

Techniques for Cooling Power and Other Electronic Devices

All electronic devices generate heat due to their unavoidable internal losses and inefficiencies. The higher the efficiency rating of the device, the less internal heat is generated within it. If we could achieve 100% efficiency, and technology is getting ever closer to that elusive goal, no heat would be generated within the device and, therefore, no cooling would be required. Until then, the generated heat must be dissipated to maximize the end product's reliability and prevent its premature failure.

There are three primary techniques of transferring or dissipating heat from power and other electronic devices: These are conduction, convection, and radiant. In all cases, the heat is being transferred from the hot electronic device to another medium that is at a lower temperature. All cooling techniques include some components of conduction, convection, and radiant cooling in their process. Heat is constantly seeking to move from its source to an object, or through a medium that is cooler.

Conduction cooling: This is defined as the transfer of heat from one hot part to another cooler part by direct contact. For example, many DC-DC converters have a flat surface (base-plate) that is designed to mount directly to an external heatsink or cold plate that will conduct the heat away from the power device by direct contact, thereby cooling it. Most power supplies use internal heatsinks that are in contact with the power devices, via a thermal conductive paste or pad, to conduct away the heat. The heatsinks, in turn, depend upon convection cooling to transfer their conducted heat to the cooler surrounding air.

Convection cooling: This involves the transfer of heat from a power device by the action of the natural air flow (air is actually a low-density fluid) surrounding and contacting the device. Many power devices are rated for natural convection cooling as long as the air surrounding the unit remains within a limited temperature range that is cooler than the device. The advantage of convection cooling is that no fans are required (Figure 1). Fans, due to their mechani-



Figure 1: Photo of a convection-cooled (no fan) AC-DC switchmode power supply. Notice the black heat sinks, some of which have fins, while others are vertically mounted black sheet metal, which also serve as heat sinks to the high power devices used in the power supply circuits. This model (ZWD-PAF) is capable of providing up to 225-watts of output power with an ambient air temperature ranging from -10°C to +50°C.

cal components, tend to reduce the mean-time-between-failures (MTBF) ratings of power supplies. Convection cooling works best when the products have a natural circulating source of air. For enclosed applications, to insure a natural exchange of air, a number of vents should be provided at various locations in the case or enclosure.

Many heat-generating electronic devices, including DC-DC converters, microprocessors, hybrid circuits, etc., require the use of heatsinks to facilitate convection cooling and to assist in transferring the heat away from the devices to the cooler air. Heatsinks utilize both conduction cooling (i.e., the device must make good thermal contact with the

heatsink) and convection cooling. Heatsinks are designed to transfer the heat from the device to the ambient air, primarily by substantially increasing the surface area that comes in contact with the air. Because the surfaces of electronic devices and heatsinks are not perfect, some type of thermally conductive interface material is necessary to fill the tiny voids. Although this material must be thermally conductive, in some instances it also needs to be an electrical insulator;

for example, a thin silicon pad. In most other applications, a thin layer of thermal grease can be used as the interface material.

Another type of convection cooling requires forced-air flow, via fans that direct the air across the power devices, with or without heatsinks. Many power supplies come with a built-in fan to provide this forced-air type of convection cooling. Other types of power devices specify the amount of air flow that must pass through or around the unit, in cubic or linear feet-per-minute (CFM or LFM), in order for the device to provide its maximum rated output power.

Radiant cooling: This is the transfer of heat by means of electromagnetic radiation (energy waves) that flows from a hot object (e.g., power device) to a cooler object. True radiant heat transfer can take place in a vacuum and does not require air. For example, our Sun not only emits light waves, but, also infrared heat waves through great distances in space, which results in our Earth having daylight and various degrees of warmth.

Other Cooling Technologies

Thermoelectric coolers: Peltier coolers, also known as thermoelectric coolers (TEC), are solid-state devices that function similar to heat pumps. TECs require an external DC power source to



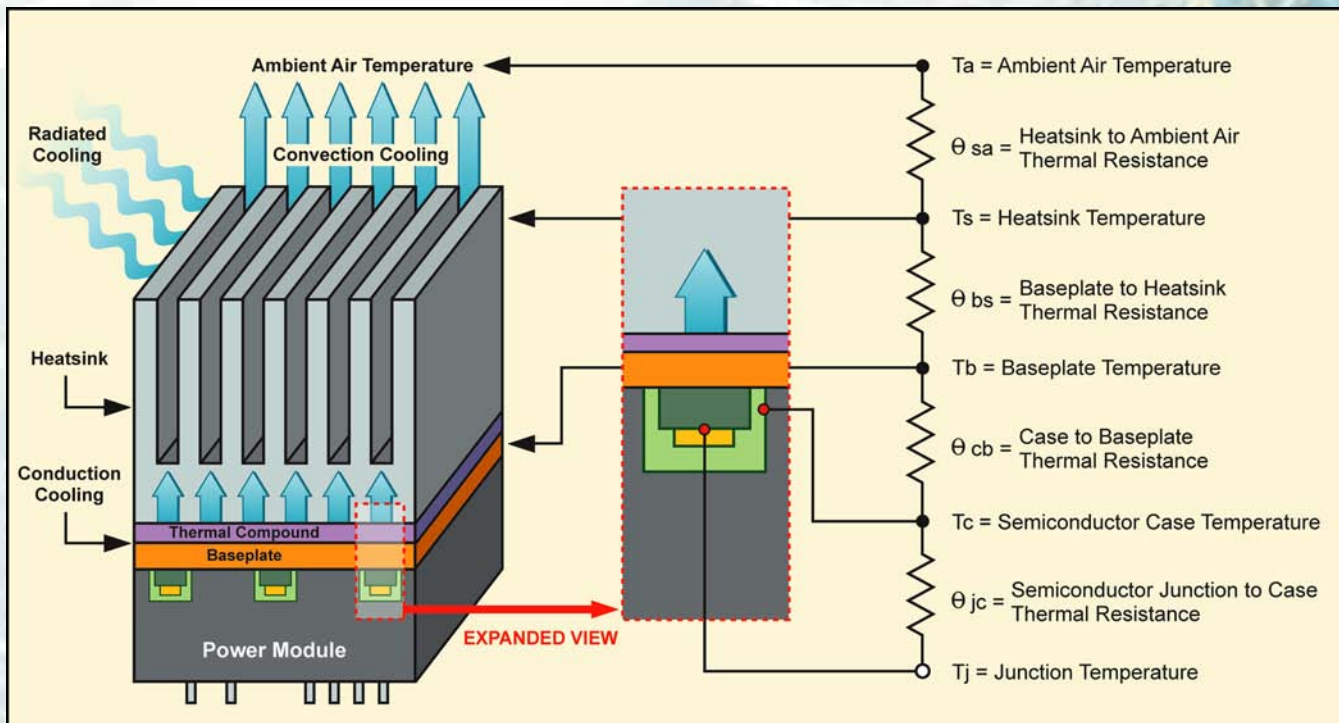


Figure 2. Diagram of typical Power Module being cooled by an attached heatsink. As shown, there are many thermal resistances which impede the free flow of the heat from the semiconductors and other devices that are internal to the Power Module. Techniques for reducing these thermal resistances include the use of thermal compounds (grease or pads), maximizing the surface area of the heatsink to suit the application, and, if necessary, adding forced air cooling.

operate them. The power device to be cooled is mounted on one side of the TEC with an appropriate thermal grease or thermal pad. When a voltage is applied to the TEC, the heat is pulled away from the power device and pumped to the opposite side that has a heatsink and sometimes a fan to dissipate the heat. Thermoelectric coolers are effective, but have low efficiencies and are more expensive than heatsinks and/or fans. However, they are used to cool laser diodes, ultra-fast microprocessors, and laboratory instruments.

Liquid cooled cold plates: In some applications where multiple electronic power devices are employed or where there is a concentrated heat load in a confined area, it may be necessary to consider the use of liquid cooled cold plates. As the name implies, these are usually comprised of aluminum or copper plates on which the power devices are mounted that contain parallel ducts or serpentine tubes through which a liquid coolant is pumped and then routed to an external heat exchanger where the liquid is cooled; then it is recycled through the pump in a continuous closed loop. This type of cooling is very effective, but also one of the most expensive techniques to employ. Nonetheless, liquid cooled cold plates are used extensively in many military,

aerospace, RF amplifier, medical, industrial, and telecom applications.

Thermal Resistances Impede Heat Transfers

The majority of cooling techniques employed today are utilized in power, semiconductor, and microprocessor devices, many of which are being introduced on a daily basis. Each of these active devices is specified to operate safely within a certain temperature range that must not be exceeded. The maximum operating temperature is commonly based on maintaining the semiconductor's internal junction temperatures below its maximum. Since the internal junction temperatures cannot be measured directly, devices such as MOSFETs, DC-DC converters, power bricks, etc., are specified to operate safely as long as its metal case, mounting tab, or baseplate temperature is kept below the specified maximum. To achieve this, a network of thermal resistances must be considered and taken into account. Thermal resistances are analogous to electronic resistances. They represent the mechanical interfaces between the various layers of materials which impede the flow of heat from one level to the next. A diagram of these series-connected thermal resistances beginning with the internal semiconductor junctions

and concluding with the ambient air is shown in Figure 2.

Current and Future Trends

The ongoing trend is to provide as many features and benefits in the smallest package possible. This trend presents increased demands and challenges to the product development and packaging engineers. With greater power densities comes the need to find improved techniques of dissipating the unwanted heat from the end-product to insure its long life and reliability. There are now many "green" initiatives and policies which are demanding vast improvements in electronic product efficiencies. There is no doubt that these improved products' efficiencies will reduce the amount of heat and energy that is now wasted. However, since achieving 100% efficiency is akin to developing a perpetual motion machine, within the foreseeable future there remains a need for designers to keep abreast of the latest techniques for cooling power and other electronic devices.

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