ALP LAB

E1M-AEN Reliability Report

MTBF / FIT prediction — Telcordia SR-332

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1 Summary

This report gives the predicted reliability of the **E1M-AEN System-on-Module** (`E1M-AEN301` through `E1M-AEN803`) expressed as **MTBF** (Mean Time Between Failures) and **FIT** (Failures In Time, where 1 FIT = 1 failure per 10^9 device-hours).

The prediction is a **parts-count reliability prediction** per **Telcordia SR-332 Issue 4**, summing the steady-state failure rate of every electrical component on the module. It is an **intrinsic, random-failure** estimate for the useful-life region of the bathtub curve. It does not model infant mortality (addressed by production screening / burn-in) or end-of-life wear-out (e.g. Flash write endurance; the module has no aluminium electrolytics and, in the standard build, no on-module RTC backup store).

Note: **Headline figure — at the +55 °C operating reference (GF):** $\lambda \approx 1004$ FIT, giving an **MTBF of ≈ 996 000 hours**, equivalent to a **5-year field survival of ≈ 95.7%** and a **10-year survival of ≈ 91.6%** under continuous 24/7 use. See Section 4 for the full result set and Section 5 for the +25…+85 °C sweep (the +85 °C row is a stress point above the rated range).

R3 status: The failure-rate budget reflects the **R3 build with both external OSPI memories fitted** (E1M-AEN803, 230 fitted electrical components taken from the R3 bill of materials; the variants without them have 228; do-not-populate parts excluded, including the RTC backup supercapacitor, which is no longer fitted in the standard build, and the on-module RF connector, which is not fitted in production builds). Several R3 part classes have no vendor or published FIT yet and are carried as labelled engineering estimates (†); see the notes under the budget table.

Vendor data update (rev 0.3): The Application SoC FIT is now the **Alif-published field-equivalent value** — ≈ 30 FIT at +55 °C / 60% confidence from the Ensemble (E4/E6/E8) HTOL qualification (**Alif REP-006**) — replacing the previous 100 FIT engineering estimate. On the R2 bill of materials this dropped the headline from ≈ 1150 FIT / 867 000 h to ≈ 856 FIT / 1 170 000 h (superseded by the R3 rebuild, rev 0.6). The Wi-Fi / BLE module (†) remained the largest term on an engineering estimate.

Reading this figure: **MTBF is a fleet statistical measure, not a service life.** An MTBF of 996 000 h does **not** mean a unit lasts 114 years; it means that, across a large fielded population in the useful-life region, one intrinsic failure is expected per 996 000 cumulative operating hours — i.e. ≈ 43 failures per 1000 units over 5 years of 24/7 use. Always quote the failure rate (FIT) and the survival probability $R(t)$ over the actual service life alongside the MTBF, and always with the ambient temperature stated.

1.1 Reference Condition

The E1M-AEN is rated for an operating ambient of **− 40 °C to +75 °C**; the upper limit is set by the Ensemble SoC (the E8 is Standard grade, with $T_a \le 75$ °C and $T_j \le 105$ °C). The standard module has no on-module RTC backup supercapacitor; the carrier's backup element (coin cell, supercapacitor or none) sets the temperature range of the RTC backup. A room-temperature assembly option with an on-module backup supercapacitor is rated − 20 °C to +60 °C and is not covered by this prediction. Self-heating under load reduces the usable ambient further. The headline figure is a reliability prediction at a single **representative operating ambient** within the rated range; it is not tied to the rated extremes. The full ambient sweep is in Section 5; it includes a +85 °C row, which is a stress point above the rated range, not the rated hot corner. This module is not rated to, nor predicted against, automotive (AEC-Q) or defense (MIL-HDBK-217) mission profiles.

Parameter	Value
Prediction standard	Telcordia SR-332 Issue 4, Method I (parts count)
Environment	Ground Fixed, Controlled (GF) — climate-controlled indoor
Rated operating range	− 40 °C to +75 °C ambient
Headline operating ambient	+55 °C (representative loaded operating point)
Component-FIT build-up	+40 °C (Telcordia generic-device reference)

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Parameter	Value
Duty cycle	100% (continuous, 24/7)
Component quality	Commercial, Quality Level II (standard supply-chain)
Electrical derating	Per Alp Lab HW design rules (≲ 60% V/I/P on stressed parts)
Confidence level	50% (point estimate)

Table 1 Reference condition for the headline prediction

2 Method

The module failure rate is the sum of the failure rates of its parts:

$$\lambda_{\text{module}} = \sum_i n_i \cdot \lambda_i$$

where n_i is the quantity of part class i and λ_i is its per-unit steady-state FIT at the reference condition. The MTBF is the reciprocal of the total failure rate:

$$\text{MTBF} = \frac{1}{\lambda_{\text{module}}}$$

Because the parts are in a **series-reliability** arrangement (any one part failing is a module failure — there is no on-module redundancy), the failure rates add directly. Each λ_i already embeds the Telcordia quality factor (π_Q) and the reference-temperature / electrical-stress factors for that part class.

The bill of materials underlying this prediction was taken directly from the released E1M-AEN R3 bill of materials. Only fitted parts are counted: parts marked do-not-populate (CAN transceiver, secure element, second EEPROM, RTC backup supercapacitor, on-module RF connector, spare resistor and capacitor positions) are excluded, as are non-electrical items (mechanical test points, tooling and fiducial features) which carry no operational failure rate. The module is a soldered LGA with no board-to-board connector. The I-PEX MHF 4L RF connector (20579-001E) is DNP in production and is an assembly option only, so no connector term is included.

3 Failure-Rate Budget

The budget table below lists the contribution of every component class, sorted by contribution. The R3 bill of materials behind the table carries **230 fitted electrical components** (E1M-AEN803 population) across the classes shown. Active silicon is ≈ **71%** of total FIT; with the Alif SoC on vendor reliability data (Section 7), the **Wi-Fi / BLE module is the single largest term** (≈ 16%), closely followed by the four DC-DC regulators (≈ 15%); the SoC and Wi-Fi module together account for ≈ **18%**.

The per-class FIT is tabulated at the **Telcordia +40 °C reference** (where the generic device FITs are defined), giving a build-up total of ≈ 386 FIT. Scaled to the **+55 °C operating headline** (Arrhenius $\pi_T \approx 3.27$ on the silicon subtotal of ≈ 272 FIT — see Section 5) the module total is ≈ **1004 FIT**, i.e. an **MTBF of ≈ 996 000 h**. The dominance ranking below holds at either point.

Build covered. The budget counts every part fitted in the R3 bill of materials, including both external OSPI memories (NOR flash and HyperRAM). That is the **E1M-AEN803** population and the worst case for the family. Variants without the external memories (E1M-AEN301 to E1M-AEN801) drop the two 15.6 FIT memory terms: ≈ 354 FIT at +40 °C and ≈ 902 FIT (MTBF ≈ 1 109 000 h) at +55 °C. The figures below are therefore conservative for those variants.

Component class	Qty	FIT/unit	FIT total	Share
Wi-Fi / BLE module †	1	60.0	60.0	15.6%
DC-DC switching regulators	4	14.0	56.0	14.5%
Ceramic capacitors (MLCC)	108	0.40	43.2	11.2%
Crystals & oscillator	3	—	34.0	8.8%
Load switches	5	5.0	25.0	6.5%

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Component class	Qty	FIT/unit	FIT total	Share
Ethernet PHY	1	18.0	18.0	4.7%
OSPI NOR flash §	1	15.6	15.6	4.0%
HyperRAM §	1	15.6	15.6	4.0%
MOSFET (small-signal)	6	2.5	15.0	3.9%
LDO regulators	2	6.0	12.0	3.1%
Chip resistors	80	0.15	12.0	3.1%
Nano-power LDOs †	2	6.0	12.0	3.1%
Application SoC (Ensemble) ‡	1	9.2	9.2	2.4%
Programmable mixed-signal power controller †	1	8.0	8.0	2.1%
LED / backlight driver	1	8.0	8.0	2.1%
Real-time clock	1	8.0	8.0	2.1%
EEPROM	1	6.0	6.0	1.6%
Power inductors	6	1.0	6.0	1.6%
Level translator	1	5.0	5.0	1.3%
Voltage supervisor †	1	5.0	5.0	1.3%
Temperature sensor	1	5.0	5.0	1.3%
Logic buffers †	2	2.0	4.0	1.0%
PCB substrate (multilayer)	—	3.0	3.0	0.8%
Total	**230**	—	**≈ 386**	**100%**

Table 2 E1M-AEN failure-rate budget by component class (+40 °C Telcordia reference build-up)

Notes: ‡ – **vendor-qualified**: the Alif-published field-equivalent FIT for the Ensemble SoC — 30 FIT at +55 °C, 60% CL, from the zero-failure HTOL qualification in **Alif REP-006** — back-referenced to the +40 °C build-up (÷ ≈ 3.27) so the silicon-Arrhenius scaling reproduces the 30 FIT figure at the +55 °C headline. See Section 7.
† – **engineering estimate** from device complexity and comparable parts, **pending vendor reliability data**; not measured and not vendor data. The estimated classes are the Wi-Fi / BLE module, the programmable mixed-signal power controller (8.0 FIT, comparable to other small mixed-signal ICs), the two nano-power LDOs (6.0 FIT each, set equal to the LDO class), the voltage supervisor (5.0 FIT), the logic buffers (2.0 FIT each). All must be replaced with supplier-published FIT before this report backs any contractual reliability commitment; FIT data has been requested from the suppliers.
Backup supercapacitor. The standard build has no on-module RTC backup supercapacitor, so the budget has no term for it. The room-temperature assembly option with one (rated − 20 °C to +60 °C) adds a wear-out item that this prediction does not cover.
§ – derived as a **chi-square 60% upper confidence limit** on a zero-failure JEDEC JESD47 HTOL qualification (3 lots × 77 units × 1000 h at 125 °C), accelerated to the +40 °C reference with $E_a = 0.7$ eV. This is a **conservative** bound consistent with the vendors' public reliability data (ISSI reliability report for the IS25WX family, to be obtained; Winbond AFR < 0.1%/yr, i.e. ≤ 114 FIT) and will tighten once a vendor aggregated-lot FIT is obtained.
Shares may not sum to 100% due to rounding.

4 Results

Metric	Value
Total failure rate, λ	1004 FIT
MTBF	996 000 h

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Metric	Value
MTBF (years, continuous)	114 yr
Survival R(1 yr)	99.12%
Survival R(3 yr)	97.39%
Survival R(5 yr)	95.70%
Survival R(10 yr)	91.58%

Table 3 Predicted reliability at the +55 °C operating headline (GF)

For reference, at the +40 °C Telcordia build-up point the figure is 386 FIT / 2.59 M h MTBF; at the +85 °C stress point (above the rated range) it is 7196 FIT / 0.14 M h. See Section 5 for the full sweep.

Under the constant-failure-rate (exponential) model, the survival probability of one unit at mission time t is $R(t) = e^{-t/\,\mathrm{MTBF}}$. The complement is the expected fraction of a fielded population that experiences an intrinsic failure by time t:

Mission time	Survival R(t)	Fails / 1000 units
1 year	99.12%	≈ 8.8
3 years	97.39%	≈ 26.1
5 years	95.70%	≈ 43.0
10 years	91.58%	≈ 84.2

Table 4 Expected intrinsic failures per 1000 fielded units (24/7, +55 °C)

Note: These are **intrinsic random-failure** expectations only. Field returns also include infant mortality, mishandling (ESD, mechanical), and application-board faults, which are outside the scope of a parts-count prediction.

5 Temperature & Environment Sensitivity

Failure rate is strongly temperature-driven: the silicon portion of the budget scales by an Arrhenius factor $\pi_T = \exp\left[\frac{E_a}{k}(1/T_{\mathrm{ref}} - 1/T)\right]$. The table below applies a generic activation energy $E_a = 0.7$ eV to the **silicon** subtotal (≈ 272 FIT at +40 °C) while holding passives, MOSFETs, crystals and the PCB roughly constant. Each row is stated at the given **ambient**, assuming device junctions approximately track ambient — representative of light-to-moderate electrical load.

Hot corner: Under heavy SoC / NPU load the junction **self-heats above ambient** by $\theta_{\mathrm{JA}} \times P_{\mathrm{diss}}$, so at the rated hot corner (+75 °C) the effective silicon temperature — and therefore the FIT — is **higher** than an ambient-only row shows. The rated hot corner (+75 °C) lies between the +70 °C and +85 °C rows below; the +85 °C row is a stress point above the rated range. All figures here are **ambient-only** values; a full-load hot-corner number requires the integrator's thermal solution (θ_{JA}) and the workload power, and should be treated as optimistic until that thermal data is folded in. The cold corner (− 40 °C) **lowers** steady-state FIT and is not a reliability concern; however − 40 °C → +75 °C **thermal cycling** drives a separate solder-joint fatigue mechanism (Coffin–Manson, see Section 8) that a steady-state MTBF does not capture.

Ambient	π_T	λ (FIT)	MTBF (h)	MTBF (yr)	R(5 yr)
+25 °C	0.27	187	5 355 000	611	99.2%
+40 °C †	1.00	386	2 593 000	296	98.3%
+55 °C *	3.27	1004	996 000	114	95.7%
+70 °C	9.66	2745	364 000	42	88.7%
+85 °C ‡	26.0	7196	139 000	16	73.0%

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Table 5 MTBF vs. ambient temperature (junction ≈ ambient)

* Headline operating point (quoted figure). † Telcordia +40 °C generic-device build-up reference. ‡ Stress point above the rated range (rated maximum ambient is +75 °C).

The practical takeaway: keeping the SoC junction — and hence the local ambient — **down** is the single highest-leverage reliability action available to the integrator. Every ≈ 15 °C of ambient reduction buys roughly a factor of 2–3 in module MTBF.

6 Dominant Contributors & Design Notes

- **Wi-Fi/BLE module = ≈ 16% of FIT — the single largest contributor** and the largest term still on an engineering-estimate FIT (†). It is also a hot part, coupling directly into the temperature sensitivity of Section 5. The **Application SoC**, previously co-dominant at the 100 FIT estimate, is now **vendor-qualified** (‡, Section 7) at ≈ 2% of FIT, so the Wi-Fi module's supplier FIT is now the single biggest lever on the headline number.
- **Wear-out-limited parts.** The module has no aluminium electrolytic capacitors. The standard build has no on-module RTC backup supercapacitor: the backup element (coin cell, supercapacitor or none) is on the carrier, and its ageing is the integrator's to assess. The room-temperature assembly option with an on-module supercapacitor (− 20 °C to +60 °C) would add a wear-out item (capacitance loss, rising ESR and leakage) that is not part of the steady-state budget. NOR Flash and EEPROM endurance is a **write-cycle** limit, not a time limit, and is governed by firmware usage rather than this prediction.
- **Interconnect.** The module is soldered to the carrier as an LGA; there is no module connector. Board-level solder-joint thermal fatigue is excluded from this prediction (see Section 8). The on-module RF connector (I-PEX MHF 4L 20579-001E) is not fitted in production builds (DNP, assembly option only), so it carries no term in the budget; where an integrator has it fitted, its real-world reliability is dominated by mating cycles.
- **Passive count is high but low-risk.** 194 passives (capacitors + resistors + inductors) contribute only ≈ 16% of FIT combined — expected for derated commercial MLCCs and thick-film chip resistors.

7 Vendor Reliability Data (Alif Ensemble SoC)

The Application SoC FIT used above is no longer an engineering estimate: it is the Alif Semiconductor field-equivalent figure for the Ensemble family (published for E4/E6/E8). The E1M-AEN301/501/701 (E3/E5/E7) use the same 22 nm FD-SOI process and FBGA194 package, and the figure is applied to them by similarity. Alif manufactures the Ensemble on GlobalFoundries' 22 nm FD-SOI process with embedded MRAM (eMRAM), in the FBGA194 package used on the module.

Parameter	Value
Life test	HTOL, readouts at 168 / 500 / 1000 h, multiple lots
Sample	395 units × 1000 h = 395 000 device-hours, **0 failures**
Acceleration	Arrhenius, $E_a = 0.7$ eV, $T_{\text{stress}} = 125°C$, $T_{\text{use}} = 55°C$ ($\text{AF} \approx 78.4$)
FIT @ 55 °C, 60% CL	≈ **30 FIT** ⟶ MTBF ≈ 3.38 × 10^7 h
FIT @ 55 °C, 90% CL	≈ 74 FIT ⟶ MTBF ≈ 1.34 × 10^7 h

Table 6 Alif Ensemble SoC field-equivalent reliability (Alif REP-006, Rev 1)

This report adopts the **60% CL** value (30 FIT) for consistency with the § memory terms and the DeepX/vendor convention across the E1M reliability set. The 30 FIT is the **SoC device** figure at the +55 °C use condition; it enters the module budget back-referenced to the +40 °C build-up (÷ ≈ 3.27) so the silicon-Arrhenius scaling of Section 5 reproduces 30 FIT at the +55 °C headline.

The Ensemble family additionally completed the full JEDEC/AEC production qualification (**Alif REP-004, Rev 3**, FBGA194, all lots 0 failures / PASS):

Stress	Condition	Result
HTOL	$T_j = 125°C$, biased, 1000 h (JESD22-A108)	PASS

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Stress	Condition	Result
HTS	$T_a = 150°C$, 1000 h (JESD22-A103)	PASS
Precon / MSL	MSL3, 30 °C/60%RH/192 h, 3× reflow 260 °C	PASS
uHAST	130 °C / 85% RH, 96 h (JESD22-A118)	PASS
Temp cycle	− 55 °C ↔ +125 °C, 1000 cyc (JESD22-A104)	PASS
Vibration	20 Hz–2 kHz, 20 g (JESD22-B103)	PASS
Mech. shock	1500 g, 0.5 ms, 6 dir (JESD22-B104)	PASS
ESD	HBM 2 kV (A114), CDM 250 V (C101)	PASS
Latch-up	± 50 mA, $V_{dd} + 10\%$ (JESD78)	PASS

Table 7 Alif Ensemble FBGA194 qualification summary (Alif REP-004, Rev 3)

Note: Alif reports are provided under NDA; the figures above are the customer-releasable summary values. Latch-up was qualified to ± 50 mA (vendor-stated maximum safe stress for the advanced node / fine-pitch package), below the JESD78 ± 100 mA default.

8 Assumptions & Limitations

1. **Parts-count, not parts-stress.** Method I uses per-class reference FITs rather than computing each part's individual electrical/thermal stress (Method II). Method I is the accepted approach at the design / datasheet stage and is typically **conservative** for a well-derated design.
2. **Series reliability.** Any single part failure is treated as a module failure. There is no on-module redundancy to credit.
3. **Mixed FIT provenance.** The Application SoC is now on **vendor field-equivalent data** (‡ — Alif REP-006, Section 7). The Wi-Fi / BLE module and the R3 classes marked † (power controller, nano-power LDOs, supervisor, logic buffers) are engineering estimates pending vendor reliability reports. Two classes (NOR flash §, HyperRAM §) are chi-square 60% upper-confidence limits derived from the JEDEC JESD47 HTOL qualification — defensible but conservative; a vendor aggregated-lot FIT will most likely **lower** them. Substituting the † Wi-Fi term is now the main remaining path to tightening the prediction.
4. **Excludes solder-joint thermal fatigue.** Board-level solder-joint life under power/thermal cycling (an IPC-9701 / Coffin-Manson analysis) is a separate study driven by the integrator's duty cycle and is not part of a steady-state parts-count MTBF.
5. **Excludes infant mortality and end-of-life wear-out.** The figure describes the flat region of the bathtub curve only.
6. **Point estimate at 50% confidence.** A lower-confidence-bound figure (e.g. 90%) can be produced on request once vendor data fixes the dominant terms.

9 Revision History

Revision	Changes	Date
0.1	• Initial parts-count MTBF prediction (Telcordia SR-332 Issue 4) from the released E1M-AEN netlist. • SoC, Wi-Fi module, HyperRAM and NOR-flash FITs are engineering estimates pending vendor data.	June 2026
0.2	• NOR-flash and HyperRAM FITs replaced with chi-square 60% UCL values derived from the JEDEC JESD47 HTOL qualification (15.6 FIT @ 40 °C each). • Headline rebased to the +55 °C operating point: ≈ 1150 FIT / 867 000 h. • SoC and Wi-Fi module remain on engineering estimates.	June 2026
0.3	• Application SoC FIT replaced with Alif vendor field-equivalent data (30 FIT @ 55 °C, 60% CL; Alif REP-006).	July 2026

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Revision	Changes	Date
	• Added the Vendor Reliability Data section (Section 7) summarising Alif REP-006 MTBF and REP-004 Rev 3 qualification (FBGA194, all PASS). • Headline improves to ≈ 856 FIT / 1 170 000 h; budget reordered (Wi-Fi module now the largest single term). • Wi-Fi / BLE module is the only remaining engineering-estimate (†) term.	
0.4	• Rated operating range changed from − 40 °C to +85 °C to − 40 °C to +75 °C ambient (limit set by the Ensemble SoC); modules with the RTC backup supercapacitor are rated − 20 °C to +60 °C. • The +85 °C row is re-labelled as a stress point above the rated range. • No FIT / MTBF values changed.	October 2026
0.5	• Added R3 status warning (budget still built from the R2 bill of materials) • wear-out and interconnect notes corrected (RTC backup supercapacitor, no module connector) • passive count corrected • NOR-flash vendor reference and SoC family applicability clarified • supercapacitor-fitted hot-corner rating added.	October 2026

0.6	• Failure-rate budget rebuilt for R3 (230 fitted components incl. both OSPI memories, i.e. the E1M-AEN803 worst case; other variants ≈ 902 FIT at +55 °C; from the R3 bill of materials):
	  ▸ board-to-board connector, CAN transceiver, secure element, voltage reference and second EEPROM removed
	  ▸ DC-DC regulators, load switches, MOSFETs, inductors and MLCCs recounted
	  ▸ added programmable mixed-signal power controller, two nano-power LDOs (including the new always-on 1.8 V LDO), voltage supervisor and logic buffers (engineering estimates †)
	  ▸ one small-signal MOSFET and one resistor added net (6 MOSFETs, 80 resistors), one level translator removed, RTC backup supercapacitor removed (not fitted in the standard build; the carrier provides the backup store).
	• Headline moves from ≈ 856 FIT / 1 170 000 h to ≈ 1004 FIT / 996 000 h at +55 °C (build-up 337 ⟶ 386 FIT at +40 °C).
	• R3 status warning replaced.
	• On-module RF connector is DNP in production: its 2.0 FIT term is removed.
		October 2026

0.7	• Release history: every entry formatted as a bullet list.	October 2026
0.8	• Table of Contents: each entry links to its section; the front-matter lists are set tighter.	October 2026
0.9	• Product name on page 1 links to the product page on alplab.ai. • On-module parts named by function; component designators removed.	November 2026

Table 8 Document revision history

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