Challenges in Preparing SSDs for Qualification Testing

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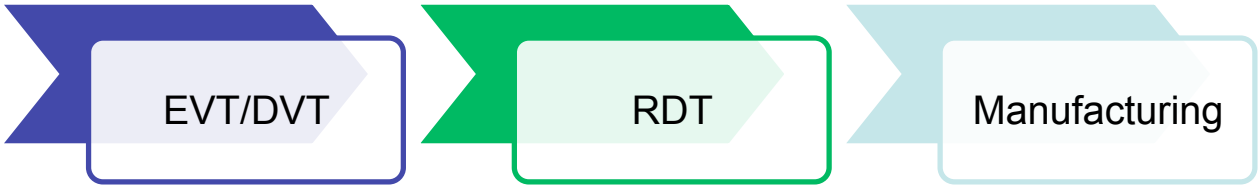
Introduction

- What is qualification testing for SSD ?



  - Engineering Verification Testing(EVT) / Design Verification Testing (DVT) – Check for functionality of the SSD drive
  - Reliability Demonstration Testing (RDT) – Check for reliability of SSD and data integrity

Introduction

- What is required to prepare SSDs for qualification testing ?
  - To make sure there are no functionality issues with the drive
    - Bring up the drive successfully
    - Run IO without any issue
  - If there are issues, find the root cause as fast as possible and fix them

Issues Occur During Preparation

- Power up failure
  - Link training issue
  - Enumeration related issue
- Link retrain/drop issue
- Failure during IO operations
  - Write failure
  - Read failure
  - Data compare failure

Traditional Methods to Debug the Issue

- Perform analysis on available logs from host as well as from drive
- Use protocol analyzer, capture bus trace and perform analysis

PCIe Analyzer on Engineering Tester

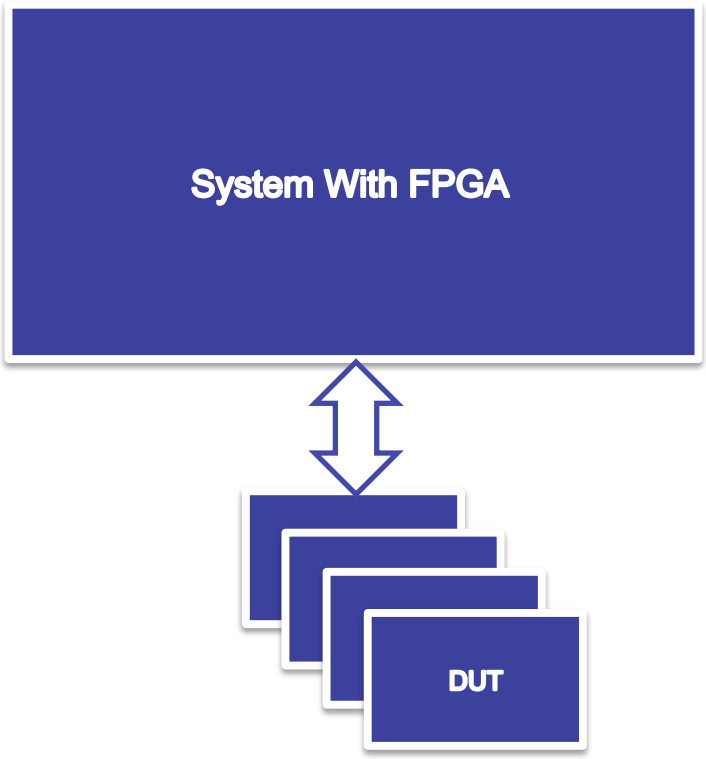
Challenges to Capture Trace Using Protocol Analyzer

- Issue may not occur on fixed slot# on tester
- Need to connect multiple protocol analyzers (PA)
- PA interposer may changes properties of the signal
- Cannot stop the on-going test on other DUTs and debug
- Have to reproduce the issue
- Cannot connect PA, if the test is running under thermal environment

Impact: Longer time to identify the issue which result in delay time to market and loss of revenue

Solution: Traffic Capture Tool

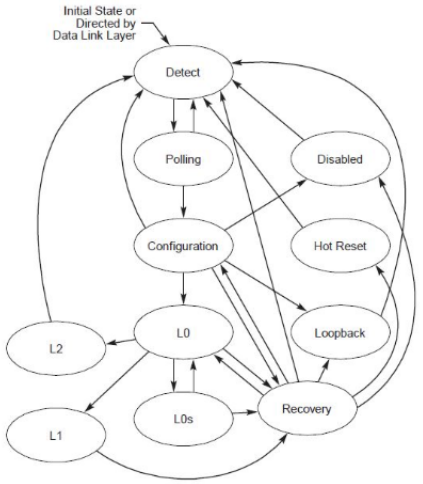
- Transaction Layer Packet capture
- Link raining & Status State Machine (LTSSM) capture
- Submission & Completion queue information
- Command log dump



Solution: Traffic Capture Tool

- Sample:

```
52304.024347256 [ 188]: delta=  1031.581 us    ltssm=00 DetQuiet    lpm
52304.024347325 [ 189]: delta=     0.069 us    ltssm=00 DetQuiet    lpm
52306.035447425 [ 190]: delta>999999.999 us    ltssm=01 DetAct      lpm
52306.035448656 [ 191]: delta=     1.231 us    ltssm=02 Poll_Act    lpm
52306.035514718 [ 192]: delta=    66.062 us    ltssm=04 Poll_Cfg    lpm
52306.035518775 [ 193]: delta=     4.057 us    ltssm=05 Cfg_LWSt    lpm
52306.035521531 [ 194]: delta=     2.756 us    ltssm=06 Cfg_LWAc    lpm
52306.035521681 [ 195]: delta=     0.150 us    ltssm=07 Cfg_LWai    lpm
52306.035523012 [ 196]: delta=     1.331 us    ltssm=08 Cfg_LNAc    lpm
52306.035523156 [ 197]: delta=     0.144 us    ltssm=09 Cfg_Done    lpm
52306.035525500 [ 198]: delta=     2.344 us    ltssm=0a Cfg_Idle    lpm
52306.035525575 [ 199]: 0x3ce469d05be004010a   RcvdTs1Ts2=0         Rcv
52306.035525575 [ 199]: delta=     0.075 us    ltssm=0a Cfg_Idle    lpm
52306.035525600 [ 200]: 0x3ce469d05c00040110   RcvdTs1Ts2=0         Rcv
52306.035525600 [ 200]: delta=     0.025 us    ltssm=10 --L0--      lpm
52306.035525606 [ 201]: delta=     0.006 us    ltssm=10 --L0--      lpm
52306.035525643 [ 202]: delta=     0.037 us    ltssm=0b Rcv_RLoc    lpm
52306.035529775 [ 203]: delta=     4.132 us    ltssm=0e Rcv_RCfg    lpm
52306.035532475 [ 204]: delta=     2.700 us    ltssm=0e Rcv_RCfg    lpm
52306.035534537 [ 205]: delta=     2.062 us    ltssm=0d Rcv_Sped    lpm
52306.035535031 [ 206]: delta=     0.494 us    ltssm=0d Rcv_Sped    lpm
52306.035636681 [ 207]: delta=   101.650 us    ltssm=0d Rcv_Sped    lpm
52306.035636693 [ 208]: delta=     0.012 us    ltssm=0d Rcv_Sped    lpm
52306.035680856 [ 209]: delta=    44.163 us    ltssm=0d Rcv_Sped    lpm
52306.036447381 [ 210]: delta=   766.525 us    ltssm=0b Rcv_RLoc    lpm
52306.036447506 [ 211]: delta=     0.125 us    ltssm=0b Rcv_RLoc    lpm
52306.036447525 [ 212]: delta=     0.019 us    ltssm=0c Rcv_Equ     lpm
52306.052443725 [ 213]: delta= 15996.200 us    ltssm=0b Rcv_RLoc    lpm
52306.052444806 [ 214]: delta=     1.081 us    ltssm=0e Rcv_RCfg    lpm
52306.052445050 [ 215]: delta=     0.244 us    ltssm=0f Rcv_Idle    lpm
52306.052445481 [ 216]: delta=     0.431 us    ltssm=10 --L0--      lpm
```




```
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
o=0  LWChg=0  RcvryDir=0
q=0
o=0  LWChg=0  RcvryDir=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
q=0
```

Example #1 Power Up Failure

- Drive link up successfully, but did not get ready within CAP.TO timeout (120 sec)

```
Site < 3, 3> ************************************
Site < 3, 3> PCIe Link Status :
Site < 3, 3> LinkUp          = true
Site < 3, 3> LTSSM           = 0x10, LTSSM_L0
Site < 3, 3> LinkWidth       = x4
Site < 3, 3> LinkSpeed       = 8.0G
Site < 3, 3> ActiveLanes     = 00001111 (0x0f)
Site < 3, 3> ValidLanes      = 00001111 (0x0f)
Site < 3, 3> LinkUpCount     = 1
Site < 3, 3> LinkRetrainCnt  = 4
Site < 3, 3> ************************************
Site < 3, 3> ERROR : Block Device is not present.
```

Example #1 Power Up Failure

- From TLP Capture:

```
36217.548193680 [ 252]: detla>999999.999 us    ltssm=0b Rcv_RLoc    lpmsm=1 LPMSM_L0          l1pmsm=0 L1PM_L10        TxEI=0  RxEI=0  Clkreq=0
36217.548194786 [ 253]: detla=     1.606 us    ltssm=0e Rcv_RCfg    lpmsm=1 LPMSM_L0          l1pmsm=0 L1PM_L10        TxEI=0  RxEI=0  Clkreq=0
36217.548194986 [ 254]: detla=     0.700 us    ltssm=0f Rcv_Idle    lpmsm=1 LPMSM_L0          l1pmsm=0 L1PM_L10        TxEI=0  RxEI=0  Clkreq=0
36217.548195453 [ 255]: detla=     0.967 us    ltssm=10 --L0--      lpmsm=1 LPMSM_L0  => LTSSM State = L0 : Link up successfully
36217.555283513 [2097]: -->DN1[ Cfg_0 RdReq ]  0x04000001 0x0000000f 0x0400007c 0xd5d32dc9 0x00000009 0x00680204 0x20000001 0x0000000f (11,0,10) - UP2DN
36217.555287506 [2086]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x00000000 0x436c4100 0x564028a5 0x00000000 0x00000000 0x00000000 (11,0,01) - DN2UP

36217.555585753 [2117]: -->DN1[ Mem32 Write ]  0x40000002 0x000000ff 0xf4c10030 0x0020970d 0x02000000 0x28b8e361 0x40000001 0x0000000f (11,0,10) - UP2DN
36217.555585773 [2118]: -->DN1[ Mem32 Write ]  0x40000001 0x0000000f 0xf4c10014 0x01004600  => Write CC.EN bit to "1":0000000f (11,0,10) - UP2DN
36217.555585813 [2119]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0x22b6f19e 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,10) - UP2DN
36217.555928773 [2104]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x                                    (11,0,01) - DN2UP
36217.659045173 [2120]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0xfb503603  => Polling CSTS.RDY bit to "1"    (11,0,10) - UP2DN
36217.659051380 [2105]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000  => Return Value = "0"          (11,0,01) - DN2UP
36217.762805893 [2121]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0x9b9e56d9 0x00000000 0x00000000 0x00000009 0x0088024c (11,0,10) - UP2DN
36217.762811860 [2106]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x00000000 0x00000000 0x0000001c 0x00000000 (11,0,01) - DN2UP
36217.866586813 [2122]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0xb4552b71 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,10) - UP2DN
36217.866592586 [2107]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x4a000001 0x04000004 0x0000001c 0x00000000 (11,0,01) - DN2UP
36217.970334353 [2123]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0x58669ccb 0x20000001 0x0000000f 0x00000009 0x00280204 (11,0,10) - UP2DN
36217.970340526 [2108]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x00000000 0x00000000 0x0000001c 0x00000000 (11,0,01) - DN2UP
36218.074099953 [2124]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0x1f7b8c00 0x00000000 0x00000000 0x00000009 0x00680394 (11,0,10) - UP2DN
36218.074105793 [2109]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x4a000001 0x04000004 0x0000001c 0x00000000 (11,0,01) - DN2UP
36218.177869973 [2125]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0xfcb0fa74 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,10) - UP2DN
36218.177875986 [2110]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x00000000 0x00000000 0x0000001c 0x00000000 (11,0,01) - DN2UP
36218.281630293 [2126]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0x6a752434 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,10) - UP2DN
36218.281636386 [2111]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,01) - DN2UP
```

Example #1 Power Up Failure

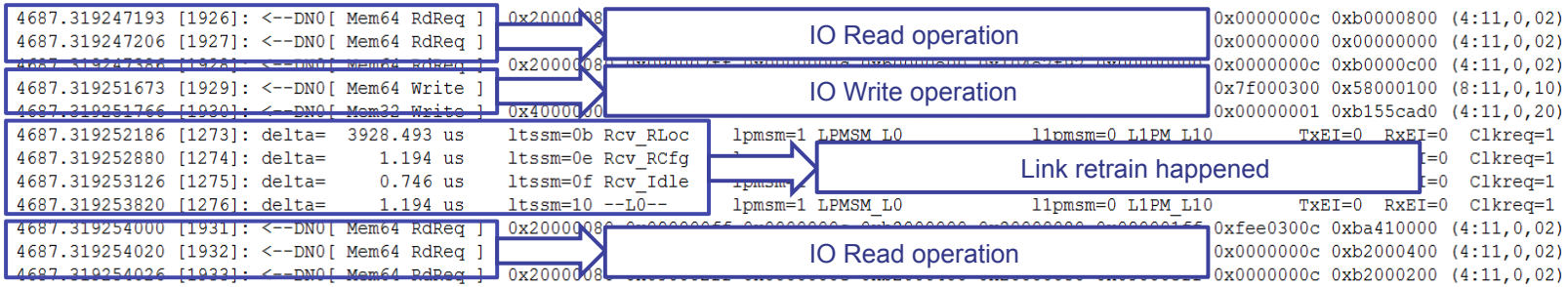
- Host kept polling for CSTS.RDY bit, drive returned value “0” even after 120 sec

```
36337.307228486 [3258]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x00000000 0x00000000 0x0000001c 0x00000000 (11,0,01) - DN2UP
36337.410984620 [3274]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0xf800bb66 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,10) - UP2DN
36337.410990460 [3259]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x1fe5272b 0x468963ef 0xb1010de5 0xf1ea9166 (11,0,01) - DN2UP
36337.514751413 [3275]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0x4c9a1821 0x20000001 0x0000000f 0x00000009 0x00280204 (11,0,10) - UP2DN
36337.514757433 [3260]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0x00000000 0x00000000 0x0000001c 0x00000000 (11,0,01) - DN2UP
36337.618508673 [3276]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0xecfeb59e 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,10) - UP2DN
36337.618514473 [3261]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0xa79829a1 0xb1a7bf4f 0xec298056 0xfb987d92 (11,0,01) - DN2UP
36337.722278653 [3277]: -->DN1[ Mem32 RdReq ]  0x00000001 0x0000000f 0xf4c1001c 0x85bbf379 0x800                                      (11,0,10) - UP2DN
36337.722284566 [3262]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x0000001c 0x00000000 0xa                                        (11,0,01) - DN2UP
36337.826109773 [3278]: -->DN1[ Cfg_0 RdReq ]  0x04000001 0x00000003 0x04000004 0xf64e34c1 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,10) - UP2DN
36337.826114066 [3263]: <--DN1[ Cpl w/ data ]  0x4a000001 0x04000004 0x00000000 0x06001000 0x00000000 0x00000000 0x00000000 0x00000000 (11,0,01) - DN2UP
```

Last read for CSTS.RDY bit, returned value was "0"

Example #2 Link Retrain Issue

- From TLP Capture: Link retrain in middle of IO operation

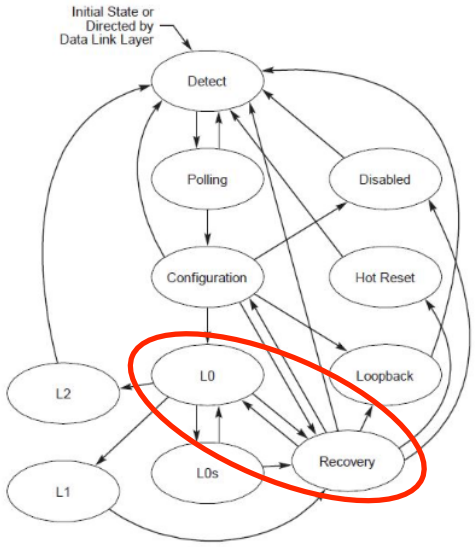


Example #2 Link Retrain Issue

- From TLP Capture: Continuous link retrain in middle of IO operation as well as during power up operation.

```
4687.936806146 [1940]: delta=     1.206 us    ltssm=10 --L0--      lpmsm=1 L
4687.940526620 [1941]: delta=  3720.974 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4687.940527313 [1942]: delta=     1.193 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4687.940527560 [1943]: delta=     0.747 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4687.940528246 [1944]: delta=     1.186 us    ltssm=10 --L0--      lpmsm=1 L
4687.941316026 [1945]: delta=   788.280 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4687.941316740 [1946]: delta=     1.214 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4687.941316973 [1947]: delta=     0.733 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4687.941317673 [1948]: delta=     1.200 us    ltssm=10 --L0--      lpmsm=1 L
4687.945038146 [1949]: delta=  3720.973 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4687.945038840 [1950]: delta=     1.194 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4687.945039093 [1951]: delta=     0.753 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4687.945039793 [1952]: delta=     1.200 us    ltssm=10 --L0--      lpmsm=1 L
4687.958213940 [1953]: delta= 13174.647 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4687.958214633 [1954]: delta=     1.193 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4687.958214880 [1955]: delta=     0.747 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4687.958215566 [1956]: delta=     1.186 us    ltssm=10 --L0--      lpmsm=1 L
4687.971389753 [1957]: delta= 13174.687 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4687.971390446 [1958]: delta=     1.193 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4687.971390680 [1959]: delta=     0.734 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4687.971391380 [1960]: delta=     1.200 us    ltssm=10 --L0--      lpmsm=1 L
4687.975111886 [1961]: delta=  3721.006 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4687.975112580 [1962]: delta=     1.194 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4687.975112813 [1963]: delta=     0.733 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4687.975113513 [1964]: delta=     1.200 us    ltssm=10 --L0--      lpmsm=1 L
4687.993734180 [1965]: delta= 18621.167 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4687.993734873 [1966]: delta=     1.193 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4687.993735106 [1967]: delta=     0.733 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4687.993735793 [1968]: delta=     1.187 us    ltssm=10 --L0--      lpmsm=1 L
4687.994335886 [1969]: delta=   600.593 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4687.994336580 [1970]: delta=     1.194 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4687.994336826 [1971]: delta=     0.746 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4687.994337513 [1972]: delta=     1.187 us    ltssm=10 --L0--      lpmsm=1 L
4688.007511680 [1973]: delta= 13174.667 us    ltssm=0b Rcv_RLoc    lpmsm=1 L
4688.007512373 [1974]: delta=     1.193 us    ltssm=0e Rcv_RCfg    lpmsm=1 L
4688.007512606 [1975]: delta=     0.733 us    ltssm=0f Rcv_Idle    lpmsm=1 L
4688.007513306 [1976]: delta=     1.200 us    ltssm=10 --L0--      lpmsm=1 L
```

```
delta=   788.280 us
delta=     1.214 us
delta=     0.733 us
delta=     1.200 us
delta=  3720.973 us
delta=     1.194 us
delta=     0.753 us
delta=     1.200 us
delta= 13174.647 us
delta=     1.193 us
delta=     0.747 us
delta=     1.186 us
delta= 13174.687 us
delta=     1.193 us
delta=     0.734 us
delta=     1.200 us
delta=  3721.006 us
delta=     1.194 us
delta=     0.733 us
delta=     1.200 us
delta= 18621.167 us
delta=     1.193 us
delta=     0.733 us
delta=     1.187 us
```



Example #2 Link Retrain Issue

- Root cause: drive controller failed to select correct preset value during equalization phase

Conclusion:

Using Traffic Capture tools on tester allow to:

- Run test on all slots at the same time, and capture required information to debug the issue
- Capture traffic log at the time of the failure, and not to reproduce the issue
- Flexibility in logic design - add/remove logic to capture more information if required

Result: Earlier identification/resolution of device issue resulting in faster time to market

Flash Memory Summit

Thank you !!!

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