ST1S40 TID TEST REPORT

3 A DC step-down switching regulator

Prepared by	Philipp Mand
Document Type	RP - Report (Technical, Budget, Cost, Manpower, Travel, Audit, etc.)
Reference	ESA-TECQEC-RP-2024-000643
Issue/Revision	1
Date of Issue	21/02/2024
Status	N/A

APPROVAL

Title	ST1S40 TID TEST REPORT		
Issue Number	1	Revision Number	0
Author	Philipp Mand	Date	21/02/2024
Approved By	Viyas Gupta	Date of Approval	21/02/2024

CHANGE LOG

Reason for change	Issue Nr	Revision Number	Date

CHANGE RECORD

Issue Number 1	Revision Number 0		
Reason for change	Date	Pages	Paragraph(s)

DISTRIBUTION

Name/Organisational Unit

Table of Contents

1. DISCLAIMER

The information contained herein is presented for informational purposes only. ESA does not make, and disclaims, any representation or warranty, express or implied, of the correctness and completeness of this information, and its fitness for a particular purpose. This information does not constitute or imply an ESA endorsement or approval for the use of any tested part in ESA activities or third-party activities. In particular, but without limitation, this is due to traceability which cannot be guaranteed on commercial components but is an important pre-requisite for the reusability of TID, TNID and SEE radiation test results. The information herein can therefore not be reused without further justifications which may vary depending on the type of space activity concerned.

Reproduction of parts of the test summary is authorised on the condition that clear reference is made to the test report number and this disclaimer.

ESA reserves the right to alter, revise, or rescind this document due to subsequent developments or additional test results. ESA intends, but cannot guarantee, that the ESARAD database always contains latest versions of the test reports.

2. INTRODUCTION

The aim of this test campaign is to evaluate the TID radiation hardness level of the ST1S40 buck converter component.

The component is selected from an ESA internal list of Commercial of-the-shelf (COTS) components, which contains components of high importance for ESA projects. The results can then be used for the different projects. Additionally, the data is used to derive information on the general TID response of this device.

3. ACRONYMS

ESTEC	European Space Research and Technology Centre
COTS	Commercial-off-the-shelf
DUT	Devices Under Test
LDMOS	Lateral-diffused metal-oxide semiconductor
MOSFET	Metal-oxide-semiconductor-field-effect transistor
PC	Power Cycle
TID	Total Ionizing Dose

4. DEVICES UNDER TEST

In Table 1 the parameters of the Device under Test (DUT), the ST1S40, is given **Error! Reference source not found.**.

Table 1: Description of the DUT

Manufacturer	Datecode	Product	Uin,max (V)	Uout,max (V)	Uout,min (V)	Id,cont,max (A)	frequency (MHz)
ST Microelectronics	1133	ST1S40	18	18	18	3	0.8

This device is a synchronous buck converter with a half bridge configuration which is used to step down a voltage with a switching application. For the device a specific application close to the usual application as presented in the datasheet, was developed. In Figure 1, a usual application for this synchronous buck converter with the internal MOSFETs (LDMOS) is given.

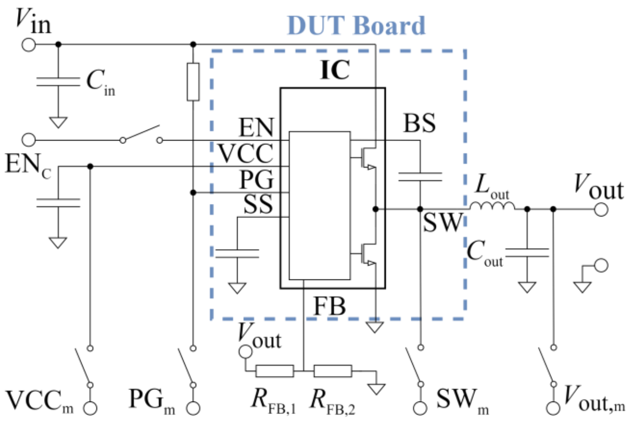

Figure 1: Typical application synchronous buck converter

In Figure 2 the Block diagram of the device is shown and in Figure 3 the component can be seen.

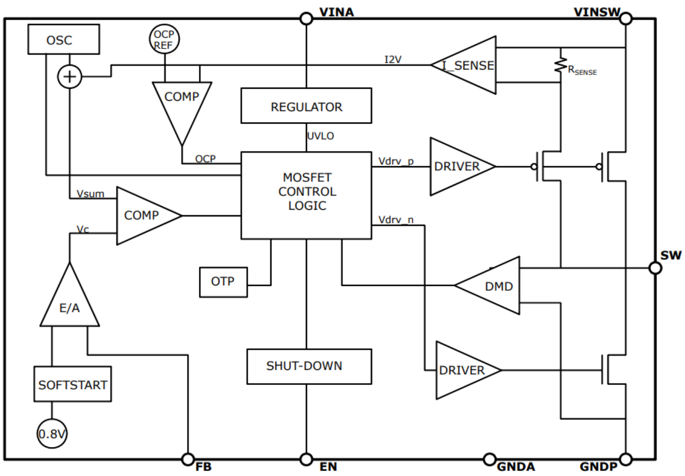

Figure 2: Block Diagram of the ST1S40

Figure 3:Microscope Picture of the ST1S40 package

5. TID SUMMARY

Table 2: TID Summary

Item	Description
Aim	TID sensitivity evaluation of different synchronous buck converter devices for Total Ionizing Dose Effects
Biasing Conditions	1. Input voltages of 15 V 50 mA output current, freq. 900 kHz 2. Unbiased
Sample size	3 devices for biased condition, 5 devices for unbiased condition
Dose Rate	350-360 rad/h
Dose Steps (krad)	1. 0, 5, 7, 15, 20.5
Environmental condition	Room temperature condition
Results	Drift in the frequency, drift in the supply currents, fully functional and steady output voltage up to the max. tested dose of 15 krad(Si)

6. DOSIMETRY AND IRRADIATION FACILITY

IRRADIATION FACILITY

Source:	C060
Localization:	ESTEC, Netherlands
Dosimetry:	Electrometer: Farmer model 2670 – s/n 491
	Ionisation chamber: PTW TW30012-10 s/n 000417

IRRADIATION TIMING

TID steps (krad(Si)):	0, 5, 7, 15, 20.5, 30, 38
Dose rate (rad(Si)/h):	350-360

ANNEALING

Conditions:

- Room Temperature Annealing (RTA) 21°C, 168 h
    - Biased for those tested biased
    - Unbiased for those tested unbiased
- High Temperature Annealing (Ageing) 100°C, 168 h
    - Biased for those tested biased
    - Unbiased for those tested unbiased

Values are provided in TID(H20), the conversion to TID(Si) is done using the conversion factor of: 0.898.

7. TEST PREPARATION

7.1. Test set-up

The test shall be performed at Co-60 facility at ESTEC. The irradiation will be performed in room temperature condition. For the test, the following equipment, Table 3, is to be used:

Table 3: Test Equipment

Equipment	Name	Description
2x Source meter	Keithley 2612A	Providing the bias voltage/current and the Relay supply current
1 x Voltage source	Keysight N6705C	Used to test voltages above 35 V (if no DSEE happened at lower voltage)
1x 4 channel oscilloscope	Keysight DSOS804A	To observe all the parameters mentioned in Table 4
1x Laptop		To acquire data and to set the test setup

In **Error! Reference source not found.** the basic test setup with the equipment and the test boards inside the vacuum chamber is visualized. Multiple different buck converters have been tested during the campaign. One of the test boards consist of the ST1S40.

In Figure 4 the DUT board can be seen. This board is then mounted on the radiation-test-board in Figure 5. Specific values for the capacitances and inductances were calculated for each board. The biasing can flexibly be adjusted by jumpers and relays. The relays can be used to switch measurements between the DUTs. In addition, the parameters of the device can be measured individually, and the device can be enabled and disabled. The relays are controlled outside the chamber with a specific designed relay-control-board.

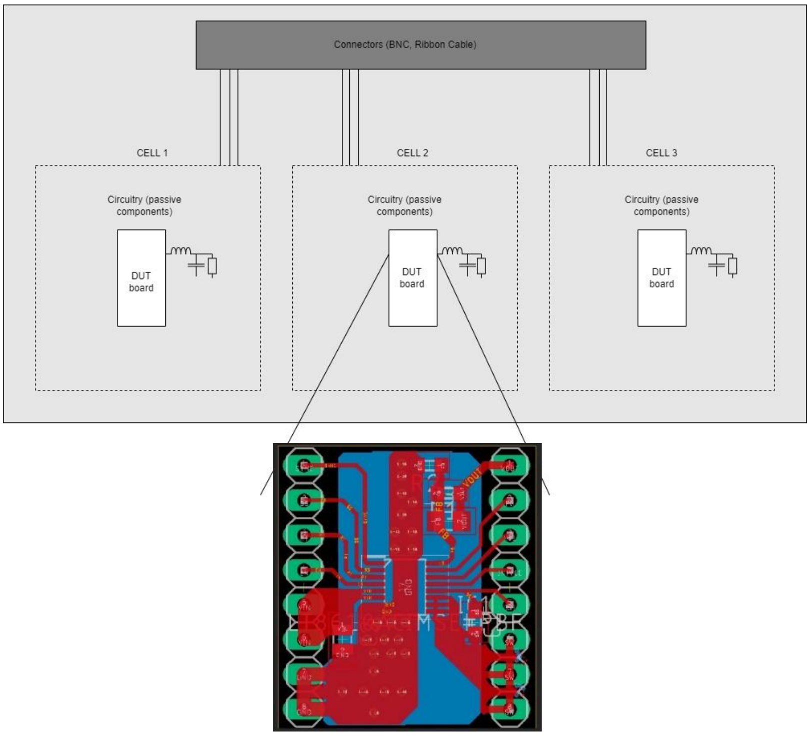

Figure 4: Visualization of the radiation-test-boards

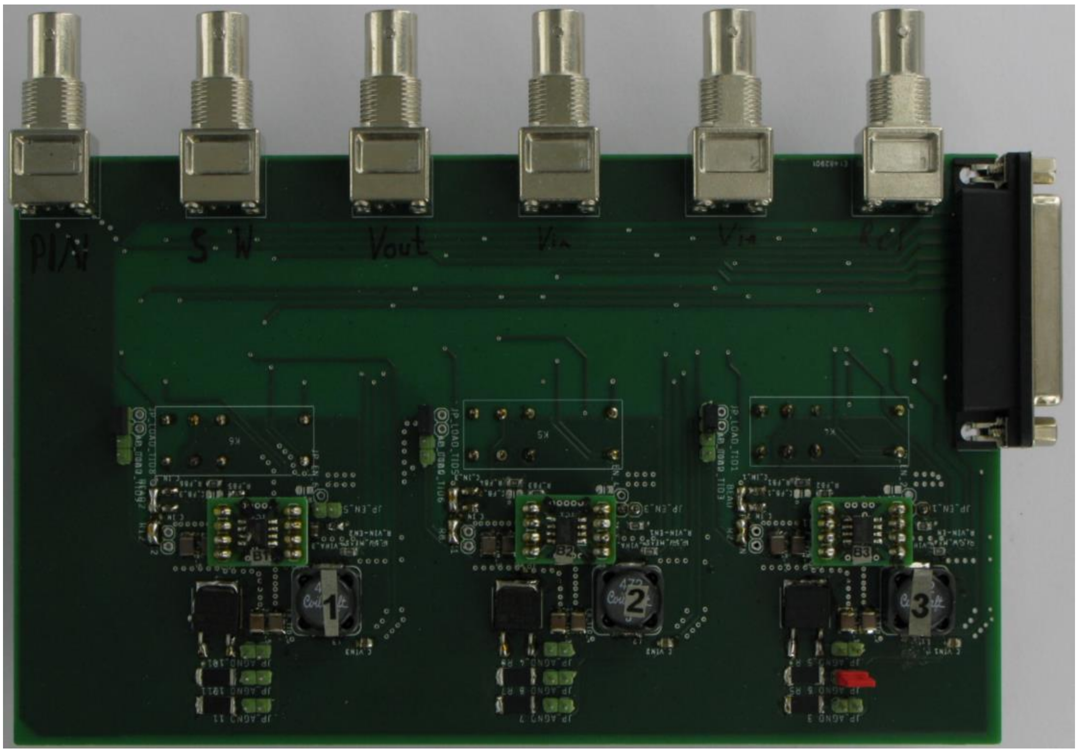

Figure 5: Top-side of the ST1S40 test board

In *Figure 6* an overview with the important capacitances is given. The value of the output capacitance is calculated to Cout = 80 µF, the input capacitance is Cin = 30 µF the output Inductance is Lout = 22 µH.

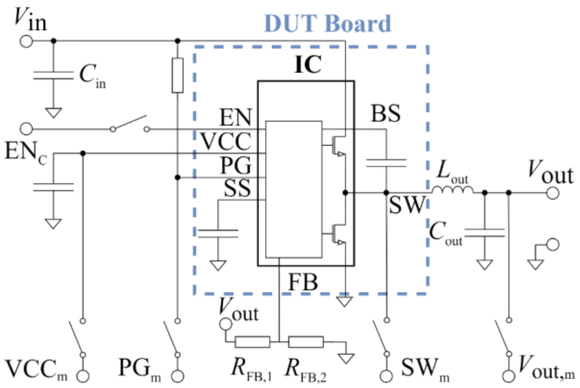

Figure 6: Simplified test setup with Cout = 80 µF, Cin = 30 µF, Lout = 22 µH.

7.2. Measurements

As stated above, the use of relays allows an individual measurement for each DUT on the radiation-test-boards. All important parameters of a device are measurable. In Table 4 the overview of these parameters is given.

Table 4: Measurement Parameters

PIN/Parameter	Description	Type of Measurement
Vinsw	Power Supply Input	SW Voltage
Vin	Voltage Input	SW Voltage
Vout	Filtered output voltage	Voltage
Iin	Input current	Current
Iq	Disabled quiescent current	Current
Iout	Output current	Current

7.3. Biasing Conditions

Two biasing conditions have been chosen and are displayed in Table 5.

Table 5: Test conditions and description

Condition	Description
Unbiased	All pins shorted together; no Pins left floating
Biased	Input Voltage = 15 V, Frequency = 900 kHz, Output Voltage 3.4 V, Output resistor = 50 Ohm

7.4. Acquisition of Data

All the data was acquired and saved with an oscilloscope. The data was then processed for three sigma calculations. The values of the TID have been calculated based on the dosimetry provided in chapter 5 and is calculated accordingly to the TID in Silicon.

8. TID EFFECTS RESULTS

8.1. Output Voltage

The output voltage of the ST1S40 was set in the beginning via a voltage divider between the output and the FB pin of the device. During the irradiation procedure no change in the output voltage was measured until the device shut down after 15 krad. This shutdown was first observed during a shutdown of the biased group and restart try via the enable pin. In Figure 6 and Figure 7 the results of the campaign are displayed. Figure 6 shows the statistical analysis with the mean from the bias and unbiased configurations as well as the tolerance limits.

In all following plots the room temperature annealing (RTA) and high temperature annealing (HTA) also called aging is displayed. The RTA was carried out for 168 hours at room temperature and the HTA for 168 hours at 100 °C. The device shut down after 30 krad and did not resume nominal operation after the RTA for the biased groups. The unbiased groups continued operation. After the HTA the operation of the device was in the nominal range.

The Upper Tolerance Limit (UTL) can be calculated as follows:

$$UTL = \delta_x + K \cdot \sigma_x \qquad 9.$$

with δ_x the mean, K the one-sided tolerance limit factor, and σ the standard deviation. The lower tolerance limit (LTL) can be calculated with

$$LTL = \delta_x - K \cdot \sigma_x. \quad 10.$$

For the given P and C, the K value is 5.311 for n = 3 and 3.4 for n = 5. **Error! Reference source not found.**

Figure 7 shows the absolute values during the TID test campaign.

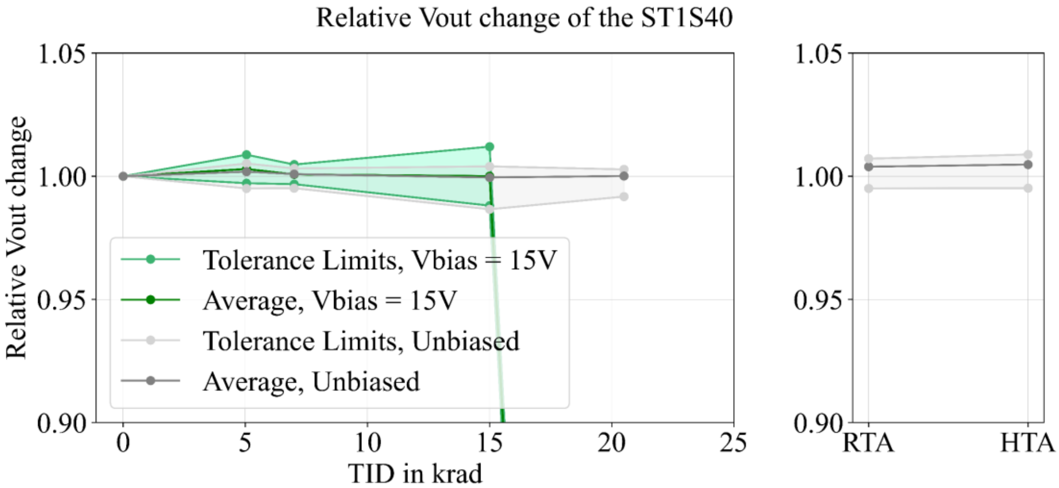

Figure 7: ST1S40 relative output voltage change (Vout(pre-rad)/Vout(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

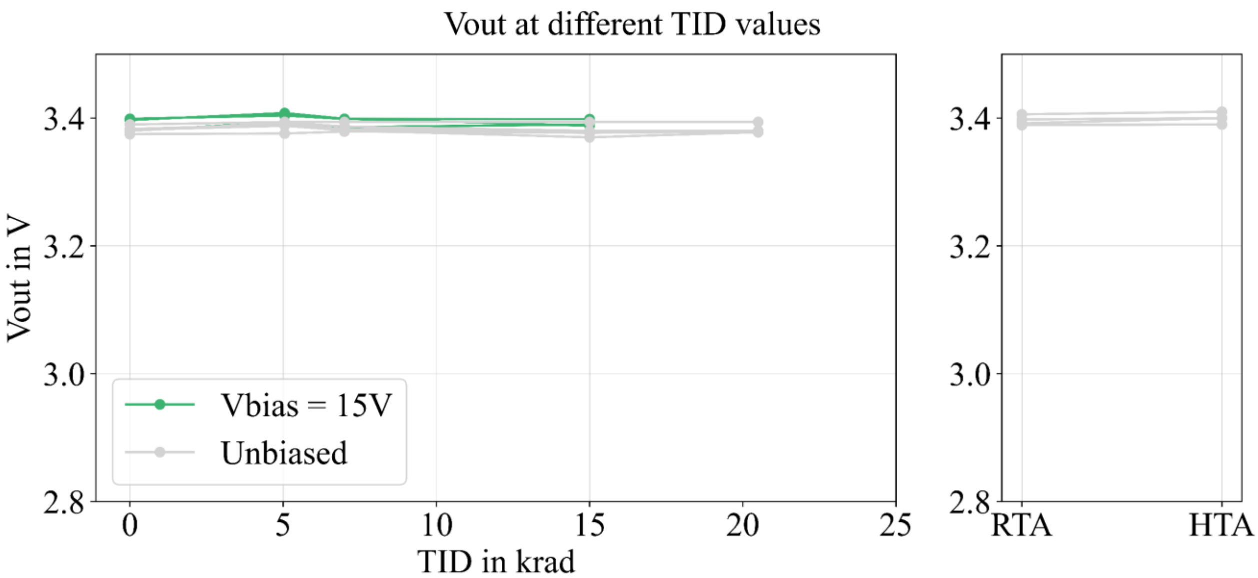

Figure 8: ST1S40 output voltage with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

10.1. Shutdown quiescent current

The shutdown quiescent current is the current that is supplying the internal circuitry in the case of a shutdown of the device when the enable pin is connected to ground. The measured current was at a voltage of 15 V. A increase in the current after 8 krad was observed. The increase was close to 1.25 times the initial value. The results are shown in Figure 9 and Figure 10. The maximum variation given in the datasheet is well above the maximum limit measured.

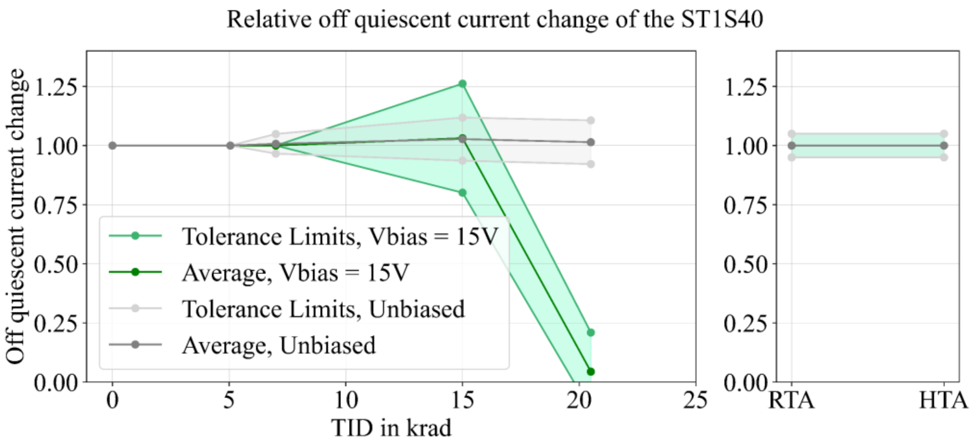

Figure 9: ST1S40 relative change in the shutdown quiescent current (Iq(pre-rad)/Iq(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

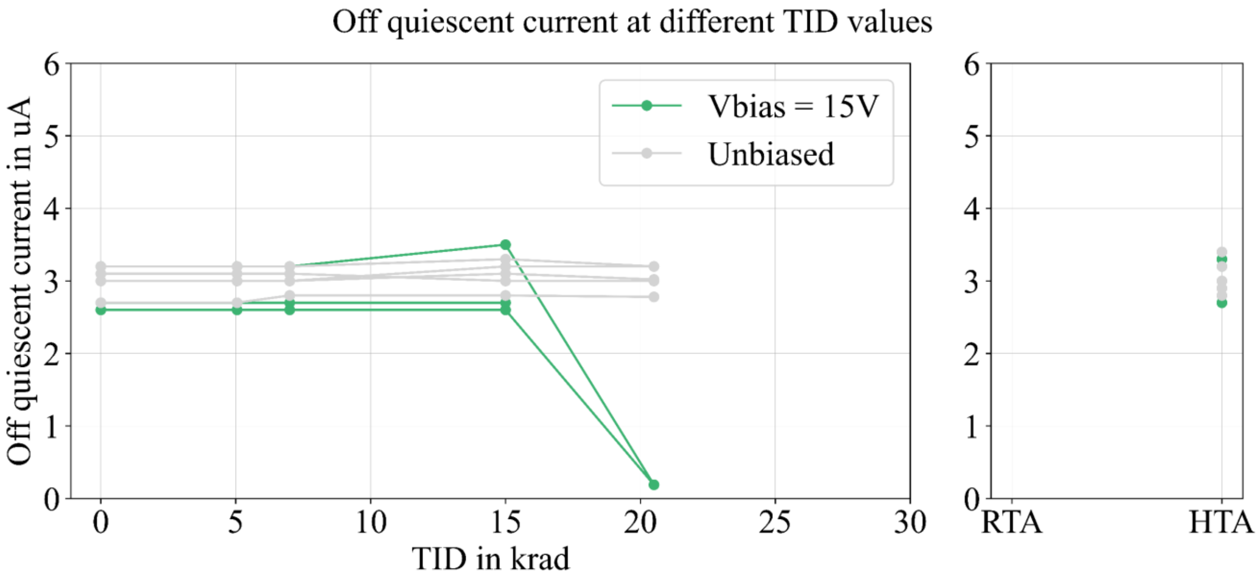

Figure 10: ST1S40 shutdown quiescent current change of the LT8610 with displayed for two bias conditions

10.2. Frequency

The second parameter is the frequency. No difference between biased and unbiased group have been observed until the shutdown of the biased group. Figure 11 and Figure 12 displays the results. No change in the frequency was observed. After 15 krad, the device shut off and the frequency was therefore 0. After the HTA the device resumed to nominal operation.

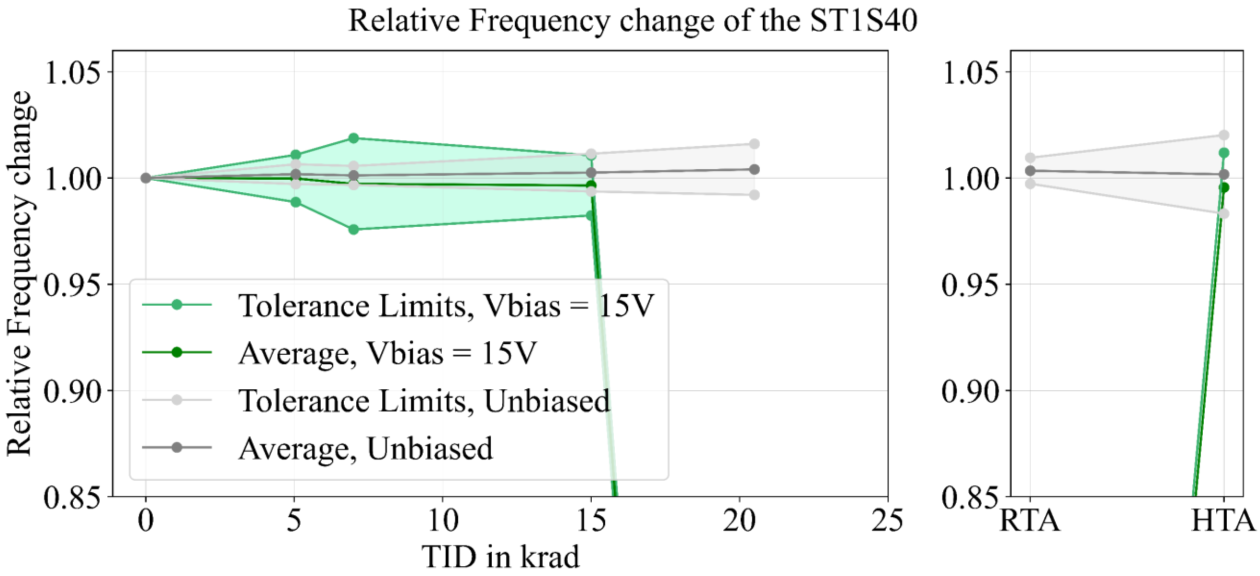

Figure 11: ST1S40 relative output voltage change (Freq(pre-rad)/Freq(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

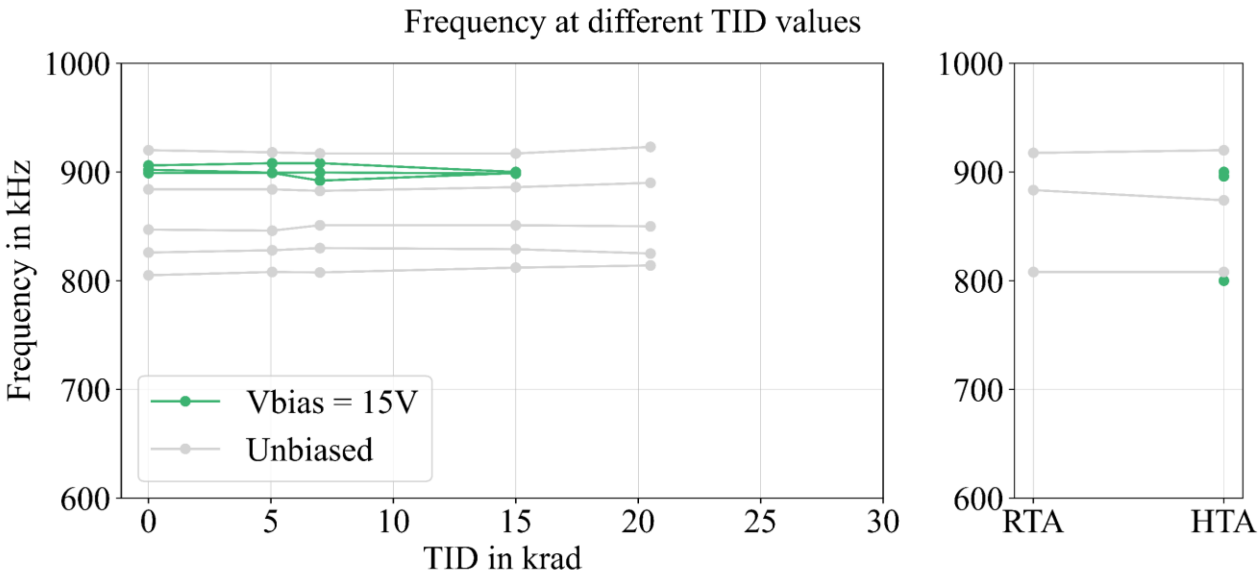

Figure 12: ST1S40 output voltage with the Room Temperature Annealing and Accelerated Ageing for two bias conditions

11. CONCLUSION

The ST1S40 converter has been tested against Total Ionizing Dose effects. Two biasing conditions have been tested. For the biased condition three DUTs have been used and for the unbiased condition (all pins shorted together) five devices have been used. For both conditions and to the maximum dose in silicon of 15 krad, no critical drift outside of the datasheet values have been observed. Full functionality is given to that dose. At higher doses the device was not operable anymore. During the annealing, no rebound effect was observed. In Table 2 a summary is given.

The data provided in the report should be handled with caution considering traceability challenges in the use of COTS. However, the data gives an overview of different kinds of TID effects and allows preparation for validation test campaigns and be able to identify possible mitigation techniques.

Table 6: TID Summary

Item UNITS	Description
Aim	TID sensitivity evaluation of different synchronous buck converter devices for Total Ionizing Dose Effects
Biasing Conditions	3. Input voltages of 15 V (run 1), 50 mA output current, freq. 900 kHz 4. Unbiased
Sample size	3 devices for biased condition, 5 devices for unbiased condition
Dose Rate (rad/h)	350-360
Dose Steps (krad in Si)	$0, 5, 7, 15, 20.5$
Environmental condition	Room temperature condition
Results	Device fully functional without drifts up to 15 krad. After that, the device is not operable anymore

12. REFERENCES

[1] UCLouvain, Heavy Ion Facility, Heavy Ion Facility (HIF) | UCLouvain\

[2] ST Microelectronics, ST1S40 3A DC step-down switching regulator, ST1S40.fm (mouser.com)

13. ANNEX

In the following tables the values of the measurements are displayed. Sample number 1-3 are biased samples, Sample number 4-9 are the unbiased samples.

TID (krad)	Off supply	EN 1	SS 1	Freq. 1	Vout 1	Vcc 1	Pgood 1	SW/LX 1	Iout 1	Vin 1	Off supply	EN 2	SS 2	Freq. 2	Vout 2	Vcc 2	Pgood 2	SW/LX 2	Iout 2	Vin 2	Off supply	EN 3	SS 3	Freq. 3	Vout 3	Vcc 3	Pgood 3	SW/LX 3	Iout 3	Vin 3
0	15	1	4	2200	3.27958	3.25722	1	1	50.83	15	15	1	4	2205	3.28	3.2409	1	1	50.73	15	15	1	4	2201	3.2905	3.2323	1	1	50.76	15
5.05	15	1	4	2209	3.28565	3.05766	1	1	50.95	15	15	1	4	2202	3.28	3.0697	1	1	51.15	15	15	1	4	2197	3.2881	3.038	1	1	50.88	15
7	15	1	4	2208	3.2835	3.251	1	1	51.01	15	15	1	4	2200	3.276	3.2425	1	1	51.28	15	15	1	4	2194.8	3.2846	3.2389	1	1	50.91	15
15	31	1	4	2204	3.289	3.2579	1	1	51.2	15	30	1	4	2200	3.2787	3.241	1	1	51.42	15	28	1	4	2191	3.283	3.236	1	1	50.95	15
20.5	42	1	4	2202	3.2875	3.26	1	1	51.16	15	40	1	4	2190	3.28	3.244	1	1	51.47	15	45	1	4	2187	3.284	3.243	1	1	51	15
30	40	1	5	2196	3.288	3.26132	1	1	52.37	15	40	1	5.12	2186	3.2822	3.244	1	1	52.69	15	46	1	4.5	2185	3.283	3.244	1	1	51.95	15
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

EN 4	SS 4	Freq. 4	Vout 4	Vcc 4	Pgood 4	SW/LX 4	Iout 4	Vin 4	Off supply	EN 5	SS 5	Freq. 5	Vout 5	Vcc 5	Pgood 5	SW/LX 5	Iout 5	Vin 5	Off supply	EN 6	SS 6	Freq. 6	Vout 6	Vcc 6	Pgood 6	SW/LX 6	Iout 6	Vin 6
1	4	2200	3.2775	3.237	1	1	50.61	15	15	1	4	2224	3.277	3.235	1	1	50.82	15	15	1	4	2213	3.2736	3.2376	1	1	50.67	15
1	4	2211	3.259	3.03422	1	1	50.69	15	15	1	4	2222	3.2	3.279	1	1	50.9	15	15		4	2216	3.2705	3.0372	1	1	50.69	15
1	4	2211	3.272	3.2419	1	1	50.7	15	15	1	4	2221	3.277	3.242	1	1	50.96	15	15		4	2214	3.2724	3.242	1	1	50.75	15
1	4	2209	3.241	3.267	1	1	50.69	15	15	1	4	2222	3.276	3.243			51.01	15	50		4	2215	3.267	3.242			50.76	15
1	4	2211	3.269	3.24778	1	1	50.69	15	15	1	4	2220	3.28115	3.2495			51.08	15	50		4	2216	3.269	3.25			50.76	15
1	4	2211	3.266	3.249	1	1	50.73	15	15	1	4	2204	3.2794	3.252			51.13	15	15		4	2216	3.27	3.25			50.85	15
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Off supply	EN 7	SS 7	Freq. 7	Vout 7	Vcc 7	Pgood 7	SW/LX 7	Iout 7	Vin 7	Off supply	EN 8	SS 8	Freq. 8	Vout 8	Vcc 8	Pgood 8	SW/LX 8	Iout 8	Vin 8	Off supply	EN 9	SS 9	Freq. 9	Vout 9	Vcc 9	Pgood 9	SW/LX 9	Iout 9	Vin 9
15	1	4	2193	3.26527	3.252	1	1	50.47	15	15	1	4	2210	3.267	3.2439	1	1	50.54		15	1	4	2215	3.2617	3.263	1	1	50.75	15
15	1	4	2192	3.2758	3.26	1	1	50.53	15	15	1	4	2210	3.27738	3.2524	1	1	50.63		15		4	2217	3.2701	3.258			50.76	15
15	1	4	2192	3.2715	3.2554	1	1	50.61	15	15	1	4	2211	3.2708	3.2459			50.62		15		4	2217	3.2731	3.259			50.79	15
15			2191	3.27	3.2537			50.69	15	15		4	2213	3.2452	3.269			50.72		35		4	2217	3.268	3.26			50.8	15
15			2194	3.276	3.263			50.77	15	15		4	2213	3.27	3.2538			50.75		35		4	2217	3.266	3.27			50.8	15
15			2190	3.274	3.2644			50.85	15	15		4	2213	3.27325	3.257			50.84		35		4	2217	3.2659	3.27			50.8	15
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0