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Thermal Considerations for PT Series ISRs

Power Trends' PT Series of Integrated Switching Regulators (ISRs) provide several configuration options for removing internally generated heat. To maximize the heat transfer and space efficiency of the PT Series, they can be mounted in vertical, horizontal, or surface mount configurations.

Background/Heat Transfer Modes

The PT Series products utilize all three modes of heat transfer; conduction, convection, and radiation. Conduction dominates, conducting 60% of the heat to the leads and outer package surfaces. Of the remaining 40%, approximately 30% is transferred by convection, and the rest by radiation.

Conduction heat transfer occurs when the energy from the heating surface starts a vibratory motion of the atoms and molecules in material. When the heat reaches the package boundaries, air begins to cool the unit. The constant that governs the conduction process is called thermal conductivity. If the thermal conductivity is known, the thermal resistance can be determined by taking into account the geometry of the package and the ambient temperature. Package designs with low thermal conductivity and/or large spatial dimensions tend to have high thermal resistances. Once optimization of these two issues have been accomplished, provisions must be made to efficiently remove the heat from the package surface. During the design of the PT Series products, extensive thermal computer simulations at various operating conditions and extensive temperature chamber testing were done to ensure reliable operation.

There are two types of convection heat transfer, natural and forced. Natural convection occurs when the air density changes due to the heating of the air. In natural convection, the amount of heat driven off from a body is strictly a function of the surface temperature, surface area exposed to the ambient air, and the ambient temperature. In many cases, natural convection sets up an airflow of 0 to 40 LFM. An airflow of 40 to 60 LFM is defined as “free air convection”. When natural or free air convection is not enough to properly cool the part, forced air convection must be used.

Forced air convection uses moving air to remove heat from the package. According to industry convention, forced air convection is generally greater than 60 LFM. This mode of heat transfer is a function of the air velocity only. These velocities usually require the use of a fan. Usually, forced air convection is needed only when the ambient temperature is greater than 60 or 70°C for PT Series products.

Radiation, the least active of the three modes, is an electromagnetic heat transfer mechanism. It requires no medium to transfer the heat, such as air or a solid. In the PT Series design, radiation aids in heat transfer working in concert with natural convection. If free air convection or forced convection is used, radiation adds very little to the heat transfer process.

Table 5

DEFINITION OF TERMS

Term	Sym	Units
Thermal resistance, junction to tab	θ_{JT}	°C/W
Thermal resistance, junction to ambient	θ_{JA}	°C/W
Thermal resistance, junction to sink	θ_{JS}	°C/W
Thermal resistance, tab to sink	θ_{TS}	°C/W
Thermal resistance, sink to ambient	θ_{SA}	°C/W
Power dissipated	P_D	Watts
Power input	P_{IN}	Watts
Power output	P_{OUT}	Watts
Efficiency	η	%
Ambient temperature	T_A	°C
Junction temperature, control IC	T_J	°C
Heatsink temperature	T_H	°C

Thermal Resistance

Thermal resistance restricts the amount of heat that can transfer through a body. It is analogous to electrical resistance. The result of this resistance is a temperature difference, also analogous to the voltage difference in an electrical circuit. The following general equation applies when conduction heat transfer occurs:

(1) . . . . . $\theta = t/kA$

where: . t is the thickness of the body
. . . . k is the thermal conductivity
. . . . A is the area perpendicular to the heat flow
. . . . θ is the thermal resistance

Thermal resistances, from junction to ambient, for the various PT Series products are shown on their respective data sheets. In general, θ_{JA} is a function of the airflow, ambient temperature, and geometry of the product. These values are conservative and there will be slight differences when airflow and ambient temperatures vary.

Thermal Model

Before thermal resistances can be used to find the operating temperatures of the PT Series products, the efficiency

Thermal Considerations for PT Series ISRs (continued)

and power dissipation must be found. The power dissipation of the ISR and its efficiency can be found on the graphs of the data sheets or can be experimentally measured. Equation 2 can be used to calculate power dissipation.

(2) .... $P_{Dissipated} = P_{In} - P_{Out}$

.... or ..... $P_{Dissipated} = (1/\eta - 1) \times P_{Out}$

There are two thermal resistances that are of particular importance in determining the operating temperature of the PT Series products, θ_{JA} and θ_{JS}. The junction to ambient thermal resistance, θ_{JA}, is shown on each data sheet or can be calculated using equation 3.

(3) .... $\theta_{JA} = (T_J - T_A)/P_D$

The junction temperature of the control IC can now be determined using equation 4.

(4) .... $T_J = T_A + (\theta_{JA} \times P_D)$

In applications where the PT Series is mounted to a heatsink, θ_{JS}, the junction to sink resistance, is the constant of importance. For a given mounting surface (heatsink) temperature, the junction temperature of the control IC can be calculated using equation 5.

(5) .... $T_J = T_H + (\theta_{JS} \times P_D)$

In these cases, the thermal resistance junction to sink θ_{JS} would calculated using equation 6.

(6) .... $\theta_{JS} = \theta_{TS} + \theta_{JT}$

The thermal resistance of the interface between the heat tab and the heat sink θ_{TS}, is typically 2°C/W for the interface resistance.

Thermal Shutdown

The PT Series products have been designed with internal thermal protection circuitry. When the junction temperature of the control IC reaches 135°C, the product will automatically shut down. When the IC shuts down, the output voltage of the product drops to zero. The product will automatically restart when the IC has cooled to 120°C. In environments where the ambient temperature is too high for the input voltage/output current operating point, the ISR will cycle on and off continuously. The designer should use a 5 to 10°C cushion when setting the operating point or the maximum ambient temperature of the ISR.

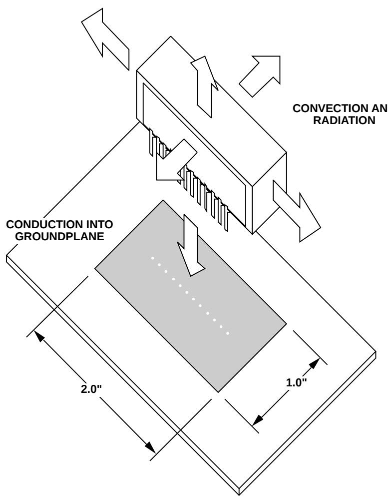
Thermal Derating Curves

The thermal derating curves published in this catalog are created from ISRs operating in a temperature controlled environment with 40 to 60 LFM of airflow. This level of airflow is necessary to keep the air surrounding the ISR to a regulated temperature and is defined as "free air convection" according to Bellcore specifications. During testing, the ISRs are soldered into a printed circuit board with one-sided 2 ounce copper facing downward as shown in Figure 11. The points on the curves represent the maximum input voltage and output current under which the ISR will operate continuously without going into thermal shutdown ($T_J \leq 135°C$).

Layout

Since most of the heat is conducted through the leads, the design of the printed circuit board can aid heat transfer to meet operational requirements. An uninterrupted 2 oz copper pattern of at least 2 square inches is recommended. Thermal relief pads should not be used because heat conduction into the ground plane will be severely limited. Using the recommended layout (see Figure 11), the thermal resistance of the product will double if one ounce copper is used.

Figure 11



Orientation

The PT Series products can be mounted in both vertical or horizontal orientations. Given the same operating conditions, the heat transfer characteristics will differ, maybe significantly, depending on the product used. When the product is horizontal, the heat transfer efficiency through the PC board is reduced. If forced airflow is used, the products should be mounted along the direction of flow. This will maximize heat transfer (see Figure 11).

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