The Laminated Metal Core PCB

The traditional metal core printed circuit board (MCPCB) or integrated metal substrate (IMS) is a 30-year old technology consisting of a triple-layer structure laminated together by an adhesive system as depicted in Figure 1.

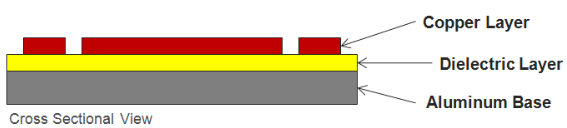


Fig.1 Cross sectional view of the MCPCB or IMS

A specially formulated dielectric layer which is thermally conductive and yet electrically insulative is laminated across the whole aluminum flat sheet. A copper layer is then laminated on top of the dielectric layer.

Figure 2 shows the typical stack-up structure of a heat removal system with a metal core printed circuit board. For an electronic system, the design goal is to ensure that the device junction temperature is below specification;

$$T_{junction} \leq T_{junction,\ spec}$$

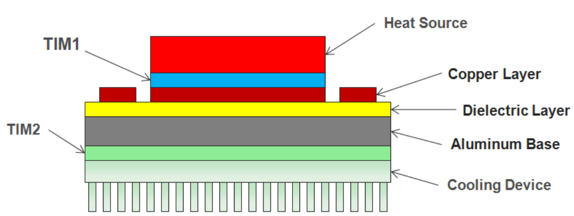


Fig. 2 Cross sectional view of the MCPCB with a heat source and a cooling device

Thermal Interface Material 1 (TIM1) and TIM2 are used to improve the contact resistances between the interfacial layers.

The function of the MCPCB or IMS is to transfer heat away from the heat source to the cooling device. At steady state, the temperature difference between $T_{junction}$ and $T_{ambient}$ is:

$$\Delta T = T_{junction} - T_{ambient} = R_{th\ total} * P_{total} \text{ .... Eqn. 1}$$

whereby, R_{th_total} is the cumulative thermal resistances of R_{TIM1}, R_{cu}, $R_{dielectric}$, R_{al}, R_{TIM2}, $R_{heat\ sink}$, $R_{th\_spreading}$, $R_{th\_convective}$. For material comparison purposes, one dimensional through-plane thermal resistance is considered. $R_{th\_spreading}$, $R_{th\_convective}$ are assumed to be similar.

$$R_{th} = t/(k*A) \text{ .... Eqn. 2}$$

whereby t is the heat path distance, k is the thermal conductivity of material and A is the heat source area.

ALOX™ Metal Substrate Technology

DSEM ALOX™ is a patented metal core substrate technology with selective dielectric and selective direct metallization on the same metal core base. This selective design flexibility allows electrically insulated thermal pad to be connected directly to the bulk aluminum base without the dielectric layer, thus, lowering thermal resistance. The direct copper metal layer on aluminum allows solder to be used as the TIM. Solder TIM has about 50W/m-K.

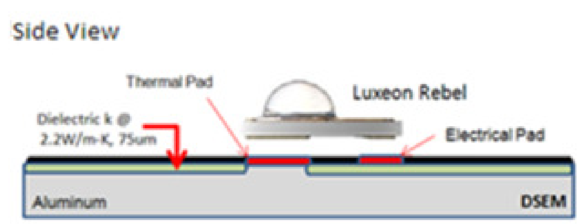


Fig. 3 Luxeon Rebel with electrically insulated thermal pad connected to AMS without dielectric

Figure 3 shows the Luxeon® Rebel implementation with much better through plane conductivity as compared to the laminated MCPCB.

Note:

Luxeon® rebel (trademark of Philips Lumileds)

The following is a generic one dimensional comparison through-plane thermal resistance assuming a one square inch heat source of various material and topology.

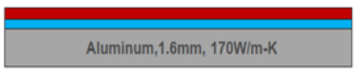
Comp A					Cum Rth
Stack-Up	Thickness (m)	k (W/m-K)	Area (m2)	Rth, °C/W	
Copper	0.00004	384.00000	0.00065	0.00014	0.00014
Dielectric	0.00008	2.20000	0.00065	0.05284	0.05298
Aluminum	0.00160	170.00000	0.00065	0.01459	0.06757
TIM	0.00010	17.00000	0.00065	0.00912	0.07669

Table 1: Cum R_{th_IMS} is 0.07°C/W without TIM

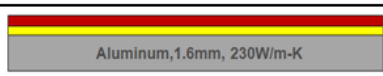
Alox A					Com Rth
Stack-Up	Thickness (m)	k (W/m-K)	Area (m2)	Rth, °C/W	
Copper	0.00004	384.00000	0.00065	0.00014	0.00014
ALOX	0.00008	8.00000	0.00065	0.01453	0.01467
Aluminum	0.00160	230.00000	0.00065	0.01078	0.02546
TIM	0.00010	30.00000	0.00065	0.00517	0.03062

Table 2: Cum R_{th_ALOX} is 0.03°C/W without TIM

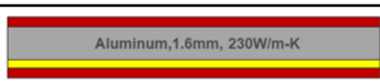
Alox B					Cum Rth
Stack-Up	Thickness (m)	k (W/m-K)	Area (m2)	Rth, °C/W	
Copper	0.00004	384.00000	0.00065	0.00014	0.00014
Aluminum	0.00160	230.00000	0.00065	0.01078	0.01092
ALOX	0.00008	8.00000	0.00065	0.01453	0.02546
Copper	0.00004	384.00000	0.00065	0.00014	0.02560
TIM	0.00010	30.00000	0.00065	0.00517	0.03076

Table 3: Cum R_{th_ALOX} is 0.03°C/W without TIM

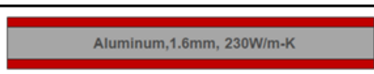
Alox C					Cum Rth
Stack-Up	Thickness (m)	k (W/m-K)	Area (m2)	Rth, °C/W	
Copper	0.00004	384.00000	0.00065	0.00014	0.00014
Aluminum	0.00160	230.00000	0.00065	0.01078	0.01092
Copper	0.00004	384.00000	0.00065	0.00014	0.01107
TIM	0.00010	30.00000	0.00065	0.00517	0.01623

Table 4: Cum $_{Rth\_ALOX}$ is 0.01°C/W without TIM

Alox_A has similar vertical thermal resistance as Alox_B; however, Alox_B has better heat spreading thus, a better overall thermal resistance. Alox_C is direct metallization to the metal base.

Alox_A, Alox_B and Alox_C topology can be fabricated at the same time.

In summary, the key features of ALOX™ metal substrate technology are;

(a) Selective dielectric on electrical pads and direct contact for thermal pads; thus, best through-plane thermal conductivity for thermal path
(b) Selective dielectric on the bottom layer allows better heat spreading; thus, high in-plane thermal conductivity
(c) Direct copper-on-aluminum for thermal pads and bottom surface; thus, enabling solder as the thermal interface material which has much higher thermal conductivity as compared to thermal grease.
(d) Solder as TIM is a proven high volume Surface Mounting technology.