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Heat Sinks for Data Converters

Design engineers constantly look for ways to reduce the effects of high operating temperatures in hybrid data converters Heat sinks provide a proven solution

By **Joe Coupal**, DATEL, Inc.

Electrical performance of high precision electronic components, such as hybrid type Data Converters, is very temperature sensitive. These devices generally operate much more effectively at room temperature (+25°C) than at higher temperatures. For the most part, the lower the temperature, the better the electrical performance, the reliability, and the mean time before failures (MTBF).

Users of hybrid products frequently ask questions regarding thermal dissipation. They usually want to know if it is normal for the hybrid to feel hot when touched. Power densities of some hybrid components are quite high and it is normal for a hybrid to feel hot. What users are actually referring to is a parameter known as the *case temperature.*

The case temperature is largely a function of the internal circuitry and circuit connections. The power dissipated in these circuits causes the temperature to rise; this temperature is generally specified as the *junction temperature.* Following is a brief overview of the differences between the case and junction temperatures.

With no power applied, the junction (chip) temperature, Tj, will be the same as the ambient or room temperature, Ta. The dissipation of power in the device raises the junction temperature. The heat produced flows outward to the case.

This temperature rise must be kept within acceptable limits or the data converter will suffer physical damage, resulting in decreased electrical performance or electrical failure.

The thermal problem is easily understood using a simple thermal analog of Ohm's law, in which current is replaced by power (Pj), voltage by temperature, and electrical resistance by thermal resistance, θ.

Ohm's Law		Thermal Version
$\frac{V}{I \times R}$	→	$\frac{T}{P \times \theta}$

Thermal resistance is a constant; the rise in temperature is proportional to the power dissipated at the junction. Table 1 shows the thermal resistance constants of interest and the equations to calculate Temperature rise.

Passive Heat Sinks Can Moderate Case-to-ambient Temperature Rises

Junction-to-case Thermal Resistance

The thermal resistance between a semiconductor device junction and the hybrid package (case) is a function of:

1. the semiconductor device size and material
2. the die and substrate mounting material and its thickness
3. the substrate material and size
4. the hybrid package material and size

Therefore, the *junction-to-case* thermal resistance is controlled by the hybrid manufacturer and cannot be modified externally by the user. Users looking to lower the temperature of the converter need to reduce the *case-to-ambient* thermal resistance. Use of heat sinks, air flow, thermionic cooling, and combinations thereof are effective design considerations.

Heat Sink Physical Description

DATEL has developed aluminum heat sinks for 24-pin DDIP and 32- and 40-pin TDIP packages. The DDIP has 0.600" spacing between the rows of pins and the TDIP has 0.900" spacing. The heat sink itself consists of a base and a cover, as Figure 1 shows.

Table 1. Calculating Temperature Rise

Formula	Measurement
$\theta j\text{–}c$	Thermal resistance between junction and case, °C/W
$\theta c\text{–}a$	Thermal resistance between case and ambient, °C/W
$\theta j\text{–}a$	Thermal resistance between junction and ambient, °C/W
$Tj\text{–}c = \theta j\text{–}c \times Pj$	Rise in junction temperature above case temperature
$Tc\text{–}a = \theta c\text{–}a \times Pj$	Rise in case temperature above ambient temperature
$Tj = Pj \times (\theta c\text{–}a + \theta j\text{–}c) + Ta$	Junction temperature
$Tc = Pj \times \theta c\text{–}a + Ta$	Case temperature
Note: Pj = power dissipation at the junction	

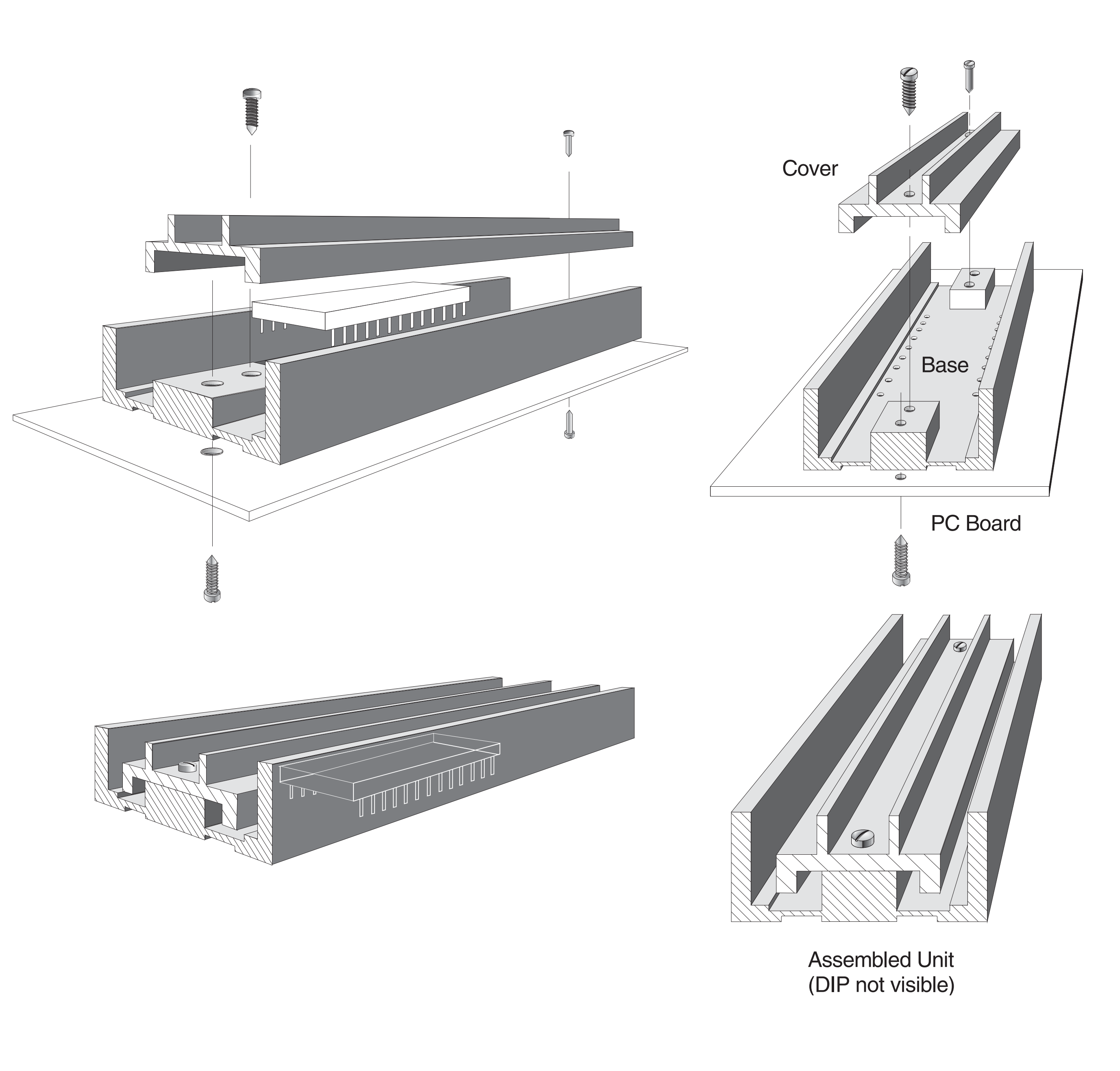


Figure 1. Datel's heat sinks for converters.

The DIP leads slip through holes in the base while the cover fits over the top surface of the component. To ensure the maximum heat flow from the component to the heat sink, a compressible, thermally-conductive silicone preform is applied to the top and bottom of the component. The two pieces are then fastened together.

This process allows the data converter's entire top and bottom surfaces to be in thermal contact with the heat sink. The base of the heat sink fastens to the printed circuit board and does not interfere with mounting dual in-line packages. For optimal heat transfer, a large copper plane should be located beneath the heat sink.

The recommended lead length for hybrid components using these heat sinks is 0.200" or greater. All the critical dimensions of the DATEL heat sinks appear at the end of this application note. The model numbers are as follows:

24-pin DDIP heat sink	Model #: HS-24
32-pin TDIP heat sink	Model #: HS-32
40-pin TDIP heat sink	Model #: HS-40

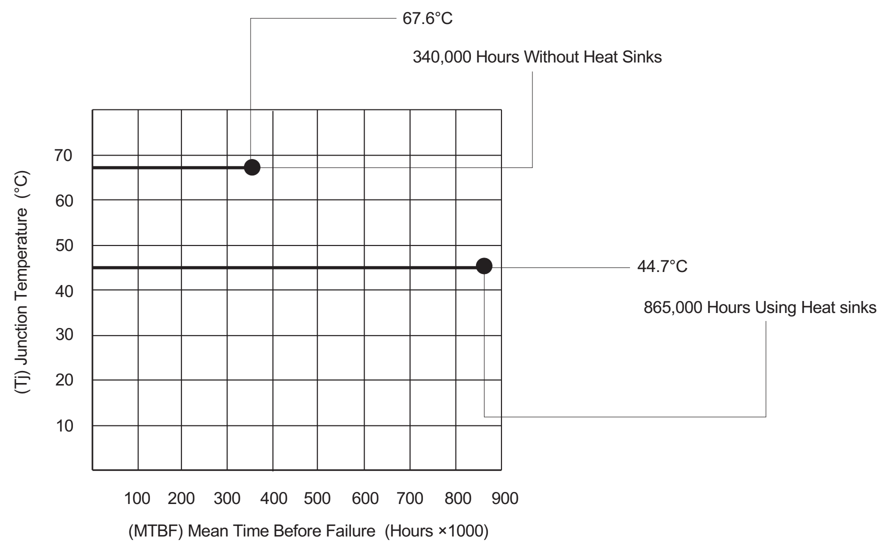


Figure 2. MTBF Increase Using Heat Sinks

Benefits of using Heat Sinks

Increased MTBF

Using a 24-pin heat sink on a DATEL ADS-117 sampling A/D converter reduces the case temperature by 37% and increases the MTBF by 250%. Refer to Figure 2. on this page.

Thermal Resistance Reduced

Heat sinks developed by DATEL are effective in reducing case-to-ambient thermal resistance, as the following analysis demonstrates. But first, an example to determine the expected temperature rise of a converter above room temperature (Ta = +25°C) during operation.

Device tested: ADS-117 Sampling A/D
Resolution: 12-bits
Conversion rate: 2.0 MHz
Power dissipation: 1.64 Watts (measured)
Thermal resistance (junction temperatures determined using infrared measurement techniques):

θj–c	3°C/Watt
θc–a	23°C/Watt
θj–a	26°C/Watt

Using the equations in Table 1, the junction and case temperatures are found to be:
Tc-a = 37.7 °C Tc = 62.7 °C Tj-c = 4.9 °C Tj = 67.6 °C

	Case Temp. (Tc)	Junction Temp. (Tj)
Without heat sinks	62.7°C	67.6°C
With heat sinks	39.8°C	44.7°C

Typical case-to-ambient thermal resistance measurements for hybrids with and without the heat sinks appear below. These measurements were made in free air using no additional air flow, which would have further reduced the case-to-ambient thermal resistances.

Using DATEL's ADS-117 as an example, let's compare the case and junction temperatures both with and without heat sinks.

Using heat sinks reduces the thermal resistances by greater than 50 percent. For the ADS-117 example, this translates into a reduction of the case and junction temperatures by 37 percent and 34 percent, respectively.

Summary

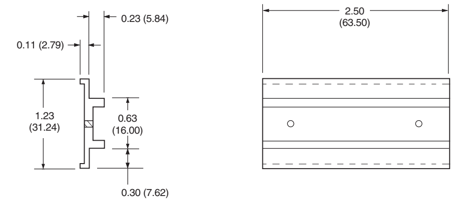
Using DATEL's heat sinks drastically reduces the case-to-ambient thermal resistance. This in turn lowers the junction, or chip, temperature further ensuring the optimum electrical performance of the device. Based on the data presented, θc-a should be less than 10 ºC/W for any of the three package types when using heat sinks.

Another advantage directly related to the reduction of junction temperatures is the increase in MTBF (by approximately 250%). This leads to higher customer satisfaction and reduced long term costs.

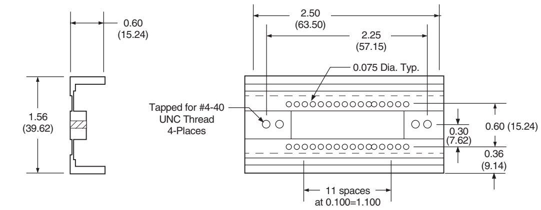
θc-a	24-PIN DDIP PACKAGE	32-PIN TDIP PACKAGE	40-PIN TDIP PACKAGE
Without heat sink	23°C/Watt	18°C/Watt	17°C/Watt
With heat sink	9°/Watt	7°C/Watt	6°C/Watt

Mechanical Dimensions Inches (mm)

Heat Sink for 24-Pin TDIP Packages

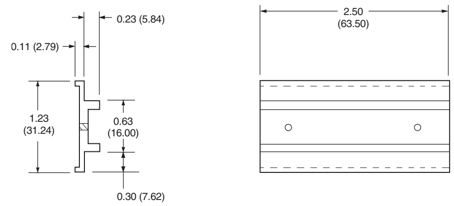


Cover, edge view Cover, top view

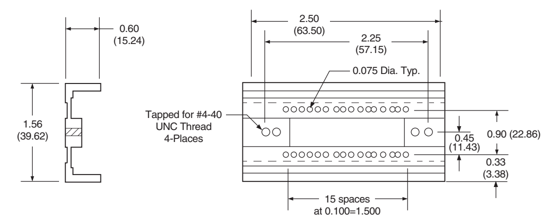


Base, edge view Base, top view

Heat Sink for 32-Pin TDIP Packages

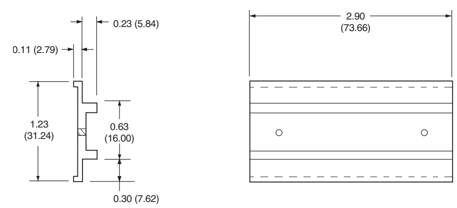


Cover, edge view Cover, top view

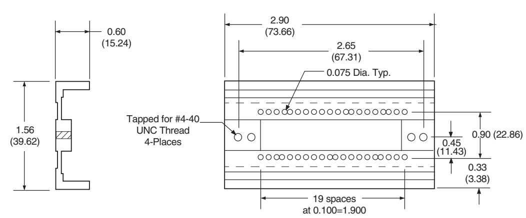


Base, edge view Base, top view

Heat Sink for 40-Pin TDIP Packages



Cover, edge view Cover, top view



Base, edge view Base, top view

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DATEL, Inc. 11 Cabot Boulevard, Mansfield, MA 02048-1151
Tel: (508) 339-3000 (800) 233-2765 Fax: (508) 339-6356
Internet: www.datel.com Email: sales@datel.com
Data Sheet Fax Back: (508) 261-2857

DATEL (UK) LTD. Tadley, England Tel: (01256)-880444
DATEL S.A.R.L. Montigny Le Bretonneux, France Tel: 01-34-60-01-01
DATEL GmbH München, Germany Tel: 89-544334-0
DATEL KK Tokyo, Japan Tel: 3-3779-1031, Osaka Tel: 6-354-2025