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DATE: December 28, 1994 PPM-95-110

TO: J. Lohr/311
FROM: K. Sahu/300.1
SUBJECT: Radiation Report on CASSINI/CIRS
Part No. MIC4429
Control No. 11530

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A radiation evaluation was performed on MIC4429 (High Current, High Speed MOSFET Driver) 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 ^{60}Co gamma ray source. During the radiation testing, eight 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, 10, 15, 20, 30 and 50 krads*. The dose rate was between 0.04 and 1.18 krads/hour, depending on the total dose level (see Table II for radiation schedule). After the 50 krad irradiation, parts were annealed at 25°C for 168 hours, after which the parts were annealed at 100°C for 168 hours. After each radiation exposure and annealing treatment, parts were electrically tested according to the test conditions and the specification limits** listed in Table III.

All parts passed initial electrical measurements. All irradiated parts passed all electrical tests up to and including the 2.5 krad level.

From the 5 krad irradiation level to the 50 krad irradiation level, all irradiated parts fell below the minimum specification limit of 4.475 V for VOH45, with readings ranging from -5 mV to -20 mV. After the 50-krad irradiation, S/N 36 read -50 mV for VOH15, which is below the minimum specification limit of 14.98 V, and the same part exceeded the maximum specification limit of 2.8 Ω for ROUT1, with a reading of 1.51 kΩ.

After annealing for 168 hours at 25°C, no significant recovery was observed and after annealing for 168 hours at 100°C, no rebound effects were observed.

It was suspected that the apparent failures in VOH45 were due to high sensitivity of this parameter to the input voltage level. This test was performed with VIL = 0.8 V, which is a "soft" zero. The permissible range for VIL is 0.0 V to 0.8 V. It was noted that if VIL was reduced to approximately 0.5 V, the parts would pass the VOH45 test. Since, in most applications, VIL is expected to be around 0.0 - 0.5V, after the 168-hour annealing at 100°C, five parts, along with one control sample, were retested from the 5 krad level to the 20 krad level. The total-dose radiation levels during the retest were 5, 10, 15 and 20 krads, and the dose rate ranged from 0.25 to 0.29 krads/hour. During this retest, VOH45 was measured under the same conditions as before, but four functional tests were added, under conditions as shown in the following table:

	VCC	VIL	
Functional Test #1	4.5 V	0.0 V	"hard" zero
Functional Test #2	4.5 V	0.8 V	"soft" zero
Functional Test #3	15.0 V	0.0 V	"hard" zero
Functional Test #4	15.0 V	0.8 V	"soft" zero

*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.

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

Results of the retest are shown in Table IV(a). As can be seen in the table, all four preirradiated parts passed Functional Tests #1 and 3 (with VIL = 0.0 V) up to 20 krads, but failed Functional Tests #2 and 4 (with VIL = 0.8 V) after 10 krads. This indicates a sensitivity of the output states, and hence VOH, to the value of VIL.

Note that, in the retest, the parts also failed the VOH45 test, because that test is performed with VIL = 0.8 V. The functional tests are equivalent to the measurement of VOH under different test conditions of VIL.

In summary, all parts passed all tests up to 30 krads and there were no VOH45 failures when VIL was 0.0 V. It is to be noted that parts did show VOH45 failures when VIL was at the maximum permissible value of 0.8 V. Therefore, in applications in the space radiation environment, it is recommended that VIL be kept to a maximum of ≤0.5 V.

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

Generic Part Number:	MIC4429
CASSINI/CIRS Part Number:	5962-8877002PA
CASSINI/CIRS Control Number:	11530
Charge Number:	EE44633
Manufacturer:	Micrel
Lot Date Code:	9418
Quantity Tested:	10
Serial Number of Control Samples:	31, 32
Serial Numbers of Radiation Samples:	33, 34, 35, 36, 37, 38, 39, 40
Part Function:	High Current, High Speed MOSFET Driver
Part Technology:	CMOS
Package Style:	8-pin DIP
Test Equipment:	3260
Test Engineer:	T. Mondy

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

TABLE II. Radiation Schedule for MIC4429

EVENTS	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	09/13/94
2) 2.5 KRAD IRRADIATION (0.15 KRADS/HOUR)	09/15/94
POST-2.5 KRAD ELECTRICAL MEASUREMENT	09/16/94
3) 5 KRAD IRRADIATION (0.04 KRADS/HOUR)	09/16/94
POST-5 KRAD ELECTRICAL MEASUREMENT	09/19/94
4) 10 KRAD IRRADIATION (0.29 KRADS/HOUR)	09/19/94
POST-10 KRAD ELECTRICAL MEASUREMENT	09/20/94
5) 15 KRAD IRRADIATION (0.26 KRADS/HOUR)	09/20/94
POST-15 KRAD ELECTRICAL MEASUREMENT	09/21/94
6) 20 KRAD IRRADIATION (0.29 KRADS/HOUR)	09/21/94
POST-20 KRAD ELECTRICAL MEASUREMENT	09/22/94
7) 30 KRAD IRRADIATION (0.17 KRADS/HOUR)	09.23/94
POST-30 KRAD ELECTRICAL MEASUREMENT	09/26/94
8) 50 KRAD IRRADIATION (1.18 KRADS/HOUR)	09/26/94
POST-50 KRAD ELECTRICAL MEASUREMENT	09/28/94
9) 168-HOUR ANNEALING @25°C	09/28/94
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	10/05/94
10) 168-HOUR ANNEALING @100°C*	10/05/94
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	10/12/94
RETEST	
1) INITIAL ELECTRICAL MEASUREMENTS (AFTER 100°C ANNEAL)	11/02/94
2) 5 KRAD IRRADIATION (0.29 KRADS/HOUR)	11/02/94
POST-5 KRAD ELECTRICAL MEASUREMENT	11/03/94
3) 10 KRAD IRRADIATION (0.25 KRADS/HOUR)	11/07/94
POST-10 KRAD ELECTRICAL MEASUREMENT	11/08/94
4) 15 KRAD IRRADIATION (0.29 KRADS/HOUR)	11/08/94
POST 15 KRAD ELECTRICAL MEASUREMENT	11/14/94
5) 20 KRAD IRRADIATION (0.25 KRADS/HOUR)	11/15/94
POST 20 KRAD ELECTRICAL MEASUREMENT	11/16/94

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

*High temperature annealing is performed to accelerate long term time dependent effects (TDE), namely, the "rebound" effect due to the growth of interface states after the radiation exposure. For more information on the need to perform this test, refer to MIL-STD-883D, Method 1019, Para. 3.10.1.

Table III. Electrical Characteristics of MIC4429

TEST #	TEST NAME	TEST CONDITIONS	+25oC MIN	+25oC MAX	-55°C MIN	-55°C MAX	+125°C MIN	+125°C MAX	UNITS
1	IINH 1/	VCC=4.5,15V VIN=VCC V	-10	+10	-10	+10	-10	+10	uA
2	IINL 1/	VCC=4.5,15V VIN=0V	-10	+10	-10	+10	-10	+10	uA
3	VOH45 1/	VCC=4.5V VIN=0.8V	4.475	-	4.475	-	4.475	-	V
4	VOH15 1/ 5/	VCC=15V VIN=0.8V	14.98	-	14.98	-	14.98	-	V
5	VOL45 1/	VCC=4.5V VIN=2.4V	-	25	-	25	-	25	mV
6	VOL15 1/	VCC=15V VIN=2.4V	-	25	-	25	-	25	mV
7	ROUT1 1/	VCC=15V VIN=0.8V IOUT=-10mA	-	2.8	-	5	-	5	Ohms
8	ROUT0 1/	VCC=15V VIN=2.4V IOUT=+10mA	-	2.5	-	5	-	5	Ohms
9	ICC1 1/	VCC=4.5,15V VIN=3V	-	1.5	-	3	-	3	mA
10	ICC0 1/	VCC=4.5,15V VIN=0V	-	150	-	400	-	400	uA
11	VIH 2/	VOUT=0.5,14.5V VCC=4.5,15V	2.4	-	2.4	-	2.4	-	V
12	VIL 2/	VOUT=0.5,14.5V VCC=4.5,15V	-	0.8	-	0.8	-	0.8	V
13	TD1 1/ 4/	VCC=15V CLOAD=2500pF VIN=0.4,5.0V	2	60	-	-	-	-	nS
14 3/	Delta ROUT1	SEE TEST 7	-0.28	+0.28	-	-	-	-	OHMS
15 3/	Delta ROUT0	SEE TEST 8	-0.25	+0.25	-	-	-	-	OHMS
16 3/	Delta ICC1	SEE TEST 9	-150	+150	-	-	-	-	uA
17 3/	Delta ICC0	SEE TEST 10	-15	+15	-	-	-	-	uA

1/ The maximum VCC voltage used for these tests is 15V and not the specified 18V. The ATE does not measure parameters of high current devices correctly with VCC=18V.

2/ VIL and VIH are tested during functional testing at 50kHz and tests 3-8. The tests are GO/NOGO.

3/ Delta limits are arbitrarily chosen and are provided for information only. Delta's are not to be used as failure criteria.

4/ A lower limit of 2nS is used to force readings of 0ns to be failures.

5/ Due to ATE accuracy, 14.98 is used as a lower limit in lieu of the specified 14.975V.

Exceptions: 1) Ipk and I are not tested due to ATE limitations.
2) TD2, TR and TF are not tested since valid readings cannot be obtained on the ATE.

Functional Test:

1 Vcc = 4.5V, VIH = 4.5V, VIL = 0.0V - hard
2 Vcc = 4.5V, VIH = 2.4V, VIL = 0.8V soft
3 Vcc = 15.0V, VIH = 4.5V, VIL = 0.0V hard
4 Vcc = 15.0V, VIH = 2.4V, VIL = 0.8V soft

TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for MIC4429 /1

Test #	Paramete	Units	Spec. Lim./2 min	Spec. Lim./2 max	Initial mean	Initial sd	Total Dose Exposure (krads) 2.5 mean	2.5 sd	5 mean	5 sd	10 mean	10 sd	15 mean	15 sd	20 mean	20 sd	30 mean	30 sd	50 mean	50 sd	Annealing 168 hrs @25°C mean	168 hrs @25°C sd	168 hrs @100°C mean	168 hrs @100°C sd
1	IINH	µA	-10.0	10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	IINL	µA	-10.0	10.0	-0.02	.07	-0.02	.08	-0.03	.08	-0.03	.08	-0.03	.08	-0.03	.08	-0.03	.08	-0.03	0	-0.03	.01	-0.01	.01
3	VOH45/3	V	4.475	-	4.50	0	4.50	0	F		F		F		F		F		F		F		4.50	0
4	VOH15/3	V	14.98	-	15.0	0	15.0	.01	15.0	.01	15.0	0	15.0	.01	15.0	0	15.0	0	4P1F		4P1F		15.0	0
5	VOL45	mV	-	25.0	2.03	.10	2.08	.09	1.83	.05	1.96	.09	1.85	.07	1.79	.05	1.76	.12	1.89	.08	1.93	.11	2.01	.05
6	VOL15	mV	-	25.0	2.05	.08	2.06	.09	1.96	.11	2.04	.06	1.96	.10	1.89	.09	1.83	.13	1.96	.04	2.01	.07	2.13	.03
7	ROUT1	ohms	-	2.80	1.40	.02	1.43	.08	1.53	.08	1.54	.08	2.34	.37	1.71	.10	1.77	.12	191	533	217	570	1.75	.09
8	ROUT0	ohms	-	2.80	1.99	.07	2.00	.11	2.05	.05	2.09	.06	2.01	.08	2.05	.09	2.13	.10	2.16	.07	2.10	.12	2.14	.07
9	ICC1	mA	-	1.50	0.34	.06	0.30	.06	0.12	.11	0.12	.11	0.12	.11	0.12	.10	0.11	.10	0.13	.09	0.09	.09	0.21	.06
10	ICC0	µA	-	150.0	60.2	11	53.5	12	23.2	22	22.4	21	24.7	21	20.9	20	19.6	19	17.8	18	17.6	18	46.7	11
11	TD1	ns	2.0	60.0	19.0	.45	16.9	.42	16.5	.42	16.4	.40	16.3	.39	15.9	.43	16.5	.40	16.2	.42	16.2	.40	15.9	.41

TABLE IV(a): Summary of Electrical Measurements after Retest of MIC4429 /1

Test #	Paramete	Units	Spec. Lim./2 min	Spec. Lim./2 max	Initial (Post-Annealing) mean	Initial (Post-Annealing) sd	Total Dose Exposure (krads) 5 mean	5 sd	10 mean	10 sd	15 mean	15 sd	20 mean	20 sd
1	IINH	µA	-10.0	10.0	0	0	0	0	0	0	0	0	0	0
2	IINL	µA	-10.0	10.0	-0.01	.01	-0.01	.01	-0.01	.01	-0.01	.01	-0.01	.01
3	VOH45/3	V	4.475	-	4.50	0	4P1F		F		F		F	
4	VOH15/3	V	14.98	-	15.0	0	15.0	.01	15.0	0	15.0	0	15.0	.01
5	VOL45	mV	-	25.0	2.04	.11	1.85	.07	1.87	.08	1.80	.05	1.93	.04
6	VOL15	mV	-	25.0	2.07	.08	1.84	.05	1.96	.09	1.92	.03	2.03	.06
7	ROUT1	ohms	-	2.80	0.89	.07	1.72	.07	1.69	.15	1.65	.12	1.77	.13
8	ROUT0	ohms	-	2.80	2.12	.10	2.12	.08	2.24	.13	2.16	.04	2.22	.05
9	ICC1	mA	-	1.50	0.23	.06	0.16	.11	0.11	.11	0.11	.11	0.10	.10
10	ICC0	µA	-	150.0	49.5	12	33.5	23	24.7	25	23.1	23	21.8	22
11	TD1	ns	2.0	60.0	16.2	.52	16.2	.52	16.2	.49	16.2	.48	16.2	.45
12	FUNC1, VCC=4.5V, VIH=4.5V, VIL=0.0V /3				P		P		P		P		P	
13	FUNC1, VCC=4.5V, VIH=2.4V, VIL=0.8V /3				P		P		1P4F		F		F	
14	FUNC3, VCC=15.0V, VIH=4.5V, VIL=0.0V /3				P		P		F		P		P	
15	FUNC4 VCC=15.0V, VIH=2.4V, VIL=0.8V /3				P		P		2P3F		1P4F		1P2F	

Notes:

1/ The mean and standard deviation values were calculated over the eight 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.

3/ In the functional Tests, "P" means that all parts passed this test at this irradiation or annealing level, "F" means that all parts failed this test at this irradiation or annealing level and "nPmF" means that n parts passed at this level and m parts failed at this level.
In the VOH tests, when all parts fell within specification limits, the actual mean and standard deviation are given.
When functional failure of one or more parts prevented actual measurement of the parameter, results are given as "nPmF" or "F".

Radiation-sensitive parameters: VOH45, VOH15 and ROUT1.

Figure 1. Radiation Bias Circuit for MIC4429