L6982 TID TEST REPORT

38 V, 2 A synchronous step-down converter with low quiescent current

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2. INTRODUCTION

The aim of this test campaign is to evaluate the TID radiation hardness level of the L6982 buck converter component, regarding total ionizing effects.

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 help to facilitate the use of COTS buck converters in space and to derive information of a Safe-Operating-Area (SOA) of this device.

The test was carried out on 4-11 August 2023 at ESTEC, the Netherlands.

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) are given.

Table 1: List and Description of the DUTs

Manufacturer	PM	Year, die	Product	Uin,max (V)	Uout,max (V)	Uout,min (V)	Id,cont,max (A)	frequency (MHz)
ST	9224	2017	L6982	38	38	0.85	2	0.2-2.2

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.

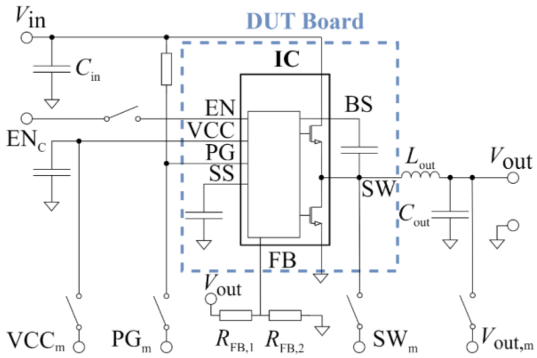

Figure 1: Typical application synchronous buck converter

In Figure 2, the capsulated component is given. Figure 3 the Block diagram of the device is shown and in Figure 4 the decapsulated die can be seen.

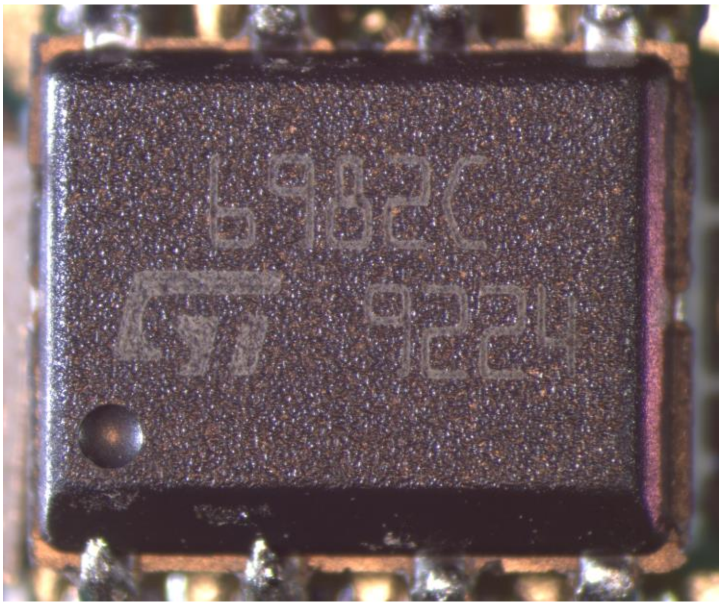

Figure 2: Package of the L6982 component

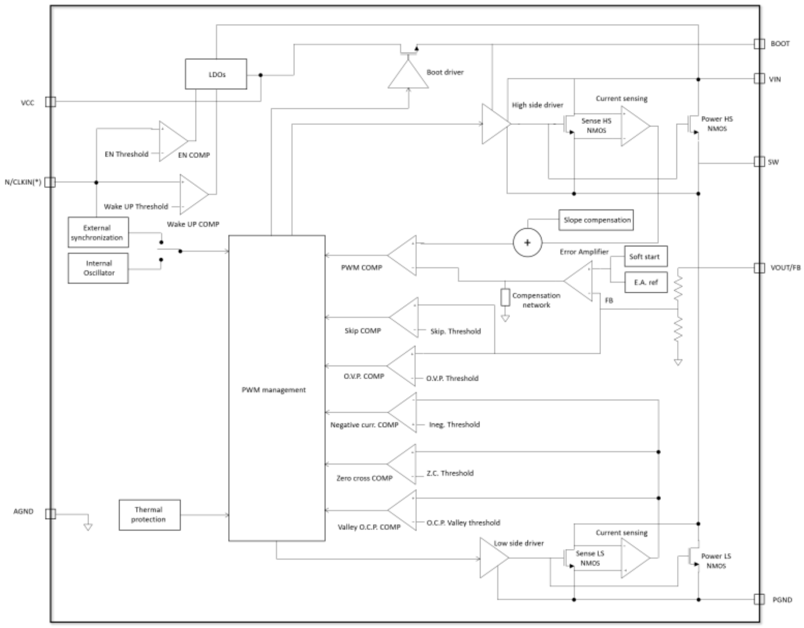

Figure 3: Block Diagram of the L6982

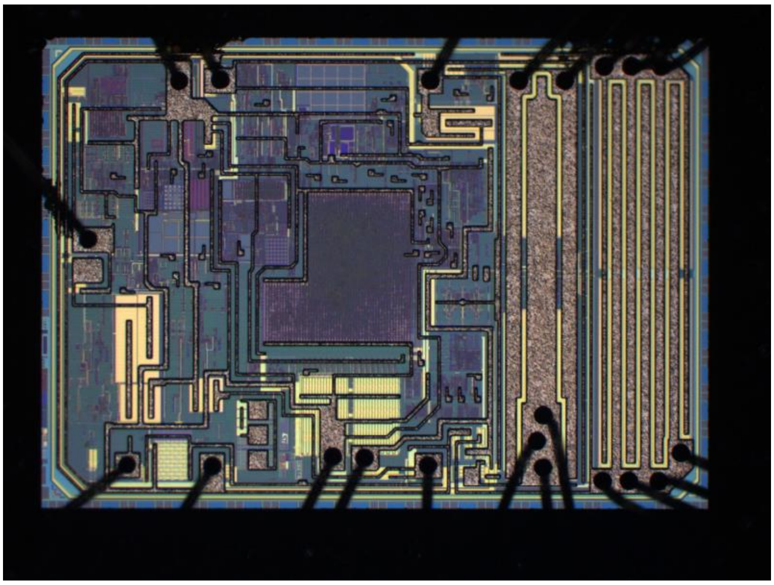

Figure 4: die of the L6982

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 (run 1) 50 mA output current, freq. 400 kHz 2. Unbiased
Sample size	3 devices for biased condition, 5 devices for unbiased condition
Dose Rate	350-360 rad/h
Dose Steps UNITS	1. 0, 5, 7, 15, 20.5, 30
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 38 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)): First test: 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
1x Laptop		To acquire data and to set the test setup

In Figure 5 the basic test setup with the equipment and the test boards is visualized. Multiple different buck converters have been tested during the campaign. One of the test boards consist of the COTS L6982.

In Figure 5 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.

In Figure 7 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 = 21 µH.

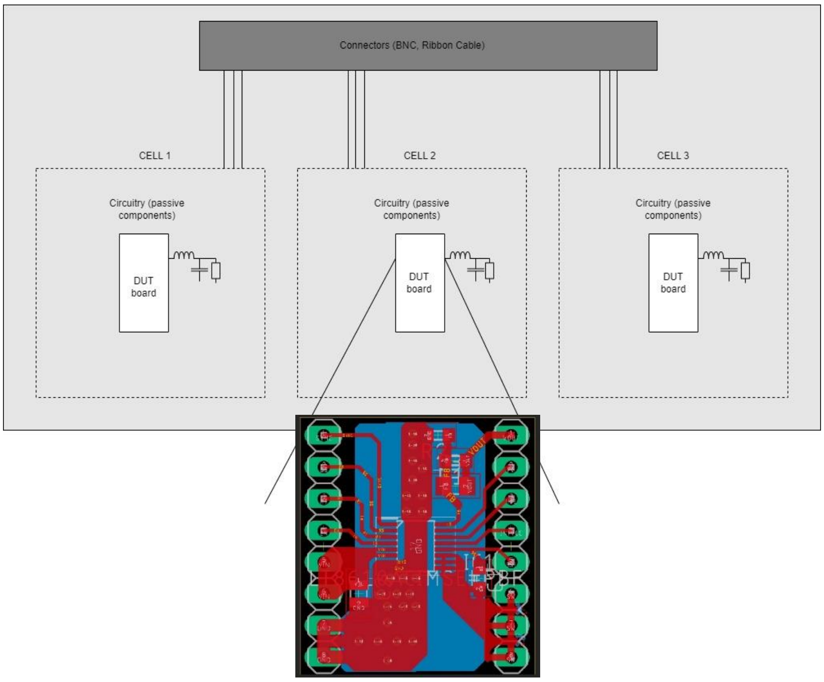

Figure 5: Visualization of the radiation-test-boards

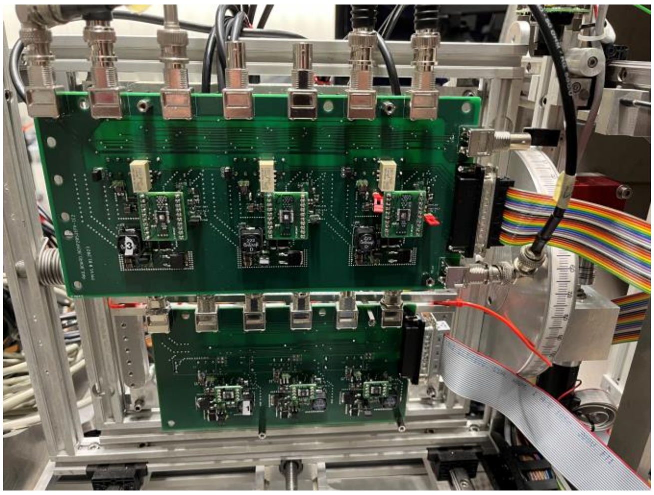

Figure 6: Test setup with the L6982 board on the bottom side

In Figure 7 an overview with the important capacitances is given. The value of the output capacitance is calculated to 80 uF, the input capacitance is 30 uF the input capacitance is 21 uH.

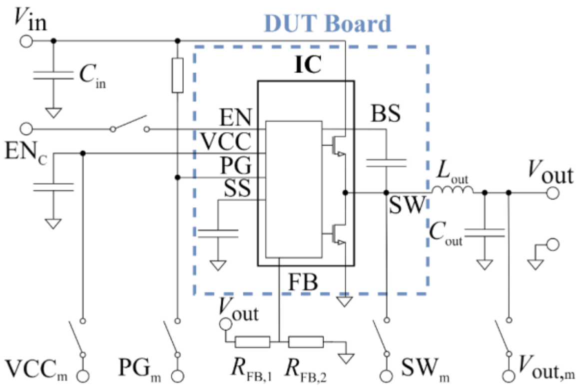

Figure 7: Simplified test setup

7.2. Measurement

As stated above, the use of relays allows an individual measurement for each DUT on the radiation-test-boards. All-important measurable device parameters are provided in Table 4

Table 4: Measurement Parameters

PIN/Parameter	Description	I/O	Measured	Type of Measurement
SW	Switching node	O	yes	SW Voltage & (Frequency)
BOOT	Bootstrap pin	I	no	-
VCC	LDO output	I/O	no	-
FB	Feedback input	I	no	-
EN	Enable input pin	I	no	-
AGND	Analog GND		no	-
Vin	Input voltage	I	yes	Input Voltage & Current
PGND	Power GND		no	-
Vout	Filtered output voltage		yes	Voltage
Iq,off	Off quiescent current		yes	current
Iin	Input current		yes	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 = 400 kHz, Output Voltage 3.3 V, Output resistor = 50 Ohm

7.4. Data acquisition

All the data was acquired and saved with an oscilloscope or a source meter. 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 L6982 was set prior to the test campaign via a voltage divider between the output and the FB pin of the device. During the irradiation procedure a change in the output voltage of the unbiased DUTs was measured. In Figure 8 and Figure 9 the results of the campaign are displayed. Figure 8 shows the statistical analysis with the mean from the bias and unbiased configurations as well as the tolerance limits. The Upper Tolerance Limit (UTL) can be calculated as followed:

$$UTL = \delta_x + K \cdot \sigma_x$$

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

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

For the given P and C, the K value is 5.311 for n = 3 and 3.4 for n = 5. Figure 9 shows the absolute values during the TID test campaign.

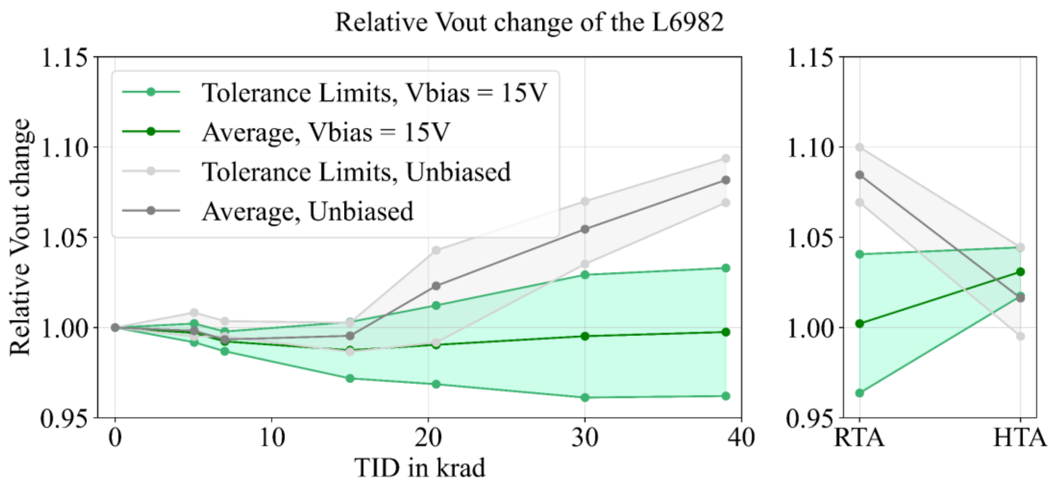

Figure 8: L6982 relative output voltage change (Vout(pre-rad)/Vout(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

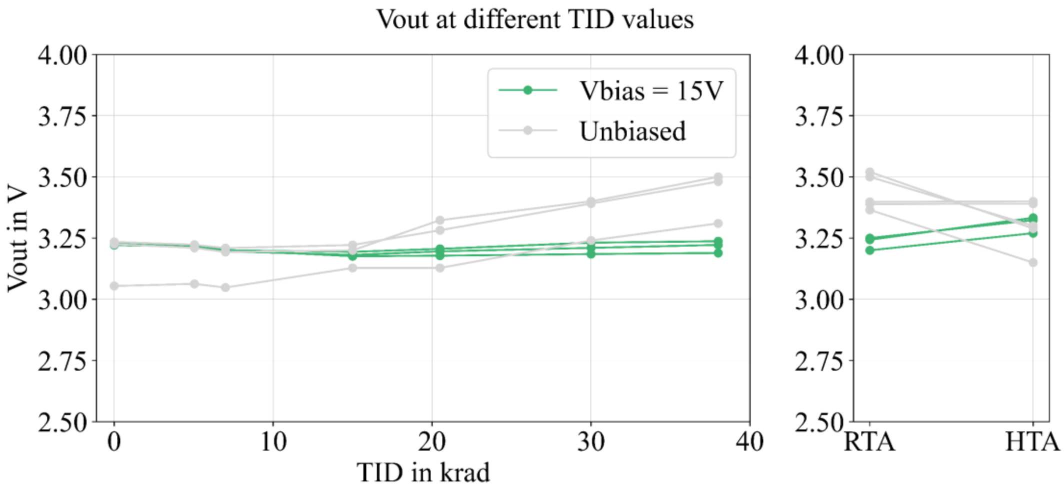

Figure 9: L6982 Output voltage with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

8.2. Off Quiescent current

The Off Quiescent current is the current that is supplying the internal circuitry in the case of a shutdown of the device via the enable pin. The measured current was at a Voltage of 15. No increase during the irradiation in the median has been observed. However, taking the statistics into account, an increase of up to 50 % to the maximum tested dose has been observed. This Values are still within the datasheet limits and displayed in Figure 10 and Figure 11.

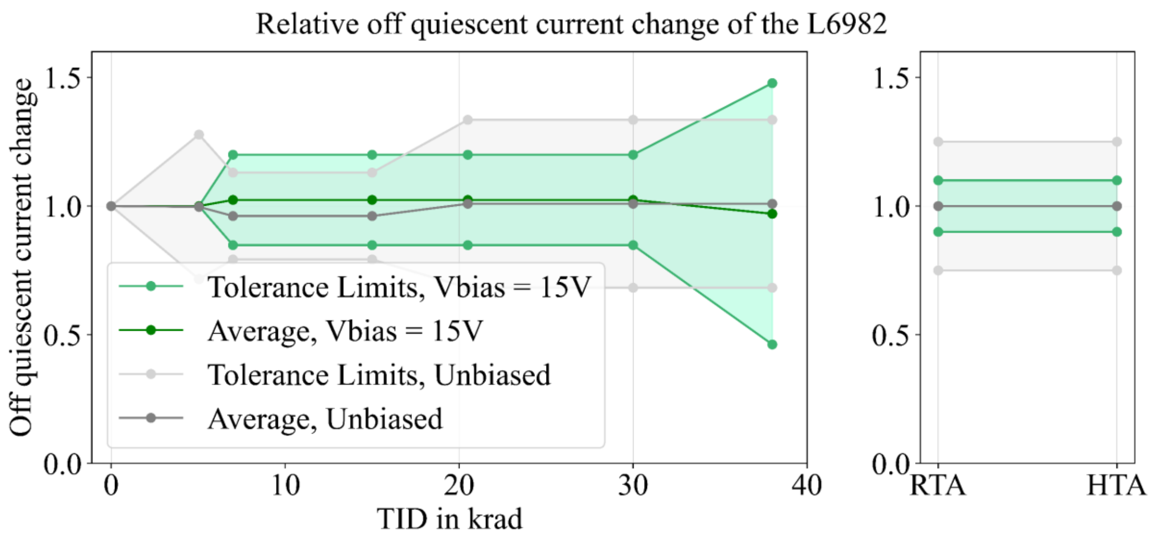

Figure 10: L6982 relative off quiescent current change (Iq(pre-rad)/Iq(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

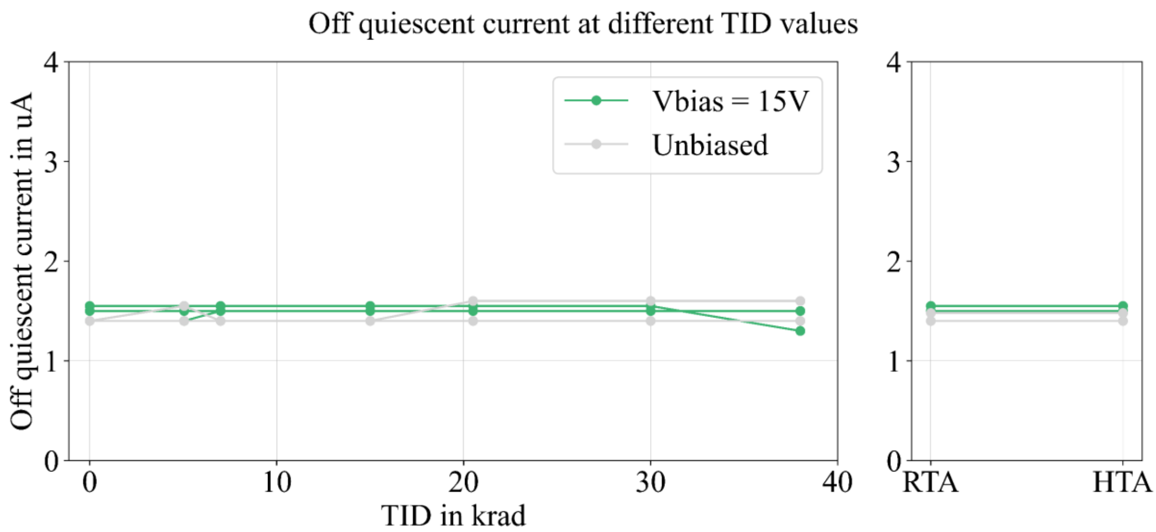

Figure 11: L6982 quiescent current with the Room Temperature Annealing and Accelerated Ageing for two bias conditions

8.3. Frequency

The Frequency changed during the irradiation period. The frequency did not change during the irradiation period. All values are within the datasheet limits of the device and displayed in Figure 12 and 13.

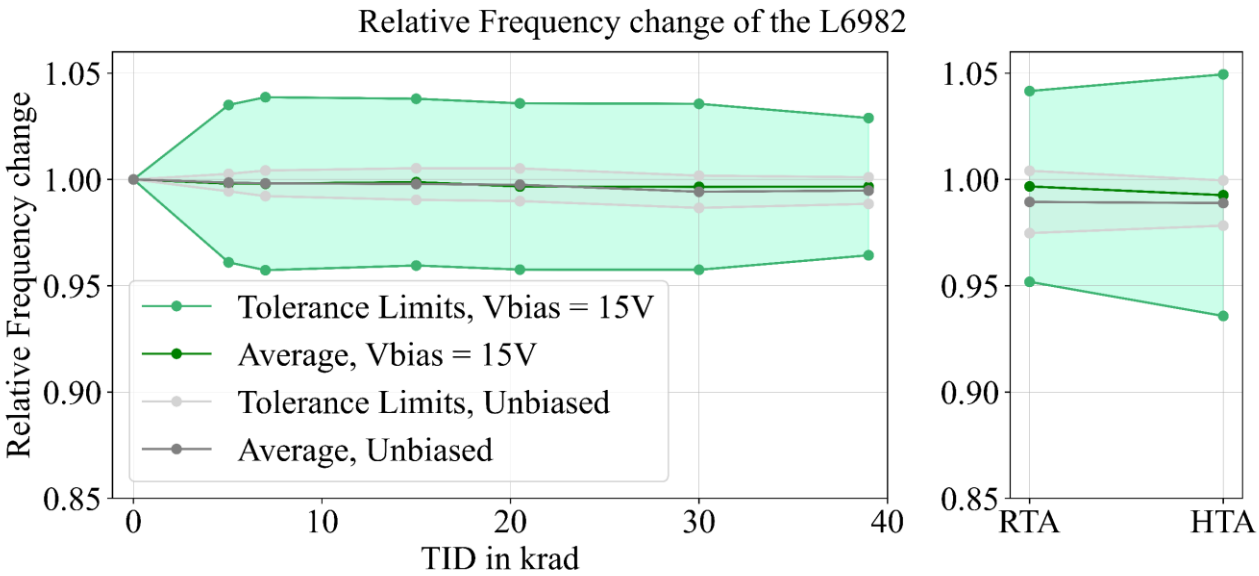

Figure 12: L6982 relative Frequency change (Frequency(pre-rad)/Frequency(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

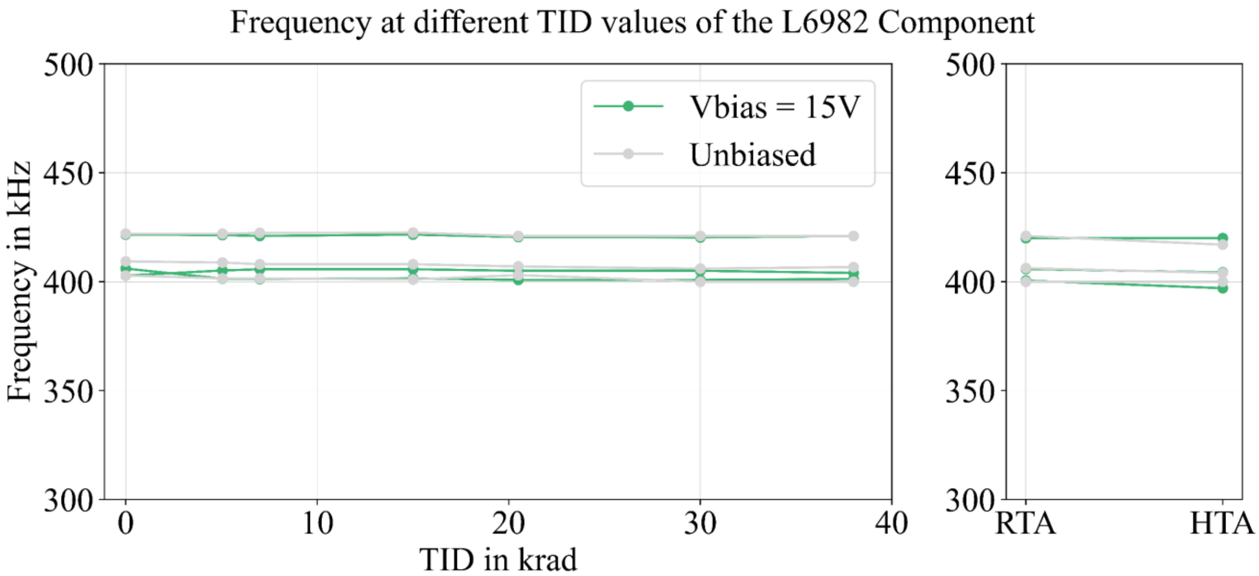

Figure 13: L6982 Output frequency with the Room Temperature Annealing and Accelerated Ageing for two bias condiditons

9. CONCLUSION

The L6982 converter with the date code 9224 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 condition and to the maximum tested dose in silicon of 38 krad, a critical drift of the output voltage above 15 krad has been observed. No other parameter exceeded the datasheet limits. The maximum increase of the output voltage was up to 9 % at 38 krad. Full functionality is given to the dose of 38 krad. 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	Description
Aim	TID sensitivity evaluation of different synchronous buck converter devices for Total Ionizing Dose Effects
Biasing Conditions	3. Input voltages of 15 V 50 mA output current, freq. 400 kHz 4. Unbiased
Sample size	3 devices for biased condition, 5 devices for unbiased condition
Dose Rate	350-360 rad/h
Dose Steps	2. 0, 5, 7, 15, 20.5, 30, 38
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 38 krad

10. REFERENCES

[1] ST Microelectronics, 38 V, 2 A synchronous step-down converter with 20 uA quiescent current, L6982 - 38 V, 2 A synchronous step-down converter with low quiescent current - STMicroelectronics

[2] ESA-ESTEC (2012). “Space product assurance, Radiation hardness assurance - EEE components, ECSS-Q-ST-60-15C”

11. 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	Off supply
0	1.55	1.5	1.38	406	3.221	3.344	1	1	59.04	15	1.5	1	1.09	402.78	3.225	3.355	1	1	51.52	15	1.4	1.1	1.09	421.6	3.226	3.357	1	1	59.7	15	43
5.05	1.55		1.38	401.4	3.215	3.346			55.64	15	1.5		1	405.14	3.2112	3.338			55.57	15	1.4	1.1	1.1	421.4	3.217	3.35			58	15	38
7	1.55		1.38	401.2	3.2	3.3437			55.3		1.5		1	405.7	3.1958	3.335			55.23		1.5		1.1	421	3.202	3.35			57.8		38
15	1.55		1.38	401.52	3.19375	3.34			56		1.5		1	405.7	3.1811	3.33487			54.8		1.5		1.1	421.6	3.1758	3.343			57.63		38
20.5	1.55	stid5	1.38	400.8	3.206	3.336			55.7		1.5		1	405	3.1956	3.333			55.2		1.5		1.1	420.5	3.178	3.34			58		38
30	1.55		1.38	400.8	3.2312	3.3325			55.7		1.5		1	405	3.21	3.33			55.9		1.5		1.1	420.3	3.1847	3.34			58.6		38
38	1.3		1.38	401.23	3.237	3.3287			57.6		1.5		1	404	3.222	3.333			55.7		1.5		1.1	421	3.189	3.342			57.94		38

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
1.6	1	409.3	3.0544	3.34	1	1	60.6	15	1.4		1.4	422	3.225	3.348	1	1	59.4	15	1.4	1.4	1.09	402.8	3.2342	3.334	1	1	62.3	15
	1	408.8	3.063	3.33			53.35		1.55		1.4	422	3.21	3.329			55.2	15	1.4		1.09	401.5	3.223	3.333			59	15
	1	408	3.048	3.327			53.17		1.4		1.4	422.4	3.193	3.337			56.5		1.4		1.09	401.5	3.209	3.324			58.9	
	1	408	3.128	3.327			53.17		1.4		1.4	422.5	3.2	3.31			57.3		1.4		1.09	401	3.2217	3.323			59.72	
	1	407	3.128	3.312			55		1.6		1.4	421	3.323	3.277			59.2		1.4		1.09	403	3.282	3.311			61.48	
	1	406	3.24	3.303			61		1.6		1.4	421	3.4	3.31			61.7		1.4		1.09	400	3.391	3.304			63.9	
	1	406.7	3.31	3.3			62.5		1.6		1.4	421	3.5	3.309			63.1		1.4		1.09	400	3.481	3.3078			66.4	