

Electrical Performance and Protection Testing

Preface

MAXMAC evaluates ion-module electrical behavior through operating-voltage and sleep-current measurements, supply transitions and reset tests, abnormal-supply exposure, and connection-fault protection. Each method records the applied condition, functional response and final judgment.

This note brings together 18 electrical tests from the Leg9 report. The records include six-sample measurements, fault and recovery observations, original bench photographs and voltage traces. Every included test received a Pass or Compliant conclusion against its stated requirements.

Four Groups of Electrical Tests

Group	Included tests	Pages in this note
Operating voltage and quiescent current	Under-/overvoltage function; operating voltage; sleep current	2-3
Supply changes and reset	Slow fall / slow rise; slow fall / fast rise; reset; controlled-supply waveform	4-5
Abnormal supply and transient disturbances	Prolonged overvoltage; reverse polarity; jump start; ripple; transient undervoltage; load dump; transient overvoltage	6-9
Connections and short-circuit protection	Connector open circuit; pin interruption; brief supply interruption; LIN short-circuit protection	9-11

Table 1 Reading structure for the 18 electrical tests. Original report locations appear on page 12.

How the Test Records Are Read

The method defines the supply voltage, temperature, operating mode, timing and functional criterion for each test. During-test observations are followed by recovery or final functional checks where specified.

Recorded Operating Range

The supply-transition procedures define **9-16 V** as the normal operating range. The separate under-/overvoltage functional test checks **8, 9, 16, 17 and 18 V** against the product's voltage/function definition.

Sample Records and Test Basis

The in-house sections identify six modules, **1#-6#**. The included external electrical records also contain six-sample groups. Test methods follow the relevant clauses of **Q/MAT 5502-2023**.

Primary source: Kunlun-DVC_R-30.01-P000025455001-009-V1.0, pp. 29-183.
 In-house tests: MAXMAC test center. Included external report: HJ2529085-G01, Shanghai Haojing Automotive Testing Technology Co., Ltd.

Operating Voltage and Under-/Overvoltage Function

Operating-Voltage Measurements across Three Temperatures

Sample	-40 °C 14 V	-40 °C 12 V	23 °C 14 V	23 °C 12 V	85 °C 14 V	85 °C 12 V
1#	14.0062	12.0042	14.0011	12.0010	14.0124	12.0118
2#	14.0055	12.0020	14.0016	12.0075	14.0125	12.0108
3#	14.0052	12.0036	14.0041	12.0073	14.0101	12.0091
4#	14.0062	12.0056	14.0119	12.0051	14.0129	12.0104
5#	14.0037	12.0047	14.0104	12.0045	14.0127	12.0099
6#	14.0053	12.0051	14.0122	12.0039	14.0120	12.0088

Table 2 Voltage in V; all 36 readings and their LIN checks were recorded as OK. Requirements: 14 ± 0.1 V and 12 ± 0.1 V. Source pp. 49-50.

Under-/Overvoltage Function

At 23 °C in mode 3.2, hold 8 V for 10 min, step to 9 V for 10 min, then check 16, 17 and 18 V at 1 V increments, each for 10 min. Monitor the defined function at each voltage.

Voltage	Six-sample current range (mA)
8 V	5.759-5.887
9 V	10.189-10.816
16 V	12.496-14.307
17 V	5.787-5.895
18 V	5.788-5.881

Table 3 Minimum-to-maximum recorded current across the six samples at each voltage; fault state: none. Source pp. 30-31.

Original Voltage-Test Arrangement



Figure 1 Original chamber arrangement for operating-voltage testing, source p. 51.

Recorded Outcomes

Operating voltage: all readings within the stated limits, LIN OK, and no visible damage after testing. Under-/overvoltage function: the source records conformity with the defined voltage/function behavior and satisfactory final current, LIN and ion-output checks. Both tests: **Pass**.

Basis: Q/MAT 5502-2023, 5.3 and 7.5. Sources: pp. 29-35 and 49-58.

Quiescent Current: Nine Temperature/Voltage Conditions

Allow the module temperature to stabilize, use **mode 2.1**, wait for sleep, then monitor the permanent-supply current for **60 min at each condition**. Repeat at -40, +23 and +85 °C, using 13, 12 and 11 V.

Sample	-40 °C 13 V	-40 °C 12 V	-40 °C 11 V	23 °C 13 V	23 °C 12 V	23 °C 11 V	85 °C 13 V	85 °C 12 V	85 °C 11 V
1#	0.0468	0.0444	0.0502	0.0466	0.0449	0.0421	0.0465	0.0391	0.0368
2#	0.0382	0.0361	0.0423	0.0370	0.0342	0.0311	0.0394	0.0354	0.0328
3#	0.0296	0.0300	0.0300	0.0310	0.0310	0.0324	0.0330	0.0303	0.0300
4#	0.0330	0.0334	0.0349	0.0355	0.0333	0.0346	0.0381	0.0352	0.0332
5#	0.0260	0.0250	0.0243	0.0278	0.0260	0.0259	0.0340	0.0316	0.0299
6#	0.0285	0.0292	0.0244	0.0300	0.0291	0.0301	0.0350	0.0321	0.0310

Table 4 All 54 quiescent-current entries in mA, source pp. 36-37. Each entry was recorded as OK.

Acceptance: average sleep current <0.1 mA (100 µA).

Recorded range: **0.0243-0.0502 mA**, equivalent to **24.3-50.2 µA**.

Maximum / limit × 100 = 0.0502 / 0.1 × 100 = 50.2%.

Temperature and Measurement Control

The procedure requires more than **10 cm** between the module and chamber edge. Establish the temperature first, then set the supply voltage and enter sleep before starting the 60-minute observation.

Recorded Result

Every sample's recorded average quiescent-current values were below 0.1 mA. The six-sample group received **Pass**.

Basis: Q/MAT 5502-2023, 7.6. Dates: 16-21 July 2025. Equipment: RDB-1200E chamber and 8962A1T power analyzer.

Original Monitoring Record

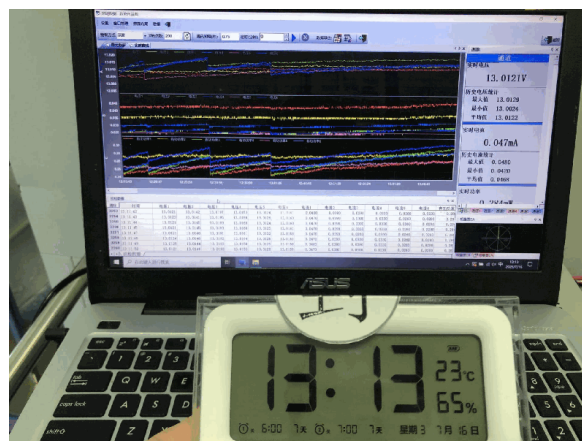


Figure 2 Original sleep-current monitoring photograph at -40 °C / 13 V, source p. 38.

Supply Ramps: Fault Thresholds and Recovery

Slow Fall / Slow Rise: Recorded Thresholds in Mode 3.2

Sample	Departure from Class A (V)	Return to Class A (V)	Reset voltage (V)
1#	4.8908	4.9946	4.0765
2#	4.9161	5.0282	4.0751
3#	4.8908	5.0200	4.0728
4#	4.9161	5.0359	4.0507
5#	4.9332	5.0589	4.0480
6#	4.8663	4.9859	4.0703

Table 5 Threshold values transcribed from the six-sample table, pp. 66-67.

Slow Fall / Slow Rise Method

Apply a **16 V → 0 V → 16 V** program at **0.5 V/min**. Test once in mode 3.2 and once in mode 2.1. In the sleep-mode test, change to mode 3.2 after the waveform without interrupting the supply.



Figure 3 Original supply-ramp monitoring photograph, source p. 69.

Recorded Result

The record states **Class A within 9-16 V** and **Class C outside**. Sleep-to-work checks restored normal operation with no fault. Overall result: **Pass**.

Slow Fall / Fast Rise Method

Lower the supply at **0.5 V/min**; hold at **0 V** for **more than 1 min** to discharge the circuit; restore the supply with a rise time **≤0.5 s**. Repeat in modes 3.2 and 2.1.

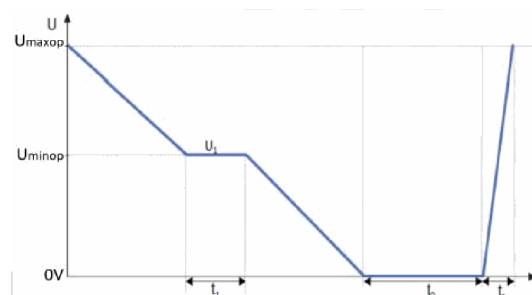
Observed Transition and Recovery

The shared result records no fault down to **4.94 V**, transition to a LIN fault while falling toward 0 V, and no fault after recovery to **16 V**. All six modules worked normally within 9-16 V and after the sleep-to-work change. Result: **Pass**.

Basis: Q/MAT 5502-2023, 7.11 and 7.12.

Slow / slow: pp. 65-73.

Slow / fast: pp. 80-86; detailed timings p. 81; observations p. 82.



Original slow-fall / fast-rise program from the method, source p. 81.

Reset Behavior and Controlled-Supply Waveforms

Reset Test: Stepped Voltage Dips

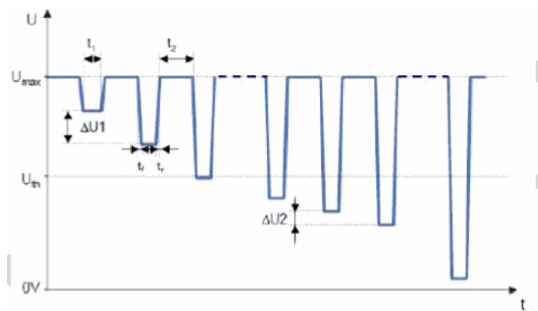
Starting from **16 V**, lower the dip level in **0.5 V** steps to **6 V**, then in **0.2 V** steps toward **0 V**. Apply two dip durations: **5 s** and **100 ms**. Test modes **3.2** and **2.1**; restore voltage and check function.

Case / mode	Recorded observation
5 s / 3.2	First departure from Class A at 4.8082 V for all six; LIN fault at and below that threshold
100 ms / 3.2	No fault or departure threshold recorded
5 s and 100 ms / 2.1	No fault after voltage recovery and switching to mode 3.2



Figure 4 Original reset-test bench, source p. 91.

Voltage ≥ 9 V meets the specified Class A requirement. Overall result: Pass. Basis: 7.13; pp. 87-94.



Original stepped-dip reset program from the method, source p. 88.

Controlled-Supply Waveform

Use mode **3.2**. Apply a waveform between **11.8 V – ΔV** and **16 V – ΔV** , with **400 ms** rise and fall times and **2 s** plateaus. Run **10 cycles** for each offset.

Case	ΔV	Lower / upper levels
1	0 V	11.8 / 16 V
2	0.7 V	11.1 / 15.3 V
3	2 V	9.8 / 14 V

Table 6 Voltage levels calculated by subtracting each recorded offset from the specified endpoints. Source p. 127.

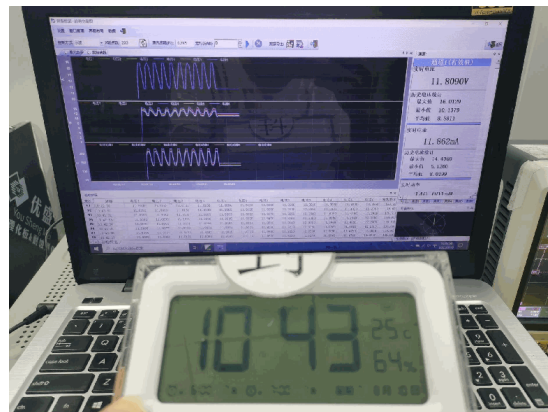


Figure 5 Original controlled-supply waveform monitoring, source p. 129.

Recorded Result

All three cases record **no fault and normal operation** for all six modules. The test met **Class A**; final judgment: **Pass**.

Basis: Q/MAT 5502-2023, 7.23. Sources: pp. 126-132.

Prolonged Overvoltage and Reverse Polarity

Prolonged Overvoltage

Parameter	Detailed method
Applied voltage	18 V
Exposure time	60 min
Temperature	Tmax -20 °C = 65 °C
Operating mode	3.2
Cycles / samples	1 / 6

Table 7 Detailed parameter table and procedure, source p. 60.

Stabilize the module temperature, apply 18 V for one hour and monitor function. Restore normal supply and check operation.



Figure 6 Original elevated-temperature record, source p. 62.

Recorded Outcome

All six samples record **no fault and Class A** during the test. Final current, LIN and ion-output checks were satisfactory. Overall judgment: **Pass**.

Basis: 7.9. Sources: pp. 59-64; conditions follow the detailed table / steps on p. 60.

Reverse-Polarity Exposure

Case	Recorded program
Static reverse	0 to -16 V; 1 V increments; T1 60 s; one cycle
Dynamic reverse	10 V / -4 V; T1 60 s; three cycles
Transitions	Rise and fall ≤10 ms
Operating mode	3.1

Apply the static and dynamic reverse-polarity programs, restore normal connections and verify function. The static recovery interval is more than 60 s and continues until the original thermal state is reached.

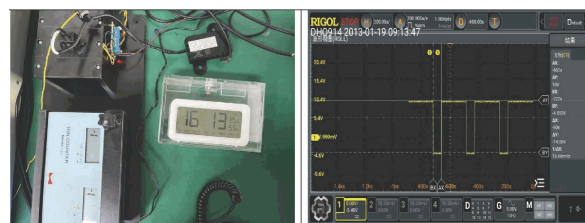


Figure 7 Original dynamic-reverse functional verification and measured trace, source p. 148.

Recorded Outcome

The report records normal sample function before and after testing and compliance with **functional status C**. Overall conclusion: **Compliant**.

Basis: 7.7. Detailed parameters p. 145; measured records pp. 147-148.

Jump Start and Superimposed Ripple

Jump-Start Program

Parameter	Recorded setting
Voltage levels	V0 0 V; V1 3 V; V2 10.8 V; V3 27 V
Time values	t1 1 s; t2 0.5 s; t3 5 s; t4 1 s; t5 60 s
Transitions	Rise <2 ms; fall <100 ms
Mode / cycles	3.2 / 1

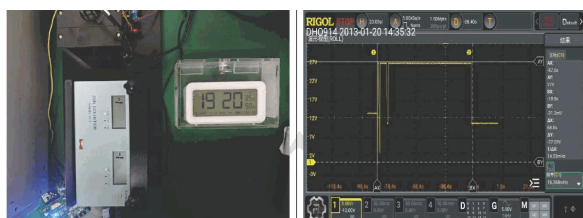


Figure 8 Original jump-start functional verification and voltage trace, source p. 151.

Observed Response

Before testing, sample function was normal. At **0 V** and **3 V**, the record describes abnormal host data and a red indicator on the monitoring board. After the test, sample function returned to normal. The group met **Class C** and was **Compliant**.

Basis: 7.10. Parameters p. 149; observations and conclusion p. 152.

Ripple-Voltage Sweep

Case	Vpp	Frequency	T1
1	2 V	15 Hz-30 kHz	120 s
2	3 V	15 Hz-30 kHz	120 s
3	6 V	15 Hz-30 kHz	120 s
4	1 V	30 Hz-200 kHz	600 s

Table 8 Recorded triangular / logarithmic sweep settings; 15 cycles in mode 3.2. Source p. 157.

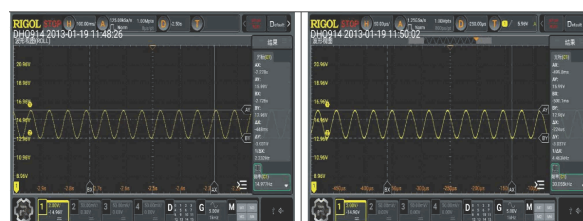


Figure 9 Original ripple calibration traces, source p. 158.

Criteria and Recorded Result

The specified requirement is **Class A** for cases **1, 2 and 4**, and at least **Class B** for case **3**. The conclusion records normal function before, during and after cases **1 and 4** and an overall **Compliant** judgment.

Basis: 7.19. Parameters / calibration pp. 157-158; final measured traces and conclusion pp. 160-161.

Transient Undervoltage and Load Dump

Transient Undervoltage

Case	Recorded program
1	10.8 to 9 V; Tr/Tf 1.8 ms; T1 500 ms; T2 1 s; 10 cycles
2	V1 10.8 V; V2 6 V; V3 8 V; V4 9 V; 10 cycles
Case 2 timing	t1-t8: 5, 20, 2, 180, 1, 300, 2 ms and 1 s
Temperature / mode	Tmax and Tmin; mode 3.2

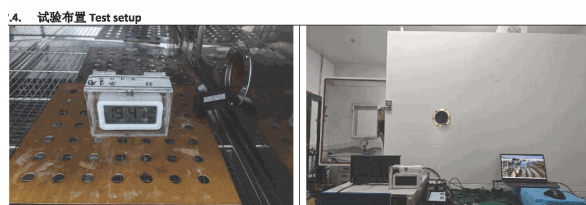


Figure 10 Original chamber and external arrangement for transient undervoltage, source p. 164.

Recorded Result

Sample function was normal before, during and after testing. The criteria require **Class A** at ≥ 9 V and **Class C** below 9 V. The final conclusion is **Compliant**.

Basis: 7.21. Parameters p. 162; measured records pp. 164-165; conclusion p. 166.

12 V-System Load Dump

The method specifies the **7637 pulse 5b** test for a 12 V system, in **mode 3.2**. The recorded clamped level is **35 V**. Apply **10 pulses** separated by **1 min**.



Figure 11 Original load-dump calibration waveform, source p. 167.

Recorded Result

The report records normal function before, during and after the exposure, meeting **functional status C**. The overall conclusion is **Compliant**.

Basis: Q/MAT 5502-2023, 7.22. Parameters / calibration p. 167; applied-test records p. 169; conclusion p. 170. The equipment record lists a Teseq NSG 5500 pulse generator.

Transient Overvoltage and Brief Supply Interruptions

Transient Overvoltage

Parameter	Recorded setting
Voltage levels	16, 17 and 18 V
Tr / Tf	1 ms / 1 ms
T1 / T2	400 ms / 600 ms
Tmax case	3 cycles; T3 2 s
Tmin case	3 cycles; T3 2 s
Room-temperature case	100 cycles; T3 8 s
Operating mode	3.2



Figure 12 Original room-temperature overvoltage traces, source p. 175.

Recorded Result

All three temperature cases record normal function before, during and after testing and compliance with **Class A**. Overall conclusion: **Compliant**.

Basis: 7.24. Parameters p. 171; measured records pp. 173-175.

Brief Supply Interruptions

Use an 11 V supply in mode 3.2. Increase interruption duration from 10 μ s to 2 s in the prescribed steps. Test two switch arrangements and allow more than 10 s recovery, continuing until full function is restored.



Figure 13 Original interruption-test voltage traces, source p. 180.

Observed Response and Recovery

For both arrangements, the record states normal operation at interruptions below 100 μ s, meeting **Class A**. At 20 ms, abnormal host data, a red monitoring-board indicator and a LIN fault were recorded. Function was normal again after the test, meeting **Class C**.

Overall conclusion: Compliant. Basis: 7.25. Parameters p. 176; measured traces pp. 179-181; observations and conclusion p. 182.

Connector Open Circuit and Pin Interruption

Connector Removal and Reconnection

At the recorded **14 V** supply, remove one connector for **10 s**, reconnect it and monitor function. Repeat in mode **3.2** and sleep mode **2.1**; after the sleep-mode test, change to mode **3.2** and check operation.

Stage	Recorded response
Disconnected / mode 3.2	LIN fault
Reconnected / mode 3.2	No fault; normal function restored
Mode 2.1, then 3.2	No fault; normal function restored

Recorded Result

All six samples met the specified **Class C** requirement. Final working current, LIN communication and ion-output checks were satisfactory, with intact appearance. Result: **Pass**.

Basis: Q/MAT 5502-2023, 7.18. Method p. 74; six-sample observations / result p. 75; photographs pp. 76-79.

Pin-Interruption Program

Case	Recorded method
1	Disconnect each pin for 10 s, then reconnect
2	Rapid interruptions; 4,000-pulse burst; T1 0.1 ms, T2 1 ms, T3 10 s
Modes / repetition	2.1 and 3.2; three cycles per case

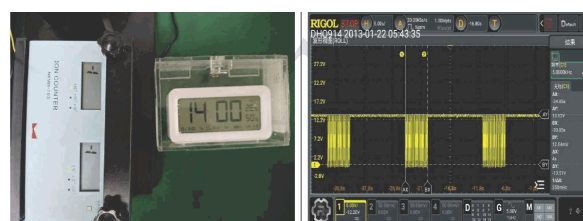


Figure 14 Original pin-interruption verification and trace, source p. 155.

Observed Response

Mode 2.1: no abnormal wake-up. In mode 3.2, pin interruption produced the recorded monitoring-board / LIN fault indications; normal function returned after testing. The group met **Class C** and was **Compliant**.

Basis: 7.17. Parameters p. 153; result p. 156.

LIN Short-Circuit Protection and Final Function

At **16 V**, short the LIN pin to supply and to ground for **60 s** per connection, then restore normal wiring and monitor function. Repeat at **9 V**. The method lists **-40 and +85 °C** and mode **3.2**. The source records the following three connection conditions.

Case	Supply / ground arrangement	Fault exposure
1	Normal supply and ground	LIN to supply; LIN to ground
2	Supply positive disconnected; ground retained	LIN to supply; LIN to ground
3	Ground disconnected; supply positive retained	LIN to supply; LIN to ground

Table 9 Tested cases 1-3 from p. 96. The procedure marks case 4 as not applicable.

Six-Sample Post-Test Verification

Sample	Current (mA)	LIN	Ion concentration	Appearance	Result
1#	13.1990	OK	>20 million ions/cm ³	Intact	OK
2#	12.9310	OK	>20 million ions/cm ³	Intact	OK
3#	12.9980	OK	>20 million ions/cm ³	Intact	OK
4#	13.1840	OK	>20 million ions/cm ³	Intact	OK
5#	13.2830	OK	>20 million ions/cm ³	Intact	OK
6#	13.5380	OK	>20 million ions/cm ³	Intact	OK

Table 10 Original final readings and observations after short-circuit testing, source p. 98.

Fault and Recovery Observations

During each recorded LIN short, the fault state was **LIN**. After normal wiring was restored, the fault state was **none** and normal operation returned. All six samples received **Pass**.

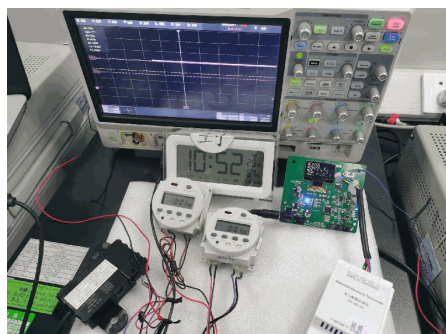


Figure 15 Original sample 1# short-circuit test arrangement, source p. 99.

Original Voltage / Current Record



Figure 16 Original voltage and current trace accompanying the sample 1# test, source p. 99.

Basis: Q/MAT 5502-2023, 7.14. Acceptance: at least Class C. Method / results pp. 95-99; connection and waveform records pp. 99-122; final photographs pp. 123-125.

Complete Test Index and Verification Records

Electrical test	Q/MAT clause	Source pages	Conclusion page	Judgment
Under-/overvoltage function	7.5	29-35	31	Pass
Quiescent current	7.6	36-48	37	Pass
Operating voltage	5.3	49-58	50	Pass
Prolonged overvoltage	7.9	59-64	61	Pass
Slow fall / slow rise	7.11	65-73	68	Pass
Connector open circuit	7.18	74-79	75	Pass
Slow fall / fast rise	7.12	80-86	83	Pass
Reset	7.13	87-94	90	Pass
LIN short-circuit protection	7.14	95-125	99	Pass
Controlled-supply waveform	7.23	126-132	128	Pass
Reverse polarity	7.7	145-148	148	Compliant
Jump start	7.10	149-152	152	Compliant
Pin interruption	7.17	153-156	156	Compliant
Superimposed ripple	7.19	157-161	161	Compliant
Transient undervoltage	7.21	162-166	166	Compliant
Load dump	7.22	167-170	170	Compliant
Transient overvoltage	7.24	171-175	175	Compliant
Brief supply interruption	7.25	176-182	182	Compliant

Table 11 Source index for all 18 electrical tests. Page numbers refer to the compiled Leg9 PDF.

Post-Test Functional Checks

The in-house functional tables record working current **≤100 mA**, LIN OK, ion output **>20 million ions/cm³** and intact appearance. The -1 ion-counter indication is identified as over-range in the source.

Functional ion-measurement setup: 13.5 ± 0.5 V, 5.5 m/s airflow, 100 mm measurement distance, 23 ± 5 °C and 45-75% RH.

Equipment in the Source Records

In-house: SDS5054X oscilloscope, SYSKON P500-060-030 programmable supply, 8962A1T power analyzer and RDB-1200E chamber. Functional checks use NKMH-103 and PROVA AVM-07.

External records include PBZ40-10 supply, RIGOL DHO914 oscilloscope, APS 801100DR simulator, Teseq NSG 5500 generator and PFS 60100A1 supply-fault simulator.
Version 1.0: 26 October 2026.