LMR38020 TID TEST REPORT

4.2V to 80 V,2 A, Synchronous SIMPLE SWITCHER Power Converter with 40 uA Iq

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2. INTRODUCTION

The aim of this test campaign is to evaluate the Total Ionizing Dose (TID) radiation hardness level of the LMR38020 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) are given.

Table 1: Description of the DUT

Manufacturer	Date Code	Product	Uin,max (V)	Uout,max (V)	Uout,min (V)	Id,cont,max (A)	frequency (MHz)
Texas Instruments	32A	LMR38020	80	75	1	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 was developed. In Figure 1, a usual application for this synchronous buck converter with the internal MOSFETs (LDMOS) is given.

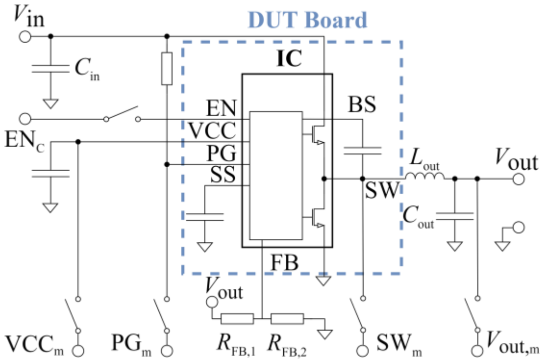

Figure 1: Typical application synchronous buck converter

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

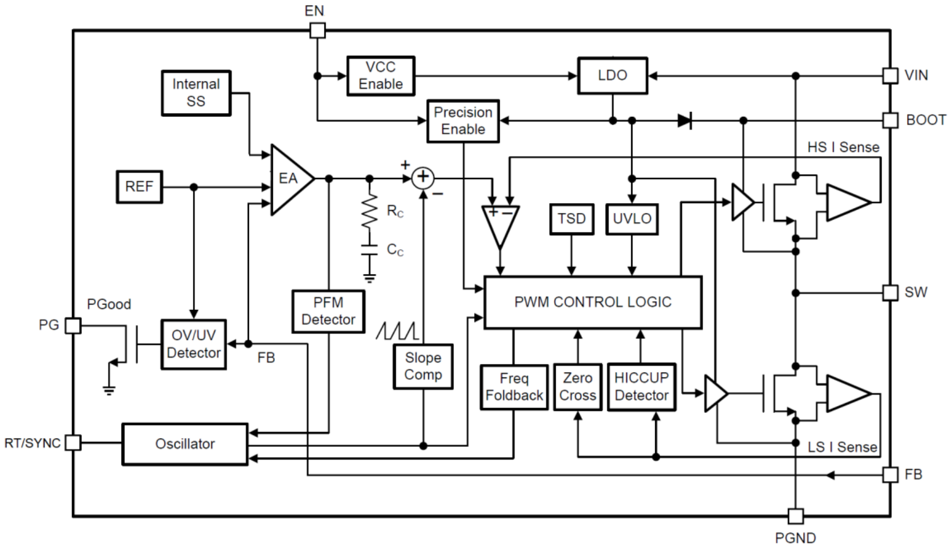

Figure 2: Block Diagram of the LMR38020 [1]

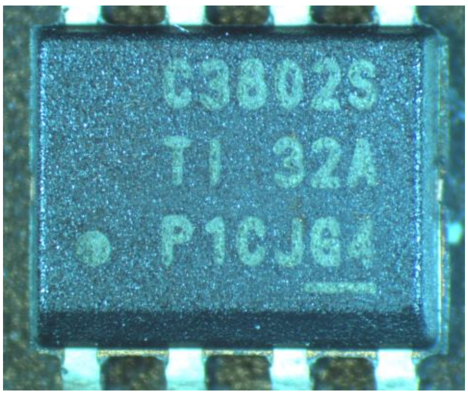

Figure 3:Microscope Picture of a LMR38020

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 30 V (run 1) and 30 V (run 2) 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 (krad)	1. 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

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 Figure 4 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 LMR38020.

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.

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 = 4.2 µH.

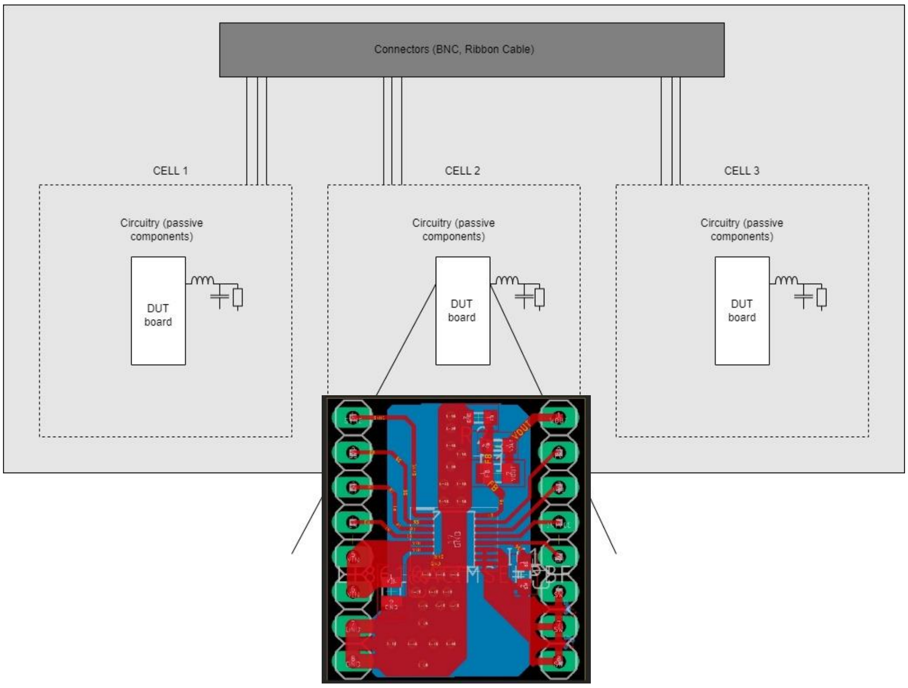

Figure 4: Visualization of the radiation-test-board

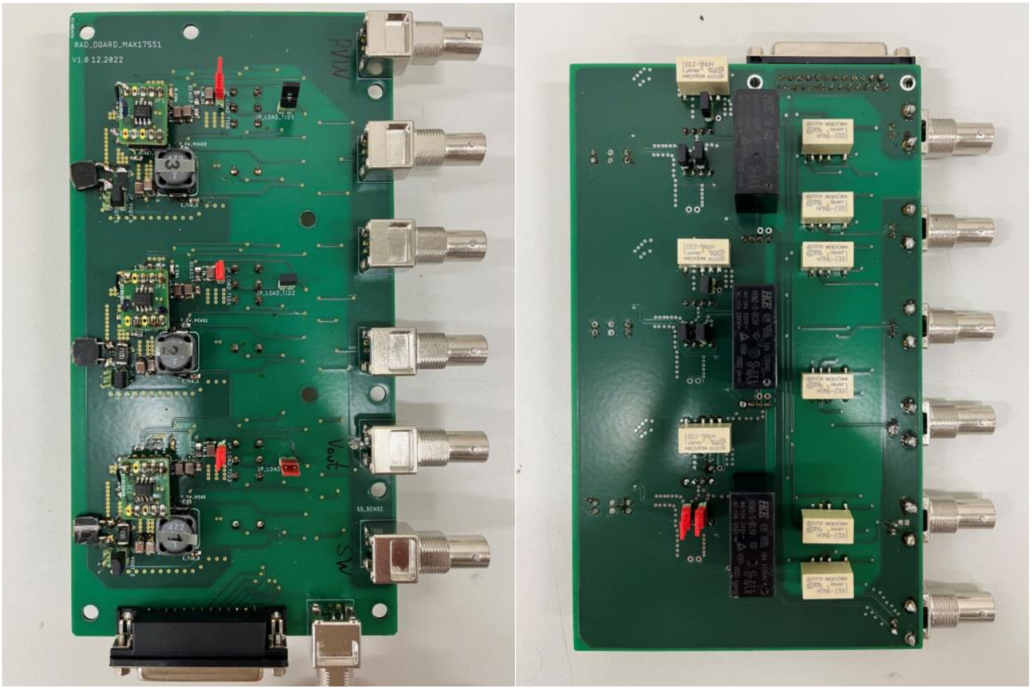

Figure 5: Top-side (left) and bottom-side (right) of the LMR39020 test board

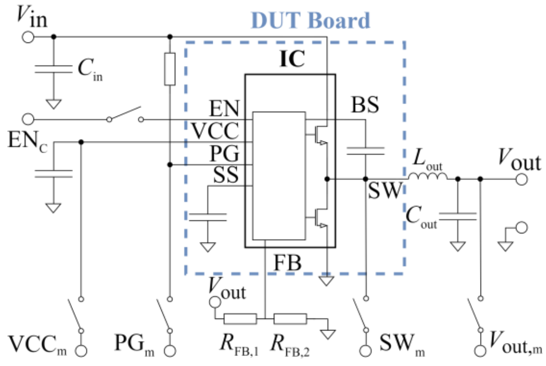

Figure 6: Simplified test setup with Cout = 80 µF, Cin = 30 µF, Lout = 4.2 µH.

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	Type of Measurement
Vin	Voltage Input	Voltage
SW	Switching node	SW Voltage & Frequency
PG	Power Good	Voltage
Vout	Filtered output voltage	Voltage
Iq	Disabled quiescent current	Current
Iin	Input 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 = 30 V, Frequency = 460 kHz, Output Voltage 4.85 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 LMR38020 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 no change in the output voltage was measured. In Figure 7 and Figure 8 the results of the campaign are displayed. Figure 7 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 7

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

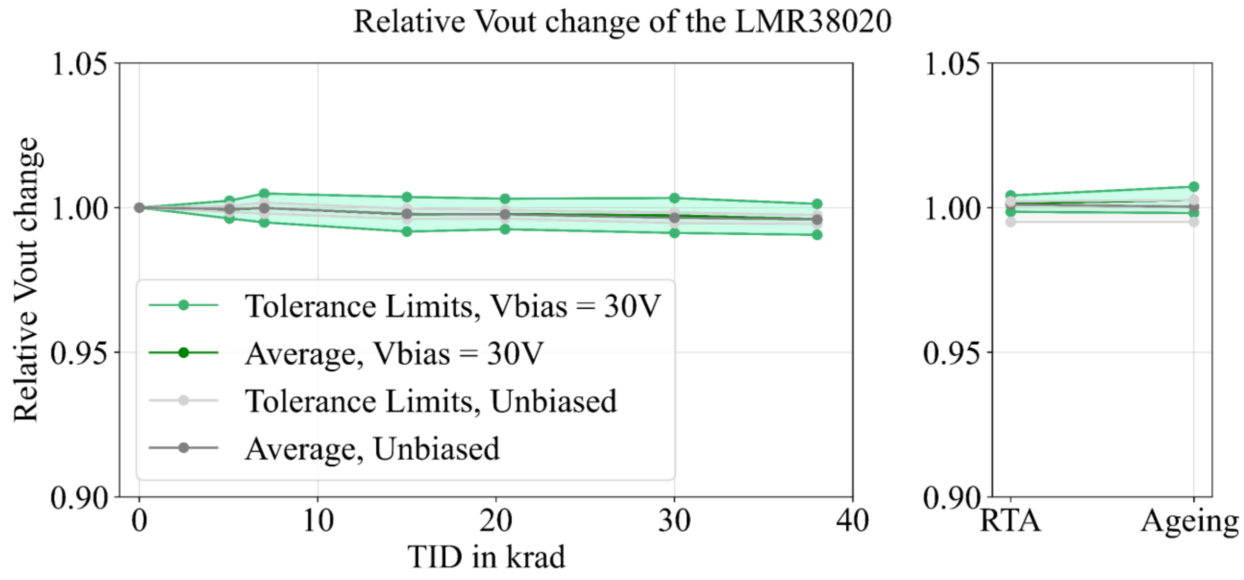

Figure 7: LMR38020 relative output voltage change (Vout(pre-rad)/Vout(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

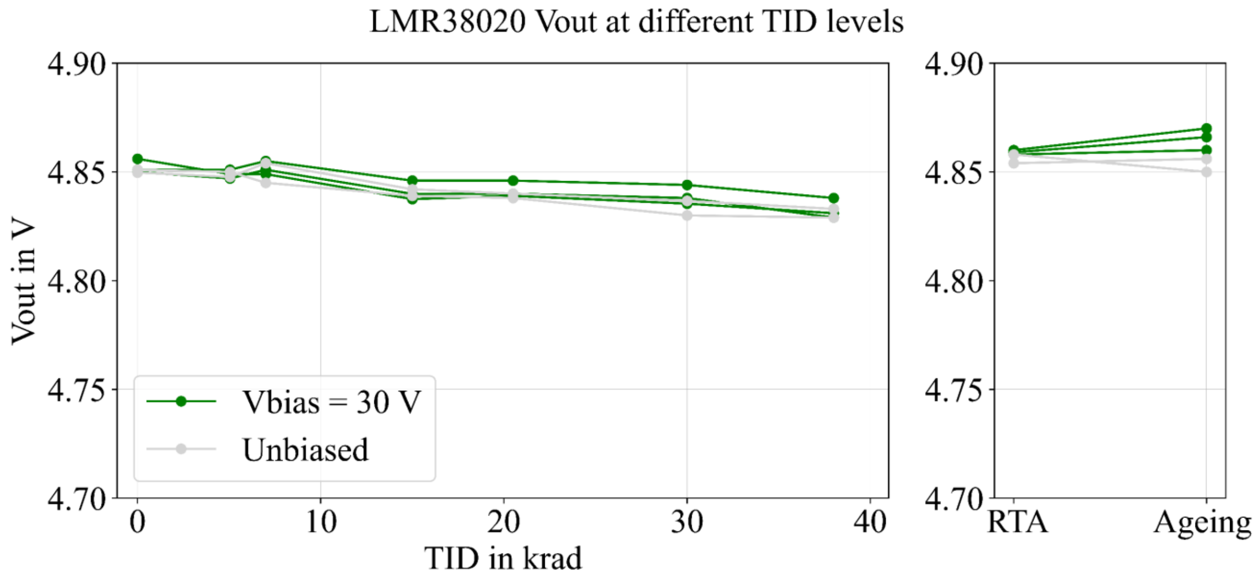

Figure 8: LMR38020 output voltage with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

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 V. A strong increase in the current after 30 krad was observed.

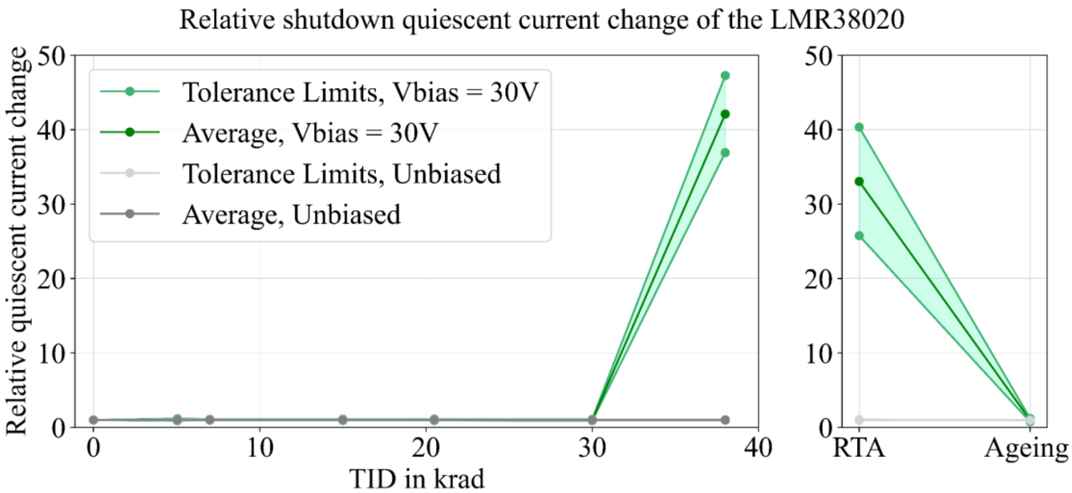

Figure 9: LMR38020 relative output voltage change (Iq(pre-rad)/Iq(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

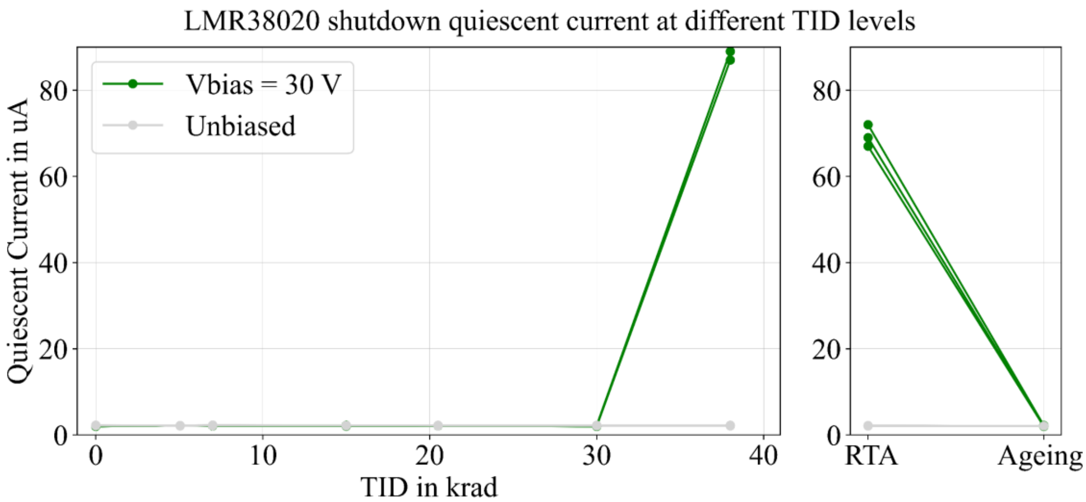

Figure 10: LT8610 Output voltage with the Room Temperature Annealing and Accelerated Ageing for two bias condiditons

8.3. Frequency

The Frequency changed during the irradiation period. The frequency changed from around 470 to around 460 kHz. No difference between biased and unbiased group have been observed.

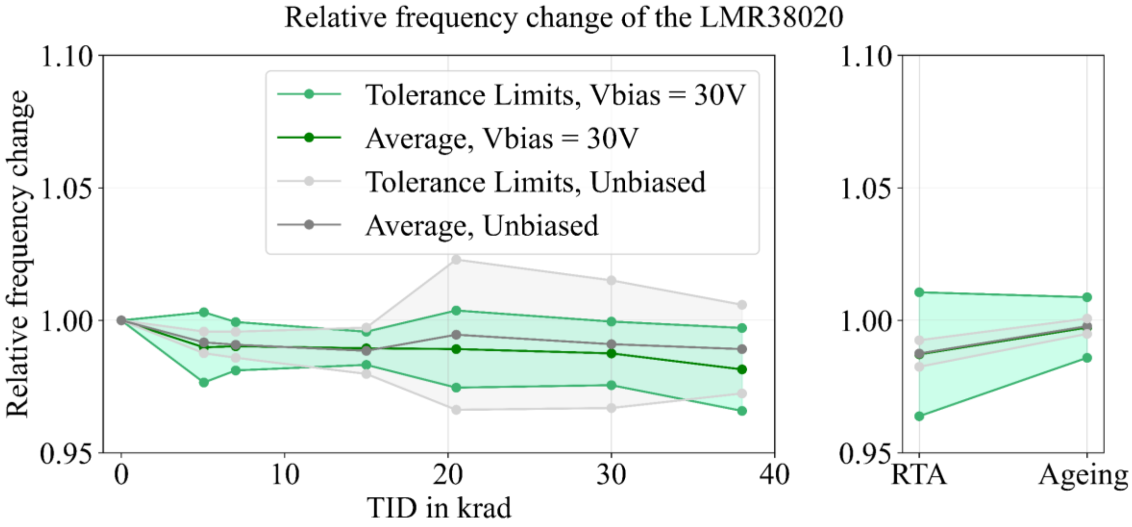

Figure 11: LMR38020 relative Frequency change (Frequency(pre-rad)/Frequency(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

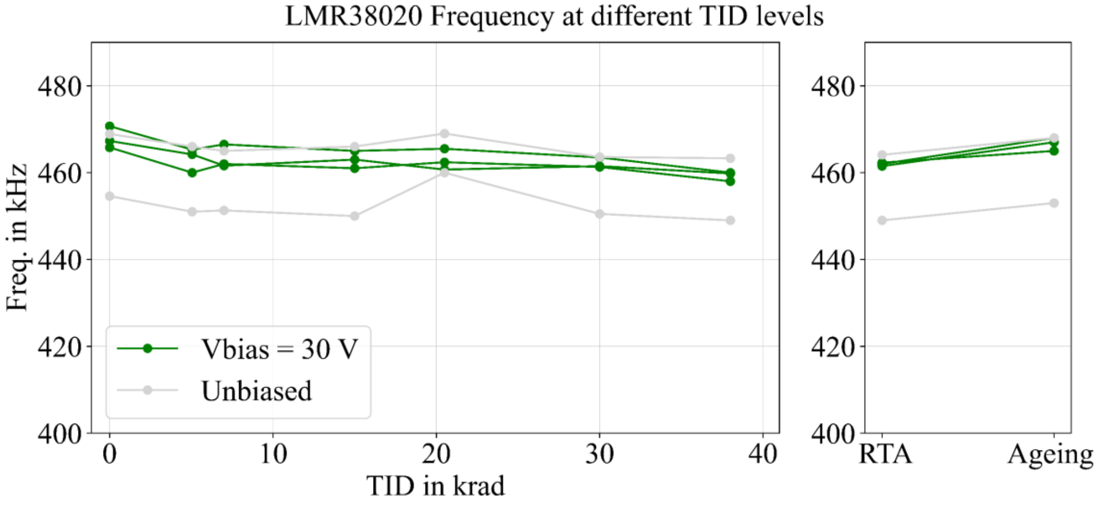

Figure 12: LT8610 Output voltage with the Room Temperature Annealing and Accelerated Ageing for two bias condiditons

9. CONCLUSION

The LMR38020 converter with the date code 32A 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, no critical drift outside of the datasheet values of all parameters except the off quiescent current have been observed. This current went to over 80 µA while the maximum value in the datasheet is 10 µA. 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 30 V (run 1) and 30 V (run 2) 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] Texas Instruments, LMR38020 4.2V to 80 V,2 A, Synchronous SIMPLE SWITCHER Power Converter with 40 uA Iq

[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.

	1										2										3									
krad	Off supply	EN	SS	Freq. (HL	Vout	Vcc	Pgood	SW/LX	Iout	Vin	Off supply	EN	SS	Freq. (HL)	Vout	Vcc	Pgood	SW/LX	Iout	Vin	Off supply	EN	SS	Freq. (HL)	Vout	Vcc	Pgood	SW/LX	Iout	Vin
0	2	1	3.86	467.3	4.85		1	1	82.48	15	2.15	1	3.63	465.8	4.851		1	1	83.36	15	2.15	1	3.63	470.7	4.856		1	1	83.2	15
5050	2.15	1	4	464.2	4.847		1	1	77.71	15	2.2	1	3.63	460	4.851		1	1	78.62	15	2.17	1	3.8	465.3	4.849		1	1	78.56	15
7000	2.1		4	461.6	4.851		1	1	77.66	15	2.25	1	3.63	462	4.855				78.77	15	2.17	1	3.8	466.5	4.849				78.5	15
15000	2.05		4	463	4.8399				77.58					461	4.846				78.7		2.14			465	4.8375				78.49	
20500	2.1			460.7	4.84				77.52		2.22			462.4	4.846				78.68					465.5	4.839				78.43	
30000	2			461.5	4.838				77.49		2.22			461.3	4.844				78.38		2.1			463.5	4.8354				78.35	
38000	87			459.8	4.829				76.88		89			458	4.838				77.6		89			460	4.831				77.6	
RTA	2			461.5	4.858				77.58		2.22			462.3	4.86				78.47		2			462	4.859				78.4	
	2				4.86				77.92						4.87				78.8						4.866				78.8	

U1										U2											U3									
Off supply	EN	SS	Freq. (HL)	Vout	Vcc	Pgood	SW/LX	Iout	Vin	Off supply	EN	SS	Freq. (HL)	Vout		Vcc	Pgood	SW/LX	Iout	Vin	Off supply	EN	SS	Freq. (HL)	Vout	Vcc	Pgood	SW/LX	Iout	Vin
2.17	1	3.63	454.6	4.8497		1	1	83.09	15	2.15	1	3.63	468.9	4.851			1	1	82.57	15	2.19	1	3.7	467.7	4.8528		1	1	83.3	15
2.2	1	3.8	451	4.8477		1	1	77.78	15	2.17	1	3.8	466	4.85					77.8	15	2.21	1	4	464	4.847		1	1	78.6	15
2.3	1	3.63	451.3	4.854				78.1	15				465	4.845					77.75	15	2.23			464	4.8525				78.64	15
2.2			450	4.842				77.7		2.15			466	4.839					77.67		2.23			462	4.84				78.51	
			460	4.84				77.57		2.18			469	4.838					77.53		2.25			461	4.837				78.33	
			450.5	4.8367				77.42					463.6	4.83					77.44					463	4.835				78.3	
2.2			449	4.833				76.56		2.2			463.3	4.829										461	4.833				77.33	
2.1			449	4.858				77.67					464.1	4.854					77.52					461.9	4.857				78.3	
				4.85				77.8						4.856					77.9						4.86				78.57	

U4										U5										Referenz									
Off supply	EN	SS	Freq. (HL)	Vout	Vcc	Pgood	SW/LX	Iout	Vin	Off supply	EN	SS	Freq. (HL)	Vout	Vcc	Pgood	SW/LX	Iout	Vin	Off supply	EN	SS	Freq. (HL)	Vout	Vcc	Pgood	SW/LX	Iout	Vin
2.27	1	3.63	463.5	4.8541		1	1	82.26	15	2.14	1	3.63	470.39	4.851		1	1	83.4	15	2.3	1	3.63	454.6	4.844		1	1	82.28	15
2.2	1	4	459.4	4.852		1	1	77.49	15	2.12			465.38	4.85				78.82	15	2.2			465	4.846					
2.2			458	4.853				78		2.15			465.4	4.85				78.64		2.2			468	4.85				77.5	15
2.2			457	4.84				77.39		2.2			463.4	4.845				78.73		2.2			470	4.842				77.52	
			458	4.8444				78.1		2.12			464.3	4.842				78.58					467	4.845				78.3	
			466.3	4.8344				77.1					460.7	4.8373				78.49											
			463.8	4.83				76.25					462.73	4.833				77.49											
			458	4.858				77.35					463	4.857				78.52						4.864					
				4.85				77.63						4.85				78.7											