Radiation Report

TPS7H3014-SP Neutron Displacement Damage (NDD) Characterization Report

ABSTRACT

This report presents the effect of neutron displacement damage (NDD) on the TPS7H3014-SP, an integrated, 3V to 14V, four-channel radiation-hardness-assured power-supply sequencer. The TPS7H3014-SP showed a strong degree of hardness to neutron irradiation up to fluence level 1 × 10^{13} n/cm^2 . The neutron irradiation test is a destructive test. Test procedure follows MIL-STD-883 method 1017 as guidance. The purpose of this test is to determine the device susceptibility to non-ionizing energy loss (NIEL) degradation. Objectives of the test are, to detect and measure the degradation of critical device parameters as a function of neutron fluence and to determine if these parameters are within specified limits after exposure to a specified level of neutron fluence.

Table of Contents

1 Device Information.....1
1.1 Product Description.....1
1.2 Device Details.....2
2 Total Dose Test Setup.....3
2.1 Test Overview.....3
2.2 Test Facility.....3
2.3 Test Setup Details.....3
2.4 Test Configuration and Condition.....3
3 NDD Characterization Test Results.....4
3.1 NDD Characterization Summary.....4
3.2 Specification Compliance Matrix.....5
4 Applicable and Reference Documents.....9
4.1 Applicable Documents.....9
4.2 Reference Documents.....9
A Appendix: NDD Report Data.....9

List of Figures

Figure 1-1. TPS7H3014-SP Device.....2

List of Tables

Table 1-1. Device and Exposure Details.....2
Table 2-1. Table 2-1. Neutron Irradiation Conditions.....3

Trademarks

All trademarks are the property of their respective owners.

1 Device Information

1.1 Product Description

The TPS7H3014-SP is an integrated, 3V to 14V, four-channel radiation-hardness-assured power-supply sequencer. Channel count can be expanded by connecting multiple devices in a daisy-chain configuration. The device provides sequence up and down control signals for integrated circuits (IC) with active high (*on*) inputs. In addition SEQ_DONE and PWRGD flags are provided to monitor the sequence and power status of the monitored power tree.

An accurate 599mV ±1% threshold voltage and a 24μA ±3% hysteresis current provide programmable rise and fall monitoring voltages. The rise and fall delay time is globally programmed through a single resistor. A time-to-regulation timer is provided to track the rising voltage on SENSEx.

In addition to these features, a FAULT detection pin is incorporated to monitor internally generated faults and provide increased system level reliability for power sequencing space applications.

The TPS7H3014-SP is packaged in a 22-pin CFP (ceramic flat package) package. A standard microcircuit drawing (SMD) is available for the QML variant, 5962R2320101VXC.

1.2 Device Details

Table 1-1 lists the device information used in the initial NDD characterization.

Table 1-1. Device and Exposure Details

TID Exposure Details	
TI Device	TPS7H3014-SP
TI Part Name	5962R2320101VXC
Package	22-pin CFP (HFT)
Technology	LBC7
Lot Number / Date Code	4000087 / 2350A
Sample Quantity	9 + 3 control units
Exposure Facility	Fast Neutron Irradiation (FNI) Facility of University of Massachusetts Lowell Research Reactor (UMLRR)
Neutron Fluence (1-MeV equivalent) Level	1×10^{12}, 5×10^{12}, 1×10^{13} n/cm^2
Irradiation Temperature	Ambient room temperature

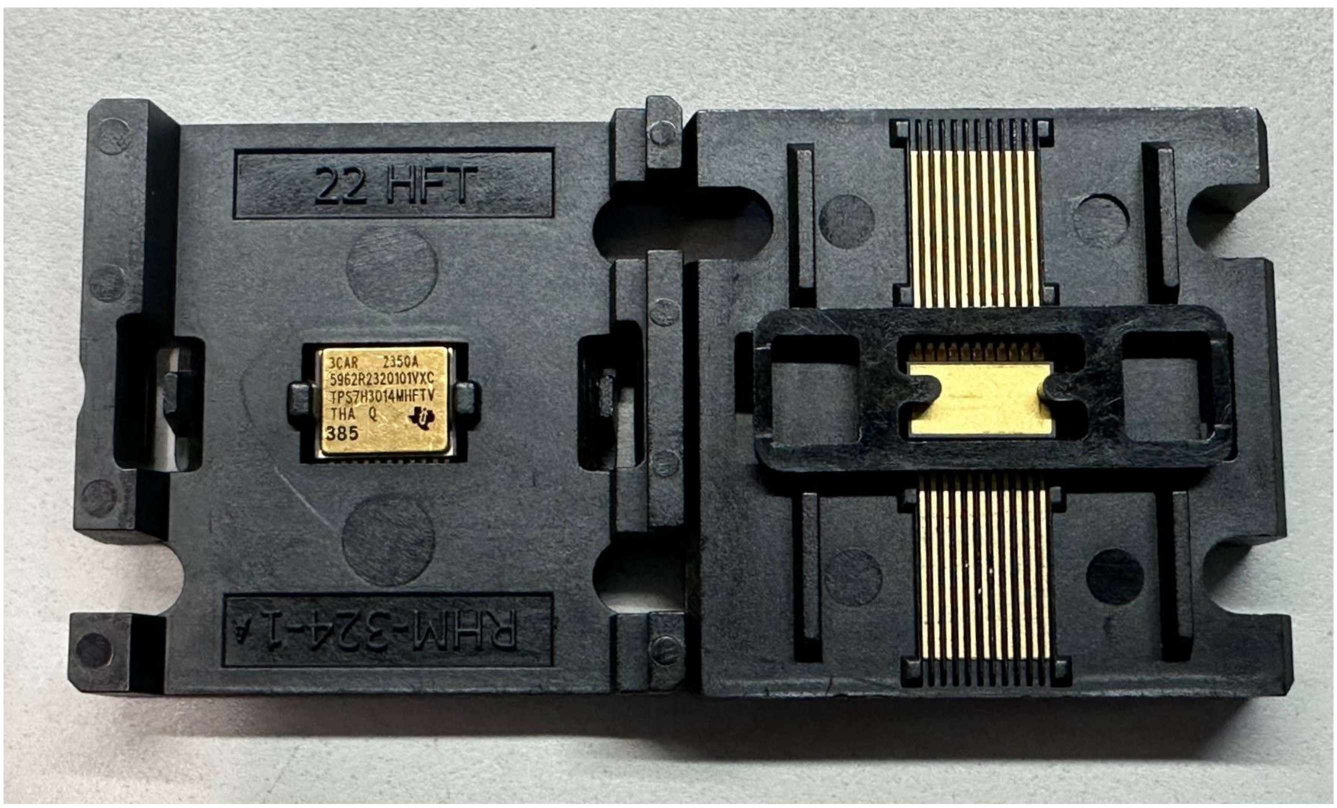

Figure 1-1. TPS7H3014-SP Device

2 Total Dose Test Setup

2.1 Test Overview

General test procedures adhere to MIL-STD-883, Method 1017 as a guide for neutron irradiation. The TPS7H3014-SP was electrically tested using the production automated test equipment (ATE) program at an ambient room temperature of 25°C before and after neutron irradiation.

2.2 Test Facility

The utilized test facility is the Fast Neutron Irradiation (FNI) Facility of University of Massachusetts Lowell Research Reactor. The neutron fluence for this irradiation was measured utilizing ASTM E-265 “Measuring Reaction Rates and Fast Neutron Fluence by Radioactivation of Sulfur-32” and correlated to the measured reactor power level. All irradiation conditions required under ASTM 722 were met, this includes: neutron fluence, distribution and uncertainty. The Average Integrated Neutron Fluence, 1-MeV(Si) equivalent, reflects these factors. Detailed information of the radiation facility is available at the following link:

UNIVERSITY OF MASSACHUSETTS LOWELL RESEARCH REACTOR

2.3 Test Setup Details

Devices were irradiated at three fluence levels in unbiased conditions: 1.0×10^{12} n/cm^2 , 5.0×10^{12} n/cm^2 and 1.0×10^{13} n/cm^2. See the details in the following table.

2.4 Test Configuration and Condition

Table 2-1. Table 2-1. Neutron Irradiation Conditions

GROUP	SAMPLE QTY	NEUTRON FLUENCE (n/cm^2)	BIAS
A	3	1.0×10^{12}	Unbias
B	3	5.0×10^{12}	Unbias
C	3	1.0×10^{13}	Unbias
Control Units	3	N/A	N/A

3 NDD Characterization Test Results

3.1 NDD Characterization Summary

The results show that all devices were fully functional and within specification limits. A sample size of nine units was exposed for neutron irradiation and an additional unirradiated control units were used as correlation. Overall, the TPS7H3014-SP showed a strong degree of hardness to Neutron irradiation up to fluence level 1 × 10^{13}n/cm^{2} . The measurements taken post-irradiation for each sample set showed a marginal shift for most parameters at each fluence level. The parameters that showed a greater degree of change between pre- and post- irradiation were still within the Electrical Performance Characteristics specified in the Data Sheet Electrical Parameters table. See Table 3-1 for the Data Sheet Electrical Parameters and Associated Tests. Electrical testing is done for pre- and post- neutron irradiation by ATE. ATE electrical test is done at an ambient room temperature of 25°C. See Appendix A for NDD report up to 1.0 × 10^{13}n/cm2 .

The parameters that did show a greater degree of change between pre- and post-irradiation were still within the electrical performance characteristics specified in the data sheet electrical parameters. See *TPS7H3014-SP Radiation-Hardeness-Assured, 14-V, 4-Channel Sequencer* data sheet for the data sheet electrical parameters and associated tests.

See Appendix A for NDD report up to 1 × 10^{13} n/cm^{2}.

3.2 Specification Compliance Matrix

3.2.1 Electrical Characteristics

Parameter	Test Conditions	Sub-Group	MIN	TYP	MAX	UNIT	Test Number
SUPPLY VOLTAGES AND CURRENTS							
V_{IN} quiescent current	In waiting to sequence up and down states with all outputs floating.	1, 2, 3		2.5	4	mA	6.0 and 6.1
V_{IN} rising undervoltage lockout		1, 2, 3	2.72	2.79	2.84	V	6.124
V_{IN} falling undervoltage lockout		1, 2, 3	2.59	2.64	2.69		6.125
Internal linear regulator output voltage	5V ≤ V_{IN} ≤ 14V	1, 2, 3	3.19	3.29	3.38	V	6.3
	V_{IN} < 3.24V	1, 2, 3	97%	99%		× V_{IN}	6.2
Internal bandgap voltage		1, 2, 3	1.188	1.2	1.212	V	6.4 and 6.5
Power on reset voltage	1.6V ≤ V_{PULL_UPx} ≤ 7V, V_{OL} ≤ 320mV with I_{ENx} = –2mA	1, 2, 3		1.41	2		6.126, 6.127, 6.128, 6.129, 6.130, 6.131, 6.132, 6.133, 6.134, 6.135, 6.136, 6.137
Power on reset voltage	V_{IN} = 0V, V_{OL} ≤ 320mV with I_{ENx} = –100µA	1, 2, 3		0.89	1.4		6.138, 6.139, 6.14, 6.141, 6.142, 6.143
SENSE1 TO SENSE4, UP AND $\overline{DOWN}$ COMPARATOR INPUTS							
Threshold voltage at SENSEx		1, 2, 3	593	599	605	mV	13.3, 13.4, 13.5, 13.6, 13.7, 13.8, 13.9, 13.1, 13.14, 13.15, 13.16,13.17, 13.18, 13.19, 13.2,13.21, 13.25, 13.26, 13.27,13.28, 13.29, 13.3,13.31, 13.32, 13.36, 13.37, 13.38,13.39, 13.4, 13.41, 13.42, 13.43
SENSEx hysteresis current	V_{SENSEx} = 700mV	1, 2, 3	23.28	24	24.72	µA	6.2, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27
Input leakage current at SENSEx	V_{SENSEx} = 500mV	1, 2, 3		2	100	nA	6.9, 6.10, 6.11, 6.12
Rising threshold voltage at UP	V_{UP} rising to 1V	1, 2, 3	580	598	615	mV	13.1, 13.12, 13.23, 13.34
Falling threshold voltage at $\overline{DOWN}$	$V_{\overline{DOWN}}$ falling from 1V	1, 2, 3	483	498	512	mV	13.2, 13.13, 13.24, 13.35
UP and DOWN hysteresis voltage		1, 2, 3		100		mV	13.11, 13.22, 13.33, 13.44
Input leakage current at UP and $\overline{DOWN}$	V_{UP} = $V_{\overline{DOWN}}$ = 500mV	1, 2, 3		2	100	nA	6.7, 6.8, 6.14, 6.15
Channel 2, 3, 4 turn off voltage		1, 2, 3	87%	89%	91%	× VLDO	6.144, 6.145, 6.146
EN1 TO EN4, SEQ_DONE AND PWRGD PUSH PULL OUTPUTS							
Low-level ENx output voltage	1.6V ≤ V_{PULL_UP1} ≤ 7V, I_{LOAD} = –2mA	1, 2, 3			10%	x V_{PULL_UP1}	6.52, 6.53, 6.54, 6.55, 6.58, 6.59, 6.6, 6.61, 6.64, 6.65, 6.66, 6.67, 6.7, 6.71, 6.72, 6.73
	I_{LOAD} = –10mA	1, 2, 3			25%		6.1, 6.101, 6.102, 6.103, 6.106A, 6.107, 6.108, 6.109, 6.112, 6.113, 6.114, 6.115, 6.118, 6.119, 6.12, 6.121
High-level ENx output voltage	1.6V ≤ V_{PULL_UP1} ≤ 7V, I_{LOAD} = 2mA	1, 2, 3	90%				6.28, 6.29, 6.3, 6.31, 6.34, 6.35, 6.36, 6.37, 6.4, 6.41, 6.42, 6.43, 6.46, 6.47, 6.48, 6.49
	I_{LOAD} = 10mA	1, 2, 3	70%				6.76, 6.77, 6.78, 6.79, 6.82, 6.83, 6.84, 6.85, 6.88, 6.89, 6.9, 6.91, 6.94, 6.95, 6.96, 6.97

3.2.1 Electrical Characteristics (continued)

Parameter	Test Conditions		Sub-Group	MIN	TYP	MAX	UNIT	Test Number
Low-level SEQ_DONE output voltage	1.6V ≤ V_{PULL_UP2} ≤ 7V	I_{LOAD} = –2mA	1, 2, 3			10%	x V_{PULL_UP2}	6.56, 6.62, 6.68, 6.74
		I_{LOAD} = –10mA	1, 2, 3			25%		6.104, 6.11, 6.116, 6.122
High-level SEQ_DONE output voltage	1.6V ≤ V_{PULL_UP2} ≤ 7V	I_{LOAD} = 2mA	1, 2, 3	90%				6.32, 6.38, 6.44, 6.5
		I_{LOAD} = 10mA	1, 2, 3	70%				6.8, 6.86, 6.92, 6.98
Low-level PWRGD output voltage	1.6V ≤ V_{PULL_UP2} ≤ 7V	I_{LOAD} = –2mA	1, 2, 3			10%		6.57, 6.63, 6.69, 6.75
		I_{LOAD} = –10mA	1, 2, 3			25%		6.105, 6.111, 6.117, 6.123
High-level PWRGD output voltage	1.6V ≤ V_{PULL_UP2} ≤ 7V	I_{LOAD} = 2mA	1, 2, 3	90%				6.33, 6.39, 6.45, 6.51
		I_{LOAD} = 10mA	1, 2, 3	70%				6.81, 6.87, 6.93, 6.99
PULL_UPx leakage current	V_{PULL_UPx} = 7V		1, 2, 3		48	121	μA	6.148, 6.149, 6.150, 6.151
Enable rising output voltage slew rate	10% to 90% of V_{PULL_UP1}, R_{LOAD} = 50kΩ, C_{LOAD} = 100pF	1.6V ≤ V_{PULL_UP1} ≤ 7V	9, 10, 11	17	125		V/μs	19.0, 19.1, 19.2, 19.3, 19.12, 19.13, 19.14, 19.15, 19.24, 19.25, 19.26, 19.27, 19.36, 19.37, 19.38, 19.39
SEQ_DONE rising output voltage slew rate	10% to 90% of V_{PULL_UP2}, R_{LOAD} = 50kΩ, C_{LOAD} = 100pF	1.6V ≤ V_{PULL_UP2} ≤ 7V	9, 10, 11	17	125			19.5, 19.17, 19.29, 19.41
PWRGD rising output voltage slew rate			9, 10, 11	17	125			19.4, 19.16, 19.28, 19.4
Enable falling output voltage slew rate	90% to 10% of V_{PULL_UP1}, R_{LOAD} = 50kΩ, C_{LOAD} = 100pF	1.6V ≤ V_{PULL_UP1} ≤ 7V	9, 10, 11	44	126			19.6, 19.7, 19.8, 19.9, 19.18, 19.19, 19.2, 19.21, 19.3, 19.31, 19.32, 19.33, 19.42, 19.43, 19.44, 19.45
SEQ_DONE falling output voltage slew rate		1.6V ≤ V_{PULL_UP2} ≤ 7V	9, 10, 11	44	126			19.11, 19.23, 19.35, 19.47
PWRGD falling output voltage slew rate			9, 10, 11	44	126			19.1, 19.22, 19.34, 19.46
EN PMOS source output resistance	I_{LOAD} = 2mA	1.6V ≤ V_{PULL_UP1} ≤ 3.3V	1, 2, 3		18	40	Ω	18.0, 18.1, 18.2, 18.3, 18.6, 18.7, 18.8, 18.9
		3.3V ≤ V_{PULL_UP1} ≤ 7V	1, 2, 3		7	20		18.12, 18.13, 18.14, 18.15, 18.18, 18.19, 18.20, 18.21
SEQ_DONE PMOS source output resistance	I_{LOAD} = 2mA	1.6V ≤ V_{PULL_UP2} ≤ 3.3V	1, 2, 3		18	40		18.5, 18.11
		3.3V ≤ V_{PULL_UP2} ≤ 7V	1, 2, 3		7	20		18.17, 18.23
PWRGD PMOS source output resistance	I_{LOAD} = 2mA	1.6V ≤ V_{PULL_UP2} ≤ 3.3V	1, 2, 3		18	40		18.4, 18.1
		3.3V ≤ V_{PULL_UP2} ≤ 7V	1, 2, 3		7	20		18.16, 18.22
EN NMOS sink output resistance	I_{LOAD} = –2mA, 1.6V ≤ V_{PULL_UP1} ≤ 7V		1, 2, 3		7	28		18.24, 18.25, 18.26,18.27, 18.3, 18.31, 18.32,18.33, 18.36, 18.37, 18.38,18.39, 18.42, 18.43, 18.44, 18.45
SEQ_DONE NMOS sink output resistance	I_{LOAD} = –2mA, 1.6V ≤ V_{PULL_UP1} ≤ 7V		1, 2, 3		7	28		18.29, 18.35, 18.41, 18.47
PWRGD NMOS sink output resistance	I_{LOAD} = –2mA, 1.6V ≤ V_{PULL_UP1} ≤ 7V		1, 2, 3		7	28		18.28, 18.34, 18.40, 18.46

3.2.1 Electrical Characteristics (continued)

Parameter	Test Conditions	Sub-Group	MIN	TYP	MAX	UNIT	Test Number
$\overline{\text{FAULT}}$ OUTPUT							
$\overline{\text{FAULT}}$ pull down resistance	$I_{\overline{FAULT}}$ = 100µA	1, 2, 3		131	512	Ω	18.48, 18.49
$\overline{\text{FAULT}}$ leakage current	$V_{\overline{FAULT}}$ = 7V	1, 2, 3		23	600	nA	6.6, 6.13
DELAY AND TIME TO REGULATION TIMERS							
Delay time	R_{DLY_TMR} = 10.5kΩ	1, 2, 3	0.205	0.268	0.342	ms	5.48, 5.49, 5.5, 5.51, 5.52, 5.53, 5.54, 5.55, 5.56, 5.57, 5.58, 5.79, 5.8, 5.81, 5.82, 5.83, 5.84, 5.85, 5.86, 5.87, 5.88, 5.89, 5.11, 5.111, 5.112, 5.113, 5.114, 5.115, 5.116, 5.117, 5.118, 5.119, 5.120, 5.141, 5.142, 5.143, 5.144, 5.145, 5.146, 5.147, 5.148, 5.149, 5.15, 5.151
	R_{DLY_TMR} = 619kΩ	1, 2, 3	10.77	12.5	14.14		5.59, 5.6, 5.61, 5.62, 5.63, 5.64, 5.65, 5.66, 5.67, 5.68, 5.9, 5.91, 5.92, 5.93, 5.94, 5.95, 5.96, 5.97, 5.98, 5.99, 5.121, 5.122, 5.123, 5.124, 5.125, 5.126, 5.127, 5.128, 5.129, 5.130, 5.152, 5.153, 5.154, 5.155, 5.156, 5.157, 5.158, 5.159, 5.16, 5.161
	R_{DLY_TMR} = 1.18MΩ	1, 2, 3	20	23.37	27.2		5.69, 5.7, 5.71, 5.72, 5.73, 5.74, 5.75, 5.76, 5.77, 5.78, 5.1, 5.101, 5.102, 5.103, 5.104, 5.105, 5.106, 5.107, 5.108, 5.109, 5.131, 5.132, 5.133, 5.134, 5.135, 5.136, 5.137, 5.138, 5.139, 5.140, 5.162, 5.163, 5.164, 5.165, 5.166, 5.167, 5.168, 5.169, 5.170, 5.171
Time to regulation	R_{REG_TMR} = 10.5kΩ	1, 2, 3	0.197	0.264	0.34		4.0, 4.1, 4.2, 4.3, 4.12,4.13, 4.14, 4.15, 4.24, 4.25, 4.26, 4.27, 4.36, 4.37, 4.38, 4.39
	R_{REG_TMR} = 619kΩ	1, 2, 3	10.8	12.4	14.1		4.4, 4.5, 4.6, 4.7, 4.16,4.17, 4.18, 4.19, 4.28, 4.29, 4.30, 4.31, 4.40, 4.41, 4.42, 4.43
	R_{REG_TMR} = 1.18MΩ	1, 2, 3	20.3	23.63	27.2		4.8, 4.9, 4.10, 4.11, 4.20, 4.21, 4.22, 4.23, 4.32, 4.33, 4.34, 4.35, 4.44, 4.45, 4.46, 4.47

3.2.2 Timing Requirements

Parameter	Test Conditions	Sub-Group	MIN	TYP	MAX	UNIT	Test Number
Start-up delay time	$V_{REFCAP} \geq 1.1V$	1, 2, 3			2.8	ms	6.147
ENx propagation delay	DLY_TMR = Open, $V_{OVERDRIVE}$ = 10mV, V_{PULL_UPx} = 1.6V, from 50% of IN to 50% OUT	1, 2, 3		3.4	6.5	µs	5.0, 5.1, 5.2, 5.3, 5.6, 5.7, 5.8, 5.9, 5.12, 5.13, 5.14, 5.15, 5.18, 5.19, 5.2, 5.21, 5.24, 5.25 5.26, 5.27, 5.3, 5.31, 5.32, 5.33, 5.36, 5.37, 5.38, 5.39, 5.42, 5.43, 5.44, 5.45
SEQ_DONE propagation delay	DLY_TMR = Open, $V_{OVERDRIVE}$ = 10mV	1, 2, 3		3.4	6.5	µs	5.4, 5.1, 5.16, 5.22, 5.28, 5.34, 5.4, 5.46
PWRGD propagation delay	DLY_TMR = Open, $V_{OVERDRIVE}$ = 10mV	1, 2, 3		3.4	6.5	µs	5.5, 5.11, 5.17, 5.23, 5.29, 5.35, 5.41, 5.47
State machine fault propagation delay	Out of order fault	1, 2, 3		3.4	4.3	µs	27.1, 27.2, 27.3, 27.4, 27.5, 27.6, 27.7, 27.8
V_{UP} rising minimum time for valid UP		4, 5, 6		0.27	0.7	µs	25.1, 25.2
V_{DOWN} rising minimum time for valid DOWN		4, 5, 6		0.42	0.9	µs	25.3, 25.4
Rising threshold on VSENSEx hold time		4, 5, 6		0.84	1.6	µs	26.1, 26.2, 26.3, 26.4, 26.5, 26.6, 26.7, 26.8
Falling threshold on VSENSEx hold time		4, 5, 6		0.35	1	µs	26.9, 26.10, 26.11, 26.12 26.13, 26.14, 26.15, 26.16

4 Applicable and Reference Documents

4.1 Applicable Documents

- Texas Instruments, *TPS7H3014-SP Radiation-Hardeness-Assured, 14-V, 4-Channel Sequencer*, data sheet.
- Texas Instruments, *TPS7H3014EVM-CVAL Evaluation Module User's Guide*, user's guide.
- Texas Instruments, TPS7H3014-SP Single-Event Effects (SEE) radiation report

4.2 Reference Documents

Texas Instruments neutron irradiation test follow the guideline from MIL-STD-883 TM 1017. The document is available in Defense Logistic Agency's website.

A Appendix: NDD Report Data

This appendix contains the NDD report data.