Diagnosing SSD Failures during Testing

Traffic Capture and Debug Tools

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SSD Testing Background

- Problem Statement
  - Identify root cause of SSD failures in a large volume testing – from test equipment perspective
- Multiple components (memory, controller, PHY, etc.)
  - System level test requires more than just pass/fail
    - System test reveals interaction issues not found during component test
    - Vendors want to know which part or parts are broken
    - Ability to reproduce the issue is vital: often takes a sequence of events with certain delays that sometimes takes days of testing with many devices
- Large volumes
  - Cost and space limits the use of “bench testing” diagnostic equipment
  - Scale in units: Engineering (one to a few, maybe a dozen), Qualification (hundreds), Production (thousands)

Bench Testing Equipment

- "High end bench testing equipment"
  - Protocol Analyzer
  - Serial Data Real-time Oscilloscope
  - Bit Error Ratio Generator
  - Vector Analyzer
- Pros
  - Large memory, relatively objective, sophisticated decode and protocol software
- Cons
  - Cost, space, power, signal alteration

Failure Categories

- Initial Questions
  - What failed? When did it fail? Why did it fail? Was the test valid? Was it the test equipment? Is it reproducible?
- Sources of Failure
  - Drive, operator, test program, test equipment
- Kinds of Failure
  - Drive: hardware, firmware
  - Operator: improper/loose connection
  - Test program: illegal or unsupported operation
  - Test equipment: hardware, firmware, software

Fault Isolation: Hardware

- Offline
  - Go/no-go self-test
  - Channel diagnostics with loopback card
    - Eye measurements to quantify channel quality
    - Different frequencies to catch different kinds of faults
    - Various patterns such as PRBS to emulate traffic, high/low frequency patterns or to exercise the channel
- Run-time
  - Temperature logging and alarms
  - Voltage/current limits

Physical/Link Layer

- Link Negotiation
  - Logging **link states** and **equalization negotiation** can be very helpful in debugging
    - Timestamped states can be correlated to test failures
    - Link state history can show progression into failure
- Example
  - Inconsistent final equalization requests for adjacent lanes to same drive
    - Lane 1 requests P4 which has zero equalization while Lane 2 requests P7 which has the highest equalization for a preset (6 dB de-emphasis, 3.5 dB pre-shoot)

```
20180723_17:59:32.020516050 [ 96]: delta= 325.244 us [ Request Preset 8 ] (Lane3, 8G, EC2)
20180723_17:59:32.020516078 [ 97]: delta=   0.028 us [ Request Preset 6 ] (Lane0, 8G, EC2)
20180723_17:59:32.020516083 [ 98]: delta=   0.005 us [ Request Preset 4 ] (Lane1, 8G, EC2)
20180723_17:59:32.020516089 [ 99]: delta=   0.006 us [ Request Preset 7 ] (Lane2, 8G, EC2)
```

Transaction Layer

- Transaction Layer capture
  - Sometimes it is helpful to see the transaction layer packets (TLP) between the tester and the drive.
    - Memory read request and corresponding completion response (or lack thereof)
    - Configuration, control and transfer commands
- Resource limitations – bandwidth and storage
- Solutions
  - Provide relatively small capture buffers for ingress/egress TLPs (buffers are small compared to those of a protocol analyzer)
    - For directed debug, enable packet filtering to extend the effective capture duration
  - Alternatively, log command/response summaries of transfer commands

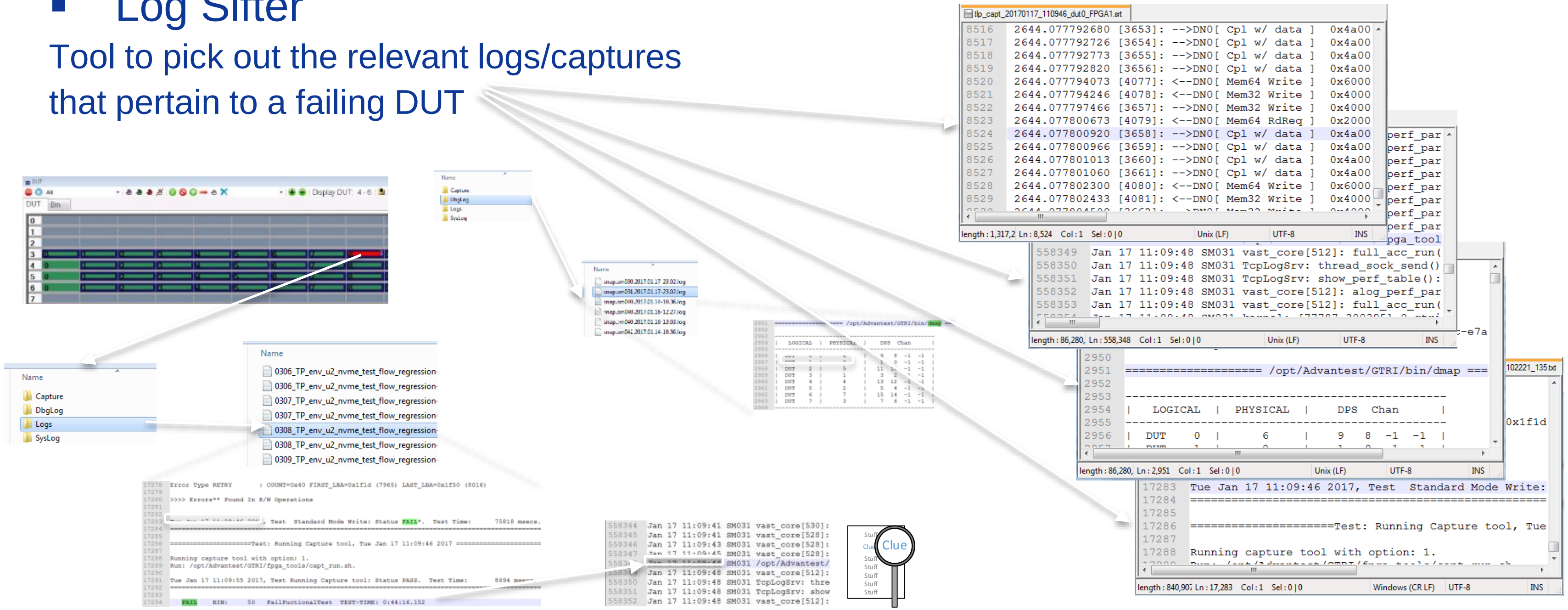
Data Collection

Layer	Feature	Tool Type
Physical	Loopback, Eye scan	Diagnostics
Link	Link state, speed, power states, lane activity, equalization, flow control	Capture
Transaction	Transaction layer packet capture/filter	Capture
Data transfer	Command, data, control registers	Capture
Global	Universal Timestamp	Capture
Software	Driver debug, test program, system health	Logs

Data Sorting

- Log Sifter

Tool to pick out the relevant logs/captures that pertain to a failing DUT



Data Analysis

Layer	Feature	Tool Type
Hardware	Self-test, loopback	Diagnostic
Physical	Equalization checker	Diagnostic
Link	Link-State checker	Diagnostic
Transaction	TLP decoder	Diagnostic
-	Comprehensive analysis	Diagnostic
-	Knowledge database	Documentation

Fault Isolation: Software

- Software installation verification
  - Loads missing components, reports/replaces incorrect versions of tools
- Software utilities
  - As a complement to GUI-based software, command line tools can allow direct access for focused debug
    - Snapshot current system state including versions and logs
    - Logging of commands, power control, link status, …
    - Running of performance tests, power cycling, …
    - Report bus enumeration and hierarchy
- Human versus software
  - With all the information gathered, who/what will make sense of it all?
    - Algorithm development for data collection, sorting, and analysis

Conclusions

- Problem
  - Drives can fail for many reasons
  - Need to differentiate between real drive issues from other issues
  - The right information is needed to isolate root cause of drive failures
  - The tools must operate within constraints
- Solution
  - System diagnostics which include self-test including loopback
  - Traffic monitoring and capture at multiple level to collect information
  - Post-processing to filter and sort the information
  - Analysis software to make sense of all the data