NASA NEEP Workshop -
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The Challenges of PEM (Plastic Encapsulated Microcircuit)

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Can PEMs be Used in Military and Space Applications?

Can Plastic Encapsulated Microcircuits (PEMs) be effectively used in Military and Space Applications?

- The short answer is yes….but you must be careful!
- Understand risk and consider the application!

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Other (Better) Reasons to use PEMs

- Reasons why PEMs are used:
  - Plastic parts are dominant in the industry and will be supported longer
  - Generally lower cost materials
  - Greater investment in supplier product improvement programs
  - Greater product variety
  - Mechanically more rugged
  - Lighter weight
  - Available in smaller/thinner packages
  - More automated assembly methods
  - Higher volume/more cost effective production
  - Increasing reliability due to supplier competition

- All of the above items will help reduce end system costs. And with the relentless pressure to reduce costs (sequestration, budget deficits, congressional gridlock, recessions in US and Europe, etc.) the ability to reduce costs are at least on par with availability as a reason to use PEMs and arguably even more important.

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What are the Typical PEM Qual Failure Types

Typical PEM Qual Failure Types:

1. Cracked Die
2. Wire breaks
3. Wire Lift
4. Delamination
5. Corrosion
6. Contamination
7. Moisture Ingress
8. Cracked Package
9. Cracked Passivation
10. Die Attach Voids

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PEM Qual: Understand Your Package / Data

- Certain packages have inherent weakness to moisture ingression
  - Very Thin Packages
  - Small Outline Devices
  - Packages with back-side paddles
  - Flip chip packages with vents

- For Example: SOT and SOT with paddle or heat sink is one of the most sensitive parts we see. They are usually inexpensive (sometimes cheap) plastic parts that need special consideration if they are to be used. Item to worry about
  - Paddles or bottom side heat sink provides an extra venue for moisture ingression; hence; higher susceptibility to moisture ingression

PEM Qual: Understand Your Package / Data

- High Power - Will it make part inherently less reliable? Tg is a big consideration – so understanding the thermal characteristic of the device (high power device) is key
- CTE Mis-match - We have seen qualification failures due to mis-match of CTE (Thermal Expansion) between molding compound and the die attach medium; epoxy die attach is far more forgiving than eutectic die attach
- Copper Bond Wire - Does the product use copper bond wires? Long term reliability data is still being collected

Is CSAM Data Useful? Does it Tell You something

- Some people swear by it and some don't think it is worth the effort to have CSAM data

- Most common interfaces looked at:
  - Die surface, die attach, die paddle, and leads / lead frame

- Delamination occurs due:
  - Stress-induced passivation damage over the die surface
  - Wire-bond degradation due to shear displacement
  - Accelerated metal corrosion
  - Die-attach adhesion
  - Intermittent electricals at high temperature
  - Popcorn cracking
  - Die cracking
  - Device latch-up

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6.2.1 Delamination The following delamination changes are measured from pre-moisture soak to post reflow. A delamination change is the change between pre- and post-reflow. The percent (%) delamination change is calculated in relation to the total area being evaluated.

6.2.1.1 Metal Lead frame Packages:

a. No delamination on the active side of the die.
b. No delamination change >10% on any wire bonding surface of the die paddle (downbond area) or the lead frame of LOC (Lead On Chip) devices.
c. No delamination change >10% along any polymeric film bridging any metallic features that is designed to be isolated (verifiable by through transmission acoustic microscopy).
d. No delamination/cracking change >10% through the die attach region in thermally enhanced packages or devices that require electrical contact to the backside of the die.
e. No surface-breaking feature delaminated over its entire length. A surface-breaking feature includes: lead fingers, tie bars, heat spreader alignment features, heat slugs, etc.

6.2.1.2 Substrate Based Packages (e.g. BGA, LGA etc.):

a. No delamination on the active side of the die.
b. No delamination change >10% on any wire bonding surface of the laminate.
c. No delamination change >10% along the polymer potting or molding compound/laminate interface for cavity and overrmolded packages.
d. No delamination change >10% along the solder mask/laminate resin interface.
e. No delamination change >10% within the laminate.
f. No delamination/cracking change >10% through the die attach region.
g. No delamination/cracking between underfill resin and chip or underfill resin and substrate/solder mask.
h. No surface-breaking feature delaminated over its entire length. A surface-breaking feature includes lead fingers, laminate, laminate metallization, PTH, heat slugs, etc.

Figure 3-1. Rejection criteria from JEDEC-J-STD-020D

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Is CSAM Data Useful? Does it Tell You Something?

- Typical CSAM usage
  - Production screening
  - During Qualification and Reliability testing
    - Pre and Post stress (life test or temperature cycle or humidity test)

- Even delamination is not necessarily a failure if the Reliability tests passed (see below from JEDEC-J-STD-020D)

Is Delamination Reject able?

6.2 Criteria Requiring Further Evaluation Delamination is not necessarily a cause for rejection. To evaluate the impact of delamination on device reliability, the semiconductor manufacturer may either meet the delamination requirements shown in 6.2.1 or perform reliability assessment using JESD22-A113 and JESD-47 or the semiconductor manufacturer’s in-house procedures. The reliability assessment may consist of stress testing, historical generic data analysis, etc. Annex A shows the logic flow diagram for the implementation of these criteria.
If the SMD Packages pass electrical tests and there is delamination on the back side of the die paddle, heat spreader, or die back side (lead on chip only), but there is no evidence of cracking, or other delamination, and they still meet specified dimensional criteria, the SMD Packages are considered to pass that level of moisture sensitivity.

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What are the Typical PEM Failure Types

- Why do DPA before starting screening or qualification?

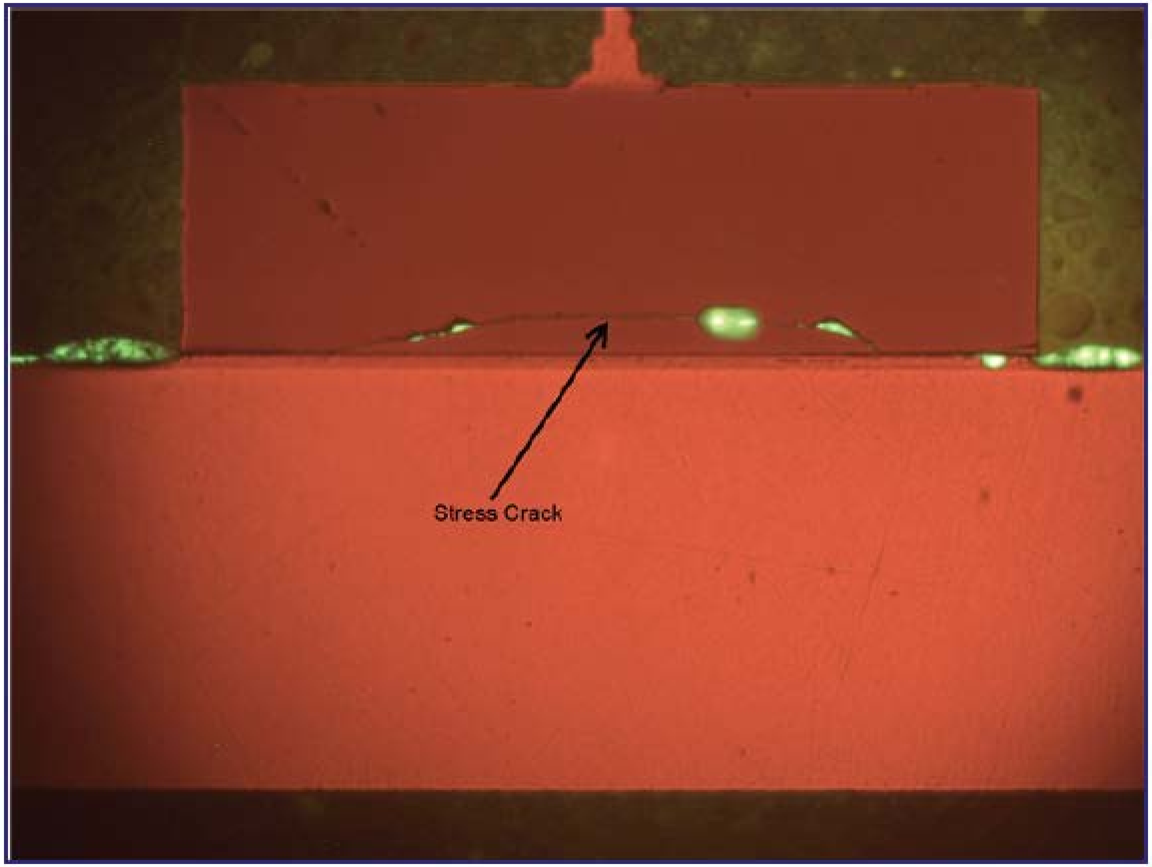

Figure 20:

S/N: 3

Caption:

Detailed view showing the internal delamination on the wire bonding surface that was observed during acoustic microscopy. The delamination shows bright green under a mercury lamp to inspect where the dye penetrant was fluorescing. Crack seen in die is indicative of a stress fracture sustained during qualification.

- **Because the reliability of some devices is questionable even before and PEM specific evaluation is started.**
- **This would have looked like a PEM Qual failure.**

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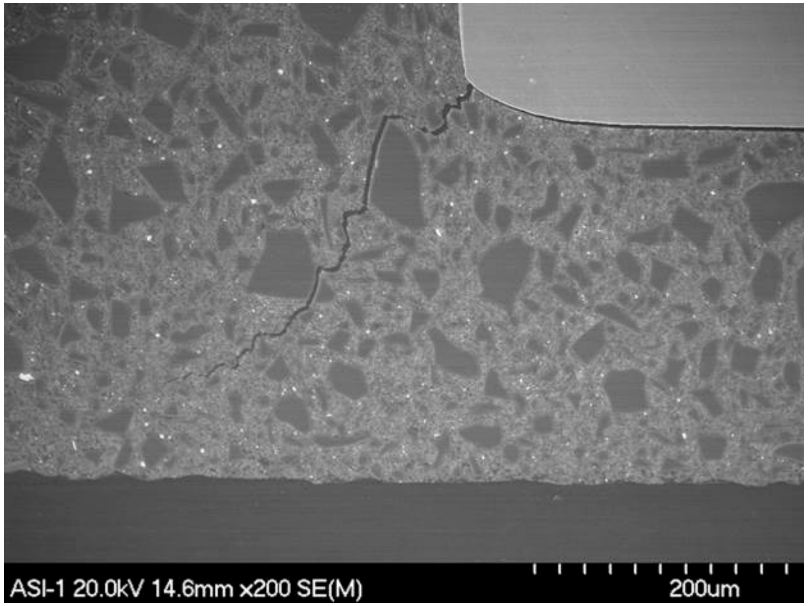
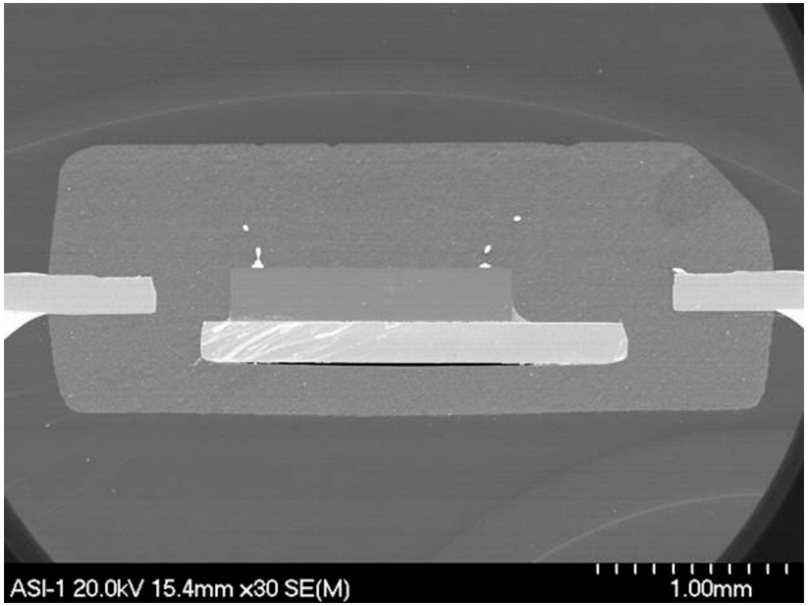
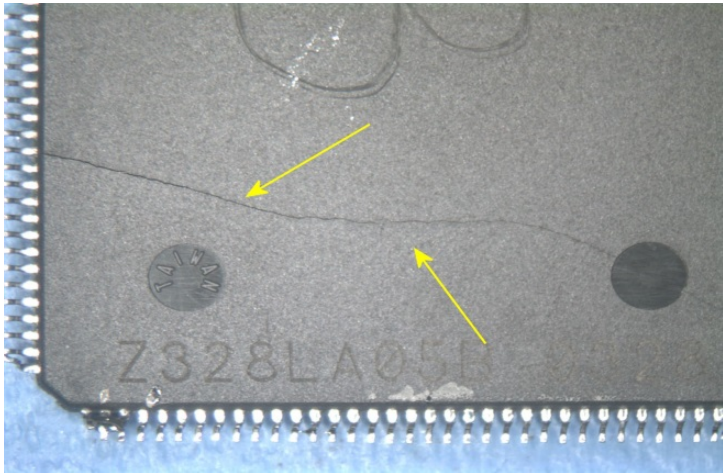
What are the Typical PEM Failure Types



Pop-corning



Delamination



Package Cracks

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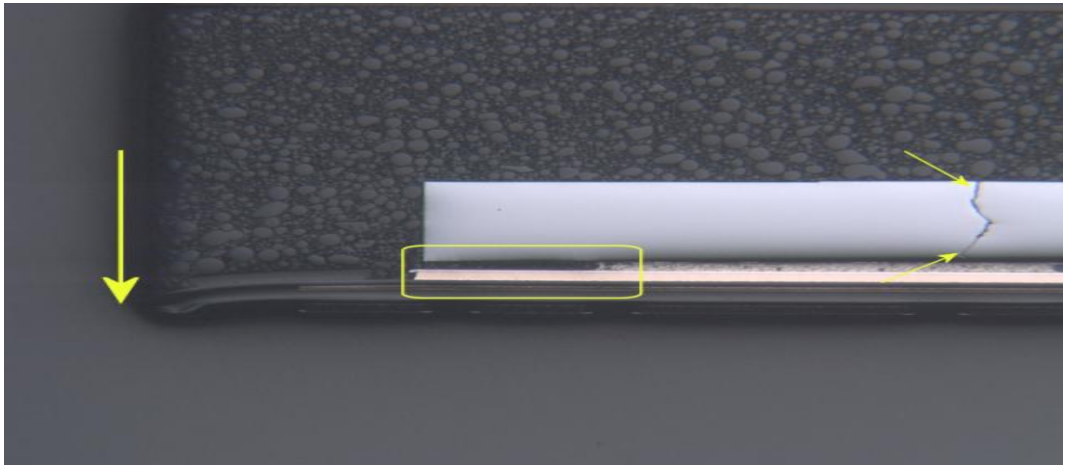
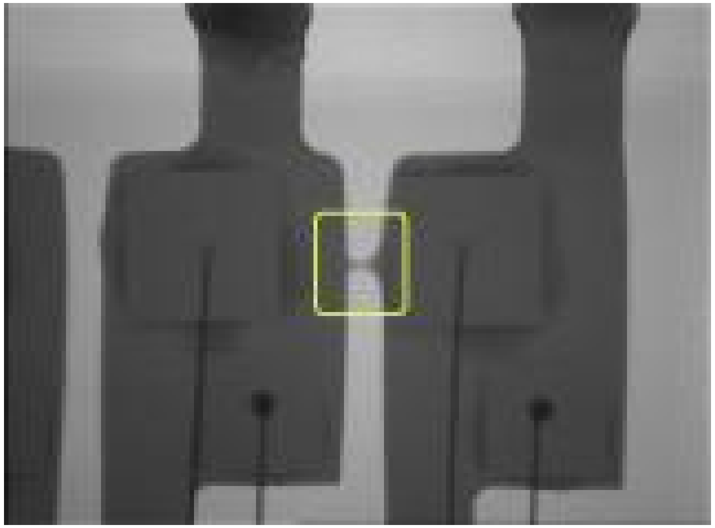
What are the Typical PEM Qual Failure Types



Cross section – PWB damage; void underneath the die and die cracking



X-Ray – Short between two lead frames

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- Best Practices When Using PEMs
  - Understand available OCM data – Does the product already show delamination or die cracking or other failures during OCMs data review?
  - Perform a detailed construction analysis data on package before the qualification starts. You will learn a lot of package weakness data before star of qual
  - Perform a DPA before using the part
  - Perform CSAM – Test may be controversial but it does provide relative data for understanding and managing risk
  - Do some kind of qualification for PEMs. No two suppliers are same or have same manufacturing practices

Current PEM Qual Standards Efforts - SAE G12 PEM Task Team

Leadership

Sultan Ali Lilani - Integra Technologies (Chair)
David Sunderland - Boeing (Co-Chair)
David Locker – US Army (Team Lead – Avionics / Terrestrial PEMs)
Rod de Leon – Boeing (Team Lead – Space)

Members

30 members attend weekly meetings (65+ members in distribution list)
Representatives from Boeing, Lockheed, NG, Harris, L-3, Aerospace, NASA, Xilinx, ON, TI, ADI, Intel, Rocketdyne, Army, Air Force, Honeywell, IRF, SWRI, Rockwell, DLA, BAE, Integra Technologies, etc.

Meetings: Weekly (started 2/25/2014)

Alternate weekly meetings between Space and Avionics / Terrestrial

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Initial Charter of the PEM Task Team

- Review existing standards for PEM qualification & screening
  - NASA: PEM-INST-001, MSFC-STD-3012
  - QML Class N, Class Y (non-hermetic microcircuits)
  - QML Class F, Class L (non-hermetic hybrids)
  - etc.
- Provide recommendations for unification
- Address concerns for Space & Terrestrial applications
- Address possible holes in current documents
- Make recommendations to improve QML Class N and Class Y
- Be resource to industry when questions come up that are not being addressed by current PEM flows

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Feedback and Key Items Learned

- Received comments from the Avionics, Space OEMS and also the DOD/Aerospace teams
- Need by the user community for plastic devices is real
- COTs are being currently purchased, up-screened and subjected to qualification.
  - Usage of plastic parts is wide spread in non-Space Terrestrial application while the Space community uses it for selected programs.
- Cost (and leadtime) is a concern. We heard that some users do not use Class N or even VID's (EP) due to cost or leadtime
- OCMs have made a strong case that plastics COTs have improved dramatically over the years from Reliability perspective
- Some QML users need all the appropriate checks and balances from process control point of view and risk is very high for them to consider non-QML plastics parts
- Not to consider Class Y flow as it for ceramic non-hermetic package
- Class N was created for non-Space, is plastic encapsulated but needs definition around flow and requirements
- Presentations from OCM showed:
  - Class N is closer to COT plastic flow
  - Typically has no burn-in (except ON flow)
  - Low demand

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Current PEM Qual Standards Efforts - SAE G12 PEM Task Team

Latest Agreement Within Task Team for Following Tasks

Task 1 (Avionics / Terrestrial):

Create a common flow for that the Avionics and Terrestrial users.

Flow with possibly two parts

- Part 1: Provide some visibility or control on the overall process. Possibly incorporate all the features of Class N and whatever else is missing
- Part 2: How to use a commercial off- the- shelf plastic part for high reliability Avionic/Ground/non-space application. Review Class N and other flows and add additional screening and test if requires

Current Status:

- Looking at either using Automotive Flow or Class N Flow to modify and adopt for Avionics / Terrestrial Usage
- At this rate; we may need till 1Q 2015 to complete

Task 2 (Space)

Based on PEM-INST-001 / EEE-INST-002 / MSFC-STD-3012 (all very similar flows)

Designed to address NASA and commercial space and could be used as a common baseline for deviations for Defense Space.

Current Status

Review of existing flows from OEM and above mentioned completed
Developing the screening flow now
NASA has agreed to provide updated EEE-INST-002 for review by October 2014
We may have a working screening and qual flow by end of the year

Task 3 (Process)

At some point, address QML PEMs for space. Best addressed after working on the above two flows

Current Status: Nothing done; waiting for Task 1 and Task 2 to be completed

Integra PEM Qual Data Overview

Time Period Covered:	**1998 through August of 2013**
Total Number of Parts Processed:	**111,183**
Total Number of Lots:	**791**
Total Number of Passing Lots:	**496**
Passing Lot Percentage:	**63%**
Total Number of Failing Lots:	**295**
Failing Lot Percentage:	**37%**
Total Customer Part Numbers:	**455**
Total Manufacturer Part Numbers:	**410**
Total Number of Manufacturers:	**73**
Total Number of Customers:	**42**
Unique Pin/Package Combinations:	**165**

Notes:

- No qualifications conducted by semiconductor manufacturers are included.
- Plastic packaged semiconductor devices only - no passives.
- Predominant test temperatures are -40, 25 & 85 and -55, 25 & 125.
- Testing temperature order is usually room, cold, hot.
- Once a qual fails it is usually stopped.
- Failures are for electric test only (no mechanical failures).
- Vast majority of testing performed to manufacturers datasheet limits.
- Virtually all electrical test programs written by Integra Technologies.

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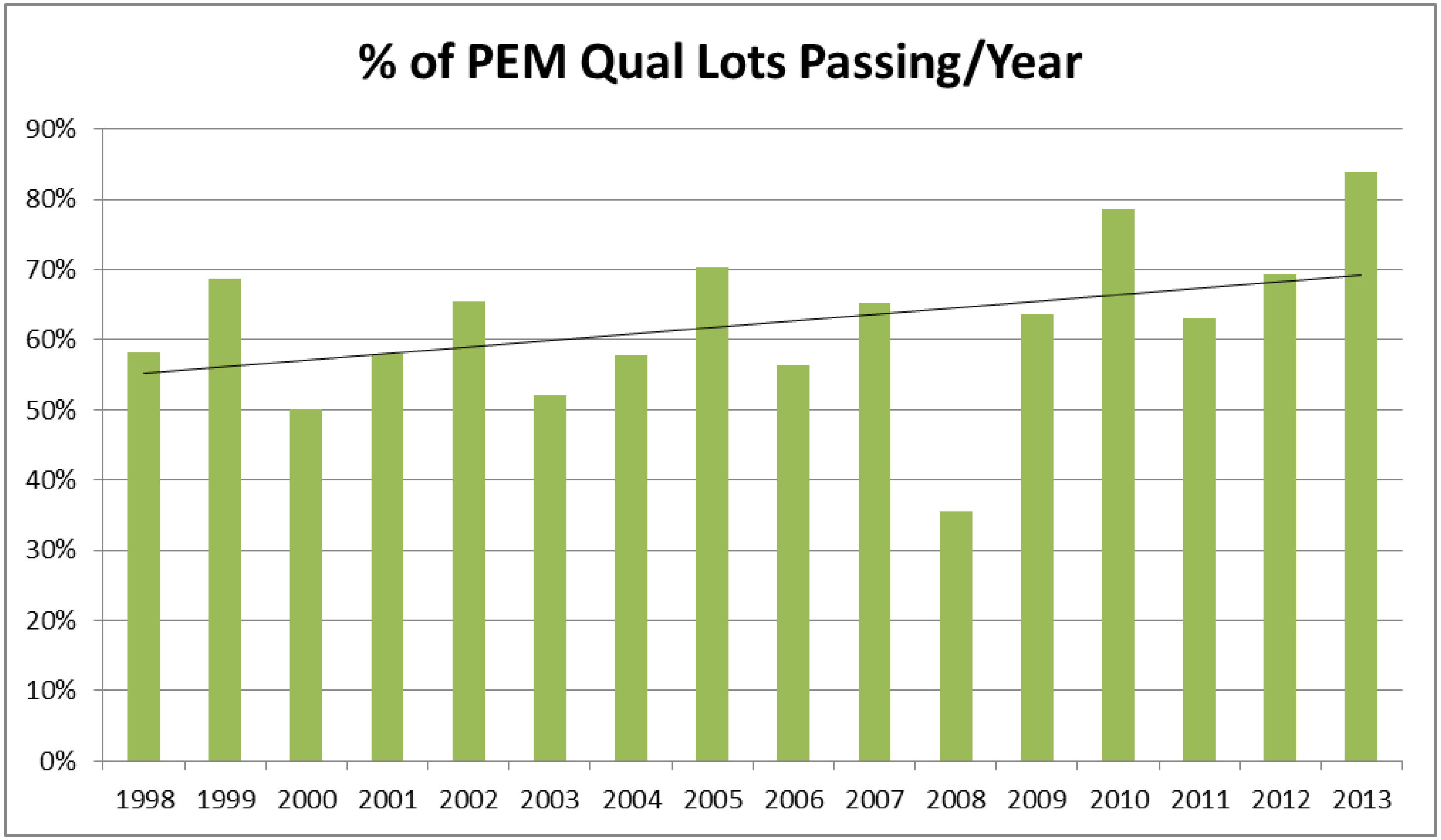
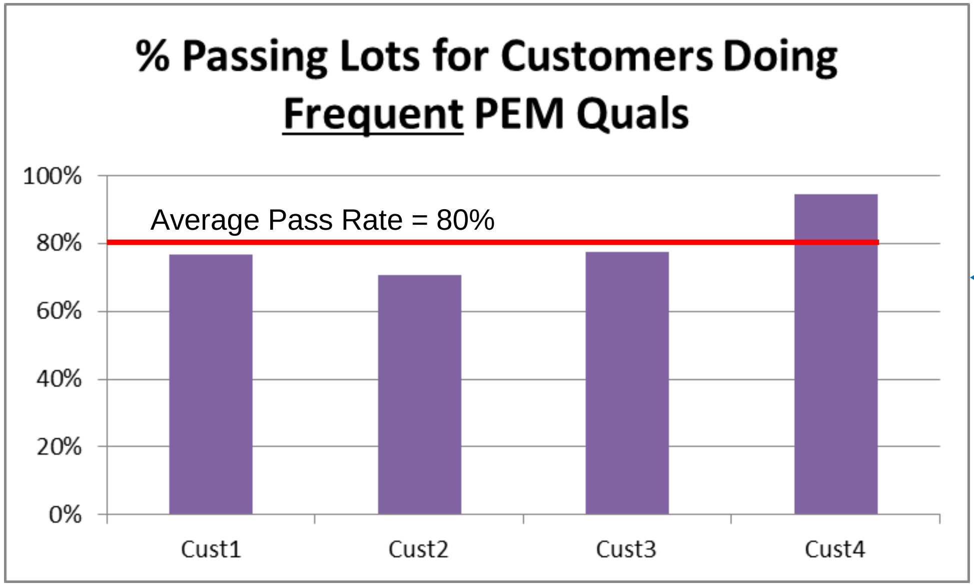
Overall PEM Pass/Fail Rate



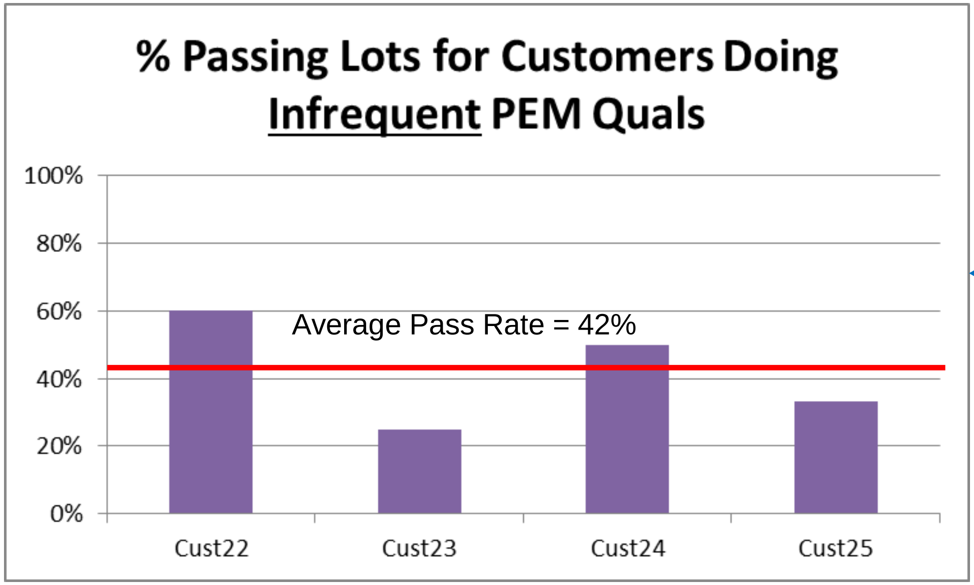
This data suggests that PEMs are getting more reliable over time or that the customers are getting smarter about which suppliers to select for PEM quals. We actually believe it to be both.

Overall Customer PEM Qual Success Rate



Customers who are more experienced with PEM Quals tend to have better success. These 4 customers averaged over 100 PEM Qual lots each over the 15 year analysis period.

The average pass rate over the entire population is 63%.



Customers who are less experienced with PEM Quals tend to have less success. These 4 customers averaged ~4 PEM Qual lots each over the 15 year analysis period.

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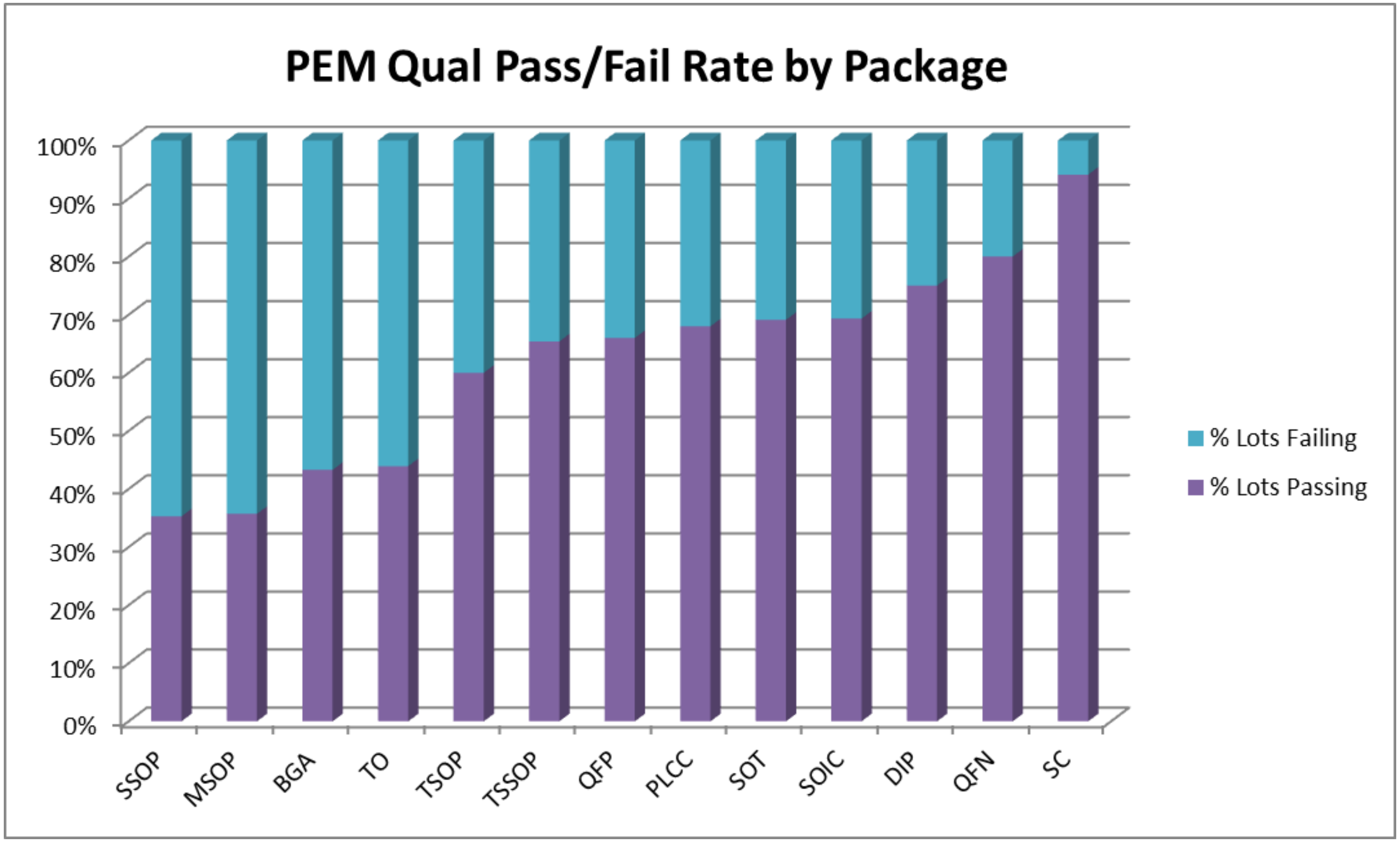
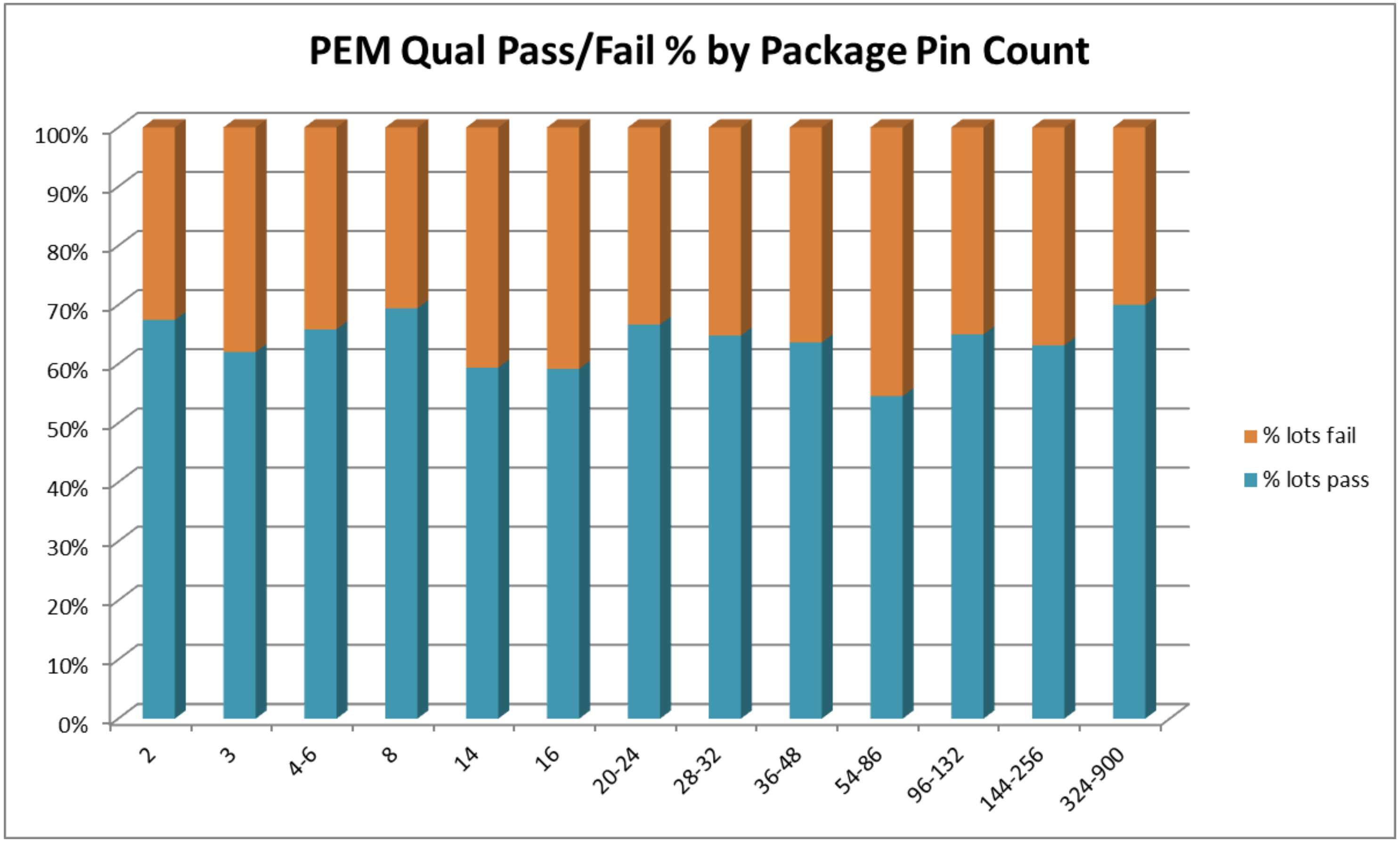
Overall PEM Qual Success Rate by Package



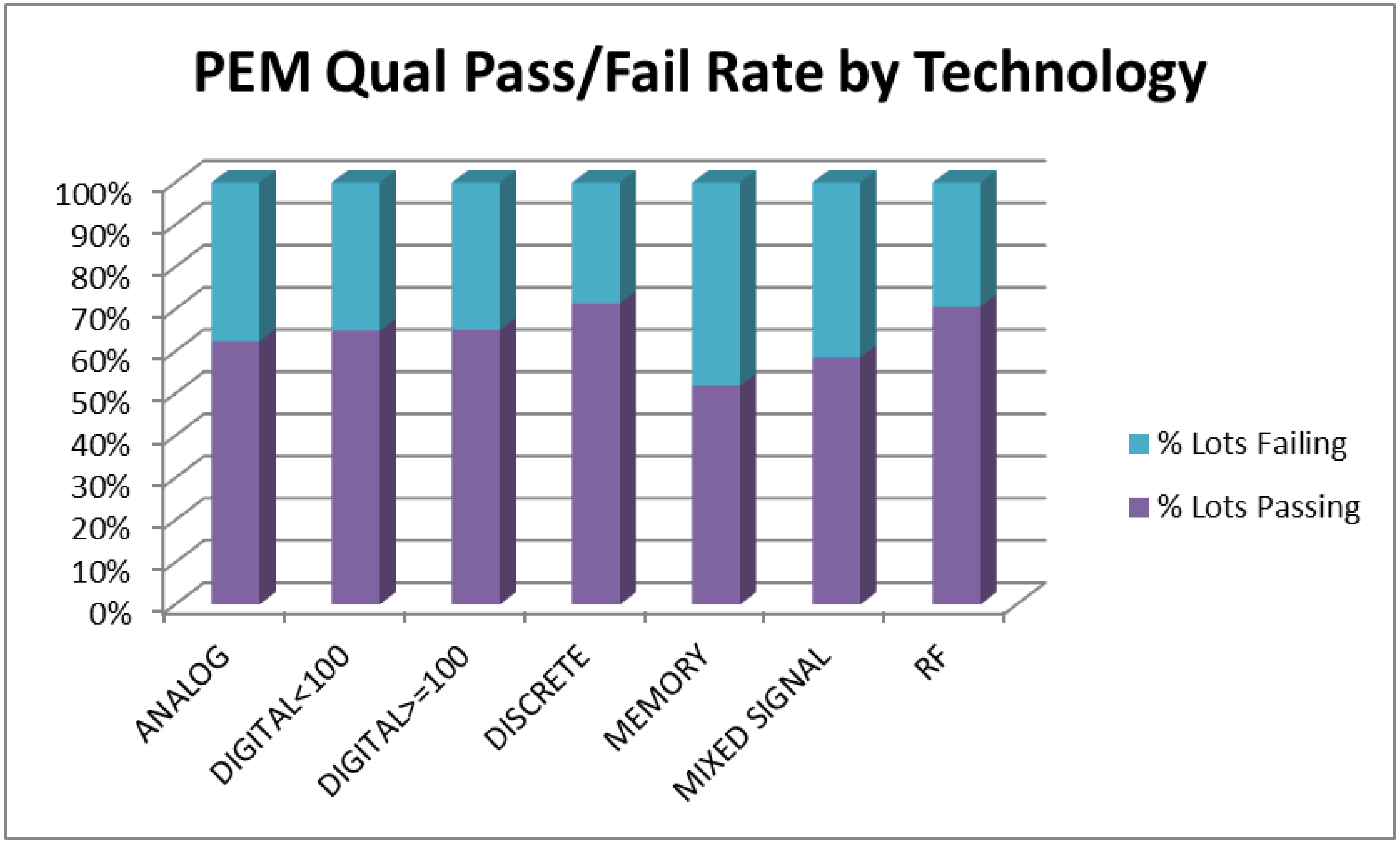
There are meaningful differences between package types in their ability to pass a PEM Qual.

Overall PEM Qual Success Rate by Package Pin Count



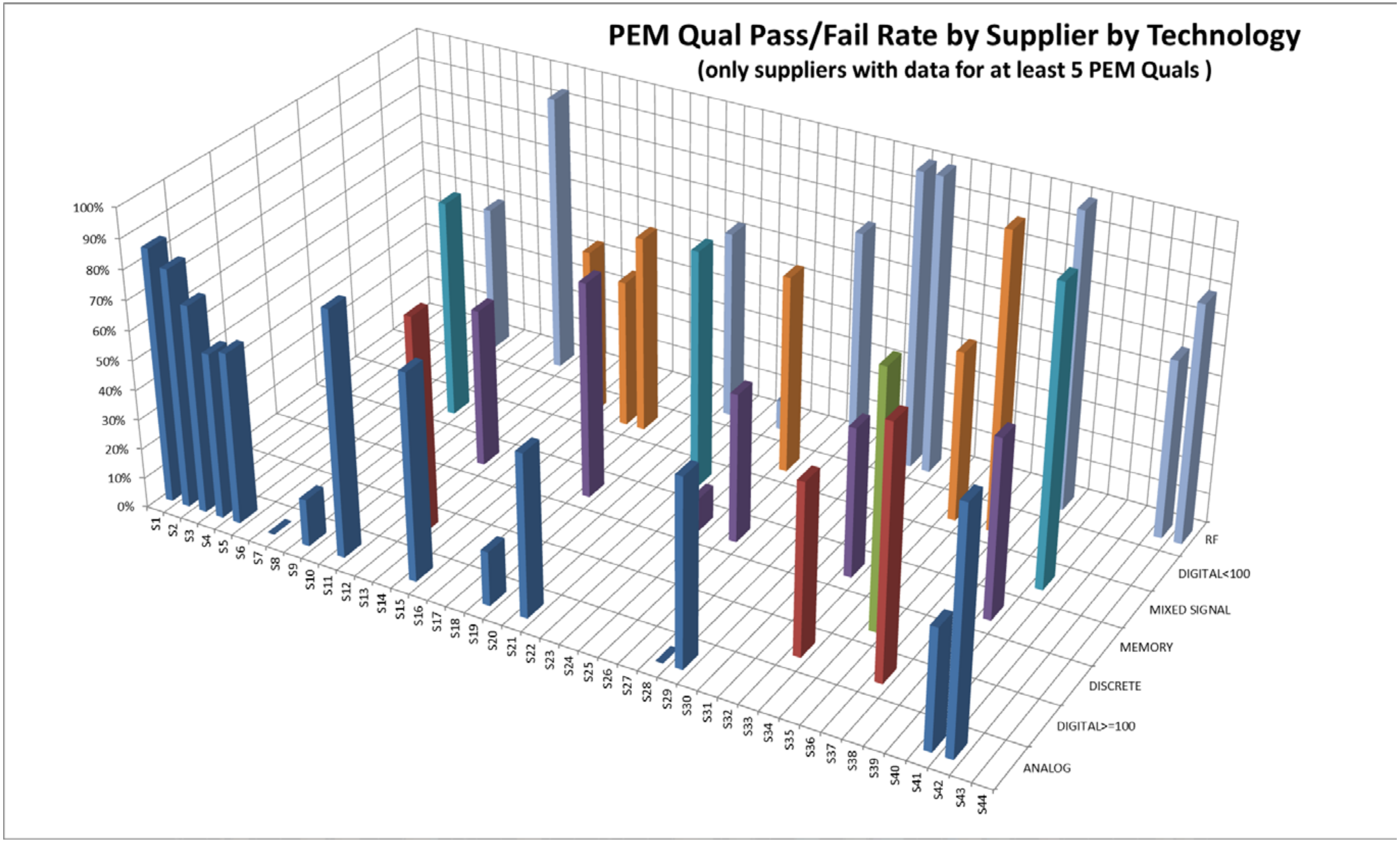
Despite the sensitivity to package type shown on the previous page, there does not appear to be a meaningful sensitivity to package pin count.

Overall PEM Qual Success Rate by Device Technology



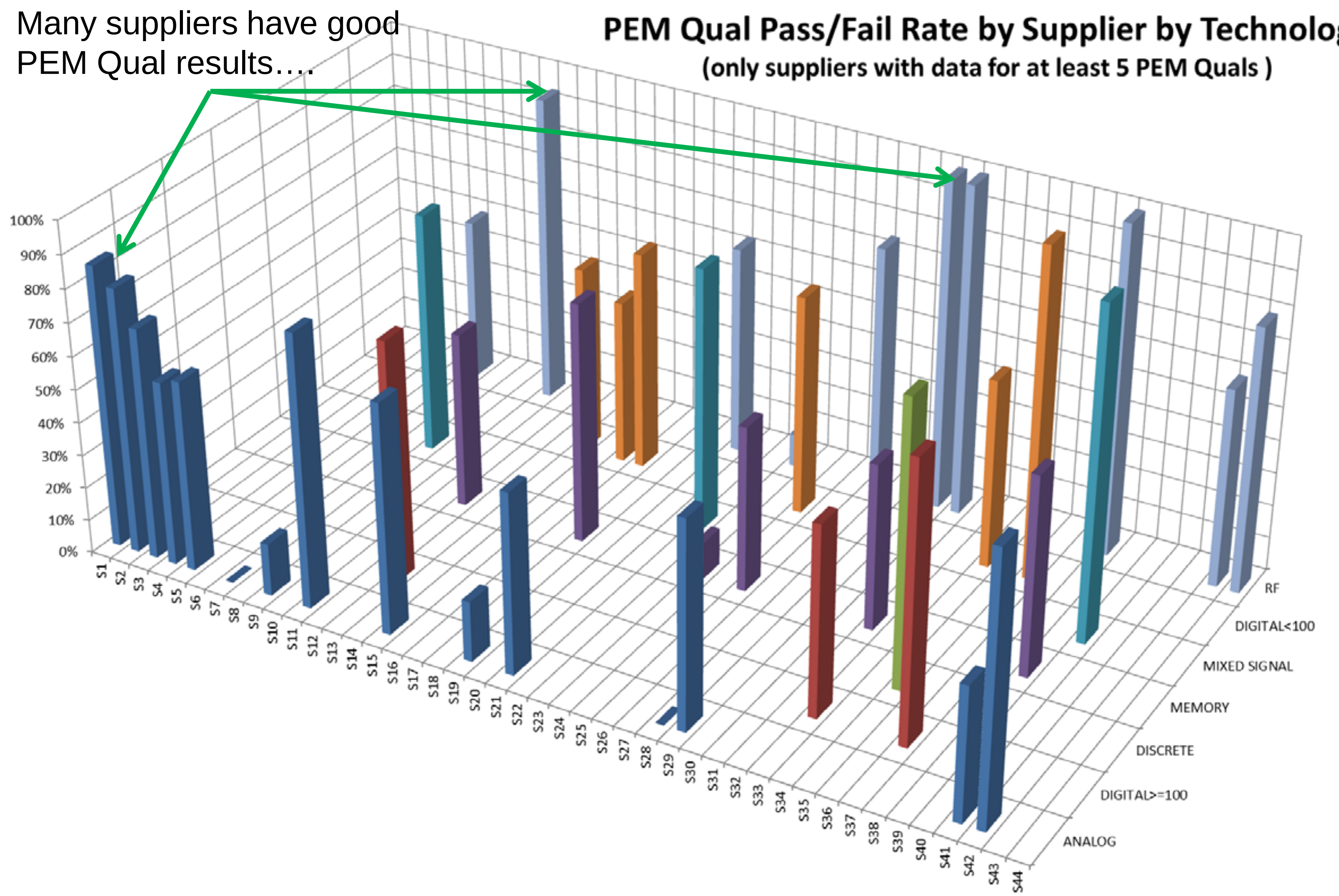
There is not a great deal of sensitivity to technology, with the exception of memory. It should be noted that the memory devices we evaluated tended to more often come in packages that were previously shown to be less reliable.

Overall PEM Qual Success Rate by Device Technology by Supplier

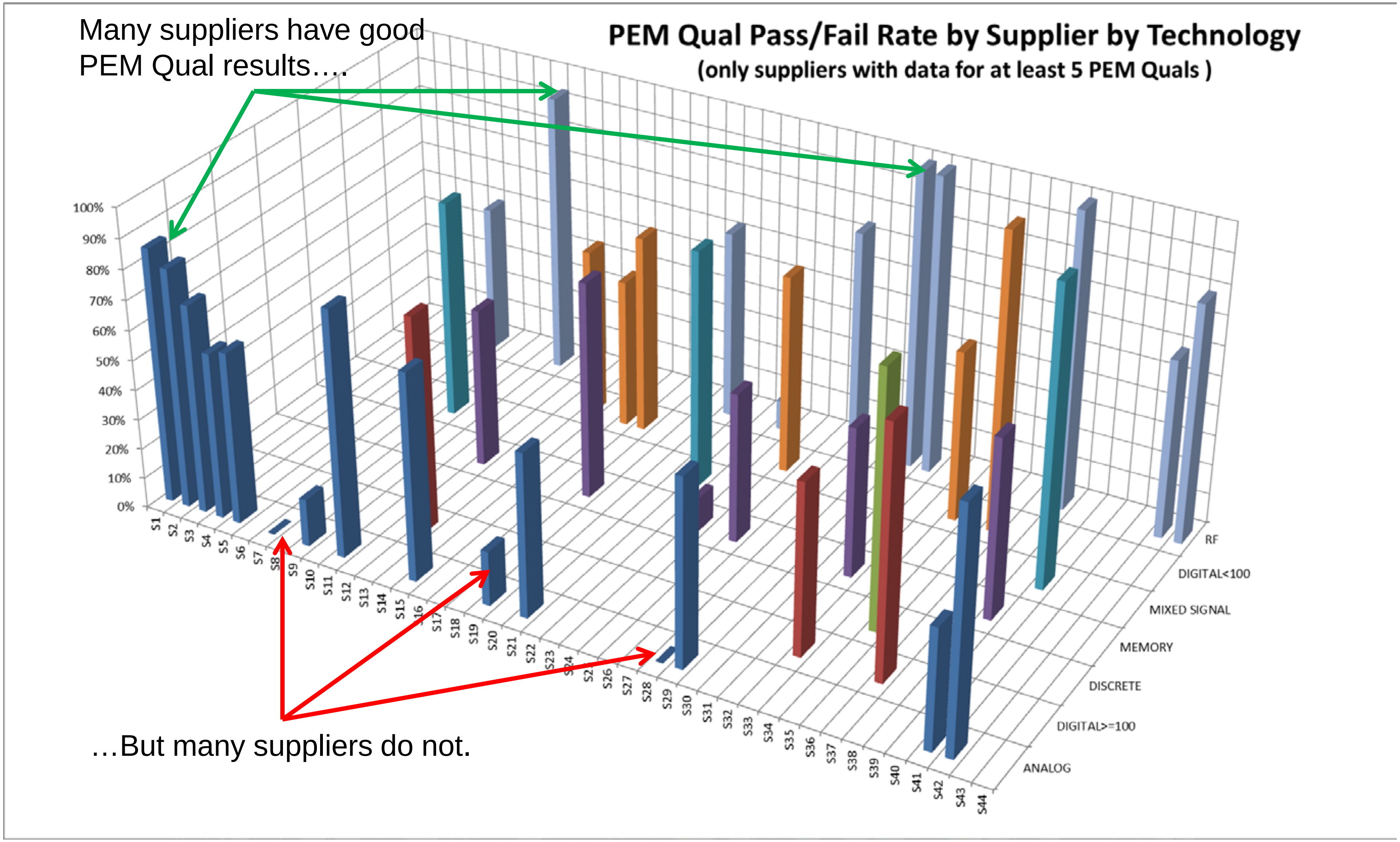


Overall PEM Qual Success Rate by Device Technology by Supplier

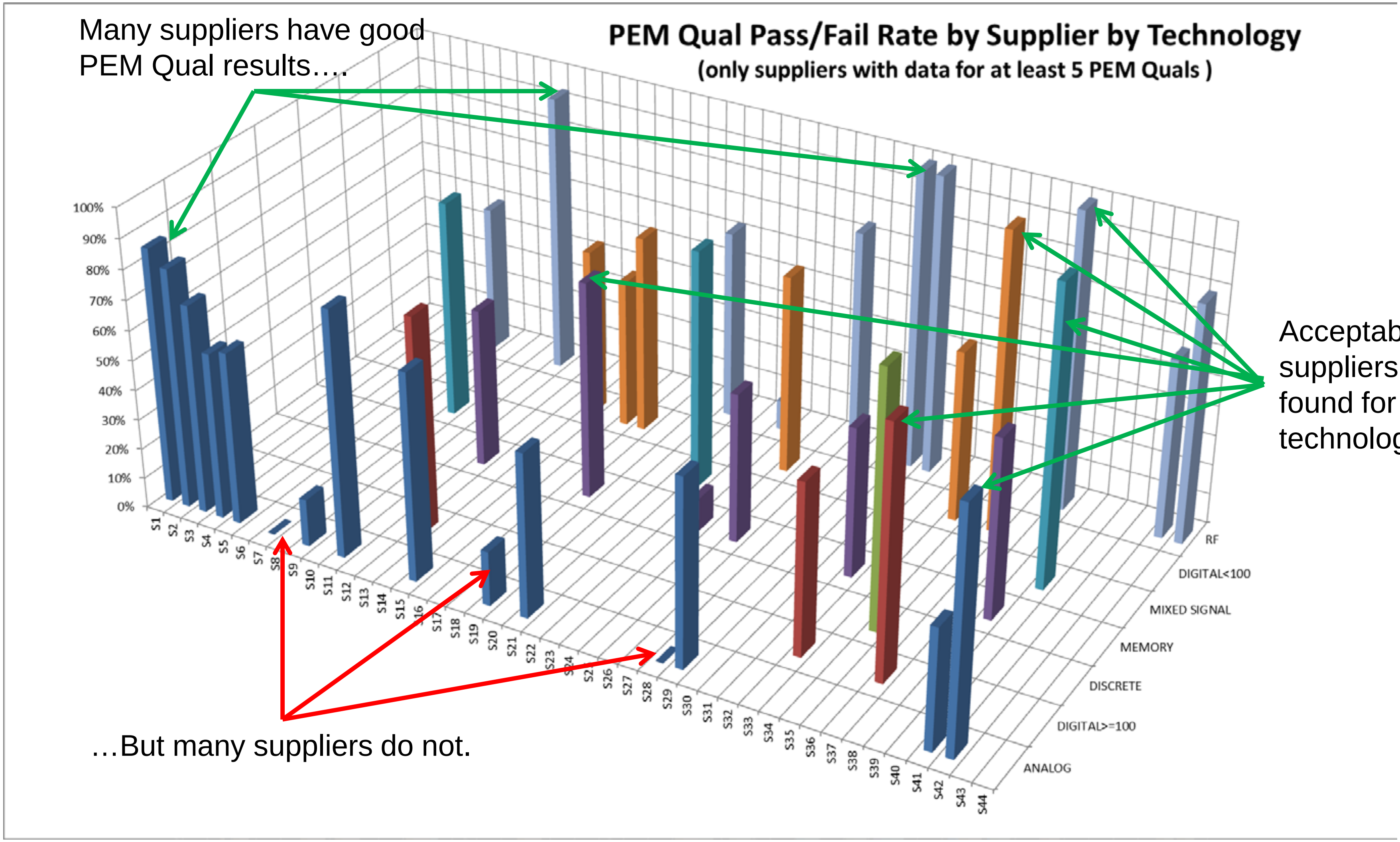
Many suppliers have good PEM Qual results….



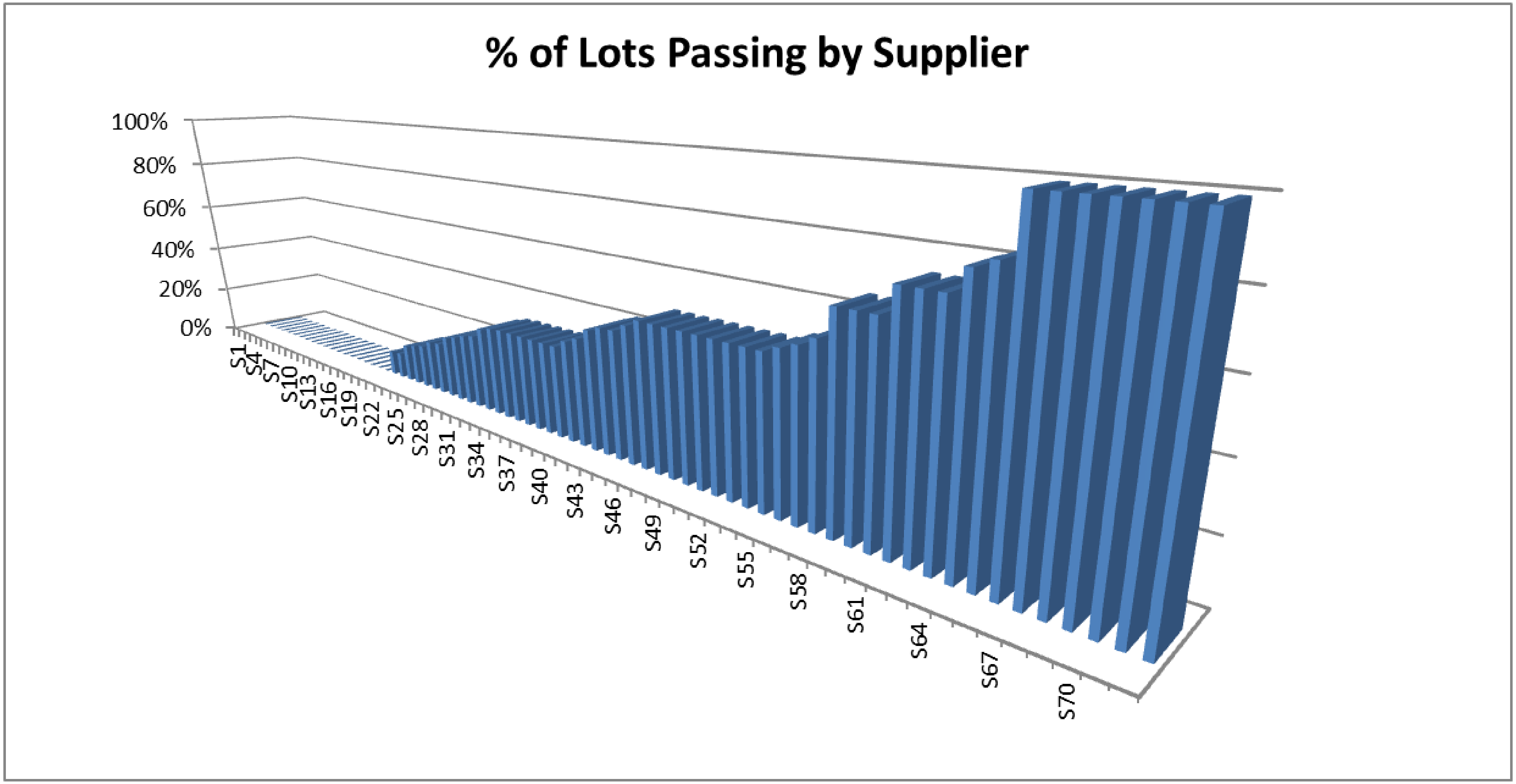
Overall PEM Qual Success Rate by Device Technology by Supplier



Overall PEM Qual Success Rate by Device Technology by Supplier



Overall PEM Qual Success Rate by Supplier



This is arguably the most important point of this data analysis – that PEM Qual success rates vary dramatically from supplier to supplier.

Overall PEM Qual Conclusions

1. There is a great variation in the success rate depending upon the supplier that is being evaluated, so it is prudent to evaluate multiple suppliers.
2. Success rate is also influenced by the package being evaluated, although not to as great an extent as by the supplier.
3. Acceptable PEM Qual success rates can be obtained with most technologies and pin counts.
4. Understanding your application needs is essential for selecting the best PEM Qual flow. By matching the PEM Qual flow to the application needs, an accurate assessment can be made at the lowest evaluation cost.

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Overall PEM Qual Conclusions (continued)

5. **Clearly understand how comprehensive the electrical test coverage is that your test supplier is providing. Insufficient electrical test coverage will allow failing devices to be counted as passing and could lead to poor system and field reliability.**
6. **PEM Quals are very complex flows with hundreds of processing steps and thousands of data points. Assure that trained project management staff is present at your test supplier to manage the flow execution and assure data integrity.**
7. **Overall, PEM Quals can be used to effectively select devices for use in non-commercial environments. In this study, approximately two-thirds of industry devices will pass PEM Qualification.**
8. **These conclusions are consistent with the conclusions reached in 1998 when we last analyzed our database, although our data indicates that PEM Qual success rates are improving.**

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Integra Technologies

Integra Technologies LLC, along with the recently acquired Analytical Solutions, has been providing one of the broadest ranges of test and evaluation services in our industry for over 30 years. Our services include:

- Test Development
- Final Test
- Characterization
- Wafer Probe
- Upscreening
- Failure Analysis
- Counterfeit Detection
- PEM Qualifications
- Qualification Services (HTOL, HAST, Temp Cycle, etc.)
- Assembly/Repackaging (outsourced to qualified partners)
- MIL-STD 883 and 750 Testing
- Volume Production Test
- Destructive Physical Analysis
- Obsolescence Management

We are approved by DLA for MIL-STD-883 & 750 processing, ITAR, ISO 9001, AS9100 and DMEA Category 1 “Trusted”

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