BD9P205EFV TID TEST REPORT

3.5V to 40V Input, 2A Single 2.2MHz Buck DC/DC Converter For Automotive

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Table of Contents

1. Disclaimer 4
2. Introduction 5
3. Devices Under Test 5
4. TID Summary 7
5. Dosimetry and Irradiation Facility 8
6. Test Preparation 8
6.1. Test set-up 8
6.2. Measurement 10
6.3. Biasing Conditions 11
6.4. Acquisition of Data 12
7. TID Effects Results 12
7.1. Output Voltage 12
9.1. Shutdown quiescent current 13
9.2. Frequency 15
10. Conclusion 16
11. References 17
12. Annex 17

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2. INTRODUCTION

The aim of this test campaign is to evaluate the TID radiation hardness level of the BD9P205EFV 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 help to facilitate the use of COTS buck converters in space and to derive information the TID response 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: Description of the DUT

Manufacturer	Datecode	Product	Uin,max (V)	Uout,max (V)	Uout,min (V)	Id,cont,max (A)	frequency (MHz)
Rohm	1133	BD9P205EFV	40	8.5	0.8	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 is given.

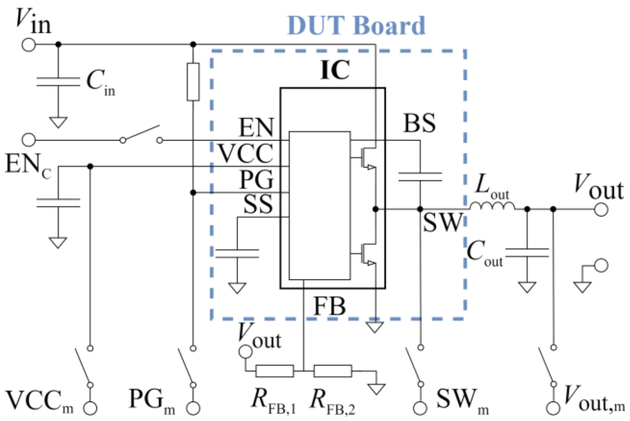

Figure 1: Typical application synchronous buck converter

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

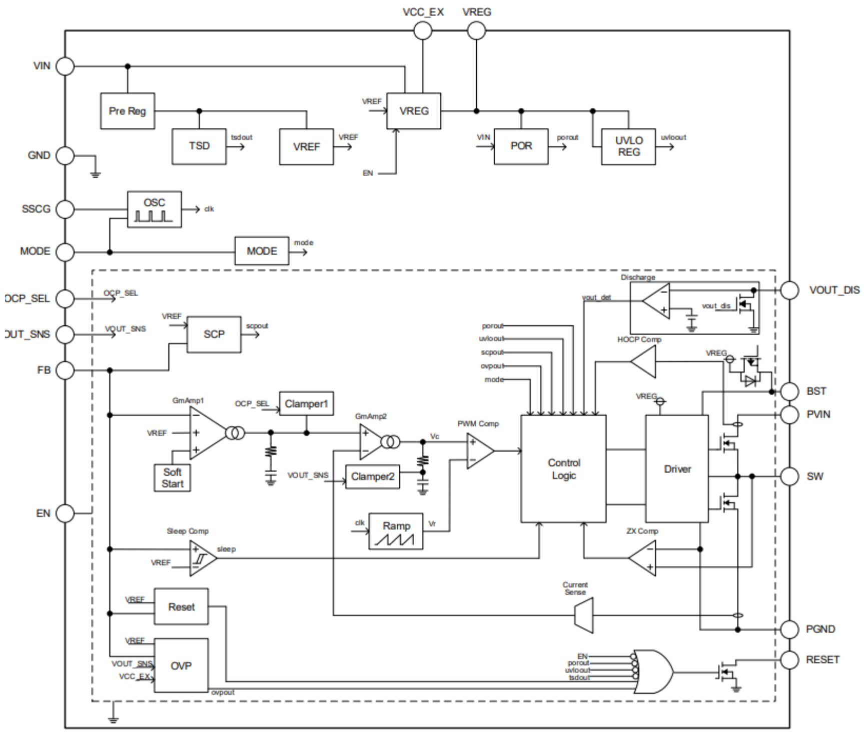

Figure 2: Block Diagram of the BD9P205EFV

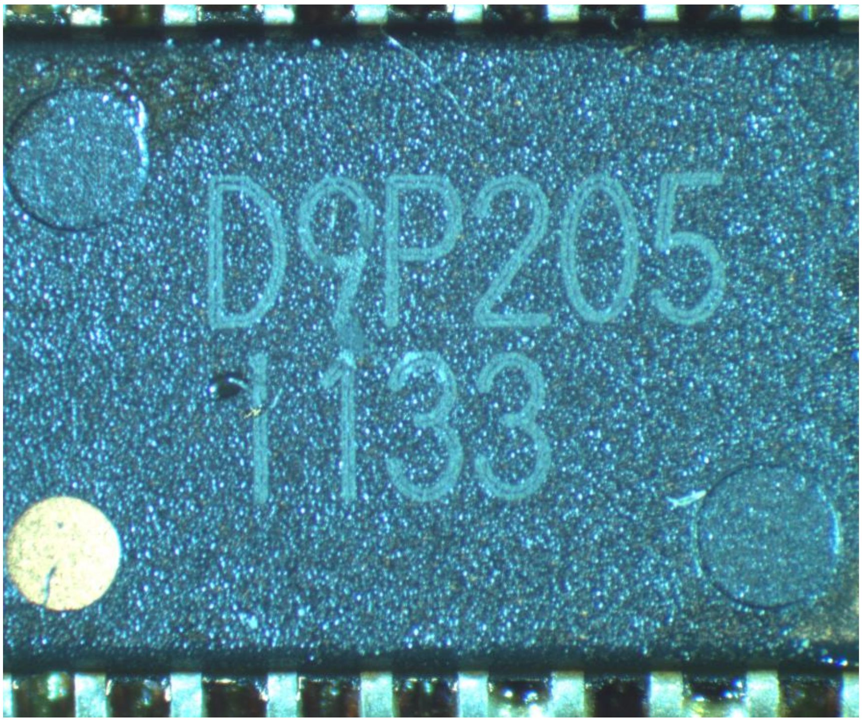

Figure 3:Microscope Picture of a decapsulated BD9P205EFV

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. 2.2 MHz 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, 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(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 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 BD9P205EFV.

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.

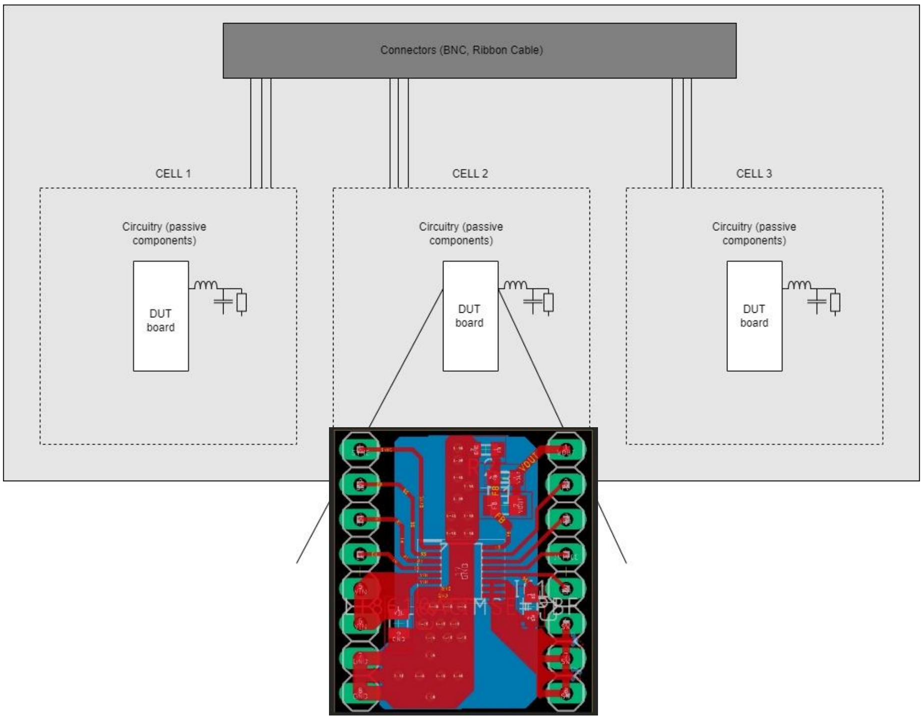

Figure 4: Visualization of the radiation-test-boards

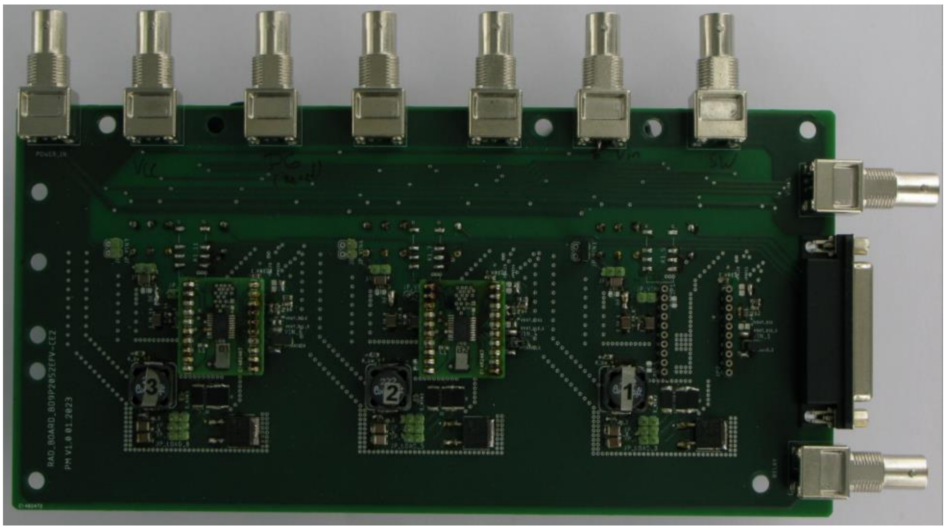

Figure 5: Top-side (left) and bottom-side (right) of the BD9P205EFV test board

In Figure 6 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 2.2 uH.

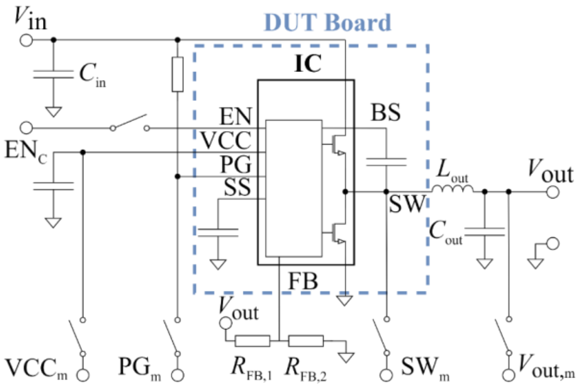

Figure 6: Simplified test setup

7.2. Measurement

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

Table 4: Measurement Parameters

PIN/Parameter	Description	I/O	Measured	Type of Measurement
EN	Enable input pin	I	no	-
Vin	Supply input	I	yes	Input Voltage & Current
PVin	Power input	I	yes	Voltage & Current
SW	Switching node	O	yes	SW Voltage & (Frequency)
BST	Bootstrap pin	I	no	-
OCP_SEL	OCP select (here GND for 3 A)	I	no	-
MODE	Auto selected (PWM, LLM) left open	I	no	-
SSCG	Spread Spectrum (deactivated)	I	no	-
RESET	Reset	I	yes	Voltage
Vout_dis	Discharges Vout	O	no	-
VOUT_SNS	Used for OVP, SCP	I	no	-
FB	Feedback pin	I	no	-
VREG	Output internal LDO	O	no	-
VCC	input internal LDO	I/O	no	-
Vout	Filtered output voltage		yes	Voltage
Ioff,q	Off quiescent current		yes	Current
Iout	Output 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 = 2.2 MHz, Output Voltage 3.3 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 BD9P205EFV 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 up to 30 krad. Inbetween 30 krad and 38 krad the device exhibited a failure in the startup circuit. During the intermediate testing at 38 krad the device a power cycle was not possible anymore. For this reason, the maximum dose where this device was safely operable is 30 krad. 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. The Upper Tolerance Limit (UTL) can be calculated as follows:

$$UTL = \delta_{\mathrm{x}} + K \cdot \sigma_{\mathrm{x}} \qquad 9.$$

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

$$LTL = \delta_{\mathrm{x}} - K \cdot \sigma_{\mathrm{x}}. \qquad 10.$$

For the given P and C, the K value is 4.259. In Figure 7 the absolute values are shown

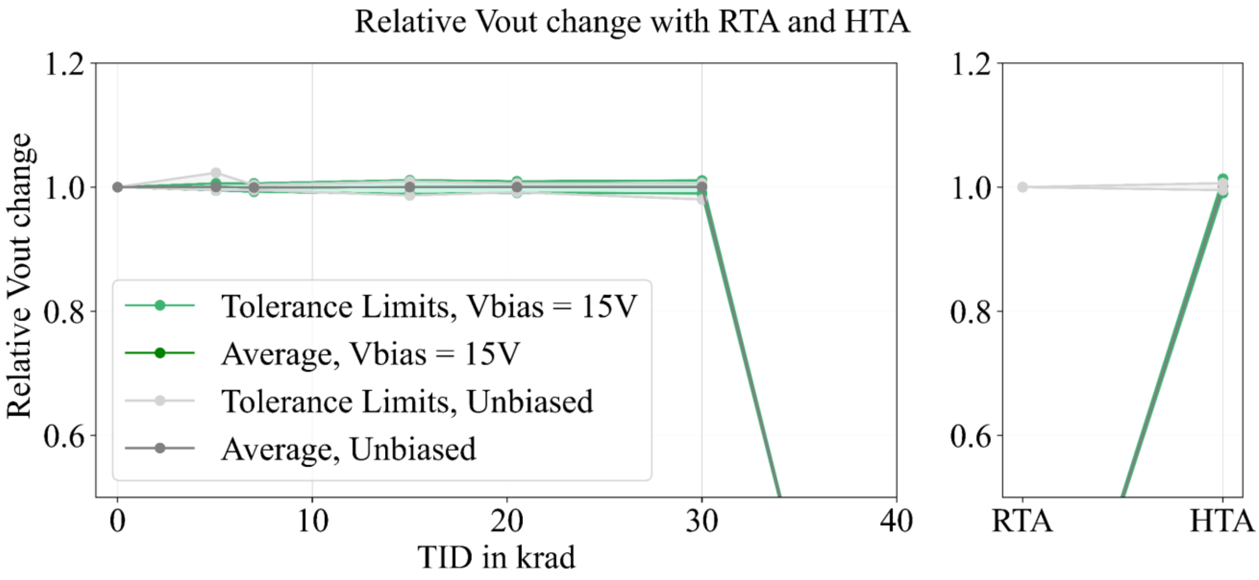

Figure 7: BD9P205EFV relative output voltage change (Vout(pre-rad)/Vout(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

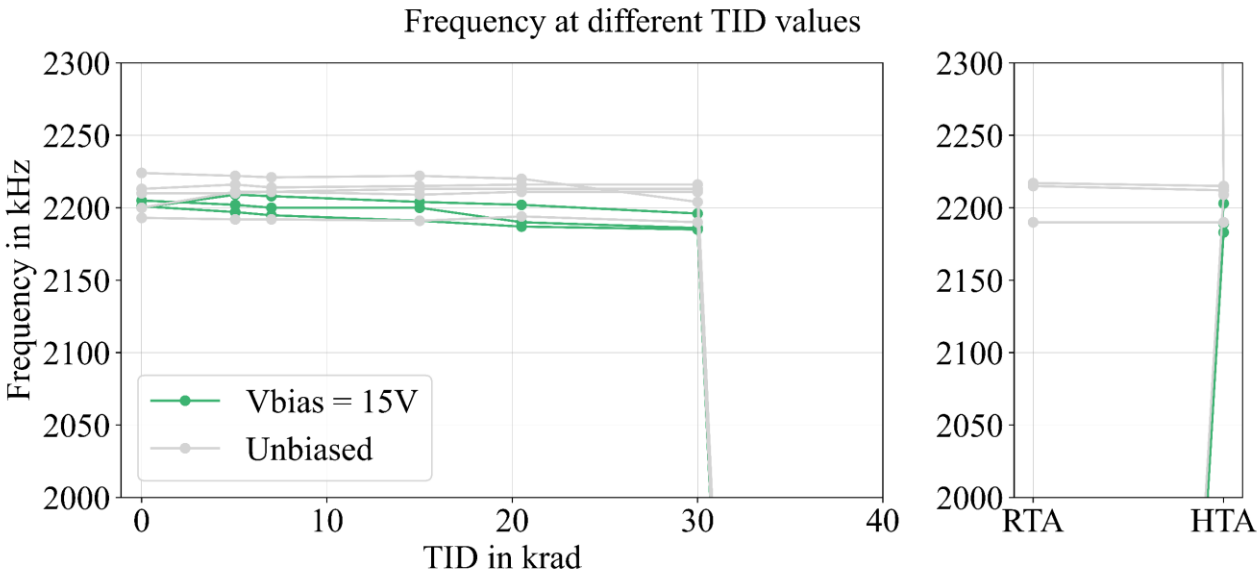

Figure 8: BD9P205EFV output voltage with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

10.1. Shutdown quiescent current

The shutdown quiescent current is the current that is supplying the internal circuitry in the case when the enable pin is connected to ground and, therefore, the device is off. The measured current was at a voltage of 15 V. A strong increase in the current after 8 krad was observed. The increase was close to 4 times the initial value. The results are shown in Figure 8 and Figure 9. The maximum variation given in the datasheet is well above the maximum limit measured.

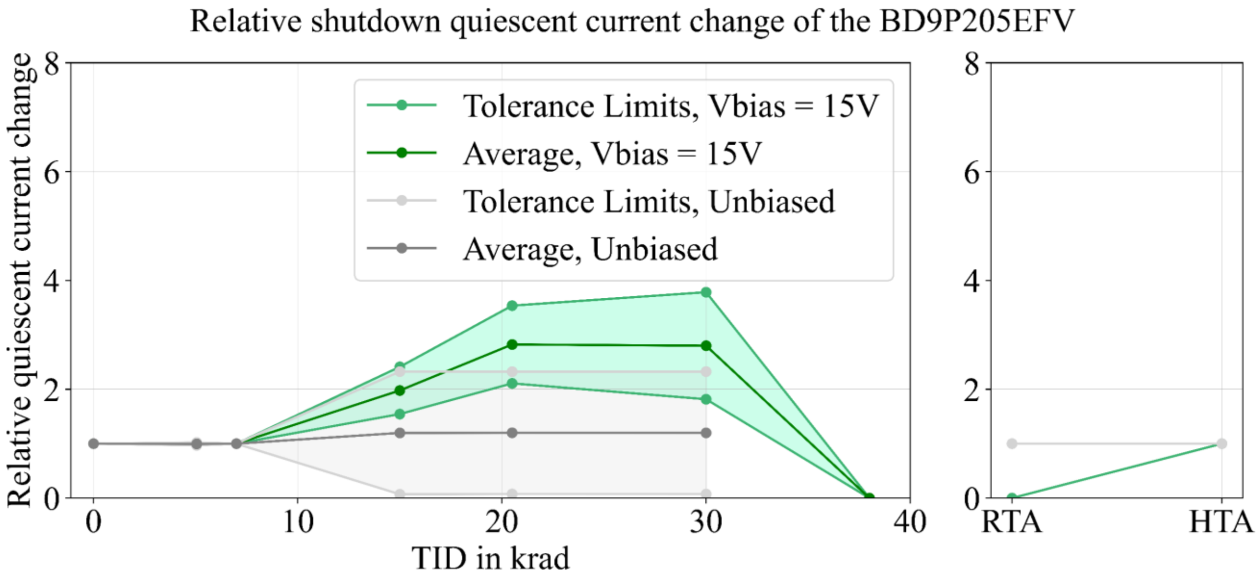

Figure 9: BD9P205EFV relative change in the shutdown quiescent current (Iq(pre-rad)/Iq(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

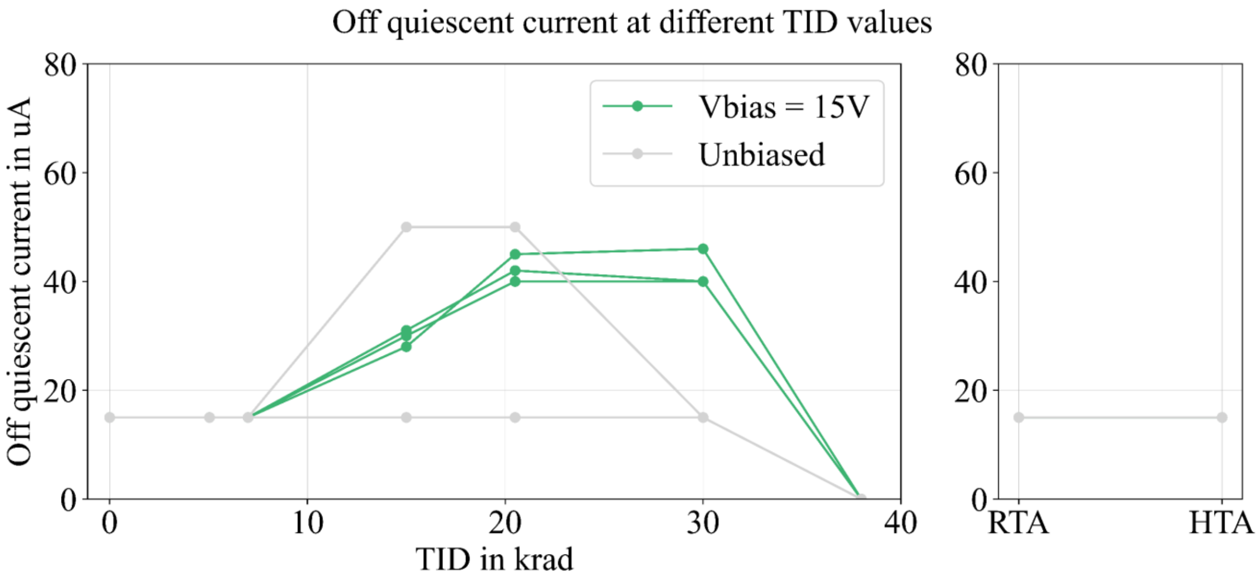

Figure 10: BD9P205EFV shutdown quiescent current change with displayed for two bias conditions

10.2. Frequency

The second parameter is the frequency. The frequency did not change during the irradiation period. No difference between biased and unbiased group have been observed. Figure 10 and Figure 11 displays the results. The change is below 6 %.

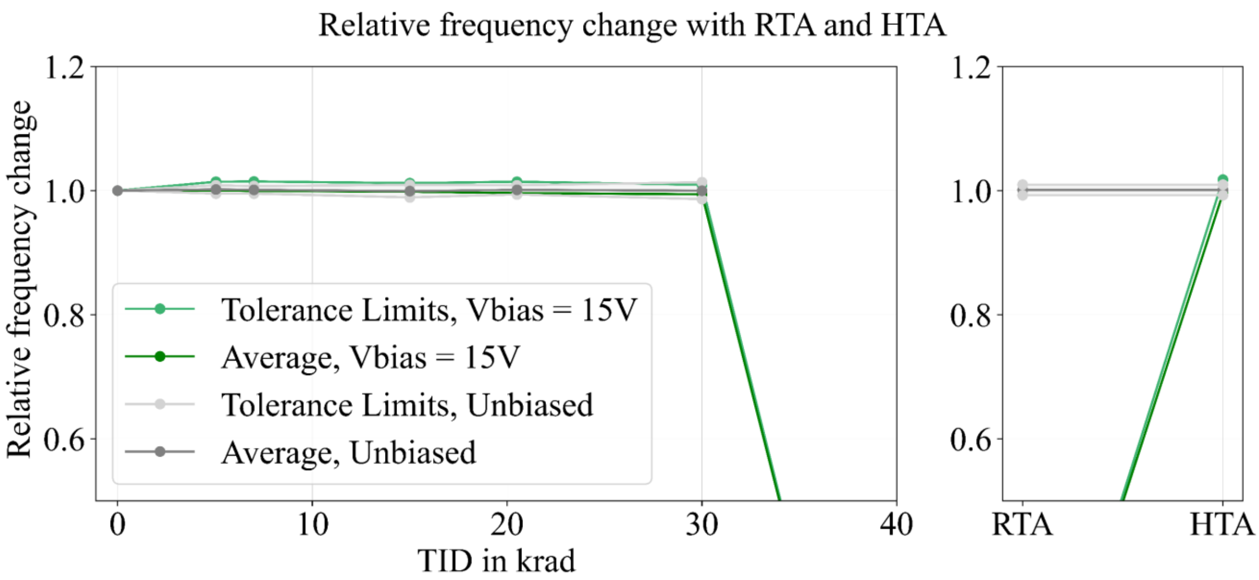

Figure 11: BD9P205EFV relative output voltage change (Freq(pre-rad)/Freq(TID)) with the Room Temperature Annealing (RTA) and Accelerated Ageing for two bias conditions with tolerance limits for different TIDs in krad(Si)

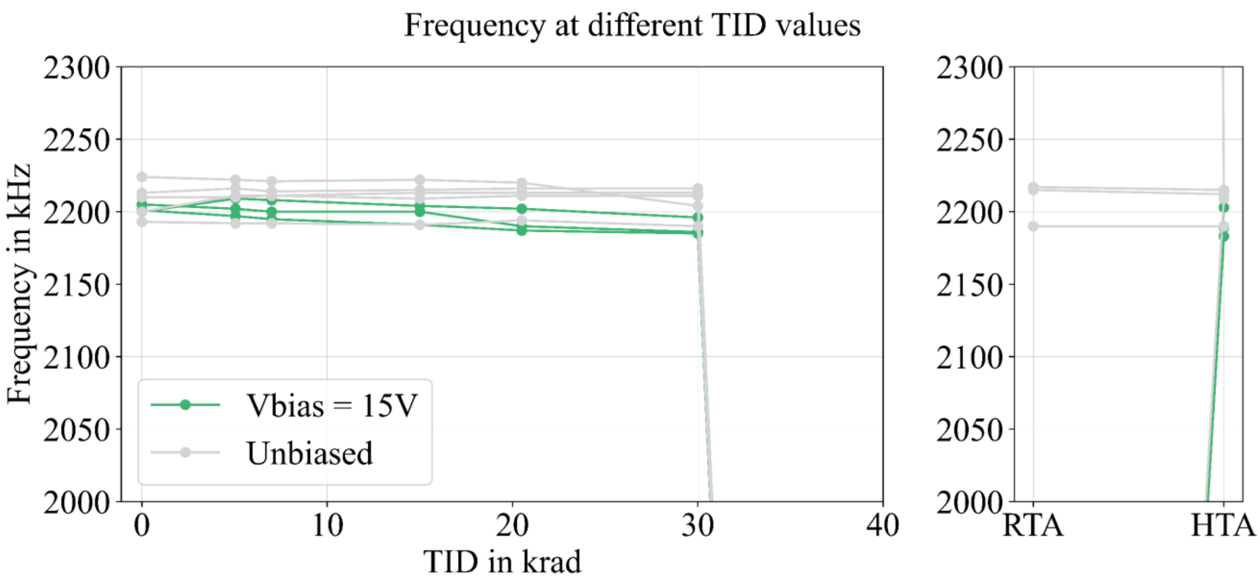

Figure 12: BD9P205EFV output voltage with the Room Temperature Annealing and Accelerated Ageing for two bias conditions

11. CONCLUSION

The BD9P205EFV 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 condition and to the maximum tested dose in silicon of 38 krad, no critical drift outside of the datasheet values have been observed up to 30 krad. Full functionality is given to that dose. No rebound effect was observed. However, after 30 krad the device shut down and was not usable again. This is the maximum dose achieved in nominal working condition. 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. 2.2 MHz 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, 30, ~~38 (not working)~~
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 30 krad(Si)

12. REFERENCES

[1] Rohm Semiconductor, BD9P205EFV-C

Nano Pulse Control™, 3.5V to 40V Input, 2A Single 2.2MHz Buck DC/DC Converter

For Automotive

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

13. ANNEX

In the following tables the whole test campaign including different COTS devices is given.

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

Off supply	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
15	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
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
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
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
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
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	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