Single-Event Latchup Testing of the Micrel MIC4424 Dual Power MOSFET Driver

J. A. Pellish[1], A. Boutte[1], H. Kim[2], A. Phan[2], and A. Topper[2]

NASA Goddard Space Flight Center
Code 561, Radiation Effects and Analysis Group
8800 Greenbelt RD
Greenbelt, MD 20771

13 October 2011

1: NASA Goddard Space Flight Center, Greenbelt, MD USA

2: MEI Technologies, Inc., Seabrook, MD USA

Snapshot Summary

We conducted 47 exposures of four different MIC4424 devices and did not observe any SEL or high-current events. This included worst-case conditions with a LET of 81 MeV-cm^2/mg, applied voltage of 18.5 V, a case temperature greater than 120 °C, and a final fluence of 1x10^7 cm^{-2}. We also monitored both the outputs for the presence of SETs. While the period of the 1 MHz square wave was slightly altered in some cases, no pulses were added or deleted.

1. Purpose

The purpose of this testing is to characterize the BiCMOS/DMOS Micrel MIC4424 dual, non-inverting MOSFET driver for single-event latchup (SEL) susceptibility. These data will be used for flight lot evaluation purposes.

2. Devices Tested

The MIC4423/4424/4425 family are highly reliable BiCMOS/DMOS buffer/driver MOSFET drivers. They are higher output current versions of the MIC4426/4427/4428. They can survive up to 5V of noise spiking, of either polarity, on the ground pin. They can accept, without either damage or logic upset, up to half an amp of reverse current (either polarity) forced back into their outputs. Primarily intended for driving power MOSFETs, the MIC4423/4424/4425 drivers are suitable for driving other loads (capacitive, resistive, or inductive) which require low-impedance, high peak currents, and fast switching times. Heavily loaded clock lines, coaxial cables, or piezoelectric transducers are some examples. The only known limitation on loading is that total power dissipated in the driver must be kept within the maximum power dissipation limits of the package.

Five (5) parts were provided for SEL testing. We prepared four parts for irradiation and reserved one piece as an un-irradiated control. More information about the devices can be found in Table 1. The parts were prepared for testing by removing the lid from the CDIP package to expose the target die. The parts were then soldered to small copper circuit adapter boards for easy handling. These parts are fabricated in a bulk BiCMOS/DMOS technology. Since we do not know the number of overlayers used in the fabrication processes, linear energy transfer calculations are determined based on the top-surface incident ion species and kinetic energy.

Table 1: Part Identification Information

Qty	Part Number	LDC	Source	Package
5	Flight: 5962-8850305PA Generic: MIC4424	1043 (date code) 9A40116M08 (lot number)	Micrel	CDIP2-T8

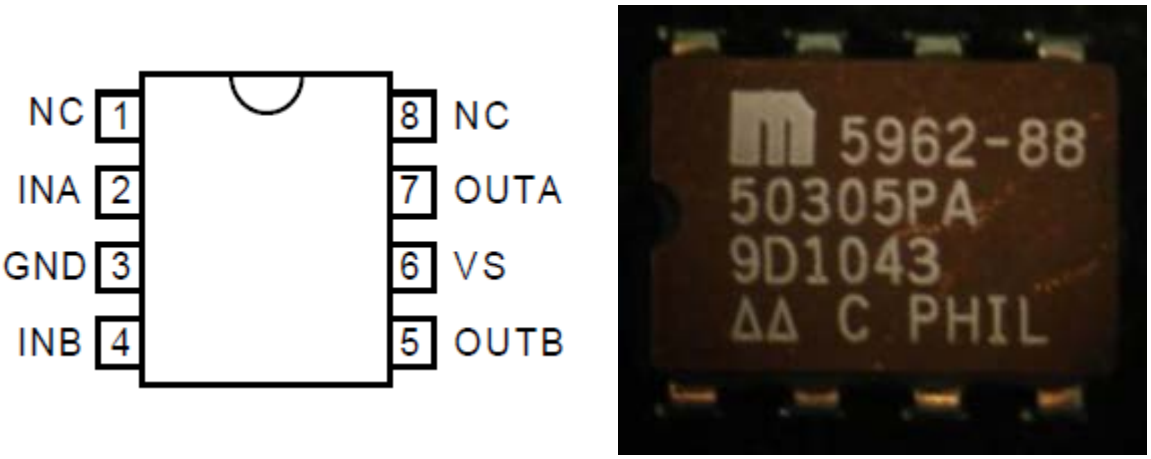

Figure 1: Pin diagram and corresponding package photo of MIC4424

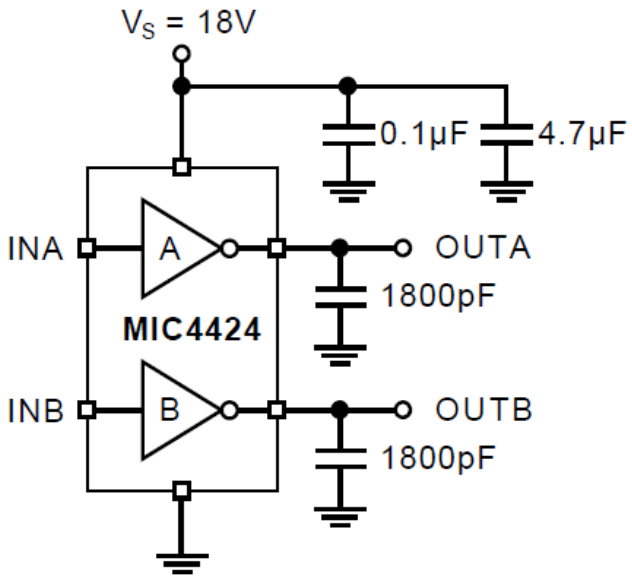

Figure 2: Test circuit used for the functional portion of the SEL test. Note that the voltage applied to VS was not necessarily 18 V throughout the test. In our test, output capacitance was 4 nF.

In addition to the passive components required to instrument the test, we also included thermistors inside the individual packages to monitor local temperature for heating requirements. Elevated device temperature was achieved using kapton strip resistive heaters.

3. Test Facility: Texas A&M University

Cyclotron Tune: 15 MeV/amu
Ions Used: Ne[20], Ar[40], Kr[84], and Ta[181]
Actual Flux Range: $9x10^3$ to $2x10^5$ ions/(cm^2 s)

Table II: Ion(s) Used for Device Irradiation

Ion	Energy (MeV)	Range in Silicon	Silicon LET (MeV cm^2/mg)
^{20}Ne	258	250	3
^{40}Ar	471	162	9
^{84}Kr	829	104	30
^{181}Ta	1521	88	81

Note that energy, range, and LET are calculated based on 1 mil aramica window and 80 mm of dry, sea-level air prior to a silicon target. Range and LET are at normal incidence.

4. Test Conditions and Error Modes

Table III: SEL/SET Test Conditions

Pin	Function	Connection/Bias
1	NC	GND
2	INA	1 MHz square wave (0 – 5 V)
3	GND	GND
4	INB	1 MHz square wave (0 – 5 V)
5	OUTB	To GND via 4 nF
6	VS	4.5, 5, 5.5, and 18 V To GND via 0.1 μF
7	OUTA	To GND via 4 nF
8	NC	GND

*Current limit set to 110% of absolute maximum rating.
*Both room and elevated temperatures were used. When elevated, the case temperature ranged between 80 and 125 °C.

OUTA and OUTB were connected to a Tektronix MSO4104 oscilloscope to record potential single-event transients (SET) on these pins as well as to check for continued device functionality. The scope was configured to trigger on either OUTA or OUTB showing at least three waveform periods with five or more vertical divisions and 5000 points/waveform. A 5% deviation pulse width trigger was used.

Test stop conditions were either an ion fluence of 1x10^7 cm^{-2} or a sustained high-current state on the power supply or input voltage lines. In the event of part destruction, the run would be repeated to confirm and then the effective LET would be set to 1/2 of the destruct condition with the same case temperature. In the event of another destructive condition, the LET would be kept the same, but the heater strip power will be removed and the device allowed to return to room temperature. This procedure can be repeated once more, at which point destructive testing will cease.

5. Test Results

We conducted 47 exposures of four different MIC4424 devices and did not observe any SEL or high-current events. This included worst-case conditions with a LET of 81 MeV-cm^2/mg, applied voltage of 18.5 V, a case temperature greater than 120 °C, and a final fluence of 1x10^7 cm^{-2}. We also monitored both the outputs for the presence of SETs. While the period of the 1 MHz square wave was slightly altered in some cases, no pulses were added or deleted.

6. Recommendation

This manufacturing date code and lot number of parts is recommended for use in NASA/GSFC spaceflight applications. This recommendation does not extend beyond the materials and conditions tested and only applies to single-event latchup. While SET data were captured, the lack of any substantial effects precludes their inclusion at this time for the purposes of the mission application in question.

7. URL for Device Data Sheet

- MIC4424: http://www.micrel.com/_PDF/mic4423.pdf

8. Appendix: Data Log

Run	Type	DUT S/N	Time	VS (V)	Trigger Channel	Temp (deg C)	Tilt (deg)	Roll (deg)	Ion	Energy @ DUT (MeV/u)	Nominal LET (MeVcm 2/mg)	Effective LET (MeVcm 2/mg)	Range in Si (um)	Effective Range in Si (um)	Live Time (s)	Dose (rad(Si))	Avg Flux (1/cm2s)	Fluence (1/cm2)	Eff Fluence (1/cm2)	High-Current State or SEL	SEL XSEC (cm2)
1	MIC4424	1	0:22	4.5	A	32	0	0	Ta	8.4	81	81.0	88.4	88	8.8	1.32E+02	1.16E+04	1.02E+05	1.02E+05	0	0
2	MIC4424	1	0:44	4.5	A	25	0	0	Ta	8.4	81	81.0	88.4	88	33.9	6.42E+02	1.46E+04	4.94E+05	4.94E+05	0	0
3	MIC4424	1	0:50	4.5	B	25	0	0	Ta	8.4	81	81.0	88.4	88	33.8	6.47E+02	1.48E+04	4.99E+05	4.99E+05	0	0
4	MIC4424	1	0:53	5.0	B	25	0	0	Ta	8.4	81	81.0	88.4	88	37.5	6.44E+02	1.32E+04	4.97E+05	4.97E+05	0	0
5	MIC4424	1	0:55	5.0	A	25	0	0	Ta	8.4	81	81.0	88.4	88	35.9	6.44E+02	1.38E+04	4.96E+05	4.96E+05	0	0
6	MIC4424	1	1:37	5.5	A	120	0	0	Ta	8.4	81	81.0	88.4	88	158.8	1.29E+04	6.29E+04	9.99E+06	9.99E+06	0	0
7	MIC4424	1	1:43	5.5	B	120	0	0	Ta	8.4	81	81.0	88.4	88	152.8	1.29E+04	6.52E+04	9.97E+06	9.97E+06	0	0
8	MIC4424	2	1:58	5.5	B	120	0	0	Ta	8.4	81	81.0	88.4	88	132.0	1.30E+04	7.60E+04	1.00E+07	1.00E+07	0	0
9	MIC4424	2	2:02	5.5	A	120	0	0	Ta	8.4	81	81.0	88.4	88	194.5	1.29E+04	5.13E+04	9.98E+06	9.98E+06	0	0
10	MIC4424	2	2:55	4.5	A	32	0	0	Kr	9.9	30.2	30.2	103.9	104	33.8	2.41E+02	1.48E+04	4.99E+05	4.99E+05	0	0
11	MIC4424	2	2:59	4.5	A	32	0	0	Kr	9.9	30.2	30.2	103.9	104	26.0	2.38E+02	1.88E+04	4.90E+05	4.90E+05	0	0
12	MIC4424	2	3:01	4.5	B	32	0	0	Kr	9.9	30.2	30.2	103.9	104	24.0	2.40E+02	2.06E+05	4.97E+05	4.97E+05	0	0
13	MIC4424	2	3:03	4.5	B	33	0	0	Kr	9.9	30.2	30.2	103.9	104	25.3	2.41E+02	1.97E+04	4.99E+05	4.99E+05	0	0
14	MIC4424	2	3:05	5.0	B	33	0	0	Kr	9.9	30.2	30.2	103.9	104	22.9	2.40E+02	2.16E+04	4.97E+05	4.97E+05	0	0
15	MIC4424	2	3:08	5.0	A	34	0	0	Kr	9.9	30.2	30.2	103.9	104	30.1	2.42E+02	1.66E+04	5.01E+05	5.01E+05	0	0
16	MIC4424	3	3:26	5.0	A	34	0	0	Kr	9.9	30.2	30.2	103.9	104	39.7	2.42E+02	1.26E+04	5.02E+05	5.02E+05	0	0
17	MIC4424	3	3:29	5.0	B	33	0	0	Kr	9.9	30.2	30.2	103.9	104	36.8	2.40E+02	1.34E+04	4.96E+05	4.96E+05	0	0
18	MIC4424	3	3:31	5.0	B	33	0	0	Kr	9.9	30.2	30.2	103.9	104	40.8	2.41E+04	1.22E+04	4.99E+05	4.99E+05	0	0
19	MIC4424	3	3:33	5.0	A	33	0	0	Kr	9.9	30.2	30.2	103.9	104	30.6	2.41E+02	1.62E+04	4.99E+05	4.99E+05	0	0
20	MIC4424	3	4:01	4.5	A	31	0	0	Ar	11.8	9	9.0	162.2	162	38.7	7.15E+01	1.29E+04	4.98E+05	4.98E+05	0	0
21	MIC4424	3	4:04	4.5	A	31	0	0	Ar	11.8	9	9.0	162.2	162	48.1	2.85E+02	4.13E+04	1.99E+06	1.99E+06	0	0
22	MIC4424	3	4:07	4.5	B	31	0	0	Ar	11.8	9	9.0	162.2	162	51.0	2.87E+02	3.89E+04	2.00E+06	2.00E+06	0	0
23	MIC4424	3	4:10	4.5	B	31	0	0	Ar	11.8	9	9.0	162.2	162	49.7	2.87E+02	4.01E+04	2.00E+06	2.00E+06	0	0
24	MIC4424	3	4:12	5.0	B	32	0	0	Ar	11.8	9	9.0	162.2	162	50.1	2.86E+02	3.97E+04	1.99E+06	1.99E+06	0	0
25	MIC4424	3	4:15	5.0	B	33	0	0	Ar	11.8	9	9.0	162.2	162	45.8	7.23E+01	1.10E+04	5.04E+05	5.04E+05	0	0
26	MIC4424	3	4:18	5.0	A	33	0	0	Ar	11.8	9	9.0	162.2	162	43.6	7.20E+01	1.15E+04	5.01E+05	5.01E+05	0	0
27	MIC4424	3	4:20	5.0	A	33	0	0	Ar	11.8	9	9.0	162.2	162	41.8	7.16E+01	1.19E+04	4.99E+05	4.99E+05	0	0
28	MIC4424	3	4:31	4.5	A	30	0	0	Ne	12.9	2.8	2.8	249.5	250	36.5	2.26E+01	1.36E+04	4.96E+05	4.96E+05	0	0
29	MIC4424	3	4:33	4.5	A	31	0	0	Ne	12.9	2.8	2.8	249.5	250	39.0	2.27E+01	1.28E+04	4.99E+05	4.99E+05	0	0
30	MIC4424	3	4:35	4.5	B	31	0	0	Ne	12.9	2.8	2.8	249.5	250	37.8	2.25E+01	1.30E+04	4.94E+05	4.94E+05	0	0
31	MIC4424	3	4:37	4.5	B	32	0	0	Ne	12.9	2.8	2.8	249.5	250	36.9	2.26E+01	1.35E+04	4.97E+05	4.97E+05	0	0
32	MIC4424	3	4:39	5.0	B	32	0	0	Ne	12.9	2.8	2.8	249.5	250	37.9	2.25E+01	1.31E+04	4.94E+05	4.94E+05	0	0
33	MIC4424	3	4:41	5.0	B	33	0	0	Ne	12.9	2.8	2.8	249.5	250	38.6	2.28E+01	1.30E+04	5.02E+05	5.02E+05	0	0
34	MIC4424	3	4:42	5.0	A	33	0	0	Ne	12.9	2.8	2.8	249.5	250	37.9	2.27E+01	1.32E+04	4.99E+05	4.99E+05	0	0
35	MIC4424	3	4:44	5.0	A	33	0	0	Ne	12.9	2.8	2.8	249.5	250	39.8	2.26E+01	1.24E+04	4.96E+05	4.96E+05	0	0
36	MIC4424	3	4:58	4.5	A	31	0	0	Ar	11.8	9	9.0	162.2	162	41.3	7.20E+01	1.21E+04	5.01E+05	5.01E+05	0	0
37	MIC4424	3	5:01	4.5	B	31	0	0	Ar	11.8	9	9.0	162.2	162	39.5	7.16E+01	1.26E+04	4.99E+05	4.99E+05	0	0
38	MIC4424	3	5:03	5.0	B	32	0	0	Ar	11.8	9	9.0	162.2	162	38.7	7.25E+01	1.30E+04	5.05E+05	5.05E+05	0	0
39	MIC4424	3	5:05	5.0	B	33	0	0	Ar	11.8	9	9.0	162.2	162	38.5	7.10E+01	1.28E+04	4.95E+05	4.95E+05	0	0
40	MIC4424	3	5:51	5.0	A	24	0	0	Ta	8.4	81	81.0	88.4	88	37.8	6.45E+02	1.32E+04	4.98E+05	4.98E+05	0	0
41	MIC4424	3	5:53	5.0	A	24	0	0	Ta	8.4	81	81.0	88.4	88	36.9	6.43E+02	1.34E+04	4.96E+05	4.96E+05	0	0
42	MIC4424	3	5:56	5.0	A	24	0	0	Ta	8.4	81	81.0	88.4	88	35.8	6.53E+02	1.40E+04	5.03E+05	5.03E+05	0	0
43	MIC4424	3	6:21	18.0	A	36	0	0	Ta	8.4	81	81.0	88.4	88	104.6	1.29E+04	9.53E+04	9.97E+06	9.97E+06	0	0
44	MIC4424	3	6:27	18.0	A	78	0	0	Ta	8.4	81	81.0	88.4	88	98.4	1.29E+04	1.01E+04	9.96E+06	9.96E+06	0	0
45	MIC4424	3	6:35	18.0	A	124	0	0	Ta	8.4	81	81.0	88.4	88	93.9	1.30E+04	1.06E+04	9.99E+06	9.99E+06	0	0
46	MIC4424	4	6:52	18.5	A	100	0	0	Ta	8.4	81	81.0	88.4	88	109.9	1.30E+04	9.09E+04	9.99E+06	9.99E+06	0	0
47	MIC4424	4	6:59	18.5	A	129	0	0	Ta	8.4	81	81.0	88.4	88	110.2	1.29E+04	9.04E+03	9.97E+06	9.97E+06	0	0