PCB Thermal Management

Meet the Presenter

RYAN MILLER
NCAB Group USA
Field Application Engineer, Medtech Specialist

Agenda

- Main causes of heat
- Importance of thermal management
- Solutions to dissipate heat
- Conclusions

Main Causes of Heat

- Active Components
- High Power
- High Frequency
- Operating Environment

The Importance of Thermal Management

Common causes of failure in electronic components

- Component defects
- Packaging failures
- Environmental conditions
- Excessive Temperature
- Excessive current
- Mechanical shock

THERMAL MANAGEMENT

Solutions to Dissipate Heat

Some suggested options include

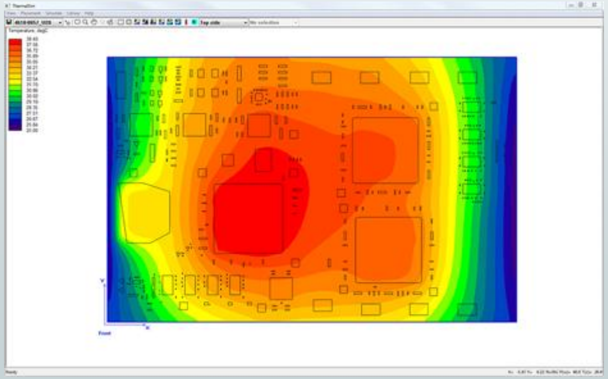
- PCB Lay Out
- Thermal Simulations
- Materials Choices
- Copper Thickness
- Thermal Via-Farms
- Insulated Metal Substrates
- Coin Technology
- Copper Pedestal Technology

Layout

- Spread out heat generating components – do not group them together.
- Allow for wider tracks to conduct heat away and use heavier copper foils on the inner layers.
- Consider heat sinks early in the process – easier to design them out, compared to having to design them in later.

Thermal simulations

* Knowing this information may help to optimize the design. This is a critical step, yet often overlooked at the start.



Material - How much heat can be transferred away?

It depends of these factors:

λ = Thermal conductivity of the material (W/mK).
This is a key characteristic of the material.

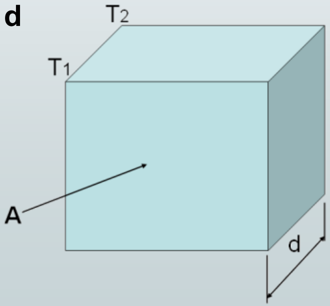
d = The thickness of the substrate.

ΔT = Difference in temperature between sides.

A = The area that will transfer the heat

Heat transfer = W = λ *A * ΔT / d

Not valid with IMS PCBs due to contact resistance



Examples below show the different levels of heat transfer when using different materials with different thermal conductivity properties, using the formula

W = λ * A * ΔT / d, where:

A = 1cm^2

ΔT = 20 ºC

d = 1.6mm

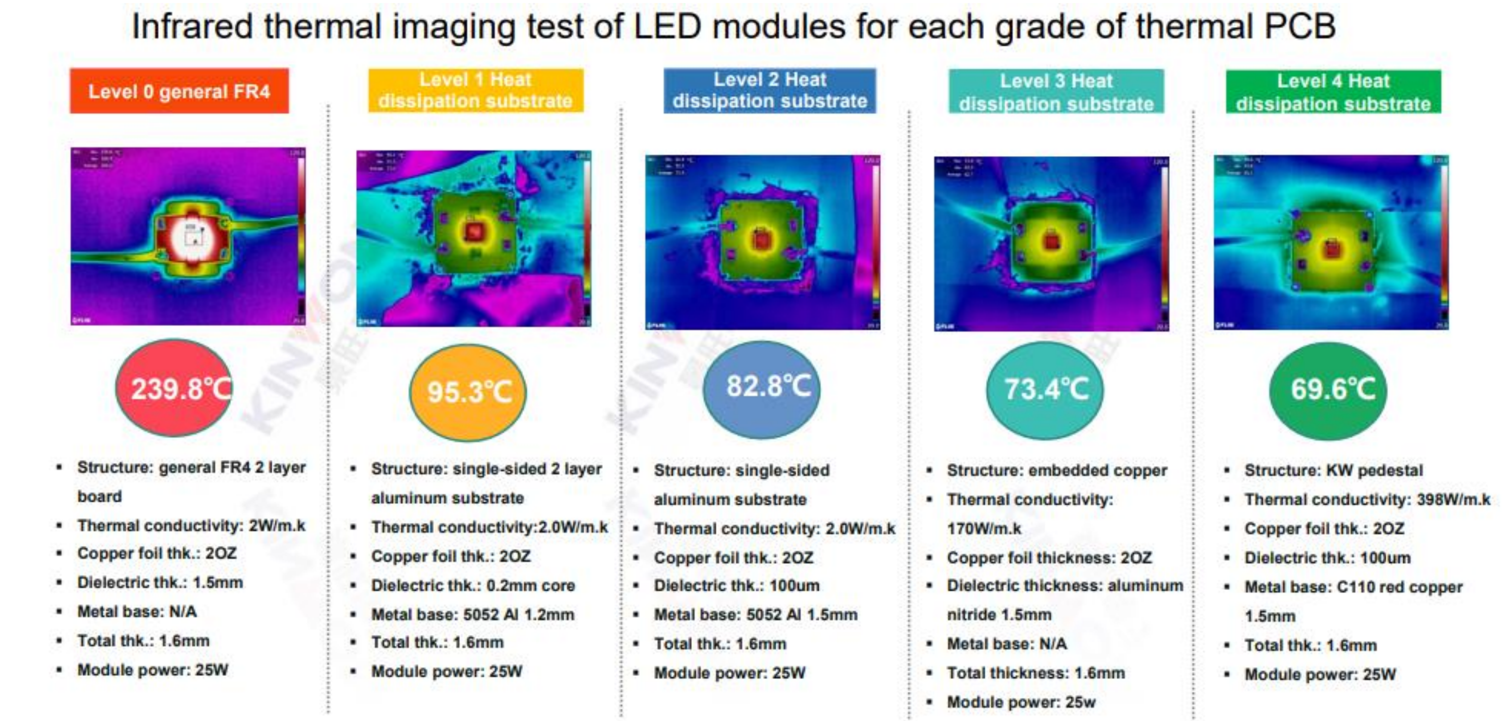
λ1 = Standard FR4 0.25 W/mK

λ2 = Thermally conductive laminate 2.2 W/m/K

Using standard FR4
W1 = 3.1 watts

Using thermally conductive laminate
W2 = 27.5 watts

Material


Infrared thermal imaging test of LED modules for each grade of thermal PCB
Level 0 general FR4
239.8℃
Structure: general FR4 2 layer board
Thermal conductivity: 2W/m.k
Copper foil thk.: 2OZ
Dielectric thk.: 1.5mm
Metal base: N/A
Total thk.: 1.6mm
Module power: 25W
Level 1 Heat dissipation substrate
95.3℃
Structure: single-sided 2 layer aluminum substrate
Thermal conductivity:2.0W/m.k
Copper foil thk.: 2OZ
Dielectric thk.: 0.2mm core
Metal base: 5052 Al 1.2mm
Total thk.: 1.6mm
Module power: 25W
Level 2 Heat dissipation substrate
82.8℃
Structure: single-sided aluminum substrate
Thermal conductivity: 2.0W/m.k
Copper foil thk.: 2OZ
Dielectric thk.: 100um
Metal base: 5052 Al 1.5mm
Total thk.: 1.6mm
Module power: 25W
Level 3 Heat dissipation substrate
73.4℃
Structure: embedded copper
Thermal conductivity: 170W/m.k
Copper foil thickness: 2OZ
Dielectric thickness: aluminum nitride 1.5mm
Metal base: N/A
Total thickness: 1.6mm
Module power: 25w
Level 4 Heat dissipation substrate
69.6℃
Structure: KW pedestal
Thermal conductivity: 398W/m.k
Copper foil thk.: 2OZ
Dielectric thk.: 100um
Metal base: C110 red copper 1.5mm
Total thk.: 1.6mm
Module power: 25W

THERMAL MANAGEMENT – SOLUTIONS TO DISSIPATE HEAT

Material

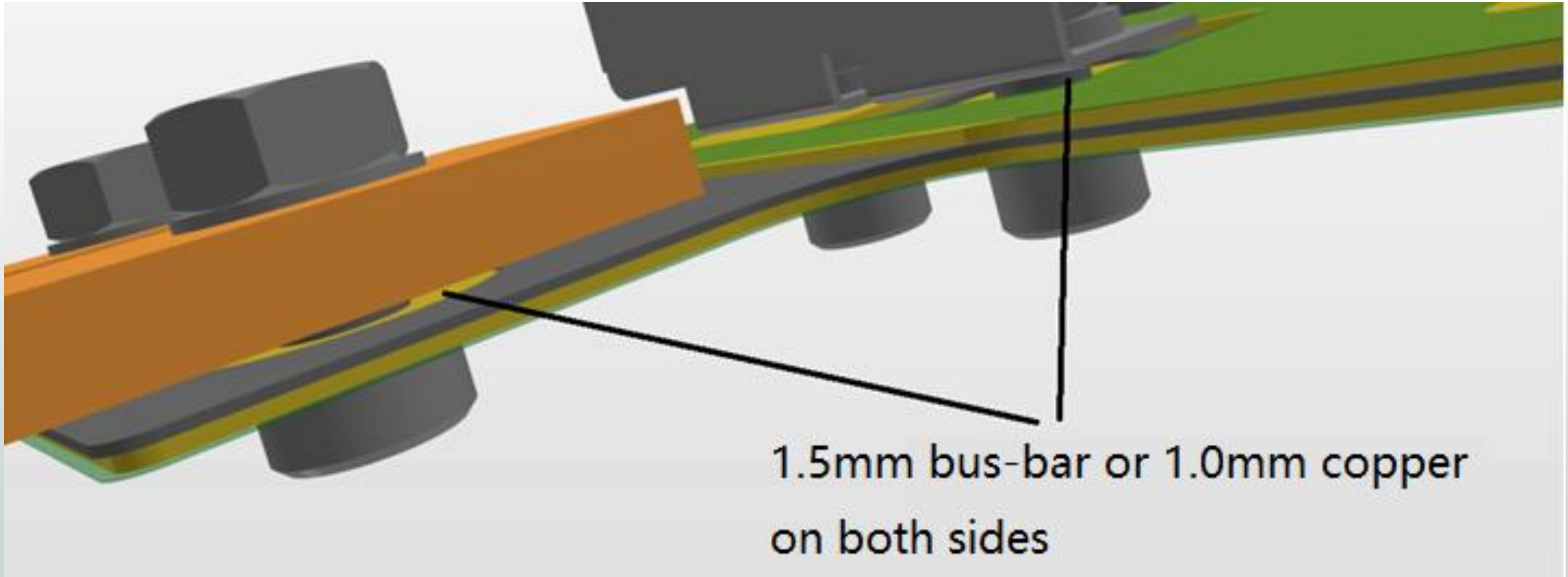
Thermally conductive laminates (used for lamination)

Material	W/mK	Comment	Thermal conductivity	Availability	Price
Standard FR4	0.2-0.6	Benchmark - Epoxy resin woven glass system	LOW MEDIUM HIGH	LOW MEDIUM HIGH	LOW MEDIUM HIGH
Shengyi ST110G	1.0	Epoxy resin woven glass system – Suitable for multilayer, thick copper, high voltage applications. Not common.	LOW MEDIUM HIGH	LOW MEDIUM HIGH	LOW MEDIUM HIGH
Shengyi ST115G	1.6	High CTI, Tg170°C, suitable for power, automobile and LED product, can be used for HDI and high layer count. **Recommended**.	LOW MEDIUM HIGH	LOW MEDIUM HIGH	LOW MEDIUM HIGH
~~Rogers 92ML~~	2.0 (average)	Epoxy resin woven glass system – Suitable for Power and Industrial control applications. Multilayer use. It is out of market since March 8, 2023.	LOW MEDIUM HIGH	LOW MEDIUM HIGH	LOW MEDIUM HIGH
Ventec VT-5A2	2.2	Ceramic filled epoxy resin woven glass – Suitable for Power and Industrial control applications. Multilayer use.	LOW MEDIUM HIGH	LOW MEDIUM HIGH	LOW MEDIUM HIGH
Rogers TC350 series	0.72 – 1.24	Ceramic filled PTFE-based woven glass reinforced - RF application, Antenna, Power amplifier, Passive device.	LOW MEDIUM HIGH	LOW MEDIUM HIGH	LOW MEDIUM HIGH
Rogers TC600	1.1	Ceramic filled PTFE-based woven glass reinforced - RF application, Antenna, Power amplifier, Passive device.	LOW MEDIUM HIGH	LOW MEDIUM HIGH	LOW MEDIUM HIGH
Rogers Curamik	24 / 90 / 170	Aluminium Oxide / Silicon Nitride / Aluminium Nitride ceramic substrates. Very high current (wind/power/rail). 1-2L. Rogers currently supply to selected customers only.	LOW MEDIUM HIGH	LOW MEDIUM HIGH	LOW MEDIUM HIGH

Copper Thickness (Track /Gap capability)

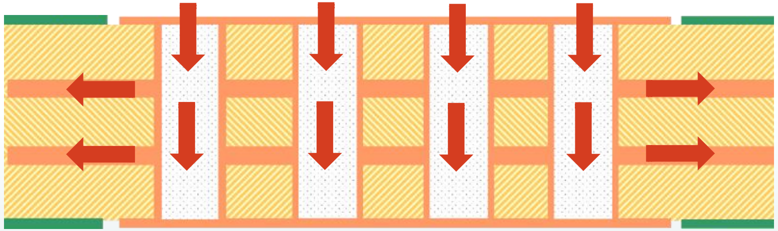
	Base Copper	Prefer Capability(mm)	Best Capability(mm)
Inner Layer Track / Gap	102.9µm (3OZ)	0.2032/0.2032	0.1778/0.1778
	137.2µm (4OZ)	0.254/0.254	0.2032/0.2032
	171.5µm (5OZ)	0.3048/0.3048	0.254/0.254
	205.7µm (6OZ)	0.3556/0.3556	0.3048/0.3048
Outer Layer Track / Gap	102.9µm (3OZ)	0.254/0.2794	0.2032/0.2032
	137.2µm (4OZ)	0.3048/0.3302	0.254/0.254
	171.5µm (5OZ)	0.3556/0.381	0.3048/0.3048
	205.7µm (6OZ)	0.4064/0.4318	0.3556/0.3556

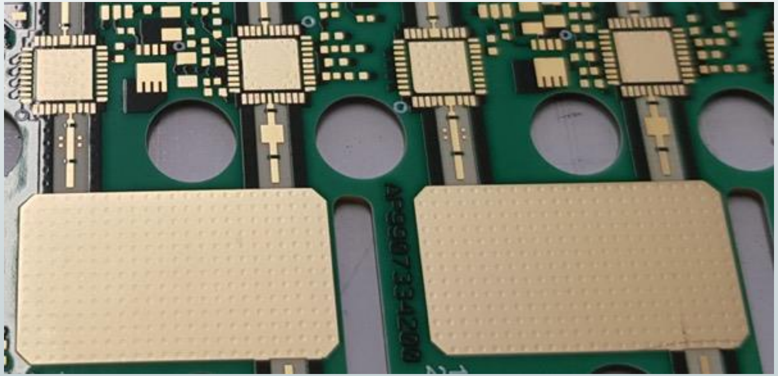
Copper Thickness (Bus-Bar)



Thermal vias / Via Farms

- Located under the component to direct heat away.
- IPC-4761, Type VII, via fill



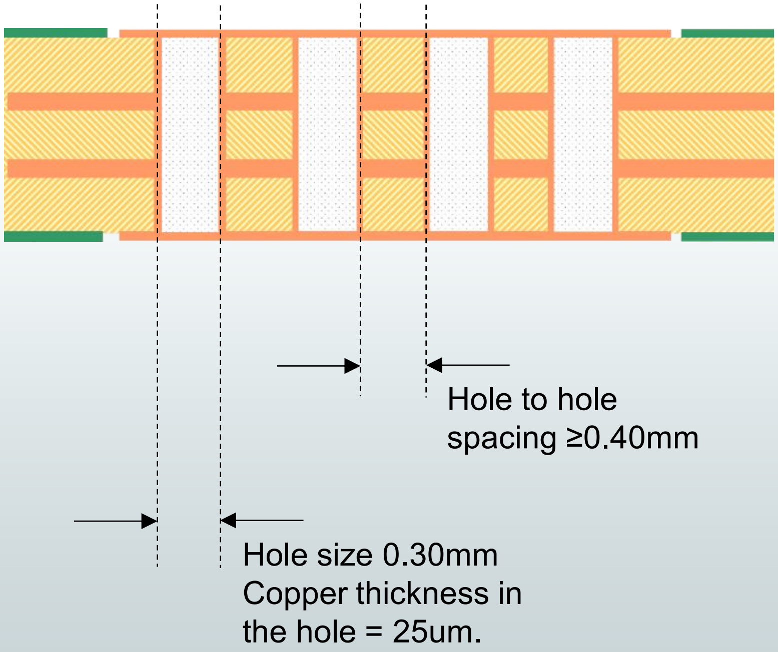


Thermal conductivity of Air
0.024 W/mK

Thermal conductivity of epoxy resin
0.20 – 0.25 W/mK

Thermal vias / Via Farms

- **Recommended:**
  - hole size ≥ 0.30mm
  - spacing ≥0.40mm
- **Thermally conductive via fill can be used to improve heat dissipation – noting CTE values.**
- **Thermal simulations to verify.**

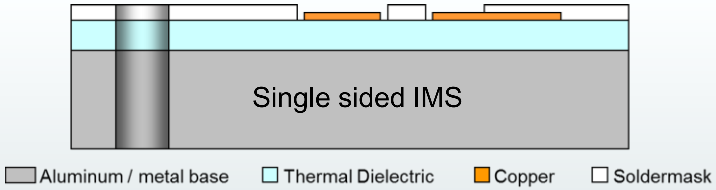


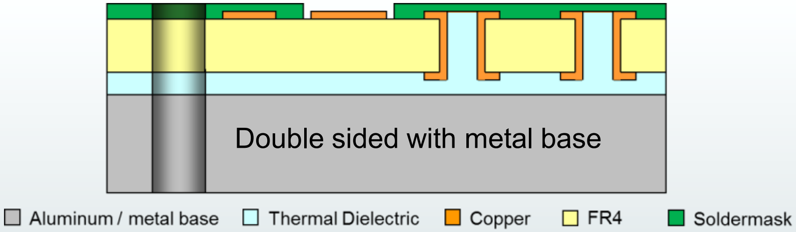
Thermal conductivity of conductive via fill
3.5 – 7.8 W/mK

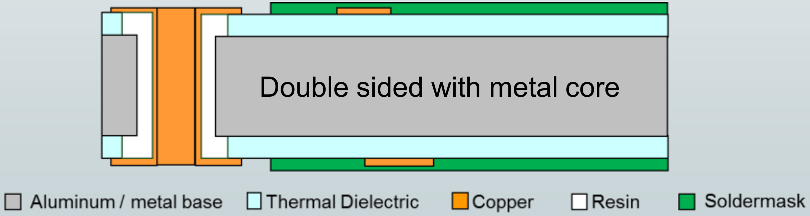
Thermal conductivity of epoxy resin
0.20 – 0.25 W/mK

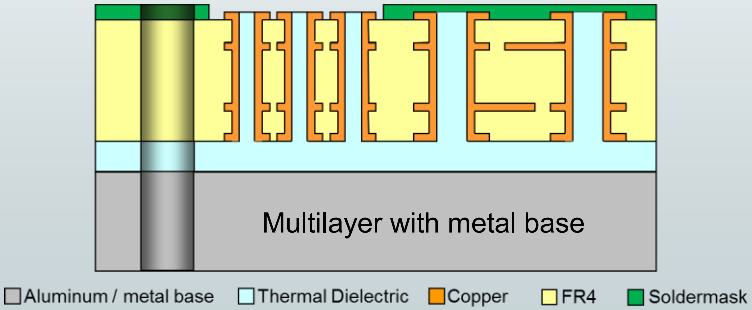
Material

Insulated metal substrates – example builds





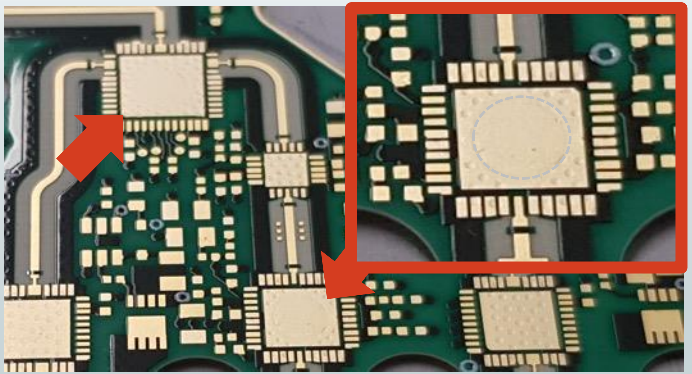




Coin Technology

The use a solid piece of copper which has been inserted or embedded into the PCB

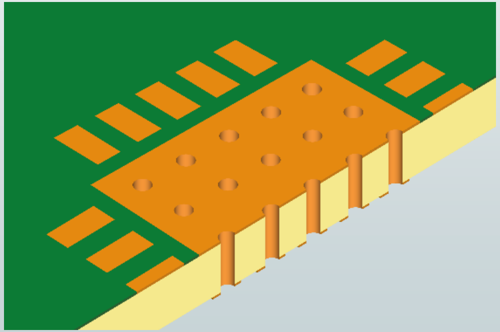
- Draws heat away from component
- Dissipates to bottom, and sometimes internal layers.

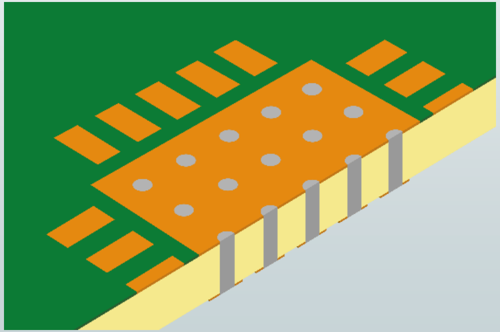


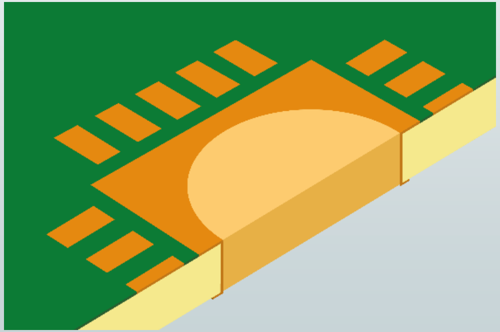
Coin Technology – Benefit of copper coins in

Thermal conductivity comparison 5mm x 5mm via farm.

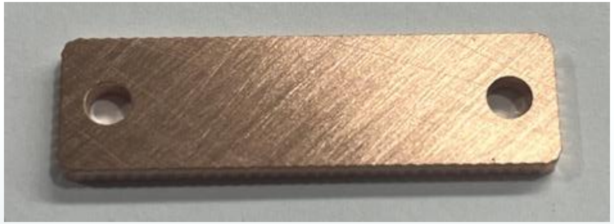
- Copper plating gives about 3w/m*k
- Conductive via fill up to 7.8w/m*k
- A Φ4mm copper coin gives about 195w/m*k.



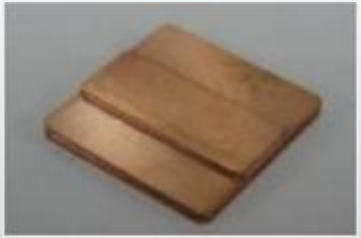




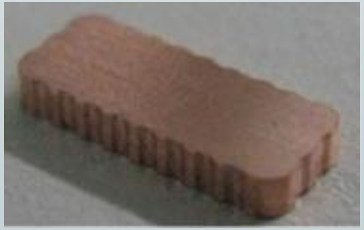
Coin Technology – Types of the coins



I- COIN

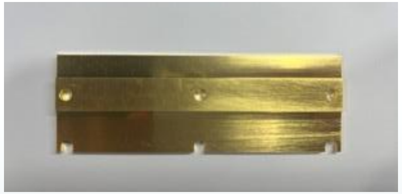


T-COIN



PRESS-FIT

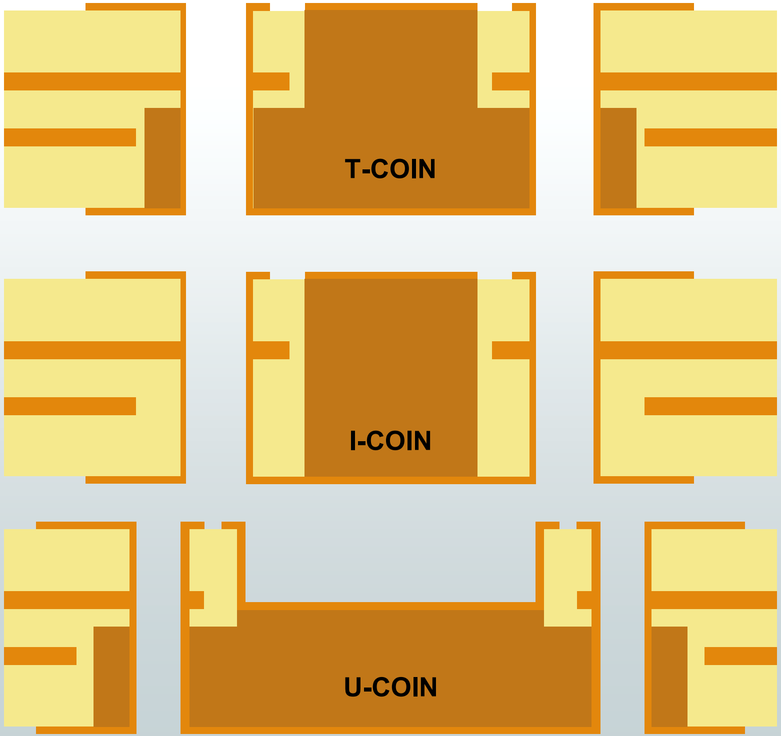
Coin Technology – Fabrication of the coins



Material - Cutting → **Drilling / Punching** → **CNC control milling** → **Profile** → **Surface treatment** (plating silver/gold/tin or browning)

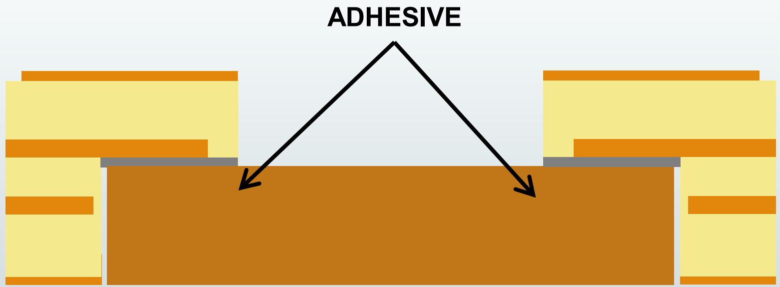
Coin Technology – Embedded Coin

- Insterted during lamination
- No-flow pre-preg
- May use grounding vias
- Same surface finish as PCB



Coin Technology – Attached Coin

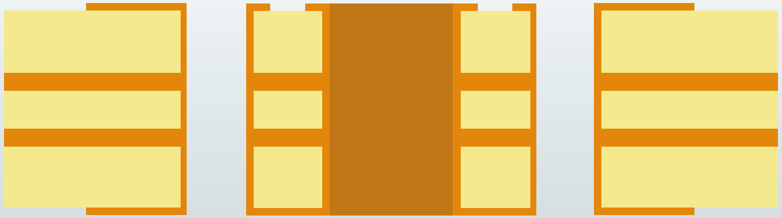
- Attached coins are added into a depth milled cavity.
- Added post PCB production
- Secured in place using a conductive adhesive
- Easiest to manufacture



ATTACHED COIN

Coin Technology – Press fit Coin

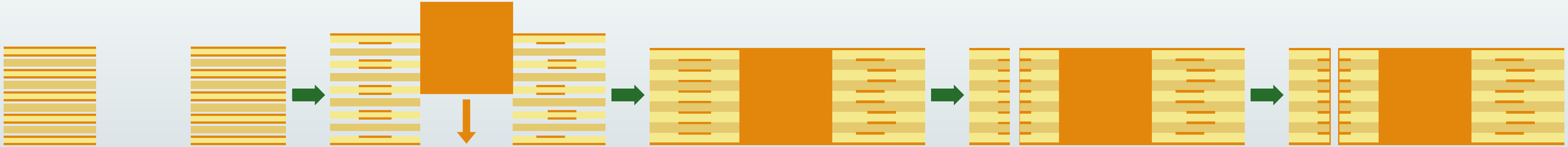
- Inserted into a pre-defined space
- It is held in place due to the compression forces.
- Insertion can take place post PCB manufacturing.



PRESS FIT COIN

Coin Technology – Manufacturing of copper coins in

Cores and PP Pre-cutting → Cores + PP + coins stack up → Lamination → Drilling → Post process



Special control

- Brown oxidization of copper coins.
- Resin flowing removed.

Coin Technology – Manufacturing of copper coins in

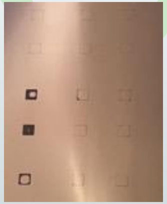
ORIGINAL COINS

BROWN OXIDE

IN-LAY

AFTER LAMINATION

AFTER LAMINATION

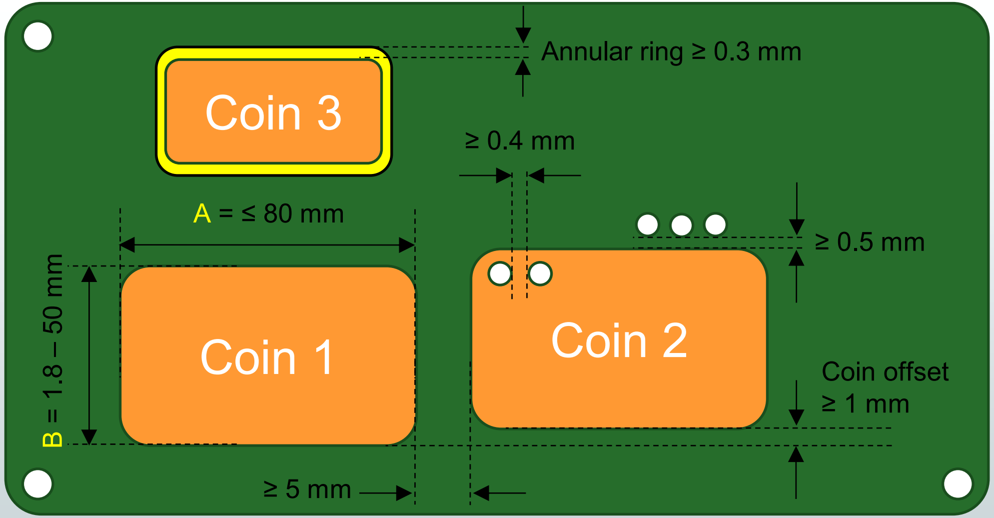


MILLING RESIN

AFTER RESIN REMOVAL

AFTER RESIN REMOVAL

Coin Technology – Design considerations



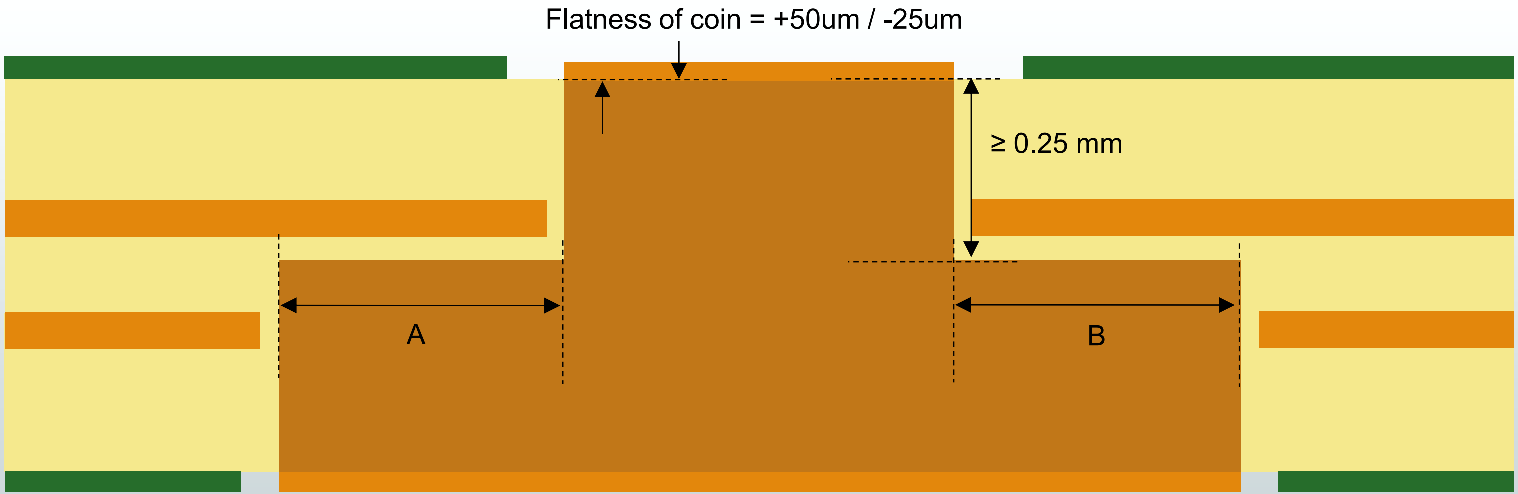
Minimum difference between dimension A and B = 0.30mm

MATERIALS FOR COPPER COIN BUILDS

370HR, EM827, IT180A, MCL-E-679, R1755V, S-1000-2M, TU768

It is recommended to have the same hole size for all holes in the coin.

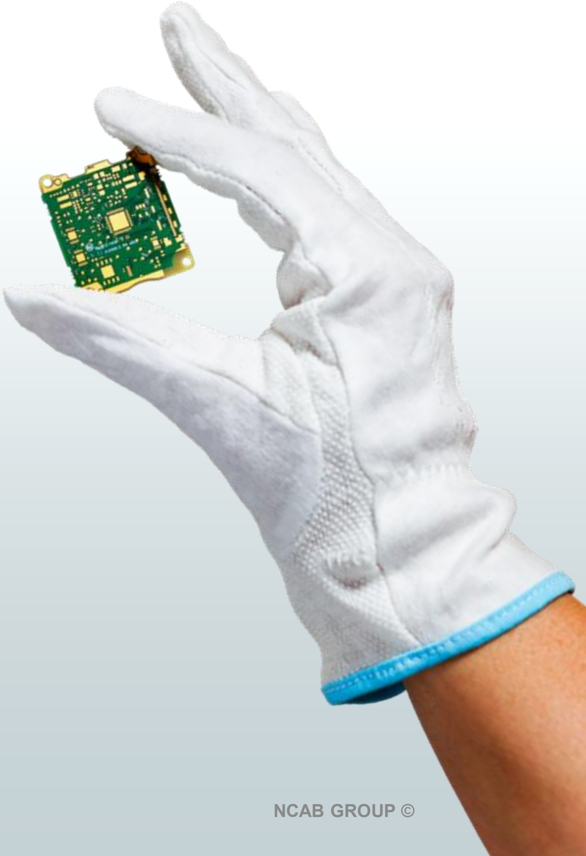
Coin Technology – Design considerations



Dimensions A and B must be the same – the shape should be symmetrical

Coin Technology – Design Tips

- **Copper coin can be used in conjunction with these technologies:**
  - High layer counts
  - IPC 4761 type VII plugging
  - HDI Constructions
  - Rigid-Flex constructions
- **Different types of coins can be in one unit, but we recommend less than 3 different types or sizes.**
- **The Aspect ratio limitation of blind via in a coin is <1:1, but for optimal production the preferred is 0.8:1.**
- **Any construction with coins must have a symmetric build.**
- **Consider copper coin design guidelines early in the process.**

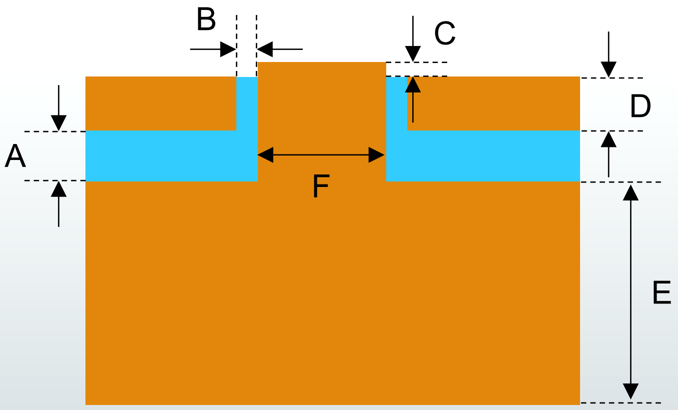


Coin Technology – Design Tips

- It is recommended to have the same hole size for all holes in the coin.
- When different size coins are used on the same unit, the size difference should be ≥1mm. If <1mm, suggest to use same size.
- Minimum difference of long size and short size of the coin preferred to be >= 1.0mm. <0.3mm will be taken as same size.
- To avoid material cracking, offset placement of coins by >1mm.
- Coin counts in one board ≤32 (same size).

PCB design guidelines (printed circuit boards) | NCAB Group

Material- Pedestal design rules



No.	Items	Prefer
A	Dielectric thickness	0.1+/0.02mm
B	Pedestal to circuit pad	>=0.25mm
C	Bump of pedestal	<=0.03mm
D	Copper thickness	<=3OZ
E	Copper base (mm)	0.8/1.0/1.2/1.5/2.0
F	Minium size of the pedestal	0.6mm * 0.6mm

Tips:

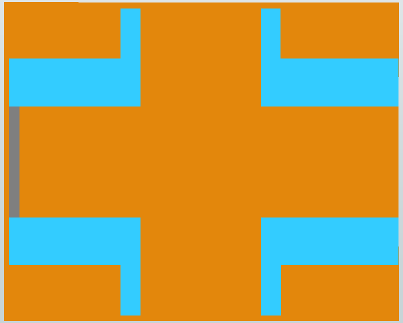
- **Copper pedestal is recommended. It is also possible for Alumnium base without plating.**
- **The dielectric is done by coating, not adhesive film normally, so, KW-ALS dielectric will be suggested normally.**

Material- types of pedestal

1L COPPER PEDESTAL

SINGLE SIDED 2L COPPER PEDESTAL

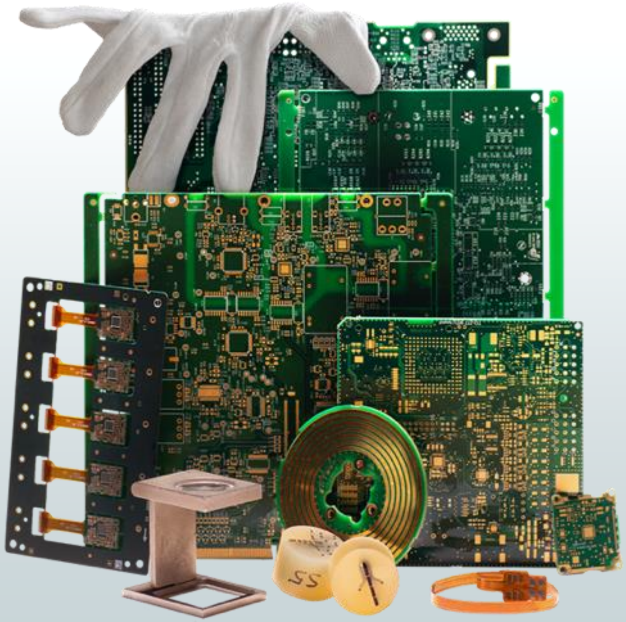
2L COPPER PEDESTAL



HDI 1L COPPER PEDESTAL

Conclusions

- Carry out thermal simulations as early as you can in the process.
- Try not to group heat generating components together.
- Determine how much heat you need to dissipate.
- You may need more than one solution.
- Consider material thermal performance.



ncabgroup.com

THANK YOU

Questions?

NCAB GROUP

Follow us

YouTube