Application Hint 17

Designing P.C. Board Heat Sinks

By Bob Wolbert

General Description

System designers increasingly face the restriction of using all surface-mounted components in their new designs; even including the power components. Through-hole components can dissipate excess heat with clip-on or bolt-on heat sinks keeping things cool. Surface mounted components do not have this flexibility and rely on the conductive traces or pads on the printed circuit board for heat transfer. This hint addresses the question "How much PC board pad area does my design require?"

We will determine if a Micrel surface mount low dropout linear regulator may operate using only a PC board pad as its heat sink. We start with the circuit requirements.

System Requirements:

V_{OUT} = 5.0V
$V_{IN\ (MAX)}$ = 9.0V
$V_{IN\ (MIN)}$ = 5.6V
I_{OUT} = 700mA
Duty cycle = 100%
T_A = 50°C

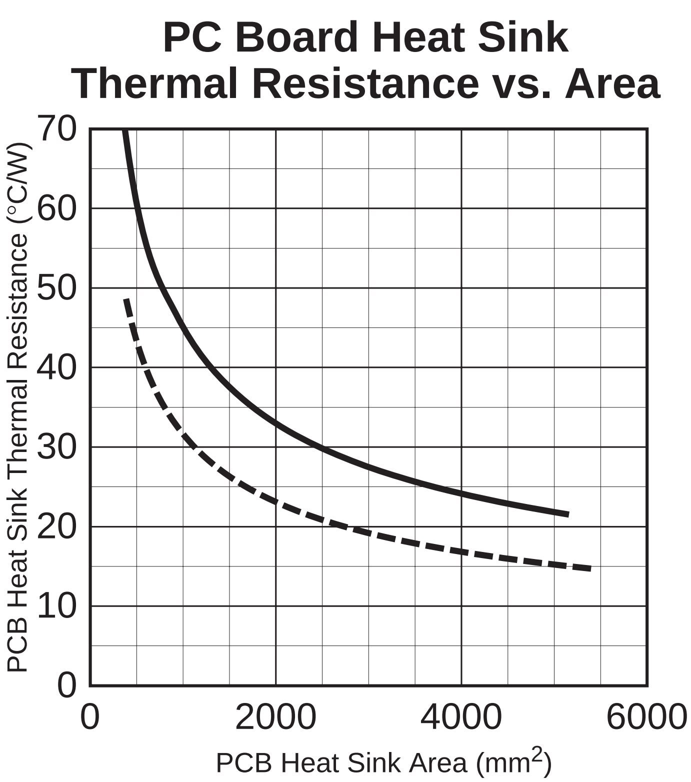

Figure 1. Graph to determine PC board area for a given thermal resistance. See text for discussion of the two curves.

This leads us to choose the 750mA MIC2937A-5.0BU voltage regulator, which has these characteristics:

$V_{OUT} = 5V \pm 2\%$ (worst case over temperature)
$T_{J\ MAX}$ = 125°C
θ_{JC} of the TO-263 = 3°C/W
$\theta_{CS} \approx$ 0°C/W (soldered directly to board)

Preliminary Calculations

$V_{OUT\ (MIN)} = 5V - 2\% = 4.9V$

$P_D = (V_{IN\ (MAX)} - V_{OUT\ (MIN)}) \times I_{OUT} + (V_{IN\ (MAX)} \times I_{GND})$
$= [9V - 4.9V] \times 700mA + (9V \times 15mA) = 3W$

Maximum temperature rise, $\Delta T = T_{J(MAX)} - T_A$
$= 125°C - 50°C = 75°C$

Thermal resistance requirement, θ_{JA} (worst case):

$$\frac{\Delta T}{P_D} = \frac{75°C}{3.0W} = 25°C/W$$

Heat sink thermal resistance, $\theta_{SA} = \theta_{JA} - (\theta_{JC} + \theta_{CS})$

$\theta_{SA} = 25 - (3 + 0) =$ **22°C/W (max)**

Heat sink physical size determination

Figure 1 shows the total area of a round or square pad, centered on the device. The solid trace represents the area of a square, single sided, horizontal, solder masked, copper PC board trace heat sink, measured in square millimeters. No airflow is assumed. The dashed line shows a heat sink covered in black oil-based paint and with 1.3m/sec (250 feet per minute) airflow. This approaches a "best case" pad heat sink.

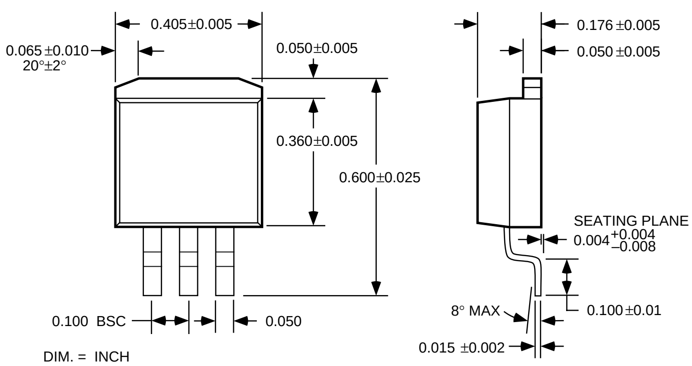

Figure 2. The TO-263 "U" Package. Derived from the popular TO-220 power package, the TO-263 has excellent thermal properties for a surface mount package.

Conservative design dictates using the solid trace data, which indicates a pad size of 5000 mm^2 is needed. This is a pad 71mm by 71mm (2.8 inches per side).

Example 2, SO-8 and SOT-223 package.

Given the following requirements, determine the safe heat sink pad area.

$V_{OUT} = 5.0V$

$V_{IN\ (MAX)} = 14V$

$V_{IN\ (MIN)} = 5.6V$

$I_{OUT} = 150mA$

Duty cycle = 100%

$T_A = 50°C$

Your board production facility prefers handling the dual-in-line SO-8 packages whenever possible. Is the SO-8 up to this task? Choosing the MIC2951-03BM, we get these characteristics:

$T_{J\ MAX} = 125°C$

θ_{JC} of the SO-8 ≈ 100°C/W

SO-8 Calculations:

$P_D = [14V – 5V] \times 150mA + (14V \times 8mA) = \mathbf{1.46W}$

Temperature rise = 125°C – 50°C = **75°C**

Thermal resistance requirement, θ_{JA} (worst case):

$$\frac{\Delta T}{P_D} = \frac{75°C}{1.46W} = \mathbf{51.3°C/W}$$

Heat sink θ_{SA} = 51 – 100 = **<u>–49 °C/W</u> (max)**

Which obviously presents a problem: without refrigeration, the SO-8 is not suitable for this application. Consider the MIC5201-5.0BS in a SOT-223 package. This package is smaller than the SO-8, but its three terminals are designed for much better thermal flow. Choosing the MIC5201-3.3BS, we get these characteristics:

$T_{J\ MAX} = 125°C$

θ_{JC} of the SOT-223 = 15°C/W

θ_{CS} = 0 °C/W (soldered directly to board)

SOT-223 Calculations:

$P_D = [14V – 4.9V] \times 150mA + (14V \times 1.5mA) = \mathbf{1.4W}$

Temperature rise = 125°C – 50°C = **75°C**

Thermal resistance requirement, θ_{JA} (worst case):

$$\frac{\Delta T}{P_D} = \frac{75°C}{1.4W} = \mathbf{54°C/W}$$

Heat sink θ_{SA} = 54 – 15 = **39°C/W (max)**

Board Area

Referring to Figure 1, a pad of 1400mm^2 (a square pad 1.5 inches per side) provides the required thermal characteristics.

Conclusion:

These formulae are provided as a general guide to thermal characteristics for surface mounted power components. Many estimations and generalizations were made; your system will vary. Please use this information as a rough approximation of board area required and fully evaluate the thermal properties of each board you design to confirm the validity of the equations.

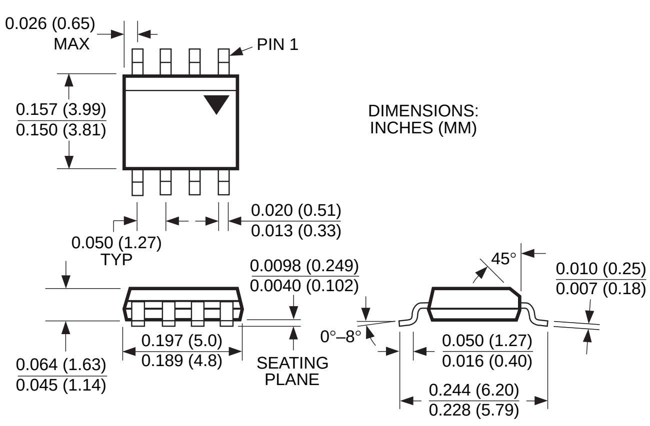

Figure 2. SO-8 Package. The SO-8 is small and very popular, but is far from ideal thermally.

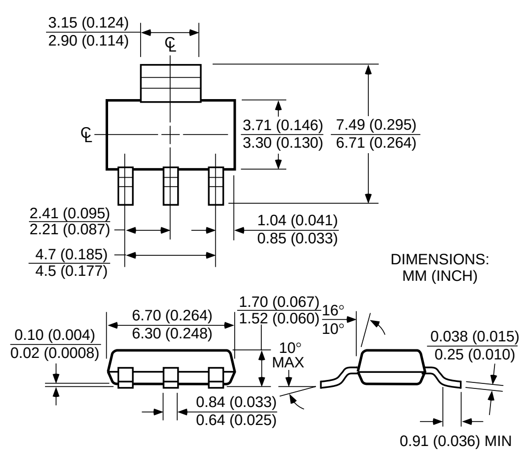

Figure 3. SOT-223 Package. Smaller than the popular SO-8, the SOT-223 has significantly better thermal characteristics.