



## ABSTRACT

This report covers the radiation characterization results of the F28377D-SEP, radiation tolerant 32-bit floating-point microcontroller unit. The study was done to determine Total Ionizing Dose (TID) effects under high dose rate (HDR) up to 30krad(Si) as a one time characterization. The results show that all samples passed within the specified limits up to 30krad(Si) . All future wafer lots are tested under the same conditions. HDR TID response is the worst case. TID HDR characterization was performed per TM 1019.

The F28377D-SEP is packaged in a space enhanced plastic package for low outgassing characteristics and is Single Event Latch-Up (SEL) immune up to 45MeV-cm<sup>2</sup>/mg, which makes the device an option for low Earth orbit space applications. Single Event Transient (SET) data is also provided in the Single Event Effects Radiation Report.

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## 1 Device Information

The F28377D-SEP has dual real-time control subsystems based on TI's 32-bit C28x floating-point CPUs, which provide 200 MHz of signal processing performance in each core. The device also features two independent CLA real-time control processors that respond to peripheral triggers and executes code concurrently with the main C28x CPU. Each CPU is further boosted by TMU accelerator, which enables fast execution of algorithms with trigonometric operations common in transforms and torque loop calculations; and the VCU accelerator, which reduces the time for complex math operations common in encoded applications.

F28377D-SEP supports up to 1MB (512KW) of onboard flash memory with error correction code (ECC) and up to 204KB (102KW) of SRAM. Two 128-bit secure zones are also available on each CPU for code protection.

### 1.1 Device Details

[Table 1-1](#) lists the device information used for TID HDR characterization and qualification.

**Table 1-1. Device and Exposure Details**

TID HDR Details: Up To 30krad(Si)	
TI Device Number	F28377D-SEP
VID Number	V62/25638
Package	PTP (HLQFP, 176)
Technology	F021 (65nm Flash CMOS)
Die Lot Number	3112273
A/T Lot Number and Date Code	5276809PHI/P06138-07G2
Quantity Tested	20 irradiated devices + 5 control
Lot Accept or Reject	Devices passed 30krad(Si)
HDR Radiation Facility	Texas Instruments CLAB in Dallas, Texas
HDR Dose Level	20krad(Si), 30krad(Si)
HDR Dose Rate	182.92rad(Si)/s ionizing radiation
HDR Radiation Source	Gammacell 220 Excel (GC-220E) Co-60
Irradiation Temperature	Ambient, room temperature

## 2 Total Dose Test Setup

### 2.1 Test Overview

The F28377D-SEP samples were irradiated at a high dose rate of 182.92rad(Si)/s up to 30krad(Si) and then put through full electrical parametric testing on the production Automated Test Equipment (ATE). The samples were functional and passed all electrical parametric tests with readings within data sheet electrical specification limits.

### 2.2 Test Description and Facilities

The F28377D-SEP HDR exposure was performed on biased AND UNBIASED devices in a Co-60 gamma cell at TI facility in Dallas, Texas. The un-attenuated dose rate of this cell is 182.92rads(Si)/s. After exposure, the devices were packed in dry ice (per MIL-STD-883 Method 1019.9 section 3.10) and full post radiation electrical evaluation using Texas Instruments ATE was conducted. ATE test limits are set per data sheet electrical limits based on 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 Test Setup Details

The devices were tested in biased and unbiased conditions as described in the following sections.

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

#### 2.3.1 Bias Diagram

Figure 2-1 shows the schematic for the board used during irradiation where 5V is inputted into the board and gets shifted to VDDIO to bias the pins.

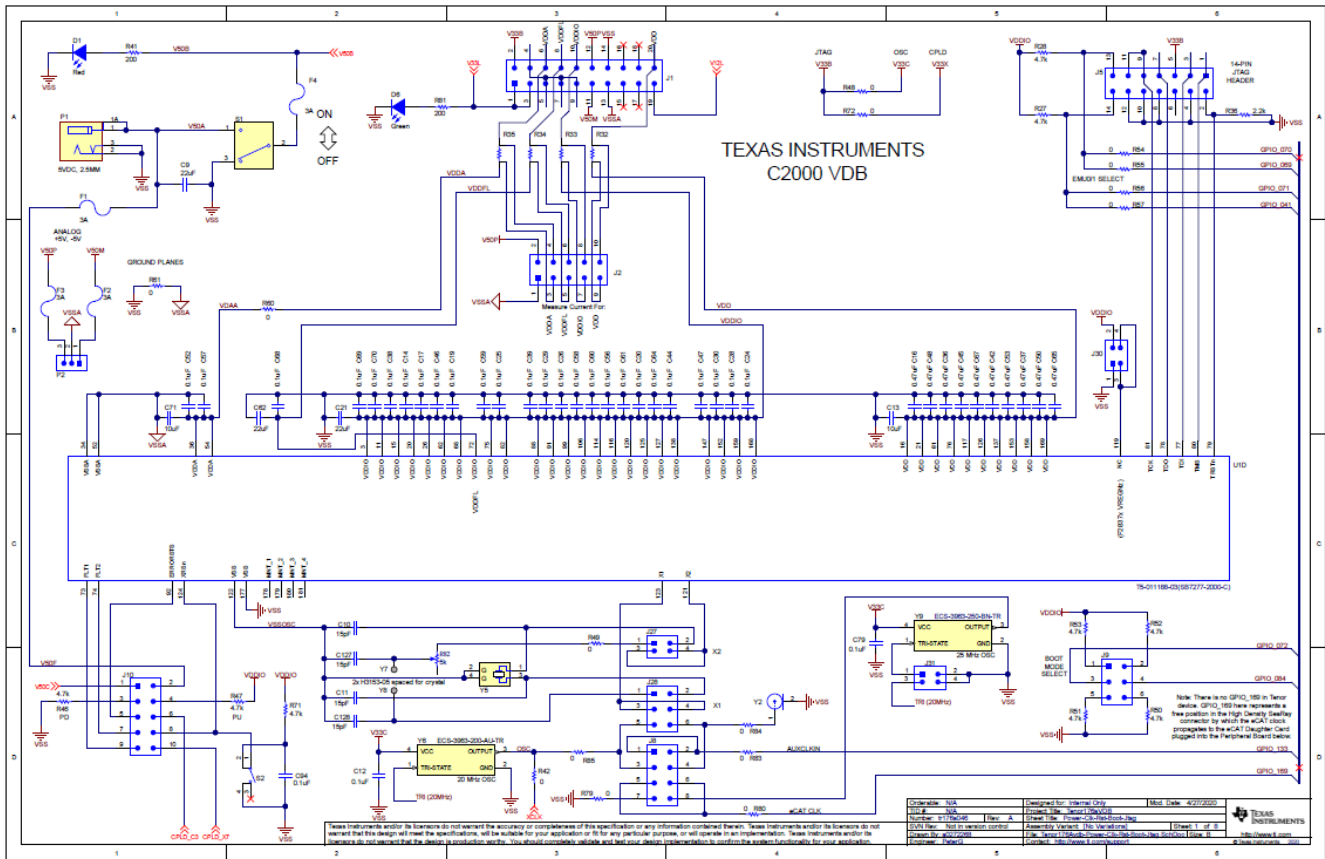


Figure 2-1. F28377D-SEP Bias Diagram

## 2.4 Test Configuration and Condition

A step stress (10k, 20k, and 30k) test method was used to determine the TID hardness level. That is, after a predetermined TID level was reached, an electrical test was performed on a given sample of parts to verify that the units are within specified data sheet electrical test limits. The HDR RLAT units were irradiated to 30krad(Si), parametrically tested on ATE. ATE parametric testing was completed before and after the anneal.

[Table 2-1](#) lists the serialized samples used for TID characterization.

**Table 2-1. HDR Device Information**

Control Group	HDR Dose Rate = 182.92rad(Si)/s			
Total Samples: 5	Total Samples: 20 Biased			
	Exposure Levels			
0krad (Si)	20krad(Si)		30krad(Si)	
Biased	Biased	Unbiased	Biased	Unbiased
26-30	1-5	6-10	11-15	16-20

### 3 Electrical Characteristics Tested

**Table 3-1. Electrical Parameters Table**

Parameter	Test Conditions	T <sub>A</sub> = -55°C to +125°C			Unit	Test Name
		MIN	NOM	MAX		
V <sub>DDIO</sub>	Device IO Supply Voltage	3.14	3.3	3.47	V	IDD_DUAL_OPER_VDDSFL
V <sub>DD</sub>	Device Supply Voltage	1.14	1.2	1.26	V	IDD_DUAL_OPER_VDD
V <sub>DDA</sub>	Analog Supply Voltage	3.14	3.3	3.47	V	IDD_DUAL_OPER_VDDA

#### Additional Test Parameters

##### FLASH

Flash shell was loaded after a high dose rate of 182.92rad(Si)/s up to 50krad(Si) and all sites read successfully.

## 4 TID HDR Data Results

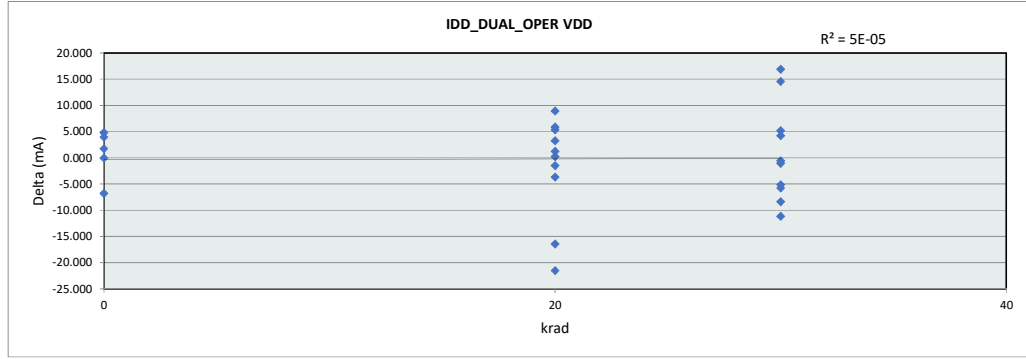
### 4.1 TID HDR Results Summary

The parametric data for the F28377D-SEP passes up to 30krad(Si) HDR TID irradiation. The drifts of the electrical parameters through HDR were within the data sheet limits.

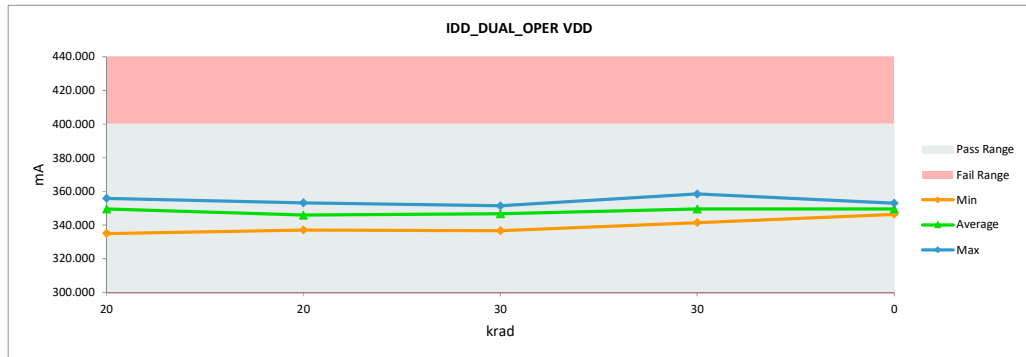
Overall, the F28377D-SEP showed a strong degree of hardness to HDR TID irradiation up to 30krad(Si). The measurements taken post-irradiation for each sample set showed a marginal shift for most parameters at each dose level. The parameters that did show a greater degree of change between pre- and post-irradiation were still within the electrical performance characteristics specified in the data sheet electrical parameters. For the data sheet electrical parameters and associated tests, see [F28377D-SEP Radiation Tolerant, Dual-Core Real-Time Microcontroller](#).

# TID Report F28377D-SEP

IDD_DUAL_OPER VDD				
Test Site				
Tester				
Test Number				
Unit	mA	mA		
Max Limit	400	400		
Min Limit	0	0		
krad	Serial #	PRE HDR	POST HDR	Delta
20	1	350.423	355.802	5.379
20	2	351.453	335.012	-16.442
20	3	350.156	353.399	3.243
20	4	353.399	351.911	-1.488
20	5	351.377	351.606	0.229
20	6	346.647	342.985	-3.662
20	7	351.949	353.170	1.221
20	8	345.502	351.377	5.875
20	9	336.347	345.274	8.927
20	10	358.511	336.996	-21.515
30	11	337.644	336.614	-1.030
30	12	355.344	346.990	-8.354
30	13	334.211	348.783	14.572
30	14	351.987	351.415	-0.572
30	15	355.612	349.851	-5.760
30	16	351.644	346.494	-5.150
30	17	338.064	354.963	16.899
30	18	353.246	358.434	5.188
30	19	342.107	346.342	4.234
30	20	352.560	341.421	-11.139
0	26	346.609	350.538	3.929
0	27	346.761	351.568	4.807
0	28	352.979	352.941	-0.038
0	29	344.663	346.418	1.755
0	30	353.246	346.456	-6.790
	Max	358.511	358.434	16.899
	Average	348.498	348.270	-0.227
	Min	334.211	335.012	-21.515
	Std Dev	6.500	6.047	8.632

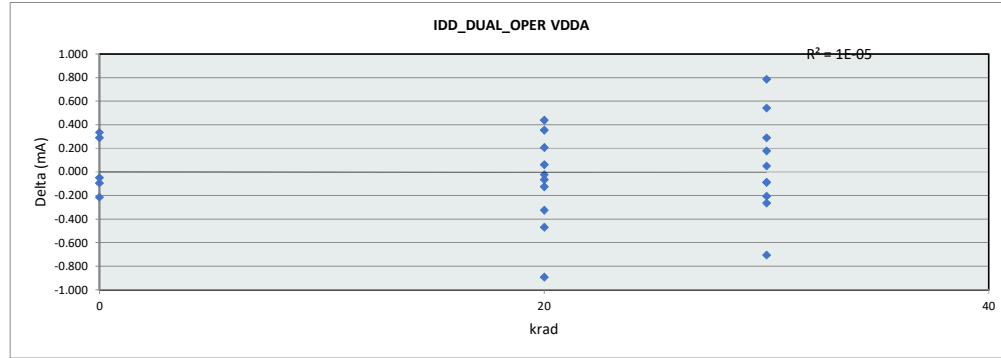


IDD_DUAL_OPER VDD					
Test Site					
Tester					
Test Number					
Max Limit	400	400			
Min Limit	0	0			
krad	20	20	30	30	0
LL	0.000	0.000	0.000	0.000	0.000
Min	335.012	336.996	336.614	341.421	346.418
Average	349.546	345.960	346.731	349.531	349.584
Max	355.802	353.170	351.415	358.434	352.941
UL	400.000	400.000	400.000	400.000	400.000

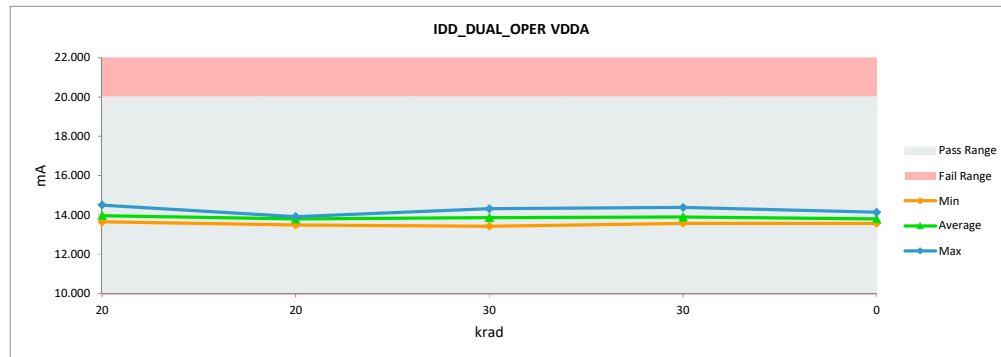


# TID Report F28377D-SEP

IDD_DUAL_OPER VDDA				
Test Site				
Tester				
Test Number				
Unit	mA	mA		
Max Limit	0	0		
Min Limit	20	20		
krad	Serial #	PRE HDR	POST HDR	Delta
20	1	14.145	14.500	0.355
20	2	13.966	13.642	-0.324
20	3	14.328	13.859	-0.469
20	4	13.870	13.931	0.061
20	5	14.000	13.874	-0.126
20	6	13.424	13.863	0.439
20	7	13.928	13.905	-0.023
20	8	13.882	13.817	-0.065
20	9	13.684	13.890	0.206
20	10	14.382	13.489	-0.893
30	11	13.493	13.672	0.179
30	12	14.126	13.420	-0.706
30	13	13.657	13.947	0.290
30	14	13.905	13.954	0.050
30	15	14.515	14.309	-0.206
30	16	13.825	13.561	-0.263
30	17	13.519	14.305	0.786
30	18	13.832	14.374	0.542
30	19	13.653	13.565	-0.088
30	20	13.733	13.645	-0.088
0	26	13.798	14.134	0.336
0	27	13.645	13.935	0.290
0	28	13.909	13.813	-0.095
0	29	13.615	13.565	-0.050
0	30	13.775	13.561	-0.214
<b>Max</b>		14.515	14.500	0.786
<b>Average</b>		13.864	13.861	-0.003
<b>Min</b>		13.424	13.420	-0.893
<b>Std Dev</b>		0.274	0.288	0.377



IDD_DUAL_OPER VDDA					
Test Site					
Tester					
Test Number					
Max Limit	0	mA			
Min Limit	20	mA			
krad	20	20	30	30	0
LL	0.000	0.000	0.000	0.000	0.000
Min	13.642	13.489	13.420	13.561	13.561
Average	13.961	13.793	13.861	13.890	13.802
Max	14.500	13.905	14.309	14.374	14.134
UL	20.000	20.000	20.000	20.000	20.000

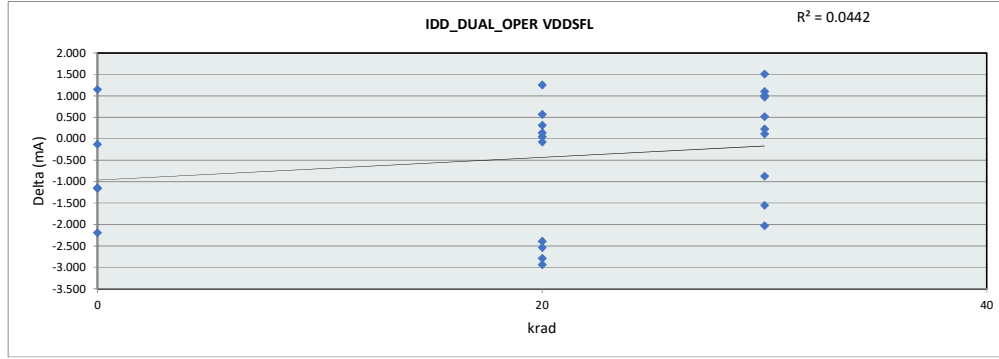




# TID Report F28377D-SEP

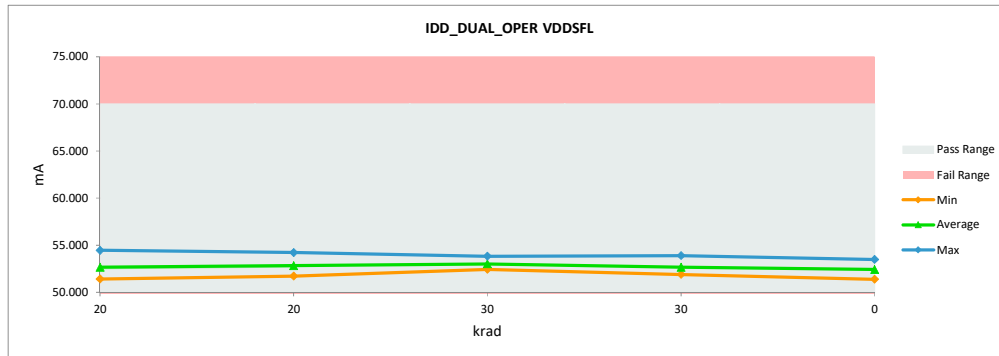
IDD_DUAL_OPER VDDSFL		
Test Site		
Tester		
Test Number		
Unit	mA	mA
Max Limit	70	70
Min Limit	0	0

krad	Serial #	PRE HDR	POST HDR	Delta
20	1	53.059	53.201	0.141
20	2	54.688	52.300	-2.388
20	3	53.887	54.456	0.568
20	4	54.833	51.900	-2.934
20	5	51.495	51.419	-0.076
20	6	53.906	54.223	0.317
20	7	52.388	52.438	0.050
20	8	55.001	52.464	-2.537
20	9	52.094	53.349	1.255
20	10	54.505	51.717	-2.789
30	11	51.476	52.449	0.973
30	12	55.028	53.002	-2.026
30	13	52.319	53.830	1.511
30	14	52.766	52.880	0.114
30	15	52.464	52.979	0.515
30	16	51.434	52.537	1.102
30	17	52.445	52.674	0.229
30	18	52.880	53.891	1.011
30	19	53.193	52.323	-0.870
30	20	53.452	51.900	-1.553
0	26	53.616	53.487	-0.130
0	27	53.624	52.468	-1.156
0	28	53.475	52.331	-1.144
0	29	51.301	52.453	1.152
0	30	53.578	51.385	-2.193
Max		55.028	54.456	1.511
Average		53.156	52.722	-0.434
Min		51.301	51.385	-2.934
Std Dev		1.144	0.816	1.410



IDD_DUAL_OPER VDDSFL		
Test Site		
Tester		
Test Number		
Max Limit	70	mA
Min Limit	0	mA

krad	20	20	30	30	0
LL	0.000	0.000	0.000	0.000	0.000
Min	51.419	51.717	52.449	51.900	51.385
Average	52.655	52.838	53.028	52.665	52.425
Max	54.456	54.223	53.830	53.891	53.487
UL	70.000	70.000	70.000	70.000	70.000



## 5 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.

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