HOW DOES YOUR PCB LAYOUT INFLUENCE THE COSTS IN PCB MANUFACTURING?

Jürgen Wolf

Co- Authors: Andreas Dreher – Holger Krause – Andreas Nies – Jens Töbeck

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

AGENDA

How does your PCB layout influence the costs in PCB manufacturing?

1. PCB size and arrays
2. Copper price development and choice of materials
3. PCB stackup
4. Mechanical processing
5. Enhanced Technologies
6. More tips & tricks
7. Summary

Jürgen Wolf
Würth Elektronik GmbH & Co. KG
Head of Advanced Solution Center

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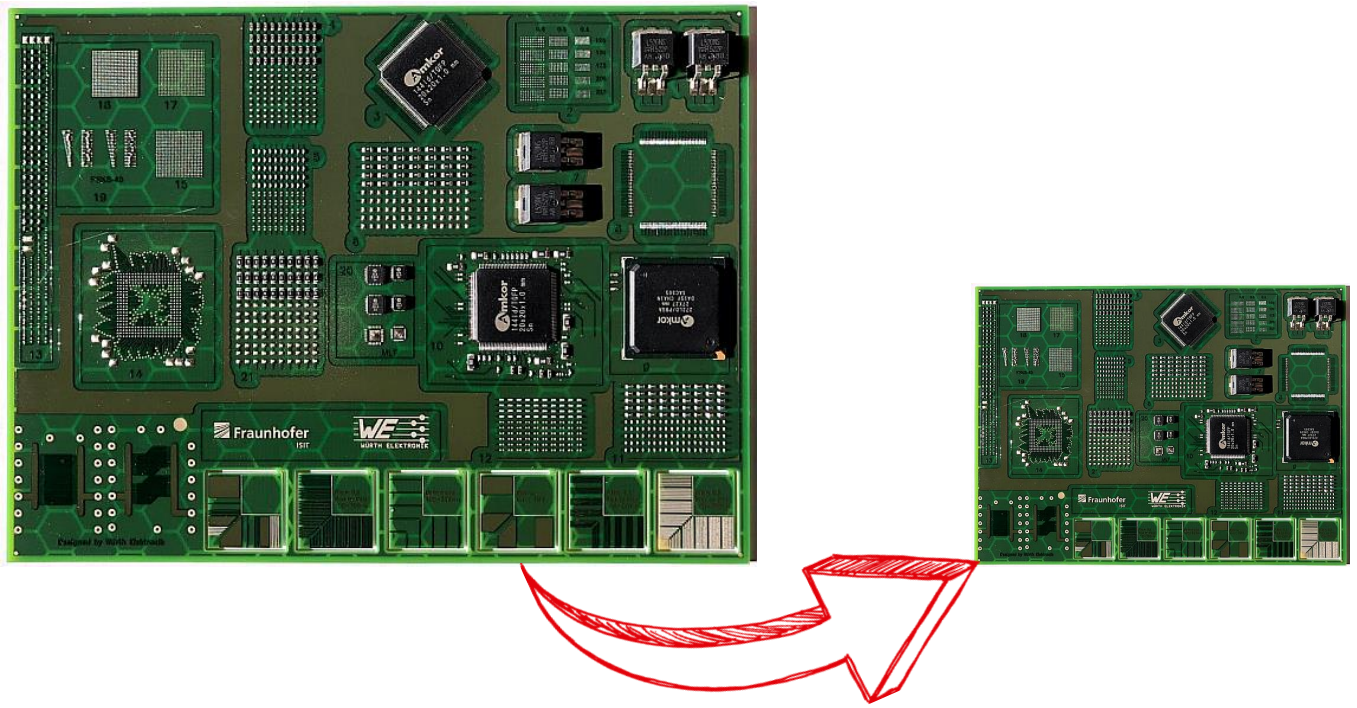
THE SIZE OF THE PRINTED CIRCUIT BOARD

It's all a question of space!

The size of the PCB

- The smaller the PCB, the higher the number of PCBs on the production panel
- Error-proneness vs. yield:
  The smaller the PCBs, the better the yield per PCB, the lower the overhead to serve the desired delivery quantity
- Sustainability:
  The less material used, the smaller the footprint of the LP.



THE PCB ARRAY

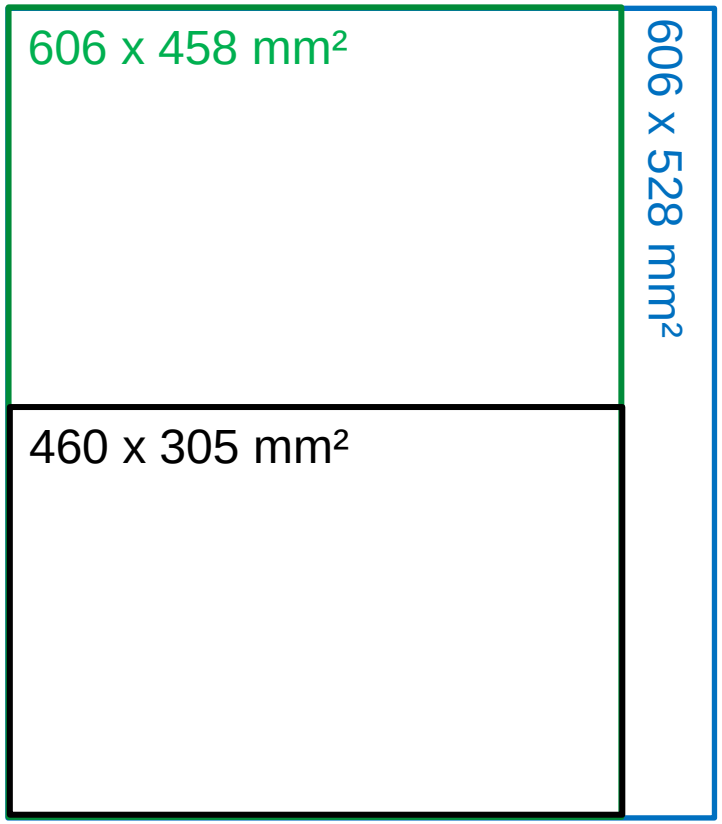
How to utilize and occupy the manufacturing panel properly?

How is the manufacturing panel occupied with PCBs?

Background information:

- PCB materials are manufactured in large panels
  90% of EU and US manufacturers of FR4 uses these formats:
  - US-Format: 1.225 x 925 mm²
  - Uni-Format: 1.225 x 1.070 mm²

- 95% of PCB manufacturers in EU & US
  use these panel formats:
  - 460 x 305 mm² (1/8 US-Format) WE sample format
  - 606 x 458 mm² (1/4 US-Format) WE standard format
  - 606 x 528 mm² (1/4 Uni-Format) WE jumbo format



THE PCB ARRAY

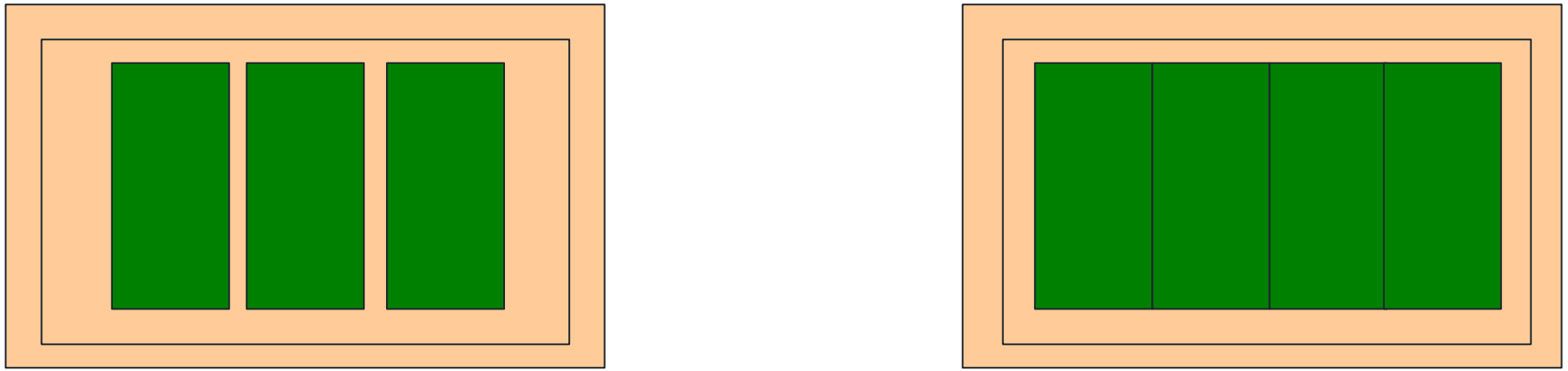
How to utilize and occupy the manufacturing panel properly?

How is the manufacturing panel occupied with PCBs?

- Every PCB manufacturer needs a border for registration and labelling → Non-useable space!

Example: Single PCBs

routing **or** **V-scoring**



In this example: 33% more circuit boards on the production panel

THE PCB ARRAY

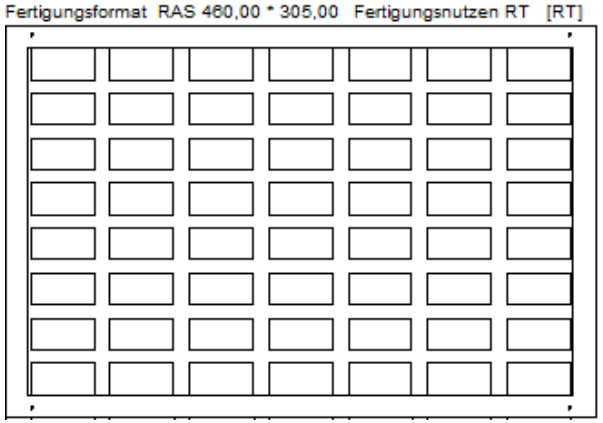
How to utilize and occupy the manufacturing panel properly?

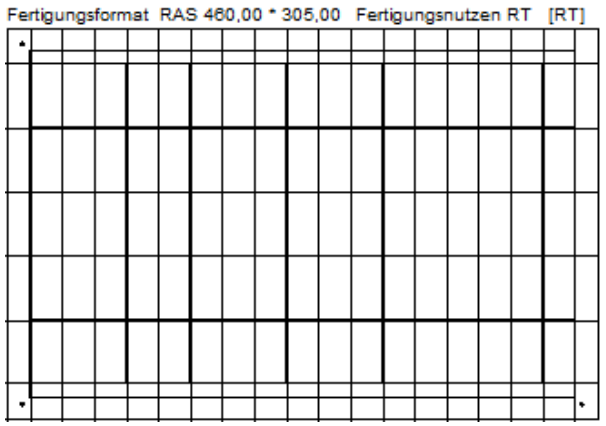
How is the manufacturing panel occupied with PCBs?

- Every PCB manufacturer needs a border for registration and labelling → Non-useable space!

Example: Single PCBs – The smaller the PCB, the greater the effect!

routing **or** **V-scoring**





In this example: 56 PCBs vs. 85 PCBs

THE PCB ARRAY

How to utilize and occupy the manufacturing panel properly?

How is the manufacturing panel occupied with PCBs?

- Every PCB manufacturer needs a border for registration and labelling → Non-useable space!

Example: PCBs in array

routing **or** **V-scoring**

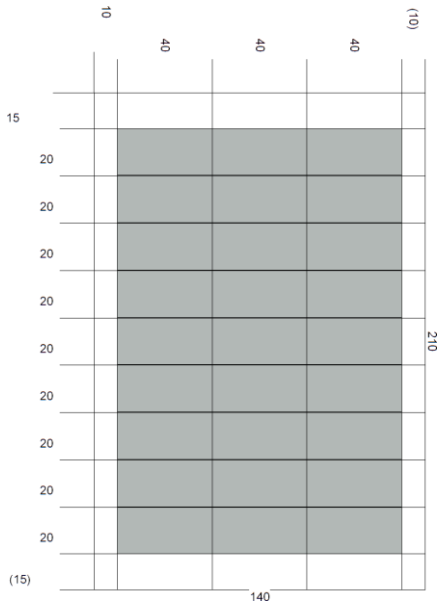
In this example: 100% more circuit boards on the production panel

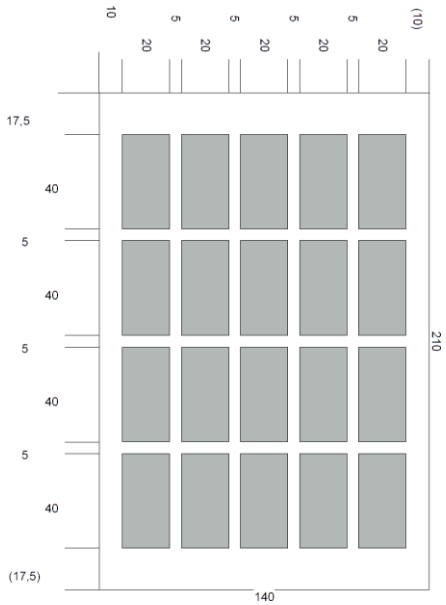
THE PCB ARRAY

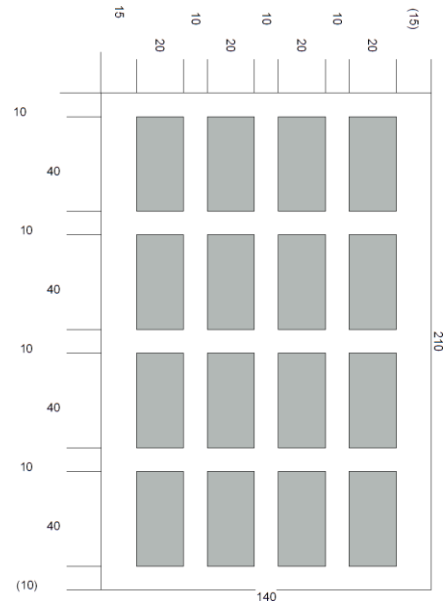
How to utilize and occupy the manufacturing panel properly?

Calculation basis:

- ML6 / Base material T_g150
- PCB size 20 x 40 mm²
- Array size 210 x 140 mm²
- 100 µm L/S
- 500 drills
- 0,20 mm smallest drill-Ø
- ENIG







PCBs on a production panel	**216**	**160**	**128**
Number of production panels (1.000 PCBs ordered)	5	7	8
PCBs in an array	27	20	16
PCB outline	**v-scored**	**routed**	**routed**
PCB distance in array	0,00 mm	5,00 mm	10,00 mm
Price indicator	**100%**	**117%**	**131%**

THE PCB ARRAY

How to utilize and occupy the manufacturing panel properly?

How is the manufacturing panel occupied with PCBs?

WE-Format		Sample format	Standard format	Jumbo format
Technologies		All technologies	Basic, rigid-flex & HDI	Basic & HDI
Plant		Rot am See	Niedernhall	Schopfheim
			Used in Schopfheim for special constructions	Niedernhall on demand
Panel size		460 x 305 mm²	606 x 458 mm²	606 x 528 mm²
Usable area		426 x 271 mm²	572 x 424 mm²	570 x 500 mm²
	Number of arrays	dimensions array		
Best array	1	426 x 271 mm²	572 x 424 mm²	570 x 500 mm²
for	2	271 x 213 mm²	424 x 286 mm²	500 x 285 mm²
v-scored outlines	4	213 x 135 mm²	286 x 212 mm²	285 x 250 mm²
	6	142 x 135 mm²	212 x 190 mm²	250 x 190 mm²
	8	135 x 106 mm²	212 x 143 mm²	250 x 142 mm²
	9	142 x 90 mm²	190 x 141 mm²	190 x 166 mm²
	12	106 x 90 mm²	143 x 141 mm²	166 x 142 mm²
	15	90 x 85 mm²	141 x 114 mm²	166 x 114 mm²

Tipps:

- Edge of array min. 5 mm
- Edge of array 8 - 10 mm for routed outlines
- 2 edges with 5 – 10 mm for v-scored outlines
- Size of array should be based on thickness of PCB (the thinner the smaller)

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DEVELOPMENT OF COPPER PRICE

Role of material price in PCB price

Copper price

Developments on the
London commodity exchange

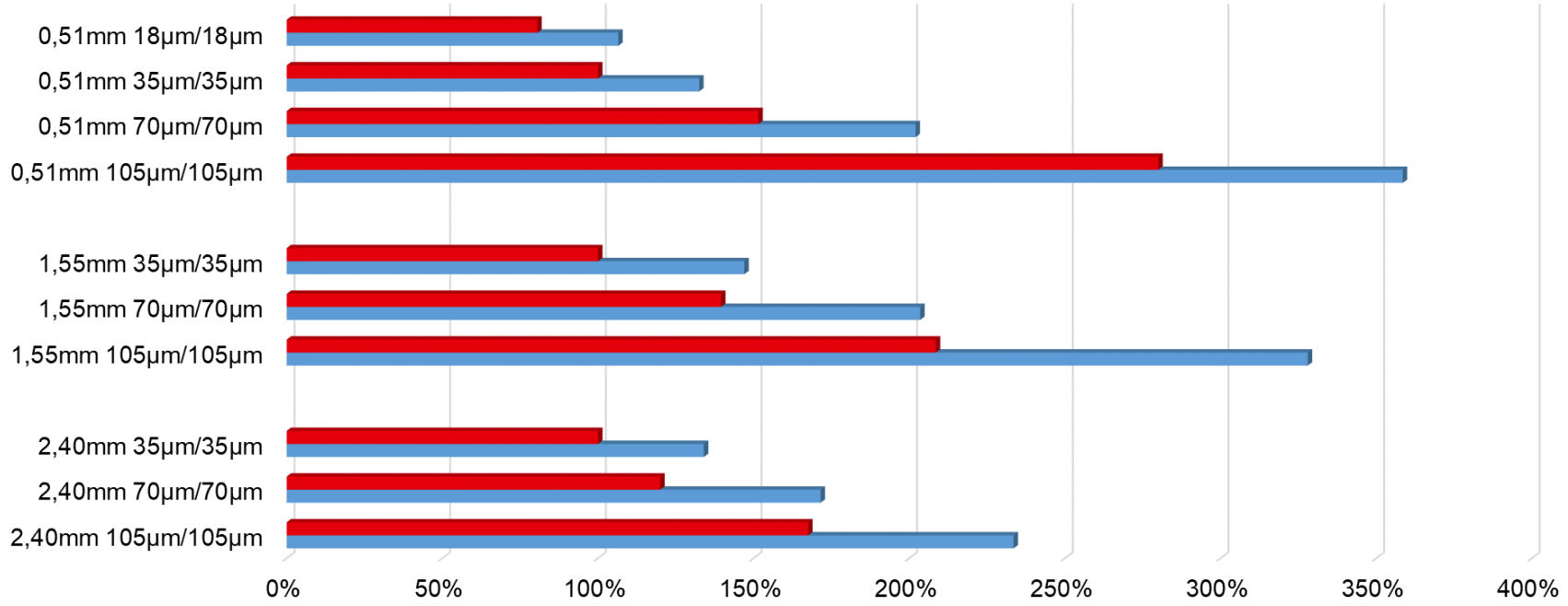
Time period:
Jan. 2016
to
April 2023

Source: http://www.boerse.de – data downloaded on 03.04.2023

DEVELOPMENT OF COPPER PRICE

Role of material price in PCB price

Comparison of material purchasing prices for FR4 (as of July 2020 / as of April 2023)



Comparison per material always with 35 µm copper laminated as 100% basis

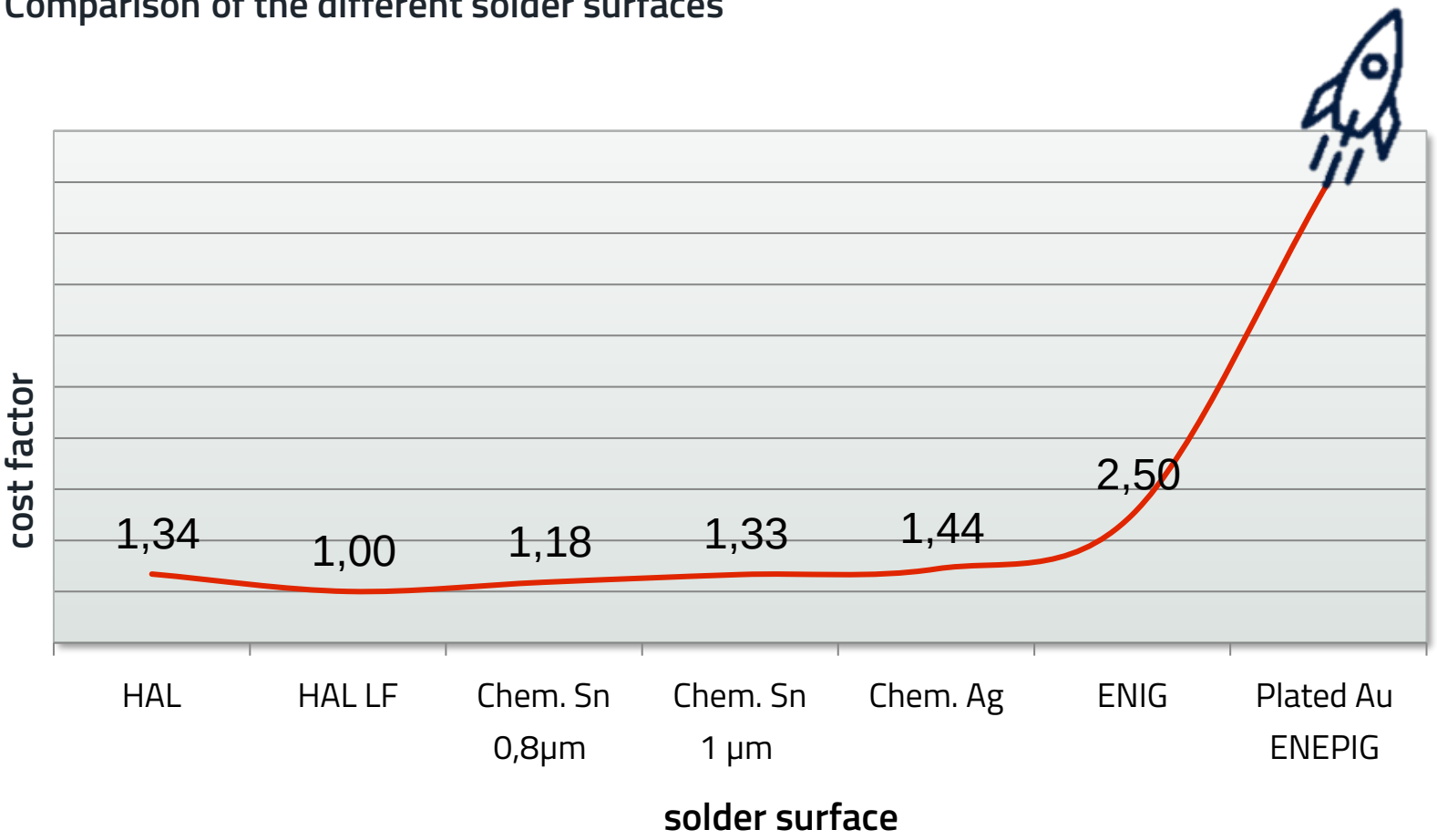
Copper plays an important role in the price of PCBs!

Hence the question: What is necessary **or** what is possible?

MATERIAL PRICE

Role of material price in PCB price

Comparison of the different solder surfaces



ENIG
Ni 5,5µm
Au 0,075µm

Electroplated Au
Ni 4-7µm
Au 1-3 µm
<< Gold 40 times thickness>>

ENEPIG
Ni 4-7µm
Au bis 0,06µm
Pd 0,05 bis 0,25µm
<< Palladium on top >>

MATERIAL PRICE

Role of material price in PCB price

Electroplated Gold

Usage of electroplated Gold

- often used for contacts as an abrasion resistant surface
- mostly selective in combination with ENIG
- with thicknesses up to 4 µm

Price indicator: up to 500% or more (depends on the current price of gold)

Source: http://www.boerse.de – data downloaded on 03.04.2020

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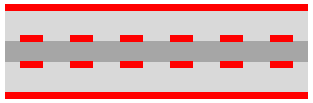
LAYER STACKUP

How does the PCB construction influence the price?

Comparison of a 4-layer multilayer with different thicknesses

- Standard: 1,55 mm / 1,60 mm
- Optimum: 1,00 mm
- Further standards: 0,80mm / 2,00 mm / 2,40 mm

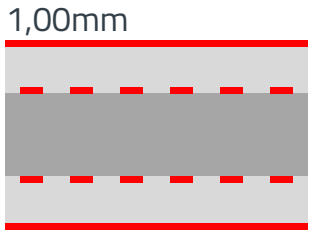


ML4_TG150_0.50_35

1x 0.10mm-035+035

4x prepreg 1080

Price indicator 107%

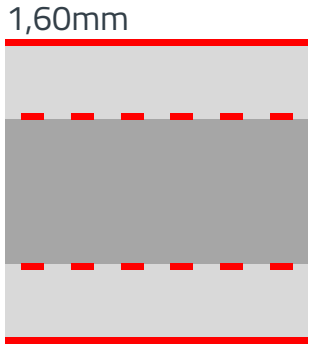


ML4_TG150_1.00_35

1x 0.41mm-035+035

4x prepreg 2116

Price indicator 96%

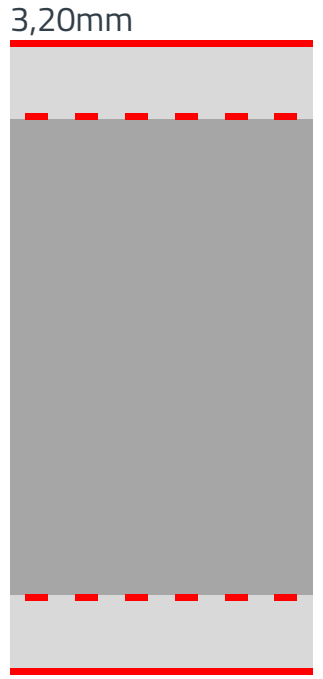


ML4_TG150_1.60_35

1x 0.71mm-035+035

4x prepreg 7628

Price indicator 100%



ML4_TG150_3.20_35

1x 2.40mm-035+035

4x prepreg 7628

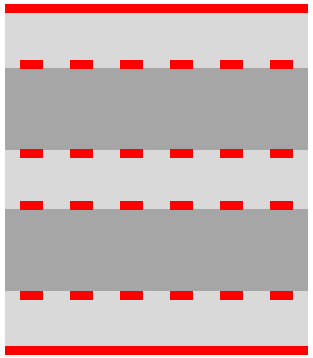
Price indicator 137%

LAYER STACKUP

How does the PCB construction influence the price?

Comparison of a 6-layer multilayer: 1,60 mm standard vs. individual stackup

Standard stackup

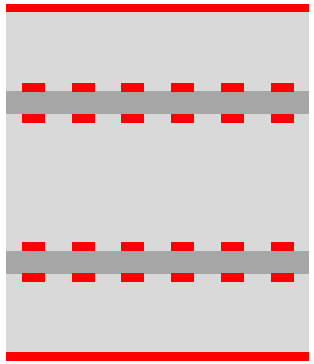


2x 0.36mm-035+035

6x prepreg 2116

Price indicator 100%

Specific stackup



2x 0.10mm-035+035

2x prepreg 2116

8x prepreg 7628

Price indicator 116%

Additional costs:

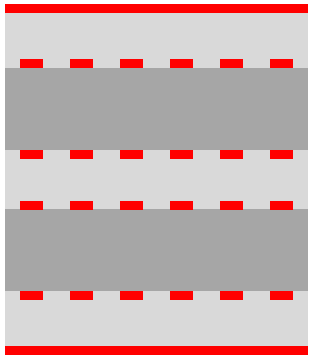
- Handling of thin laminate
- 4 prepregs more in stackup

LAYER STACKUP

How does the PCB construction influence the price?

Comparison of a 6-layer multilayer: 1,60 mm standard vs. individual stackup

Standard stackup

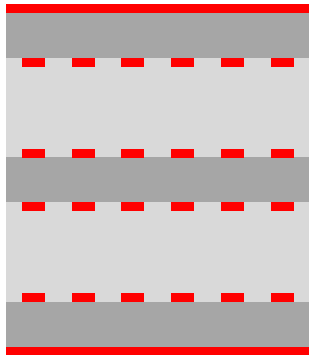


2x 0.36mm-035+035

6x prepreg 2116

Price indicator 100%

Core-based stackup



3x 0.20mm-035+035

4x prepreg 2116

2x prepreg 7628

Price indicator 122%

Additional cost:

- Multiple exposures of the outer layer cores (processed like an 8-layer PCB)
- More cores

Further cost drivers

- Filling cores in stackup

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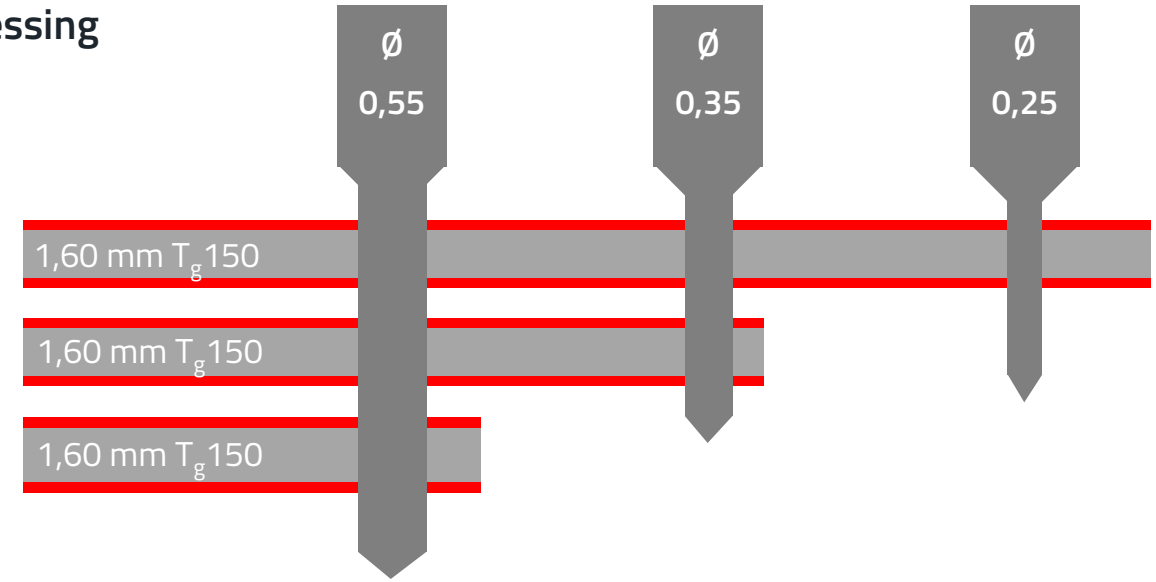
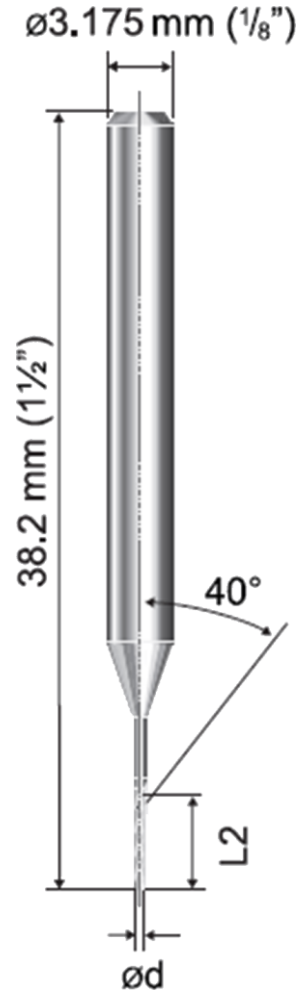
MECHANICAL PROCESSING

Which influence do the drilling tools have on the PCB costs?

Panel stacking for mechanical processing

using „via drilling“ as an example





Tool life Panel stacking	1.250 strokes stack of 3	1.000 strokes stack of 2	500 strokes stack of 1
Time to drill 15.000 vias	0,2 h	0,4 h	0,8 h
Usage of drill bits for15.000 vias	4	7,5	30
Price indicator (drilling process only)	**100%**	**200%**	**460%**

MECHANICAL PROCESSING

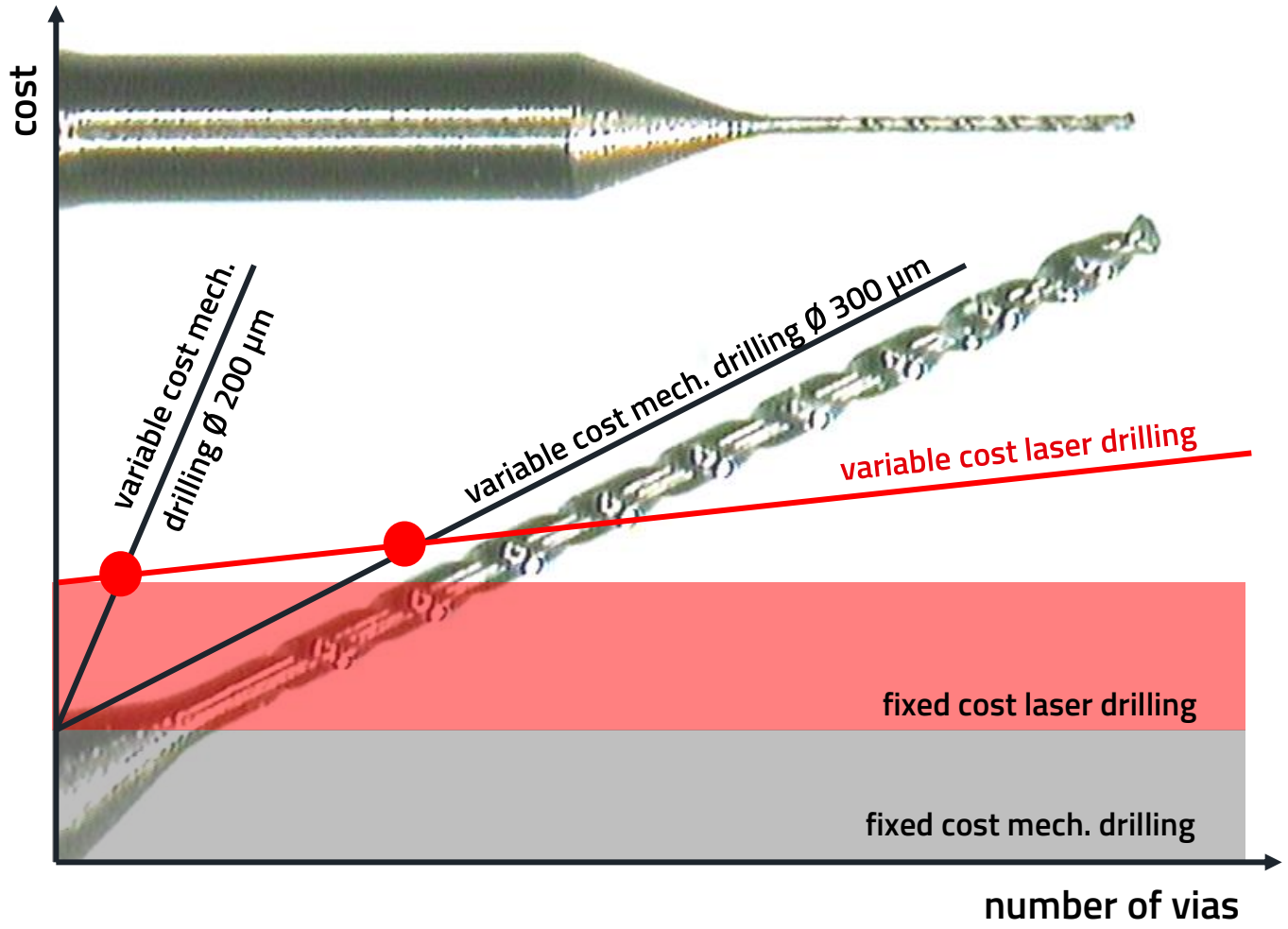
Which influence do the drilling tools have on the PCB costs?

Comparison:

Ø 0,5 mm, Ø 0,35 mm und Ø 0,25 mm drill bits on 5 mm x 5 mm checkered paper

MECHANICAL PROCESSING

Which influence do the drilling tools have on the PCB costs?



Ø 0,2 mm (0,55 € per bit)
Tool life: 750 strokes
Drilling frequency: 3 / s

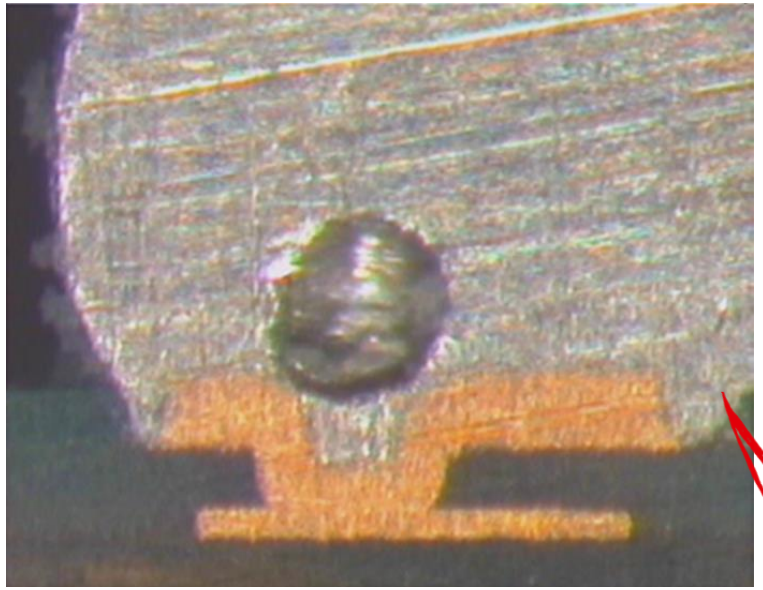
Ø 0,3 mm (0,50 € per bit)
Tool life: 1.000 strokes
Drilling frequency: max. 8 / s

Microvia
Ø 0,125 mm
Drilling frequency: 150–180 / s

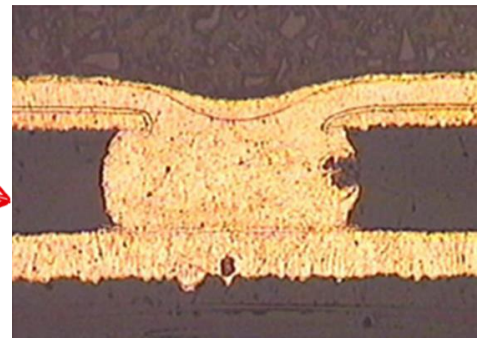
MECHANICAL PROCESSING

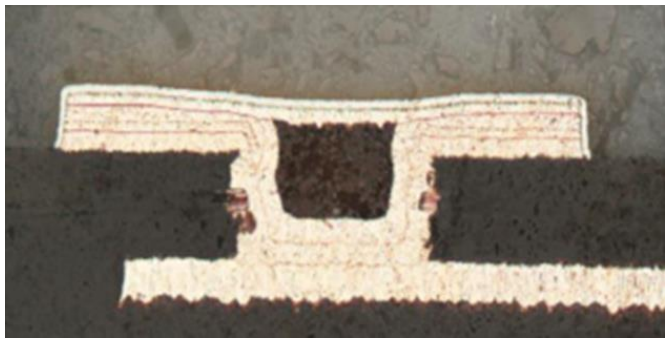
Copper- or resin-filled Microvias

Filling of Microvias or not? This is the question here!



filling





IPC-7095C – Table A-3 – Class III:
Max. „22% of the image diameter“

The formation of voids depends, among other things, on:

- Flux / solder paste
- Temperature profile of the solder process
- Uniform heating or through-heating of the circuit board

Every user has to define for himself how to manufacture!

MECHANICAL PROCESSING

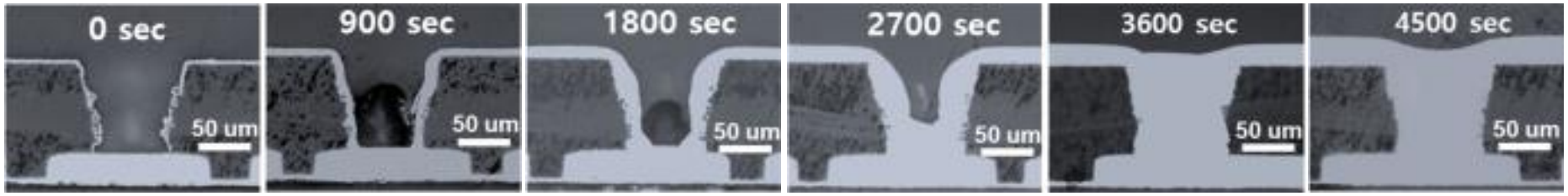
Copper-filled Microvias

Sequence Cu-filling process (Source//publication: MacDermid Enthone Electronic Solutions / 2018)

(1) (2) (3) (4)

- Wetter/Suppressor — Molecules occupy the surface and block the deposition of Cu
- Leveler — Molecules accumulate at the location of the highest current density and block the deposition of Cu
- Brightener — Brightener for the reduction of Cu crystal sizes

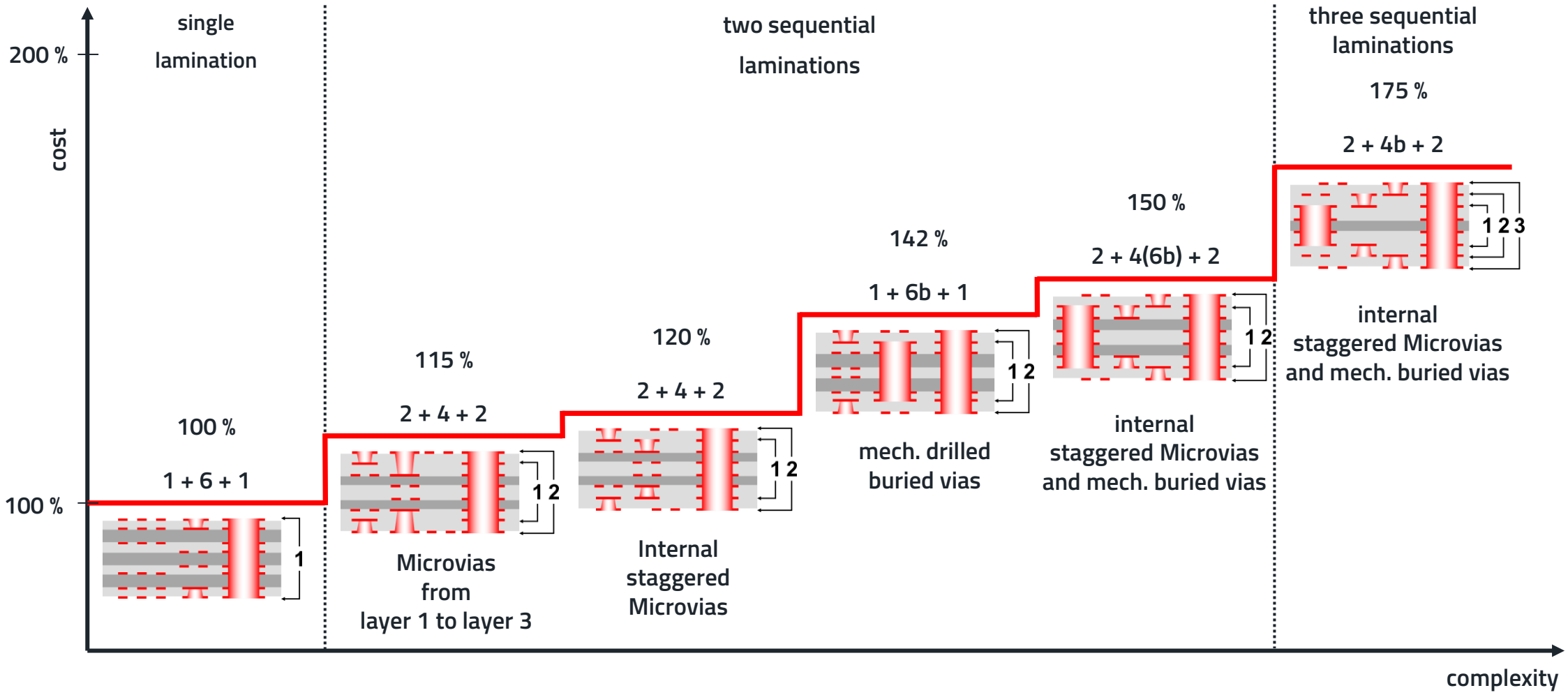
Time sequence (Source/publication: KAIST / 2019)



Process takes factor 2-3 longer compared to standard

MECHANICAL PROCESSING

What influence does the HDI layer construction have?

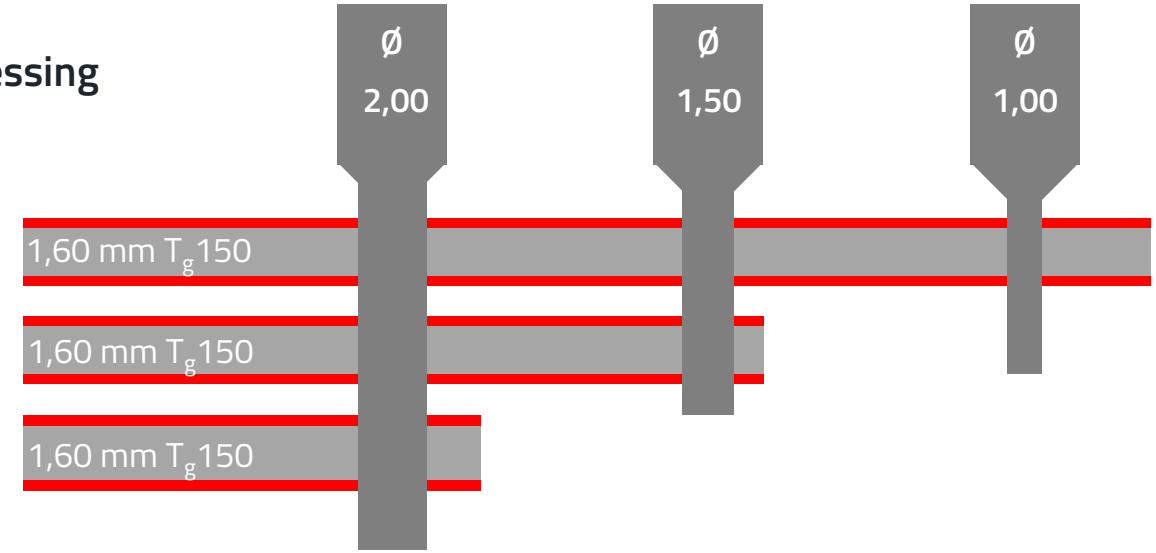


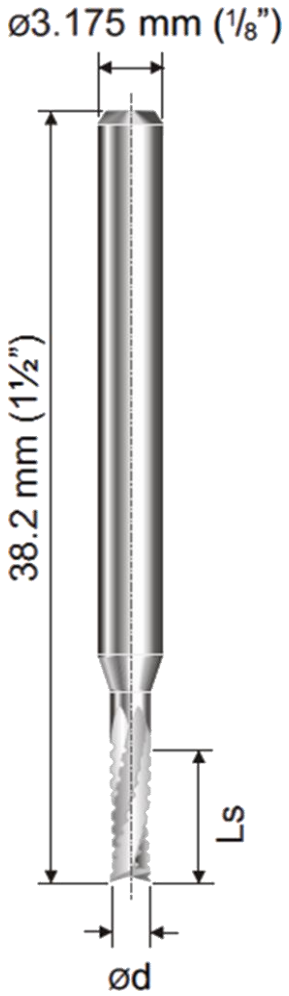
MECHANICAL PROCESSING

Which influence do the routing tools have on the PCB costs?

Panel stacking for mechanical processing

using „routing“ as an example





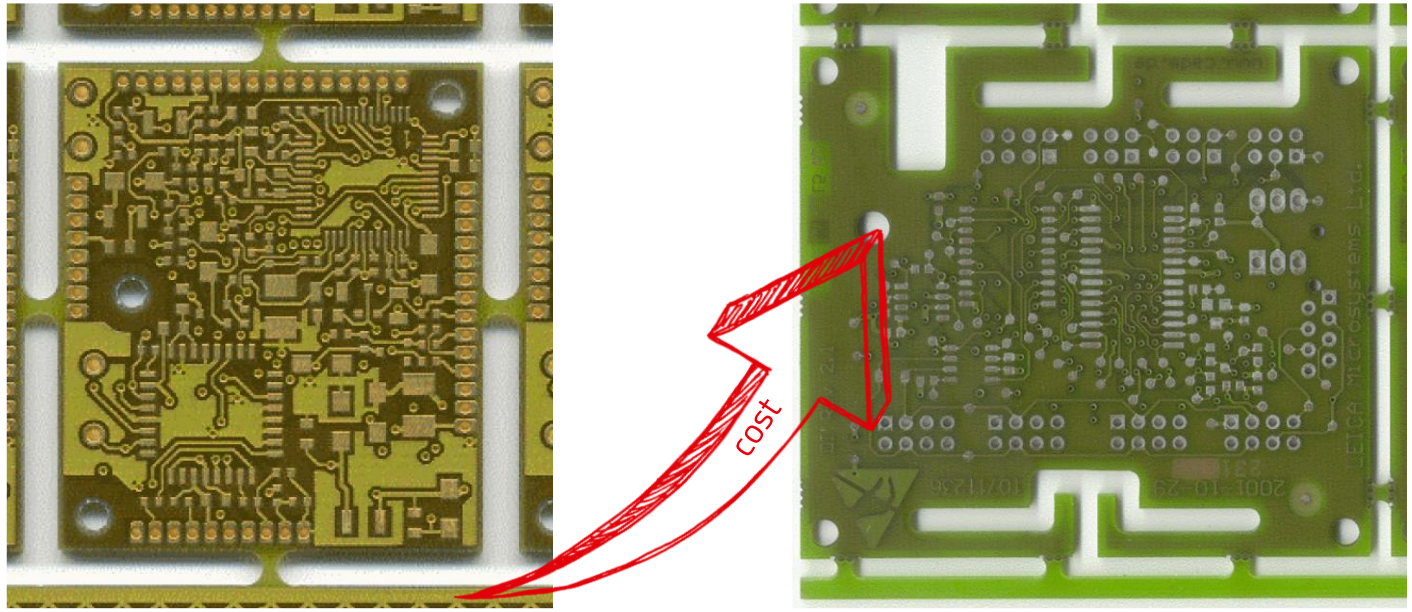
Tool life	15 m	5 m	3 m
Panel stacking	stack of 3	stack of 2	stack of 1
Tools for 100 PCBs with 0,5m routing path	1,1	5	16,7
Feed	1,2 m/min	0,7 m/min	0,3 m/min
Time to route 100 PCBs with 0,5m routing path	0,2 h	0,6 h	2,8 h
Price indicator (routing process only)	**100%**	**270%**	**1200%**

MECHANICAL PROCESSING

What else has an influence on the price of PCBs?

Routing contours

Complex routing contours
can lengthen the routing paths and
have a negative influence on the
routing tool diameter



Standard routing contour

- 4x change in direction
- routing tool 2,4 mm

Complex routing contour

- approx. 30x change in direction
- high routing time
- routing tool 1,8 mm

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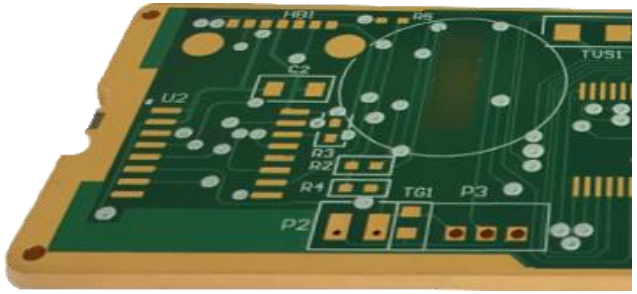
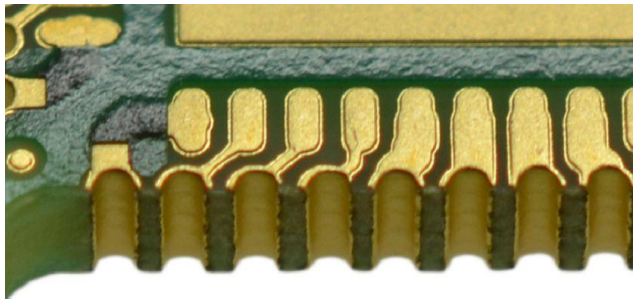
ENHANCED TECHNOLOGIES

What else has an influence on the price of PCBs?

Further cost drivers!

- PCB thickness / layer count
  → not only relevant for drilling & routing…
- Number of laminations
- Edge plating / side plating
- Castellated holes / Castellation





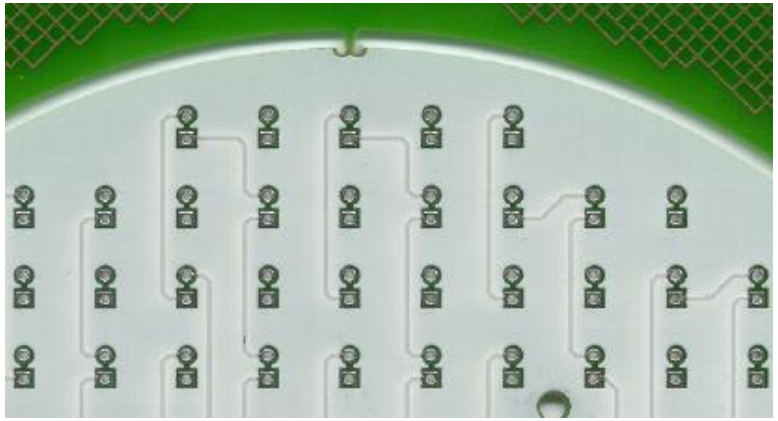
ENHANCED TECHNOLOGIES

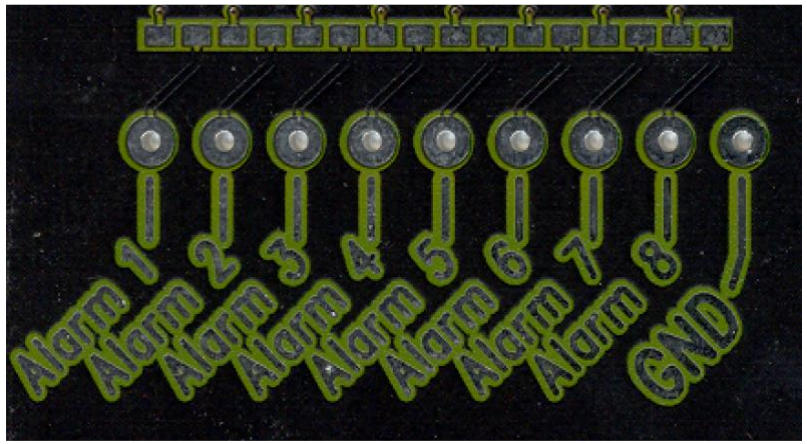
What else has an influence on the price of PCBs?

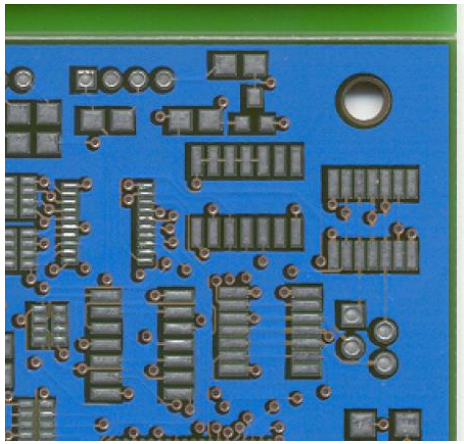
Further cost drivers!

- Coloured solder resists
  - White / black / red / blue
  - The problem: demand extremely low
  - Question: Does it always have to be solder resist - or is it sufficient to mark PCBs with a coloured legend printing (e.g. additional red/yellow for prototypes / samples without series approval)

- Legend printing
  - How small must be printed? Danger: printing onto pads



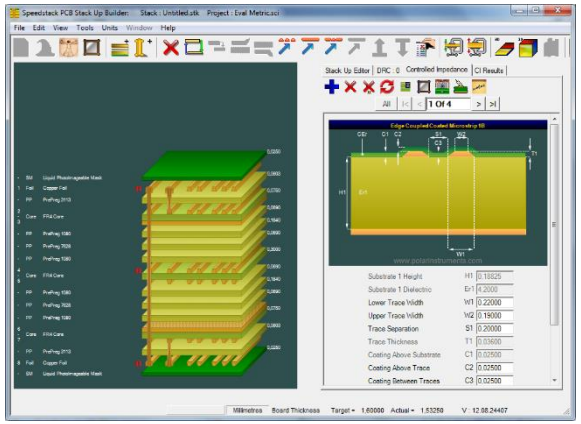


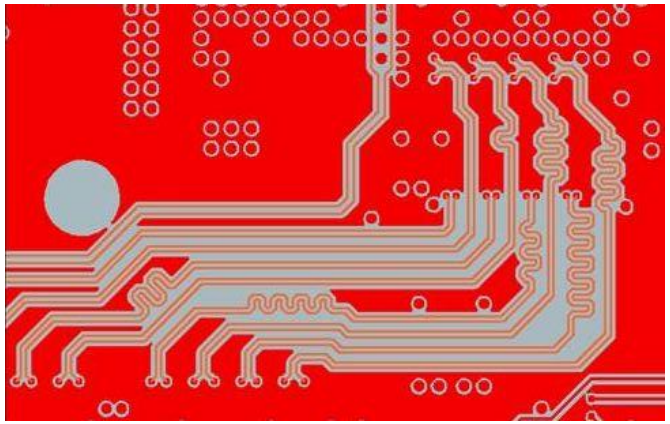


ENHANCED TECHNOLOGIES

What else has an influence on the price of PCBs?

Required or needed impedances





- Impedance watching / controlled dielectric
  - Calculated stackup and tracks, no TDR coupons

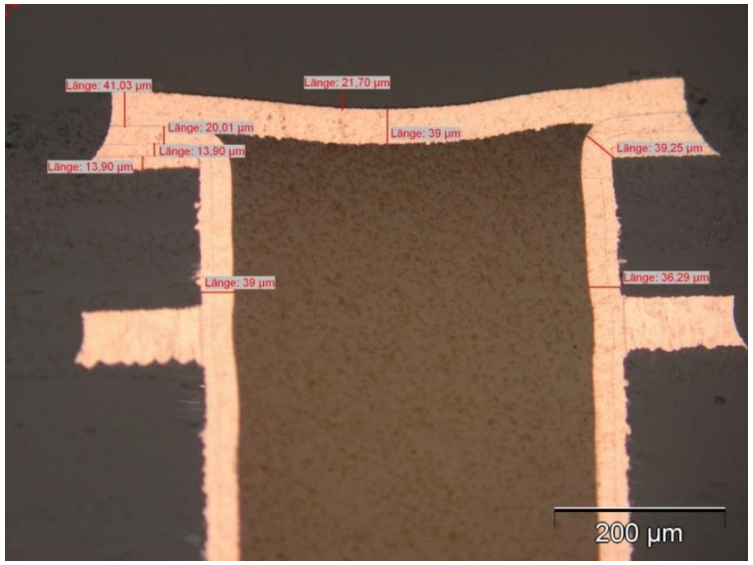
- Impedance control
  - additional TDR coupon (or coupons) on manufacturing panel
  - reduced number of PCBS on manufacturing panel

ENHANCED TECHNOLOGIES

What else has an influence on the price of PCBs?

Filled and Capped Via (IPC 4761 – Type VII Via)

Via filled with resin and over-plated with Cu



Necessary or to be avoid

with intelligent design?

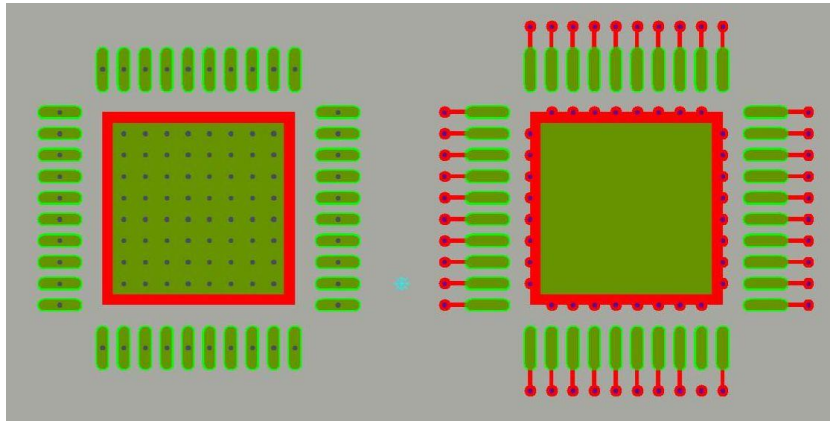
usage:

e.g.

cooling areas

vias in solder pads

vacuum tightness



ENHANCED TECHNOLOGIES

What else has an influence on the price of PCBs?

Request: IPC Class 3

The requirement of 25µm copper in the barrel is often mistaken with the requirement of IPC Class 3 production:

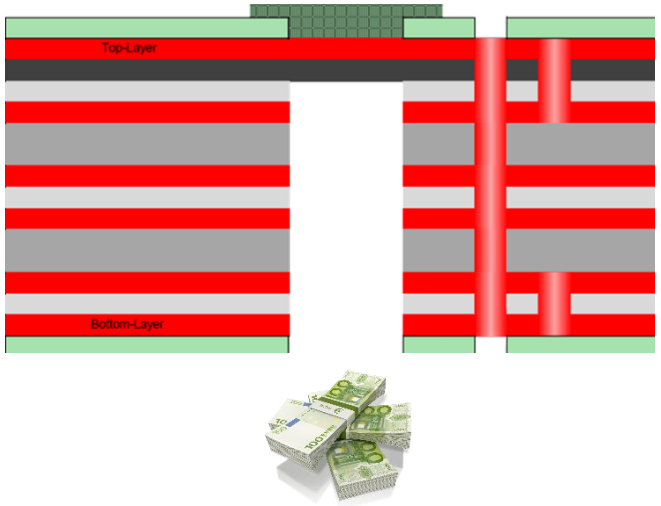
- 25µm barrel copper is only a part of the requirement of IPC Class 3

- Tougher test criteria in accordance with IPC Class 3 lead to
  - a lower yield
  - less space on the production panel due to more coupons
  - higher inspection effort, e.g. evaluation of several coupons to check the "inner values"
  - higher price!

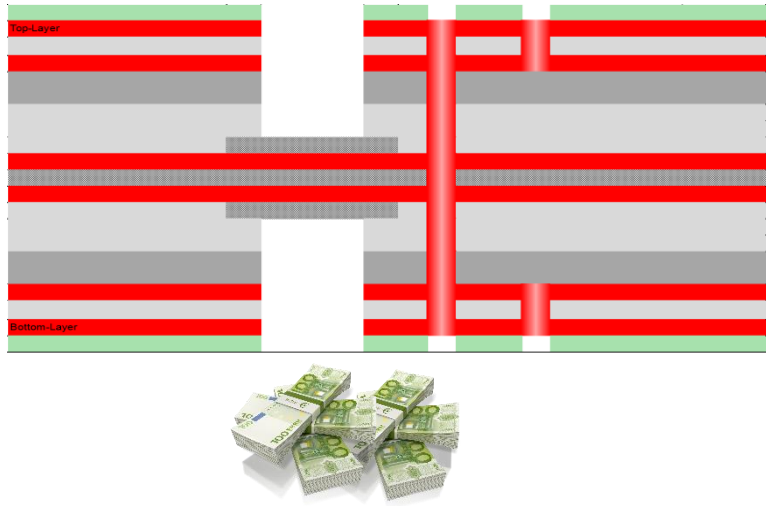
ENHANCED TECHNOLOGIES

How about rigid-flex stackups?

Flex-Rigid 1F-5Ri / HDI 1-4-1



Flex-Rigid 2Ri-2F-2Ri / HDI 1-4-1



- Single sided vs. double sided effort for mechanical depth milling
- Huge price differences for the flex material: copper on one or both sides
- Screen-printed flexible solder resist is cheaper than routed and laminated coverlay
- For higher reliability with xRi-2F-xRi: Partial coverlay (Bikini coverlay) required

AGENDA

How does your PCB layout influence the costs in PCB manufacturing?

1. PCB size and arrays
2. Copper price development and choice of materials
3. PCB stackup
4. Mechanical processing
5. Enhanced Technologies
6. More tips & tricks
7. Summary

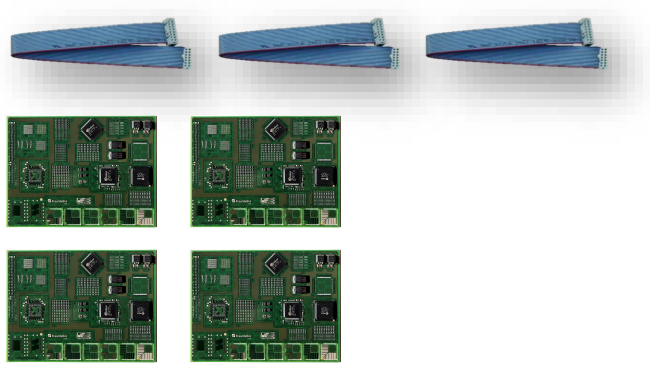
MORE TIPS & TRICKS

Complexity

Total Cost of Ownership / System costs using the example of a system with 4 PCBs

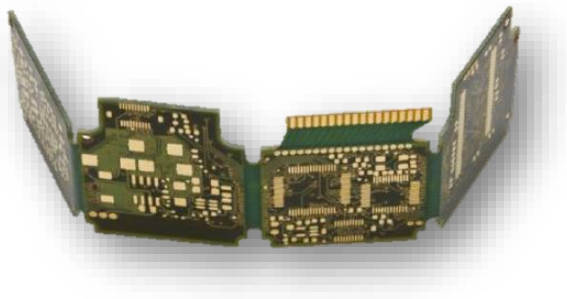
Rigid PCBs with connectors

- 4 layouts
- handling of 7 parts
- min. 4 soldering processes
- min. 4 test runs
- logistics for 7 parts



Rigid-flex PCB

- 1 layout
- handling of 1 part
- min. 1 soldering process
- min. 1 test run
- logistics for 1 part



Profit

- Only one layout routing logic
- No uneven quantities of parts in storage
- Less set-up time during assembly
- Less time spent in testing
- Logistics and handling simplified in complexity

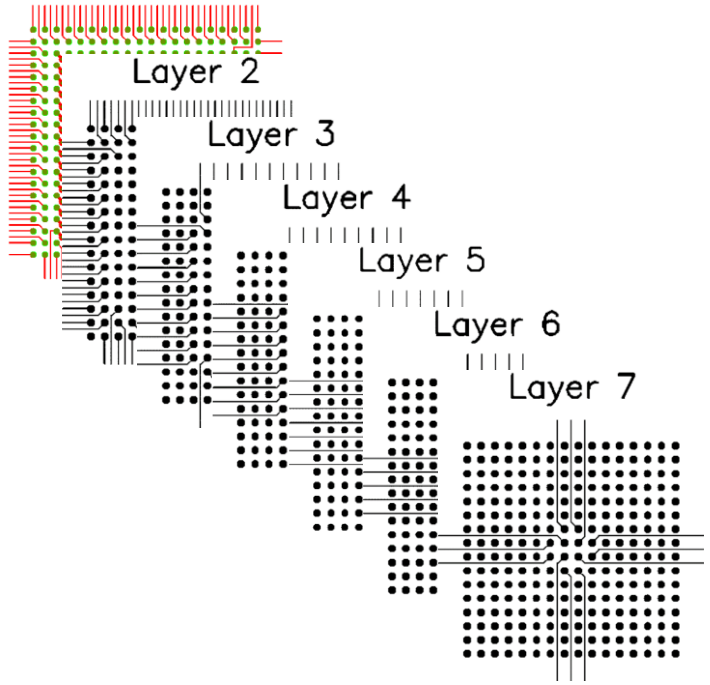
MORE TIPS & TRICKS

Reduce prejudices!

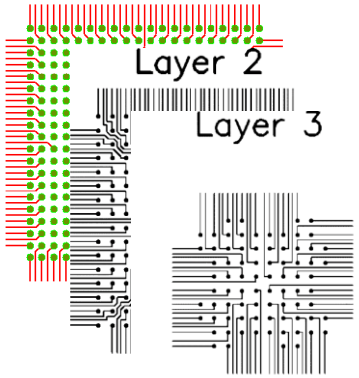
An HDI PCB is too expensive! IS that right? Fact check!

Fact 1 – Fan-out | Based on BGA with Pitch 0,8mm / 400 Pins / 10 rows

- Plated Through Holes



- HDI-Microvia

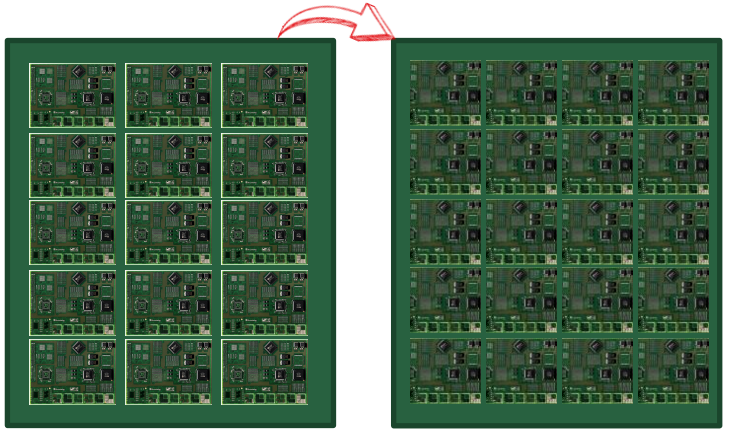


- By using Microvias, the number of fan-out layers required can be significantly reduced

Fact 2

By using Microvias, the LP size can usually be reduced by 10-20%

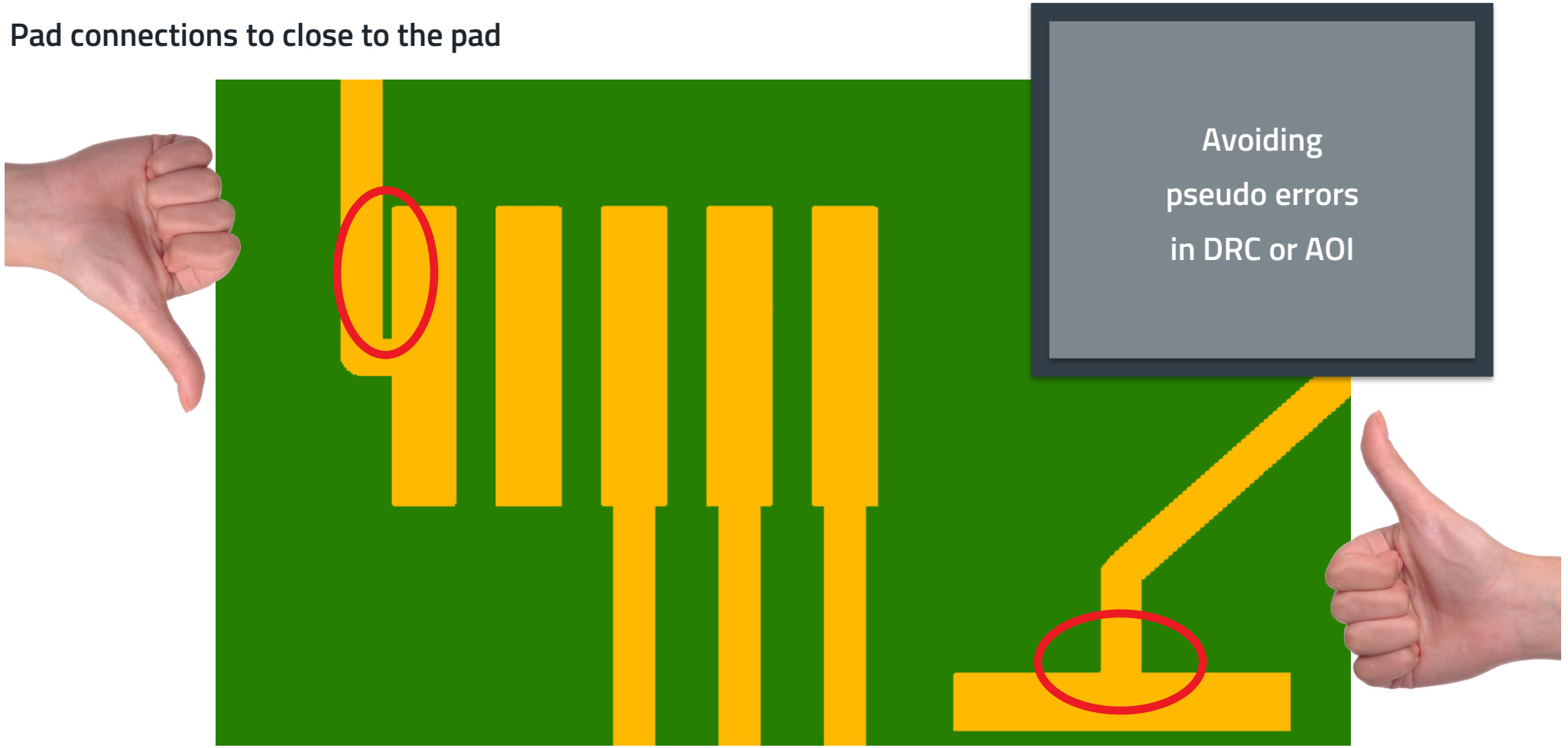
⇨ More PCBs on a production panel



MORE TIPS & TRICKS

Error prevention

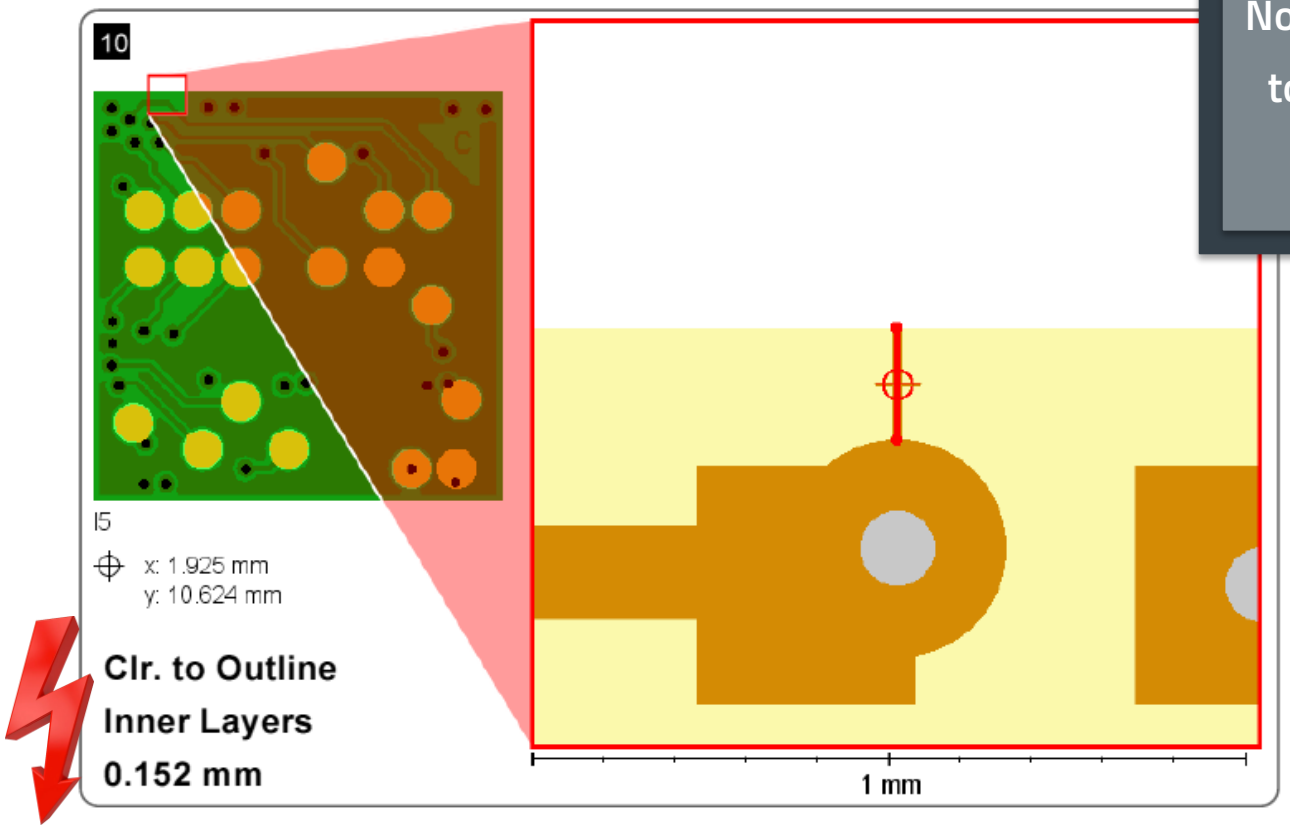
Pad connections to close to the pad



MORE TIPS & TRICKS

Error prevention

Clearance to outline of planes, lines and holes incl. pads



Follow the
design rules!
Non-compliance often leads
to non- manufacturability
or at least higher costs!

MORE TIPS & TRICKS

Special processes

Special request in packaging

Manufacturing

- Double-sided PCB semi-circular

- 198 PCBs per production panel
- Order quantity: 2.600 PCBs
  ⇨ 14 production panel

First packaging unit

- 4 PCBs on top of each other

- Fixed by hand with an adhesive strip

Second packaging unit

- 10 packages of the first unit

- Dimensions of base carton exactly specified

Result: 10 hours of packaging effort

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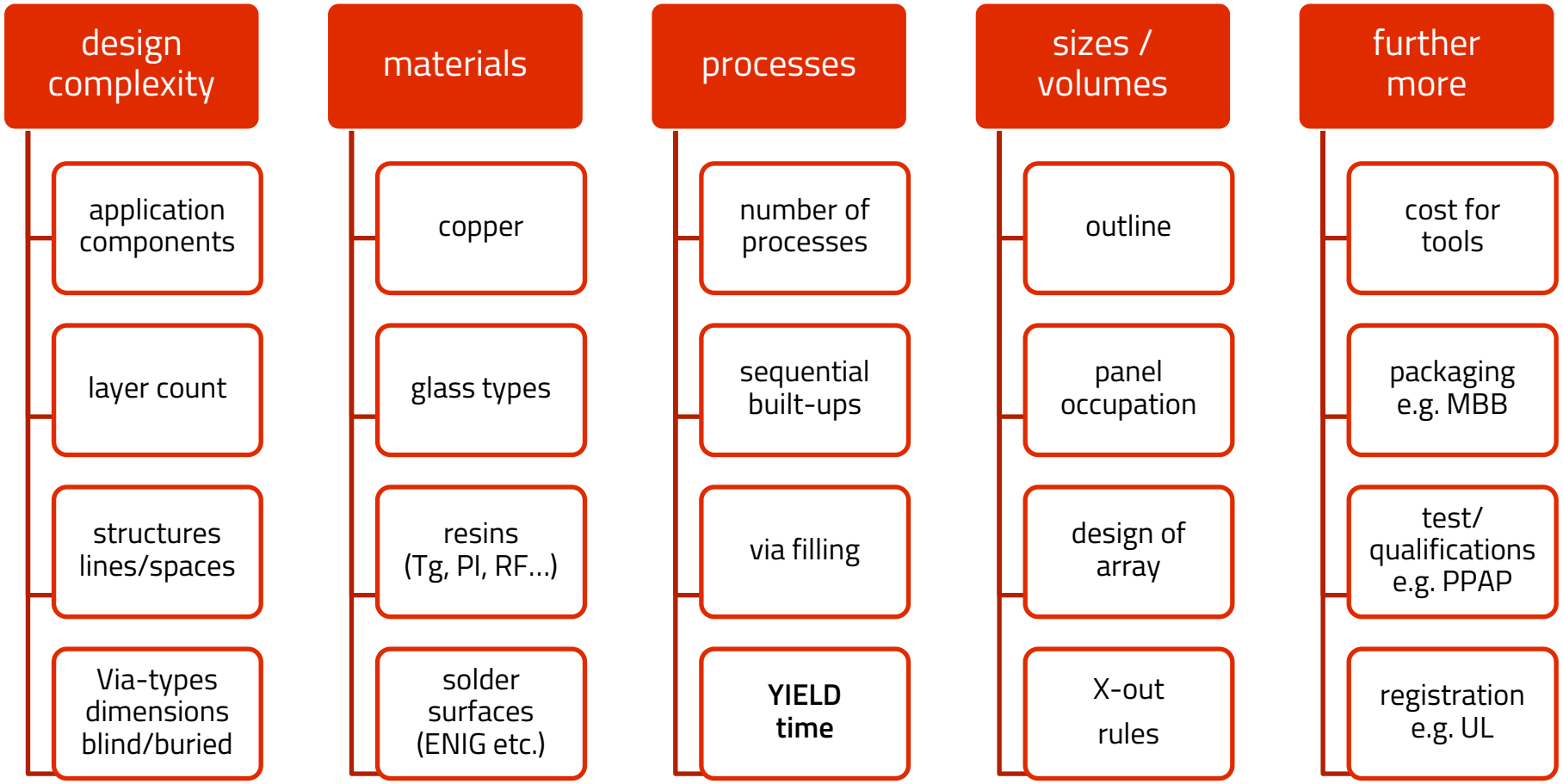
HOW DOES YOUR PCB LAYOUT INFLUENCE THE COSTS IN PCB MANUFACTURING

Things to consider when manufacturing PCBs:



THANK YOU VERY MUCH FOR YOUR ATTENTION!

What kind of Application do you have?
How can WE support You ?

Contact:
Würth Elektronik GmbH & Co. KG
Advanced Solutions Center
+49 7940 946-1234
asc@we-online.com