



ESA ESTEC
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands

LT1009_TID_TEST_REPORT

LT1009IDR

Date Code: 1125

2.5V Bandgap Voltage Reference

Texas Instruments

LT1009S8#TRPBF

Date Code: 2029

2.5V Bandgap Voltage Reference

Analog Devices

Prepared by Florian Krimmel

Document Type

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1. INTRODUCTION

The current report presents the TID results on the Bandgap Voltage Reference LT1009

- LT1009IDR, date code: 1125, Texas Instruments
- LT1009S8#TRPBF, date code: 2029, Analog Devices

The test campaign was performed between the 24th January and 18th February 2022 at the ESTEC 60Co facility.

Additional information on the context is provided in the test plan [RD01].

2. DOCUMENTS

2.1. Applicable documents

AD01 ESCC22900 Total Dose Steady-state irradiation test method, June 2016

2.2. Reference documents

RD01 TID_COTS_Bandgap-ref_test_plan

RD02 RA0005344 Radiation Test Summary

3. PART & PROCUREMENT INFORMATION

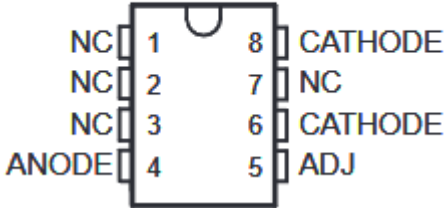
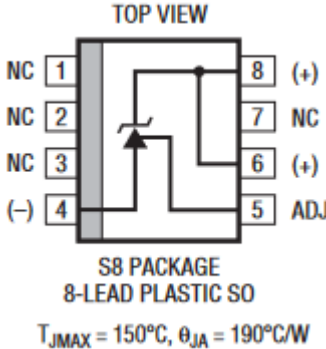
Part number	LT1009IDR	LT1009S8#TRPBF
Manufacturer	Texas Instruments	Analog Devices
Function	2.5V Bandgap Voltage Reference	2.5V Bandgap Voltage Reference
Technology	Bipolar	Bipolar
Package	<p>D OR PW PACKAGE (TOP VIEW)</p> 	<p>TOP VIEW</p> 
Date Code [yyww]	1125	2029
Distributor	Farnell	Mouser
Part # (sample n°) date code	5 samples unbiased (n° B90 to B94) 5 samples biased (n° B95 to B99) 1 reference unbiased (n° REF19) 1 reference biased (n° REF69)	5 samples unbiased (n° C00 to C04) 5 samples biased (n° C05 to C09) 1 reference unbiased (n° REF20) 1 reference biased (n° REF70)

Table 1: Part & procurement information

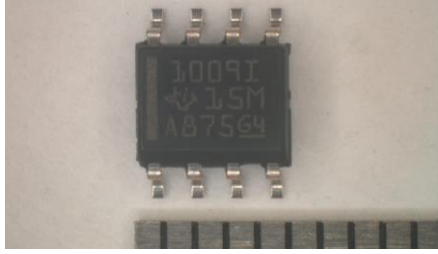
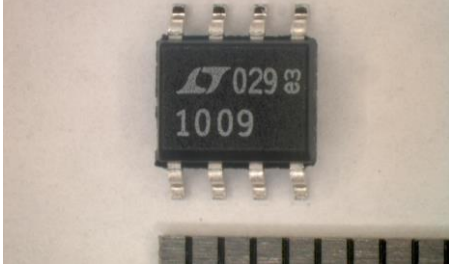
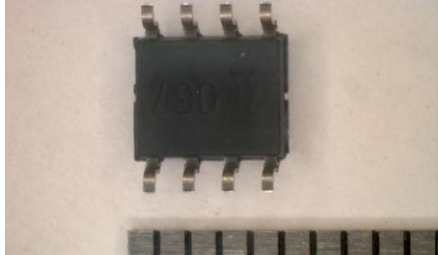
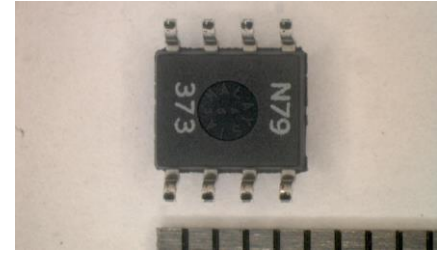
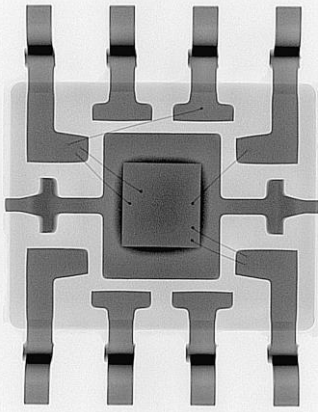
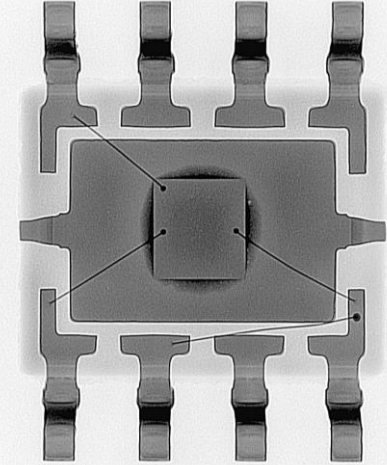
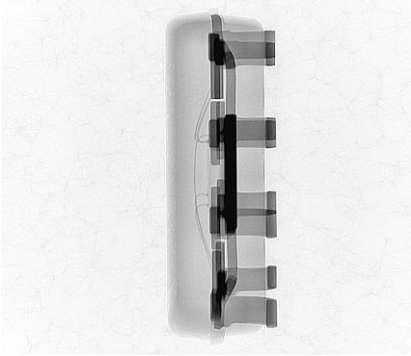
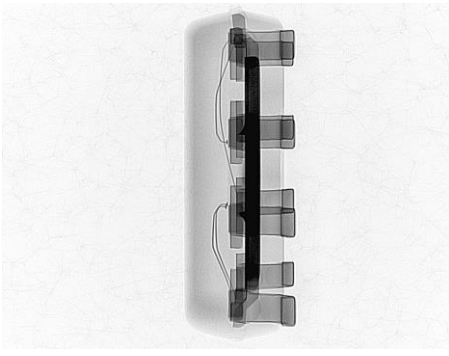
Part number	LT1009IDR	LT1009S8#TRPBF
Package marking top		
Package marking bottom		
X-ray top view		
X-ray side view		

Table 2: Package marking X-ray of the DUT



4. 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, 10, 15, 20, 38.2, 50, 80.5, 100
 Dose rate (rad(Si)/h) 240 - 260

ANNEALING TIMING	Condition during annealing
Annealing 22°C 24 h	Biased for those tested biased Unbiased for those tested unbiased
Ageing 100°C 168h	ON for those tested ON Unbiased for those tested unbiased

Values are provided in TID(H₂O), the conversion to TID(Si) is done using the conversion factor of: 0.898.

5. TEST SET-UP

5.1. Test set-up overview

The set-up to measure at specific TID steps outside the irradiation chamber is schematically depicted in the Figure 1. Inside the radiation chamber the component boards with the DUTs on it are connected to the biasing boards which have a determined resistor to create the right value of biasing current (typical current acc. to datasheet) from a 12V supply for each biased component. Additionally to that, there are also 0-Ohm resistors on the biasing boards to connect all pins of the unbiased components.

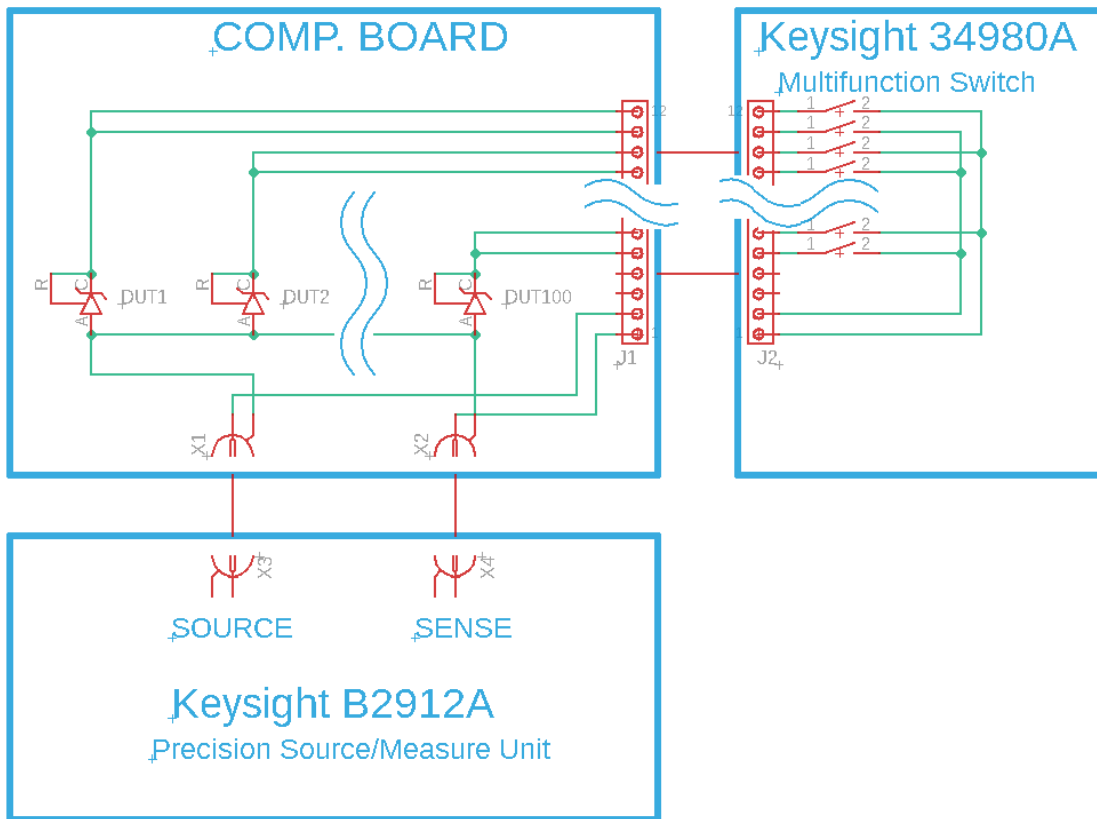


Figure 1: Simplified schematic of the overall test set-up

Four PCBs which were specially designed for this purpose could allow to accommodate both biased and unbiased components for this component and also other bandgap reference components at the same time on a 12 x 22 cm² PCB. This size of the boards limits the TID variation across board to less than 10%. Set-up pictures are provided in Annex B.

During each defined TID step a PC laptop was used to acquire the voltage (V_z) as well as the input current (I_z) of each of the samples from the source measure unit (SMU). The laptop time is synchronised to the time used for controlling the Co60 facility.



5.2. Test equipment

TEST EQUIPMENT

1 x Keysight B2912A 2412A Precision Source/Measure Unit (SMU)

1 x Keysight 34980A Multifunction Switch

1 x Laptop with LabView

PARAMETER MEASURED

Providing 6 different I_z currents acc. to datasheet of the components:

I_{min} , $0.8 \times I_{typ}$, I_{typ} , $3.14 \times I_{typ}$, $10 \times I_{typ}$, I_{max}

$V_{max} = 5.0 \text{ V}$

Switching through all up to 100 samples solder on one board.

Logging and saving the V_z and I_z measurements using an in-house VI.

6. TEST PARAMETERS

The following two parameters are measured:

PARAMETERS	SYMBOLS
Reverse Breakdown Voltage	V_z
Reverse Current	I_z

7. BIASING CONDITIONS

All biased samples are continuously biased with the typical value of I_z according to the datasheet of each part type:

Table summarised the main biasing conditions

PART TYPE	Value	Unit
LT1009IDR	1	mA
LT1009S8#TRPBF	1	mA

Table 2: Biasing conditions during irradiation



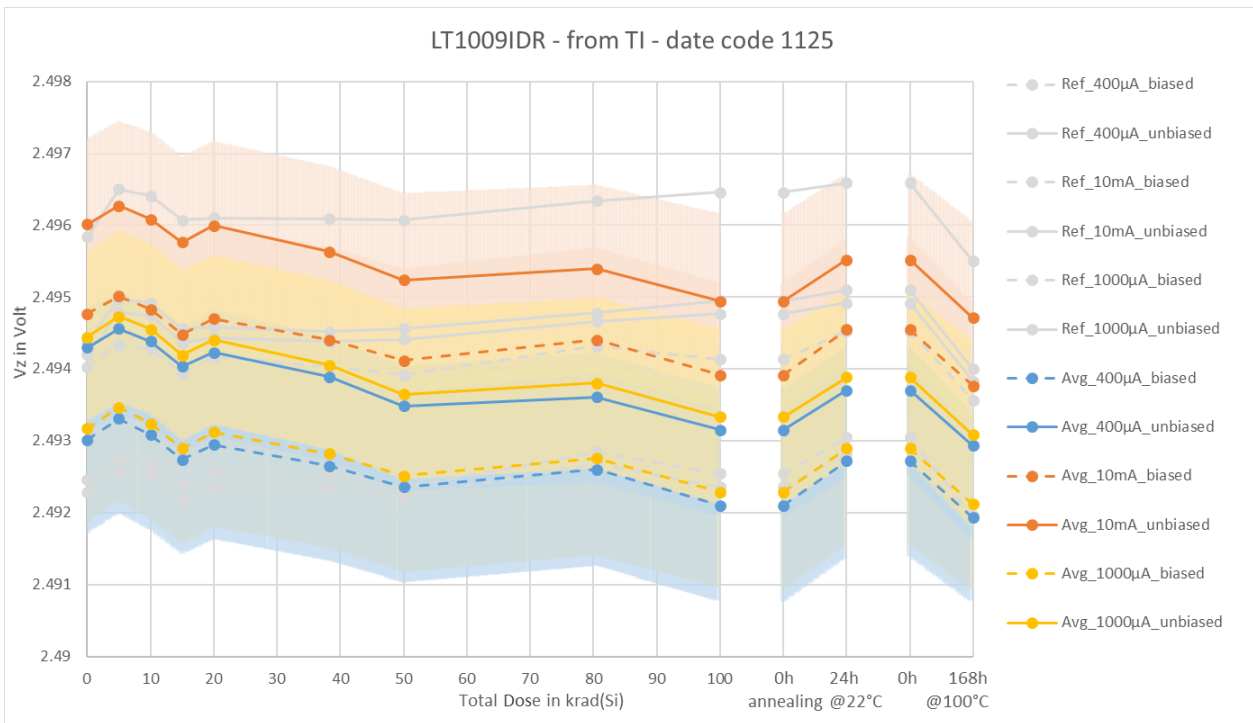
8. TID RESULTS

8.1. TID RESULTS - LT1009IDR - from TI - date code 1125

LT1009IDR - from TI - date code 1125 - @ I-min 400µA												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
B90	unbiased	2.4943	2.4946	2.4944	2.4941	2.4943	2.4939	2.4934	2.4936	2.4931	2.4936	2.4926
B91		2.4951	2.4953	2.4951	2.4948	2.4950	2.4946	2.4943	2.4944	2.4940	2.4945	2.4940
B92		2.4933	2.4935	2.4934	2.4930	2.4932	2.4929	2.4925	2.4927	2.4922	2.4928	2.4919
B93		2.4958	2.4961	2.4959	2.4956	2.4957	2.4954	2.4950	2.4952	2.4947	2.4953	2.4947
B94		2.4930	2.4933	2.4931	2.4927	2.4929	2.4926	2.4922	2.4923	2.4918	2.4924	2.4916
B95	biased	2.4930	2.4933	2.4931	2.4927	2.4930	2.4926	2.4923	2.4925	2.4921	2.4927	2.4922
B96		2.4950	2.4953	2.4951	2.4948	2.4950	2.4947	2.4944	2.4947	2.4942	2.4948	2.4938
B97		2.4915	2.4917	2.4915	2.4911	2.4913	2.4911	2.4908	2.4910	2.4905	2.4911	2.4907
B98		2.4932	2.4934	2.4932	2.4929	2.4931	2.4927	2.4925	2.4928	2.4922	2.4929	2.4919
B99		2.4925	2.4928	2.4925	2.4922	2.4924	2.4921	2.4918	2.4921	2.4916	2.4922	2.4911
REF19	Ref unbiased	2.4942	2.4948	2.4948	2.4944	2.4944	2.4944	2.4944	2.4947	2.4948	2.4949	2.4938
REF69	Ref biased	2.4923	2.4926	2.4926	2.4922	2.4923	2.4923	2.4922	2.4927	2.4924	2.4928	2.4918

LT1009IDR - from TI - date code 1125 - @ I-typ 1000µA Limit acc. DS: Vz = 2.5V ± 1% (2.475V – 2.525V)												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
B90	unbiased	2.4945	2.4948	2.4946	2.4942	2.4944	2.4941	2.4936	2.4937	2.4932	2.4937	2.4927
B91		2.4952	2.4955	2.4953	2.4949	2.4952	2.4948	2.4944	2.4946	2.4941	2.4947	2.4941
B92		2.4934	2.4937	2.4936	2.4932	2.4934	2.4931	2.4927	2.4929	2.4924	2.4930	2.4921
B93		2.4960	2.4963	2.4961	2.4957	2.4959	2.4956	2.4952	2.4953	2.4949	2.4955	2.4948
B94		2.4932	2.4935	2.4933	2.4929	2.4931	2.4928	2.4924	2.4925	2.4920	2.4925	2.4918
B95	biased	2.4932	2.4934	2.4933	2.4929	2.4931	2.4928	2.4925	2.4927	2.4923	2.4929	2.4924
B96		2.4952	2.4955	2.4952	2.4949	2.4951	2.4948	2.4946	2.4948	2.4944	2.4950	2.4940
B97		2.4917	2.4919	2.4916	2.4913	2.4915	2.4912	2.4909	2.4911	2.4907	2.4913	2.4909
B98		2.4933	2.4936	2.4934	2.4930	2.4933	2.4929	2.4927	2.4929	2.4924	2.4930	2.4921
B99		2.4926	2.4929	2.4927	2.4924	2.4926	2.4923	2.4919	2.4922	2.4918	2.4924	2.4913
REF19	Ref unbiased	2.4944	2.4950	2.4949	2.4946	2.4946	2.4945	2.4946	2.4948	2.4950	2.4951	2.4940
REF69	Ref biased	2.4925	2.4927	2.4927	2.4924	2.4926	2.4925	2.4924	2.4929	2.4926	2.4931	2.4920

LT1009IDR - from TI - date code 1125 - @ I-max 10mA												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
B90	unbiased	2.4961	2.4963	2.4962	2.4958	2.4961	2.4956	2.4952	2.4954	2.4949	2.4954	2.4944
B91		2.4968	2.4971	2.4969	2.4966	2.4968	2.4964	2.4960	2.4962	2.4958	2.4963	2.4958
B92		2.4949	2.4952	2.4950	2.4947	2.4950	2.4946	2.4942	2.4944	2.4940	2.4946	2.4936
B93		2.4975	2.4978	2.4976	2.4973	2.4975	2.4971	2.4968	2.4969	2.4965	2.4971	2.4964
B94		2.4948	2.4950	2.4948	2.4945	2.4947	2.4943	2.4939	2.4941	2.4936	2.4942	2.4934
B95	biased	2.4948	2.4950	2.4949	2.4945	2.4947	2.4944	2.4941	2.4944	2.4939	2.4945	2.4941
B96		2.4967	2.4969	2.4968	2.4964	2.4966	2.4964	2.4961	2.4964	2.4959	2.4965	2.4955
B97		2.4933	2.4935	2.4933	2.4929	2.4931	2.4928	2.4926	2.4928	2.4924	2.4930	2.4926
B98		2.4949	2.4952	2.4950	2.4946	2.4949	2.4946	2.4942	2.4945	2.4941	2.4947	2.4937
B99		2.4943	2.4945	2.4943	2.4940	2.4942	2.4939	2.4936	2.4939	2.4934	2.4940	2.4929
REF19	Ref unbiased	2.4958	2.4965	2.4964	2.4961	2.4961	2.4961	2.4961	2.4963	2.4965	2.4966	2.4955
REF69	Ref biased	2.4940	2.4943	2.4943	2.4939	2.4942	2.4940	2.4939	2.4943	2.4941	2.4945	2.4936



For all curves, which show an average over all measured samples, the coloured interval behind the curves represent +/- one standard deviation.

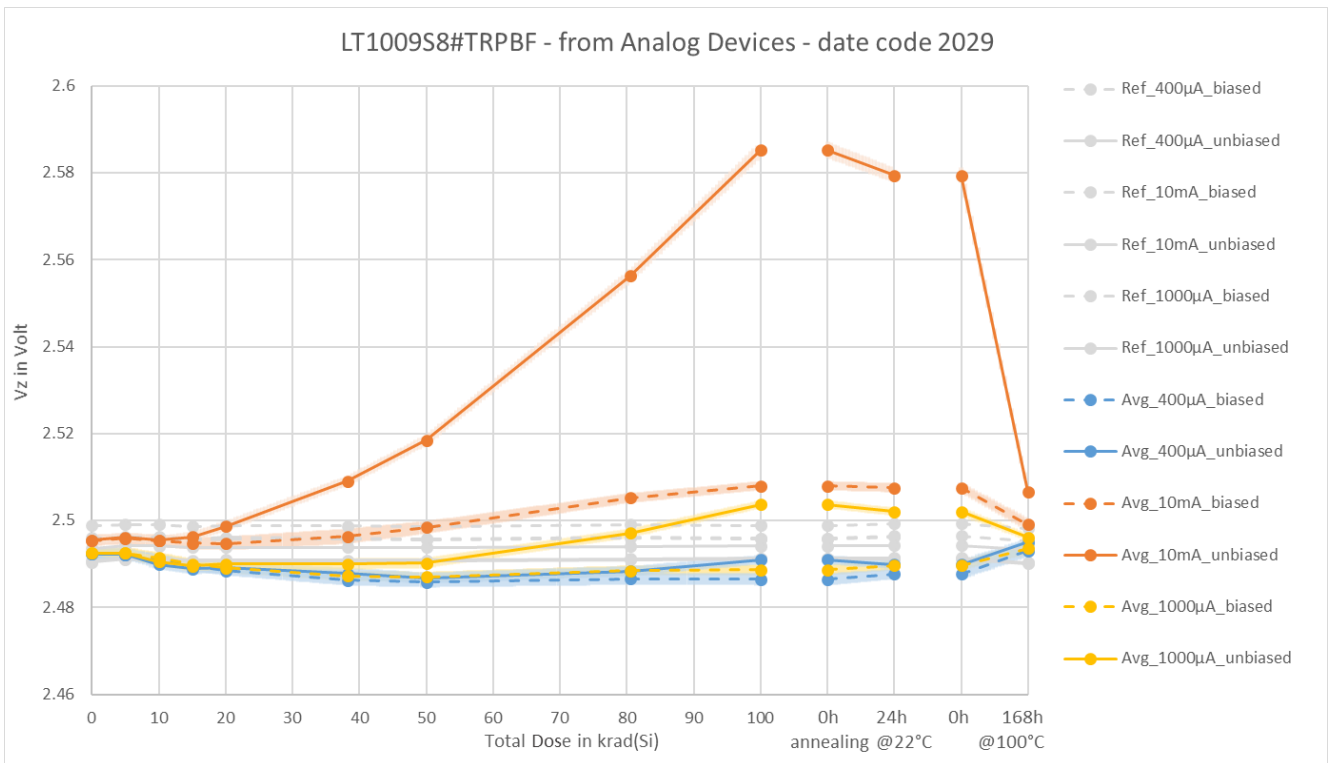


8.2. TID RESULTS - LT1009S8#TRPBF - from Analog Devices - date code 2029

LT1009S8#TRPBF - from Analog Devices - date code 2029 - @ I-min 400µA												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
C0	unbiased	2.4917	2.4911	2.4883	2.4870	2.4874	2.4858	2.4847	2.4867	2.4895	2.4884	2.4943
C1		2.4937	2.4935	2.4913	2.4902	2.4906	2.4893	2.4882	2.4898	2.4923	2.4913	2.4964
C2		2.4924	2.4924	2.4900	2.4886	2.4888	2.4878	2.4870	2.4887	2.4913	2.4901	2.4949
C3		2.4923	2.4921	2.4899	2.4891	2.4896	2.4881	2.4869	2.4884	2.4910	2.4899	2.4948
C4		2.4916	2.4918	2.4899	2.4896	2.4899	2.4882	2.4870	2.4883	2.4910	2.4898	2.4949
C5	biased	2.4917	2.4919	2.4909	2.4897	2.4888	2.4863	2.4854	2.4859	2.4857	2.4870	2.4926
C6		2.4908	2.4909	2.4896	2.4885	2.4878	2.4869	2.4872	2.4880	2.4875	2.4882	2.4921
C7		2.4916	2.4915	2.4905	2.4893	2.4885	2.4863	2.4851	2.4848	2.4846	2.4861	2.4919
C8		2.4934	2.4930	2.4912	2.4889	2.4873	2.4844	2.4845	2.4866	2.4868	2.4879	2.4935
C9		2.4940	2.4940	2.4928	2.4913	2.4901	2.4874	2.4868	2.4877	2.4879	2.4891	2.4952
REF20	Ref unbiased	2.4905	2.4911	2.4910	2.4906	2.4907	2.4907	2.4907	2.4910	2.4912	2.4912	2.4901
REF70	Ref biased	2.4957	2.4961	2.4961	2.4956	2.4959	2.4957	2.4956	2.4961	2.4958	2.4962	2.4952

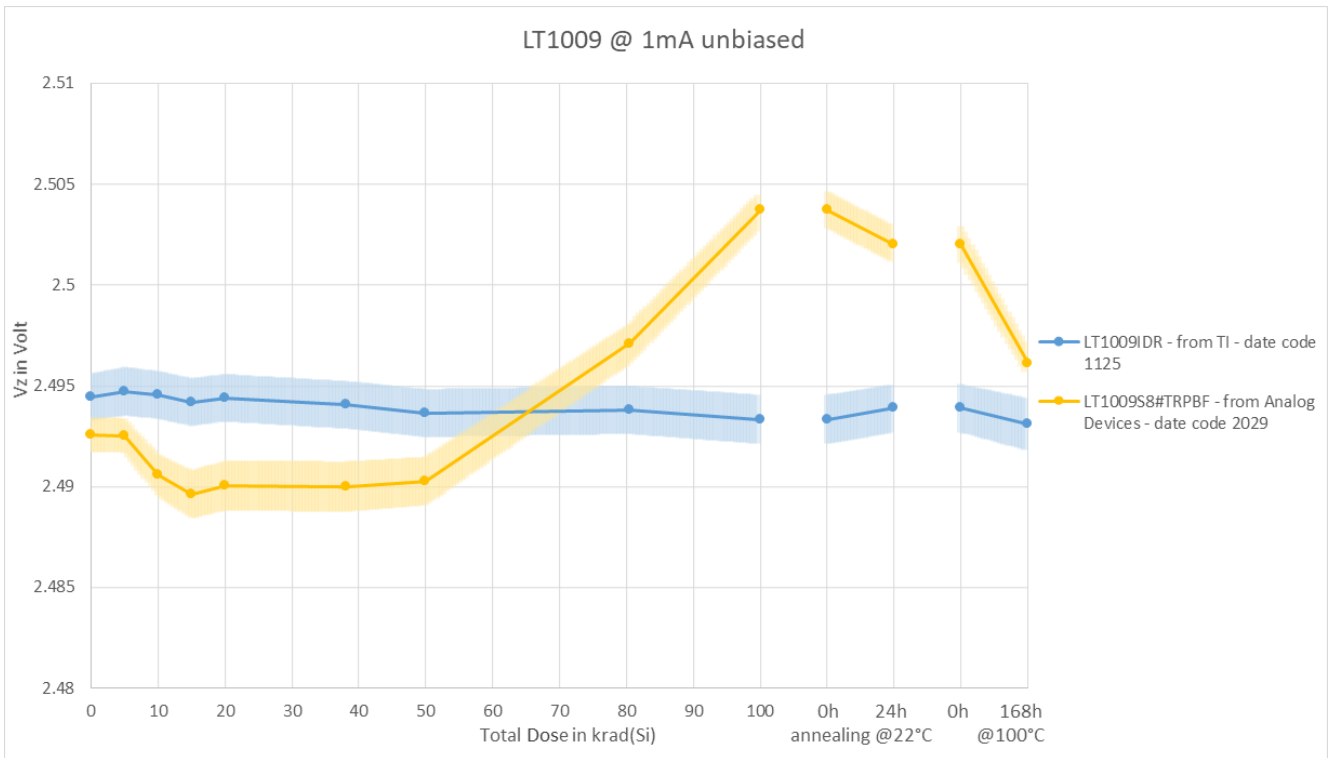
LT1009S8#TRPBF - from Analog Devices - date code 2029 - @ I-typ 1000µA Limit acc. DS: Vz = 2.5V ± 0.6% (2.485V – 2.515V)												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
C0	unbiased	2.4919	2.4916	2.4890	2.4877	2.4882	2.4880	2.4883	2.4955	2.5024	2.5007	2.4955
C1		2.4939	2.4939	2.4920	2.4909	2.4914	2.4914	2.4916	2.4983	2.5049	2.5032	2.4974
C2		2.4926	2.4927	2.4908	2.4894	2.4897	2.4899	2.4904	2.4971	2.5035	2.5018	2.4960
C3		2.4925	2.4925	2.4906	2.4898	2.4904	2.4903	2.4905	2.4973	2.5039	2.5022	2.4959
C4		2.4919	2.4921	2.4906	2.4903	2.4906	2.4904	2.4905	2.4972	2.5039	2.5022	2.4959
C5	biased	2.4919	2.4922	2.4914	2.4902	2.4894	2.4873	2.4868	2.4879	2.4881	2.4892	2.4931
C6		2.4911	2.4911	2.4899	2.4889	2.4883	2.4877	2.4882	2.4895	2.4894	2.4900	2.4926
C7		2.4918	2.4918	2.4909	2.4899	2.4892	2.4874	2.4865	2.4869	2.4870	2.4883	2.4925
C8		2.4936	2.4933	2.4916	2.4895	2.4879	2.4854	2.4857	2.4884	2.4889	2.4899	2.4940
C9		2.4942	2.4943	2.4933	2.4918	2.4908	2.4885	2.4881	2.4897	2.4901	2.4912	2.4958
REF20	Ref unbiased	2.4908	2.4914	2.4913	2.4909	2.4910	2.4909	2.4909	2.4912	2.4914	2.4915	2.4904
REF70	Ref biased	2.4960	2.4963	2.4963	2.4958	2.4961	2.4960	2.4959	2.4963	2.4960	2.4965	2.4954

LT1009S8#TRPBF - from Analog Devices - date code 2029 - @ I-max 10mA												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
C0	unbiased	2.4948	2.4951	2.4940	2.4945	2.4970	2.5075	2.5170	2.5555	2.5850	2.5794	2.5062
C1		2.4969	2.4975	2.4968	2.4975	2.4999	2.5101	2.5193	2.5568	2.5858	2.5801	2.5080
C2		2.4955	2.4962	2.4955	2.4959	2.4981	2.5082	2.5173	2.5539	2.5822	2.5766	2.5065
C3		2.4954	2.4961	2.4955	2.4966	2.4992	2.5098	2.5194	2.5576	2.5868	2.5807	2.5064
C4		2.4947	2.4957	2.4955	2.4970	2.4994	2.5099	2.5194	2.5574	2.5864	2.5804	2.5063
C5	biased	2.4948	2.4956	2.4955	2.4953	2.4954	2.4972	2.4991	2.5057	2.5083	2.5079	2.4987
C6		2.4941	2.4944	2.4934	2.4929	2.4928	2.4948	2.4971	2.5038	2.5066	2.5061	2.4983
C7		2.4947	2.4953	2.4951	2.4950	2.4954	2.4977	2.4994	2.5055	2.5081	2.5076	2.4980
C8		2.4965	2.4967	2.4956	2.4942	2.4935	2.4943	2.4966	2.5045	2.5077	2.5073	2.4995
C9		2.4970	2.4976	2.4973	2.4967	2.4966	2.4979	2.4998	2.5066	2.5094	2.5090	2.5013
REF20	Ref unbiased	2.4937	2.4942	2.4942	2.4938	2.4939	2.4938	2.4938	2.4941	2.4942	2.4943	2.4933
REF70	Ref biased	2.4989	2.4991	2.4991	2.4987	2.4989	2.4988	2.4987	2.4991	2.4989	2.4993	2.4982



8.1. Comparison Manufacturer and Date Code

The following graph shows the different behaviour of all measured LT1009 voltage references with different date code.

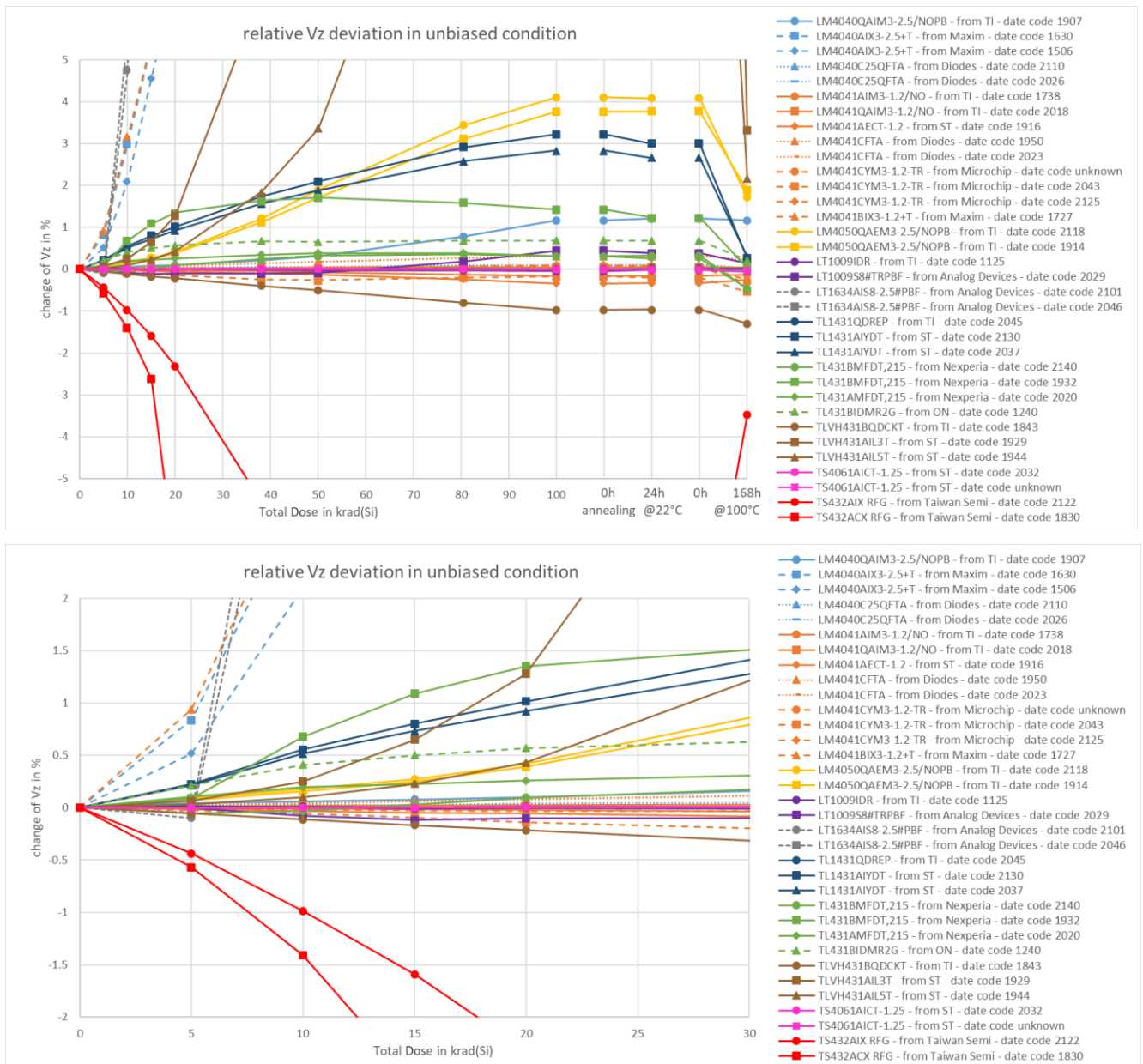


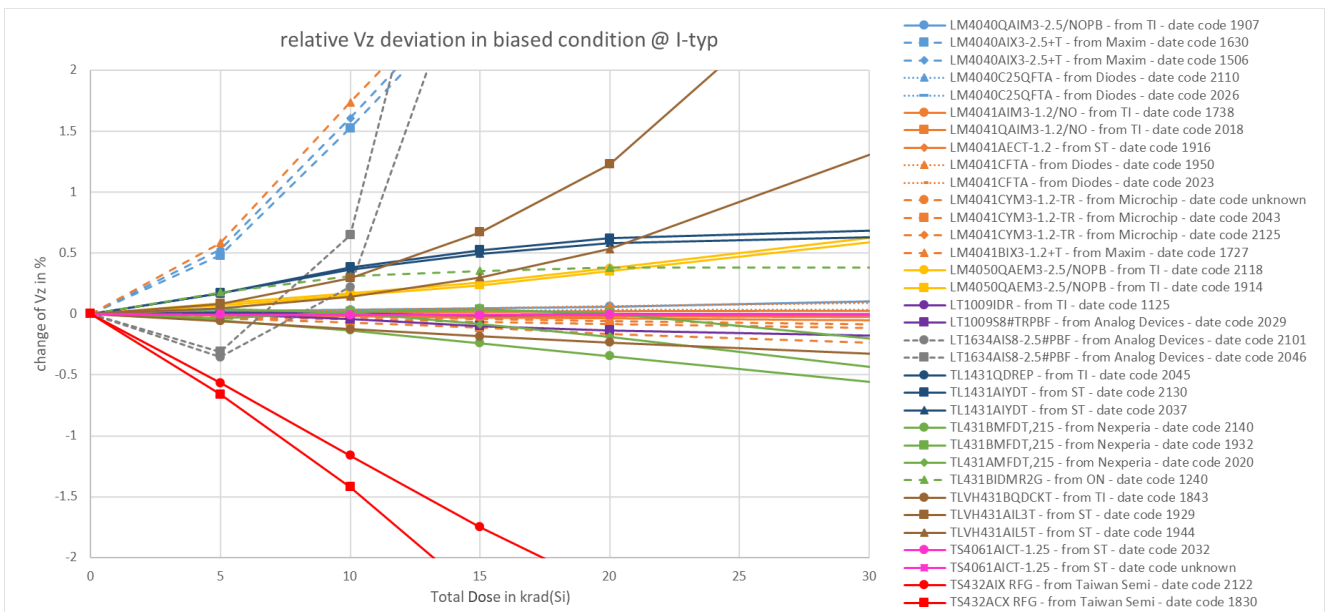
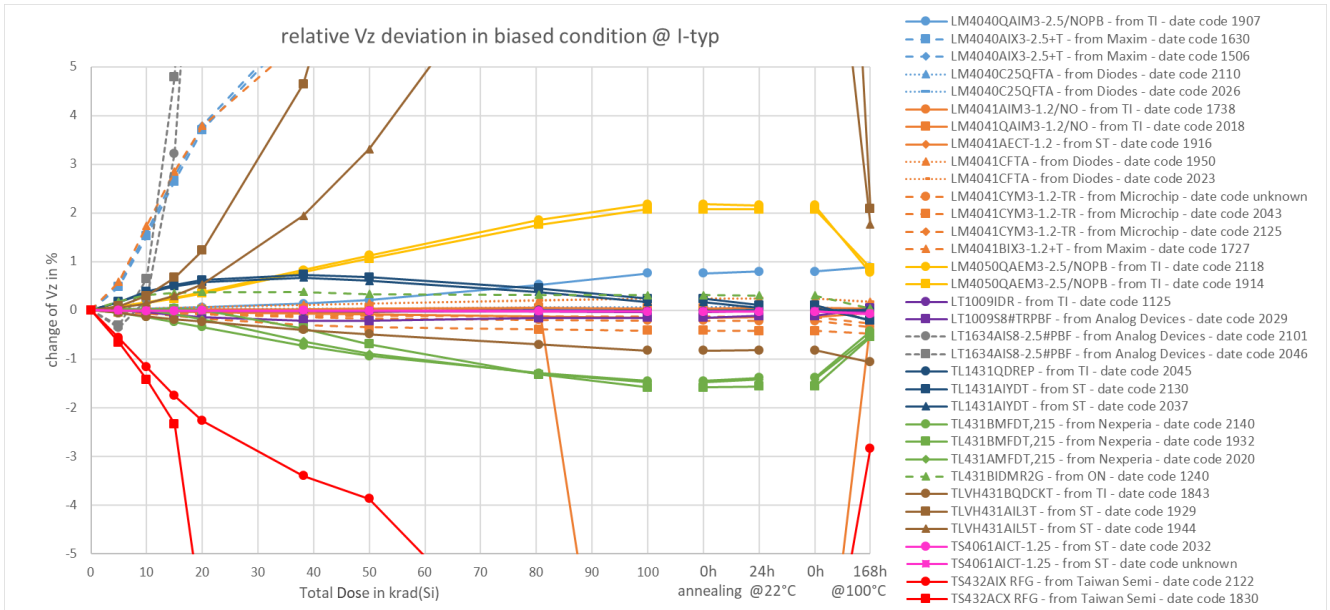
All curves plotted show the average value of all unbiased tested samples (worst case) and the interval behind the curves represent +/- one standard deviation.



8.2. Comparison with other tested Bandgap References

The following four graphs show the results of the LT1009 Bandgap Voltage References compared to different Bandgap References part types, which were tested at the same time with the same test setup than the LT1009. Additional information on these tests is provided in the Radiation Test Summary [RD02].





9. CONCLUSION

Up to the maximal tested dose of 100krad the deviation of all tested samples stayed inside the tolerances according to the datasheet.

The deviation of tested components from the two different manufactures show a significant different behaviour in respect of TID effects.

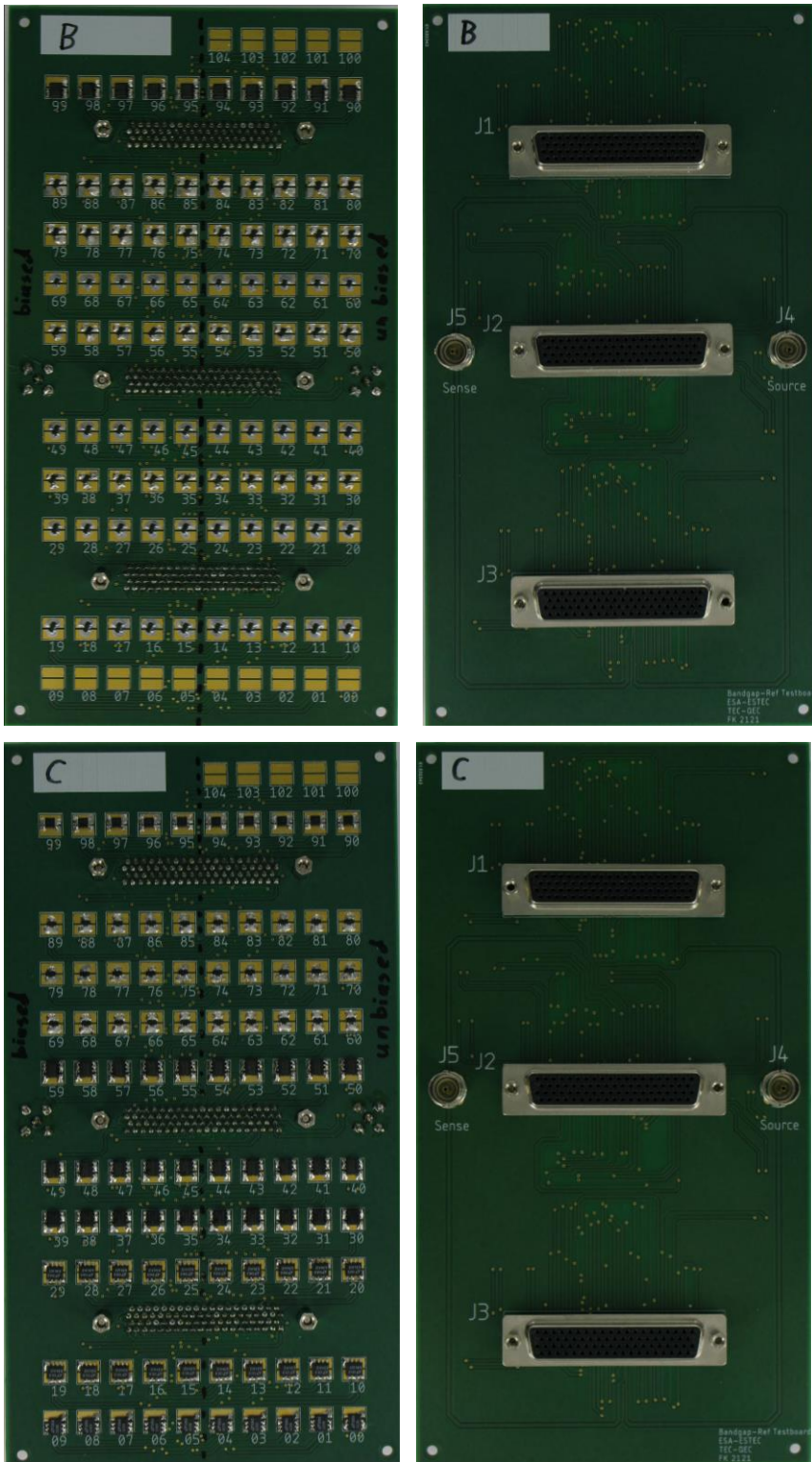
In general, a higher deviation was found for the unbiased samples.

ANNEX A – DATASHEET

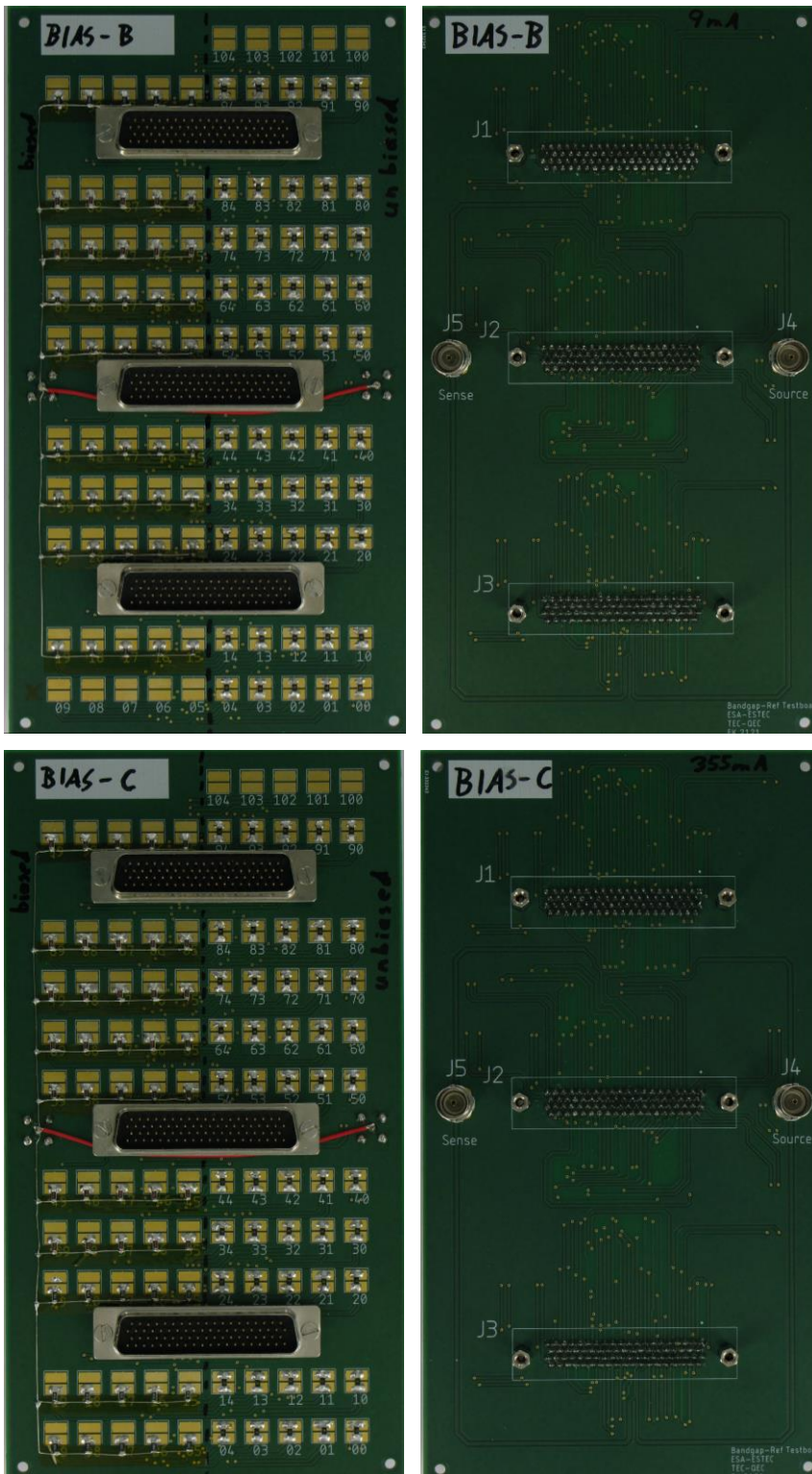
Part Type	Manufacturer	Link to Datasheet
LT1009IDR	Texas Instruments	https://www.ti.com/lit/ds/symlink/lt1009.pdf?HQS=dis-dk-null-digikeymode-dsf-pf-null-ww&ts=1617892474582
LT1009S8#TRPBF	Analog Devices	https://www.analog.com/media/en/technical-documentation/datasheets/LT1009.pdf

ANNEX B – SET-UP

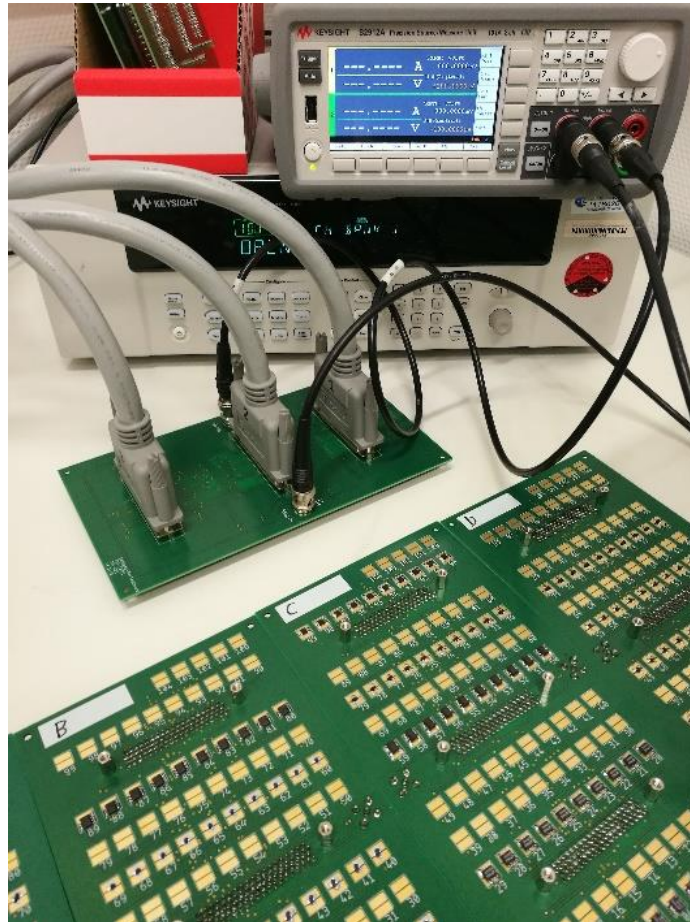
Test board front- and backside with the LT1009 on position 90 to 99 on board B and position 00 to 09 on board C:



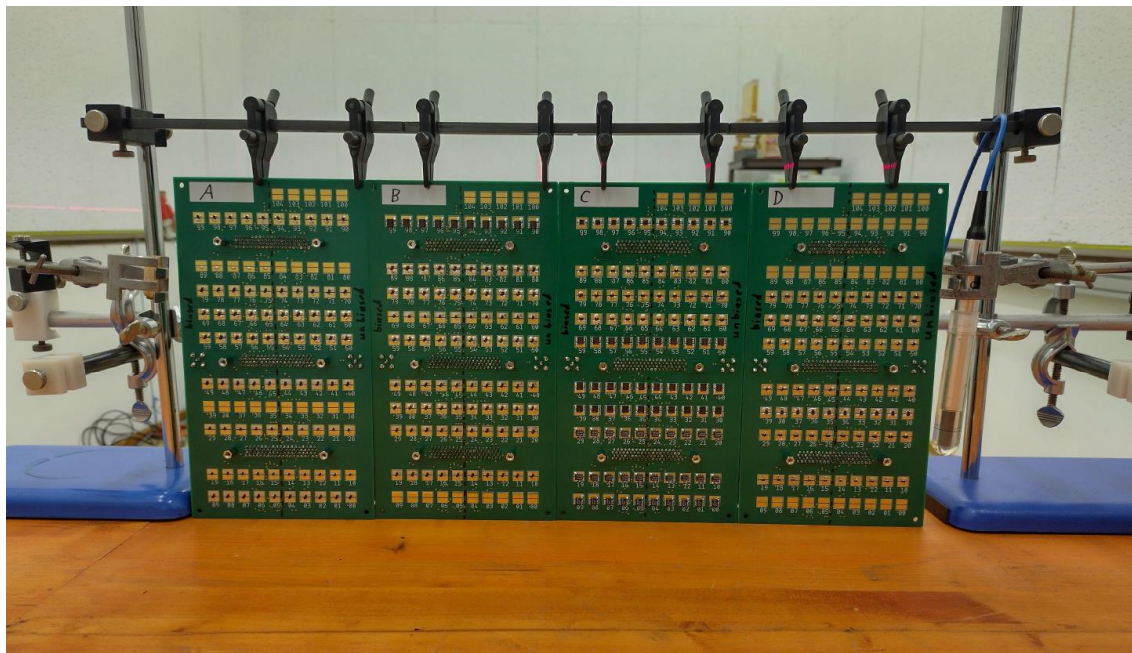
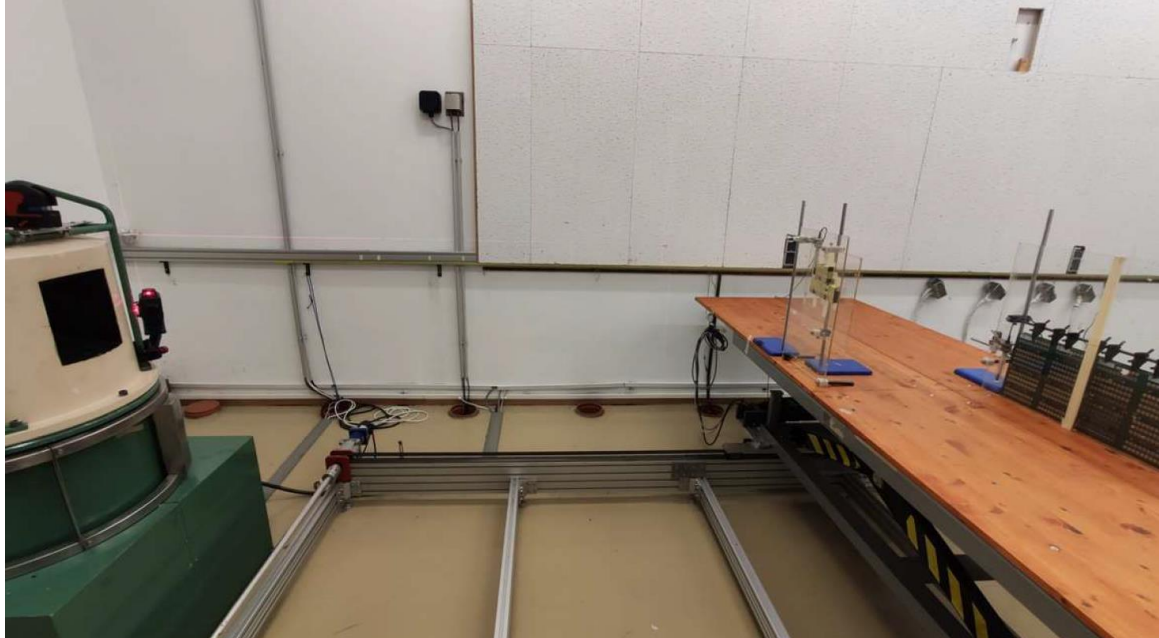
Biassing board front- and backside with the biassing resistors on it:



Measurement setup with the cable connection from the Test Board to the Switching Matrix and the Source Measure Unit:



Position of the boards inside the Co60 irradiation chamber:



ANNEX C – RADIATION TEST SUMMARY – IRRADIATION STEPS

Irr. Run	Start Date & Time (CET)	End Date & Time (CET)	Total Ionising Dose (water)	Dose Rate (water)
1	24-01-2022 18:11:39	25-01-2022 13:37:10	55.69 Gy	2.867 Gy/h
2	25-01-2022 15:13:42	26-01-2022 11:52:43	55.67 Gy	2.696 Gy/h
3	26-01-2022 13:30:18	27-01-2022 10:16:45	55.68 Gy	2.680 Gy/h
4	27-01-2022 12:11:47	28-01-2022 08:55:59	55.68 Gy	2.685 Gy/h
5	28-01-2022 10:31:55	31-01-2022 09:30:00	202.3 Gy	2.851 Gy/h
6	31-01-2022 11:18:44	02-02-2022 09:21:12	131.8 Gy	2.863 Gy/h
7	02-02-2022 11:05:44	07-02-2022 09:55:08	339.6 Gy	2.858 Gy/h
8	07-02-2022 11:41:36	10-02-2022 15:46:14	217.1 Gy	2.854 Gy/h
Total			1.114 kGy	

Note: The uncertainty budgets (according to TEC-QEC/PR001 section 12) are: 4.2 % (k=2) for absorbed dose to water and 4.4% (k=2) for absorbed dose rate to water

	units	Min.	Max.	Time-weighted Average
Temperature	°C	20.9	21.2	20.93
Pressure	mbar	996.6	1034.5	1019.01
Relative Humidity	%	47.1	54	51.45

Dosimeter position relative to ⁶⁰ Co source		
X	cm	36.5
Y	cm	292
Z	cm	-21

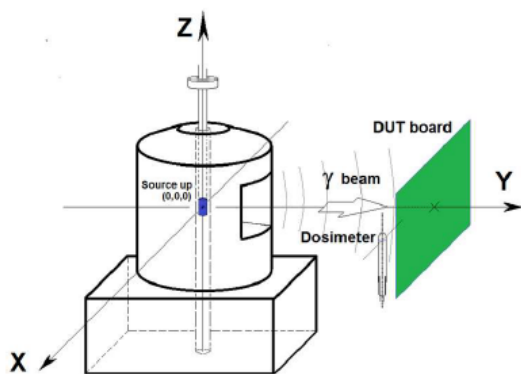


Figure 1 Co-60 irradiator head and board positioning sketch

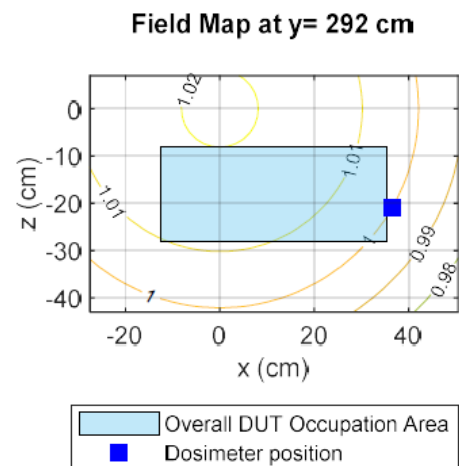


Figure 2: Qualitative indication of dose rate distribution normalized to dosimeter readings. Axes origin located at source centre. Graphs for information only, of the run with highest dose rate.