Output Characteristics of the Ex 457 Digital Output Module

11.8 Analog Value Processing with Intrinsically Safe Modules

11.8.1 6ES5 467-8EE11 Ex Analog Input Module 2 x 4 to 20 mA

The Ex 467 analog input module converts analog process signals to digital values for processing by the CPU.

The Ex analog input module is certified as associated apparatus under type of protection [EEx ib] IIC. This Ex analog input module must be used with the 6ES5 700-8EA11 Ex bus unit (Section 11.5). Additionally, the Ex analog input module must be segregated from non-Ex modules with a 6ES5 497-8EA11 partition (Section 11.6). The inputs of the two channels are intrinsically safe. They are metallically isolated from the S5 bus but not from each other.

You can connect two-wire and four-wire transducers to the Ex analog input module. The module converts the 4 to 20 mA input current to a 12-bit wide digital signal.

Connecting two-wire **and four-wire transducers**

With the Ex analog input module, the two-wire transducers are powered via the module itself. The two-wire transducer then converts the applied voltage to a current of 4 to 20 mA.

- On the Ex analog input module, Terminals 1 and 2 should not be connected.
- The terminals of unused inputs should not be short-circuited.
- Allocate the channels in ascending order.
- The permissible differences in reference potentials between inputs must not exceed 1 V. Provide the sensors with a common reference potential.

The wiring is shown in Figure 11.20.

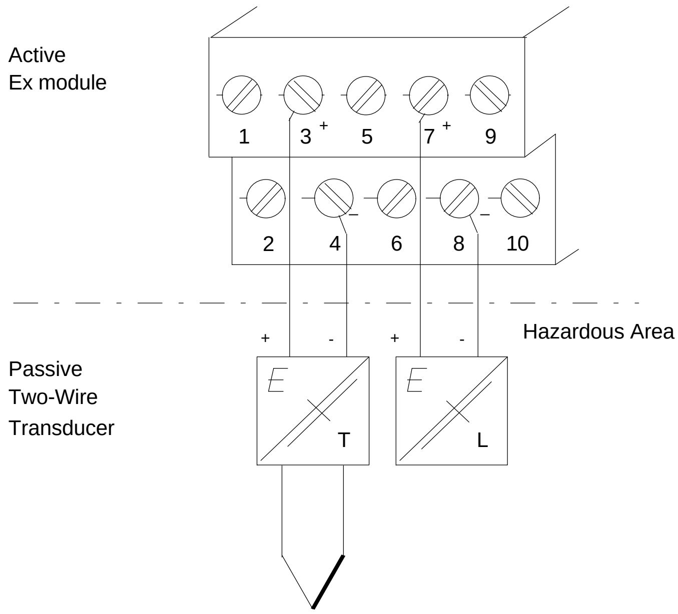


Figure 11.20 Connecting Two-Wire Transducers

Interaction between an Ex analog input module and a two-wire transducer

To ensure reliable interaction between two-wire transducers and Ex modules, the following values have been specified:

1. Power supply for the transducer

   No-load voltage U_0: 12 to 16 V
   Short-circuit current I_k: 22 mA

2. Current-dependent monitoring points

   a) Open-circuit monitoring

   If the current consumption of the two-wire transducer drops below a certain value, it is assumed that there is an open-circuit or a corresponding fault in the two-wire transducer. The line open-circuit monitor responds in the current range of < 2 mA.

   b) Line short-circuit monitoring

   If the current consumption of the two-wire transducer exceeds a value of 22 mA, the module signals a line short-circuit.

Interaction between an Ex analog input module and a four-wire transducer

If you use four-wire transducers, they must be connected as follows (Figure 11.21).

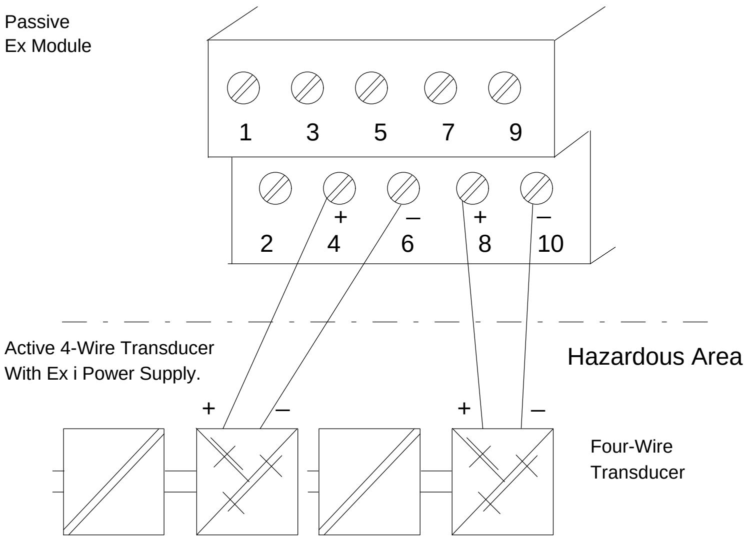


Figure 11.21 Connecting Four-Wire Transducers to the 6ES5 467-8EE11 Ex Analog Input Module

Note that four-wire transducers require a separate, intrinsically safe power supply and that the positive terminal of the four-wire transducer must be connected to the corresponding terminal on the terminal block. This connection arrangement is the reverse of that for two-wire transducers.

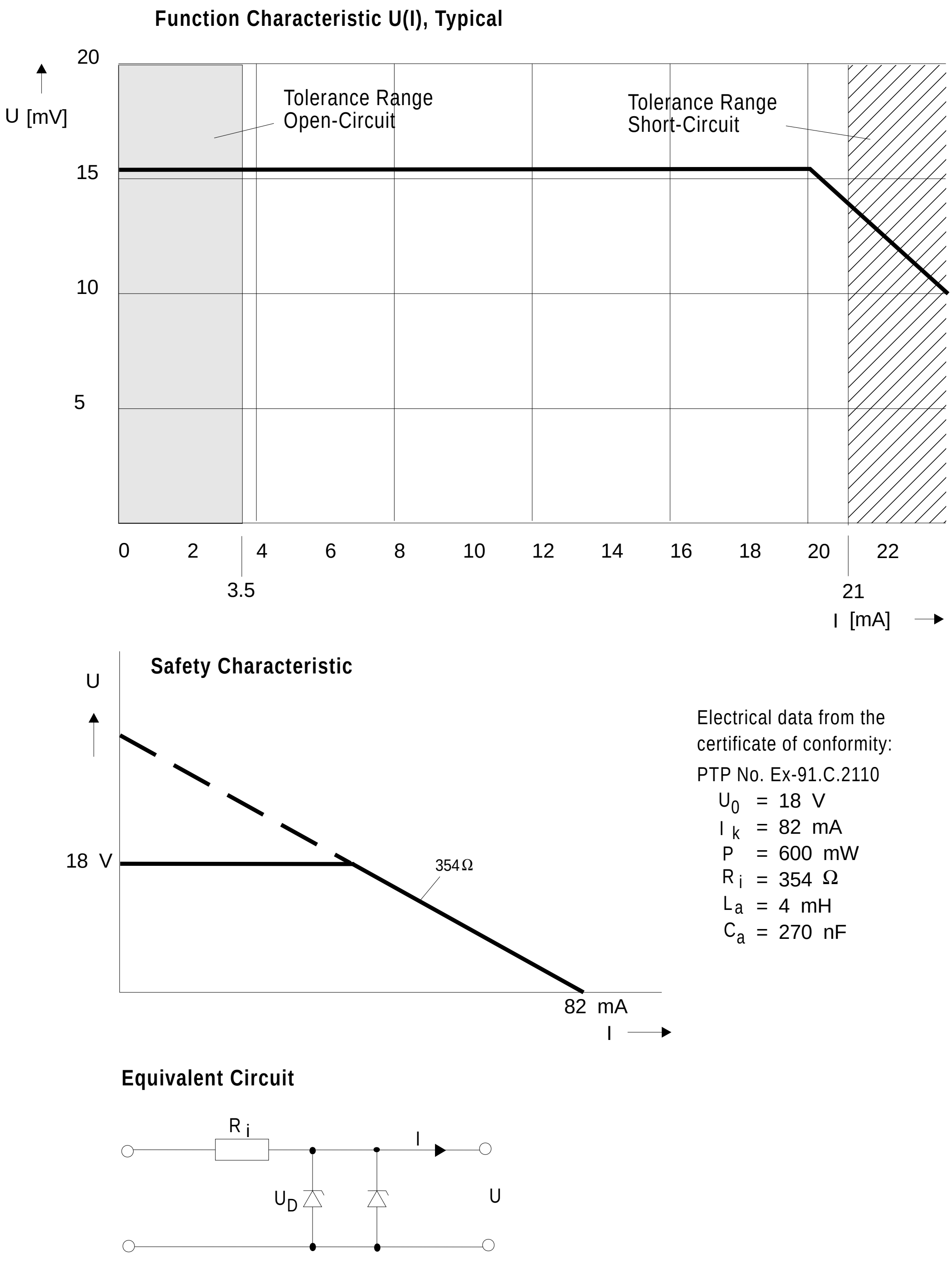


Figure 11.22 Input Characteristics of the 6ES5 467-8EE11 Ex Analog Input Module

Startup of the 6ES5 467-8EE11 Ex analog input module

You must set the intended mode of operation on the operating mode switch of the Ex analog input module. The switch is situated on the upper right of the module front.

Line frequency: Set the module to the line frequency with Switches 1 and 4. This selects the integration time of the A/D converters for optimum interference voltage suppression.

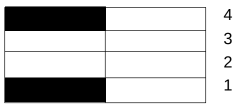
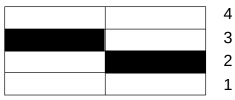
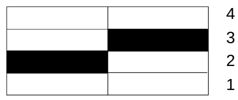
50 Hz line frequency	Integration time	20 ms
60 Hz line frequency	Integration time	16.66 ms

Operation: Use Switches 2 and 3 to set the number of channels you will allocate on the Ex analog input module.

Open-circuit: In the event of open-circuit of one of the lines to the sensor or in the sensor itself, the red LED lights up. Simultaneously, open-circuit error bit 0 in byte 1 is set for the faulty channel.

Short-circuit: In the event of a short-circuit of one of the lines to the sensor or in the sensor itself, the red LED lights up. Simultaneously, short-circuit error bit 0 in byte 1 is set for the faulty channel.

Table 11.6 Settings on the Operating Mode Switch for the 467-8EE11 Ex Analog Input Module

Function	Settings on the Operating Mode Switch	
Line frequency	50 Hz 	60 Hz 
Operation	Single channel (Ch0) 	Two-channel (Ch0 and Ch1) 

Analog value representation of the 6ES5 467-8EE11 Ex analog input module

Every analog process signal must be presented in a digital form to be processed by the CPU. The analog signals are converted to a binary number written in two bytes. The powers of two are in certain positions in the bit pattern (Table 11.7). Analog values are represented in two's complement.

Table 11.7 Representation of an Analog Input Value as a Bit Pattern

	High Byte								Low Byte							
Bit number	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Analog value representation	SN	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	X	X	OF

SN Sign bit	0 = "+", 1 = "-"
X Irrelevant bits	0 = Absolute measured value, up to 4095 units
OF Overflow bit	1 = Absolute measured value ≥ 4096 units

Shown in the following table is the analog value representation of the Ex analog input module in two-byte format.

Table 11.8 Value Representation of the 6ES5 467-8EE11 Ex Analog Input Module (Absolute Amounts)

Units	Measured Value in mA	High Byte	Low Byte	Range*)
> 4095	> 32.769	0 1 1 1 1 1 1 1	1 1 1 1 1 0 0 1	Overflow
4095 2561	31.992 20.008	0 1 1 1 1 1 1 1 0 1 0 1 0 0 0 0	1 1 1 1 1 0 0 0 0 0 0 0 1 0 0 0	Overrange
2560 2048 512	20.0 16.0 4.0	0 1 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Rated range
511 384 0 - 1	3.92 3.0 0.0 - 0.008	0 0 0 0 1 1 1 1 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1	1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 0	Overrange
≤ - 4095	≤ - 32.769	1 0 0 0 0 0 0 0	0 0 0 0 1 0 0 1	Transducer damaged

*) The converted value may also be in the negative range (e.g. FFF8H -> unit: -1) These deviations are caused by tolerances of the components used in the module.

Fault messages of the 6ES5 467-8EE11 Ex analog input module

The Ex analog input module indicates a fault on the red fault LED at the front of the module. A fault occurs when a value is no longer within the rated range, e.g. when the input current

- drops below a value of approx. 2 mA,
- or exceeds a value of approx. 22 mA.

The red fault LED flashes to indicate a fault on a channel. If the fault LED remains continuously lit, both channels are faulty.

Open-circuit: In the event of an open-circuit of one of the lines to the sensor or in the sensor itself, the red LED lights up. Simultaneously, open-circuit error bit 0 in byte 1 is set for the faulty channel.

Short-circuit: In the event of a short-circuit of one of the lines to the sensor or in the sensor itself, the red LED lights up. Simultaneously, short-circuit error bit 0 in byte 1 is set for the faulty channel.

Table 11.9 Fault Indications of the Ex 467 Analog Input Module

LED red	Bit No. in the Low Byte			Meaning
	2	1	0	
Off	X	X	0	No fault
On	X	X	1	Open-circuit < 2 mA
On	X	X	1	Overflow > 22 mA

11.8.2 6ES5 477-8EC11 Ex Analog Output Module 2 x 4 to 20 mA

The Ex 477 analog output module converts the bit pattern emitted by the CPU into analog output currents.

The Ex analog output module is certified as associated apparatus under type of protection [EEx ib] IIC. The Ex analog output module must be used together with the 6ES5 700-8EA11 Ex bus unit (Section 11.5). Additionally, the Ex 477 analog output module must be segregated from non-Ex modules with a 6ES5 497-8EA11 partition (Section 11.6). The actuators are powered by the module.

Connecting actuators to the 6ES5 477-8EC11 Ex analog output module

You need make no settings when connecting actuators to the Ex analog output module. You must observe the following before connecting the actuators:

- Permissible potential difference between outputs, 60 V AC max.
- Unused outputs are left open.

Figure 11.23 shows how to connect actuators to the current outputs of the 477 module.

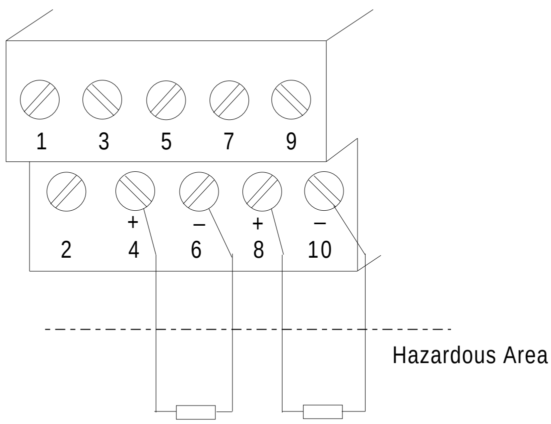
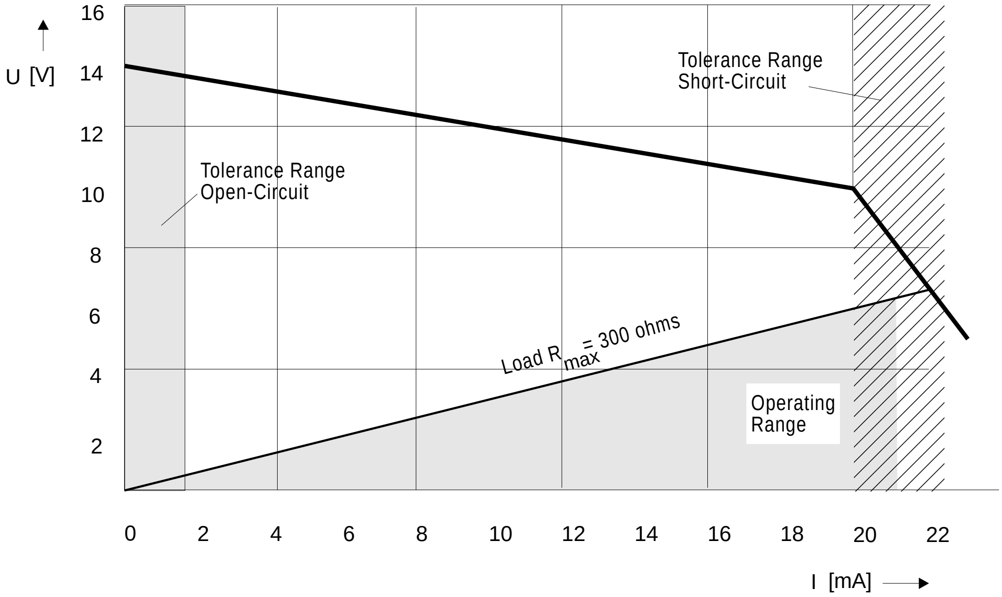
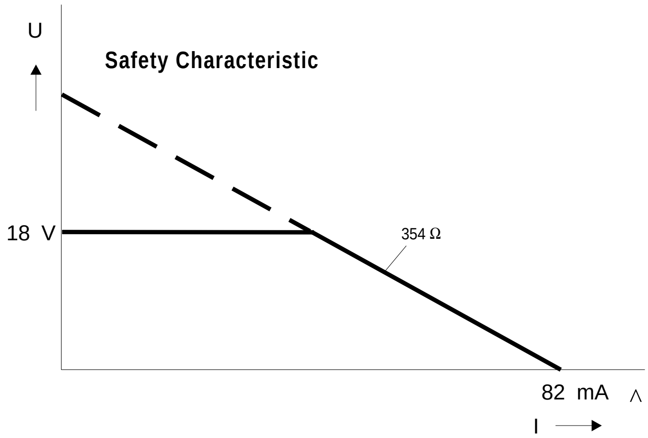


Figure 11.23 Connecting a Load to the Ex 477 Analog Output Module

Function Characteristic U(I), Typical





Electrical data from the certificate of conformity:
PTB No. Ex-91.C.2109

U_0 = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 Ω
L_a = 4 mH
C_a = 270 nF

Equivalent Circuit

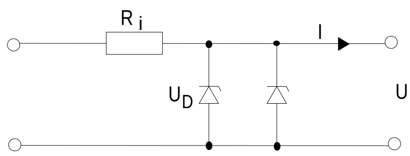


Figure 11.24 Output Characteristic of the 6ES5 477-8EC11 Ex Analog Output Module

Analog value representation of the 6ES5 477-8EC11 Ex analog output module

Table 11.10 shows how the analog value to be output must be stored in the process output image.

Table 11.10 Representation of an Ex Analog Output Value as a Bit Pattern

	High Byte								**Low Byte**							
Bit number	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Analog value representation	SN	2^{10}	29	2^8	2^7	26	2^5	2^4	2^3	2^2	2^1	2^0	X	X	X	X

X = Error bits (see Table 11.12)

Shown in the following table are the currents allocated to the bit patterns.

Table 11.11 Output Currents with the Ex 477 Analog Output Module (Unipolar)

Units	Output values [mA]	High Byte (PIQ)	Low Byte (PIQ)	Range
1280	24.0	0 1 0 1 0 0 0 0	0 0 0 0 x x x x	Overrange
1025	20.016	0 1 0 0 0 0 0 0	0 0 0 1 x x x x	
1024	20.0	0 1 0 0 0 0 0 0	0 0 0 0 x x x x	Rated range
512	12.0	0 0 1 0 0 0 0 0	0 0 0 0 x x x x	
1	4.016	0 0 0 0 0 0 0 0	0 0 0 1 x x x x	
0	4.0	0 0 0 0 0 0 0 0	0 0 0 0 x x x x	
- 1	3.984	1 1 1 1 1 1 1 1	1 1 1 1 x x x x	Overrange
- 256	0.0	1 1 1 1 0 0 0 0	0 0 0 0 x x x x	
- 512	- 4.0	1 1 0 0 0 0 0 0	0 0 0 0 x x x x	
- 1024	- 12.0	1 1 0 0 0 0 0 0	0 0 0 0 x x x x	
- 1280	- 16.0	1 0 1 1 0 0 0 0	0 0 0 0 x x x x	

Diagnostic functions of the 6ES5 477-8EC11 Ex analog output module

The Ex 477 analog output module indicates faults on the red fault LED at the front of the module. Additionally, the corresponding fault is acknowledged separately for each channel via the S5 bus. This information can be interpreted via the control program (PII).

Short-circuit: Shorts in the output circuit are not monitored.

Open-circuit: In the event of open-circuit of a line to the actuator or of the actuator itself, the red LED lights up. Simultaneously, the open-circuit error bit 0 in byte 1 is set for the faulty channel.

The meanings of the error bits are given in the following table:

The diagnostic message of the Ex analog output module is stored in the PII.

Table 11.12 Fault Indications of the Ex 477 Analog Output Module

LED red	Bit No. in Low Byte (PII)				Meaning
	3	2	1	0	
Off	0	0	0	0	No fault
On	0	0	0	1	Open-circuit (< 3.7 mA)
On	0	1	0	0	Overflow substitute value (21.99 mA)
On	0	1	0	0	Sign substitute value (4 mA)
On	0	1	0	0	Internal power supply fault
On	0	1	0	1	Open-circuit + substitute value

Note

The diagnostic data of the Ex analog output module which can be read back must be evaluated as digital signals. The FB 250 function block cannot be used for this purpose.

Responses in the event of incorrect programming

If the Ex analog output module is programmed by the users so that

- a current of less than 4 mA
- or a negative current

should be present at the output, a substitute value of 4 mA is output by the module.

If the Ex analog output module should have a current of > 22 mA = 1151 units, the module signals a fault and holds the current value at 22 mA.

11.8.3 Connecting Ex SMART Transducers to Ex Analog Input and Output Modules

Ex two-wire SMART transducers can be connected to the Ex analog input and output module. It is also possible to parameterize the SMART transducers during operation (see Figure 11.25); the Ex analog modules are HART-compatible. It is not possible to assign parameters via the Ex analog modules. For the Ex analog input module, an additional external resistor is required in the circuit (see Figure 11.26).

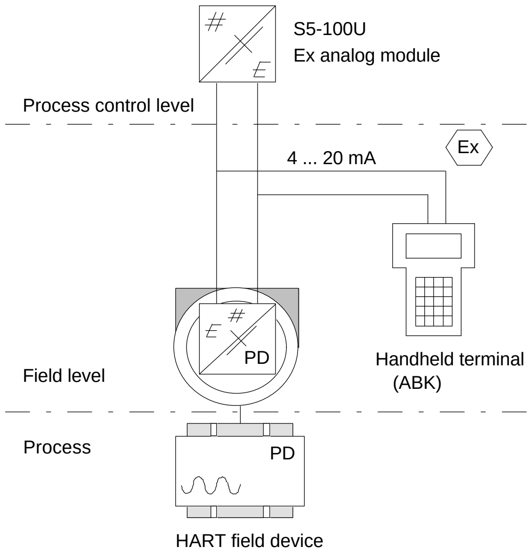


Figure 11.25 Connection of an Ex SMART Transducer to Ex Analog Modules

1. Operation of Ex SMART transducer with:

   a) Ex analog output module (6ES5 477-8EC11)

   The Ex analog output module permits trouble-free interaction with the Ex SMART transducers; even if the transducer is parameterized from the handheld terminal, the output signal during operation is not corrupted.

   b) Ex analog input module (6ES5 467-8EE11)

   If an Ex SMART transducer connected to an Ex analog input module is parameterized from a handheld terminal using the HART protocol, make sure that a 200 ohms/1.0 W resistor is connected in series since the current input of the S5-100 Ex analog input module has a low impedance. In addition, the maximum supply voltage (U_{iMU}) is only 11 V after fitting the resistor; this should also be taken into account when selecting a SMART transformer.

   Explanations concerning the supplementary resistance:
   According to the HART specification (ROSEMOUNT), the resistance of the circuitry leading to the transducer should be approximately 250 ohms.

   The overall resistance of the circuitry is composed of the following:

   - Input resistance of the Ex analog input module (R_{iAE});
   - Line resistance ($R_{L1/L2}$);
   - Internal resistance of the transducer (R_{iMU}).

   The input resistance of the Ex analog input module is 31.5 ohms and the line resistance is estimated at 10 ohms.This results in the supplementary external resistance of 200 ohms/1.0 W (R_{HART}).

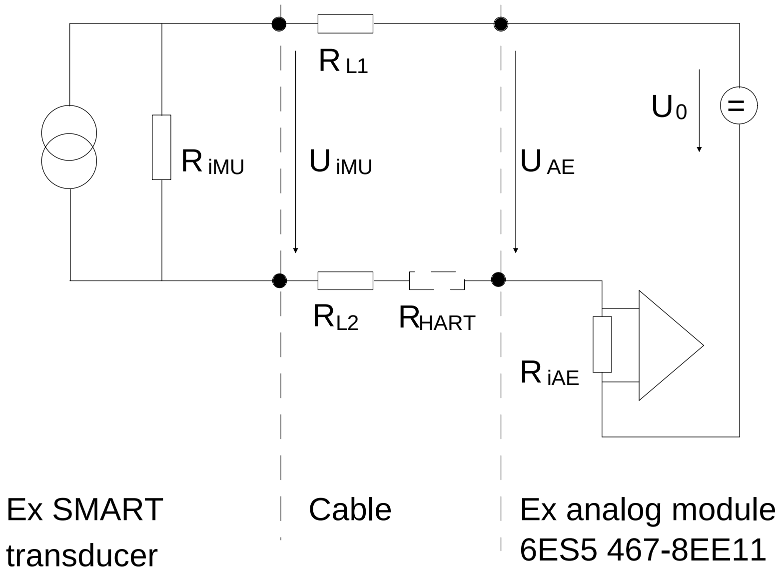


Figure 11.26 Circuit Including an Ex SMART Transducer and an Ex Analog Input Module (4 to 20 mA)

Legend:

U_0	= No-load voltage of Ex analog input module
U_{AE}	= Operating voltage of Ex analog input module
U_{iMU}	= Supply voltage of transducer
R_{iMU}	= Internal resistance of transducer
R_{iAE}	= Input resistance of Ex analog input module
$R_{L1/L2}$	= Line resistance
R_{HART}	= Supplementary resistance for HART mode (200 ohms/1.0 W)

2. Use of the external resistance in Ex zone 1 or 2

   If this resistance is used in hazardous areas, it is obligatory that the maximum permissible temperature be calculated.
   For this calculation, the fault current I_K specified in the relevant certificate of conformity for the Ex analog module is to be used.

   Temperature classes T1 to T6 (450 °C to 85 °C) can be determined from the temperature rise in the resistance.

   A heat test need not be performed if the external resistance is used outside the Ex area. The certificate issued by the Physikalisch-Technische Bundesanstalt for the Ex analog module is also valid for the external resistance. The entire circuit is still intrinsically safe in accordance with type of protection EEx ib IIC even after installing the resistance.

Note on SMART transducers

In addition to converting a physical magnitude into a proportional current in the range of 4 to 20 mA, Ex SMART transducers can also be parameterized via the signal lines by means of a handheld terminal. For this purpose, a data current signal with two different frequencies is superimposed on the current signal supplied by the Ex transducer.

11.8.4 6ES5 467-8EA11 Ex Analog Input Module 4 x ± 50 mV

The Ex analog input module of type 467-8EA11 transforms analog process signals supplied, for instance, by thermocouples into digital values so that these values can be processed by centralized modules of the S5-95U/100U and ET 100U/200U programmable controllers.

The analog input module is certified as associated electrical apparatus for type of protection [EEx ib] IIC. In order to be able to operate the module within a system, it must be incorporated in a 6ES5 700-8EA11 Ex bus unit (Section 11.5). Additionally, the Ex modules must be isolated from non-Ex modules by means of a 6ES5 497-8EA11 partition (Section 11.6). The four input channels (terminals 3 to 10) and the compensation input (terminals 1/2) are intrinsically safe. They are electrically isolated from the S5 bus but not from one another.

The Ex analog input module can be operated with one, two or four channels. When connecting thermocouples as transducers, there are various possibilities for compensation of the comparison point temperature:

- Stabilization of the comparison point temperature (e.g. 0 °C);
- Measurement of the comparison point temperature (e.g. with Pt 100) and arithmetic compensation via software;
- Connection of a compensation box;
- Using the module as a comparison point with integral temperature compensation.

Analog/digital conversion of the measured values is carried out using the dual-slope integration procedure. This suppresses any interference voltages originating in the supply system.

General remarks on connecting transducers to the 467-8EA11 module

When connecting thermocouples or other voltage sensors, the following rules should be adhered to:

- The following thermocouples can be connected to the 467-8EA11 module:

DIN 43710, Edition 12.85		DIN IEC 584, Edition 1.84	
Cu - Cu Ni	Type U(-200 to +600 °C)	Cu/Cu Ni	Type T (-200 to 400 °C)
Fe - Cu Ni	Type L (-200 to +900 °C)	Fe/Cu Ni	Type J (-210 to 1200 °C)
		Ni Cr/Ni	Type K (-270 to 1370 °C)
		Pt 10%/Rh/Pt	Type S (-50 to 1760 °C)
		Pt 13%/Rh/Pt	Type R (-50 to 1760 °C)
		Pt 30%/Rh/Pt 6% Rh	Type B (0 to 1820 °C)

- During multi-channel operation of the module, the channels should be assigned in ascending order. This reduces data cycle times.
- Terminals 1 and 2 are intended for connection of a compensation box.
- The terminals of unassigned inputs (even at the compensation input) must be shorted.
- The permissible difference between the input potentials and with respect to the central grounding point must not be exceeded.

Connecting thermocouples and voltage sensors

Both thermocouples and other voltage sensors can be connected to this module.

Only those voltage sensors that are certified as "intrinsically safe" or "associated apparatus" can be connected. The specifications in the relevant certificate of conformity (see Appendix A) must be adhered to under any circumstances.

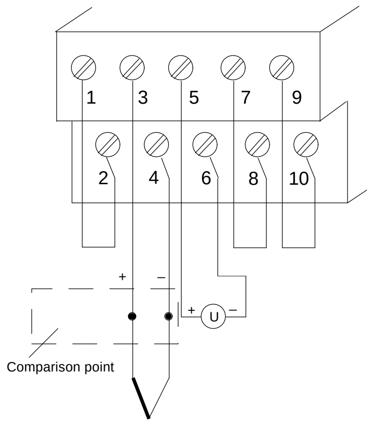


Figure 11.27 Connection of Thermocouples and Voltage Sensors

Connecting thermocouples to a compensation box

The compensation box supplies a compensation voltage which is a function of the temperature difference between the comparison point and the reference temperature. It must be matched to the type of thermocouple used. Therefore only thermocouples of one and the same type may be connected to the module in this mode. Parameterization switches S5/S6 on the front panel must be set to the following mode: "Compensation of comparison point - external".

Note: Since the compensation box is connected to the intrinsically safe circuits of the module (Figure 11.28), you may only use compensation boxes that are certified as "associated apparatus" with the type of protection required at the particular location.

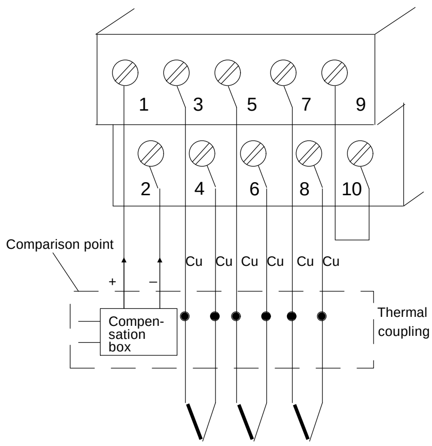


Figure 11.28 Connecting Thermocouples and a Compensation Box

Connecting thermocouples to a comparison point on the module

When connecting thermocouples direct to the terminal block of a module, the terminal block itself serves as a comparison point. In this case, the difference between the temperature of the terminal block and the reference temperature must be compensated for.

Set parameterization switches S5/S6 on the front panel to the type of thermocouple used. An internal temperature sensor compensates the measured value in accordance with the current temperature of the terminal block. In this mode, too, only thermocouples of the same type may be connected to a module.

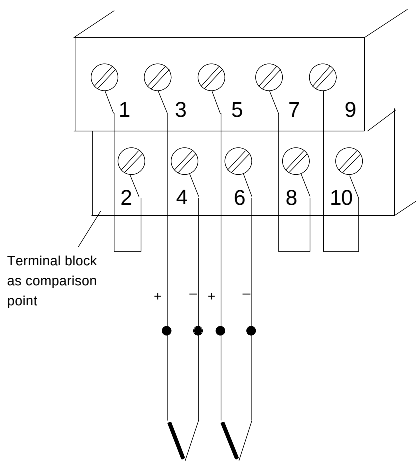


Figure 11.29 Connecting Thermocouples to a Comparison Point on the Module

Compensating the comparison point temperature

The thermal e.m.f. of the thermocouples specified in the DIN standards is referred to a comparison point temperature of 0 °C. Depending on the method employed for compensating the comparison point temperature, different arithmetic operations are required for determining the measured temperature value. These operations can be programmed in STEP 5 so that they can be processed by the programmable controller. Examples for calculating the temperature value according to the various compensation methods are given below.

- Stabilization of the comparison point temperature

If a stabilized comparison point temperature of 0 °C is used, you obtain the value for the measured thermal e.m.f. by multiplying the digital measured value displayed on the module by the degree of sensitivity of the module. Using this result, you can look up the measuring point temperature on the relevant pages of the DIN standard.

Example:

Digital measured value	Meas. val. = 400_{hex} = 1024 units
Thermocouple	Type J
Comparison point temperature	T_V = 0 °C
Sensitivity of the module	Sens. = 24.41 µV/unit
Measuring voltage	U_M = Meas. val. * Sens. = 1024 units * 24.41 µV/unit = 24996 µV

The DIN IEC 584 standard (basic values for thermal e.m.f.) specifies a temperature of 457 °C for a thermocouple of type J.

If the comparison point temperature is stabilized at another point than 0 °C, then proceed as described under "Measuring the comparison point temperature". Use the stabilized temperature value for the comparison point temperature T_V.

- Measuring the comparison point temperature

If the temperature of the comparison point is not stabilized, it must be measured, for example by means of a Pt 100 resistance thermometer and the measured value must be adjusted by way of an arithmetic operation.

Example:

Digital measured value	Meas. val. = 400_{hex} = 1024 units
Thermocouple	Type J
Thermal coefficient Type J	k_{Th} = 51.41 µV/degrees (at 20 °C)
Comparison point temperature	T_V = 40 °C
Module sensitivity	Sens. = 24.41 µV/unit
Measuring voltage	U_M = Meas. val. * sens. = 1024 units * 24.41 uV/unit = 24996 µV
Compensation voltage	U_K = k_{Th} * T_V = 51.41 µV/degrees * 40 degrees = 2056 µV
Compensated voltage	U_{corr} = U_M + U_k = 24996 µV + 2056 µV = 27052 µV

The DIN IEC 584 standard specifies a temperature of 494 °C for a thermocouple of type J.

Table 11.13 Drop of Thermal e.m.f. in the Case of a Deviation of the Comparison Point Temperature from the 0 °C Reference Temperature

Comparison Point Temperature	Drop of Thermal e.m.f.							
	Type T mV	Type U mV	Type J mV	Type L mV	Type K mV	Type S mV	Type R mV	Type B mV
20 °C	0.789	0.80	1.019	1.05	0.798	0.113	0.111	-0.003
50 °C	2.035	2.05	2.585	2.65	2.022	0.299	0.296	0.002
60 °C	2.467	2.48	3.115	3.19	2.436	0.365	0.363	0.006
70 °C	2.908	2.91	3.649	3.73	2.850	0.432	0.431	0.011

- Use of a compensation box

If a compensation box is used, a compensation voltage is superimposed on the measured voltage. The compensation voltage corresponds to the difference between the comparison point temperature and the reference temperature 0 °C.

Evaluation of the measured value is as under "Stabilization of the comparison point temperature at 0 °C" (see above).

- Internal compensation of the comparison point temperature

The module permits internal compensation of the comparison point temperature. An integral temperature sensor acquires the absolute temperature of the comparison point (in this case, the temperature of the module’s terminal block) and generates a compensation voltage depending on the thermocouple type selected (note the parameters for the setting) which is superimposed on the measured voltage. The compensation voltage is 52.06 µV/K for types J and L and 40.98 µV/K for thermocouple types K, T and U. Since the comparison point temperature measurement is absolute, a compensation must be carried out in relation to the reference temperature. If the reference temperature is 0 °C, the compensation must be -273 degrees.

Example:

Digital measured value	Meas. val. = 400_{hex} = 1024 units
Thermocouple	Type J
Thermal coefficient Type J	k_{Th} = 52.06 µV/degrees (at 20 °C)
Comparison point temperature	recorded automatically
Module sensitivity	Sens. = 24.41 µV/unit
Measuring voltage	U_M = Meas. val. * sens. = 1024 units * 24.41 µV/unit = 24996 µV
Compensation voltage	$U_K = k_{Thmod} * T_{corr}$ = 52.06 µV/degrees * (-273) degrees = 14212 µV
Compensated voltage	$U_{corr} = U_M + U_k$ = 24996 µV + (-14212) µV = 10784 µV

The DIN IEC 584 standard specifies a temperature of 200 °C for a thermocouple of type J.

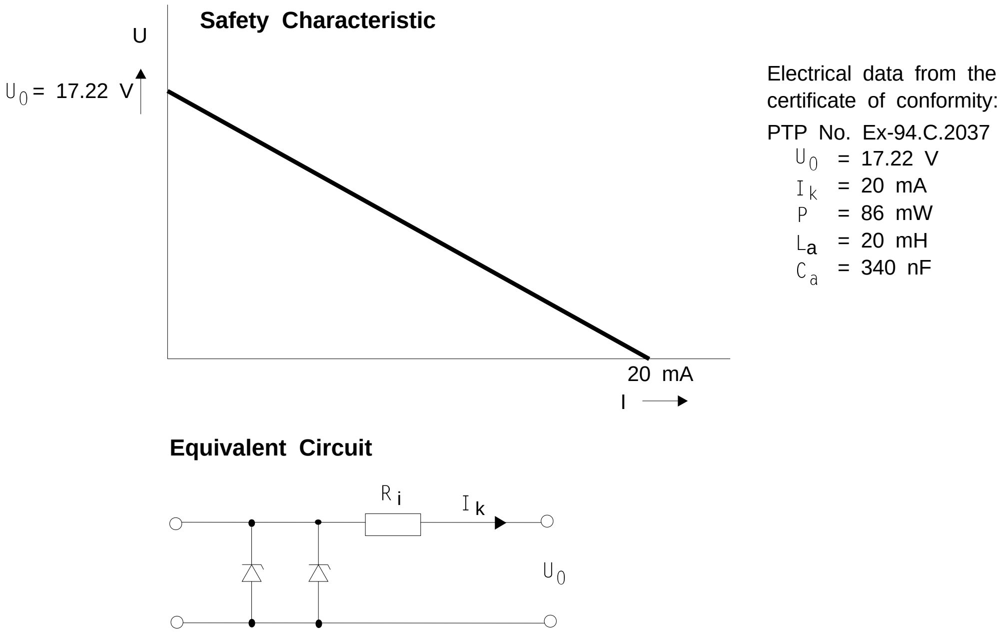


Figure 11.30 Safety Characteristic and Equivalent Circuit

Start-up of the 6ES5 467-8EA11 Ex analog input module

Use the two triple DIL switches on the front of the module for parameterizing the module. The switches are designated with "operating mode" and numbered from 1 to 3 or 4 to 6.

Operation Set the number of channels you require on the analog input module. The positions of switches 1 and 2 determine the number - 1, 2 or 4 - of active channels in accordance with the number of transducers connected. If less than 4 channels are selected, the address area is reduced and the measured values can be updated at shorter intervals.

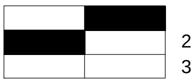
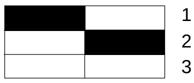
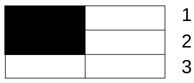
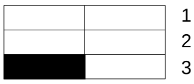
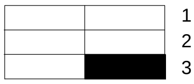
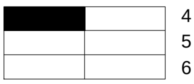
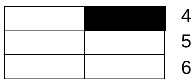
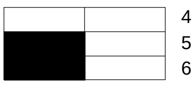
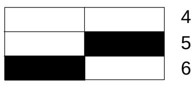
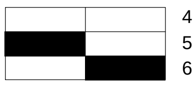
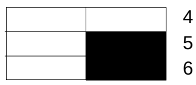
Line frequency Use switch 3 to set the line frequency available: 50 or 60 Hz. In this way, you can select the integration time for the A/D converters that ensures optimum interference voltage suppression.
Line frequency: 50 Hz → Integration time: 20 ms
Line frequency: 60 Hz → Integration time: 16 2/3 ms

Open-circuit If you have activated the open-circuit signalling function, the red LED above the operating mode switch lights up if one of the lines to the sensor (thermocouple) or the sensor itself is interrupted. The open-circuit error bit F (bit 1, byte 1) is simultaneously set for the faulty channel.

The module "detects" a open-circuit by applying a test current to the input terminals and then monitors the resulting voltage for a limit value. If the input signal is measured by means of a digital voltmeter, the test current pulses cause apparent signal variations. The test current is switched off by deactivating the open-circuit message.

Type of thermocouple Switches 6 and 5 are used for setting the type of the thermocouple connected if thermocouples are to be linked directly and the module itself is used as a comparison point (Figure 11.29). If an external comparison point is used, switches 5 and 6 are to be set to "external".

Table 11.14 Parameterizing the 6ES5 467-8EA11 Ex Analog Input Module

Function	**Settings of the Operating Mode Switch**			
Channels	1 Channel (Ch 0) 	2 Channels (Ch 0,1) 	4 Channels (Ch 0..3) 	
Line frequency	50 Hz 	60 Hz 		
Open-circuit test	"On" 	"Off" 		
Compensation of comparison point temperature	External or Type B 	Internal or Type K, T, U 	Internal or Type J, L 	Not permissible 

Analog value representation on the 467-8EA11 Ex analog input module

An analog process signal cannot be processed unless it is converted into digital format. The module therefore converts the analog measured voltage values into the respective digital numbers and represents these in a two-byte binary word in the two's complement. The 16-bit data word has 12 bits for the measured value, 1 sign bit and 3 bits for additional information (e.g. for fault recognition).

Table 11.15 Representation of an Analog Input Value as Binary Pattern

	High Byte								Low Byte							
Bit Number	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Analog Value Representation	SN	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	X	E	OF

SN	Sign bit	0 = "+", 1 = "-"
X	Irrelevant bits	
OF	Overflow bit	0 = Absolute amount of meas. val.: 4095 units max.
		1 = Absolute amount of meas. val.: greater or equal to 4096 units
E	Error bit	0 = No error
		1 = Error

The following table shows the digital value representation of the Ex analog input module in 2-byte format.

Table 11.16 Value Representation of the 467-8EA11 Module (Absolute Amounts)

Units	Measured Value in mV	High Byte	Low Byte	
≥ 4096	≥ 100.000	0000 0000	0000 00x1	Overflow
4095 2049	99.976 50.024	0111 1111 0100 0000	1111 10x1 0000 10x0	Overrange
2048 1024 512 1 0 -1 -1024 -2048	50.000 25.000 12.500 0.02441 0.00 - 0.02441 - 25.000 - 50.000	0100 0000 0010 0000 0001 0000 0000 0000 0000 0000 1111 1111 1110 0000 1100 0000	0000 00x0 0000 00x0 0000 00y0 0000 10x0 0000 0000 1111 10x0 0000 00x0 0000 00x0	Rated range
-2049 -4095	- 50.024 - 99.976	1010 0000 1000 0000	0000 00x0 0000 10x0	Overrange
≤ - 4096	≤ - 100.000	0000 0000	0000 00x1	Overflow
		xxxx xxxx	xxxx xx1x	Open circuit

For scaling and linearizing the analog value, the standard function blocks, such as FB 250 (read in analog value) and FB 117 (polygon function), can be used.

In FB 250, channel type 6 "fixed-point number bipolar" is to be set. FB 117 can be used to linearize the non-linear temperature/voltage characteristic of the thermocouples with the help of vertices. The vertices are specified in conjunction with the standard characteristics of the respective thermocouple types in the DIN IEC 584 or DIN 43710 standards.

Fault messages of the 467-8EA11 Ex analog input module

The module indicates faults in two different ways:

- Via the red fault LEDs on the front of the module;
- Signalling the fault to the system via the error bits in the low-order byte of the data word.

The faults are detected and signalled for each individual channel. The module recognizes the following types of fault:

- Overflow of the measuring range: input voltage ≥ 100 mV or ≤ 100 mV;
- Open-circuit (for approx. ≤ 100 nF).

A open-circuit is signalled if the input resistance exceeds approx. 6 kohms. The following table lists all fault indications output by the module.

Table 11.17 Fault Indication for a Channel of the 467-8EA11 Ex Analog Input Module

Resd LED	**Bit No. in Low Byte**				**Meaning**	
	3	2	1	0	Switch 4	
Off	X	X	0	0	On	No fault
On	X	X	1	0	Off	Open-circuit test disabled
On	X	X	1	X	On	Open-circuit
Off	X	X	X	1	-	Overflow

Note

Switch 4 - open-circuit test On/Off - must always be set to "On" (at the front of the module) in normal operation. The open-circuit test may also be disabled for maintenance and testing purposes. The module then responds as in the case of a open-circuit.

11.8.5 6ES5 467-8EF11 Ex Analog Input Module 2 x Pt100 (± 500 mV)

The 467-8EF11 Ex analog input module transforms electrical resistance values - especially values from Pt100 resistance thermometers - into digital values, which can be processed by centralized modules of the S5-95/100 programmable controllers and the ET 100/200 distributed I/O system.

The analog input module is certified as associated apparatus with type of protection [EEx ib] IIC. In order to be able to operate the module within a system, it must be incorporated in a 6ES5 700-8EA11 Ex bus unit (see Section 11.5). Additionally, the Ex module must be isolated from non-Ex modules by means of a 6ES5 497-8EA11 partition (see Section 11.6). The two input channels are intrinsically safe. They are electrically isolated from the S5 bus but not against one another.

The Ex analog input module can be operated with one or two channels. The module has an extremely stable 2.5 mA power supply for measuring resistances in the range from 0 to 200 (400) ohms (-200 to +850 °C in the case of Pt 100). The voltage applied to the resistance thermometer is measured in Kelvin. This ensures high-precision measuring results.

The resistances can be connected via two, three or four wires. A second measuring range, called climatic measuring range, permits measurements with a higher resolution, i.e. in the range from 60 to 140 ohms (-100 to +100 °C in the case of the Pt100). This range is available only for two-wire and four-wire circuits.

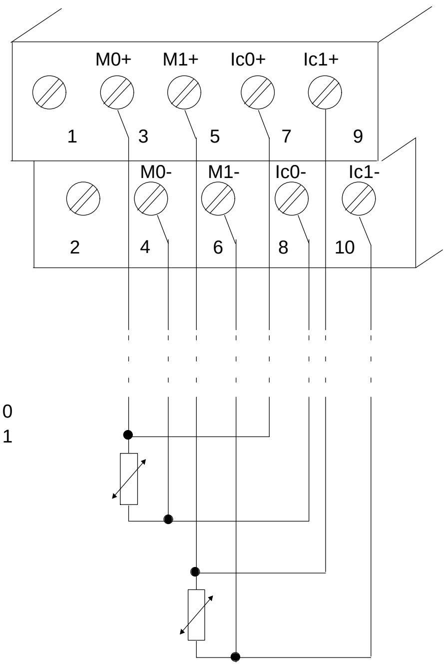
Analog/digital conversion of measured values is carried out using the dual-slope integration procedure. This suppresses any interference voltages originating in the supply system.

General remarks on connecting transducers to the 467-8EF11 module

When connecting Pt100 resistance thermometers or other resistance-type sensors, the following rules should be adhered to:

- During single-channel operation of the module, channel 0 should be used. This reduces data cycle times.
- The terminals of unused inputs must be shorted.
- The permissible difference between the input potentials and with respect to the central grounding point must not be exceeded.

Pt100 resistance thermometers in a four-wire circuit



Assignment:
(3/4): Measuring line M0
(5/6): Measuring line M1
(7/8): Constant-current line Ic 0
(9/10):Constant-current line Ic 1

Figure 11.31 Connection of Resistance Thermometers in a Four-Wire Circuit

Pt100 resistance thermometers in a two-wire circuit

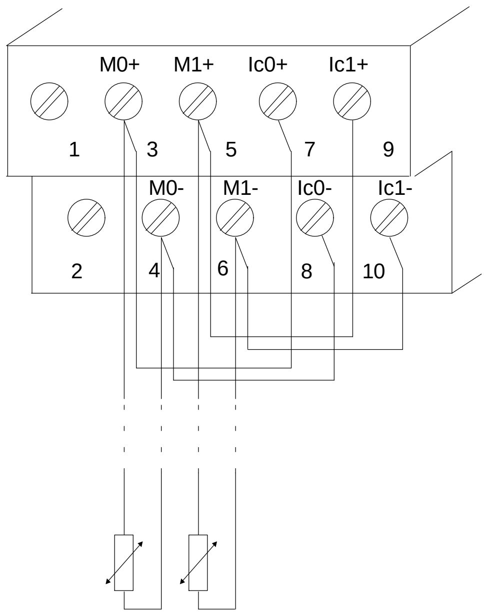


Figure 11.32 Connection of Resistance Thermometers in a Two-Wire Circuit

PT 100 resistance thermometers in a three-wire circuit

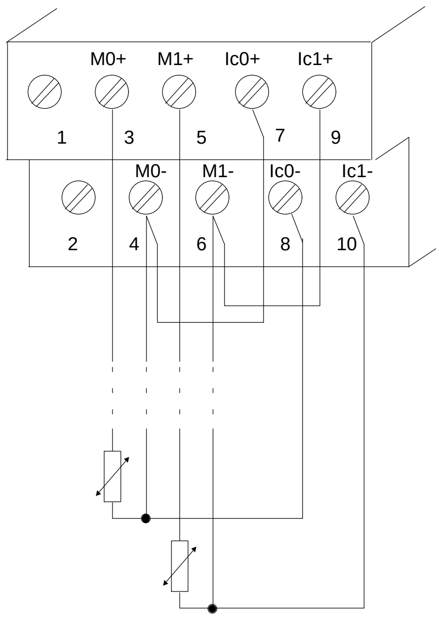


Figure 11.33 Connection of Resistance Thermometers in a Three-Wire Circuit

Voltage measurement with the 467-8EF11 module

Besides the connection of resistance thermometers, the analog input module also permits the measurement of voltages within the rated range ± 500 mV.

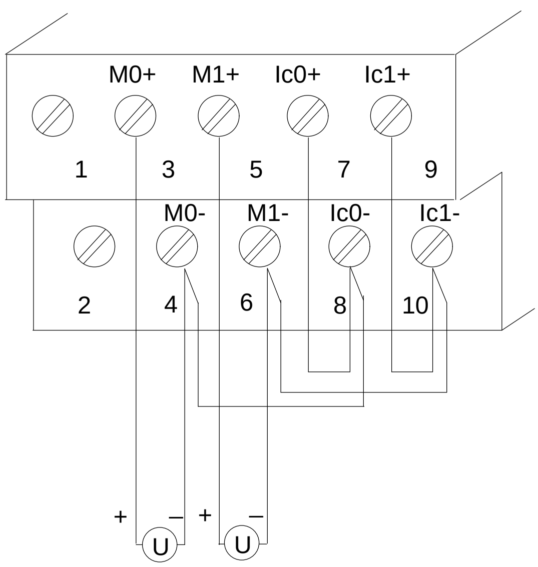
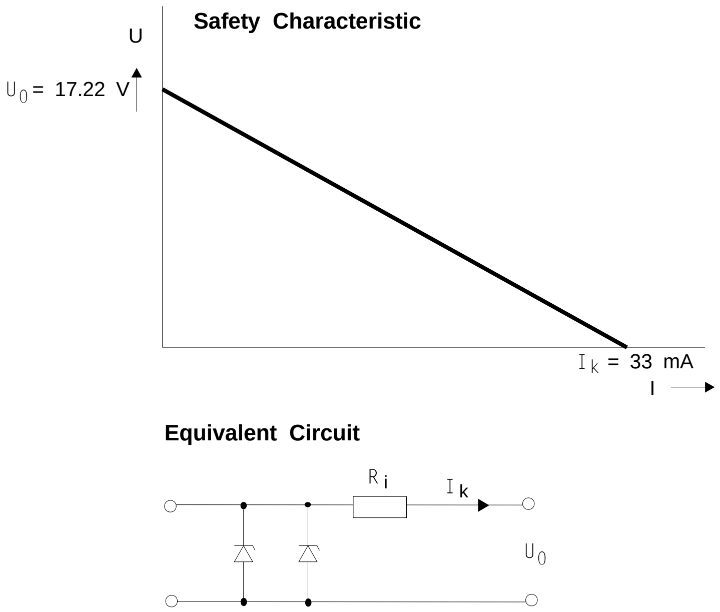


Figure 11.34 Connection of Voltage Sensors



Electrical data from the certificate of conformity:
PTP No. Ex-94.C.2036

U_0 = 17.22 V
I_k = 33 mA
P = 142 mW
L_a = 10 mH
C_a = 340 nF *)

*) When connecting to sensors with the highest values U = ± 1 V, I = 20 mA which cause voltage or current to increase by these values:
L_a = 10 mH, C_a = 240 nF

Figure 11.35 Safety Characteristic and Equivalent Circuit

Start-up of the 467-8EF11 Ex analog input module

Use the two triple DIL switches on the front of the module for parameterizing the module. The switches are designated with "operating mode" and numbered from 1 to 3 or 4 to 6.

Operation Set the number of channels you require on the analog input module. The positions of switches 1 and 2 determine the number - 1 or 2 - of active channels in accordance with the number of transducers connected.

Line frequency Use switch 3 to set the line frequency available: 50 or 60 Hz. In this way, you can select the integration time for the A/D converters that ensures optimum interference voltage suppression.
Line frequency: 50 Hz → Integration time: 20 ms
Line frequency: 60 Hz → Integration time: 16 2/3 ms

Open-circuit If you have activated the open-circuit signalling function (switch 4), the red LED above the operating mode switch lights up if one of the lines to the sensor or the sensor itself is interrupted. The open-circuit error bit F (bit 1, byte 1) is simultaneously set for the faulty channel.

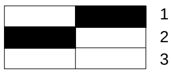
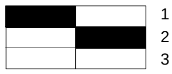
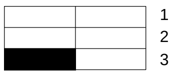
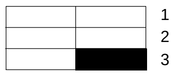
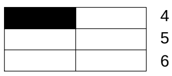
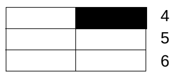
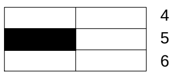
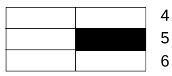
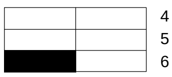
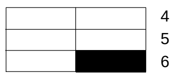
The module "detects" a open-circuit by applying a test current to the input terminals and then monitors the resulting voltage for a limit value. If the input signal is measured by means of a digital voltmeter, the test current pulses cause apparent signal variations. The test current is switched off when deactivating the open-circuit message.

Measuring range Switch 5 is used for determining the measuring range (standard or climatic range, see above).

Sensor connection Switch 6 is used for setting the type of connection of the transducer (4/2 or 3-wire circuit).

For voltage measurement, the module must be set to "4/2 wire operation" and "standard measuring range".

Table 11.18 Parameterizing the 6ES5 467-8EF11 Ex Analog Input Module

Function	Settings of "Operating Mode" Switch	
Channels	1 Channel (Ch 0) 	2 Channels (Ch 0,1) 
Line frequency	50 Hz 	60 Hz 
Open-circuit test	"Off" 	"On" 
Measuring range	Standard range 	Climatic range 
Sensor connection	3-wire circuit 	4/2-wire circuit 

Analog value representation on the 467-8EF11 Ex analog input module

An analog process signal cannot be processed unless it is converted into digital format. The module therefore converts the analog measured voltage values into the respective digital numbers and represents these in a two-byte binary word in the two’s complement. The 16-bit data word has 12 bits for the measured value, 1 sign bit and 3 bits for additional information (e.g. for fault recognition).

Table 11.19 Representation of an Analog Input Value as Binary Pattern

	High Byte								**Low Byte**							
Bit Number	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Analog Value Representation	SN	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	X	E	OF

SN	Sign bit	0 = "+", 1 = "-"
X	Irrelevant bits	
OF	Overflow bit	0 = Absolute amount of meas. val.: 4095 units max.
		1 = Absolute amount of meas. val.: greater or equal to 4096 units
E	Error bit	0 = No error
		1 = Error

Table 11.20 shows the digital value representation of the 467-8EF11 Ex analog input module in 2-byte format both for the standard range and the climatic range (i.e. higher resolution in the range from -100 °C to +103 °C; parameterization via switch 5).

The assignment of temperature to base values of the measuring resistance is based on DIN standard 43760 "Electrical thermometers".

Table 11.20 Value Representation of the 467-8EF11 Module (Absolute Amounts)

Standard range, Pt100

Units	Degrees C	Ohms	mV	High Byte	Low Byte (T F OV)	
≥ 4096	Undefined	≥ 400.00	≥ 1000.0	0000 0000	0000 00x1	Overflow
4095 3997 3996 2049	Undefined Undefined 850.00 266.69	399.90 390.33 390.26 200.10	999.76 975.83 975.65 500.24	0111 1111 0111 1100 0111 1100 0100 0000	1111 10x0 1110 10x0 1110 00x0 0000 10x0	Overrange
2048 1024 512 189	266.42 0.00 -125.14 -200.00	200.00 100.00 50.00 18.49	500.00 250.00 125.00 46.23	0100 0000 0010 0000 0001 0000 0000 0101	0000 00x0 0000 00x0 0000 00y0 1110 10x0	Rated range
188 1 0	Undefined Undefined Undefined	18.36 0.61035 0.00	45.89 0.24414 0.00	0000 0101 0000 0000 0000 0000	0000 00x0 0000 00x0 0000 00y0	Undefined

Climatic range, Pt100

Units	Degrees C	Ohms	mV	High Byte	Low Byte (T F OV)	
≥ 4096	Undefined	≥ 140.00	≥ 100.00	0000 0000	0000 00x1	Overflow
4095 2049	103.92 51.60	139.99 120.01	99.976 50.024	0111 1111 0100 0000	1111 10x0 0000 10x0	Overrange
2048 1024 512 1 0 -1 -512 -1024 -2048	51.58 25.69 12.82 0.025 0.00 -0.025 -12.77 -25.49 -50.78	120.00 110.00 105.00 100.01 100.00 99.99 95.00 90.00 80.00	50.000 25.000 12.500 0.02441 0.00 -0.02441 -12.500 -25.000 -50.000	0100 0000 0010 0000 0001 0000 0000 0000 0000 0000 1111 1111 0001 0000 1110 0000 1100 0000	0000 00x0 0000 00x0 0000 00x0 0000 10x0 0000 00x0 1111 10x0 0000 00x0 0000 00x0 0000 00x0	Rated range
-2049 -4095	-50.80 -100.60	79.99 60.01	-50.024 -99.976	1010 0000 1000 0000	0000 00x0 0000 10x0	Overrange
≤ -4096	≤ -100.63	≤ -60.00	≤ -100.000	0000 0000	0000 00x1	Overflow

For scaling and linearizing the analog value in connection with the Pt100, the standard function blocks, such as FB 250 (read in analog value) and FB 117 (polygon function), can be used.

In FB 250, channel type y = 4 "Unipolar representation " is to be set. FB 117 can be used to linearize the non-linear temperature/voltage characteristic of the Pt100 with the help of vertices. The vertices are specified in conjunction with the standard characteristics of the Pt100 in the DIN IEC 751 standard.

Fault messages of the 467-8EF11 Ex analog input module

The module indicates faults in two different ways:

- Via the red fault LEDs on the front of the module;
- Signalling the fault to the system via the error bits in the low-order byte of the data word.

The faults are detected and signalled for each individual channel. If one of the fault LEDs lights up, a fault has occurred on the associated channel. The module recognizes the following types of fault:

- Overflow of the measuring range: input voltage ≥ ±1 V;
- Open-circuit.

The following table lists all fault indications output by the module.

Table 11.21 Fault Indication for a Channel of the 467-8EA11 Ex Analog Input Module

Red LED	**Bit-No. in Low Byte**				**Meaning**	
	3	2	1	0	Switch 4	
Off	X	X	0	0	On	No fault
On	X	X	1	0	Off	Open-circuit test disabled
On	X	X	1	X	On	Open-circuit
Off	X	X	X	1	-	Overflow

Note

Switch 4 - open-circuit test On/Off - must always be set to "On" (at the front of the module) in normal operation. The open-circuit test may also be disabled for maintenance and testing purposes. The module then responds as in the case of a open-circuit.

11.8.6 Analog Value Function Blocks FB 250 and FB 251

Reading and scaling an analog value - FB 250

This function block reads an analog value of an Ex analog input module, and issues a value XA at the output in a range defined (scaled) by the user.

The type of analog value representation of the module (channel type) must be specified in parameter KNKT. The user defines the desired range with the parameters for upper limit OGR and lower limit UGR.

Table 11.22 Invoking and Assigning Parameters to FB 250

Parameter	Meaning	Type	Assignments	STL
BG	Slot number	D KF	0 to 7	**; JU FB 250** **NAME: RLG:AE** **BG :** **KNKT :** **OGR :** **UGR :** **EINZ :** **XA :** **FB :** **BU :**
KNKT	Channel number Channel type	D KY	KY = x,y x= 0 to 3 y= 3 to 6 3: Value representation (4 to 20mA) 4: Unipolar representation 5: Absolute value, bipolar 6: Fixed point no., bipolar	
OGR	Upper limit of output value	D KF	-32768 to +32767	
UGR	Lower limit of output value	D KF	-32768 to +32767	
EINZ	Not relevant			
XA	Output value	A W	Scaled analog value "0" for open-circuit	
FB	Fault bit	A BI	"1" for open-circuit, invalid channel or slot number or invalid channel type	
BU	Overrange	A BI	"1" if rated range is exceeded	

Scaling diagram

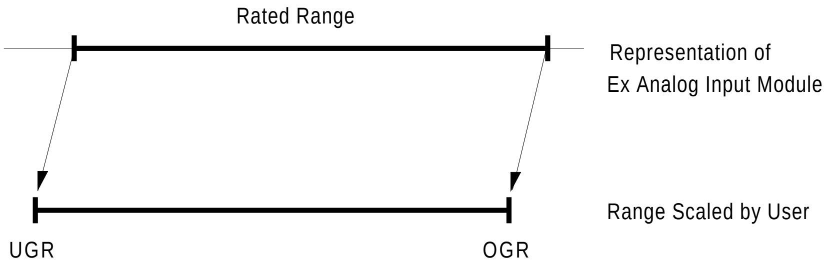


Figure 11.36 Scaling Diagram of FB 250

Analog value output - FB 251

Analog values can be output to Ex analog output modules with this function block. Values from the range between the parameters for lower limit UGR and upper limit OGR are converted to the rated range of the particular module.

Table 11.23 Invoking and Assigning Parameters to FB 251

Parameter	Meaning	Type	Assignments	STL
XE	Analog value to be output	I W	Input value (two's complement) in range UGR to OGR	**; JU FB 251** **NAME: RLG:AA**
BG	Slot number	D KF	0 to 7	**XE :**
KNKT	Channel number Channel type	D KY	KY=x,y x= 0;1 y= 0;1 0: Unipolar representation 1: Fixed point no., bipolar	**BG :** **KNKT :** **OGR :** **UGR :** **FEH :**
OGR	Upper limit of output value	D KF	-32767 to +32767	**BU :**
UGR	Lower limit of output value	D KF	-32767 to +32767	**BU :**
FEH	Error in presetting limit	A BI	"1" if UGR = OGR, for invalid channel or slot number or invalid channel type	**BU :**

Table 11.23 continued

Parameter	Meaning	Type	Assignments	STL
BU	Input value exceeds UGR or OGR	A BI	If "1", XE is out of range (UGR; OGR). XE assumes limit value.	

Example: Indicating the refilling amount for a tank

The refilling amount for a cylindrical 30 m^3 tank is to be indicated on a three-digit display. The individual digits must be set with BCD code.

The filling height is determined by a reflection and echo measurement with a range of 80 to 2000 cm using a transducer (4 to 20 mA).

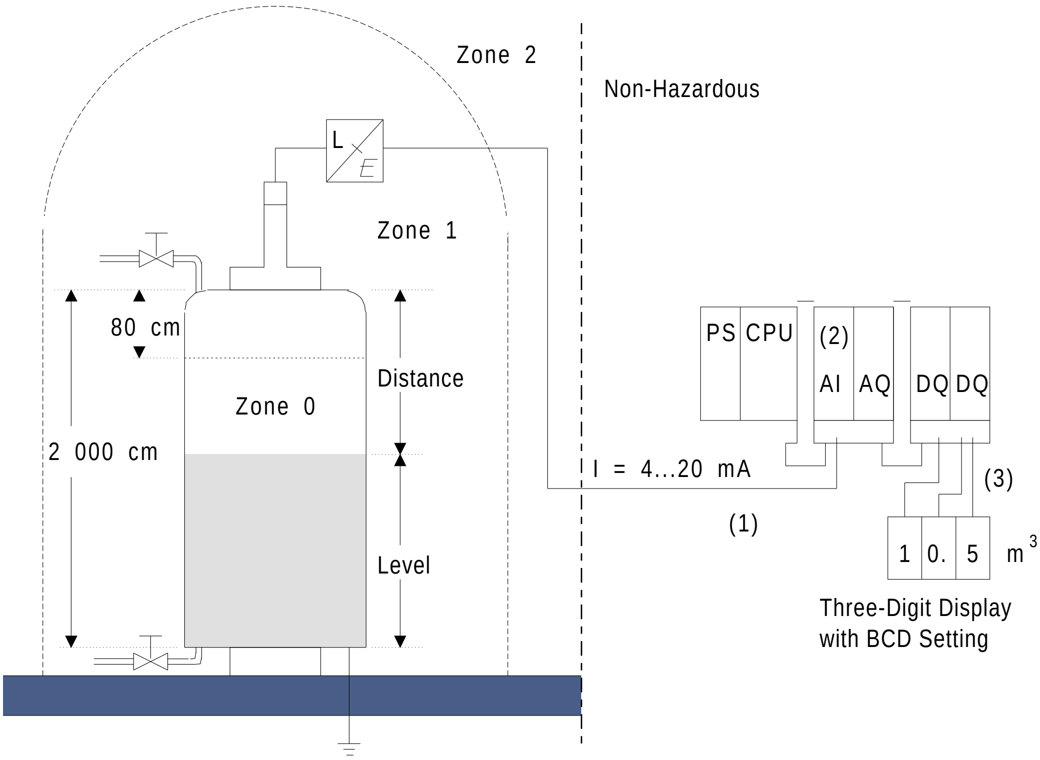


Figure 11.37 Basic Diagram of the Example for Indicating the Refilling Amount for a Tank

(1) The level transducer provides a constant current in the range 4 to 20 mA, which is proportional to the distance between sensor and liquid. The current is fed to the Ex analog input module at Slot 0, Channel 0.

(2) The FB 250 converts the range 4 to 20 mA to the range 0 to 30 m^3. This value is stored as a fixed point number in flag word 1. Parameter assignment takes place in the invoking block. The fixed point number is converted to a BCD number with FB 241.

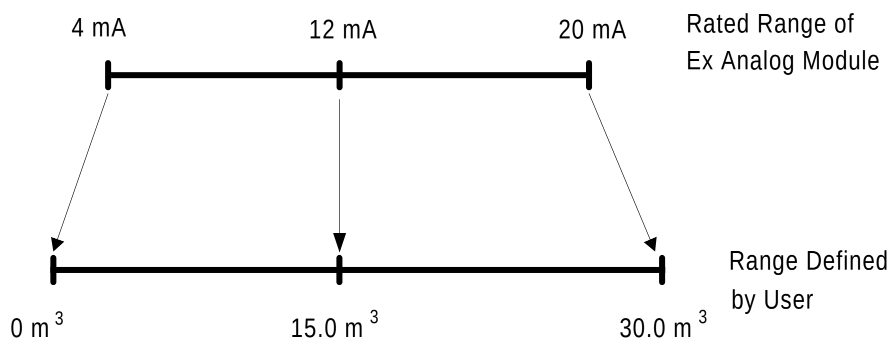


Figure 11.38 Conversion of the Rated Range to the Defined Range

Program segment for converting the measured signal to physical units

STL	Explanation
JU FB 250 Name : RLG:AE BG : 0 KNKT : 0.3 OGR : 300 UGR : 0 EINZ : XA : FW 1 FB : M0.0 BU : M0.1 JU FB 241 . . .	Unconditional call Slot 0 Channel 0, channel type 3 Upper limit: 30.0 m^3 Lower limit: 0.0 m^3 No significance Store refilling amount in flag word 1 as fixed point number "1" if open-circuit "1" if tank overfilled Conversion: fixed point no. to BCD no.

(3) The BCD number is stored in flag bytes 11 to 13. The number is output via two 8-channel digital output modules at Slots 2 and 3. BCD tetrads 5 and 6, stored in flag byte 11, need not be output because the number has only 3 digits.

Program segment for reading out the BCD number

STL	Explanation
. . . L FW 12 T QW 2 BE	Read tetrads 0 to 3 of the BCD number and transfer them to the output modules.

Determining the tank content

The tank content is determined from the refilling amount.

STL	Explanation
L KF +300	Maximum tank content
L FW 1	Refilling amount
-F	Form the difference
T FW 20	Store tank content in FW 20
. . .	

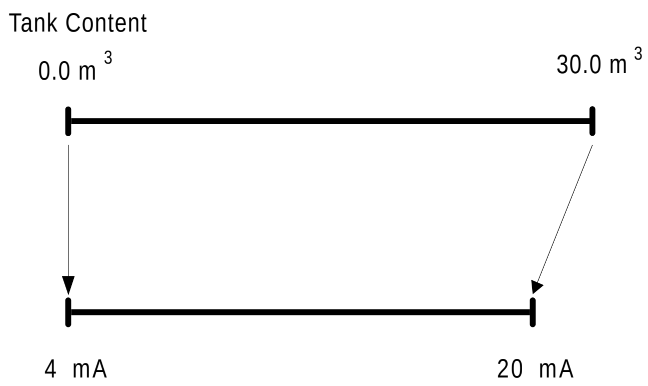


Figure 11.39 Conversion of Analog Value to Rated Range

Parameters UGR and OGR of FB251 relate to the rated range of the Ex analog output module. Parameter UGR must therefore be assigned the value -300.

STL	Explanation
. . .	
JU FB 251	Unconditional call
Name : RLG:AA	
XE : FW 20	Tank content
BG : 1	Slot 1
KNKT : 0.1	Channel 0, channel type 1
OGR : 300	Upper limit: 30.0 m^3
UGR : -300	Lower limit: -30.0 m^3
FEH : M0.2	"1" if open-circuit
BU : M0.3	"1" if tank overfilled
BE	

12 Module Addressing

Figures

12 Module Addressing

To allow the inputs and outputs to be selected, they must be assigned particular addresses. The assignment of addresses is different for the S5-95U/S5-100U PLC and the ET 100U/ET 200U:

- S5-95U / S5-100U PLC: fixed slot addressing
- ET 100U / ET 200U: variable slot-independent addressing

12.1 Addressing of the S5-95U/S5-100U PLC

The I/O addresses are oriented on the module slots. This means that as soon as you have snap-fitted a module at a slot on a bus unit, the module is assigned a slot number and, therefore, a fixed byte address in one or both process images.

Sensors and actuators are connected at the connection block of the Ex bus unit.

You specify the channel number by selecting the terminal.

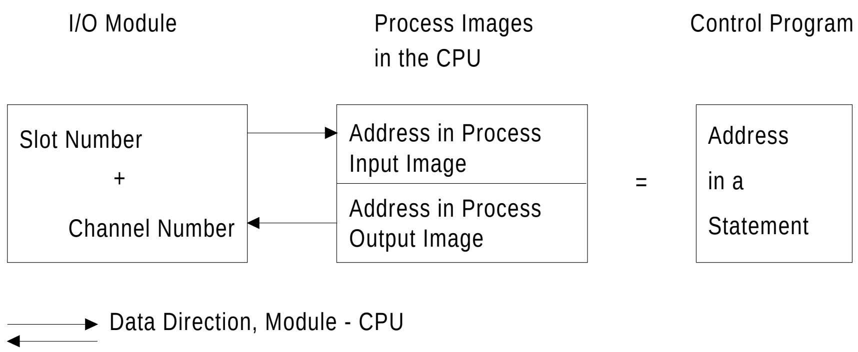


Figure 12.1 Addressing

12.1.1 Slot Numbering in the S5-95U/S5-100U PLC

The PLC can be assembled in up to four tiers. You can use up to 16 bus units (32 slots). The slots have consecutive numbering. This begins with slot number "0" to the right of the CPU. Whether or not a module is inserted does not affect the numbering.

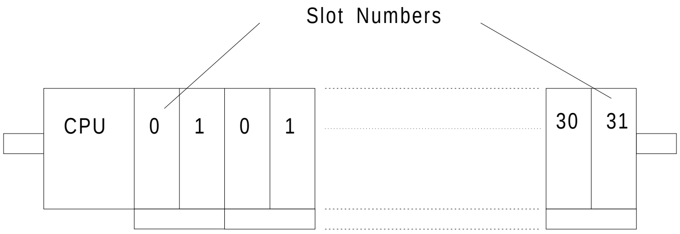


Figure 12.2 Consecutive Numbering of Slots for a Single-Tier Arrangement

If the programmable controller is assembled over two or more tiers, numbering of the expansion tiers continues from the slot on the extreme left.

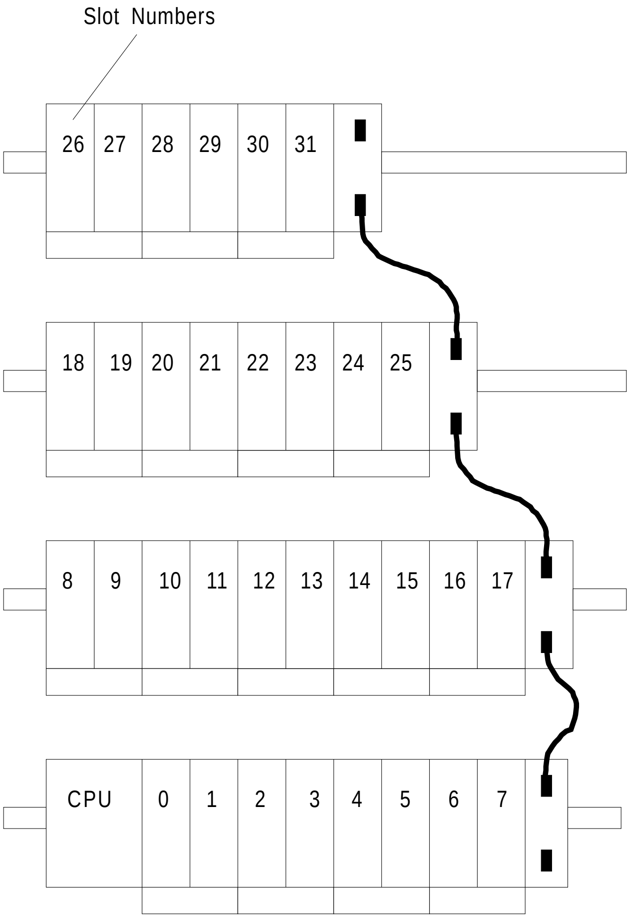


Figure 12.3 Slot Numbering for Multi-Tier Arrangement

When expanding, you add the new bus units to the top tier and to the right of the last bus unit. Otherwise you change the slot numbering. You would then have to take this into account in the control program.

> **Note**
>
> After each expansion, ensure that the addressing in the control program agrees with the actual configuration.

12.1.2 Addressing of Digital Modules in the S5-95U/S5-100U PLC

Digital modules can be inserted at all slots (0 to 31). Two information states per channel ("0" or "1", "OFF" or "ON") can be transferred from or to a digital module.

Each channel of a digital module is thus represented by a bit. Each bit must therefore be assigned its own number. This results in the following form for a digital address:

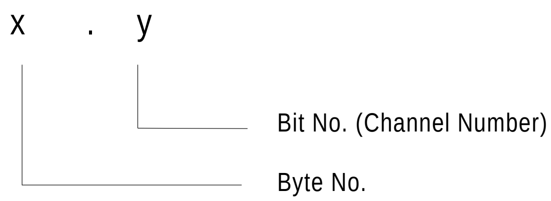


Figure 12.4 Structure of a Digital Address

Address X.Y consists of the following two components:

Byte address X (slot number X)

The byte address is given by the slot number at which the module is inserted.

Channel number Y (bit address Y)

The channel number is given by the connection of actuators or sensors to the terminals on the terminal block. The allocations of channel numbers and numbers of terminals are printed on the front plate of the module.

> **Note**
>
> Four-channel digital modules can only be addressed with channel numbers 0 to 3. Channel numbers 4 to 7 printed on the front plates are only relevant in the ET 100U system.

12.1.3 Addressing of Analog Modules in the S5-95U/S5-100U PLC

Analog modules can only be used at slots 0 to 7. Although only the information "0" or "1" ("OFF" or "ON") per channel can be transferred from or to a digital module (memory requirement of 1 bit), 65536 different items of information per channel can be transferred from or to an analog module (memory requirement of 16 bits = 2 bytes = 1 word). The modules are addressed with byte or word-oriented load or transfer operations.

The increased memory requirement is taken into account by the PLC when an analog module is inserted:

- Eight bytes (= four words) are reserved per slot.
- Two bytes (= one word) are thus reserved per channel.
- The address range of the slot is switched over.
- The permissible address space ranges from Byte 64 (Slot 0, Channel 0) to Byte 127 (Slot 7, Channel 3).

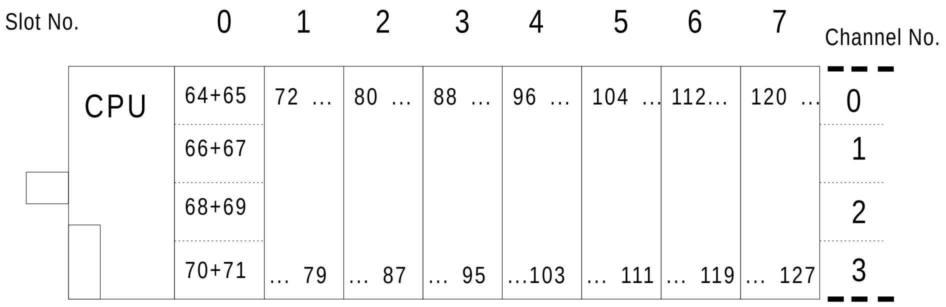


Figure 12.5 Address Assignments for Analog Modules

Examples

1. Bytes 88 + 89 = analog module at Slot 3, Channel Number 0

2. Address of Channel 1 of an analog module at Slot 5?
   Answer: Bytes 106 + 107

> **Note**
>
> Arbitrary combinations of analog and digital modules are allowed at Slots 0 to 7.

12.2 Addressing in the ET 100U/ET 200U Systems

Address assignments of Ex modules in the ET 100U and ET 200U are made via COM ET 100 and COM ET 200 (manual for the ET 100U and ET 200U). Given in the following are some notes on addressing an ET 100U/ET 200U station.

Before configuring a slave station (ET 100U/ET 200U), you must:

- Separate the address ranges for digital and analog modules to avoid address overlaps

- Define the configuration of the individual stations (subsequent modifications and expansions result in difficulties with address assignments)

Example for organizing the digital and analog I/O area:

- Use address "0" as the first free address for digital modules.

- Enter "128" as the first free address for analog modules.

This organization of the I/O area corresponds to the usual one for the SIMATIC normal area, but can be arranged individually.

Configuring

The numbers over the input fields in the "configuration field" identify the slots of the ET 100U/ET 200U station.

- For each module in the ET 100U/ET 200U station, assign the appropriate address identifier (Table 12.1). The slots must be assigned in ascending order, and no slots may be skipped. If no module is to be inserted at a slot, enter address identifier "000" there for an empty slot.

- If you are addressing via page frames, you must note the following:
  With page addressing, I/O byte 255 is reserved for page selection.

Enter the address identifier as a module code (e.g. 4DI). In the ET 200U, a decimal number can also be used as an address identifier (e.g. 008).

Module	**Address Identifier ET 100U**	**Address size (Byte)**	**Address Identifier ET 200U**	**Address Size (Byte)**	**Address Range**	**Current Consumption (mA)**
Digital input module 6ES5 437-8EA12	4DI	1/2	4DI or 008	1	digital	50
Digital input module (with diagnostics) 6ES5 437-8EA21	8DI	1	8DI or 009	1	digital	50
Digital output module 6ES5 457-8EA12	4DQ	1/2	4DQ or 048	1	digital	55
Analog input module 4x 'thermocouple' 6ES5 467-8EA11	Single-ch.: 1AI 2-channel: 2AI 4-channel: 4AI	2 4 8	Single-ch.: 1AI or 012 2-channel: 2AI or 013 4-channel: 4AI or 015	2 4 8	analog	270
Analog input module 2x '4 to 200 mA' 6ES5 467-8EE11	Single-ch.: 1AI 2-ch.: 2AI	2 4	Single-ch.: 1AI or 012 2-ch.: 2AI or 013	2 4	analog	320
Analog input module 2x 'Pt 100' 6ES5 467-8EF11	Single-ch.: 1AI 2-channel: 2AI	2 4	Single-ch.: 1AI or 012 2-channel: 2AI or 013	2 4	analog	270
Analog output module 6ES5 477-8EC11	2AX	4Q + 4I *)	2AX or 029	4Q + 4I *)	analog	350
Power supply module 6ES5 935-8ME11	4DI/4DI	1	4DI/4DI or 008/008	2	digital	-

*) The address size is needed for both inputs and outputs, i.e. if the address has two bytes, two bytes are required for the inputs and two bytes for the outputs. Since the COM ET 100U/200U freely assigns the addresses for these modules, inputs and outputs can have different start addresses.

A Certificates of Conformity

A Certificates of Conformity

Shown on the following pages are the certificates of conformity for the S5-100U Ex modules from the Physikalisch-Technischen Bundesanstalt and the Swiss Electrotechnical Association. The technical data listed on these certificates can be found in Appendix F. The technical data of the Ex modules are also given in the context.

Physikalisch-Technische Bundesanstalt

(1) **KONFORMITÄTSBESCHEINIGUNG**

(2) PTB Nr. Ex-88.B.2149 X

(3) Diese Bescheinigung gilt für das elektrische Betriebsmittel

Digitaleingabe-Baugruppe Typ 6ES5 437-8EA11 und
Digitalausgabe-Baugruppe Typ 6ES5 457-8EA11

(4) der Firma Siemens AG, Unternehmensbereich Energie- und Automatisierungstechnik, D-7500 Karlsruhe

(5) Die Bauart dieses elektrischen Betriebsmittels sowie die verschiedenen zulässigen Ausführungen sind in der Anlage zu dieser Konformitätsbescheinigung festgelegt.

(6) Die Physikalisch-Technische Bundesanstalt bescheinigt als Prüfstelle nach Artikel 14 der Richtlinie des Rates der Europäischen Gemeinschaften vom 18. Dezember 1975 (76/117/EWG) die Übereinstimmung dieses elektrischen Betriebsmittels mit den harmonisierten Europäischen Normen

Elektrische Betriebsmittel für explosionsgefährdete Bereiche

EN 50 014:1977 + A1...A4 (VDE 0170/0171 Teil 1/5.84) Allgemeine Bestimmungen
EN 50 020:1977 + A1 (VDE 0170/0171 Teil 7/9.80) Eigensicherheit "i"

nachdem das Betriebsmittel mit Erfolg einer Bauartprüfung unterzogen wurde. Die Ergebnisse dieser Bauartprüfung sind in einem vertraulichen Prüfprotokoll festgelegt.

(7) Das Betriebsmittel ist mit dem folgenden Kennzeichen zu versehen:

[EEx ib] IIC

(8) Der Hersteller ist dafür verantwortlich, daß jedes derart gekennzeichnete Betriebsmittel in seiner Bauart mit den in der Anlage zu dieser Bescheinigung aufgeführten Prüfungsunterlagen übereinstimmt und daß die vorgeschriebenen Stückprüfungen erfolgreich durchgeführt wurden.

(9) Das elektrische Betriebsmittel darf mit dem hier abgedruckten gemeinschaftlichen Unterscheidungszeichen gemäß Anhang II der Richtlinie des Rates vom 6. Februar 1979 (79/196/EWG) gekennzeichnet werden.

Im Auftrag Braunschweig, 23.01.1989

Dr.-Ing. Schebsdat
Regierungsdirektor

V 15 - 320 007 - 12.85

Physikalisch-Technische Bundesanstalt

A N L A G E

zur Konformitätsbescheinigung PTB Nr. Ex-88.B.2149 X

Die Digitaleingabe-Baugruppe Typ 6ES5 437-8EA11 sowie die Digitalausgabe-Baugruppe Typ 6ES5 457-8EA11 sind steckbare Peripheriebaugruppen des speicherprogrammierbaren Automatisierungsgerätes SIMATIC S5, das sich für den Einsatz bei kleineren Automatisierungsaufgaben eignet.

Die Digitaleingabe-Baugruppe ist zum Anschluß von passiven Schaltern und von bescheinigten eigensicheren Gebern geeignet.

Die Digitalausgabe-Baugruppe ist z.B. zum Anschluß von bescheinigten eigensicheren Magnetventilen vorgesehen.

Die Baugruppen müssen mit dem zugehörigen Busmodul Typ 6ES5700-8EA11 zusammen verwendet werden.

Die höchstzulässige Umgebungstemperatur beträgt 60 °C.

Elektrische Daten

Versorgung .... (über die 15polige Bussteckverbindung)	$U_{\_}$ = 9 V (Versorgung aus Stromversorgungsbaugruppen mit Betriebsspannungen unter 250 V)
Ein- bzw. Ausgangsstromkreise .... (Klemmen 3,4; 5,6; 7,8 und 9,10)	in Zündschutzart Eigensicherheit EEx ib IIC Höchstwerte (je Stromkreis): $U_{\_}$ = 10,1 V $I_{\_}$ = 200 mA P = 326 mW höchstzulässige äußere Induktivität 0,5 mH höchstzulässige äußere Kapazität 3 µF

Die eigensicheren Ein- bzw. Ausgangsstromkreise sind von den übrigen Stromkreisen bis zu einem Scheitelwert der Nennspannung von 375 V sicher galvanisch getrennt.

Prüfungsunterlagen	unterschrieben am
1. Beschreibung (8 Blatt)	17.11.1988
2. Zeichnung Nr. C79451-A3354-B1-*-11 (3 Blatt)	17.11.1988
C79451-A3355-B1-*-11 (3 Blatt)	17.11.1988
C79451-A3354-X1-*-26	08.07.1988
W79040-C6016-J1-*-26	08.07.1988
C79451-A3354-B1-*-26	14.12.1988
C79451-A3355-B1-*-26	08.07.1988
C79451-A3355-X1-*-26	08.07.1988

3. Prüfmuster

Blatt 1/2

v 15-755 320 17 - 4.88

Physikalisch-Technische Bundesanstalt

Anlage zur Konformitätsbescheinigung PTB Nr. Ex-88.B.2149 X

Besondere Bedingung

Werden nichteigensichere Busmodule neben eigensichere Busmodule montiert, so ist zwischen beide eine Trennwand gemäß Zeichnung Nr. C79451-A3354-X1-*-26 bzw. C79451-A3355-X1-*-26 einzufügen, so daß das Fadenmaß zwischen den eigensicheren und den nichteigensicheren Anschlußteilen mindestens 50 mm beträgt.

Im Auftrag

Braunschweig, 23.01.1989

Dr.-Ing. Schebsdat
Regierungsdirektor

Blatt 2/2

V 15-755 320 17-4.88

Physikalisch-Technische Bundesanstalt

1. N A C H T R A G
zur Konformitätsbescheinigung PTB Nr. Ex-88.B.2149 X

der Firma Siemens AG, Unternehmensbereich Energie- und
Automatisierungstechnik, D-7500 Karlsruhe

Die Digitaleingabe-Baugruppe und die Digitalausgabe-Baugruppe dürfen künftig auch unter der Typenbezeichnung

6ES5 437-8EA12 und
6ES5 457-8EA12

entsprechend den unten aufgeführten Unterlagen gefertigt werden.

Elektrische Daten	Typen 6ES5 437-8EA12 und 6ES5 457-8EA12
Ein- bzw. Ausgangsstromkreise (Klemmen 3,4; 5,6; 7,8 und 9,10)	in Zündschutzart Eigensicherheit EEx ib IIC Höchstwerte (je Stromkreis): U_ = 10,1 V I¯ = 43 mA P = 97 mW höchstzulässige äußere Induktivität 20 mH höchstzulässige äußere Kapazität 3 µF

Die übrigen Angaben, Daten sowie die "Besonderen Bedingungen" bleiben unverändert.

Prüfungsunterlagen

1. Beschreibung (2 Blatt)
2. Zeichnung Nr. C79451-A 3354-B2-*-11 (3 Blatt)
   C79451-A 3355-B2-*-11 (3 Blatt)
   C79451-A 3354-B2-*-26
   C79451-A 3354-X2-*-26
   C79451-A 3355-X2-*-26
   C79451-A 3355-B2-*-26

) unterschrieben am 29.06.1989

Im Auftrag

Dr.-Ing. Schebsdat
Regierungsdirektor

Braunschweig, 14.09.1989

PHYSIKALISCH-TECHNISCHE BUNDESANSTALT 24

[EEx ib] IIC

Blatt 1/1

V 13-755 320 17-9.88

Physikalisch-Technische Bundesanstalt

(1) KONFORMITÄTSBESCHEINIGUNG

(2) **PTB Nr. Ex-91.C.2110**

(3) Diese Bescheinigung gilt für das elektrische Betriebsmittel

Analogeingabe-Baugruppe Typ 6ES5467-8EE11

(4) der Firma Siemens AG
D-7500 Karlsruhe

(5) Die Bauart dieses elektrischen Betriebsmittels sowie die verschiedenen zulässigen Ausführungen sind in der Anlage zu dieser Konformitätsbescheinigung festgelegt.

(6) Die Physikalisch-Technische Bundesanstalt bescheinigt als Prüfstelle nach Artikel 14 der Richtlinie des Rates der Europäischen Gemeinschaften vom 18. Dezember 1975 (76/117/EWG) die Übereinstimmung dieses elektrischen Betriebsmittels mit den harmonisierten Europäischen Normen

Elektrische Betriebsmittel für explosionsgefährdete Bereiche

EN 50 014:1977 + A1...A5 (VDE 0170/0171 Teil 1/1.87) Allgemeine Bestimmungen
EN 50 020:1977 + A1...A2 (VDE 0170/0171 Teil 7/1.87) Eigensicherheit "i"

nachdem das Betriebsmittel mit Erfolg einer Bauartprüfung unterzogen wurde. Die Ergebnisse dieser Bauartprüfung sind in einem vertraulichen Prüfprotokoll festgelegt.

(7) Das Betriebsmittel ist mit dem folgenden Kennzeichen zu versehen:

[EEx ib] IIC

(8) Der Hersteller ist dafür verantwortlich, daß jedes derart gekennzeichnete Betriebsmittel in seiner Bauart mit den in der Anlage zu dieser Bescheinigung aufgeführten Prüfungsunterlagen übereinstimmt und daß die vorgeschriebenen Stückprüfungen erfolgreich durchgeführt wurden.

(9) Das elektrische Betriebsmittel darf mit dem hier abgedruckten gemeinschaftlichen Unterscheidungszeichen gemäß Anhang II der Richtlinie des Rates vom 6. Februar 1979 (79/196/EWG) gekennzeichnet werden.

Im Auftrag

Braunschweig, 30.10.1991

Dr.-Ing. Schebsdat
Regierungsdirektor

PHYSIKALISCH-TECHNISCHE BUNDESANSTALT 24

Prüfbescheinigungen ohne Unterschrift und ohne Dienststempel haben keine Gültigkeit.
Die Bescheinigungen dürfen nur unverändert weiterverbreitet werden.
Auszüge oder Änderungen bedürfen der Genehmigung der Physikalisch-Technischen Bundesanstalt. Bundesallee 100, Postfach 33 45, D-3300 Braunschweig.

V 15-320 C07 · 12.85

Physikalisch-Technische Bundesanstalt

A N L A G E

zur Konformitätsbescheinigung PTB Nr. Ex-91.C.2110

Die Analogeingabe-Baugruppe Typ 6ES5467-8EE11 dient zur Digitalisierung und Übertragung der Eingangssignale auf das Bussystem eines angeschlossenen Automatisierungsgerätes.

Die höchstzulässige Umgebungstemperatur beträgt 60 °C.

Elektrische Daten

Hilfsenergie .... (15polige Bussteckverbindung)	U_{-} = (9 ± 0,5) V; ca. 0,32 A (nur zum Anschluß an Geräte mit Betriebsspannungen bis 250 V)
Eingangsstromkreise .... Kanal 0 (Klemmen 3 u. 4 bzw. 4 u. 6) Kanal 1 (Klemmen 7 u. 8 bzw. 8 u. 10)	in Zündschutzart Eigensicherheit EEx ib IIC

Höchstwerte (je Kanal) U_o = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 Ω

Kennlinie: trapezförmig

höchstzulässige äußere Induktivität L_a = 4 mH
höchstzulässige äußere Kapazität C_a = 270 nF

Die Eingangsstromkreise sind von der Hilfsenergie bis zu einem Scheitelwert der Nennspannung von 375 V sicher galvanisch getrennt.

Prüfungsunterlagen	unterschrieben am
1. Beschreibung (8 Blatt)	15.03.1991
2. Zeichnung Nr. C79451-A3400-X1-*-26	15.03.1991
6ES5 467-8EE11	15.03.1991
C79451-A3400-B1-*-11(4 Blatt)	15.03.1991
C79451-A3400-B1-*-26(2 Blatt)	19.04.1991
C79453-A3049-B285; B286	15.03.1991
W79040-K156-C16-*-26	15.03.1991

Im Auftrag

Braunschweig, 30.10.1991

Dr.-Ing. Schebsdat
Regierungsdirektor

PHYSIKALISCH-TECHNISCHE BUNDESANSTALT 24

Blatt 1/2

Physikalisch-Technische Bundesanstalt

(1) KONFORMITÄTSBESCHEINIGUNG

(2) **PTB Nr. Ex-91.C.2109**

(3) Diese Bescheinigung gilt für das elektrische Betriebsmittel

Analogausgabe-Baugruppe Typ 6ES5477-8EC11

(4) der Firma Siemens AG
D-7500 Karlsruhe 21

(5) Die Bauart dieses elektrischen Betriebsmittels sowie die verschiedenen zulässigen Ausführungen sind in der Anlage zu dieser Konformitätsbescheinigung festgelegt.

(6) Die Physikalisch-Technische Bundesanstalt bescheinigt als Prüfstelle nach Artikel 14 der Richtlinie des Rates der Europäischen Gemeinschaften vom 18. Dezember 1975 (76/117/EWG) die Übereinstimmung dieses elektrischen Betriebsmittels mit den harmonisierten Europäischen Normen

Elektrische Betriebsmittel für explosionsgefährdete Bereiche

EN 50 014:1977 + A1...A5 (VDE 0170/0171 Teil 1/1.87) Allgemeine Bestimmungen
EN 50 020:1977 + A1...A2 (VDE 0170/0171 Teil 7/1.87) Eigensicherheit "i"

nachdem das Betriebsmittel mit Erfolg einer Bauartprüfung unterzogen wurde. Die Ergebnisse dieser Bauartprüfung sind in einem vertraulichen Prüfprotokoll festgelegt.

(7) Das Betriebsmittel ist mit dem folgenden Kennzeichen zu versehen:

[EEx ib] IIC

(8) Der Hersteller ist dafür verantwortlich, daß jedes derart gekennzeichnete Betriebsmittel in seiner Bauart mit den in der Anlage zu dieser Bescheinigung aufgeführten Prüfungsunterlagen übereinstimmt und daß die vorgeschriebenen Stückprüfungen erfolgreich durchgeführt wurden.

(9) Das elektrische Betriebsmittel darf mit dem hier abgedruckten gemeinschaftlichen Unterscheidungszeichen gemäß Anhang II der Richtlinie des Rates vom 6. Februar 1979 (79/196/EWG) gekennzeichnet werden.

Im Auftrag Braunschweig, 22.10.1991

Dr.-Ing. Schebsdat
Regierungsdirektor

Prüfbescheinigungen ohne Unterschrift und ohne Dienststempel haben keine Gültigkeit.
Die Bescheinigungen dürfen nur unverändert weiterverbreitet werden.
Auszüge oder Änderungen bedürfen der Genehmigung der Physikalisch-Technischen Bundesanstalt, Bundesallee 100, Postfach 33 45, D-3300 Braunschweig.

V 15-320 0C7 · 12.85

Physikalisch-Technische Bundesanstalt

A N L A G E

zur Konformitätsbescheinigung PTB Nr. Ex-91.C.2109

Die Analogausgabe-Baugruppe Typ 6ES5477-8EC11 dient zur Umwandlung eines digitalen Eingangssignals in ein analoges Ausgangssignal (4..20mA).

Die höchstzulässige Umgebungstemperatur beträgt 60°C.

Elektrische Daten

Hilfsenergie (15polige Bussteckverbindung)	$U_=$(9±0,5) V; ca. 0,35 A (nur zum Anschluß an Geräte mit Betriebsspannungen bis 250 V)
Ausgangsstromkreise Kanal 0 (Klemmen 4 u. 6) Kanal 1 (Klemmen 8 u. 10)	in Zündschutzart Eigensicherheit EEx ib IIC Höchstwerte (je Kanal): U_0= 18 V I_k= 82 mA P = 600 mW R_i= 354 Ω Kennlinie: trapezförmig höchstzulässige äußere Induktivität L_a= 4 mH höchstzulässige äußere Kapazität C_a= 270 nF

Die Ausgangsstromkreise sind von der Hilfsenergie bis zu einem Scheitelwert der Nennspannung von 375 V sicher galvanisch getrennt.

Die Ausgangsstromkreise sind untereinander galvanisch getrennt.

Prüfungsunterlagen	alle unterschrieben am: 19.04.1991
1. Beschreibung (9 Blatt)	
2. Zeichnung Nr.:	C79451-A3401-X1-*-26 6ES5 477-8EC11 C79451-A3401-B1-*-11 (4 Blatt) C79451-A3401-B1-*-26 (2 Blatt) C79453-A3049-B285; B286 W79040-K156-C16-*-26

Im Auftrag

Braunschweig, 22.10.1991

Dr.-Ing. Schebsdat
Regierungsdirektor

(Stempel: Physikalisch-Technische Bundesanstalt 24)

Blatt 1/1

V 13-755 320 17-9.88

Eidgenössisches Starkstrominspektorat
Inspection fédérale des installations à courant fort
Ispettorato federale degli impianti a corrente forte

ZULASSUNG ADMISSION AMMISSIONE

NR. 91/1 10112/02

GÜLTIG BIS: 23/07/1996

SIEMENS-ALBIS AG
FREILAGERSTR. 28
8047 ZÜRICH

KENNZEICHNUNG (+S) 787/676

EX-KENNZEICHNUNG GEMÄSS BEILAGE 2

AUFGRUND DER ANGABEN EINES PRÜFBERICHTES
NR. 91/1 10112/01 VOM 22/07/1991
ERTEILT DAS EIDGENÖSSISCHE STARKSTROMINSPEKTORAT DER OBEN GENANNTEN FIRMA DAS RECHT, DAS NACHSTEHEND AUFGEFÜHRTE ERZEUGNIS IN DER SCHWEIZ IN VERKEHR ZU BRINGEN.

ERZEUGNIS: DIGITALEIN-UND DIGITALAUSGABE-BAUGRUPPEN

MATERIAL-CODE: 1640

HANDELSMARKE: SIMATIC-S5

TYPENBEZEICHNUNG	NENNDATEN
6ES5 437-8EA11	
6ES5 437-8EA12	
6ES5 457-8EA11	
6ES5 457-8EA12	GEMÄSS BEILAGEN 1 UND 2

SCHUTZKLASSE: --

SCHUTZGRAD: --

BESCHREIBUNG: GEMÄSS BEILAGE 1

HINWEISE: GEMÄSS BEILAGE 2

BESONDERE
BEDINGUNGEN: GEMÄSS BEILAGE 2

GEBÜHR: FR. 500.00

ZÜRICH, DEN 23/07/1991 FB

EIDGENÖSSISCHES
STARKSTROMINSPEKTORAT
ABT. MATERIAL + APPARATE

D. MARTY

01

Siehe Rückseite voir au verso vedasi a tergo

Schweizerischer Elektrotechnischer Verein
Association Suisse des Electriciens
Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnial Association

PRÜFSTELLE ZÜRICH | AUFTRAGS-NR. 91/1 10112/01

ZERTIFIKAT | DATUM: 22.07.1991

ADRESSE:	AUFTRAGGEBER SIEMENS-ALBIS AG FREILAGERSTR. 28 8047 ZÜRICH	
HERSTELLER:	SIEMENS AG	D-7500 KARLSRUHE
PRÜFOBJEKT:	DIGITALEIN-UND DIGITALAUSGABE-BAUGRUPPEN	1640
HANDELSMARKE:	SIMATIC-S5	

TYPENBEZEICHNUNG	NENNDATEN
6ES5 437-8EA11 6ES5 437-8EA12 6ES5 457-8EA11 6ES5 457-8EA12	GEMÄSS BEILAGEN 1 UND 2

KENNZEICHNUNG:	GEMÄSS BEILAGE 2
BESCHREIBUNG:	GEMÄSS BEILAGE 1
HINWEISE:	GEMÄSS BEILAGE 2
BESONDERE BEDINGUNGEN:	GEMÄSS BEILAGE 2
SCHUTZKLASSE:	--
SCHUTZGRAD:	--
PRÜFBESTIMMUNG:	EN 50014.1977 + A1...A4 EN 50020.1977 + A1

Geschäftssitz/Siège social
Seefeldstrasse 301
CH-8008 Zürich

Briefe/Lettres
Postfach/Case postale
CH-8034 Zürich

Tel. 01 / 384 91 11
Tx 817 431 sev ch
Fax 01 / 55 14 26

Postcheck 80 - 600-2
Bank/Banque
SKA Zürich-Seefeld

Schweizerischer Elektrotechnischer Verein
Association Suisse des Electriciens
Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnial Association

SEV ASE

PRÜFSTELLE ZÜRICH

AUFTRAGS-NR. 91,1 10112,01

ZERTIFIKAT

DATUM: 22.07.1991

BLATT: 02

ERGEBNIS: PRÜFUNG BESTANDEN

ABT: EX
EXP: ESTEVEZ, LUIS

SCHWEIZ. ELEKTROTECHN. VEREIN
PRÜFSTELLE ZÜRICH

IV A. EGGENBERGER
ABTEILUNGSLEITER

BEILAGEN: ERWÄHNT

01

Geschäftssitz/Siège social
Seefeldstrasse 301
CH-8008 Zürich

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CH-8034 Zürich

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Schweizerischer Elektrotechnischer Verein
Association Suisse des Electriciens
Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnical Association

Beilage 1 zu Zertifikat A.Nr. 91.1 10112

Siemens Albis AG, 8047 Zürich

Beschreibung

Die Digitaleingabe-Baugruppe Typ 6ES5 437-8EA11 und Typ 6ES5 437-8EA12 sowie die Digitalausgabe-Baugruppe Typ 6ES5 457-8EA11 und Typ 6ES5 457-8EA12 sind steckbare Peripheriebaugruppen des speicherprogrammierbaren Automatisierungsgerätes SIMATIC S5, das sich für den Einsatz bei kleineren Automatisierungsaufgaben eignet.

Die Digitaleingabe-Baugruppe ist zum Anschluss von passiven Schaltern und von bescheinigten eigensicheren Gebern geeignet.

Die Digitalausgabe-Baugruppe ist z.B. zum Anschluss von bescheinigten eigensicheren Magnetventilen vorgesehen.

Nenndaten

Versorgung (über die 15-polige Bussteckverbindung)	U = 9 V (Versorgung aus Stromversorgungsbaugruppen mit Betriebsspannungen unter 250 V)

Typen 6ES5 437-8EA11 und 6ES5 457-8EA11

Ein- bzw. Ausgangsstromkreise (Klemmen 3, 4; 5, 6; 7, 8 und 9, 10)	in Zündschutzart Eigensicherheit EEx ib IIC Höchstwerte (je Stromkreis): U = 10,1 V I = 200 mA P = 326 mW höchstzulässige äussere Induktivität 0,5 mH höchstzulässige äussere Kapazität 3 µF

Typen 6ES5 437-8EA12 und 6ES5 457-8EA12

Ein- bzw. Ausgangsstromkreise (Klemmen 3,4; 5, 6; 7, 8 und 9, 10)	in Zündschutzart Eigensicherheit EEx ib IIC Höchstwerte (je Stromkreis): U = 10,1 V I = 43 mA P = 97 mW höchstzulässige äussere Induktivität 20 mH höchstzulässige äussere Kapazität 3 µF

Die höchstzulässige Umgebungstemperatur beträgt +60 °C.

Geschäftssitz/Siège social
Seefeldstrasse 301
CH-8008 Zürich

Briefe/Lettres
Postfach/Case postale
CH-8034 Zürich

Tel 01 / 384 91 11
Tx 817 431 sev ch
Fax 01 / 55 14 26

Postcheck 80-600-2
Bank/Banque
SKA Zürich-Seefeld

Schweizerischer Elektrotechnischer Verein
Association Suisse des Electriciens
Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnical Association

Beilage 2 zu Zertitifkat A.Nr. 91.1 10112

Siemens Albis AG, 8047 Zürich

Hinweise

1. Die Baugruppen müssen mit dem zugehörigen Busmodul Typ 6ES5700-BEA11 zusammen verwendet werden.

2. Die eigensicheren Ein- bzw. Ausgangsstromkreise sind von den übrigen Stromkreisen bis zu einem Scheitelwert der Nennspannung von 375 V sicher galvanisch getrennt.

Besondere Bedingungen

Werden nichteigensichere Busmodule neben eigensichere Busmodule montiert, so ist zwischen beiden eine Trennwand gemäss Zeichnung Nr. C79451-A3354-X1-*-26 bzw. C79451-A3355-X1-*-26 einzufügen, so dass das Fadenmass zwischen den eigensicheren und den nichteigensicheren Anschlussteilen mindestens 50 mm beträgt.

Kennzeichnung

[EEx ib] IIC

ASEV 91.1 B10112X

Zürich, 22. Juli 1991
Ex/L. Estevez/mk

Geschäftssitz/Siège social
Seefeldstrasse 301
CH-8008 Zürich

Briefe/Lettres
Postfach/Case postale
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Fax 01 / 55 14 26

Postcheck 80-600-2
Bank/Banque
SKA Zürich-Seefeld

Eidgenössisches Starkstrominspektorat
Inspection fédérale des installations à courant fort
Ispettorato federale degli impianti a corrente forte

ZULASSUNG ADMISSION AMMISSIONE

NR. 91,1 12724,03 SIEMENS-ALBIS AG

GÜLTIG BIS: 11/03/1997 FREILAGERSTR. 28
8047 ZÜRICH

KENNZEICHNUNG (+S) 787,676

EX - KENNZEICHNUNG GEMÄSS BEILAGE 2

AUFGRUND DER ANGABEN EINES PRÜFBERICHTES
NR. 91,1 12724,01 VOM 10/03/1992
ERTEILT DAS EIDGENÖSSISCHE STARKSTROMINSPEKTORAT DER OBEN GENANNTEN FIRMA DAS RECHT, DAS NACHSTEHEND AUFGEFÜHRTE ERZEUGNIS IN DER SCHWEIZ IN VERKEHR ZU BRINGEN.

ERZEUGNIS: ANALOGEINGABEBAUGRUPPE

MATERIAL-CODE: 1640

HANDELSMARKE: SIMATIC S5

TYPENBEZEICHNUNG	NENNDATEN
6ES5 467-8EE11	GEMÄSS BEILAGE 1

SCHUTZKLASSE: -

SCHUTZGRAD: IP 20

BESCHREIBUNG: GEMÄSS BEILAGE 1

HINWEISE: GEMÄSS BEILAGE 1

EX-KLASSIF.: GEMÄSS BEILAGE 2

PRÜFUNGS-
UNTERLAGEN: GEMÄSS BEILAGE 2

GEBÜHR: FR. 340.00

ZÜRICH, DEN 11/03/1992 MI

EIDGENÖSSISCHES
STARKSTROMINSPEKTORAT
ABT. MATERIAL + APPARATE
D. MARTY

01 Mi

Siehe Rückseite voir au verso vedasi a tergo

Schweizerischer Elektrotechnischer Verein
Association Suisse des Electriciens
Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnial Association

PRÜFSTELLE ZÜRICH AUFTRAGS-NR. 91.1 12724.01

ZERTIFIKAT DATUM: 10.03.1992

ADRESSE:	AUFTRAGGEBER SIEMENS-ALBIS AG FREILAGERSTR. 28 8047 ZÜRICH	
HERSTELLER:	SIEMENS AG	D-7500 KARLSRUHE
PRÜFOBJEKT:	ANALOGEINGABEBAUGRUPPE	1640
HANDELSMARKE:	SIMATIC S5	

TYPENBEZEICHNUNG	NENNDATEN
6ES5 467-8EE11	GEMÄSS BEILAGE 1

KENNZEICHNUNG:	GEMÄSS BEILAGE 2
BESCHREIBUNG:	GEMÄSS BEILAGE 1
HINWEISE:	GEMÄSS BEILAGE 1
EX-KLASSIF.:	GEMÄSS BEILAGE 2
PRÜFUNGS-UNTERLAGEN:	GEMÄSS BEILAGE 2
SCHUTZKLASSE:	-
SCHUTZGRAD:	IP 20
PRÜFBESTIMMUNG:	EN 50014.1977 + A1...A5 EN 50020.1977 + A1...A2
ERGEBNIS:	PRÜFUNG BESTANDEN

ABT: EX
EXP: ESTEVEZ, LUIS

SCHWEIZ. ELEKTROTECHN. VEREIN
PRÜFSTELLE ZÜRICH

IV A. EGGENBERGER
ABTEILUNGSLEITER

BEILAGEN: ERWÄHNT

31

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Schweizerischer Elektrotechnischer Verein
Association Suisse des Electriciens
Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnical Association

Beilage 1 zu Zertifikat A. Nr. 91.1 12724.01

Siemens Albis AG, 8047 Zürich

Beschreibung

Die Analogeingabe-Baugruppe Typ 6ES5467-8EE11 dient zur Digitalisierung und Uebertragung der Eingangssignale auf das Bussystem eines angeschlossenen Automatisierungsgerätes.

Nenndaten

Hilfsenergie.................. U = (9±0,5) V; ca. 0,32 A
(15 polige Bussteckverbindung) (nur zum Anschluss an Geräte mit Betriebsspannung bis 250 V)

Eingangsstromreise.......... in Zündschutzart Eigensicherheit EEx ib IIC
Kanal 0 (Klemmen 3 u. 4 bzw. 4 u. 6)
Kanal 1 (Klemmen 7 u. 8 bzw. 8 u. 10)

Höchstwerte (je Kanal) : U_o= 18 V
I_k= 82 mA
P = 600 mW
R_i= 354 Ω

Kennlinie: trapezförmig

höchstzulässige äussere Induktivität L_a = 4 mH
höchstzulässige äussere Kapazität C_a = 270 nF

Die höchstzulässige Umgebungstemperatur beträgt + 60 °C

Hinweise

Die eingensicheren Eingangsstromkreise sind von der Hilfsenergie bis zu einem Scheitelwert der Nennspannung von 375 V sicher galvanisch getrennt.

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Beilage 2 zu Zertifikat A. Nr. 91.1 12724.01

Siemens Albis AG, 8047 Zürich

Ex - Klassifikation
[EEx ib] IIC

Kennzeichnung
Siemens Albis AG, Zürich
ASEV 91.1 C12724

Prüfungsunterlagen
Konformitätsbescheinigung PTB Nr. Ex - 91. C. 2110 einschliesslich Beschreibung mit Anlage und Zeichnungen.

Zürich, 4. März 1992
Ex / L. Estevez / MM

Es.

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Bank/Banque
SKA Zürich-Seefeld

Eidgenössisches Starkstrominspektorat
Inspection fédérale des installations à courant fort
Ispettorato federale degli impianti a corrente forte

ZULASSUNG ADMISSION AMMISSIONE

NR. 91,1 12724,04

GÜLTIG BIS: 11/03/1997

SIEMENS-ALBIS AG
FREILAGERSTR. 28
8047 ZÜRICH

KENNZEICHNUNG (+S) 787,676

EX - KENNZEICHNUNG GEMÄSS BEILAGE 2

AUFGRUND DER ANGABEN EINES PRÜFBERICHTES
NR. 91,1 12724,02 VOM 10/03/1992
ERTEILT DAS EIDGENÖSSISCHE STARKSTROMINSPEKTORAT DER OBEN GENANNTEN FIRMA DAS RECHT, DAS NACHSTEHEND AUFGEFÜHRTE ERZEUGNIS IN DER SCHWEIZ IN VERKEHR ZU BRINGEN.

ERZEUGNIS: ANALOGAUSGABEBAUGRUPPE

MATERIAL-CODE: 1640

HANDELSMARKE: SIMATIC S5

TYPENBEZEICHNUNG	NENNDATEN
6ES5 477-8EC11	GEMÄSS BEILAGE 1

SCHUTZKLASSE: -

SCHUTZGRAD: IP 20

BESCHREIBUNG: GEMÄSS BEILAGE 1

HINWEISE: GEMÄSS BEILAGE 1

EX-KLASSIF.: GEMÄSS BEILAGE 2

PRÜFUNGS-
UNTERLAGEN: GEMÄSS BEILAGE 2

BEILAGEN: ERWÄHNT

GEBÜHR: FR. 340.00

ZÜRICH, DEN 11/03/1992 MI

EIDGENÖSSISCHES
STARKSTROMINSPEKTORAT
ABT. MATERIAL + APPARATE

D. MARTY

01

Siehe Rückseite voir au verso vedasi a tergo

Schweizerischer Elektrotechnischer Verein
Association Suisse des Electriciens
Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnial Association

PRÜFSTELLE ZÜRICH AUFTRAGS-NR. 91,1 12724,02

ZERTIFIKAT DATUM: 10.03.1992

ADRESSE: AUFTRAGGEBER
SIEMENS-ALBIS AG
FREILAGERSTR. 28
8047 ZÜRICH

HERSTELLER: SIEMENS AG D-7500 KARLSRUHE

PRÜFOBJEKT: ANALOGAUSGABEBAUGRUPPE 1640

HANDELSMARKE: SIMATIC S5

TYPENBEZEICHNUNG	NENNDATEN
6ES5 477-8EC11	GEMÄSS BEILAGE 1

KENNZEICHNUNG: GEMÄSS BEILAGE 2

BESCHREIBUNG: GEMÄSS BEILAGE 1

HINWEISE: GEMÄSS BEILAGE 1

EX-KLASSIF.: GEMÄSS BEILAGE 2

PRÜFUNGS-
UNTERLAGEN: GEMÄSS BEILAGE 2

SCHUTZKLASSE: -

SCHUTZGRAD: IP 20

PRÜFBESTIMMUNG: EN 50014.1977 + A1...A5
EN 50020.1977 + A1...A2

ERGEBNIS: PRÜFUNG BESTANDEN

ABT: EX
EXP: ESTEVEZ, LUIS

SCHWEIZ. ELEKTROTECHN. VEREIN
PRÜFSTELLE ZÜRICH

IV A. EGGENBERGER
ABTEILUNGSLEITER

BEILAGEN: ERWÄHNT

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Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnical Association

Beilage I zu Zertifikat A. Nr. 91.1 12724.02

Siemens Albis AG, 8047 Zürich

<u>Beschreibung</u>

Die Analogausgabe-Baugruppe Typ 6ES5477-8EC11 dient zur Umwandlung eines digitalen Eingangssignals in ein analoges Ausgangssignal (4 . . 20 mA).

<u>Nenndaten</u>

Hilfsenergie (15 polige Bussteckverbindung)	U = (9±0,5) V; ca. 0,35 A (nur zum Anschuss an Geräte mit Betriebsspannung bis 250 V)
Ausgangsstromreise Kanal 0 (Klemmen 4 u. 6) Kanal 1 (Klemmen 8 u. 10)	in Zündschutzart Eigensicherheit EEx ib IIC
	Höchstwerte (je Kanal) : U_o = 18 V I_k = 82 mA P = 600 mW R_i = 354 Ω
	Kennlinie: trapezförmig
	höchstzulässige äussere Induktivität L_a = 4 mH höchstzulässige äussere Kapazität C_a = 270 nF

Die höchstzulässige Umgebungstemperatur beträgt + 60 °C

<u>Hinweise</u>

Die eingensicheren Ausgangsstromkreise sind von der Hilfsenergie bis zu einem Scheitelwert der Nennspannung von 375 V sicher galvanisch getrennt.

Die eigensicheren Ausgangsstromkreise sind untereinander galvanisch getrennt.

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Associazione Svizzera degli Elettrotecnici
Swiss Electrotechnical Association

Beilage 2 zu Zertifikat A. Nr. 91.1 12724.02

Siemens Albis AG, 8047 Zürich

Ex - Klassifikation
[EEx ib] IIC

Kennzeichnung
® Siemens Albis AG, Zürich
ASEV 91.1 C12724

Prüfungsunterlagen
Konformitätsbescheinigung PTB Nr. Ex - 91. C. 2109 einschlisslich Beschreibung mit Anlage und Zeichnungen.

Zürich, 4. März 1992
Ex / L. Estevez / MM

Es.

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B Planning Documentation

B Planning Documentation / Configuring Aids

When planning your measurement and control systems, you can use the enclosed forms for "Ex classification", i.e. to determine the required explosion protection.

These have already been (partly) filled out for the example of a tank installation. However, there is a blank form for each of the following sheets:

- Basic sheet for Ex classification E01
- For the classification of critical substances (gases/dusts) E02
- For the classification of critical details E03
- Ex zone plan of the installation E04
- Installation certificate E05

SIEMENS *progress in automation: Siemens*

Ex-Classification

Dept.: E. Engineering	Installation: Tank	Edition: [ ] dated Jan. 23, 92
Name: Smith	Sheet No.: 1	Revision: [ ] dated ...... changes/new:
Tel.: 4711	No. of sheets: 3	Revision: [ ] dated ...... changes/new ......
	Figs: 1	Revision: [ ] dated ...... changes/new: ......

Ex Classification:
Serial No. 1

Installation No.: K 1
Installation: Tank filling

Remarks: VbF

Installation .... [ ]
Installation .... [ ]
Installation .... [ ]
Installation .... [ ]
Installation .... [ ]
Installation .... [ ]

(* = with deviations)

Y=yes
N=no

Substances
see sheet [ ] Details see sheet [ ] and the following

Additionally valid notices: .... Date: .... App. No.: [ ]
.... Date: .... App. No.: [ ]
.... Date: .... App. No.: [ ]

Any other stipulations and previous versions are superseded.

If additional or different substances are used or in the event of a change in circumstances relating to operations or layout which could affect the Ex classification, the user of the installation is under the obligation to verify the Ex classification. Changes must be in writing and, if necessary, a new Ex classification must be carried out.

Agreement:
Date Signature ....
Code Name ....
Date Signature ....
Code Name ....
Date Signature ....
Code Name ....

Distribution: 1)Control Dept. 4)____________ 7)____________ 10)__________
2)____________ 5)____________ 8)____________ 11)__________
3)____________ 6)____________ 9)____________ 12)__________

E01

SIEMENS (progress in automation: Siemens)	Ex Classification Substances	Installation: Tank Sheet No.: 2 No. of sheets: 3	Date: Jan. 29, 1992 Edition: 1 Revision:

Substances affecting the classification:

	Flash Point	Ignition Temp.	Temp. Class	Ex Group	Hazard Class to VbF
Substance a	- 35 °C	145 °C	T4		
Substance b	148 °C	485 °C	T4		
	°C	°C			
	°C	°C			
	°C	°C			

For other substance data see Sheet ____ and ____

Figures and Drawings:

Fig. No.	Drawing No.	Revision	Subject
1	Ex 01 123		Layout plan (Ex zone plan)

Other enclosures

E02

SIEMENS *progress in automation: Siemens*	Ex Classification Details	Installation Tank Sheet No. 3 No. of sheets 3	Date: Jan. 29, 92 Edition: 1 Revision:

Basic data for avoiding ignition sources:

Gas (vapor) air mixture

Flash point	Ignition temp.	Temp. class	Ex. group
	145	T4	IIB
	485	T4	IIB

Dust-air mixture

Smouldering temp.	Ignition temp.	Dust Ex class

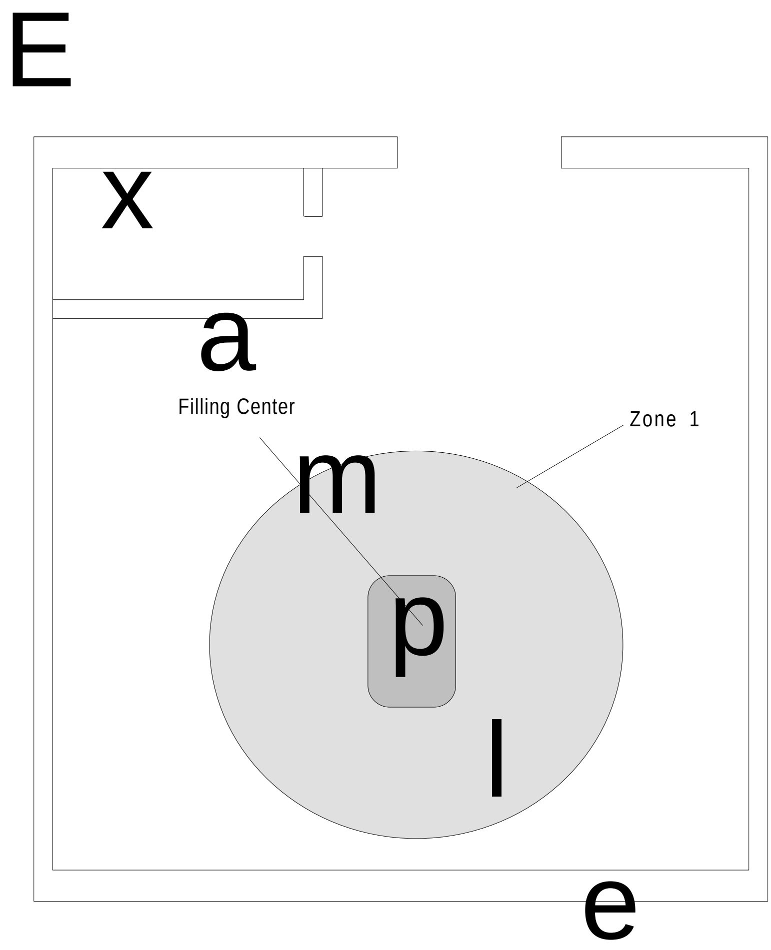
Basis of the Classification:

Location	Fig.	Item No.	Zone	Technical requirements prim. Ex protect. measures	Example
K 10 Tank filling	1		1	Formation of system operationally possible. Spreading of spilled liquids is prevented.	EX-RL 2.1.3.1

Remarks:

E03

SIEMENS progress in automation: Siemens	Ex Classification **Zone plan**	Installation Tank Sheet No. 1 No. of sheets 1	Date: Jan. 29, 93 Edition: 1 Revision:



		Subject Dept		Scale	Drawing No. C79458-B2573-C01
	Date	Name	Dept	Installation: 5	Fig.: 1
Signed					
Checked					

E04

SIEMENS progress in automation: Siemens

Ex-Classification

Installation Tank

Sheet No. [ ]

No. of sheets [ ]

Figs [ ]

Edition: [ ] dated ....

Revision: [ ] dated ....

changes/new:

Revision: [ ] dated ....

changes/new ....

Revision: [ ] dated ....

changes/new: ....

Dept.: ....

Name: ....

Tel.: ....

Ex Classification:

Serial No. [ ]

Installation No.: ....

Installation: ....

Remarks:

	VbF
Installation	[ ]
Installation	[ ]
Installation	[ ]
Installation	[ ]
Installation	[ ]
Installation	[ ]

(* = with deviations)

Y=yes
N=no

Substances
see sheet [ ] Details see sheet [ ] and the following

Additionally valid notices: .... Date: .... App. No.: [ ]

.... Date: .... App. No.: [ ]

.... Date: .... App. No.: [ ]

Any other stipulations and previous versions are superseded.

If additional or different substances are used or in the event of a change in circumstances relating to operations or layout which could affect the Ex classification, the user of the installation is under the obligation to verify the Ex classification. Changes must be in writing and, if necessary, a new Ex classification must be carried out.

Agreement:

Date Signature ....
Code Name ....

Date Signature ....
Code Name ....

Date Signature ....
Code Name ....

Distribution: 1)__________ 4)__________ 7)__________ 10)__________
2)__________ 5)__________ 8)__________ 11)__________
3)__________ 6)__________ 9)__________ 12)__________

SIEMENS progress in automation: Siemens	Ex Classification Substances	Installation	Date:
		Sheet No.	Edition:
		No. of sheets	Revision:

Substances affecting the classification:

Substance	Flash Point	Ignition Temp.	Temp. Class	Ex Group	Hazard Class to VbF
	°C	°C			
	°C	°C			
	°C	°C			
	°C	°C			
	°C	°C			

For other substance data see Sheet ____ and ____

Figures and Drawings:

Fig. No.	Drawing No.	Revision	Subject

Other enclosures

SIEMENS progress in automation: Siemens	Ex Classification Details	Installation Sheet No. No. of sheets	Date: Edition: Revision:

Basic data for avoiding ignition sources:

Gas (vapor) air mixture

Flash point	Ignition temp.	Temp. class	Ex. group

Dust-air mixture

Smouldering temp.	Ignition temp.	Dust Ex class

Basis of the Classification:

Location	Fig.	Item No.	Zone	Technical requirements prim. Ex protect. measures	Example

Remarks:

SIEMENS progress in automation: Siemens	Ex Classification **Zone plan**	Installation Sheet No. No. of sheets	Date: Edition: Revision:

	Subject	Scale	Drawing No.

	Date	Name	Dept		Installation:	Fig.:
Signed						
Checked						

E04

SIEMENS

progress in automation: Siemens

Confirmation

according to § 12 Paragraph 4 of the regulations for electrical equipment in hazardous areas (ElexV)

To:

____

(Client's address)

____

____

We hereby confirm that the following electrical installation

____

____

(Precise details of type and location)

____

____

has been implemented according to requirements of the regulations for electrical equipment in hazardous areas (ElexV).

The sole purpose of this confirmation is to release the user from the obligation of testing the electrical installation, or from having it tested, before being placed in service (§ 12 Par. 1,4 of ElexV).

Warranty and liability claims under civil law will not be met by this confirmation.

SIEMENS AKTIENGESELLSCHAFT

____ _____________________ Date: ______________

C Application Examples

Figures

Tables

C Application Examples

Presented in this section are six typical application examples for the use of SIMATIC S5-100U Ex modules.

The choice of apparatus with intrinsically safe circuits for installation in hazardous areas must involve two important aspects:

- An assessment of the location (e.g. Zone 1 IIB T4) of the apparatus
- A **safety assessment** of all apparatus must be made when planning intrinsically safe circuits, and
- a **functional assessment** must be made for proper and fault-free functioning.

The safety assessment takes into account the requirements of Section 6.3 for the interconnection of two or more items of associated electrical apparatus; the safety-related maximum values in intrinsically safe circuits will thus be met.

Table C.1 Comparison: Field Device + Cable/Associated Apparatus

Field Device + Cable	Comparison	Associated Apparatus
U_{max}	≥	U_0
I_{max}	≥	I_k
P_{max}	≥	P
C_i field device + C cable	≤	C_a
L_i field device + L cable	≤	L_a

Notes on representation of the application examples:

- The usual graphical symbols to DIN 19227 for process engineering are taken as a basis in representing the individual solutions.
- Intrinsically safe circuits should normally be installed ungrounded, and all solutions are therefore presented in an ungrounded configuration.

1. Receiving binary signals from initiators or contacts (Figure C.1)

The Ex digital input module is suitable for the connection of binary sensors, e.g. NAMUR sensors (of the Standardization Steering Committee for Measurement and Control in the Chemical Industry), of capacitive or inductive initiators and of specially wired contacts. This module has metallic isolation between the I/O bus side and the intrinsically safe input side.

Both contacts and initiators to DIN 19234 normally require no certification from a testing station, because this apparatus can be used as passive, intrinsically safe apparatus with observance of the limit values in Zones 1 or 2.

The safety-related assessment of an initiator requires that its limits U, I, P, C_i and L_i be known. An assessment of safety-related values is based on a comparison between safety-related limits. The difference C_a - C_i between the permissible external capacitance C_a and internal capacitance C_i of the initiator governs the permissible line length.

Safety-related data:

Table C.2 Comparison: Ex Digital Input Module/Proximity Switch

Proximity Switch 3RG 4623-1NA00	**Comparison**	**Ex Digital Input Module 6ES5 437-8EA12**
U ≤ 15.5 V	≥	U_0 = 10.1 V
I ≤ 52 mA	≥	I_k = 43 mA
P ≤ 170 mW	≥	P = 97 mW
L_i ≤ 48 µH	≤	L_a ≤ 20 mH
C_i ≤ 100 nF	≤	C_a ≤ 3000 nF

Permissible line capacitance C_L, i.e. length:

$C_i = C_a - C_i$ = 3000 nF - 100 nF = 2900 nF ≙ approx. 14.5 km line length

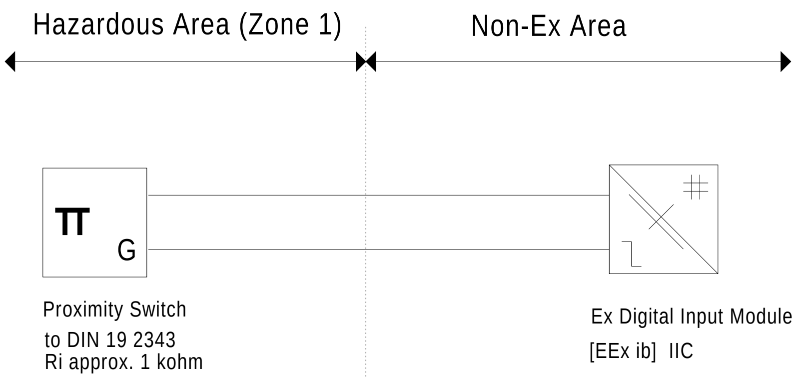


Figure C.1 Signal Circuit: Ex Digital Input Module and Proximity Switch

2. Output of binary signals to solenoid valves (Figure C.2)

Apart from signalling devices such as LEDs, the most frequently used actuators are low-power solenoid valves. Single or double-acting pneumatic drives can be actuated with these valves. In the functional assessment of the solenoid valve, the low-power electrical circuit is decisive. To carry out a precise assessment, the basic characteristic of the Ex digital output module used is also considered (Figure C.3).

Design and function of an intrinsically safe solenoid valve

Intrinsically safe solenoid valves with low electrical power consumption (approx. 20 mW) comprise two parts: the E/P converter followed by the booster. The E/P signal converter converts the electrical binary signal to a pneumatic binary signal. The booster switches back to the rest position governed by the spring. When a logic low electrical signal is present, an outlet nozzle is closed by the energized solenoid. The solenoid valve changes its control state.

This system is well-proven and achieves a service life of approximately ten years in harsh duty. Intrinsically safe solenoid valves are available as 3/2, 5/2 or 6/2-way boosters with, for example, NAMUR connection diagram for installation on rotary actuators.

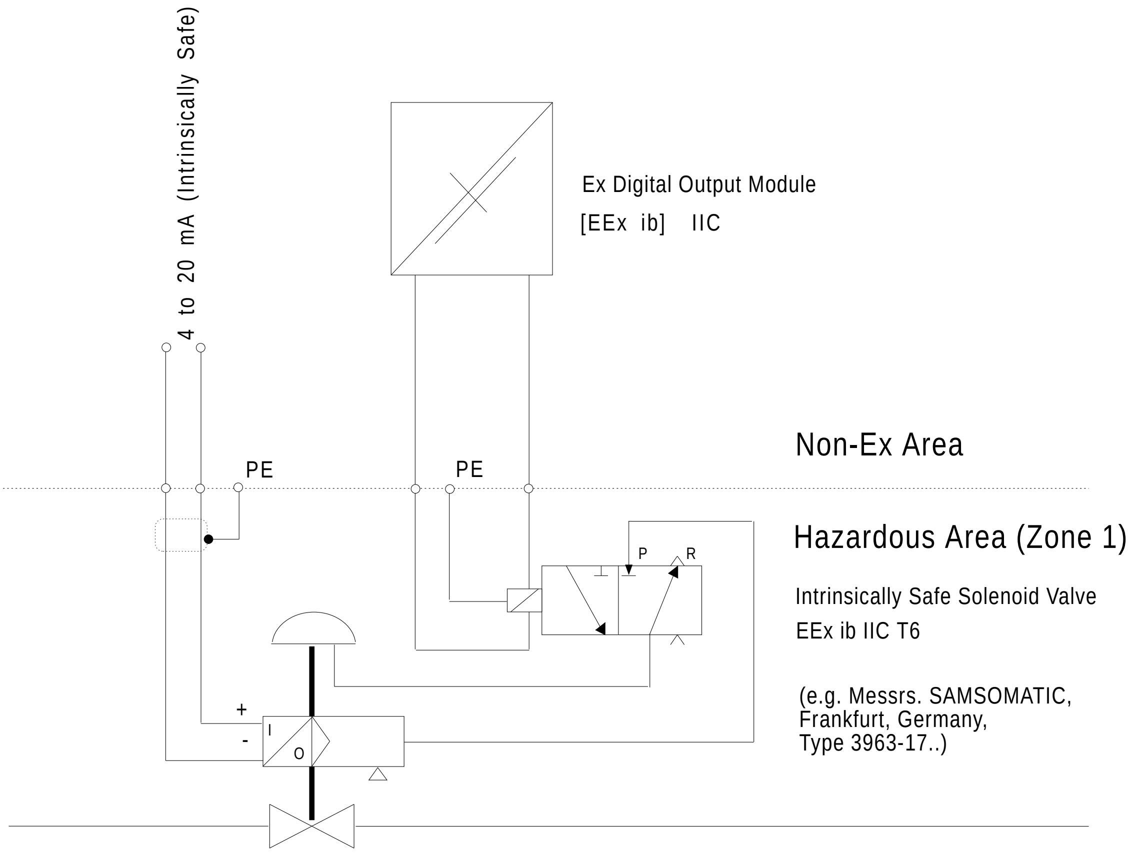


Figure C.2 Intrinsically Safe Control Circuit of an Ex Digital Output Module with Solenoid Valve (Example Shows Rapid Air Relief)

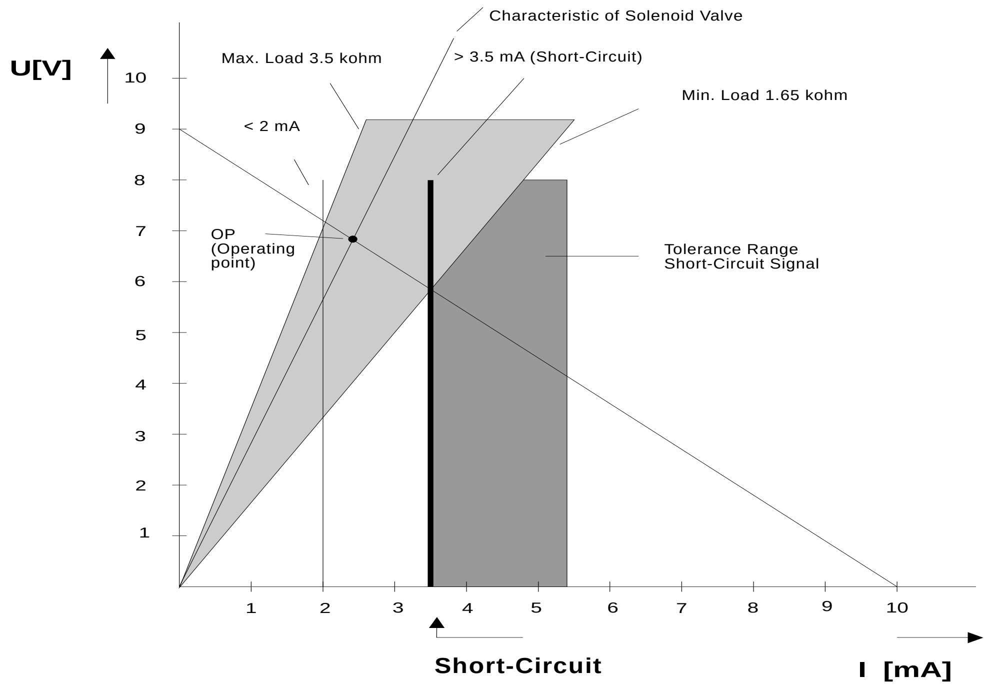


Figure C.3 Basic Characteristic of the Ex Digital Output Module

A comparison with the values of the solenoid valve confirms that the interconnection is permissible.

Table C.3 Comparison: Ex Digital Output Module/Solenoid Valve (SAMSOMATIC Type 3963-17..)

Solenoid Valve (SAMSOMATIC Type 3963-17..)	**Comparison**	**Ex Digital Output Module 6ES5 457-8EA12**
U_{max} = 28 V	≥	U_0 = 10.1 V
I_{max} = 110 mA	≥	I_k = 43 mA
P	≥	P = 97 mW
L_i (negligible) + L_{Line}	≤	L_a ≤ 20 mH
C_i (negligible) + C_{Line}	≤	C_a ≤ 3.0 µF

In this example, the permissible line length is governed by the Ex digital output module.

3. Measurement of temperatures with resistance thermometers (Figure C.4)

Resistance thermometers can be connected in three different configurations. Two, three or four-wire circuits are used, according to the application and precision of the measuring circuit. The receiving of analog measured signals from a temperature transducer (SITRANS T) with Pt 100 is considered here.

In a **two-wire circuit**, the line resistance is in series with the measurement resistance. The line resistance must usually be trimmed to a precisely defined value. Measurement errors can be caused by temperature-related changes in resistance.

In the **three-wire circuit**, the effect of the line resistance on the measured value is sensed and compensated for with a third lead.

In a **four-wire circuit**, the measurement resistance is fed with a constant current of about 2 mA. The voltage drop over the Pt 100 is picked off with another pair of wires. The line resistance has practically no effect on the precision of the measurement.

The SITRANS T measurement transducer can be used with a two, three or four-wire circuit as required.

Considered in the following is an application for temperature measurement comprising an Ex analog input module and a transducer with a two-wire circuit (Figure C.4). In this application, the S5-100U PLC supplies power to the transducer.

The safety-related assessment is in two parts.

Firstly, the interconnection of the Ex analog input module with the transducer must be examined. A comparison of safety-related data results in the following:

Table C.4 Comparison: Ex Analog Input Module/SITRANS T Transducer

SITRANS T Transducer	Comparison	Ex Analog Input Module 6ES5 467-8EE11
U_{max} = 30.0 V	≥	U_0 = 18.0 V
I_{max} = 100 mA	≥	I_k = 82 mA
P_{max} = 750 mW	≥	P = 600 mW
L_i ≤ 1 mH	≤	L_a ≤ 4 mH
C_i ≤ 6 nF	≤	C_a ≤ 270 nF

Permissible line capacitance C_L between Ex digital input module and transducer

$C_i = C_a - C_i$ = 270 nF - 6 nF = 264 nF $\triangleq$ approx. 1.3 km

Safety-related data of the transducer on the sensor side (Pt 100):

U_L = 6 V
I_k = 20 mA
C_a = 59 µF
L_a = 72 mH

For connection to the transducer, the following values apply:

U = 2 V
I = 20 mA
C_i = 12 µF
L_i = 9 mH

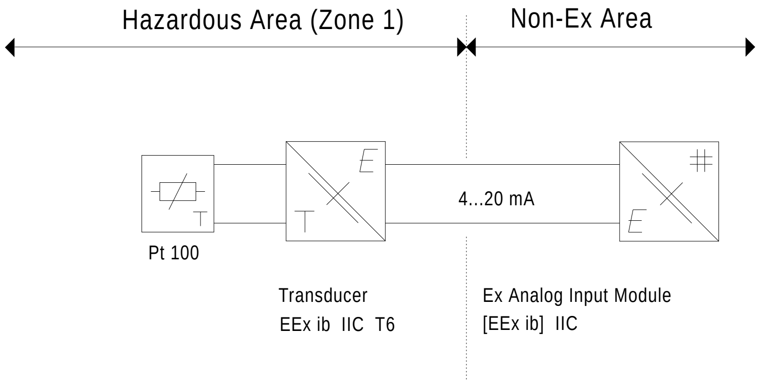


Figure C.4 Measuring Circuit: Ex Analog Input Module with Transducer and Pt 100

Note: The SITRANS T transducer also allows connection of the Pt 500, Pt 1000, Ni 100 or CU 100.

4. Measurement of temperatures with thermocouples (Figure C.6)

Design and principle of operation of thermocouples

A thermocouple comprises

- the thermocouple wires (sensor)
- and the required assembly and connection elements.

The two thermocouple wires are made of different metals or metal alloys, and their ends are soldered or welded (Figure C.5).

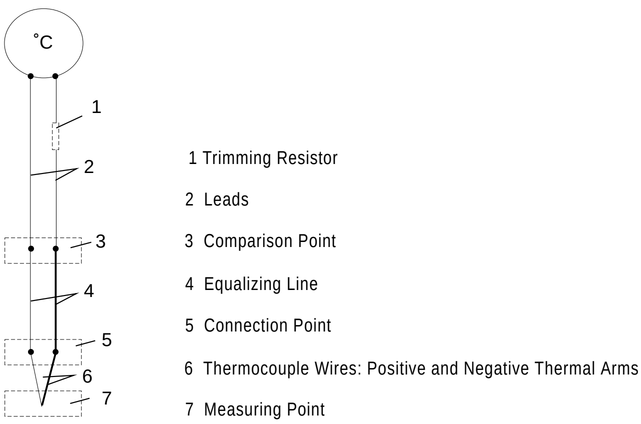


Figure C.5 Thermocouple

When the measuring point is subjected to a temperature other than that of the free ends of the thermocouple, a thermal EMF is produced between the free ends (Seebeck effect). The magnitude of thermal EMF depends on the difference between temperature of the measuring point and the temperature at the free ends, as well as on the type of material combination of the thermocouple. Since a thermocouple always measures a temperature difference, the free ends must be kept on a comparison point at a constant and known temperature, in order to determine the temperature of the measuring point.

The thermocouple wires are extended from their connection point with **equalizing leads** to a point with as constant as possible a temperature (comparison point).

The equalizing leads have the same color coding as the thermocouple wires; the positive lead is red. Correct polarity must be ensured when connecting, otherwise great measurement errors can occur. At up to 200 °C, the same basic values and tolerances apply to the equalizing line as to the corresponding thermocouple wires.

The effect of temperature fluctuations at the comparison point can be compensated for by an **equalizing circuit**, e.g. an **Ex compensation box**. The reference temperature is 0 °C or 20 °C.

However, the comparison points can also be kept at a constant temperature of 50, 60 or 70 °C with a **thermostat** (for two or more measuring points). Since the thermal EMFs are very low, an ungrounded configuration of the measuring circuit is recommended. Measurement errors caused by potential difference, interference voltage or leakage currents can thus be reliably avoided. Additionally, the measuring line should be shielded and grounded at the installation point. If the comparison point is integrated in the transducer, the equalizing line should be laid as far as the comparison point.

Although a thermocouple is considered as active apparatus with its own power source, it needs no certificate for operation in Zones 1 and 2 on account of its low characteristic values and maximum values (see DIN EN 50014 and Figure 6.9).

The choice of transducer is based on various selection criteria:

- Thermocouple to DIN 43710 or IEC 584-1
- Measuring range
- Internal or external comparison point compensation
- Reference temperature with external compensation
- Sensor open-circuit monitoring
- Desired output signal
- Voltage linearity or programmable linearization function

Discussed in the following is a measuring circuit with an Ex analog input module, transducer using a two-wire circuit and a thermocouple. In this application, the Ex analog input module supplies power to the transducer.

The safety-related assessment is in two parts.

Firstly, the interconnection of the Ex analog input module with the transducer is examined with the following comparison between safety-related data:

Table C.5 Comparison: Ex Analog Input Module/SITRANS T Transducer

SITRANS T Transducer	Comparison	Ex Analog Input Module 6ES5 467-8EE11
U_{max} = 30.0 V	≥	U_0 = 18.0 V
I_{max} = 100 mA	≥	I_k = 82 mA
P_{max} = 750 mW	≥	P = 600 mW
L_i ≤ 1 mH	≤	L_a ≤ 4 mH
C_i ≤ 6 nF	≤	C_a ≤ 270 nF

Secondly, a safety-related assessment of the measuring circuit between transducer and thermocouple must be made, e.g. for Zone 0 operation with the following maximum values of the sensor (the transducer is operational in Zone 1):

U_L = 2 V
I_k = 20 mA
C_i ≤ 0.5 µF
L_i ≤ 1 mH

Since there is metallic isolation between the Ex analog input module and within the measuring circuit of the transducer, connection to equipotential bonding is dispensed with.

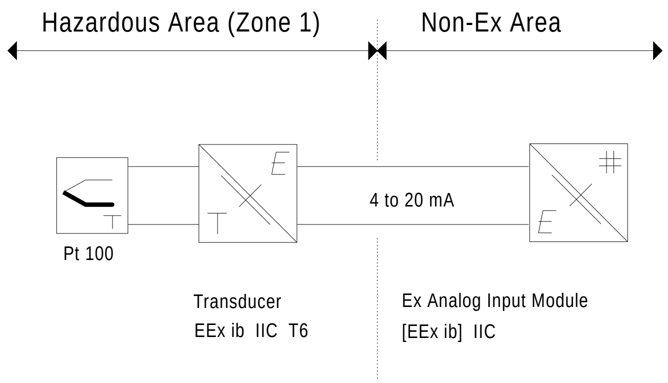


Figure C.6 Measuring Circuit: Ex Analog Input Module with Transducer and Thermocouple

5. Receiving measurement signals with intrinsically safe transducers in a two-wire configuration (Figure C.7)

Transducers in a two-wire configuration are very commonly used for measuring pressure, differential pressure, flow and levels as well as the temperatures of chemicals and the like. These transducers can also be installed in the hazardous area (Zone 1). As intrinsically safe apparatus, they require approval by a testing station.

A common feature of transducers in the two-wire configuration is that the auxiliary power and signal current flow in the same circuit. Depending on the measured quantity, these transducers apply a current of 4 to 20 mA to the circuit.

Considered in the following is the input of analog measurement signals from a two-wire transducer at the Ex analog input module with simultaneous supply of power to the transducer.

The use of the Ex analog input module, which simultaneously has the function of a transducer power supply unit, is relatively simple in conjunction with two-wire transducers. Both the functional and safety-related assessment is limited to a comparison of data between the transducer and the Ex analog input module.

Table C.6 Comparison: Ex Analog Input Module/Transducer for Level Measurement (Siemens SITRANS P 7MF 4620)

Transducer for Level Siemens SITRANS P 7MF 4620	Comparison	Ex Analog Input Module 6ES5 467-8EE11
U_0 = 30 V	≥	U_0 = 18.0 V
I_k = 100 mA	≥	I_k = 82 mA
P = 0.75 W	≥	P = 0.6 W
L_i = 0.6 mH	≤	L_a ≤ 4 mH
C_i = 6 nF	≤	C_a ≤ 270 nF

The capacitance and inductance of the line must additionally be taken into account.

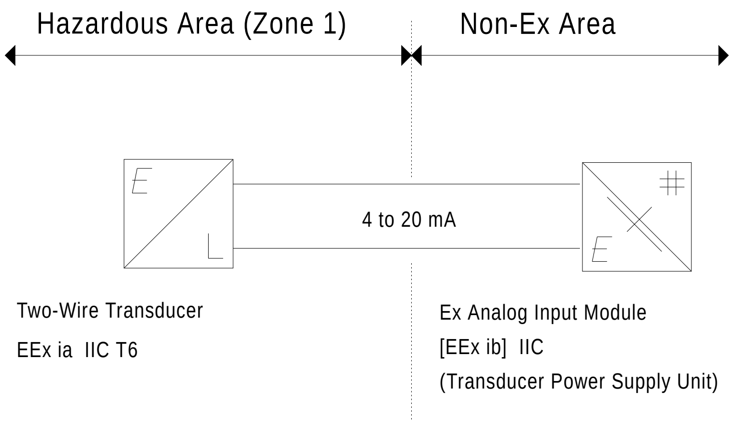


Figure C.7 Auxiliary Power/Signal Circuit of the Ex Analog Input Module with a Level Measurement Transducer

6. **Output of analog signals to actuators** (Figure C.8)

The most frequently used actuators have pneumatic positioners which are less expensive than electric positioners. The current (4 to 20 mA) is converted to a pneumatic standardized signal (0.2 to 1 bar). This apparatus requires approval if it is to be used as intrinsically safe apparatus in a hazardous area.

Discussed in this application is the output of analog signals by the Ex analog output module to an I/P converter in two-wire configuration. Since the Ex analog output module is used, the actuating signal circuit can be ungrounded and floating.

The safety-related assessment is limited to a direct comparison of data of the I/P converter and the Ex analog output module:

Table C.7 Comparison: Ex Analog Output Module / I/P Converter

I/P Converter Type 6DR3000-1E/2E	**Comparison**	**Ex Analog Output Module 6ES5 477-8EC11**
U_{max} = 30 V	≥	U_0 = 18 V
I_{max} = 100 mA	≥	I_k = 82 mA
P = 1000 mW	≥	P = 600 mW
L_i = negligible	≤	L_a ≤ 4 mH
C_i = negligible	≤	C_a ≤ 270 nF

The permissible line length is only limited by the external capacitance Ca of the analog output module.

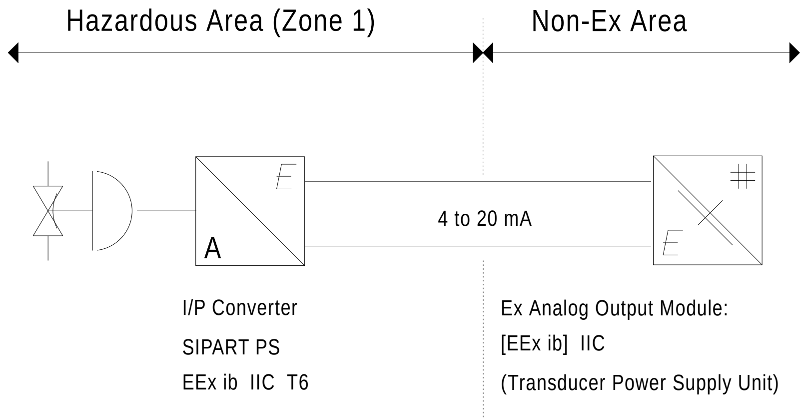


Figure C.8 Auxiliary Power/Signal Circuit of the Ex Analog Output Module with I/P Converter in Two-Wire Configuration

7. Signal output via LEDs

In the chemical and petrochemical industries, semi-conductor-based indicator lights are used, which are also called LEDs. They offer the following advantages over incandescent lamps:

- They have an average service life of 10 years and thus rarely need to be replaced;
- Vibration has no effect on the life of an LED;
- The high inrush currents (up to 18 times the operational current) of incandescent lamps never occur in LEDs;
- The power loss of an LED is lower than that of an incandescent lamp;
- An LED has smaller dimensions.

If LEDs are to be installed in a hazardous area, they have to conform to a type of protection in accordance with DIN EN 50 014 to 50 020. LEDs have been manufactured and used in compliance with type of protection "flameproof/explosion-proof enclosure" combined with type of protection "increased safety" for quite some time. An additional solution is offered by the type of protection "intrinsic safety".

According to the installation regulations (DIN VDE 0165), intrinsically safe electrical equipment need not be submitted to a type test and idenfication procedure to DIN EN 50 020 if no internal power supply is available and if the electrical characteristics and temperature rise characteristics are known.

Note

According to DIN VDE 0165 02.91, Section 6.1.3.1.3, individual semiconductor elements need not be submitted to a type test if the temperature rise characteristics of the semiconductors are known.
This applies for:
- Switches
- Connectors
- Terminal boxes
- Measuring shunts
- **Individual semiconductor elements (e.g. LEDs)**
- Coils (moving-coil elements)
- Capacitors
- Electrical position sensors to DIN 19 234 (partly)

The S5-457 Ex digital output module permits the use of individual LEDs. Up to 4 LEDs can be controlled directly from a PLC.

Interaction of an LED with the Ex digital output module

The output of the Ex digital output module has an output voltage of 7.0 to 7.5 V under operating conditions.

Electrical characteristics in certificate of conformity (6ES5 437-8EA12)
(to file number EX-88.B.2140x plus supplement of the Physikalisch-Technische Bundesanstalt)

U_0 = 10.1 V
I_K = 43 mA
P_{max} = 97 mW

Calculating the internal resistance of the Ex module:

$R_I = U_{max} / I_{max}$ = 10.1 V/43 mA = 237 ohms

The internal resistance of the Ex module is 240 ohms and is used for current limiting.

Description of LED

Commercially available LEDs usually operate with a rated operational current of 10 to 20 mA and a rated operational voltage (U_F) of 1.6 to 2.0 V. The absolute junction temperature may be between 70 °C and 100 °C. Since the junction itself is encapsulated, the heat dissipation towards the LED is negligible.

Electrical characteristics of the LED (e.g. Siemens 5 mm LED, type LR 5460):

Operational temperature	-55 °C to 100 °C
Junction temperature	+100 °C
Conducting-state current	45 mA
Power loss Ptot	150 mW
Thermal resistance: junction/air	500 K/W
Conducting-state voltage	typically 1.6 V (max. 2 V)

Thermal characteristics of the LED

The following applies for the LR 5460 LED R_{thJ-L} = 500 K/W (according to data sheet)
R_{thJ-G} = 250 K/W

thus

$R_{thG-L} = R_{thJ-L} - R_{thJ-G}$ = 500 K/W - 250 K/W = 250 K/W

The maximum temperature rise for the LED housing is therefore
$\Delta T = R_{thG-L} \times P_{max}$ = 250 K/W x 97 mW = 25 K

Max. housing temperature:
TG = TU + ΔT = 60 °C + 25 °C = 85 °C

At an ambient temperature of 60 °C, the temperature at the surface rises to max. 85 °C. This temperature permits applications of temperature class T5 (100 °C).

Note

The temperature rise is even lower for LEDs encapsulated in metal housings.

The intrinsically safe circuit thus suffices for applications conforming to class EEx ib IIC T5.

Calculating the series resistance for the LED

The LED operates at a rated operational voltage (IB) of 1.6 V to 2.0 V. The resulting operational current for the LED is calculated as follows:

$I_B = (U_A - U_{LED}) / R_I = (7.25\ V - 2.0\ V) / 240\ ohms = 22\ mA$

In order to avoid triggering of the short-circuit monitor of the Ex digital output module, the maximum permissible current of 5 mA must not be exceeded. This means that an additional series resistor must be connected in the intrinsically safe circuit. The value of the series resistor is thus calculated as follows:

- Voltage drop on series resistor:
  $U_{Rser} = U_B - U_F = 7.5\ V - 1.5\ V = 6$
  $R_{ser} = U_{Rser} / I_B = 6\ V / 5\ mA =$ approx. 1.2 kohms

In order to compensate for component tolerances, the series resistor should be in the range between 1.4 and 1.6 kohms.

Temperature rise of the series resistor

The series resistor heats up depending on the maximum power output (max. 97 mW) of the Ex digital output module in the case of a fault. If a 0.5 W resistance has been selected, the temperature rise of the series resistance is negligible even at higher temperatures.

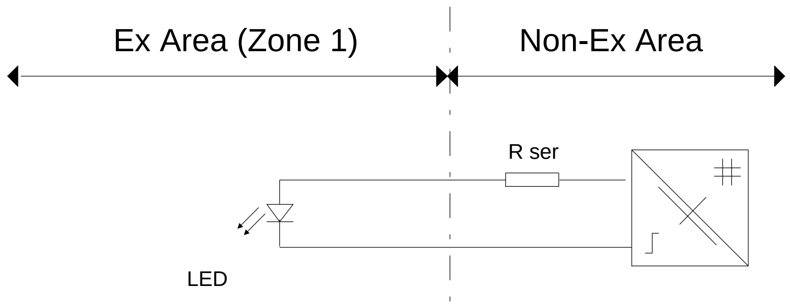


Figure C.9 Ex Digital Output with LED

D Safety Assessment for the Interconnection of Intrinsically Safe Circuits

D Safety Assessment for the Interconnection of Intrinsically Safe Circuits

Ex sensors/actuators which can be connected to SIMATIC S5 Ex modules in Zone 1/2

Measurement/ Variable	Sensor/Actuator or Measuring Method	PTB Certificate Needed?	Ex Module	Example **) (APPLI No.)
Switching point Contact	Initiator - Inductive - Capacitive	Yes	Ex digital input module 6ES5 437-8EA12/21	1xxx
	- Floating contact	No, because passive apparatus *)		
Position (OPEN/ CLOSED) Signal value (ON/OFF)	- Solenoid valve - E/P valve	Yes	Ex digital output module 6ES5 457-8EA12	2xxx
	- LED, lamp - Electroluminescence	No, because passive apparatus *)		
Temperature	Transducer - R. thermometer (Pt 100, Ni 100) - Thermocouple - Radiation pyrometer	Yes	Ex analog input module 6ES5 467-8EA11/8EF11 (Two-wire configuration)	4xxx
Pressure	Transducer with elastic element for absolute and differential pressure and capacitive, inductive or piezoelectric signal conversion	Yes	Ex analog input module 6ES5 467-8EE11 (Two-wire configuration)	5xxx
Level, density	Transducer with sensor for - Hydrostatic measuring method - Radiometric measuring method - Electrical and electronic methods - Reflectometry	Yes		6xxx
Flow, mass flow	Transducer with - Magnetic-inductive signal conversion - Ultrasound measuring method - Differential-pressure method	Yes		7xxx
Variables in liquids	Transducer for measuring - Conductivity - pH value - Viscosity - Redox potential	Yes		8xxx
Position (continuous)	Positioner - Electro-pneumatic - Electro-hydraulic	Yes	Ex analog output module 6ES5 477-8EC11 (Two-wire configuration)	3xxx
Signal value (continuous)	Signal converter - Electro-pneumatic			9xxx
	Indicator - Electrical methods - Electronic methods	No, because passive apparatus *)		

***)** The temperature rise, internal capacitance and inductance must be known.
The apparatus must meet EN 50014/50020, e. g. 500 V test voltage with respect to ground; housing class of protection at least IP 20.

****)** Recommended circuitry for permissible interconnection of intrinsically safe circuits

Connection of an inductive proximity switch

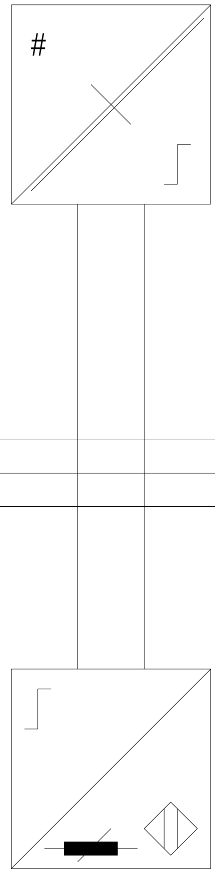
Cabinet

Non-Ex Area

SIEMENS Ex digital input module

6ES5 437 - 8EA12
[EEx ib] IIC
PTB Nr. Ex- 88.B.2149 X
U_o = 10,1 V
I_k = 43 mA
P = 97 mW
L_a = 20 mH
C_a = 3 µF

Permissible line length: 200 m



Plant

Ex Area

SIEMENS BERO 3RG4 inductive proximity switch to NAMUR and DIN 19234

3RG46..-1NA00
PTB No. Ex- 88.B.2145
Max. values of the apparatus:
U_o = 15,5 V
I_k = 52 mA
P = 169 mW
L_i = 48 µH
C_i = 100 nF

SIEMENS

APPL 1001

Connection of a sensor with contacts

Cabinet

Non-Ex Area

SIEMENS Ex digital input module

6ES5 437 - 8EA12
[EEx ib] IIC
PTB Nr. Ex- 88.B.2149 X
U_o = 10,1 V
I_k = 43 mA
P = 97 mW
L_a = 20 mH
C_a = 3 µF

Permissible line length: 200 m

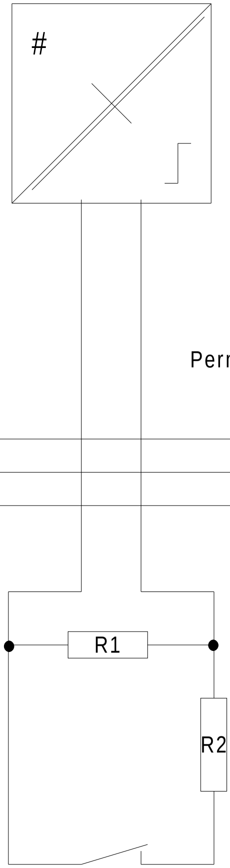
Plant

Ex Area

SIEMENS Pushbutton switch, e.g. 3SB1

PTB No. not needed because this is passive apparatus. Max. permissible rating of R1 and R2 should not be exceeded.

L_i = negligible
C_i = negligible



R1 = 9 to 11 kilohms / 0.5 W
R2 = 1 to 1.5 kilohms / 0.5 W

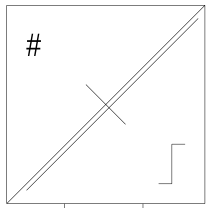
SIEMENS

APPL 1002

Connection of an intrinsically safe solenoid valve

Cabinet

Non-Ex Area



SIEMENS Ex digital output module

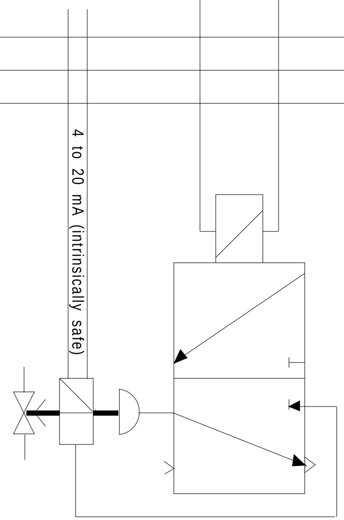
6ES5 457 - 8EA12

[EEx ib] IIC
PTB Nr. Ex- 88.B.2149 X
U_o = 10.1 V
I_k = 43 mA
P = 97 mW
L_a = 20 mH
C_a = 3 µF

Permissible line length: 200 m

Plant

Ex Area



Samsomatic e.g. 3/2-way solenoid valve
Frankfurt Type: 3963-17..

EEx ia IIC T6
PTB No. Ex- 90.C.2100
Max. values of the apparatus:

U_{max} = 28 V
I_{max} = 110 mA
L_i = negligible
C_i = negligible

SIEMENS

APPL 2001

Driving an LED

Cabinet

Non-Ex Area

SIEMENS Ex digital output module

6ES5 457 - 8EA12

[EEx ib] IIC

PTB No. Ex- 88.B.2149 X

U_o = 10.1 V

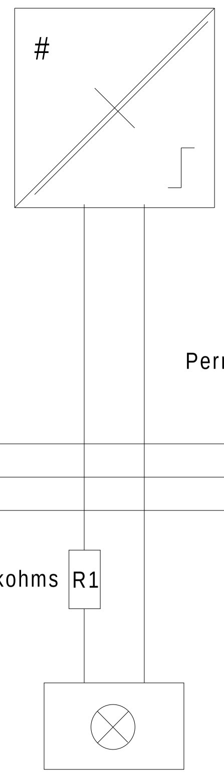
I_k = 43 mA

P = 97 mW

L_a = 20 mH

C_a = 3 µF

Permissible line length: 200 m



R1 = 1.2 kohms

Plant

Ex Area

SIEMENS e. g. RED LH 5424-Q0 (S), 150 mW at 25 °C

PTB No. not needed because this is passive apparatus

Max. values of the apparatus:

U_R = 3 V

U_F = approx. 1.75 V

I_F = 45 mA

L_i = negligible

C_i = negligible

P_{tot} = 150 mW

$R_{thJ\text{-}G}$ = 250 K/W

SIEMENS

APPL 2002

Driving an LED

Cabinet	Plant
Non-Ex Area	Ex Area

Cabinet – Non-Ex Area

SIEMENS Ex digital output module

6ES5 457 - 8EA12

[EEx ib] IIC

PTB No. Ex- 88.B.2149 X

U_o = 10.1 V

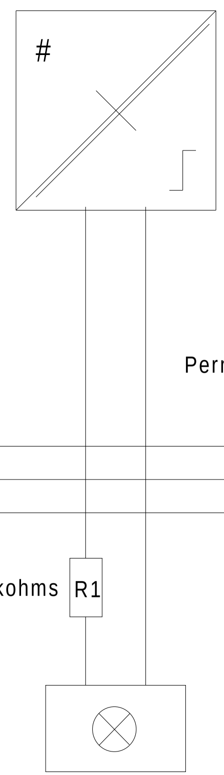
I_k = 43 mA

P = 97 mW

L_a = 20 mH

C_a = 3 µF

Permissible line length: 200 m



R1 = 1.2 kohms

Plant – Ex Area

SIEMENS e. g. RED LS 3341-MQ, 150 mW at 25 °C

PTB No. not needed because this is passive apparatus

Max. values of the apparatus:

U_R = 5 V

U_F = approx. 2.0 V

I_F = 45 mA

L_i = negligible

C_i = negligible

P_{tot} = 150 mW

$R_{thJ\text{-}G}$ = 250 K/W

SIEMENS

APPL 2003

Connection of a positioner

Cabinet

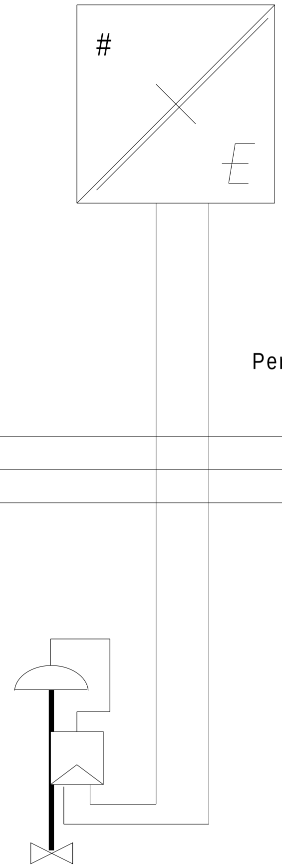
Non-Ex Area

SIEMENS Ex analog output module

6ES5 477 - 8EC11

[EEx ib] IIC
PTB No. Ex- 88.B.2149 X

U_o = 18 V
I_k = 82 mA
P = 600 mW
L_a = 4 mH
C_a = 270 nF
R_i = 354 ohms



Permissible line length: 200 m

Plant

Ex Area

SIEMENS Positioner SIPART PS
6 DR 300 - 1E / 2E

EEx ib IIC T6
PTB No. Ex- 91.C.2138
Max. values of the apparatus:

U_{max} = 30 V
I_{max} = 100 mA
P_{max} = 1 W
L_i = negligible
C_i = negligible

SIEMENS

APPL 3001

Measuring temperatures with the Pt 100

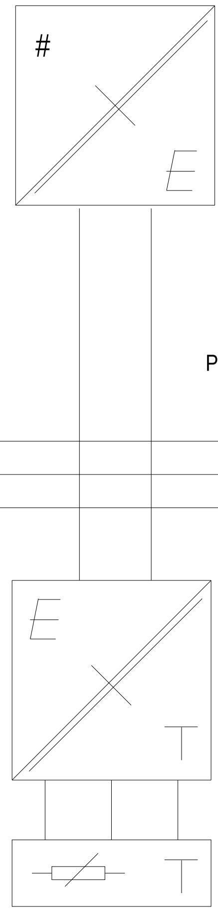
Cabinet

Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110
U_o = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 ohms
L_a = 4 mH
C_a = 270 nF

Permissible line length: 200 m



Plant

Ex Area

SIEMENS SITRANS T 90
7NG3022-3J

EEx ia / ib IIC T6
PTB No. Ex-91.C.2078X
Max. values on the output side:
U_{max} = 30 V
I_{max} = 100 mA
P_{max} ≦ 750 mW
L_i = 1 mH
C_i ≦ 6 nF

Max. values on the sensor side:
U = 2 V
I = 20 mA
C_a ≦ 12 µF
L_a ≦ 9 mH

SIEMENS

APPL 4001

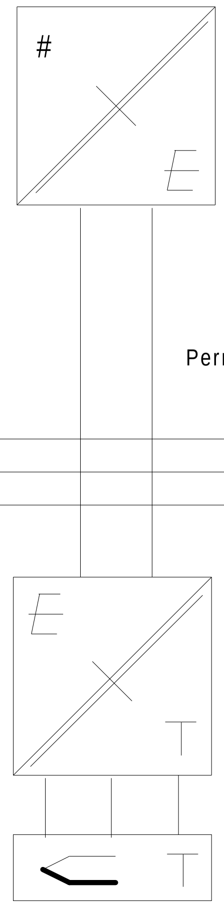
Measuring temperatures with thermocouples

Cabinet — Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110
U_o = 18 V
I_k = 82 mA
P = 600 mW
L_a = 4 mH
C_a = 270 nF
R_i = 354 ohms

Permissible line length: 200 m



Plant — Ex Area

SIEMENS SITRANS T
7NG3022 - 3J + ia 0

EEx ia/ib IIC T6
PTB No. Ex-91.C.2078X
Max. values on the output side:
U_{max} = 30 V
I_{max} = 100 mA
$P_{max} \leq$ 750 mW
L_i = 1 mH
$C_i \leq$ 6 nF

Max. values on the sensor side:
U = 2 V
I = 20 mA
L_a = 12 µH
C_a = 6 nF

SIEMENS

APPL 4002

Measuring temperatures with a resistance-type sensor

Transducer in the sensor head

Cabinet

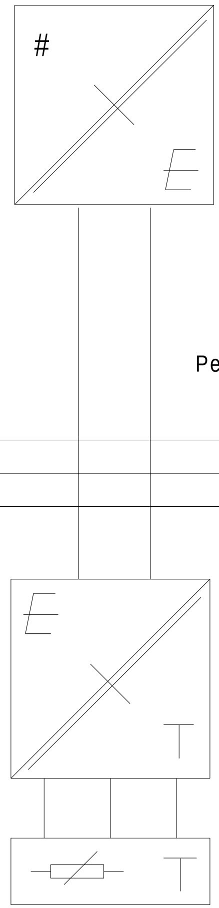
Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110

U_o = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 ohms
L_a = 4 mH
C_a = 270 nF

Permissible line length: 200 m



Plant

Ex Area

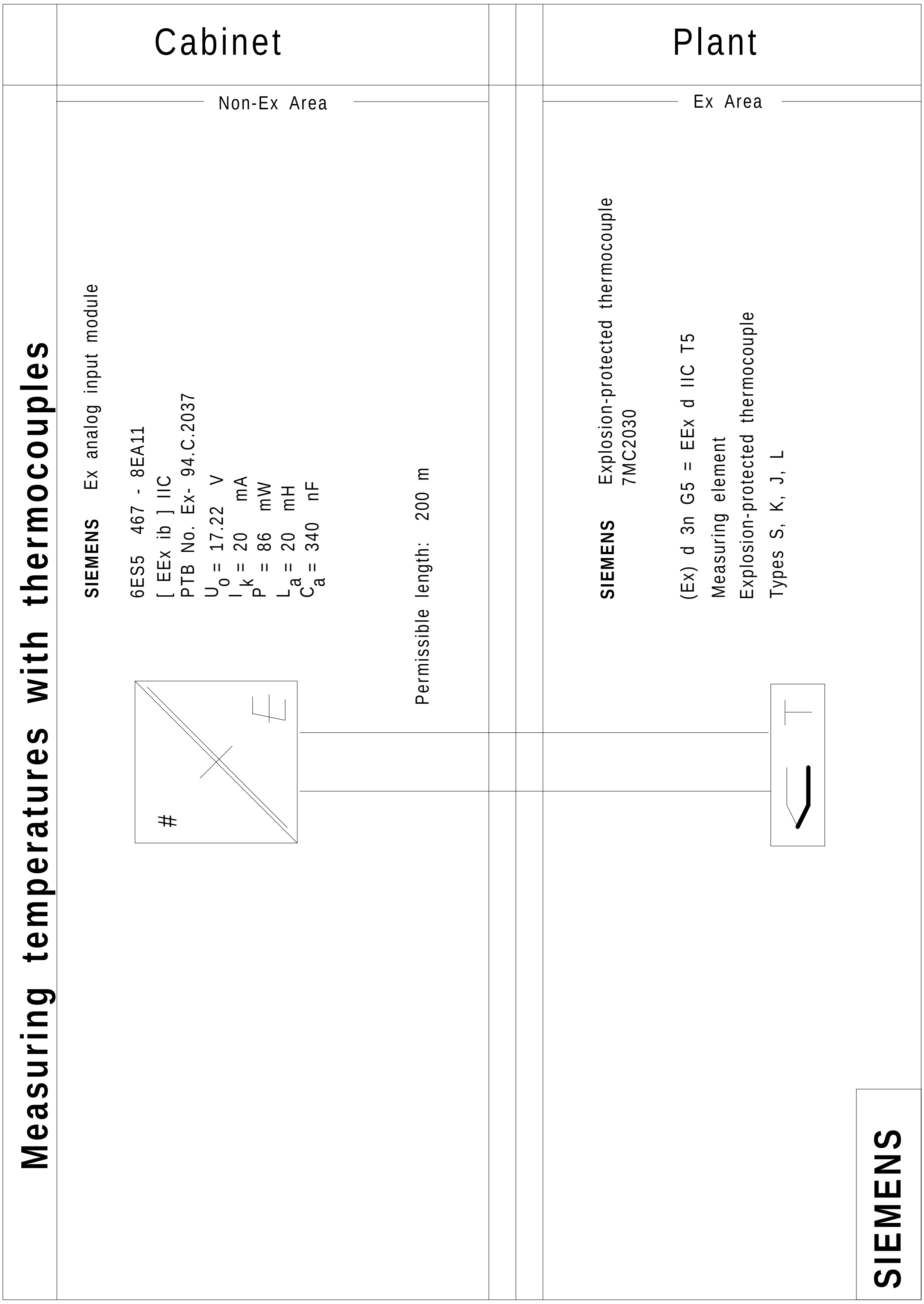
SIEMENS Transducer for temperature
7NG2202 - * ++ 43 - Z

EEx ib [ia] IIC T6
PTB No. Ex-85 / 2185X
Max. values of the apparatus:

U_{max} = 30 V
I_{max} = 100 mA
$P_{max} \leq$ 1 W
L_i = 1 mH
C_i ≤ 1 nF

SIEMENS

APPL 4003


Measuring temperatures with thermocouples
Cabinet
Plant
Non-Ex Area
Ex Area
SIEMENS Ex analog input module
6ES5 467 - 8EA11
[EEx ib] IIC
PTB No. Ex- 94.C.2037
U_o = 17.22 V
I_k = 20 mA
P = 86 mW
L_a = 20 mH
C_a = 340 nF
Permissible length: 200 m
SIEMENS Explosion-protected thermocouple 7MC2030
(Ex) d 3n G5 = EEx d IIC T5
Measuring element
Explosion-protected thermocouple
Types S, K, J, L
SIEMENS

APPL 4004

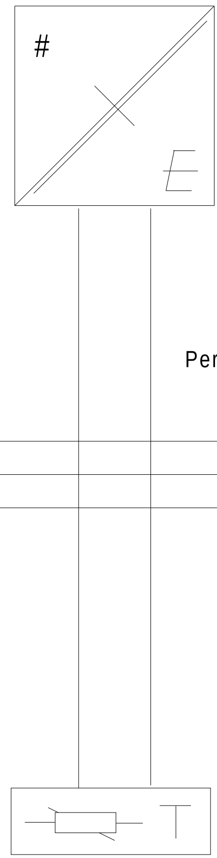
Measuring temperatures with thermocouples

Cabinet

Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EF11
[EEx ib] IIC
PTB No. Ex- 94.C.2036
U_o = 17.22 V
I_k = 33 mA
P = 142 mW
L_a = 10 mH
C_a = 240 nF



Permissible length: 200 m

Plant

Ex Area

SIEMENS Explosion-proof
resistance thermometer
7MC1037

EEx de IIC T6
Measuring element with a Pt measuring resistance
in 2-wire, 3-wire or 4-wire configuration

SIEMENS

APPL 4005

Measurement of pressure

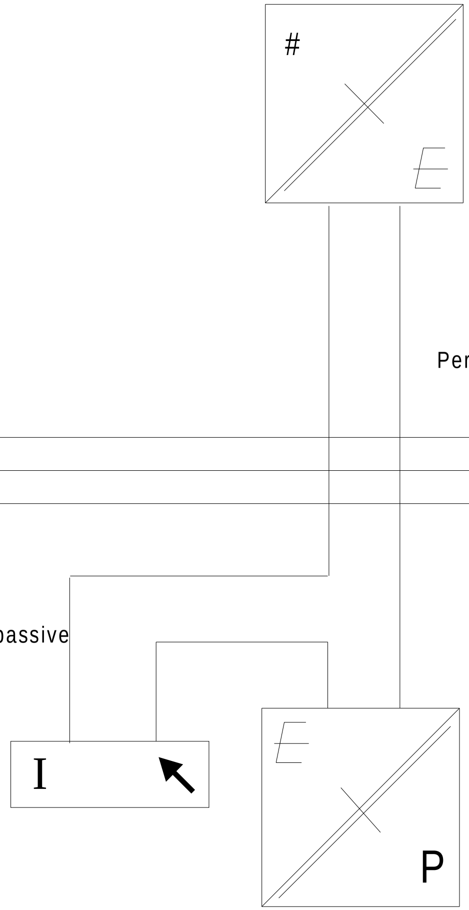
Cabinet	Plant
Non-Ex Area	Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110

U_0 = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 ohms
L_a = 4 mH
C_a = 270 nF

Permissible line length: 200 m



SIEMENS Transducer type micro-K
7MF 3*0/1/4 - for pressure

EEx ia IIC T5
PTB No. Ex-91.C.2125
Max. values of the apparatus:

U_0 = 28 V
I_k = 93 mA
P = 650 mW
L_i = 0.5 mH
C_i = 6.5 nF

SIEMENS Indicator

PTB No. not needed because passive
Max. values of the apparatus:

L_i = 0.25 mH
C_i = 1 nF

SIEMENS

APPL 5001

Measurement of differential pressure

Cabinet

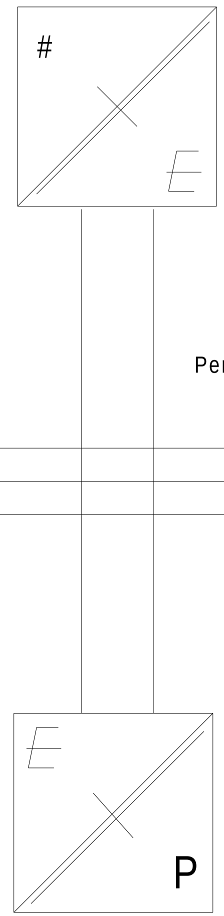
Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110

U_o = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 ohms
L_a = 4 mH
C_a = 270 nF

Permissible line length: 200 m



Plant

Ex Area

SIEMENS Transducer micro-K for differential pressure
7 MF 3*2/3*-

EEx ia IIC T5
PTB No. Ex-91.C.2125
Max. values of the apparatus:

U_0 = 28 V
I_k = 93 mA
P = 650 mW
L_i = 0,5 mH
C_i = 6.5 nF

SIEMENS

APPL 5002

Measurement of absolute pressure

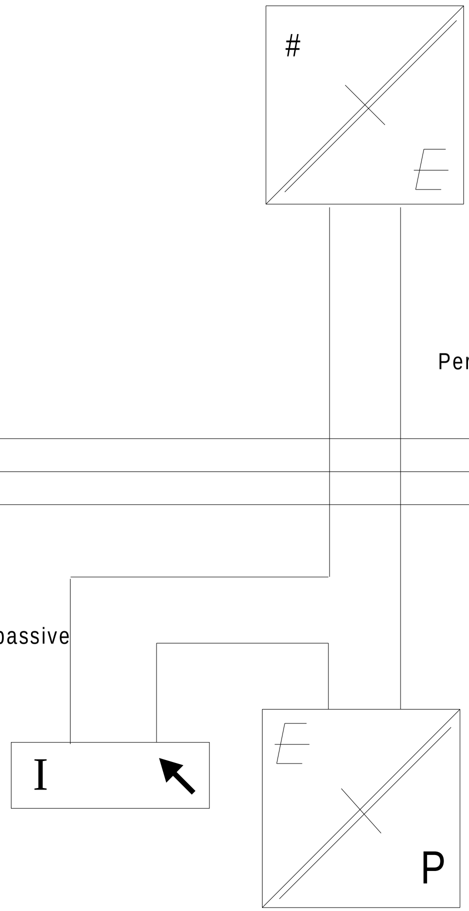
Cabinet

Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110
U_o = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 ohms
L_a = 4 mH
C_a = 270 nF

Permissible line length: 200 m



Plant

Ex Area

SIEMENS Transducer SITRANS P for absolute pressure 7MF 4320

EEx ia IIC T6
PTB No. Ex-92.C.2146
Max. values of the apparatus:
U_0 = 30 V
I_k = 100 mA
P = 0.75 W
L_i = 0.6 mH
C_i = 6 nF

SIEMENS Indicator

PTB No. not needed because passive
Max. values of the apparatus:
U_{max} = 0.06 V
I_{max} = 20 mA
L_i = 12.4 µH
C_i = negligible
R_i = 3.1 ohms

SIEMENS

APPL 5003

Measurement of differential pressure / flow

Cabinet

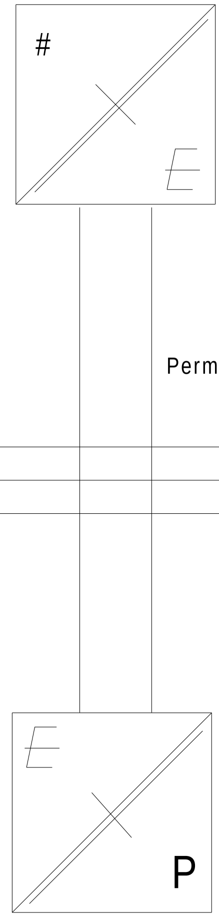
Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110

U_o = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 ohms
L_a = 4 mH
C_a = 270 nF

Permissible line length: 200 m



Plant

Ex Area

SIEMENS Transducer SITRANS P for differential pressure and flow 7 MF 44/5**-*****-18

EEx ia IIC T6
PTB No. Ex-92.C.2146
Max. values of the apparatus:

U_0 = 30 V
I_k = 100 mA
P = 0.75 W
L_i = 0.6 mH
C_i = 6 nF

SIEMENS

APPL 5004

Measurement of pressure (e. g. level)

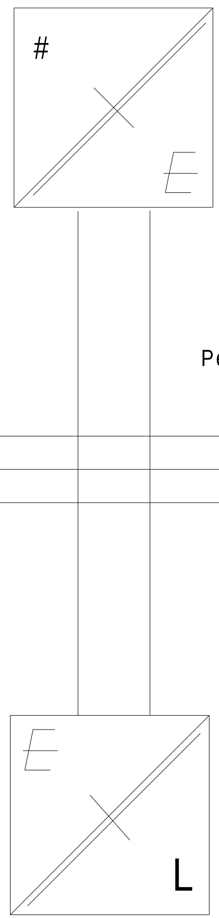
Cabinet

Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110
U_o = 18 V
I_k = 82 mA
P = 600 mW
R_i = 354 ohms
L_a = 4 mH
C_a = 270 nF

Permissible line length: 200 m



Plant

Ex Area

SIEMENS Transducer SITRANS P for pressure 7MF 40/3/6xx-

EEx ia IIC T6
PTB No. Ex-92.C.2146
Max. values of the apparatus:
U_0 = 30 V
I_k = 100 mA
P = 0.75 W
L_i = 0.6 mH
C_i = 6 nF

SIEMENS

APPL 6001

Connection of an electro-pneumatic signal converter

Cabinet

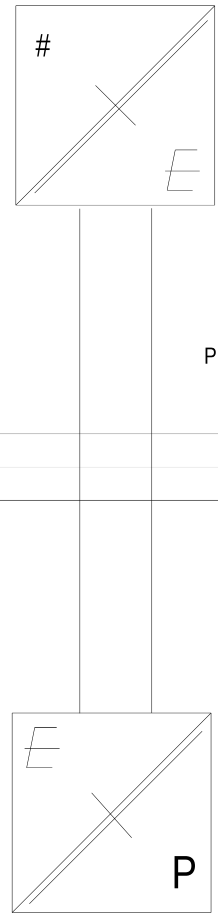
Non-Ex Area

SIEMENS Ex analog input module

6ES5 467 - 8EE11
[EEx ib] IIC
PTB No. Ex- 91.C.2110

U_o = 18 V
I_k = 82 mA
P = 600 mW
L_a = 4 mH
C_a = 270 nF
R_i = 354 ohms

Permissible line length: 200 m



Plant

Ex Area

SIEMENS Electro-pneumatic signal converter
M 77740

EEx ib IIC T6
PTB No. Ex-88.B.2141
Max. values of the apparatus:
U_{max} = 28 V
I_{max} = 100 mA
L_i = negligible
C_i = negligible

SIEMENS

APPL 9001

The following procedure is suitable for testing interconnections for intrinisic safety:

1. Verify that the total I_k of active apparatus is less than the I_{max} of each item of apparatus.

   Result: 82 mA < 100 mA for No. 2,
   83 mA < 110 mA for No. 3.

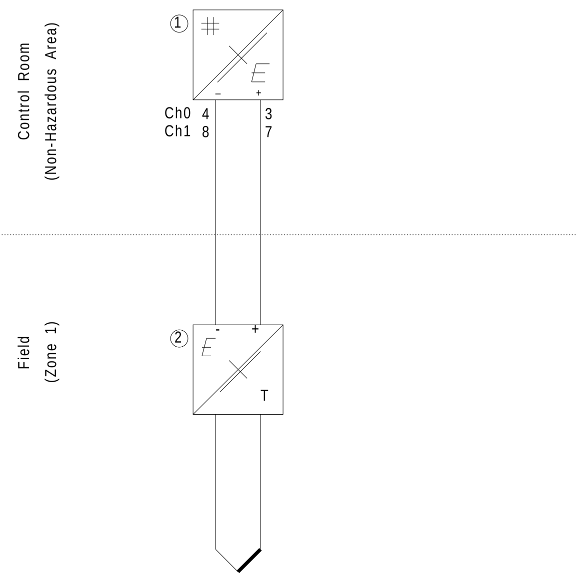
2. Verify that the total of all U_0 of active apparatus is less than the U_{max} of each item of apparatus.

   Result: 18 V < 30 V for No. 2,
   18 V < 28 V for No. 3.

3. Verify that the total C_i of all apparatus including cables is less than the permissible C_a of each item of apparatus

Result (without cable):	Total C_i = 6nF < 270 nF;	remainder 270 nF - 6 nF = 264 nF available for the cable
	Total L_i = 1 mH < 4 mH;	remainder 4 mH - 1 mH = 3 mH available for the cable.

The following forms contain three examples for equipment interconnections in which the current values for U_0 and I_k as well as for the inductances and capacitances are entered. A blank form is attached in each case for the characteristic values and for plotting the overall characteristic.



Electrical characteristic values of the apparatus

No.	Designation	Manufact.	Type	No. of Certificate of Conformity	L_a [mH]	L_i [mH]	C_a [nF]	C_i [nF]	U_o [V]	U_{max} [V]	I_k [mA]	I_{max} [mA]	R [ohms]	P [mW]
1	Analog input	SIEMENS	6ES5 467-8EE11	PTB NoEx-91.C.2110	4	negl.	270	negl.	18		82		354	600
2	SITRANS-MU T 90	SIEMENS	7NG3022-3JN-Z	PTB No. Ex-91.C.2078X		1		6		30		100		750
3														
4														
5														

L_i = Internal inductance L_a = External inductance C_i = Internal capacitance C_a = External capacitance

U_o = No-load voltage I_k = Short-circuit current R = Internal resistance P = Max. power

Evidence of intrinsic safety of the interconnection

	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]
Passive Apparatus Interconnected with the Power Source	2	1	6									
	∑	1	6	∑			∑			∑		
Active apparatus	1	4	270	2								
	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]

Additional fault assessment for interconnections with more than one item of active apparatus

Fault case 1: Series connection of the active apparatus

Addition of no-load voltages: $\hat{U}_o$ = + + + = V

Determining C_a from the min. igniting curves with $\hat{U}_o$ C_a = nF

Total of all remaining C_i C_i = nF

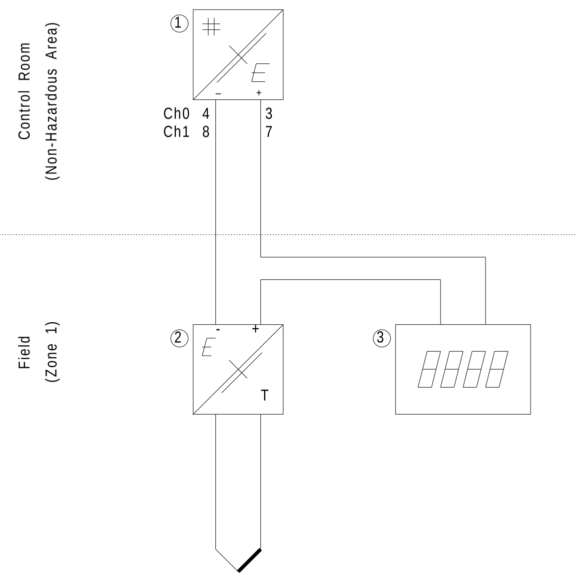
Fault case 2: Parallel connection of the active apparatus

Addition of short-circuit currents $\hat{I}_k$ = + + + = mA

Determining L_a from the min. igniting curves with $\hat{I}_k$ L_a = mH

Total of all remaining L_i L_i = mH

				199	Date	Name	Meas. & control Position No.
				Signed			Designation:
				Check			
				Stand.			**Evidence of intrinsic safety of interconnection**
							Plant: / Building
No.	Revision	Date	Name	Dept.			Installation:



Electrical characteristic values of the apparatus

No.	Designation	Manufact.	Type	No. of Certificate of Conformity	L_a [mH]	L_i [mH]	C_a [nF]	C_i [nF]	U_o [V]	U_{max} [V]	I_k [mA]	I_{max} [mA]	R [ohms]	P [mW]
1	Analog input	SIEMENS	6ES5 467-8EE11	PTB NoEx-91.C.2110	4	negl.	270	negl.	18		82		354	600
2	SITRANS-MU T 90	SIEMENS	7NG3022-3JN-Z	PTB No. Ex-91.C.2078X		1		6		30		100		750
3	Digital indicator	Knick	803 R	PTB No. Ex 83/2129	—	negl.	—	negl.	—	28	—	110		
4														
5														

L_i = Internal inductance L_a = External inductance C_i = Internal capacitance C_a = External capacitance

U_o = No-load voltage I_k = Short-circuit current R = Internal resistance P = Max. power

Evidence of intrinsic safety of the interconnection

	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]
Passive Apparatus Interconnected with the Power Source	2	1	6									
	3	v.k.	v.k.									
	∑	1	6	∑			∑			∑		
Active apparatus	1	4	270	2								
	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]

Additional fault assessment for interconnections with more than one item of active apparatus

Fault case 1: Series connection of the active apparatus

Addition of no-load voltages: $\hat{U}_o$ = + + + = V

Determining C_a from the min. igniting curves with $\hat{U}_o$ C_a = nF

Total of all remaining C_i C_i = nF

Fault case 2: Parallel connection of the active apparatus

Addition of short-circuit currents $\hat{I}_k$ = + + + = mA

Determining L_a from the min. igniting curves with $\hat{I}_k$ L_a = mH

Total of all remaining L_i L_i = mH

				199	Date	Name
				Signed		
				Check		
				Stand.		
No.	Revision	Date	Name	Dept.		

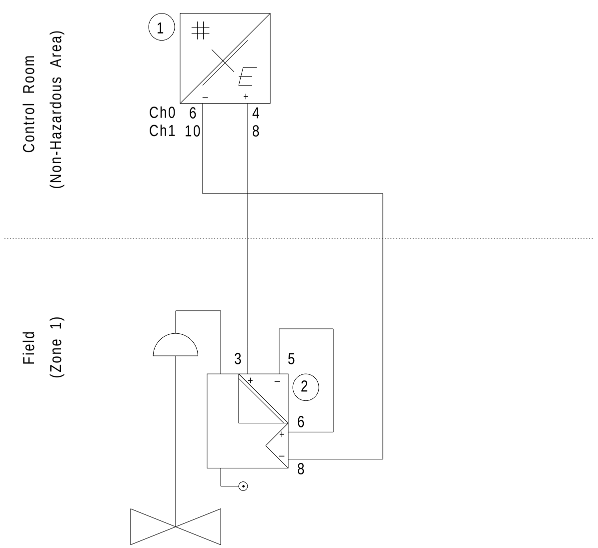
Meas. & control Position No.

Designation:

Evidence of intrinsic safety of interconnection

Plant: Building

Installation:



Electrical characteristic values of the apparatus

No.	Designation	Manufact.	Type	No. of Certificate of Conformity	L_a [mH]	L_i [mH]	C_a [nF]	C_i [nF]	U_o [V]	U_{max} [V]	I_k [mA]	I_{max} [mA]	R [ohms]	P [mW]
1	Analog output	SIEMENS	6ES5 477-8EC11	PTB NoEx-91.C.2109	4	negl.	270	negl.	18		82		354	600
2	SIPART PS	SIEMENS	6DR3000-1E/2E	PTB No.Ex-91.C.2138		negl.		negl.		30		100		1000
3														
4														
5														

L_i = Internal inductance L_a = External inductance C_i = Internal capacitance C_a = External capacitance

U_o = No-load voltage I_k = Short-circuit current R = Internal resistance P = Max. power

Evidence of intrinsic safety of the interconnection

	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]
Passive Apparatus Interconnected with the Power Source	2	v.k.	v.k.									
	∑	v.k.	v.k.	∑			∑			∑		
Active apparatus	1	4	270									
	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]

Additional fault assessment for interconnections with more than one item of active apparatus

Fault case 1: Series connection of the active apparatus

Addition of no-load voltages: $\hat{U}_o$ = + + + = V

Determining C_a from the min. igniting curves with $\hat{U}_o$ C_a = nF

Total of all remaining C_i C_i = nF

Fault case 2: Parallel connection of the active apparatus

Addition of short-circuit currents $\hat{I}_k$ = + + + = mA

Determining L_a from the min. igniting curves with $\hat{I}_k$ L_a = mH

Total of all remaining L_i L_i = mH

				199	Date	Name
				Signed		
				Check		
				Stand.		
No.	Revision	Date	Name	Dept.		

Meas. & control Position No.

Designation: S5 ET 100 Analog output 6ES5 477-8EC11 and positioner SIPART PS

Evidence of intrinsic safety of interconnection

Plant: Building

Installation:

Electrical characteristic values of the apparatus

No.	Designation	Manufact.	Type	No. of Certificate of Conformity	L_a [mH]	L_i [mH]	C_a [nF]	C_i [nF]	U_o [V]	U_{max} [V]	I_k [mA]	I_{max} [mA]	R [ohms]	P [mW]
1														
2														
3														
4														
5														

L_i = Internal inductance L_a = External inductance C_i = Internal capacitance C_a = External capacitance

U_o = No-load voltage I_k = Short-circuit current R = Internal resistance P = Max. power

Evidence of intrinsic safety of the interconnection

	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]	No.	L_i [mH]	C_i [nF]
Passive Apparatus Interconnected with the Power Source												
	∑			∑			∑			∑		
Active apparatus												
	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]	No.	L_a [mH]	C_a [nF]

Additional fault assessment for interconnections with more than one item of active apparatus

Fault case 1: Series connection of the active apparatus

Addition of no-load voltages: $\hat{U}_o$ = + + + = V

Determining C_a from the min. igniting curves with $\hat{U}_o$ C_a = nF

Total of all remaining C_i C_i = nF

Fault case 2: Parallel connection of the active apparatus

Addition of short-circuit currents $\hat{I}_k$ = + + + = mA

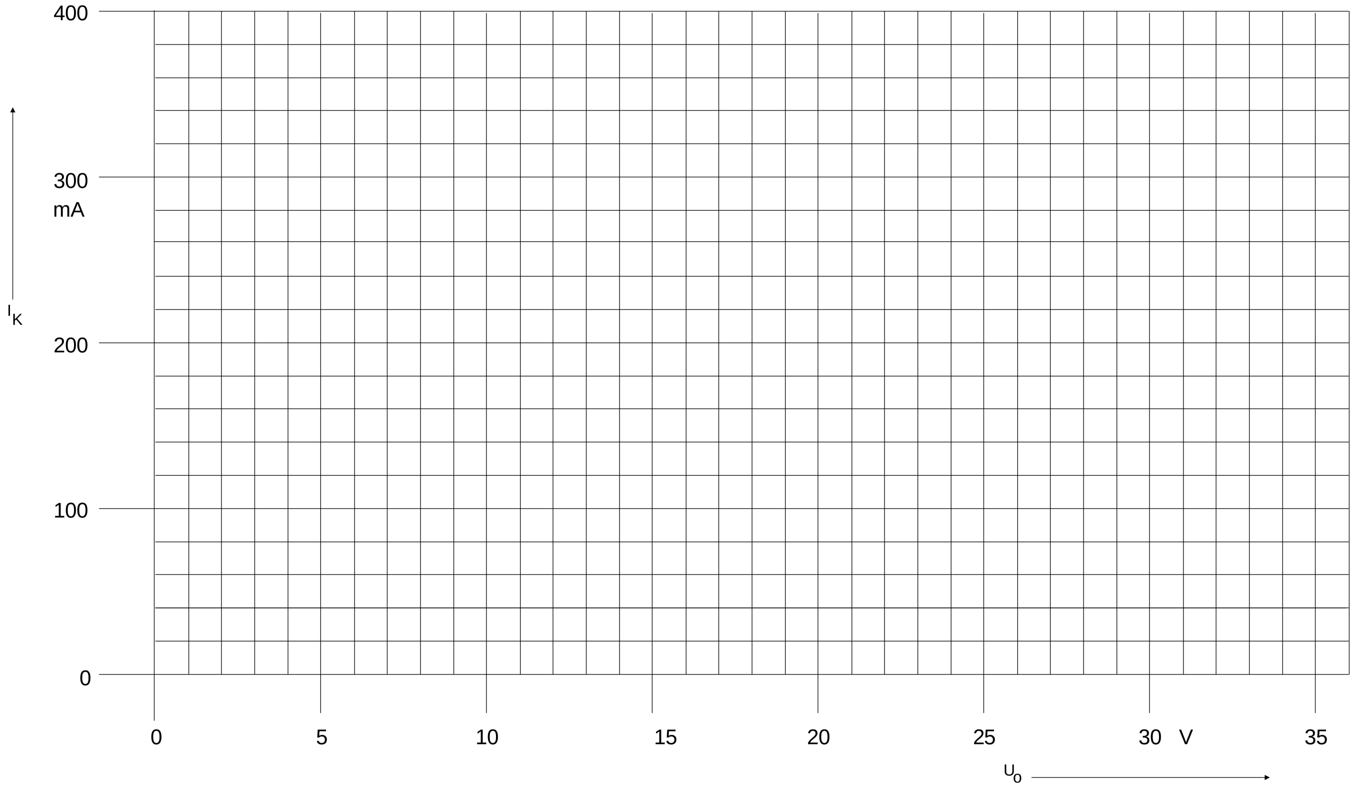
Determining L_a from the min. igniting curves with $\hat{I}_k$ L_a = mH

Total of all remaining L_i L_i = mH

				199	Date	Name	Meas. & control Position No.
				Signed			Designation:
				Check			
				Stand.			**Evidence of intrinsic safety of interconnection**
							Plant: / Building
No.	Revision	Date	Name	Dept.			Installation:

Overall characteristic

Designation / Type	Basic Points															
	U_0/ I_k		U_0/ I_k		U_0/ I_k		U_0/ I_k		U_0/ I_k		U_0/ I_k		U_0/ I_k		U_0/ I_k	



E Dimension Drawings

Figures

E Dimension Drawings

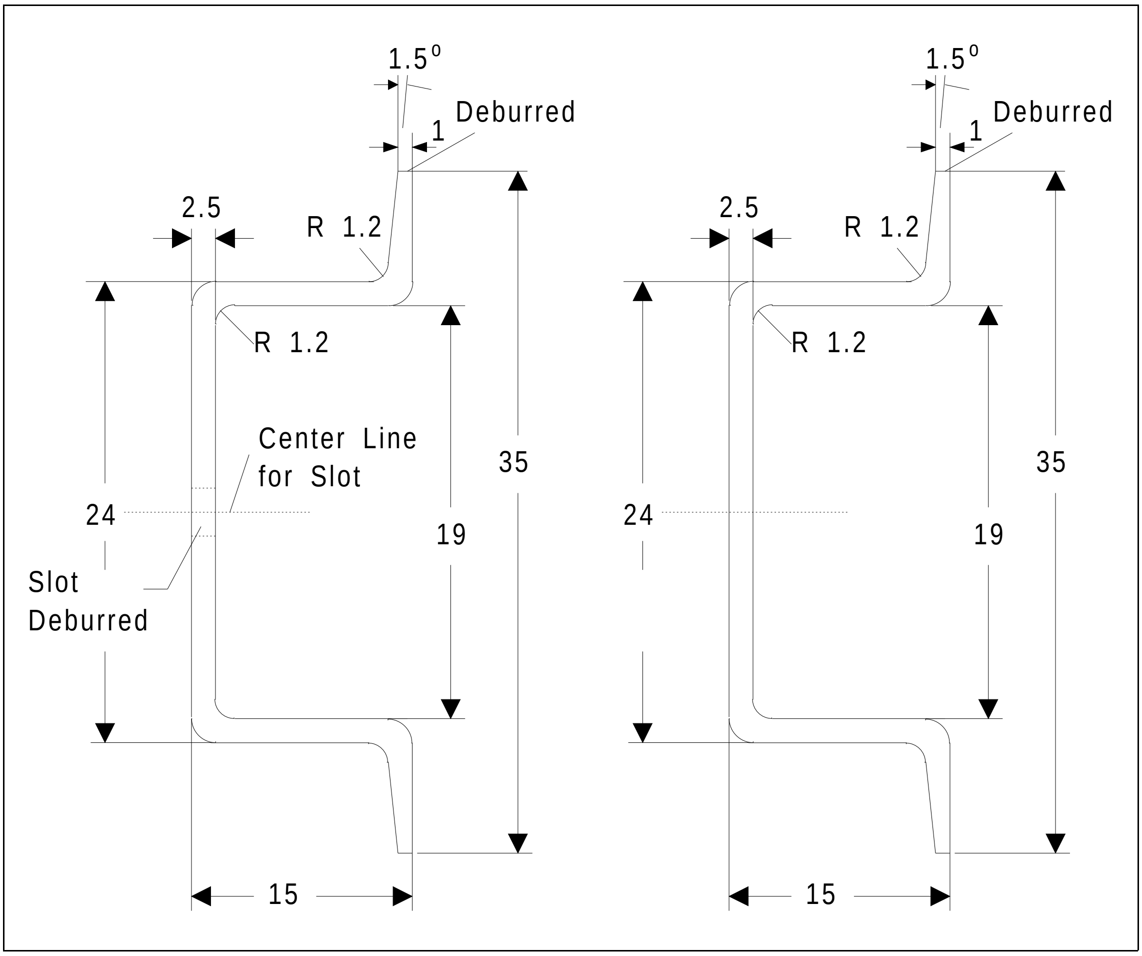


Figure E.1 Cross-Sections of the Standard Sectional Rail

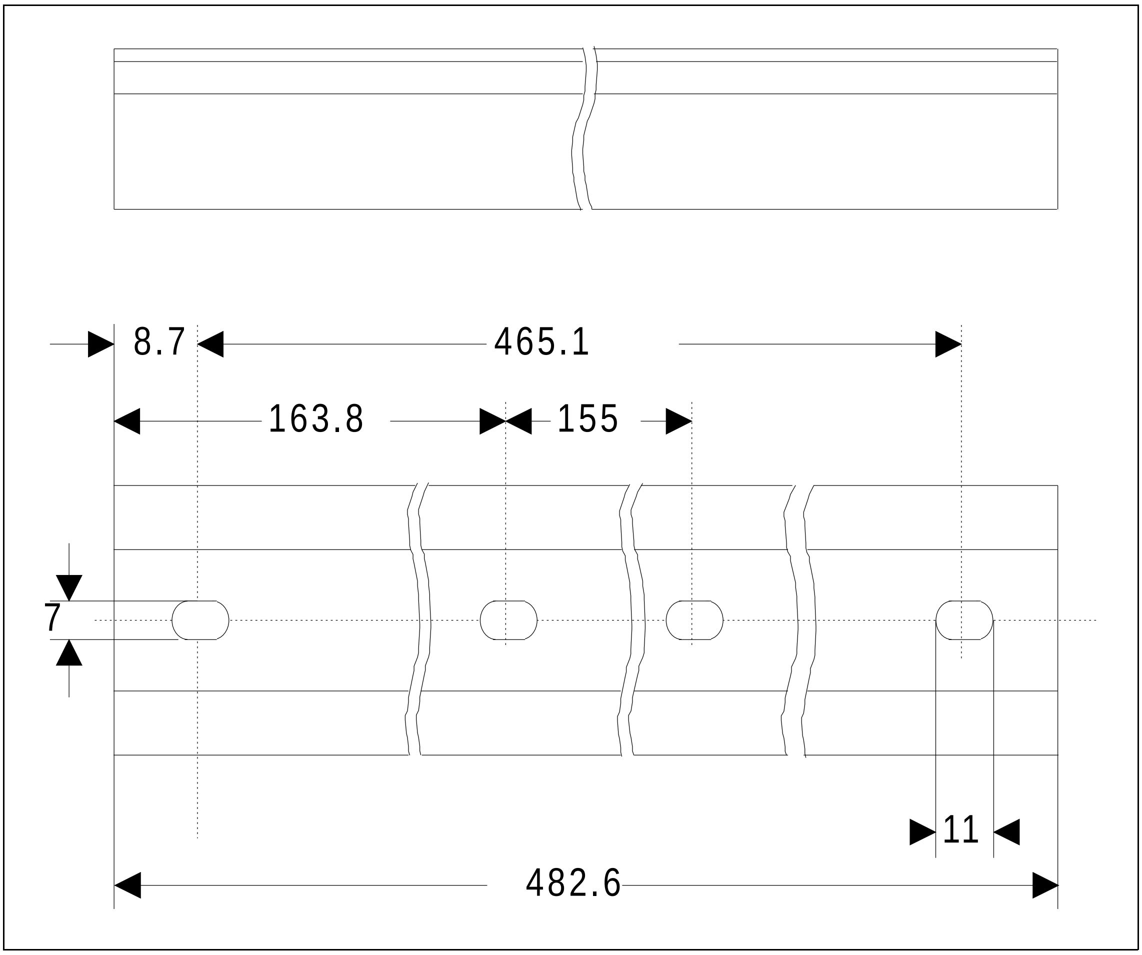


Figure E.2 Dimension Drawing of the 483 mm (19") Standard Sectional Rail

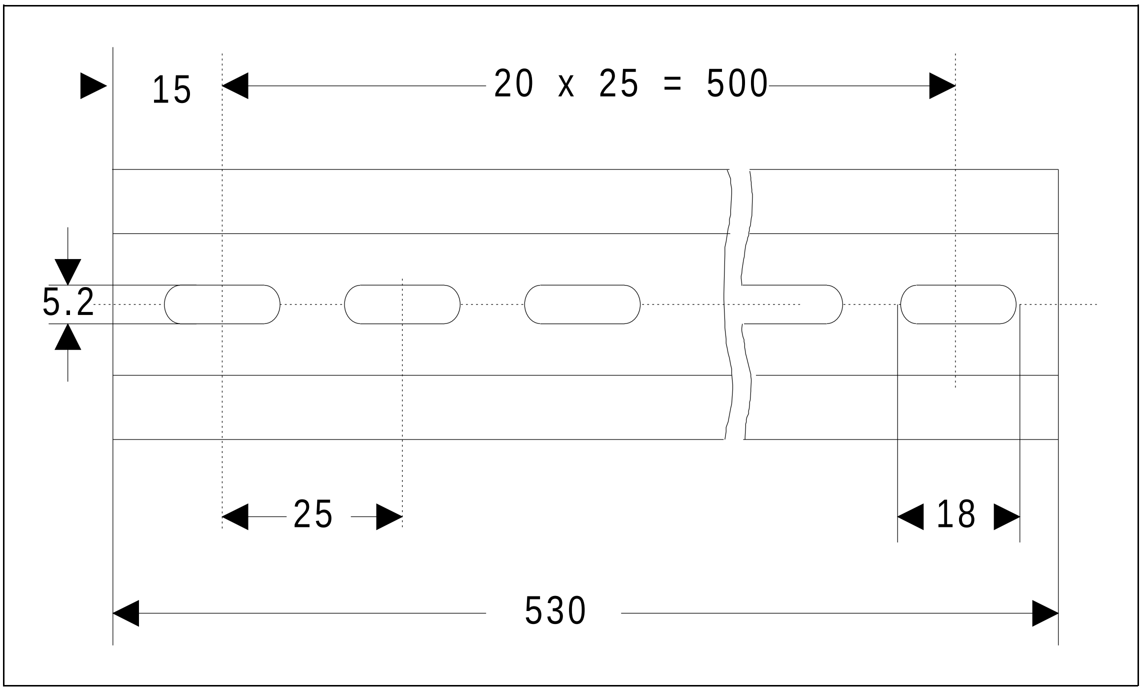


Figure E.3 Dimension Drawing of the 530 mm Standard Sectional Rail

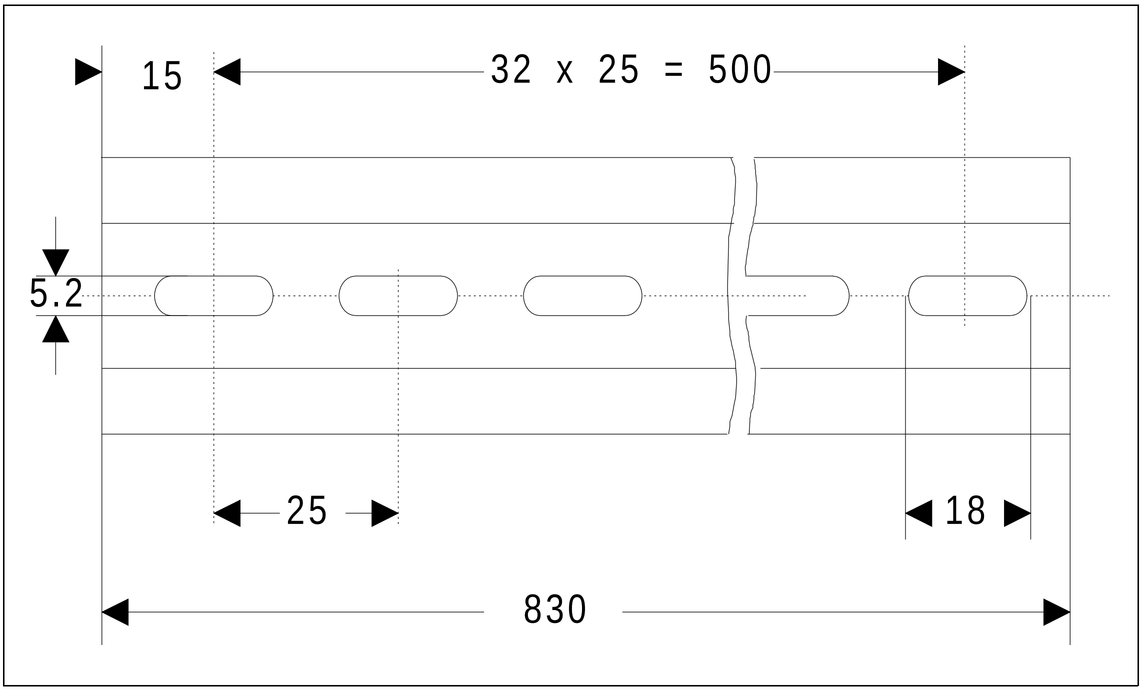


Figure E.4 Dimension Drawing of the 830 mm Standard Sectional Rail

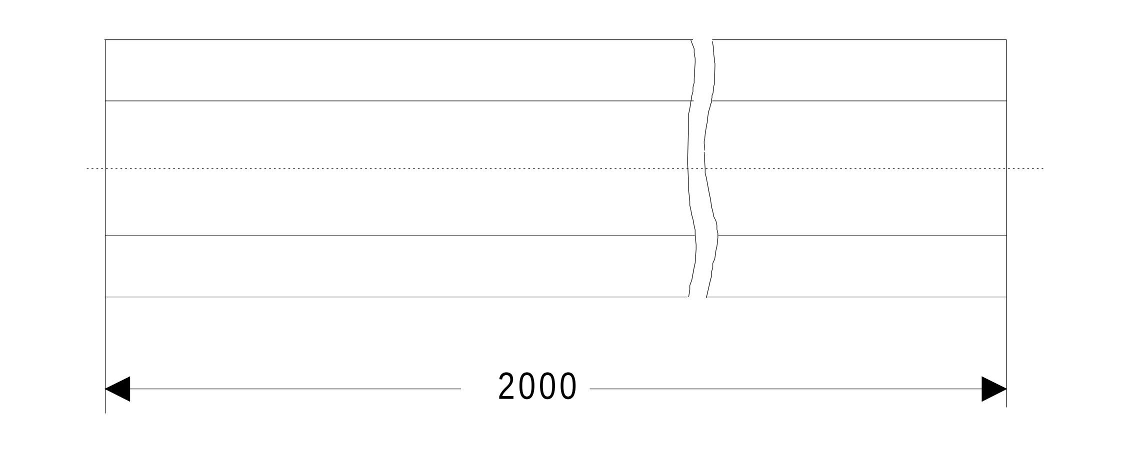


Figure E.5 Dimension Drawing of the 2 m Standard Sectional Rail

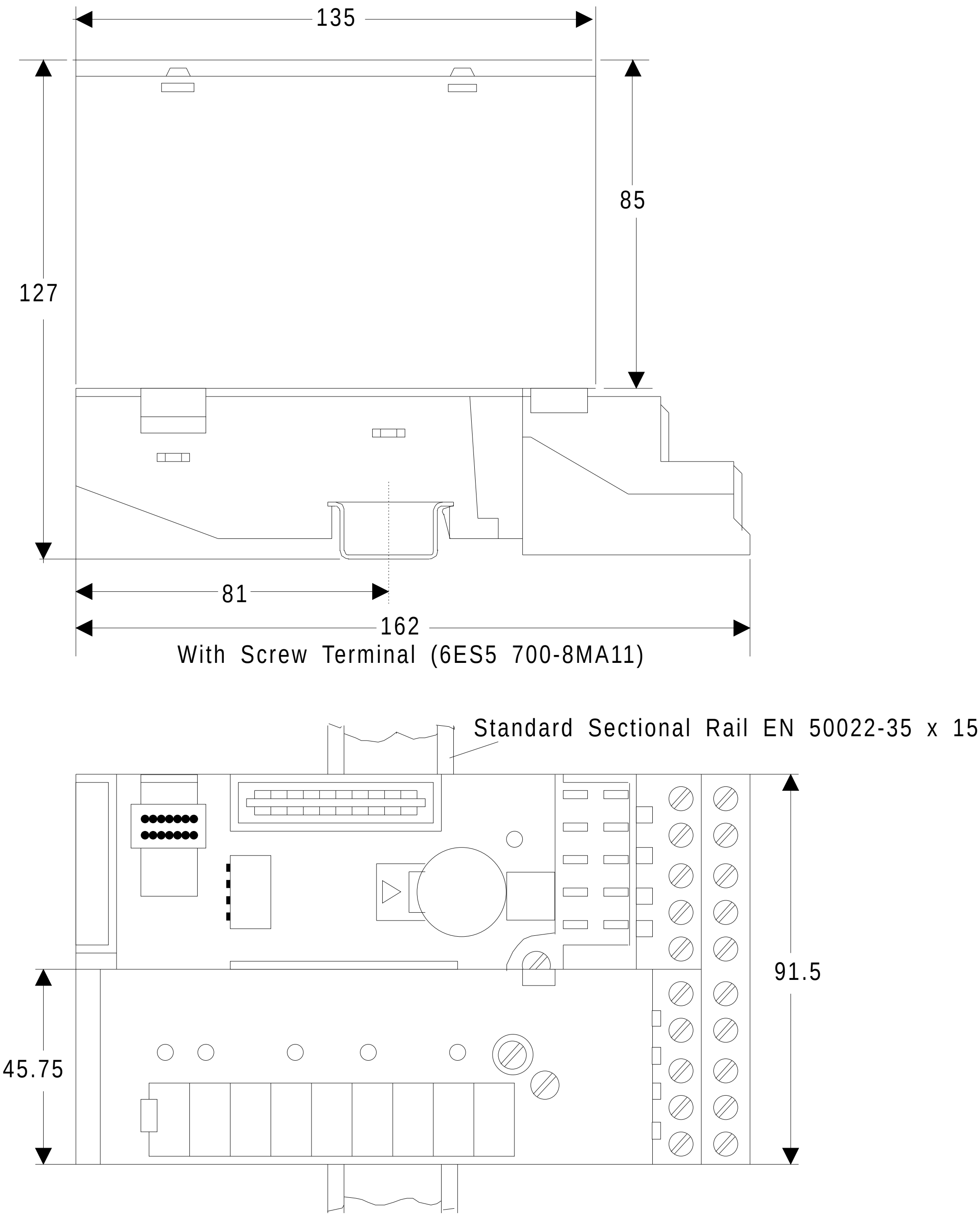


Figure E.6 Dimension Drawing of the Bus Unit (SIGUT) with Ex I/O Module

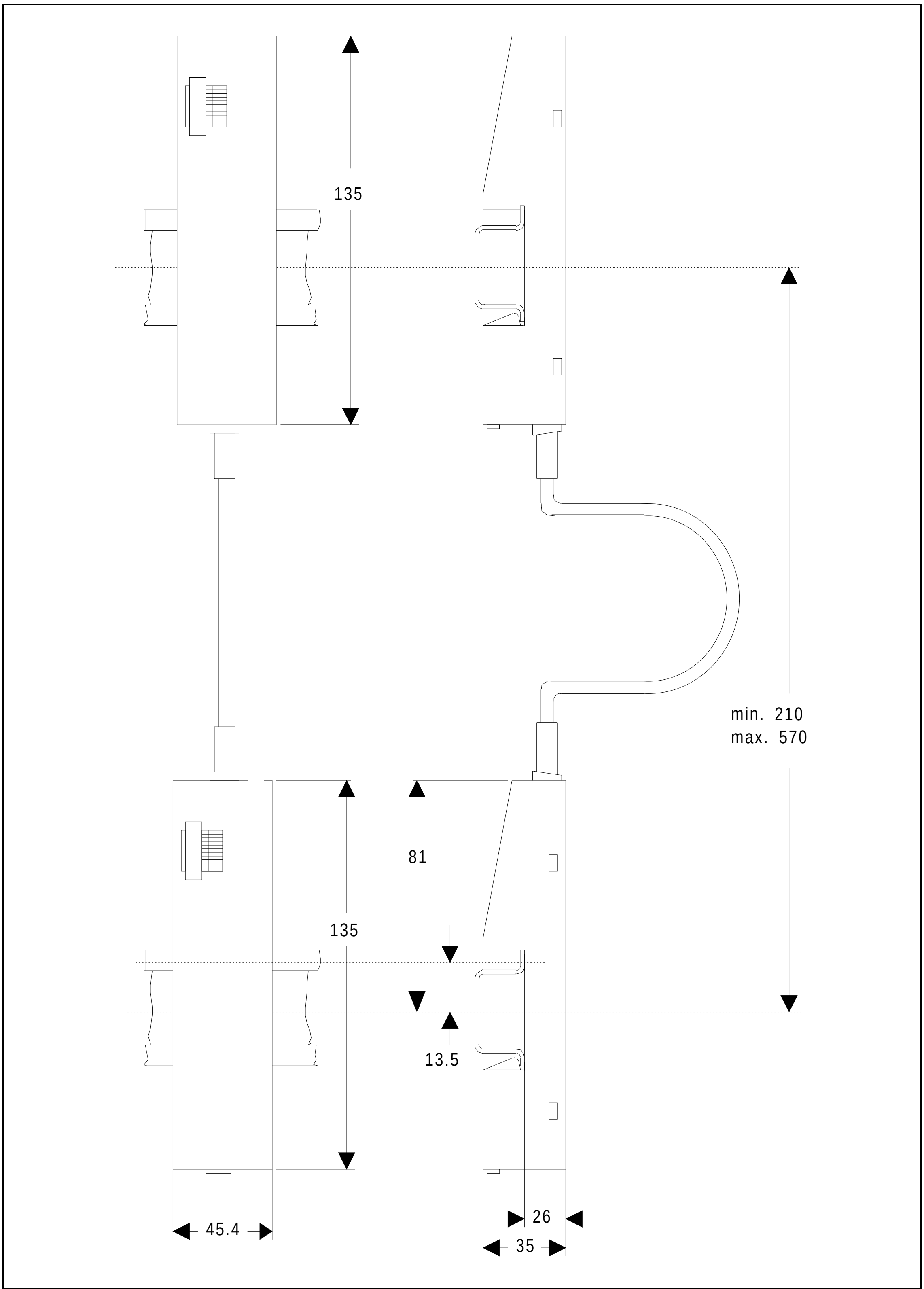


Figure E.7 Dimension Drawing of the IM 315 Interface Module

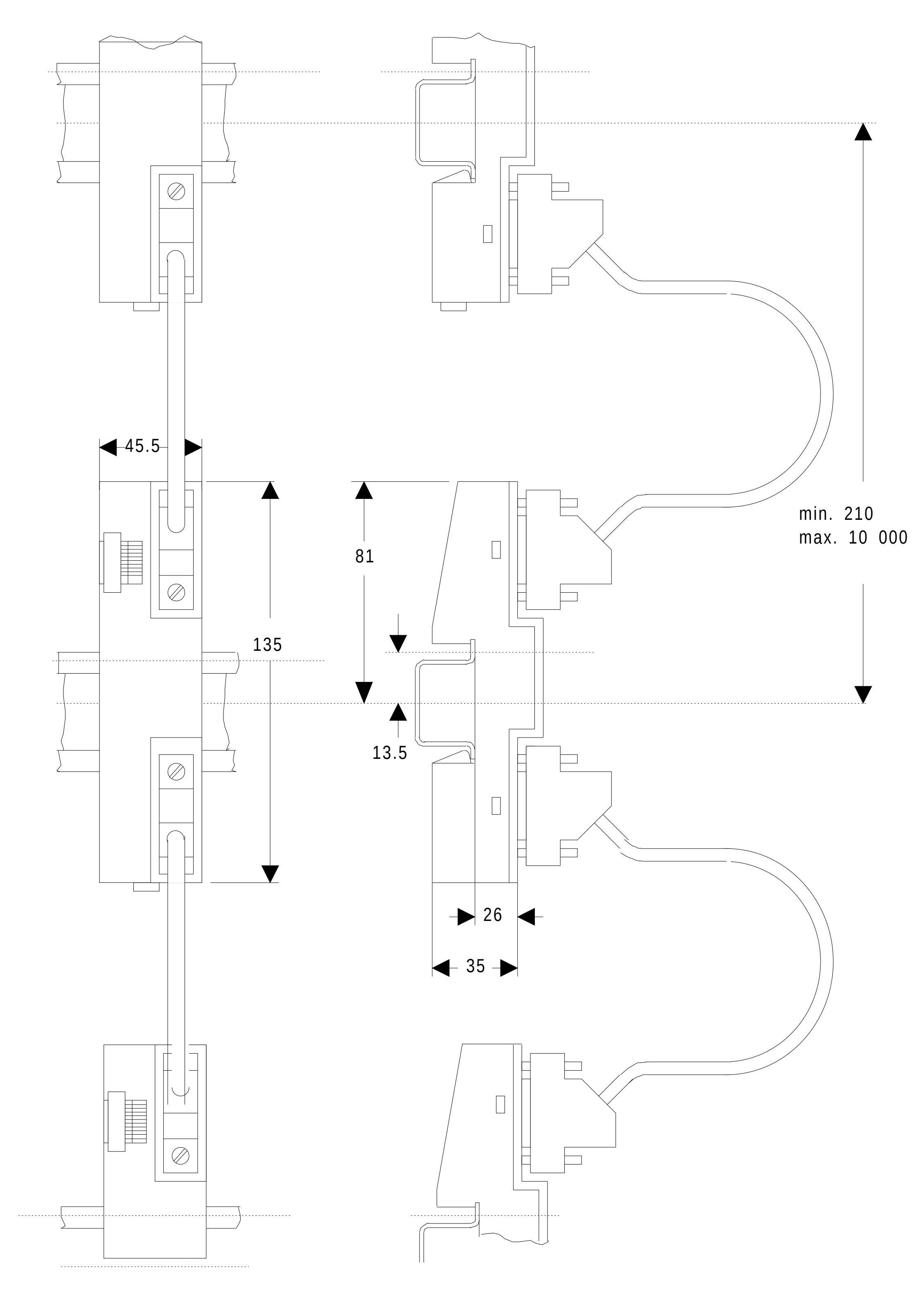


Figure E.8 Dimension Drawing of the IM 316 Interface Module

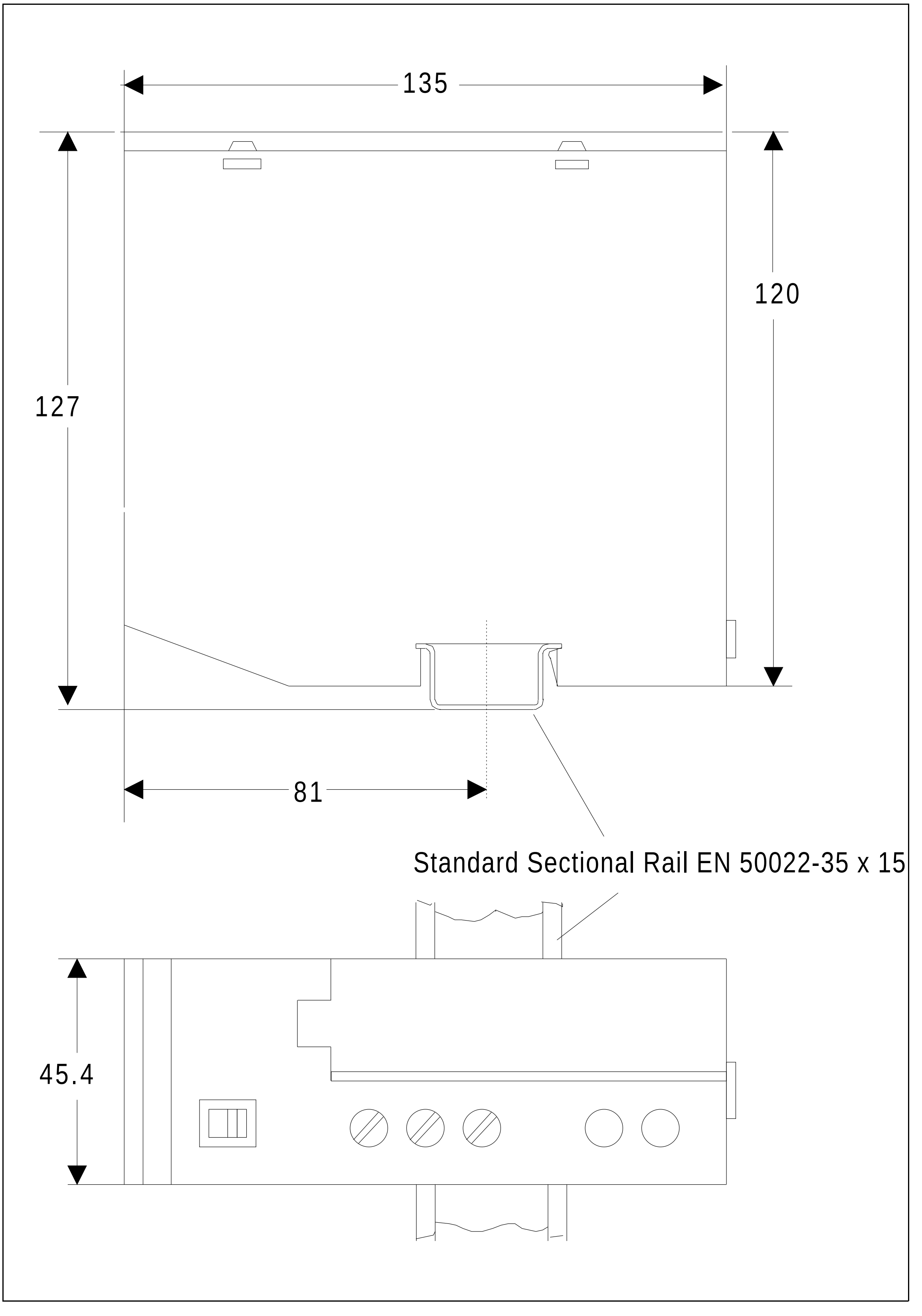


Figure E.9 Dimension Drawing of the Power Supply Module PS 935

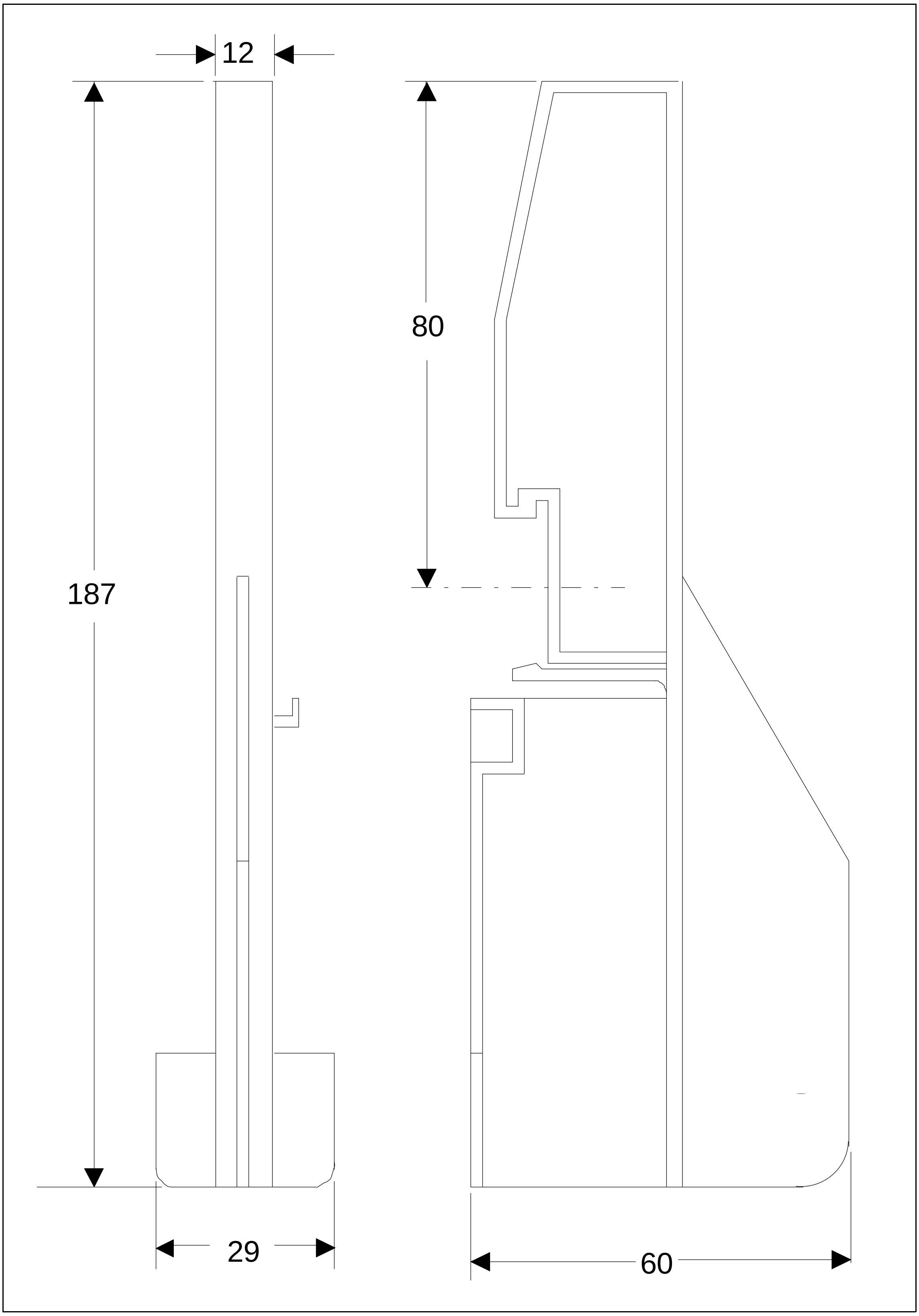


Figure E.10 Dimension Drawing of the Partition

F Technical Specifications

F Technical Specifications

General Technical Specifications of the S5-95/100 Programmable Controllers and the ET 100/200

Climatic environment conditions

Temperature Operating - horizontal mounting - vertical mounting	 0 to +60 °C 0 to +40 °C (Air-intake temperature, measured on the underside of the module)
Non-operating	- 40 to + 70 °C
Temperature change - operating - non-operating	 max. 10 °C/h max. 20 °C/h
Relative humidity (to DIN 40040)	15 to 95% (indoor) noncondensing
Atmospheric pressure - operating - non-operating	 860 to 1060 hPa 660 to 1060 hPa
Pollutants - SO_2 - H_2S	 ≤ 0.5 ppm (rel. humidity < 60%, noncondensing) ≤ 0.1 ppm (rel. humidity < 60%, noncondensing)

Mechanical environment conditions

Vibration - tested with	to IEC 68-2-6 10 to 57 Hz, (const. ampl. 0.15 mm) 57 to 150 Hz, (const. accel. 2 g)
Shock - tested with	to IEC 68-2-27 12 shocks (semisinusoidal 15 g/11 ms)
Free fall - tested with	to IEC 68-2-31 height of fall 50 mm

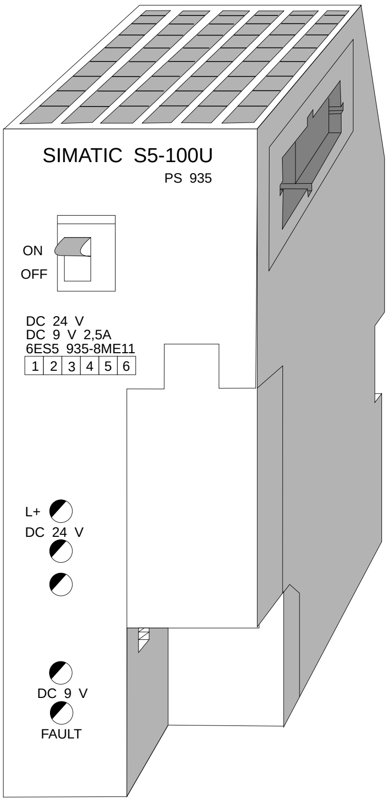
Electromagnetic compatibility (EMC)
Noise immunity

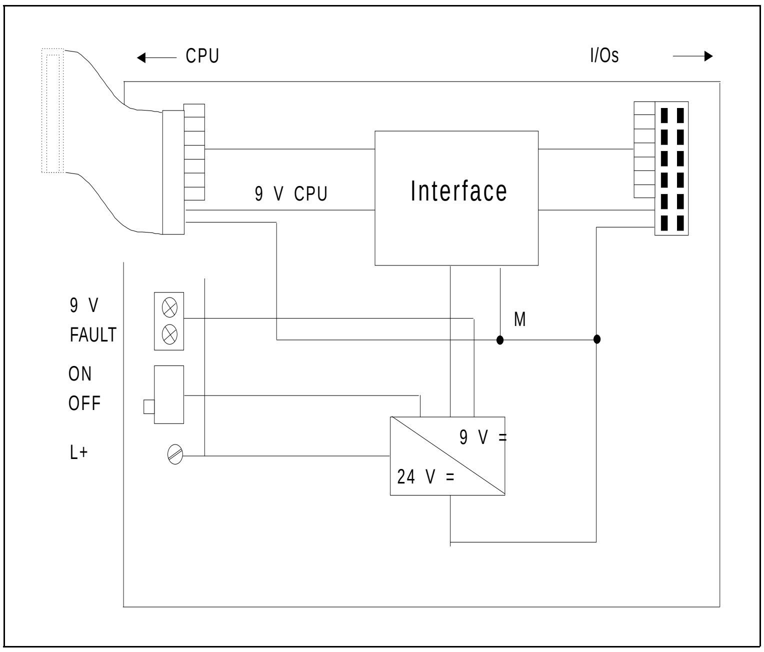
Electrostatic discharge test	to IEC 801-2 (Discharge on all parts that are accessible to the operator during normal operation)
- Test voltage	2.5 kV (rel. humidity 30 to 95%)
Radiated electromagnetic field test	to IEC 801-3 field strength 3 V/m
Fast transient burst Power supply modules - supply voltage 24 V DC - analog input/output modules - digital input/output modules for V = 24 V	to IEC 801-4, class III 1 kV 1 kV 1 kV

IEC/VDE safety information

Degree of protection - type - class	to IEC 529 IP 20 I to IEC 536
Insulation rating - between electrically independent circuits **and** with circuits connected to a central grounding point - between all circuits **and** a central grounding point (standard mounting rail)	to VDE 0160 (05.1988) to VDE 0160 (05.1988) to VDE 0160 (05.1988)
Test voltage for a rated voltage U_{input} of the circuits (AC/DC) U_{input} = 0 to 50 V U_{input} = 50 to 125 V U_{input} = 125 to 250 V	sine, 50 Hz 500 V 1250 V 1500 V

PS 935 power supply module: 24 V DC, 9 V/2.5 A DC **(6ES5 935-8ME11)**





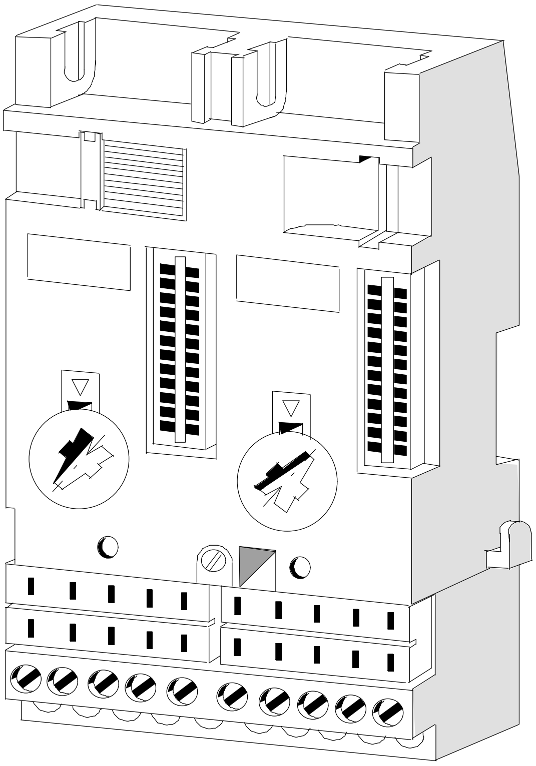
PS 935 power supply module: 24 V DC, 9 V/2.5 A DC (continued) (6ES5 935-8ME11)

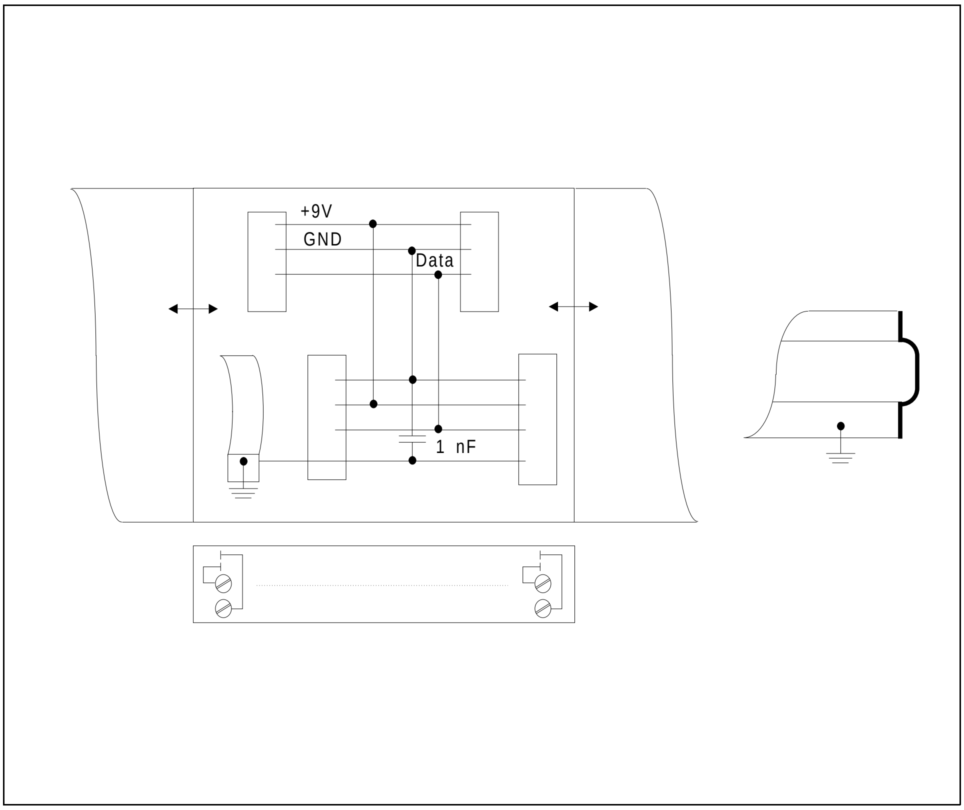
Technical specifications

Address identifier (only for ET 100/ET 200)	4 DI/4 DI (2 slots)
Input voltage - rated value - permissible range - reverse voltage protection	24 V DC Dynamic 18.5 to 30.2 V DC Static 20.4 to 28.8 V DC Yes
RFI suppression level	A to VDE 0871
Input current at 24 V DC - rated value - inrush current limiting - protection	 1.25 A 15-times rated current line protection LS-C 4A
Efficiency	Approx. 75 %
Power consumption	Approx. 30 W
Output voltage - rated value - permissible range - open-circuit protection	 9 V DC 8.55 to 9.45 V Yes
Output current - rated value - permissible range - overload detection	 2.5 A 0.0 to 2.5 A 2.5 to 2.7 A
Permissible ambient temperature of the module - horizontal mounting - vertical mounting	 0 to 60 °C 0 to 40 °C
Buffering during voltage dips - duration of dip - repetition rate	 20 ms at 20.4 V/2.5 A 1 s
Short-circuit protection (Output side)	Yes, electronic shutdown, non-latching
Fault indication	Yes
Diagnostics	Yes
Class of protection	Class 1
Isolation	No
Conductor cross-section - flexible *) - solid	 2 x 0.5 to 1.5 mm^2 2 x 0.5 to 1.5 mm^2
Dimensions W x H x D (mm)	 45.4 x 135 x 120 (Mounting clearance + 5 mm)
Power dissipation of the module	7.5 W typical
Weight	approx. 500 g

*) With ferrules

Bus unit (SIGUT) **(6ES5 700-8EA11)**





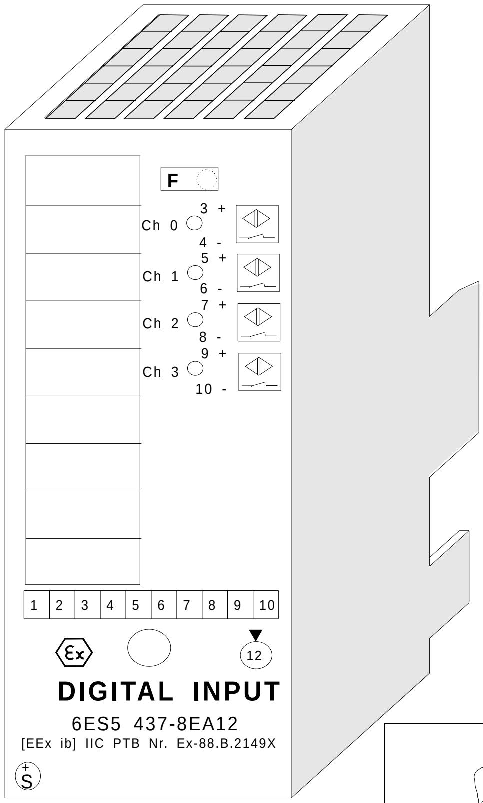
Bus Unit (SIGUT) (continued) **(6ES5 700-8AE11)**

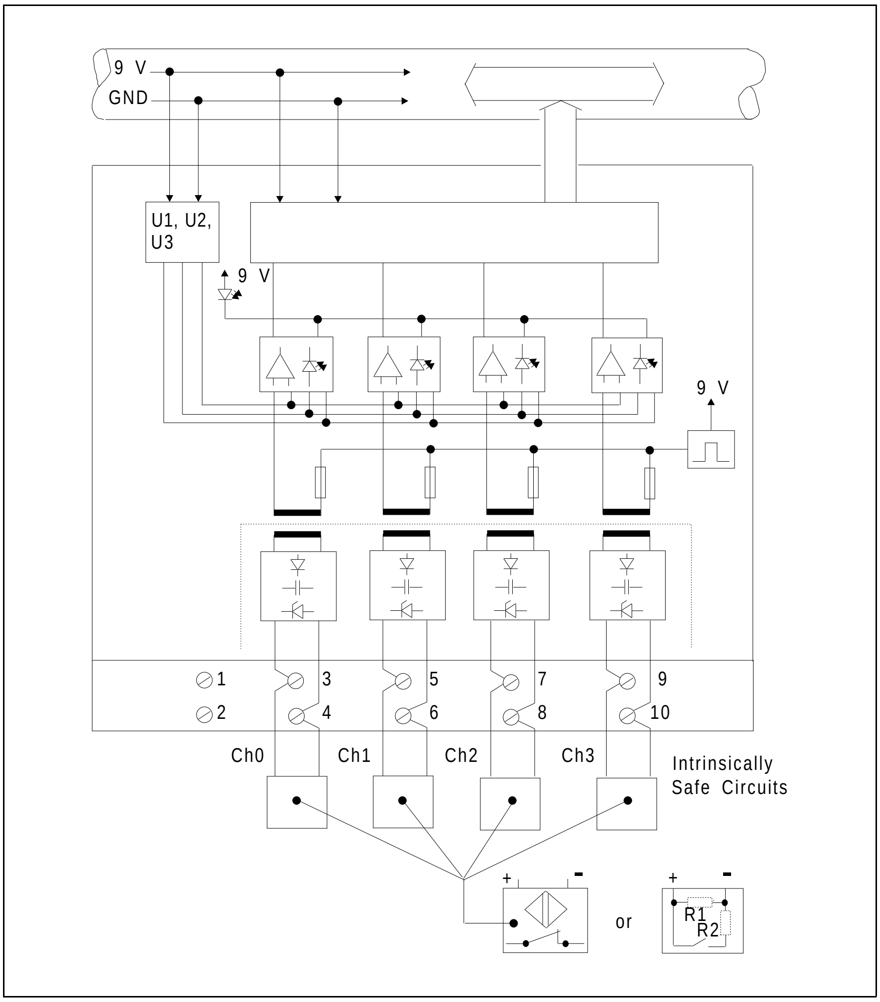
Technical specifications

Type of connection	SIGUT connection system
Number of pluggable Ex modules	2
Number of bus units per PLC	16 max.
Connection between two bus units	Ribbon cable
Terminals per slot	10
Insulation rating	To VDE 0160
Rated insulation voltage (+ 9 V to ⏚)	12 V AC
- insulation group	1 x B
- tested at	500 V AC
Conductor cross-section	
- flexible *	2 x 0.5 to 1.5 mm^2
- solid	2 x 0.5 to 1.5 mm^2
Current consumption	
- at + 9 V (CPU)	1 mA typical
Dimensions	
W x H x D (mm)	91.5 x 162 x 39
Weight	Approx. 300 g

*) With ferrules

Digital input module 4 x NAMUR **(6ES5 437-8EA12)**



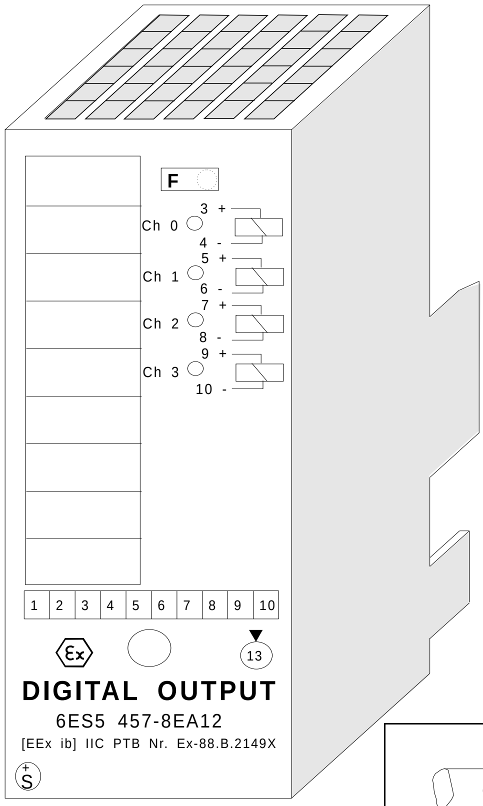


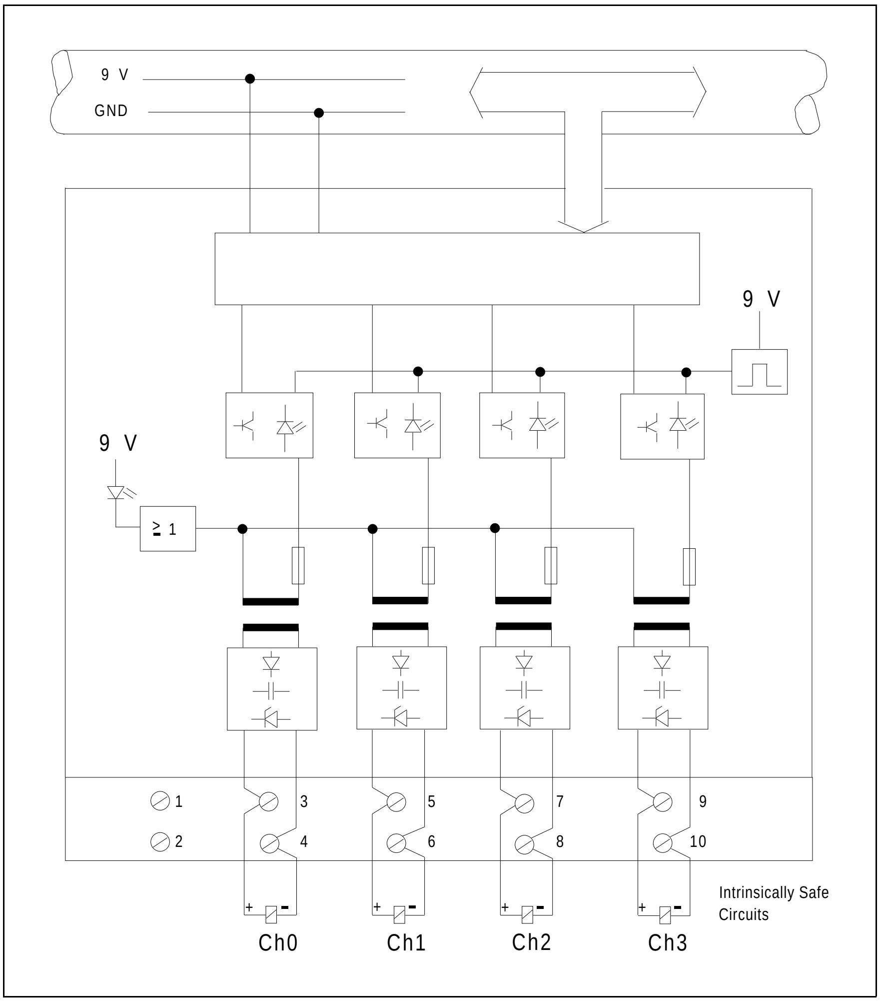
Ex digital input module 4 x NAMUR **(6ES5 437-8EA12)**

Technical specifications

Address identifier	
for ET 100U	4 DI
for ET 200U	4 DI / 008
Number of inputs	4
Isolation	Yes
- in groups of	1
Input voltage	
- rated value	8.2 V typical
Input current at	
Logic “1"	≥ 2.1 mA typical
Logic ”0"	≤ 1.2 mA typical
Delay	
- from “0" to ”1"	40 ms typical
- from “1" to ”0"	5 ms typical
Input frequency	10 Hz max.
Line length (shielded)	200 m max.
Maximum line resistance	R_L = (8.2 - U_S)/7 mA; U_S = oper. voltage of sensor
Coincidence factor	100 %
Insulating rating	To VDE 0160
Rated insulation voltage (+ 9 V to ⏚)	12 V AC
- insulation group	1 x B
- tested at	500 V AC
Short-circuit current	7 mA
Short-circuit protection	Short-circuit protected input
Rated insulation voltage between inputs	60 V AC
- insulation group	1 x B
- tested at	1500 V AC
Fault indication (red LED)	Short-circuit
Status indication (green LED)	Per channel
Fault diagnostics	On the module
Type of protection/certificate	[EEx ib] IIC to EN 50020
PTB No.	Ex-88.B.2149X
Max. values of input currents:	(per Channel)
• U_0	10.1 V
• I_k	43 mA
• P	97 mW
• Permissible external inductance L_a	< 20 mH
• Permissible external capacitance C_a	< 3 µF
Permissible ambient temperature of the module	
- horizontal mounting	0 to 60 °C
- vertical mounting	0 to 40 °C
Connection of 2-wire BERO	Possible (NAMUR sensor to DIN 19234)
- quiescent current	≤ 1.5 mA
Current consumption	
- at + 9 V (CPU/ET/PS 935)	50 mA typical
Rated insulation (between input and + 9 V)	60 V AC
- insulation group	1 x B
- tested at	2500 V AC
Power dissipation of the module	0.45 W typical
Weight	Approx. 200 g

Ex digital output module 4 x 7 V/2 mA DC **(6ES5 457-8EA12)**





Ex digital output module 4 x 7 V/2mA DC (continued) **(6ES5 457-8EA12)**

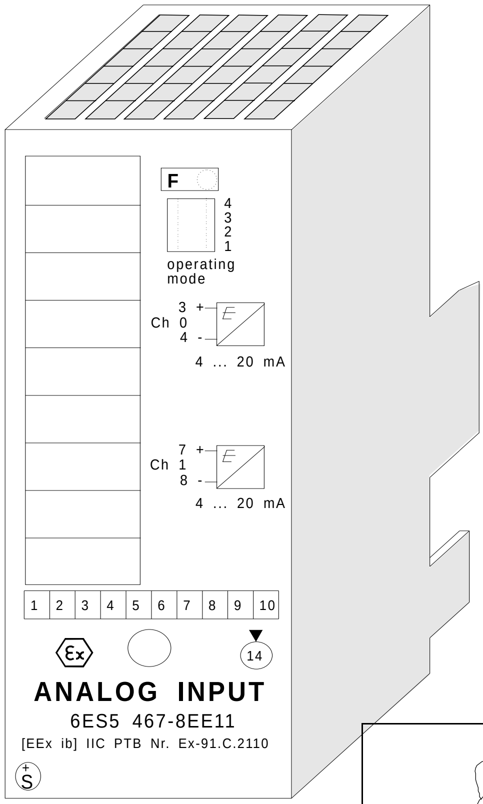
Technical specifications

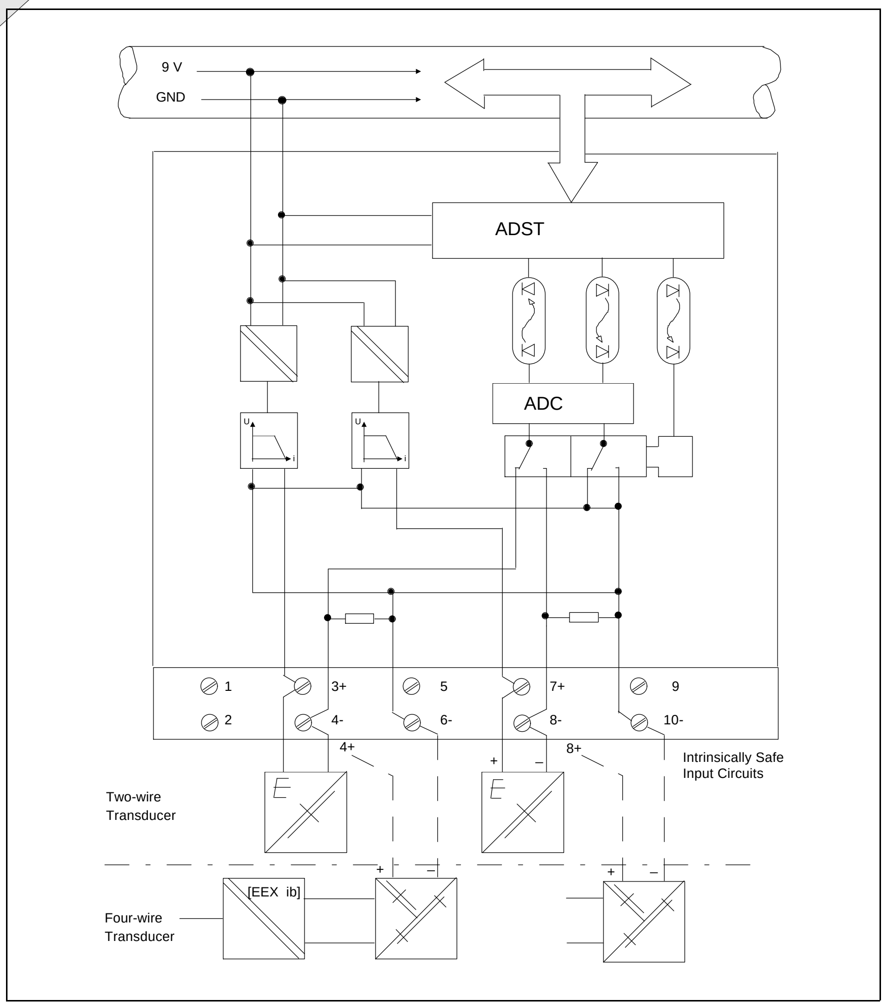
Address identifier for ET 100U for ET 200U	 4 DQ 4 DQ / 048
Outputs	4
Isolation - in groups of	Yes 1
Line length (shielded)	200 m max.
Maximum line resistance	R_L = (9 V - U_A)/3.5 mA U_A = Min. operational voltage of actuator
Output current for logic 1 - rated value - permissible range - permissible load	 2 mA 2 to 3.5 mA 1.65 kilohms min. 3.5 kilohms max.
Residual current for logic 0	0 mA
Output voltage - for logic 1	 7 V DC max.
Short-circuit	> 5 mA
Short-circuit protection	Short-circuit protected output with auto. reclosing as soon as short-circuit removed
Delay - for 0 to 1 - for 1 to 0	 1 ms typical 6 ms typical
Fault indication (red LED)	Short-circuit
Status indication	Per channel
Fault diagnostics	On module
Switching frequency with - resistive load - inductive load	 100 Hz max. 2 Hz max.
Coincidence factor	100 %
Parallel connection of outputs	Possible (observe Ex conditions)
Type of protection/certificate	[EEx ib] IIC to EN 50020
PTB No.	Ex-88.B.2149X
Max. values of output currents:	(per channel)
• U_0 • I_k • P • Permissible external inductance La • Permissible external capacitance Ca	10.1 V 43 mA 97 mW < 20 mH < 3 µF
Permissible ambient temperature of the module - horizontal mounting - vertical mounting	 0 to 60 °C 0 to 40 °C
Line length - unshielded	 100 m max.
Insulation rating	To VDE 0160
Rated insulation voltage (+ 9 V to ⏚) - insulation group - tested at	12 V AC 1 x B 500 V AC
Rated insulation (between input and +9 V) - insulation group - tested at	60 V AC 1 x B 2500 V AC

Ex digital output module 4 x 7 V/2mA DC (continued) (6ES5 457-8EA12)

Current consumption - at + 9 V (CPU/ET/PS 935)	55 mA typical
Power dissipation of the module	0.5 W typical
Weight	Approx. 200 g

Ex analog input module 2 x + 4 to 20 mA **(6ES5 467-8EE11)**





Ex analog input module 2 x + 4 to 20 mA (continued) **(6ES5 467-8EE11)**

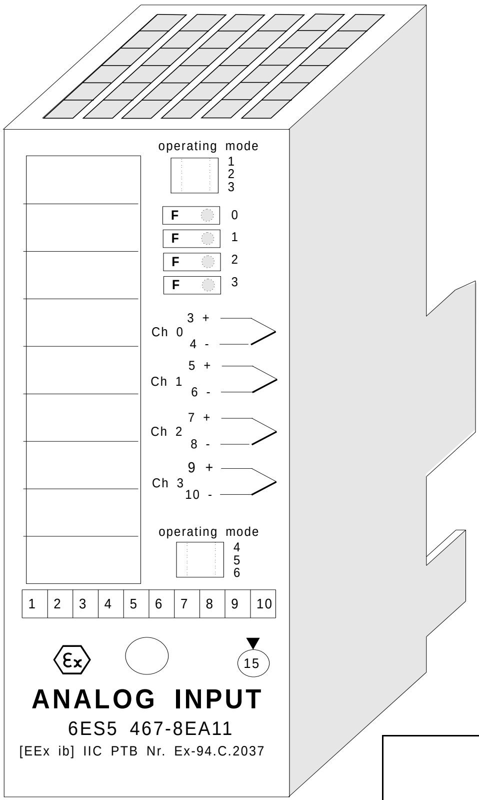
Technical specifications

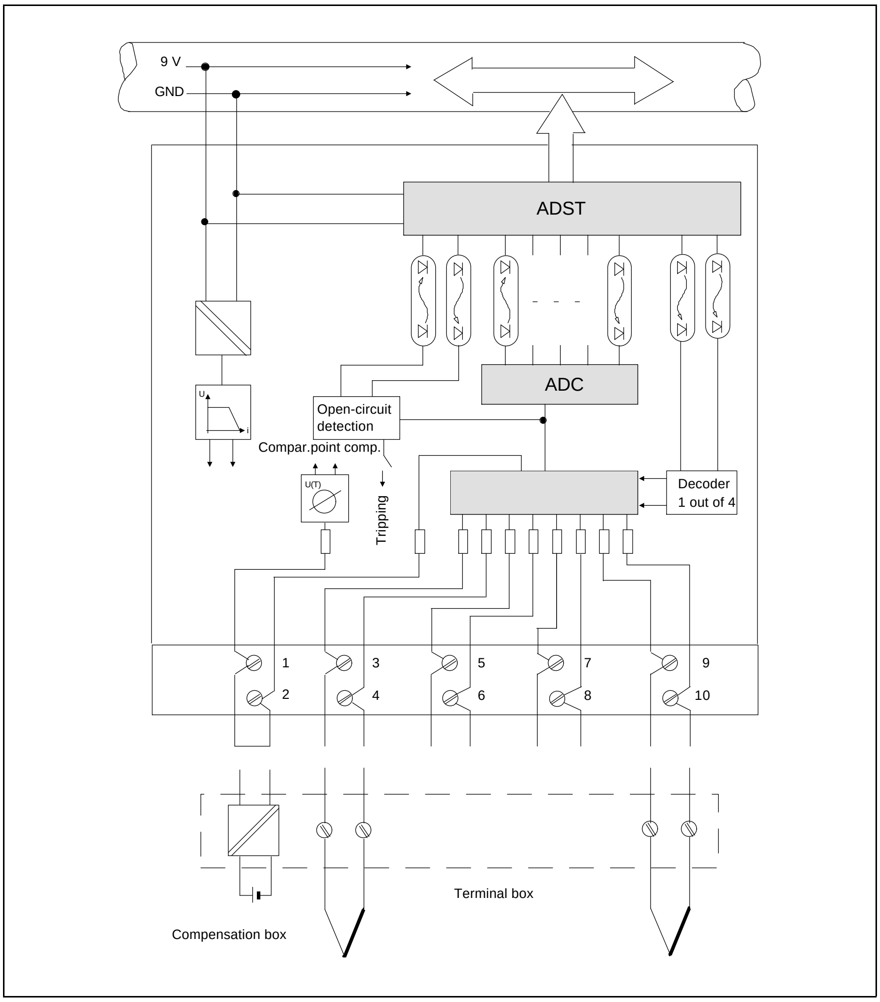
Address identifier	
for ET 100U single-channel for ET 100U two-channel for ET 200U single-channel for ET 200U two-channel	1 AI 2 AI 1 AI or 012 2 AI or 013
Input ranges (rated values)	+ 4 to 20 mA
Inputs	1 or 2 (selectable)
Isolation	Yes (inputs with respect to ground point, not between input)
Input resistance	≥ 31.25 ohms
Line length (shielded)	200 m max.
Maximum line resistance	R_L = (16 V - U_{TD})/20 mA U_{TD} = Min. oper. voltage of two-wire transducer
Type of connection for sensors	Two-wire connection with supply via the module
Supply voltage of two-wire transducer	16 V (at 20 mA)
Digital representation of input signal	12 bits + sign (2048 units = rated value)
Measured value representation	Two's complement (left-justified)
Measuring principle	Integrating
Conversion principle	Voltage-time conversion (dual slope)
Integration time (adjustable for optimum interference voltage suppression)	20 ms at 50 Hz 16.6 ms at 60 Hz
Encoding time per input - for 2048 units - for 4095 units	 60 ms max. at 50 Hz / 50 ms max. at 60 Hz 80 ms max. at 50 Hz / 66.6 ms max. at 60 Hz
Permissible potential difference - between inputs - inputs with respect to central ground point	 ± 1 V max. 75 V DC/ 60 V DC max.
Permissible input current (destruction limit)	82 mA max.
Fault indication (red LED)	Open-circuit, overflow
Short-circuit protection	Short-circuit protected input
Fault message for - overrange - open-circuit of sensor lines - open-circuit group indication	 Yes (more than 4095 units) Yes Yes
Interference voltage suppression for f = nx (50/60 Hz ± 1 %): Common-mode interference (U_{pp}= 1 V)	 86 dB min.
- Differential-mode interference (Peak value of interference < rated value of input range)	40 dB min.
Intrinsic error limit	± 0,15 %
Operational limit (0 to 60 °C)	± 0,4 %
Individual error - linearity - tolerance	 ± 0,05 % ± 0,05 %
Temperature error - final value - zero point	 ± 0,01 %/K ± 0,002 %/K
Type of protection/certificate	[EEx ib] IIC to EN 50020

Ex analog input module 2 x + 4 to 20 mA (continued) **(6ES5 467-8EE11)**

PTB No.	Ex-91.C.2110
Max. values per channel:	
• U_0	18 V
• I_k	82 mA
• P	600 mW
• R_i	354Ω
• L_a	4 mH
• C_a	270 nF
Supply voltage L + for two-wire transducer	
- rated value	15 V DC
Auxiliary power from module	14 to 16 V DC
Insulation rating	To VDE 0160
Rated insulation voltage (+ 9 V to ⏚)	12 V AC
- insulation group	1 x B
- tested at	500 V AC
Rated insulation (between inputs and +9 V)	60 V AC
- insulation group	1 x B
- tested at	2500 V AC
Current consumption	
- At +9 V (CPU/ET/PS 935)	320 mA
Power dissipation of the module	
- for two-wire transducer	3 W typical
- for four-wire transducer	0.7 W typical
Weight	Approx. 250 g

Ex analog input module 2 x ± 50 mV **(6ES5 467-8EA11)**





Ex analog input module 2 x ± 50 mV (continued) **(6ES5 467-8EA11)**

Technical specifications

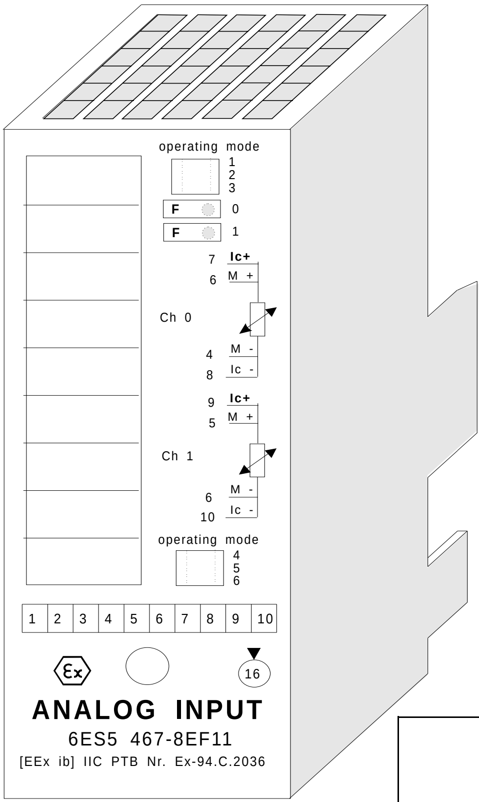
Address identifier	
for ET 100U, single-channel for ET 100U, two-channel for ET 100U, four-channel for ET 200U, single-channel for ET 200U, two-channel for ET 200U, four-channel	1 AI 2 AI 4 AI 1 AI or 012 2 AI or 013 4 AI or 015
Input ranges (rated values)	± 50 mV
Inputs	1, 2 or 4 (selectable)
Isolation	Yes (inputs with respect to ground point, not between inputs)
Input resistance	≥ 10 Mohms (M+, M-)
Line length (shielded)	200 m max.
Type of connection for sensors	Two-wire connection
Digital representation of input signal	12 bits plus sign (2048 units = rated value)
Sensitivity	24.41 µV/unit
Measured value representation	Two's complement (left-justified)
Measuring principle	Integrating
Conversion principle	Voltage-time conversion (dual slope)
Integration time (adjustable for optimum interference voltage suppression)	20 ms at 50 Hz 16.6 ms at 60 Hz
Encoding time per input - for 2048 units - for 4095 units	 max. 58 ms at 50 Hz / max. 50 ms at 60 Hz max. 78 ms at 50 Hz / max. 66.6 ms at 60 Hz
Permissible potential difference - between inputs - inputs with respect to central grounding point	 max. ± 15 V max. 75 V DC/60 V AC
Permissible input voltage (destruction limit)	max. ± 15 V
Short-circuit protection	Short-circuit protected input
Fault message for - overrange - open-circuit of sensor-lines - open-circuit group indication	 Yes (more than 4095 units) Yes, channel-specific One red LED per channel
Interference voltage suppression for f = nx (50/60 Hz ± 1 %): - common-mode interference (U_{pp} = 1 V)	 min. 60 dB
- differential-mode interference (Peak value of interference rated value of input range)	min. 40 dB
Intrinsic error limit[1]	± 0.3 %, typically ± 0.15 %
Operational limit (0 to 60 °C)[1]	± 0.5 %, typically ± 0.2 %
Linearity	± 0.05 %
Temperature error	± 0.01 %/K (final value)
Error of internal comparison point compensation	± 6 K, typically ± 3 K
Type of protection/certificate	[EEx ib] IIC to EN 50020
PTB No.	Ex-94.C.2037

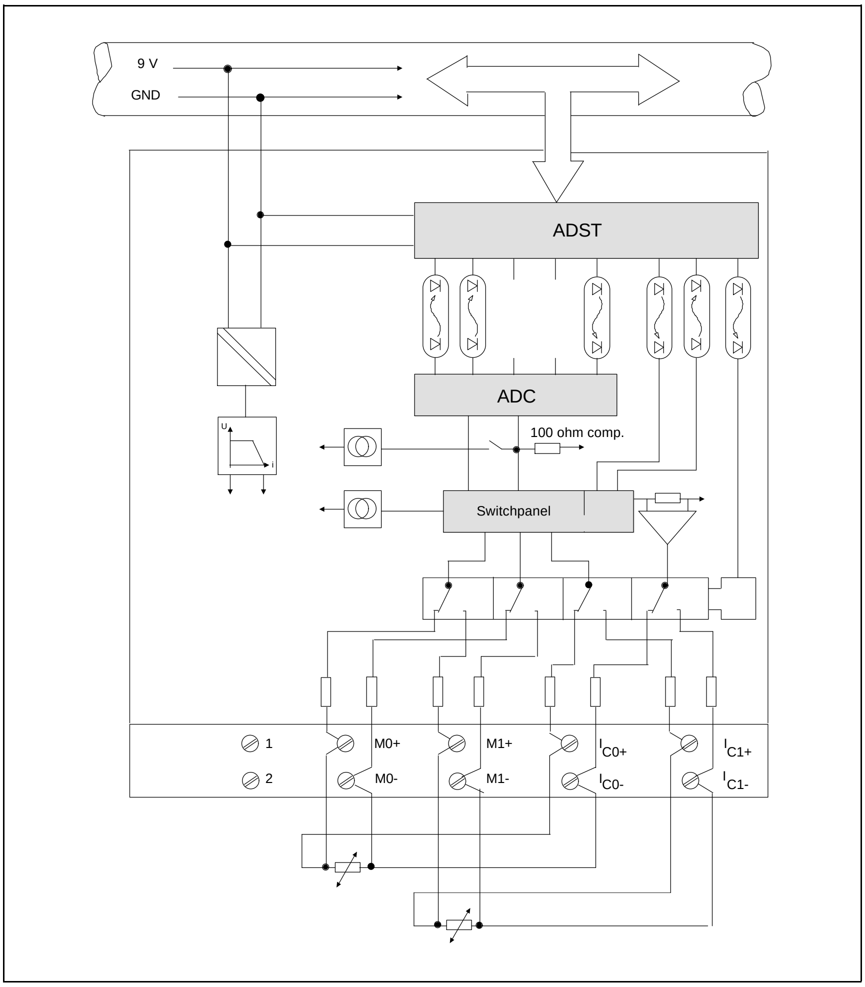
[1] *Error for external compensation of comparison point temperature*

Ex analog input module 2 x ± 50 mV (continued) **(6ES5 467-8EA11)**

Max. values per channel:	
• U_0	17.22 V
• I_k	20 mA
• P	86 mW
• L_a	20 mH
• C_a	340 nF
Insulation rating	To VDE 0160
Rated insulation voltage (+9 V to ⏚)	12 V AC
- insulation group	1 x B
- tested at	500 V AC
Rated insulation (between inputs and +9 V)	60 V AC
- insulation group	1 x B
- tested at	2500 V AC
Current consumption	
- at +9 V (CPU/ET/PS 935)	270 mA
Power loss of the module	2.5 W typical
Weight	Approx. 250 g

Ex analog input module 2 x Pt100 (± 500 mV) (continued) (6ES5 467-8EF11)





Ex analog input module 2 x Pt100 (± 500 mV) (continued) **(6ES5 467-8EF11)**

Technical specifications

Address identifier		
for ET 100U, single-channel	1 AI	
for ET 100U, two-channel	2 AI	
for ET 200U, single-channel	1 AI or 012	
for ET 200U, two-channel	2 AI or 013	
Input ranges (rated values)		
- resistance thermometers (Pt100)	0 to 200 ohms (max. 400 ohms)	
- voltage sources	± 500 mV	
Inputs	1 or 2 (selectable)	
Isolation	Yes (inputs with respect to ground point; not between inputs)	
Input resistance	≥ 10 Mohms (M+, M-)	
Line length (shielded)	200 m max.	
Type of connection for sensors	2/4 or 3-wire connection	
Digital representation of input signal	12 bits plus sign (2048 units = rated value)	
Measured value representation	Two's complement (left-justified)	
Measuring principle	Integrating	
Conversion principle	Voltage-time conversion (dual slope)	
Integration time (adjustable for optimum interference voltage suppression)	20 ms at 50 Hz 16.6 ms at 60 Hz	
Encoding time per input		
- for 2048 units	max. 58 ms at 50 Hz / max. 50 ms at 60 Hz	
- for 4095 units	max. 78 ms at 50 Hz / max. 66.6 ms at 60 Hz	
Permissible potential difference		
- between inputs	max. ± 15 V	
- inputs with respect to central grounding point	max. 75 V DC/60 V AC	
Permissible input voltage (destruction limit)	max. ± 15 V	
Short-circuit protection	Short-circuit protected input	
Fault message for		
- overrange	Yes (more than 4095 units)	
- open-circuit of sensor lines	Yes, channel-specific	
- open-circuit group indication	One red LED per channel	
Interference voltage suppression for f = nx (x = 50/60 Hz ± 1 %; n = 1,2..):		
- common-mode interference (U_{pp} = 1 V)	60 dB min.	
- differential-mode interference (Peak value of interference rated value of input range)	40 dB min.	
Error limits, 4-wire circuit	Standard range:	Climatic range:
- intrinsic error limit	± 0.3 % (typ. 0,1 %)	± 0,5 % (typ. 0,2 %)
- operational limit (0 to 60 °C)	± 0.5 % (typ. 0,2 %)	± 1.0 % /typ. 0.5 %)
- linearity	± 0.05 %/K	
- temperature error	± 0.01 %/K	
Error limits, 3-wire circuit	Standard range:	
- intrinsic error limit	± 0.5 % (typ. 0.3 %)	
- operational limit (0 to 60 °C)	± 1.2 %	
- linearity	± 0.05 %/K	
- temperature error	± 0.02 %/K	
Type of protection/certificate	[EEx ib] IIC to EN 50020	
PTB No.	Ex-94.C.2036	

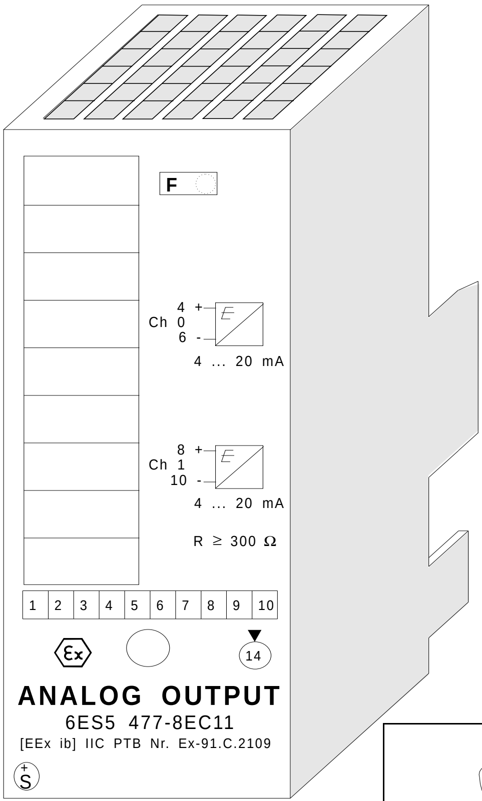
Ex analog input module 2 x Pt100 (± 500 mV) (continued) (6ES5 467-8EF11)

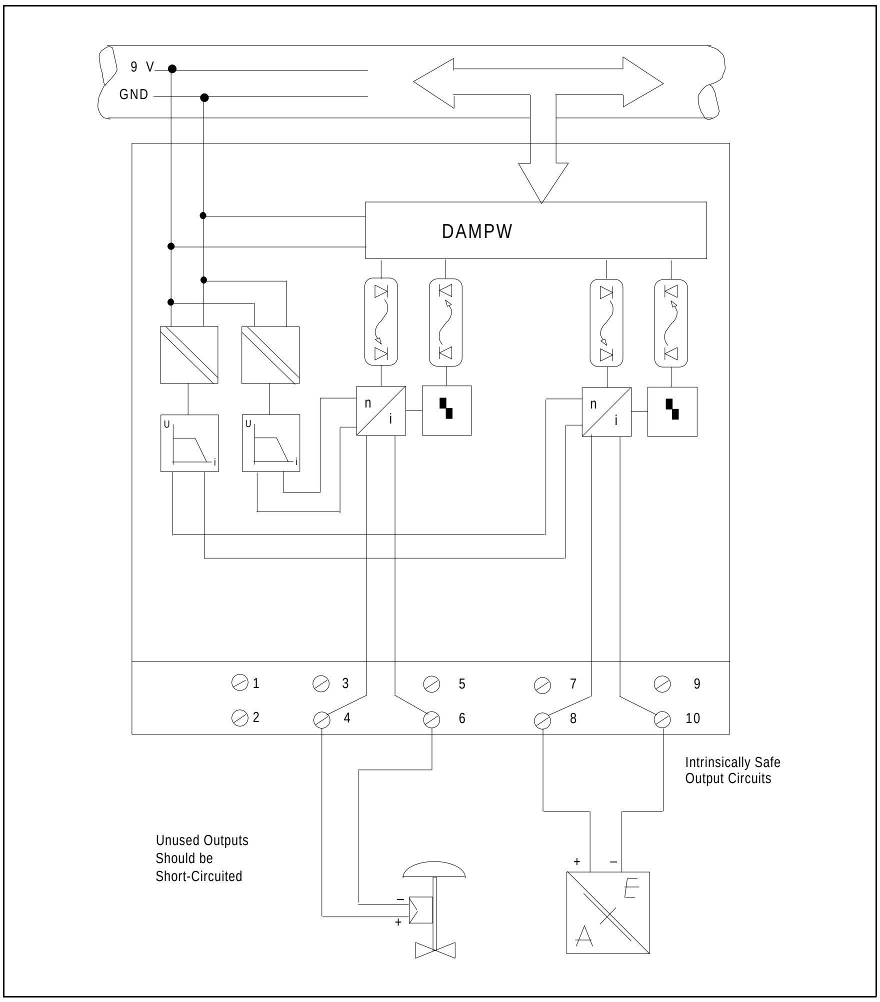
Max. values per channel:	
• U_0	17.22 V
• I_k	33 mA
• P	142 mW
• L_a	10 mH
• C_a	240 nF *)
Insulation rating	To VDE 0160
Rated insulation voltage (+9 V to ⏚)	12 V AC
- insulation group	1 x B
- tested at	500 V AC
Rated insulation (between inputs and +9 V)	60 V AC
- insulation group	1 x B
- tested at	2500 V AC
Current consumption	
- at +9 V (CPU/ET/PS 935)	270 mA
Power loss of the module	2.5 W typical
Weight	Approx. 250 g

*) *When connecting to sensors with maximum values U = ± 1 V, I = 20 mA which cause an addition of voltages or currents by these values:*

L_a = 10 mH, C_a = 240 nF

Analog output module 2 x ± 4 to 20 mA **(6ES5 477-8EC11)**





Ex analog output module 2 x + 4 to 20 mA (continued) **(6ES5 477-8EC11)**

Technical specifications

Address identifier - for ET 100U - for ET 200U	 2 AX 2 AX or 029
Output range (rated value)	4 to 20 mA
Number of outputs	2
Isolation	Yes (between outputs and between outputs and ground)
Load	R ≥ 300 ohms
Line length (shielded)	200 m max.
Maximum line resistance	R_L = (16 V - U_{TD})/20 mA U_{TD} = Min. oper. voltage of two-wire transducer
Type of connection for actuators	Two-wire connection for two-wire actuators, e.g. I/P controller, indicators
Digital representation of output signal	11 bits + sign (1024 units = rated value)
Supply voltage for actuators - rated value - permissible range (including ripple)	 14 V DC 12 to 16 V
Measured value representation	Two's complement (left-justified)
Conversion time (0 to 100 %)	 300 ms max.
Permissible overdriving	25 % max.
Short-circuit protection	Short-circuit protected output
Short-circuit current	27 mA typical
Fault indication (red LED)	Open-circuit, short-circuit
Permissible potential difference with respect to ground and between outputs	75 V DC/ 60 V AC max.
Intrinsic error limit	± 0.5 %
Operational limit (0 to 60 °C) - linearity - temperature error	± 0.6 % ± 0.2 % ± 0.01 %/K
Type of protection/certificate	[EEx ib] IIC to EN 50020
PTB No.	Ex-91.C.2109
Max. values per channel:	
• U_0	18 V
• I_k	82 mA
• P	600 mW
• R_i	354 Ω
• Permissible external inductance L_a	4 mH
• Permissible external capacitance C_a	270 nF
Insulation rating	To VDE 0160
Rated insulation voltage (+9 V to ⏚) - insulation group - tested at	12 V AC 1 x B 500 V AC
Rated insulation (between outputs) - insulation group - tested at	60 V AC 1 x B 1500 V AC
Rated insulation (between output and +9 V) - insulation group - tested at	60 V AC 1 x B 2500 V AC

Ex analog output module 2 x + 4 to 20 mA (continued) **(6ES5 477-8EC11)**

Current consumption - at + 9 V (CPU/ET/PS 935)	350 mA typical
Power dissipation of the module	3.2 W typical
Weight	Approx. 250 g

G Terminology for Explosion Protection and Intrinsic Safety (Glossary)

G Terminology for Explosion Protection and Intrinsic Safety (Glossary)

Explosive atmosphere
This is a gas/vapor/air mixture which explodes because of ignition under atmospheric conditions (0.8 bar - 1.1 bar, 20 °C). Self-ignition and detonation cannot occur under atmospheric conditions.

Dangerous explosive atmosphere
An explosive atmosphere in a dangerous amount. An amount is considered dangerous if, when it is ignited, persons can be injured directly or indirectly.

Zone 0
This covers hazardous areas in which a dangerous, explosive atmosphere is present continuously or for a long time.

Zone 1
This covers hazardous areas in which a dangerous, explosive atmosphere occasionally occurs.

Zone 2
This covers areas in which it can be expected that a dangerous, explosive atmosphere occurs only rarely and for a short time.

Zone 10
Zone 10 covers areas in which a dangerous, explosive dust-laden atmosphere is present for a long time or frequently.

Zone 11
This covers areas in which it can be expected that a dangerous, explosive atmosphere occurs occasionally and for a short time on account of whirling of deposited dust.

Minimum ignition energy
of a gas or vapor-air mixture is the lowest level of electrical energy required, which can cause ignition of the most explosive mixture of a gas or vapor with air at a pressure of 1 bar and temperature of 20 °C.

Ignition temperature
The ignition temperature is the lowest temperature of the ignition source at which a flammable gas/air mixture can be ignited and will continue burning without a supply of heat.

Smoldering temperature
This indicates the minimum temperature of an exposed surface at which a dust layer of 5 mm can just barely be ignited. With greater layer thicknesses, smoldering may begin at less than this smoldering temperature. Coal dust, flour dust, metal dusts are particularly hazardous.

Flash point
The flash point is the lowest temperature at which, in a standard cup, sufficient vapor can develop to be ignited by an extraneous ignition source.

Density

The density of a substance is given by the ratio of its mass to its volume; with gases and vapours, it particularly depends on the prevailing pressure and existing temperature. With deposited dusts, the density also depends on, amongst other things, the type of deposit and the grain size.

Density ratio

For gases and vapors, the density ratio is often given in the corresponding tables; this indicates how many times heavier or lighter than air the medium is, under the same temperature and pressure. This indicates whether the mixture will mainly remain in the lower or upper zones of the room.

Volatility number

To assess the evaporation rate of a liquid and therefore the risk of formation of explosive mixtures, a volatility number has been defined. This indicates the ratio of the time required for evaporation of the relevant liquid to the time needed for evaporation of the same amount of ether.

A common distinguishing mark to confirm that the apparatus complies with the certificate of conformity and has been subjected to a routine test by the manufacturer.

ia/ib

Categories of intrinsically safe apparatus to EN 50020:

ia = suitable for operation within Zone 0
ib = suitable for operation within Zones 1 and 2

IIA / IIB / IIC

These are explosion groups to EN 50014. For intrinsically safe electrical apparatus, they are based on the ratio of minimum ignition current (MIC) of the gases and vapors to the minimum ignition current of laboratory methane. They show the relationship between the energy with can be introduced in the hazardous area by the electrical apparatus, and the minimum ignition energy of the dangerous, explosive atmosphere.

Intrinsic safety

A circuit is intrinsically safe if it cannot ignite an explosive mixture in normal operation or during a fault as a result of electrical sparks or temperature rise, under stipulated test conditions. With intrinsic safety, the type of ignition relates to the entire circuit.

Safety factors

Zone 1 When a fault occurs in an intrinsically safe circuit, intrinsic safety must be maintained.

Zone 0 When two independent faults occur, intrinsic safety must be maintained.

Temperature classes T1 - T6

With temperature classes T1 to T6, the maximum surface temperatures of apparatus installed in the hazardous area are considered in relation to the minimum ignition temperatures of the possible, dangerous explosive atmosphere. The maximum surface temperature must always be less than the minimum ignition temperature.

Associated electrical apparatus does not require temperature classes because it must not be operated in the hazardous areas; thermal ignition by the associated apparatus is therefore ruled out.

Spark testing unit

Intrinsically safe circuits are tested with the spark testing unit. This equipment is mandatory in EN 50020, as the international standard testing unit for intrinsically safe circuits according to IEC Publication 79-3.

Infallible components

No fault is expected with these components; according to EN 50020 they do not require redundancy. They include AC power transformers, low-voltage transformers, optocouplers, relays, damper windings and resistors for current limiting.

Components susceptible to faults

These include semiconductor components and capacitors. According to EN 50020, they may only be subjected to a particular percentage of their rated values, e.g. for current and voltage.

Constructional requirements

Two aspects are particularly important in the construction of apparatus with intrinsically safe circuits, according to the European standard designated DIN EN 50020/VDE 0170/0171 Part 7/5.78:

a) Protection of the intrinsically safe circuits against pickup of interference voltages, and protection against the development of excessive potential with respect to ground

b) Current and voltage limiting, allowing for a safety factor

Apparatus

A distinction is made between the following types of apparatus:

a) **Intrinsically safe apparatus**
Electrical apparatus in which all circuits are intrinsically safe.

b) **Associated apparatus**
Electrical apparatus containing both intrinsically safe and non-intrinsically safe circuits which may affect the safety of intrinsically safe circuits.
Note:
Associated electrical apparatus may be either electrcal apparatus with another type of protection listed in European standard EN 50014 and suitable for use in explosive areas, or electrical apparatus that is not appropriately protected and which must therefore not be used in hazardous areas.

Intrinsically safe apparatus is subdivided into:

c) **Passive intrinsically safe apparatus**
Apparatus solely with intrinsically safe circuits, on which the intrinsic safety does not depend, such as photoelements, dynamic telephone capsules, contacting control devices, resistance-type sensors, terminal boxes and plug-in connectors.
With respect to intrinsic safety, all these items of apparatus produce no or only negligible sparking energy, which can occur in intrinsically safe circuits, and do not develop excessive temperature rise.
They need not be certified in the Federal Republic of Germany.

d) **Passive intrinsically safe apparatus with energy stores**
Apparatus which, although having no power source of its own, can store magnetic, electrical and thermal energy. This includes measuring instruments, sensors of inductive proximity switches, loudspeakers, suppressor capacitors, capacitive probes and light emitting diodes.
This apparatus is only certified in the Federal Republic of Germany if the user, who is responsible, is not fully aware of the energy storage capability and insists on a test by the testing station.

Installation of intrinsically safe systems

Although the construction of apparatus with intrinsically safe circuits complies worldwide with very similar, and in Europe even harmonized specifications, there are considerable differences in the installation of intrinsically safe circuits. These installations are still generally regarded as a national matter.

Installation of intrinsically safe systems in the Federal Republic of Germany (to DIN VDE 0165/2.91)	Intrinsically safe circuits are particularly at risk because low amounts of energy are sufficient to counteract intrinsic safety. The purpose, therefore, of the installation specifications in DIN VDE 0165/2.91 is the clear identification of intrinsically safe circuits as such, and to protect them from external effects.
Adjacent non-intrinsically safe circuits	Intrinsically safe circuits must be installed separately from non-intrinsically safe circuits, and clearly marked. For example, conductors of intrinsically safe and non-intrinsically safe circuits must not be routed together in cables, lines, conduits, ducts and groups. All apparatus into which intrinsically safe circuits are introduced must be certified, irrespective of whether they are situated within or outside the hazardous area.
Equipotential bonding	To keep the risk of sparking caused by different potentials in hazardous areas as low as possible, equipotential bonding is mandatory. This requires that all conductive structural elements accessible to contact, such as supports, containers and piping, be connected to each other and to the protective conductor. Equipotential bonding must be implemented according to DIN VDE 0100, Part 410 and Part 540.
Installation in Zone 2	Zone 2 is only hazardous in exceptional cases. At present, according to DIN VDE 0165/2.91, measuring instruments and telecommunications equipment may be used both in the explosion-protected versions and in the normal design, if they do not contain parts which produce sparks during operation.
Installation in Zone 0	Since there is a continuous risk of a dangerous, potentially explosive atmosphere in Zone 0, the electrical systems must comply with particularly high safety requirements. For operation in Zone 0, all apparatus must be certified for this Zone 0 according to DIN VDE 0165/2.91. For example, it must comply with apparatus of Category "ia".
CENELEC	European Committee for Electrotechnical Standardization The participants are the countries of the EC as well as Austria, Finland, Greece, Norway, Portugal, Sweden, Switzerland and Spain.

H Ex Apparatus and Accessories

H Ex Apparatus and Accessories

H.1 Additional Siemens Ex Apparatus

1. Explosion-protected, three-phase low-voltage motors

   Publication: EEx'e' - Three-Phase Low-Voltage Motors
   Order No. E20001-P111-A105

   Catalog: Three-Phase Low-Voltage Motors (Squirrel-Cage Motors): M11

2. FM 100 field multiplexer

   Manual: Order No. C79000-G8000-C12 (German)

3. SIWAREX P weighing and proportioning systems

   Catalog: MP14, Electromechanical Balances

4. Explosion-protected transducers

   - Pressure and level measuring instruments
   - Electrical transducers for pressure
   - Electrical transducers for differential pressure
   - Pneumatic positioners
   - Thermocouples and transducers

   Catalog: MP01, Standard Products for Process Engineering

5. Indicators and limit monitors

   Catalog: MP12

6. SIMDAS S5 electrical engineering for mining

   Catalog: Sch 7.3, Order No. E86010-K2107-B301-A3

H.2 Accessories

1. **35 mm standard sectional rails**

for 19" racks, 483 mm length	6ES5 710-8MA11
for 600 mm cabinets, 530 mm length	6ES5 710-8MA21
for 900 mm cabinets, 830 mm length	6ES5 710-8MA31
2000 mm length, without holes	6ES5 710-8MA41

2 **Power supply modules**

PS 931 power supply module	
115 V/230 V AC, 24 V 2 A DC	6ES5 931-8MD11
6EW1 load power supply unit	
115 V/230 V AC, 24 V 2 A DC	6EW1 380-0AA
115 V/230 V AC, 24 V 4 A DC	6EW1 380-1AA
115 V/230 V AC, 24 V 10 A DC	6EW1 380-4AAB01

3. **Interface modules**

IM 315 interface module	6ES5 315-8MA11
IM 316 interface module	6ES5 316-8MA12
- Connecting cable (0.5 m)	6ES5 712-8AF00
- Connecting cable (2.5 m)	6ES5 712-8BC50
- Connecting cable (5.0 m)	6ES5 712-8BF00
- Connecting cable (10 m)	6ES5 712-8CB00

J Index

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Guidelines for Handling
Electrostatically Sensitive Devices (ESD)

1 What is ESD?

VSLI chips (MOS technology) are used in practically all SIMATIC and TELEPERM modules. These VLSI components are, by their nature, very sensitive to overvoltage and thus to electrostatic discharge:

They are therefore defined as
Electrostatically **S**ensitive **D**evices: "ESD"

"ESD" is the abbreviation used internationally.

The following warning label on the cabinets, subracks and packing indicates that electrostatically sensitive components have been used and that the modules concerned are susceptible to touch:

ESDs can be destroyed by voltage and energy levels which are far below the level perceptible to human beings. Such voltages already occur when a component or a module is touched by a person who has not been electrostatically discharged. Components which have been subjected to such overvoltages cannot, in most cases, be immediately detected as faulty; the fault occurs only after a long period in operation.

An electrostatic discharge
– of 3500 V can be felt
– of 4500 V can be heard
– must take place at a minimum of 5000 V to be seen.

But just a fraction of this voltage can already damage or destroy an electric component.

The typical data of a component can suffer due to damage, overstressing or weakening caused by electrostatic discharge; this can result in temporary fault behavior, e.g. in the case of

– temperature variations,
– mechanical shodks,
– vibrations,
– change of load.

Only the consequent use of protective equipment and careful observation of the precautions for handling such components can effectively prevent functional disturbances and failures of ESD modules.

2 When is a Static Charge Formed?

One can never be sure that the human body or the material and tools which one is using are not electrostatically charged.

Small charges up to 100 V are very common; these can, however, very quickly rise up to 35 000 V!

Examples of static charge:

– Walking on a carpet	up to	35 000 V
– Walking on a PVC flooring	up to	12 000 V
– Sitting on a cushioned chair	up to	18 000 V
– Plastic desoldering unit	up to	8 000 V
– Books, etc. with a plastic binding	up to	8 000 V
– Plastic bag	up to	5 000 V
– Plastic coffee cup	up to	5 000 V

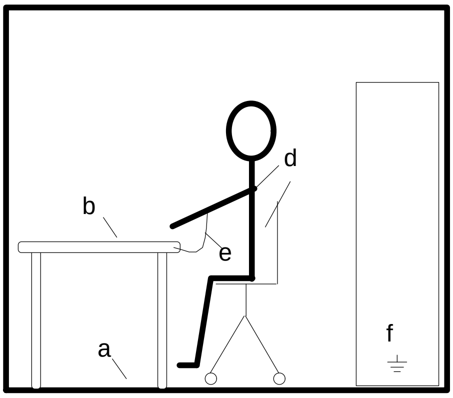
3 Important Protective Measures against Static Discharge

- Most plastic materials are highly susceptible to static charge and must therefore be kept as far away as possible from ESDs!
- Personnel who handle ESDs, the work table and the packing must all be carefully grounded!

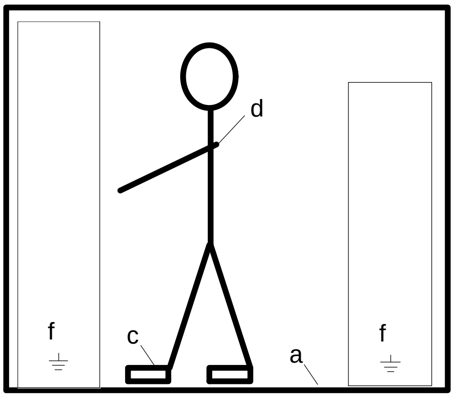
4 Handling of ESD Modules

- One basic rule to be observed is that electronic modules should be touched by hand only if this is necessary for any work to be done on them. Do not touch the component pins or the conductors.
- Touch components only if
  – the person is grounded at all times by means of a wrist strap
  or
  – the person is wearing special anti-static shoes or shoes with a grounding strip.
- Before touching an electronic module, the person concerned must ensure that (s)he is not carrying any static charge. The simplest way is to touch a conductive, grounded item of equipment (e.g. a blank metallic cabinet part, water pipe, etc.) before touching the module.
- Modules should not be brought into contact with insulating materials or materials which take up a static charge, e.g. plastic foil, insulating table tops, synthetic clothing, etc..
- Modules should only be placed on conductive surfaces (table with anti-static table top, conductive foam material, anti-static plastic bag, anti-static transport container).
- Modules should not be placed in the vicinity of visual display units, monitors or TV sets (minimum distance from screen > 10 cm).

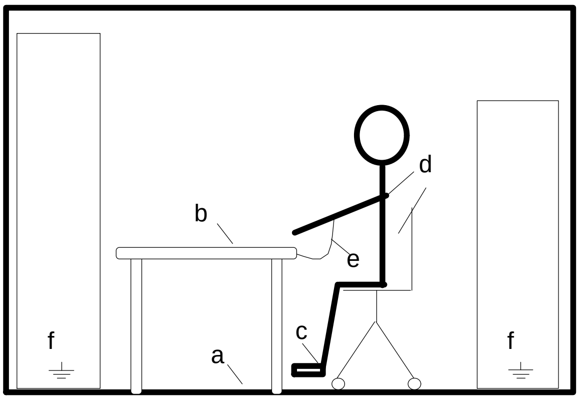
The diagram on the next page shows the required protective measures against electrostatic discharge.



Sitting position



Standing position



Standing/sitting position

- a Conductive flooring
- b Anti-static table
- c Anti-static shoes
- d Anti-static coat
- e Grounding wrist strap
- f Grounding connection of the cabinets

5 Measurements and Modifications to ESD Modules

- Measurements on modules may only be carried out under the following conditions:
  - the measuring equipment is grounded (e.g. via the PE conductor of the power supply system) or
  - when electrically isolated measuring equipment is used, the probe must be discharged (e.g. by touching the metallic casing of the equipment) before beginning measurements.
- Only grounded soldering irons may be used.

6 Shipping of ESD Modules

Anti-static packing material must always be used for modules and components, e.g. metalized plastic boxes, metal boxes, etc. for storing and dispatch of modules and components.

If the container itself is not conductive, the modules must be wrapped in a conductive material such as conductive foam, anti-static plastic bag, aluminum foil or paper. Normal plastic bags or foils should not be used under any circumstances.

For modules with built-in batteries ensure that the conductive packing does not touch or short-circuit the battery connections; if necessary cover the connections with insulating tape or material.

Notes

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