POWER SUPPLIES FOR HIGH-ALTITUDE APPLICATIONS

This technical note describes how CoolX 600 and CoolX 1000 modular power supplies help mitigate the safety and regulatory risks when designing for end applications where altitude is a factor.

INTRODUCTION

For the design engineer, the main considerations when designing for applications where altitude is a factor is understanding how high altitude can negatively impact the electronics within, as well as surrounding the power supplies, and complying with the safety regulations for these applications.

Advanced Energy's modular, fanless power supplies, the Excelsys CoolX® 600 and CoolX® 1000 Series, take into account the specific needs for demanding applications that must maintain high-reliability and efficiency at high altitudes. This paper describes the challenges altitude presents and explains how the CoolX 600 and CoolX 1000 offer unique benefits to meet both application and regulatory requirements.

TYPICAL HIGH-ALTITUDE ENVIRONMENTS

Among the many harsh-environment, high-reliability applications where altitude must be considered are:

- Aircraft applications (rotary and fixed wing aircraft), including cabin entertainment, medical transport, passenger seat power plugs, airborne instrumentation and surveillance
- Drones, surveillance balloons, ROVs, surveillance, and airborne survey-mapping instrumentation
- Pressurized and unpressurized airborne systems in commercial and military applications.
- Broadcast towers, repeaters, transmitters, and radar/weather and other applications.
- Medical and industrial applications, globally, where geographic areas include high-altitude operation (Peru, China (GB 4943.1-2011), India, Chile and others)

WHY ALTITUDE IS A FACTOR

Let's review the physics involved in power electronics design. As altitude is increased, the air is less dense. The cooling capacity of the air decreases as altitude increases (decreased density) making heat removal via air flow less effective.

According to Paschen's Law, the dielectric properties of air changes with altitude. The creepage and clearance of the power supply has to take this into account. At higher altitude, the air is not as good of an insulator as it is at sea level — until you reach a vacuum.

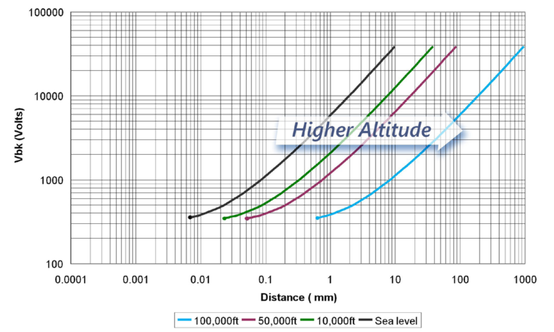

Figure 1: Paschen curves illustrate the dependency of breakdown voltage on distance between conductors and altitude

Simply stated, to maintain safety ratings for an approved medical and or industrial power supply, the creepage, and clearance must be taken into consideration. Paschen's curve (Figure 1) describes electric discharge voltage as a function of atmospheric pressure and wiring/electrode separation (defining the minimum voltage for breakdown in air to be 327V at one atmosphere pressure [sea level].) Voltages, steady-state or repeated transients higher than 327V are referred as high voltages.

Power supplies routinely have 240 to 265 VAC and 380 or more VDC internally, as well as high-frequency high-voltage AC energy. Thus, considerations for breakdown and processing high voltage must be considered for use in the end application.

Air at high altitude is less dense than air at sea level, reducing its convective capability and overall heat transfer capacity. Therefore, all electronics that rely on natural or forced convection to dissipate heat will experience increased air and component temperature rise for the same amount of power at higher altitudes. Thermal derating above 2000 meters of 1°C per 305 meters (1000 ft) must be employed to take into account the lower density of the atmosphere and its ability to remove heat from the system.

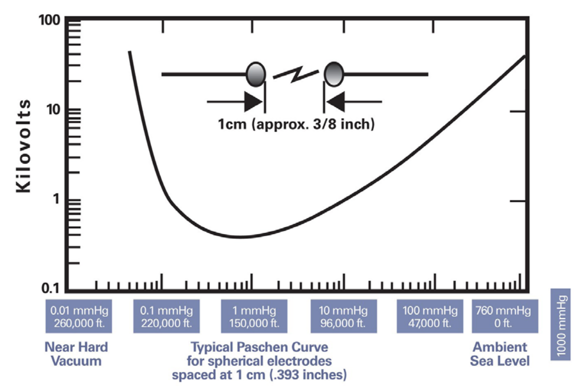

Figure 2: Dielectric breakdown vs. altitude for a 1 CM gap vs. altitude. The higher the altitude the more gap is needed to prevent breakdown up to about 220K ft., until a near vacuum is achieved.

As Figure 1 shows, breakdown voltages vary approximately proportional to pressure (altitude) and inversely proportional to temperature. The higher the altitude, the greater the creepage and clearance distance required to prevent breakdown. Figure 2 shows the voltage withstanding/dielectric breakdown of a 1CM gap at various altitudes.

CREEPAGE AND CLEARANCE

Figure 3 illustrates how creepage and clearance can be defined. Clearance is the shortest distance through air between two conductors; this is the path where damage is caused by short-duration maximum peak voltage. Clearance relates to flashover — creepage relates to tracking. These separations must be increased at higher altitudes.

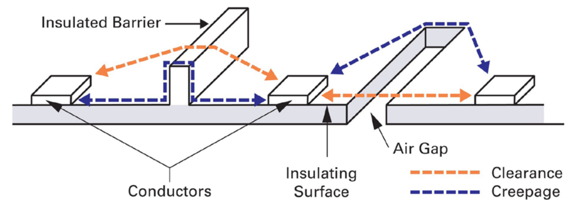

Figure 3: Creepage and clearance defined.

Creepage is defined as the shortest distance between two conductive parts along the surface of any insulating material common to both parts. The breakdown of the creepage distance is a slow phenomenon based upon DC or RMS voltage. Creepage and clearance distances, to meet medical and industrial spec at sea level, will need to be greater at altitude to meet safety specifications and prevent breakdown. Conformal coating cannot be used to substitute for proper creapage and clearance distances.

ALTITUDE SPECIFICATIONS FOR POWER SUPPLIES

It is important to note that when rating a power supply for a given altitude, it is insufficient to specify it as working at "X" altitude. It must be specified to meet its specification at that altitude. In other words, for a medical power supply, the creapage and clearance used must allow the power supply to meet medical power supply requirements for safety at a given, specified altitude. The following standards specify performance at altitude:

- GB 4943.1-2011
- IEC 60601 for medical – with multiplier
- IEC 60950 going to 62368-1 with multiplier
- Storage (non-operational) altitude for industrial and medical supplies is generally limited by the lowest temperature rating of the product; in most cases 8000 metres is typical.

In the case of equipment manufactured or sold in China, the standard GB 4943.1-2011 assumes your product must be suitable for use at altitudes up to 5000 m. This will require a clearance limit 1.48 times of IEC/UL 60950-1 or greater – unless your device is marked as suitable for use only up to 2000 m. In that case, it has to be so marked. IPC-2221B requirements are typically used with a multiplier added for a given maximum altitude where the equipment will need to operate. Table 1 shows temperature deratings at altitude. As you can see in the highlighted "Multiplier" columns, if you need fans, the need for derating is even greater.

Table 1: Temperature Rise Multiples for High Altitudes

Altitude m (ft)	Multiplier		
	Fan-Cooled (General)	Fan-Cooled (High Power)	Naturally Cooled-Conduction
0	1	1	1
1,500 (5,000)	1.2	1.16	1.1
3,000 (10,000)	1.45	1.35	1.21
4,500 (15,000)	1.77	1.58	1.33
6,000 (20,000)	2.18	1.86	1.48

POWER SUPPLY IMPLEMENTATION

The CoolX600 and CoolX1000 Series of modular fanless power supplies (Figure 4) have been designed to exceed regulatory safety requirements at 5000 M for creepage and clearance. They not only works at that altitude, but also meet medical and industrial safety standards with margin at 5000m altitude.

Figure 4: Advanced Energy's Excelsys CoolX1000 power supply

Fanless CoolX power supplies are not dependent on air cooling to the greatest extent possible. Therefore they have much improved thermal derating performance at higher altitudes, which gives more design freedom to the system engineer and requires less over specification. Overall, the power supplies can work at greater altitudes with higher flexibility, greater margin and design freedom, and with higher reliability.

CoolX 600 and CoolX 1000 power supplies feature extra efficiency even in harsh, remote applications, and are able to withstand input voltage line surge disturbances of up to 300 Volts AC. In addition to achieving maximum power output with fanless natural convection cooling at up to 40°C ambient with no derating, the power supply series can further enhance thermal performance using system fans or external conduction cooling. Increased system reliability and results in system lifetimes that are typically 25% longer than alternative approaches. Designed for high efficiency, the CoolX 600 and CoolX 1000 Series do not dissipate as much heat in the first place, so heat removal is easier.

EXCELSYS PRODUCT OFFERINGS

Table 2 provides an overview of the various Advanced Energy Excelsys power supply product families and their altitude performance. The CoolX 600 and 1000 platforms, as well as the other Advanced Energy product offerings, offer a wide range of solutions to meet many of the global requirements where altitude is a consideration. Please contact Advanced Energy applications engineering for further information and or assistance with your requirements.

Table 2: Excelsys Power Supply Product Series Altitude Performance

Standard	CoolX	Xsolo	UltiMod/Xgen
Medical (60601)	5000 m	3000 m	2000 m
Industrial (60950, 62368)	5000 m	5000 m	2000 m
Storage (Max. Altitude)	8000 m	8000 m	8000 m

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