Powering Communications in Harsh Environments

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The use of power supplies in harsh, remote environments brings with it many fundamental design issues that must be fully understood if long-term reliability is to be attained. For designers of communications equipment downtime is not an option. Both revenues and safety can be compromised under such circumstances. For example, cell enhancers and repeaters using bi-directional amplifiers for on-line signal repeating and boosting are widely deployed around the world for improving network coverage in buildings, tunnels, metros, stadiums and other areas of poor signal propagation. Problems with public mobile radio systems can be particularly serious in applications such as transport communications systems, particularly those used by the emergency services.

In this context, power supplies are critical components and, outside of electrical connectors, potentially the most likely cause of problems because of the thermal management issues surrounding even the most efficient of them. Power supplies also have a role to play in protecting system electronics from the vagaries of mains voltage variations, transients, surges and drop-outs.

Electronic systems used in remote locations are often sealed against the elements. This makes the removal of unwanted heat particularly difficult. The use of forced-air cooling is undesirable as it increases system size, adds the maintenance issue of cleaning or replacing filters, and adds a moving electromechanical component – the fan- which itself is prone to wear-out, particularly in tough environments.

The most common solution adopted by system designers is to use a standard power supply and change the mechanical design to enable removal of heat from the sealed system. However, this simple work-around does not really address the fundamental issues of power supply design for the applications described and a more practical approach is to select a power supply that has been designed specifically for sealed enclosure applications.

Power Supply Design Issues

The power supply design has to take into account three main factors. Firstly, the extremes of ambient temperature encountered in remote sites can range from several tens of degrees below freezing to over +40 °C. Furthermore, it is not uncommon for the temperature within the enclosure to rise some 15 – 20 °C above the external temperature. The positioning of the power supply within the enclosure can help minimize the ambient temperature in which it operates and this can have a dramatic effect on system reliability. As a rule of thumb, MTBF (meant time between failures) halves with every 10 °C rise in temperature. Power supplies therefore need to be able to operate from –40 °C to +65 °C as a minimum. Secondly, system enclosures are typically sealed to IP65 or IP66 standards to prevent ingress of dust or water. Removal of heat from RF power amplifiers and power supplies in a situation with negligible airflow is the challenge. From the power system perspective, the most effective solution is to remove the heat using a heatsink that is external to the enclosure. However, most standard power supplies cannot provide an adequate thermal path between the heat-dissipating components within the unit and the external environment.

Finally, the potentially poor mains supply means that the power supply must be able to deliver the required output across its full input (90 to 264VAC) and load range. Manufacturers of communications systems for remote sites often sell their products internationally. In Western Europe and the US, we are used to high quality mains supplies but the same situation does not apply in many developing countries where low mains voltage, flat-topped waveforms, brown outs and transient surges can be an everyday issue. In these circumstances a well-designed power supply provides protection for the main system electronics.

Designing for Reliability in Sealed Enclosures

Conventional power supplies dissipate heat into small on-board heatsinks or onto a U-section chassis. The basic construction is shown in Figure 1. Most of the heat goes into the enclosure in which the power supply is used. Such units typically have to be derated from 50 °C, delivering 50% of their full rated power at 70 °C. The derating is a general guide based on not exceeding the maximum operating temperature of individual components within the power supply. Furthermore, units rated above 200 Watts or so with power factor correction (PFC) to EN610000-3-2 usually have to be derated by 25% once the input voltage drops below 110 VAC. This is due to the higher input current needed at lower voltages and the need to ensure that the current ratings of inductors within the EMC and power factor correction circuits are not exceeded. A worst-case power factor of 0.99 is the standard specification to ensure that at least 99% of the AC input is real (in phase) power.

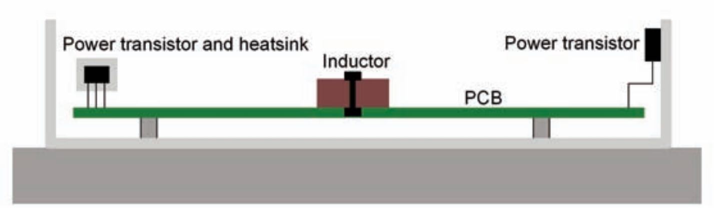
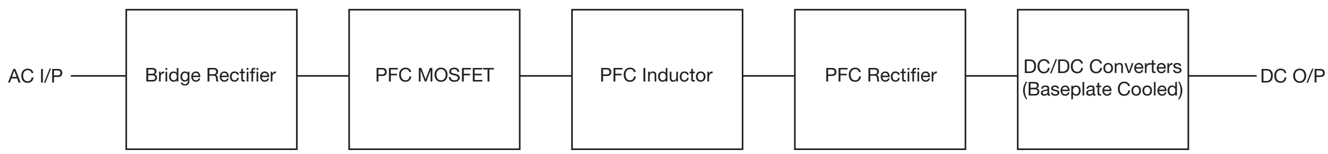


Figure 1
Construction of typical industrial AC-DC Power Supply

Fundamentally, successful design of a power supply for use within sealed enclosures means creating a path with low thermal resistance through which heat can be conducted from heat-generating components to the outside world.

The components that generate the most heat in a power supply are distributed throughout the design, from input to output.

They include the Bridge Rectifier, the power MOSFET used in an active PFC circuit, the PFC inductor, rectifier(s), and baseplate-cooled DC/DC converters (where these are used). Heat can be removed from these components by mounting them directly onto a substantial baseplate that in turn can be affixed to a heatsink, rather than onto the PCB. As mentioned earlier, the heatsink is then located outside of the enclosure.



The BCC series power supply from XP is an example of a power supply designed in this way. In this instance, reliability is further enhanced by ensuring that all aluminium electrolytic capacitors are rated for operation to +105 °C and DC/DC converters with failure rates of less than 50ppm are selected.

These 200-400 Watt, AC/DC, single output power supplies use a 6mm thick aluminium baseplate to conduct heat away from the unit. Aluminium is the optimum material with respect to conductivity, cost, and manufacturability. Copper, for example, is a better conductor but the cost far exceeds that of aluminium. Versions of the BCC capable of operating at –40 °C are available through the use of hold-up electrolytic capacitors rated down to this temperature.

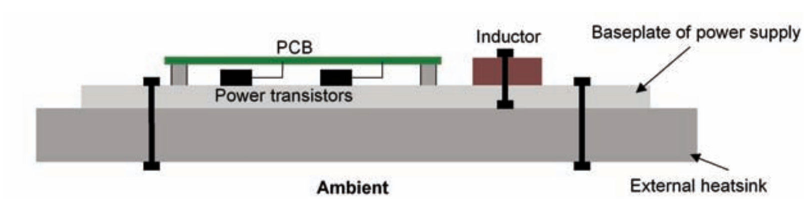


Figure 2
Construction of BCC Series power supply for harsh environment applications

Figure 2 shows the basic construction with all of the major heat-generating components fixed directly to the baseplate.

This construction does demand accurate pre-forming of the leads of the components mounted on the baseplate, and accurate positioning of the PCB with respect to the baseplate, but there is no significant increase in manufacturing complexity or costs.

With the appropriate heatsink, removal of heat is so effective that there is no need to de-rate the unit until the ambient temperature reaches +70 °C. This eliminates the need to over-engineer the power supply for the application.

Active power sharing is an important consideration where multiple units are used in parallel. This is achieved by monitoring the output current from each power supply in a system and feeding back any differences via an error amplifier to make small adjustments in output voltage that then corrects any imbalance. In the BCC product, this keeps the units running within ±3% of each other in terms of power output and further enhances long-term reliability.

Finally, input filtering enables the BCC to meet EN61000-4-5 specifications with respect to surge, EN61000-4-4 for transients and EN610000-4-2 with respect to ESD.

Dissapating the Heat: Heatsink Calculations

The 6mm aluminium baseplate of the BCC power supply is designed to be fixed to a heatsink surface. Three basic mechanisms then contribute to heat dissipation: conduction, radiation and convection. All mechanisms are active to some degree but once heat is transferred from the baseplate to the heatsink by conduction, free convection is the dominant one.

Effective conduction between surfaces demands very flat surfaces in order to achieve low thermal resistance. Heat transfer can be maximised by the use of a thermal compound that fills any irregularities on the surfaces. System designers should aim to keep thermal resistance between baseplate and heatsink to below 0.1 °C/W. This is the performance offered by most commonly used bonding pastes when applied in accordance with manufacturers' instructions. Radiation accounts for less than 10% of heat dissipation and precise calculations are complex. In any case, it is good practice to consider this 10% to be a safety margin.

The degree of convection cooling depends on the heatsink size and type. Heatsink selection involves the following steps:

1. Calculate the power dissipated as waste heat from the power supply. The efficiency and worst case load figures are used to determine this using the formula:

$$\text{Waste heat} = \frac{1 - \text{Eff\%}}{\text{Eff\%}} \times \text{Pout}$$

$$= \left[\frac{1}{\text{Eff\%}} - 1\right] \times \text{Pout}$$

2. Estimate the impedance of the thermal interface impedance between the power supply baseplate and the heatsink. This is typically 0.1 °C/W when using a thermal compound and this figure can be used as a rule-of-thumb.

3. Calculate the maximum available temperature rise on the baseplate. In the example of the BCC product, the maximum allowable baseplate temperature TB is +85 °C. The available temperature rise is simply:

$T_B – T_A$ where T_A is the maximum ambient temperature outside of the cabinet.

4. The required heatsink is firstly defined in terms of its thermal impedance using the formula:

$$ØH = \frac{T_B - T_A}{\text{Waste Heat}} - ØTII$$

Where ØH is the thermal impedance of the heatsink and ØTII is the thermal impedance of the baseplate to heatsink interface.

5. The final choice is then made based on the best physical design of heatsink for the application that can deliver the required thermal impedance. The system's construction will determine the maximum available area for contact with the baseplate of the power supply and the available space outside of the enclosure will then determine the size, number and arrangement of cooling fins on the heatsink to meet the dissipation requirement.

6. Conclusion

The reliability of remotely sited communications equipment is fundamentally dependent upon power supply reliability. The most cost-effective approach to power system design is to use power supplies designed for the application that conduct heat via large, flat baseplates to heatsinks that can be mounted outside of the enclosure.

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