

Temperature-Cycling Endurance Testing

Preface

MAXMAC evaluates ion modules through repeated powered temperature cycles between -40°C and $+85^{\circ}\text{C}$. The procedure defines the temperature ramp, hold time, operating modes and recovery steps, with electrical and ion-output checks linked to the sample record.

Six modules completed 385 cycles and met the Class A requirement after testing. Recorded checks cover working current, standby current, LIN communication, ion output and appearance. Subsequent X-ray and cross-section records document two inspected boards.

Cycle Conditions

Parameter	Specified setting
Temperature limits	-40°C / $+85^{\circ}\text{C}$
Starting temperature	$+23^{\circ}\text{C}$
Ramp rate	$4\text{--}10^{\circ}\text{C}/\text{min}$
Hold at each limit	15 min after reaching the required ambient temperature
Cycle count	385
Operating modes	3.1 / 3.2; powered
Samples	6 modules; 77#-82#

Prescribed Temperature Profile

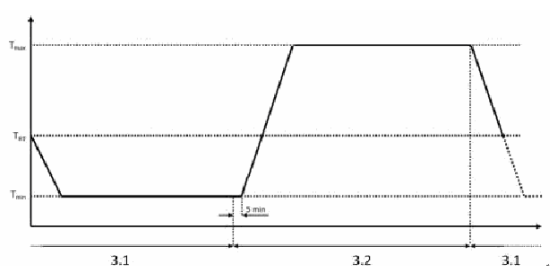


图 39 测试波形图 Test pulse

Figure 1 Original programmed profile, including mode 3.1 and 3.2 segments.

Temperature span:

$$\Delta T = 85 - (-40) = 125^{\circ}\text{C}.$$

Arrangement and Test Sequence

Maintain $\geq 100\text{ mm}$ between modules and from chamber walls. The chamber changes temperature while the modules follow the specified powered operating profile.

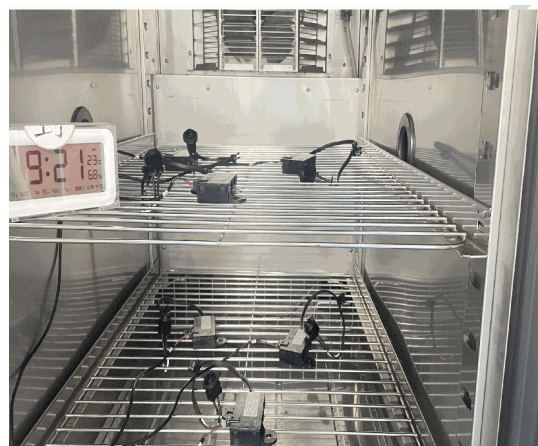


Figure 2 Original chamber arrangement.

1. Record the initial current, LIN, ion-output and appearance checks.
2. Load the temperature program and complete 385 cycles in modes 3.1 / 3.2.
3. Record working current, standby current and LIN status during the program.
4. Allow natural recovery to room temperature and repeat the functional checks.

Ion-output measurement after cold exposure: stand for more than 2 hours and allow condensation to evaporate before measuring.

Test basis: Q/MAT 5502-2023, 12.2; DIN EN 60068-2-14.

Equipment: GFS-400-10 chamber, 8962A1T power analyzer, NKMH-103 ion counter and PROVA AVM-07 anemometer.

Measured Results and Original Process Records

All six samples passed. Working-current readings were below the **100 mA** limit; every recorded standby-current reading was **0.03 mA**, below the **0.1 mA** requirement. LIN communication was recorded as OK at all three check stages.

Sample	Before: working current (mA)	During: working current (mA)	During: standby current (mA)	After: working current (mA)
77#	13.291	15.5	0.03	13.6020
78#	13.532	11.5	0.03	13.5300
79#	13.051	11.2	0.03	13.1320
80#	13.046	11.7	0.03	13.1230
81#	13.209	11.4	0.03	13.5540
82#	13.580	11.5	0.03	13.3460

Table 1 Original stage readings, source p. 61. Before and after testing, every sample recorded ion-counter over-range above 20 million ions/cm³ and an OK appearance result.

Sample 77#: Before Cycling

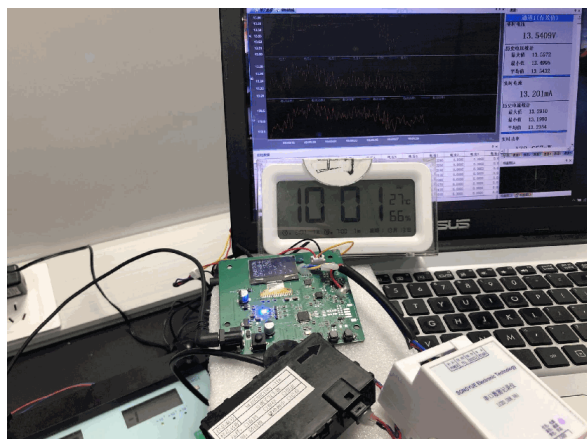


Figure 3 Original initial functional record.

The photograph retains the ion counter, electrical measurement and LIN monitoring arrangement.

Sample 77#: After Cycling

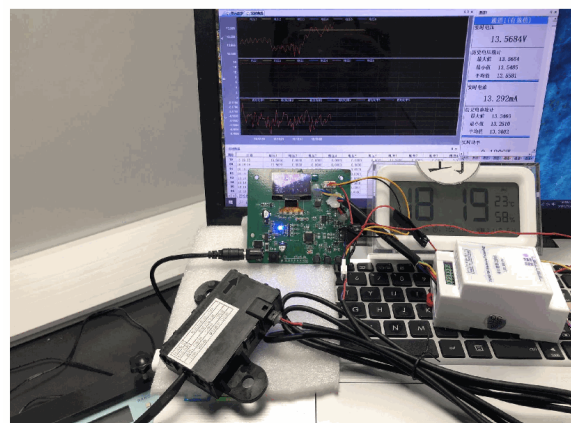


Figure 4 Original final functional record.

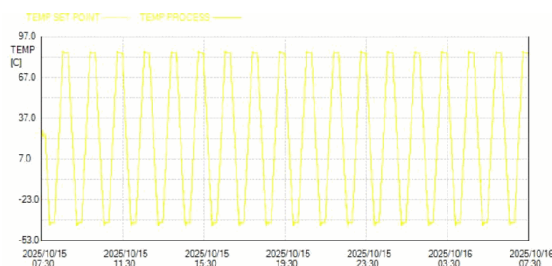
The photograph retains the ion counter, electrical measurement and LIN monitoring arrangement.

Recorded Functional and Physical Outcomes

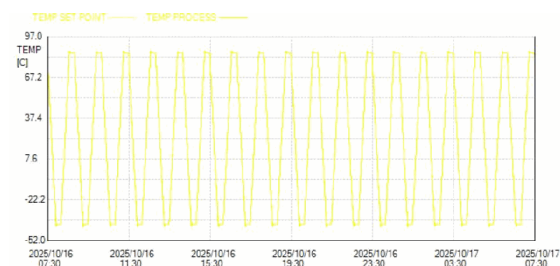
Check	Recorded result
LIN communication	OK before, during and after testing.
Ion output before / after	Over-range indication above 20 million ions/cm ³ for all samples.
Appearance before / after	OK for all samples.
Overall conclusion	Class A after the completed program; Pass.

Table 2 Results summarized from the six-sample record on pp. 61-62.

Original Temperature and Monitoring Records



Initial 24-hour record.



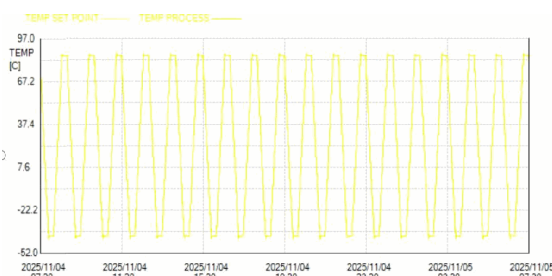
Initial 48-hour record.



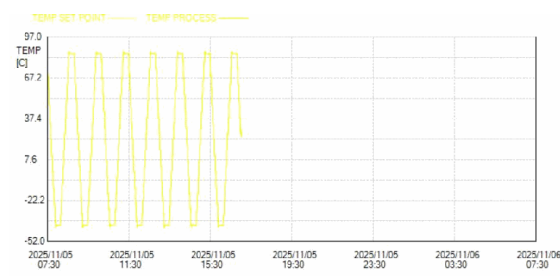
During testing: 240-264 h.



During testing: 264-288 h.



Near completion: 480-504 h.



Test completion: 504-513 h.

Figure 5 Six original chamber-curve windows spanning the start, middle and end of the recorded program.

Powered Monitoring Arrangement



Figure 6 Original monitoring and connection arrangement outside the chamber.

Reading the Process Record

The original plots display repeated temperature changes across the specified cold and hot limits. The selected windows retain their recorded timestamps and the setpoint/process trace labels. Current and LIN measurements are listed separately in the stage-results table.

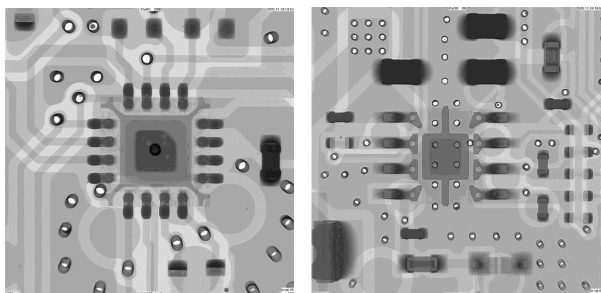
Samples 77#-82# were retained through the 385-cycle program. The functional record, chamber curves and individual sample photographs are documented together on source pp. 60-67.

Post-Cycling X-ray and Cross-section Inspection

Two post-cycling samples, 77# and 78#, were examined at two specified board locations. X-ray images record the soldered areas; mounted, ground and polished cross-sections were examined under a microscope following IPC-TM-650-2.1.1F. The inspection received a **Pass** judgment.

X-ray Inspection

Sample 77# - Positions 1 and 2



Sample 78# - Positions 1 and 2

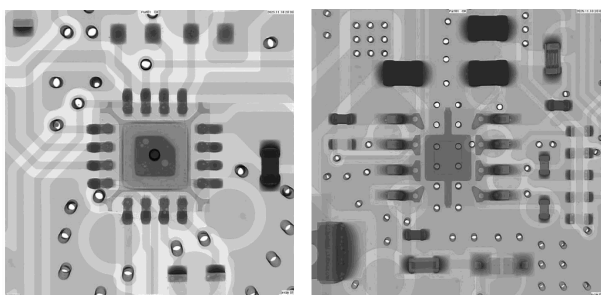


Figure 7 Original X-ray images of both inspected positions on each board.

Inspection Locations

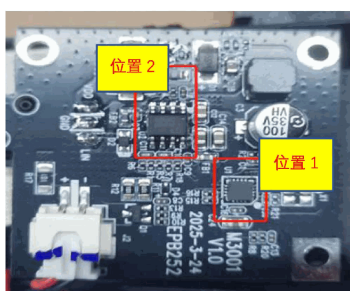
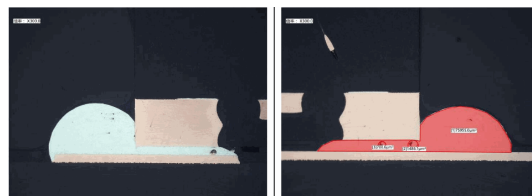


Figure 8 Original board location photograph.

Cross-section Detail Images

Sample 77#

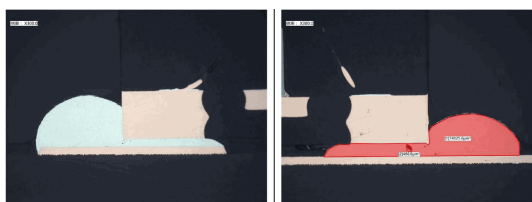


Position 1

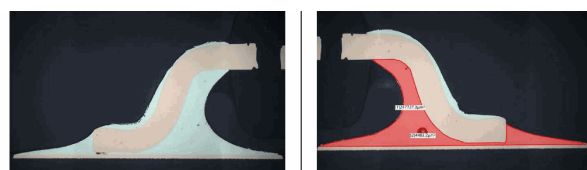


Position 2

Sample 78#



Position 1



Position 2

Figure 9 Original microscopic detail views, retaining the laboratory overlays.

Sample	Position 1: void ratio	Position 2: void ratio	Recorded observation
77#	2.9%	3.4%	No solder-joint cracks or obvious abnormalities.
78#	0.7%	1.8%	No solder-joint cracks or obvious abnormalities.

Table 3 Cross-section results from source p. 133.

Records: Leg2 pp. 60-67 and 127-137. Cycling: 13 October-5 November 2025, MAXMAC laboratory. Internal inspection: 14-21 November 2025, Guangdong Weipu Standard Technology Co., Ltd.; report SZA03-25115264-QC-01FR2. Version 1.0: 26 October 2026.