

Basics of Enclosure Cooling White Paper

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As electronic and power components are designed into denser, smaller packages, it becomes increasingly important to consider how well the equipment dissipates heat. Such equipment has specific operating temperature ranges and when put inside of cabinets and enclosures, temperature can become a big issue. Excessive waste heat generated by equipment within a cabinet is the single most important factor effecting equipment performance, reliability and failure. Cooling should be considered early in the design process. Having an effective cooling strategy can help in adequately dealing with heat dissipation.

Heat Transfer

Heat transfer takes place in one of three ways: through radiation, conduction and natural or forced convection. Heat transfer via radiation occurs through electromagnetic waves, an example being the sun's energy reaching the earth. Heat can also be transferred through conduction between objects in contact; for instance, a microprocessor chip cooled using a heat sink, making direct contact with the chip.

Most systems remove heat through a combination of methods, even though one may be emphasized. For example, a processor chip may be cooled using a heat sink (conduction) that includes a fan (forced convection). The key to keeping equipment cool is to remove heat from the cabinet while supplying cool air to the places that need it. Enclosure manufacturers can provide guidance to users in selecting the proper cooling approaches.

The most commonly used cooling methods for enclosures, in order of increasing cost, are natural convection, forced convection (such as fans and blowers) and air conditioning.

Natural Convection

Natural convection cooling is adequate for most applications that generate mild heat. Usually, enclosure temperatures may exceed room temperature, yet remain below the temperature limits of the components inside. The key is making sure that the cabinet interior offers an unrestricted airflow path. The cabinet should have sufficient venting at both the top and bottom to promote airflow and a chimney effect. The best way natural airflow is circulated within a cabinet is when it is drawn from the bottom up through the top of the enclosure.

Top covers can be either fixed or removable and ventilated, or non-ventilated. While fixed covers are cheaper, they block access from the top and make it difficult to machine cable-access or fan-mounting holes. Ventilating covers allow natural exhausting of hot air and help keep the rack cool inside. Some manufacturers provide ventilated tops with pre-punched holes for mounting an exhaust fan if one is needed.

One problem associated with bringing air into an enclosure is the entry of dust and unwanted particles. Louvers are a popular form of air entry and exit for convection

cooling because they provide some protection against dust entry while hiding the contents of the cabinet.

Forced Convection

Where natural convection is inadequate, forced convection via fans and blowers can be used. The main difference between fans and blowers is in their flow and pressure characteristics. Fans provide airflow parallel to the fan blade axis and can deliver high airflow rates. However, they are suitable for low to moderate backpressure only where there is little resistance to airflow by equipment inside the cabinet. Blowers normally deliver air in a direction perpendicular to the blower axis. They are suitable for moderate to high airflow against high backpressure. A combination of a blower and an exhaust fan sometimes works best in densely packed cabinets.

Fans

There are several types of fans, the most common being propeller, tube-axial and vane-axial styles. Propeller fans are the simplest, consisting of only a motor and propeller. However, poor performance under resistance or backpressure and the potential for air turbulence caused by tip vortices makes them unsuitable for electronic enclosures. The tube-axial fan is the most common type used in electronic cooling systems. It is similar to a propeller fan except for a venturi tube placed around the propeller to reduce vortices. The vane-axial fan has vanes that trail behind the propeller in the airflow to straighten the swirling flow of accelerated air.

Typically used for exhausting hot air from a system as well as honing in on specific hot spots, tube-axial fans with ball bearings typically offer long life. Exhaust fans can be mounted inside or outside the top of the cabinet. In some applications, exhaust fans are also mounted on the front, back or sides.

Blowers

When a cabinet is stuffed with equipment, exhaust fans alone may not be enough to remove hot air due to high airflow resistance. For such conditions, blowers are used to blow cool ambient air into the cabinet.

A blower can be used at the bottom of the cabinet to create high internal pressure within the cabinet. Hot air can then be exhausted through the top of the cabinet through vents. Priority should be to pump air into the cabinet, so small cracks around doors and openings exhaust the air and prevent entry of dust and lint through these openings. Sometimes, adding an exhaust fan at the top can improve air flow. Most blowers are fitted with a filter at the air inlet side to prevent dust and lint from entering the cabinet. When selecting fans or blowers, pay attention to noise ratings. Blowers typically have noise ratings from 50 dB to 65 dB, while 30 dB to 55 dB is typical for tube-axial fans. Designers must ensure that devices, whether fans or blowers, provide adequate airflow (typically measured in cubic feet per minute, or cfm) under actual backpressure conditions. Most device manufacturers provide a performance chart that indicates airflow for various levels of backpressure. Static back pressure requirements need to be determined through empirical measurement – they can't be calculated.

Carefully positioning fans and blowers in the cabinet improves cooling efficiency. Mount blowers near cold air inlets preferably at the bottom of a cabinet, away from major heat sources such as transformers and power supplies. If possible, hot devices should be placed near the exhaust so that heat can vent directly to the outside. Also, avoid openings between the air inlet and outlet, which will disturb the efficiency of the air flow.

Fan Trays

Cabinets filled with equipment such as card cages, servers, drawers and shelves may still have hot spots that are difficult to cool because of restricted airflow. So, in addition to a blower and an exhaust fan, fan trays are used to direct airflow to these hot spots. A fan tray is basically a chassis with a bank of small tube-axial fans daisy-chained together and connected to a common power source. This chassis can be mounted directly below the sensitive equipment or a hot spot.

Air Conditioning

For most cooling applications, a combination of natural air removal and fans and/or blowers will do the trick. For critical and thermally sensitive applications, and also for sealed cabinets, air conditioners or cabinet coolers provide the greatest capacity to transfer heat. They also provide the ability to cool cabinets to temperatures lower than the ambient air. A typical cabinet cooler has two heat exchangers. The interior fan draws hot air over the heat exchanger inside the cabinet and blows the cooled air back into the cabinet. The heat absorbed is transferred to an outside heat exchanger where it is cooled by the ambient air using another fan. An air conditioner uses compressed Freon or other refrigerant for the cooling process.

Most air-conditioned cabinets are sealed with only inside air circulated inside the cabinet. This prevents moist air from entering the cabinet and causing condensation that could harm sensitive equipment. However, if cabinets are not properly sealed and interior components are kept at lower than ambient temperature, silica or other dehumidifying means would be needed to prevent condensation. To size an air conditioner for an enclosure, use software provided by the manufacturer.

Basic Airflow Calculations

The amount of airflow that must be provided to achieve a desired cooling performance is expressed by the following equations that relate airflow to ΔT :

For ΔT in degrees F:

$$\text{Airflow (ft}^3\text{/min)} = \text{BTU/hr} / (1.08 \times \Delta T_F) = (3170 \times \text{kW}) / \Delta T_F$$

For ΔT in degrees C:

$$\text{Airflow (ft}^3\text{/min)} = \text{BTU/hr} / (1.95 \times \Delta T_C) = (1760 \times \text{kW}) / \Delta T_C$$

Typical values for ΔT are 10C and 18F. Add 25 percent for a safety margin (12.5C and 23F). Note that ΔT represents the temperature rise over ambient air temperature. If

ambient is too high, it may be difficult or impossible to maintain a safe operating temperature without air conditioning.

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