Guidelines for the Assembly of SMD10 Devices

Introduction

This application note gives details of thermal characteristics and mounting considerations for the SMD10 surface mount package from International Rectifier. With a proven track record for mounting on IMS board in International Rectifiers' own POW**IR**TRAIN™ modules, the SMD10 package is ideally suited for reliably surface mounting large chip power devices of many types. A few suppliers of such substrate materials are mentioned at the end of this Application Note.

Die types which may be mounted in SMD10 include:-

- Diodes - standard recovery, fast recovery, FRED and Schottky.
- MOSFETs
- IGBTs - standard, fast, ultrafast and short circuit rated either singly or in combination with a FRED.

Die sizes up to and including IR die size 7 - 0.35" square - can be accommodated.

Since the SMD10 package was designed exclusively for surface mount, it is compatible with many of the processes commonly used in surface mount assembly. Also, our experience with IMS board mounting provides a basis for helping to choose optimum process conditions.

The thermal performance of surface mount components is influenced by mounting conditions and board design as well as the basic package construction and the choice of board materials. We have performed measurements of thermal resistance in a variety of configurations supported by theoretical models to provide the information reported below.

Thermal Characteristics

Data sheets for SMDs typically give values for $R_{\Theta JC,}$ in effect junction to PCB, and $R_{\Theta JA}$ under defined conditions for PCB mounting. Standard conditions, especially for higher power SMDs, are usually taken as mounting on a 1" square of 0.05" thick PCB with 2 oz copper cladding. The SMD10 is too large to be measured in this way so the datasheet gives only $R_{\Theta JC.}$ The data below (Table 1) fills in more detail giving figures for some typical situations. At best these can only provide the designer with a rough guide to estimate junction temperatures in a given situation since factors such as airflow and board layout are not considered.

Board	Heatsink	Die type/size	Part Nos.	$R_{\Theta JA}$ - ^{O}C/W
FR4 - 1.6mm, 2oz Cu	None	IGBT/5	IRG4Z*50**	25
FR4 - 1.6mm, 2oz Cu	Aluminium block	IGBT/5	IRG4Z*50**	9.0
IMS - 3mm, 3oz Cu	None	IGBT/5	IRG4Z*50**	6.0
IMS - 3mm, 3oz Cu	Aluminium block	IGBT/5	IRG4Z*50**	1.0
DBC - 0.38mm, 0.3mm Cu	None	IGBT/5	IRG4Z*50**	24
DBC - 0.38mm, 0.3mm Cu	Aluminium block	IGBT/5	IRG4Z*50**	1.0
IMS - 3mm, 3oz Cu - 600 volt	Water cooled Al block	IGBT/7	IRG4Z*70**	0.80
IMS - 3mm, 3oz Cu - 1200 volt	Water cooled Al block	IGBT/7	IRG4Z*70**	0.85
None	Water cooled Al block	IGBT/7	IRG4Z*70**	0.50

Table 1

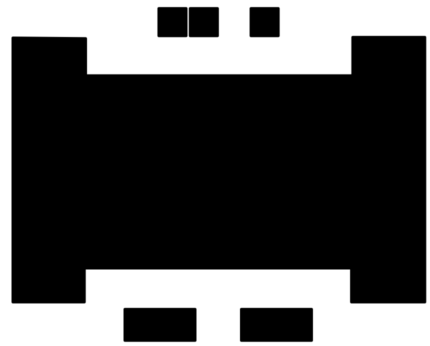
The performance of ordinary PCB structures can be improved by choice of board type or layout. Some examples and estimates of improvements in power dissipation capability are listed and illustrated below.

Extended copper area to provide heatsink on board - 1.25 x the power dissipation

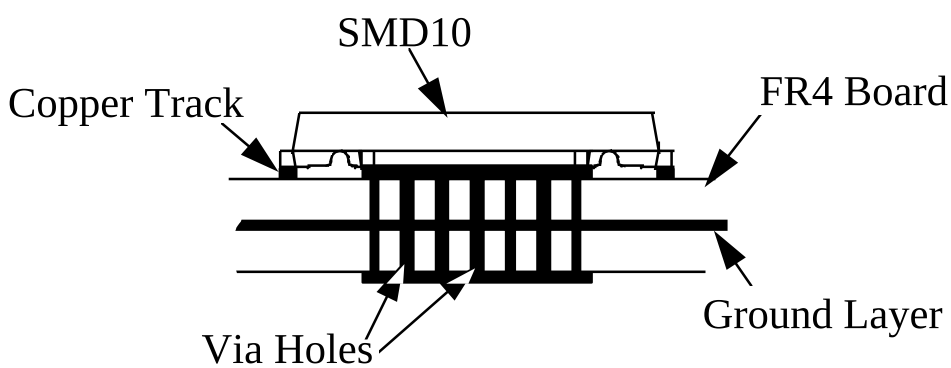
Board with ground layer and heatsink as above - 2 x

Via holes to ground layer and copper area on reverse side of board - 3 x

SMD10 Footprint



SMD10 Footprint with extended heat disspiation ‘wings’.



Commercially available surface mount heatsinks, like some designed for D3PAK Power devices, may improve power dissipation significantly, depending , of course, on their thermal resistance. Some even fit over the top of the SMD-10 as well as on the backside of the board shown in the above drawing.

Figure 1 below shows how thermal resistance values can be calculated for epoxy glass boards with different copper foil thickness.

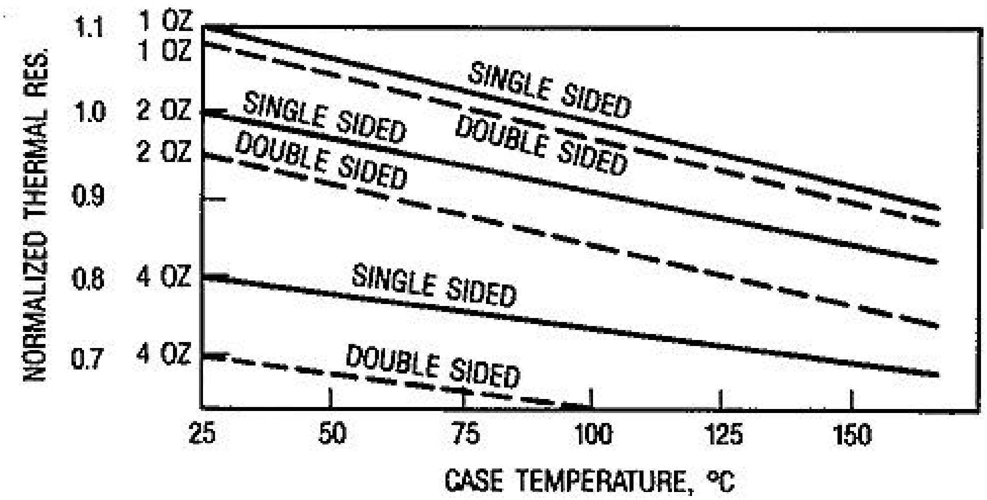


Figure 1. Normalised Thermal Resistance vs. Case Temperature

Measurement of RQJA

Total thermal resistance ($R_{\Theta JA}$) for any semiconductor device consists of the sum of all thermal resistance between the junction and the ambient environment. The formula for junction to ambient thermal resistance is:-

$$R_{\Theta JA} = (T_j - T_A)/P_d$$

To measure the junction temperature, a temperature sensitive parameter such as Vce(on) for an IGBT is used. This is first calibrated at maximum junction temperature. The device is self heated by applying a known power (P_d) until the temperature stabilises and the temperature rise (T_j - T_A) is recorded. From these figures $R_{\Theta JA}$ can be calculated.

In the case of SMDs the device has to be board mounted for this measurement. This introduces additional contributions to thermal resistance from the board and the interface between the SMD and the board. For smaller SMDs standard boards can be used for this test but the SMD10 package is too big and powerful for them. The list below shows the breakdown of the different contributions to thermal resistance for an IGBT in SMD10 mounted on IMS.

Thermal Resistance Junction-to-Case - 0.36 ^{o}C/W maximum

Thermal Resistance Junction-to-Base Plate of 3mm thick IMS

600 volt - 0.53 ^{o}C/W typical

1200volt - 0.58 ^{o}C/W typical

Thermal Resistance Base Plate-to-Heatsink, flat, greased surface - 0.27 ^{o}C /W typical

Measurement of RQJC

Because of the need for accurate calculation of junction temperatures International Rectifier provides $R_{\Theta JC}$ for SMD packages where the die is mounted on a heatspreader. Values for SMD10 were measured by modifying the leads so that devices could be mounted on a water cooled heatsink; effectively an 'infinite heatsink'. A thermocouple was inserted into the copper of the heatspreader so that the case-to-sink term was eliminated from the measurement.

The value of $R_{\Theta JC}$ for the SMD10 package is also affected by die size. The figures given in the above paragraph are for IR die size 7 which is the largest die offered in SMD10. $R_{\Theta JC}$ for die size 5 is about 50% higher.

The Effect of Substrate Material on Thermal Resistance

As with any surface mounted device, the heatsink is usually the printed circuit board or ceramic substrate to which the SMD10 device is soldered. The sink-to-ambient thermal impedance will depend on the board or substrate material, the pad area available for heat spreading, the proximity of other additional thermal loads on the board, and the velocity of air flow (in the case of forced cooling). Figure 2 shows how the thermal resistance of a three-inch square printed circuit board varies with pad area and air velocity. The data given in this graph should be used with caution, since local air flow can be modified by the shadowing effect of other components. Often, only prototype testing can prove the adequacy of a particular thermal design.

The heat sinking capacity of the board or substrate depends on the thermal conductivity of the board material. The reduction in thermal resistance that can be obtained depends on the material, the thickness of the material, and on the effective area of the board, as well as the air velocity. These factors can interact in a non-linear manner.

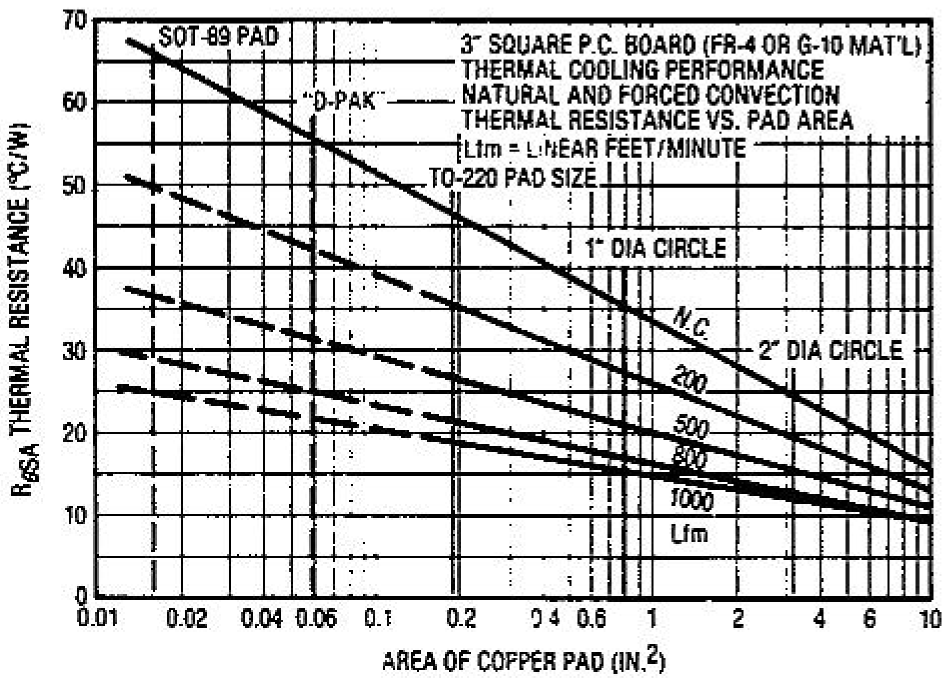


Figure 2. Thermal Resistance of 3-inch Square Printed circuit Board

All of the above data concerns the use of epoxy-glass substrates with various weights of copper cladding. SMD10s may also be used in hybrid modules where the substrates may be alumnae (Al2O3), aluminium nitride AIN, IMS (insulated metal substrate) usually aluminium with a film insulator and copper cladding up to 4 oz/sq. ft., or occasionally beryllium oxide BeO for some military or hi-rel hybrids. All of these substrate materials are superior to epoxy-glass substrates. Figure 3 shows their relative thermal resistance compared with FR-4 epoxy-glass.

Note that BeO is a toxic substance and is rapidly being phased out in military and hi-rel applications.

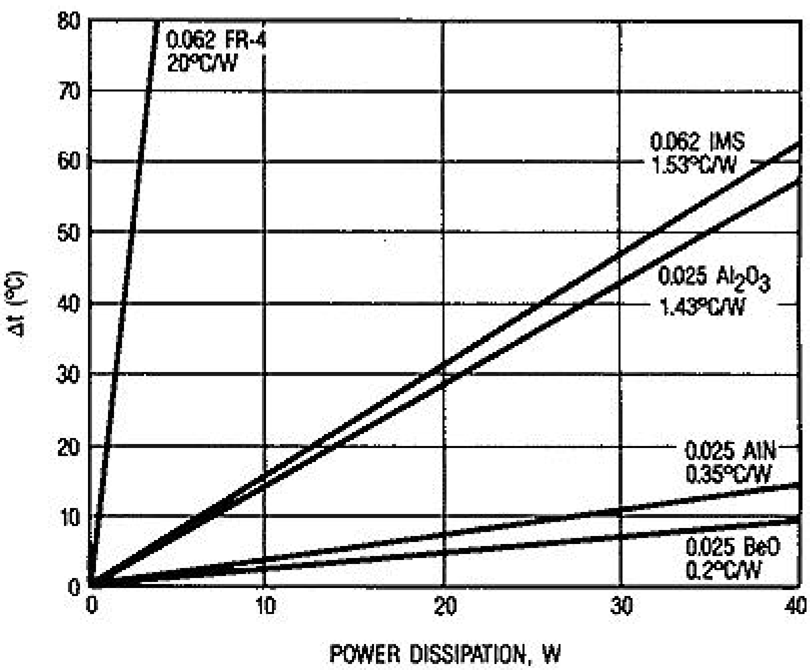


Figure 3. Thermal Resistance of 1" x 1" Substrates at 100deg.C

SMD Mounting

The most popular approach is to solder the device to the substrate using a low melting point solder such as Sn60/Pb40.

There are many different ways of doing this and they can all be broken down into the following three operations.

1. Applying solder and placing the devices in the correct locations before soldering.

3. Applying heat to fuse the solder.

4. Cleaning the assembly to remove flux residues. (If necessary)

These operations are described in detail below with advice concerning the most effective methods for SMD10.

SMD10 Attachment

Surface mount components are by definition leadless and rely on the strength of the solder joint alone for mechanical support. Because the base of the SMD10 package comprises largely the tin/lead plated copper of the die heatspreader, methods using adhesives to maintain the position of the device prior to soldering are not appropriate. The preferred method of attachment is to use a solder paste. This approach combines the fluxing and attachment stages into a single step.

Solder pastes have three main constituents:-

1. The solder itself - in the form of solder balls. Ball size and alloy composition are possible variables.

2. Flux - Rosin activated (RA) or rosin mildly activated (RMA) resins are both suitable. Water soluble fluxes are also available.

3. Solvent - used to aid the application of the paste acting as a vehicle to allow printability. A curing stage can be used after placement to improve component adhesion prior to reflow.

The size and therefore also weight of the SMD10 package compared to most other SMDs influences the choice of solder paste in two ways. Firstly, the long pre-heat time in the reflow cycle means that solvents mustn't evaporate too quickly. More importantly though, great care must be taken to minimise the occurrence of voids in the solder during reflow due to the large surface area of the copper heatspreader. Solder alloy composition and ball size do not have much influence on void formation but flux activity has been found to be a critical factor so RA fluxes are recommended.

Often print patterns which break up the solder window are suggested as a means of reducing the effect of voiding but this is not necessary with the SMD10 which has a waffle pattern on the underside of the heatspreader to give the same effect. Thus the screen pattern is the same as the recommended footprint shown below.

A thick layer of solder paste is required to ensure solder voiding under the device is kept to a minimum. It is therefore recommended that the stencil area associated with the SMD10 device is 0.01 inch thick.

The large area flat top and even weight distribution of the SMD10 allow easy automatic placement of the device using conventional pick and place equipment.

Reflow Soldering

The SMD10 package is designed for reflow soldering so it is compatible with most types of process such as Hot-Plate, Convection and Vapour Phase. However Infra-red heating is not recommended as heating from the top side gives rise to temperature gradients which cause differential expansion of the plastic encapsulant relative to the chip. Flow soldering methods such as Wave Solder and Solder Immersion are not suitable for the SMD10.

Whichever method is used, care must be taken to avoid thermal shock during the reflow cycle. This is achieved by using a carefully controlled pre-heat stage and also a post cool sequence. The temperature/time profile also influences the formation of voids under the heatspreader. Pre-heat time and reflow time above the melting point of the solder were found to be the most critical factors; longer pre-heat and reflow times giving the best results. When mounting on IMS the thermal capacity of the IMS must be taken into account in establishing the reflow profile. Figure 3 shows the profile used by International Rectifier.

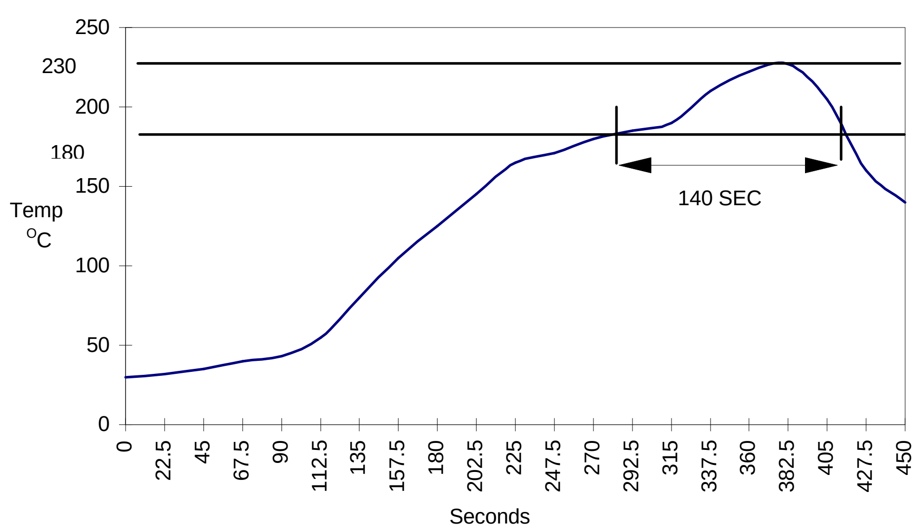


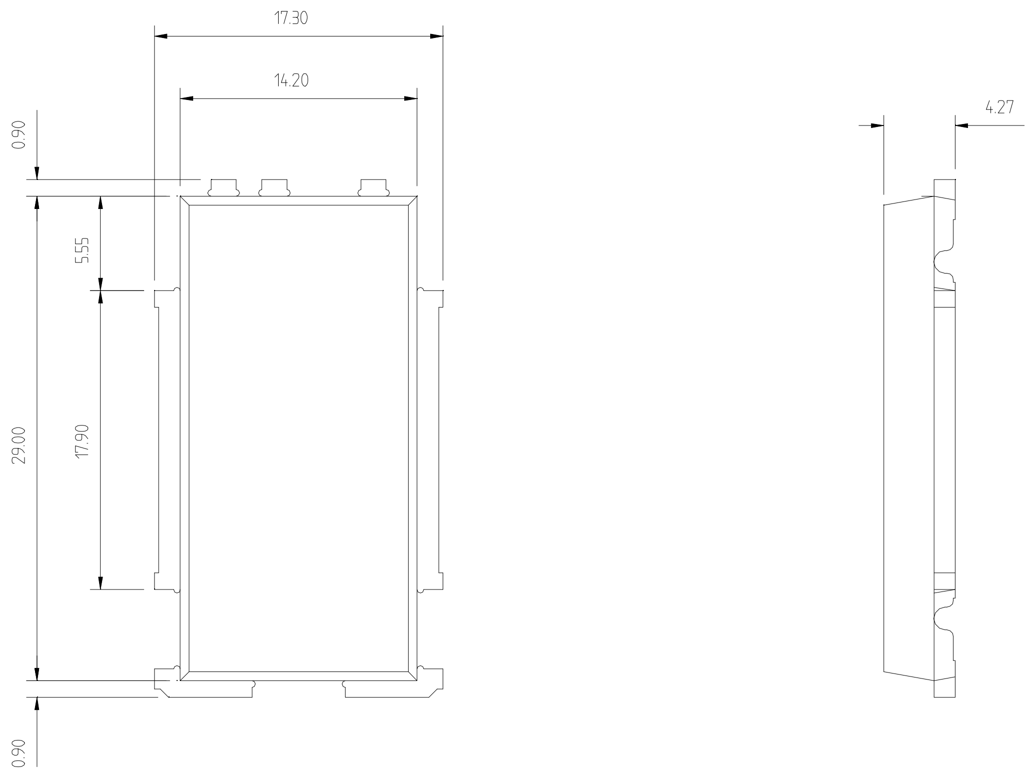
Fig. 3 Reflow Profile

Figure 3. Reflow Soldering Temp/Time Profile

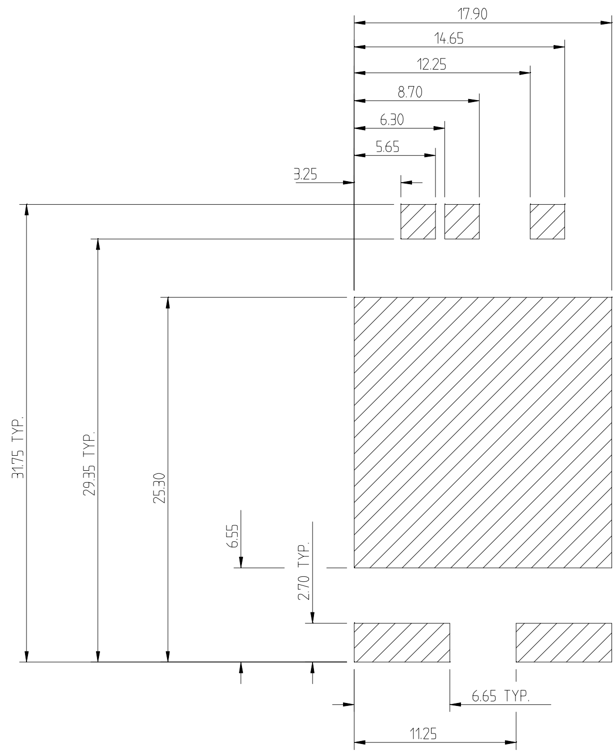
Flux Removal

Most commonly used cleaning methods can be used for the SMD10 though we have found that full immersion is generally better than spraying. The SMD10 package has wash grooves at both ends to ensure that residues are readily removed from between the heatspreader and the leads.

SMD10 Outline



SMD10 Footprint



Here are two potential Insulated metal substrate suppliers, with addresses known to date . These may serve as a lead to finding suitable substrates to mount the SMD-10

THE BERQUIST COMPANY

The Berquist Company
5300 Edina Industrial Estate
Minneapolis, MN 55439
Telephone: (612) 835-2322
Fax: (612) 835-4156
Toll Free: (800) 347-4572

Berquist European Office
P.O. Box 276
1250 AG Laren
The Netherlands
Telephone: 31-35-5380684
Fax: 31-35-5380295

Berquist UK Ltd
Unit 27 Darin Court Crownhill Ind. Est.
Milton Keynes, MK8 0AD
Telephone: 44-(1908) 263-663
Fax: 44-(1908) 263-773

<u>DENKA</u>

Head Office
1-4-1 Yurakucho, Chiyoda-ku,
Tokyo 100, Japan
Telephone: (03) 3507-5295,5297
Facsimile: (03) 3507-5078

Denka Corporation
780 Third Avenue,
32nd Floor,
New York, NY 10017, U.S.A.
Telephone: (212) 688-8700
Facsimile: (212) 688-8727

Denka Chemicals GmbH
Konigsallee 60,
40212 Dusseldorf,
Germany
Telephone: (0211) 130990
Facsimile: (0211) 329942