Government Systems Group

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DATE: September 12, 1995
TO: G. Kramer/311
FROM: K. Sahu/300.1 KS
SUBJECT: Radiation Report on: 28C256
Project: AXAF/Gulton
Control #: 13781
Job #: EE56461
Project part #: 28C256EF-25

PPM-95-175

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A radiation evaluation was performed on 28C256 (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^{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 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18 and 20 krads*. The dose rate was between 0.06 and 0.13 krads/hour (see Table II for radiation schedule). After the 3 krad exposure, the parts were annealed for 24 hours at 25°C, and after the 20 krad exposure, the parts were annealed for 192 hours at 25°C. After each radiation exposure, parts were electrically tested according to the test conditions and the specification limits** listed in Table III 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. After the start of the radiation exposures, two additional functional tests were added to the original six: READ CHKBD at Vcc = 4.5 V and READ CHKBD at Vcc = 5.5 V.

All parts passed initial electrical measurements. All irradiated parts passed all electrical parametric tests throughout all irradiation steps up to and including the 16 krad irradiation level (for details of parametric test results, see Appendix A).

All irradiated parts (S/N 52, 53, 54 and 55) passed all functional tests throughout all irradiation steps up to and including the 2 krad irradiation level; however, S/N 52 began failing functional tests at the 3 krad level.

A brief summary of the results of the functional testing is as follows:

- S/N 53, 54 and 55 passed all WR/RD ZEROES, WR/RD ONES and WR/RD CHKBD tests at Vcc = 4.5 and 5.5 V up to and including 14 krads.
- S/N 52 passed all WR/RD ZEROES, WR/RD ONES and WR/RD CHKBD tests at Vcc = 4.5 and 5.5 V up to and including 2 krads.
- S/N 52 failed WR/RD CHKBD at Vcc = 5.5 V after 3 krads, after 24 hours annealing at 25°C and after 4 krads, but passed WR/RD CHKBD at Vcc = 4.5 V.
- S/N 52 passed WR/RD CHKBD at Vcc = 4.5, 5 and 5.25 V, but failed at Vcc = 5.5 V after 4 krads and 5 krads.

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

- S/N 52 passed WR/RD CHKBD at 4.5 and 5 V and failed at 5.25 and 5.5 V after 6, 7, 8 and 9 krads.
- S/N 52 failed WR/RD CHKBD at 5.0, 5.25 and 5.5 V, but passed at 4.5 V at 10, 12 and 14 krads.
- Note that, with increasing radiation exposure, S/N 52 failed WR/RD CHKBD at progressively lower values of Vcc.

At the 16 krad level and above, other radiation-induced functional and parametric failures began to be observed in other parts.

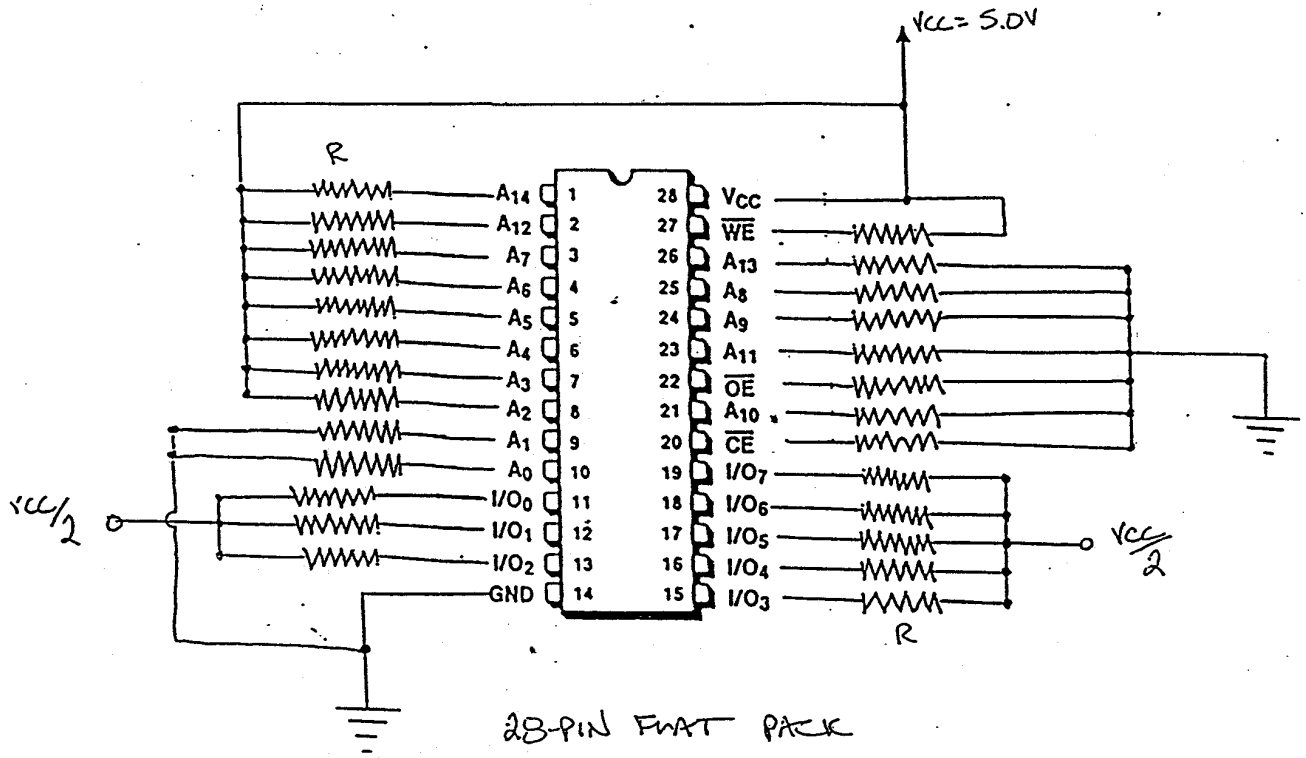
During the course of the testing, many changes were made in the sequence of functional tests in order to determine the cause of the premature functional failures in S/N 52. These changes are detailed in Appendix A. It was ultimately determined that these failures were due to the inability to write a valid checkerboard pattern with Vcc greater than some value intermediate between 4.5 and 5.5 V depending on the value of accumulated radiation dose.

In summary, except for S/N 52, no functional or parametric radiation-induced failures were observed up to and including the 14 krad level.

Table IV provides a summary of the functional test results and the mean and standard deviation values for each parameter after each irradiation exposure 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.

Figure 1. Radiation Bias Circuit for 28C256



1) Vcc = +5.0 VDC ± 0.5 VDC, Vcc/2 = 2.5 VDC ± 0.25 VDC

2) All resistors R = 2.0K Ohms ± 10%, 1/4 W

TABLE I. Part Information

Generic Part Number:	28C256*
AXAF/Gulton Part Number	28C256EF-25
AXAF/Gulton Control Number:	13781
Charge Number:	EE56461
Manufacturer:	SEEQ
Lot Date Code (LDC):	9526
Quantity Tested:	6
Serial Number of Control Samples:	50, 51
Serial Numbers of Radiation Samples:	52, 53, 54, 55
Part Function:	EEPROM
Part Technology:	MOSFET
Package Style:	28-pin Flatpack
Test Equipment:	S-50
Engineer:	K. Kim

* No radiation tolerance/hardness was guaranteed by the manufacturer for this part.

TABLE II. Radiation Schedule for 28C256

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	05/17/95
2) 1 KRAD IRRADIATION (0.059 KRADS/HOUR)	07/17/95
POST-1 KRAD ELECTRICAL MEASUREMENT	07/18/95
3) 2 KRAD IRRADIATION (0.059 KRADS/HOUR)	07/18/95
POST-2 KRAD ELECTRICAL MEASUREMENT	07/19/95
4) 3 KRAD IRRADIATION (0.058 KRADS/HOUR)	07/19/95
POST-3 KRAD ELECTRICAL MEASUREMENT	07/20/95
5)24 HOUR ANNEALING @ 25°C	07/20/95
POST-24 HOUR ANNEAL ELECTRICAL MEASUREMENT	07/21/95
6) 4 KRAD IRRADIATION (0.059 KRADS/HOUR)	07/23/95
POST-4 KRAD ELECTRICAL MEASUREMENT	07/24/95
7) 5 KRAD IRRADIATION (0.059 KRADS/HOUR)	07/24/95
POST-5 KRAD ELECTRICAL MEASUREMENT	07/25/95
8) 6 KRAD IRRADIATION (0.059 KRADS/HOUR)	07/25/95
POST-6 KRAD ELECTRICAL MEASUREMENT	07/26/95
9) 7 KRAD IRRADIATION (0.059 KRADS/HOUR)	07/26/95
POST-7 KRAD ELECTRICAL MEASUREMENT	07/27/95
10) 8 KRAD IRRADIATION (0.059 KRADS/HOUR)	07/27/95
POST-8 KRAD ELECTRICAL MEASUREMENT	07/28/95
11) 9 KRAD IRRADIATION (0.059 KRADS/HOUR)	07/31/95
POST-9 KRAD ELECTRICAL MEASUREMENT	08/01/95
12) 10 KRAD IRRADIATION (0.059 KRADS/HOUR)	08/01/95
POST-10 KRAD ELECTRICAL MEASUREMENT	08/02/95
13) 12 KRAD IRRADIATION (0.12 KRADS/HOUR)	08/02/95
POST-12 KRAD ELECTRICAL MEASUREMENT	08/03/95
14) 14 KRAD IRRADIATION (0.12 KRADS/HOUR)	08/03/95
POST-14 KRAD ELECTRICAL MEASUREMENT	08/04/95
15) 16 KRAD IRRADIATION (0.13 KRADS/HOUR)	08/06/95
POST-16 KRAD ELECTRICAL MEASUREMENT	08/07/95
16) 18 KRAD IRRADIATION (0.12 KRADS/HOUR)	08/07/95
POST-18 KRAD ELECTRICAL MEASUREMENT	08/08/95
17) 20 KRAD IRRADIATION (0.12 KRADS/HOUR)	08/08/95
POST-20 KRAD ELECTRICAL MEASUREMENT	08/09/95
18) 192-HOUR ANNEALING @25°C	08/09/95
POST-192 HOUR ANNEAL ELECTRICAL MEASUREMENT	08/17/95

PARTS WERE IRRADIATED AND ANNEALED UNDER BIAS; SEE FIGURE 1.

Table III. Electrical Characteristics of 28C256

PVT OR INITIAL EM'S FUNCTIONAL TESTS PERFORMED

PARAMETER	VCC	VIL	VIH	PATTERN	CONDITIONS	PINS	LIMITS
FUNCT # 1	4.5V	0.0V	4.5V	WR/RD ZEROS	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 2	4.5V	0.0V	4.5V	WR/RD ONES	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 3	4.5V	0.0V	4.5V	WR/RD CHKBD	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 4	5.5V	0.0V	5.5V	WR/RD ZEROS	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 5	5.5V	0.0V	5.5V	WR/RD ONES	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 6	5.5V	0.0V	5.5V	WR/RD CHKBD	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V

POST RADIATION/ANNEALING EM'S FUNCTIONAL TESTS PERFORMED

PARAMETER	VCC	VIL	VIH	PATTERN	CONDITIONS	PINS	LIMITS
FUNCT # 1	4.5V	0.0V	4.5V	READ CHKBD	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 2	5.5V	0.0V	5.5V	READ CHKBD	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 3	4.5V	0.0V	4.5V	WR/RD ZEROS	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 4	4.5V	0.0V	4.5V	WR/RD ONES	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 5	4.5V	0.0V	4.5V	WR/RD CHKBD	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 6	5.5V	0.0V	5.5V	WR/RD ZEROS	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 7	5.5V	0.0V	5.5V	WR/RD ONES	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V
FUNCT # 8	5.5V	0.0V	5.5V	WR/RD CHKBD	FREQ=0.5 MHZ	I/O'S	VOL<1.0V , VOH>2.0V

DC PARAMETRIC TESTS PERFORMED

PARAMETER	VCC	VIL	VIH	CONDITIONS	PINS	LIMITS @ +25C
VOL	4.5V	0.8V	2.0V	LOAD = +2.1MA	OUTS	> 0.0V , < 0.45V
VOH	4.5V	0.8V	2.0V	LOAD = -400UA	OUTS	> 2.4V , < 4.5V
IIL	5.5V	0.1V	5.5V	TSTV = +0.1V	INS	>-100NA , <+100NA
IIH	5.5V	0.0V	5.5V	TSTV = +5.5V	INS	>-100NA , <+100NA
IOZL	5.5V	0.1V	5.5V	TSTV = +0.1V	OUTS	>-500NA , <+500NA
IOZH	5.5V	0.0V	5.5V	TSTV = +5.5V	OUTS	>-500NA , <+500NA
IOE	5.5V	0.0V	5.5V	TSTV = +13.0V	OE	>-10UA , <+100UA
ICC1	5.5V	0.0V	5.5V	FREQ = 5.0MHZ	VCC	> 0MA , < 80MA
ICCL2	5.5V	0.8V	2.0V	CE=VIH, VI&OE=VIL	VCC	> 0MA , < 3MA
ICCH2	5.5V	0.8V	2.0V	VI&CE=VIH, OE=VIL	VCC	> 0MA , < 3MA
ICCL3	5.5V	0.0V	5.2V	CE=VIH, VI=VIL	VCC	> 0UA , < 350UA
ICCH3	5.5V	0.0V	5.2V	CE=VIH, VI=VIH	VCC	> 0UA , < 350UA

TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for 28C256 /1

Notes 1-11 are found on Page 10.

#	Functional Tests /2	Pattern	Initial	
1	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 0's	P	
2	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 1's	P	
3	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD CHKBD	P	
4	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD 0's	P	
5	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD 1's	P	
6	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD CHKBD	P	

#	Functional Tests /3	Pattern	Total Dose Exposure (TDE) (krad) 1		2		3		Annealing 24 hrs@25°C		TDE 4	
1	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	READ CHKBD	P		P		3P1F		3P1F		3P1F	
2	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	READ CHKBD	P		P		3P1F		3P1F		3P1F	
3	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 0's	P		P		P		P		P	
4	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 1's	P		P		P		P		P	
5	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD CHKBD	P		P		P		P		P	
6	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD 0's	P		P		P		P		P	
7	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD 1's	P		P		P		P		P	
8	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD CHKBD	P		P		3P1F		3P1F		3P1F	

#	Parameters	Units	Spec. Lim./9 min	max	Initial mean	sd	#	Parameters	Units	Spec. Lim./9 min	max	1 mean	sd	2 mean	sd	3 mean	sd	24 hrs@25°C mean	sd	4 mean	sd
1	VOL	mV	0	450	82.9	1.6	1	VOL	mV	0	450	83.2	1.8	83.2	2.2	82.7	1.8	/10		84.7	2.1
2	VOH	V	2.4	4.5	3.65	.01	2	VOH	V	2.4	4.5	3.65	.01	3.66	.02	3.66	.01	/10		3.65	.01
3	IIL	µA	-10	10	0	0	3	IIL	µA	-10	10	0	0	0	0	0	0	/10		0	0
4	IIH	µA	-10	10	0	0	4	IIH	µA	-10	10	0	0	0	0	0	0	/10		0	0
5	IOZL	µA	-10	10	0	0	5	IOZL	µA	-10	10	0	0	0	0	0	0	/10		0	0
6	IOZH	µA	-10	10	0	0	6	IOZH	µA	-10	10	0	0	0	0	0	0	/10		0	0
7	IOE	µA	-10	100	7.79	.16	7	IOE	µA	-10	100	7.83	.17	8.02	.30	7.98	.19	/10		7.89	.18
8	ICC1	mA	0	80	7.40	.09	8	ICC1	mA	0	80	7.46	.10	7.59	.22	7.31	.51	/10		7.22	.50
9	ICCL2	mA	0	3	1.71	.02	9	ICCL2	mA	0	3	1.68	.02	1.72	.12	1.65	.01	/10		1.61	.01
10	ICCH2	mA	0	3	1.71	.02	10	ICCH2	mA	0	3	1.68	.02	1.72	.12	1.65	.02	/10		1.61	.02
11	ICCL3	µA	0	350	40.0	0	11	ICCL3	µA	0	350	40.0	0	44.8	3.9	40.0	0	/10		36.5	4.5
12	ICCH3	µA	0	350	42.0	3.5	12	ICCH3	µA	0	350	37.8	3.9	41.6	3.2	35.5	4.5	/10		38.8	3.9

TABLE IV (Cont'd.): Summary of Electrical Measurements after Total Dose Exposures and Annealing for 28C256 /1

Notes 1-11 are found on Page 10.

#	Functional Tests /4	Pattern	Retest /5		TDE	
			4		5	
1	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	READ CHKBD	3P1F		3P1F	
2	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	READ CHKBD	3P1F		3P1F	
3	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	READ CHKBD	3P1F		3P1F	
4	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	READ CHKBD	3P1F		3P1F	
5	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 0's	P		P	
6	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 1's	P		P	
7	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD CHKBD	P		P	
8	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD 0's	P		P	
9	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD 1's	P		P	
10	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD CHKBD	P		P	
11	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD 0's	P		P	
12	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD 1's	P		P	
13	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD CHKBD	P		P	
14	Vcc=5.5V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD 0's	P		P	
15	Vcc=5.5V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD 1's	P		P	
16	Vcc=5.5V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD CHKBD	3P1F		3P1F	

#	Parameters	Units	Spec. Lim./9 min	Spec. Lim./9 max	4 mean	4 sd	5 mean	5 sd
1	VOL	mV	0	450	/10		84.3	1.9
2	VOH	V	2.4	4.5	/10		3.65	.01
3	IIL	µA	-10	10	/10		0	0
4	IIH	µA	-10	10	/10		0	0
5	IOZL	µA	-10	10	/10		0	0
6	IOZH	µA	-10	10	/10		0	0
7	IOE	µA	-10	100	/10		7.98	.18
8	ICC1	mA	0	80	/10		7.30	.51
9	ICCL2	mA	0	3	/10		1.59	.02
10	ICCH2	mA	0	3	/10		1.59	.02
11	ICCL3	µA	0	350	/10		35.5	4.5
12	ICCH3	µA	0	350	/10		44.0	4.0

#	Functional Tests /6	Pattern	Total Dose Exposure (TDE) (krads) 6		7		8		9	
1	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	READ CHKBD	3P1F		3P1F		3P1F		3P1F	
2	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	READ CHKBD	3P1F		3P1F		3P1F		3P1F	
3	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	READ CHKBD	3P1F		3P1F		3P1F		3P1F	
4	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	READ CHKBD	3P1F		3P1F		3P1F		3P1F	
5	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 0's	P		P		P		P	
6	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 1's	P		P		P		P	
7	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD CHKBD	P		P		P		P	
8	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD 0's	P		P		P		P	
9	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD 1's	P		P		P		P	
10	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD CHKBD	3P1F		3P1F		3P1F		3P1F	
11	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD 0's	P		P		P		P	
12	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD 1's	P		P		P		P	
13	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD CHKBD	P		P		P		P	
14	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD 0's	P		P		P		P	
15	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD 1's	P		P		P		P	
16	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD CHKBD	3P1F		3P1F		3P1F		3P1F	

#	Parameters	Units	Spec. Lim./9 min	Spec. Lim./9 max	6 mean	6 sd	7 mean	7 sd	8 mean	8 sd	9 mean	9 sd
1	VOL	mV	0	450	84.1	1.9	83.9	2.1	84.3	2.0	84.8	2.2
2	VOH	V	2.4	4.5	3.66	6.5	3.66	7.1	3.66	.01	3.65	.01
3	IIL	µA	-10	10	0	0	0	0	0	0	0	0
4	IIH	µA	-10	10	0	0	0	0	0	0	0	0
5	IOZL	µA	-10	10	0	0	0	0	0	0	0	0
6	IOZH	µA	-10	10	0	0	0	0	0	0	0	0
7	IOE	µA	-10	100	8.05	.19	8.11	.18	8.15	.19	8.17	.18
8	ICC1	mA	0	80	7.36	.52	7.38	.51	7.40	.52	7.43	.49
9	ICCL2	mA	0	3	1.58	.02	1.56	.01	1.54	.02	1.51	.02
10	ICCH2	mA	0	3	1.58	.02	1.55	.02	1.54	.02	1.52	.02
11	ICCL3	µA	0	350	31.0	0	42.0	3.5	42.0	3.5	39.8	6.0
12	ICCH3	µA	0	350	37.8	3.9	44.0	4.0	40.0	0	31.0	0

TABLE IV (Cont'd.): Summary of Electrical Measurements after Total Dose Exposures and Annealing for 28C256 /1

Notes 1-11 are found on Page 10.

#	Functional Tests /7	Pattern	Total Dose Exposure (TDE) (krads) 10	12	14	16	18	20	Annealing /8 192 hrs@25°C
1	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	READ CHKBD	3P1F	P	P	3P1F	2P2F	2P2F	F
2	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	READ CHKBD	3P1F	P	P	3P1F	2P2F	2P2F	F
3	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	READ CHKBD	3P1F	P	P	3P1F	2P2F	2P2F	F
4	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	READ CHKBD	3P1F	P	P	3P1F	2P2F	2P2F	F
5	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD 0's	P	P	P	P	P	P	P
6	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD 1's	P	P	P	P	3P1F	2P2F	1P2F
7	Vcc=5.0V,Vil=0.0V,Vih=5.0V,Freq.=0.5MHz	WR/RD CHKBD	3P1F	3P1F	3P1F	2P2F	1P3F	F	1P2F
8	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD 0's	P	P	P	P	3P1F	P	P
9	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD 1's	P	P	P	P	3P1F	2P2F	P
10	Vcc=5.25V,Vil=0.0V,Vih=5.25V,Freq.=0.5MH	WR/RD CHKBD	3P1F	3P1F	3P1F	2P2F	1P3F	F	1P2F
11	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD 0's	P	P	P	P	3P1F	P	2P1F
12	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD 1's	P	P	P	P	3P1F	3P1F	2P1F
13	Vcc=5.5V,Vil=0.0V,Vih=5.5V,Freq.=0.5MHz	WR/RD CHKBD	3P1F	3P1F	3P1F	2P2F	1P3F	F	1P2F
14	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 0's	P	P	P	P	3P1F	P	2P1F
15	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD 1's	P	P	P	P	2P2F	2P2F	1P2F
16	Vcc=4.5V,Vil=0.0V,Vih=4.5V,Freq.=0.5MHz	WR/RD CHKBD	P	P	P	3P1F	2P2F	F	1P2F

#	Parameters	Units	Spec. Lim./9 min	max	10 mean	sd	12 mean	sd	14 mean	sd	16 mean	sd	18 mean	sd	20 mean	sd	192 hrs@25°C mean	sd
1	VOL	mV	0	450	84.9	2.3	84.9	2.4	85.4	2.5	F/11		F/11		F/11		F/11	
2	VOH	V	2.4	4.5	3.65	.01	3.65	.02	3.66	.01	3.66	.01	2.75	1.6	3.66	.01	3.65	.01
3	IIL	µA	-10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	IIH	µA	-10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	IOZL	µA	-10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	IOZH	µA	-10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	IOE	µA	-10	100	8.18	.19	8.24	.18	8.31	.18	8.44	.17	8.50	.17	8.56	.17	8.48	.18
8	ICC1	mA	0	80	7.71	.07	7.75	.06	7.82	.07	7.61	.45	7.41	.56	6.95	.08	7.27	.54
9	ICCL2	mA	0	3	1.50	.02	1.48	.02	1.45	.02	1.43	.02	1.40	.02	1.37	.02	1.36	.02
10	ICCH2	mA	0	3	1.51	.02	1.49	.02	1.45	.02	1.43	.02	1.40	.02	1.37	.02	1.37	.02
11	ICCL3	µA	0	350	37.8	3.9	44.0	4.0	44.0	4.0	44.0	4.0	50.3	3.9	52.5	4.5	40.0	0
12	ICCH3	µA	0	350	39.8	6.0	42.0	3.5	48.0	0	46.0	3.5	48.0	0	57.0	0	48.3	6.9

TABLE IV (Cont'd.): Summary of Electrical Measurements after Total Dose Exposures and Annealing for 28C256 /1

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/ "P" indicates that all parts passed this test at this irradiation or annealing level. "F" indicates that all parts failed this test at this irradiation or annealing level. "nPmF" indicates that n parts passed and m parts failed this test at this irradiation or annealing level.

3/ Prior to the first irradiation, a checkerboard pattern was written into the parts to be irradiated. After the start of irradiation, the test program was modified to include additional tests (see Table III).

4/ After the 3 krad irradiation, a modified set of functional tests was used (see text).

5/ The irradiated parts were retested after the functional test program modification.

6/ After the 5 krad irradiation, the functional test program was again modified (see text).

7/ After the 9 krad irradiation, the functional test program was again modified (see text).

8/ S/N 52, which began to fail functional tests at the 3 krad level, was removed from testing before the annealing step and returned to Tim Canales/Gulton for testing, therefore statistical data at this step are for 3 samples.

9/ These are manufacturer's pre-irradiation data sheet specification limits. No post-irradiation limits were provided by the manufacturer at the time these tests were performed.

10/ No data for these parameters were available at this level.

11/ No valid mean could be calculated for this parameter at these levels.

APPENDIX A

After the 3 krad irradiation, S/N 52 failed Functional Tests # 1 and 2 (READ CHKBD) and Functional Test # 8 (WR/RD CHKBD) at Vcc = 5.5 V. All other irradiated parts passed all other functional and parametric tests at this level.

After annealing for 24 hours at 25°C, no recovery was observed.

After the 4 krad irradiation, the same functional failures were observed in S/N 52. All other irradiated parts passed all other functional and parametric tests at this level.

At this point, it was decided to modify the functional test program in order to determine the Vcc level at which S/N 52 failed the READ CHKBD test , and whether the failure was due to a write or read problem. A new set of sixteen functional tests was devised as follows:

Functional Tests 1-4: READ CHKBD tests at gradually increasing Vcc levels, namely 4.5, 5.0, 5.25 and 5.5 V,
Functional Tests 5-7 WR/RD 0's, WR/RD 1's and WR/RD CHKBD at Vcc = 4.5 V,
Functional Tests 8-10: the same tests at Vcc = 5.0 V,
Functional Tests 11-13: the same tests at Vcc = 5.25 V,
Functional Tests 14-16: the same tests at Vcc = 5.5 V.

The purpose of this modification was to determine at which level S/N 52 failed the READ CHKBD tests, and whether this was due to a read or write problem. No modification was made to the parametric test program.

After this modification, the parts were retested using the new test program. In this test, S/N 52 failed Functional Tests # 1-4 (READ CHKBD) and Functional Test # 16 (WR/RD CHKBD @ Vcc = 5.5 V). All other irradiated parts passed all other functional and parametric tests at this level.

After the 5 krad irradiation, the same functional failures were observed in S/N 52. All other irradiated parts passed all other functional and parametric tests at this level.

After the 5 krad irradiation, the functional test program was again modified, as follows:

Functional Tests 1-4: READ CHKBD tests at gradually increasing Vcc levels, namely 4.5, 5.0, 5.25 and 5.5 V,
Functional Tests 5-7 WR/RD 0's, WR/RD 1's and WR/RD CHKBD at Vcc = 4.5 V,
Functional Tests 8-10: the same tests at Vcc = 5.5 V,
Functional Tests 11-13: the same tests at Vcc = 5.0 V,
Functional Tests 14-16: the same tests at Vcc = 5.25 V.

The purpose of this modification was a further attempt to determine at which level S/N 52 failed the READ CHKBD tests, and whether this was due to a read or write problem.

After the 6 krad irradiation, The same functional failures were observed in S/N 52 and, in addition, S/N 52 failed Functional Test # 10 (WR/RD CHKBD @ Vcc = 5.0 V). All other irradiated parts passed all other functional and parametric tests at this level.

The same failures continued throughout the 7, 8 and 9 krad irradiations. All other irradiated parts passed all other functional and parametric tests at these levels.

After the 9 krad irradiation, it was determined that the READ CHKBD and WR/RD CHKBD failures in S/N 52 were due to a problem in writing the checkerboard pattern at higher voltages. The functional test program was again modified as follows:

Functional Tests 1-4: READ CHKBD tests at gradually increasing Vcc levels, namely 4.5, 5.0, 5.25 and 5.5 V,

Functional Tests 5-7 WR/RD 0's, WR/RD 1's and WR/RD CHKBD at Vcc = 5.0 V,
Functional Tests 8-10: the same tests at Vcc = 5.25 V,
Functional Tests 11-13: the same tests at Vcc = 5.5 V,
Functional Tests 14-16: the same tests at Vcc = 4.5 V.

The reason for deviating from the previous increasing values of Vcc for the last three tests, i.e., writing and reading the checkerboard pattern at 4.5 V instead of 5.5 V, is that, since it had been determined that the failure in S/N 52 was a write, rather than a read problem, and that it occurred at higher values of Vcc, writing the checkerboard pattern at Vcc = 4.5 V just before the next irradiation insured that a valid checkerboard pattern would be written into all the parts before irradiation.

After the 10 krad irradiation, S/N 52 failed Functional Tests # 1-4 (READ CHKBD) and Functional Tests # 7 (WR/RD CHKBD @ Vcc = 5.0 V), 10 (WR/RD CHKBD @ Vcc = 5.25 V) and 16 (WR/RD CHKBD @ Vcc = 4.5 V). All other irradiated parts passed all other functional and parametric tests at this level.

After the 12 krad irradiation, S/N 52 continued to fail Functional Tests # 7, 10 and 16, but passed Functional Tests 1-4. All other irradiated parts passed all other functional and parametric tests at this level.

After the 14 krad irradiation, the same failures were observed in S/N 52. All other irradiated parts passed all other functional and parametric tests at this level.

After the 16 krad irradiation, the same failures were observed in S/N 52. In addition, S/N 50 failed Functional Tests # 1-4 and Functional Tests # 7 (WR/RD CHKBD @ Vcc = 5.0 V), 10 (WR/RD CHKBD @ Vcc = 5.25 V), 13 (WR/RD CHKBD @ Vcc = 5.25 V) and 16 (WR/RD CHKBD @ Vcc = 4.5 V). All other irradiated parts passed all other functional and parametric tests at this level.

After the 18 krad irradiation, the same failures were observed in S/N 52. S/N 50 failed all functional tests except # 5 ((WR/RD 0's @ Vcc = 4.5 V). S/N 53 failed Functional Tests # 1.4, 7, 10, 13, 15 (WR/RD 1's @ Vcc = 4.5 V) and 16. In addition, S/N 50 read 0.0 V for VOH, indicating functional failure, and S/N read -1.011 V for VOL, also indicating functional failure. All other irradiated parts passed all other functional and parametric tests at this level.

After the 20 krad irradiation, S/N 50 failed Functional Tests # 1-4, 6, 7, 9, 10, 12, 13, 15 and 16, S/N 51 and 52 failed Functional Tests # 7, 10, 13 and 16 and S/N 53 failed Functional Tests # 1-4, 6, 7, 9, 10, 13, 15 and 16. S/N 50 read within specification limits for VOH, but all irradiated parts read -1.011 V for VOL. All irradiated parts passed all other functional and parametric tests at this level.

After annealing for 192 hours at 25°C, no recovery was observed.