A radiation evaluation was performed on FM28C256 (EEPROM) to determine the total dose tolerance of these parts. A brief summary of the test results is provided below. For detailed information, refer to Tables I through IV and Figure 1.

The total dose testing was performed using a Co\textsuperscript{60} gamma ray source. During the radiation testing, four parts were irradiated under bias (see Figure 1 for bias configuration), and two parts were used as control samples. The total dose radiation levels were 2.5, 5, 7.5, 10, 20 and 30 krads\textsuperscript{*}. The dose rate was between 0.08 and 0.59 krads/hour, depending on the total dose level (see Table II for radiation schedule). In previous testing of these parts (Report # PPM-95-147), parts were irradiated at extremely low dose rates (0.02-0.30 krads/hour), to a total dose of 30 krads over a period of 48 days, compared to a total dose of 30 krads over a period of 9 days in this report. After each radiation exposure and annealing treatment, parts were electrically tested according to the test conditions and the specification limits\textsuperscript{**} listed in Table III. These tests included two functional tests (READ CHKBD) at 0.5 Mhz, one with Vcc and Vih = 4.5 V and one with Vcc and Vih = 5.5 V.

All parts passed initial electrical measurements. The initial electrical measurements included six functional tests: three with Vcc = 4.5 V (WR/RD ZEROES, WR/RD ONES, WR/RD CHKBD) and the same three with Vcc = 5.5 V. Prior to the first irradiation, a checkerboard pattern was written into the parts to be irradiated. However, after the start of the radiation exposures, only the reading of the checkerboard pattern was performed after each irradiation step. No writing of zeroes, ones or the checkerboard was done after the start of the radiation. The tests were performed this way in order to determine if the parts retained the checkerboard pattern during the irradiation steps.

All irradiated parts passed all electrical tests up to and including the 10 krad level. At the 15 krad irradiation level, all irradiated parts exceeded the maximum specification limit of 350 \(\mu\)A for ICCL3 and ICCH3 with readings in the range of 786 \(\mu\)A to 1716 \(\mu\)A. In addition S/N 1231 exceeded the maximum specification limit of 3 mA for ICCL2 and ICCH2 with a reading of 3.2 mA.

At the 20 krad irradiation level, all parts continued to exceed the maximum specification limit for ICCL3 and ICCH3 with readings in the range of 1891 \(\mu\)A to 7139 \(\mu\)A. In addition S/N 1231 exceeded the maximum specification limit of \pm 10 \(\mu\)A for IOZH with a reading of 18 \(\mu\)A and all parts exceeded the maximum specification limit for ICCL2 and ICCH2 with readings in the range of 3.3mA to 8.5 mA respectively.

After the 30 krad irradiation, all parts continued to exceed the maximum specification limit for ICCL3 and ICCH3, ICCL2 and ICCH2 with readings in the range of 1891 \(\mu\)A to 7139 \(\mu\)A and 12.4 mA to 16 mA respectively. In addition, all parts exceeded the maximum specification limit for IOZH with readings in the range of 38 \(\mu\)A and 104 \(\mu\)A. In addition S/N 1231 and S/N 1257 exceeded the maximum specification limit of \pm 10 \(\mu\)A for IOZL with readings in the range of 13 mA to -21mA respectively.

\textsuperscript{*}The term rads, as used in this document, means rads(silicon). All radiation levels cited are cumulative.

\textsuperscript{**}These are manufacturer's pre-irradiation data specification limits. No post-irradiation limits were provided by the manufacturer at the time these tests were performed.
After annealing for 168 hours at 25°C, all parts continued to exceed the maximum specification limit for ICCL3 and ICCH3 with readings in the range of 768 μA to 3331 μA respectively and S/N 1231 and S/N 1236 continued to exceed the maximum specification limit for ICCL2 and ICCH2 with readings in the range of 3.5 mA to 4.7 mA. In addition S/N 1231 continued to exceed the maximum specification limit for IOZH with a reading of 13 μA and S/N 1252 and S/N 1257 exceeded the maximum specification limit for TAVQVLH with readings in the range of 280 nS to 1000 nS respectively.

After annealing for 168 hours at 100°C, no rebound effects were observed in the parts.

In summary, comparing results from the previous report, in which the overall mean dose rate was approximately 0.6 krad/day to results in this report, in which the overall mean dose rate was approximately 3.3 krad/day, results in the parametric tests were, in most cases, approximately the same, and some functional failures (2 out of 4 parts) were observed at the 25 and 30 krad levels in the previous report, whereas in this case, at a 5-times higher dose rate, no functional failures were observed. It should be noted that the functional failures in the previous report may be due to variations in parts performance from the same lot, rather than directly due to dose rate effects.

Table IV provides a summary of the mean and standard deviation values for each parameter after different irradiation exposures and annealing step.

Any further details about this evaluation can be obtained upon request. If you have any questions, please call me at (301) 731-8954.

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TABLE I. Part Information

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic Part Number</td>
<td>28C256</td>
</tr>
<tr>
<td>TOMS Part Number</td>
<td>5962-8852503ZC</td>
</tr>
<tr>
<td>TOMS Control Number</td>
<td>13358</td>
</tr>
<tr>
<td>Charge Number</td>
<td>C52822</td>
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<tr>
<td>Manufacturer</td>
<td>Seeq Technology Inc</td>
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<td>Lot Date Code</td>
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<td>Serial Number of Control Samples</td>
<td>1242, 1245</td>
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<tr>
<td>Serial Numbers of Radiation Samples</td>
<td>1231, 1236, 1252, 1257</td>
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<tr>
<td>Part Function</td>
<td>EEPROM</td>
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<td>Part Technology</td>
<td>CMOS</td>
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<tr>
<td>Package Style</td>
<td>FP-28 pin</td>
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<tr>
<td>Test Equipment</td>
<td>S-50</td>
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<tr>
<td>Test Engineer</td>
<td>Ki Kim</td>
</tr>
</tbody>
</table>

* No radiation tolerance/hardness was guaranteed by the manufacturer for this part.
TABLE II. Radiation Schedule for 28C256

<table>
<thead>
<tr>
<th>EVENTS</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) INITIAL ELECTRICAL MEASUREMENT</td>
<td>06/05/95</td>
</tr>
<tr>
<td>2) 2.5 KRAD IRRADIATION (0.15 KRADS/HOUR)</td>
<td>06/05/95</td>
</tr>
<tr>
<td>POST-2.5 KRAD ELECTRICAL MEASUREMENT</td>
<td>06/06/95</td>
</tr>
<tr>
<td>3) 5 KRAD IRRADIATION (0.15 KRADS/HOUR)</td>
<td>06/06/95</td>
</tr>
<tr>
<td>POST-5 KRAD ELECTRICAL MEASUREMENT</td>
<td>06/07/95</td>
</tr>
<tr>
<td>4) 7.5 KRAD IRRADIATION (0.15 KRADS/HOUR)</td>
<td>06/07/95</td>
</tr>
<tr>
<td>POST-7.5 KRAD ELECTRICAL MEASUREMENT</td>
<td>06/08/95</td>
</tr>
<tr>
<td>5) 10 KRAD IRRADIATION (0.15 KRADS/HOUR)</td>
<td>06/08/95</td>
</tr>
<tr>
<td>POST-10 KRAD ELECTRICAL MEASUREMENT</td>
<td>06/09/95</td>
</tr>
<tr>
<td>6) 15 KRAD IRRADIATION (0.08 KRADS/HOUR)</td>
<td>06/09/95</td>
</tr>
<tr>
<td>POST-15 KRAD ELECTRICAL MEASUREMENT</td>
<td>06/12/95</td>
</tr>
<tr>
<td>7) 20 KRAD IRRADIATION (0.29 KRADS/HOUR)</td>
<td>06/12/95</td>
</tr>
<tr>
<td>POST-20 KRAD ELECTRICAL MEASUREMENT</td>
<td>06/13/95</td>
</tr>
<tr>
<td>8) 30 KRAD IRRADIATION (0.59 KRADS/HOUR)</td>
<td>06/13/95</td>
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<tr>
<td>POST-30 KRAD ELECTRICAL MEASUREMENT</td>
<td>06/14/95</td>
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<tr>
<td>9) 168-HOUR ANNEALING @25°C</td>
<td>06/14/95</td>
</tr>
<tr>
<td>POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT</td>
<td>06/21/95</td>
</tr>
<tr>
<td>10) 168-HOUR ANNEALING @100°C*</td>
<td>06/21/95</td>
</tr>
<tr>
<td>POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT</td>
<td>06/28/95</td>
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</table>

PARTS WERE IRRADIATED AND ANNEALED UNDER BIAS; SEE FIGURE 1.
Table III. Electrical Characteristics of 28C256

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VCC</th>
<th>VIL</th>
<th>VIH</th>
<th>PATTERN</th>
<th>CONDITIONS</th>
<th>PINS</th>
<th>LIMITS @ +25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

**INITIAL EM'S FUNCTIONAL TESTS PERFORMED**

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>#1</th>
<th>4.5V</th>
<th>0.0V</th>
<th>4.5V</th>
<th>WR/RD ZEROES</th>
<th>FREQ = 0.5 MHZ</th>
<th>I/O'S</th>
<th>VIL</th>
<th>VIH</th>
<th>VOL&lt;1.0V</th>
<th>VOL&gt;2.0V</th>
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</thead>
<tbody>
<tr>
<td>FUNCTION</td>
<td>#2</td>
<td>4.5V</td>
<td>0.0V</td>
<td>4.5V</td>
<td>WR/RD ONES</td>
<td>FREQ = 0.5 MHZ</td>
<td>I/O'S</td>
<td>VIL</td>
<td>VIH</td>
<td>VOL&lt;1.0V</td>
<td>VOL&gt;2.0V</td>
</tr>
<tr>
<td>FUNCTION</td>
<td>#3</td>
<td>4.5V</td>
<td>0.0V</td>
<td>4.5V</td>
<td>WR/RD CHKBD</td>
<td>FREQ = 0.5 MHZ</td>
<td>I/O'S</td>
<td>VIL</td>
<td>VIH</td>
<td>VOL&lt;1.0V</td>
<td>VOL&gt;2.0V</td>
</tr>
<tr>
<td>FUNCTION</td>
<td>#4</td>
<td>5.5V</td>
<td>0.0V</td>
<td>5.5V</td>
<td>WR/RD ZEROES</td>
<td>FREQ = 0.5 MHZ</td>
<td>I/O'S</td>
<td>VIL</td>
<td>VIH</td>
<td>VOL&lt;1.0V</td>
<td>VOL&gt;2.0V</td>
</tr>
<tr>
<td>FUNCTION</td>
<td>#5</td>
<td>5.5V</td>
<td>0.0V</td>
<td>5.5V</td>
<td>WR/RD ONES</td>
<td>FREQ = 0.5 MHZ</td>
<td>I/O'S</td>
<td>VIL</td>
<td>VIH</td>
<td>VOL&lt;1.0V</td>
<td>VOL&gt;2.0V</td>
</tr>
<tr>
<td>FUNCTION</td>
<td>#6</td>
<td>5.5V</td>
<td>0.0V</td>
<td>5.5V</td>
<td>WR/RD CHKBD</td>
<td>FREQ = 0.5 MHZ</td>
<td>I/O'S</td>
<td>VIL</td>
<td>VIH</td>
<td>VOL&lt;1.0V</td>
<td>VOL&gt;2.0V</td>
</tr>
</tbody>
</table>

**POST RADIATION/ANNEALING EM'S FUNCTIONAL TESTS PERFORMED**

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<tr>
<th>FUNCTION</th>
<th>#1</th>
<th>4.5V</th>
<th>0.0V</th>
<th>4.5V</th>
<th>READ CHKBD</th>
<th>FREQ = 0.5 MHZ</th>
<th>I/O'S</th>
<th>VIL</th>
<th>VIH</th>
<th>VOL&lt;1.0V</th>
<th>VOL&gt;2.0V</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNCTION</td>
<td>#2</td>
<td>5.5V</td>
<td>0.0V</td>
<td>5.5V</td>
<td>READ CHKBD</td>
<td>FREQ = 0.5 MHZ</td>
<td>I/O'S</td>
<td>VIL</td>
<td>VIH</td>
<td>VOL&lt;1.0V</td>
<td>VOL&gt;2.0V</td>
</tr>
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</table>

**DC PARAMETRIC TESTS PERFORMED**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VCC</th>
<th>VIL</th>
<th>VIH</th>
<th>CONDITIONS</th>
<th>PINS</th>
<th>LIMITS @ +25°C</th>
</tr>
</thead>
<tbody>
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**AC PARAMETRIC TESTS**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VCC</th>
<th>VIL</th>
<th>VIH</th>
<th>CONDITIONS</th>
<th>PINS</th>
<th>LIMITS @ +25°C</th>
</tr>
</thead>
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The initial electrical measurements included six functional tests: three with Vcc = 4.5 V (WR/RD ZEROES, WR/RD ONES, WR/RD CHKBD) and the same three with Vcc = 5.5 V. Prior to the first irradiation, a checkerboard pattern was written into the parts to be irradiated. However, after the start of the radiation exposures, only the reading of the checkerboard pattern (FUNCTION1 and FUNCTION2) was performed after each irradiation step. No writing of zeroes, ones or the checkerboard was done after the start of the radiation. The tests were performed this way in order to determine if the parts retained the checkerboard pattern during the irradiation steps. This was done at the request of the project.
### TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for 28C256 /1

| Test # | Parameters | Units | Spec. Lim./2 | Initial | 2.5 | 5 | 7.5 | 10 | 15 | 20 | 30 | 168 hrs | 168 hrs |
|--------|------------|-------|--------------|---------|-----|---|-----|-----|-----|----|----|------|-------|---------|---------|
|        |            |       | min          | max     | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd |
| 1      | VOL        | mV    | 0            | 450     | 79.4 | 2.04| 80.2 | 2.67| 78.6 | 2.16| 78.7 | 1.98| 77.0 | 1.97| 75.9 | 1.84|
| 2      | VOH        | V     | 2.4          | 4.5     | 3.68 | 0.01| 3.68 | 0.02| 3.69 | 0.01| 3.69 | 0.01| 3.71 | 0.01| 3.73 | 0.02|
| 3      | HIH        | nA    | -10000       | 10000   | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | -49.0| 0.0  | 69.7 |
| 4      | IOZL       | nA    | -10000       | 10000   | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | 343.0| 209 |
| 5      | IOZH       | nA    | -10000       | 10000   | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | 0.0 | 0.0  | 257.0| 479 |
| 6      | JOE        | µA    | -10          | 100     | 6.38 | 0.49| 6.52 | 0.45| 6.61 | 0.51| 6.70 | 0.51| 6.87 | 0.51| 7.27 | 0.56|
| 7      | ICC1       | µA    | 0            | 80      | 6.51 | 0.28| 6.56 | 0.31| 6.75 | 0.28| 6.87 | 0.29| 7.07 | 0.26| 8.81 | 0.24|
| 8      | ICC2       | µA    | 0            | 3       | 1.75 | 0.02| 1.71 | 0.03| 1.68 | 0.02| 1.66 | 0.02| 1.67 | 0.04| 2.72 | 0.34|
| 9      | ICC3       | µA    | 0            | 3       | 1.75 | 0.02| 1.70 | 0.03| 1.68 | 0.02| 1.65 | 0.02| 1.68 | 0.04| 2.72 | 0.35|
| 10     | ICC4       | µA    | 0            | 3       | 1.75 | 0.02| 1.70 | 0.03| 1.68 | 0.02| 1.65 | 0.02| 1.68 | 0.04| 2.72 | 0.35|
| 11     | TAVQVLH    | nS    | 0            | 250     | 86.3 | 5.89| 86.9 | 6.61| 85.3 | 5.69| 85.3 | 5.66| 84.1 | 5.46| 82.9 | 4.75|
| 12     | TAVQVHL    | nS    | 0            | 250     | 80.7 | 2.71| 81.1 | 3.0 | 80.1 | 2.80| 80.2 | 2.79| 79.4 | 2.83| 79.6 | 2.69|

Notes:
1/ The mean and standard deviation values were calculated over the four parts irradiated in this testing. The control samples remained constant throughout the testing and are not included in this table.
2/ These are manufacturer's pre-irradiation data sheet specification limits. No post-irradiation limits were provided by the manufacturer at the time the tests were performed.

**Radiation-sensitive parameters:** IOZL, IOZH, ICCL2, ICCH2, ICCL3, ICCH3, TAVQVLH and TAVQVHL.
Figure 1. Radiation Bias Circuit for 28C256

1) $V_{cc} = +5.0 \text{ VDC} \pm 0.5 \text{ VDC}$, $V_{cc}/2 = 2.5 \text{ VDC} \pm 0.25 \text{ VDC}$

2) All resistors $R = 2.0K \Omega$ms $\pm 10\%$, $1/4$ W