Single-Event Latchup Testing of the Linear Technology LTC2054HV Micropower Zero-Drift Operational Amplifier

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1. Purpose

The purpose of this testing is to characterize the Linear Technology LTC2054HV micropower zero-drift operational amplifier for single-event latchup (SEL) susceptibility. These data will be used for flight lot evaluation purposes.

2. Devices Tested

The LTC2054HV is a low power, low noise, single zero-drift operational amplifiers. It is packaged in a TSOT-23 (ThinSOT™) package. It operates from a single 2.7 V minimum supply and supports ± 5.5 V applications. The current consumption is typically 150 μA for the LTC2054HV. The input common mode voltage ranges from the negative supply up to typically 0.5V below the positive supply. The open-loop gain is typically 140 dB. The LTC2054 also features a 1.6 μVP-P DC to 10 Hz noise and a 500 kHz gain-bandwidth product.

Ten (10) parts were provided for SEL testing. We prepared four parts for irradiation and kept the remaining pieces as spares. More information about the devices can be found in Table 1. The parts were prepared for testing by acid etching the plastic package and encapsulant away from the target die. The parts were then soldered to small copper circuit adapter boards for easy handling. These parts are fabricated in a 1.2 μm bulk CMOS 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: LTC2054HVMPS5 Generic: LTC2054	1047T (date code) Z18744.1 (lot number)	Linear Technology Corp.	TSOT-23

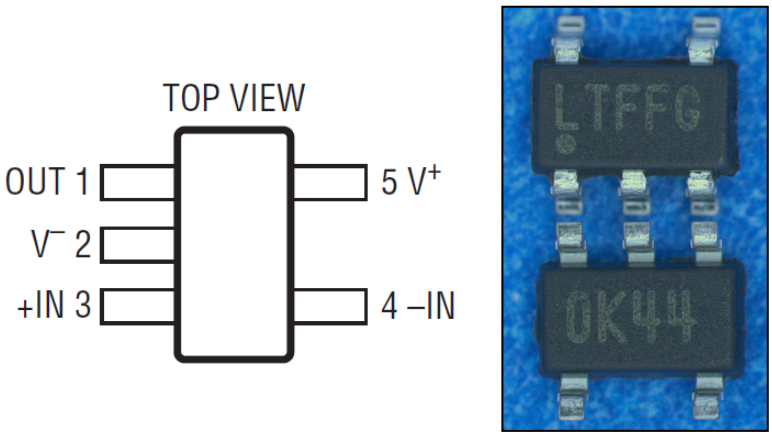

Figure 1: Pin diagram and corresponding package photo of LTC2054HV OpAmp

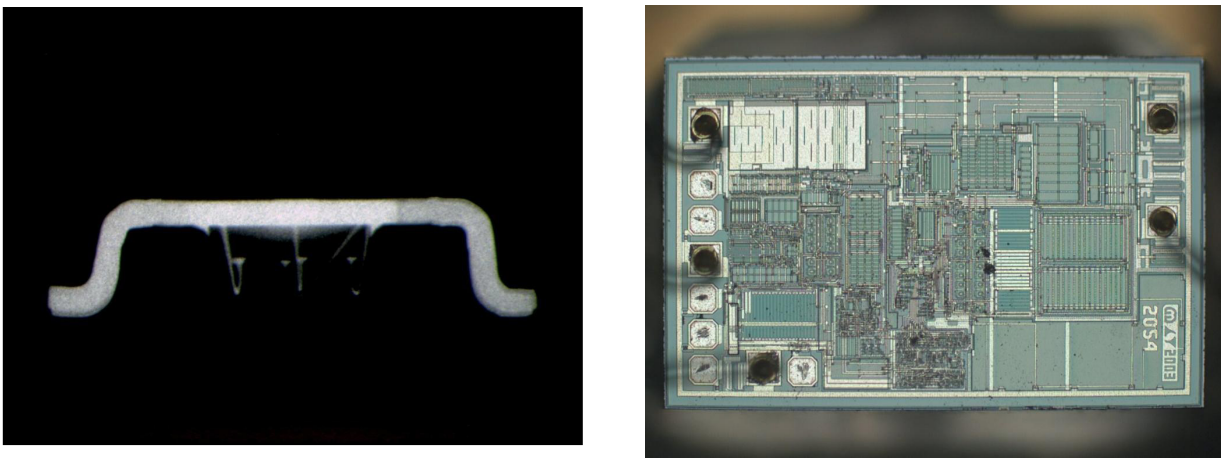

Figure 2: LTC2054HV package radiography and die image. Note that this die to is mounted upside down. The die photo was taken after acid etching/decapsulation.

As shown in Figure 2, this die is oriented towards the bottom of the TSOT-23 package, which made mounting the components on the two-sided Cu-clad adapter board challenging. The parts essentially had to be soldered upside down in addition to making room for the thermistor.

3. Test Facility

Facility: Texas A&M University Radiation Effects Facility. Tune: 15 MeV/amu
Flux: 6×10^{4} to 1×10^{5} ions cm^{-2} s^{-1}
Fluence: All tests run to a fluence of 1×10^{7} cm^{-2} or until a high-current event is observed

Table II: Ion(s) Used for Device Irradiation

Ion	Energy (MeV)	Range in Silicon	Silicon LET (MeV cm^2/mg)
^{181}Ta	2076	119	77

Note that energy, range, and LET are calculated based on 1 mil aramica window and 30 mm of air prior to the silicon target.

4. Test Conditions and Error Modes

	LTC2054HV
Test Temperature	60° C
Operating Frequency	Static
Power Supply Voltage	+/- 5 Vdc
Parameters of Interest	LET_{th}, temperature, supply voltage
SEE Conditions	Prolonged and self-sustained high-current state*

*Current limit set to 110% of absolute maximum rating.

5. Test Setup

The test circuits for all devices were built to model/approximate the intended application. However, these SEL tests were static with a DC bias on V+ and V- supply lines (+/- 5 V) and inputs tied for a closed loop configuration. Decoupling capacitors were used on power lines.

The test setup is fairly simple, requiring only the digital I/O, relays, power supplies, and data logging equipment. The power supplies were located in the TAMU irradiation cave, while the data logging equipment were located in the high-bay. The digital I/O and relays on the test board allowed for rapid switching between parts to make testing more efficient – this includes power, Kapton heaters, and thermistors. The test board actually contained three different part types of which the LTC2054HV is only one. A picture of the test board is shown in Figure 3.

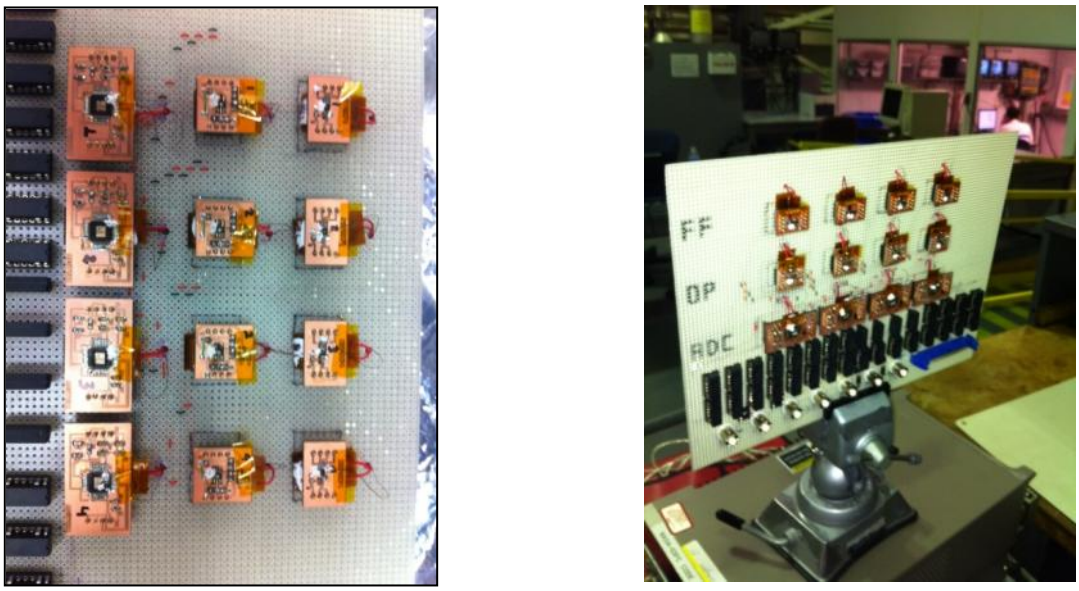

Figure 3: Test board configuration for the SEL test of the LTC2054HV operational amplifier. The LTC2054HV is located on the middle row in the left image and the middle row in the right image. The other parts on the test board were evaluated during the same run, but are not covered in this report.

6. Test Results

Many exposures were conducted, covering irradiations on four separate devices from the same manufacturing date code and material lot. None of the devices experienced a sustained high current state that required user-intervention to correct. Heavy ion strikes to the operational amplifier produced transients on both the positive and negative supply lines, but none of them were sustained and all were within device specification. The device also proved to have current draw highly correlated to temperature. The data in Figure 4 are representative of all exposures conducted.

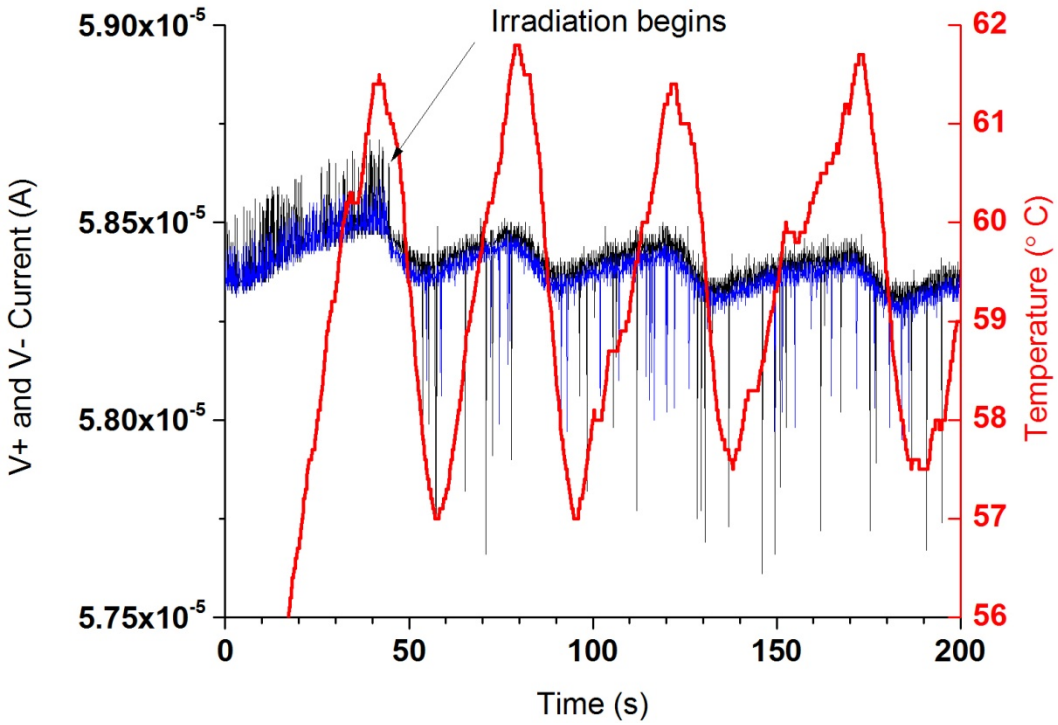

Figure 4: Example of a 164 s 15 MeV/amu Ta irradiation of the LTC2054HV operational amplifier. Note the device current and temperature correlation.

7. Recommendation

This manufacturing lot of parts is recommended for use in NASA/GSFC spaceflight applications. This recommendation does not extend beyond the conditions tested and only applies to single-event latchup. No single-event upset or transient behavior is included.

8. URL for Device Data Sheet

- LTC2054HV: http://cds.linear.com/docs/Datasheet/20545fc.pdf

9. Run Log

Run	Type	DUT S/N	Temp (°C)	Tilt (deg)	Roll (deg)	Ion	Energy @ DUT (MeV/u)	Nominal LET (MeVcm2/mg)	Effective LET (MeVcm2/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)
10	OPAMP	1	60	0	0	Ta	11.5	77	77	119	119	150.00	1.24E+04	6.68E+04	1.00E+07	1.00E+07	0	1.00E-07
11	OPAMP	1	60	0	0	Ta	11.5	77	77	119	119	164.00	1.24E+04	6.11E+04	1.00E+07	1.00E+07	0	1.00E-07
12	OPAMP	2	60	0	0	Ta	11.5	77	77	119	119	165.00	1.24E+04	6.04E+04	9.98E+06	9.98E+06	0	1.00E-07
13	OPAMP	2	60	0	0	Ta	11.5	77	77	119	119	146.00	1.24E+04	6.82E+04	9.98E+06	9.98E+06	0	1.00E-07
14	OPAMP	3	60	0	0	Ta	11.5	77	77	119	119	184.00	1.24E+04	5.42E+04	9.98E+06	9.98E+06	0	1.00E-07
15	OPAMP	3	60	0	0	Ta	11.5	77	77	119	119	175.00	1.24E+04	5.74E+04	1.00E+07	1.00E+07	0	1.00E-07
16	OPAMP	4	60	0	0	Ta	11.5	77	77	119	119	46.00	3.25E+03	5.70E+04	2.62E+06	2.62E+06	0	3.82E-07
17	OPAMP	3	70	0	0	Ta	11.5	77	77	119	119	148.00	1.24E+04	6.75E+04	1.00E+07	1.00E+07	0	1.00E-07
18	OPAMP	3	70	0	0	Ta	11.5	77	77	119	119	166.00	1.24E+04	6.05E+04	1.00E+07	1.00E+07	0	1.00E-07
26	OPAMP	1	60	45	0	Ta	10.6	79	111	111	78	138.00	1.79E+04	1.03E+05	1.41E+07	1.00E+07	0	1.00E-07
27	OPAMP	1	60	45	0	Ta	10.6	79	111	111	78	138.00	1.78E+04	1.02E+05	1.41E+08	9.99E+07	0	1.00E-08
30	OPAMP	2	60	45	0	Ta	10.6	79	111	111	78	139.00	1.78E+04	1.02E+05	1.41E+07	9.98E+06	0	1.00E-07
31	OPAMP	2	60	45	0	Ta	10.6	79	111	111	78	140.00	1.78E+04	1.01E+05	1.41E+07	1.00E+07	0	1.00E-07
34	OPAMP	3	60	45	0	Ta	10.6	79	111	111	78	138.00	1.78E+04	1.02E+05	1.41E+07	9.98E+06	0	1.00E-07
35	OPAMP	3	60	45	0	Ta	10.6	79	111	111	78	144.00	1.78E+04	9.85E+04	1.41E+07	1.00E+07	0	1.00E-07
46	OPAM	1	60	45	90	Ta	10.6	79	111	110	78	137.00	1.78E+	1.03E+	1.41E+	9.97E+	0	1.00E-

	P											04	05	07	06		07
47	OPAMP	1	60	45	90	Ta	10.6	79	111	110	78	138.00	1.78E+04	1.02E+05	1.41E+07	1.00E+07	0	1.00E-07
48	OPAMP	2	60	45	90	Ta	10.6	79	111	110	78	132.00	1.78E+04	1.08E+05	1.41E+07	1.00E+07	0	1.00E-07
49	OPAMP	2	60	45	90	Ta	10.6	79	111	110	78	135.00	1.79E+04	1.05E+05	1.41E+07	1.00E+07	0	1.00E-07
50	OPAMP	3	60	45	90	Ta	10.6	79	111	110	78	132.00	1.79E+04	1.08E+05	1.41E+07	1.00E+07	0	1.00E-07
51	OPAMP	3	60	45	90	Ta	10.6	79	111	110	78	127.00	1.79E+04	1.12E+05	1.41E+07	1.00E+07	0	1.00E-07
52	OPAMP	4	60	45	90	Ta	10.6	79	111	110	78	63.00	9.53E+03	1.19E+05	7.57E+06	5.35E+06	0	1.87E-07
71	OPAMP	1	60	0	0	Kr	12.3	28	28	134	134	76.00	4.48E+03	1.31E+05	1.00E+07	1.00E+07	0	1.00E-07
72	OPAMP	2	60	0	0	Kr	12.3	28	28	134	134	101.00	4.45E+03	9.85E+04	1.00E+07	1.00E+07	0	1.00E-07
101	OPAMP	1	60	0	0	Ta	11.5	77	77	119	119	74.00	1.24E+04	1.36E+05	1.00E+07	1.00E+07	0	1.00E-07
102	OPAMP	2	60	0	0	Ta	11.5	77	77	119	119	74.70	1.23E+04	1.33E+05	9.97E+06	9.97E+06	0	1.00E-07
103	OPAMP	3	60	0	0	Ta	11.5	77	77	119	119	69.30	1.25E+04	1.45E+05	1.00E+07	1.00E+07	0	1.00E-07
104	OPAMP	4	60	0	0	Ta	11.5	77	77	119	119	63.75	1.23E+04	1.56E+05	9.93E+06	9.93E+06	0	1.01E-07