ESA ESTEC
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands

TS432_TID_TEST_REPORT

TS432AIX RFG
Date Code: 2122
1.24V Adjustable Voltage Reference
Taiwan Semiconductor

TS432ACX RFG
Date Code: 1830
1.24V Adjustable Voltage Reference
Taiwan Semiconductor

Prepared by	Florian Krimmel

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DISTRIBUTION

Name/Organisational Unit

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1. INTRODUCTION

The current report presents the TID results on the Bandgap Voltage Reference TS4061

- TS432AIX RFG, date code: 2122, Taiwan Semiconductor
- TS432ACX RFG, date code: 1830, Taiwan Semiconductor

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

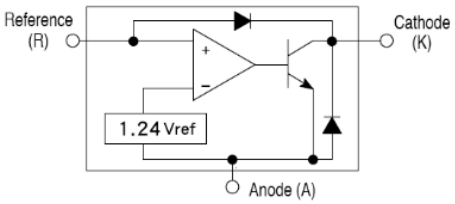
Part number	TS432AIX RFG	TS432ACX RFG
Manufacturer	Taiwan Semiconductor	
Function	1.24V Adjustable Voltage Reference	
Technology	Bipolar	
Package	 **Pin Definition:** 1. Reference 2. Cathode 3. Anode 	
Date Code [yyww]	2122	1830
Distributor	Mouser	Mouser
Part # (sample n°) date code	5 samples unbiased (n° D60 to D64) 5 samples biased (n° D65 to D69) 1 reference unbiased (n° REF36) 1 reference biased (n° REF86)	5 samples unbiased (n° D70 to D74) 5 samples biased (n° D75 to D79) 1 reference unbiased (n° REF37) 1 reference biased (n° REF87)

Table 1: Part & procurement information

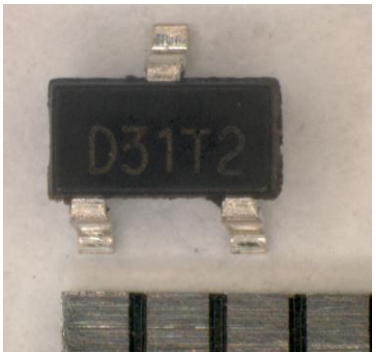
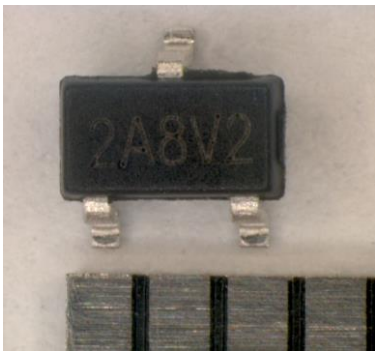
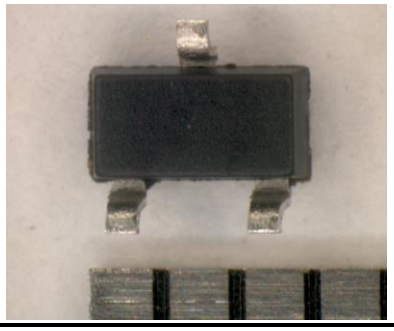
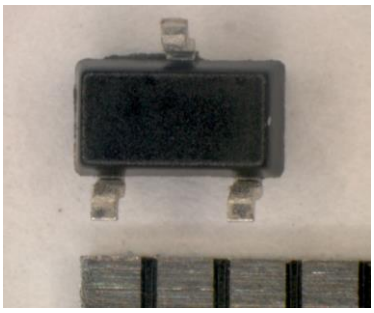
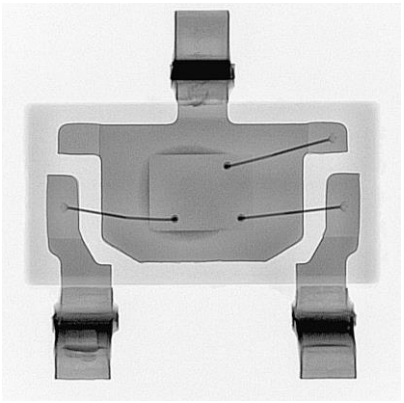
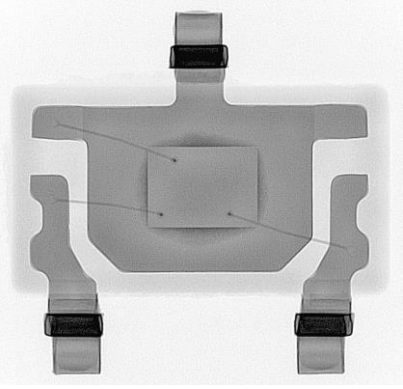
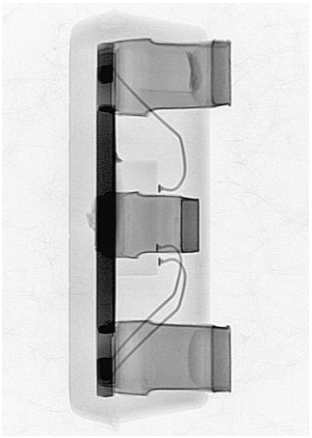
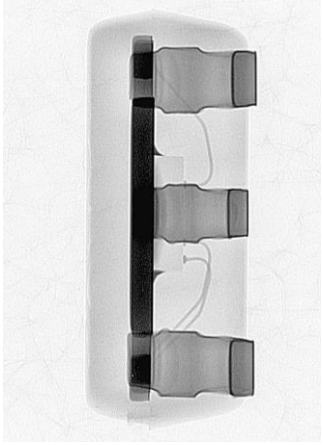
Part number	TS432AIX RFG	TS432ACX RFG
Package marking top		
Package marking bottom		
X-ray top view		
X-ray side view		

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(H_20), 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.

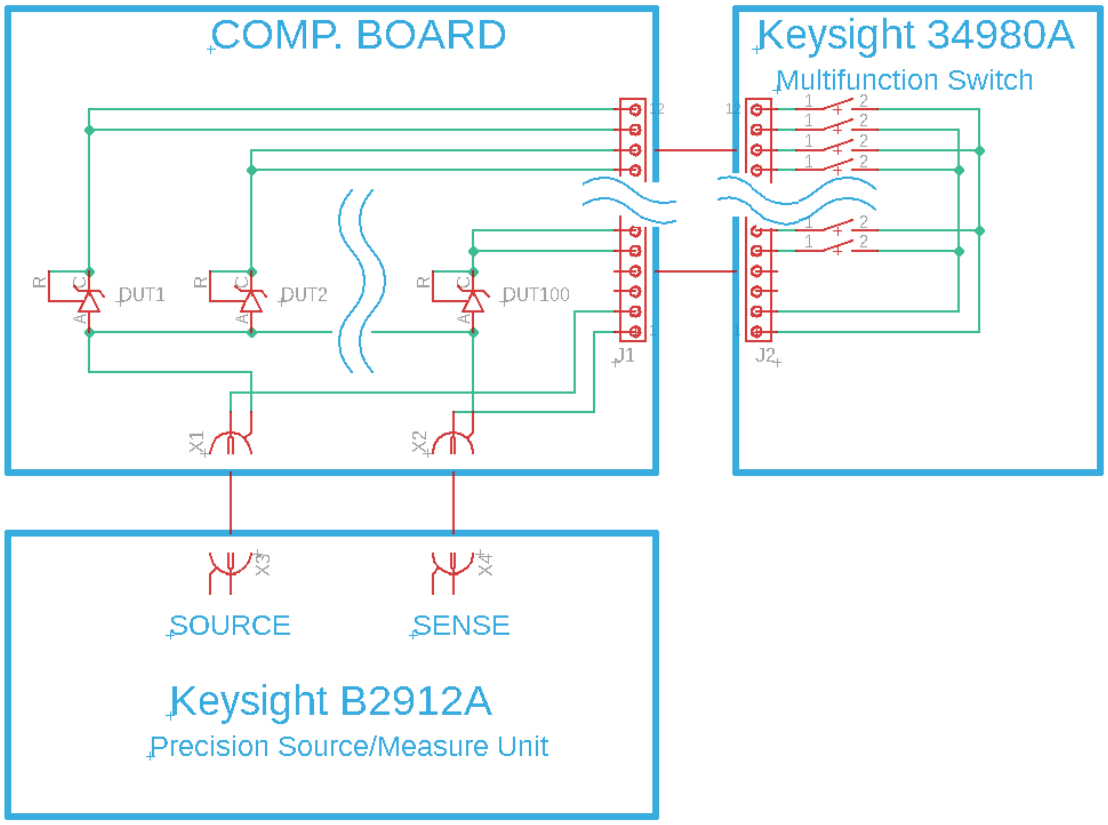


Figure 1: Simplified schematic of the overall test set-up

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	PARAMETER MEASURED
1 x Keysight B2912A 2412A Precision Source/Measure Unit (SMU)	Providing 6 different I_Z currents acc. to datasheet of the components: I_{min}, $0.8xI_{typ}$, I_{typ}, $3.14xI_{typ}$, $10xI_{typ}$, I_{max} V_{max} = 5.0 V
1 x Keysight 34980A Multifunction Switch	Switching through all up to 100 samples solder on one board.
1 x Laptop with LabView	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
TS432AIX RFG	10	mA
TS432ACX RFG	10	mA

Table 2: Biasing conditions during irradiation

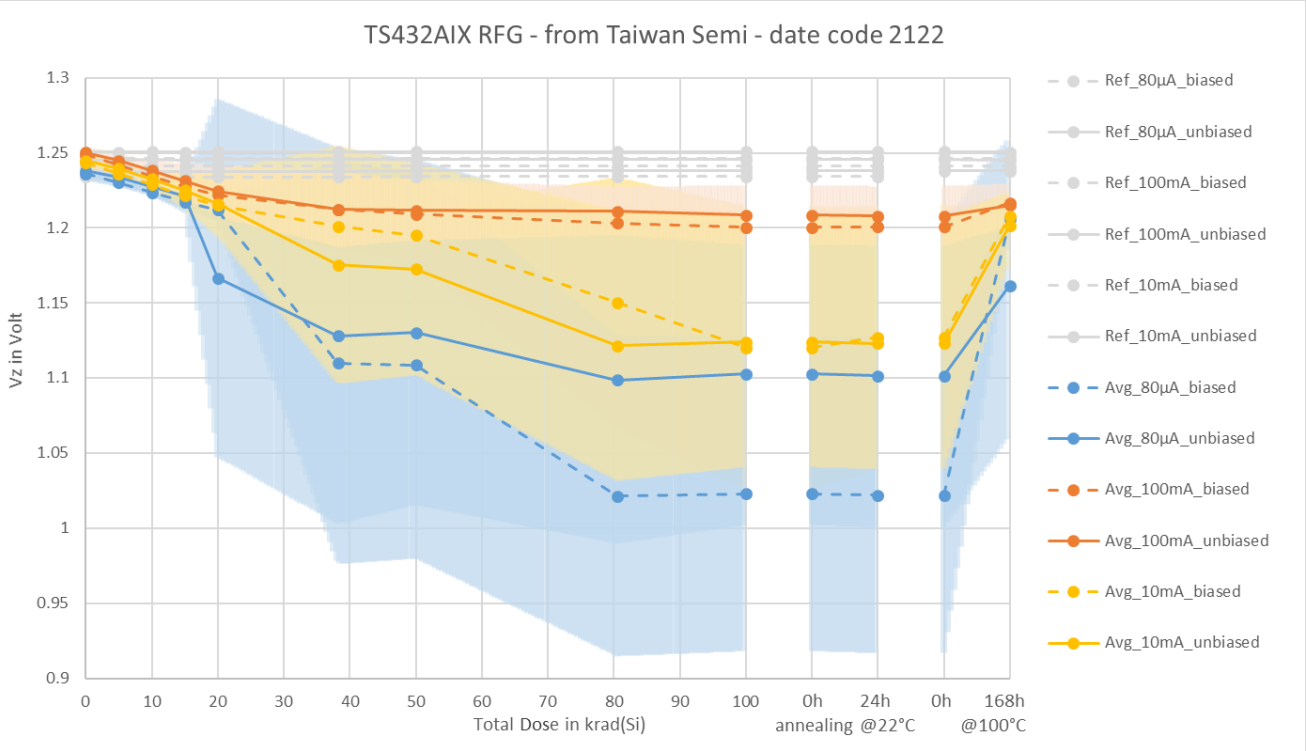
8. TID RESULTS

8.1. TID RESULTS - TS432AIX RFG - from Taiwan Semi - date code 2122

TS432AIX RFG - from Taiwan Semi - date code 2122 - @ I-min 80µA												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
D60	unbiased	1.2312	1.2282	1.2244	1.2205	1.2171	1.2063	1.1957	0.9970	1.0112	1.0102	1.1948
D61		1.2421	1.2386	1.2353	1.2330	1.2312	1.2268	1.2246	1.2188	1.2152	1.2150	1.2236
D62		1.2410	1.2343	1.2234	1.2084	0.9545	1.0068	1.0219	1.0495	1.0574	1.0552	0.9860
D63		1.2395	1.2366	1.2338	1.2314	1.2294	1.2239	1.2206	1.2130	1.2066	1.2063	1.2188
D64		1.2363	1.2309	1.2222	1.2127	1.2011	0.9767	0.9897	1.0147	1.0233	1.0216	1.1853
D65	biased	1.2299	1.2272	1.2251	1.2235	1.2221	1.2179	1.2161	1.2118	1.2094	1.2095	1.2155
D66		1.2356	1.2286	1.2204	1.2123	1.2033	0.9674	0.9747	0.9849	0.9873	0.9858	1.2007
D67		1.2412	1.2343	1.2264	1.2194	1.2148	1.2030	1.1959	0.9633	0.9649	0.9641	1.2075
D68		1.2348	1.2288	1.2222	1.2166	1.2127	1.2025	1.1961	0.9779	0.9797	0.9787	1.2040
D69		1.2392	1.2322	1.2237	1.2151	1.2069	0.9597	0.9612	0.9697	0.9731	0.9719	1.2013
REF36	Ref unbiased	1.2375	1.2376	1.2377	1.2376	1.2377	1.2376	1.2381	1.2380	1.2380	1.2380	1.2379
REF86	Ref biased	1.2338	1.2339	1.2339	1.2339	1.2339	1.2339	1.2343	1.2343	1.2343	1.2343	1.2341

TS432AIX RFG - from Taiwan Semi - date code 2122 - @ I-typ 10mA											Limit acc. DS: Vz = 1.24V ± 1.29% (1.224V – 1.256V)	
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
D60	unbiased	1.2382	1.2343	1.2297	1.2253	1.2214	1.2077	1.1982	1.0326	1.0408	1.0401	1.1971
D61		1.2489	1.2445	1.2406	1.2381	1.2360	1.2306	1.2276	1.2210	1.2169	1.2169	1.2267
D62		1.2479	1.2395	1.2271	1.2103	1.1853	1.0400	1.0571	1.0859	1.0941	1.0923	1.1734
D63		1.2462	1.2424	1.2391	1.2364	1.2342	1.2274	1.2234	1.2145	1.2086	1.2085	1.2216
D64		1.2432	1.2364	1.2265	1.2152	1.2035	1.1721	1.1559	1.0537	1.0597	1.0587	1.1898
D65	biased	1.2370	1.2338	1.2314	1.2295	1.2279	1.2231	1.2205	1.2153	1.2125	1.2126	1.2195
D66		1.2424	1.2343	1.2250	1.2151	1.2050	1.1842	1.1778	1.1637	1.0323	1.0642	1.2030
D67		1.2487	1.2404	1.2317	1.2238	1.2181	1.2048	1.1982	1.1834	1.1759	1.1766	1.2089
D68		1.2418	1.2346	1.2272	1.2206	1.2157	1.2045	1.1986	1.1841	1.1751	1.1758	1.2056
D69		1.2463	1.2380	1.2287	1.2185	1.2086	1.1884	1.1807	1.0048	1.0063	1.0063	1.2031
REF36	Ref unbiased	1.2453	1.2453	1.2454	1.2453	1.2454	1.2454	1.2454	1.2454	1.2454	1.2454	1.2453
REF86	Ref biased	1.2410	1.2411	1.2412	1.2412	1.2412	1.2412	1.2412	1.2412	1.2412	1.2412	1.2411

TS432AIX RFG - from Taiwan Semi - date code 2122 - @ I-max 100mA												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
D60	unbiased	1.2436	1.2397	1.2352	1.2311	1.2275	1.2158	1.2085	1.1892	1.1782	1.1778	1.2076
D61		1.2542	1.2498	1.2460	1.2436	1.2416	1.2367	1.2341	1.2285	1.2252	1.2251	1.2331
D62		1.2533	1.2450	1.2333	1.2186	1.2015	1.1769	1.1870	1.2154	1.2224	1.2210	1.2018
D63		1.2515	1.2477	1.2444	1.2418	1.2397	1.2334	1.2299	1.2224	1.2177	1.2176	1.2281
D64		1.2487	1.2418	1.2324	1.2222	1.2126	1.1989	1.1991	1.2007	1.1992	1.1987	1.2058
D65	biased	1.2426	1.2394	1.2370	1.2350	1.2334	1.2288	1.2264	1.2215	1.2190	1.2191	1.2257
D66		1.2482	1.2400	1.2311	1.2222	1.2139	1.2029	1.2036	1.2026	1.2014	1.2012	1.2145
D67		1.2540	1.2458	1.2373	1.2298	1.2247	1.2134	1.2083	1.1992	1.1952	1.1955	1.2169
D68		1.2474	1.2402	1.2331	1.2270	1.2228	1.2141	1.2098	1.2015	1.1977	1.1979	1.2148
D69		1.2515	1.2432	1.2341	1.2246	1.2161	1.2022	1.1980	1.1916	1.1893	1.1897	1.2119
REF36	Ref unbiased	1.2506	1.2506	1.2507	1.2507	1.2507	1.2507	1.2507	1.2507	1.2507	1.2507	1.2506
REF86	Ref biased	1.2463	1.2465	1.2465	1.2465	1.2465	1.2465	1.2465	1.2466	1.2465	1.2465	1.2464



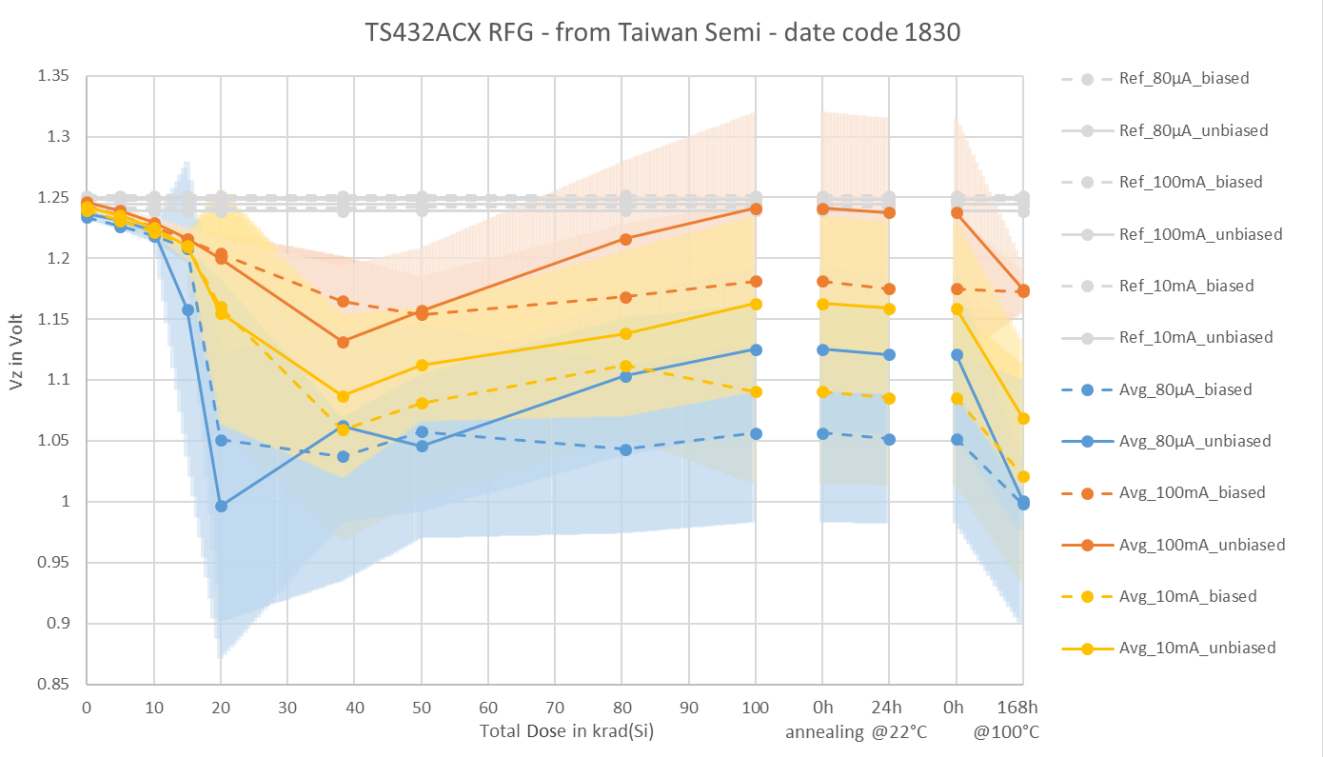
For all curves, which show an average over all measured samples, the coloured interval behind the curves represent +/- one standard deviation.

8.2. TID RESULTS - TS432ACX RFG - from Taiwan Semi - date code 1830

TS432ACX RFG - from Taiwan Semi - date code 1830 - @ I-min 80µA												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
D70	unbiased	1.2390	1.2331	1.2251	1.2107	0.9456	1.0395	1.0802	1.1512	1.1771	1.1708	1.0097
D71		1.2349	1.2288	1.2201	1.2049	0.9495	1.0275	1.0575	1.1080	1.1255	1.1222	1.0127
D72		1.2362	1.2303	1.2224	1.2116	0.9053	0.9866	1.0213	1.0810	1.1027	1.0982	0.9629
D73		1.2345	1.2314	1.2270	1.2227	1.2180	1.1939	0.9662	1.0059	1.0260	1.0244	0.9833
D74		1.2393	1.2310	1.2183	0.9423	0.9652	1.0651	1.1051	1.1723	1.1950	1.1897	1.0358
D75	biased	1.2312	1.2235	1.2143	1.2016	0.9290	0.9915	1.0162	1.0504	1.0605	1.0575	0.9705
D76		1.2343	1.2242	1.2126	1.1935	0.9623	1.0532	1.0873	1.1453	1.1666	1.1555	0.9458
D77		1.2342	1.2270	1.2187	1.2089	0.9360	0.9885	1.0136	1.0476	1.0573	1.0543	0.9711
D78		1.2343	1.2281	1.2216	1.2156	1.2085	0.9466	0.9752	1.0198	1.0344	1.0308	0.9265
D79		1.2343	1.2295	1.2259	1.2226	1.2195	1.2068	1.1967	0.9538	0.9632	0.9615	1.1769
REF37	Ref unbiased	1.2388	1.2389	1.2389	1.2389	1.2389	1.2389	1.2392	1.2393	1.2392	1.2392	1.2390
REF87	Ref biased	1.2414	1.2414	1.2415	1.2415	1.2415	1.2415	1.2418	1.2419	1.2419	1.2419	1.2417

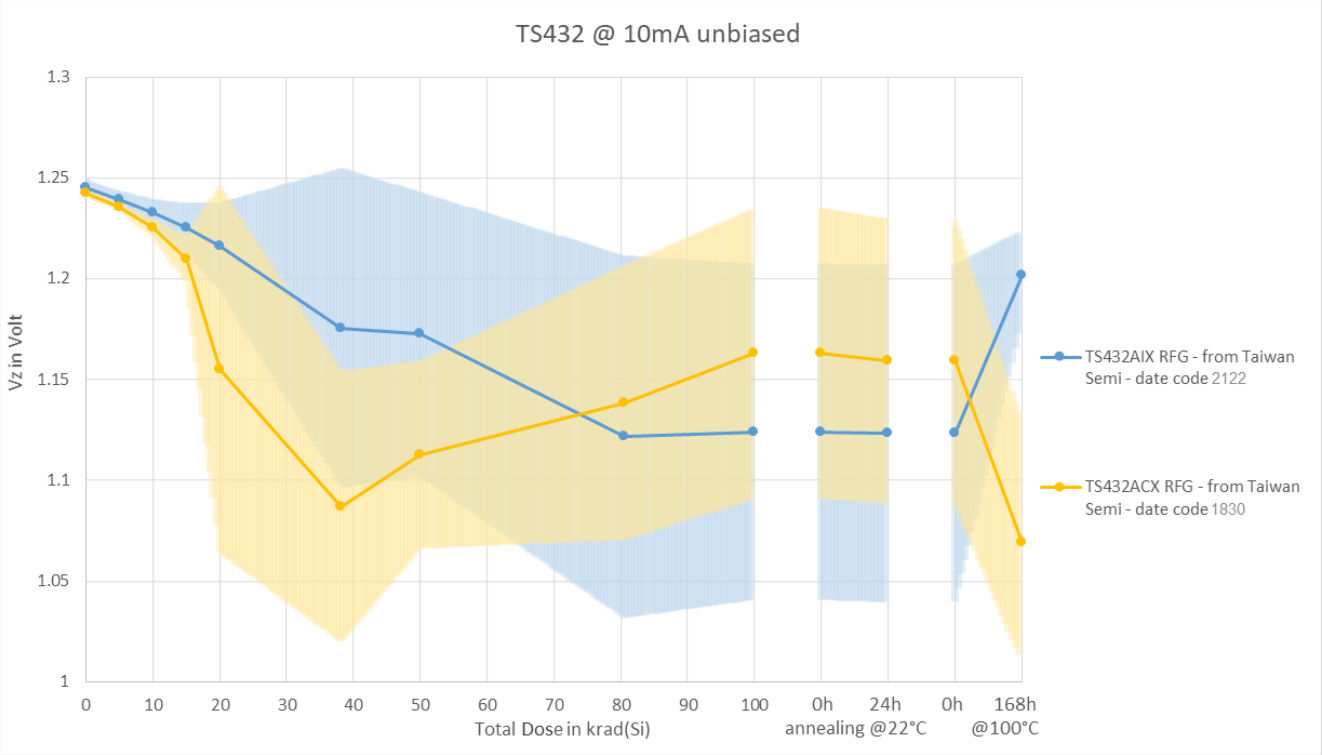
TS432ACX RFG - from Taiwan Semi - date code 1830 - @ I-typ 10mA											Limit acc. DS: Vz = 1.24V ± 1.29% (1.224V – 1.256V)	
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
D70	unbiased	1.2445	1.2373	1.2271	1.2118	1.1859	1.0695	1.1110	1.1867	1.2183	1.2127	1.0479
D71		1.2406	1.2330	1.2217	1.2063	1.1823	1.0612	1.0943	1.1501	1.1708	1.1679	1.0657
D72		1.2423	1.2352	1.2256	1.2124	1.1928	1.0142	1.0488	1.1073	1.1305	1.1267	0.9959
D73		1.2401	1.2363	1.2311	1.2256	1.2197	1.1958	1.1733	1.0384	1.0574	1.0563	1.1612
D74		1.2451	1.2353	1.2194	1.1935	0.9946	1.0937	1.1361	1.2097	1.2372	1.2324	1.0743
D75	biased	1.2369	1.2280	1.2166	1.2028	1.1845	1.0214	1.0483	1.0873	1.0991	1.0959	1.0039
D76		1.2400	1.2284	1.2144	1.1953	0.9892	1.0811	1.1171	1.1804	1.2049	1.1918	0.9684
D77		1.2402	1.2319	1.2217	1.2099	1.1953	1.0171	1.0443	1.0821	1.0928	1.0895	1.0022
D78		1.2401	1.2331	1.2257	1.2181	1.2094	0.9698	0.9981	1.0441	1.0594	1.0556	0.9533
D79		1.2389	1.2338	1.2296	1.2256	1.2218	1.2079	1.1981	1.1666	0.9956	0.9952	1.1795
REF37	Ref unbiased	1.2443	1.2444	1.2444	1.2444	1.2444	1.2444	1.2444	1.2445	1.2444	1.2444	1.2443
REF87	Ref biased	1.2473	1.2474	1.2474	1.2474	1.2474	1.2475	1.2474	1.2475	1.2475	1.2475	1.2474

TS432ACX RFG - from Taiwan Semi - date code 1830 - @ I-max 100mA												
DUT No.	krad (Si)	0	5	10	15	20	38.2	50	80.5	100	Room Temp. annealing	100°C annealing
D70	unbiased	1.2482	1.2410	1.2314	1.2181	1.1995	1.1173	1.1542	1.2503	1.2962	1.2898	1.1712
D71		1.2442	1.2367	1.2261	1.2130	1.1971	1.1693	1.1929	1.2617	1.2899	1.2866	1.1981
D72		1.2460	1.2390	1.2297	1.2174	1.2011	1.0398	1.0687	1.1272	1.1531	1.1494	1.1441
D73		1.2440	1.2402	1.2351	1.2299	1.2244	1.2046	1.1918	1.1684	1.1569	1.1577	1.1867
D74		1.2489	1.2391	1.2243	1.2034	1.1779	1.1271	1.1770	1.2723	1.3101	1.3055	1.1727
D75	biased	1.2407	1.2318	1.2208	1.2085	1.1944	1.1445	1.1398	1.1859	1.2031	1.1991	1.1624
D76		1.2440	1.2325	1.2194	1.2033	1.1822	1.1155	1.1547	1.2325	1.2653	1.2460	1.1506
D77		1.2443	1.2360	1.2262	1.2156	1.2039	1.1708	1.1498	1.1700	1.1792	1.1754	1.1761
D78		1.2439	1.2368	1.2296	1.2224	1.2143	1.1811	1.1218	1.0693	1.0841	1.0806	1.1838
D79		1.2422	1.2371	1.2330	1.2291	1.2255	1.2129	1.2046	1.1838	1.1745	1.1748	1.1907
REF37	Ref unbiased	1.2481	1.2481	1.2482	1.2482	1.2482	1.2482	1.2482	1.2482	1.2482	1.2482	1.2481
REF87	Ref biased	1.2514	1.2515	1.2515	1.2515	1.2515	1.2515	1.2515	1.2516	1.2515	1.2516	1.2515



8.3. Comparison Date Code

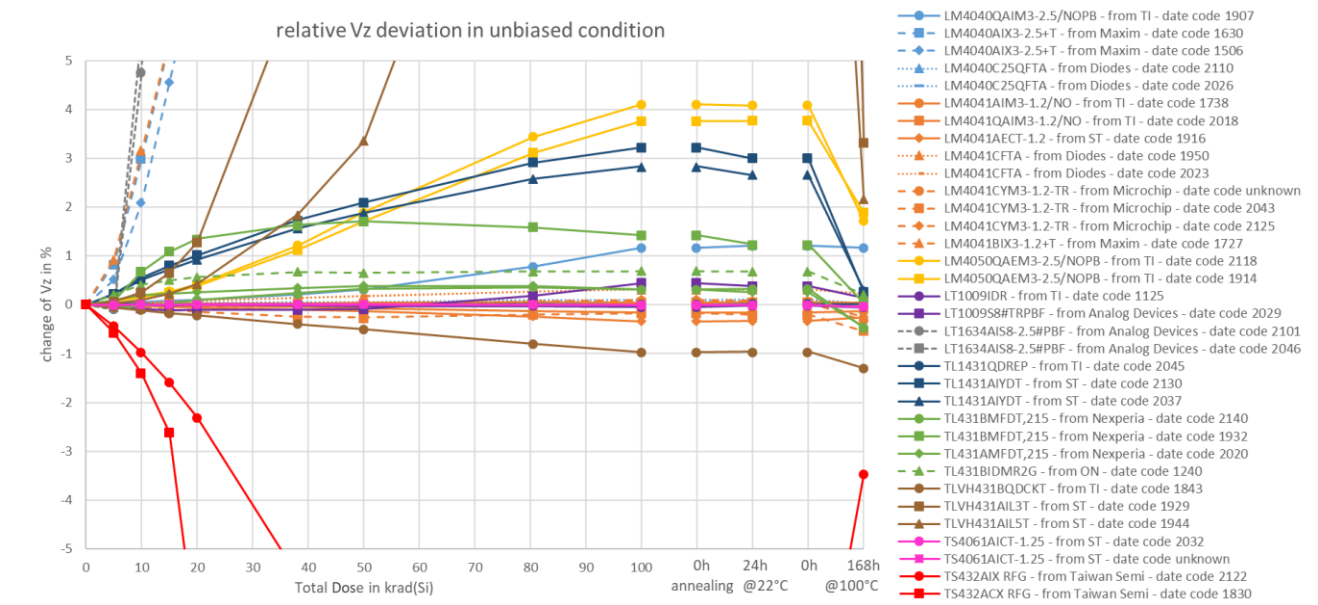
The following graph shows the different behaviour of all measured TS432 voltage references with different date codes.

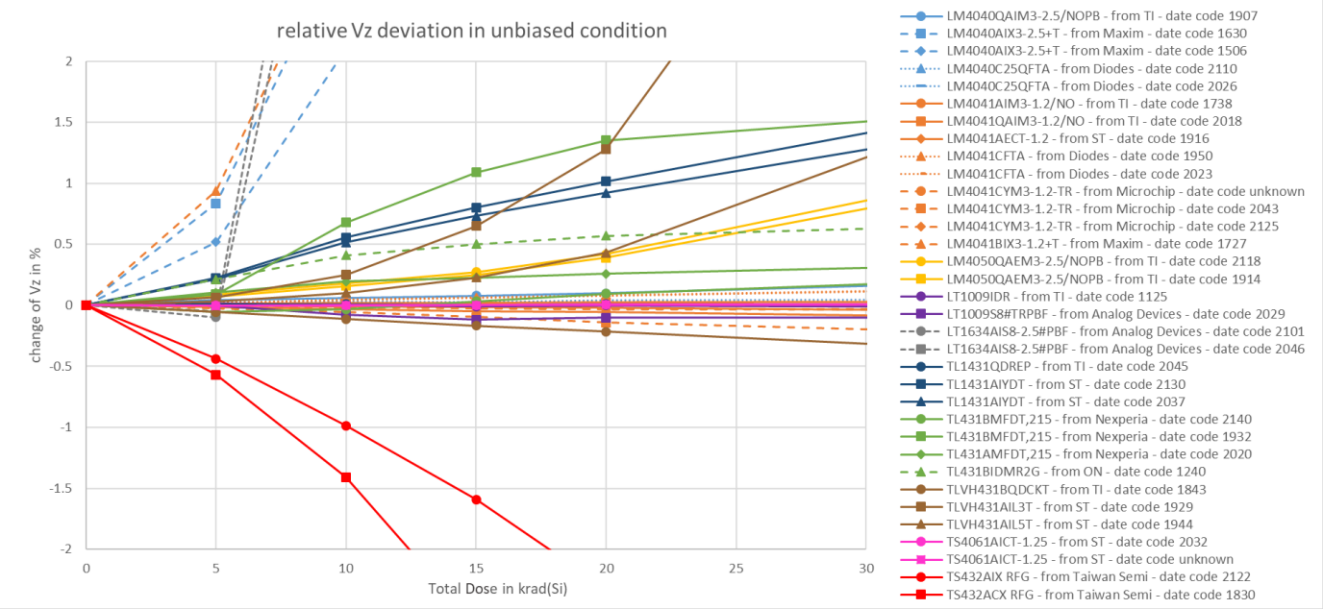


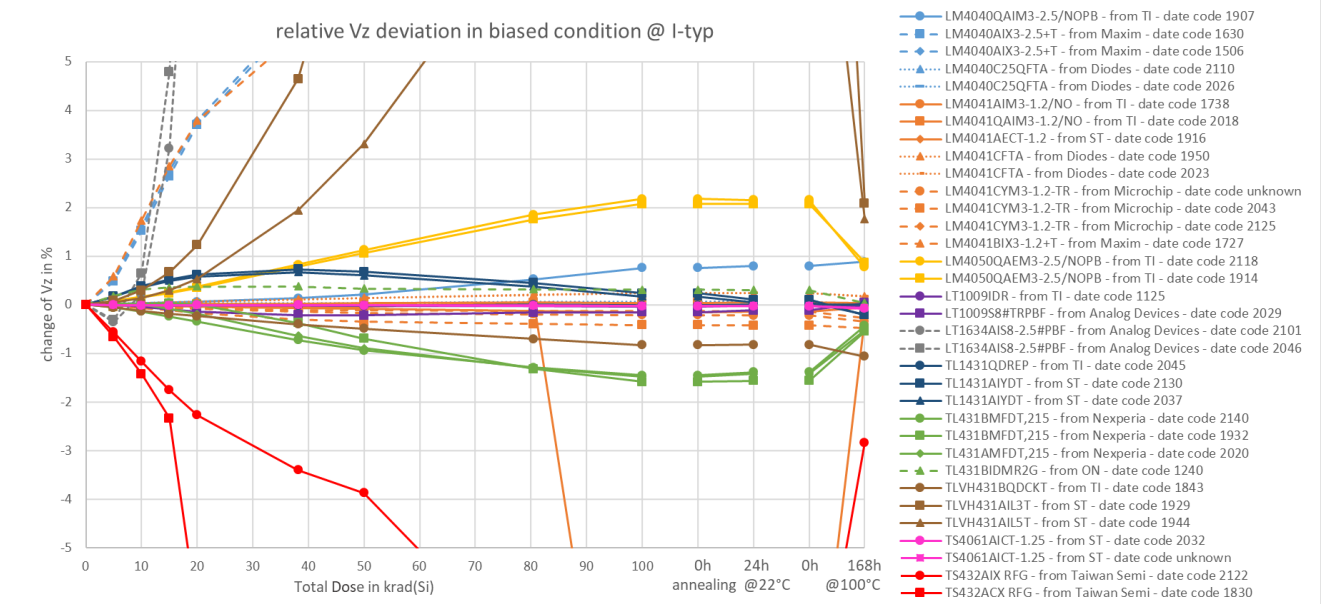
All curves plotted show the average value of all unbiased tested samples (worst case) and the interval behind the curves represent +/- one standard deviation.

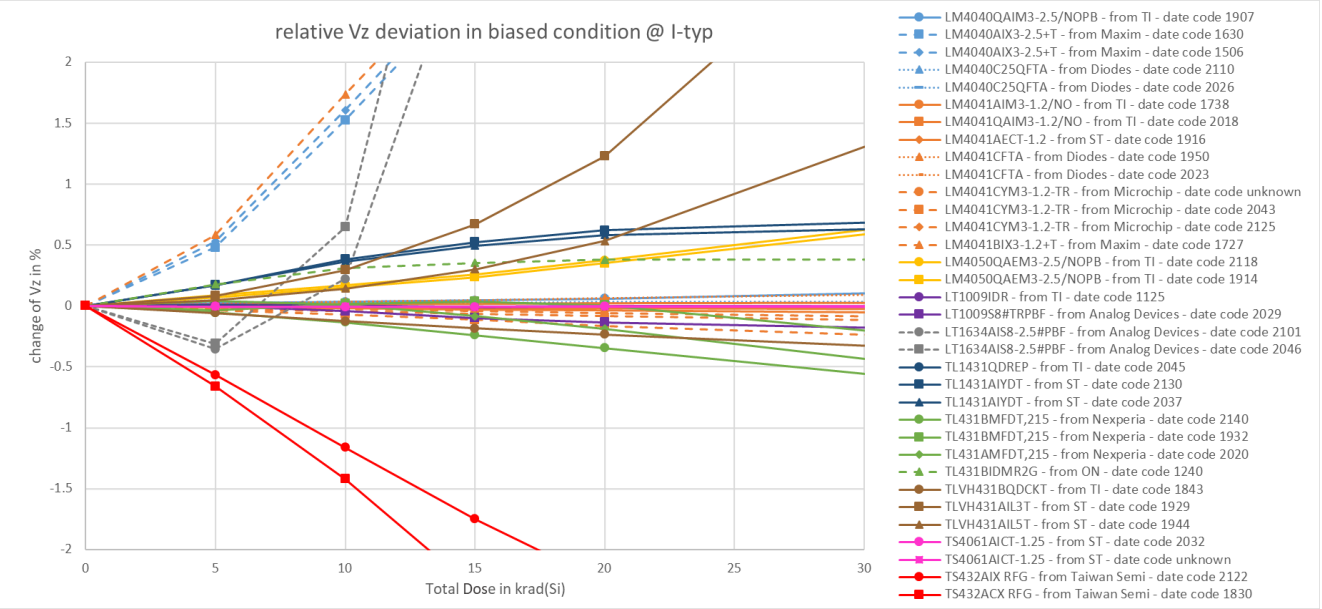
8.4. Comparison with other tested Bandgap References

The following four graphs show the results of the TS432 Bandgap Voltage References compared to different Bandgap References part types, which were tested at the same time with the same test setup than the TS432. Additional information on these tests is provided in the Radiation Test Summary [RD02].






relative Vz deviation in biased condition @ I-typ
change of Vz in %
Total Dose in krad(Si)
0h
24h
0h
168h
annealing @22°C
@100°C
LM4040QAIM3-2.5/NOPB - from TI - date code 1907
LM4040AIX3-2.5+T - from Maxim - date code 1630
LM4040AIX3-2.5+T - from Maxim - date code 1506
LM4040C25QFTA - from Diodes - date code 2110
LM4040C25QFTA - from Diodes - date code 2026
LM4041AIM3-1.2/NO - from TI - date code 1738
LM4041QAIM3-1.2/NO - from TI - date code 2018
LM4041AECT-1.2 - from ST - date code 1916
LM4041CFTA - from Diodes - date code 1950
LM4041CFTA - from Diodes - date code 2023
LM4041CYM3-1.2-TR - from Microchip - date code unknown
LM4041CYM3-1.2-TR - from Microchip - date code 2043
LM4041CYM3-1.2-TR - from Microchip - date code 2125
LM4041BIX3-1.2+T - from Maxim - date code 1727
LM4050QAEM3-2.5/NOPB - from TI - date code 2118
LM4050QAEM3-2.5/NOPB - from TI - date code 1914
LT1009IDR - from TI - date code 1125
LT1009S8#TRPBF - from Analog Devices - date code 2029
LT1634AIS8-2.5#PBF - from Analog Devices - date code 2101
LT1634AIS8-2.5#PBF - from Analog Devices - date code 2046
TL1431QDREP - from TI - date code 2045
TL1431AIYDT - from ST - date code 2130
TL1431AIYDT - from ST - date code 2037
TL431BMFDT,215 - from Nexperia - date code 2140
TL431BMFDT,215 - from Nexperia - date code 1932
TL431AMFDT,215 - from Nexperia - date code 2020
TL431BIDMR2G - from ON - date code 1240
TLVH431BQDCKT - from TI - date code 1843
TLVH431AIL3T - from ST - date code 1929
TLVH431AIL5T - from ST - date code 1944
TS4061AICT-1.25 - from ST - date code 2032
TS4061AICT-1.25 - from ST - date code unknown
TS432AIX RFG - from Taiwan Semi - date code 2122
TS432ACX RFG - from Taiwan Semi - date code 1830


relative Vz deviation in biased condition @ I-typ
change of Vz in %
Total Dose in krad(Si)
LM4040QAIM3-2.5/NOPB - from TI - date code 1907
LM4040AIX3-2.5+T - from Maxim - date code 1630
LM4040AIX3-2.5+T - from Maxim - date code 1506
LM4040C25QFTA - from Diodes - date code 2110
LM4040C25QFTA - from Diodes - date code 2026
LM4041AIM3-1.2/NO - from TI - date code 1738
LM4041QAIM3-1.2/NO - from TI - date code 2018
LM4041AECT-1.2 - from ST - date code 1916
LM4041CFTA - from Diodes - date code 1950
LM4041CFTA - from Diodes - date code 2023
LM4041CYM3-1.2-TR - from Microchip - date code unknown
LM4041CYM3-1.2-TR - from Microchip - date code 2043
LM4041CYM3-1.2-TR - from Microchip - date code 2125
LM4041BIX3-1.2+T - from Maxim - date code 1727
LM4050QAEM3-2.5/NOPB - from TI - date code 2118
LM4050QAEM3-2.5/NOPB - from TI - date code 1914
LT1009IDR - from TI - date code 1125
LT1009S8#TRPBF - from Analog Devices - date code 2029
LT1634AIS8-2.5#PBF - from Analog Devices - date code 2101
LT1634AIS8-2.5#PBF - from Analog Devices - date code 2046
TL1431QDREP - from TI - date code 2045
TL1431AIYDT - from ST - date code 2130
TL1431AIYDT - from ST - date code 2037
TL431BMFDT,215 - from Nexperia - date code 2140
TL431BMFDT,215 - from Nexperia - date code 1932
TL431AMFDT,215 - from Nexperia - date code 2020
TL431BIDMR2G - from ON - date code 1240
TLVH431BQDCKT - from TI - date code 1843
TLVH431AIL3T - from ST - date code 1929
TLVH431AIL5T - from ST - date code 1944
TS4061AICT-1.25 - from ST - date code 2032
TS4061AICT-1.25 - from ST - date code unknown
TS432AIX RFG - from Taiwan Semi - date code 2122
TS432ACX RFG - from Taiwan Semi - date code 1830

9. CONCLUSION

All tested components with different date codes and from different manufacturers stayed inside specification limits up to a dose around 5 krad.

The deviation of tested components from the two different date codes shows a different behaviour in respect of TID effects.

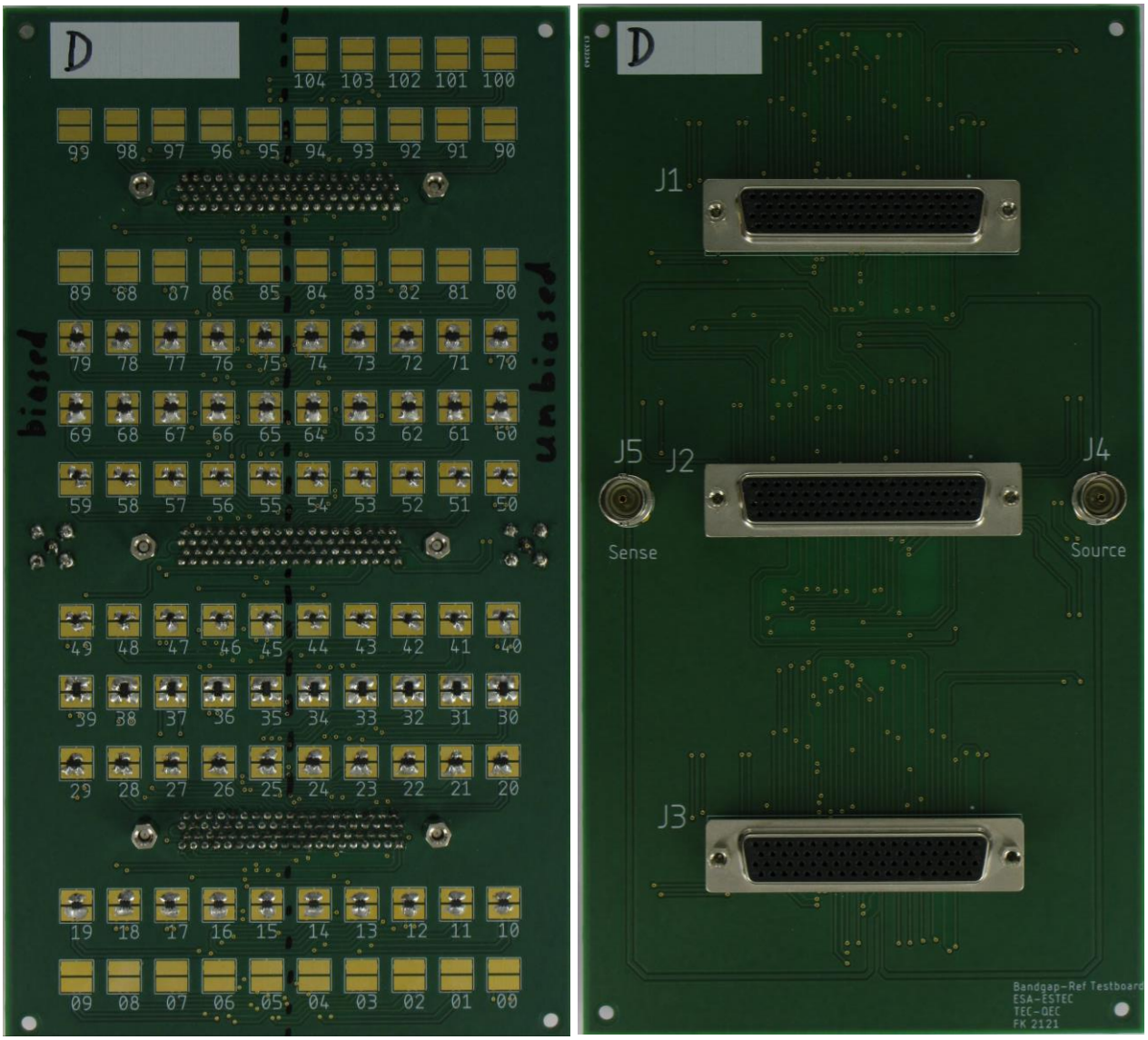
In general, a higher deviation was found for the samples in unbiased condition.

ANNEX A – DATASHEET

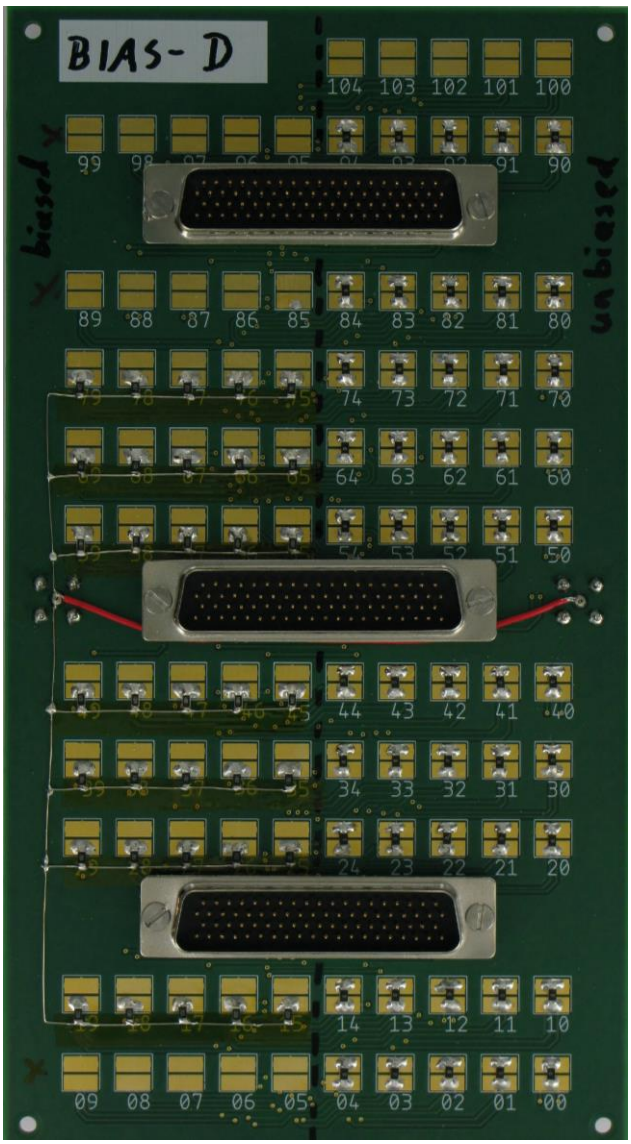
Part Type	Manufacturer	Link to Datasheet
TS432AIX RFG	Taiwan Semiconductor	https://www.taiwansemi.com/assets/uploads/datasheet/TS432_F15.pdf
TS432ACX RFG		

ANNEX B – SET-UP

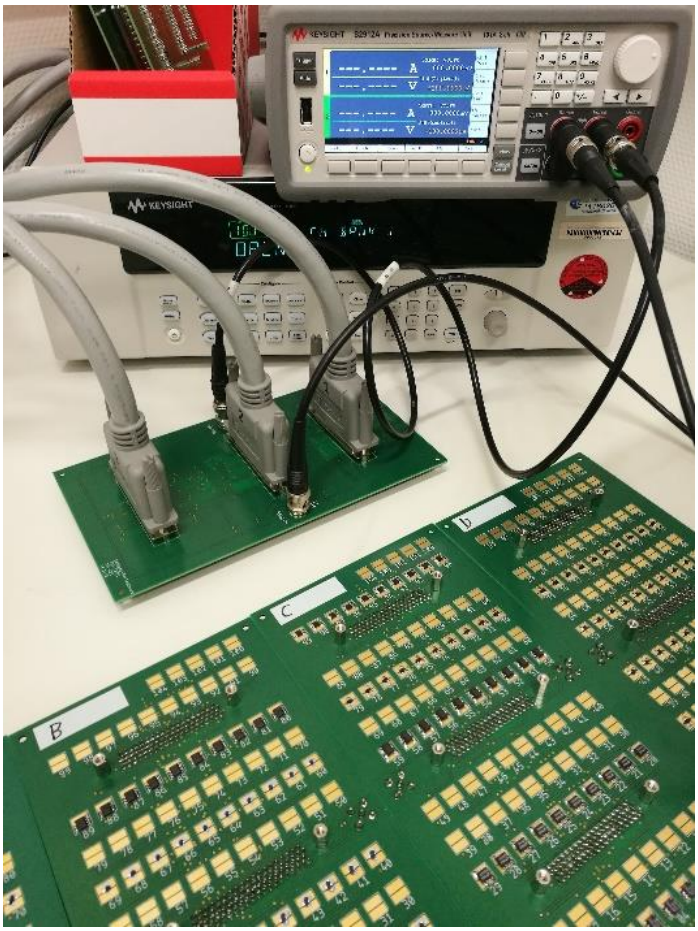
Test board front- and backside with the TS432 on position 60 to 79 on board D:



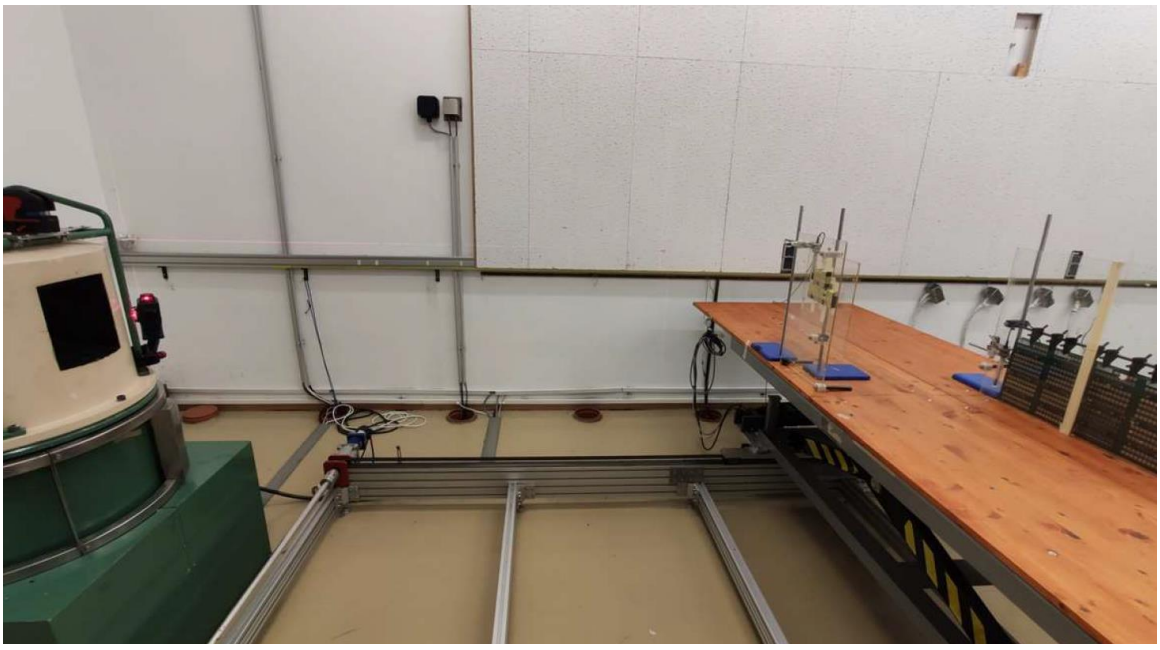
Biasing board front- and backside with the biasing resistors on it:

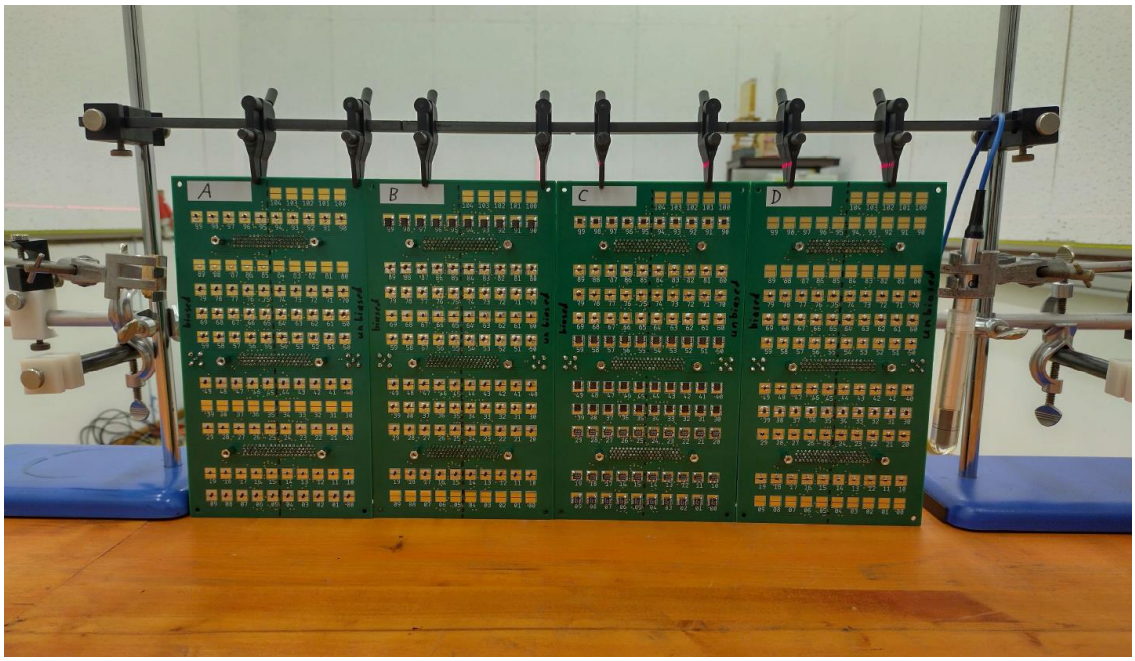


Measurement setup with the cable connection from the Test Board to the Switching Matrix and the Source Measure Unit:



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

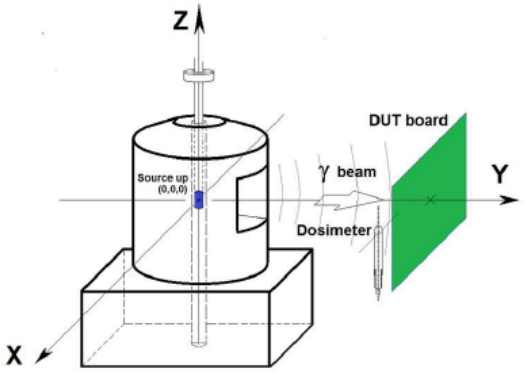


Figure 1 Co-60 irradiator head and board positioning sketch

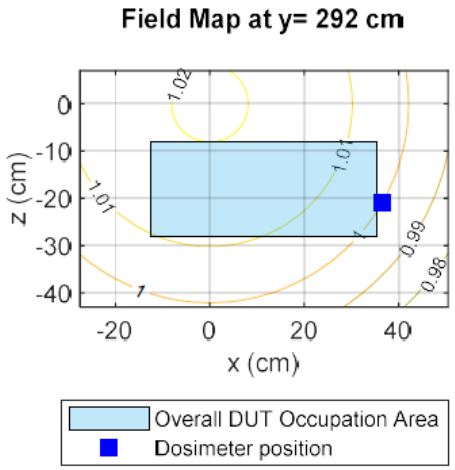


Figure 2: Qualitative indication of dose rate distribution normalized to dosemeter readings. Axes origin located at source centre. Graphs for information only, of the run with highest dose rate.