Application Note – AN1701

How to Select Power Supplies for High-Altitude Applications

Abstract: This paper describes how CoolX600 modular power supplies help customers 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 supply, the CoolX600 series, takes 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 CoolX600 offers 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 less effective.

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

Simply stated, to maintain safety ratings for an approved medical and or industrial power supply, the creapage 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 240-265 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 degree 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.

As Figure 1 shows, breakdown voltages vary approximately proportional to pressure (altitude) and inversely proportional to temperature. For example: 1 cm gap – 30 kV DC @ sea level, 1.2 kV @ 50,000 ft and 327 V @ 100,000 ft. The higher the altitude, the greater the creapage and clearance distance required to prevent breakdown. Figure 2 shows the voltage withstanding/ dielectric breakdown of a 1 CM gap at various altitudes.

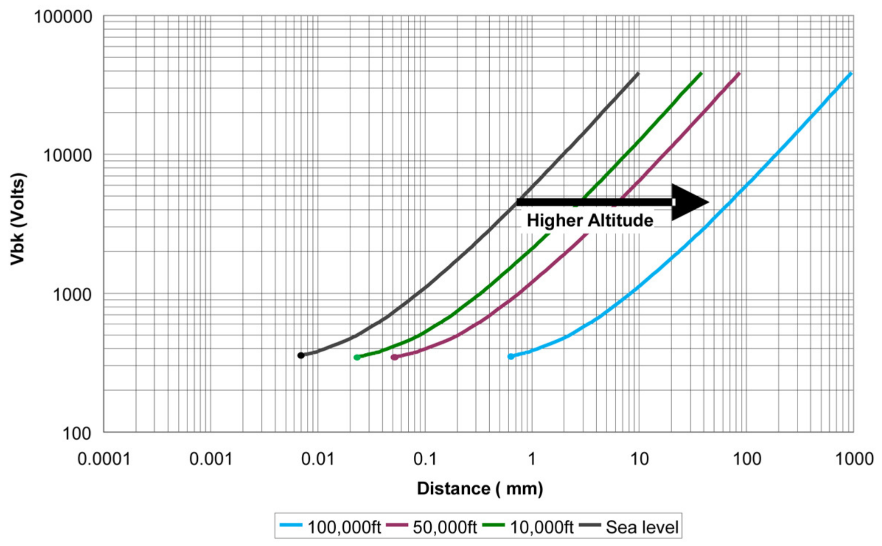

Figure 1. *Paschen curves illustrate the dependency of breakdown voltage on distance between conductors and altitude.*

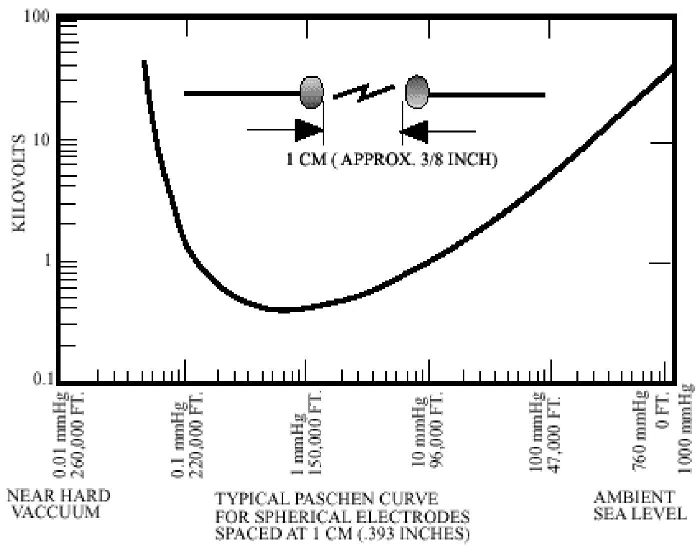

Figure 2. Dielectric breakdown vs. altitude for a 1 CM gap vs. altitude. The higher the altitude the more gap is needed to prevent breakdown up to about 220 K ft., until a near vacuum is achieved.

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.

Conformal coating cannot be used to substitute for proper creepage and clearance distances. 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.

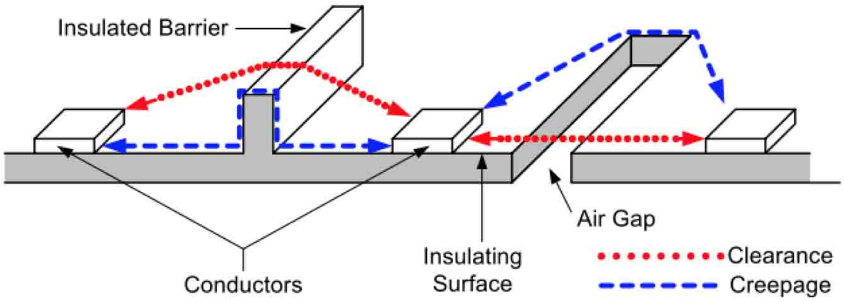

Figure 3. *Creepage and clearance defined.*

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
- IEC60601 for medical – with multiplier
- IEC60950 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 meters 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/UL60950-1 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.

Temperature rise multipliers for high altitudes			
Altitude	Multiplier		
m(ft)	Fan-Cooled (General)	Fan-Cooled (High Power)	Naturally Cooled
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

Table 1. Temperature deratings at altitude.

Power Supply Implementation

The CoolX series of modular fanless power supplies (Figure 4) has been designed to exceed regulatory safety requirements at 5000 M for creepage and clearance. It not only works at that altitude, it also meets medical and industrial safety standards with margin at 5000-M altitude.

Figure 4. *The CoolX600 power supply.*

The fanless CoolX isn't dependent on air cooling to the greatest extent possible, so that the thermal derating needed at altitude is less, 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.

The power supply features extra efficiency even in harsh, remote applications, able to withstand input voltage line surge disturbances of up to 300 Volts AC. In addition to achieving 600 Watts output with fanless natural convection cooling at up to 40 degrees 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 series does not dissipate as much heat in the first place, so heat removal is easier.

Advanced Energy Low Voltage Product Offerings

The CoolX platform, as well as the other low voltage product offerings, perform well in meeting 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 provides an overview of the various low voltage power supply product families and their altitude performance.

Low Voltage Power Supply Product Series

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

Table 2. Low voltage power supplies' altitude performance.

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About Advanced Energy

Advanced Energy (AE) has devoted more than three decades to perfecting power for its global customers. AE designs and manufactures highly engineered, precision power conversion, measurement and control solutions for mission-critical applications and processes.

AE's power solutions enable customer innovation in complex semiconductor and industrial thin film plasma manufacturing processes, demanding high and low voltage applications, and temperature-critical thermal processes.

With deep applications know-how and responsive service and support across the globe, AE builds collaborative partnerships to meet rapid technological developments, propel growth for its customers and power the future of technology.

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