Intrinsically Safe Power Supply Design: A Step-by-Step Guide

SIGNAL CRAFT TECHNOLOGIES

Why Intrinsically Safe?

As the Internet of Things (IoT) becomes of growing importance, so does the need for the many sensors and monitoring devices that will exist in the IoT universe. For example, many of these devices monitor the processing of oil and gas wells and pipelines. By the very nature of the processes, a single stray spark near flammable material in these locations could ignite a fire or explosion. These monitoring devices are in place to mitigate the risk of danger to human life and significant damage to assets.

Special considerations and design practices need to be kept in mind—and specific steps followed—when designing for hazardous locations (HazLoc). One such design strategy to meet these goals is “intrinsically safe design.”

> Special considerations and design practices need to be kept in mind – specific steps followed – when designing for hazardous locations (HazLoc). One such design strategy to meet these goals is “intrinsically safe design.”

Intrinsic safety (IS) is the principle of ensuring circuits, sensors, and other electrical equipment operate safely in hazardous environments—in which flammable liquids, gases, vapors, or combustible dust exist. The intrinsically safe design technique does this by ensuring that any device brought into a hazardous environment limits the accidental discharge of energy to a safe level well below the energy required to initiate an explosion or fire. The IS technique prevents explosions rather than containing them, which is obviously preferable when possible.

This white paper can help designers gain insight into the IS design process by demonstrating some best practices to follow when designing a power supply for a HazLoc environment. First, it provides a high-level overview for engineers to follow — with an eye towards certification.

Then, the latter portion of the paper details three examples that walk engineers through fundamental calculations. These examples describe steps necessary for the design of externally powered, battery-powered, and dual-powered supplies.

To achieve an IS certification, a device must go through a rigorous set of tests put forth by experts in the field of safety.

The Road to Certification

To achieve an IS certification, a device must go through a rigorous set of tests put forth by experts in the field of safety. Products that pass these tests and adhere these standards are considered “Intrinsically Safe Certified.”

Each region in the world will typically have a specific compliance standard to meet. The most common ones are:

- Atmosphere Explosible (ATEX) - EU region
- National Electrical Code (NEC) - US
- Canadian Electrical Code (CEC) - Canada
- International Electrotechnical Commission Explosive (IECEx) - Global

NOTE: Unlike the preceding standards, IECEx certification does not permit a product to be used in a specific region – a regional certification must be obtained. However, IECEx tests are used by many regions as part of their compliance standards – typically with some custom regional deviations. Therefore, having an IECEx certification will greatly reduce the testing effort if additional regions are required (obtained either at the same time or later).

Several different authorizing agencies certify IS equipment. Any equipment used in hazardous locations must be certified by one of them.

In the United States, the Underwriters Laboratories (UL) is the most prevalent authorizing body, while in Canada the Canadian Standards Association (CSA) is the most well-known. However, there are numerous independent labs besides these two that are authorized to conduct the complete safety assessment required for the certification process. Organizations in Europe must follow the ATEX directive and many testing agencies are also available in EU countries. The testing agencies will typically be able to also provide IECEx certification to assist in obtaining worldwide compliance.

Manufacturers must take their IS product through an often lengthy and expensive certification process for the desired safety standard. The last thing any manufacturer needs is to be forced to take several passes through the certification process to achieve compliance. For this reason, it’s recommended that those unfamiliar with IS design principles engage the expertise of the authorizing agency, or other subject matter expert, early in the design process to provide consultation on what safety provisions will be necessary to ensure intrinsically safe operation. This preventive measure can save significant time, design costs, and other headaches when the product design is submitted for the formal safety assessment and certification.

Five Steps to Optimal Intrinsically Safe Power Supply Design

The power supply is a critical component of any product and requires extra attention for IS products. Engineers should consider following the steps laid out in this white paper when designing a power supply for IS products. These steps can be clearly delineated because the IS technique is accepted throughout the world. The rationales for IS certification are well documented and are consistent regardless of the level of protection sought.

Intrinsically safe design provides a straightforward approach to mitigating the potential risks of operating electrical equipment in hazardous areas. Through careful design practice, restricting the potential energy discharge for equipment operating under failure conditions can be the most cost-effective safeguarding technique.

> Through careful design practice, restricting the potential energy discharge for equipment operating under failure conditions can be the most cost-effective safeguarding technique.

Step One: Define the Safety Level Sought

The various IS standards define a range of safety levels and operating environments. Products that support more severe environments will have more market appeal, but will inevitably be more expensive and difficult to design. Establishing the appropriate safety level and operating environment is a critical first step.

Determining safety-level parameters will serve to dictate the available power budget. This budget places limits on how much power that the IS product can consume. In some HazLoc environments, products that consume over a certain power limit cannot be made intrinsically safe. If this occurs, then a different design strategy must be employed (based on containment) or the product’s functionality changed to fit within the allowable power budget. Thus, even before the design process starts, engineers need to ensure the intrinsically safe design is a viable approach for their product.

To find the appropriate safety level for the power supply for which they seek IS certification, engineers will follow the process outlined in this section.

First, determine the standard of compliance sought. This depends on factors such as the market location (for example, NEC for North America only or ATEX for the EU) and the type of HazLoc environment in which the product will operate. As mentioned previously, consideration of the global IECEx standard along with the appropriate regional standard can greatly ease the process of being certified in multiple regions.

Next, engineers must choose the level of protection their design needs to provide. We will explore these considerations in more detail for ATEX/IECEx definitions as defined in IEC 60079-11. The intrinsic safety levels from highest to lowest protection level are:

- ia – Very High Protection
- ib – High Protection
- ic – Low Protection

Associated with the protection levels are 2 key concepts:

- Operating zones
- Fault tolerance

The operating zone defines the likelihood that an explosive atmosphere is present.

- Zone 0, 20 – Locations where an explosive atmosphere is continually present
- Zone 1, 21 – Locations where an explosive atmosphere is likely to be present in normal operation
- Zone 2, 22 – Locations where an explosive atmosphere is not likely to be present in normal operation, and if present will, it only is present for short periods
    - (NOTE: Zones 0-2 apply for a gas hazard atmosphere and 20-22 apply for a dust hazard atmosphere.)

Fault conditions arise when certifying agencies evaluate designs. To find faults within a design, the certifier attempts to identify and expose the circuit to all conceivable failure mechanisms by running what-if scenarios and analyzing results. These applied faults can be considered as either “countable” or “non-countable.”

> To find faults within a design, the certifier attempts to identify and expose the circuit to all conceivable failure mechanisms by running what-if scenarios and analyzing results.

A fault is only considered “countable” if the product conforms to all construction and spacing requirements at the point of where the fault is applied. Depending on the level of protection, the product may be required to tolerate up to two countable faults. However, the certifier may choose to apply an unlimited number of non-countable faults as part of the evaluation. So, for a protection level requiring two countable faults, the application of up to two countable faults must not lead to a discharge of sufficient energy to potentially cause an explosion for the specified safety level.

As an example, the certifying agency may apply a fault by shorting two contacts in a circuit. If the circuit is constructed such that the minimum spacing is met between the two contacts, the fault is considered countable. If the minimum spacing is not met, the fault is non-countable. Regardless of whether the fault is countable or not, the product must not discharge sufficient energy to exceed the limits set by the target safety level or the product will fail compliance. **NOTE: Under fault conditions, the product does not have to maintain its normal functionality but must not create a safety hazard.**

The following table shows the relationship between the protection level, operating Zone and fault tolerance as per IEC 60079-11.

IS Protection Level	Allowed Operating Zone	Countable Fault Tolerance
ia	0,1,2 or 20,21,22	2
ib	1,2 or 21,22	1
ic	2 or 22	0

Next, the atmosphere group must be selected. This will be either a gas or dust hazard atmosphere.

The severity of the gas environment is summarized below from most to least severe:

- Group I – Coal mining location with typical methane gas
- Group IIA – Surface or other location with methane, propane, or similar
- Group IIB – Surface or other locations with ethylene or similar
- Group IIC – Surface of other locations with hydrogen, acetylene, or similar

The severity of the dust environments is summarized below from most to least severe:

- Group IIIA – Surface or other locations with combustible airborne material

- Group IIIB – Surface or other locations with non-conductive airborne material
- Group IIIC – Surface or other locations with conductive airborne material

Finally, as part of this first step, the engineer will choose the temperature class in which the product will operate. The IECEx standard defines temperature groups from T1-T6 where T1 is the most permissive (surface temperature up to 450°C) and T6 is the most restrictive (surface temperature up to 85°C).

Although these parameters were presented from the viewpoint of IECEx, similar or equivalent parameters will exist for other regional standards previously mentioned.

Narrowing choices in this manner will lead engineers to the available power budget which they need to work within. Knowing this available power budget can assure design viability or highlight the need to employ another strategy to ensure safe operation in a particular hazardous environment.

After finding the available power budget, engineers will next need to verify the budget will work with the power supply they intend to use.

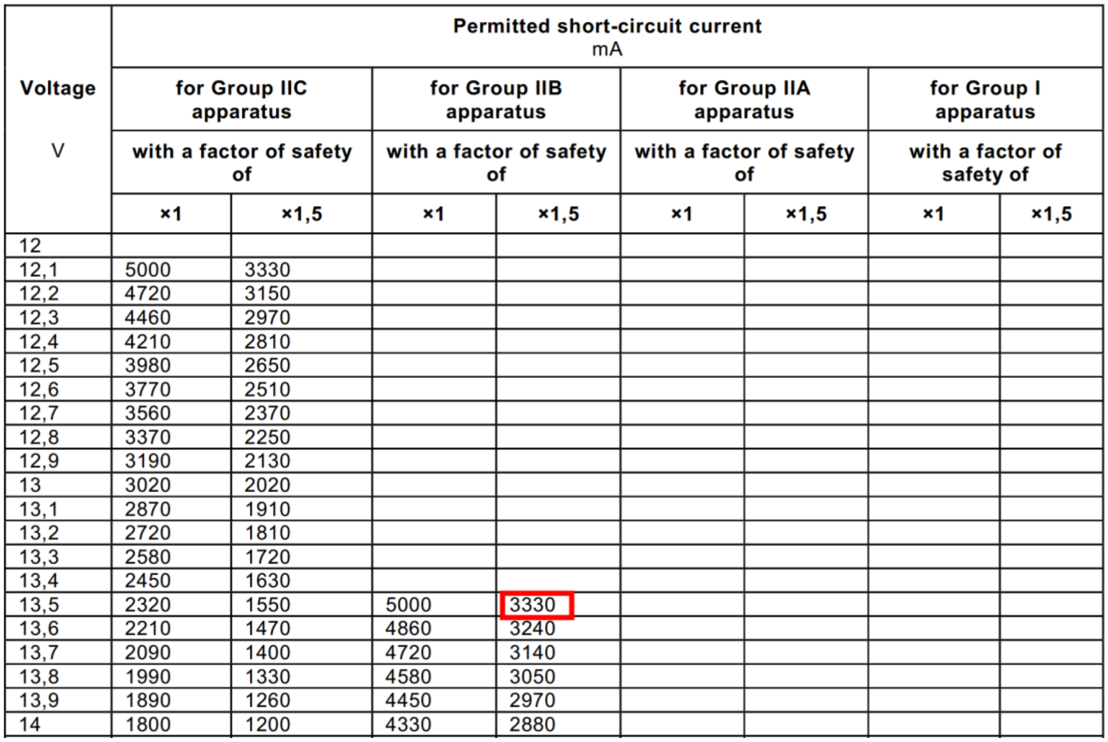
Step Two: Verify the Power Budget

After finding the available power budget, engineers will next need to verify the budget will work with the power supply they intend to use. To do this, they must make certain that the chosen power supply's total peak power requirement falls within allowable power limits for the given operating environment.

These power limits are defined within tables and curves provided in the various safety standards. In the case of IECEx, this can be analyzed by looking at the "Permitted short-circuit current corresponding to the voltage and apparatus group" tables. The snippets below show a small section of this table from IEC 60079-11.

In these tables, there are values for 1x and 1.5x safety factors. In general, the more restrictive 1.5x safety factor is used in calculations when an "ia" or "ib" protection level is required whereas the less restrictive 1x safety factor is used for the "ic" protection level. The notable exception is when evaluating the limits for surface temperature where the 1x safety factor applies in all cases.

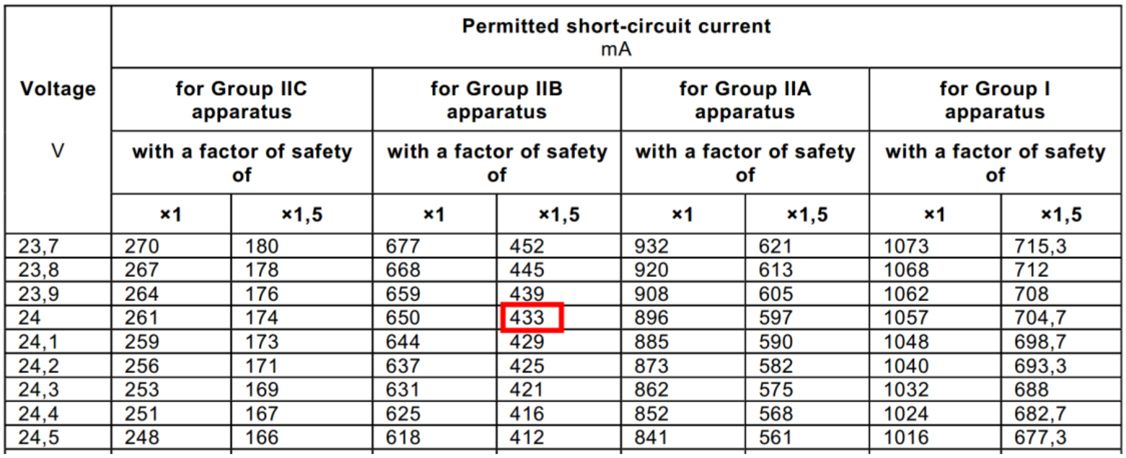
Table A.1 – Permitted short-circuit current corresponding to the voltage and the apparatus group



Voltage V	Permitted short-circuit current mA							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
12								
12,1	5000	3330						
12,2	4720	3150						
12,3	4460	2970						
12,4	4210	2810						
12,5	3980	2650						
12,6	3770	2510						
12,7	3560	2370						
12,8	3370	2250						
12,9	3190	2130						
13	3020	2020						
13,1	2870	1910						
13,2	2720	1810						
13,3	2580	1720						
13,4	2450	1630						
13,5	2320	1550	5000	3330				
13,6	2210	1470	4860	3240				
13,7	2090	1400	4720	3140				
13,8	1990	1330	4580	3050				
13,9	1890	1260	4450	2970				
14	1800	1200	4330	2880				

Source: IEC

Table A.1 (*continued*)



Voltage V	Permitted short-circuit current mA							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
23,7	270	180	677	452	932	621	1073	715,3
23,8	267	178	668	445	920	613	1068	712
23,9	264	176	659	439	908	605	1062	708
24	261	174	650	433	896	597	1057	704,7
24,1	259	173	644	429	885	590	1048	698,7
24,2	256	171	637	425	873	582	1040	693,3
24,3	253	169	631	421	862	575	1032	688
24,4	251	167	625	416	852	568	1024	682,7
24,5	248	166	618	412	841	561	1016	677,3

Source: IEC

As an example, for Group IIB with the 1.5x safety factor, the maximum power limit is at 13.5V and 3.33A or 45.0W. We can see that as the required voltage rises, the current drops significantly. For example, at 24V for Group IIB, the current limit with a 1.5x safety factor is 0.433A, which is 10.4W.

Similarly, dropping the voltage does not permit additional current. A 3.3V system is still limited to 3.33A or 11.0W. In light of this, the engineer must be sure to give consideration to the operating voltage and to the total power to ensure they are compliant.

This is a key point because if the designer has some freedom, he or she can find a sweet spot in the requirements that allows for the most available power for their product.

Besides the total power, engineers must also take system capacitance and inductance into account. Capacitance becomes severely restricted at higher voltages. For power supplies, the low level of permitted capacitance can be extremely challenging.

For capacitance limits, we reference IEC 60079-11, Table A.2, “Permitted capacitance corresponding to the voltage and the apparatus group” tables. Examining Group IIB, the capacitive limit for a 3.3V system with a 1.5x safety factor is 1000uF (this is the same limit that would be applied for 6.0V) – but the limit for a 12V system is down to only 9uF and at 24V is down to 0.93uF.

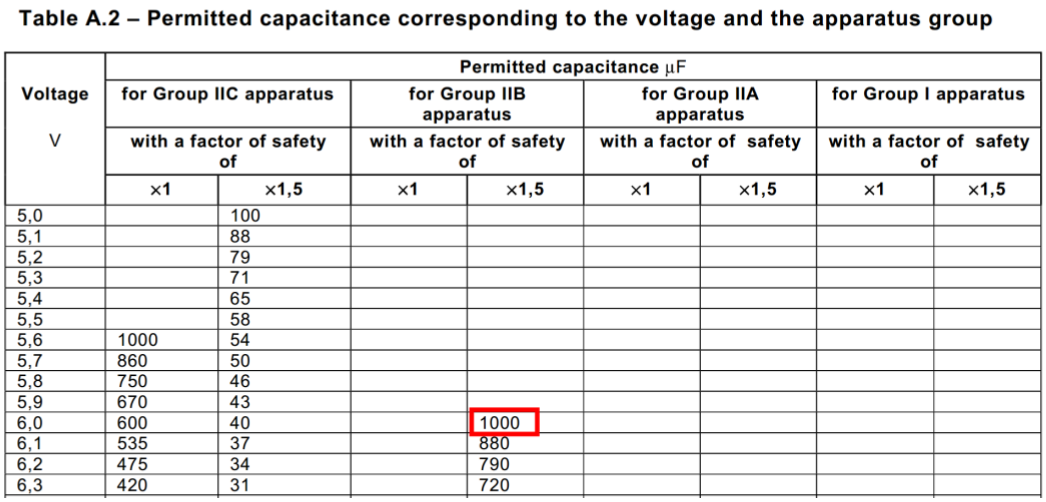
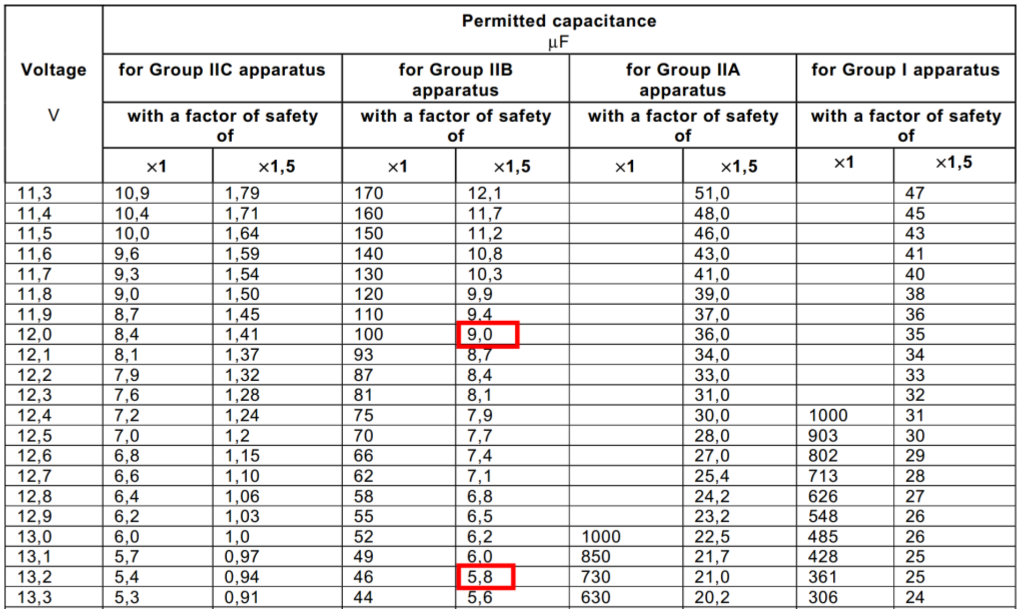


Table A.2 – Permitted capacitance corresponding to the voltage and the apparatus group

Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
5,0		100						
5,1		88						
5,2		79						
5,3		71						
5,4		65						
5,5		58						
5,6	1000	54						
5,7	860	50						
5,8	750	46						
5,9	670	43						
6,0	600	40		1000				
6,1	535	37		880				
6,2	475	34		790				
6,3	420	31		720				

Source: IEC

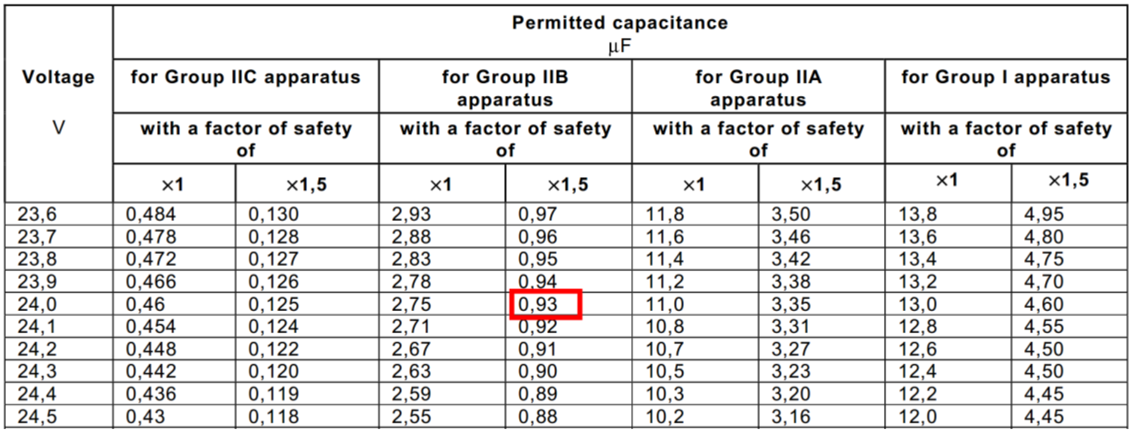
Table A.2 (*continued*)



Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
11,3	10,9	1,79	170	12,1		51,0		47
11,4	10,4	1,71	160	11,7		48,0		45
11,5	10,0	1,64	150	11,2		46,0		43
11,6	9,6	1,59	140	10,8		43,0		41
11,7	9,3	1,54	130	10,3		41,0		40
11,8	9,0	1,50	120	9,9		39,0		38
11,9	8,7	1,45	110	9,4		37,0		36
12,0	8,4	1,41	100	9,0		36,0		35
12,1	8,1	1,37	93	8,7		34,0		34
12,2	7,9	1,32	87	8,4		33,0		33
12,3	7,6	1,28	81	8,1		31,0		32
12,4	7,2	1,24	75	7,9		30,0	1000	31
12,5	7,0	1,2	70	7,7		28,0	903	30
12,6	6,8	1,15	66	7,4		27,0	802	29
12,7	6,6	1,10	62	7,1		25,4	713	28
12,8	6,4	1,06	58	6,8		24,2	626	27
12,9	6,2	1,03	55	6,5		23,2	548	26
13,0	6,0	1,0	52	6,2	1000	22,5	485	26
13,1	5,7	0,97	49	6,0	850	21,7	428	25
13,2	5,4	0,94	46	5,8	730	21,0	361	25
13,3	5,3	0,91	44	5,6	630	20,2	306	24

Source: IEC

Table A.2 (*continued*)



Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
23,6	0,484	0,130	2,93	0,97	11,8	3,50	13,8	4,95
23,7	0,478	0,128	2,88	0,96	11,6	3,46	13,6	4,80
23,8	0,472	0,127	2,83	0,95	11,4	3,42	13,4	4,75
23,9	0,466	0,126	2,78	0,94	11,2	3,38	13,2	4,70
24,0	0,46	0,125	2,75	0,93	11,0	3,35	13,0	4,60
24,1	0,454	0,124	2,71	0,92	10,8	3,31	12,8	4,55
24,2	0,448	0,122	2,67	0,91	10,7	3,27	12,6	4,50
24,3	0,442	0,120	2,63	0,90	10,5	3,23	12,4	4,50
24,4	0,436	0,119	2,59	0,89	10,3	3,20	12,2	4,45
24,5	0,43	0,118	2,55	0,88	10,2	3,16	12,0	4,45

Source: IEC

Step Three: Determine Voltage Conversion, if Necessary

In industrial HazLoc environments, externally provided voltage typically ranges between 12V and 24V. These levels only permit a very limited amount of capacitance.

In industrial HazLoc environments, externally provided voltage typically ranges between 12V and 24V. As shown in the previous section, these levels only permit a very limited amount of capacitance (and to a lesser extent, current). With the limited capacitance at higher voltages, the only practical solution is to reduce the main working to typically 5V or 3.3V. Using the example from before, this will then permit up to 1000uF of capacitance for Group IIB with a 1.5x safety factor.

A typical solution is to use a buck voltage converter to drop a higher input voltage to the main working voltage of the circuit. For IS design, however, additional protection elements must be added to the buck converter that would usually not be required in a non-IS application. A key requirement is that the higher voltage side of the buck converter is totally isolated from the lower voltage side where the higher capacitance exists – even while under fault conditions (such as shorting the input to the output of the buck converter). This typically requires a combination of voltage-limiting devices (i.e. Zener diodes) and current-limiting devices (i.e. fuses). This will be examined in further detail in the design example cases.

The protection must be present and sufficient in scope to maintain safe operating conditions during the application of the specified number of fault conditions. Depending on the level of safety being sought, this may involve two “countable” faults.

Step Four: Define the External Supply Specification, if Needed

Products used in HazLoc environments may use internal power (battery source) or be provided power from an external source. If external power is provided, the requirements and limitations of this power source must be defined by “input-entity parameters.”

IS products must include drawings that depict how the device will be attached to external devices. These cover all connections including signaling and power connections.

For input power connections, engineers need to define input-entity parameters for the external power source. This defines what level of input can be safely absorbed by the circuit and the characteristics presented to the external power supply. We include the definition of the following acronyms.

- Ui = Input voltage
- Ii = Input current
- Pi = Input power
- Li = Input inductance
- Ci = Input capacitance

Typically, the external power will originate from a safe area outside of the hazardous location. When the power crosses the boundary between safe and hazardous areas, special barrier circuitry is required as part of the installation to limit the energy that can be discharged into the hazardous area. By defining the input entity parameters, the requirements for the barrier are determined. These parameters must be provided to the installer, so a suitable source and barrier are used when supplying power to the device.

Given all these constraints, engineers must ensure that enough power can still be provided to the device to meet its peak demand.

Step Five: Select Safety Devices

The power supply must contain safety components that prevent any spark or heat energy of a sufficient level to cause an explosion under prescribed fault conditions. It is the responsibility of the engineer to incorporate these protective components into the design while still maintaining proper operation. This is seldom an easy task.

In this step, engineers will analyze potential faults and will put preventative measures in place to prevent discharges of energy that could result in an explosion if these faults were to occur. These preventative measures typically take the form of safety devices that limit the energy discharge to safe levels. Such safety devices include fuses, diodes, Zener diodes, and resistors. In each case, the devices dissipate power and must be properly rated. This includes limits on voltage, power dissipation and the surface temperature that the device will reach under the fault conditions.

When multiple countable faults must be tolerated, redundant copies of the safety components are necessary.

It should be noted that during a safety assessment, a certifier will typically be very hesitant to analyze the use of complex safety devices. (i.e. integrated semiconductor devices.) In these cases, the certifier may reject

> The power supply must contain safety components that prevent any spark or heat energy of a sufficient level to cause an explosion under prescribed fault conditions.

the design or require sample testing under numerous fault conditions to permit IS certification, which could prove costly and time-consuming.

Design in Action

The following examples use the IECEx limits from IEC 60079-11. These are questions to ask to ensure you have an optimal IS design.

In the examples, we will not explicitly specify a temperature class. The temperature class will typically dictate the physical size requirements of selected protection devices. The more restrictive the temperature class (i.e. the lower the temperature that can be tolerated), the larger these protection devices need to in order to keep their surface temperatures low enough to be safe.

Design Example — External Power

Step One: Define the Safety Level Sought

For this example:

- The target class is Group IIB with safety level “ia”
- The main external input voltage is specified as 12V +/- 10% or 10.8V to 13.2V.
- The active circuit is designed to run at 3.3V with a peak current of 700mA.

Step Two: Verify the Power Budget

Can the power needs of the product design be met with the allowance imposed by the Safety Standard? Our example product’s circuit can draw up to 700mA at 3.3V. At 13.5V, which is the lowest voltage specified by Table A.1, a restriction of 3.33A is defined when considering the 1.5x safety factor. Therefore, from the perspective of current, safety standard’s power restrictions will not an issue for this design example.

Next, determine if the power limits from a capacitive limit can be met. Again, with a 1.5x safety factor, Table A.2 limits that total capacitance must be less than 1000uF for 3.3V. The designer must be certain that the total circuit capacitance connected to the 3.3V rail is kept below 1000uF.

Step Three: Determine Voltage Conversion, if Necessary

For this example, a buck voltage converter will be used to convert the external 12V input to the 3.3V required by the example design's circuits.

First, determine if the safety standard's input current restrictions can be met. Assume a typical buck DC-DC power converter is used with 90 percent efficiency. The worst-case input side current draw of the buck converter will be (3.3V * 0.70A) / 10.8V / 0.9 = 0.238A.

With the 1.5x safety factor applied, Table A.1 limits current to 3.33A at 13.2V. The needs of the buck converter are well below the imposed safety limit and from a current perspective, the safety power limitations are not an issue.

Next, determine if the capacitive restrictions of the safety standard can be met. Again, with a 1.5x safety factor, the limits on capacitance for 13.2V is 5.8uF. This then limits the design of the buck converter input side to at most 5.8uF. The designer must work within this limit.

Step Four: Define the External Supply Specification, if Needed

The entity parameters for the power supply would be specified as follows:

- Ui = 13.2V max (12V +/- 10%, therefore maximum is 13.2V)
- Ii = 250mA (from the previous section, 238mA was the worst-case – we round up to a normally available fuse size of 250 mA)
- Pi = 3.3 W max (from calculation of Ui and Ii)
- Li = Typically negligible for switching power supplies
- Ci = TDB from final power supply design, but 5.8uF maximum

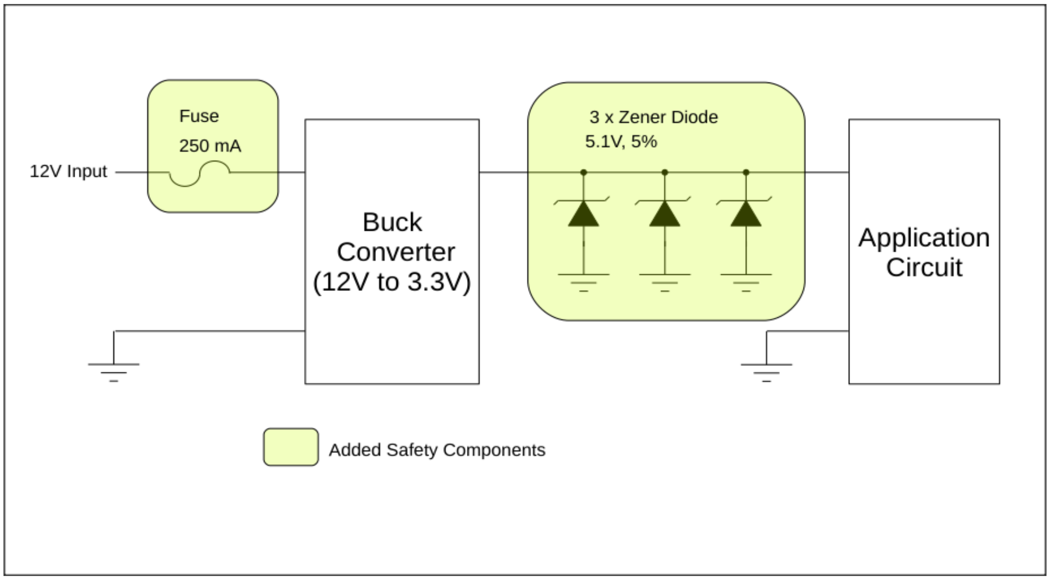
Step Five: Select Safety Devices

For this example, a typical list of safety devices would include the following:

- Fuse to limit current. A 250mA size device is sensible for functional purposes on the 12V input However, for intrinsic safety calculations, this must be multiplied by a 1.7x safety factor. Therefore, the trip limit would be assumed to be 425 mA.

- The voltage on the active circuit side must be limited to 6.0V to allow the full maximum 1000uF capacitance on that side.
- A typical voltage clamping device would be a Zener diode. But the diode must take into consideration the worst-case tolerance. For example, if a 5.1V Zener diode with 5% tolerance is chosen, then the limiting voltage for calculations would be set at 5.36V.
- Taking the fusing current and voltage of the Zener into account, the Zener must handle 5.36V * 425 mA = 2.28W. Again, a 1.5x safety factor must be applied and a diode rated to handle at least 3.42W must be chosen.
- To handle two countable faults, three identical Zener diodes would have to be used and sized and spaced accordingly. This redundancy ensures protection in the case the Zener diodes fail open.
- The physical size of all components must be analyzed to ensure that the specified temperature class can be met. This must be evaluated under the most stressful conditions.

A design to meet these requirements may look like the following:



External Supply Design Example

Design Example — Battery Power

Step One: Define the Safety Level Sought

For this example:

- The target class is Group IIB with safety level “ia”
- The product is powered with a 3.6V primary lithium cell with a 400mA peak current. Assuming a 10 percent tolerance on voltage, a maximum of 4.0V can be used.
- The battery is supplemented with a supercapacitor that is capable of sourcing up to 5A peak current. This is a common setup with devices using RF transceivers, where the RF circuitry could have a relatively high peak current requirement to support transmit bursts but a much lower typical operating current.
- The active circuit is designed to run using 3.3V with a peak current of 700mA.

Step Two: Verify the Power Budget

First, we verify the active circuit side is acceptable: 3.3V and 700mA. The 1.5x safely limit will apply. The lowest voltage specified from the Table A.1 is 13.5V and will apply even though the maximum voltage is 4.0V. The corresponding current limit is 3.33A. The current draw of the example design is well below this limit and is thereby not a problem.

Unfortunately, the supercapacitor’s 5A peak current sourcing capability far exceeds the 3.33A safety limit, and therefore the example design must employ additional safety measures to mitigate this risk.

Next, determine if the power limits from a capacitive limit can be met. Again, with a 1.5x safety factor, the limit is 1000 uF for 4.0V. The designer must ensure that total circuit capacitance associated with the 4.0V does not exceed this limit.

Step Three: Determine Voltage Conversion, if Necessary

For this example, only the battery is used and no voltage conversion is necessary.

Step Four: Define the External Supply Specification, if Needed

For this example, only the battery is used and no external supply specification is needed.

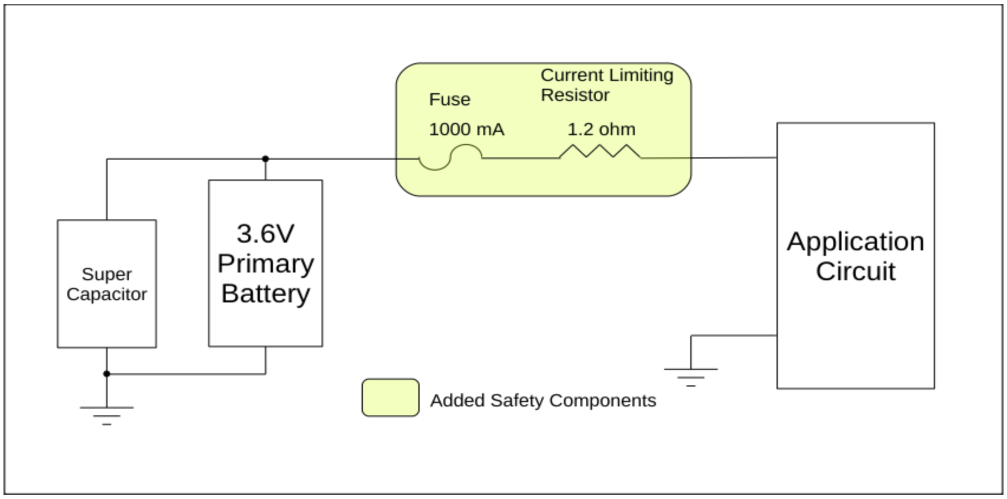
Step Five: Select Safety Devices

For this example, a typical list of safety devices would include the following:

- Fuse to limit current. A 1000mA device is sensible for functional purposes. However, for intrinsic safety calculations, this must be multiplied by a 1.7x safety factor. Therefore, the trip limit would be assumed to be 1700 mA. The peak from the design was at 700mA, so a 750mA fuse could be used. However, for batteries, the voltage will sag under load, so allowing for more peak current is a prudent decision – thus a fuse rating of 1000mA is chosen.
- A short circuit must be limited to 3.33A. Since the supercapacitor could supply up to 5A, a series resistor must be used to limit this current. Assuming the worst-case 4.0V input, the required resistor would be 4.0V / 3.3 A = 1.2 ohms.
- When selecting the resistor, the tolerance of the resistor must be factored in (typically 1%). If the fuse has a rated resistance, then that can also be incorporated as part of the total series resistance (but only the minimum specified value can be applied).
    - **NOTE:** This series resistance imposes a significant voltage drop on the circuit during the peak current draw of 700mA. The voltage drop will be 0.70A* 1.2 ohms = 0.84V. Therefore, the voltage provided by the battery could drop as low as 2.46V on a near end of life lithium cell voltage of 3.3V. The designer must take this into consideration as part of the system design.
- The voltage on the active circuit side must be limited to 6.0V to allow the maximum 1000uF capacitance on that side. However, since this is battery powered and limited to 4.0V, this would not be a concern.

When selecting the resistor, the tolerance of the resistor must be factored in (typically 1%).

A design to meet these requirements may look like the following:



Battery Powered Design Example

Design Example — Dual Power Support

Step One: Define the Safety Level Sought

For this example:

- The target class is Group IIB with safety level “ia”
- The main external input voltage is specified as 12V +/- 10% or 10.8V to 13.2V.
- Battery backup power is provided with 3.6V primary lithium cell with a 400mA peak current. Assuming a 10% tolerance on voltage, a maximum of 4.0V can be used.
- The battery backup is supplemented by a supercapacitor capable of sourcing a peak current of 5A.
- The active circuit is designed to run using 3.3V with a peak current of 700mA.
- Automatic switchover to using the battery when external power is not available.

Step Two: Verify the Power Budget

From the previous analysis, the power budget can be met.

Step Three: Determine Voltage Conversion, if Necessary

The voltage conversion used will be the same as the first example.

Step Four: Define the External Supply Specification, if Needed

The external supply specifications will be the same as the first example.

Step Five: Select Safety Devices

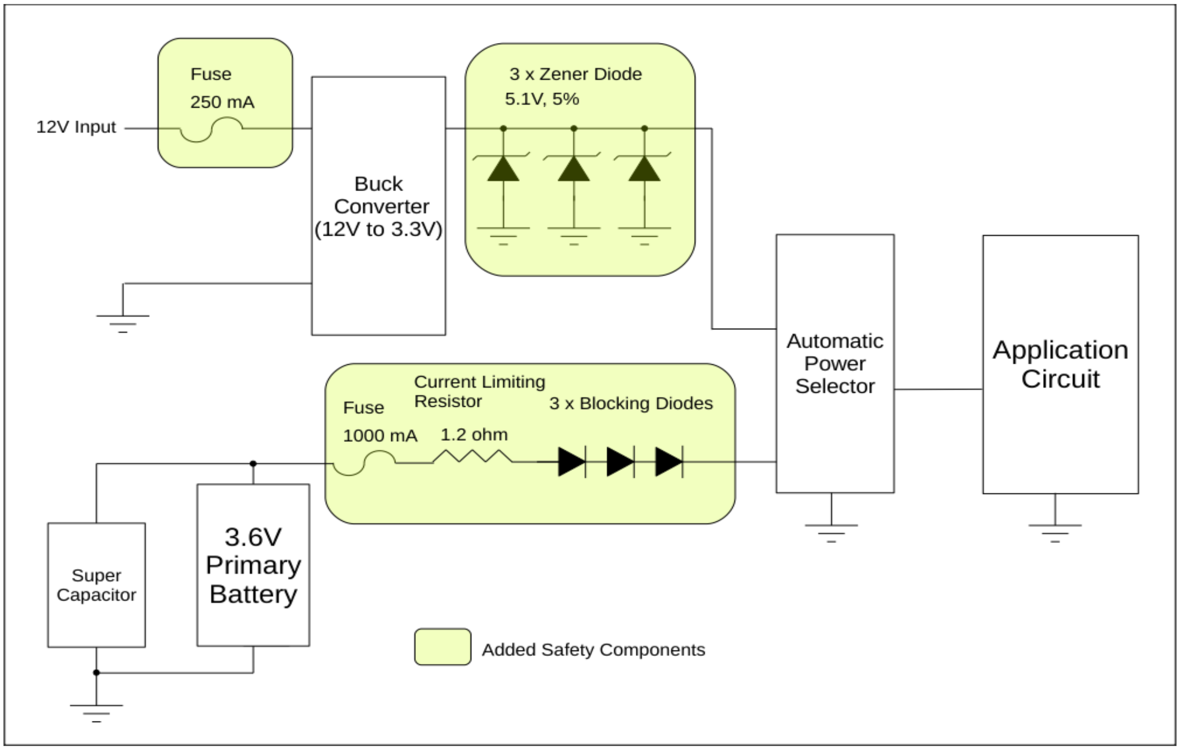
For this example, a typical list of safety devices would include the following:

- Use all safety elements of the previous two example designs (i.e. external DC supply and lithium primary cell battery)

Add the following devices:

- The circuit that selects the power derived from the external 12V input (a 3.3V buck converter) or the lithium battery (3.6V) must provide a mechanism to never allow current to flow into the battery. **Primary lithium batteries cannot be charged as there is a high risk of an explosion.**
- A common protection circuit would be a series blocking diode in the primary battery path.
- But to meet 2 countable faults (of possible shorting the blocking diodes), 3 series diodes would be required.
- A total of 3 series diode drops must be considered to see if the circuit will still operate. In many cases, this will result in a non-functional circuit.
- Alternative designs to use lower voltage drop devices (like MOSFETs) are possible. However, the circuit must again have up to 3 copies and work under all conditions - this includes when the battery is drained. Furthermore, the control circuitry to manage a switched device like a MOSFET will come under scrutiny from certifying agency. As explained previously, protection devices beyond simple components are more difficult to evaluate and may not be accepted. This is one example of the many complexities and trade-offs that must be made when doing IS design.

A design to meet these requirements may look like the following:



Dual Powered Design Example

Summary

Intrinsic safety is the natural choice for installing low voltage instrumentation devices in hazardous locations. Wireless IoT instrumentation that is certified to be intrinsically safe, such as SignalCraft's Canary product family, allows for risk-free remote control and monitoring of industrial processes within in hazardous locations. These types of monitoring applications include oil and gas sensors, utilities, water management systems, and oil pipeline and distribution equipment.

By following the five design steps this white paper covers, engineers will be able to ensure the power supply in their product is able to achieve IS certification, regardless of the type of authorization sought. The paper uses examples with specific target values from IECEx, but the principles apply to all standards.

By following the five design steps this white paper covers, engineers will be able to ensure the power supply in their product is able to achieve IS certification, regardless of the type of authorization sought.

Speeding up the design and certification process will save an engineering company both time and money and get the product to market faster. By knowing which safety device to use with the power supply, for example, engineers can readily choose the correct devices and don’t waste time designing those that won’t meet with requirements of the safety standards.

Are you ready to implement the IS process when designing a power supply for a HazLoc environment? Contact us for more information.

About SignalCraft Technologies

We build brilliantly designed, high frequency digital and RF products, 100% in-house from the ground up to your specs and schedule. From leading global test brands to industrial communications startups, technical leaders trust SignalCraft as their wireless product development partner.

signalcraft.com