National Aeronautics
and Space Administration

2022 NEPP ETW

Plastic Encapsulated Microcircuit (PEM) Glass Transition Temperature (T_G) Study

Jason Heidecker

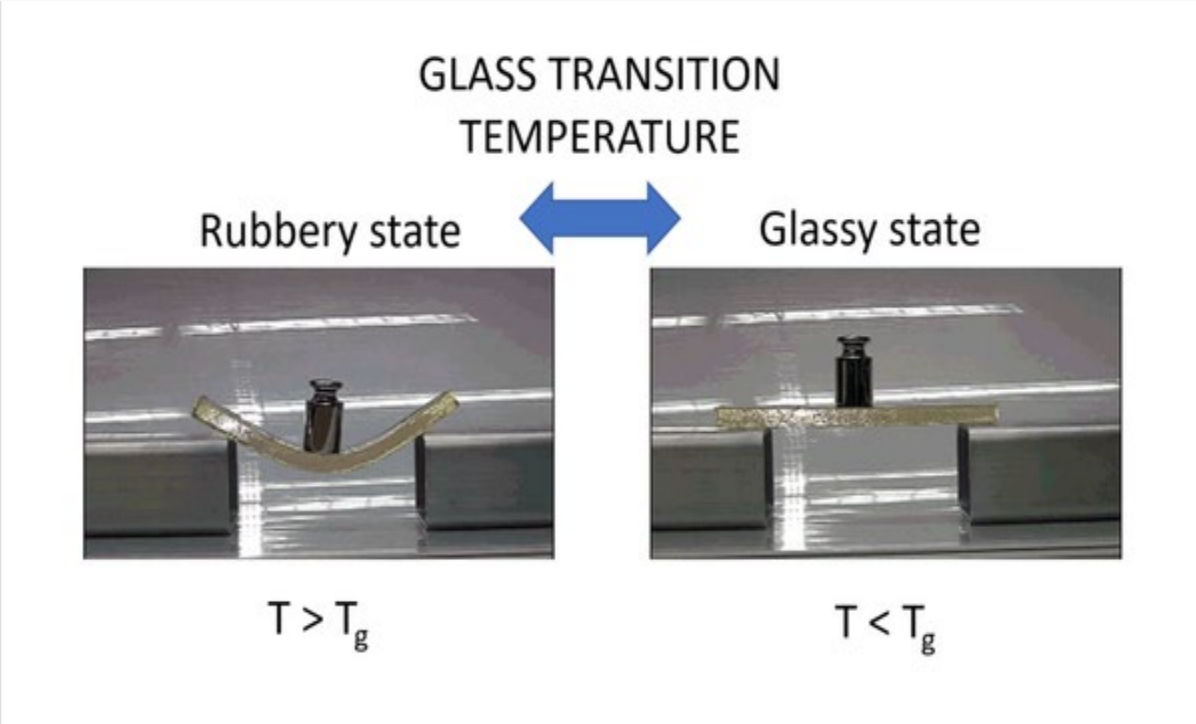
Jet Propulsion Laboratory / California Institute of Technology

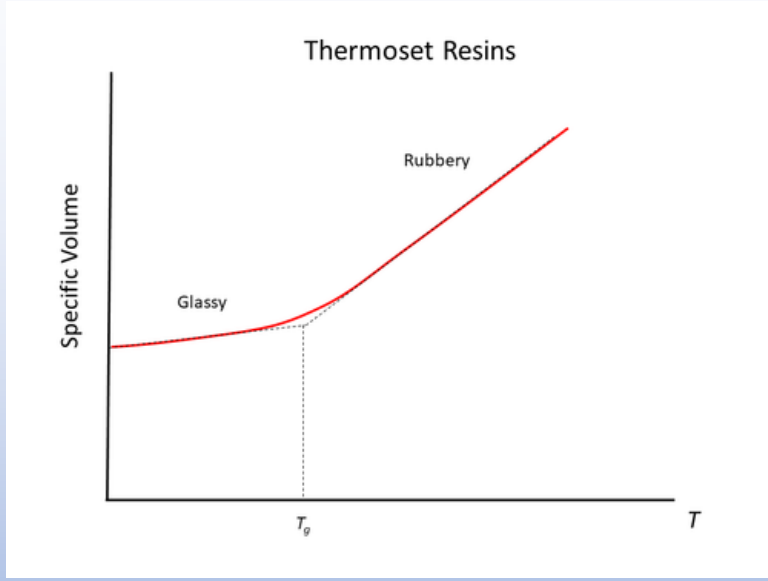
Pasadena, CA

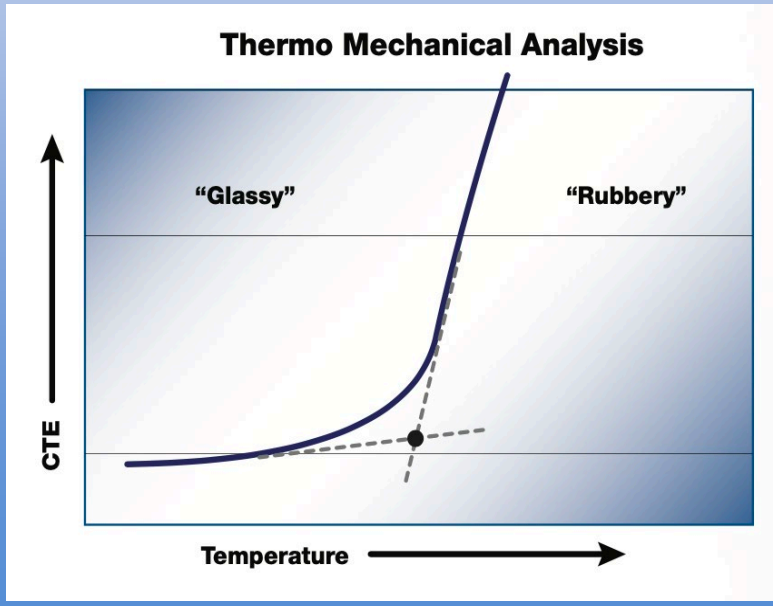
Government Sponsorship is acknowledged.

National Aeronautics
and Space Administration

Background







The epoxies used to encapsulate PEMs transition from rigid to rubbery when $T > T_G$, which, in theory, could lead to wire bond fatigue failure due to CTE mismatches if the transition occurs frequently. But how much stress (number of temperature cycles) is needed for this occur?

Background

- For several years, JPL has been limiting the maximum temperature during the temperature cycling screening step (20 cycles from -55C to +125C) for COTS PEMS to $T<T_G$ in order to avoid overstressing flight parts (CTE mismatch and temp cycling leading to wire bond failure).
- Limiting the temperatures during electrical test and burn-in was not part of the process as the number of glass/rubber transitions is limited to just a few cycles for these steps.

TABLE 1. 100% Screening Requirements

Test Step	CLASS 1	2+	2	3	TEST DESCRIPTION	MIL-STD-883 TEST METHOD	CONDITION	COMMENTS
1	X	X	X	X	Serialization			para. 4.2
2	1/				Pre-Screen Tests	-		para. 4.0
3	X	X	X	X	External Visual	2009		
4	X	X	X	X	Temperature Cycling	1010	Condition B (-55°C to +125°C)	20 cycles. para. 5.3
5	X	X	X	X	Pre-burn-in electrical testing		25°C, end point temperatures as specified in Detail Specification	para. 5.2
6	X	X	X	X	Burn-in, 240 hours minimum Burn-in, 160 hours minimum	1015, Cond. D.	125°C ambient	para. 5.4
7	X	X	X	X	Final electrical test		25°C, end point temperatures (see Detail Specification for end-point temps)	para. 5.2
8	X	X	X	X	Delta calculations			para. 5.5
9	X	X	X	X	PDA calculation			para. 5.6
10	X	X	X	X	External visual	2009		
11	X	X	X	X	Stabilization Bake			para. 5.7

1/ When required by the Detail Specification.

Background

- Limiting the temperatures during high-temperature operating life (HTOL) and extended temperature cycling (100-200 cycles) was also not limited in order to demonstrate the robustness of the packaging when going beyond T_G.
- More than 30 lots (100%) passed the qual testing with no failures, which included 22-45pc undergoing 100-200 temp cycles (-55C to +125C) followed by 1000-hr/125C HTOL.

TABLE 2. Lot Qualification Requirements

Test Step	CLASS 1	CLASS 2+	CLASS 2	CLASS 3	TEST DESCRIPTION	MIL-STD-883 TEST METHOD	CONDITION	SAMPLE SIZE 1/	COMMENTS
1	X	X	X		Pre-conditioning	-		Class 1: 45(0) or 22(0) 2/ Class 2+ or Class 2: 22(0) w/ 1000-hr life test	para. 6.2
2	X	X	X		Temperature cycling	1010	Condition B (-55°C to +125°C) Class 1: 500 cycles Class 2/2+: 200 cycles		para. 6.3
3	X	X	X		Post temp cycle electricals	-	25°C, end-point temperatures (see Detail Specification for end-point temps)		para. 6.4.1
4	X	X	X		High Temperature Operating Life (HTOL)	1005	Cond. D 125°C ambient temp		para. 6.4
5	X	X	X		Post-168-hour Interim electrical tests (168 hours total HTOL)	-	25°C		para. 6.4.1
6	X	X	X		Post-504-hour Interim electrical tests (504 hours total HTOL)	-	25°C		para. 6.4.1
7	X	X	X		Final electrical testing	-	25°C, end-point temperatures (see Detail Specification for end-point temps)		para. 6.4.1
8	X	X	X		External visual	2009			
9	X	X	X		DPA	-		Per Detail Specification	para. 6.6

1/ All lot qualification samples (45pc or 22pc) will undergo the testing in steps 1 thru 8.
2/ The life test may be 45pc or 22pc. For 45pc, the duration is 1,000 hours. For 22pc, the duration is 2,000 hours.

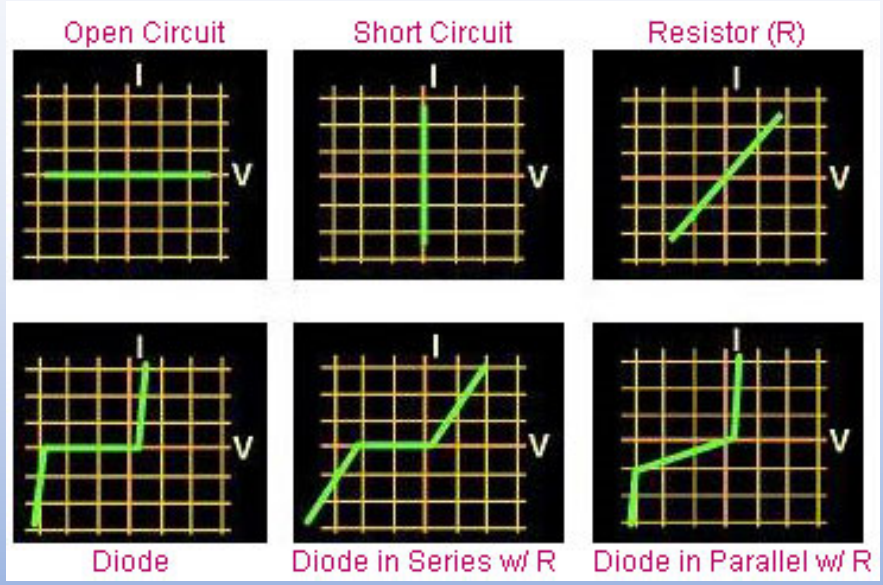
Background

- The practice of limiting temperatures screening has led to confusion with test vendors and even led to scrapping of lots leading to costly delays for JPL projects.
- **The goal of this task is to provide additional evidence that limiting temperatures during screening to a value less than T_G is not needed in order to make the screening process simpler and avoid confusion in the future.**

National Aeronautics
and Space Administration

Test Plan

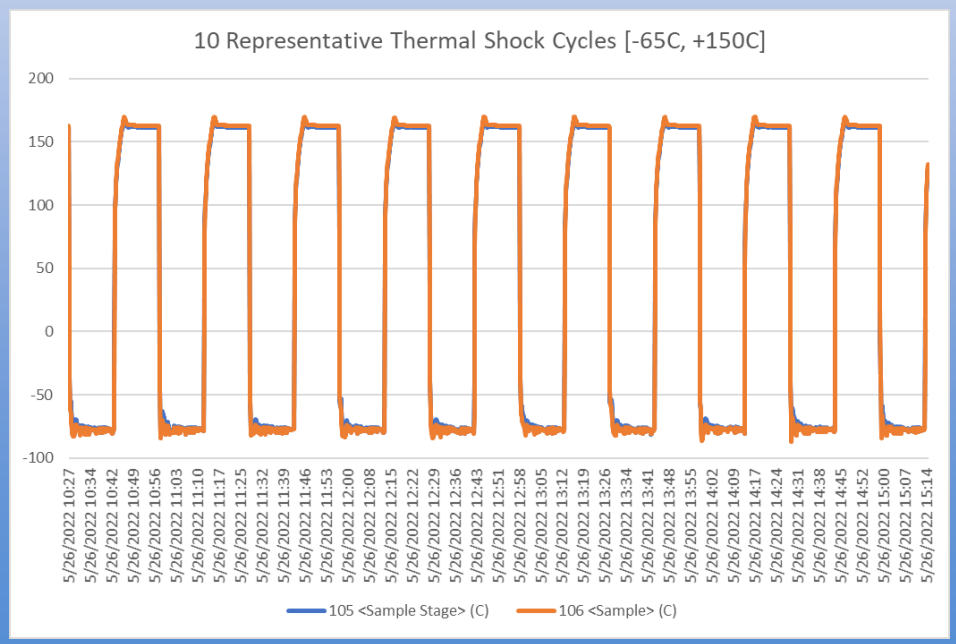
- **Goal:** Measure wire bond integrity with respect to temperature cycling. Wire bond integrity is determined by curve tracing the pins.
- Temperature cycling per MIL-STD-883 TM 1010, Cond. C, **-65C to +150C**
- **Sample Size:** 5pc of 5 different part numbers.
- **Other Testing:**
  - DSC to verify T_G of epoxy encapsulant. (Based on previous testing, all expected to be between 75C and 150C.)
  - XRF or EDS to identify wire bond and pad materials in case failures can be correlated to wire bonding technology.



P/N	Manuf.	Description	T_G (°C)	Package	No. Pins	Quantity
SS41	Honeywell	Hall effect sensor	75	flat TO-92	3	5
AD8007AKS-R2	ADI	Op amp	TBD	5-lead SC70	5	5
IL711S-3E	NVE	Digital isolator	112	SOIC-8	8	5
LT3845MPFE	Linear Tech	Step-down controller	118	TSSOP-16	16	5
MT29F2G08AACWP	Micron	NAND Flash	TBD	TSOP-48	48	5

Preliminary Results

P/N	100 Cycles	300 Cycles	500 Cycles
SS41	No change	No change	In progress
AD8007AKS-R2	No change	No change	In progress
IL711S-3E	No change	No change	In progress
LT3845MPFE	No change	No change	In progress
MT29F2G08AACWP	No change	No change	In progress



Conclusion / Follow-on Work

- The test results suggest that excursions beyond T_G is not detrimental to the parts for up to at least 300 temperature cycles.
- Due to budget and schedule constraints in FY22, the following limitations resulted:
  1. Unable to test more than 5 part numbers
  2. Unable to test to failure, which would support Weibull analysis and more accurate assessment of wire bond reliability
  3. Unable to performed XRF/EDS testing of wire bonds/pads prior to starting temperature cycling; therefore, parts tested blindly.
- Although these five part numbers support the original hypothesis that reasonable temperature excursions beyond TG are not stressful to the part, having data for all representative packages and wire bond technology would be useful.