

ITC 2026 P28: Memory Characterization using Advanced Pattern Rank-Trajectory Analysis (PRTA) utilizing state-of-the-art Frequency-Voltage (Shmoo) Tests



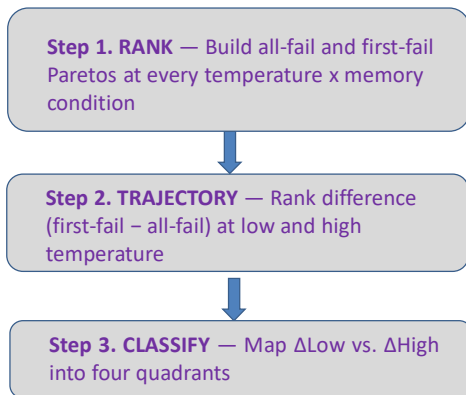
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Why Shmoo Analysis Must Evolve

1. Shmoo (F-V) testing is the industry standard for operating boundaries, but its analysis has not scaled with modern SoCs
2. One packet spans patterns x conditions x fail types x temperatures: ~14 M rows, ~600 Shmoo/Pareto artifacts
3. Industry practice Paretos each condition alone, missing cross-condition behavior which is the most actionable signal
4. Manual analysis takes weeks, forcing engineers to shrink the dataset

The PRTA Framework



First-Fail vs. All-Fail: The Key Signal

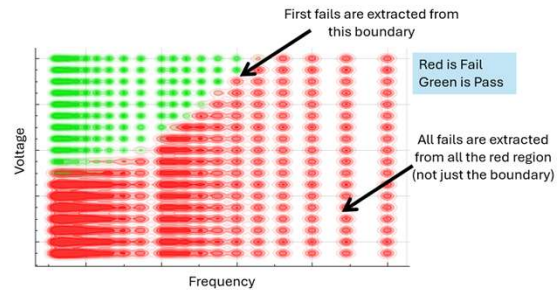


Fig. 1 — F-V Shmoo contour: green = pass, red = fail. First fails come only from the pass/fail boundary; all fails from the entire red region.

Rank Trajectory from Pareto Pairs

Rank 1 = least-failing pattern; a higher rank value means it fails more often. Pattern BB is the #1 failer in the all-fail Pareto but only 10th in first-fail. PRTA tracks exactly that rank movement across thousands of Shmoos.

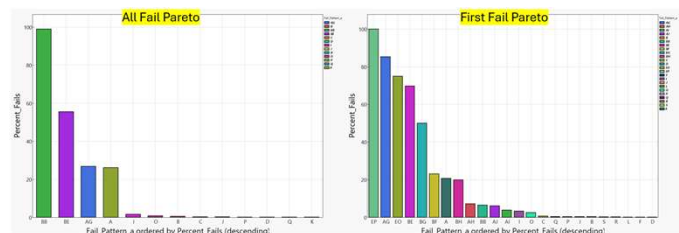


Fig. 2 — (a) The all-fail Pareto is dominated by a few patterns; (b) the first-fail Pareto is far more distributed. This contrast is the foundation of PRTA.

Results: Four Quadrants Replace 100+ Dimensions

Each pattern is plotted as Δ Rank at low temperature (X) vs. high temperature (Y). Pearson $r = 0.63-0.92$ across memory types, all $p < 0.05$.

Each pattern's quadrant is then tracked across memory types. Mostly green = correlated behavior; red hotspots expose memory-specific sensitivities; blanks are missing ranks.

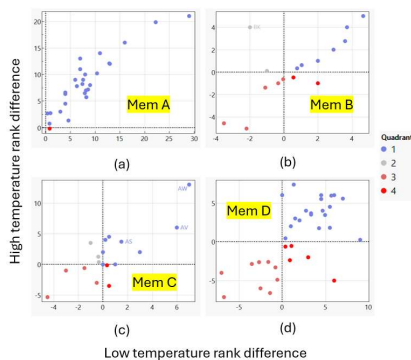


Fig. 3 — PRTA quadrant map for four memory types; ~70–80% of patterns correlate positively across temperature.

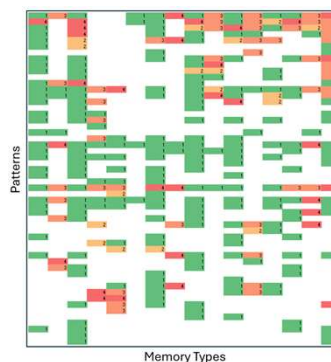


Fig. 4 — Quadrant heatmap: patterns (rows) x memory types (columns). Green = Q1, red = Q4; blanks are missing ranks.

What the Quadrants Mean — and What It Saved

Q1 ($\Delta+$, $\Delta+$) — fails more in first-fail at both temperatures → localized physical defects. Action: process yield debug.

Q2 ($\Delta-$ cold, $\Delta+$ hot) — temperature-sensitive process/design marginality. Action: correlate to physical parameters.

Q3 ($\Delta-$, $\Delta-$) — gross, non-pattern-specific fails across most patterns. Action: process yield.

Q4 ($\Delta+$ cold, $\Delta-$ hot) — inverse of Q2; opposite electrical signature, so a different mitigation is required. Could be test instability related.

IMPACT: 14 M data points → 602 groups (~10⁶-fold reduction) • ~600 Shmoo/Pareto artifacts → 4 quadrants • hundreds of patterns → <10 with clear next steps • weeks of manual analysis → ~4 hours on one workstation (JMP 17 Pro).