Radiation Report

Single-Event Effects (SEE) Radiation Report of the ADS1278QML-SP

TEXAS INSTRUMENTS

ABSTRACT

The purpose of this study is to characterize the single-event effects (SEE) performance due to heavy-ion irradiation of the ADS1278QML-SP. Heavy-ions with LET_{EFF} of 51 MeV×cm^2 /mg were used to irradiate three production devices. Flux of 1 × 10^5 ions×cm^2/s and fluence of 1 × 10^7 ions/cm^2 per run were used for the characterization. The results demonstrated that the ADS1278QML-SP is SEL-free up to 51 MeV×cm^2/mg at T = 125°C.

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1 Introduction

The ADS1278QML-SP is a 24-bit, delta-sigma (ΔΣ) analog-to-digital converter (ADC) with data rates up to 128k samples per second (SPS), allowing simultaneous sampling of eight channels.

Traditionally, industrial delta-sigma ADCs offering good drift performance use digital filters with large pass-band droop. As a result, these devices have limited signal bandwidth and are mostly used for DC measurements. High-resolution ADCs in audio applications offer larger usable bandwidths, but the offset and drift specifications are significantly weaker than respective industrial counterparts. The ADS1278QML-SP combines these types of converters, allowing high-precision industrial measurement with excellent DC and AC specifications.

The high-order, chopper-stabilized modulator achieves very low drift with low in-band noise. The onboard decimation filter suppresses modulator and signal out-of-band noise. These ADCs provide a usable signal bandwidth up to 90% of the Nyquist rate with less than 0.005dB of ripple.

The device is offered in an 84-pin ceramic package. General device information and test conditions are listed in the overview information table. For more detailed technical specifications, user's guides, and application notes, please go to the device product page.

Table 1-1. Overview Information

DESCRIPTION (1)	DEVICE INFORMATION
TI Part Number	ADS1278QML-SP
Orderable Part Number	5962L2521001VXC
VID/SMD Number	5962L2521001VXC
Device Function	Data Converter
Technology	0.35u-TSMC
Exposure Facility	Radiation Effects Facility, Cyclotron Institute, Texas A&M University
Heavy Ion Fluence per Run	1.00×10^6 – 1.00×10^7 ions/cm^2
Irradiation Temperature	125°C (for SEL testing)

2 Single-Event Effects (SEE)

The primary concern for the ADS1278QML-SP is the robustness against the destructive single-event effect (DSEE) single-event latch-up (SEL).

SEL can occur if excess current injection caused by the passage of an energetic ion is high enough to trigger the formation of a parasitic cross-coupled PNP and NPN bipolar structure (formed between the p-sub and n-well and n+ and p+ contacts) [1,2]. The parasitic bipolar structure initiated by a single-event creates a high-conductance path (inducing a steady-state current that is typically orders-of-magnitude higher than the normal operating current) between power and ground that persists (is "latched") until power is removed, the device is reset, or until the device is destroyed by the high-current state. The ADS1278QML-SP was tested for SEL at the maximum recommended operating conditions of AVDD = 5V, DVDD = 1.95V, and IOVDD = 3.6V. Output was monitored through a GUI interface to confirm continued operation of the device. During testing of the three devices, the ADS1278QML-SP did not exhibit any SEL with heavy-ions with LET_{EFF} = 51 MeV×cm^2 /mg at flux ≈10^5 ions×cm^2/s , fluence of ≈10^7 ions/cm^2, and a die temperature of 125°C.

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3 Device and Test Board Information

The ADS1278QML-SP is packaged in an 84-pin CFP ceramic package as shown in Figure 3-1. The ADS1278QML-SP evaluation module (EVM) was used to evaluate the performance and characteristics of the ADS1278QML-SP under heavy ion radiation. The EVM is shown in Figure 3-2. The EVM schematic is shown in Figure 3-3.

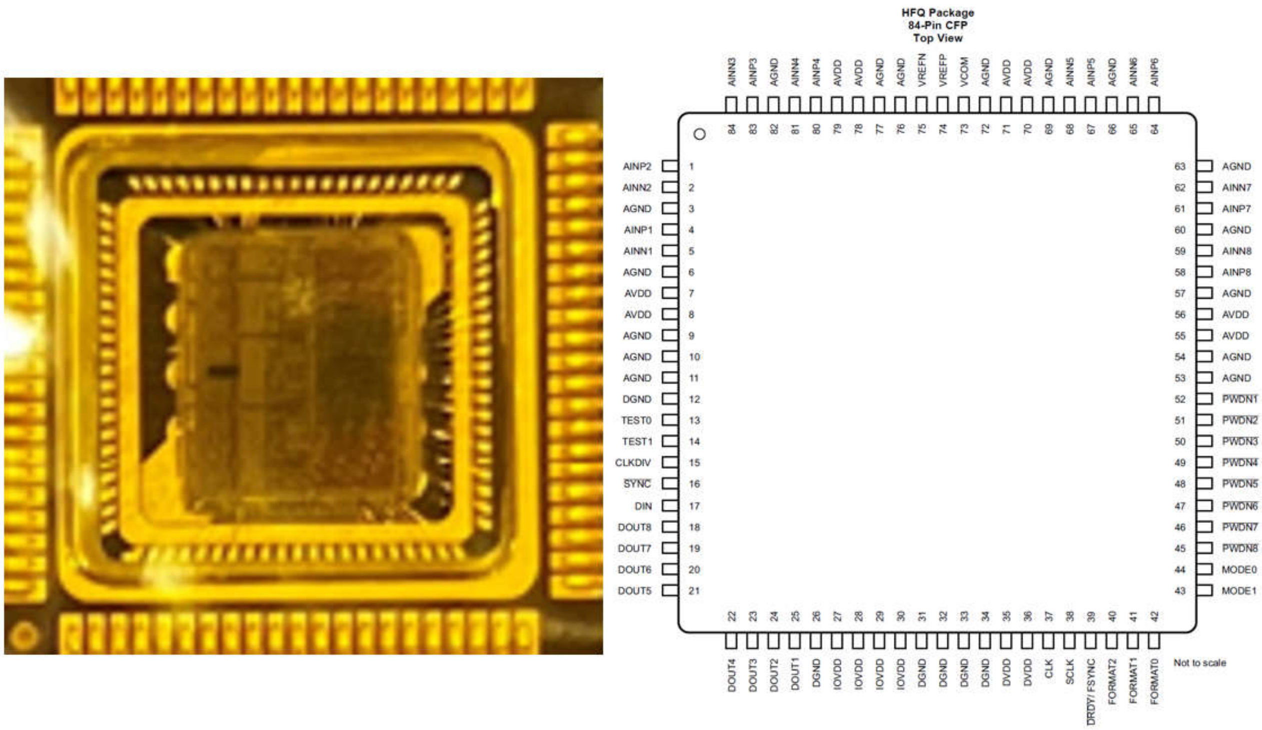

Figure 3-1. Photograph of Delidded ADS1278QML-SP [Left] and Pinout Diagram [Right]

Note: The package was delidded/decapped to reveal the die face for all heavy-ion testing.

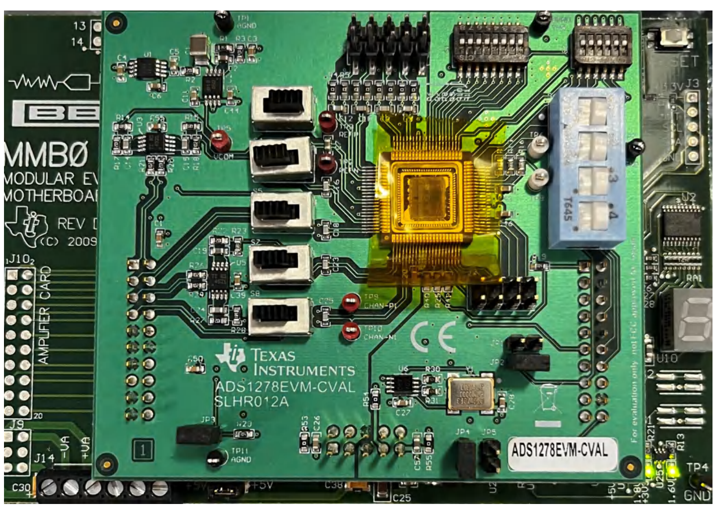

Figure 3-2. ADS1278QML-SP EVM Top View

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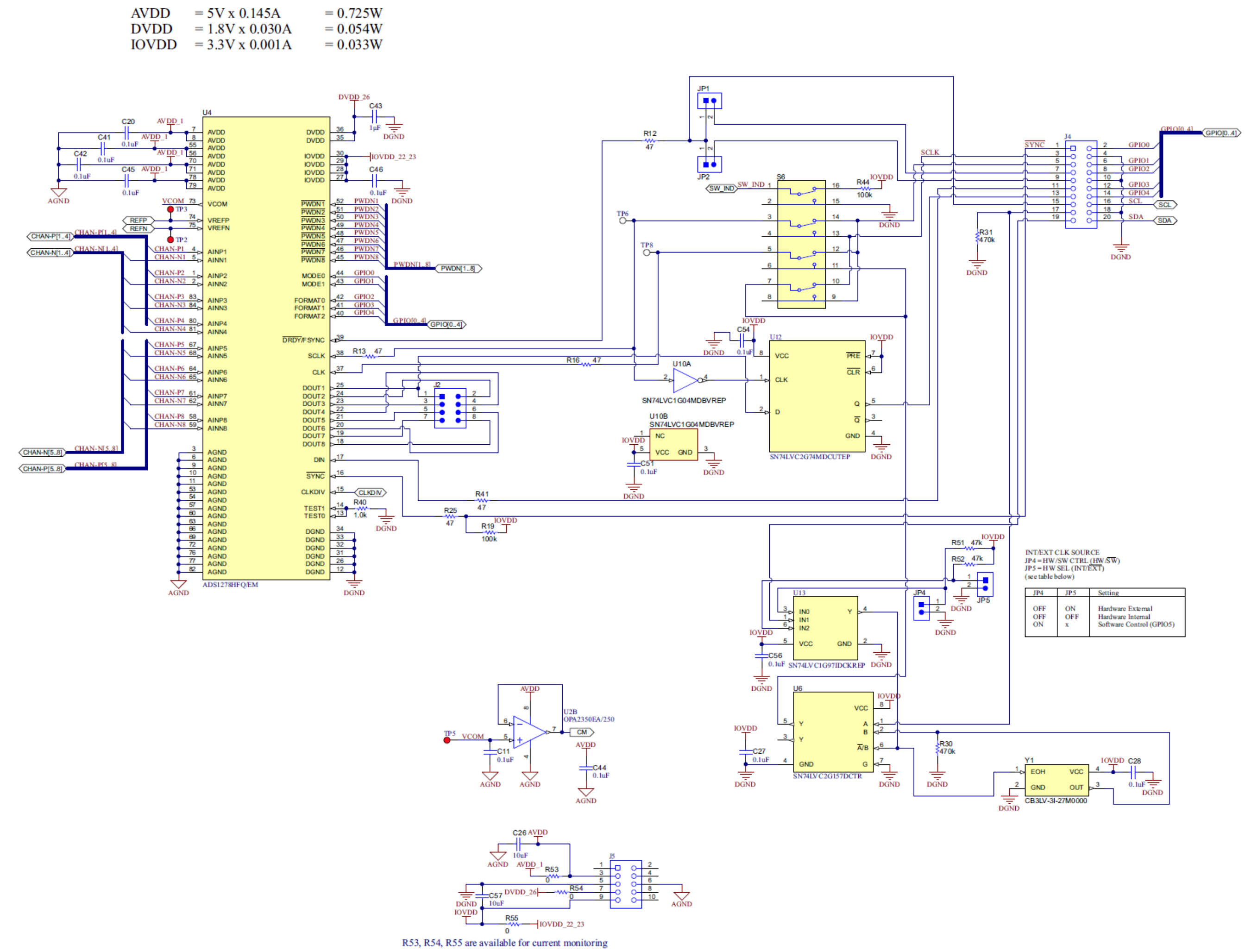

Figure 3-3. ADS1278QML-SP EVM Schematics

4 Irradiation Facility and Setup

The heavy-ion species used for the SEE studies on this product were provided and delivered by:

- Texas A&M University (TAMU) Cyclotron Radiation Effects Facility using a K500 superconducting cyclotron and an advanced electron cyclotron resonance (ECR) ion source. At the fluxes used, ion beams had good flux stability and high irradiation uniformity over a 1-in diameter circular cross-sectional area for the in-air station. Uniformity is achieved by magnetic defocusing. The flux of the beam is regulated over a broad range spanning several orders of magnitude. For these studies, ion flux of 1×10^5 ions/cm^2 ·s was used to provide heavy-ion fluences of 1×10^6 – 1×10^7 ions/cm^2. The TAMU facility uses a beam port that has a 1-mil Aramica window to allow in-air testing while maintaining the vacuum within the particle accelerator. The in-air gap between the device and the ion beam port window was maintained at 40mm for all runs.

For the experiments conducted on this report, there was 1 ion used, ^{109}Ag. ^{109}Ag at an angle of 15 degrees was used to obtain LET_{EFF} of 51MeV×cm^2/mg. The total kinetic energies for each of the ions were:

^{109}Ag = 1.634GeV (15MeV/nucleon)

- – Ion uniformity for these experiments was between 93% and 96%

Figure 4-1 shows the ADS1278QML-SP EVM in front of the beam line at the TAMU facility.

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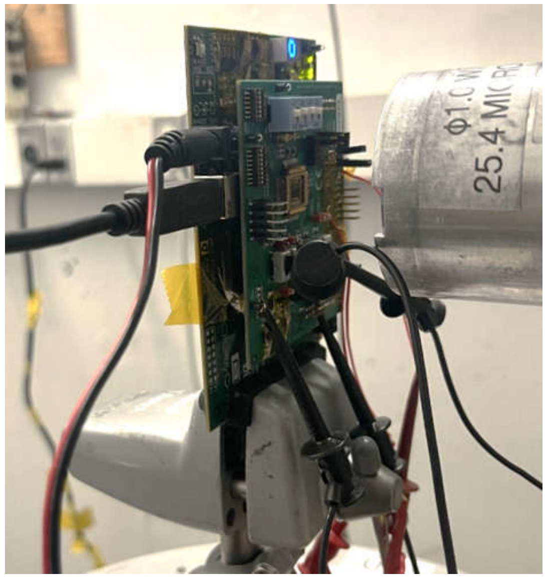

Figure 4-1. ADS1278QML-SP EVM in Front of the Heavy-Ion Beam Exit Port at the Texas A&M Cyclotron

5 LET_{EFF} and Range Calculation

Accounting for energy loss through the degrader, copper foil, beam port window, air gap, and the BEOL stack of the ADS1278QML-SP, the effective LET (LET_{EFF}) at the surface of the silicon substrate and the range was determined with SEUSS 2024 software (provided by TAMU and based on the latest SRIM-2013 [7] models)

The results are shown in Table 5-1.

Table 5-1. Ion LET_{EFF} and Range in Silicon

Facility	Beam Energy (MeV/ nucleon)	Ion Type	Degrader Steps (#)	Degrader Angle (°)	Copper Foil Width (µm)	Beam Port Window	Air Gap (mm)	Angle of Incidence (°)	LET_{EFF} (MeV·cm^2/ mg)	Range in Silicon (µm)
TAMU	15	109Ag	0	0	-	1-mil Aramica	40	15	51	130

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6 Test Setup and Procedures

There were four supplies used to power the ADS1278QML-SP which provided A_{IN}, AVDD, DVDD, and IOVDD.

Device output was continuously monitored to confirm device functionality through USB connection and external GUI.

Power supply equipment was controlled and monitored using a custom-developed LabVIEW™ program (PXI-RadTest) running on a HP-Z4 desktop computer. The computer communicates with the PXI chassis via an MXI controller and NI PXIe-8381 remote control module.

Table 6-1 shows the connections, limits, and compliance values used during the testing. Figure 6-1 shows a block diagram of the setup used for SEE testing of the ADS1278QML-SP.

Table 6-1. Equipment Settings and Parameters Used During the SEE Testing of the ADS1278QML-SP

PIN NAME	EQUIPMENT USED	CAPABILITY	COMPLIANCE	RANGE OF VALUES USED
AIN	NI-PXIe 4139 (CH # 1)	±60V, 3A	3A	5V
AVDD	E36311A (CH # 1)	5V,5A	0.1A	5V
DVDD	E36311A (CH # 2)	5V,5A	0.1A	1.95V
IOVDD	E36311B (CH # 1)	5V,5A	0.1A	3.6V

All boards used for SEE testing were fully checked for functionality. Dry runs were also performed to maintain that the test system was stable under all bias and load conditions prior to being taken to the test facility. During the heavy-ion testing, the LabVIEW control program powered up the ADS1278QML-SP device and set the sourcing functions of the external equipment. After functionality and stability was confirmed, the beam shutter was opened to expose the device to the heavy-ion beam. The shutter remained open until the target fluence was achieved (determined by external detectors and counters). During irradiation, the external GUI continuously monitored the signals. No sudden increases in current were observed (outside of normal fluctuations) on any of the test runs and indicated that no SEL events occurred during any of the tests.

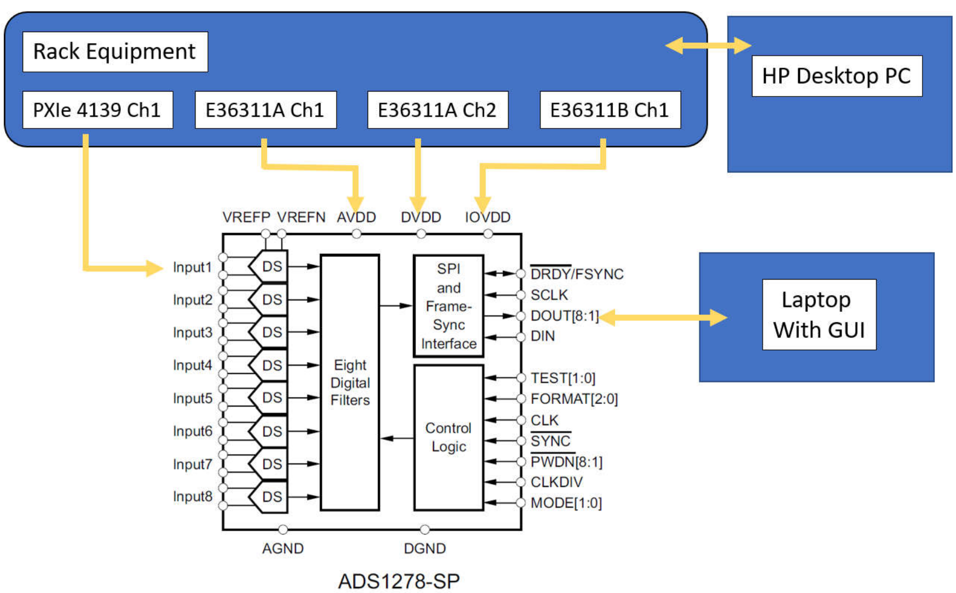

Figure 6-1. Block Diagram of the SEE Test Setup for the ADS1278QML-SP

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7 Destructive Single-Event Effects (DSEE)

7.1 Single-Event Latch-up (SEL) Results

During the SEL testing the device was heated to 125°C by using a closed-Loop PID controlled heat gun (MISTRAL 6 System (120V, 2400W). The temperature of the die was constantly monitored during testing at TAMU through an IR camera integrated into the control loop to create closed-loop temperature control.

The species used for SEL testing was ^{109}Ag at 15 MeV/nucleon (for more details refer to Table 5-1. Ion LET_{EFF} and range in Silicon). Flux of approximately 1 × 10^5 ions×cm^2/s and a fluence of approximately 1 × 10^7 ions/cm^2 per run was used. Run duration to achieve this fluence was approximately two minutes. The three devices were powered up and exposed to the heavy-ions using the maximum recommended operating voltages of AVDD = 5V, DVDD = 1.95V, and IOVDD = 3.6V. No SEL events were observed, indicating that the ADS1278QML-SP is SEL-free up to 51 MeV×cm^2/mg. Table 7-1 shows the SEL test conditions and results. Figures 7-1, 7-2, and 7-3 show plots of the current vs time for run # 14.

Table 7-1. Summary of ADS1278QML-SP SEL Test Condition and Results

Run #	Unit #	Facility	Ion	LET_{EFF} (MeV·cm^2/mg)	Flux (ions·cm^2/mg)	Fluence (# ions)	AIN	AVDD	DVDD	IOVDD	SEL (# Events)
13	5	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0
14	5	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0
15	5	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0
23	4	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0
24	4	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0
25	4	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0
8	2	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0
9	2	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0
10	2	TAMU	109Ag	51	1.0 x 10^5	1 x 10^7	5	5	1.95	3.6	0

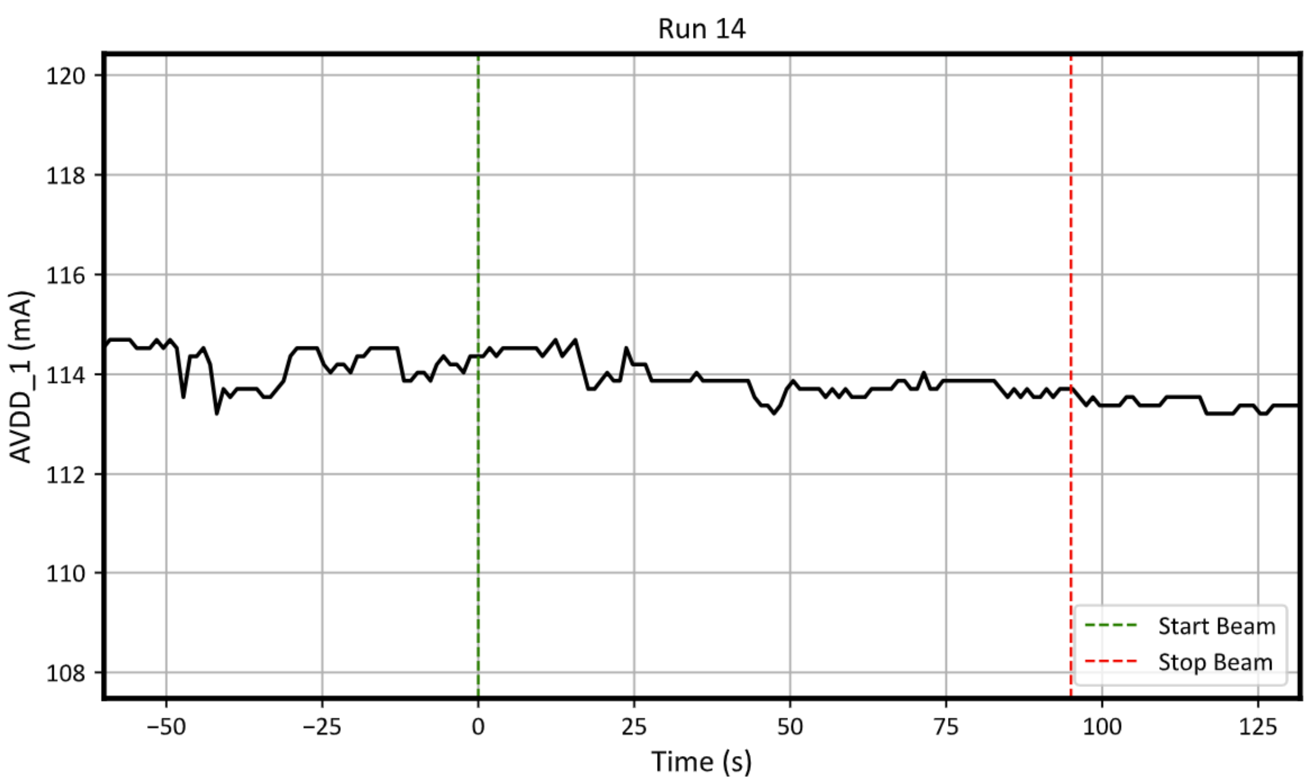

Figure 7-1. AVDD Current versus Time for Run #14 of the ADS1278QML-SP at T = 125°

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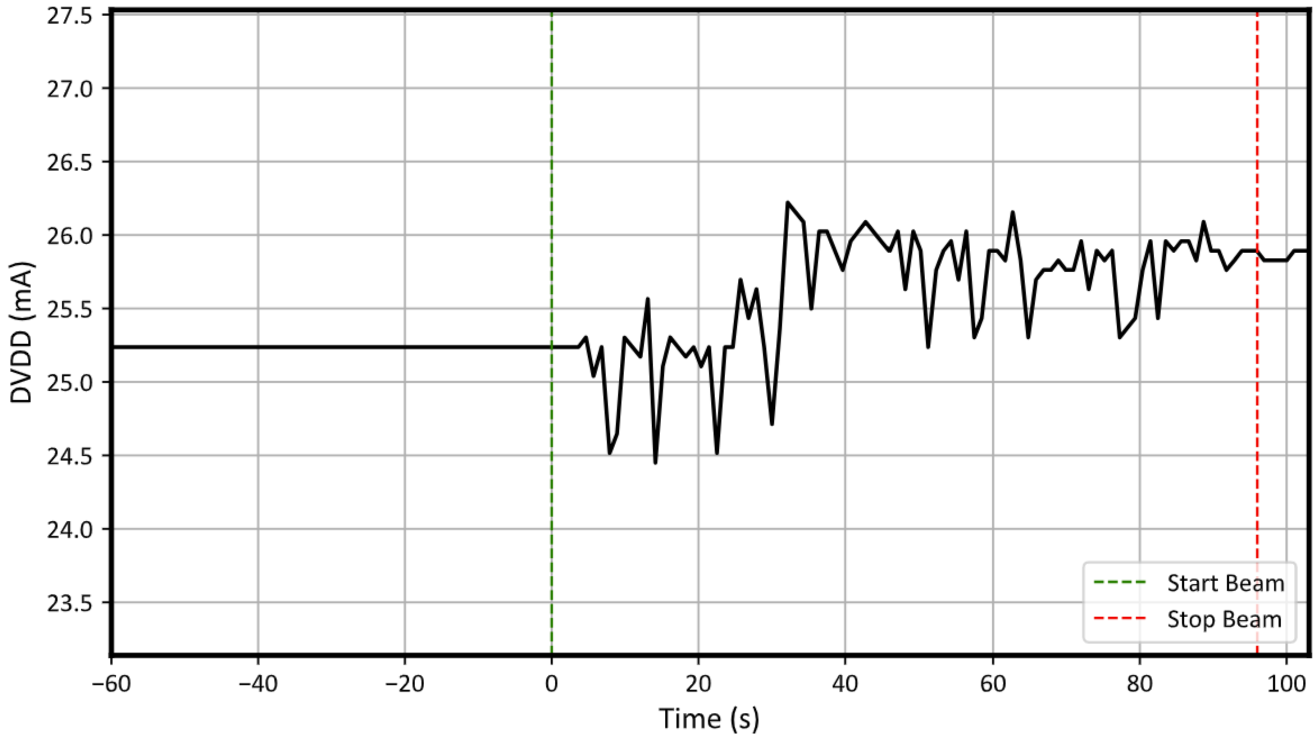

Figure 7-2. DVDD Current versus Time for Run # 23 of the ADS1278QML-SP at T = 125°

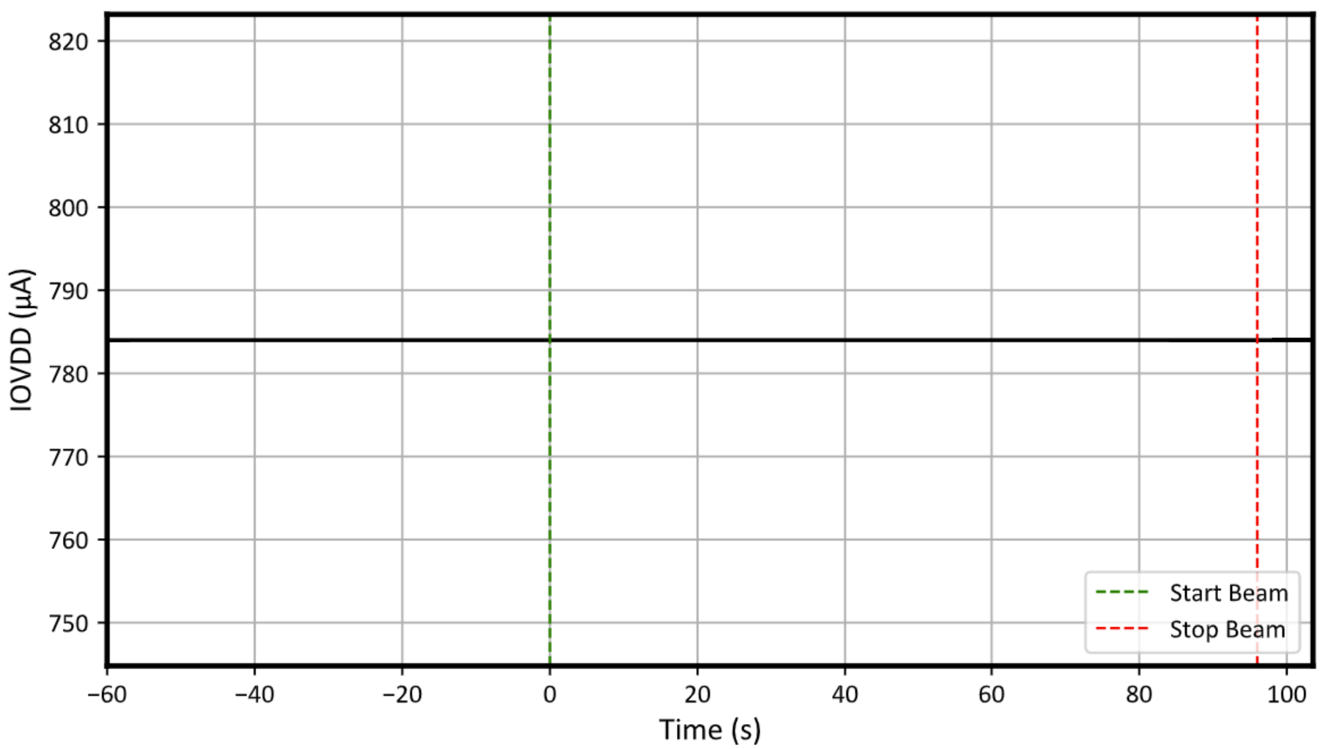

Figure 7-3. IOVDD Current versus Time for Run #23 of the ADS1278QML-SP at T = 125°

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8 Summary

The purpose of this study was to characterize the effect of heavy-ion irradiation on the single-event effect (SEE) performance of the ADS1278QML-SP 24-bit, delta-sigma analog-to-digital converter (ADC). Heavy-ions with LET_{EFF} = 51 MeV×cm^2/mg were used for the SEE characterization campaign. Flux of ≈10^4 to 10^5 ions/cm^2 ×s and fluences of ≈10^6 to 10^7 ions/cm^2 per run were used for the characterization. The SEE results demonstrated that the ADS1278QML-SP is free of destructive SEL at LET_{EFF} = 51 MeV×cm^2/mg and across the full electrical specifications.

9 References

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