Unisys

DATE: April 21, 1999 PPM-99-019
TO: T. O'Connor/Ball Aerospace
FROM: K. Sahu/S. Kniffin/300.1
SUBJECT: Radiation Report on **MIC4424 (Micrel) (LDC 9832)**
PROJECT: Ball Aerospace (GOES)

cc: M. D'Ordine/Ball Aerospace, R. Reed/562, A. Sharma/562, OFA Library/300.1

A radiation evaluation was performed on **MIC4424 Dual 3A-Peak Low-Side MOSFET Driver (Micrel)** to determine the total dose tolerance of these parts. The total dose testing was performed using a Co^{60} gamma ray source. During the radiation testing, ten parts were irradiated under Bias Condition B and ten parts were irradiated under Bias Condition C (see Figures 1 and 2 for bias configurations) and two parts were used as control samples. The total dose radiation levels were 5.0, 10.0, 15.0, 20.0, 25.0, 30.0, 40.0, 50.0, and 75.0kRads.[1] The dose rate was 0.21kRads/hour (0.058Rads/s). See Table II for the radiation schedule and effective dose rate calculation. After the 75.0kRad irradiation, the parts were annealed under bias at 25°C for 72 and 168 hours and at 100°C for 72 and 168 hours.[2] After each radiation exposure and annealing treatment, parts were electrically tested **at V_S = 15V** according to the test conditions and the specification limits[3] listed in Table III. An executive summary of the test results is provided below in bold, followed by a detailed summary of the test results after each radiation level and annealing step.

For Bias Condition B (see Figure 1), all parts passed Functional Test 1 up to 25kRads. From 30 to 75kRads, parts failed Functional Test 1 which was performed with V_{IL} = 0.8V, V_{IH} = 2.4V. After 30kRads, Functional Test 2 was added with V_{IL} = 0V, V_{IH} = 4.5V. All parts passed Functional Test 2 up to 75kRads. From 20 to 75kRads, parts showed marginal degradation in TPD_A and TPD_B. At 75kRads, all parts showed excessive readings for Vol and Iol. After annealing the parts under bias at 25°C for 72 and 168 hours, all parts showed no significant recovery in any radiation sensitive parameters. After annealing the parts under bias at 100°C for 72 and 168 hours, all parts showed no rebound effects.

For Bias Condition C (see Figure 2), all parts passed Functional Test 1 up to 20kRads. From 25 to 75kRads, parts failed Functional Test 1 which was performed with V_{IL} = 0.8V, V_{IH} = 2.4V. After 30kRads, Functional Test 2 was added with V_{IL} = 0V, V_{IH} = 4.5V. All parts passed Functional Test 2 up to 75kRads. From 15 to 75kRads, some parts showed marginal degradation in TPD_B. After 50kRads, one part and after 75kRads, all parts, showed excessive readings for Vol and Iol. After annealing the parts under bias at 25°C for 72 and 168 hours, all parts showed no significant recovery in any radiation sensitive parameters. After annealing the parts under bias at 100°C for 72 and 168 hours, all parts showed no rebound effects.

Initial electrical measurements were made on 22 samples. Ten samples (SN's 71, 72, 73, 74, 75, 76, 77, 78, 79, and 80) were used as radiation samples while SN 70 was used as a control sample for bias condition B. Ten samples (SN's 81, 82, 83, 84, 85, 86, 87, 88, 89, and 90) were used as radiation samples while SN 80 was used as a control sample for bias condition C. All parts passed functional tests and all other tests during initial electrical measurements.

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[1] The term Rads, as used in this document, means Rads (silicon). All radiation levels cited are cumulative.
[2] The temperature 25°C as used in this document implies room temperature.
[3] These are manufacturer's pre-irradiation data specification limits. The manufacturer provided no post-irradiation limits at the time these tests were performed.

Bias Condition B

All parts passed all Functional Tests up to 20kRads and all other tests up to 10kRads.

After the 15.0kRad irradiation, one part marginally exceeded the specification limit of 75ns for TPD_B with a reading of 79ns. **All parts passed all other tests.**

After the 20.0kRad irradiation, four parts marginally exceeded the specification limit for TPD_B with readings of 79ns. **All parts passed all other tests.**

After the 25.0kRad irradiation, four parts failed Functional Test 1. One part marginally exceeded the specification limit of 75ns for TPD_A with a reading of 79ns. Five parts marginally exceeded the specification limit for TPD_B with readings of 79ns. **All parts passed all other tests.**

After the 30.0kRad irradiation, nine parts failed Functional Test 1 which was performed with V_{IL} = 0.8V, V_{IH} = 2.4V. At this step, Functional Test 2 was added with V_{IL} = 0V, V_{IH} = 4.5V. All parts passed Functional Test 2. Two parts marginally exceeded the specification limit for TPD_A with readings of 76 and 79ns. Six parts marginally exceeded the specification limit for TPD_B with readings in the range of 79 to 86ns. **All parts passed all other tests.**

After the 40.0kRad irradiation, all parts passed Functional Test 2 but failed Functional Test 1. Two parts marginally exceeded the specification limit for TPD_A with readings of 76 and 79ns. Nine parts marginally exceeded the specification limit for TPD_B with readings in the range of 79 to 94ns. **All parts passed all other tests.**

After the 50.0kRad irradiation, all parts passed Functional Test 2 but failed Functional Test 1. Six parts marginally exceeded the specification limit for TPD_A with readings of 79ns. All parts marginally exceeded the specification limit for TPD_B with readings in the range of 79 to 94ns. **All parts passed all other tests.**

After the 75.0kRad irradiation, all parts passed Functional Test 2 but failed Functional Test 1. Most parts gave excessive readings for Vol and Iol. All parts had readings of >14V for Vol with a specification limit of 25mV and many parts gave readings of <-30nA for Iol with a specification limit of 10nA. All parts marginally exceeded the specification limit for TPD_A with readings in the range of 79 to 90ns. All parts marginally exceeded the specification limit for TPD_B with readings in the range of 87 to 114ns. **All parts passed all other tests.**

After annealing the parts for 72 and 168 hours at 25°C, all parts showed no significant recovery in any radiation sensitive parameter.

After annealing the parts for 72 and 168 hours at 100°C, all parts showed no rebound effects.

Bias Condition C

All parts passed all Functional Tests up to 20kRads and all other tests up to 10kRads.

After the 15.0kRad irradiation, one part marginally exceeded the specification limit of 75ns for TPD_B with a reading of 79ns. **All parts passed all other tests.**

After the 20.0kRad irradiation, two parts marginally exceeded the specification limit for TPD_B with readings of 76 and 79ns. **All parts passed all other tests.**

After the 25.0kRad irradiation, two parts failed Functional Test 1. One part marginally exceeded the specification limit of 75ns for TPD_A with a reading of 76ns. Two parts marginally exceeded the specification limit for TPD_B with readings of 79ns. **All parts passed all other tests.**

After the 30.0kRad irradiation, four parts failed Functional Test 1 which was performed with V_{IL} = 0.8V, V_{IH} = 2.4V. At this step, Functional Test 2 was added with V_{IL} = 0V, V_{IH} = 4.5V. All parts passed Functional Test 2. Three parts marginally exceeded the specification limit for TPD_B with readings in the range of 79 to 83ns. **All parts passed all other tests.**

After the 40.0kRad irradiation, eight parts failed Functional Test 1 but all parts passed Functional Test 2. Four parts marginally exceeded the specification limit for TPD_B with readings of 79ns. **All parts passed all other tests.**

After the 50.0kRad irradiation, all parts failed Functional Test 1 but all parts passed Functional Test 2. One part gave excessive readings for Vol and Iol. Five parts marginally exceeded the specification limit for TPD_B with readings in the range of 79 to 89ns. **All parts passed all other tests.**

After the 75.0kRad irradiation, all parts failed Functional Test 1 but all parts passed Functional Test 2. All parts gave excessive readings for Vol and Iol. All parts had readings of >14V for Vol with a specification limit of 25mV and many parts gave readings of <-30nA for Iol with a specification limit of 10nA. One part marginally exceeded the specification limit for TPD_A with a reading of 76ns. All parts marginally exceeded the specification limit for TPD_B with readings in the range of 79 to 94ns. **All parts passed all other tests.**

After annealing the parts for 72 and 168 hours at 25°C, all parts showed no significant recovery in any radiation sensitive parameter.

After annealing the parts for 72 and 168 hours at 100°C, all parts showed no rebound effects.

Table IV provides a summary of the test results with 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 us at (301) 731-8954.

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Figure 1. Radiation Bias Circuit for MIC4424
Bias Condition B

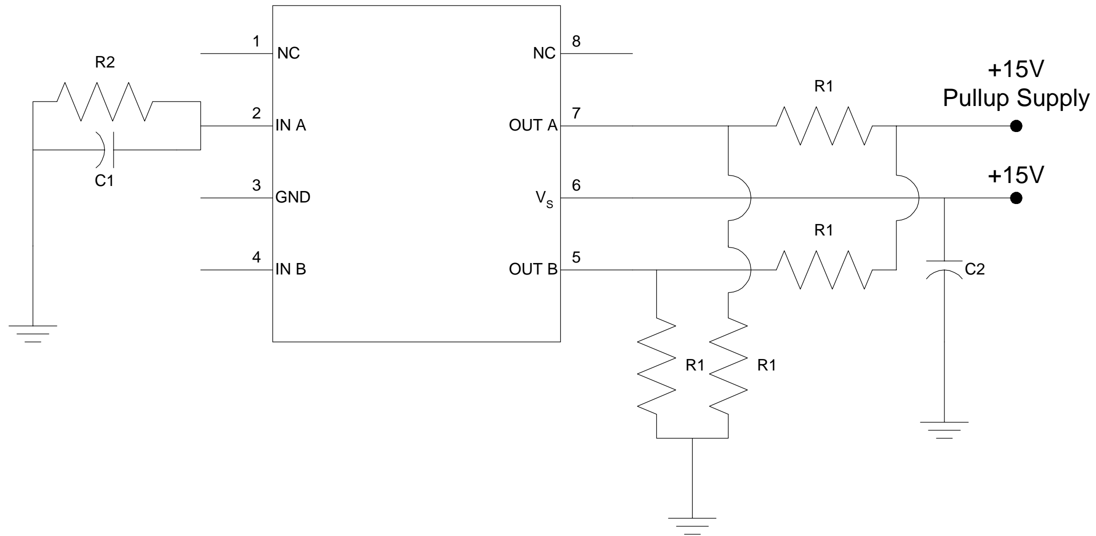
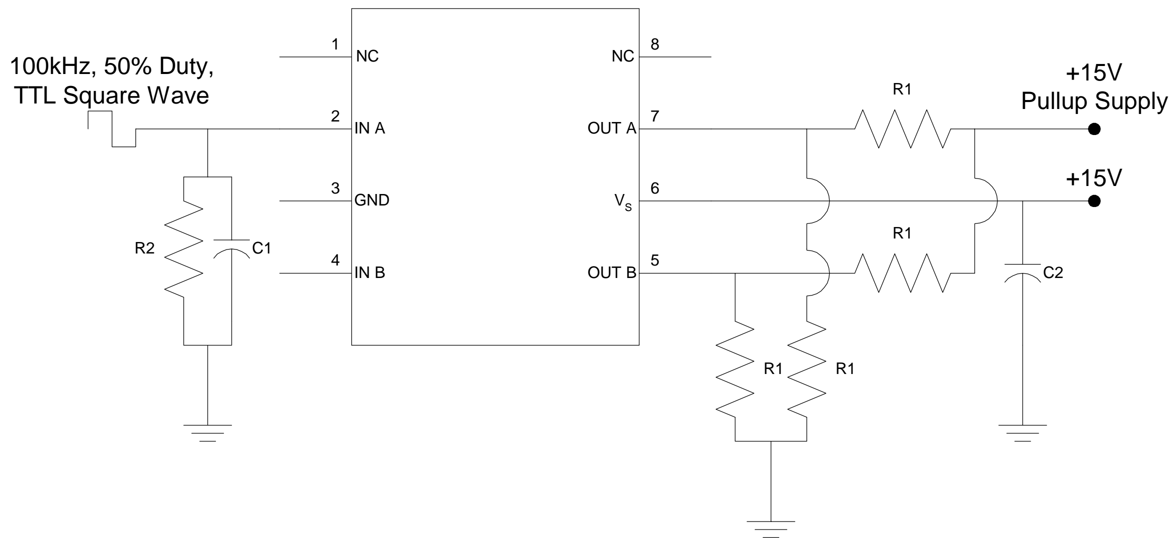


Figure 2. Radiation Bias Circuit for MIC4424
Bias Condition C



Notes:
1. R_1 = 500Ω ±5%, ½W.
2. R_2 = 150kΩ ±5%, ½W.
3. C_1 = 1800pF, 10%, 25V.
4. C_2 = 0.1µF, 10%, 100V.

TABLE I. Part Information

Generic Part Number:	MIC4424
GOES Part Number	MIC4424
Charge Number:	D-0326-0012-0000-002-0
Manufacturer:	Micrel
Lot Date Code (LDC):	9832
Quantity Tested:	22
Serial Number of Control Samples:	70, 80
Serial Numbers of Radiation Samples:	71, 72, 73, 74, 75, 76, 77, 78, 79, 80 81, 82, 83, 84, 85, 86, 87, 88, 89, 90
Part Function:	Dual 3A-Peak Low-Side MOSFET Driver
Part Technology:	BI-CMOS
Package Style:	8-Pin DIP
Test Equipment:	HP82000
Test Engineer:	Alix Duvalsaint

- The manufacturer for this part guaranteed no radiation tolerance/hardness.

TABLE II. Radiation Schedule for MIC4424

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	03/03/98
2) 5.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/11/98
POST-5.0 KRAD ELECTRICAL MEASUREMENT	03/12/99
3) 10.0 KRAD IRRADIATION (0.089 KRADS/HOUR)	03/12/98
POST-10.0 KRAD ELECTRICAL MEASUREMENT	03/15/99
4) 15.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/15/98
POST-15.0 KRAD ELECTRICAL MEASUREMENT	03/16/99
5) 20.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/16/98
POST-20.0 KRAD ELECTRICAL MEASUREMENT	03/17/99
6) 25.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/17/98
POST-25.0 KRAD ELECTRICAL MEASUREMENT	03/18/99
7) 30.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/18/98
POST-30.0 KRAD ELECTRICAL MEASUREMENT	03/19/99
8) 40.0 KRAD IRRADIATION (0.154 KRADS/HOUR)	03/19/99
POST-40.0 KRAD ELECTRICAL MEASUREMENT	03/22/99
9) 50.0 KRAD IRRADIATION (0.244 KRADS/HOUR)	03/22/99
POST-50.0 KRAD ELECTRICAL MEASUREMENT	03/24/99
10) 75.0 KRAD IRRADIATION (0.062 KRADS/HOUR)	03/24/99
POST-75.0 KRAD ELECTRICAL MEASUREMENT	03/26/99
11) 72 HOUR ANNEALING @25°C	03/26/99
POST-72 HOUR ANNEAL ELECTRICAL MEASUREMENT	03/29/99
12) 168 HOUR ANNEALING @25°C	03/26/99
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/02/99
13) 72 HOUR ANNEALING @100°C	04/02/99
POST-72 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/05/99
14) 168 HOUR ANNEALING @100°C	04/02/99
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/09/99

Effective Dose Rate = 75,000 RADS/15 DAYS=208.3 RADS/HOUR=0.058 RADS/SEC

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

Table III. Electrical Characteristics of MIC4424 /1

Test #	Parameter	Units	Spec. min	Lim. max	Test Conditions /2
F1	Funct. Test 1	P/F	V_{OL}<0.5V	V_{OH}>4.5V	V_{IL} = 0V, V_{IH} = 4.5V, Freq. = 1MHz
F2	Funct. Test 2	P/F	V_{OL}<0.5V	V_{OH}>4.5V	V_{IL} = 0.8V, V_{IH} = 2.4V, Freq. = 1MHz
B1	Ipeak	P/F			Peak current tested to 1.12A
B2	Ipeak	P/F			Peak current tested to 1.12A
1	Voh A	V	13.0	15.0	V_{IL} = 0.8V, V_{IH} = 2.4V
2	Voh B	V	13.0	15.0	V_{IL} = 0.8V, V_{IH} = 2.4V
3	Vol A	mV	0	25	V_{IL} = 0.8V, V_{IH} = 2.4V
4	Vol B	mV	0	25	V_{IL} = 0.8V, V_{IH} = 2.4V
5	Iih A	nA	-1000	1000	V_{IH} = 15V
6	Iih B	nA	-1000	1000	V_{IH} = 15V
7	Iil A	nA	-1000	1000	V_{IL} = 0V
8	Iil B	nA	-1000	1000	V_{IL} = 0V
9	Ioh A	mA	-30	-10	V_{IL} = 0.8V, V_{IH} = 2.4V
10	Ioh B	mA	-30	-10	V_{IL} = 0.8V, V_{IH} = 2.4V
11	Iol A	mA	10	30	V_{IL} = 0.8V, V_{IH} = 2.4V
12	Iol B	mA	10	30	V_{IL} = 0.8V, V_{IH} = 2.4V
13	RO_high A	mV	10	50	V_{IL} = 0.8V, I_{OUT} = 10mA
14	RO_high B	mV	10	50	V_{IL} = 0.8V, I_{OUT} = 10mA
15	RO_low A	V	14.9	15.0	V_{IL} = 2.4V, I_{OUT} = 10mA
16	RO_low B	V	14.9	15.0	V_{IL} = 2.4V, I_{OUT} = 10mA
17	Is_0V	μA	0	250	V_{IL} = 0V, (Both Inputs)
18	TPD A	ns	1	75	V_{IL} = 0V, V_{IH} = 5.0V
19	TPD B	ns	1	75	V_{IL} = 0V, V_{IH} = 5.0V

Notes:

1/ These are the manufacturer's non-irradiated data sheet specification limits. The manufacturer provided no post-irradiation limits at the time the tests were performed.

2/ V_{SUPPLY} is 15V for all tests unless otherwise specified.

TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for MIC4424 /1

Bias Condition B

							Total Dose Exposure (kRads Si)																		Annealing							
Test			Spec. Lim. /2		Initial		5.0		10.0		15.0		20.0		25.0		30.0		40.0		50.0		75.0		72 hours @25°C		168 hours @25°C		72 hours @100°C		168 hours @100°C	
#	Parameters	Units	min	max	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
F1	Functional Test	P/F	/3		P		P		P		P		P		P		6P/4F		1P/9F		F		F		F		F		1P/9F		2P/8F	
F2	Functional Test	P/F	/3														P		P		P		P		P		P		P		P	
B1	Peak Output Current		/4		P		P		P		P		P		P		P		P		P		P		P		P		P		P	
B2	Peak Output Current		/4		P		P		P		P		P		P		P		P		P		P		P		P		P		P	
1	Voh A	V	13.0	15.0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0	14.3	0
2	Voh B	V	13.0	15.0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0
3	Vol A	mV	0	25	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0.5	F		1P/9F		2P/8F		1	0.5	1	0.5
4	Vol B	mV	0	25	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	2	0.5	F		1P/9F		2P/8F		1	0.5	1	0.5
5	Iih A	nA	-1000	1000	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1
6	Iih B	nA	-1000	1000	14	0	14	0	14	0	14	0	14	0	14	0	14	1	14	1	14	1	14	1	14	1	14	1	14	1	14	1
7	Iil A	nA	-1000	1000	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	11	1	10	1	10	1	10	1	10	1
8	Iil B	nA	-1000	1000	11	0	11	0	11	0	11	0	11	0	11	0	11	0	11	0	11	1	11	1	11	1	11	1	11	0	11	1
9	Ioh A	mA	-30	-10	-26	1	-26	1	-26	1	-26	1	-27	1	-26	1	-26	1	-26	1	-25	1	-26	1	-25	1	-25	1	-26	2	-26	1
10	Ioh B	mA	-30	-10	-26	0	-26	0	-27	1	-27	1	-27	1	-27	1	-27	1	-27	1	-27	1	-27	1	-26	1	-26	1	-28	2	-28	1
11	Iol A	mA	10	30	24	1	24	1	24	1	24	1	24	1	24	1	24	1	24	1	24	1	8P/2F		24	1	23	1	23	1	24	1
12	Iol B	mA	10	30	23	0	23	0	24	1	25	1	24	1	24	1	24	1	24	1	24	1	6P/4F		8P/2F		7P/3F		24	1	25	1
13	RO_high A	mV	10	50	34	0.5	34	1	34	1	34	1	34	1	34	1	34	1	34	1	34	1	36	1	36	1	36	1	36	1	34	1
14	RO_high B	mV	10	50	37	0	38	1	35	1	35	1	37	1	36	1	36	1	35	1	36	1	36	1	37	1	36	1	35	1	35	1
15	RO_low A	V	14.9	15.0	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01
16	RO_low B	V	14.9	15.0	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.93	0.01	14.94	0.01	14.94	0.01	13.93	0.01	13.93	0.01	13.93	0.01	13.93	0.01	14.94	0.01	14.94	0.01
17	Is_0V	mA	0	250	100	12	88	9	88	9	76	10	71	12	69	10	68	10	64	7	61	6	53	4	54	4	54	4	85	4	86	6
18	TPD A	ns	1	75	70	1.2	71	1.1	71	1.1	72	1.2	73	1.3	74	2.0	74	2.1	76	2.3	77	2.0	81	3.7	80	2.9	80	2.7	76	1.7	76	1.7
19	TPD B	ns	1	75	70	2.1	71	1.0	72	0.9	74	2.0	76	2.8	77	2.5	78	3.7	82	6.3	85	6.2	96	7.5	96	7.4	95	5.8	84	6.9	84	6.8

Notes:

1/ The mean and standard deviation values were calculated over the ten parts irradiated in this testing. The control samples remained constant throughout 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.

3/ P (F) implies that all parts passed (failed) this test at this level. nPmF implies that n parts passed and m parts failed this test at this level.

4/ The peak output current was tested (GO-NO GO) to 1.12A to prevent damaging the part even though the typical reading per the manufacturer is 3A.

Radiation sensitive parameters: Functional Test 1, Vol A, Vol B, Iol A, Iol B, TPD A, TPD B.