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Texas Instrument DRV8881 2.5A Dual H-Bridge Motor Driver Heavy-Ion Single-Event Effects Test Report

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Table of Contents

1. Introduction

The purpose of this test was to characterize the single-event effects (SEE) susceptibility of the Texas Instrument (TI) DRV8881 2.5A Dual H-Bridge Motor Driver. The device's output was monitored for changes during exposure to heavy-ions at Lawrence Berkeley National Laboratory (LBNL) 88-inch Cyclotron. The main goal of testing was to test for destructive SEEs. Non-destructive SEEs were recorded during testing but not fully characterized. Testing was performed on November 9th and 11th, 2022.

2. Test Result Summary

The DRV8881 did not experience any destructive SEEs during heavy ion irradiation up to Xe at normal incidence with a linear energy transfer (LET) of 51.7 MeV-cm^2/mg. The device had multiple SEFI signatures (current spikes, current dropouts, and sustained elevated currents). The DRV8881 had a SEFI threshold of less than LET of 8 MeV-cm^2/mg. Due to time constraints Ar was the lowest LET ion tested.

3. Devices Tested

3.1. Part Background

The DRV8881 is a bipolar stepper motor driver [1]. The DRV8881 output stage consist of two n-channel power MOSFET H-bridge drivers. It can drive up to 2.5A peak current or 1.4A rms current per H-bridge.

3.2. Device Under Test (DUT) Information

Ten (10) parts of DRV8881s were provided for heavy ion testing. Eight devices were decapsulated, and two devices were used as controls. Device information can be found in the DRV8881 datasheet. The relevant device parameters for this test can be found in Table 1.

Table 1. Part Identification Information

Part Number	DVR8881
REAG ID#	22-014
Manufacturer	Texas Instruments
Lot Date Code	n/a
Quantity Tested	10
Part Function	Motor Driver
Part Technology	Bipolar/MOSFET
Package	HTSSOP

An image of the DVR8881 die after de-lidding can be seen in Figure 1.

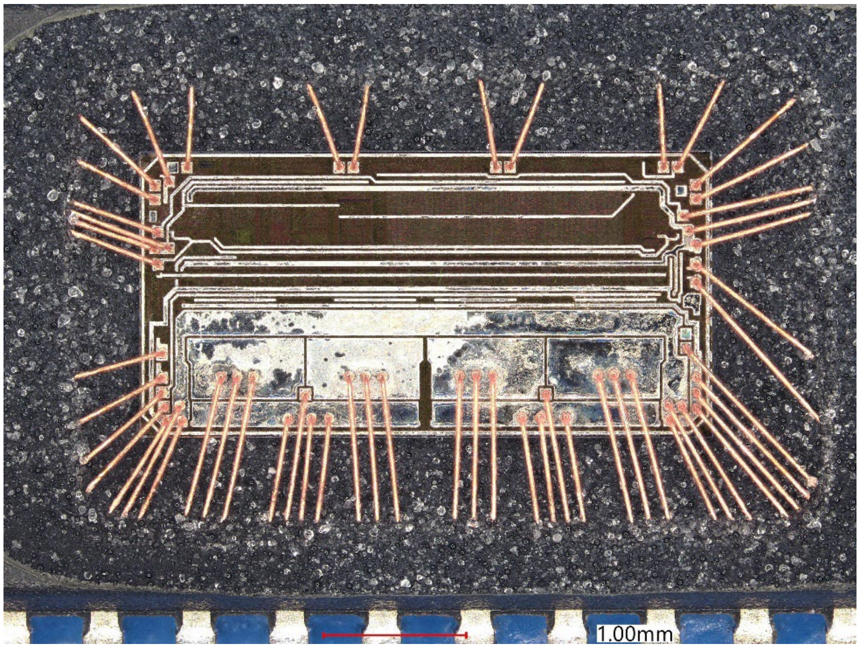

Figure 1: DVR8881 die

4. Test Setup

The test circuit for the DVR8881 were built to approximate the application circuit. Figure 2 shows the circuit diagram implemented on the PCB.

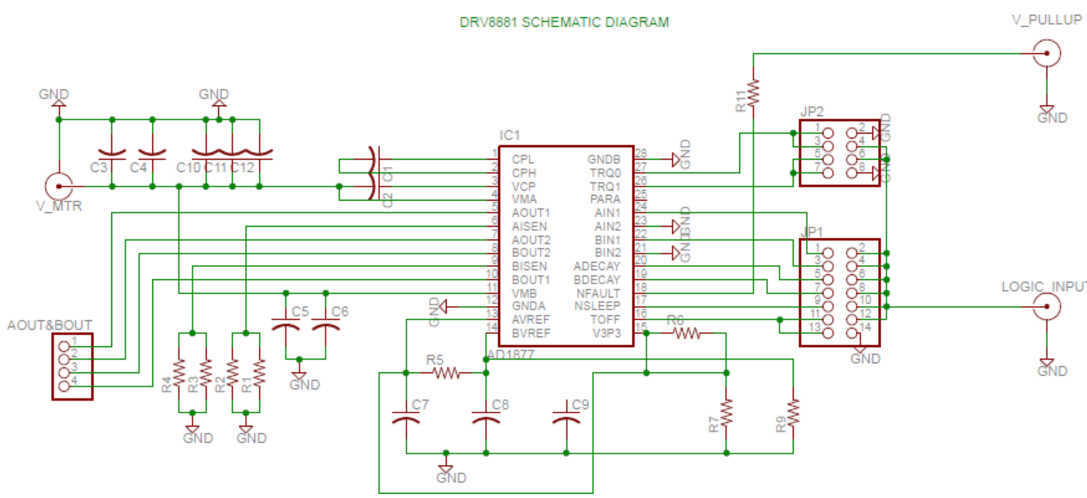

Figure 2: Schematic of the DRV8881 test circuit.

The test setup required a DC power supply, an oscilloscope for capturing the current and voltage, and a laptop equipped with LabVIEW for saving the data. Parts were serialized randomly. Figure 3 shows a block diagram of the experiment setup and Figure 4 shows a device under test (DUT) in the beamline.

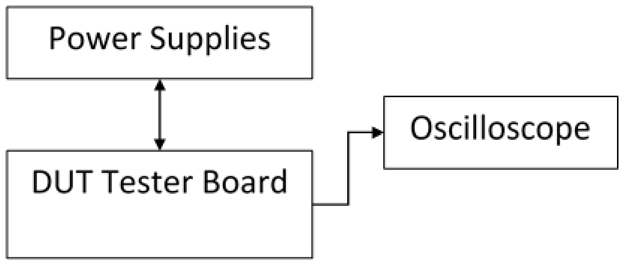

Figure 3: Block Diagram

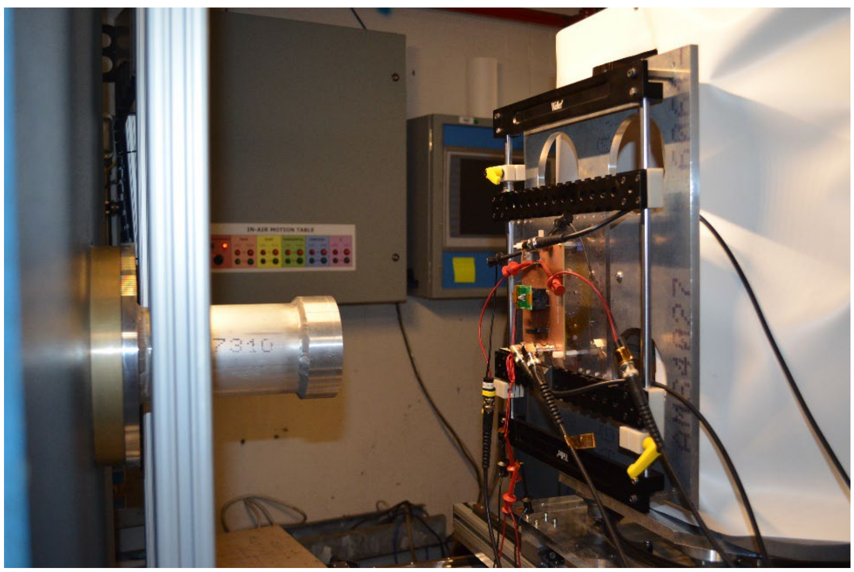

Figure 4: Experiment Test Set-up

The following equipment listed in Table 2 was used for testing.

Table 2: List of necessary equipment

Make	Model	NASA ECN	Comments
Tektronix	DSA 72004	2173383	Oscilloscope
Agilent Technologies	N6702A	M161871	Power supply
Mounting board	N/A	N/A	Mounting board
Cables	N/A	N/A	Cables to make connections

5. Test Facility

SEE testing is done by exposing a decapsulated die to heavy-ions to see the radiation response over various LET. This is done by changing the ion used in the beam. The number of ions is counted until an SEE is detected to determine the event cross section.

Facility: Lawrence Berkeley National Laboratory 88" Cyclotron Facility
Type of Radiation: Heavy ions
Facility Configuration: 16MeV/amu tune
Flux: 1 x 10^3 to 1 x 10^5 particles/cm^2/s
Fluence: All tests will be run to the lesser of 1 x 10^7 ions/cm^2 or a destructive event occurs
Ion Species: Table 3 shows the surface-incident beam properties

Table 3: Notional Energy, Range, and LET Estimates for Accelerated Ions at 16 MeV/amu

Ion	Tilt Angle (°)	Energy (MeV)	Range (µm)	Nominal Incident LET (MeV-cm2/mg)*
^{18}Ar	0	546	201.6	8.07
^{29}Cu	0	788	137.1	18.9
^{36}Kr	0	1024	130.7	28.6
^{47}Ag	0	1219	106.8	45.2
^{54}Xe	0	1523	120.4	51.7

*Air gap 2.54 cm

6. Test Conditions

Test Temperature: 75°C
Vacuum: No
Power Supply (VM): 24V
Logic Voltage: 3.3V
nFault Voltage: 5V
Error Modes: The primary purpose of this test to identify destructive SEEs. All events were captured by the oscilloscope

7. Test Methods and Procedures

The conditions tested during irradiation are shown in table 3. The DUT was powered with 24V power supply. The test conditions are stated in Section 6. A polyimide heater was used to increase the temperature of the DUT to 75°C. LabVIEW was used to monitor and control the DUT temperature. For all conditions tested, transients with positive and negative amplitudes were captured.

8. Test Personnel

Tom Carstens (NASA), Michael Campola (NASA), Matt Joplin (NASA), and Anthony Phan (SSAI).

9. Test Results

During heavy ion irradiation the DRV8881 did not experience any destructive SEEs up to a LET of 51.7 MeV-cm^2/mg. However, SEFIs occurred during each heavy ion irradiation. Three different types of SEFIs were identified (Current spike SEFIs, current dropouts SEFIs, and sustained elevated current SEFIs).

During run 023 the DRV8881 experienced a single large supply current spike when it was irradiated with Ar ions (LET of 8.07 MeV-cm^2/mg). Figure 5 shows the current spike. During the next run with Ar ions the DUT experienced a current dropout. The current drop out is shown in Figure 6. The current never returned to nominal operating conditions during exposure. The DRV8881 had a threshold LET for SEFIs of less than 8.07 MeV-cm^2/mg. Due to time constraints Ar was the lowest LET ion tested.

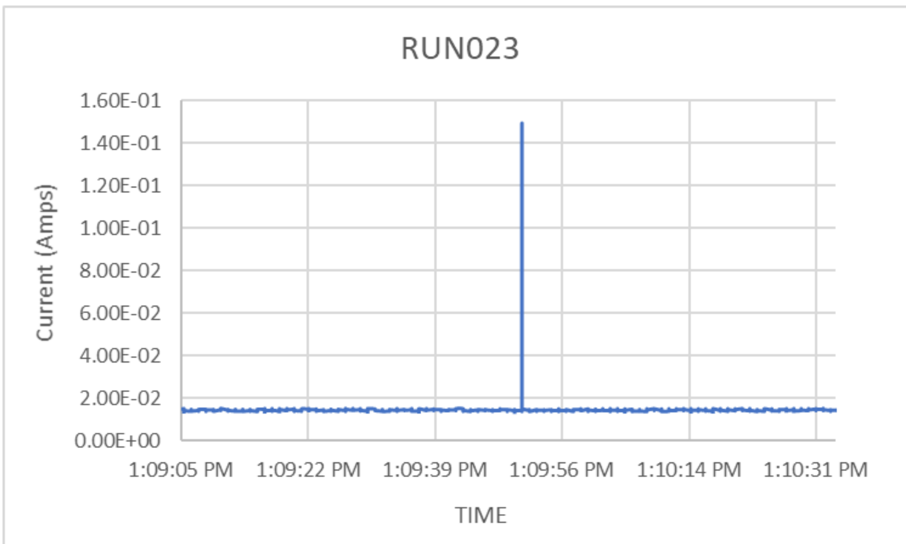

Figure 5: Current Spike During Ar Irradiation with LET of 8.07 MeV-cm^2/mg

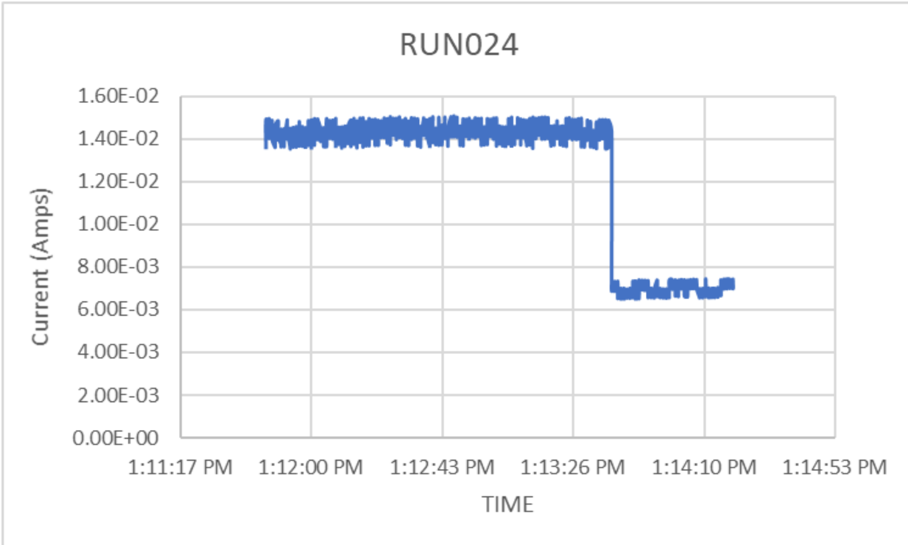

Figure 6: Current Drop During Ar Irradiation with LET of 8.07 MeV-cm^2/mg

When the DRV8881 was irradiated with Cu ions (LET of 18.9 MeV-cm^2/mg) the DUT demonstrated more complicated behavior as seen Figure 7. The output current exhibited both contained current spikes and current dropouts. The current spikes had different amplitudes, and only lasted for a short period of time. In addition, the current dropouts lasted for various amounts of time. The smallest dropout was under one second and the longest was close to 22 seconds. After each current change, the output current returned to the nominal level without intervention.

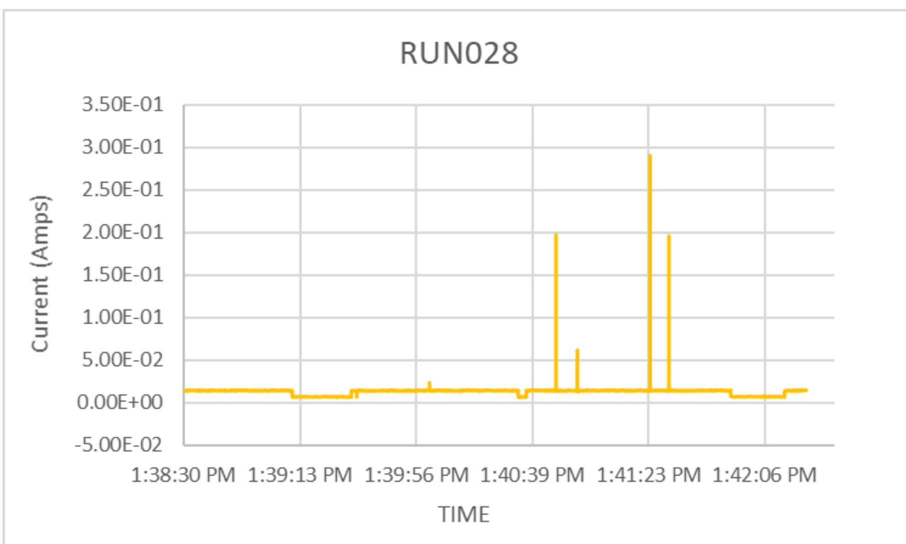

Figure 7: Current Spikes and Current Drops During Cu Irradiation with LET of 18.9 MeV-cm^2/mg

When the DRV8881 was irradiated with Kr ions (LET of 28.6 MeV-cm^2/mg) the DUT experienced multiple different types of SEFIs, seen in Figure 8. The current contained multiple current spikes, current dropouts, and sustained high currents. The current spikes had different amplitudes and only lasted for a short period of time. In addition, the current dropouts lasted for different amounts of time and eventually returned to nominal conditions. At the end of irradiation for run 30, the DUT stayed in a high current state.

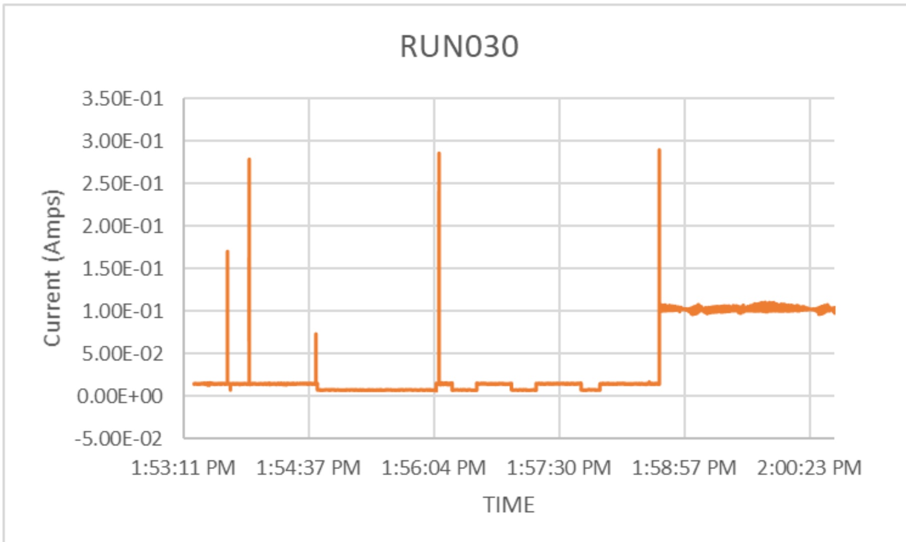

Figure 8: Current Spikes, Current Drops, and Sustained High Currents During Kr Irradiation with LET of 28.6 MeV-cm^2/mg

When the DRV8881 was irradiated with Ag ions (LET of 45.2 MeV-cm^2/mg) the DUT experienced complicated current behavior which can be seen in figure 9. The current contained multiple current spikes, current dropouts, and sustained high currents. Each current dropout lasted for different amount of time. There were multiple instances of sustained high currents. Each sustained high current event lasted for different amounts of time. All these sustained high current events had the same current of 0.1 amps. The current spikes had more variation in the amplitude. The current spikes lasted for short period of time.

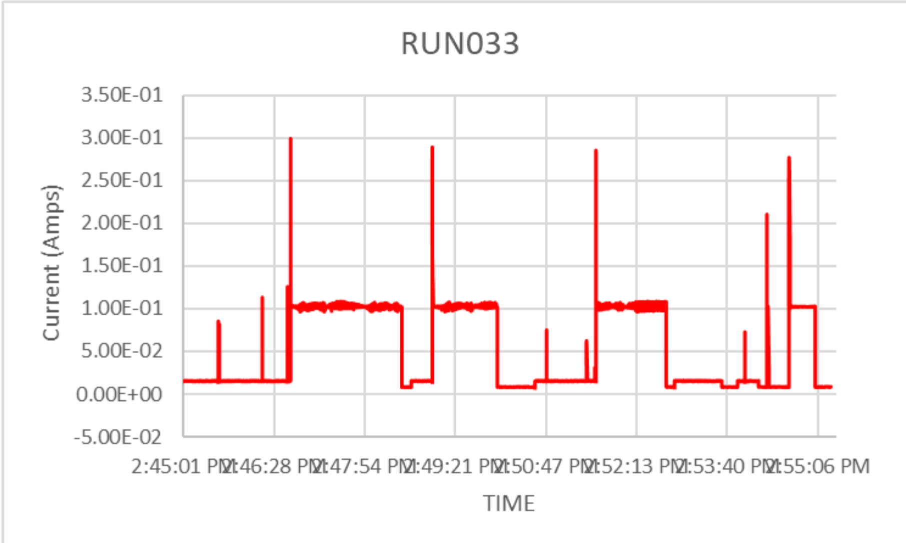

Figure 9: Current Spikes, Current Dropouts, and Sustained High Currents During Ag Irradiation with LET of 45.2 MeV-cm^2/mg

When the DRV8881 was irradiated with Xe ions (LET of 51.7 MeV-cm^2/mg) the DUT shown complicated behavior as seen figure 10. The current experienced no current spikes. The current did experience dropouts and sustained high currents. The current dropouts lasted for different amounts of time. At the end of irradiation for run 11, the DUT stayed in a high current state. The cross section for the SEFI was not measured during this heavy ion test. Additional testing will be required to fully determine the SEFI cross section for the DVR8881.

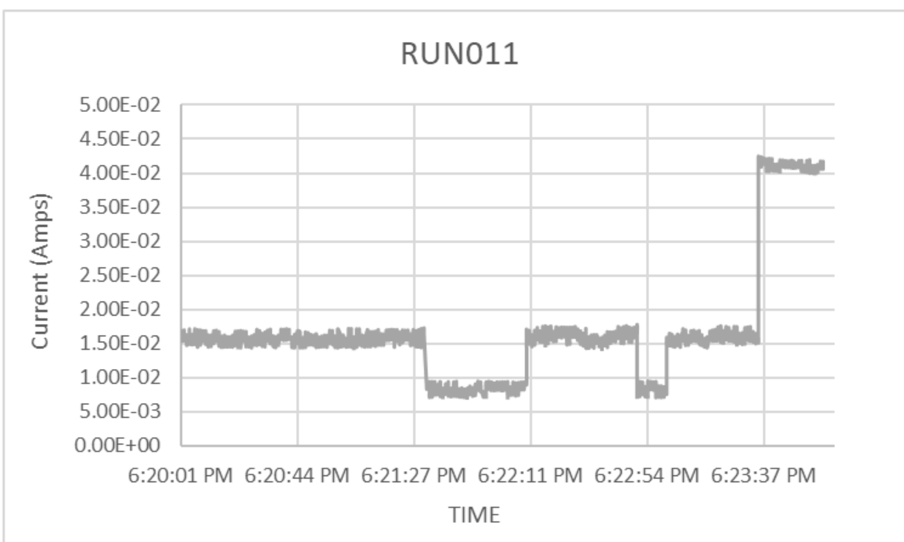

Figure 10: Current Spikes, Current Dropouts, and Sustained High Currents During Xe Irradiation with LET of 51.7 MeV-cm^2/mg

10. REFENCES

[1] Texas Instruments, "DRV881 2.5-A Dual H-Bridge Motor Driver", DRV881 datasheet, June 2015[Revised July 2015].