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PWB Document # PWB-150316

Record of Change:

Rev:	Change:
2015-03-18	Original Document release
2019-09-03	Reference ESA (ECSS-Q-ST-70-60C) rather than DRAFT QT/2014/030/SHv2
2019-10-11	Section 3.3 – Change sequence - bake prior to soldering connectors to align with ESA (ECSS-Q-ST-70-60C)

European Space Agency (ESA) Requirements for IST Coupon Pre-screening, IST Testing and Report Writing

1. **Scope:** The scope of this document is to establish a standard prescreening, testing and reporting format for all IST work completed to confirm compliance to ESA specifications (ECSS-Q-ST-70-60C). This document identifies the procedures required to complete electrical pre-screening, IST testing protocol and reporting formats.

2. **Applicability:** This procedure is in addendum to ESA (ECSS-Q-ST-70-60C) and is subject to approval by ESA. This protocol will be shared with vendors who either utilize IST equipment within their facility or subcontract to a test house using IST equipment. PWB Interconnect Solutions Inc. can provide quotations for independent IST testing services upon request.

   Note 1: IST coupon designs, manufactured coupons or IST test methods do not fall under confidentiality clauses or contain any proprietary information however IST testing results may be deemed confidential.

3. **IST Testing**
   - **3.1. Coupon Design:** As specified by ESA (ECSS-Q-ST-70-60C)
     - 3.1.1. Testing as per ESA (ECSS-Q-ST-70-60C) unless otherwise directed by ESA.

3.2. Sample Size: All coupons manufactured will be prescreened and made available for IST testing.

3.3. Prescreening: (For detailed activities see Appendix A

3.3.1. Coupons will be visually inspected, counted and the coupon name recorded.

3.3.2. All coupons will be checked for open and shorts.

3.3.3. Drilled hole to internal layer registration and the planarization will be measured and recorded.

3.3.4. The “As received” capacitance is measured and recorded.

3.3.5. Coupons shall be baked per ESA (ECSS-Q-ST-70-60C) unless otherwise directed.

3.3.6. 4-pin headers will be soldered to the heating and sense circuits that will be tested.

3.4. IST Testing Protocol: The number of coupons to be selected for IST evaluation is specified by ESA (ECSS-Q-ST-70-60C). The selected coupons will be subjected to the following IST testing protocol.

3.4.1. The resistance measurements are taken on the IST tester and a standard statistical evaluation is completed at the end of test.

3.4.2. All coupons will be preconditioned as per the ESA procurement documentation stating number of cycles and test temperature.

3.4.3. The “After preconditioning” capacitance is measured and recorded.

3.4.4. IST testing will be completed as per ESA procurement documentation stating number of cycles and test temperature.

3.4.5. Testing will continue until end of test, any test circuit measures exceeds the percent increase in resistance stated in the acceptance criteria or until any fail criterion has been reached.

3.4.6. The “End of test” capacitance is measured and recorded.

3.5. Acceptance/Rejection criteria:

3.5.1. All coupons must meet the “Requirements for IST Endurance` as stated in section 5.3 of the ESA (ECSS-Q-ST-70-60C) document.

4. Microsection Evaluation

4.1 Microsectioning of coupons when required shall be performed in accordance with IPC-TM-650, Method 2.1.1 or 2.1.1.2. The number of microsections for compliance with ESA (ECSS-Q-ST-70-60C)

5. Report Writing

5.1. Conformance Reporting: (For an example of a conformance report see Appendix B, beginning on page 20)

5.1.1. There will be a report generated for each tested group. Reports for multiple groups can be presented in one document if required. The report for each independent test group must include:

- Clearly define pertinent information for traceability (e.g. Part number, work order number, lot number, Date code).

- The test results clearly indicating the pass/fail results for each individual coupon and a statistical analysis of the group/lot performance.
- Protocol used.
- The prescreening measurements as taken by the IST system prior to testing.
- All relevant data accumulate during prescreening in table format (e.g. Planarization, RTD measurements).
- A table containing the capacitance data including measurements taken “As received” “After preconditioning” and “End of test” and a table demonstrating the capacitance change expressed as a percentage.

5.2. Reliability/ DOE Reporting: (For an example of a Reliability/ DOE report see Appendix C, beginning on page 24)

5.2.1. There will be a report generated for each tested group. Reports for multiple groups can be presented in one document. The report must include:

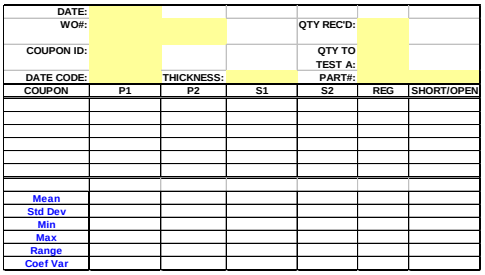
- Opening preamble stating the date, the intent of the IST testing, the provider of the test services, any pertinent information for traceability (e.g. Part numbers, work order numbers, lot numbers, Date codes) and any other information deemed necessary by the author.
- Test methods used.
- The test results clearly indicating the pass/fail results for each individual coupon and a statistical analysis of the group/lot performance.
- The prescreening measurements as taken by the IST system prior to testing.
- All relevant data accumulate during prescreening in table format (e.g. Planarization, RTD measurements).
- A table containing the capacitance data including measurements taken “As received” “After preconditioning” and “End of test” and a table demonstrating the capacitance change expressed as a percentage.
- Observations and analysis of results including microsection images.
- Conclusion and comments.

Appendix A

1. Electrical prescreening

1.1 The following equipment is recommended to perform electrical prescreening:

Table A.1

• **Computer with a spreadsheet program: Commonly Microsoft Excel is used.** • **A basic working knowledge of working with spreadsheet is preferred** • **PWBIS can supply workbook templates containing all associated work sheets**	
• **Four-wire micro-volt / milliohm resistance meter: E.g. - Keithley 197 / Keithley 580 / Etc. set on auto range or to 200 milliohm** • **Used in conjunction with the PWB supplied "4-wire cable"**	
• **Four-wire Resistance Cable** • **Note: In house modification**	
• **Continuity / Ohm meter with audible tone: E.g. - Fluke Multi-meter**	

- **Soldering iron and solder:**
- **Soldering Iron Tips - Type 7 or 8 conical recommended**
- **Basic soldering skills required**

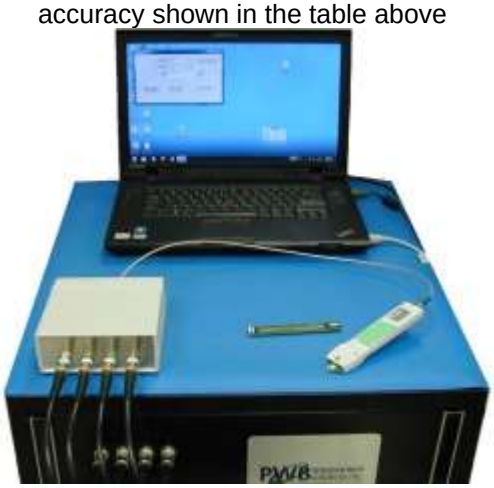
- **Marker pens or engraving tool with variable speed and small precision router/engraver bits**
- **Note: Indelible ink is recommended**

- **Capacitance Meter with Kelvin Capability:**

Or **DELAM System**

Test Conditions	PWB Measurement Range	Typical Set-up
Frequency	300 KHz - 1 MHz	1 MHz
Accuracy	+/- 0.5%	+/- 0.5%
Range	100 Pf – 1000 Pf	400 Pf
Test Temp °C	23°C +/- 3°C	23°C
Test Temp °F	(73°F +/-5°F)	73°F

The meter should have the capability and accuracy shown in the table above



1.2 Labelling of Individual Coupons

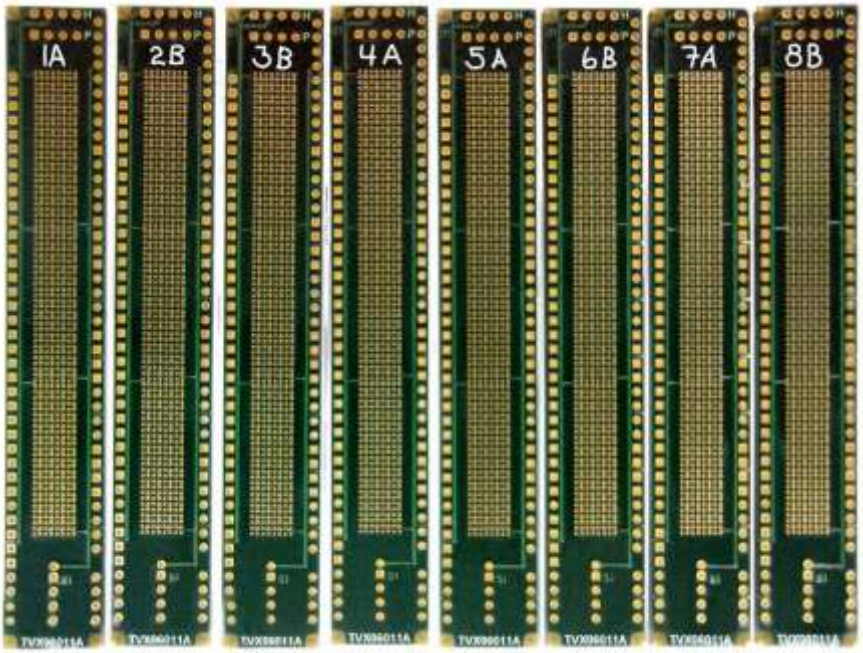
1.2.1 After a job number has been specified it is important to establish a cross-reference to all associated coupons received and to be tested within the specific production lot.

1.2.2 The label should be legible using an engraving tool or marked with an indelible marker on the top-side of the coupon, to ensure permanency.

.2.3 The size of the coupons label should contain as few characters as possible, while still maintaining trace-ability to prevent possible confusion and spacing issues during data graphing and analysis.

.2.4 Using the panel serial number and coupon location is an example of a simple label. Below in Figure A1 there are 8 coupons labelled with their corresponding panel numbers (1 to 8) followed by the coupon Location (A or B).

Example of labelled Coupons - Figure A1



.2.5 Alternative coupon labelling for DOE panels:
For a coupon from production lot # **16**, panel #**2**, and coupon location: **A**, the coupon might be labelled as **16_2_A (underscores optional)**
Or if there are, for example, multiple test parameters, different metal finishes, different material types or different coupon designs to be tested. You may include these differences in the labelling.

Note A1: To prevent confusion every coupon must have its own unique label, there should be no duplications.

.3 Preparing and Completing the Prescreening Worksheet

1.3.1 In the prescreening worksheet on your computer input in the “Header” section all available information related to the product/Customer such as: job number, date, work order number, coupon design, date code, quantity received and quantity to be tested and the associated part number (See Figure A2).

1.3.2 Ensure there are sufficient columns and rows to record: the coupon labels, the resistance measurement readings for all circuits, the coupon’s registration and to record shorted or opened circuits. It must be large enough for all received coupons. (See Figure A2).

1.3.3 In the “Statistical Field” confirm the calculations for each circuit group, they include mean, standard deviation, minimum, maximum, range and coefficient of variation. The coefficient of variation is the standard deviation divided by the mean, expressed as a percentage. Ensure range is expanded to include all coupons. (See Figure A2).

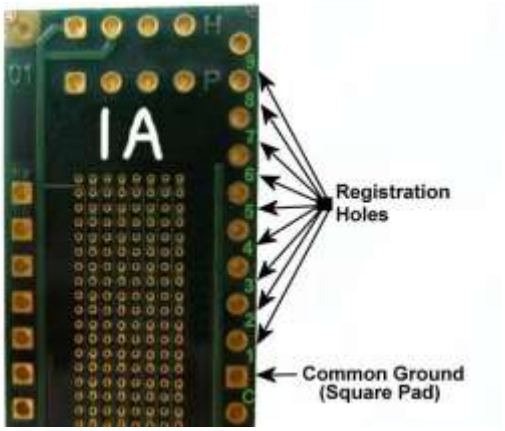
Prescreening Spreadsheet - Figure A2

HEADER →	CUSTOMER:	ABCDE			JOB#:	J15_1234
	DATE:	30-Jul-15	Lot#:	8050021		
	Customer WO#:	12345_6789	Cage Code:	L3352	QTY Received:	18
	COUPON ID:	TVX06011A	Part #:	AA25S-123X Rev B	QTY to be tested:	18
	DATE CODE:	1526	THICKNESS:	0.125		
DATA INPUT →	COUPON	H	P	S1	REGISTRATION	SHORT/OPEN
	1A	327	299	308	3	OK
	2B	322	295	295	3	OK
	3B	323	296	295	5	OK
	4A	325	294	299	3	OK
	5A	333	298	298	3	OK
	6B	319	292	289	7	OK
	7A	320	295	295	3	OK
	8B	322	296	312	5	OK
STATISTICAL FIELD →						
	Mean	322	296	299	4	
	Std Dev	2.8	2.3	8.9	1.6	
	Min	319	292	289	3	
	Max	327	299	312	7	
	Range	8	7	23	4	
	Coef Var	0.9%	0.8%	3.0%		

1.3.4 Measure and record in the header section the thickness of each coupon type using a calliper (micrometer).

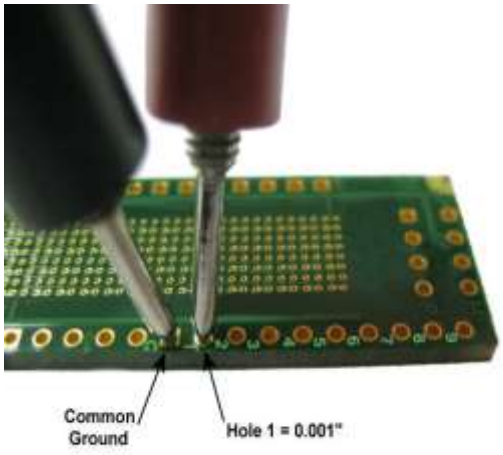
1.3.5 To measure the degree of drilled hole to internal layer registration use a milliohm meter set to emit an audible beep when there is continuity. Complete steps a. to c. for each coupon.

Figure A3



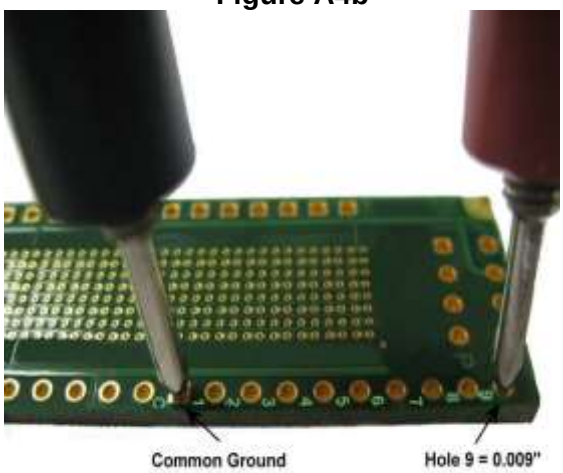
a. The 1.1mm/.043” hole with the square pad is the common ground; it is connected to all internal layers. The remaining 1.1mm/.043” holes are drilled into anti-pads (clearances) with increasing diameters that extend the distances between the edge of the drill and the edge of the internal copper foil.
b. The hole next to the square pad, above, is labelled with a 1 and is referenced as hole **1,** followed by holes **2**, **3, 4, 5, 6, 7, 8** and **9** respectively. The reference number represents the minimum internal clearance in inches (.000”) of that hole. Hole 1 has a 0.025mm/.001” internal annular clearance while hole 9 has a 0.225mm/.009” annular clearance.
c. With one probe of the ohmmeter in contact with the common ground hole, begin contacting, with the other probe, the remaining holes one at a time, from hole **1** all the way to hole **9** (see figure A4a and to A4b). The last hole that “beeps” reflects the minimum shift in the registration between the drilled hole and the internal clearance. This measurement is recorded in the prescreening worksheet.

Figure A4a



Leads in Common Ground and hole 1

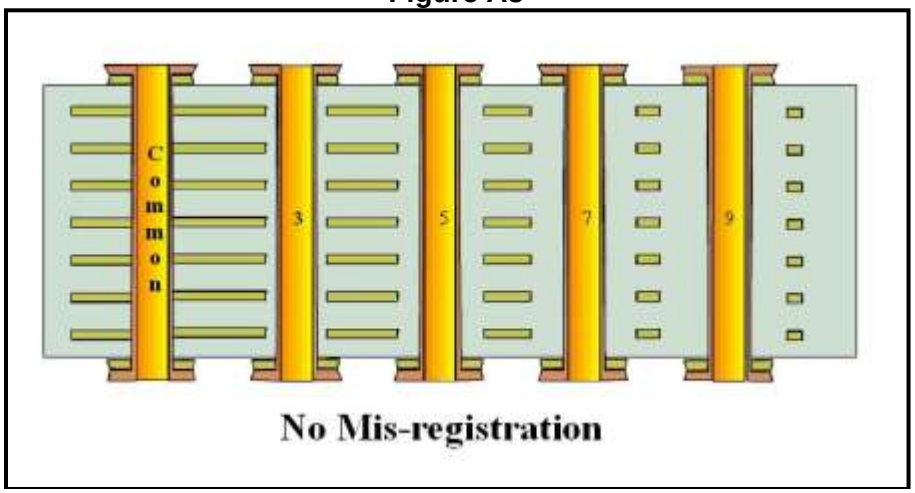
Figure A4b



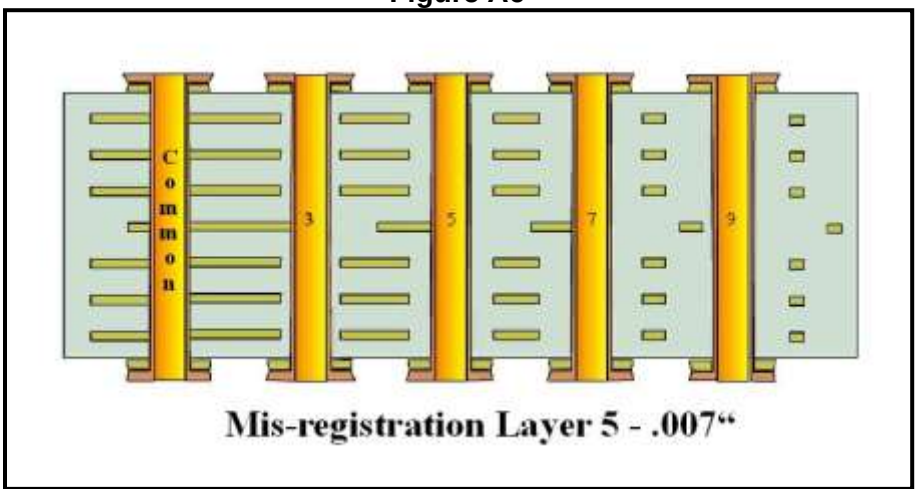
Leads in Common Ground and hole 9

Example: If hole **7** beeps and hole **9** does not beep the registration shift is greater than .007" but is less than .009". Enter a **7** in the worksheet.

Cross Section of Registration
Coupon with Good Registration
Figure A5



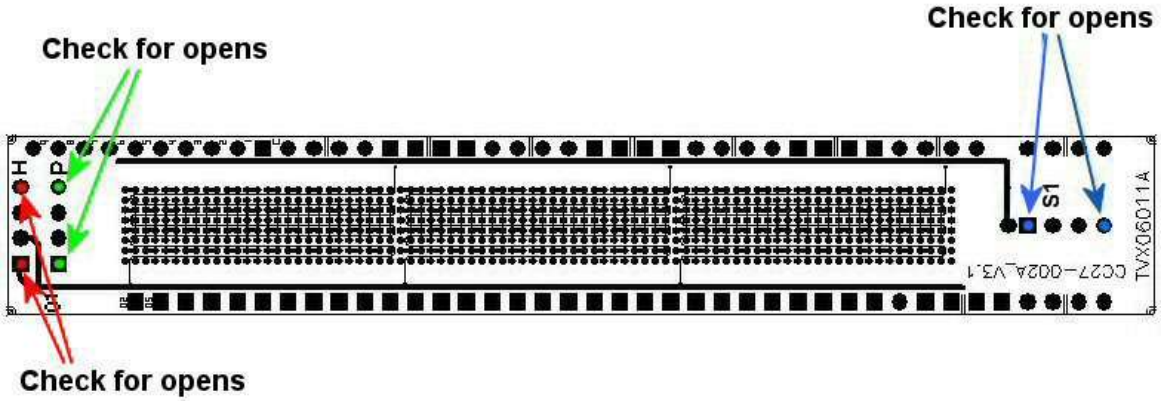
Cross Section of Registration
Coupon A1 Misregistration on Layer 5
Figure A6



1.3.6 Statistical calculation of the registration data is reviewed and includes mean, standard deviation, minimum, maximum and range. The coefficient of variation is not considered for registration analysis.

1.3.7 Opens and shorts verification is performed by using a milliohm meter set to emit an audible beep if there is continuity. Check for opens by probing between the first and the forth via on all test circuits. (See Figure A7) If any open circuits are found record the word “Open” in the spreadsheet column labelled **SHORTS/OPEN**. (See Figure A8)

Figure A7



Note A2: If a random open circuit is found the coupon circuit is not testable. Further evaluation is recommended to understand the root cause. If all received coupons have an open circuit it is more likely that a design error is responsible for the condition. Communicate any issues to the engineering or CAD/CAM department.

Check for shorts by probing between any individual via in the power circuit against the vias in all other test circuits and the capacitance holes, repeat process for the sense circuit. (See Figure A7) If any short circuits are found record what circuits/vias are shorting in the spreadsheet column labelled **SHORTS/OPEN**. (See Figure A8)

Figure A8

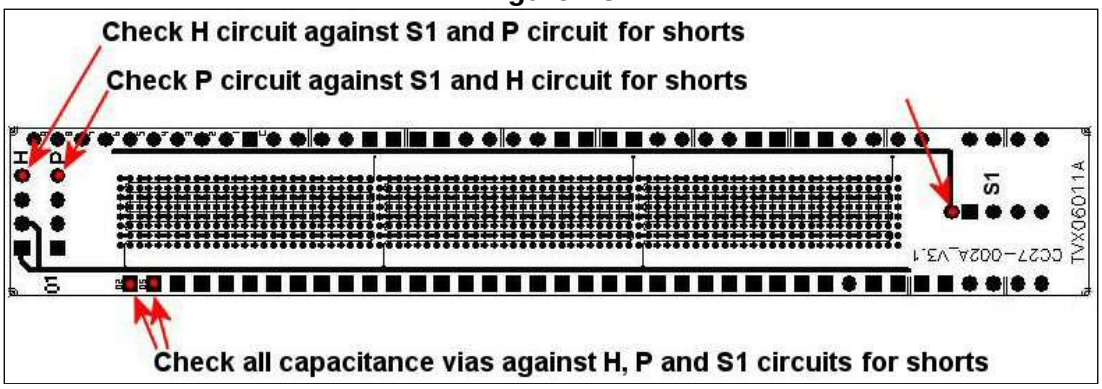


Figure A9

CUSTOMER:	ABCDE			JOB#:	J15_1234
DATE:	30-Jul-15	Lot#:	8050021		
Customer WO#:	12345_6789	Cage Code:	L3352	QTY Received:	18
COUPON ID:	TVX06011A	Part #:	AA25S-123X Rev B	QTY to be tested:	18
DATE CODE:	1526	THICKNESS:	0.125		
COUPON	H	P	S1	REGISTRATION	SHORT/OPEN
1A	327	125	308	3	P/S1 Short
2B	Open	295	295	3	H Open
3B	323	296	295	5	OK
4A	325	294	299	3	OK
5A	333	298	298	3	OK
6B	319	292	289	7	P/Layer 2 Short
7A	320	295	295	3	OK
8B	322	296	312	5	OK
Mean	322	296	299	4	
Std Dev	2.8	2.3	8.9	1.6	
Min	319	292	289	3	
Max	327	299	312	7	
Range	8	7	23	4	
Coef Var	0.9%	0.8%	3.0%		

Note A3: If a random short circuit is found the coupon circuit is not testable. Further evaluation is recommended to understand the root cause. If all received coupons have a common short circuit it is more likely that a design error is responsible for the condition. Communicate any issues to the engineering or CAD/CAM department.

1.3.8 To measure the resistance for each test circuit in the IST coupon you will need a four-wire resistance meter and a four-wire cable with a 4-pin header installed. Complete steps a. and b. for each coupon.

a. Each end of the coupon can contain one or more sets of circuit connector vias, each set contains four 1.1mm/0.043" plated through holes. The letter associated to each connector type should be entered into the prescreening workbook, just below the header, to the right of the word "Coupon". (See figure A12e) In this example the letters "**P**", "**H**" and **"S1"** are next to the circuit connector via holes. (See figure A10a and A10b)

b. Insert the 4-pin male connector from the meter into the coupon's four connector holes (See figure A11c), once the meter reading is stable (See figure A11d), record measurement into the appropriate cell of the prescreening worksheet. (See figure A12)

Figure A10a

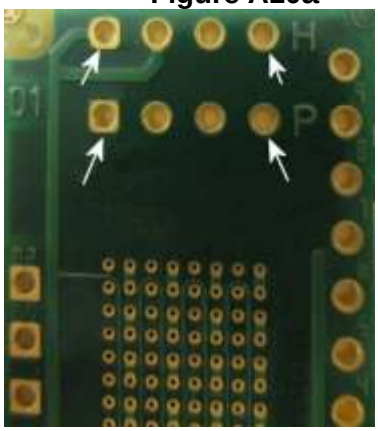
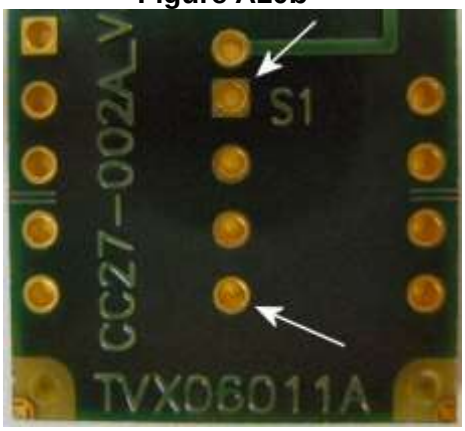
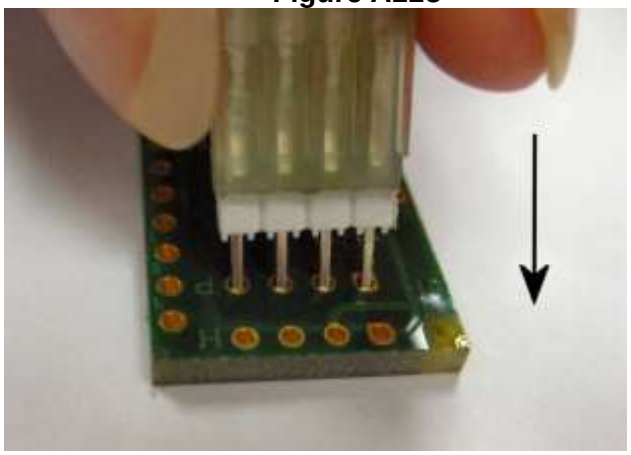


Figure A10b



Select circuits for measurement

Figure A11c



Insert meter connector

Figure A11d

Read measurement

Figure A12

CUSTOMER:	ABCDE			JOB#:	J15_1234
DATE:	30-Jul-15	Lot#:	8050021		
Customer WO#:	12345_6789	Cage Code:	L3352	QTY Received:	18
COUPON ID:	TVX06011A	Part #:	AA25S-123X Rev B	QTY to be tested:	18
DATE CODE:	1526	THICKNESS:	0.125		

COUPON	H	P	S1	REGISTRATION	SHORT/OPEN
1A	326	288	711		
2B					
3B					
4A					
5A					
6B					
7A					
8B					
Mean					
Std Dev					
Min					
Max					
Range					
Coef Var					

Record measurement

1.3.9 To measure the baseline resistance for each RTD layer in the IST coupon you will need a four-wire resistance meter and a four-wire cable with a 4-pin header installed. Complete steps a. to e. for each coupon.

a. In the prescreening worksheet create a table that contains the header RTD.

b. Create columns to record the coupon label, the RTD position and layer and the resistance measurement readings.

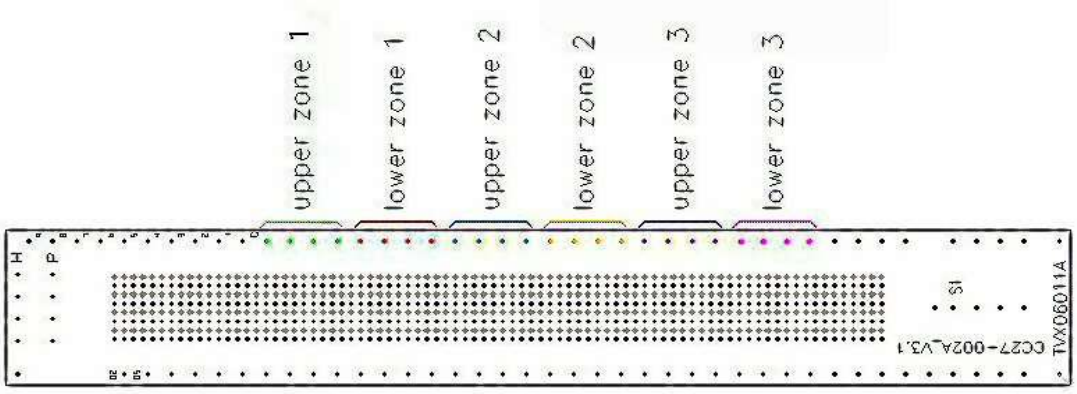
c. Create calculations for each circuit group that includes mean, standard deviation, minimum, maximum, range and coefficient of variation. The coefficient of variation is the standard deviation divided by the mean, expressed as a percentage. Ensure the statistic fields range include all the cells where the data is recorded. (see figure A13)

Figure A13

RTD						
COUPON ID	**UZ1-L#X**	**LZ1-L#X**	**UZ2-L#X**	**LZ2-L#X**	**UZ2-L#X**	**LZ3-L#X**
Mean	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Std Dev	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Min	0	0	0	0	0	0
Max	0	0	0	0	0	0
Range	0	0	0	0	0	0
Coef Var	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

d. On the edge of the coupon you will find sets of RTD vias; each set of RTD consist of 4 vias. Reference the CAM drawing for the RTD zone labels. (see figure A14)

Figure A14



e. Insert the 4 pin male connector from the meter into the first set of 4 RTD vias, once meter reading is stable record measurement in spreadsheet. Repeat until all coupon RTDs have been measured.

Figure A15a

Read measurement

Figure A15b

	RTD					
COUPON ID	UZ1-L#X	LZ1-L#X	UZ2-L#X	LZ2-L#X	UZ2-L#X	LZ3-L#X
1_A	235	203	255	320	256	295
2_B	295	256	245	210	245	286
3_C						
4_D						
5_E						
6_F						
Mean	265	230	250	265	251	291
Std Dev	42.4	37.5	7.1	77.8	7.8	6.4
Min	235	203	245	210	245	286
Max	295	256	255	320	256	295
Range	60	53	10	110	11	9
Coef Var	16.0%	16.3%	2.8%	29.4%	3.1%	2.2%

Record measurement

1.3.10 To measure the resistance for each planarized layer in the IST coupon you will need a four-wire resistance meter and a four-wire cable with a 4-pin header installed. Complete steps a. to e. for each coupon.

a. In the prescreening worksheet create a table that contains the header Planarization,

b. Create columns to record the coupon label and the resistance measurement readings for all planarized layers.

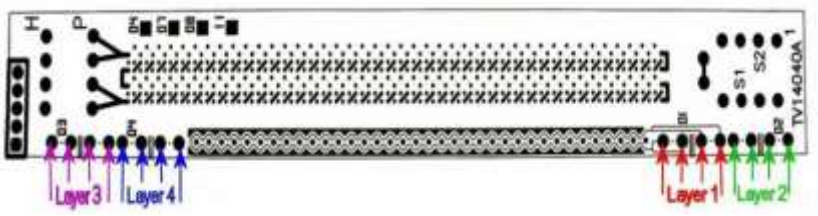
c. Create calculations for each circuit group that includes mean, standard deviation, minimum, maximum, range and coefficient of variation. The coefficient of variation is the standard deviation divided by the mean, expressed as a percentage. Ensure the statistic fields range include all the cells where the data is recorded. (see figure A13)

Figure A16

PLANARIZATION				
COUPON ID	Layer	Layer	Layer	Layer
Mean	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Std Dev	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Min	0	0	0	0
Max	0	0	0	0
Range	0	0	0	0
Coef Var	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

d. On edges of the coupon you will find one or more lines of 4 holes labelled with the layer that has had Planarization as part of it's fabrication process (see figure A17)

Figure A17



e. Insert the 4 pin male connector from the meter into the first set of 4 planarization holes, once meter reading is stable record measurement in spreadsheet (see figure A18a). Repeat until all coupon layers have been measured (see figure A18b).

Figure A18a

Read measurement

Figure A18b

PLANARIZATION				
COUPON	Layer X	Layer X	Layer X	Layer X
1_1				
1_2				
1_3				
1_4				
1_5				
1_6				
Mean	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Std Dev	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Min	0	0	0	0
Max	0	0	0	0
Range	0	0	0	0
Coef Var	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Record measurement

1.4 Capacitance Measurements

1.4.1 **Manua**l: To manually measure the capacitance for each plane in the IST coupon you will need a capacitance meter measuring in Pico farads. Complete steps a. to e. for each coupon.

Note 4A**:** When taking the capacitance measurements with LCR equipment the capability and accuracy should be as shown in table A2. It is also recommended that specifically design test probes are used to ensure repeatability and reproducibility of measurements. Confirm equipment accuracy with in-house calibration procedures, device and/or standard. Allow test equipment 30 minutes to warm up and stabilize.

Table A2

Test Conditions	PWB Measurement Range	Typical Set-up
Frequency	300 KHz - 1 MHz	1 MHz
Accuracy	+/- 0.5%	+/- 0.5%
Range	100 Pf – 1000 Pf	400 Pf
Test Temp °C	23°C +/- 3°C	23°C
Test Temp °F	(73°F +/-5°F)	73°F

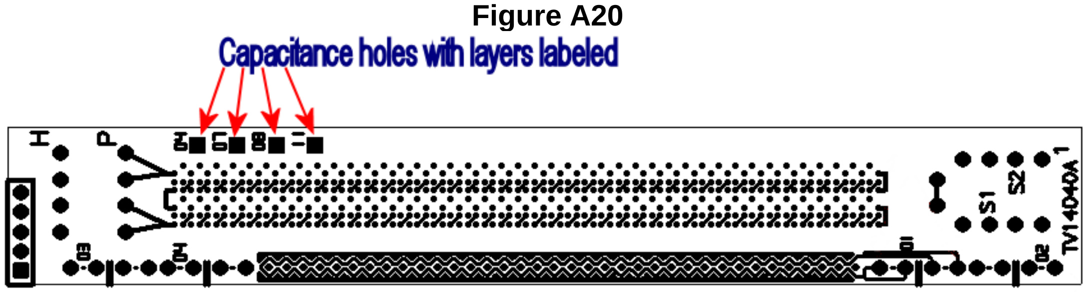
a. In the capacitance worksheet ensure the capacitance table has sufficient columns and rows to record: the coupon labels, the layer identification and the capacitance measurement for “As received”, “After preconditioning” and “End of test” for all coupons. (See figure A19).

Figure A19

HEADER →	JOB#		CUSTOMER:				DATE
	CALIBRATION VALUE:		CALIBRATION VALUE:		CALIBRATION VALUE:		
Capacitance Measurements →	Capacitance Data						
	Layer						
Percent of Change from Initial Measurement →	Capacitance in Picofarads						
	Layer	A2	A3	A4	B3	B2	B3
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

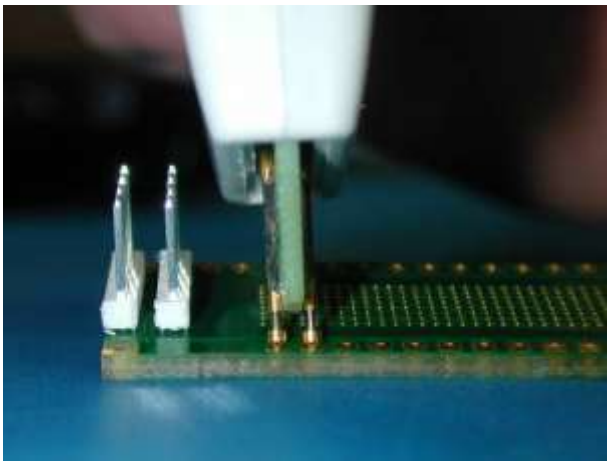
b. Orientate the coupon with the via identifications in numerical order with the lowest connected layer on the left hand side (See figure A20), probe/measure the first two adjacent vias (See figure A21a) and record the capacitance values in the spreadsheet (See figure A21b).

Figure A20



Orientate coupon

Figure A21a **Figure A21b**



Take measurement

JOB#	CUSTOMER:				DATE
CALIBRATION VALUE:	CALIBRATION VALUE:		CALIBRATION VALUE:		

Capacitance Data

Layer	6A	6B	7A	7B	11A	11B
2/4	164	166	167	165	165	164
	164	166	167	165	165	164
	163	165	166	164	164	163
4/6	173	175	174	174	173	171
	174	175	174	174	173	170
	172	174	172	173	172	169
6/8	215	215	215	213	215	209
	215	215	215	213	215	209
	213	213	213	211	213	207
8/10	251	242	252	240	250	254
	251	243	252	239	250	253
	248	240	249	237	248	251
10/11	178	177	174	177	176	179
	178	177	174	177	176	179
	176	175	172	175	175	177
11/12	328	330	316	329	328	327
	328	330	317	330	328	327
	326	327	314	327	326	324

Record measurement

c. Continue to measure and record each pair of adjacent vias, in sequence (E.g. 1 to 2, 2 to 3, 3 to 4, Etc.), until complete. Repeat procedure for all coupons.

d. Review collected data for any measurement anomalies and repeat measurement to confirm for correctness any anomalies. (See figure A22).

Figure A22

Capacitance in Picofarads

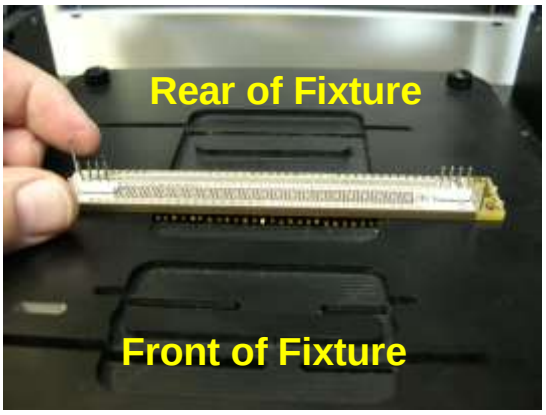
Layer	A2	A3	A4	B3	B2	B3
2/4						
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
4/6						
	0.6%	0.0%	0.0%	0.0%	0.0%	-0.6%
	-0.6%	-0.6%	-1.2%	-0.6%	-0.6%	-1.2%
6/8						
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-1.0%
8/10						
	0.0%	0.4%	0.0%	-0.4%	0.0%	-0.4%
	-1.2%	-0.8%	-1.2%	-1.3%	-0.8%	-1.2%
10/11						
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	-1.1%	-1.1%	-1.2%	-1.1%	-0.6%	-1.1%
11/12						
	0.0%	0.0%	0.3%	0.3%	0.0%	0.0%
	-0.6%	-0.9%	-0.6%	-0.6%	-0.6%	-0.9%

e. Statistically compare data for consistency. Initial analysis should establish a reference for subsequent measurements which will be completed after each thermal excursion (Preconditioning, IST Etc).

1.4.2 **Automated**: To measure the capacitance for each plane in the IST coupon you will need a DELAM system which measures in Pico farads. Complete steps a. and b. for each coupon.

a. Orientate the coupon with the top side up and place on the DELAM system. (See figure A23a and A23b), Close fixture (See figure A21a) and record the capacitance measurements will be automatically be entered into a spreadsheet (See figure A24).

Figure A23a



Place coupon in DELAM system

Figure A23b

Close fixture

Figure A24

J15_1234																	
As Received						After Prescreening						After Precon					
1_A	2_B	3_C	4_D	5_E	6_F	1_A	2_B	3_C	4_D	5_E	6_F	1_A	2_B	3_C	4_D	5_E	6_F
135.76	136.86	140.97	133.75	136.87	139.66	131.99	133.87	137.4	129.24	132.89	139.86	139.02	141.15	145.34	142.36	132.89	139.86
187.19	185.01	187.83	194.22	189.8	193.64	182.86	179.42	180.53	188.27	183.92	193.59	190.28	187.09	188.14	195.02	183.92	193.59
150.62	157.57	159.26	154.37	163.81	164.2	146.77	151.95	154.86	149.45	159.48	164.17	151.42	156.98	160.02	164.02	159.48	164.17
185.1	183.76	186.64	191.98	188.7	192.56	176.54	177.56	180.28	184.88	182.95	192.49	180.29	182.32	185.15	191.41	182.95	192.49
155.42	168.48	160.54	159.99	164.43	163.84	137.22	160.45	155.87	146.54	156.07	163.85	139.97	164.45	159.74	162.83	156.07	163.85
193.9	186.18	192.41	197.51	191.76	198.32	186.59	179.3	180.68	190.37	182.83	198.27	189.82	183.61	184.26	196.88	182.83	198.28
154.29	159.13	166.16	159.85	168.37	164.11	149.51	154.72	160.61	153.07	163.6	164.1	151.86	158.07	164.21	163.06	163.6	164.1
192.68	186.4	192.03	199.11	193.02	198.44	186.44	176.57	182.27	191.65	184.59	198.37	189.6	180.41	186.32	197.1	184.59	198.37
156.53	169.28	165.41	163.53	166.82	168.84	149.73	164.19	160.61	154.45	161.79	168.86	152.86	167.96	164.29	167.72	161.78	168.86
191.2	191.46	187.28	198.55	198.62	191	186.22	185.24	180.25	192.12	192.11	190.93	190.5	190.35	184.93	189.85	192.11	190.93
159.7	163.2	162.57	157	168.2	161.28	152.73	159.13	158.23	150.48	163.61	161.23	156.93	164.16	163.2	160.96	163.61	162.23
189.83	188.41	184.92	197.52	195.06	194.09	184.89	183.85	177.81	191.15	188.1	194.06	191.73	191.62	185.22	195.27	188.1	194.06
145.98	148.77	151.85	144.49	149.56	149.12	143	145.48	148.28	140.69	145.86	149.26	150.76	153.79	156.77	151.82	145.86	149.26

b. Statistically compare data for consistency. Initial analysis should establish a reference for subsequent measurements which will be completed after each thermal excursion (Preconditioning, IST Etc).

Appendix B

Example of ESA IST Test Report (Conformance)

Header: Table B1 demonstrates the report header which contains pertinent information for traceability.

Date: DD MM YYYY

Table B1

Job Number jYY_XXXX	**Test Cycles** 400	**Precon Cycles** 6
Lot Number 123456	**Test Temp** 170	**Precon Temp** 230
Customer ABCDE	**Coupon Type** PTH	**Fail Method:** Power/Sense
Cage Code # N/A	**Test Vehicle #** LLNNNNN	**Date Code:** YYMM
Coupon Rec 8	**Incoming Tested** 8	**Coupons Passed** 8
Customer Req ESA (ECSS-Q-ST-70-60C)	**Part #** XXXXXXX	**WO #** XXXXXXX

Test Results: Table B2 is an example of the IST test results, statistical field and compliance to the test protocol (PASS/FAIL).

Table B2
TEST RESULTS

Coupon ID	Pwr Cycles	Pwr %	PTH Cycles	PTH %	Results
1A	400	0.9	400	1.7	Accept
2B	400	1.3	400	2.3	Accept
3B	400	1	400	2	Accept
4A	400	1.3	400	2.3	Accept
5A	400	0.5	400	1.4	Accept
6B	400	0.1	400	0.8	Accept
7A	400	0.4	400	1.2	Accept
8B	400	0.6	400	1	Accept
					Cus Spec
Mean	**400**	**0.8**	**400**	**1.6**	**N/A**
Std Dev	0.0	0.4	0.0	0.6	
Min	400	0.1	400	0.8	**Pass**
Max	400	1.3	400	2.3	
Range	0	1.2	0	1.5	**N/A**
Coef Var	0%		0%		

TEST PROTOCOL: ESA (ECSS-Q-ST-70-60C)

----------PASS----------

Min Cyc to Fail	Min Avg Cyc to Fail	Max Coefficient Variation	Percent Change (%)	Applied to:	
				POWER	SENSE
400	**N/A**	**N/A**	**2**	**YES**	**YES**
NOTES: N/A					

Electrical prescreening: Table B3 displays the measurements for the power and sense which were recorded by the IST tester at ambient as a baseline for subsequent measurements. Measurements are in milliohms.

Table B3
Electrical Prescreening Results

Coupon ID	Power	Sense
1A	386.8	176
2B	382.1	167.4
3B	384.6	166.3
4A	376.6	169.9
5A	388.3	170.5
6B	384.8	169
7A	382.1	169.9
8B	384.4	170.4
Mean	**384**	**170**
Std Dev	3.6	2.9
Min	377	166
Max	388	176
Range	12	10
Coef Var	1%	2%

Planarization: Table B4 is an example of the Planarization data measured in milliohms. This table is dependant on the presents of Planarization vias in the coupon design.

Table B4

PLANARIZATION				
COUPON	**Layer 7**	**Layer 1**	**Layer 10**	**Layer 11**
A_1	1006	250	570	526
A_2	1060	243	619	631
A_3	1053	231	579	543
A_4	1055	233	599	614
A_5	1052	246	565	553
A_6	1050	254	592	636
Mean	**1046**	**243**	**587**	**584**
Std Dev	19.9	9.2	20.1	48.6
Min	1006	231	565	526
Max	1060	254	619	636
Range	54	23	54	110
Coef Var	1.9%	3.8%	3.4%	8.3%

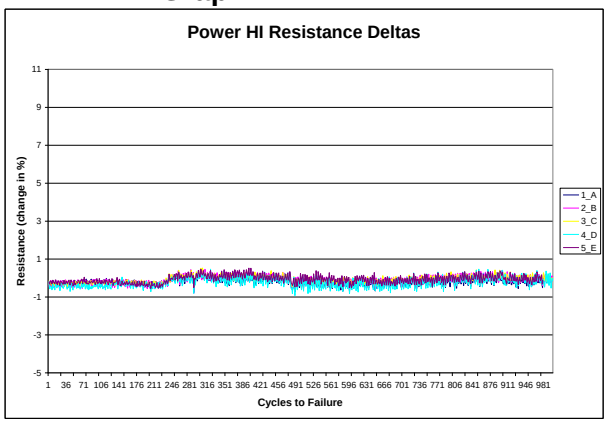
Planarization: Table B5 is an example of the RTD data measured in milliohms. This table is only required if there are RTD vias in the coupon design.

Table B5

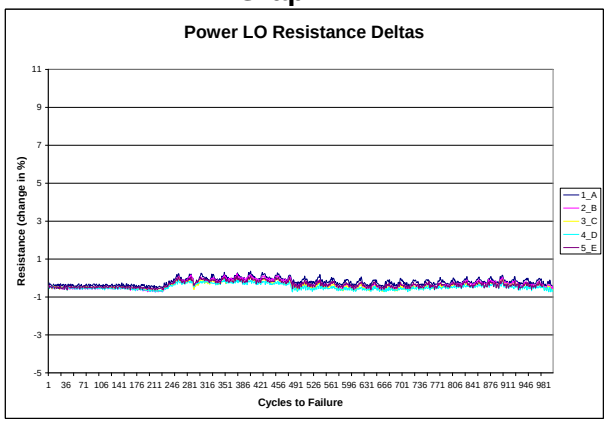
	RTD					
COUPON	**UZ1-L3**	**LZ1-L4**	**UZ2-L3**	**LZ2-L4**	**UZ3-L3**	**LZ3-L4**
1A	**287**	**292**	**293**	**292**	**297**	**292**
2B	**288**	**286**	**289**	**291**	**287**	**291**
3B	**286**	**282**	**295**	**287**	**285**	**293**
4A	**302**	**293**	**253**	**295**	**305**	**291**
5A	**292**	**282**	**293**	**280**	**291**	**282**
6B	**298**	**290**	**268**	**283**	**304**	**285**
Mean	**292**	**288**	**282**	**288**	**295**	**289**
Std Dev	6.5	4.9	17.3	5.7	8.5	4.4
Min	286	282	253	280	285	282
Max	302	293	295	295	305	293
Range	16	11	42	15	20	11
Coef Var	2.2%	1.7%	6.1%	2.0%	2.9%	1.5%

Resistance Graphs: Graphs 1 to 4 are examples of the resistance delta in milliohms.

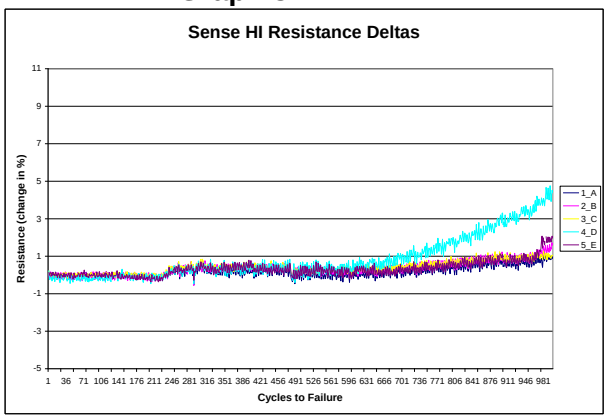
Graph 1



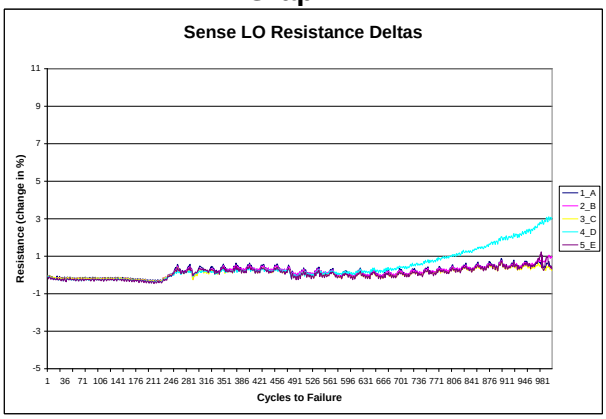
Graph 2



Graph 3



Graph 4



Capacitance Data: Table B6 illustrates the capacitance measurement results.

Key

Capacitance Legend
As Received
After Preconditioning
End of test
N/A
Above Acceptable Limit

Table B6

Delamination Evaluation						
Capacitance in Pico farads						
Design: SL20044A						
Layer	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**
2/5	160	161	159	160	159	161
	159	160	158	159	159	160
	157	158	157	157	157	159
5/8	171	171	170	169	170	171
	169	169	168	168	170	171
	167	166	166	165	167	168
8/10	212	214	213	211	214	210
	210	213	211	210	213	210
	207	209	208	206	209	206
10/11	262	264	264	265	263	278
	261	263	262	264	262	278
	257	259	258	259	257	273
11/14	172	174	173	171	172	175
	171	172	172	170	171	174
	169	169	170	167	168	171
14/15	341	336	346	336	339	338
	340	333	343	334	338	337
	335	328	340	329	333	332
15/16	357	367	364	357	362	361
	355	365	362	357	361	360
	350	360	357	352	356	355
16/19	161	162	163	161	164	163
	160	161	162	160	163	162
	159	159	160	158	162	160

Percent Change						
Layer	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**
2/5						
	0.6%	0.6%	0.6%	0.6%	0.0%	0.6%
	1.9%	1.9%	1.3%	1.9%	1.3%	1.2%
5/8						
	1.2%	1.2%	1.2%	0.6%	0.0%	0.0%
	2.3%	2.9%	2.4%	2.4%	1.8%	1.8%
8/10						
	0.9%	0.5%	0.9%	0.5%	0.5%	0.0%
	2.4%	2.3%	2.3%	2.4%	2.3%	1.9%
10/11						
	0.4%	0.4%	0.8%	0.4%	0.4%	0.0%
	1.9%	1.9%	2.3%	2.3%	2.3%	1.8%
11/14						
	0.6%	1.1%	0.6%	0.6%	0.6%	0.6%
	1.7%	2.9%	1.7%	2.3%	2.3%	2.3%
14/15						
	0.3%	0.9%	0.9%	0.6%	0.3%	0.3%
	1.8%	2.4%	1.7%	2.1%	1.8%	1.8%
15/16						
	0.6%	0.5%	0.5%	0.0%	0.3%	0.3%
	2.0%	1.9%	1.9%	1.4%	1.7%	1.7%
16/19						
	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
	1.2%	1.9%	1.8%	1.9%	1.2%	1.8%

Appendix C

Examples of Information to be included in the IST Failure Analysis Report

Title: Microsection Report J15_1234

Preamble: Clearly define pertinent information for traceability (e.g. Part number, work order number, lot number, Date code, materials) and the purpose of the DOE (e.g. material study, plating evaluation).

Coupon Design Features: Provide a brief description of the circuit features in the coupon design. (See Example 1)

Example 1
Design SLX16004A is a 16 layer, sequentially laminated, dual sense coupon.

- The “P” circuit is a L1 to L8 (top) and L16 to L9 (bottom) Blind via (BV) with interconnects on layers 2 and 3 (top) and layers 15 and 14 (bottom).
- The sense circuit “S1” is a L1 to L8 and L16 to L9 BV
- The sense circuit “S2” is a L3 to L4, L5 to L6 and L14 to L13, L12 to L11 buried via.

Testing Protocol: Provide a brief explanation of the test method used to test the coupons. (See Example 2)

Example 2
The coupons were tested using ESA test requirements Specification (ECSS-Q-ST-70-60C):

- Preconditioning (Assembly Simulation) 10 coupons for 6 cycles to 230°C.
- One coupon each from panel was IST tested to 170°C, powering on the “P” circuit and sensing on the S1 and S2 circuits using a dual sensing protocol.
- IST testing continued to an increase in the bulk resistance, of either circuit, to 10% or end of test at 400 cycles.

Overview of test results: Provide an overview of the test results in either word form (See Example 3) or table form (See example 4)

Example 3
Two coupons failed in preconditioning exceeding the 10% fail criteria during cycle three and eight coupons completed preconditioning (6 cycles to 230°C). The eight coupons that did not fail in preconditioning continued into IST testing; the eight coupons reached end of test (1000 cycles).

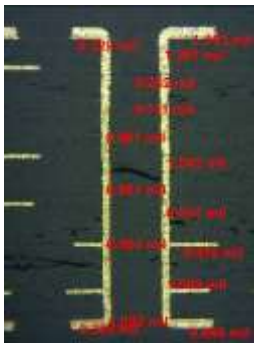
Example 4

Overview of IST Results						
	Pwr Cycles	Pwr %	SenseA (S1)Cycles	SnsA (S1)%	SenseB (S2)Cycles	SnsB (S2)%
Mean	350	-0.2	350	1.6	350	1.1
Std Dev	0	0.2	0	1.9	0	0.6
Min	350	-0.5	350	0.1	350	0.5
Max	350	0.1	350	4.9	350	2.1
Range	0	0.6	0	4.8	0	1.6
Coef Var	0%		0%		0%	

Via Structure Dimensions: Include the dimensions of the via structure in table format (See Example 5) or image form (See example 6)

Example 5

Via Structure Measurments					
Contact:	John Smith				
Customer	ABCDE		Job Number	J15_1234	
Notes:	Measurements are in mils		Interconnect	0.668	0.676
Cross Section #	4545		Electrolytic Cu 1	1.515	1.564
Manufacturer	ABCDE Inc.		Foil 2	0.550	0.599
Coupon ID	1_A		Below Knee 3	1.901	1.776
Coupon Design	TVX06011A		4	1.515	1.749
Preconditioning	6 X 260°C		5	1.580	1.633
Test Conditions	1000 X 210°C		6	1.418	1.604
IST Failure Mode	S1		7	1.392	1.653
Cycles to Failure	890		8	1.535	1.700
			Below Knee 9	1.660	1.701
			Foil 10	0.578	0.509
Drilled Hole	10.33	10.676	Electrolytic Cu 11	1.632	1.702
Finished Hole	7.693	7.65	Mean Barrel	1.572	1.688



Observations with images/photos: Provide any observations to support or refute the IST test findings (See Example 6). Provide descriptions and images of any major defects determined to be the cause of the coupon's rejection. (See Figure C1a and C1b) Provide descriptions and images of any minor defects that may have the potential to hinder future processes, as an example: plating nodules which can interfere with assembly.

Example 6

1. **Butt Joint Failure:** The failure mode was determined to be a "Butt joint failure". In a "butt joint failure" the wrap of the buried via is missing, most often its due to an aggressive skiving or planarization process. The condition makes the barrel of the buried via terminate in a flat and perhaps weaker interconnection which has difficulty maintaining contact with the cap during the expansion of the "Z" axis during thermal cycling. (See photo C1a).

Figure C1a

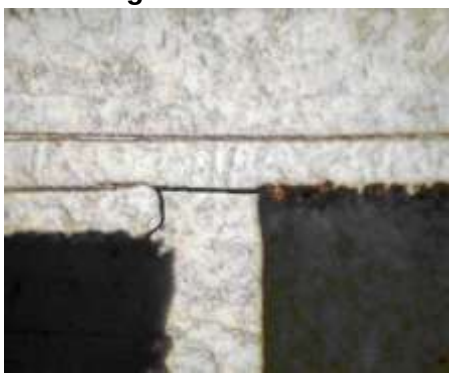
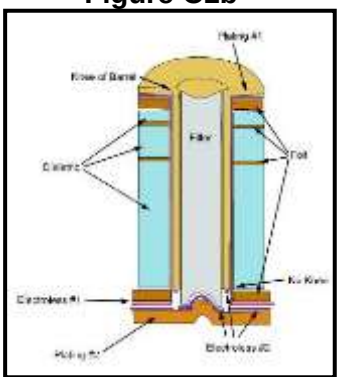


Figure C1b



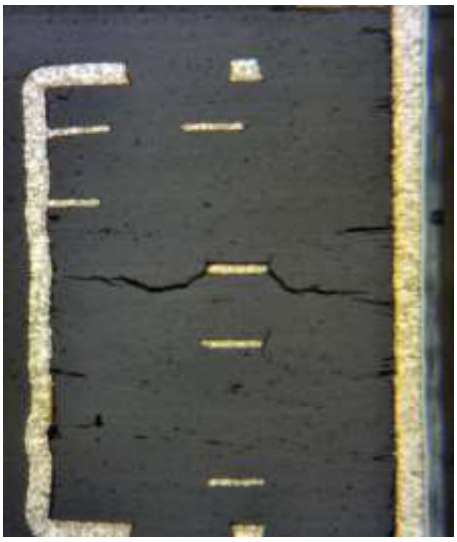
Photos : Provide a set of labelled photos (minimum 6 photos) for each microsection. Include a full image of the via structure, the major failure mode, any minor defects or points of interest and a view of the material. (See Example 7)

Example 7

XS# 4545 – Coupon 1_A – S1 Circuit, 6 X 230°C, 390 X170°C

Photo 25a

Photo 25b



Test Results: Include in the report the full IST testing data including the prescreening data and capacitance data. (See Example 8 as a partial example)

Example 8

30 July 2015

Job Number j08_1234	**Test Cycles** 400	**Precon Cycles** 6
Lot Number	**Test Temp** 150	**Precon Temp** 230
Customer ABCDE	**Coupon Type** PTH	**Test Runs** 1
Cage Code #	**Test Vehicle #** GT40800D	**Date Code:** 3008
Coupon Rec 6	**Incoming Tested** 6	**Coupons Passed** 6
Customer Req 123456-250	**Part #** KIT-123X REV.B	**WO #** J08_1234

TEST RESULTS

Coupon ID	Pwr Cycles	Pwr %	PTH Cycles	PTH %	Results
1_1	**400**	-0.2	**400**	0.3	Accept
1_5	**400**	-0.1	**400**	0.4	Accept
1_6	**400**	-0.2	**400**	0.3	Accept
					Cus Spec
Mean	**400**	**-0.1**	**400**	**0.4**	**N/A**
Std Dev	0	0.1	0	0.1	**N/A**
Min	400	-0.2	400	0.3	**Pass**
Max	**400**	1	**400**	1	
Range	0	1.2	0	0.7	

TEST PROTOCOL: _123456_400

----------PASS----------

Min Cyc to Fail	Min Avg Cyc to Fail	Max Std Dev	Percent Change (%)	Applied to:	
				POWER	SENSE
400	**N/A**	**N/A**	**2**	**YES**	**YES**
NOTES: N/A					

Appendix D

Q U O T A T I O N

(Please see important shipping instructions below)

DATE

COMPANY REF#

ESA IST Compliance Testing covered under Spec. (LATEST REV).
A Purchase Order (P.O.) must be sent to PWB Interconnect Solutions Inc. prior to testing by PWB. The results will not be released until an official P.O. is received.

ITEM	DESCRIPTION:	UNIT PRICE	QTY	TOTAL COST
1	IST Testing to the requirements of the ESA Compliance Protocol:	$725.00	1	$725.00
	Testing and Reporting will be completed as per PWB Document # 150306			0
				0
	SUB TOTAL		($USF)	$725.00
	Taxes GST			0
	TOTAL		($USF)	$725.00
Note: FOR ADDITIONAL TESTING AND ANALYSIS, REFER TO IST TESTING PRICE LIST				

TERMS OF PAYMENT: PAYABLE IN U.S FUNDS, Net 30 Days. This quotation is valid for 60 days. For additional information related to this quote, please see contact information above.

Shipping Instructions: via your preferred courier, **paid by sender**, tightly wrapped so coupons are not damaged in transit. Please identify GLOVER CUSTOMS BROKER INC. as the responsible Canadian customs broker to clear all incoming shipments.

Commercial Invoice should read: Description = # coupons, for destructive testing**,** NO commercial/resale value, **UNIT VALUE = $US 0.50 / coupon.**

IMPORTANT: If the Commercial Invoice is different from the above, the shipment will be subject to Canadian Customs and Clearance charges. Such charges be will be added to your invoice.

Returning coupons to Customer: If you would like your coupons returned after testing, **at your cost,** your courier name and account number must be provided, otherwise the coupons will be destroyed.

IST SERVICE PRICE LIST

	DESCRIPTION:	UNIT PRICE
	Product pre-screening (up to 100 coupons)	$270.00
	Product Pre-conditioning simulated assembly (per coupon)	$12.00
	Capacitance Measurement -DELAM protocol (up to 100 coupons)	$270.00
	Single sense to 500 cycles	$80.00
	Failure Location (up to 100 coupons)	$270.00
	Micro sectioning (up to 6 pictures/micro section – additional pictures $10 each)	$ 85.00
	Failure Analysis (per hour)	$150.00
	Report Writing (per hour)	$150.00
	New Custom coupon design service charge	$300.00
	TMA – Thermal Mechanical Analysis (per sample)	$160.00
	DMA – Dynamic Mechanical Analysis (per sample)	$160.00
	Single sense to 50 cycles	$55.00
	Single sense to 1000 cycles	$110.00
	Single sense to 1500 cycles (additional 500 cycles @ $75/coupon)	$160.00
	Dual sense to 50 cycles	$95.00
	Dual sense to 250 cycles	$125.00
	Dual sense to 500 cycles	$140.00
	Dual sense to 750 cycles	$170.00
	Dual sense to 1000 cycles	$200.00
	Dual sense to 1500 cycles (additional 500 cycles @ $75/coupon)	$260.00
	Single sense to 500 cycles - RUSH Turnaround	$135.00
	Single sense to 1000 cycles - RUSH Turnaround	$160.00
	Dual sense to 500 cycles - RUSH Turnaround	$260.00
	Dual sense to 1000 cycles - RUSH Turnaround	$285.00
	Administrative charge (< 12 coupons)	$110.00
	Micro sectioning – Large/Custom Format (up to 6 pictures/micro section)	$170.00
	Micro section Regrinds (per micro section- up to 2 pictures/micro section)	$50.00
	Micro section Solder Floats (per micro section)	$20.00
	Additional statistical analysis- Weibull (per hour)	$130.00
	Payment made by Bank Wire Transfer	$25.00
	Discount of 7% on cycling testing for quantities exceeding 100 coupons (discount will be applied on the final invoice when 100+ coupons have been tested)	