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Effect of Environmental Stress on PowerSites™

Environmental stresses were imposed upon PowerSite™ samples to determine the effect on thermal resistance. PowerSites are a new automated thermal solution in power supply assemblies. The PowerSite assembly process involves a high temperature lamination of 1 oz copper foil to an aluminum substrate via proprietary thermoplastic polyimide (TPI) film, based on Kapton™ MT with a thin coating of polyimide adhesive on both sides. (The power device is then soldered to the PowerSite patch.)

The thermal performance of this technology is dependent upon the reliability and repeatability of the lamination. Environmental stresses were designed to test the integrity of the lamination at the aluminum-TPI and TPI-copper interfaces as well as the solder joint interface. The Analysis Tech™ Thermal Analyzer Phase VI was used to measure the thermal resistance of the samples before and after stress.

There was no statistically significant change in thermal resistance as a result of exposure to:

- High-temperature aging at 150°C for 1000 hours
- Liquid-to-liquid thermal shock (200 cycles, ASTM D1674, -50 to 150°C)
- Thermal cycling (1000 hours/1000 cycles, –50 to 150°C)
- 85°C/85% humidity for 1000 hours

A summary of the normalized test data is presented below.

ENVIRONMENTAL STRESS	Conditions	**Thermal Resistance After Exposure** (Before Exposure = 1.00)
High-Temperature Aging	150°C for 1000 hours	0.98
Thermal Shock (Liquid-to-liquid)	200 cycles, -50 to 150°C	0.96
Thermal Cycling	1000 cycles, –50 to 150°C	1.03
High Heat + High Humidity	85°C/85%RH for 1000 hours	1.01

Therefore, no change in thermal performance would be expected with PowerSites during operation, even with the most severe environmental stress. In all cases, the integrity of the lamination was maintained, and the solder joint was unaffected.

TEST CONDITIONS:

The Analysis Tech™ Thermal Analyzer Phase VI was used to evaluate the thermal resistance via the electric pulse technique. 25 Watts were dissipated from the TO-247 package to ambient which approximated a 150°C junction temperature. Temperature readings were taken at the junction per given voltage, at the center of the aluminum substrate beneath the junction[1], at the heat sink[2], and at ambient within the wind tunnel. From these readings, the $R_{junction\text{-}sink}$ and $R_{junction\text{-}ambient}$ were deduced. The backside of the aluminum slug was adhered to the heat sink using T412 Thermattach™ tape (1 in x 1 in).

[1]36 gauge Type T precision thermocouple wire was inserted into a silicone greased (Dow Corning 340) hole bored with a #65 drill
[2]36 gauge Type T precision thermocouple wire was encapulated in a thermally conductive silicone elastomer

RESULTS:

The following data tables illustrate the "before" and "after" thermal resistance for each data set. The $R_{j\text{-}AL}$ appears in bold, because a change in thermal resistance at this interface would indicate a change in the lamination as a result of the stress. Each sample was assigned a group number for organizational purposes. A total of 120 assemblies were prepared. Every sixth assembly from 1-120 falls within the same stress grouping. The data below is the average, standard deviation, and coefficient of variation for twenty samples.

A summary of the data is provided below for the change in $R_{j\text{-}AL}$ for each of the environmental tests. The environmental tests did not cause any significant change in the thermal resistance of the PowerSite. From the baseline data of the 120 PowerSite samples, the average thermal resistance was 1.01 °C/W with one standard deviation of 0.075. Thus, with 95% confidence, the thermal resistance of the PowerSite assembly is between 0.94 and 1.09 °C/W. Changes resulting from the environmental stress were well within the one standard deviation. Also, the average increase in thermal resistance of the 80 environmental-stressed samples is 0.04 °C/W. This relatively small change in thermal resistance can also be questioned knowing the limits and tolerances of the thermocouples, etc.

BASELINE VERIFICATION

Baseline Thermal Data

	Group	Q, watt	Tj	Tal	Tsink	Tamb	**Rj-AL**	Rj-s	Rj-a	Ral-s	Rs-a
Average	2	25.34	135.94	110.96	94.46	25.23	**0.99**	1.64	4.37	0.65	2.73
Std Dev	2	0.14	3.0	2.8	1.1	0.8	**0.03**	0.11	0.11	0.10	0.03
Coeff of Var	2	0.6%	--	--	--	--	**2.9%**	6.8%	2.5%	15.0%	1.1%

After Room Temperature "Aging"

	Group	Q, watt	Tj	Tal	Tsink	Tamb	**Rj-AL**	Rj-s	Rj-a	Ral-s	Rs-a
Average	2	24.88	133.47	108.95	93.94	25.55	**0.98**	1.59	4.33	0.60	2.75
Std Dev	2	0.09	2.2	2.5	1.3	1.1	**0.03**	0.06	0.06	0.06	0.02
Coeff of Var	2	0.4%	--	--	--	--	**2.8%**	3.6%	1.3%	10.5%	0.8%

HIGH-TEMPERATURE AGING

	Group	Q, watt	Tj	Tal	Tsink	Tamb	Rj-AL	Rj-s	Rj-a	Ral-s	Rs-a
Baseline Thermal Data											
Average	3	25.34	136.33	110.11	94.52	25.44	**1.03**	1.65	4.37	0.62	2.73
Std Dev	3	0.23	4.8	5.1	0.7	0.5	**0.06**	0.20	0.19	0.21	0.02
Coeff of Var	3	0.9%	--	--	--	--	**6.0%**	12.0%	4.4%	33.9%	0.7%

	Group	Q, watt	Tj	Tal	Tsink	Tamb	Rj-AL	Rj-s	Rj-a	Ral-s	Rs-a
After High-Temperature Aging											
Average	3	25.18	137.14	111.72	94.12	25.77	**1.01**	1.70	4.42	0.70	2.71
Std Dev	3	0.17	5.0	4.5	3.0	1.3	**0.05**	0.15	0.18	0.14	0.06
Coeff of Var	3	0.7%	--	--	--	--	**5.1%**	8.7%	4.0%	19.6%	2.3%

THERMAL CYCLING

	Group	Q, watt	Tj	Tal	Tsink	Tamb	Rj-AL	Rj-s	Rj-a	Ral-s	Rs-a
Baseline Thermal Data											
Average	4	25.32	135.39	109.15	94.96	24.84	**1.04**	1.60	4.37		
Std Dev	4	0.13	4.0	5.4	3.7	1.0	**0.14**	0.23	0.17		
Coeff of Var	4	0.5%	--	--	--	--	**13.3%**	14.2%	3.9%		

	Group	Q, watt	Tj	Tal	Tsink	Tamb	Rj-AL	Rj-s	Rj-a	Ral-s	Rs-a
After High-Temperature Aging											
Average	4	25.28	138.85	111.60	93.47	25.24	**1.08**	1.79	4.49		
Std Dev	4	0.15	6.5	4.9	1.1	1.0	**0.08**	0.26	0.24		
Coeff of Var	4	0.6%	--	--	--	--	**7.0%**	14.5%	5.3%		

THERMAL SHOCK

	Group	Q, watt	Tj	Tal	Tsink	Tamb	Rj-AL	Rj-s	Rj-a	Ral-s	Rs-a
Baseline Thermal Data											
Average		25.12	135.11	109.25	94.22	25.13	**1.03**	1.63	4.38	0.60	3.35
Std Dev		0.14	3.36	2.86	1.03	0.71	**0.07**	0.14	0.13	0.13	0.11
Coeff of Var		0.6%	--	--	--	--	**6.5%**	8.6%	2.9%	21.1%	3.4%

	Group	Q, watt	Tj	Tal	Tsink	Tamb	Rj-AL	Rj-s	Rj-a	Ral-s	Rs-a
After Thermal Shock											
Average		25.21	137.2	110.6	94.4	25.5	**1.06**	1.70	4.43	0.64	3.38
Std Dev		0.16	3.3	2.7	1.6	1.1	**0.05**	0.12	0.11	0.11	0.10
Coeff of Var		0.4%	--	--	--	--	**4.3%**	6.8%	2.6%	17.0%	3.0%

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HIGH HEAT + HIGH HUMIDITY

Baseline Thermal Data										
Group	Q, watt	Tj	Tal	Tsink	Tamb	**Rj-AL**	Rj-s	Rj-a	Ral-s	Rs-a
Average	25.12	134.9	109.6	94.9	25.9	**1.00**	1.59	4.34	0.59	2.75
Std Dev	0.11	3.6	3.5	1.0	0.8	**0.05**	0.16	0.14	0.16	0.02
Coeff of Var	0.4%	--	--	--	--	**5.1%**	9.8%	3.2%	27.2%	0.8%

After High Heat + High Humidity										
Group	Q, watt	Tj	Tal	Tsink	Tamb	**Rj-AL**	Rj-s	Rj-a	Ral-s	Rs-a
Average	25.15	140.6	115.0	95.4	27.2	**1.01**	1.80	4.51	0.78	2.71
Std Dev	0.17	3.9	2.8	1.9	1.4	**0.07**	0.12	0.11	0.10	0.03
Coeff of Var	0.7%	--	--	--	--	**6.9%**	6.4%	2.3%	13.2%	0.9%