Radiation Report

TPS7H1111-SEP Single-Event Effects (SEE)

ABSTRACT

The purpose of this study is to characterize the single-event effects (SEE) performance due to heavy-ion irradiation of the TPS7H1111-SEP. Heavy-ions with LET_{EFF} of 48 MeV·cm^2 /mg were used to irradiate 6 production devices. Flux of 10^4 to 10^5 ions/cm^2·s and fluence of 10^6 to 10^7 ions/cm^2 per run were used for the characterization. The results demonstrated that the TPS7H1111-SEP is SEL-free up to 48 MeV·cm^2/mg at T = 125°C and SEB/SEGR free up to 48 MeV·cm^2/mg at T = 25°C. SET transients performance for output voltage excursions ≥ |3%| from the nominal voltage and PG < 0.5-V (Negative Edge) were setup, however, the TPS7H1111-SEP showed to be V_{OUT} transient free at 48 MeV·cm^2/mg.

Table of Contents

List of Figures

List of Tables

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1 Introduction

The TPS7H1111-SEP is an ultra-low noise, high PSRR, low dropout (LDO) linear regulator optimized for powering RF (radio frequency) devices in a space environment. It is capable of sourcing up to 1.5A over a 0.85-V to 7-V input range with a 2.2-V to 14-V bias supply.

The high performance of the device limits power-supply generated phase noise and clock jitter, making this device ideal for powering high-performance ADCs, DACs, VCOs, PLLs, SerDes, and other RF components in satellites. For digital loads (such as FPGAs and DSPs) requiring low voltage operation, the exceptional accuracy and excellent transient performance ensure optimal system performance.

The device is offered in a 28-pin plastic package. General device information and test conditions are listed in Table 1-1. For more detailed technical specifications, user-guides, and application notes see the TPS7H1111-SEP product page.

Table 1-1. Overview Information

DESCRIPTION(1)	DEVICE INFORMATION
TI Part Number	TPS7H1111-SEP
Orderable Number	TPS7H1111MPWPTSEP
Device Function	Ultra-Low Noise Low Dropout (LDO) Linear Regulator
Technology	Linear BiCMOS 7 (LBC7)
Exposure Facility	Radiation Effects Facility, Cyclotron Institute, Texas A&M University (15 MeV/nucleon)
Heavy Ion Fluence per Run	1.00×10^6 – 1.00×10^7 ions/cm^2
Irradiation Temperature	25°C (for SEB/SEGR testing), 25°C (for SET testing), and 125°C (for SEL testing)

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2 Single-Event Effects (SEE)

The primary concern for the TPS7H1111-SEP is the robustness against the destructive single-event effects (DSEE): single-event latch-up (SEL), single-event burnout (SEB), and single-event gate rupture (SEGR). In mixed technologies such as the BiCMOS process used on the TPS7H1111-SEP, the CMOS circuitry introduces a potential for SEL susceptibility.

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) [,]. 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 TPS7H1111-SEP was tested for SEL at the maximum recommended input voltage (V_{IN}) of 7-V and the maximum recommended bias voltage (V_{BIAS}) of 14-V. Two different output voltage (V_{OUT}) conditions were tested to achieve minimum, 0.4-V, and maximum, 5.5-V, operating conditions. The output loads varied depending on V_{OUT} with a load of 0.38 ohms, 1.05-A, for the 0.4-V output condition and 3.8 ohms, 1.5-A, for the 5.5-V output condition. The difference in output loads was based on device temperature and ensuring the device reached, but did not exceed 125°C. During testing of the 4 devices, the TPS7H1111-SEP did not exhibit any SEL with heavy-ions with LET_{EFF} = 48 MeV·cm^2/mg at flux of 10^5 ions/cm^2·s, fluence of 10^7 ions/cm^2, and a die temperature of 125°C.

The TPS7H1111-SEP was evaluated for SEB/SEGR at a maximum voltage of 14-V in the enabled and disabled mode. Because it has been shown that the MOSFET susceptibility to burnout decrement with temperature [5], the device was evaluated while operating under room temperatures. The device was tested with no external thermal control device. Different output loads were used in order to achieve the highest possible load without exceeding a temperature too high for valid SEB testing. A load of 4 ohms, 100mA, was used for the 0.4-V output condition and a load of 3.8 ohms, 1.5-A, was used for the 5.5-V output condition. During the SEB/SEGR testing, not a single current event was observed, demonstrating that the TPS7H1111-SEP is SEB/SEGR-free up to LET_{EFF} = 48 MeV·cm^2/mg at a flux of 10^5 ions/cm^2·s, fluences of 10^7 ions/cm^2, and a die temperature of 25°C.

The TPS7H1111-SEP was characterized for SET at flux of 8.43×10^3 to 1.07×10^4 ions/cm^2·s, fluences of 1.00×10^6 ions/cm^2, and room temperature. The device was characterized at V_{IN} of 2.5-V and V_{BIAS} of 5, 12, and 14-V. Different V_{BIAS} conditions were used to test the TPS7H1111-SEP in "golden configuration" (5-V) and "silver configuration" (12-V). Heavy-ions with LET_{EFF} of 48-MeV·cm^2/mg were used to characterize the transient performance. To see the SET results of the TPS7H1111-SEP, please refer to Section 8.

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3 Device and Test Board Information

The TPS7H1111-SEP is packaged in a 28-pin thermally-enhanced plastic package as shown in Figure 3-1. The TPS7H1111-SEP evaluation module was used to evaluate the performance and characteristics of the TPS7H1111- SEP under heavy ion radiation. The TPS7H1111-SEP EVM (Evaluation Module) is shown in Figure 3-2. Board schematics are shown in Section 3.1.

Note

The package was exposed to reveal the die face for all heavy-ion testing.

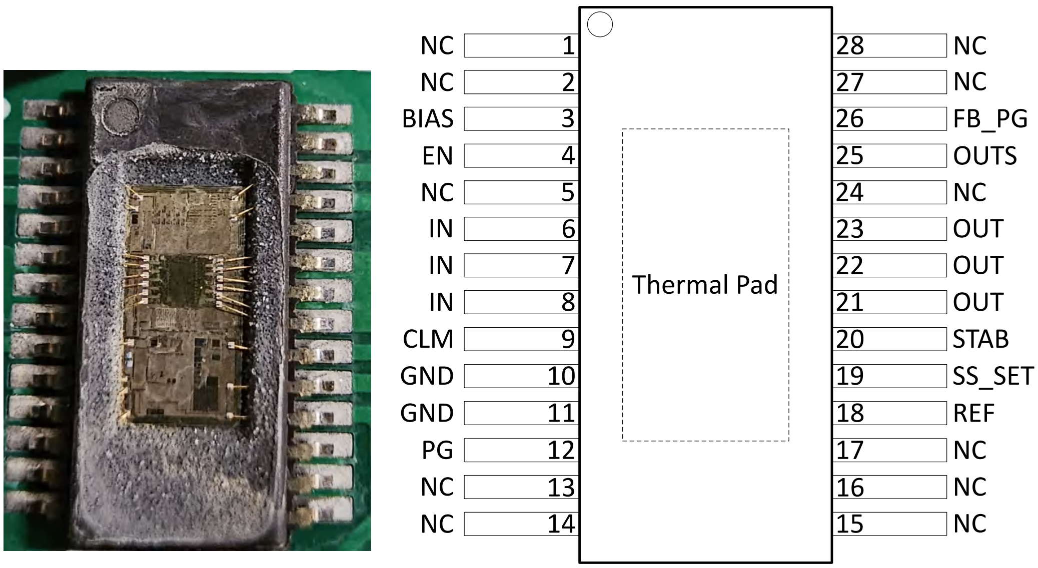

Figure 3-1. Photograph of Exposed TPS7H1111-SEP [Left] and Pinout Diagram [Right]

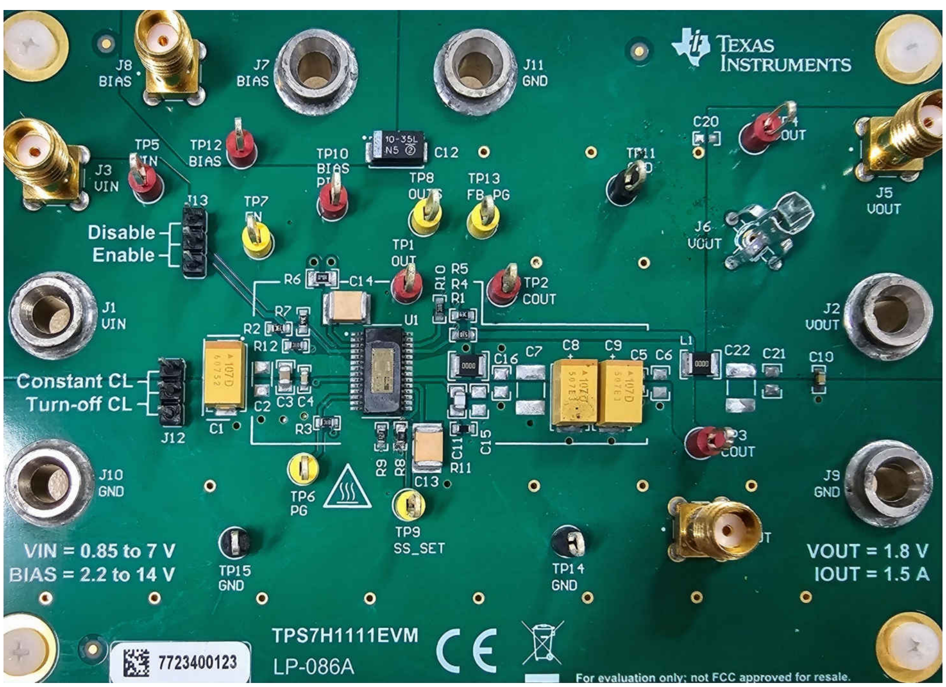

Figure 3-2. TPS7H1111-SEP SEE Test Board Top View

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3.1 TPS7H1111-SEP SEE Test Board Schematics

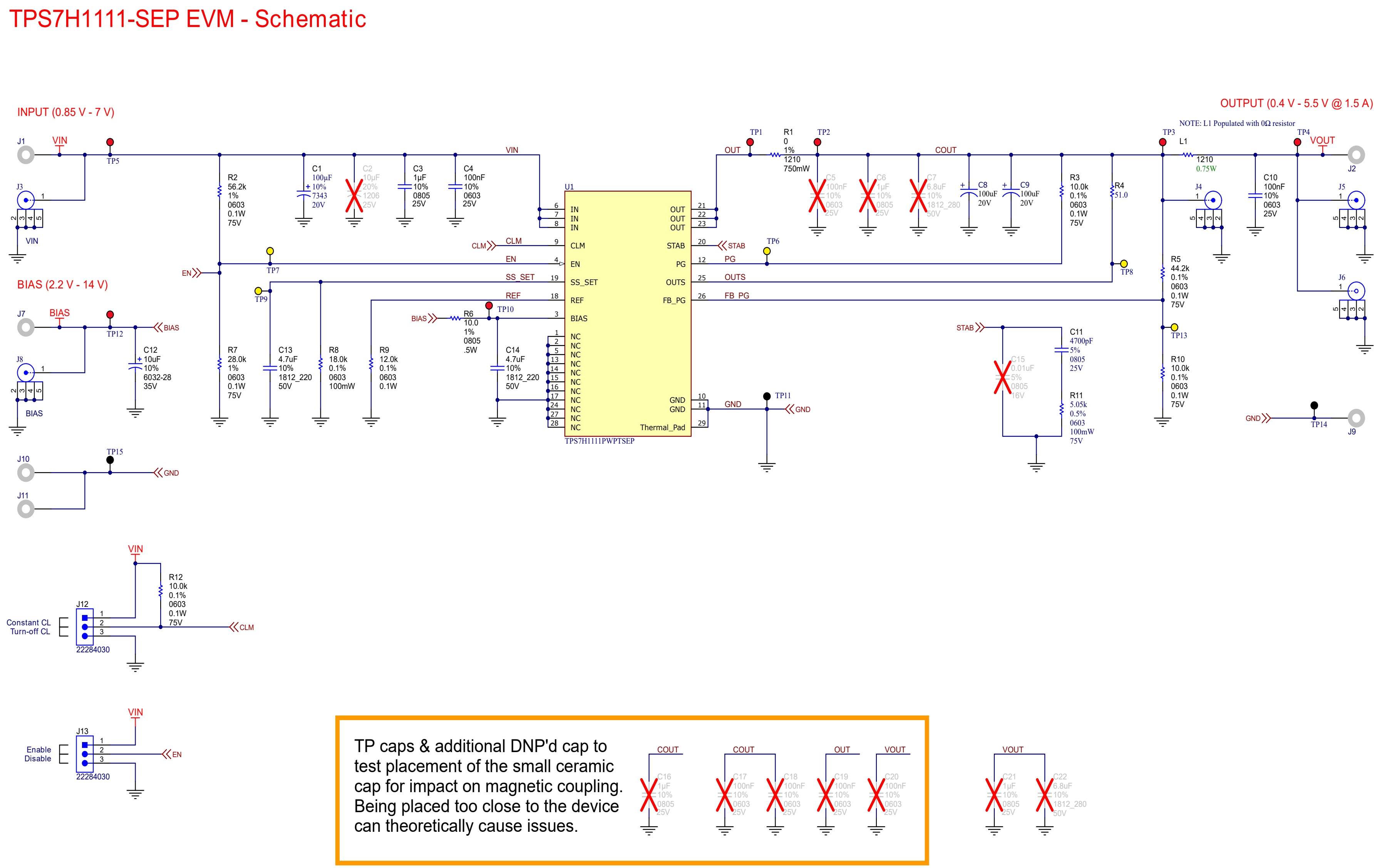

Figure 3-3. TPS7H1111-SEP SEE Test Board Schematics

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4 Irradiation Facility and Setup

The heavy-ion species used for the SEE studies on this product were provided and delivered by the TAMU Cyclotron Radiation Effects Facility using a 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 1.02×10^4 to 1.12×10^5 ions/cm^2·s were used to provide heavy-ion fluences of 1.00×10^6 to 1.00×10^7 ions/cm^2.

For the experiments conducted on this report there was 1 ion used, ^{109}Ag. ^{109}Ag was used to obtain LET_{EFF} of 48 MeV·cm^2/mg. The total kinetic energys for each of the ions was ^{109}Ag = 1.634 GeV (15 MeV/nucleon) – Ion uniformity for these experiments was between 93 and 96%

Figure 4-1 shows the TPS7H1111-SEP EVM used for the data collection at the TAMU facility. Although not visible in this photo, the beam port has a 1-mil Aramica window to allow in-air testing while maintaining the vacuum within the accelerator with only minor ion energy loss. The in-air gap between the device and the ion beam port window was maintained at 40 mm for all runs.

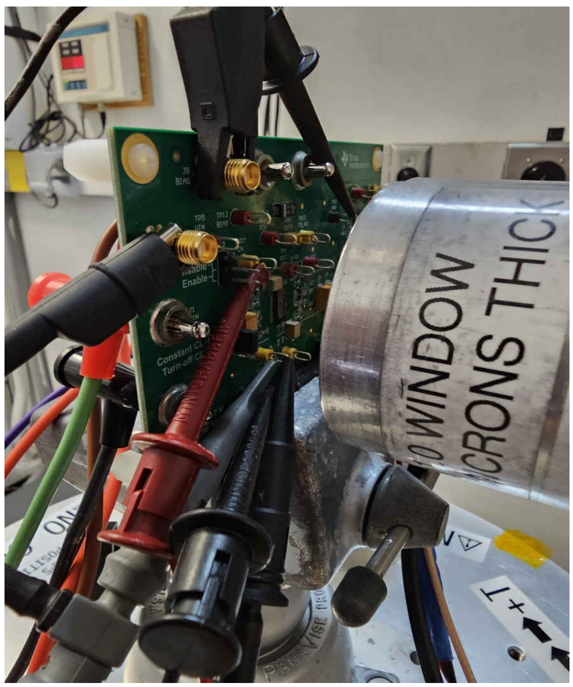

Figure 4-1. Photograph of the TPS7H1111-SEP EVM in Front of the Heavy-Ion Beam Exit Port at the Texas A&M Cyclotron

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5 Depth, Range, and LET$_{EFF}$ Calculation

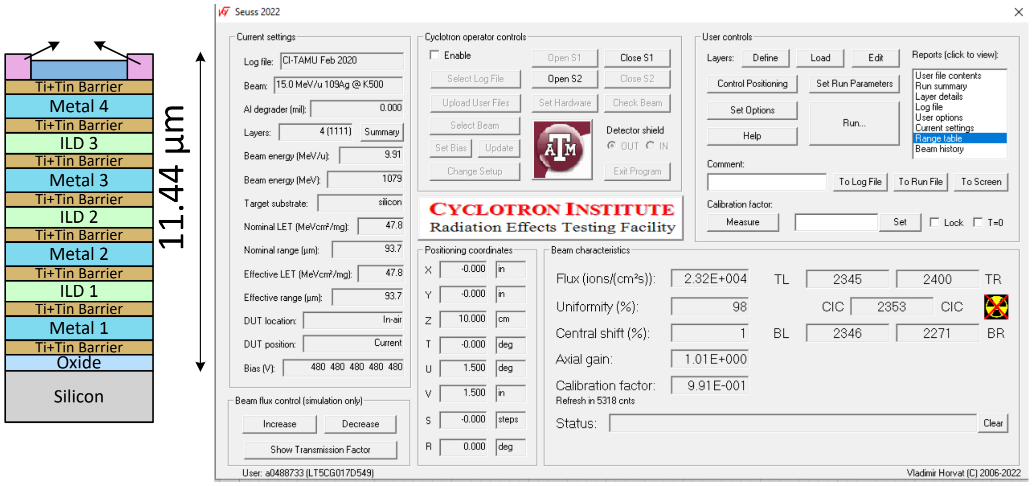

Figure 5-1. Generalized Cross-Section of the LBC7 Technology BEOL Stack on the TPS7H1111-SEP [Left] and SEUSS 2022 Application Used to Determine Key Ion Parameters [Right]

The TPS7H1111-SEP is fabricated in the TI Linear BiCMOS 250-nm process with a back-end-of-line (BEOL) stack consisting of 4 levels of standard thickness aluminum. The total stack height from the surface of the passivation to the silicon surface is 11.44 µm based on nominal layer thickness as shown in Figure 5-1. Accounting for energy loss through the 1-mil thick Aramica beam port window, the 40-mm air gap, and the BEOL stack over the TPS7H1111-SEP, the effective LET (LET$_{EFF}$) at the surface of the silicon substrate, the depth, and the ion range was determined with the SEUSS 2022 Software (provided by the Texas A&M Cyclotron Institute and based on the latest SRIM-2013 models). The results are shown in Table 5-1. The LET$_{EFF}$ vs range for the used heavy-ion are shown below. The stack was modeled as a homogeneous layer of silicon dioxide (valid since SiO_2 and aluminum density are similar).

Table 5-1. Ion LET$_{EFF}$, Depth, and Range in Silicon

ION TYPE	BEAM ENERGY (MeV/nucleon)	ANGLE OF INCIDENCE	RANGE IN SILICON (µm)	LET$_{EFF}$ (MeV·cm^2/mg)
^{109}Ag	15	0	95.1	48

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6 Test Setup and Procedures

There were three input supplies used to power the TPS7H1111-SEP which provided V_{IN}, V_{BIAS} and EN. The V_{IN} for the device was provided via Ch. 1 of an N6705C power module and ranged from 2.5V for SET to 7-V for SEL and SEB/SEGR. The V_{BIAS} for the device was provided by a National Instruments (NI) PXIe-4139 SMU and ranged from 5-V to 14-V depending on the type of test. The last input supply was Ch. 1 of an E36311A power supply and ranged from 0-V for SEB Off to 2.5-V for most SET testing and 5-V for all DSEE testing.

The instrument used to load the TPS7H1111-SEP was a Chroma E36300 E-Load that was used in Constant Resistance (CR) mode. The value of CR was adjusted depending on the type of test. For the SEB testing during the V_{OUT} = 0.4-V case the CR value had to be set such that the load on the device would not heat the device too much in order to ensure the test would remain valid. For the SEL testing during the V_{OUT} = 0.4-V case the CR value was set to achieve a load of 1-A as this load provided the correct amount of device heating to achieve a die temperature of 125°C.

The primary signal monitored on the EVM was V_{OUT} and this was done using two instruments. The first was a NI PXIe-5172 Scope card which was set to trigger on a 3% window based on the nominal value of V_{OUT}.

The second was a TDS7404B with the same 3% window trigger based on its measured value of V_{OUT}. All SEB On, SEL, and SET testing used these conditions with only the SEB Off testing having different conditions.

The conditions for SEB Off were a positive edge trigger at 0.5V which would check to see if the device ever incorrectly turned on while it was disabled.

All equipment other than the TDS7404B 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. The TDS7404B was used using the manufacturer interface. The DPO was set to fast-frame for all SET's data collection.

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 TPS7H1111-SEP.

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Table 6-1. Equipment Settings and Parameters Used During the SEE Testing of the TPS7H1111-SEP

PIN NAME	EQUIPMENT USED	CAPABILITY	COMPLIANCE	RANGE OF VALUES USED
V_{IN}	N6705C (CH#1)	20.4-V, 50-A	5-A	2.5 to 7-V
V_{BIAS}	N6705C (CH#3)	60V, 17.4-A	3-A	5 to 14-V
EN	E36311A (CH#1)	5V, 5A	0.1A	0-V, 5-V
V_{OUT}, PG	TDS7404B	40 GS/s	—	2.5 and 5 GS/s
V_{OUT}	PXIe-5172 (1)	100 MS/s	—	100 MS/s
PG	PXIe-5172 (2)	100 MS/s	—	2.5 and 5 GS/s
V_{OUT}	Chroma E36300 Load	80A	Low	—

All boards used for SEE testing were fully checked for functionality. Dry runs were also performed to ensure that the test system was stable under all bias and load conditions prior to being taken to the TAMU facility. During the heavy-ion testing, the LabVIEW control program powered up the TPS7H1111-SEP device and set the external sourcing and monitoring 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 NI scope cards continuously monitored the signals. When the output voltage (V_{OUT}) exceeded the pre-defined 3% window trigger, a data capture was initiated. In addition to monitoring the time duration of the two scopes (V_{OUT} and PG), V_{IN} current was monitored at all times. No sudden increases in current were observed (outside of normal fluctuations) on any of the test runs and indicated that no SEL or SEB/SEGR events occurred during any of the tests.

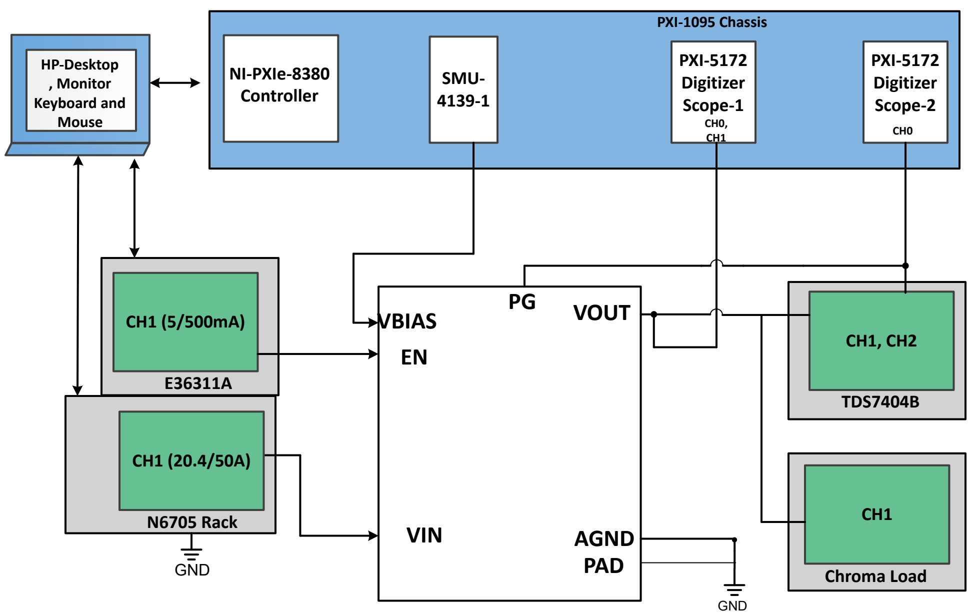

Figure 6-1. Block Diagram of the SEE Test Setup for the TPS7H1111-SEP

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7 Destructive Single-Event Effects (DSEE)

7.1 Single-Event Latch-Up (SEL) Results

During the SEL tesing 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 verified using thermal camera prior to exposure to heavy ions.

The ion species used for the SEL testing was Silver (^{109}Ag @ 15 MeV/nucleon). An LET_{EFF} = 48 MeV·cm^2/mg was achieved with an angle of incidence of 0°. Flux of approximately 10^5 ions/cm^2·s and a fluence of approximately 10^7 ions/cm^2 per run was used. Run duration to achieve this fluence was approximately 2 minutes. The four devices were powered up and exposed to the heavy-ions using the maximum recommended input voltage of 7-V, the maximum recommended bias voltage of 14-V. Two different output conditions were tested, the minimum recommended output voltage of 0.4-V and the maximum recommended output voltage of 5.5-V. No SEL events were observed during all four runs, indicating that the TPS7H1111-SEP is SEL-free up to 48 MeV·cm$^{\mathbf{2}}$/mg. Table 7-1 shows the SEL test conditions and results. Figure 7-1 shows a plot of the current vs time for run #1.

Table 7-1. Summary of TPS7H1111-SEP SEL Test Condition and Results

RUN #	UNIT #	ION	LET_{EFF} (MeV·cm^2/mg)	FLUX (ions·cm^2/mg)	FLUENCE (ions·cm^2/mg)	V_{IN}	V_{BIAS}	V_{OUT}	I_{OUT} (A)	SEL EVENTS
1	1	^{109}Ag	48	1.52×10^5	1×10^7	7	14	5.5	1.5	0
2	2	^{109}Ag	48	1.03×10^5	1×10^7	7	14	5.5	1.5	0
3	3	^{109}Ag	48	1.33×10^5	1×10^7	7	14	0.4	1	0
4	4	^{109}Ag	48	1.22×10^5	1×10^7	7	14	0.4	1	0

Using the MFTF method described in*Single-Event Effects (SEE) Confidence Interval Calculations* application note and combining (or summing) the fluences of the four runs @ 125°C (4×10^7), the upper-bound cross-section (using a 95% confidence level) is calculated as:

$\sigma_{SEL} \leq 9.22 \times 10^{-8}$ cm^2/device for LET_{EFF} = 48 MeV·cm^2/mg and T = 125°C.

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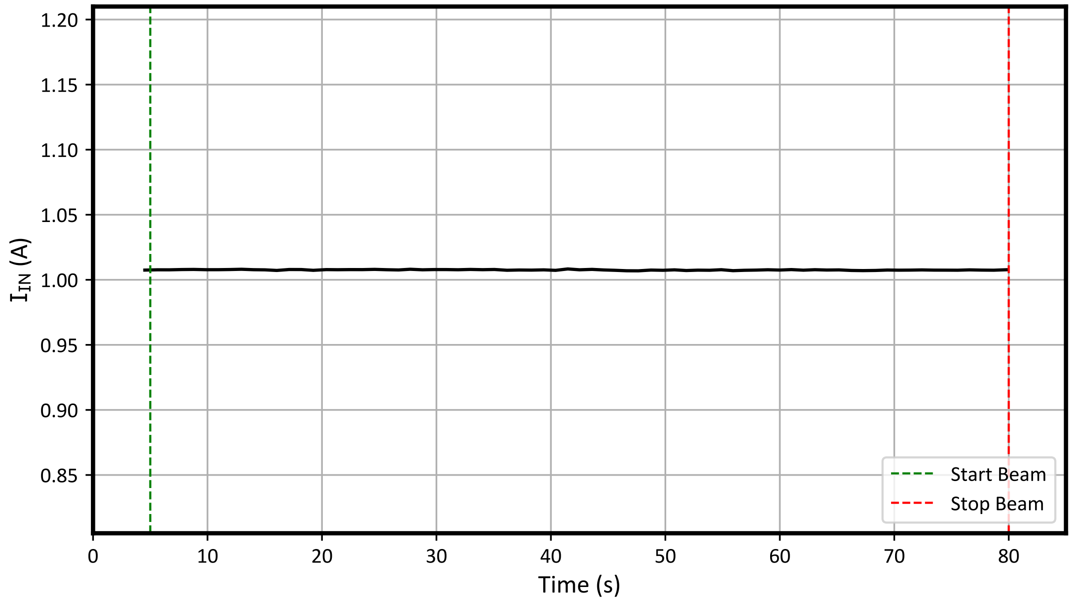

Figure 7-1. Current vs Time for Run #1 of the TPS7H1111-SEP at T = 125°C (0.4-V)

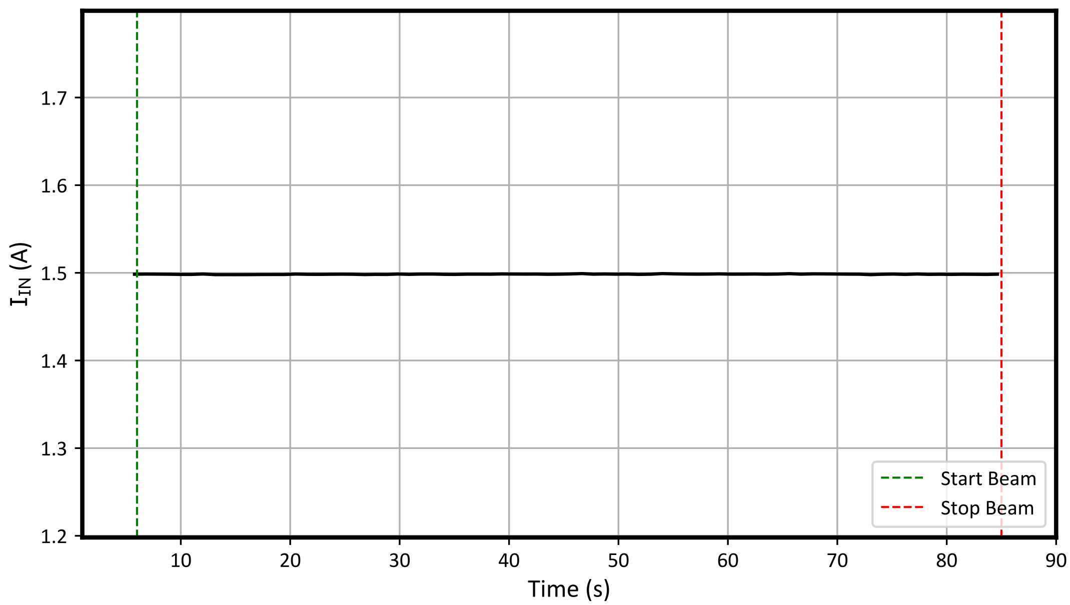

Figure 7-2. Current vs Time for Run #3 of the TPS7H1111-SEP at T = 125°C (5.5-V)

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7.2 Single-Event Burnout (SEB) and Single-Event Gate Rupture (SEGR) Results

During the SEB/SEGR characterization, the device was tested at room temperature of approximately 25°C. The device was tested under both the enabled and disabled mode. For the SEB-OFF mode the device was disabled using the EN-pin by forcing 0-V (using CH # 1 of a E36311A Keysight PS). During the SEB/SEGR testing with the device enabled/disabled, not a single input current event was observed.

The species used for the SEB and SEGR testing was Silver (^{109}Ag) ion with an angle-of-incidence of 0°, for an LET_{EFF} = 48 MeV·cm^2/mg. Flux of approximately 10^5 ions/cm^2·s and a fluence of approximately 10^7 ions/cm^2 was used for the run. Run duration to achieve this fluence was approximately 2 minutes. The four devices (same as used in SEL testing) were powered up and exposed to the heavy-ions using the maximum recommended input voltage of 7-V, the maximum recommended bias voltage of 14-V. Two different output conditions were tested, the minimum recommended output voltage of 0.4-V and the maximum recommended output voltage of 5.5-V. No SEB/SEGR current events were observed during the 8 runs, indicating that the TPS7H1111-SEP is SEB/SEGR-free up to LET_{EFF} = 75 MeV·cm^2/mg and across the full electrical specifications. Table 7-2 shows the SEB and SEGR test conditions and results. Figure 7-3 shows the current versus time for run #5 (Disabled) and Figure 7-4 shows the current versus time for run #6 (Enabled).

Table 7-2. Summary of TPS7H500x-SEP SEB/SEGR Test Condition and Results

RUN #	UNIT #	ION	LET_{EFF} (MeV·cm^2/mg)	FLUX (ions·cm^2/mg)	FLUENCE (# ions)	ENABLED STATUS	V_{IN}	V_{BIAS}	V_{OUT}	I_{OUT} (mA)	SEB EVENT?
5	1	^{109}Ag	48	1.39×10^5	1×10^7	Disabled	7	14	0	0	No
6	1	^{109}Ag	48	1.39×10^5	1×10^7	Enabled	7	14	0.4	100	No
7	2	^{109}Ag	48	1.43×10^5	1×10^7	Disabled	7	14	0	0	No
8	2	^{109}Ag	48	1.34×10^5	9.97×10^6	Enabled	7	14	0.4	100	No
9	3	^{109}Ag	48	1.13×10^5	1×10^7	Disabled	7	14	0	0	No
10	3	^{109}Ag	48	1.17×10^5	1×10^7	Enabled	7	14	5.5	100	No
11	4	^{109}Ag	48	9.96×10^4	9.97×10^6	Disabled	7	14	0	0	No
12	4	^{109}Ag	48	1.04×10^5	9.97×10^6	Enabled	7	14	5.5	100	No

Using the MFTF method described in *Single-Event Effects (SEE) Confidence Interval Calculations* application note, the upper-bound cross-section (using a 95% confidence level) is calculated as:

$\sigma_{SEB} \leq 4.61 \times 10^{-8}$ cm^2/device for LET_{EFF} = 75 MeV·cm^2/mg and T = 25°C.

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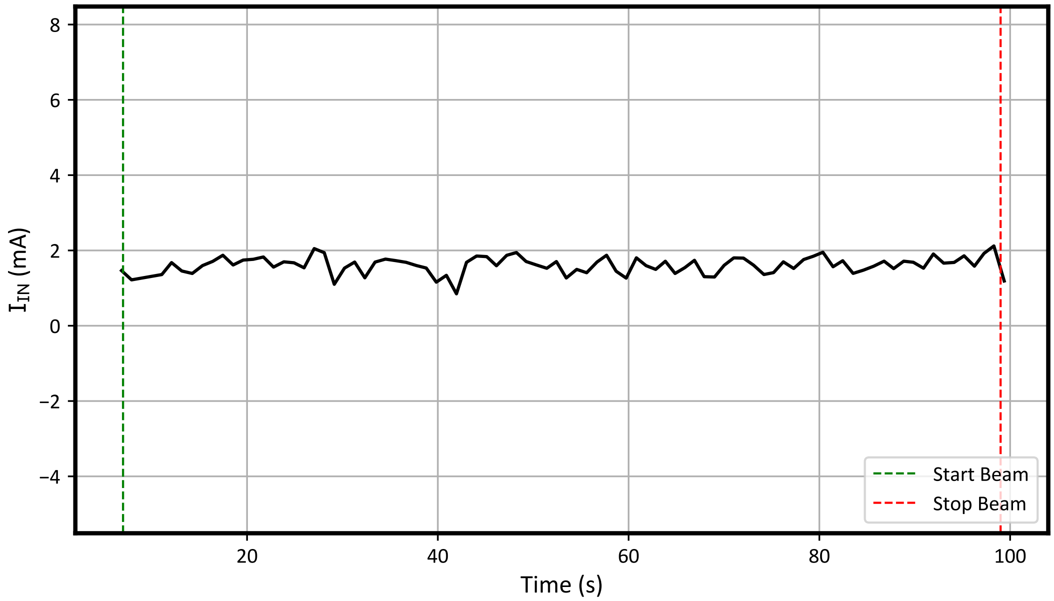

Figure 7-3. Current vs Time for Run #5 (Disabled) for the TPS7H1111-SEP at T = 25°C (0.4-V)

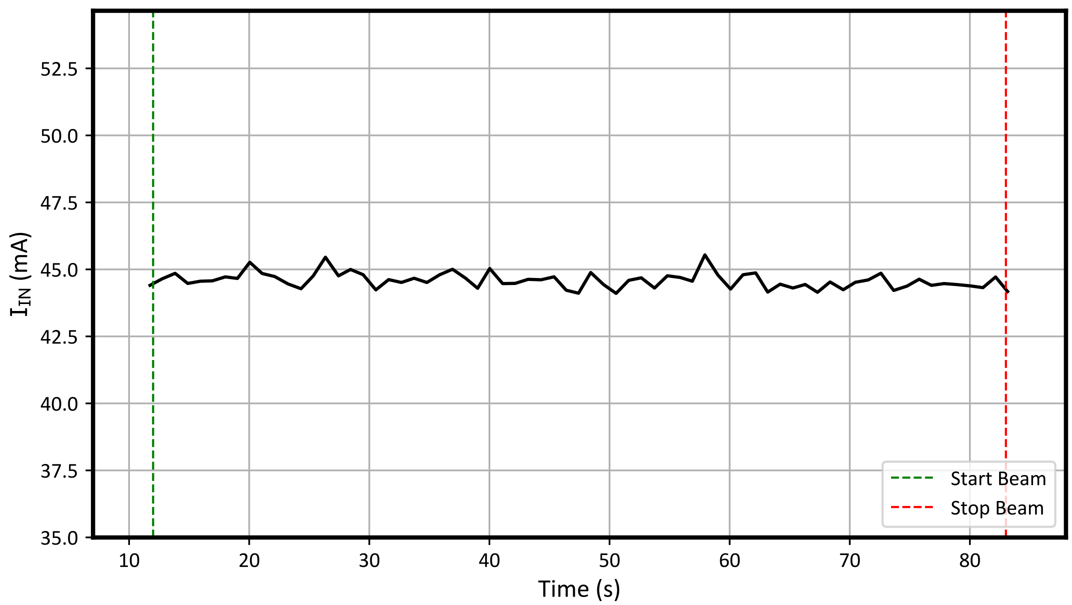

Figure 7-4. Current vs Time for Run #6 (Enabled) for the TPS7H1111-SEP at T = 25°C (0.4-V)

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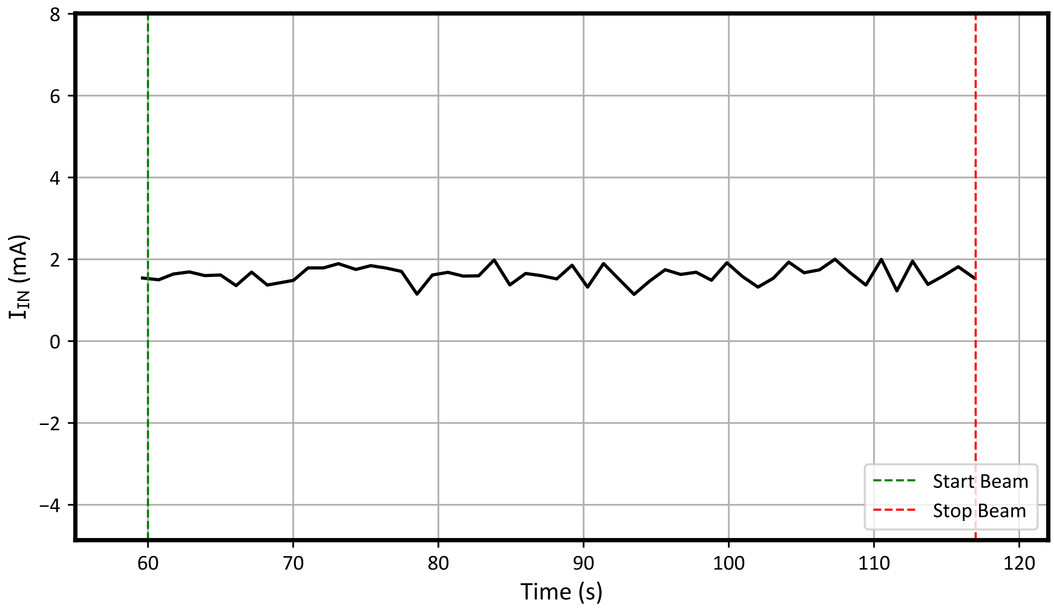

Figure 7-5. Current vs Time for Run #9 (Disabled) for the TPS7H1111-SEP at T = 25°C (5.5-V)

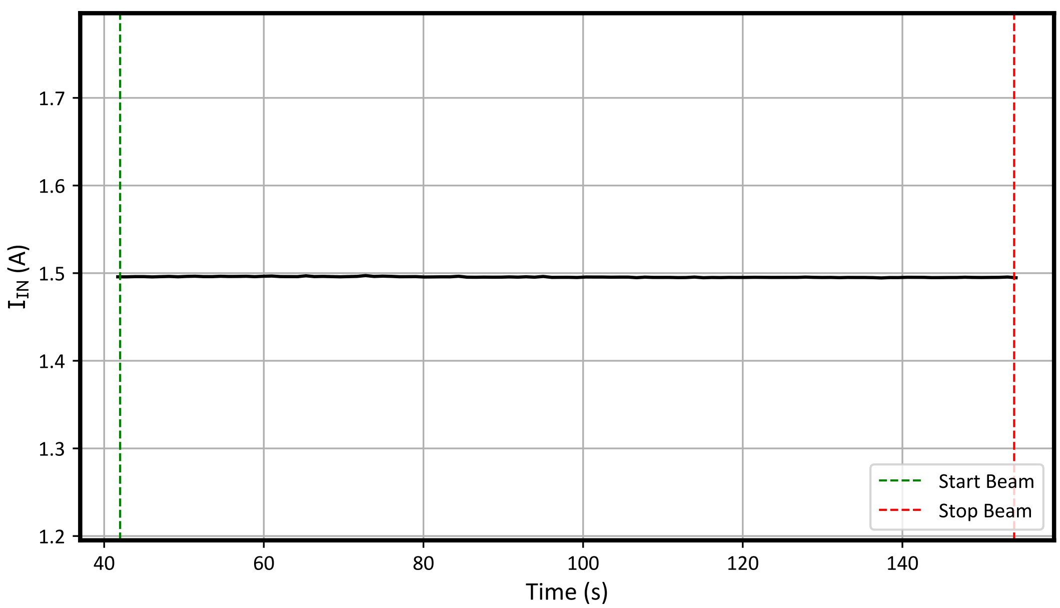

Figure 7-6. Current vs Time for Run #10 (Enabled) for the TPS7H1111-SEP at T = 25°C (5.5-V)

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8 Single-Event Transients (SET)

SET are defined as heavy-ion-induced transients upsets on the V_{OUT} and PG of the TPS7H1111-SEP.

Testing was performed at room temperature (no external temperature control applied). The heavy-ions species used for the SET testing were Silver (^{109}Ag) for an LET_{EFF} = 48 MeV·cm²/mg, for more details refer to Ion LET_{EFF}, Depth, and Range in Silicon. Flux of ≈10^4 ions/cm²·s and a fluence ≈10^6 ions/cm² per run were used for the SET characterization.

SET testing was catagorized as:

1. Golden Config: V_{IN}=2.5-V (Nominal), V_{BIAS}=5-V (Nominal)
2. Silver Config: V_{IN}=2.5-V (Nominal), V_{BIAS}=12-V

Waveform size, sample rate, trigger type, value, and signal for all scopes used is presented in Table 8-1.

Table 8-1. Scope Settings

Note: Only one signal was used as a trigger source at a time, this table just presents all possible sources for a given scope, the same is valid for the trigger type. All percentage specified on the trigger value are deviation from the nominal value.

SCOPE MODEL	TRIGGER SIGNAL	TRIGGER TYPE	TRIGGER VALUE	RECORD LENGTH	SAMPLE RATE
TDS7404B	V_{OUT}	Window	±3%	20 µs/div	250 MS/s
	PG	Edge/Negative	0.5-V		
PXIe-5172	V_{OUT}	Window	±3%	20k	100 MS/s
PXIe-5172	PG	Edge/Negative	0.5-V	2.5k	20 MS/s

8.1 Single-Event Transients (SET)

V_{IN}=2.5-V (nominal) and V_{BIAS} = 5-V (Nominal)

For the "golden configuration" of V_{IN} = 2.5-V and V_{BIAS} = 5-V with a V_{OUT} of 1.8-V two units were characterized at 48 MeV. ^{109}Ag was used to achieve LET_{EFF} = 48 MeV. A DPO and two PXIe-5172 scopes were used to monitor the V_{OUT} and PG signals of the TPS7H1111-SP with V_{OUT} triggering off a 3% window and PG triggering off a negative edge. The following tables summarize the results for the two units. As the summarization of results shows, the onset for the TPS7H1111-SEP in "golden configuration" occurs at an LET_{EFF} of 48MeV.

Table 8-2. Summary of TPS7H1111-SEP SET Test Condition

Run #	Unit #	ION	LET_{EFF} (MeV·cm²/mg)	FLUX (ions·cm²/mg)	FLUENCE (# ions)	Configuration	# TDS7404B ≥ 3% (V_{OUT})	PG < 0.5-V
13	5	^{109}Ag	48	1.07 × 10^4	1 × 10^6	Golden	0	1
14	6	^{109}Ag	48	8.95 × 10^3	1 × 10^6	Golden	0	3
15	5	^{109}Ag	48	1.10 x 10^4	1 × 10^6	Silver	0	12
16	6	^{109}Ag	48	8.40 × 10^3	1 × 10^6	Silver	0	7

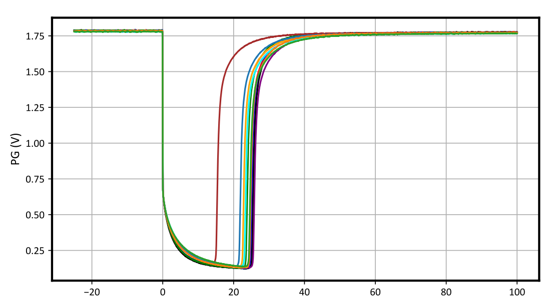

Figure 8-1. All PG Upsets for Run #15 (Silver Config)

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9 Event Rate Calculations

Event rates were calculated for LEO (ISS) and GEO environments by combining CREME96 orbital integral flux estimations and simplified SEE cross-sections according to methods described in *Heavy Ion Orbital Environment Single-Event Effects Estimations* application report. We assume a minimum shielding configuration of 100 mils (2.54 mm) of aluminum, and “worst-week” solar activity (this is similar to a 99% upper bound for the environment). Using the 95% upper-bounds for the SEL and the SEB/SEGR, the event rate calculation for the SEL and the SEB/SEGR is shown on Table 9-1 and Table 9-2, respectively. **It is important to note that this number is for reference since no SEL or SEB/SEGR events were observed.** SET orbit rate for V_{OUT} with Golden and Silver configuration is presented on SEB/SEGR Event Rate Calculations for Worst-Week LEO and GEO Orbits.

Table 9-1. SEL Event Rate Calculations for Worst-Week LEO and GEO Orbits

Orbit Type	Onset LET_{EFF} (MeV-cm²/mg)	CREME96 Integral FLUX (/day/cm²)	σSAT (cm²)	Event Rate (/day)	Event Rate (FIT)	MTBE (Years)
LEO (ISS)	48	4.50×10^{-4}	9.22×10^{-8}	4.15×10^{-11}	1.73×10^{-3}	6.60×10^{7}
GEO		1.48×10^{-3}		1.36×10^{-10}	5.67×10^{-3}	2.01×10^{7}

Table 9-2. SEB/SEGR Event Rate Calculations for Worst-Week LEO and GEO Orbits

Orbit Type	Onset LET_{EFF} (MeV-cm²/mg)	CREME96 Integral FLUX (/day/cm²)	σSAT (cm²)	Event Rate (/day)	Event Rate (FIT)	MTBE (Years)
LEO (ISS)	48	4.50×10^{-4}	4.61×10^{-8}	2.08×10^{-11}	8.65×10^{-4}	1.32×10^{8}
GEO		1.48×10^{-3}		6.81×10^{-11}	2.84×10^{-3}	4.03×10^{7}

Table 9-3. SET (Golden and Silver configuration) Event Rate Calculations for Worst-Week LEO and GEO Orbits

Orbit Type	Onset LET_{EFF} (MeV-cm²/mg)	CREME96 Integral FLUX (/day/cm²)	σSAT (cm²)	Event Rate (/day)	Event Rate (FIT)	MTBE (Years)
LEO (ISS)	48	$4.50 \text{ x } 10^{-4}$	9.22×10^{-7}	4.15×10^{-10}	1.73×10^{-2}	6.60×10^{6}
GEO		$1.48 \text{ x } 10^{-3}$		1.36×10^{-9}	5.67×10^{-2}	2.01×10^{6}

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10 Summary

The purpose of this study was to characterize the effect of heavy-ion irradiation on the single-event effect (SEE) performance of the TPS7H1111-SEP ultra-low noise, high PSRR, low dropout linear regulator (LDO). Heavy-ions with LET_{EFF} = 48 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 TPS7H1111-SEP is free of destructive SEL and SEB LET_{EFF} = 48 MeV·cm^2/mg and across the full electrical specifications. Transients at LET_{EFF} = 48 MeV·cm^2 /mg on PG are presented. CREME96-based worst week event-rate calculations for LEO(ISS) and GEO orbits for the DSEE and SET (at V_{IN}=2.5-V and V_{BIAS}=5 and 12-V) are presented for reference.

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