HS-6664RH

Radiation Characterization Report

AN9522
Rev.1.00
Apr 16, 2020

1. Introduction

The Harris 64K CMOS PROM (HS-6664RH - Mask Set 51070), built in the Harris 1.25µm bulk CMOS process known as AVLSI1-RF, has been characterized over several different types of radiation: 1) neutron, 2) total dose (including rebound), 3) dose-rate, and 4) heavy ion single-event. All of the results are summarized in this report.

2. Neutron Results

Summary

Although the 64K PROM is built on a CMOS process, it uses NPN transistors in the memory cell and row driver to deliver the necessary fusing current. Therefore it was characterized for any sensitivity to neutron radiation. The effect of this sensitivity would be a degradation in NPN gain, resulting in an increased access time (T_{ELQV}) from pre-exposure.

The neutron exposure was done by Sandia personnel using their pulse reactor facility per the procedure outlined below. The post-exposure electrical tests were done by Harris using the same automated test equipment and test program as the pre-exposure tests. No significant differences in the pre- and post-exposure AC or DC parameters were seen.

Procedure

Test Samples - A test sample of 10 parts from lot T40140 was randomly selected. All sample parts met all of the requirements of a data sheet part. Each part was serialized to enable pre and post test identification and comparison.

Pre-Exposure Electrical Tests - Pre-exposure electrical tests were performed on each part per the data sheet test program. All pre-exposure data were recorded.

Exposure Set-Up - Each device was mounted unbiased with its terminal leads all shorted. Test devices were mounted such that the total variation of fluence over the entire sample did not exceed 20 percent. Reactor facility personnel positioned the fixtures and determined the appropriate pulse level required to achieve the specified neutron fluence level.

Exposure - Five (5) test devices were exposed to a neutron fluence of $10^{13}/cm^2$ and five (5) test devices were exposed to a neutron fluence of $10^{14}/cm^2$. All exposures were made at $20^oC \pm 10^oC$ and were correlated to a 1MeV equivalent fluence.

Post-Exposure Electrical Tests - The temperature of the sample devices was maintained at $20^o \pm 10^oC$ from the time of the exposure until the post electrical tests were made. These tests were made within approximately 1 week of exposure. All required data were recorded for each device.

Post-Neutron Delta Test Results

Post-neutron testing on Lot T40140 showed no functional failures out of the 10 samples tested. Testing was done with product test options at $+25^oC$ only. No DC parametric shifts were observed and only small AC deltas were recorded.

The access time of the 64K PROM is largely a function of the low current gain of the memory cell NPN, and any degradation of that gain should result in a higher access time. As shown in Table 1, a delta shift of only 1ns to 2ns was observed, with the post-neutron access times now faster for the T_{ELQV} and T_{GLQV} AC tests. This could be attributed to test equipment calibration, or a slight radiation-induced threshold degradation. The parts that were exposed to a neutron fluence of $10^{13}/cm^2$ also received 4.75×10^3 rad(Si) of total dose exposure, and the parts that were exposed to a neutron fluence of $10^{14}/cm^2$ received a total dose exposure of 3.85×10^4 rad(Si). The fact that the units that received the higher dosage shifted by a larger margin tends to support the latter assumption.

Conclusions

From these results it can therefore be concluded that the bipolar devices in the row drivers and memory cells are not affected to any large degree by neutron exposure up to a neutron fluence of $10^{14}/cm^2$. The access time, which is largely a function of the low current gain, actually decreases slightly after exposure for some devices, probably due to a total dose induced Vt shift.

TABLE 1. NEUTRON DELTA TEST RESULTS

SN	DELTA T_{GLQV} AT 4.5V (ns)	DELTA T_{GLQV} AT 5.5V (ns)	DELTA T_{ELQV} AT 4.5V (ns)	DELTA T_{ELQV} AT 5.5V (ns)	NEUTRON DOSAGE $/cm^2$
101	0.96	0.96	1.12	1.12	1×10^{13}
104	0.80	0.80	1.28	1.12	1×10^{13}
114	0.80	0.80	0.96	0.96	1×10^{13}
121	0.80	0.64	0.79	0.80	1×10^{13}
122	0.79	0.96	0.96	0.96	1×10^{13}
123	0.48	0.48	1.28	1.28	1×10^{14}
125	0.48	0.64	1.92	1.44	1×10^{14}
126	0.64	0.80	2.40	1.44	1×10^{14}
129	0.64	0.80	1.28	1.12	1×10^{14}

TABLE 1. NEUTRON DELTA TEST RESULTS (Continued)

SN	DELTA T_{GLQV} AT 4.5V (ns)	DELTA T_{GLQV} AT 5.5V (ns)	DELTA T_{ELQV} AT 4.5V (ns)	DELTA T_{ELQV} AT 5.5V (ns)	NEUTRON DOSAGE /cm^2
130	0.32	0.80	1.28	1.12	1×10^{14}

3. Total Dose and Rebound Results

Total Dose Summary

Total dose radiation testing was performed on several production and design verification lots of the 64K PROM. All units were tested to the datasheet electrical and total dose parameters. In addition to this standard datasheet testing, characterization was also performed on units at total dose ranging from 50K to 1.5M rads(Si). The data from both efforts are summarized in this section.

300K Rad(Si) Total Dose Go/No Go Testing

All units were tested in accordance with MIL-STD-883D Method 1019. Units from 3 production lots and 2 design verification lots were tested go/no go to the data sheet electrical parameters to a total dose of 300K rads(Si). As shown in Table 2, there were no failures noted and no significant changes in AC or DC performance in any of the lots tested.

Procedure

Samples - The number of test samples used and their respective lot numbers are shown in Table 2.

Pre-Exposure Electrical Tests - Pre-exposure electrical tests were performed on each serialized part per the data sheet test program.

Exposure - All devices were exposed in a gamma cell at a dose rate of approximately 175 rad(Si)/sec. The units were exposed to a total dose of 300K rads(Si). All inputs were biased high, as shown in Figure 12, with a supply voltage of 5.5V during exposure to ensure maximum threshold shifts.

Post-Exposure Electrical Tests - The post-exposure electrical tests were performed within 30 minutes of exposure. Mobile bias was not used. The temperature of the sample devices was maintained at 20°C ± 10°C from the time of the exposure until the post electrical tests were made.

TABLE 2. 300K rad(Si) TOTAL DOSE RESULTS

LOT	TYPE	UNITS TESTED	UNITS PASSED
T40844-0	DV	4	4
T40257-0	DV	2	2
T42262-0	PROD	6	6
T42263-0	PROD	6	6
T42265-0	PROD	6	6

Conclusions

The results of the total dose go/no go testing indicate that the device is very capable of meeting the required 300K rad(Si) total dose requirement.

50K to 1.5M rad(Si) Total Dose Go/No Go Testing

Eight units from 3 different lots were tested at 50K, 100K, 300K, 500K, 1M and 1.5M rads(Si), with full data sheet testing done after each irradiation step. The units performed normally after each exposure with only a slight decrease in access time performance to 500K rad(Si), after which the measurements moved back towards the pre-irradiation readings. No other changes in AC performance and no significant changes in DC performance were noted throughout the entire characterization.

Procedure

Samples - 8 units consisting of 3 units from T42262-0, 3 units from T42265-0 and 2 units from T41659-0 were tested. S/N 217, 218, and 219 were from lot T42262-0. S/N 524, 528, and 530 were from lot T42265-0. S/N 910 and 911 were from lot T41659-0.

Pre-Exposure Electrical Tests - Pre-exposure electrical tests were performed on each part per the data sheet test program.

Exposure - All devices were exposed in a gamma cell at a dose rate of approximately 175 Rad(Si)/sec. All inputs were biased high, as shown in Figure 12, with a supply voltage of 5.5V during exposure to ensure maximum threshold shifts.

All total dose rates are cumulative. After the initial dose of 50K Rads(Si), the units were tested and then irradiated for another 50K Rads (100K rad(Si) cumulative). This procedure was repeated for cumulative doses of 300K, 500K, 1M, and 1.5M rads(Si).

Post-Exposure Electrical Tests - Post-exposure electrical tests were performed within 15 minutes of exposure. Mobile bias was not used. The temperature of the sample devices was maintained at 20°C ± 10°C from the time of the exposure until the post electrical tests were made.

Post-Exposure Total Dose Results

Figures 1- 3 illustrate that there was virtually no shifts in any of the leakage current or output drive parameters. A slight decrease in access time (T_{ELQV}) was noted at dose rates up to 500K Rads(Si). It then moved towards the original pre-irradiation measurements at higher total dose rates. For the other AC parameters, the observed shift was only 1.5ns or less up to a total dose rate of 1.5M rads(Si). All of the devices easily passed the data sheet requirements up to 1.5M Rads(Si).

Conclusions

From the characterization data, coupled with the go/no go total dose testing, it can be concluded that the 64K PROM easily exceeds its data sheet specifications of 300K rad(Si). No failures and only slight changes in key performance parameters were observed up to a total dose rates as high as 1.5M rad(Si).

Rebound Summary

The 64K PROM was also characterized for radiation rebound effects. A total of 11 units from 4 different diffusion lots were used. The samples consisted of 3 units each from lots T42262, T42265, T41748, and 2 units from lot T41659. The results are summarized in this section.

The units were characterized in accordance with MIL-STD-883D Method 1019. The procedure and data are outlined in the following sections. The units performed normally after exposure with a slight decrease in access time performance. After rebound, the measurements moved back towards the pre-radiation readings. No significant changes in DC performance were noted throughout the test.

Procedure

Samples - 11 units from 4 different diffusion lots were used. The samples consisted of 3 units from lots T42262, T42265, T41748, and 2 units from lot T41659.

Pre-Exposure Electrical Test - Pre-exposure electrical testing was performed on each part per the data sheet test program. All pre-exposure data was recorded.

Exposure - The devices were exposed in a gamma cell at dose rate of approximately 165 rad(Si)/sec. The units remained in the Gamma Cell long enough to received a total dose of 300K rads(Si). All inputs were biased high, as shown in Figure 12, with a supply voltage of 5.5V during exposure to ensure maximum threshold shifts.

Post-Exposure Electrical Test - The temperature of the sample devices was maintained at $20^oC \pm 10^oC$ from the time of the exposure until the post electrical tests were made. The tests were made within 30 minutes of exposure using the data sheet test program. Mobile bias was not used. All required data was recorded for each device.

Rebound - Directly after post exposure electrical testing, the units were re-exposed in the Gamma Cell until the samples had been exposed to a total dose of 150K rads(Si), which is 50% of the initial exposure. The units were then placed on static Burn-In per the configuration outlined in the HS-6664RH data sheet, and shown in Figure 13, at 100^oC for 168 hours. The elapsed time from the exposure to burn-in was less than 30 minutes.

Post-Rebound Electrical Test - Electrical testing was performed within 1 hour after the units were removed from burn in. The same data sheet test program was used and all required data was recorded for each device.

Figures 4 -11 show the results of the rebound characterization for the HS-6664RH. These graphs are comparisons of the pre-rad, post-rad, and post Burn-In measurements for the critical parameters of each of the 11 units tested. The critical parameters include the standby current (I_{DDSB}), the output three-state currents (I_{OZH}, I_{OZL}), output drives (V_{OL}, V_{OH}) and some AC parameters.

Conclusions

For the 64K PROM and the AVLSI1-RF process, this characterization showed very little drift in any of the test parameters that could be attributed to rebound and thus meets the requirements of MIL-STD-883D Method 1019.4. All shifts were within test system tolerances with the exception of T_{ELQV} (access time) which improved slightly immediately following irradiation but then moved back towards the original pre-radiation measurement after annealing.

4. Dose Rate Results

Summary

Dose-rate testing of the 64K PROM was done by Harris personnel at Honeywell - Clearwater, using their Flash X-Ray Machine. The PROM's output upset threshold of about 5×10^8 rad(Si)/sec was successfully determined and no evidence of latchup, or any other anomalous behavior up to about 5.5×10^{11} rad(Si)/sec was seen. All testing was done at room temperature.

Procedure

Radiation Source - A Flash X-Ray (FXR) machine, in the photon mode was used, with a pulse width of less than 200ns (for narrow pulse width measurements). The machine was located at Honeywell - Clearwater, FL. The dose rate at the location of the device under test was adjustable between 10^6 and about 6×10^{11} rad(Si)/sec.

Test Samples and Instrumentation - Eight (8) fully functional units from lot T40740 were used. Four (4) had a special pattern blown in them, 2 had location 0 blown to all 1's (FF_{16}) with the rest of the locations blank, and 2 were completely blank. The special pattern, best described as a continuous count-up/count-down pattern (0-255, 255-0, etc.), was used to test for address or data upset. This pattern was chosen so that if a single address or data latch was upset, the change in output would be noted. The other programmed pattern was to be used as a simple upset test pattern with the first and last addresses having complimentary data. The blank (virgin) parts were used for latch-up screening.

The test fixture had the programming pin ($\overline{P}$) hardwired high to prevent any potential accidental programming. A function generator controlled the address pins, $\overline{CE}$ and $\overline{G}$. Shielded, terminated cabling connected the test circuit fixture, located in the radiation field, to the test instrumentation located in the radiation safe area. A DVM was used to monitor the regulated power supply voltage and a current probe was used to monitor the current drawn by the device under test. Digitizing oscilloscopes were used to monitor 4 of the outputs.

Pre-Exposure Electrical Tests - Pre-exposure electrical tests were performed on each part per the data sheet test program. All pre-exposure data were recorded.

Test Procedure - The initial device to be tested for output upset threshold was first biased at minimum V_{DD} (4.5V) so that the outputs were all in a HIGH state. The function generator was stopped at that location, holding the address pins in the required states, and holding $\overline{CE}$ and $\overline{G}$ low. ($\overline{P}$ is hardwired high.) While maintaining those input conditions, the circuit was then exposed to a series of radiation pulses (~20ns), beginning at about 1×10^8 rad(Si)/sec and increasing by decades until an upset condition was observed on at least 1 of the monitored outputs. A change in the output pattern or a specified voltage transient indicated that upset had occurred. The dose rate of the pulse which caused a voltage transient equal to the specified value was the upset level. The power supply peak transient current was also recorded during the radiation pulses. After an upset level had been determined on a particular part, another part was used and the procedure was repeated with the determined level.

Transient Output Upset - The transient output upset levels depended on the output voltage levels chosen (i.e., 0.8V for a low and 2.4V for a high, or some percentage of the voltage supply). At room temperature, with V_{DD} = 4.5V, the upset levels ranged from about 5 x 10^8 rad(Si)/sec to 7 x 10^8 rad(Si)/sec, with an output low being the worst case. The outputs would always recover to their original states in less than 4µs. This was verified on several parts, using different patterns.

Output Upset - Total output upset (permanent change of states) did not occur until 6 x 10^9 rad(Si)/sec, with an output high being the worst case. The outputs returned to their correct states after the toggling of $\overline{CE}$.

Latch-up - No evidence of radiation induced latch-up, a permanent high current state, or any other form of anomalous behavior was seen on two parts (programmed and blank) at a maximum operating V_{DD} (5.5V) and the maximum machine output (in the pinched mode) of about 5.5 x 10^{11} rad(Si)/sec. Although the outputs (sense amps) upset to the opposite state, they recovered correctly with the toggling of CE.

During testing all inputs were biased high (addresses = all 1's), except $\overline{CE}$, which was held low by the function generator, and $\overline{G}$, which was biased low. The circuit was exposed while maintaining those input conditions.

Conclusions

A minimum transient output upset level of 5 x 10^8 rad(Si)/sec was obtained with no evidence of latch-up at 5 x 10^{11} rad(Si)/sec. A permanent change of state of the outputs occurred at 6 x 10^9 rad(Si)/sec. Although the transient output upset level on the Flash X-Ray was less than the preliminary data sheet goal of 1 x 10^9 rad(Si)/sec, it should be noted that independent testing by the Naval Surface Warfare Center - Crane Division achieved in excess of 1 x 10^9 rad(Si)/sec on a LINAC, probably due to a quieter test set-up.

5. Heavy Ion Single Event Results

Summary

Single event phenomena includes any manifestation of upset induced by a single ion strike, including soft errors (bit flips or SEU), hard errors, latchup and burnout. For the 64K PROM, the array itself is inherently immune to bit flips, but the address and data latches are susceptible to upset. Single event upset and latch-up testing of the 64K PROM was performed at Brookhaven National Laboratories using their Tandem Van de Graaff generator. With the setup used, only the data latches could be monitored for upset and it was found that they did not upset up to an effective LET of 116 (Gold at a 45 degree angle).

Procedure

Radiation Source - The Tandem Van de Graaff generator at Brookhaven National Laboratory (BNL) in Upton, Long Island, New York, was used to provide the heavy ions. The tandem beams have small emittance and extreme energy stability allowing them to be focused down to less than 1mm in diameter, or, on the other hand, easily defocussed and/or swept for uniformly exposing large areas. A minimum exposure fluence of 10^6 ions/cm^2 should be used (10^7 ions/cm^2 preferred), with an exposure flux of at least 10^4 ions/cm^2/second (10^5ions/cm^2/second preferred). The preferred fluence and flux were usually achieved.

Ion Species - The two ion species used were: Bromine (Z = 35, A = 79, MEV = 285, MEV/AMU = 3.61, Range = 36.4µm, LET = 37.3 MEV/mg/cm^2) and Gold (Z = 79, A = 197, MEV = 345, MEV/AMU = 1.75, Range = 27.9µm, LET = 82.3 MEV/mg/cm^2). The effective LETs were able to be increased by increasing the angle of incidence.

Test Samples - Six (6) fully functional parts from lot T40740 were used. Four (4) were programmed with a special count up/count down pattern blown in them (see dose rate description), 1 had a physical checkerboard pattern blown in it (01010101), 1 had location 0 blown to a checkerboard (10101010) pattern, the last location blown to all 1's (11111111) and all other locations blank. The last part had location 0 blown to all 1's (11111111), the last location blown to a checkerboard (10101010) pattern, and all other locations blank. These patterns were chosen so that if any address or data latch is upset, a change in one of the 8 outputs could be noted.

Pre-Exposure Electrical Tests - Pre-exposure electrical tests were performed on each part per the data sheet test program. All pre-exposure data were recorded.

Test Procedure - The 6 devices described previously were loaded onto a specially built board and placed inside the vacuum chamber. A ribbon cable connected each device to cinch connector in the bottom of the vacuum chamber. Another ribbon cable connected to the other side and ran to the test setup. All inputs and outputs were accessible externally. Proper operation of all of the parts and monitoring equipment was verified prior to exposure. During testing the address pins were set to the desired state, $\overline{CE}$ and $\overline{G}$ were held low (active with the outputs enabled), and the minimum bias of 4.5V applied. All testing was done at room temperature.

The first device tested was exposed to a Bromine ion at an incident angle of 0 degrees while maintaining $\overline{CE}$ high. During exposure, the device outputs were monitored to ensure multiple upsets were not occurring which could indicate that the flux rate was too high. After exposure, the device outputs were monitored for upset with a DVM, and device current was monitored on the current meter. No upset was observed after the first exposure so the angle was increased to 45 degrees and the exposure repeated. No upset was again observed, so it was proceeded to the next device to be tested and the procedure was repeated until all 6 devices had been tested. No upsets were observed on any of the parts.

The beam was changed to Gold and the entire procedure was repeated, and again no upsets were recorded. The bias voltage of the PROM was then decreased to about 3.0V and the procedure was repeated with the same results - no upsets.

Conclusions

Although the PROM array is inherently immune to single event upsets, it was believed that the data latches could be upset. However, testing proved that the hardened design used for the sense amps/data latches was very effective in preventing upsets, with none being seen up to an effective LET of 116MEV. No evidence of latch-up was observed either.

6. Summary of Results

The Harris 64K CMOS PROM (HS-6664RH) was characterized for the following types of radiation environments: 1) neutron, 2) total dose and rebound, 3) dose-rate, and 4) heavy ion single-event. No sensitivity to a neutron fluence of $10^{14}/cm^2$ was seen. The 64K PROM easily exceeds its data sheet total dose specification of 300K rad(Si), with only minor parametric shifts noted and no evidence of rebound.

As for dose rate irradiation, a minimum transient output upset level of 5 x 10^8 rad(Si)/sec was obtained with no evidence of latch-up at 5 x 10^{11} rad(Si)/sec. A permanent change of state of the outputs occurred at 6 x 10^9 rad(Si)/sec.

The PROM array is inherently immune to single event upsets and heavy ion testing was used to successfully prove how effective the hardened design used for the sense amps/data latches were in preventing upsets, with none being seen up to an effective LET of 116MEV. No evidence of latch-up was observed either.

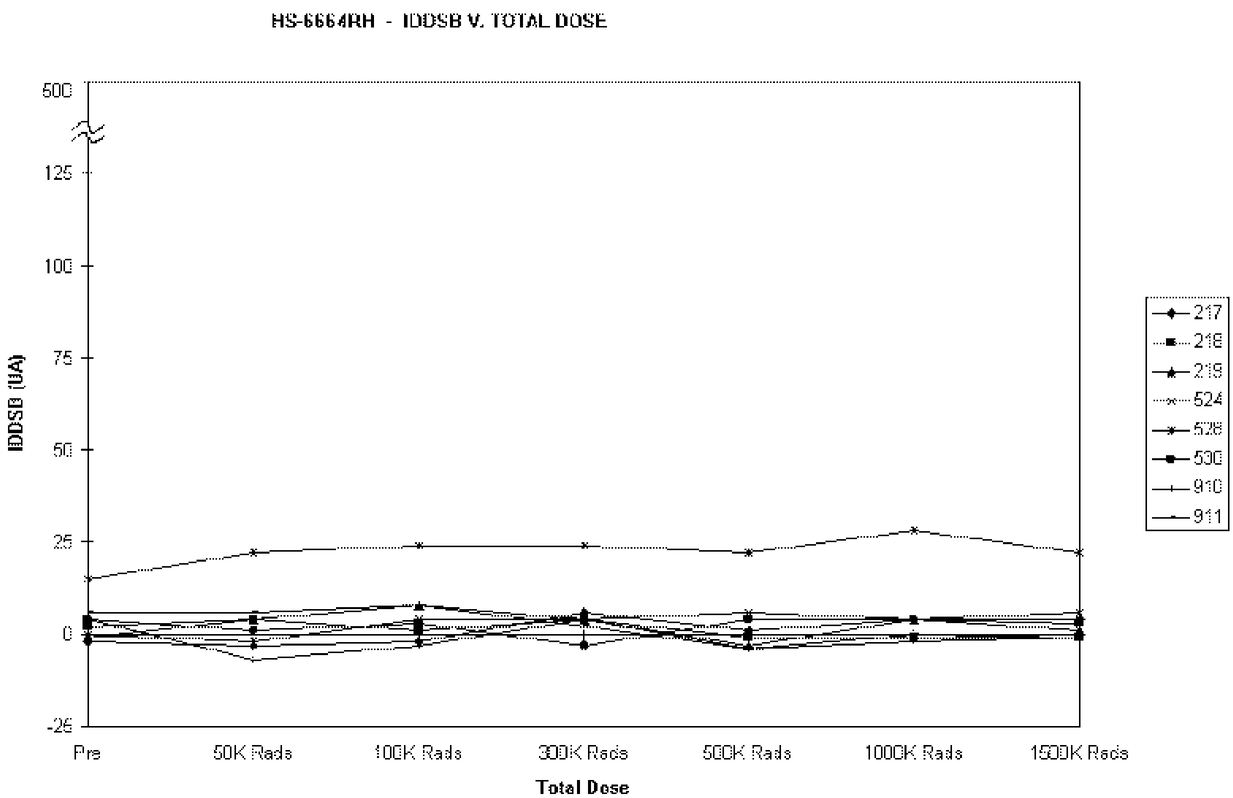

FIGURE 1. 64K PROM STANDBY CURRENT (I_{DDSB}) OVER TOTAL DOSE

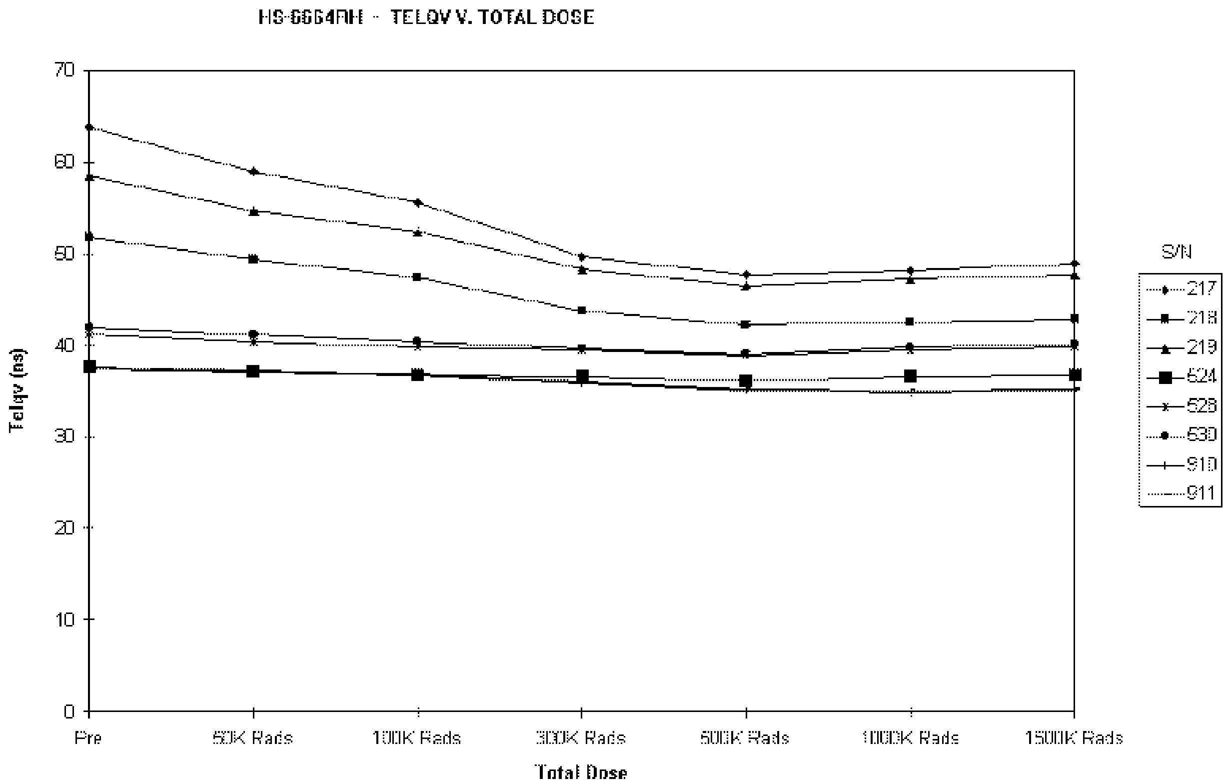

FIGURE 2. 64K PROM ACCESS TIME (T_{ELQV}) OVER TOTAL DOSE

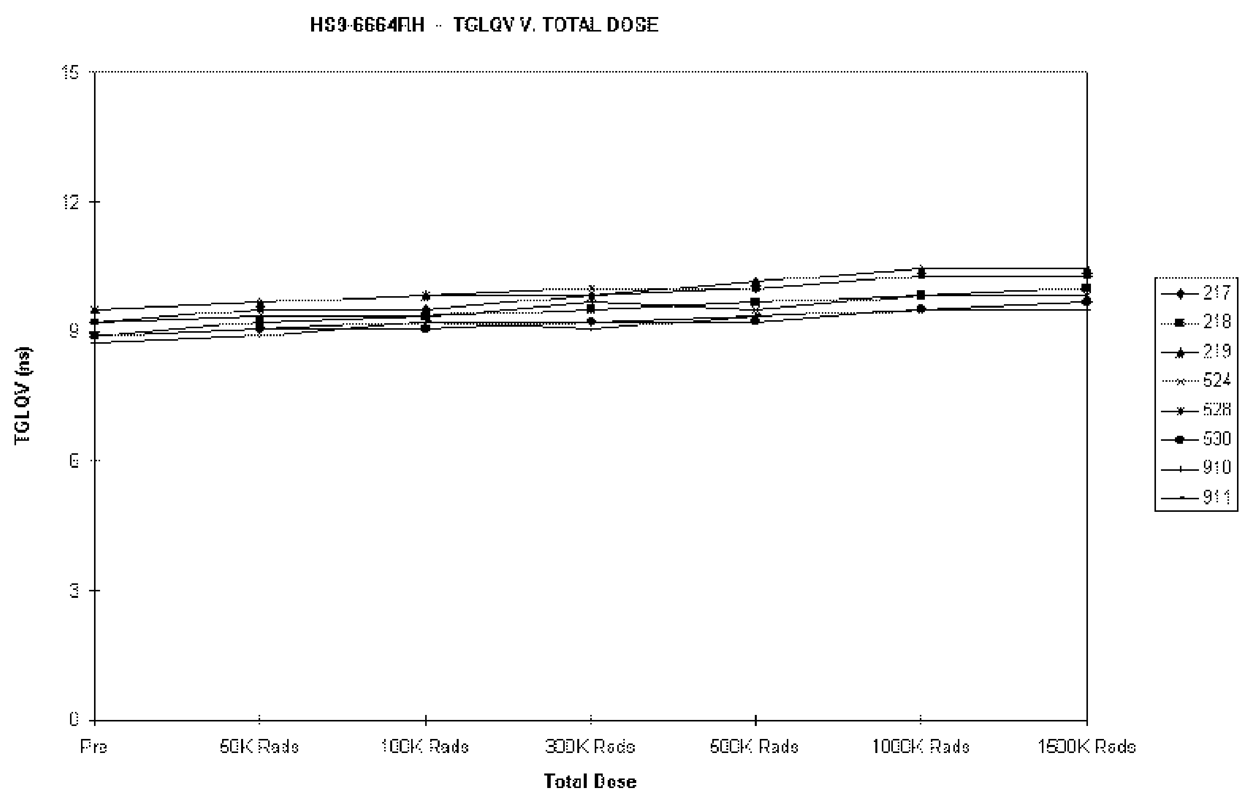

FIGURE 3. 64K PROM OUTPUT ENABLE TIME (T_{GLQV}) OVER TOTAL DOSE

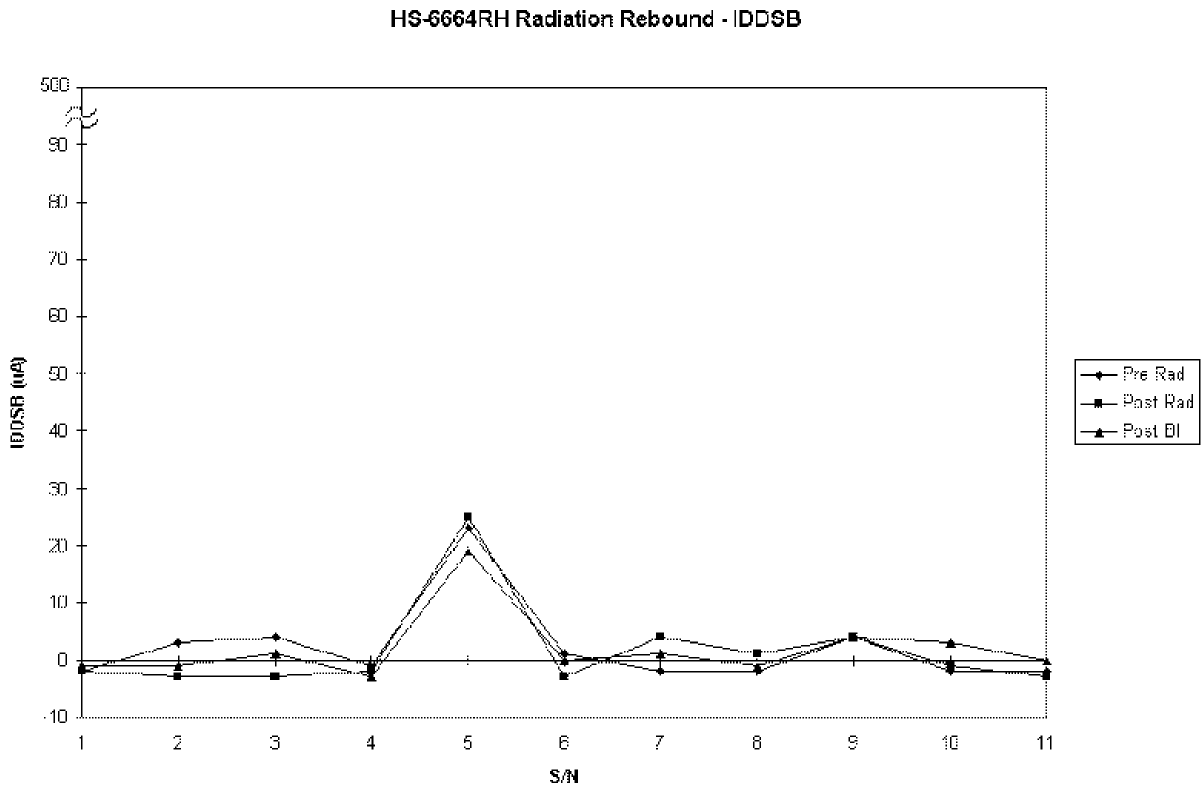

FIGURE 4. COMPARISON OF THE 64K PROM'S STANDBY CURRENT (I_{DDSB}) FROM PRE-RAD TO POST-RAD TO POST BURN-IN FOR 11 UNITS TESTED

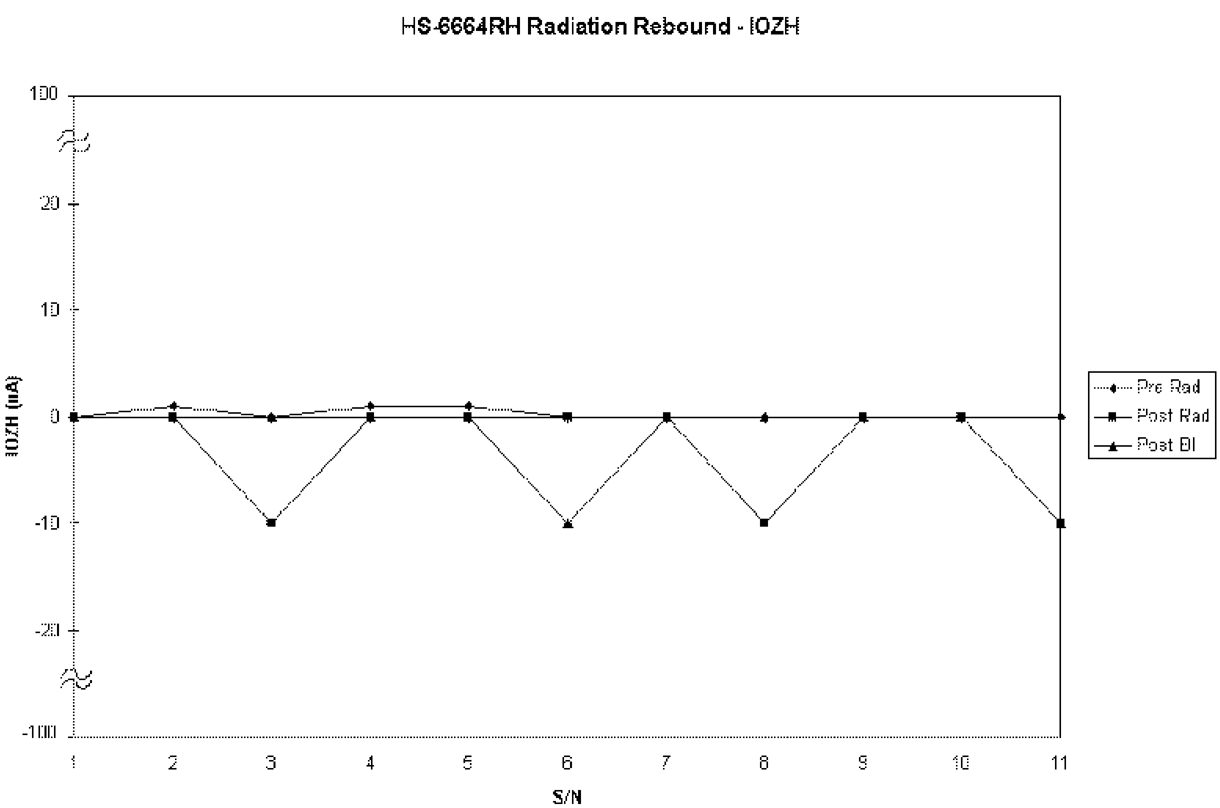

FIGURE 5. COMPARISON OF 64K PROM OUTPUT DRIVE CURRENT HIGH (I_{OZH})

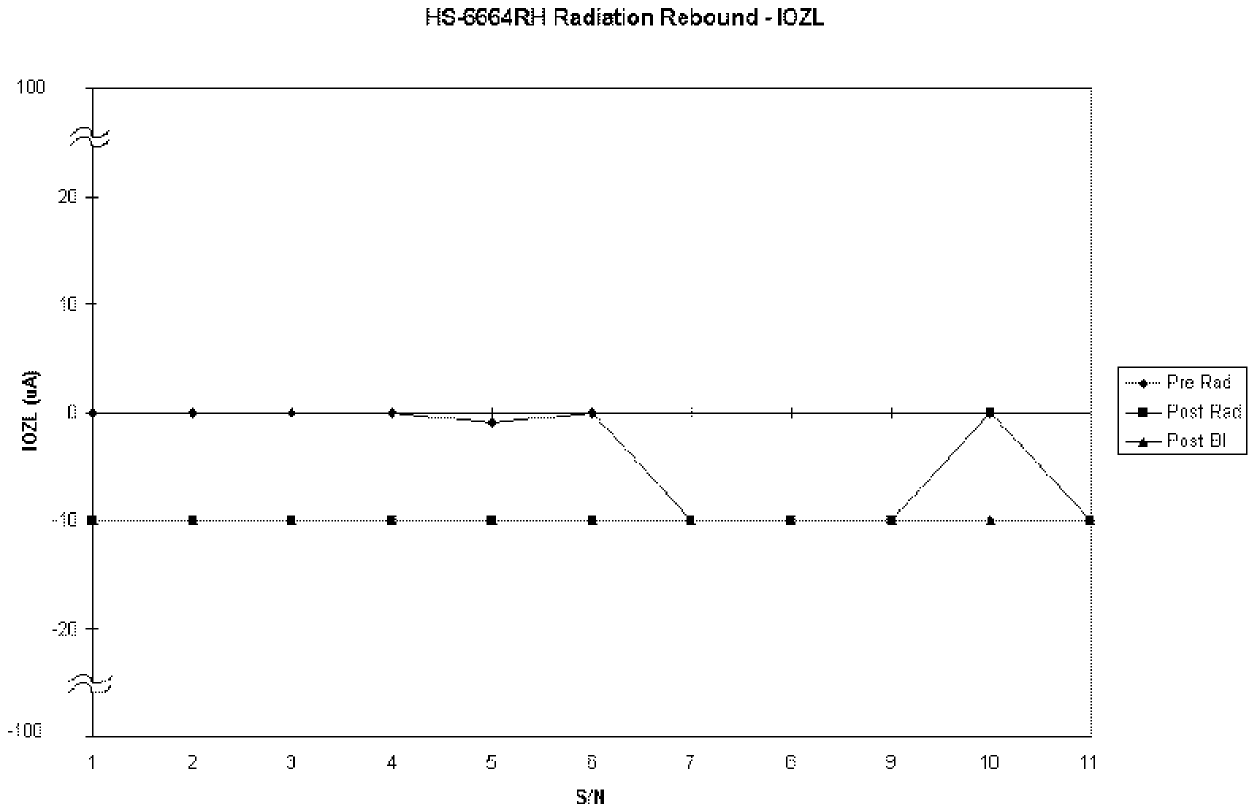

FIGURE 6. COMPARISON OF 64K PROM OUTPUT DRIVE CURRENT LOW (I_{OZL})

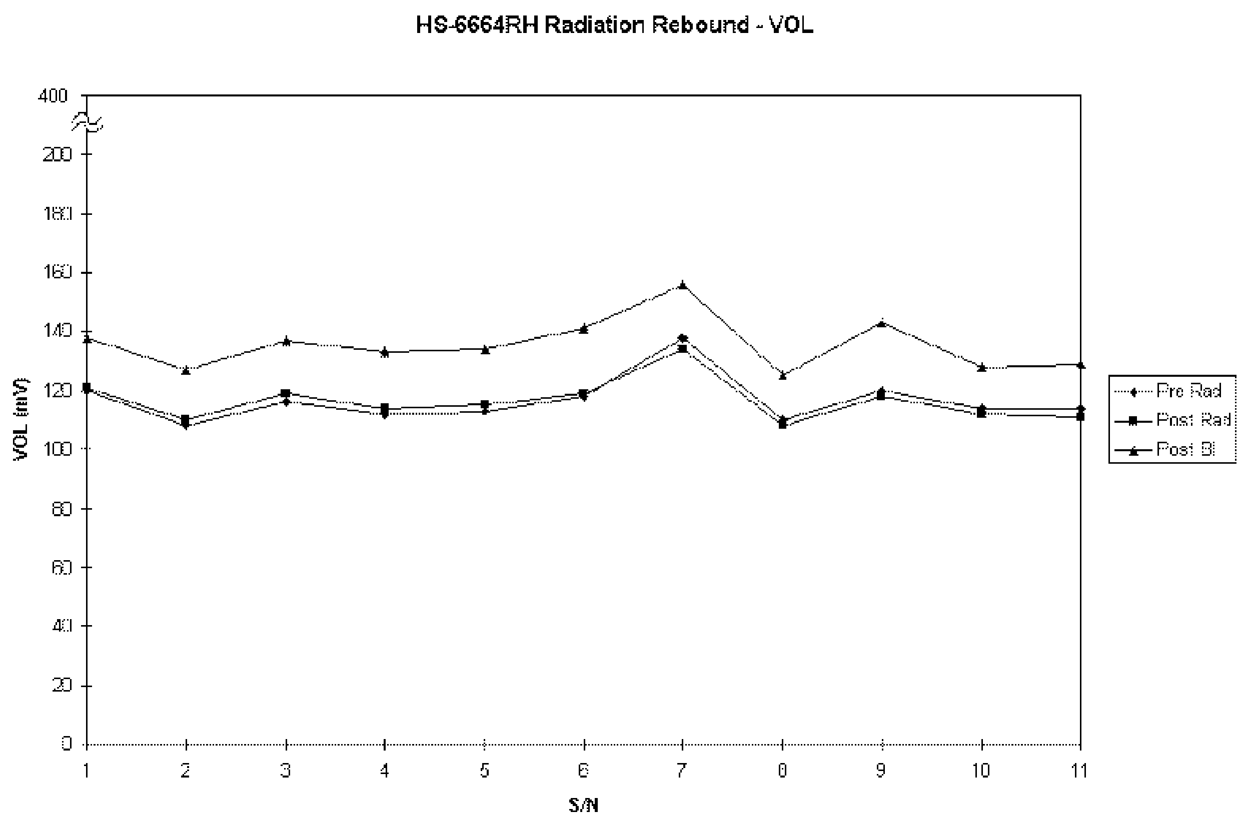

FIGURE 7. COMPARISON OF 64K PROM OUTPUT DRIVE VOLTAGE LOW (V_{OL})

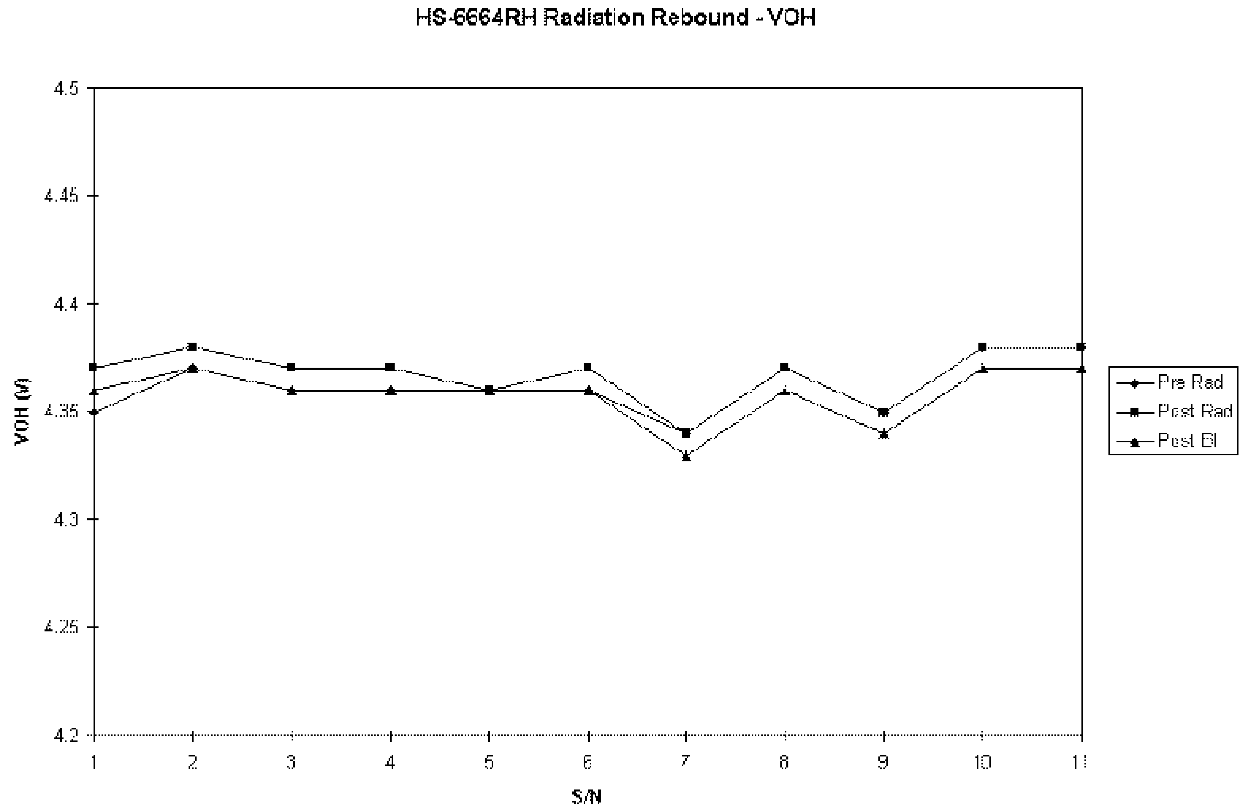

FIGURE 8. COMPARISON OF 64K PROM OUTPUT DRIVE VOLTAGE HIGH (V_{OH})

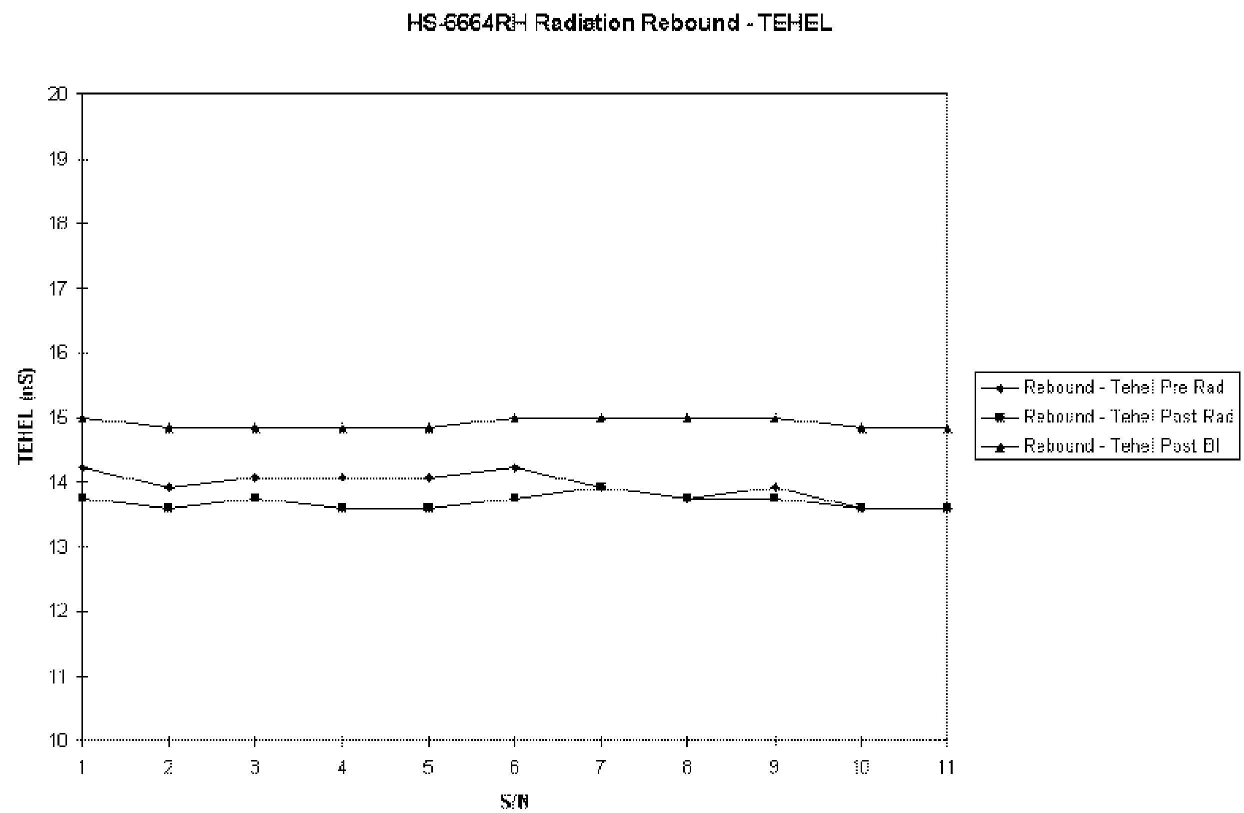

FIGURE 9. COMPARISON OF 64K PROM ENABLE HIGH TO ENABLE LOW TIME (T_{EHEL})

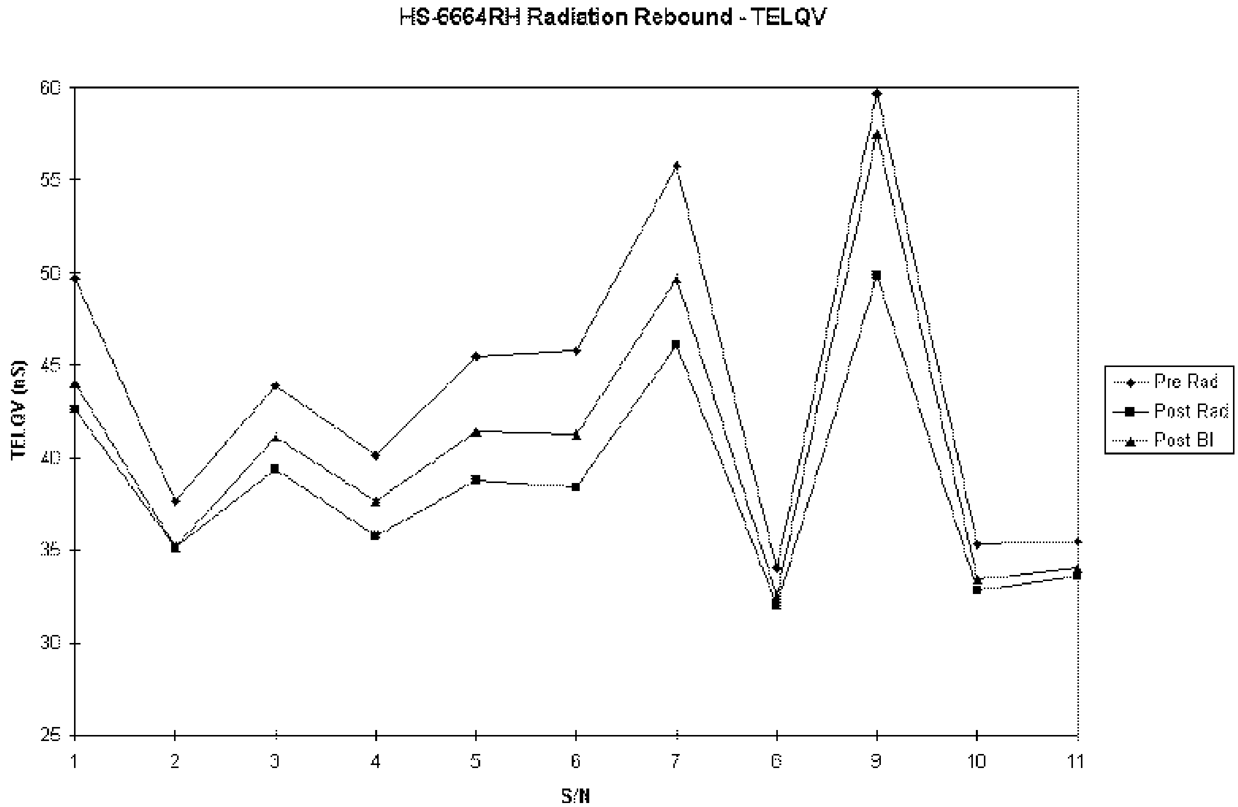

FIGURE 10. COMPARISON OF 64K PROM ACCESS TIME (T_{ELQV})

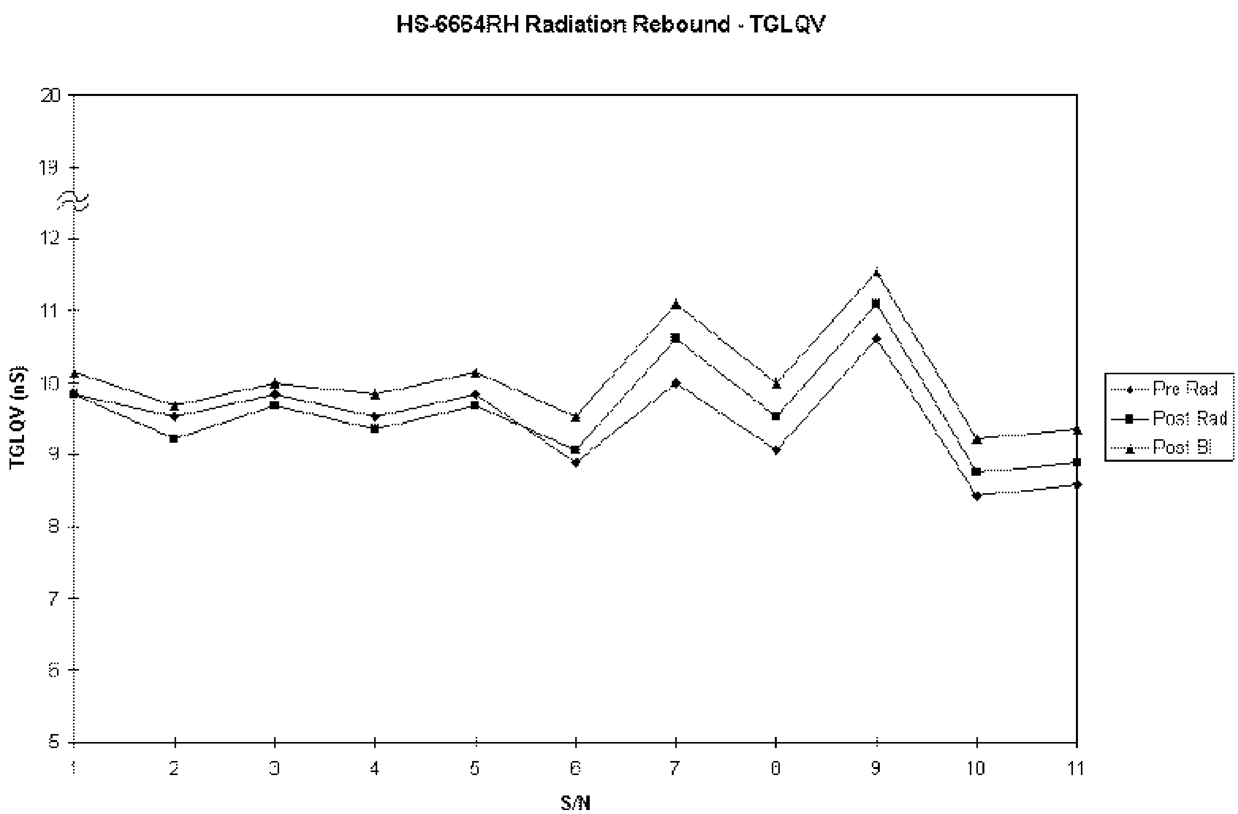

FIGURE 11. COMPARISON OF 64K PROM OUTPUT ENABLE TO OUTPUT VALID (T_{GLQV})

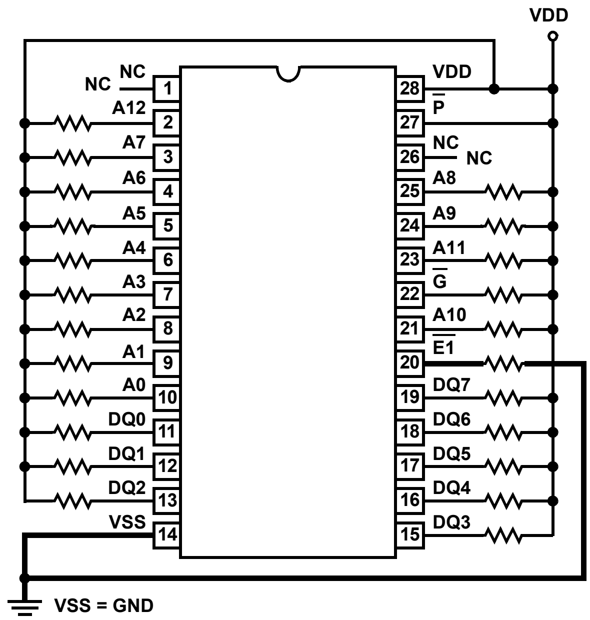

FIGURE 12. IRRADIATION CONFIGURATION HS1-6664RH (8K x 8 PROM DIP)

NOTES:

1. Power Supply: VDD = 5.5V ±0.5V
2. Resistors = 47kΩ ±10%

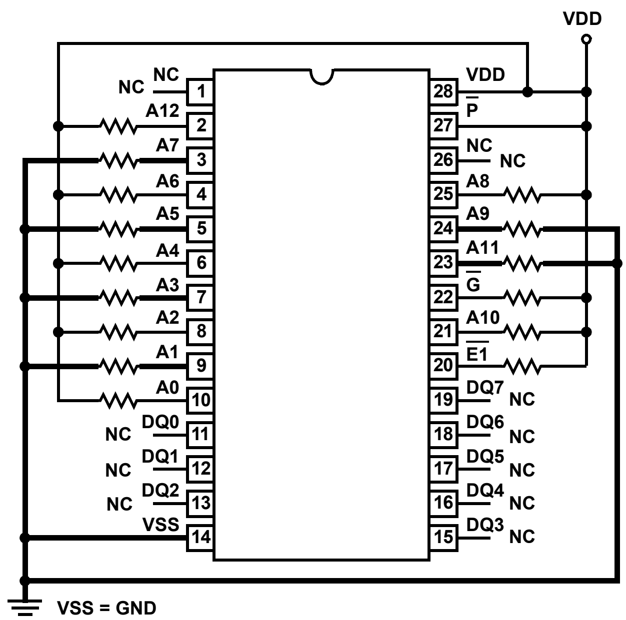

FIGURE 13. STATIC BURN-IN CONFIGURATION HS1-6664RH (8K x 8 PROM DIP), HS9-6664RH (8K X 8 PROM FLATPACK)

NOTES:

1. Power Supply: VDD = 5.5V minimum
2. Resistors = 10kΩ ±10%

IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES (“RENESAS”) PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers skilled in the art designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only for development of an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising out of your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Rev.1.0 Mar 2020)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/