Thermal Management

Abstract: This paper will give the reader an insight into the different options available for thermal management when designing a power supply. It will look at a number of options , and will also discuss the implementation of using fans to provide convection cooling.

Background:

One of the first laws of Physics that we learn during our schooling is that energy can neither be created or destroyed, but can only be changed from one form to another. This naturally remains true for power supplies.

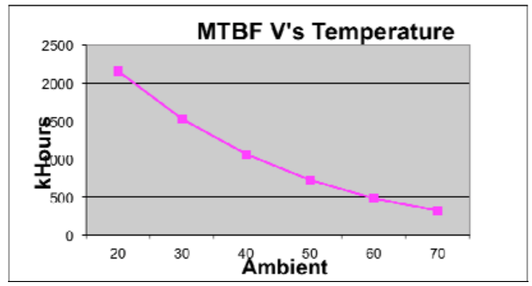
For each conversation stage we will have some inefficiencies, which results in the output power always being less than that of the input power. These inefficiencies will be converted to another form of energy , and in a power supply the only medium available is to convert this to heat. However it is this heat that is the number one item for reducing the reliability of the finished design. So in order to combat this power supply designers must implement a solution to keep the effect of this to a minimum.. We will look at a number of these methods, along with some key considerations associated with each of these choices.

Introduction:

Firstly we need to look at some of the significant power dissipators in any given power convertor. Each of these will produce heat which must be conducted to their surface. Some examples of these are

- Power switches.
- Filter capacitors with significant ripple current
- Transformer cores and windings
- Current sense resistors.

Good thermal practice is not just for the benefit of the operating range of the design , it also has a direct impact on the reliability and MTBF of the final design. If we review the effect that heat has on the calculated MTBF of a power supply , you can clearly observe the impact of this.



As you can see from Fig 1 above for every 10 degree rise in ambient temperature we see a 50% reduction in the calculated MTBF. This is clear if we work our way though the maths behind this.

Cooling Methods:

The idea of thermal management is to remove the heat from these devices, and direct it away from your supply. This can be achieved in a number of different mediums.

The most commonly used mechanisms for heat transfer in electronics design are conduction and convection.

Conduction is defined as the transfer of heat through contact with another stationary material. In the same way that water and current move , heat will flow through the material if there is a temperature differential across it. The heat flow will be from the higher temperature to the lower temperature, and the rate of heat flow will depend upon the temperature differential and the thermal conductivity of the material.

Convection is defined as the transfer of heat from the surface of an object to a moving fluid. This can either be a gas or liquid. If the fluid flow is created by gravitational forces on the fluid as its density varies, it is referred to as natural or free convection. If the fluid flow is created by external means such as fans or blowers, it is referred to as forced convection. The most commonly used fluid is air.

Potting material:

A common method of conduction cooling is to use a potting material. This involves encapsulating the power supply (or parts of) in a material which will draw heat away fom heat generating components and distribute it in a more evenly fashion across a broader system. Further methods can then be used to get this heat away from the entire system, such as heat sinking.

The main types of potting compounds available are:

- Epoxy resin
- Polyurethane resin
- Silicone resin
- Polyester system

Each of these approaches has their own merits , and there is no one type of resin which fits all purposes. For example , while Silocone based resins have excellent for use at very high continuous operating temperatures, above 180°C, they are typically more expensive. On the other hand, while polyurethane based resins are becoming more dominant due to their cost and curing capabilities , they can be prone to attack by water, particularly at high temperatures.

One further item that you also need to consider when using any type of potting material, is that the potting compound will act as a capacitor and change the behaviour of the electronic circuit, especially at high frequencies. It has been found in practice that the use of certain potting compounds affects EMC by shifting the frequency distribution and amplifying certain frequencies.

Heat Sinks:

The key to fully utilising a heat sink is to understand correctly what you need it to achieve and what occurs when you attached a component to a heat sink.

Heat will flow from an area of high termal resistance to an are of low thermal resistance. The rate in which this heat can be transferred is also controlled by the thermal difference between the two points and the thermal resistance of the connection between the two points. This is why we typically see a thermal pad sandwiched between the component and the heat sink. Air has a very high thermal impedance, so the pad will ease the transfer of heat from the component case temperature to the heatsink.

Using a fan:

While conduction methods can be suitable in a lot of designs, sometimes they are just not enough. Convection cooling offers the designer a much more effective method to get heat away from components. Of course this is not without its comprimises. Since fans are mechanical parts, the mindset if often that these are much more likely to fail before the likes of an electrolytic capacitor or a power FET (assuming these are properly derated in the design). However, in recent years the choice of good quality fans has increased significantly, and if you choose your vendor carefully you can achieve high lifetime of fans in your system.

The choice of a fan will of course depend on the system rqeuirements.The cooling effect of fans is purely based on the ability to push a specific volume of air across the components to be cooled. Other items such as pressure, density, noise, cost, operating etc, must also be considered when choosing your fan, but the primary function of the fan will be to move a volume of air.

Generally, efficiency increases and fan size decreases as specific speed increases. This figure can be used to determine the most efficient size and type of fan for a particular application.

For lowest noise output, fans should always be operated near their peak efficiency point. A common mistake is to use a fan that is too small , aby running it too fast, you risk the wear out mechanism.

Variable airflow applications can also cause noise problems. While the perception might be that the since the power supply runs quieter at lower loads, the reality might be that it will run much louder under actual loading conditions in the application.

Summary & Conclusions:

Often designers will use a combination of some or all of the above heat transfer techniques. Of course the easiest way to tackle this is to reduce the amount of heat in the first place, which means increasing the efficiency. But irrespective of how much success you achieve in this, you can always improve on the reliability of your design, if you can reduce the heat in your power supply. The ongoing challenge remains to make designs smaller , while at the same time maintaining reliability. If we are to achieve this then thermal management needs to be a high focal point on any power supply design.

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