

D0 ENGINEERING NOTE

No. 3823.112-EN-411

D0 SILICON UPGRADE

3 CHIP LADDER
HEAT TRANSFER

September 19, 1994

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Approved: *Herman J. Stuedde*

3 Chip Ladder Heat Transfer

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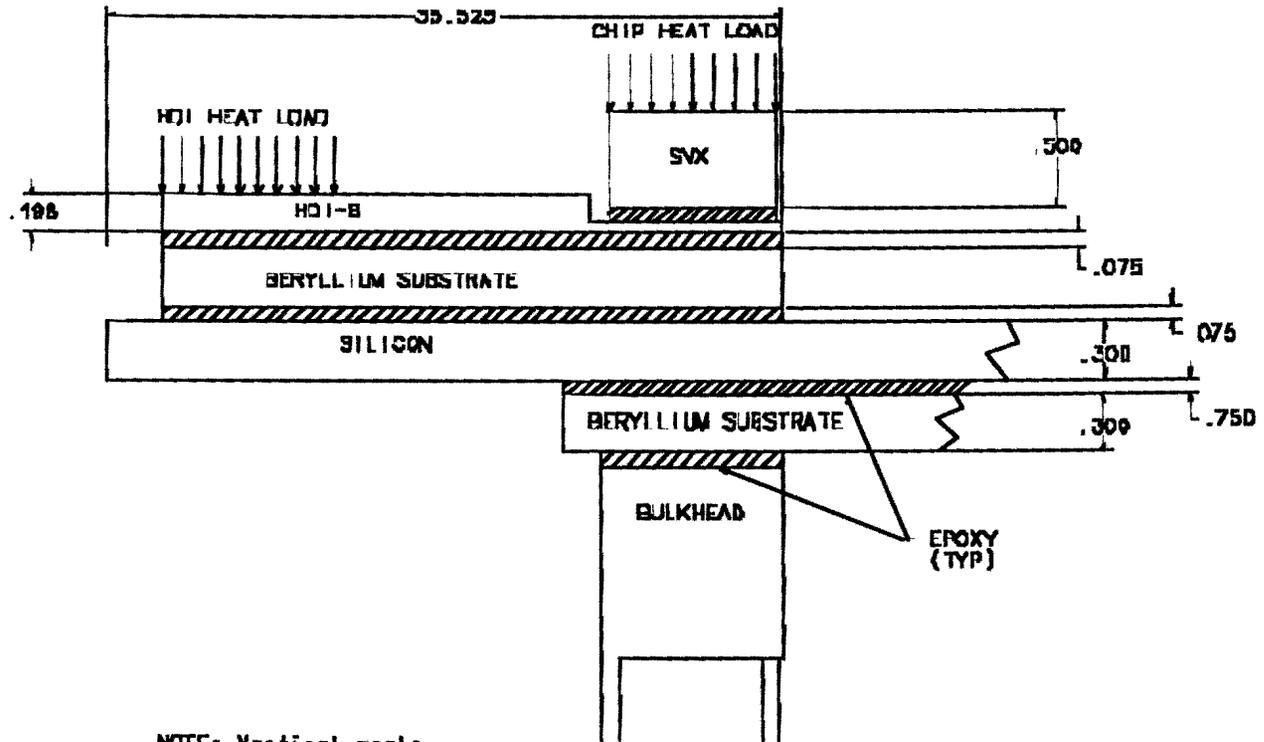
August 17, 1994

The Silicon Mechanical group has submitted a 3 chip ladder drawing to the Fermilab Analysis Group (Zhijing Tang) to determine the temperature distribution in the ladder during detector operation. Heat transfer by convection and radiation is assumed negligible and two dimensional FEA conduction solutions were performed.

The heat flux at the SVX II chip region is assumed to be 8.359 mW/mm^2 which corresponds to roughly 0.48 W per SVX II chip. The heat flux in the region of the transceiver is assumed 8.801 mW/mm^2 , corresponding to 1.6 W in this region. Total heat load of the 3 chip ladder is assumed to be 3.04 W .

The 3 chip ladder submitted for analysis is shown in the figure below. The multi-chip module (MCM) is mounted on beryllium plate which serves to carry the heat load of the chips and the transceiver to the cooling channel. Adhesive thermal conductivity is 1.6 W/m-K , based on the published value of the selected adhesive. Actual measurements of thermally conductive adhesives indicate that the assumed 1.6 W/m-K is high [1]. Experience gained in measuring adhesive thermal conductivity indicates $0.9\text{-}1.2 \text{ W/m-K}$ as a more reasonable number to use. The effect of the uncertainty of the adhesive thermal conductivity on silicon temperature is discussed in [2].

Figure 1, 3 Chip Ladder



NOTE: Vertical scale
10 x Horizontal

The following set of thermal conductivities was given to Zhijing for the FEA calculations, along with the corresponding thicknesses:

<u>Material</u>	<u>K (W/m-K)</u>	<u>Thickness (microns)</u>	
silicon	149	300	
beryllium	190	300	
wirebonds	237	25	
epoxy	1.6	75	
SVX chip	149	500	
			<u>Number of layers</u>
HDI-transceiver			
kapton	0.12	25.4	2
Cu	200.5	17.8	4
adhesive	0.22	25.4	2
pre-preg	0.12	25.4	1
HDI-chip			
kapton	0.12	25.4	1
Cu	401	17.8	2

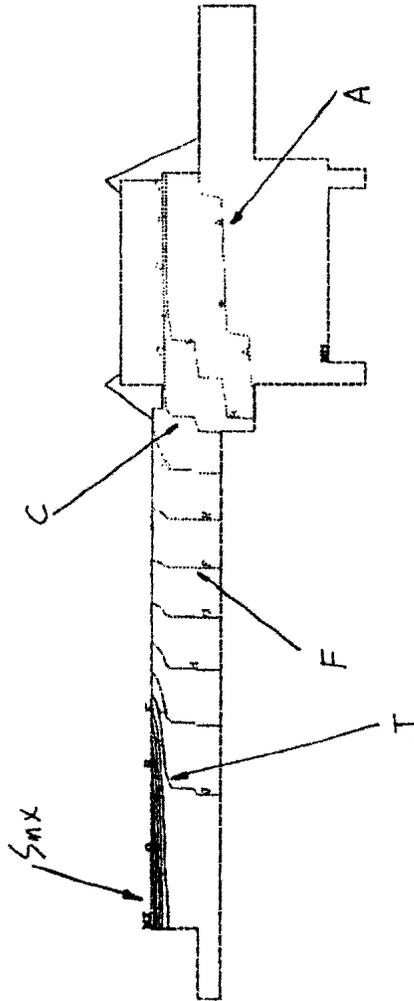
Table 1 Thermal Conductivity and Component Thicknesses, 3 Chip Ladder

Below is shown the results of the analysis.

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ANSYS 5.0
JUN 6 1994
08:41:17
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
TEMP
SMX =20.797
A =1
B =2.3
C =3.6
D =4.9
E =6.2
F =7.5
G =8.8
H =10.1
I =11.4
J =12.7
K =14
L =15.3
M =16.6
N =17.9
O =19.2

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Ladder detector cooling analysis (# 7)

Figure 2, Analysis #7, 3 Chip Temperature Distribution

The cooling channel surface temperature has been assumed at 0 degrees C for the solution. Silicon and ladder component temperatures may then determined by adding the true temperature of the channel surface to the output temperatures, since

convective and radiative heat transfer is negligible on the ladder surface. Bulk temperature of the coolant is expected to be 5°C , with a channel surface temperature of 8.5°C due to the temperature gradient in the coolant.

The maximum temperature occurs on the ladder at the same location as in the 5 chip ladder, that is, in the transceiver region. For a 0°C cooling channel the 3 chip ladder solution results in a maximum temperature of 20.8°C compared to a maximum temperature of 18°C for the 5 chip solution. Taking into account the assumed 8.5°C channel surface temperature, the maximum temperature in the 3 chip ladder is 29.3°C .

It is likely that a higher temperature results in the 3 chip ladder due to less beryllium on the ladder underside in the 3 chip design. The maximum silicon temperature is roughly 14°C in both the 3 chip and the 5 chip solutions with the 0°C channel, or 22.5°C when considering the true channel temperature. Also, the 5 chip ladder solution material properties were slightly different than for the 3 chip solution. The Cu conductivity for the 5 chip solution in the transceiver region was 401 W/m-K , compared to 200.5 W/m-K in the 3 chip solution.

As of August 17, 1994, the ladder design is in flux. The 3 chip ladder final design will be given to the Analysis Group for re-analysis.

[1] H. Jostlein, T. Heger. private communication

[2] P. Ratzmann, 5 Chip Ladder Heat Transfer and Ambient Temperature Analysis, 1994

Addendum to 3 Chip Ladder Heat Transfer
 Paul Ratzmann
 November 21, 1994

Two changes to the 3 chip ladder in recent months significantly affect the temperature distribution in the HDI region of the ladder.

1. The HDI was extended from 12 to 16 mm to accommodate additional length requirements of the HDI.
2. To reduce the length of the bimetal effect the underside beryllium piece was extended.

The effect of (1) is calculated. The average thermal resistance is calculated by:

$$R_{ave} = \frac{L}{2 * A * K_{ave}}$$

$$K_{ave} = \frac{K_1 + K_2}{2}$$

K_{ave} , for beryllium and silicon is 170 W/m-K. For the 12 mm region on the original heat transfer calculations the thermal resistance is calculated to be 117.6 K/W per mm depth. The heat flux from the transceivers is 8.801 mW/mm², or 8.801 mw/mm per mm depth. Total heat transfer per mm is 8.801*9 = 79.2 mW. The calculated gradient in the 12 mm HDI region is:

$$\Delta T = Q * R$$

which is 9.3°C. This compares to roughly 8.5°C in the HDI region measured directly from the FEM plot.

To determine the gradient in the 16 mm HDI, the thermal resistance is scaled by length, $R = 117.6 * (16/12) = 156.8$ K/W, resulting in a temperature gradient of $0.0792 * 156.8 = 12.4$ °C. The transceiver region is then 12.4-9.3, or 3.1°C warmer.

In (2) there is a reduction in the temperature gradient due to the lower thermal resistance in this region. The extension of the beryllium is approximately 12 mm. The thermal resistance in this region is the same as calculated above, 117.6 K/W. With the additional beryllium piece the equivalent resistance is calculated using three resistors in parallel, two of which are beryllium:

$$R_{eq} = \frac{R_{be}^2 * R_{si}}{2 * R_{be} * R_{si} + R_{be}^2}$$

The equivalent resistance is calculated to be 75.6 K/W. The temperature gradient is calculated to be $0.0792 * 117.6 = 9.3$ °C in the original model, compared to $0.0792 * 75.6 = 6.0$ °C with the beryllium extension. The difference is $9.3 - 6.0 = 3.3$ °C.

Effectively the effects of (1) and (2) trade off and the max temperature in the transceiver region is expected to be unchanged. This will be submitted for final a FEM solution once the ladder design has been finalized.

Approved. W.E. Cooper 5