TPS7H4001-SP Total Ionizing Dose (TID) Lookahead

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ABSTRACT

This report discusses the results of the Total Ionizing Dose (TID) testing for the Texas Instruments 7-V, 18-A synchronous step-down converter TPS7H4001-SP. The study was done to determine TID effects under low dose rate (LDR) and high dose rate (HDR) up to 100 krad(Si). The results show that all samples passed within the specified limits up to 100 krad(Si).

Contents

List of Figures

List of Tables

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1 Device Information

1.1 Product Description

The TPS7H4001-SP is a radiation-hardness-assured, 7-V, 18-A synchronous buck converter with integrated low resistance high-side and low-side MOSFETs in a thermally enhanced 34-pin ceramic flatpack package. High efficiency and reduced component count are achieved through current mode control.

TheTPS7H4001-SP can be configured in master-slave mode to provide up to 36-A of output current or with the SYNC2 pin, 4 devices can be configured in parallel to provide up to 72-A of output current without the need of an external clock.

1.2 Device Details

Table 1 lists the device information used in the initial TID LDR/HDR characterization.

Table 1. Device and Exposure Details

TID HDR and LDR Details: 50 krad(Si) and 100 krad(Si)	
Package	34-pin CFP (HKY)
Technology	LBC7
Quantity Tested	LDR - 20, HDR - 12
HDR Radiation Facility	Texas Instruments SVA Group, Santa Clara, CA
HDR Dose Level	50 krad(Si), 100 krad(Si)
HDR Dose Rate	72.28 rads(Si)/s [65.05 to 79.51 rad(Si)/s]
HDR Radiation Source	Gammacell 220 Excel (GC-220E) Co-60
LDR Radiation Facility	Cobham RAD's, Colorado Springs, CO
LDR Dose Level	50 krad(Si), 100 krad(Si)
LDR Dose Rate	0.01 rad(Si)/s
LDR Radiation Source	Gamma cell Co60 (JLS-81-22)
Irradiation Temperature	Ambient, room temperature

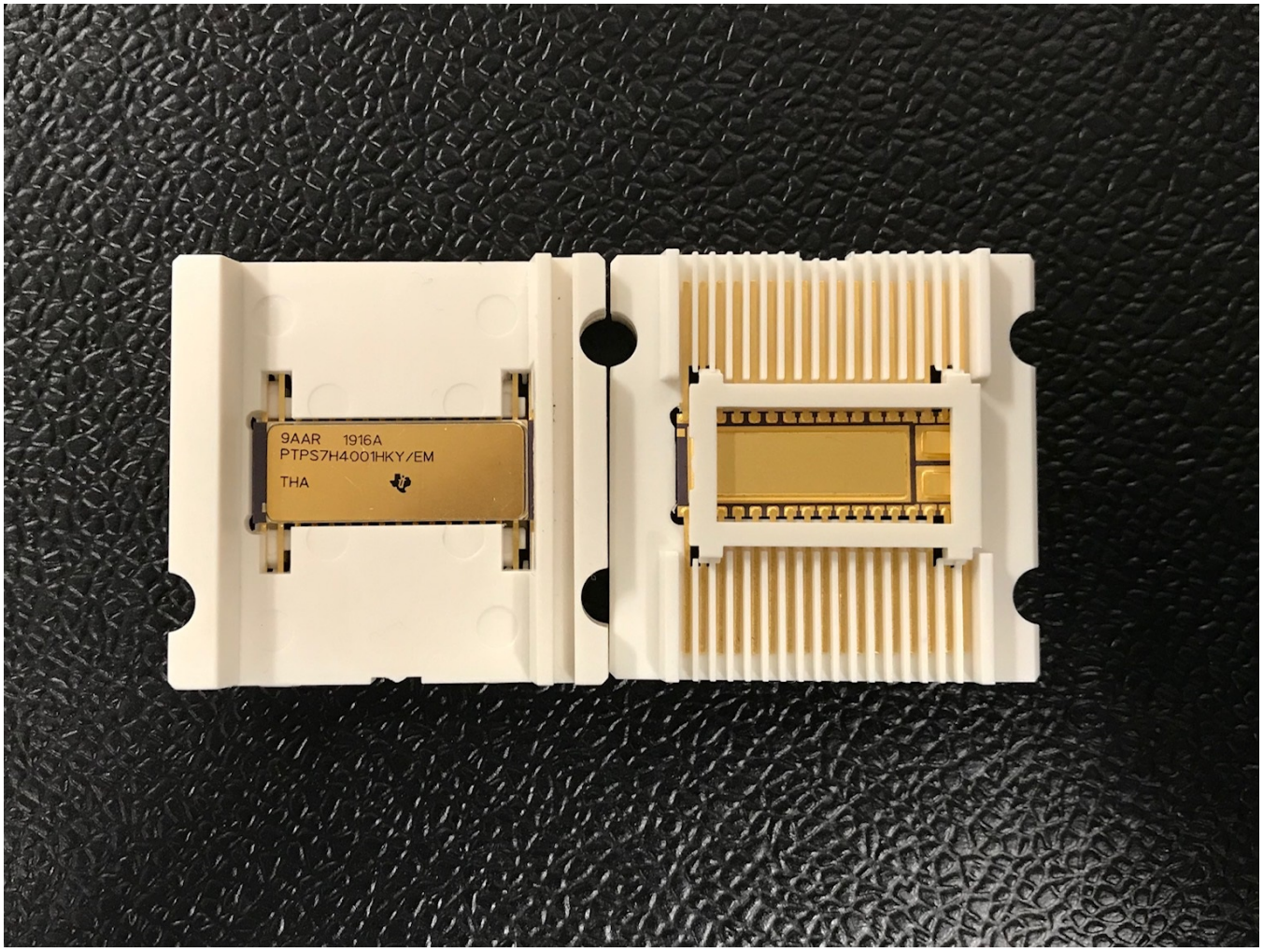

Figure 1. TPS7H4001-SP Devices Used in Exposure

2 Total Dose Test Setup

2.1 Test Overview

The TPS7H4001-SP was tested according to MIL-STD-883, Test Method 1019.9. For this testing, Conditions A and D were used. For this test, the product was irradiated up to the target radiation level, and then put through electrical parametric testing on the Automated Test Equipment (ATE). Post irradiation testing showed that the devices were functional, passing all parametric tests.

2.2 Test Description and Facilities

The TPS7H4001-SP HDR exposure was performed on biased and unbiased devices in a Co-60 gamma cell at TI SVA facility in Santa Clara California. The un-attenuated dose rate of this cell is 72.28 rad(Si)/s. After exposure, the devices were packed in dry ice (per MIL-STD-883 Method 1019.9 section 3.10) and returned to TI Dallas for a post-radiation electrical evaluation using Texas Instruments Automated Test Equipment (ATE). ATE test limits are set per SMD electrical limits based on initial qualification and characterization data. Post-radiation measurements were taken within 30 minutes of removing the devices from the dry ice container. The devices were allowed to reach room temperature prior to electrical post-radiation measurements.

The TPS7H4001-SP LDR exposure was performed on biased and unbiased devices in a Co60 gamma cell under a 10-mrad(Si)/s exposure rate. The dose rate of the irradiator used in the exposure ranges from < 10 mrad(Si)/s to a maximum of approximately 84 rad(Si)/s, determined by the distance from the source. For the LDR (10 mrad(Si)/s) exposure, the test box was positioned approximately 2 m from the source. The exposure boards are housed in a lead-aluminum box (as specified in MIL-STD-883 TM 1019.9) to harden the gamma spectrum and minimize dose enhancement effects. The irradiator calibration is maintained by Logmire Laboratories using Thermoluminescence Dosimeters (TLDs) traceable to the National Institute of Standards and Technology (NIST) and the dosimetry was verified using TLDs prior to the radiation exposures. After exposure, the devices were packed in dry ice (per MIL-STD-883 Method 1019.9 section 3.10) and returned to TI Dallas for a post radiation electrical evaluation using Texas Instruments production Automated Test Equipment (ATE). ATE test limits are set per SMD electrical limits based on initial qualification and characterization data. Post-radiation measurements were taken within 30 minutes of removing the devices from the dry ice container. The devices were allowed to reach room temperature prior to electrical post-radiation measurements.

2.3 Irradiation Setup Details

The devices under HDR and LDR exposure were irradiated in both biased and unbiased conditions. Both conditions are described as follows.

2.3.1 Unbiased

For the unbiased HDR and LDR conditions, the exposure was performed with all pins grounded.

2.3.2 Biased

Figure 2 shows the diagram for HDR and LDR exposure with biased condition.

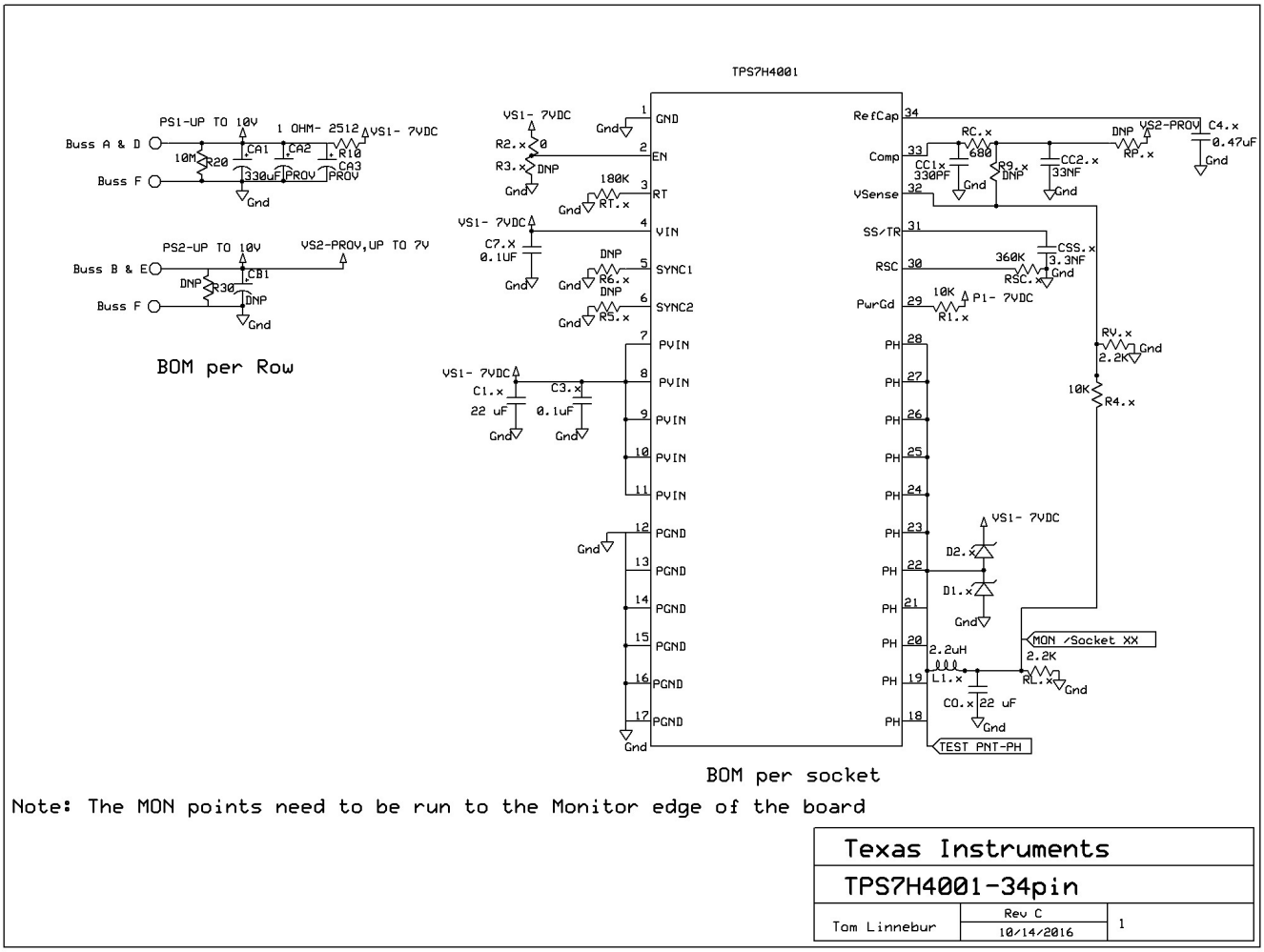

Figure 2. Bias Diagram Used in TID Exposure

2.4 Test Configuration and Condition

HDR and LDR devices were stressed at 50 krad(Si) and 100 krad(Si) for biased and unbiased conditions.

Table 2. HDR = 50 and 100-krad(Si)/s Biased Device Information

Total Samples: 6	
Exposure Levels:	
50 krad(Si)	100 krad(Si)
1, 2, 3	7, 8, 9

Table 3. HDR = 50 and 100-krad(Si)/s Unbiased Device Information

Total Samples: 6	
Exposure Levels:	
50 krad(Si)	100 krad(Si)
4, 5, 6	10, 11, 12

Table 4. LDR = 50 and 100-krad(Si)/s Biased Device Information

Total Samples: 10	
Exposure Levels:	
50 krad(Si)	100 krad(Si)
1, 2, 3, 4, 5	11, 12, 13, 14, 15

Table 5. LDR = 50 and 100-krad(Si)/s Unbiased Device Information

Total Samples: 10	
Exposure Levels:	
50 krad(Si)	100 krad(Si)
6, 7, 8, 9, 10	16, 17, 18, 19, 20

3 TID Characterization Test Results

3.1 TID Characterization Summary Results

The parametric data for the TPS7H4001-SP passes up to 100-krad(Si) HDR and LDR TID.

The drift of SMD electrical parameters through HDR and LDR were within the pre-rad characterization limits.

Overall, the TPS7H4001-SP showed a strong degree of hardness to HDR TID irradiation up to 100 krad(Si) for both biased and unbiased exposure conditions. The measurements taken post-irradiation for each sample set showed a marginal shift for most parameters at each dose level for both biased and unbiased. The parameters that did show a greater degree of change between pre- and post-irradiation were still within the SMD electrical specification. Table 6 show the minimum and maximum values measured post-irradiation for each sample set, and the average of that sample set, at each dose level.

See Appendix A and Appendix B for graphs and drifts.

3.2 Specification Compliance Matrix

Table 6. TPS7H4001-SP Specification Compliance Matrix

Parameter	Test Condition	TPS7H4001-SP Data Sheet				Test #
		MIN	TYP	MAX	Unit	
VIN internal UVLO threshold	VIN rising	2.71	2.75	2.8	V	5.0
VIN internal UVLO hysteresis		134	150	178	mV	5.2
VIN shutdown supply current	VEN = 0 V		2.32	2.85	mA	4.1, 4.3
VIN operating – non switching supply current	V_{SENSE} = VBG		4	6	mA	4.0, 4.2
Enable Threshold	Rising	1.122	1.14	1.172	V	7.0, 7.6
	Falling	1.09	1.11	1.148	V	7.1, 7.7
Input Current	V_{EN} = 1.1 V	4.8	6.1	7.6	µA	7.3, 7.9
Hysteresis current	V_{EN} = 1.3 V	2.4	3.0	3.9	µA	7.5, 7.11
Internal voltage reference	0 A ≤ Iout ≤ 18 A, 25℃, measured at COMP	0.599	0.605	0.612	V	3.6, 3.7, 3.8
REFCAP voltage	REFCAP = 470 nF	1.191	1.209	1.226	V	3.3, 3.4, 3.5
High-side switch resistance	PVIN = VIN = 3.0 V, 25℃, lead length = 3 mm		22	25	mΩ	10.0
High-side switch resistance	PVIN = VIN = 5.0 V, 25℃, lead length = 3 mm		20	22	mΩ	10.1
Low-side switch resistance	PVIN = VIN = 3.0 V, 25℃, lead length = 3 mm		9	12	mΩ	11.0
Low-side switch resistance	PVIN = VIN = 5.0 V, 25℃, lead length = 3 mm		9	11	mΩ	11.1
Error amplifier input offset voltage	V_{SENSE} = 0.6 V	–2		2	mV	3.10, 3.11, 3.12
Error amplifier transconductance (gm)	–2 µA < I_{COMP} < 2 µA, $V_{(COMP)}$ = 1 V	1150	1800	2400	µS	9.0, 9.3
Error amplifier source	$V_{(COMP)}$ = 1 V, 100-mV input overdrive	100	140	190	µA	9.2, 9.5
Error amplifier sink	$V_{(COMP)}$ = 1 V, 100-mV input overdrive	100	140	190	µA	9.1, 9.4
Internally set frequency	RT = Open, VIN = 3 V	444	473	499	kHz	22.0, 22.1, 22.2, 22,3
Internally set frequency	RT = Open, VIN = 5 V	449	502	554	kHz	22.4, 22.5, 22.6, 22.7
Externally set frequency	RT = 1.07 MΩ (1%) , VIN = 5 V	80	100	120	kHz	13.0
	RT = 165 kΩ (1%), VIN = 5 V	455	503	550	kHz	13.2
	RT = 73.2 kΩ (1%), VIN = 5 V	760	986	1212	kHz	13.1
SYNC1/SYNC2 out low-to-high rise time (10%/90%)	Cload = 25 pF		70	180	ns	22.8, 22.10, 22.12, 22.14
SYNC1/SYNC2 out high-to-low fall time (90%/10%)	Cload = 25 pF		10	21	ns	22.9, 22.11, 22.13, 22.15
SYNC1/SYNC2 out high level threshold[(1)]	IOH = 50 µA	VIN – 0.3			V	22.0, 22.1, 22.4, 22.5
SYNC1/SYNC2 out low level thresholdd[(1)]	IOL = 50 µA			600	mV	22.2, 22.3, 22.6, 22.7
Minimum on time	Measured at 10% to 90% of VIN, 25°C, I_{PH} = 2 A		190	235	ns	13.3
SS charge current		1.5	2.5	3	µA	9.6, 9.7

(1) Parameter is a functional test parameter. Test procedures to guarantee functional parameters can potentially require test(s) that do not reflect the actual line item specification.

Table 6. TPS7H4001-SP Specification Compliance Matrix (continued)

VSENSE threshold	V_{SENSE} falling (fault)	90	91		% Vref	20.0, 20.6
	$V_{SENS}E$ rising (good)		94	97	% Vref	20.1, 20.7
	V_{SENSE} rising (fault)		109	111	% Vref	20.2, 20.8
	$V_{SENS}E$ falling (good)	103	106		% Vref	20.3, 20.9
Output high leakage	V_{SENSE} = Vref, $V_{(PWRGD)}$ = 5 V		30	181	nA	20.4, 20.10
Output low	$I_{(PWRGD)}$ = 2 mA			0.3	V	20.5, 20.11
Minimum VIN for valid output	$V_{(PWRGD)}$ < 0.5 V at 100 µA		0.6	1	V	5.3

4 Applicable and Reference Documents

4.1 Applicable Documents

- *TPS7H4001-SP Radiation-Hardness-Assured 3-V to 7-V Input 18-A Synchronous Buck Converter data sheet*
- *TPS7H4001EVM-CVAL Evaluation Module (EVM) user's guide*

4.2 Reference Documents

Texas Instruments total ionizing dose radiation (total dose) test procedure follows the standards put forth in MIL-STD-883 TM 1019. The document can be found at the DLA website.

HDR LOOKAHEAD TID Report

LDR LOOKAHEAD TID Report

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