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MICROELECTRONICS TESTING AND TECHNOLOGY OBSOLESCENCE PROGRAM

Memory Device Characterization: Pre and Post Radiation Effects

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Memory Device Characterization: Pre and Post Radiation Effects

- **Abstract – Military and space commercial systems are remaining in service and in active use far beyond their planned operational lifetime. This extended service is leading to a shortage of replacement components, many of which are now obsolete or will become obsolete within the near future. When the Military went from MIL-Specs to performance-based specs (the Perry Initiative) and started using more commercial-off-the-shelf (COTS) products, the need for an advanced design and testing facility to qualify the electrical, environmental and radiological performance of COTS microelectronics and other lower assemblies to meet military and commercial standards dramatically increased. The Advanced Microelectronics Laboratory (AML) at New Mexico Tech Energetic Materials Research and Testing Center (EMRTC), Microelectronics Testing and Technology Obsolescence Program (METTOP) has been designed to support the needs of our military and commercial customers by qualifying components for use in satellites, space platforms, and legacy and future combat systems (FCS) that are subject to radiation effects. Here we demonstrate some of the capabilities of the AML facility as applied to commonly used microelectronics and lower assemblies. In particular we report on the pre and post characterization results of a total dose radiation test done on an SST28SF040A / SST39LF040A 4 MB (512K x8) SuperFlash EEPROM chip, a non-volatile flash memory device.**

- Our objectives to the White Sands Missile Range DATTS facility were to perform post radiation characterization of CMOS technology flash memory devices. A quantity of 30 SST39VF040 and 50 SST25LF080A parallel input Super Flash Memory devices with CMOS split-gate cell technology to test at various dose rates. Devices were tested in the LINAC (Linear Accelerator) with different dose rates and in the Gamma Range Facility. Devices were first baselined at the METTOP facility for DC output parameters and some specific patterns to the chip, including a chip erase pattern, a checkerboard pattern and a stripes pattern. Figure 1 & Figure 2 shows the circuit diagram for the SST39LF040A test circuit. The test procedure involved placing the DUT under bias in a radiation chamber connected to test equipment outside the chamber. Dose rates were monitored by the voltage response of the UM7204 diode located at the DUT.

SST39LF Bias Board

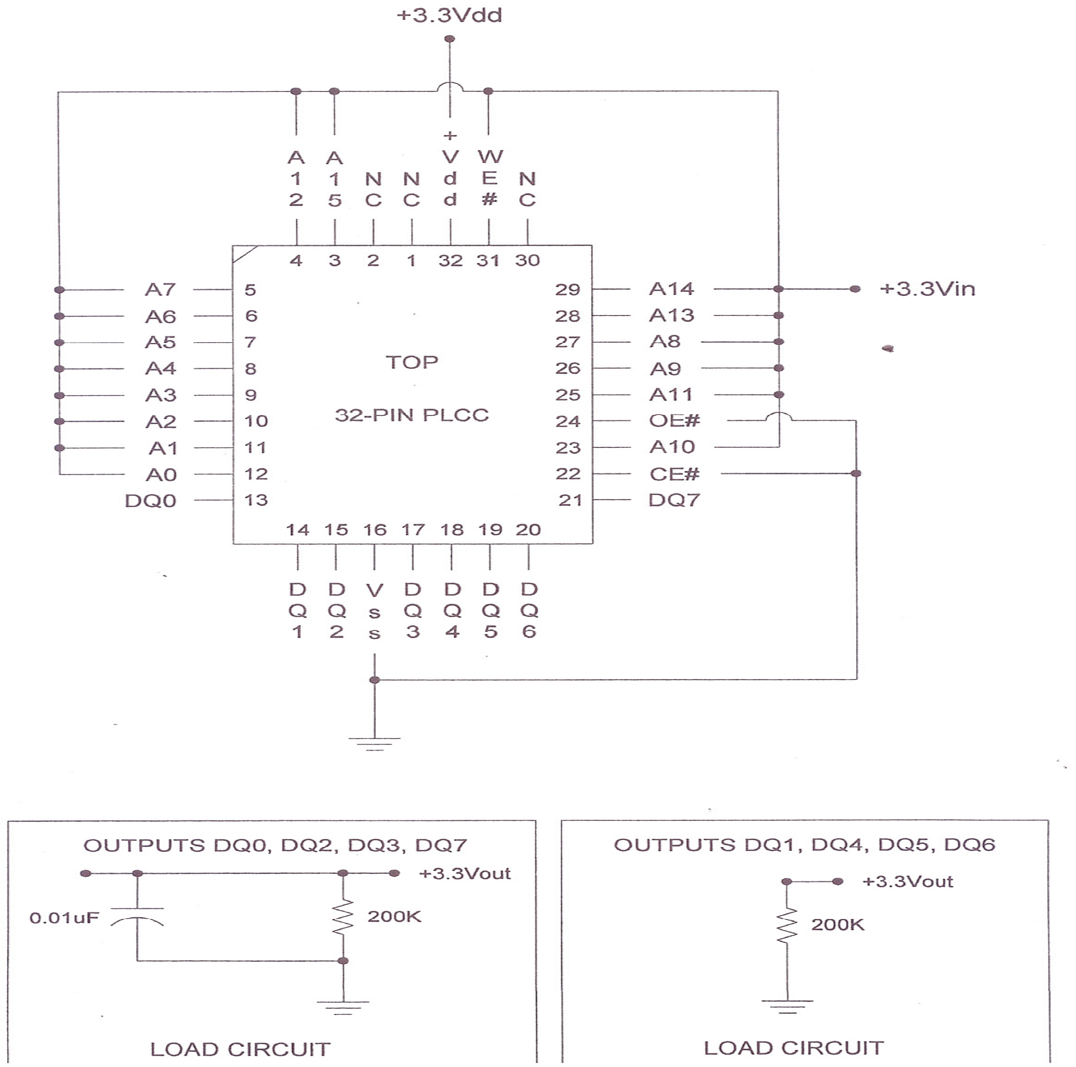


Figure 1. Circuit diagram of the SST39LF bias board.

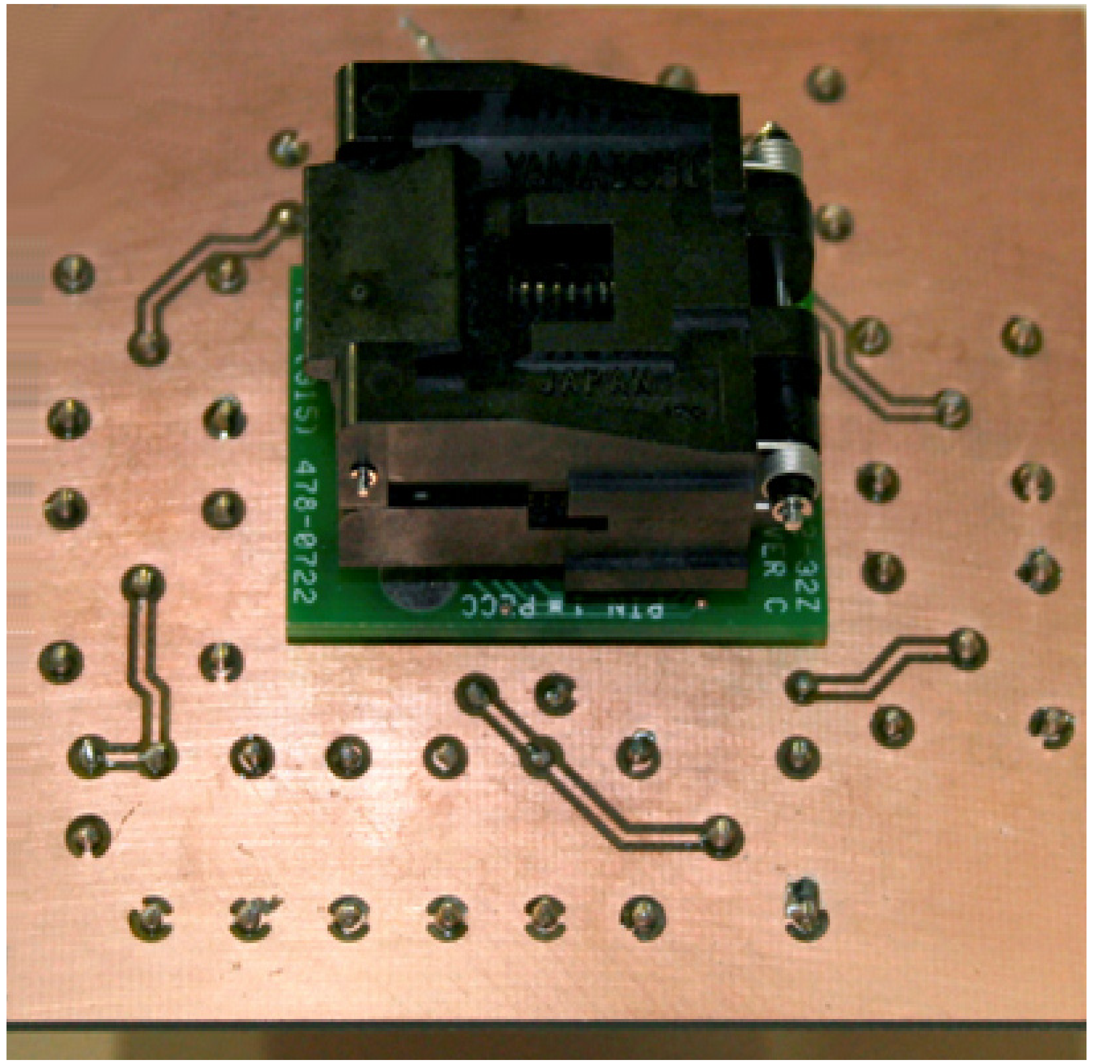
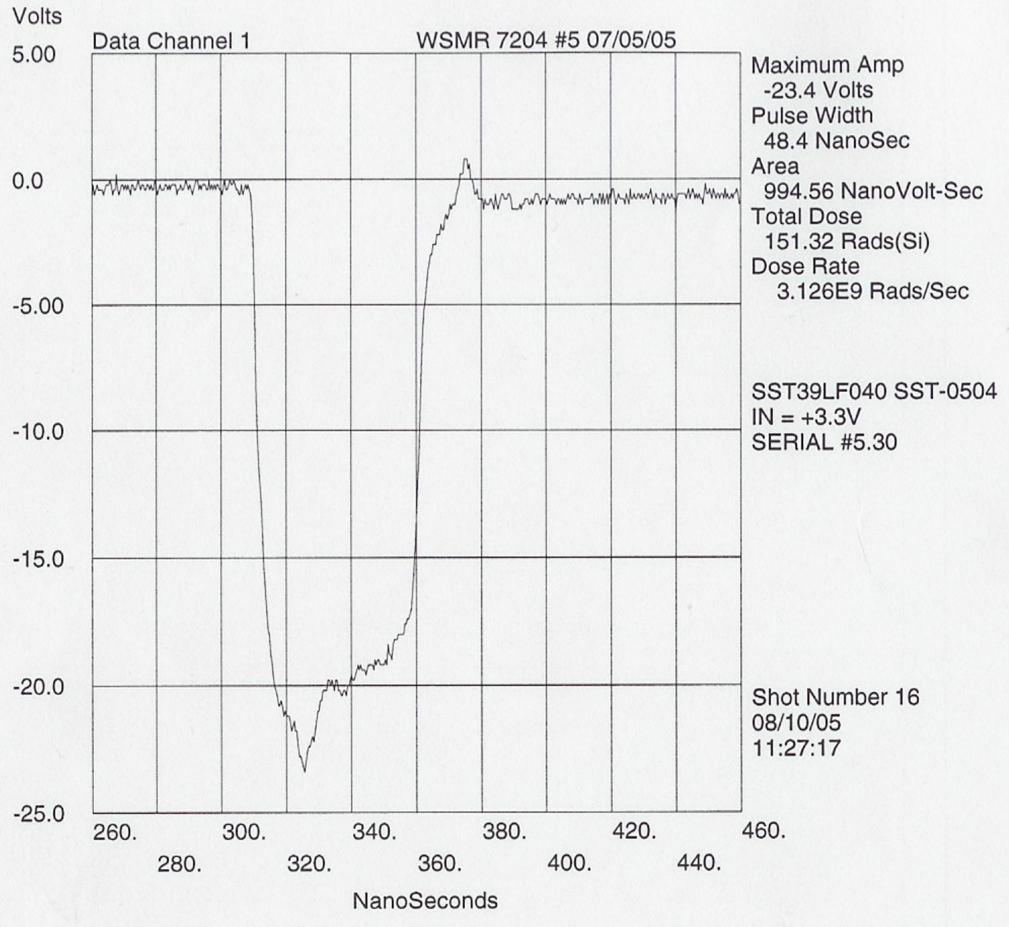


Figure 2. DUT, SST39LF Bias Circuit for Radiation Testing. Monitored output pins for the circuit were : DQ0, DQ2, DQ3 and DQ7. Input Voltage applied was 3.3V

Gamma Dot Output Data

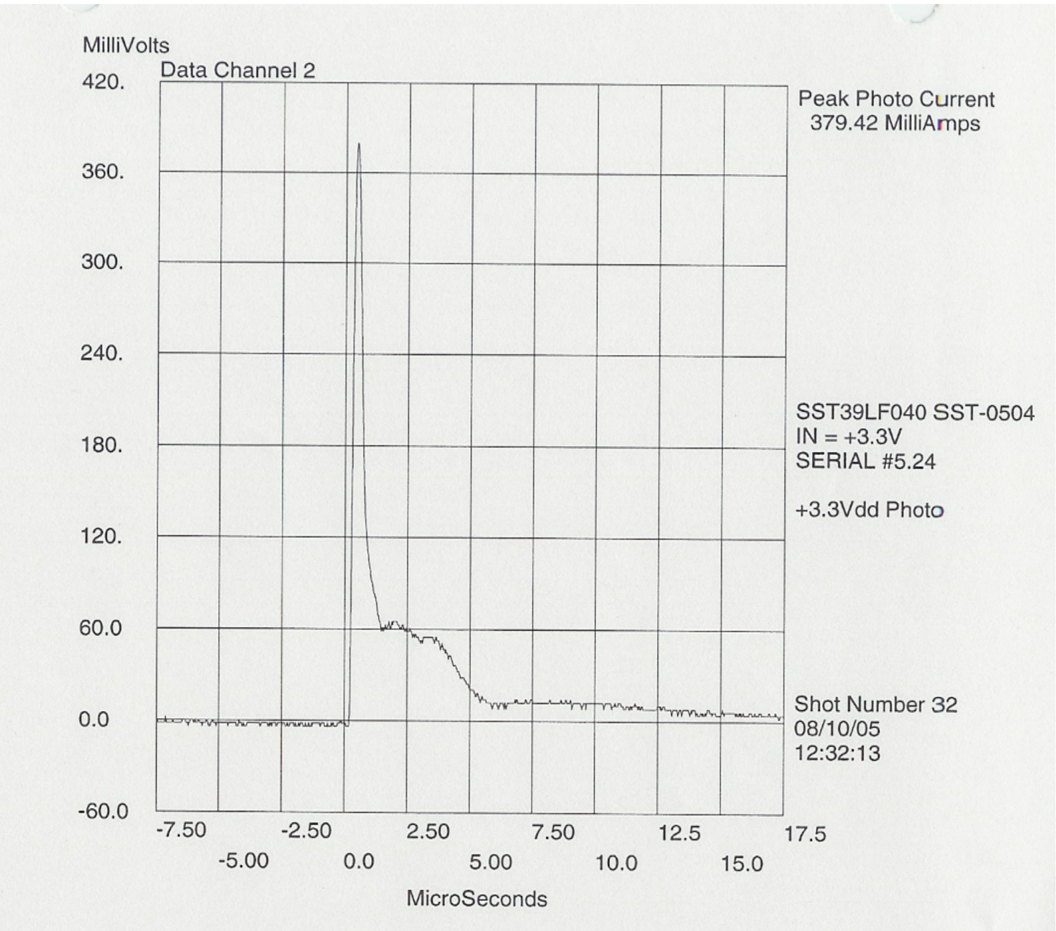


Maximum Amp
-23.4 Volts
Pulse Width
48.4 NanoSec
Area
994.56 NanoVolt-Sec
Total Dose
151.32 Rads(Si)
Dose Rate
3.126E9 Rads/Sec

SST39LF040 SST-0504
IN = +3.3V
SERIAL #5.30

Shot Number 16
08/10/05
11:27:17

Figure 5. Output Voltage (V) vs. time (ns) of the UM7204 diode measuring the intensity and pulse shape of the gamma dot radiation pulse. Graph taken from LINAC Courtesy of White Sands Missile Range (WSMR), New Mexico



Peak Photo Current
379.42 MilliAmps

SST39LF040 SST-0504
IN = +3.3V
SERIAL #5.24

+3.3Vdd Photo

Shot Number 32
08/10/05
12:32:13

Figure 6. Photocurrent surge (379.42 mA) under Gamma Dot 1.2E10 Rad/Sec 49.6 ns. Graph taken from LINAC printout of data from WSMR Gamma Range Facility.

Photo Current vs Dose Rate

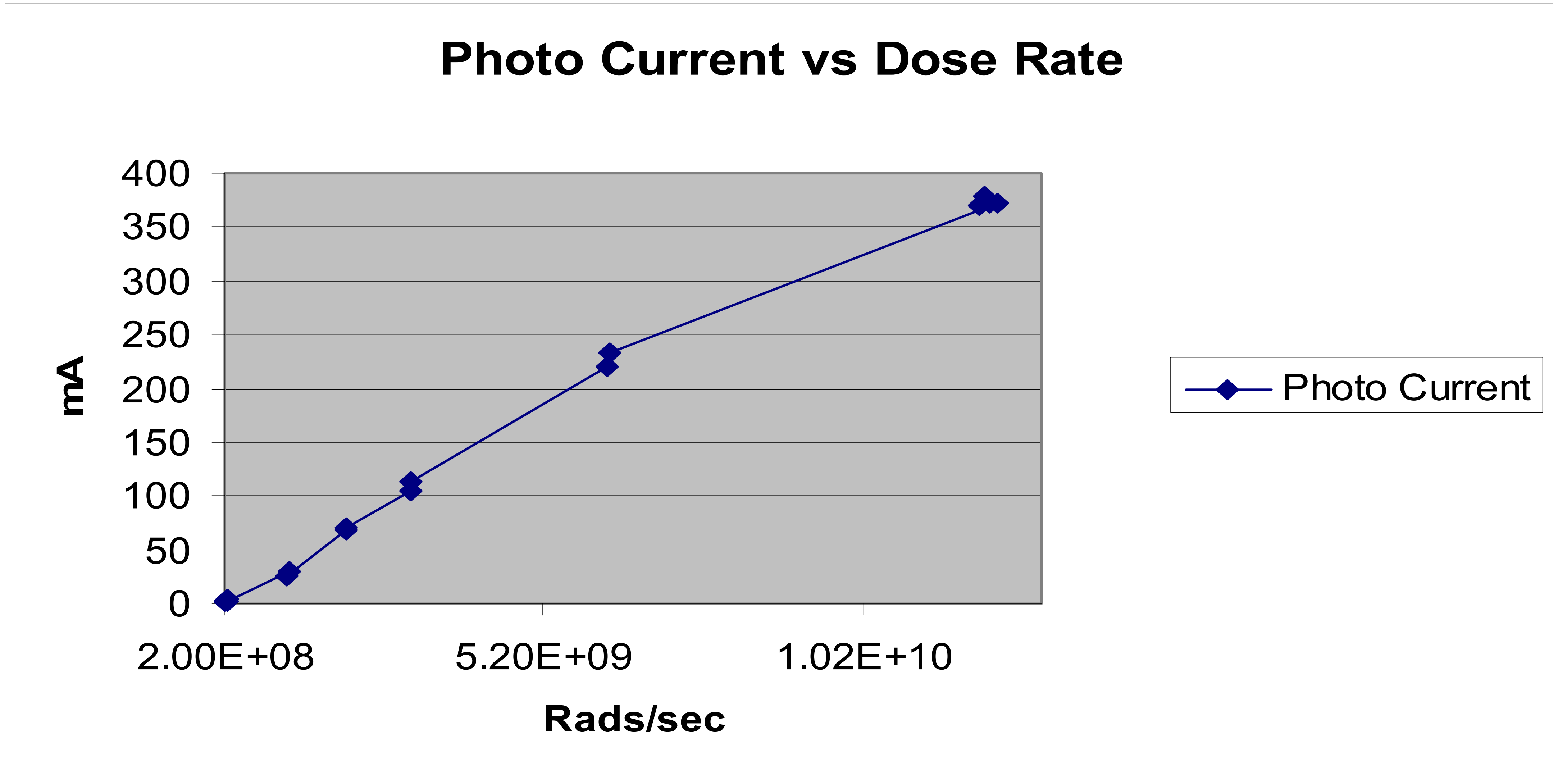


Figure 7. Vdd photocurrent (mA) vs. dose rate (Rads/sec) for sample size of twenty (20) SST39LF040 (512KB x 8) Super Flash Memory devices.

PK2 Memory Tester and Output Data

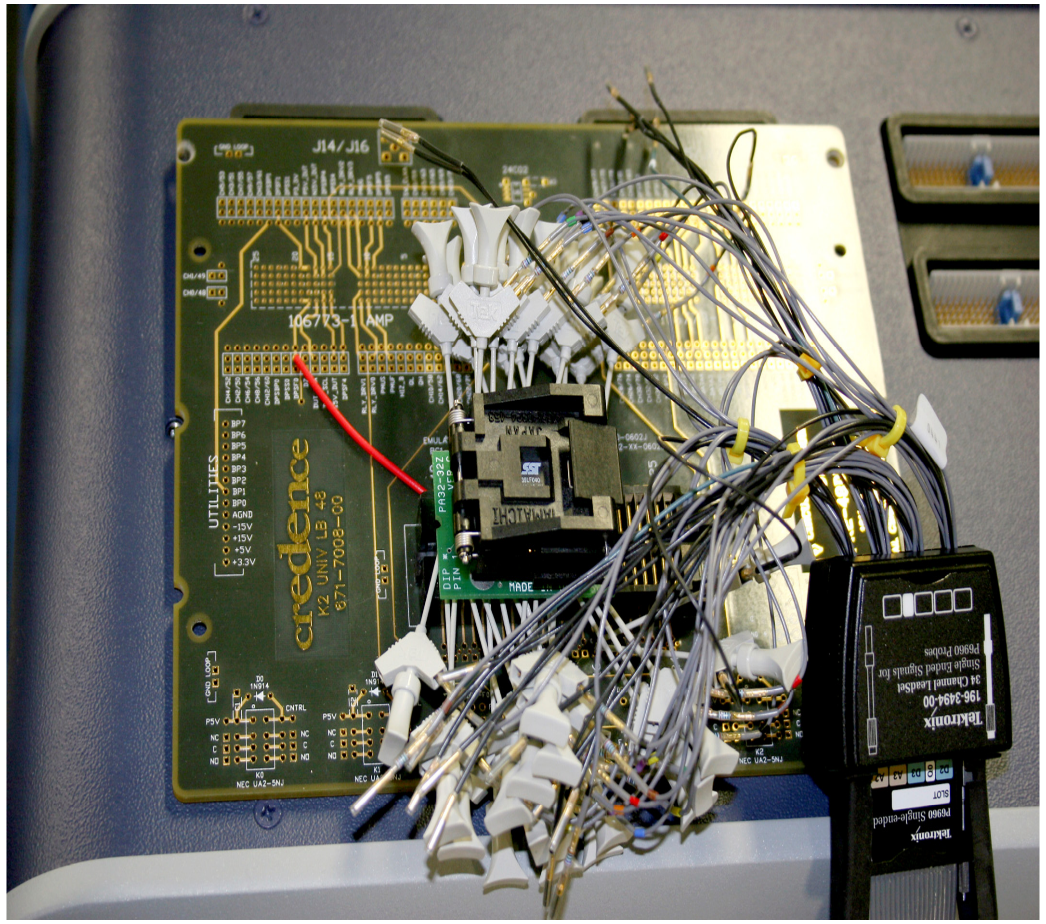
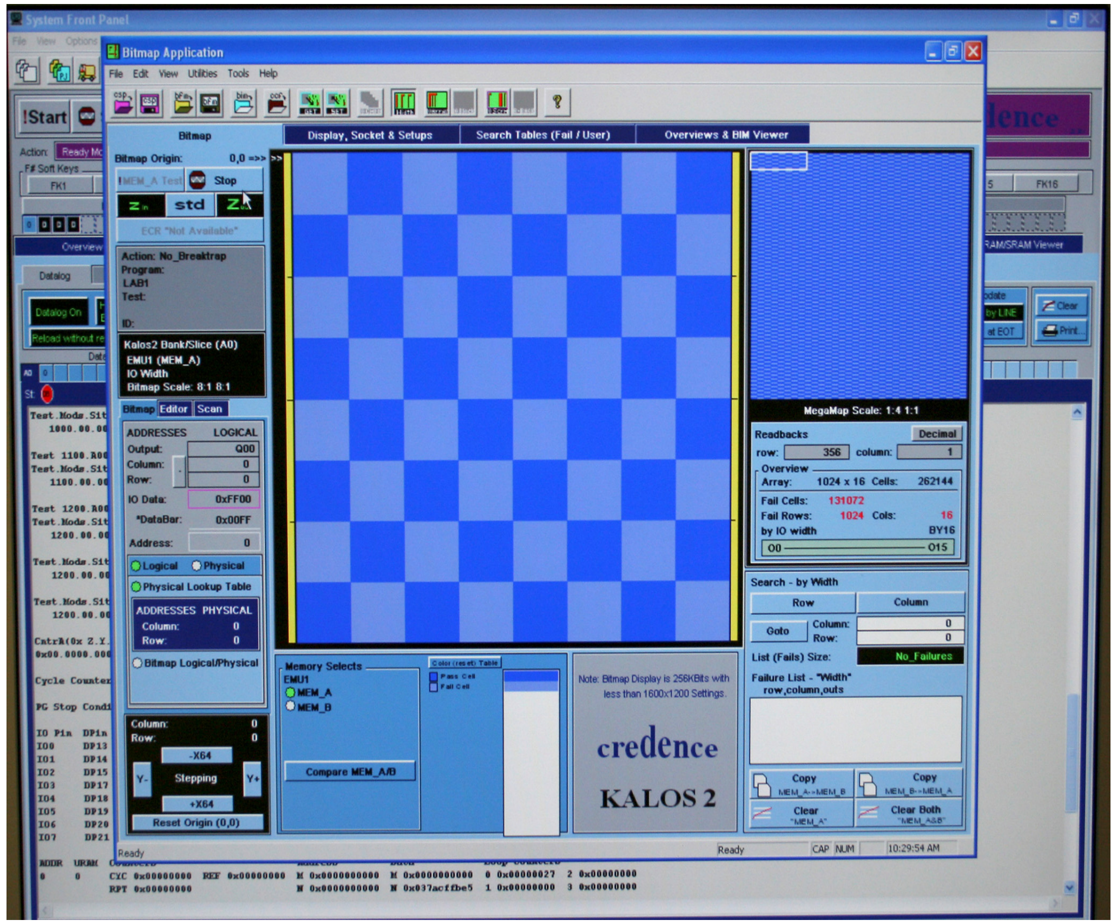


Figure 3. PK-2 Memory Tester Test Head with 48-pin universal load board and adapter socket. The Logic Analyzer Probes are also seen connected to the circuit for verification of read and write cycle time and output data.



Bitmap Origin: 0,0

ECR "Not Available"

Action: No_Breaktrap
Program:
LAB1
Test:
ID:

Kalos2 Bank/Slice (A0)
EMU1 (MEM_A)
IO Width
Bitmap Scale: 8:1 8:1

ADDRESSES LOGICAL
Output: Q00
Column: 0
Row: 0
IO Data: 0xFF00
*DataBar: 0x00FF
Address: 0

● Logical ○ Physical
● Physical Lookup Table

ADDRESSES PHYSICAL
Column: 0
Row: 0

○ Bitmap Logical/Physical

Column: 0
Row: 0

Memory Selects
EMU1
● MEM_A
○ MEM_B

Note: Bitmap Display is 256KBits with less than 1600x1200 Settings.

MegaMap Scale: 1:4 1:1

Readbacks
row: 356 column: 1

Overview
Array: 1024 x 16 Cells: 262144
Fail Cells: 131072
Fail Rows: 1024 Cols: 16
by IO width BY16
O0 — O15

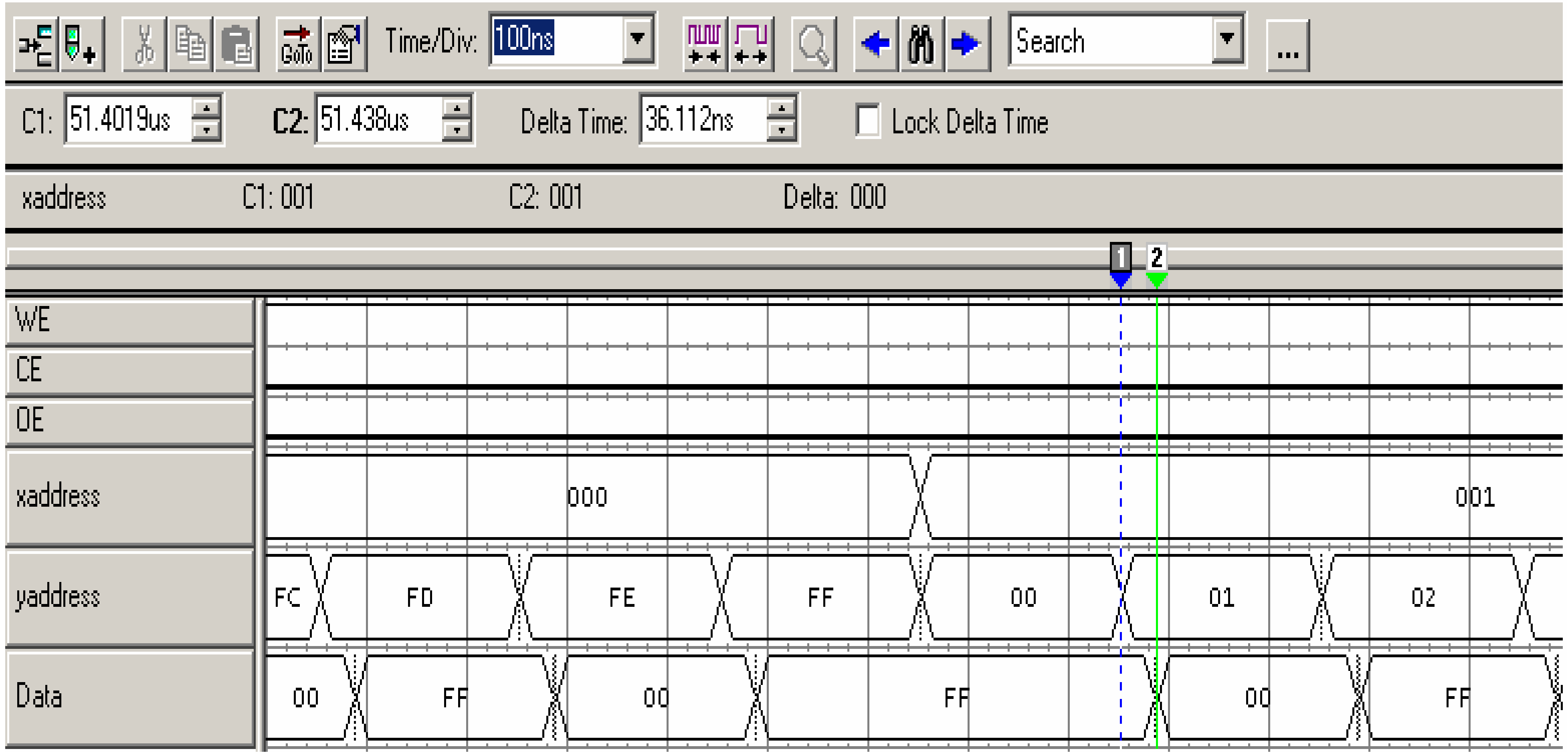
Search - by Width
Column: 0
Row: 0
List (Fails) Size: No_Failures
Failure List - "Width"
row,column,outs

```
IO Pin  DPin
IO0     DP13
IO1     DP14
IO2     DP15
IO3     DP17
IO4     DP18
IO5     DP19
IO6     DP20
IO7     DP21

ADDR  URAM
0     0      CYC 0x00000000  REF 0x00000000  M 0x000000000  M 0x000000000  0 0x00000027  2 0x00000000
             RPT 0x00000000                  N 0x000000000  N 0x037acffbe5  1 0x00000000  3 0x00000000
```

Figure 8. Credence Personal Kalos 2 (PK2) Memory Tester Output of post radiation checkerboard pattern, graphical view.

Post Radiation Logic Analyzer Output Timing



Time/Div: 100ns

C1: 51.4019us
C2: 51.438us
Delta Time: 36.112ns
☐ Lock Delta Time

xaddress C1: 001 C2: 001 Delta: 000

Figure 4. TLA721 Logic Analyzer timing screenshot of a post radiation post device annealed, checkerboard pattern showing 36 ns delay time through device after address changes compared to 45 ns minimum delay as specified in manufacturers parts data sheet.

Post Radiation Memory Testing input/outputs from the PK-2 Memory Tester

```
Tester ID: PK2-107     Date: August 11,2005 11:59AM
Program: LAB1  Device: deviceName  Flow: PARAMETRIC_Flow  Serial: 1
Kalos2: A00  Lot: Alpha-numeric
Operator: Will
DibPart: NA
DibSerial: NA
Comment: Post Rad Parametrics 7.5K
Users_C: ..user message..
Test 100.A00.001.***  OPENS
Test.Mods.Site.PHY  Pin/Grp  Test Description     Force/Range     Measure/Range    Max / Min    PassFail
 100.A00.001.***   A0                              OPENS          -100uA/250uA  -444.95mV/12.5 V      NA/-1 V      PASS
 100.A00.001.***   A1                              OPENS          -100uA/250uA  -444.95mV/12.5 V      NA/-1 V      PASS
 100.A00.001.***   A2                              OPENS          -100uA/250uA  -444.645mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A3                              OPENS          -100uA/250uA  -444.645mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A4                              OPENS          -100uA/250uA  -444.645mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A5                              OPENS          -100uA/250uA  -446.476mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A6                              OPENS          -100uA/250uA  -448.001mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A7                              OPENS          -100uA/250uA  -446.17mV/12.5 V      NA/-1 V      PASS
 100.A00.001.***   A8                              OPENS          -100uA/250uA  -444.645mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A9                              OPENS          -100uA/250uA  -408.939mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A10                             OPENS          -100uA/250uA  -443.424mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A11                             OPENS          -100uA/250uA  -444.034mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A12                             OPENS          -100uA/250uA  -445.255mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A13                             OPENS          -100uA/250uA  -443.729mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A14                             OPENS          -100uA/250uA  -445.255mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A15                             OPENS          -100uA/250uA  -406.498mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A16                             OPENS          -100uA/250uA  -443.729mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A17                             OPENS          -100uA/250uA  -444.034mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   A18                             OPENS          -100uA/250uA  -444.95mV/12.5 V      NA/-1 V      PASS
 100.A00.001.***   DQ0                             OPENS          -100uA/250uA  -501.407mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   DQ1                             OPENS          -100uA/250uA  -491.947mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   DQ2                             OPENS          -100uA/250uA  -456.852mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   DQ3                             OPENS          -100uA/250uA  -466.312mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   DQ4                             OPENS          -100uA/250uA  -519.107mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   DQ5                             OPENS          -100uA/250uA  -530.399mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   DQ6                             OPENS          -100uA/250uA  -465.091mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   DQ7                             OPENS          -100uA/250uA  -455.936mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   CE                              OPENS          -100uA/250uA  -443.729mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   OE                              OPENS          -100uA/250uA  -403.446mV/12.5 V     NA/-1 V      PASS
 100.A00.001.***   WE                              OPENS          -100uA/250uA  -444.645mV/12.5 V     NA/-1 V      PASS
```

Post Radiation Memory Testing input/outputs from the PK-2 Memory Tester

```
Test 200.A00.001.***                                   SHORTS
 Test.Mods.Site.PHY  Pin/Grp  Test Description    Force/Range    Measure/Range   Max / Min   PassFail
 200.A00.001.***   A0                        SHORTS           100uA/250uA  606.075mV/12.5 V       NA/200mV      PASS
 200.A00.001.***   A1           SHORTS           100uA/250uA  604.244mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A2           SHORTS           100uA/250uA  599.667mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A3           SHORTS           100uA/250uA  605.16mV/12.5 V       NA/200mV        PASS
 200.A00.001.***   A4           SHORTS           100uA/250uA  608.822mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A5           SHORTS           100uA/250uA  609.127mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A6           SHORTS           100uA/250uA  611.263mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A7           SHORTS           100uA/250uA  605.465mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A8           SHORTS           100uA/250uA  609.127mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A9           SHORTS           100uA/250uA  2.31231 V/12.5 V      NA/200mV        PASS
 200.A00.001.***   A10          SHORTS           100uA/250uA  612.179mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A11          SHORTS           100uA/250uA  606.381mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A12          SHORTS           100uA/250uA  606.686mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A13          SHORTS           100uA/250uA  602.108mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A14          SHORTS           100uA/250uA  604.244mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A15          SHORTS           100uA/250uA  2.62085 V/12.5 V      NA/200mV        PASS
 200.A00.001.***   A16          SHORTS           100uA/250uA  608.212mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A17          SHORTS           100uA/250uA  606.991mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   A18          SHORTS           100uA/250uA  598.141mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   DQ0          SHORTS           100uA/250uA  629.269mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   DQ1          SHORTS           100uA/250uA  624.996mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   DQ2          SHORTS           100uA/250uA  631.71mV/12.5 V       NA/200mV        PASS
 200.A00.001.***   DQ3          SHORTS           100uA/250uA  625.302mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   DQ4          SHORTS           100uA/250uA  627.743mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   DQ5          SHORTS           100uA/250uA  632.931mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   DQ6          SHORTS           100uA/250uA  631.405mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   DQ7          SHORTS           100uA/250uA  622.86mV/12.5 V       NA/200mV        PASS
 200.A00.001.***   CE           SHORTS           100uA/250uA  614.926mV/12.5 V      NA/200mV        PASS
 200.A00.001.***   OE           SHORTS           100uA/250uA  2.40234 V/12.5 V      NA/200mV        PASS
 200.A00.001.***   WE           SHORTS           100uA/250uA  608.212mV/12.5 V      NA/200mV        PASS

Test 300.A00.001.***  INPUTLEAKAGELOW
Test.Mods.Site.PHY  Pin/Grp  Test Description    Force/Range    Measure/Range   Max / Min     PassFail
300.A00.001.***   INPUTSALLINPUTLEAKAGELOW  0 V/12.5 V  80nA/25uA   5uA/-5uA         PASS
Test 400.A00.001.***  INPUTLEAKAGEHIGH
Test.Mods.Site.PHY  Pin/Grp  Test Description    Force/Range    Measure/Range   Max / Min     PassFail
400.A00.001.***   INPUTSALLINPUTLEAKAGEHIGH 3.6 V/12.5 V  118nA/25uA  5uA/-5uA      PASS
Test 500.A00.001.***  OUTPUTLEAKAGELOW
Test.Mods.Site.PHY  Pin/Grp  Test Description    Force/Range    Measure/Range   Max / Min     PassFail
500.A00.001.***   DBUS     OUTPUTLEAKAGELOW  0 V/12.5 V 24nA/2.5uA      1uA/-1uA         PASS
Test 800.A00.001.***  ICC_TEST
Test.Mods.Site.PHY  Pin/Grp  Test Description    Force/Range    Measure/Range   Max / Min     PassFail
800.A00.001.***   VCC0     ICC_TEST          3.59997 V/7.5 V  3.4068mA/500mA   20mA/NA       PASS
Kalos2 A00 DUT 0 Result=PASS, SortBin=1, SoftBin=1
```

Post Radiation Analysis

- Read Access Time
  - No noticeable changes post radiation seen from timing measurements taken from Logic Analyzer

- Photocurrent
  - Surge (379.42 mA) under Gamma Dot 1.2 E10 Rad/Sec 49.6 ns LINAC testing (Figure 6).

- Memory Tester Output at Increased Dose Rate.
  - At a 7.5k rads, 75 seconds Total Dose Gamma, there was a slight increase in Leakage Current, rising only in the range of 50uA-100uA

- Voltage levels
  - Held constant at 3.3V throughout the duration of the tests.

- Active/Standby currents
  - Only small increases (30 uA) in bus current post radiation

- Tests Run for Baselining and Post Testing:
  - Input/Output Leakage high/low
  - Open/Shorts Test
  - Checkerboard Pattern written and read from the device.

- Read operations verified by a checkerboard pattern, readout from the PK-2 Memory Tester we also verified by a logic analyzer. A three dimensional 3D Schmoo Plot by the PK2 will provide additional detailed useful information on the part but is not presented here.

Conclusion

None of the 30 chips from the two types of devices failed or showed any major change to the baseline data. None of the chips appeared fail on the post test, with slight changes to current, increasing only about .01 mA’s as the dose rate went up. As the dose rate went up using the Gamma Range facility, there were no significant changes happening to the devices even up to dose rate to 20k rads/sec. In doing so the parts still did not seem to fail. The part did not show any sign of latch up under the dose levels of interest. This tells us that the SST parts are ok for relatively low doses of radiation.

References

MIL-STD-883 F
Method 1020.1 Dose Rate induced Latch Up Test Procedure
Method 1021.2 Dose Rate Upset Testing of Digital Microcircuits
The Fundamentals of Digital Semiconductor Testing
Guy Perry, Soft-Test Incorporated
For More Information visit:
http://mettop.emrtc.nmt.edu

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