Vitronics Soltec

Advanced Technology Group
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ZEVA v

RE-HEN-13013
Preheat – Forced Convection
23/12/2013

Temperature uniformity - minimize dT on topside board

Introduction:

The board has to be preheated in order to activate the flux for good soldering. The heating has to be uniform in order to meet the flux specifications all over the assembly. Forced convection heating is an effective way to heat a printed circuit board. This test is to verify the performance of this system in this new prototype.

Objective:

The objective of these tests is to verify the forced convection performance in the ZEVA$_v$ and define differences (if there are) with the IR concept in the selective soldering machines.
The test covers 3 tests:
1. Measure dT on a plain FR4 test-board 1.6 mm thick
2. Measure dT on FR4 and FR4 + Cu plated 2.5 mm thick test-board of 25 mm square coupons
3. Measure dT between shiny and matt coupon (50x50 mm – 2mm metal)

Results:

1. High preheat temperatures in combination with high power result in a larger dT. To heat the FR4 test-board in 60 seconds to 140 ºC the forced convection of the ZEVA $_v$ scored better than the IR lamps:

Machine	Method	Settings	dT
ZEVA $_v$	Forced convection	180 ºC – 75%	12
mySelective 6748	Forced convection	180 ºC – 38Hz	19
ZEVA $_v$	IR lamps	60%	16
mySelective 6748	IR lamps	60%	29

2. Power of 50% is preferred for a low dT on test-board 2. The Cu plated boards have smaller dT. The forced convection outperforms the IR heating of the ZEVA and mySelective:

Machine	Method	Settings	dT
ZEVA $_v$	Forced convection	180 ºC – 50%	7
mySelective 6748	Forced convection	180 ºC – 25Hz	17
ZEVA $_v$	IR lamps	60%	36
mySelective 6748	IR lamps	60%	71

3. The comparison between a matt and shiny coupon result in a smaller dT than for similar conditions in the mySelective 6748.

Machine	Method	Settings	dT
ZEVA $_v$	Forced convection	180 ºC – 50%	3
mySelective 6748	Forced convection	180 ºC – 25Hz	12

Test 1 FR4 test-board plain 1.6 mm:

The first test was heating a FR4-1.6mm plain test board. In order to get more feeling of the performance of the unit a DOE was performed having the air temperature, power and time as the three variables. The FR4 test-board is positioned with probe 1 to the front rail and the right side against the blocking device.

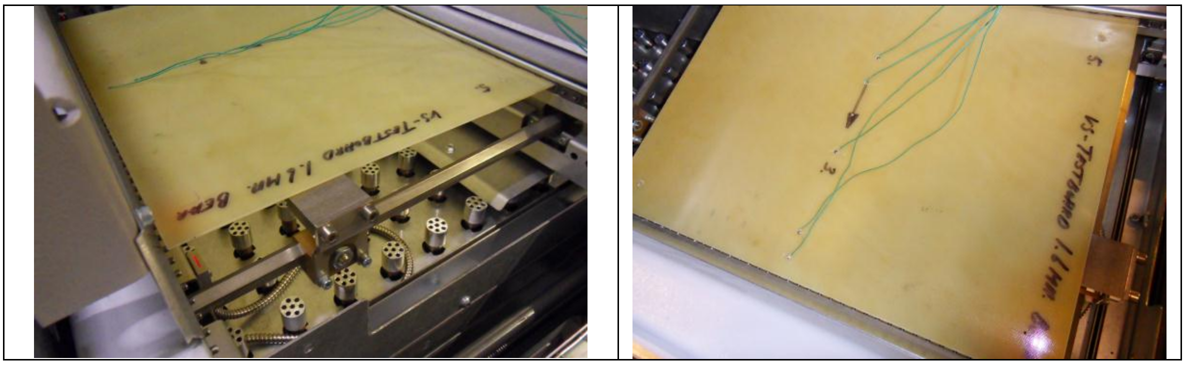


Figure 1: FR4 test board – measuring the dT across the board.

1.6 mm FR4			ZEVA $_v$ - FR4 test board 400x285						
Temp [ºC]	**Power [%]**	**Time [s]**	**T1**	**T2**	**T3**	**T4**	**T5**	**dT**	T_{avg}
140	**25**	**30**	64.8	-	63.3	61.4	62.6	3.4	63.0
		60	87.4	-	83.4	83.6	83.9	4	84.6
140	**75**	**30**	92.6	86.5	88.4	95.7	90.6	6.1	90.8
		60	114.1	110.6	109.1	116.5	112.5	7.4	112.6
160	**25**	**30**	74.2	-	73.9	75.6	74.6	1.7	74.6
		60	101.6	-	95.8	101.1	99.1	5.3	99.4
160	**75**	**30**	104.3	96.6	-	113.1	105.7	16.5	104.9
		60	129.4	125.2	-	135.2	130.1	10	130.0
180	**25**	**30**	80.9	-	77.2	73.5	73.2	7.7	76.2
		60	111.4	-	106.1	102.3	100.6	10.8	105.1
180	**75**	**30**	111.1	-	104.9	116.5	109.9	11.6	110.6
		60	141.0	-	134.1	145.9	140.3	11.8	140.3

Table 1: Forced convection unit in ZEVA $_v$

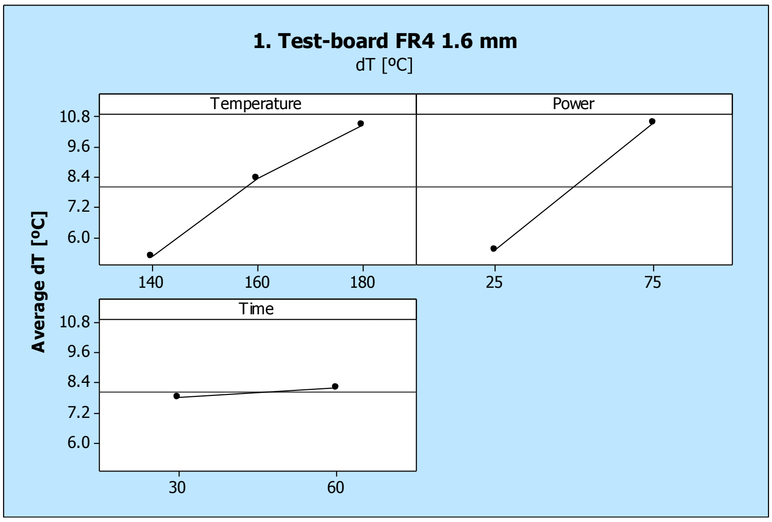


Figure 2: In order to minimize dT the board should be heated with the lowest power and temperature.

Analyse Factorial Design:

General Linear Model: dT versus Temperature, Power, Time

Factor	Type	Levels	Values
Temperature	fixed	3	140, 160, 180
Power	fixed	2	25, 75
Time	fixed	2	30, 60

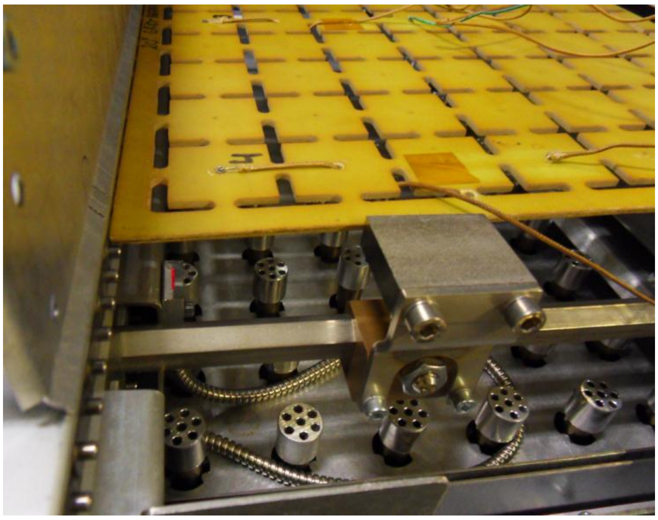
Analysis of Variance for dT, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	2	65.526	63.012	31.506	21.76	0.002
Power	1	36.260	30.943	30.943	21.37	0.004
Time	1	10.853	10.853	10.853	7.49	0.034
Error	6	8.688	8.688	1.448		
Total	10	121.327				

S = 1.20335   R-Sq = 92.84%   R-Sq(adj) = 88.06%

The analysis from the Minitab shows that temperature and power are significant factors and affect the dT.

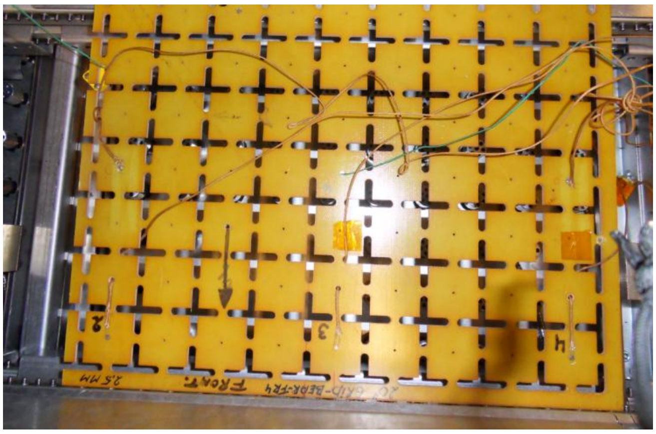
Test 2 FR4 and FR4-Cu plated test-boards 2.5 mm:



The test-board is placed with the thermocouples 2, 3, and 4 to the front rail of the conveyor. The front side of the board is against the blocking device.

The thermo-couples are connected to the Datapaq that records the temperature over time.

The test-board is placed in section 3 (the second forced convection unit). The forced convection unit in section 2 has the same settings as section 3. In section 4 is an IR heater which is switched off.



A Design of Experiment is set-up with Power, Temperature and Time as parameters. The Power is a factor that is not used often to affect the board temperature. This test should learn what impact the Power has on the dT.

A Full Factorial Design is done with all factors at three levels. (See appendix 1)

Data analysis in Minitab shows very consistent data:

General Linear Model: dT versus Temperature, Power, Time, Test-board

Factor	Type	Levels	Values
Temperature	fixed	3	140, 160, 180
Power	fixed	3	25, 50, 75
Time	fixed	3	30, 60, 90
Test-board	fixed	2	FR4, FR4+Cu

Analysis of Variance for dT, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	2	46.330	50.281	25.140	12.36	0.000
Power	2	95.846	102.944	51.472	25.30	0.000
Time	2	34.064	52.168	26.084	12.82	0.000
Test-board	1	95.118	86.023	86.023	42.28	0.000
Temperature*Power	4	147.695	158.111	39.528	19.43	0.000
Temperature*Test-board	2	47.448	54.906	27.453	13.49	0.000
Power*Test-board	2	36.133	34.354	17.177	8.44	0.001
Time*Test-board	2	16.616	16.616	8.308	4.08	0.026
Error	32	65.114	65.114	2.035		
Total	49	584.365				

S = 1.42647   R-Sq = 88.86%   R-Sq(adj) = 82.94%

Conclusions from the data:

- There is no significant difference for heating the both test-boards, but there is a smaller dT for the Cu plated board. (Average 2.5 ºC)
- The power of 50% is preferred (this corresponds to the 25Hz setting of the mySelective 6748).

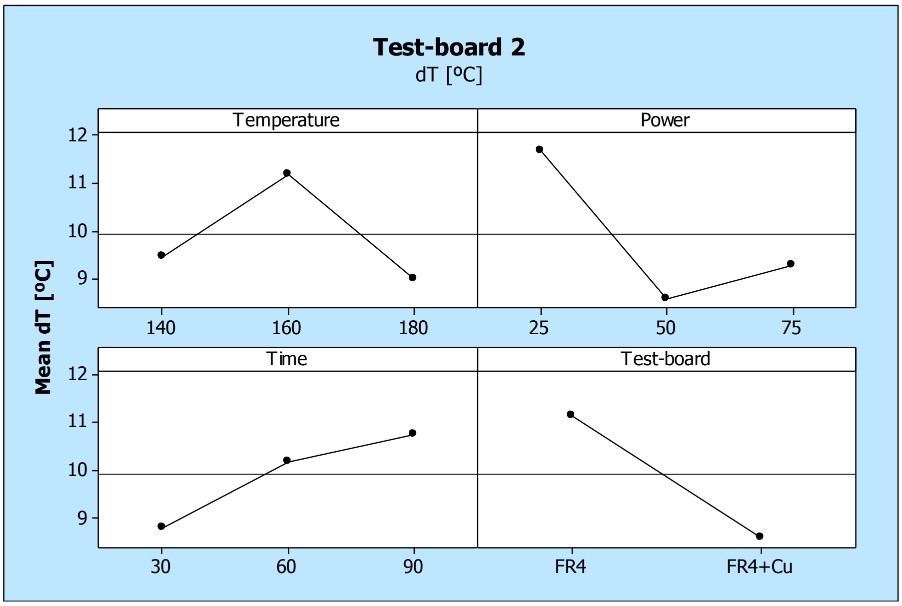
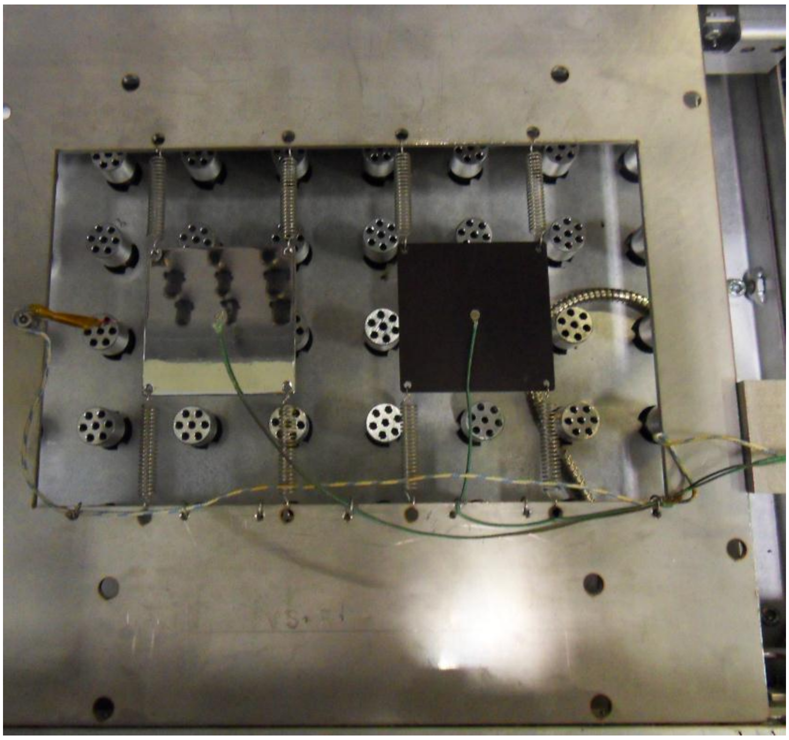


Figure 3: The lower dT the better. No linear behaviour for temperature and power.

Test 3 Shiny versus matt 50x50 mm:



The test is to define the heat transfer of radiation versus convection.

The dT between the shiny and matt coupon is an indication for the amount of radiation.

The measured temperatures of the test are listed in appendix 2.

There is only a very small temperature difference between the shiny and matt coupon as shown in figure 4.

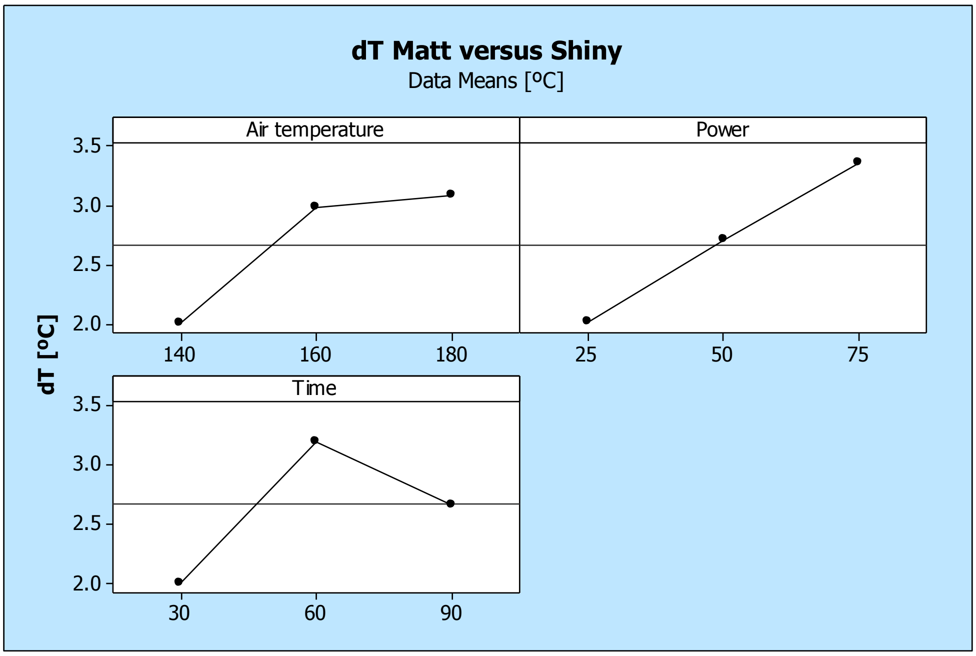


Figure 4: temperature difference between matt and shiny (matt is always hotter than the shiny coupon).

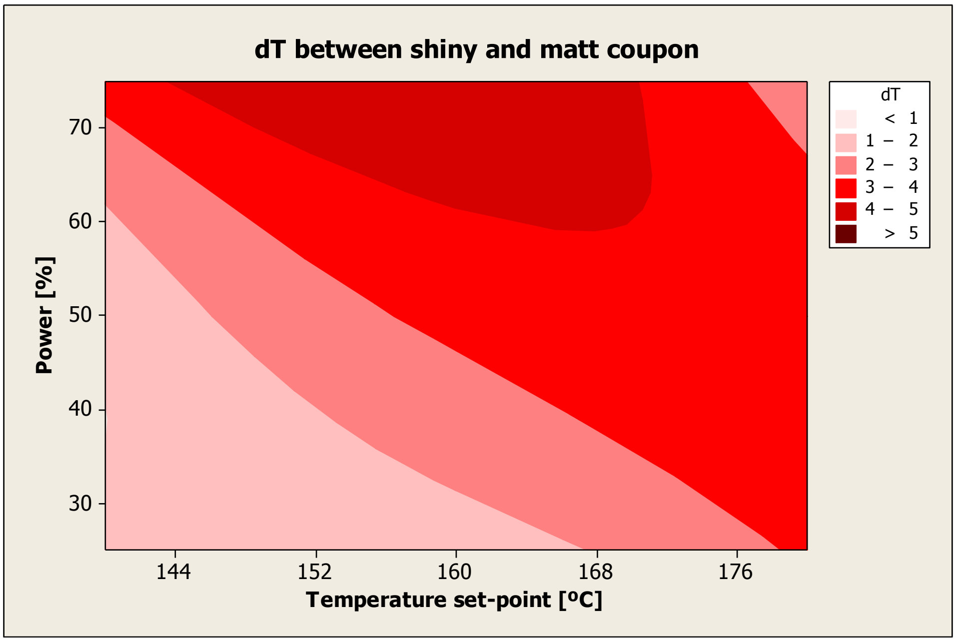


Figure 5: Showing the dT between the coupons at different settings for temperature and power.

Summary:

For all the tests the ZEVA outperforms the mySelective data. The forced convection as designed in the ZEVA is a unit that is able to preheat the assemblies to the required topside temperature with the smallest temperature difference over the board.

Appendix 1 – Data test 2

RunOrder	Air temperature	Power	Time	FR4	FR4-dT	Cu	Cu-dT
#	[ºC]	[%]	[s]	[ºC]	[ºC]	[ºC]	[ºC]
1	140	25	90	87.7	18.6	88.6	12.2
2	140	50	90	103.3	6	100.1	3.1
3	140	25	30	54.7	13.2	52.1	6.5
4	160	75	60	110.5	7.9	111.8	10.8
5	140	75	60	98.9	9.6	99.6	6.2
6	160	75	90	125.4	7.7	126.3	11.5
7	140	75	90	111.6	10.3	113.7	7.8
8	180	75	30	90.1	10.2	90.3	5.7
9	160	50	90	112.5	11.3	114.7	8.6
10	140	75	30	75.6	9.2	73.6	3.4
11	160	25	30	59.6	12.7	56.5	9.6
12	140	25	60	73.7	16.5	88.6	12.3
13	160	25	90	97.3	16.6	98.6	14.5
14	180	50	90	122.7	12.1	125.9	9.9
15	160	25	60	81.4	15.9	81.2	16.7
16	180	50	30	76.4	11.1	75.4	4.4
17	180	25	60	88.8	9	89.3	5.5
18	180	50	60	104.3	11	107.4	7
19	180	75	60	119.3	8.6	120.9	13.3
20	180	25	30	63.9	8.1	60.7	5.9
21	180	25	90	106.7	10.1	109.1	6.5
22	140	50	30	64.1	9	64.9	4.6
23	160	50	30	71.1	9.2	71.5	7.5
24	160	75	30	84.1	11.2	82.8	9.9
25	140	50	60	85.7	9	88.8	4.4
26	160	50	60	96.3	10.4	98.6	9.4
27	180	75	90	136.6	11.1	138.2	17.1

Appendix 2 – Data test 3

RunOrder	Air temperature	Power	Time	Shiny	Matt	dT	Air
#	[ºC]	[%]	[s]	[ºC]	[ºC]	[ºC]	[ºC]
1	140	25	90	43.2	44	0.8	118.4
2	140	50	90	113.2	117.8	4.6	147.6
3	140	25	30	73	74.8	1.8	122.7
4	160	75	60	73.4	76.9	3.5	151.9
5	140	75	60	76.6	78.8	2.2	165.1
6	160	75	90	86.3	90.8	4.5	162.4
7	140	75	90	96.9	99.8	2.9	145.7
8	180	75	30	72.7	74.4	1.7	127.6
9	160	50	90	68.6	70.6	2	137.9
10	140	75	30	100.9	103.3	2.4	129.4
11	160	25	30	60.9	64.9	4	126.2
12	140	25	60	87.6	88.8	1.2	128.3
13	160	25	90	59.8	61.2	1.4	121.8
14	180	50	90	65.4	69.2	3.8	144.6
15	160	25	60	49.6	50.1	0.5	134.3
16	180	50	30	52.8	53.6	0.8	124.3
17	180	25	60	51.3	54.2	2.9	149.6
18	180	50	60	56.3	59.1	2.8	142.5
19	180	75	60	79.3	82.9	3.6	144.9
20	180	25	30	107.3	110.2	2.9	166.7
21	180	25	90	91.4	94.5	3.1	153.4
22	140	50	30	94.3	99.4	5.1	145.8
23	160	50	30	83.9	86.1	2.2	139.7
24	160	75	30	60.4	63.3	2.9	159.3
25	140	50	60	85	89	4	128.4
26	160	50	60	105.9	110	4.1	163.9
27	180	75	90	127.9	129.6	1.7	166.9