SGS-THOMSON MICROELECTRONICS

APPLICATION NOTE

TO 220AB - TOP 3 - TOPLESS THERMAL RESISTANCE AND MECHANICAL ASSEMBLY

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The behaviour of a semiconductor device is directly related to the temperature of its silicon chip.

To preserve the performances of the component and to ensure optimal reliability, is to limit temperature by mastering the heat transfer between the chip and the ambient atmosphere.

The purpose of this note is to underline the importance of the mechanical assembly of the component on its heat sink by comparing different possibilities.

A - IMPORTANCE OF THE MECHANICAL ASSEMBLY

1 - THERMAL RESISTANCE

Review : The thermal resistance (R_{th}) of a semiconductor assembly is the parameter which characterizes its aptitude to channel the heat flow generated by the junction during operation.

It is expressed by : $R_{th} = \frac{\Delta T\ (°C/W)}{P}$

Where P is the power dissipated by the component.

When a semiconductor component is assembled on a heat sink, the total thermal resistance should be taken into account. It is given by the following equation

Thermal resistance between junction and case

$$R_{th(j-c)} = \frac{T_j - T_c}{P}$$

T_j : Junction temperature

T_c : Case temperature

This value is specified in the data sheets and it varies according to the type of component.

Thermal resistance between case and heat sink or contact thermal resistance.

$$R_{th(c-h)} = \frac{T_c - T_h}{P}$$

T_h : Heat sink temperature

Thermal resistance between heat sink and ambient air.

It is related mainly to the quality of the contact.

$$R_{th(ha)} = \frac{T_h - T_a}{P}$$

T_a : Ambient temperature

The thermal balance is expressed by the equation :

$T_j - T_a = P \times R_{th(j-a)}$

where the thermal resistance between junction and ambient air is :

$R_{th\,(j-a)} = R_{th\,(j-c)} + R_{th\,(c-h)} + R_{th\,(h-a)}$

This equation of thermal balance helps to calculate the junction temperature of the component.

A junction temperature which approaches the maximum temperature of the component could lead to a decrease in the electrical characteristics and a reduction of the safety margin. A temperature exceeding the maximum junction temperature risks damaging the semiconductor device. The junction temperature should be known at all times.

2 - TYPES OF ASSEMBLY

The conventional assemblies can be divided into two types :

- assembly on heat sink,
- assembly in the air (without heat sink).

The choice of the assembly results in a compromise between the following criteria :

- convenience of use : the component should be connectable and accessible for testing or replacement,
- cost,
- possibility of heat dissipation,
- mechanical resistance,
- aging and fiability.

TYPES OF ASSEMBLY AS A FUNCTION OF THE POWER (P) AND THE TYPE OF CASE USED BY THE COMPONENT.

Power Range	Types of Cases			Types of Assembly
$P \geq 50$ W	TOP 3			Heat Sink with Cooling Fins
2 W < P < 50 W	TO 220	TOP 3		Plain Heat Sink
$P \leq 2$ W	TO 220	TOP 3	TOPLESS	Assembly in the Air (printed circuit board)

B - ASSEMBLY OF TOP 3 AND TO 220 ON HEAT SINKS

Among the various parameters of assembly on heat sinks, three are particularly important :

- the shape and condition of the heat sink surface,
- the pressure of the component on the heat sink,
- the contact grease (different types exist).

The layer spread on the flat heat sink surface should be thin and uniform.

The $R_{th\,(c-h)}$ of contact without grease $\approx 1.5 R_{th\,(c-h)}$ of contact with grease.

1 - ATTACHMENT BY SCREW (figure *1*)

Example : TO 220

$R_{th\,(c-h)} = 2°C/W$ for F = 25N

$R_{th\,(c-h)} = 1.5 \times 2 = 3°C/W$ for F = 5N

with F = force

Advantages

- good mechanical resistance
- easy and quick disassembly
- easy to perform for short series.

Figure 1 : Attachment of the TO 220 or TOP 3 (insulated) by M3 Screw.

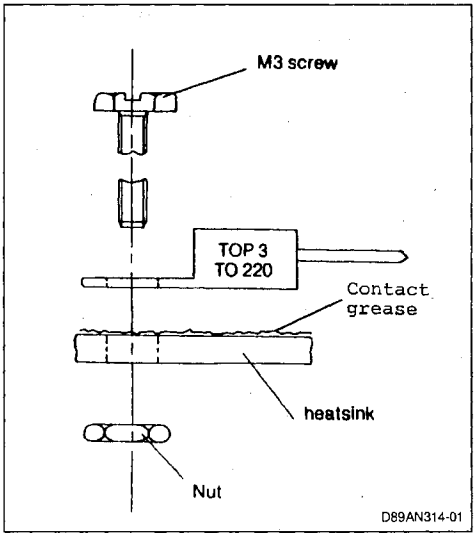
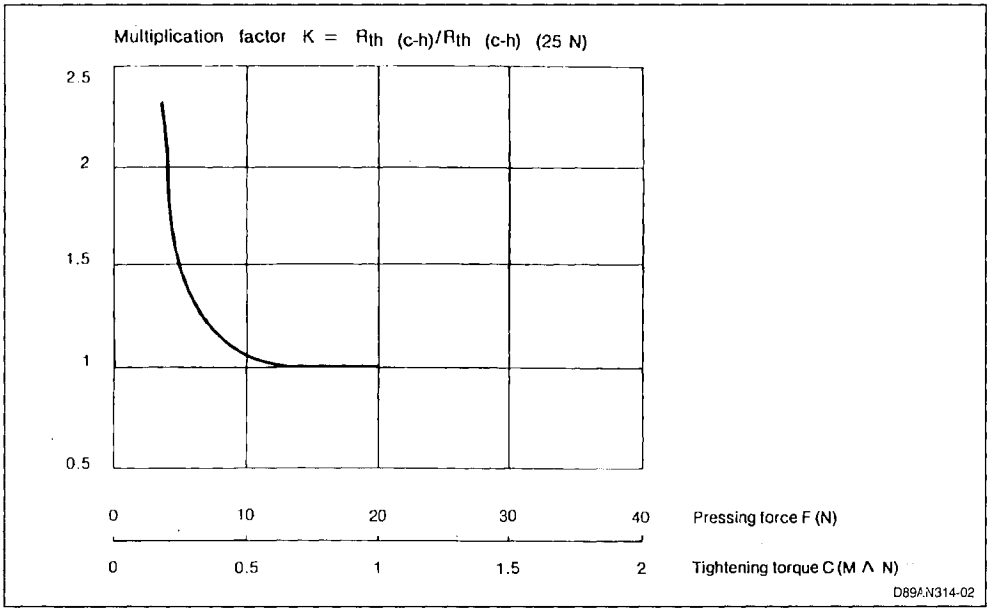


Figure 2 : Relative Variation of the Thermal Resistance of the Contact as a Function of the Pressure and the Tightening Torque for an M3 Screw like Figure 1.



The contact thermal resistance of assembly by screw changes with the pressure of the case on the heat sink. This force depends on the tightening torque (*figure 2*).

Disadvantages :

- deburring of the heat sink hole
- mastering of the screw tightening torque
- assembly not suitable for long series.

2 - ATTACHMENT BY RIVET (*figure 3*)

Advantages :

- good mechanical resistance
- quick assembly suitable for long series

Disadvantages :

- difficult to disassemble
- risk of deforming the plastic case during assembly
- deburring of the attachment hole
- difficult to master the force applied by the riet.

3 - ATTACHMENT BY CLIP

Two types of assembly by clip exist : (*figures 4a and 4b*)

Figure 3 : Attachment of the TO 220 or TOP 3 (insulated) by Rivet.

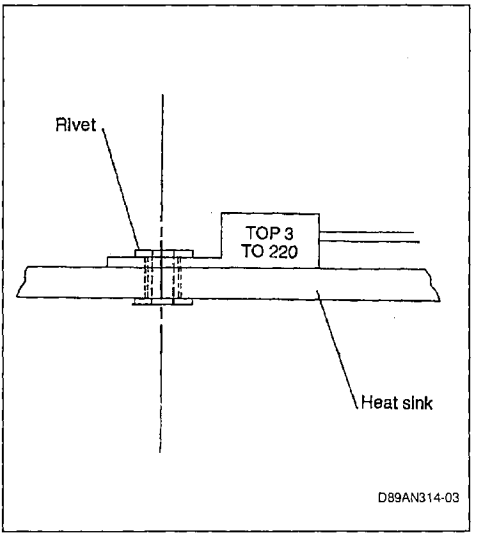
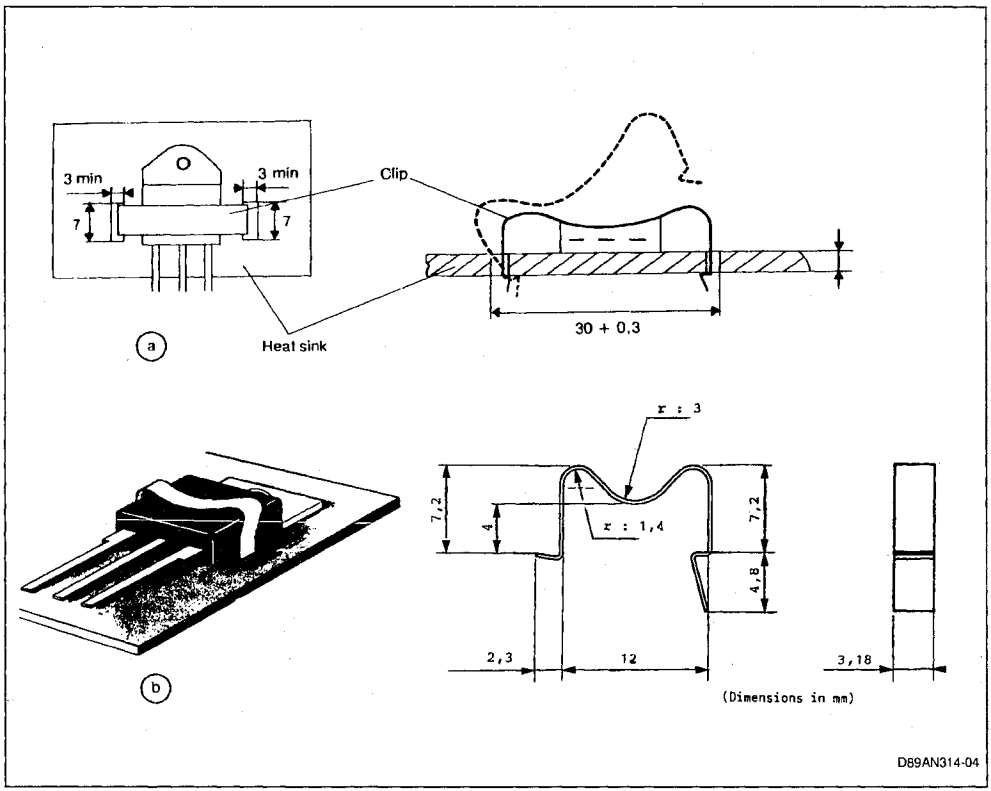


Figure 4 : Example of Attachment by Clip a. for TOP 3 (ref. mP 18055) b. for TO 220.



Advantages :

- rapidity of assembly and disassembly (automatization),
- low cost,
- facility in controlling the pressure exercised by the component on the heat sink,
- stability in time.

Example :

Clip MP 18055

F = 20N

Disadvantages :

- difficulty in positioning the case with respect to the heat sink.

N.B. : The fact of using a non-insulated component for an application in which the case should not be at the same potential as the heat sink makes the use of an insulator necessary (mica).

This insulator whose thickness is about 0.1 mm introduces an additional thermal (contact) resistance of :

- $R_{th\ (c-h)} \equiv 0.8$ °C/W for the TO 220 case
- $R_{th\ (c-h)} \equiv 0.5$ °C/W for the TOP 3

} Mica insulator

C - ASSEMBLY IN THE AIR (WITHOUT HEAT SINK) OF THE TO 220 - TOP 3 - TOPLESS

The components in direct contact with the air (on a printed circuit board) can only dissipate low power. For example :
TO 220 :

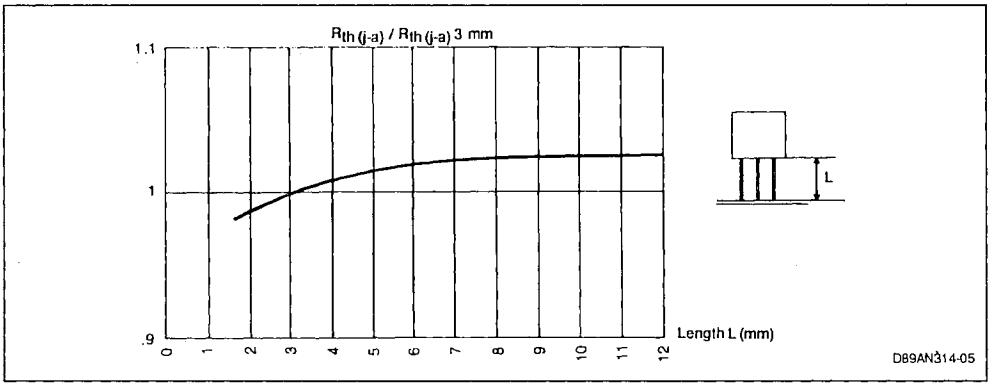
$$\text{Maximum dissipated power} = \frac{T_j - T_a}{R_{th\,(j-a)}} = \frac{110 - 50}{60} = 1W$$

The evacuation of the heat produced during operation takes place at several levels :

- the case,
- the connections,
- the soldering points of connections on the PC board.

The influence of the length of connections, on one hand, and the area of copper at the soldering point, on the other hand, is given on figure 5 and figure 6.

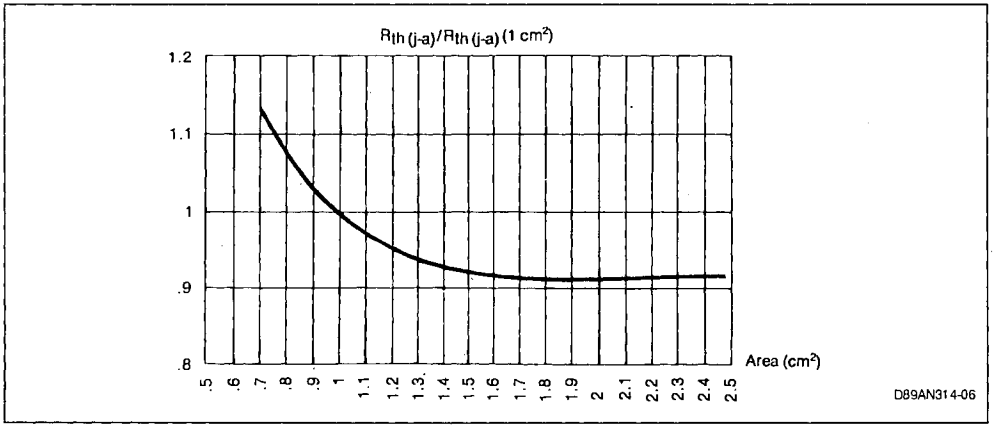
Figure 5 : Relative Variation of the Thermal Resistance (junction-air) as a Function of the Length L of Connections.



THERMAL RESISTANCE VALUES (junction-air)

	TOPLESS	TO 220	TOP 3
Rth (j-a) (°C/W)	75	60	50

Figure 6 : Relative Variation of the Thermal Resistance (junction-air) as a Function of the Area of Copper at the Soldering Point.

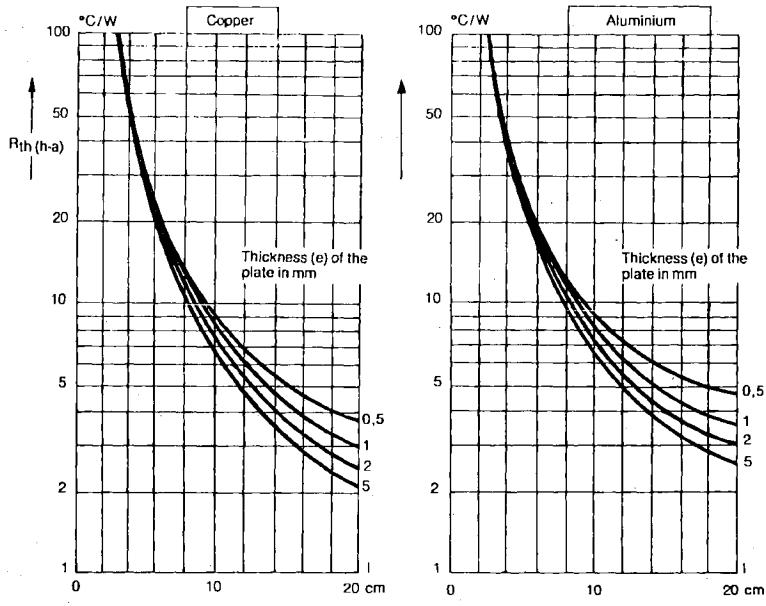


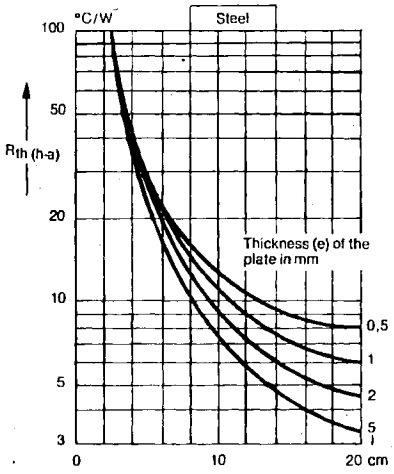
CONCLUSION

When designing assembly of a plastic-case semiconductor device on a heat sink, several precautions need to be taken, particularly never to exceed the maximum junction temperature (Tj max.).

The best assembly system is the one which satisfies the thermal requirements in the simplest manner. The clip assembler, in most cases, meets these requirements. This assembly, because of the ease with which it can be performed, the uniform pressure exercised on the case and the low cost, enables obtaining optimal contact thermal resistance and mechanically reliable assembly.

CHART FOR EVALUATION OF A FIAT HEAT SINK

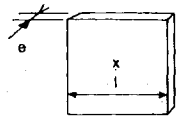




Conditions :

- Bare convector
- Vertical
- Semiconductor device at the centre
- No ventilation
- x 0.7 if painted black
- square

l = length of one side of the square with an area S



Example : Copper heat sink, thickness e = 1 mm
$R_{th\ (h-a)}$ = 9°C/W l = 10 cm

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