The Proportional Land Dimensioning Concept

Rainer Taube

TAUBE ELECTRONIC GmbH/FED

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- Current Calculation Concepts
- Risks
- Terminal Types
- The Proportional Concept
- The FED Verification Project

Why do we need a new Calculation Concept for SMT-Landpattern?

Previously

IPC-782

Publication	03/87
Rev. A	08/93
AM 1	10/96
AM 2	04/99

Tolerances were added
F-Tol = 0.2mm P-Tol = 0.2mm

Solder joint strength is greatly determined by solder volume.

The more solder
the more reliable Solder Joint

Current IEC

IEC-61188-5-xx

Publication 2002
no Revision till now
Stability Date 2020

Complies mostly with IPC-782A inclusive of AM 1 and AM 2

Implementation of 3-tier System Maximum - Median - Minimum

Assumption: The more solder the more reliable solder joint

Current IPC

IPC-7351

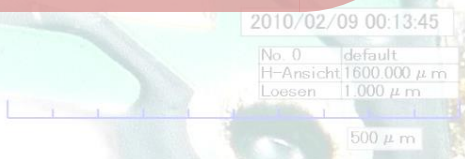
Publication	02/05
Rev. A	02/07
Rev. B	06/10

Rev. C in progress

Further Development of IPC-782
Implementation of Density Level

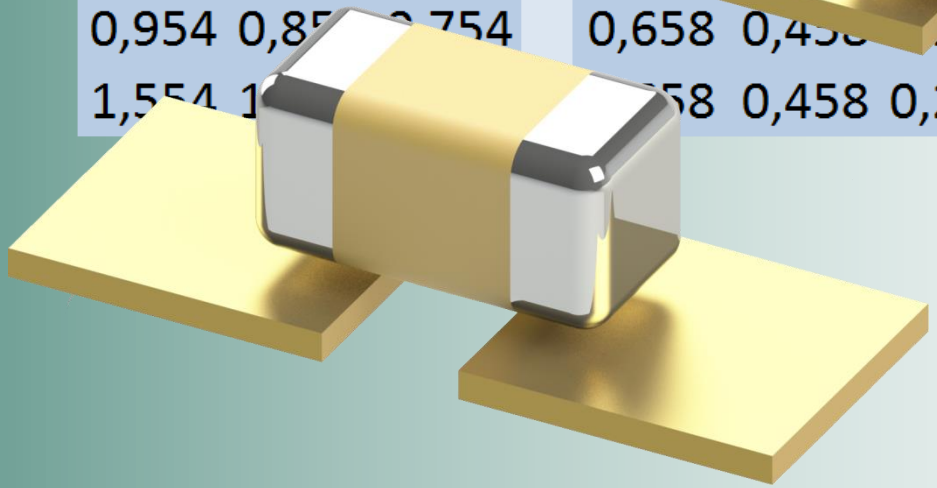
Combination with PCB Libraries
Landpattern Calculator

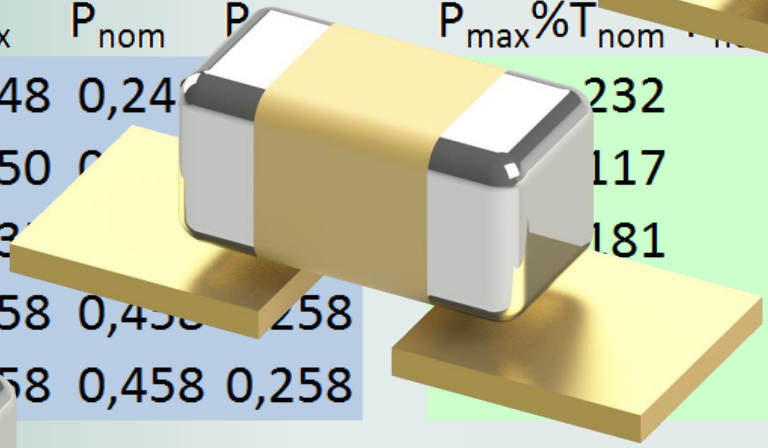
Reduced Tolerances
F-Tol = 0.1mm P-Tol = 0.05mm

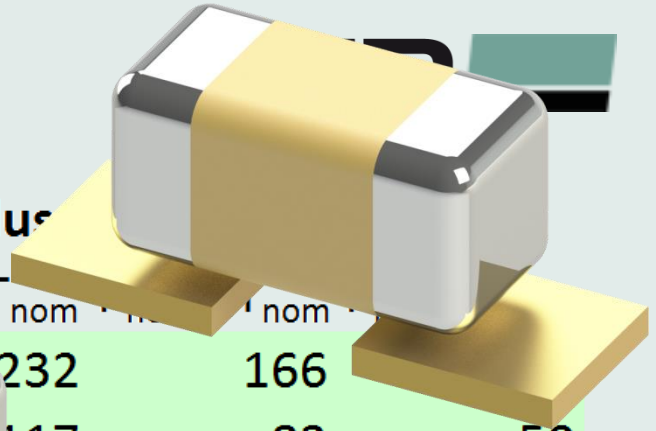


Examples of the 3-tier concept

Pad Center			Protrusion			Anschlu		
$c/2_{max}$	$c/2_{nom}$	$c/2_{min}$	P_{max}	P_{nom}	P	P_{max} %T_{nom}		$_{nom}$
0,370	0,320	0,270	0,348	0,24		232	166	
0,482	0,432	0,382	0,350			117	83	50
0,855	0,755	0,655	0,63			181	124	67
0,954	0,85	754	0,658	0,45	258		92	52
1,554	1		658	0,458	0,258		92	52

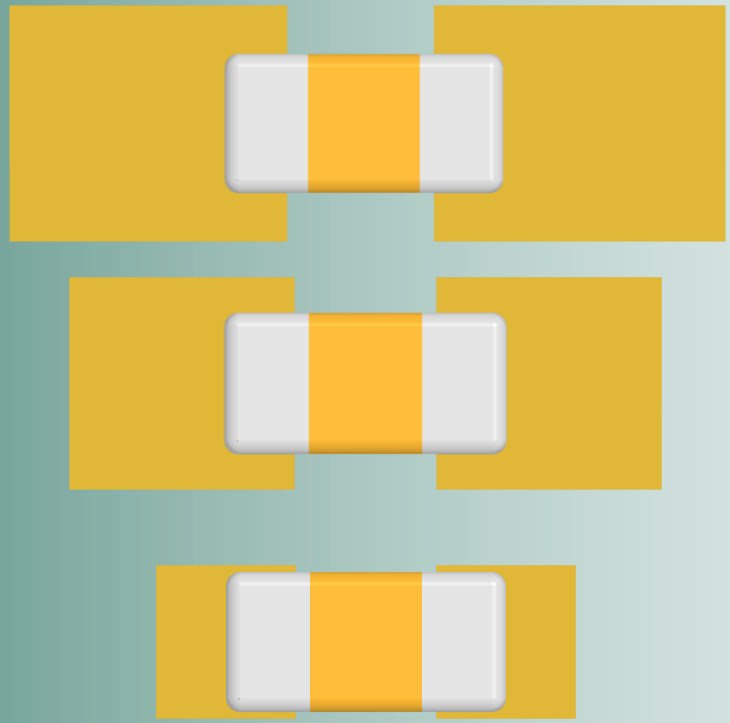




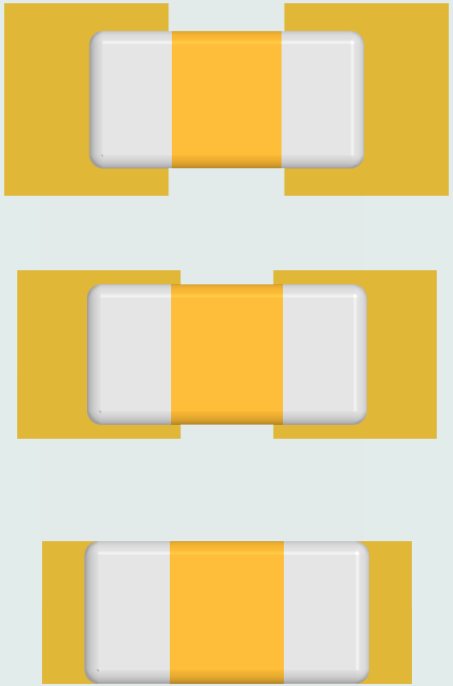


Comparison IEC ⇔ IPC

IEC 61188-5-2

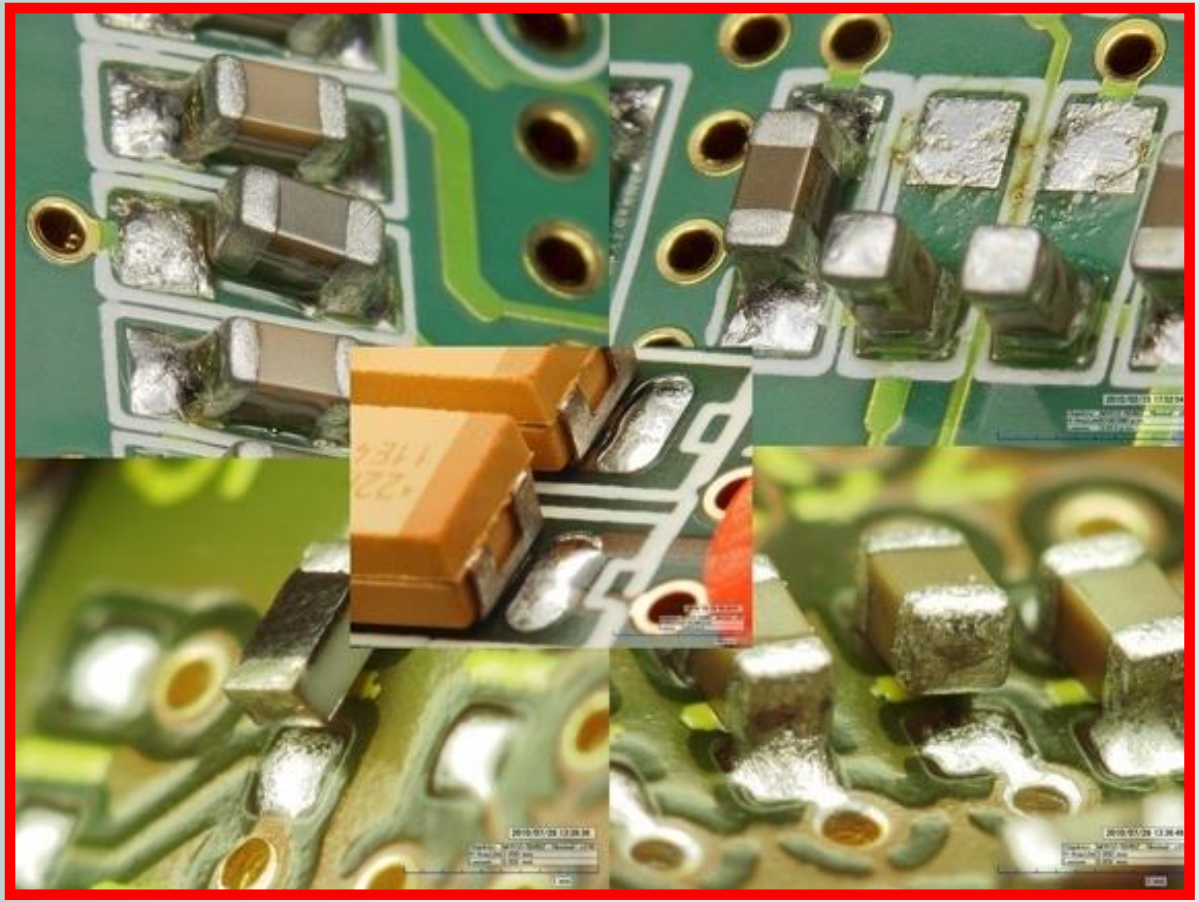


IPC 7351B

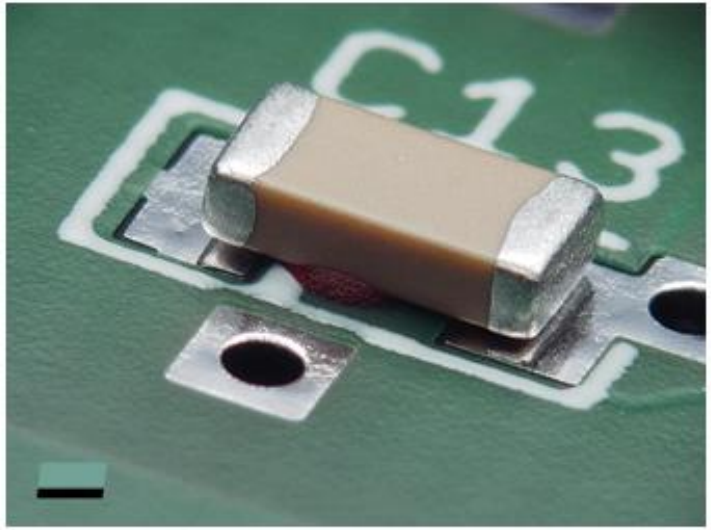


Consequences

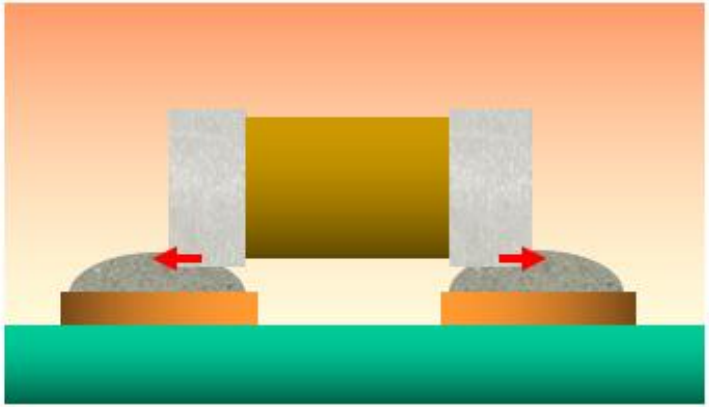
- Twisting
- Shifting
- Tombstoning
- Open Solder Joints
- Trailers



Reflow versus Wave Solering



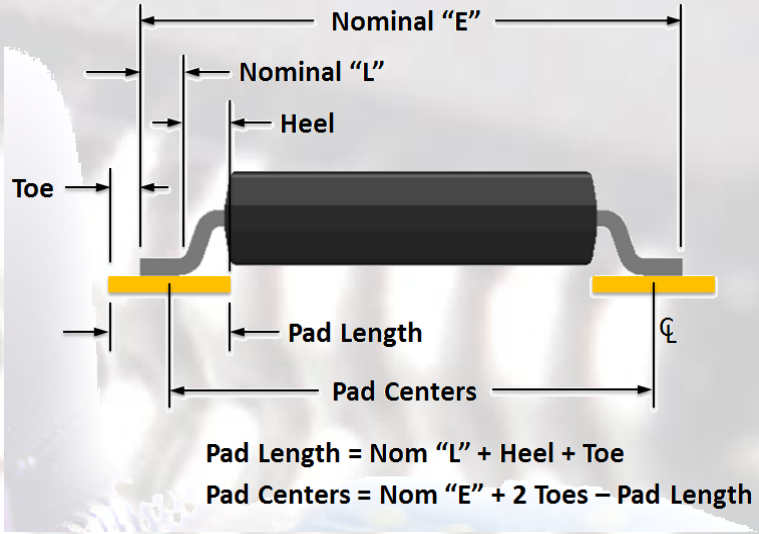
No movement possible during soldering
Max. landsize not critical
Min. landsize critical
Nearly unlimited volume of solder



Risk of movement during soldering
Max and min landsize critical
Limited solder volume

Gullwing Pitch

Pitch	Package Example
1.27mm	SO-08, SO-14, SO-16 etc.
1.00mm	QFP
0.80mm	TQFP-44
0.65mm	TSSOP-16
0.50mm	MSOP-10
0.40mm	TQFP-100



Gullwing Solder Joint

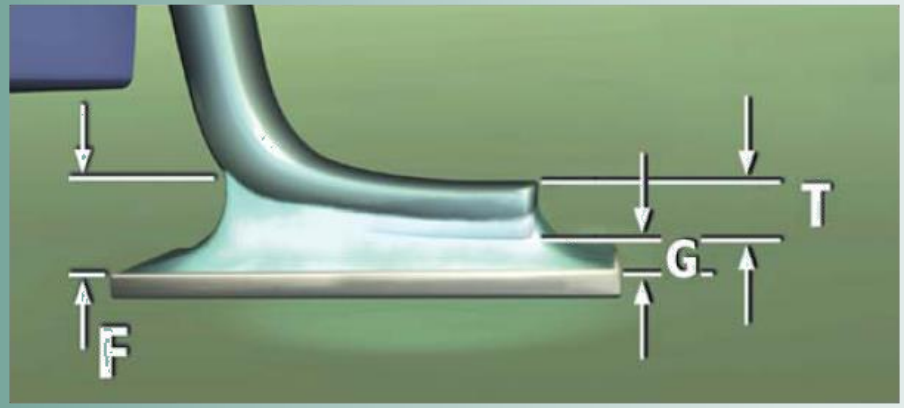


Figure 8-102

Acceptable – Class 3

- Minimum heel fillet height (F) is equal to solder thickness (G) plus lead thickness (T) at connection side.

A good heel fillet equals a wetting angle of approximately 45°
Toe of terminal mostly is not wettable, no solder joint requirement
Heel fillet is most important for reliablity
Thus heel protrusion should be more than toe protrusion

IPC-7351 Gullwing Tables

Table 3-2 Flat Ribbon L and Gull-Wing Leads (greater than 0.625 mm pitch) (unit: mm)

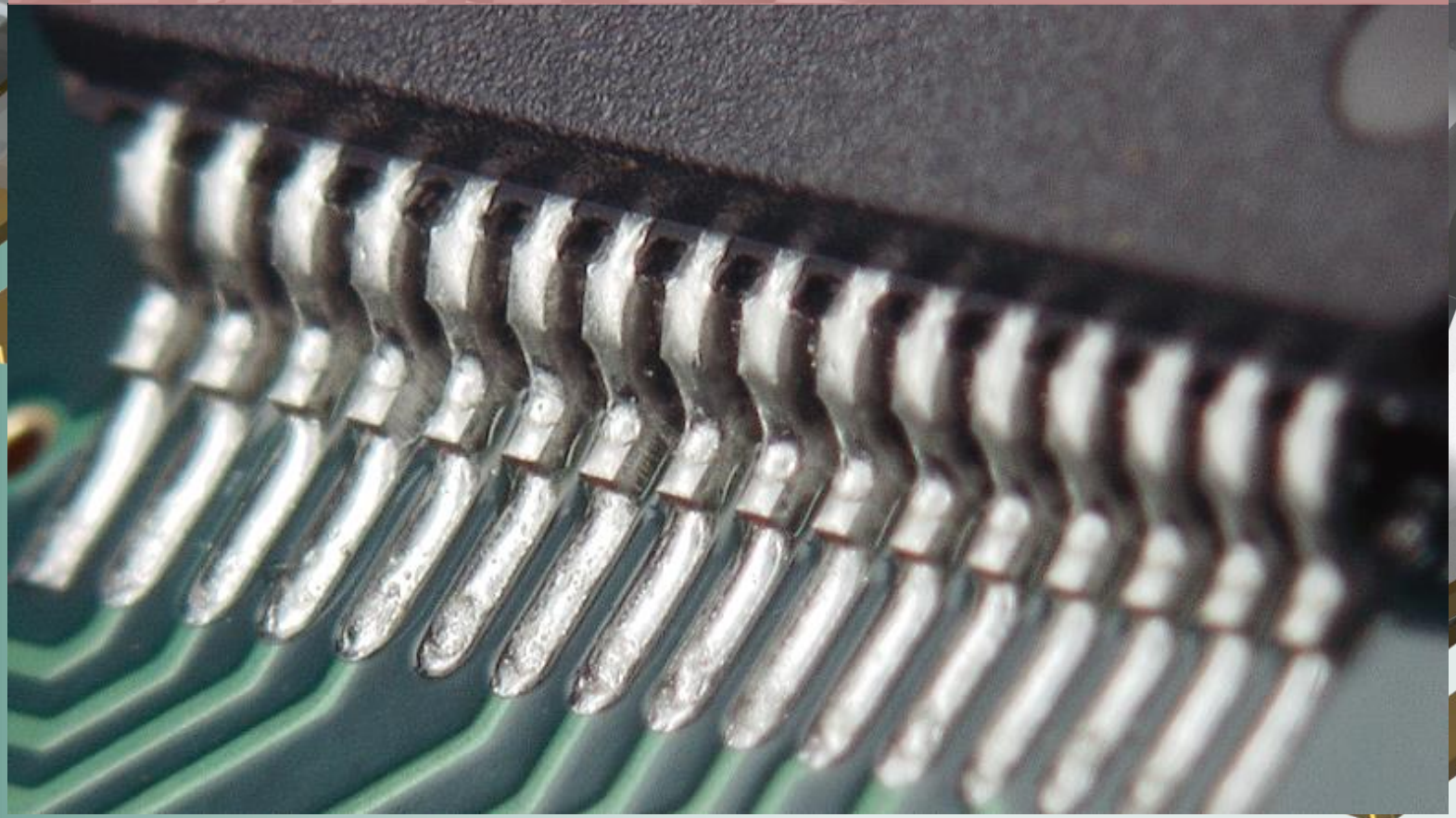
Lead Part	Maximum (Most) Density Level A	Median (Nominal) Density Level B	Minimum (Least) Density Level C
Toe (J_T)	0.55	0.35	0.15
Heel (J_H)[1]	0.45	0.35	0.25
Side (J_S)	0.05	0.03	0.01
Round-off factor	Round off to the nearest two place decimal, i.e., 1.00, 1.05, 1.10, 1.15		
Courtyard excess	0.5	0.25	0.1

Table 3-3 Flat Ribbon L and Gull-Wing Leads (less than or equal to 0.625 mm pitch) (unit: mm)

Lead Part	(Most) Density Level A	(Nominal) Density Level B	(Least) Density Level C
Toe (J_T)	0.55	0.35	0.15
Heel (J_H)[1]	0.45	0.35	0.25
Side (J_S)	0.01	-0.02	-0.04
Round-off factor	Round off to the nearest two place decimal, i.e., 1.00, 1.05, 1.10, 1.15		
Courtyard excess	0.5	0.25	0.1

Only Difference: Side Protrusion J_S

Example: TQFP-100



Constant land increase by F & P

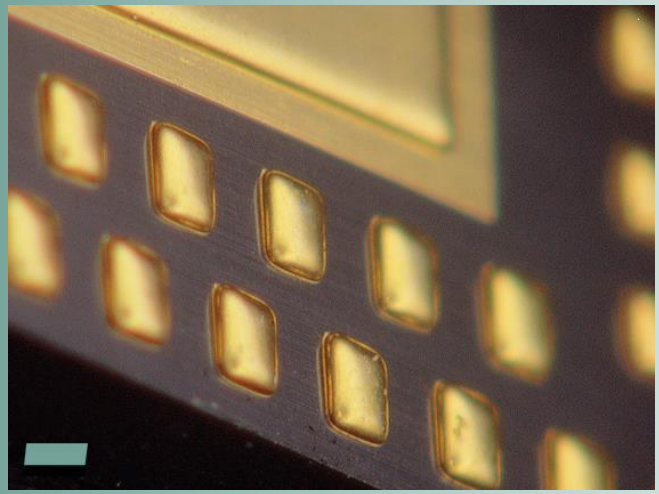
With F = 0.050 mm and P = 0.025 mm the resulting increase is of land in each dimension is 0.056 mm.
This is an absolute amount which leads to a significant expansion of land area for small components (0402, 0201 and less).

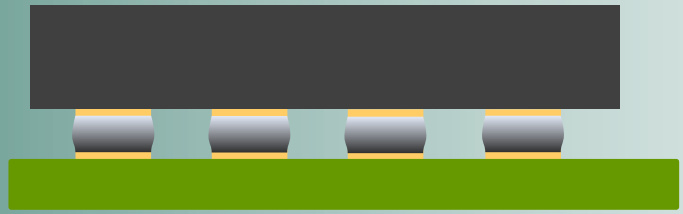
Further is important, whether the component dimensions are used with nominal or min/max. values.

The New Proportional Land Dimensioning Concept

Basic Idea

Two Terminal Classes





Facing wettable areas

Facing & vertical wettable areas

Terminal Type 1

Facing flat wettable areas

1:1 optimized stress distribution in solder joint – higher reliability

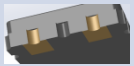
J-STD-001		Type	Land Size
7.5.3		Bottom Only Chip	1:1
7.5.12		Tall Profile Bottom Only	1:1
7.5.14		BGA	1:1
7.5.15		BTC	1:1

No protrusion required

Terminal Type 2

Flat facing and vertical wettable areas

Protrusion required

J-STD-001		Typ	Protrusion
7.5.4		Rectangular or Square End Chip	% Terminal Height
7.5.5		Cylindrical End Cap	% Terminal Diameter
7.5.6		Castellated	% Terminal Height
7.5.7		Gull Wing	% Leadframe Thickness
7.5.9		J-Leads	% Leadframe Thickness
7.5.11		Flat Lug Leads	% Leadframe Thickness
7.5.13		L-Inward	% Terminal Height

Solder Joint Requirements

Solder Joint Requirements according to J-STD-001 and IPC-A-610					
J-STD-001	Dim.	Description	Minimum Fillet Hight Requirement		
Termination Type			Class 1	Class 2	Class 3
7.5.3	F	Bottom Only Chip	Good wetting	Good wetting	Good wetting
7.5.4	F	Rectangular or Square End Chip	Good wetting on vertical surfaces		G+25%H max 0.50 mm
7.5.5	F	Cylindrical End Cap	Good wetting on vertical surfaces		G + 25%W max 1.00 mm
7.5.6	F	Castellated	Good wetting	G+25%H	G+50%H
7.5.7	F	Gull Wing - T < = 0.40 mm	Good wetting	G+T	G+T
7.5.7	F	Gull Wing - T > 0.40 mm	Good wetting	G+50%T	G+T
7.5.8	F	Round & Flattened Leads	Good wetting	G+50%T	G+T
7.5.9	F	J-Leads	G+50%T	G+50%T	G+T
7.5.10	F	I-Leads (Butt I)	0.50 mm	0.50 mm	NA
7.5.10.1	F	I-Leads Solder Charged	Hole is filled	Hole is filled	Hole is filled
7.5.11	F	Flat Lug Leads	Good wetting	Good wetting	G+T
7.5.12	F	Tall Profile Bottom Only	None	None	None
7.5.13	F	L-inward	Good wetting on vertical surfaces	G+25%H max 0.50 mm	G+25%H max 0.50 mm
7.5.14	F	BGA	None	None	None
7.5.15	F	BTC (QFN)	None	None	None
7.5.16	F	Bottom Thermal Plane	None	None	None
7.5.17	F	Flattened Post	Good wetting	Good wetting	NA
7.5.18	F	P-termination	Good wetting	25%H	25%H

The Proportional Concept

Proportional Land Dimensioning Calculations				Protrusion			
Description	Protrusion	Land Size	Calculation	Toe Limit	Toe	Side *	Heel
Bottom Only Chip	No	1:1	-		opt: 50µm	opt: 50µm	opt: 50µm
Rectangular or Square End Chip	Yes		Termination Height	0.50 mm	40%	10%	10%
Cylindrical End Cap	Yes		Termination Diameter	1.00 mm	60%	0%	5%
Castellated	Yes		Termination Height		50%	10%	10%
Gull Wing - T < = 0.40 mm	Yes		Leadframe Thickness		100%	10%	150%
Gull Wing - T > 0.40 mm	Yes		Leadframe Thickness		100%	10%	150%
Round & Flattened Leads	Yes		Lead Thickness/Diameter		100%	10%	150%
J-Leads	Yes		Leadframe Thickness		150%	10%	150%
I-Leads (Butt I)	Yes		Height Requirement		0.50 mm	0.25 mm	0.50 mm
I-Leads Solder Charged	Yes		Upper Hole Edge		50%	10%	50%
Flat Lug Leads	Yes		Leadframe Thickness		100%	10%	5%
Tall Profile Bottom Only	No	1:1	-		opt: 50µm	opt: 50µm	opt: 50µm
L-inward	Yes		Termination Height	0.50 mm	10%	10%	40%
BGA	No	1:1	-		opt: 50µm	opt: 50µm	opt: 50µm
BTC (QFN)	No	1:1	-		opt: 50µm	opt: 50µm	opt: 50µm
Bottom Thermal Plane	NoYes		Leadframe Thickness		100%	10%	150%
Flattened Post	Yes						
P-termination	Yes		Termination Hight		50%	20%	50%

opt: = optional

* Alternative to % in most cases 50% of

Advantages

Land dimensions are defined by

- Solder Joint Requirements
- Terminal Type
- Terminal Size
- New: Terminal Height

Proportional Gullwing

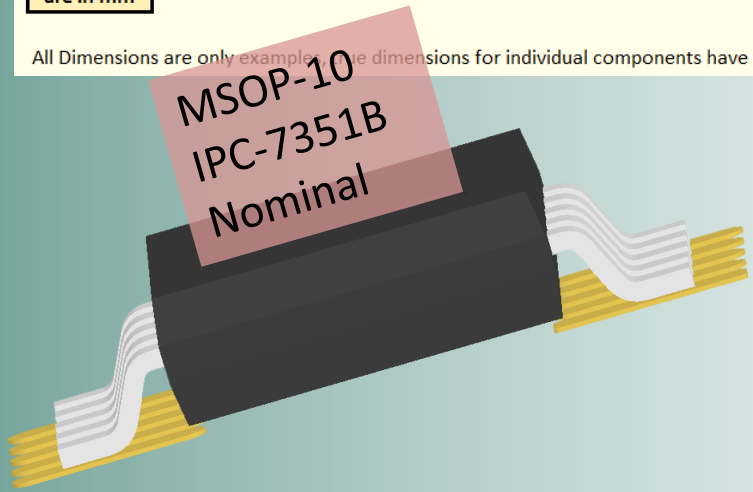
Proportional SMD Pad Stack

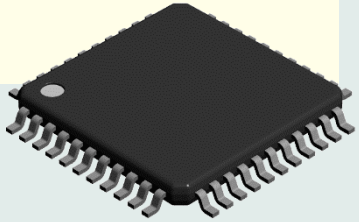
Gullwing	Package Example	Package Dimensions			Nominal Terminal			Toe (%TH)	Heel (%TH)	Side (%TH)	Land (Pad)		
Pitch		Length	Width €	Height	Length	Width	Height (c)*	100	150	5	Length	Width	Center
1,27	SO-14	8,65	6,00	1,75	0,800	0,50	0,25	0,250	0,375	0,013	1,425	0,525	2,538
0,95	SOT-23-6	2,80	2,90	1,00	0,450	0,40	0,12	0,120	0,180	0,006	0,750	0,412	1,145
0,80	TQFP-44	12,00	12,00	1,60	0,600	0,37	0,15	0,150	0,225	0,008	0,975	0,385	5,663
0,65	TSSOP-16	5,00	6,40	1,20	0,600	0,25	0,20	0,200	0,300	0,010	1,100	0,270	2,150
0,50	MSOP-10	4,90	3,00	1,10	0,550	0,22	0,18	0,180	0,270	0,009	1,000	0,238	2,130
0,40	TQFP-100	14,00	14,00	1,20	0,600	0,18	0,15	0,150	0,225	0,008	0,975	0,195	6,663

All dimensions are in mm

*Height = Leadframe Thickness

All Dimensions are only example. The dimensions for individual components have to be filled in from datasheet





Advantages

Easy scalable

Also for future components

Smoother Assembly

Less Risks

Higher Reliability

Additional Design Space

Disadvantages

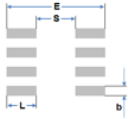
No Generic Footprints

FED Proportional Verification Projekt

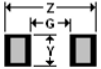
		Period	Starting Date
1	Creation of Library Parts	3 weeks	16.05.2016
2	Design of Testboard	3 weeks	06.06.2016
3	Testboard Production	3 weeks	27.06.2016
4	Assembly of Testboard	2 weeks	11.07.2016
5	Solder Joint Inspection & Documentation	3 weeks	01.08.2016
6	Präsentation of Results at FED-Conference		15.09.2016

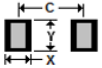
FED – IPC Reference Calculator

Current Sample
SO-14, pitch 1.27 mm
Fairchild 74ACT14SCX



IPC Incremental SMD Reference Calculator





Samples
Rectangular End Cap
C0201 R0201
C0402 R0402
C0603 R0603
Gull Wing Examples
SO-14 Pitch 1.27
SOT-23 Pitch 0.95
TQFP-44 Pitch 0.80
TSSOP-16 Pitch 0.65
MSOP-10 Pitch 0.50
TVSOP-24 Pitch 0.40
Inward L
3216-18A 7343-31D
Cylindrical
MiniMelf Melf
Flat Protruded
SOT-563
Castellated
TC-164

Enter Data:			
Emin	6,00	Toe Goal	0,35
Emax	6,00	Heel Goal	0,35
Etol =	0,00	Side Goal	0,03
Lmin	0,50		
Lmax	0,90	Place Rnd	0,02
Ltol =	0,40	Size Rnd	0,01
bmin	0,35		
bmax	0,51	Fab Tol +/-	0,050
btol =	0,16	Place Tol +/-	0,025

Calculation:			
Stol =	0,80	Toe Tol =	0,11180
Stol (RMS) =	0,57	Zmax =	6,81180
Sdiff =	0,23	Heel Tol =	0,57663
Smax =	5,00	Gmin =	3,60621
Smin =	4,20	Side Tol =	0,19519
New Smax =	4,88	Yref =	0,60519
New Smin =	4,32		
		Place Round Factor =	50
		Size Round Factor =	100

Result:			
C =	5,20	Toe Max =	0,40
X =	1,60	Toe Min =	0,34
Y =	0,61	Toe Goal	0,35
		Heel Max =	0,64
		Heel Min =	0,35
		Heel Goal	0,35
		Side Max =	0,13
		Side Min =	0,03
		Side Goal	0,03

FED Proportional SMD Reference Calculator

Enter Data:	
Enom =	6,00
Lnom =	0,70
bnom =	0,43
cnom =	0,30
e (pitch) =	1,27

cnom = Terminal Thickness or Height

Goal Determination	
Toe Goal (%)	100
Heel Goal (%)	150
Side Goal (%)	5

Goals are a percentage of cnom

Calculation:	
Z =	6,60000
G =	3,70000
Y =	0,46000

Result:	
C =	5,16
C/2 =	2,58
X =	1,45
Y =	0,64

* if Y < pitch/2
Y= pitch/2

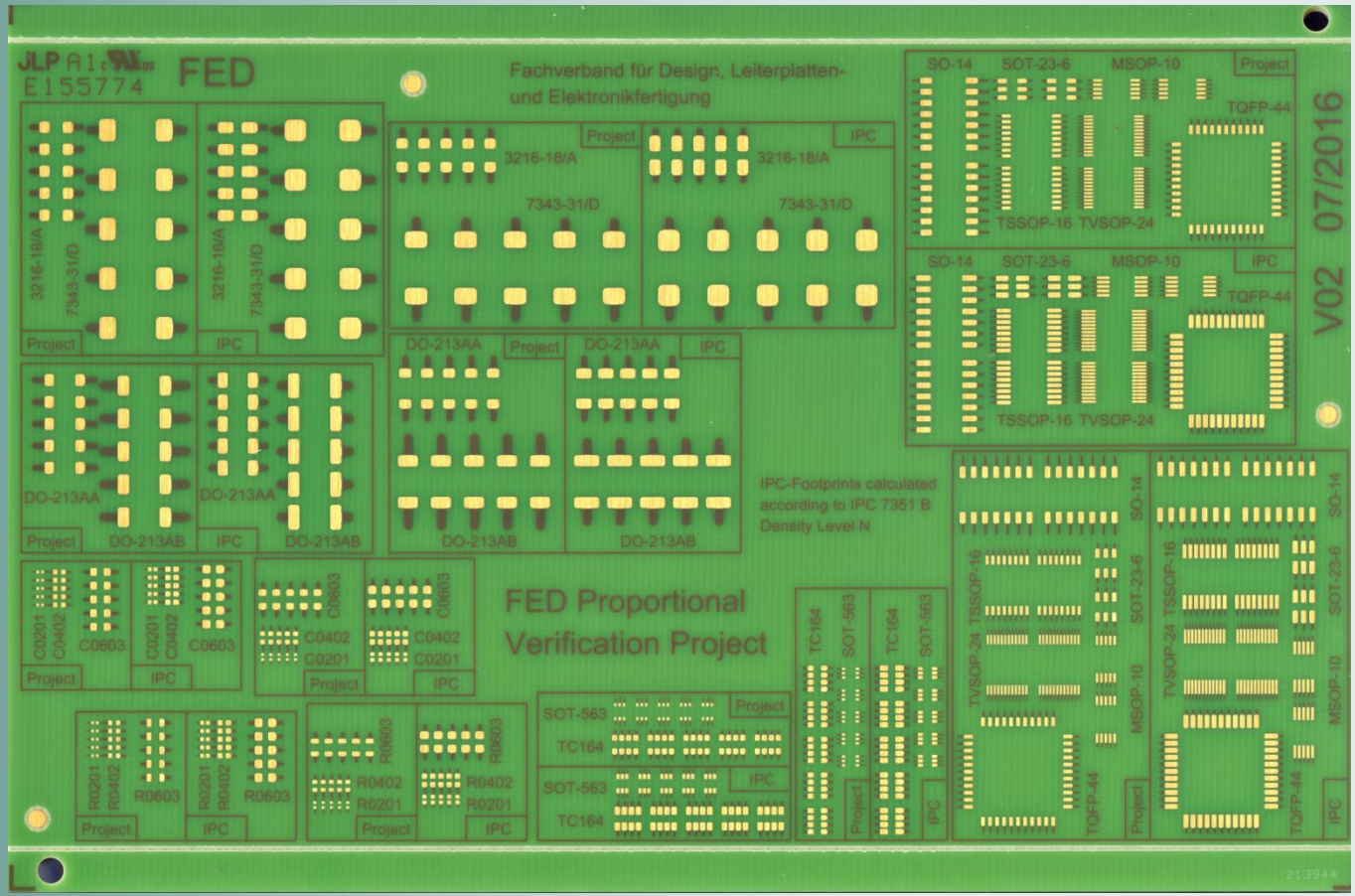
Risk observation	
Toe Max =	0,305
Toe Min =	0,249
Toe Goal =	0,300
Heel Max =	0,591
Heel Min =	0,303
Heel Goal =	0,450
Side Max =	0,143
Side Min =	0,045
Side Goal =	0,015

PCB Libraries

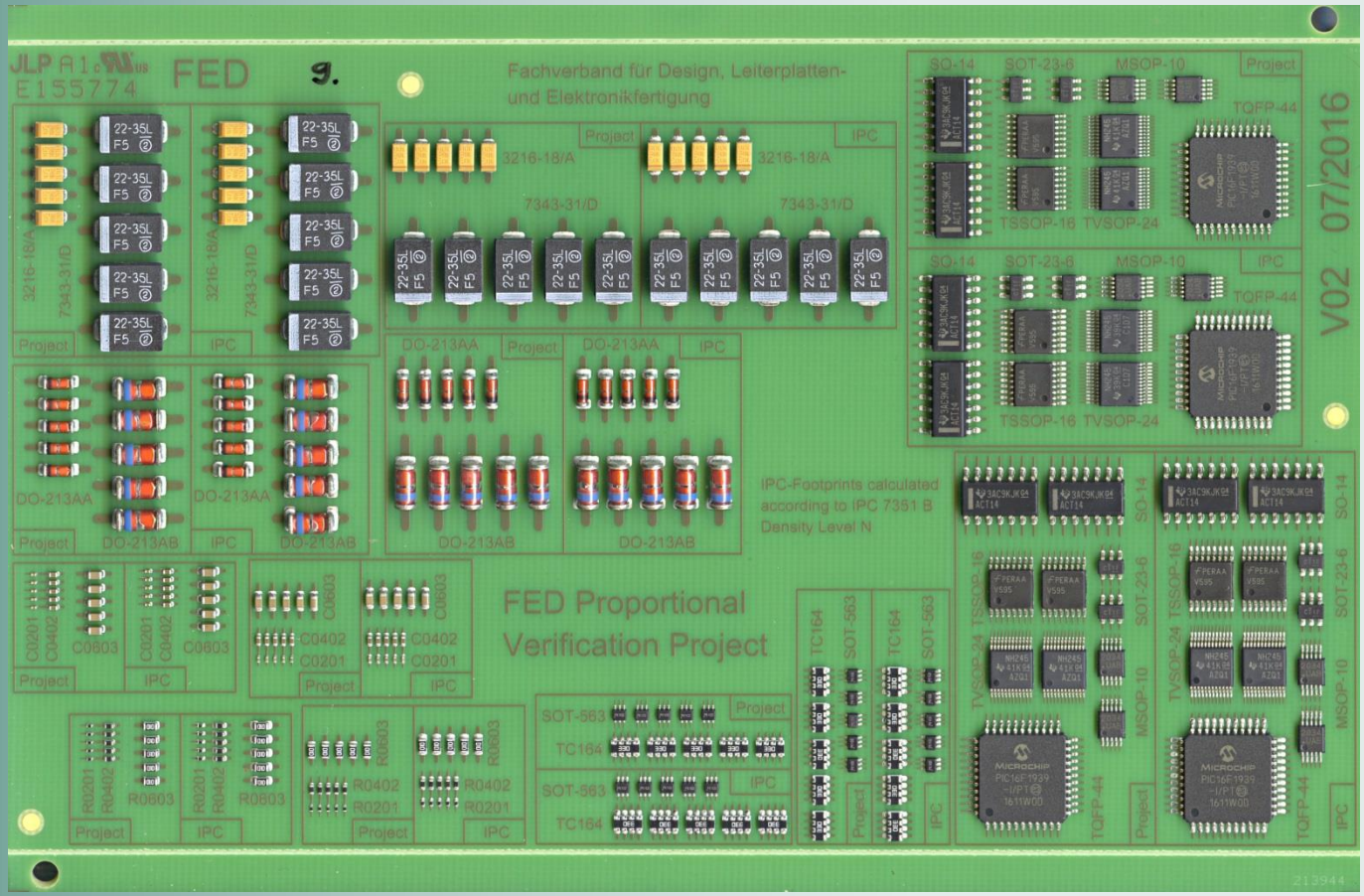
Version 1.3 (Mai 2018)

modified 23.05.2018/R. Taube

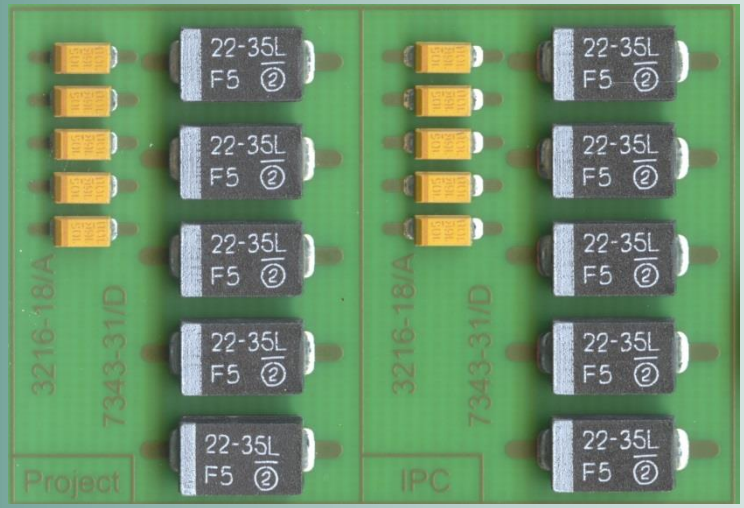
FED Verification Testboard

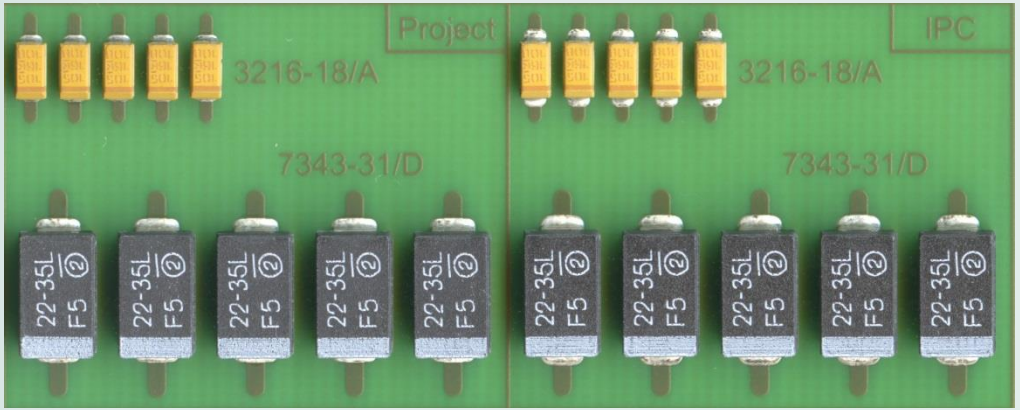


Testboard with Components

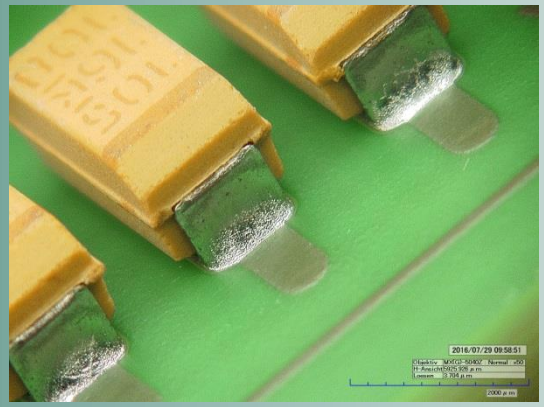


Group 1 – Inward L - Tantal A and D

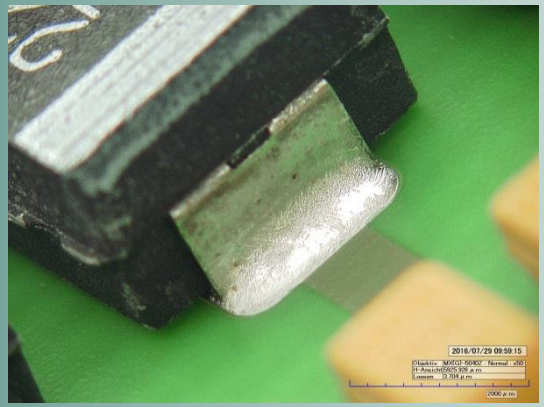




Group 1 – In-L -Tantal A and D solder joints



P I



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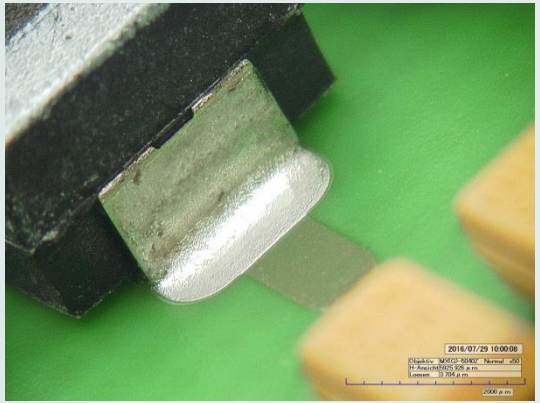
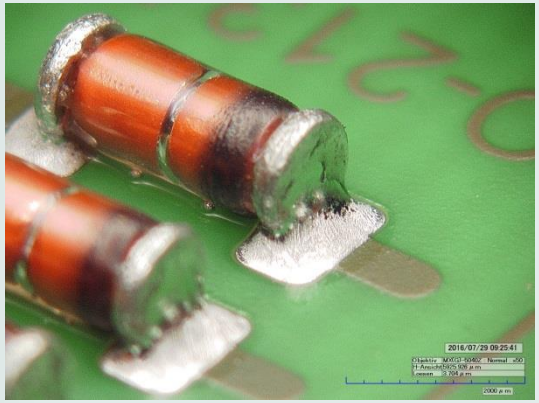


P= Proportional
I = IPC-7351

Group 2 – MiniMelf and Melf – solder joints

P I



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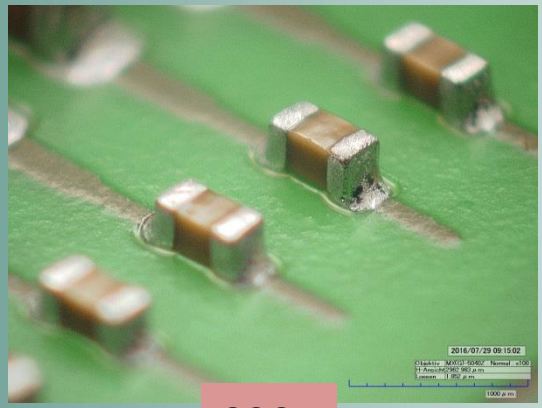
Group 3 – MLCC solder joints



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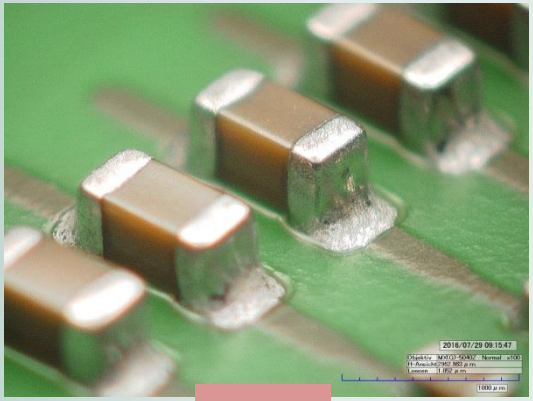

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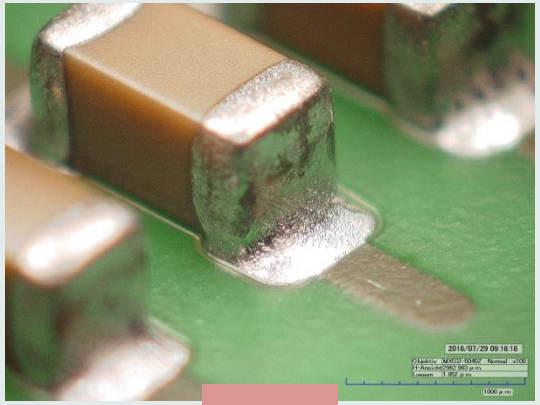

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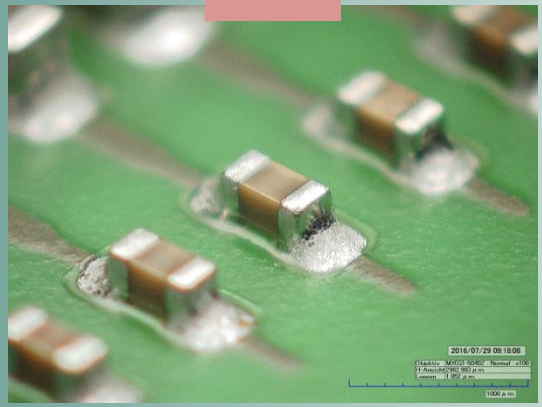
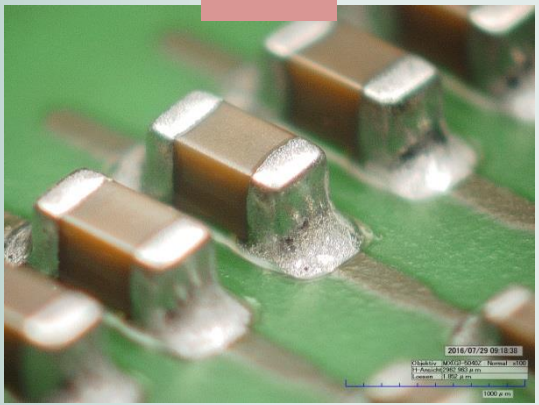
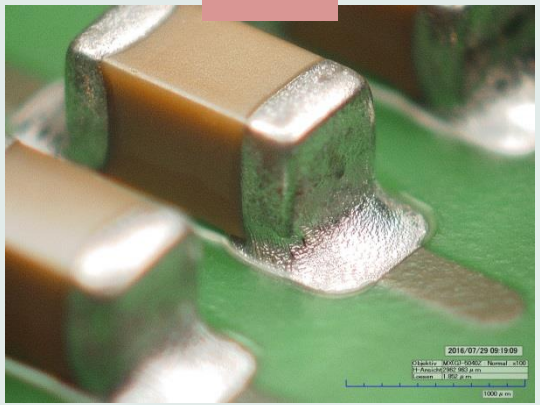
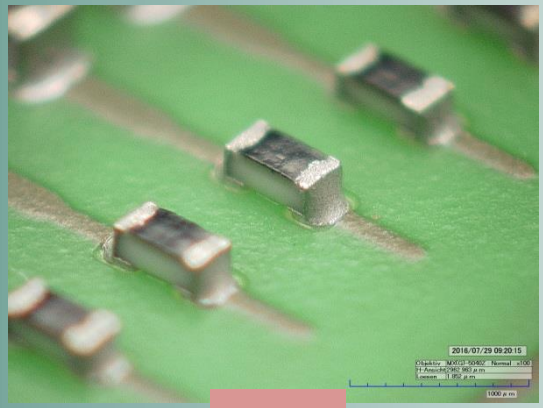






Group 4 – Resistor solder joints



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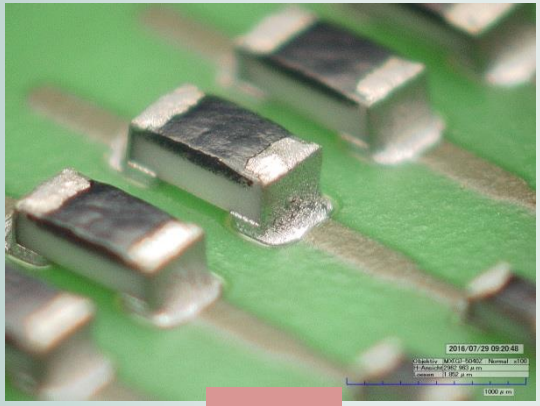

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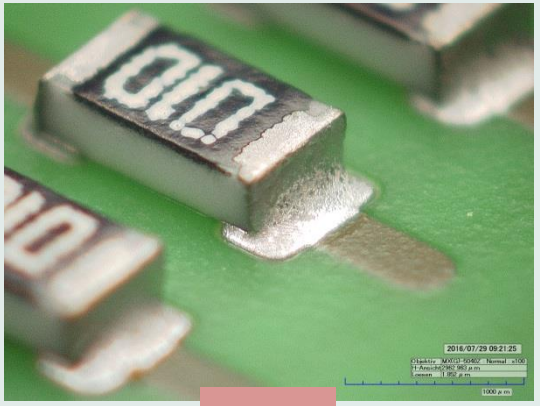

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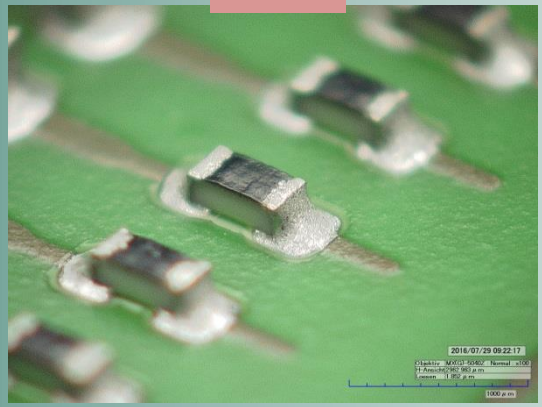
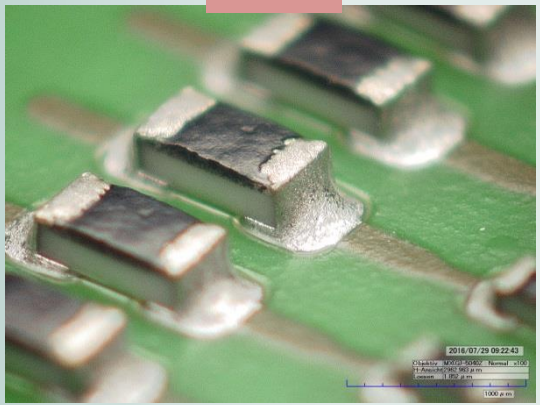
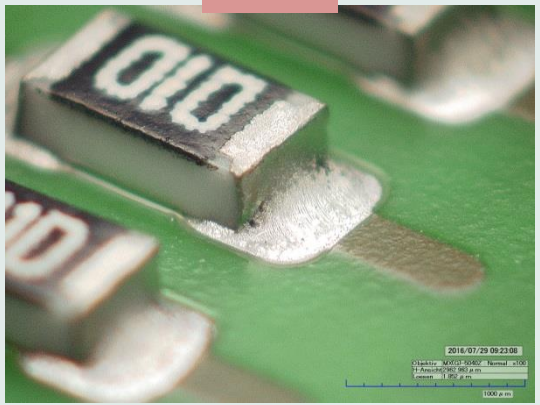
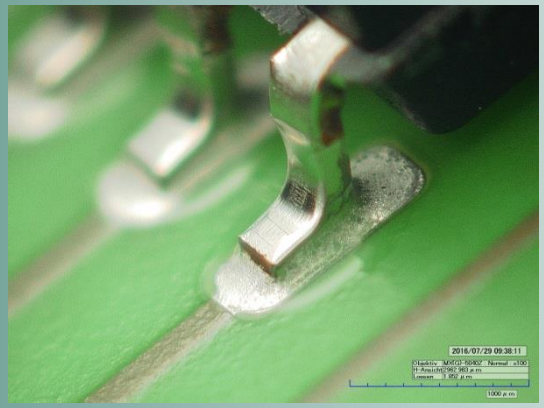
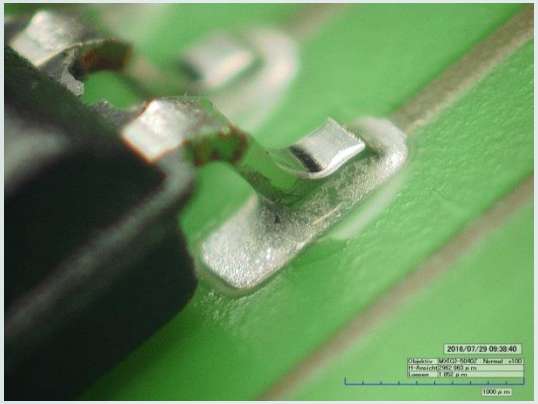






Group 5 – SO-14 solder joints – Pitch 1.27





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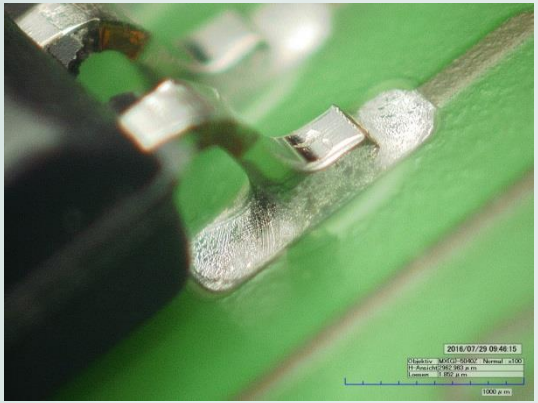
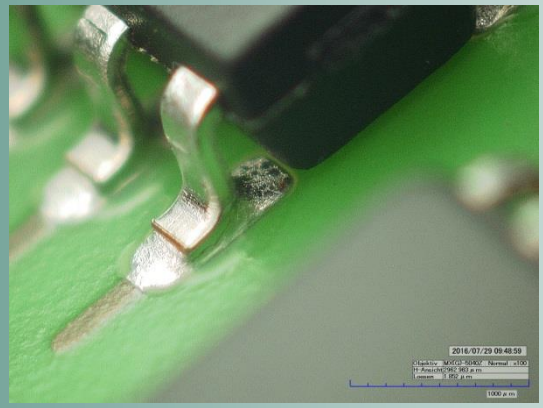
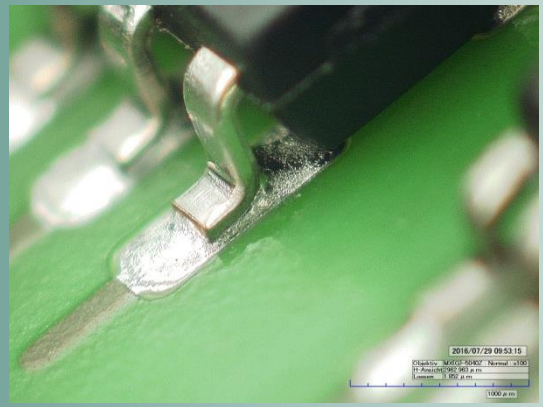


Group 5 – SOT-23-6 solder joints – Pitch 0.95





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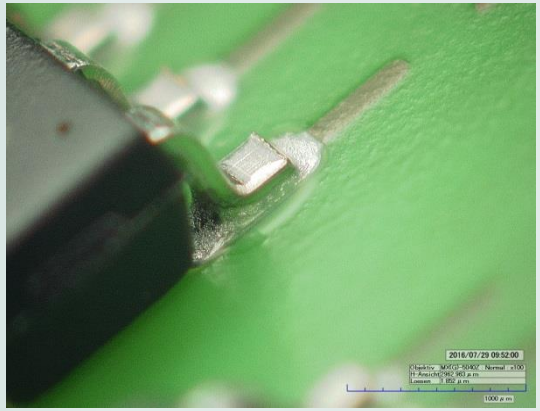
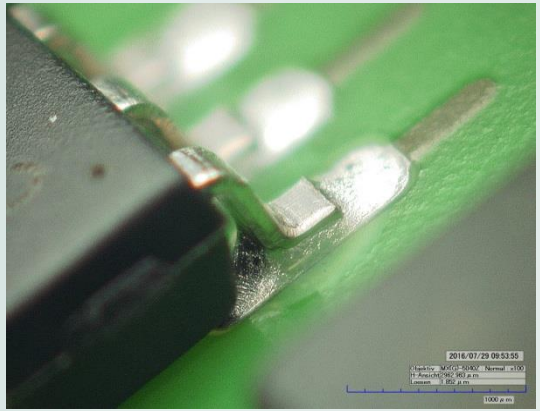
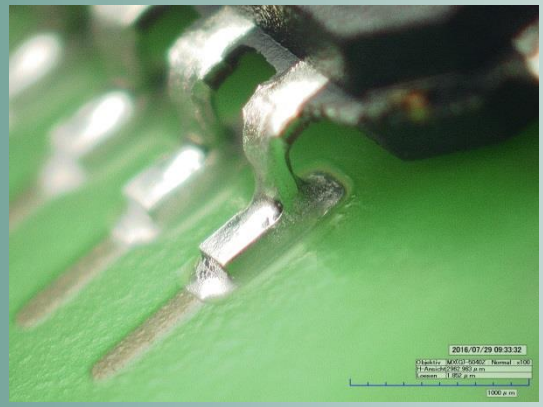




Group 5 – QFT-44 joints – Pitch 0.8



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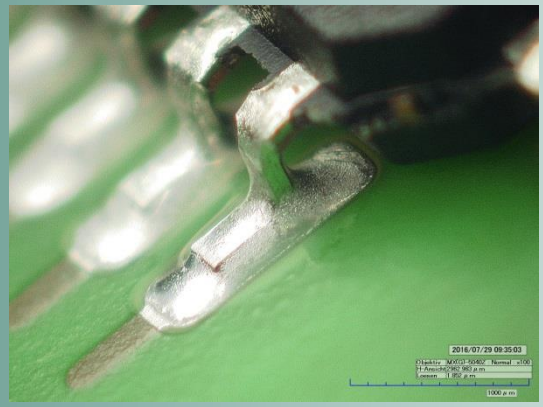
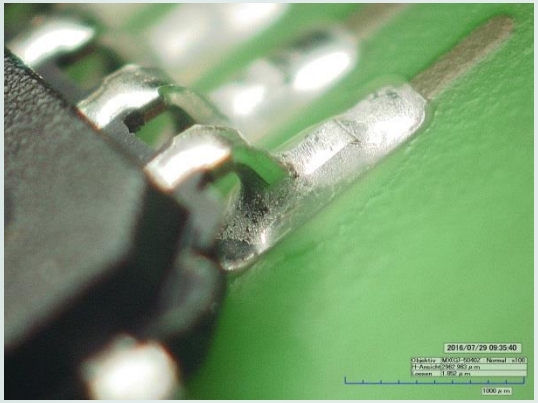
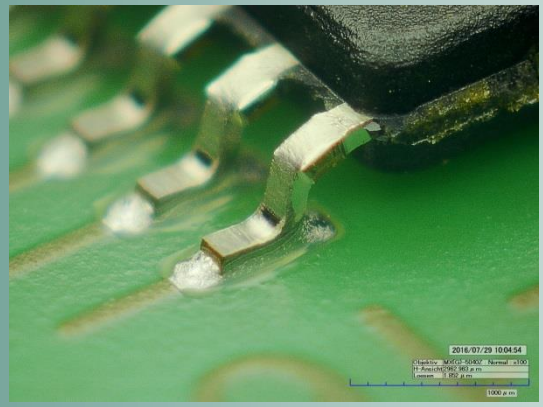
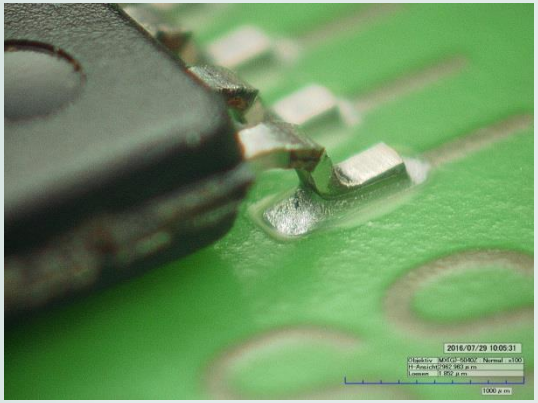




Gruppe 5 – TSSOP-16 joints – Pitch 0.65





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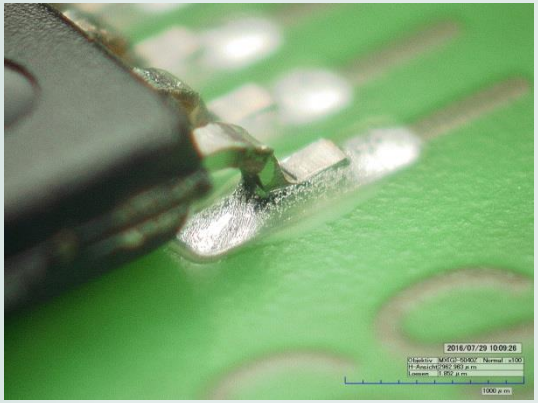
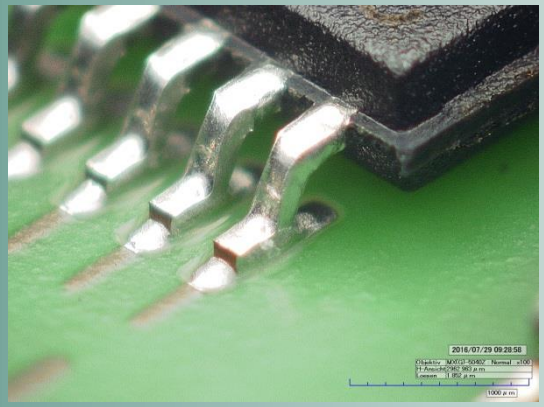
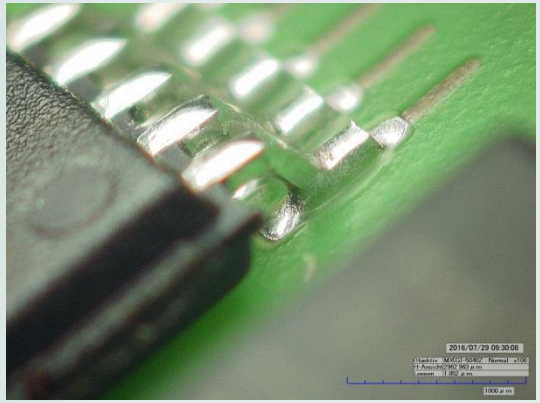


Group 5 – MSOP-10 joints – Pitch 0.5





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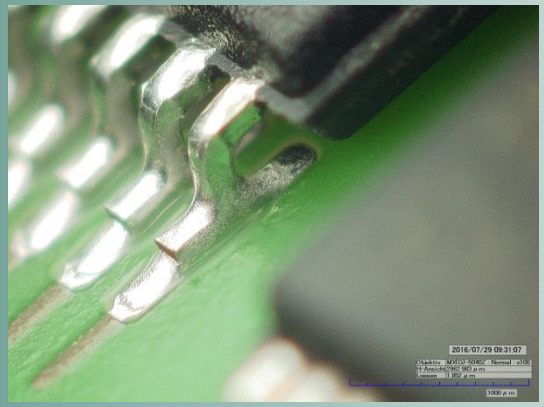
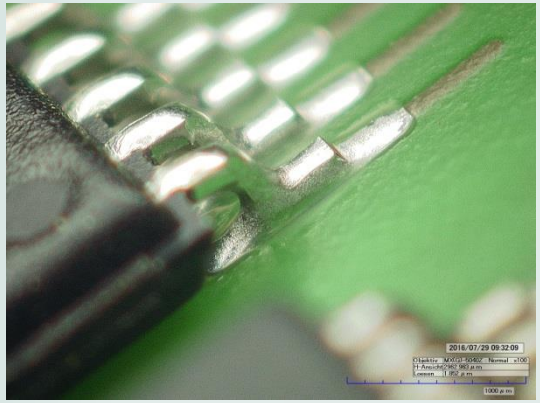
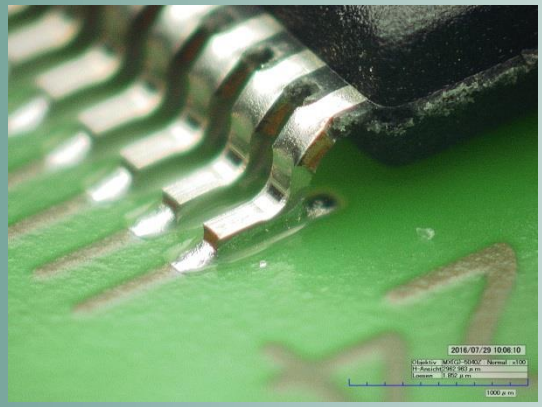
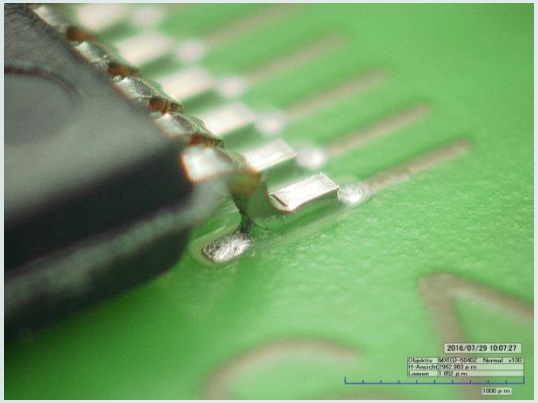




Group 5 – TVSOP-24 joints – Pitch 0.4





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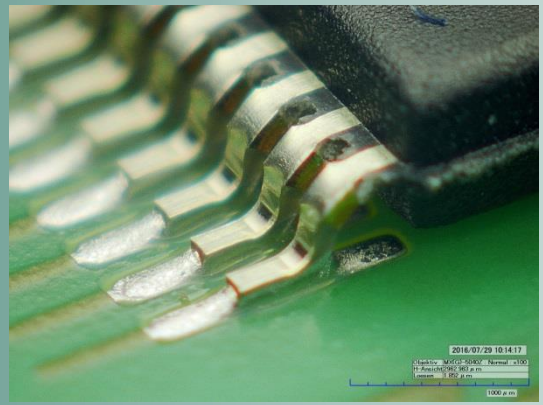
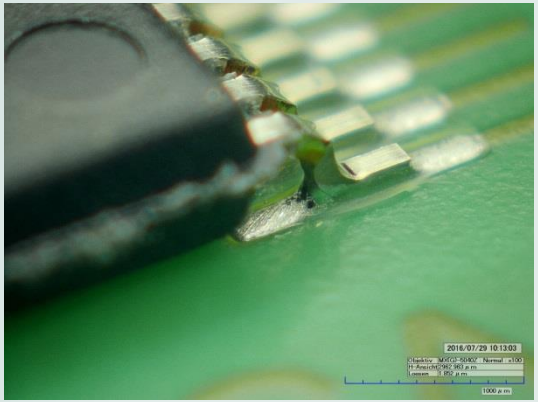
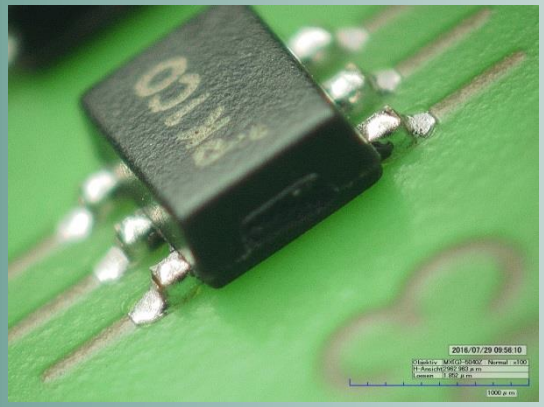
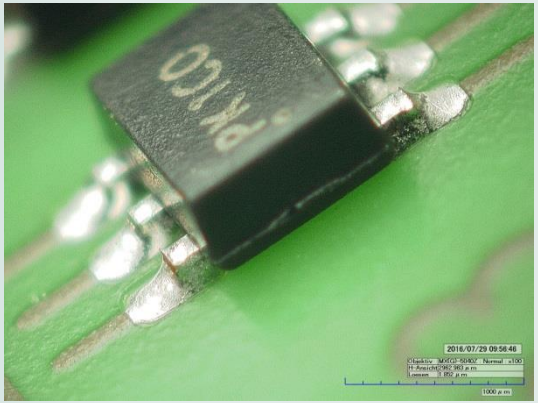




Group 6 – SOT-563 und TC164 joints





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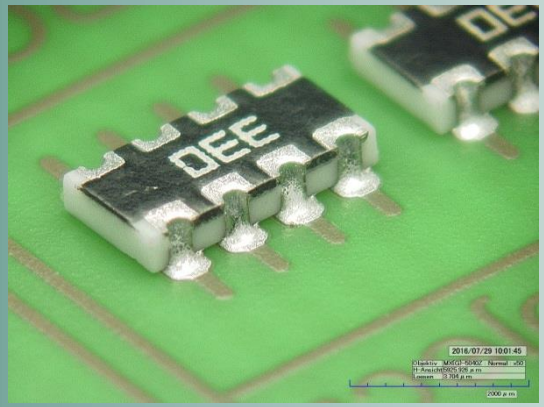
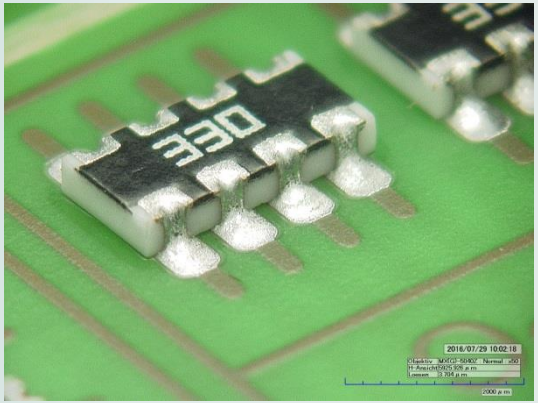
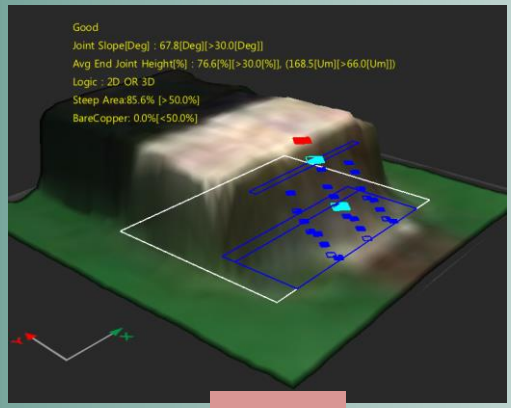




AOI – Resistor



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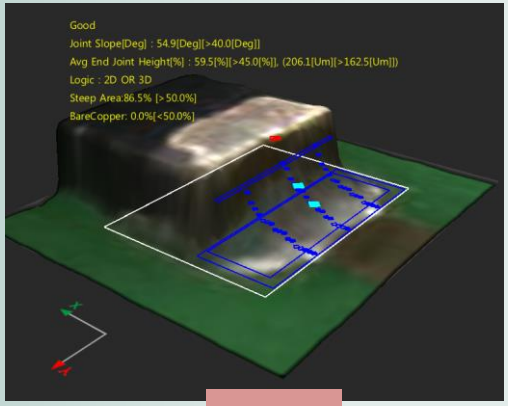

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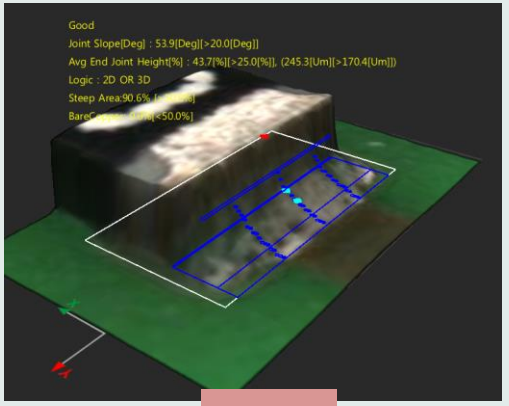

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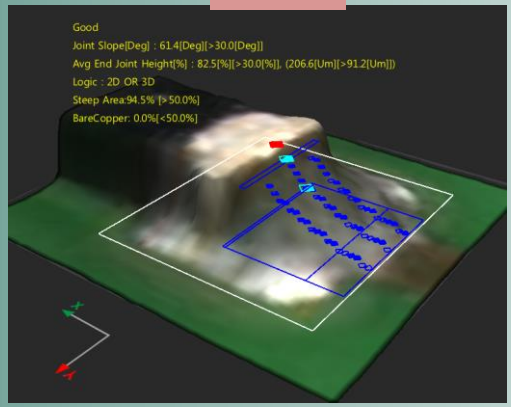
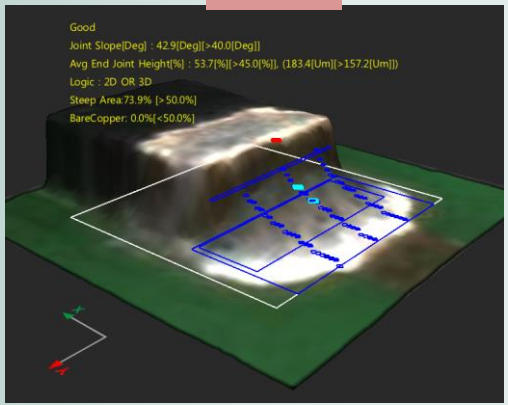
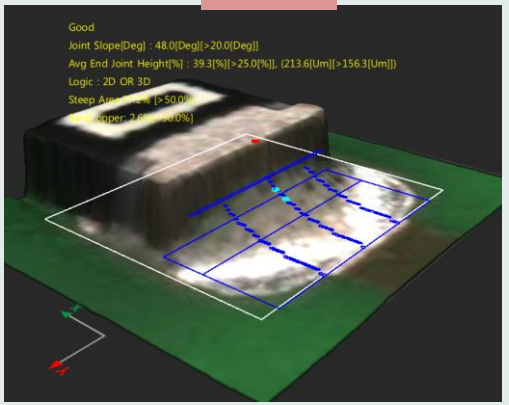
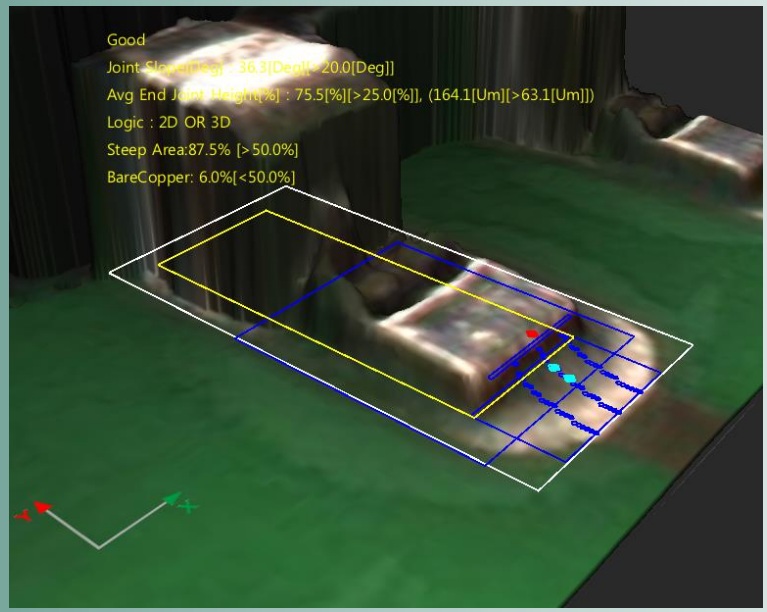






AOI– SO-14 – Pitch 1.27



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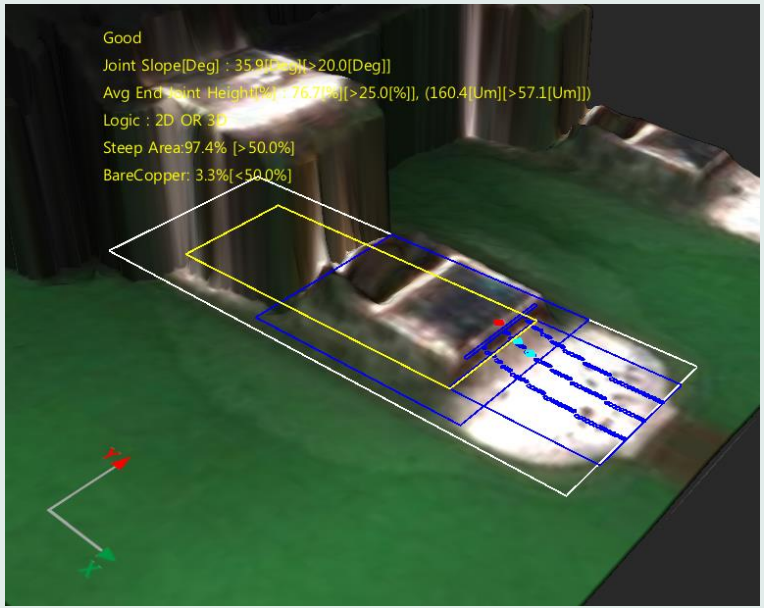
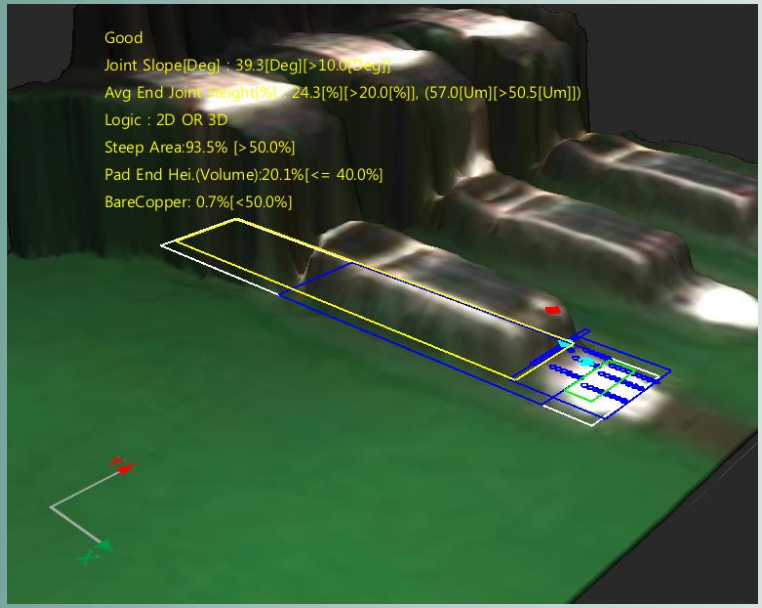


AOI– TVSOP-24 – Pitch 0.4



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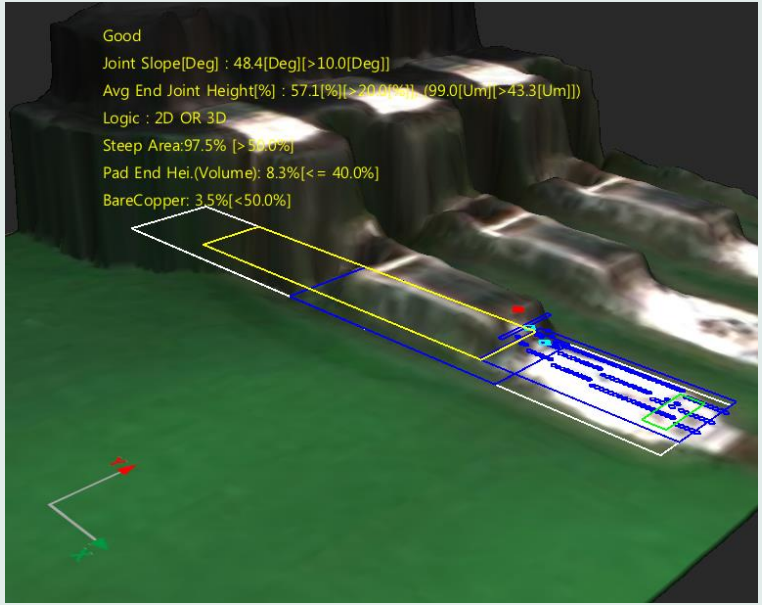

Investigation results of Marco Huber

3. Feststellung

3. Findings

The results of the investigation concerning placement and solder joints and their wetting behaviour are acceptable and fulfil the requested geometries (with little exceptions Melf)

Based on the total pictures the 4 assemblies of Taube and Prettl are very similar. Also the solder joints do not show significant differences – all components are properly processed.

4.

4. Recommendations

The results under 3. allows to document the accomplished pad definitions und to implement them in practical design or to publish them in a FED-guideline.

Marco Huber

Results

- Requirements of IPC-A-610 Class 2 & 3 fulfilled
- except Cylindrical – additional solder volume required

Acknowledgement

Thanks to all who supported the Proportional Project, especially to

Wolfgang Kühn for the perfect project plan

Olaf Hollinger, Carl Zeiss AG in Jena for the patience designing the testboard

Sven Nehrdich, Jenaer Leiterplatten for production of bare boards

Stefan Burmeister and his colleagues at Prettl Electronics in Lübeck for assembly and AOI of testboards

Marco Huber, Huber Consulting in Würenlos Switzerland for inspection of solder joints

Erika Reel for continuous support of all projects which serve the FED and his members

Tom Hausherr, PCBLibraries for uncountable discussions about the best landpattern design

Contact

TAUBE ELECTRONIC GmbH
Nostitzstraße 30
D-10965 Berlin
Telefon 030 69 59 25 0
e-mail: r.taube@taube-electronic.de