Radtest Ltd

Total dose radiation and electrical testing of 2N2222A bipolar transistors

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Title	Total dose radiation and electrical testing of 2N2222A bipolar transistors
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Contents

1 Introduction 4

2 Reference documents 4

3 Description of the components to be tested 4

3.1 PACKAGE PREPARATION 4
3.2 FUNCTIONAL DESCRIPTION OF THE SAMPLES 5
3.3 SAMPLE DISPOSITION 5

4 Parameters measured 6

5 Test conditions and hardware 7

5.1 TEST CONDITIONS 7
5.2 BIAS CONDITIONS DURING IRRADIATION 7
5.3 POST-IRRADIATION PROCEDURE 8
5.4 TEST INSTRUMENTATION 8

6 Radiation environment 9

6.1 RADIATION SOURCE 9
6.2 DOSIMETRY 9
6.3 RADIATION DOSE STEPS 9
6.4 RADIATION DOSE RATE 9

7 Results 10

7.1 $V_{BR(CBO)}$ 11
7.2 $V_{BR(CEO)}$ 12
7.3 $V_{BR(EBO)}$ 13
7.4 I_{CBO} 14
7.5 I_{EBO} 15
7.6 I_{CEX} 16
7.7 $V_{CE(SAT)}1$ 17
7.8 $V_{CE(SAT)}2$ 18
7.9 $V_{BE(SAT)}1$ 19
7.10 $V_{BE(SAT)}2$ 20
7.11 H_{FE} 21
7.12 TABULATED DATA 27

1 Introduction

Die Devices has contracted Radtest Ltd (“Radtest”) to undertake the electrical and total dose radiation testing of a set of 2N2222A bipolar transistors. This report describes the samples and the test procedure and summarises the results.

2 Reference documents

The following documents form part of and shall be read in conjunction with this report. The relevant issues shall be those in effect on the date of issue of this document.

RD1 Radtest Ltd quotation reference DIE0124, dated 22 January 2024;
RD2 Die Devices purchase order number SS1387;
RD3 ESCC basic specification no. 22900, issue 5, “Total dose steady-state irradiation test method”, June 2016;
RD4 Mil-Std-883, method 1019.9, “Ionizing Radiation (Total Dose) Test Procedure”;
RD5 “Total dose test plan for 2N2222A bipolar transistors for Die Devices”, Radtest Ltd test plan reference REP572, issue 2, dated 16/02/2024;
RD6 “NPN transistor bare die, 2N2222A”, Die Devices data sheet rev. 1.0, dated 02/09/17.

3 Description of the components to be tested

Manufacturer’s designation: 2N2222A
Manufacturer’s name: Die Devices
Manufacturer’s address: Trafalgar House, Tharston Industrial Estate, Norwich, NR15 2PD
Package designation: TO-39
Component family: bipolar transistor
Component group: NPN transistor
Component designation: 2N2222A
Generic test specification number: N/A
Detail test specification number: N/A
Datasheet reference: RD6

Sample size: five biased, five unbiased and one control sample
Wafer lot identification: 8AHP-1047 Wafer #2
Date code: 2415

3.1 PACKAGE PREPARATION

Figs. 1 shows the package and the labelling on the outside of the packaged samples, as received. Individual sample serial numbers were scribed onto each package prior to irradiation. No package preparation is required for total dose testing.

Fig. 1: set of samples

3.2 FUNCTIONAL DESCRIPTION OF THE SAMPLES

The 2N2222A is a low power NPN bipolar transistor.

3.3 SAMPLE DISPOSITION

Table 1 shows the selection of samples for the irradiation.

Sample number	To be used for
1	Control
2	Biased
3	Biased
5	Biased
6	Biased
7	Biased
8	Unbiased
9	Unbiased
11	Unbiased
12	Unbiased
13	Unbiased

Table 1: disposition of the test samples

4 Parameters measured

The following measurements were made, as listed in table 2. The DUTs were powered by low noise, ripple-free, Agilent B1500A SMUs during the measurements. All measurements were made to an accuracy of ±1% or better.

Parameter	Test conditions
$V_{BR(CBO)}$	I_C=10μA
$V_{BR(CEO)}$	I_C=10mA
$V_{BR(EBO)}$	I_E=10μA
I_{CBO}	V_{CB}=50V
I_{EBO}	V_{EB}=4V
I_{CEX}	V_{CE}=30V, V_{EB}=0.5V
$V_{CE(sat)}$ pulsed	IB=15mA, I_C=150mA IB=50mA, I_C=500mA
$V_{BE(sat)}$ pulsed	IB=15mA, I_C=150mA IB=50mA, I_C=500mA
hFE	V_{CE}=10V, I_C=0.1mA V_{CE}=10V, I_C=1mA V_{CE}=10V, I_C=10mA V_{CE}=10V, I_C=150mA pulsed V_{CE}=1V, I_C=100mA V_{CE}=10V, I_C=500mA pulsed

Table 2: list of electrical parameters measured

5 Test conditions and hardware

5.1 TEST CONDITIONS

Electrical testing was undertaken before irradiation and after each of six dose steps and two annealing stages, as listed in table 3. This test was carried out with electrical measurements conducted in the not in-flux manner. Electrical bias was removed from the samples and the samples were transported on the bias board between the irradiation facility and the measurement facility and back again for the next irradiation.

5.2 BIAS CONDITIONS DURING IRRADIATION

The custom bias board comprised ten individual sockets, as shown in fig. 2. Samples 2 to 6 were irradiated under the electrical bias condition shown in fig. 3 (‘biased on’). Samples 7 to 11 were irradiated with their leads electrically shorted together (‘biased off’).

The supply voltage and current were monitored at intervals of one minute during irradiation. No deviations were observed.

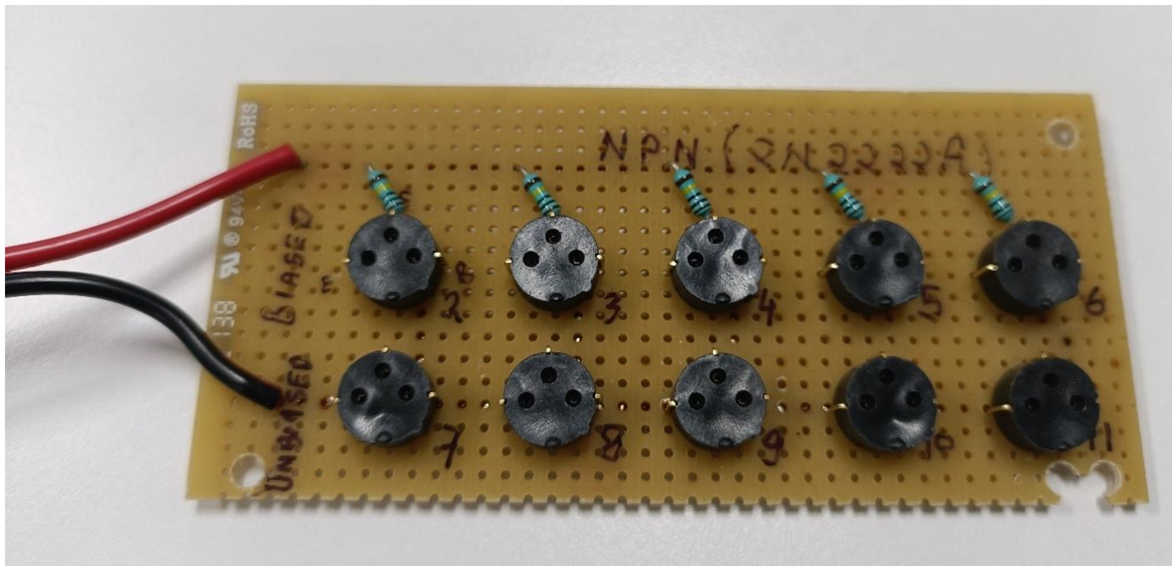


Fig. 2: the bias board used for this work

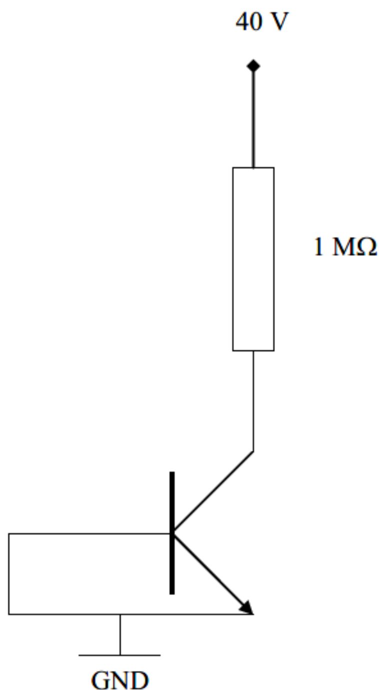


Fig. 2: bias arrangement during irradiation

5.3 POST-IRRADIATION PROCEDURE

In accordance with RD3, the time between the end of an irradiation and the start of the electrical measurements was no more than one hour. The time to perform the electrical measurements and to return the devices for the subsequent irradiation, if any, was no more than two hours from the end of the previous irradiation.

The sequence of electrical measurements was the same for each set of measurements made.

5.4 TEST INSTRUMENTATION

Table 3 lists the test instruments used during the work and provides details of their calibration status.

Code	Manufacturer	Description	Serial no	Date last calibrated	Date next calibration due
DS01	PTW	Unidos E dosemeter	1250	16/09/2022	16/09/2024
DS03	PTW	TN31010 ion chamber	5937	14/09/2022	14/09/2024
ET01	Agilent	B1500A parameter analyser	JP49320110	07/03/2024	07/03/2025
ET34	Lufft	Opus 20 barometer	169.0314.0802.022	27/06/2023	27/06/2024

Table 3: list of calibrated instruments used for the work.

6 Radiation environment

6.1 RADIATION SOURCE

MRC Cell 4 at Harwell was used for the irradiation. This facility is fitted with four cobalt-60 sources emitting gamma radiation with a mean energy of 1.25MeV/photon. All four sources were used for this work.

6.2 DOSIMETRY

The dose rate was determined by measurements with a TN31010-1 ionisation chamber, manufactured by PTW and allocated the reference number DS03 in Radtest's calibration register, in conjunction with a Unidos E reader, reference number DS01. These measurements were made on 14 March 2024.

6.3 RADIATION DOSE STEPS

Table 4 lists the start and end times for each irradiation and both annealing stages. All irradiations were carried out on 20 March 2024.

Level	Dose step (krad[Si])	Start date/time	End date/time
1	1	20/03/24 07:45:00	20/03/24 07:45:17
2	10	20/03/24 09:31:22	20/03/24 09:34:20
3	25	20/03/24 11:01:30	20/03/24 11:06:22
4	40	20/03/24 12:35:00	20/03/24 12:39:52
5	50	20/03/24 14:16:00	20/03/24 14:19:15
6	100	20/03/24 15:34:30	20/03/24 15:50:43

Table 4: radiation test levels and times

6.4 RADIATION DOSE RATE

The measured dose rate was 2.07 kGy[H_2O]/hr, with an uncertainty of ± 10%. This dose rate was converted to silicon as a reference material by multiplying by a factor of 0.916, giving a dose rate of 1.90 kGy[Si]/hr or 190 krad[Si]/hr.

The irradiation sequence covered a period of less than 24 hours and so no correction for the decay of the radioisotope was applied.

7 Results

The results are presented firstly as graphs of each parameter, with data for each test sample at each dose step. Data for the control samples are indicated by a black line. Data for the irradiated samples are shown as red ('biased on') or blue ('biased off') lines.

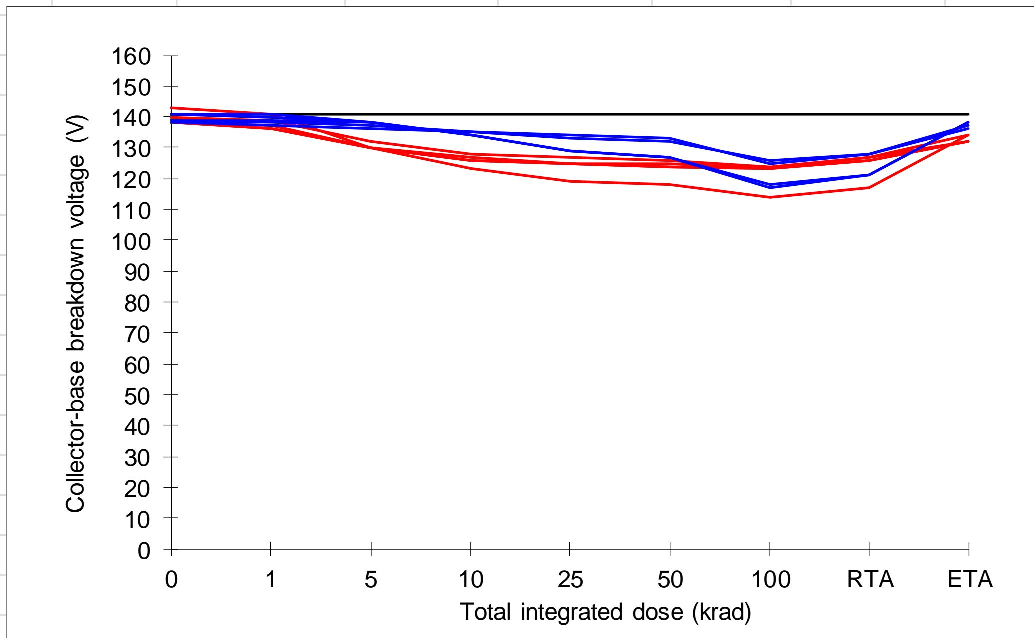
Secondly, the results are presented in tabular format, with the measured data from each dose step shown as an individual table page.

For all of the parameters except gain, at no point during the work did any of the test samples show a measurement result that fell outside of the specification limits. For gain, there were some out of specification measurement results after 100krad and the room temperature anneal for collector current values of 0.1, 1, 10 and 150mA. However, these all recovered to be back within specification after the elevated temperature anneal, except for one sample. This sample had a measured value of gain of 34 at a collector current of 0.1mA, compared with the specification limit of 35.

A mechanical problem was encountered with sample number 8 at the 25krad dose step. The cap of the package became detached from the base and all electrical measurements failed, suggesting that one or more bond wires had become broken. Subsequently, two further devices suffered a similar event, although no change in the electrical measurements was noted for these. This mechanical issue was clearly not radiation-related but no data are available for this sample at higher doses.

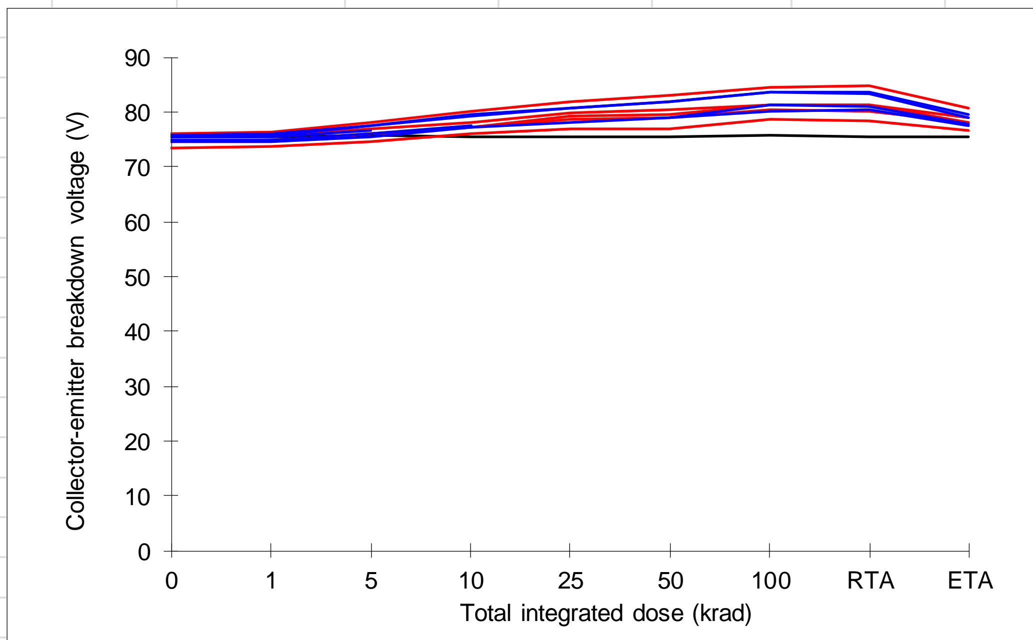
7.1 $V_{BR(CBO)}$

Type number:	2N2222A	Test dates: 14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples: 1/10
Manufacturer:	Die Devices	Spec. Min. 75V
Parameter:	Collector-base breakdown voltage (I_C=10µA)	
Test equipment:	B1500A	
Ambient temperature during irradiation:	20°C	
Radiation source:	MRC cell 4, Harwell, UK	
Radiation type:	Gamma	
Energy:	1.25 MeV/photon	
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased	



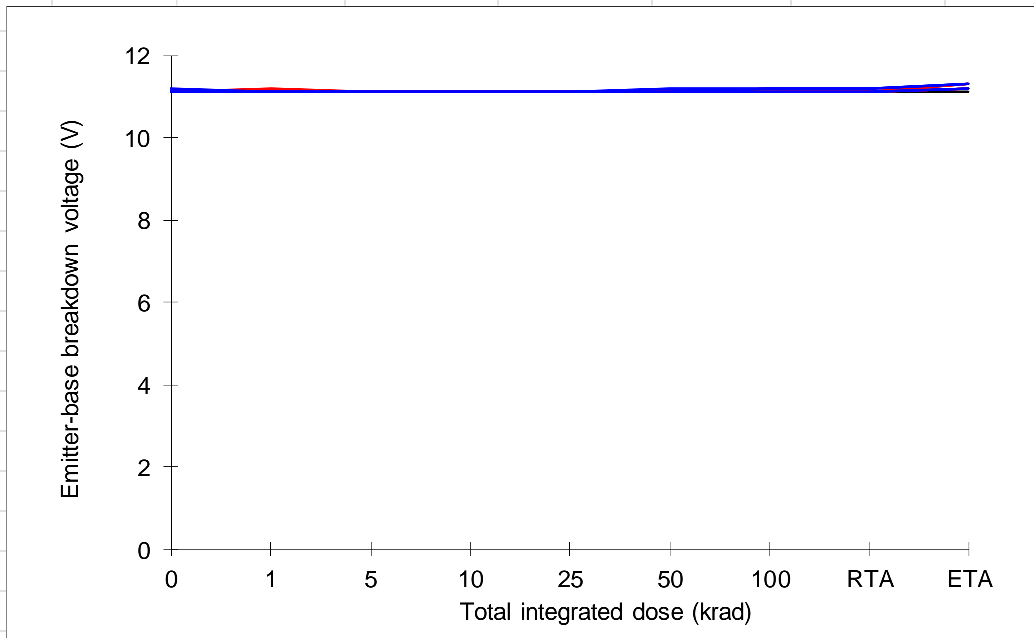
7.2 $V_{BR(CEO)}$

Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Min. 40V
Parameter:	Collector-emitter breakdown voltage (I_C=10mA)		
Test equipment:	B1500A		
Ambient temperature during irradiation:	20°C		
Radiation source:	MRC cell 4, Harwell, UK		
Radiation type:	Gamma		
Energy:	1.25 MeV/photon		
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased		



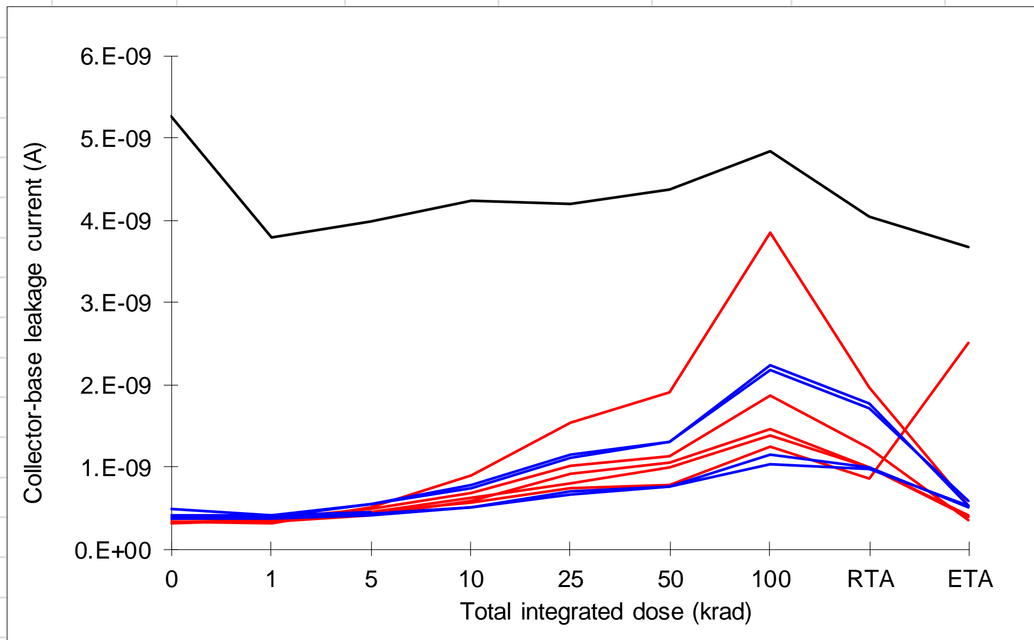
7.3 $V_{BR(EBO)}$

Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Min. 6V
Parameter:	Emitter-base breakdown voltage (I_E=10μA)		
Test equipment:	B1500A		
Ambient temperature during irradiation:	20°C		
Radiation source:	MRC cell 4, Harwell, UK		
Radiation type:	Gamma		
Energy:	1.25 MeV/photon		
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased		



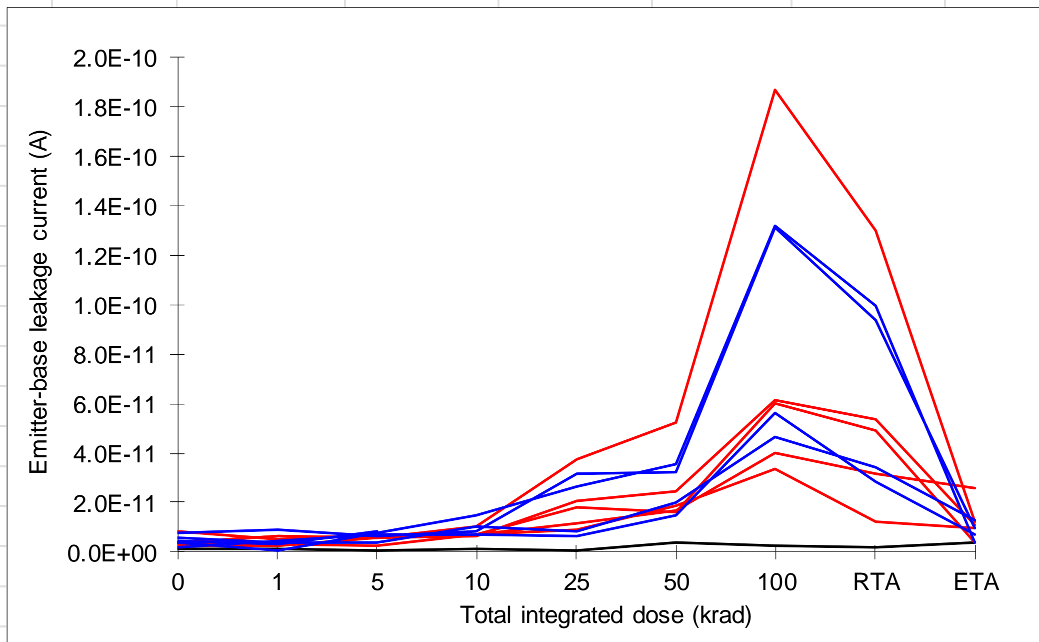
7.4 I_{CBO}

Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Max. 10nA
Parameter:	Collector-base leakage current (V_{CB}=60V)		
Test equipment:	B1500A		
Ambient temperature during irradiation:	20°C		
Radiation source:	MRC cell 4, Harwell, UK		
Radiation type:	Gamma		
Energy:	1.25 MeV/photon		
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased		



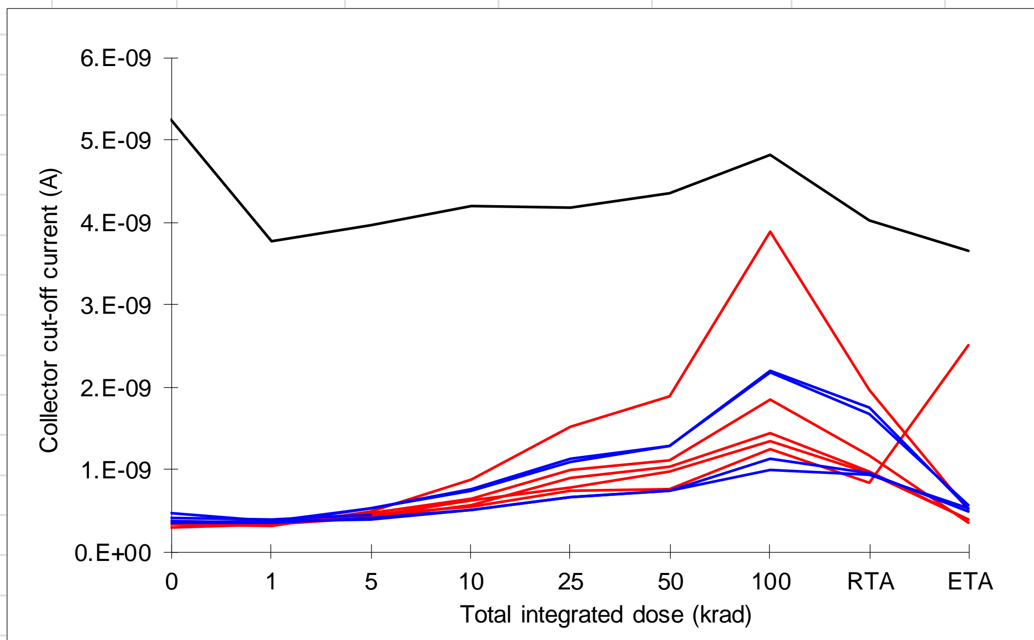
7.5 I_{EBO}

Type number:	2N2222A		Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor		Samples:	1/10
Manufacturer:	Die Devices		Spec.	Max. 100nA
Parameter:	Emitter-base leakage current (V_{EB}=3V)			
Test equipment:	B1500A			
Ambient temperature during irradiation:		20°C		
Radiation source:	MRC cell 4, Harwell, UK			
Radiation type:	Gamma			
Energy:	1.25 MeV/photon			
Electrical conditions during irradiation:		Devices 2 - 6 biased, 7 - 11 unbiased		



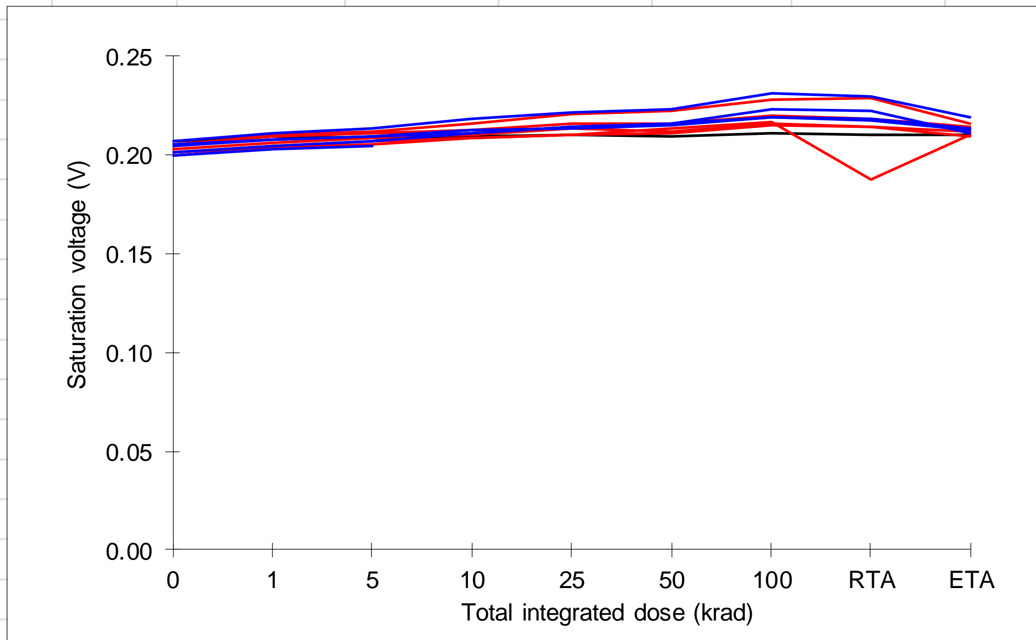
7.6 I_{CEX}

Type number:	2N2222A		Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor		Samples:	1/10
Manufacturer:	Die Devices		Spec.	Max. 10nA
Parameter:	Collector cut-off current (V_{CE}=60V, V_{EB}=3V)			
Test equipment:	B1500A			
Ambient temperature during irradiation:		20°C		
Radiation source:	MRC cell 4, Harwell, UK			
Radiation type:	Gamma			
Energy:	1.25 MeV/photon			
Electrical conditions during irradiation:		Devices 2 - 6 biased, 7 - 11 unbiased		



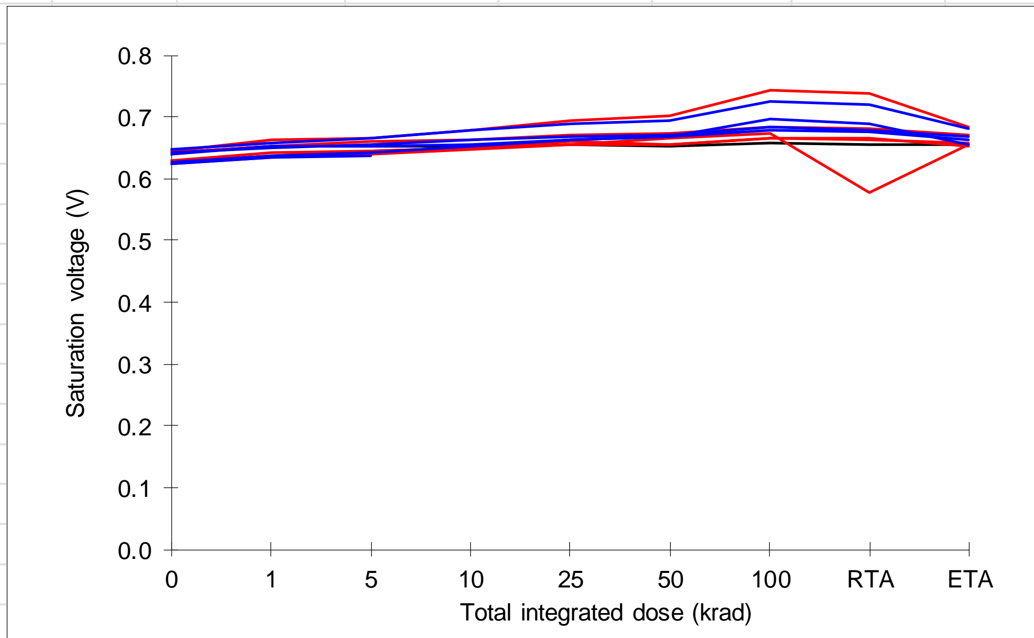
7.7 $V_{CE(SAT)}$1

Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Max. 0.3V
Parameter:	$V_{CE(sat)}$ saturation voltage (I_B=15mA, I_C=150mA)		
Test equipment:	B1500A		
Ambient temperature during irradiation:	20°C		
Radiation source:	MRC cell 4, Harwell, UK		
Radiation type:	Gamma		
Energy:	1.25 MeV/photon		
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased		



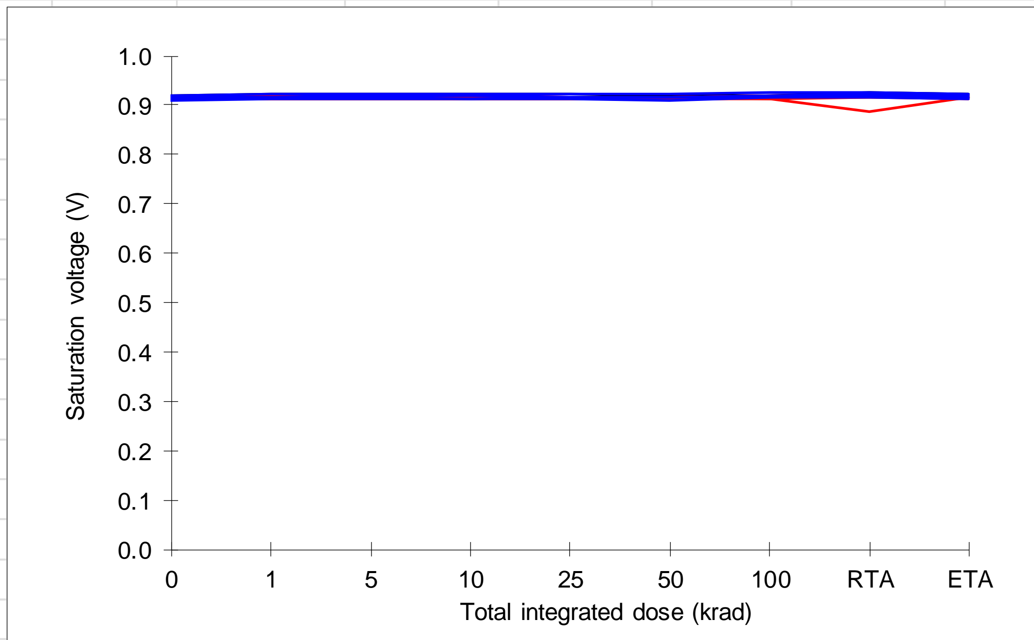
7.8 $V_{CE(SAT)}2$

Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Max. 1.0V
Parameter:	$V_{CE(sat)}$ saturation voltage (I_B=50mA, I_C=500mA)		
Test equipment:	B1500A		
Ambient temperature during irradiation:	20°C		
Radiation source:	MRC cell 4, Harwell, UK		
Radiation type:	Gamma		
Energy:	1.25 MeV/photon		
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased		



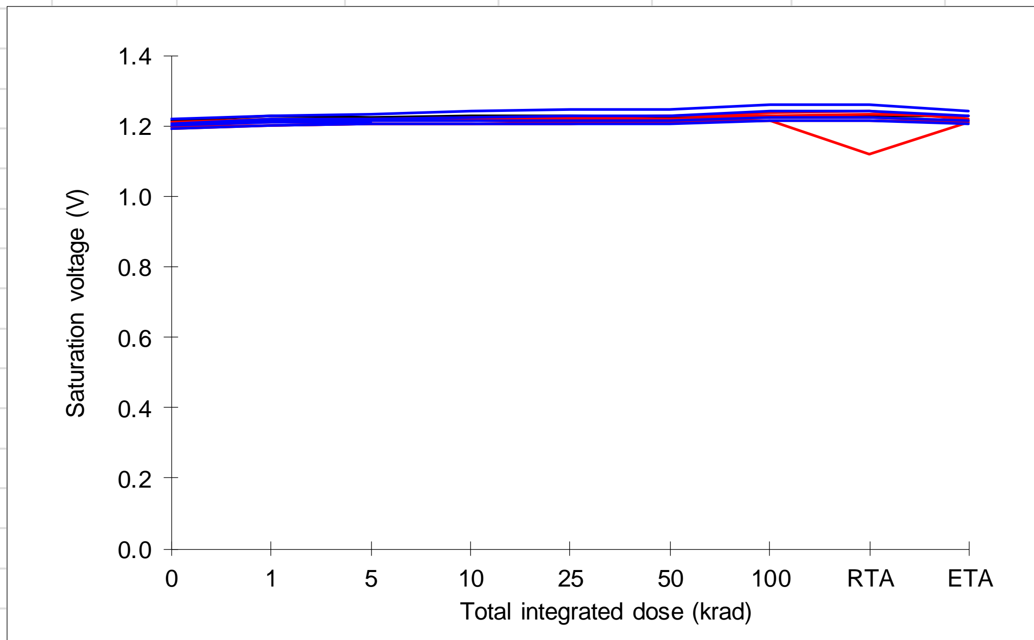
7.9 $V_{BE(SAT)}$1

Type number:	2N2222A	Test dates: 14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples: 1/10
Manufacturer:	Die Devices	Spec. Min. 0.6V, max. 1.2V
Parameter:	$V_{BE(sat)}$ saturation voltage (I_B=15mA, I_C=150mA)	
Test equipment:	B1500A	
Ambient temperature during irradiation:	20°C	
Radiation source:	MRC cell 4, Harwell, UK	
Radiation type:	Gamma	
Energy:	1.25 MeV/photon	
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased	



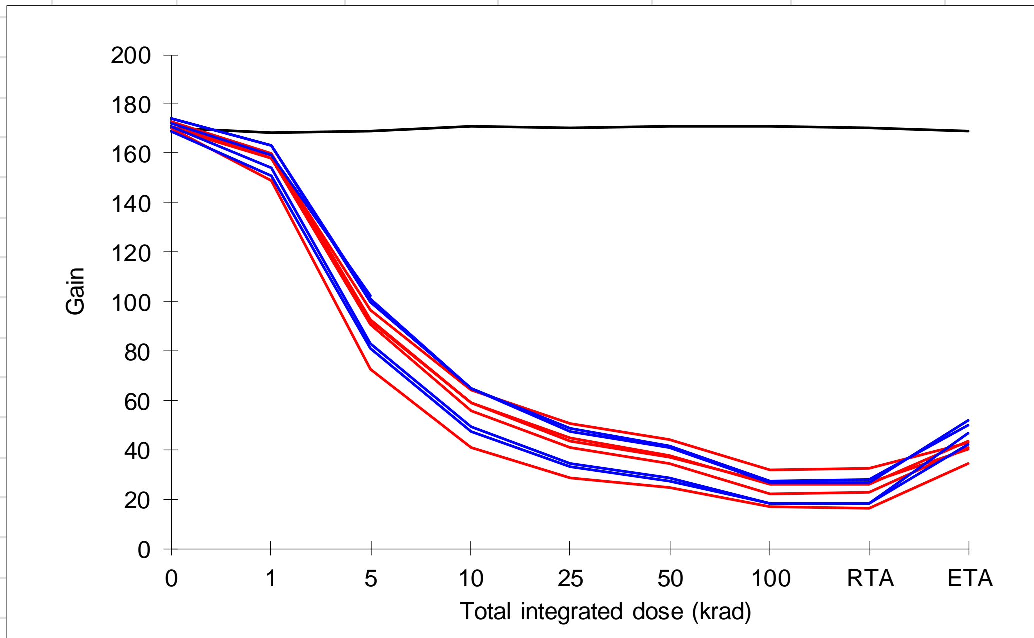
7.10 $V_{BE(SAT)}2$

Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Max. 2.0V
Parameter:	$V_{BE(sat)}$ saturation voltage (I_B=50mA, I_C=500mA)		
Test equipment:	B1500A		
Ambient temperature during irradiation:	20°C		
Radiation source:	MRC cell 4, Harwell, UK		
Radiation type:	Gamma		
Energy:	1.25 MeV/photon		
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased		

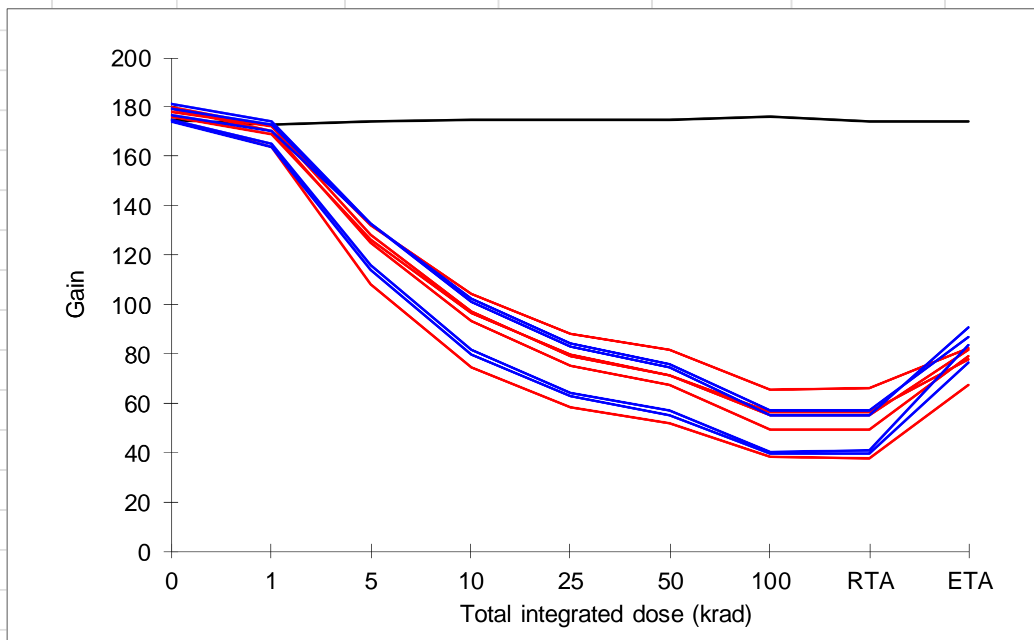


7.11 H_{FE}

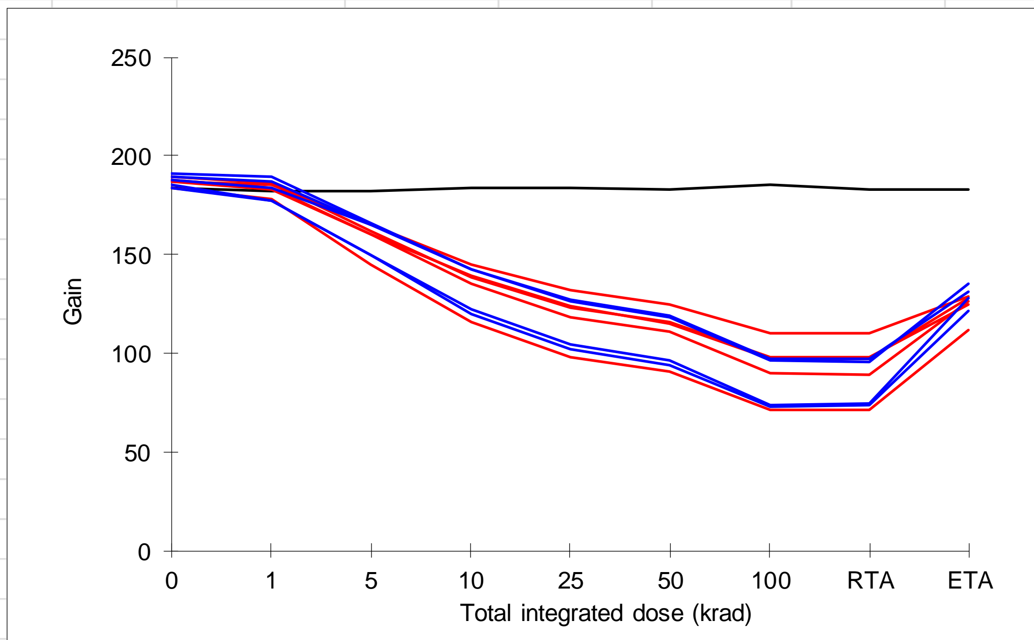
Type number:	2N2222A		Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor		Samples:	1/10
Manufacturer:	Die Devices		Spec.	Min. 35
Parameter:	hFE gain (V_{CE}=10V, I_C=0.1mA)			
Test equipment:	B1500A			
Ambient temperature during irradiation:		20°C		
Radiation source:	MRC cell 4, Harwell, UK			
Radiation type:	Gamma			
Energy:	1.25 MeV/photon			
Electrical conditions during irradiation:		Devices 2 - 6 biased, 7 - 11 unbiased		



Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Min. 50
Parameter:	hFE gain (V_{CE}=10V, I_C=1mA)		
Test equipment:	B1500A		
Ambient temperature during irradiation:	20°C		
Radiation source:	MRC cell 4, Harwell, UK		
Radiation type:	Gamma		
Energy:	1.25 MeV/photon		
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased		

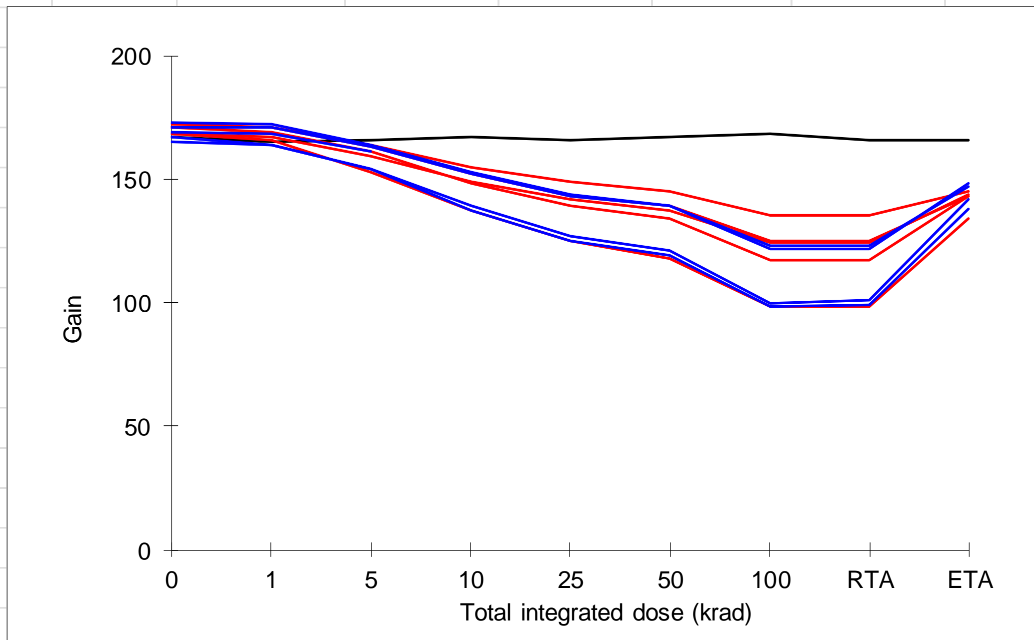


Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Min. 75
Parameter:	hFE gain (V_{CE}=10V, I_C=10mA)		
Test equipment:	B1500A		
Ambient temperature during irradiation:	20°C		
Radiation source:	MRC cell 4, Harwell, UK		
Radiation type:	Gamma		
Energy:	1.25 MeV/photon		
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased		



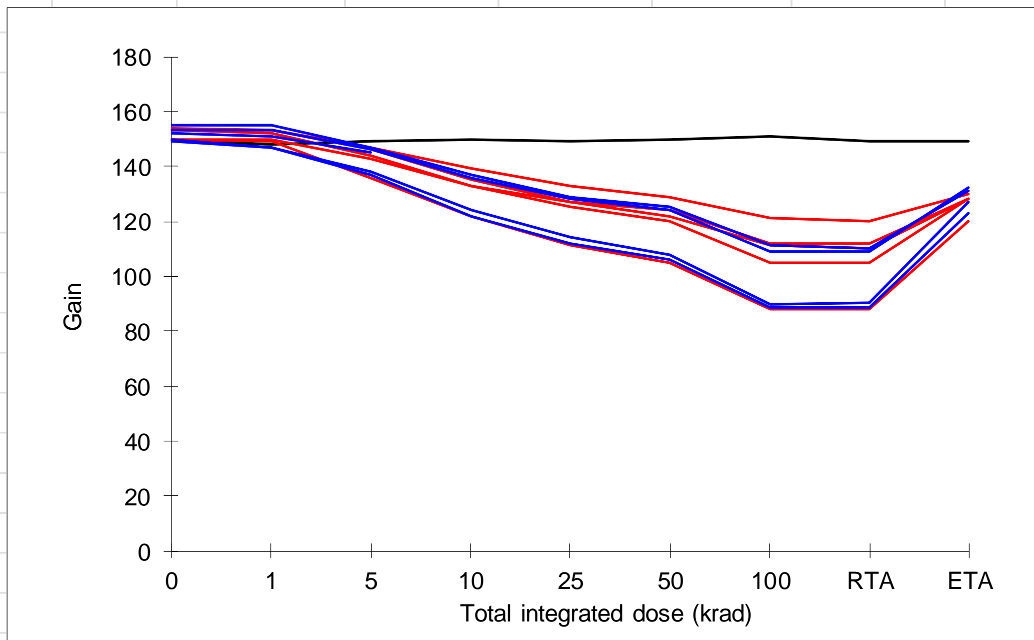
Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Min. 100, max. 300

Parameter:	hFE gain (V_{CE}=10V, I_C=150mA)
Test equipment:	B1500A
Ambient temperature during irradiation:	20°C
Radiation source:	MRC cell 4, Harwell, UK
Radiation type:	Gamma
Energy:	1.25 MeV/photon
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased



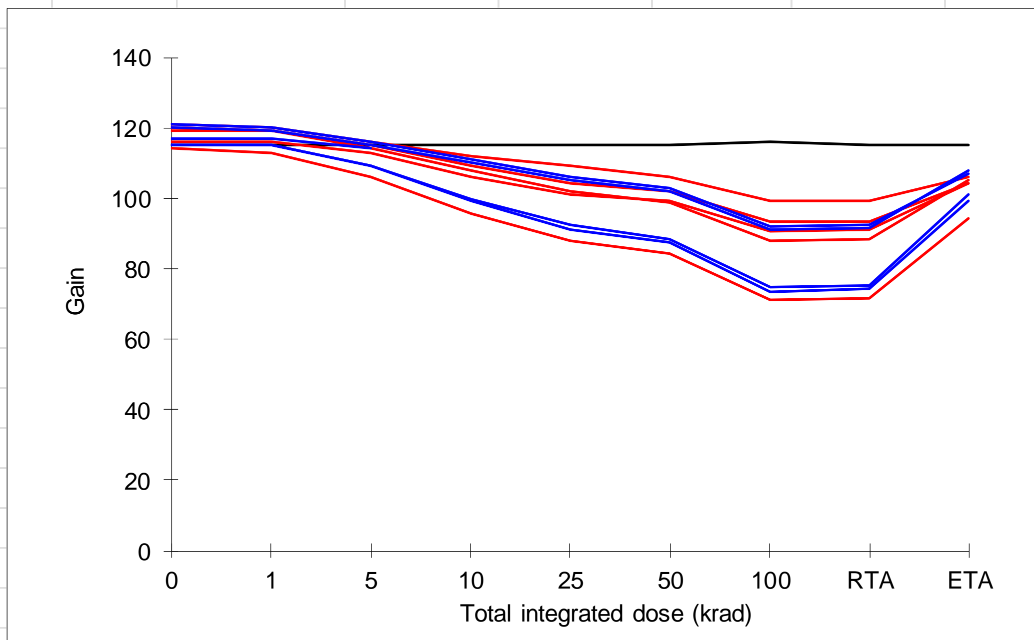
Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Min. 50

Parameter:	hFE gain (V_{CE}=1V, I_C=100mA)
Test equipment:	B1500A
Ambient temperature during irradiation:	20°C
Radiation source:	MRC cell 4, Harwell, UK
Radiation type:	Gamma
Energy:	1.25 MeV/photon
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased



Type number:	2N2222A	Test dates:	14/03/2024 - 28/03/2024
Category:	NPN bipolar transistor	Samples:	1/10
Manufacturer:	Die Devices	Spec.	Min. 40

Parameter:	hFE gain (V_{CE}=10V, I_C=500mA)
Test equipment:	B1500A
Ambient temperature during irradiation:	20°C
Radiation source:	MRC cell 4, Harwell, UK
Radiation type:	Gamma
Energy:	1.25 MeV/photon
Electrical conditions during irradiation:	Devices 2 - 6 biased, 7 - 11 unbiased



7.12 TABULATED DATA

Type number:	2N2222A	Test number:	1
Category:	NPN bipolar transistor	Date:	14/03/2024
Manufacturer:	Die Devices	Time:	15:44
Date code:	N/K	Total integrated dose:	0 krad
Test equipment:	B1500A	Time since irradiation:	-
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		I_{EBO} A ± 1%	I_{CBO} A ± 1%	I_{CEX} A ± 1%	$V_{(BR)EBO}$ V ± 1%	$V_{(BR)CBO}$ V ± 1%	$V_{(BR)CEO}$ V ± 1%
1	Control	1.05E-12	5.27E-09	5.25E-09	11.10	141	76
2		2.45E-12	3.38E-10	3.28E-10	11.10	143	76
3		3.70E-12	3.72E-10	3.64E-10	11.10	138	75
5		3.70E-12	3.11E-10	3.00E-10	11.10	138	74
6		3.15E-12	3.37E-10	3.45E-10	11.10	140	76
7		8.05E-12	3.72E-10	3.59E-10	11.10	138	75
8		4.25E-12	4.08E-10	4.03E-10	11.10	139	75
9		7.40E-12	4.81E-10	4.73E-10	11.10	141	76
11		5.40E-12	3.64E-10	3.55E-10	11.10	139	75
12		3.90E-12	3.86E-10	3.61E-10	11.10	141	76
13		1.65E-12	3.71E-10	3.55E-10	11.20	138	75

DUT		$V_{CE(sat)}1$ V ± 1%	$V_{CE(sat)}2$ V ± 1%	$V_{BE(sat)}1$ V ± 1%	$V_{BE(sat)}2$ V ± 1%
1	Control	0.207	0.642	0.918	1.216
2		0.205	0.645	0.914	1.201
3		0.202	0.627	0.912	1.192
5		0.203	0.630	0.913	1.196
6		0.200	0.624	0.917	1.210
7		0.206	0.642	0.913	1.202
8		0.200	0.624	0.913	1.200
9		0.201	0.627	0.915	1.206
11		0.205	0.638	0.915	1.203
12		0.207	0.647	0.920	1.221
13		0.205	0.641	0.910	1.193

Tested by: NG

Type number:	2N2222A	Test number:	1
Category:	NPN bipolar transistor	Date:	14/03/2024
Manufacturer:	Die Devices	Time:	15:44
Date code:	N/K	Total integrated dose:	0 krad
Test equipment:	B1500A	Time since irradiation:	-
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	170	175	184	167	150	115
2		170	175	184	168	150	114
3		173	179	188	171	153	119
5		171	178	187	171	153	121
6		170	176	187	168	150	116
7		173	180	189	172	154	120
8		172	177	188	169	152	117
9		171	175	185	167	150	115
11		174	179	189	171	153	120
12		169	174	184	165	149	115
13		174	181	191	173	155	121

Tested by: NG

Type number:	2N2222A	Test number:	2
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	08:27
Date code:	N/K	Total integrated dose:	1 krad
Test equipment:	B1500A	Time since irradiation:	0h 42m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		I_{EBO} A ± 1%	I_{CBO} A ± 1%	I_{CEX} A ± 1%	$V_{(BR)EBO}$ V ± 1%	$V_{(BR)CBO}$ V ± 1%	$V_{(BR)CEO}$ V ± 1%
1	Control	1.10E-12	3.79E-09	3.76E-09	11.10	141	76
2		2.80E-12	3.20E-10	3.09E-10	11.10	141	76
3		6.25E-12	3.65E-10	3.55E-10	11.10	136	75
5		6.15E-12	3.50E-10	3.39E-10	11.20	137	74
6		3.35E-12	3.38E-10	3.28E-10	11.10	139	76
7		5.30E-12	3.44E-10	3.28E-10	11.10	136	75
8		2.85E-12	4.00E-10	3.85E-10	11.10	139	75
9		8.75E-12	4.02E-10	3.76E-10	11.10	141	76
11		3.85E-12	3.77E-10	3.69E-10	11.10	138	75
12		8.00E-13	3.85E-10	3.47E-10	11.10	140	76
13		4.40E-12	3.83E-10	3.46E-10	11.10	137	75

DUT		$V_{CE(sat)}1$ V ± 1%	$V_{CE(sat)}2$ V ± 1%	$V_{BE(sat)}1$ V ± 1%	$V_{BE(sat)}2$ V ± 1%
1	Control	0.210	0.652	0.923	1.228
2		0.210	0.663	0.918	1.214
3		0.205	0.637	0.914	1.201
5		0.206	0.641	0.913	1.202
6		0.204	0.635	0.919	1.218
7		0.209	0.653	0.917	1.212
8		0.203	0.633	0.916	1.208
9		0.205	0.636	0.917	1.217
11		0.208	0.651	0.917	1.213
12		0.211	0.657	0.922	1.229
13		0.208	0.650	0.913	1.201

Tested by: NG

Type number:	2N2222A	Test number:	2
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	08:27
Date code:	N/K	Total integrated dose:	1 krad
Test equipment:	B1500A	Time since irradiation:	0h 42m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	168	173	182	165	148	115
2		149	164	178	166	149	113
3		158	170	184	169	152	119
5		159	172	185	171	153	120
6		158	169	183	167	150	116
7		160	172	186	171	153	119
8		159	170	184	168	151	117
9		154	165	177	164	147	115
11		163	173	187	171	153	119
12		151	164	177	164	147	115
13		163	174	189	172	155	120

Tested by: NG

Type number:	2N2222A	Test number:	3
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	09:52
Date code:	N/K	Total integrated dose:	10 krad
Test equipment:	B1500A	Time since irradiation:	0h 18m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		I_{EBO}	I_{CBO}	I_{CEX}	$V_{(BR)EBO}$	$V_{(BR)CBO}$	$V_{(BR)CEO}$
		A ± 1%	A ± 1%	A ± 1%	V ± 1%	V ± 1%	V ± 1%
1	Control	8.50E-13	3.98E-09	3.96E-09	11.10	141	76
2		5.50E-12	5.01E-10	4.87E-10	11.10	130	78
3		5.45E-12	4.78E-10	4.67E-10	11.10	130	76
5		5.40E-12	4.55E-10	4.43E-10	11.10	130	75
6		2.70E-12	4.15E-10	4.06E-10	11.10	132	77
7		6.95E-12	4.45E-10	4.33E-10	11.10	130	76
8		8.55E-12	4.55E-10	4.52E-10	11.10	138	77
9		6.30E-12	5.44E-10	5.25E-10	11.10	138	78
11		3.90E-12	4.12E-10	3.97E-10	11.10	137	76
12		7.35E-12	5.37E-10	5.25E-10	11.10	138	78
13		6.85E-12	4.30E-10	4.16E-10	11.10	136	75

DUT		$V_{CE(sat)}1$	$V_{CE(sat)}2$	$V_{BE(sat)}1$	$V_{BE(sat)}2$
		V ± 1%	V ± 1%	V ± 1%	V ± 1%
1	Control	0.209	0.652	0.923	1.225
2		0.212	0.666	0.916	1.214
3		0.207	0.646	0.912	1.203
5		0.209	0.645	0.913	1.203
6		0.205	0.640	0.919	1.218
7		0.211	0.660	0.916	1.213
8		0.205	0.637	0.916	1.210
9		0.207	0.641	0.918	1.217
11		0.210	0.653	0.916	1.213
12		0.214	0.666	0.921	1.233
13		0.210	0.655	0.913	1.203

Tested by: NG

Type number:	2N2222A	Test number:	3
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	09:52
Date code:	N/K	Total integrated dose:	10 krad
Test equipment:	B1500A	Time since irradiation:	0h 18m
Test program:	-		
Parameters tested:	Multiple parameters		

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	169	174	182	166	149	115
2		73	108	145	153	136	106
3		90	125	160	161	144	114
5		97	132	165	164	147	116
6		92	126	160	159	143	113
7		93	128	162	163	146	115
8		102	133	165	161	145	114
9		83	116	150	154	138	109
11		101	133	165	163	146	115
12		81	114	150	154	137	109
13		100	133	166	164	147	116

Tested by: NG

Type number:	2N2222A	Test number:	4		
Category:	NPN bipolar transistor	Date:	20/03/2024		
Manufacturer:	Die Devices	Time:	11:20		
Date code:	N/K	Total integrated dose:		25 krad	
Test equipment:	B1500A	Time since irradiation:		0h 14m	
Test program:	DIE 2N2222A test V1-00				
Parameters tested:	Multiple parameters				

DUT		I_{EBO}	I_{CBO}	I_{CEX}	$V_{(BR)EBO}$	$V_{(BR)CBO}$	$V_{(BR)CEO}$
		A ± 1%	A ± 1%	A ± 1%	V ± 1%	V ± 1%	V ± 1%
1	Control	1.00E-12	4.23E-09	4.20E-09	11.10	141	76
2		1.00E-11	8.99E-10	8.82E-10	11.10	123	80
3		6.10E-12	6.85E-10	6.43E-10	11.10	127	77
5		6.80E-12	5.61E-10	5.48E-10	11.10	126	76
6		6.85E-12	5.73E-10	5.58E-10	11.10	128	78
7		7.10E-12	6.23E-10	6.14E-10	11.10	126	77
8							
9		8.60E-12	7.45E-10	7.39E-10	11.10	134	79
11		1.01E-11	5.12E-10	5.08E-10	11.10	135	78
12		1.47E-11	7.76E-10	7.55E-10	11.10	134	79
13		6.95E-12	5.14E-10	4.97E-10	11.10	135	77

DUT		$V_{CE(sat)}1$	$V_{CE(sat)}2$	$V_{BE(sat)}1$	$V_{BE(sat)}2$
		V ± 1%	V ± 1%	V ± 1%	V ± 1%
1	Control	0.209	0.653	0.921	1.226
2		0.216	0.678	0.916	1.217
3		0.209	0.649	0.912	1.204
5		0.210	0.649	0.913	1.204
6		0.208	0.648	0.919	1.223
7		0.213	0.664	0.916	1.215
8					
9		0.211	0.653	0.918	1.223
11		0.211	0.656	0.914	1.212
12		0.218	0.679	0.922	1.242
13		0.213	0.662	0.913	1.206

Tested by: NG

Type number:	2N2222A	Test number:	4
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	11:20
Date code:	N/K	Total integrated dose:	25 krad
Test equipment:	B1500A	Time since irradiation:	0h 14m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	171	175	184	167	150	115
2		41	74	116	137	122	96
3		56	93	135	148	133	108
5		64	104	145	155	139	112
6		59	96	139	149	133	106
7		59	97	138	152	135	109
8							
9		49	82	122	139	124	100
11		65	101	142	152	136	110
12		47	80	120	137	122	99
13		65	102	142	153	137	111

Tested by: NG

Type number:	2N2222A	Test number:	5
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	12:57
Date code:	N/K	Total integrated dose:	40 krad
Test equipment:	B1500A	Time since irradiation:	0h 18m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		I_{EBO} A ± 1%	I_{CBO} A ± 1%	I_{CEX} A ± 1%	$V_{(BR)EBO}$ V ± 1%	$V_{(BR)CBO}$ V ± 1%	$V_{(BR)CEO}$ V ± 1%
1	Control	3.00E-13	4.19E-09	4.17E-09	11.10	141	75
2		3.74E-11	1.53E-09	1.51E-09	11.10	119	82
3		2.04E-11	1.01E-09	9.84E-10	11.10	125	79
5		8.80E-12	7.45E-10	7.31E-10	11.10	125	77
6		1.80E-11	9.12E-10	8.84E-10	11.10	127	80
7		1.18E-11	7.92E-10	7.76E-10	11.10	125	79
8							
9		3.13E-11	1.11E-09	1.08E-09	11.10	129	81
11		8.20E-12	6.68E-10	6.57E-10	11.10	133	0
12		2.67E-11	1.15E-09	1.13E-09	11.10	129	81
13		6.05E-12	6.96E-10	6.54E-10	11.10	134	78

DUT		$V_{CE(sat)}1$ V ± 1%	$V_{CE(sat)}2$ V ± 1%	$V_{BE(sat)}1$ V ± 1%	$V_{BE(sat)}2$ V ± 1%
1	Control	0.210	0.656	0.922	1.227
2		0.221	0.694	0.916	1.223
3		0.210	0.656	0.913	1.206
5		0.214	0.660	0.914	1.211
6		0.210	0.654	0.916	1.225
7		0.216	0.671	0.916	1.217
8					
9		0.214	0.663	0.917	1.228
11		0.214	0.664	0.916	1.214
12		0.222	0.689	0.923	1.244
13		0.214	0.668	0.912	1.206

Tested by: NG

Type number:	2N2222A	Test number:	5
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	12:57
Date code:	N/K	Total integrated dose:	40 krad
Test equipment:	B1500A	Time since irradiation:	0h 18m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	170	175	184	166	149	115
2		29	58	98	125	111	88
3		41	75	118	139	125	102
5		51	88	132	149	133	109
6		44	80	124	142	127	101
7		44	79	123	143	127	104
8							
9		34	64	104	127	114	92
11		48	83	126	143	128	105
12		33	63	102	125	112	91
13		49	84	127	144	129	106

Tested by: NG

Type number:	2N2222A	Test number:	6
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	14:36
Date code:	N/K	Total integrated dose:	50 krad
Test equipment:	B1500A	Time since irradiation:	0h 17m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		I_{EBO}	I_{CBO}	I_{CEX}	$V_{(BR)EBO}$	$V_{(BR)CBO}$	$V_{(BR)CEO}$
		A ± 1%	A ± 1%	A ± 1%	V ± 1%	V ± 1%	V ± 1%
1	Control	3.70E-12	4.37E-09	4.35E-09	11.10	141	76
2		5.20E-11	1.90E-09	1.88E-09	11.10	118	83
3		2.46E-11	1.13E-09	1.11E-09	11.10	125	79
5		1.87E-11	7.69E-10	7.61E-10	11.10	124	77
6		1.62E-11	1.04E-09	1.02E-09	11.10	126	80
7		1.70E-11	9.95E-10	9.68E-10	11.10	124	79
8							
9		3.23E-11	1.31E-09	1.28E-09	11.10	127	82
11		2.00E-11	7.56E-10	7.41E-10	11.10	132	79
12		3.54E-11	1.31E-09	1.28E-09	11.20	127	82
13		1.47E-11	7.52E-10	7.34E-10	11.10	133	79

DUT		$V_{CE(sat)}1$	$V_{CE(sat)}2$	$V_{BE(sat)}1$	$V_{BE(sat)}2$
		V ± 1%	V ± 1%	V ± 1%	V ± 1%
1	Control	0.209	0.653	0.919	1.225
2		0.222	0.702	0.916	1.226
3		0.213	0.664	0.913	1.213
5		0.212	0.655	0.915	1.210
6		0.211	0.656	0.917	1.226
7		0.216	0.674	0.916	1.218
8					
9		0.216	0.667	0.916	1.229
11		0.216	0.667	0.916	1.216
12		0.223	0.694	0.923	1.247
13		0.215	0.669	0.910	1.206

Tested by: JV

Type number:	2N2222A	Test number:	6
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	14:36
Date code:	N/K	Total integrated dose:	50 krad
Test equipment:	B1500A	Time since irradiation:	0h 17m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	171	175	183	167	150	115
2		25	52	91	118	105	84
3		34	67	111	134	120	99
5		44	81	125	145	129	106
6		37	71	115	137	122	99
7		37	71	116	139	124	102
8							
9		29	57	96	121	108	88
11		41	75	118	139	124	102
12		28	55	94	119	106	87
13		41	76	119	139	125	103

Tested by: JV

Type number:	2N2222A	Test number:	7
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	16:24
Date code:	N/K	Total integrated dose:	100 krad
Test equipment:	B1500A	Time since irradiation:	0h 34m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		I_{EBO} A ± 1%	I_{CBO} A ± 1%	I_{CEX} A ± 1%	$V_{(BR)EBO}$ V ± 1%	$V_{(BR)CBO}$ V ± 1%	$V_{(BR)CEO}$ V ± 1%
1	Control	2.80E-12	4.84E-09	4.81E-09	11.10	141	76
2		1.87E-10	3.85E-09	3.89E-09	11.20	114	85
3		6.11E-11	1.87E-09	1.85E-09	11.10	123	81
5		3.33E-11	1.24E-09	1.25E-09	11.20	123	79
6		6.01E-11	1.45E-09	1.43E-09	11.10	124	81
7		4.03E-11	1.37E-09	1.34E-09	11.20	123	80
8							
9		1.31E-10	2.24E-09	2.20E-09	11.20	118	84
11		4.62E-11	1.15E-09	1.12E-09	11.10	126	81
12		1.32E-10	2.17E-09	2.17E-09	11.20	117	84
13		5.63E-11	1.02E-09	9.95E-10	11.10	125	80

DUT		$V_{CE(sat)}1$ V ± 1%	$V_{CE(sat)}2$ V ± 1%	$V_{BE(sat)}1$ V ± 1%	$V_{BE(sat)}2$ V ± 1%
1	Control	0.211	0.657	0.920	1.226
2		0.228	0.742	0.918	1.237
3		0.217	0.674	0.913	1.214
5		0.216	0.666	0.913	1.213
6		0.215	0.666	0.919	1.230
7		0.220	0.685	0.915	1.224
8					
9		0.223	0.696	0.919	1.242
11		0.219	0.679	0.916	1.223
12		0.231	0.725	0.925	1.259
13		0.219	0.683	0.915	1.213

Tested by: NG

Type number:	2N2222A	Test number:	7
Category:	NPN bipolar transistor	Date:	20/03/2024
Manufacturer:	Die Devices	Time:	16:24
Date code:	N/K	Total integrated dose:	100 krad
Test equipment:	B1500A	Time since irradiation:	0h 34m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	171	176	185	168	151	116
2		17	38	71	98	88	71
3		22	50	90	117	105	88
5		32	65	110	135	121	99
6		26	55	97	124	111	91
7		27	56	98	125	112	93
8							
9		18	40	74	100	90	75
11		26	55	96	122	109	91
12		18	40	73	99	88	74
13		28	57	97	123	111	92

Tested by: NG

Type number:	2N2222A	Test number:	8
Category:	NPN bipolar transistor	Date:	21/03/2024
Manufacturer:	Die Devices	Time:	17:22
Date code:	N/K	Total integrated dose:	100 krad + RTA
Test equipment:	B1500A	Time since irradiation:	25h 32m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		I_{EBO} A ± 1%	I_{CBO} A ± 1%	I_{CEX} A ± 1%	$V_{(BR)EBO}$ V ± 1%	$V_{(BR)CBO}$ V ± 1%	$V_{(BR)CEO}$ V ± 1%
1	Control	2.15E-12	4.04E-09	4.02E-09	11.10	141	76
2		1.30E-10	1.96E-09	1.96E-09	11.10	117	85
3		5.34E-11	1.22E-09	1.17E-09	11.10	127	81
5		1.24E-11	8.61E-10	8.36E-10	11.10	126	78
6		4.90E-11	1.00E-09	9.73E-10	11.10	127	81
7		3.17E-11	9.82E-10	9.51E-10	11.10	126	80
8							
9		9.40E-11	1.76E-09	1.74E-09	11.20	121	83
11		3.45E-11	1.00E-09	9.58E-10	11.10	128	81
12		9.94E-11	1.70E-09	1.67E-09	11.20	121	84
13		2.84E-11	9.78E-10	9.39E-10	11.10	128	80

DUT		$V_{CE(sat)}1$ V ± 1%	$V_{CE(sat)}2$ V ± 1%	$V_{BE(sat)}1$ V ± 1%	$V_{BE(sat)}2$ V ± 1%
1	Control	0.210	0.656	0.924	1.228
2		0.229	0.738	0.919	1.240
3		0.188	0.578	0.887	1.121
5		0.215	0.662	0.915	1.213
6		0.214	0.664	0.920	1.231
7		0.219	0.682	0.917	1.224
8					
9		0.222	0.690	0.922	1.241
11		0.217	0.676	0.918	1.223
12		0.229	0.720	0.926	1.260
13		0.218	0.679	0.915	1.213

Tested by: NG

Type number:	2N2222A	Test number:	8	
Category:	NPN bipolar transistor	Date:	21/03/2024	
Manufacturer:	Die Devices	Time:	17:22	
Date code:	N/K	Total integrated dose:		100 krad + RTA
Test equipment:	B1500A	Time since irradiation:		25h 32m
Test program:	DIE 2N2222A test V1-00			
Parameters tested:	Multiple parameters			

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	170	174	183	166	149	115
2		16	38	71	99	88	72
3		23	50	89	117	105	88
5		32	66	110	135	120	99
6		26	55	97	124	110	91
7		27	56	98	125	112	94
8							
9		18	41	74	101	90	75
11		27	55	96	122	109	91
12		18	40	73	99	89	74
13		28	57	97	123	110	92

Tested by: NG

Type number:	2N2222A	Test number:	9
Category:	NPN bipolar transistor	Date:	28/03/2024
Manufacturer:	Die Devices	Time:	12:20
Date code:	N/K	Total integrated dose:	100 krad + ETA
Test equipment:	B1500A	Time since irradiation:	188h 30m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		I_{EBO}	I_{CBO}	I_{CEX}	$V_{(BR)EBO}$	$V_{(BR)CBO}$	$V_{(BR)CEO}$
		A ± 1%	A ± 1%	A ± 1%	V ± 1%	V ± 1%	V ± 1%
1	Control	3.75E-12	3.67E-09	3.65E-09	11.10	141	76
2		1.19E-11	5.15E-10	4.99E-10	11.30	134	81
3		1.07E-11	3.50E-10	3.40E-10	11.20	132	78
5		9.60E-12	2.50E-09	2.51E-09	11.20	132	77
6		3.75E-12	3.90E-10	3.80E-10	11.20	134	79
7		2.56E-11	4.14E-10	3.85E-10	11.30	132	78
8							
9		9.70E-12	5.21E-10	5.16E-10	11.30	138	79
11		1.30E-11	5.03E-10	4.92E-10	11.20	137	78
12		3.75E-12	5.77E-10	5.67E-10	11.30	138	80
13		6.95E-12	5.28E-10	5.15E-10	11.20	136	77

DUT		$V_{CE(sat)}1$	$V_{CE(sat)}2$	$V_{BE(sat)}1$	$V_{BE(sat)}2$
		V ± 1%	V ± 1%	V ± 1%	V ± 1%
1	Control	0.210	0.654	0.923	1.227
2		0.216	0.682	0.916	1.219
3		0.210	0.655	0.915	1.210
5		0.212	0.657	0.913	1.210
6		0.210	0.651	0.919	1.226
7		0.214	0.670	0.916	1.216
8					
9		0.211	0.655	0.919	1.226
11		0.213	0.662	0.916	1.216
12		0.219	0.682	0.923	1.242
13		0.214	0.667	0.913	1.206

Tested by: NG

Type number:	2N2222A	Test number:	9
Category:	NPN bipolar transistor	Date:	28/03/2024
Manufacturer:	Die Devices	Time:	12:20
Date code:	N/K	Total integrated dose:	100 krad + ETA
Test equipment:	B1500A	Time since irradiation:	188h 30m
Test program:	DIE 2N2222A test V1-00		
Parameters tested:	Multiple parameters		

DUT		h_{FE} ± 1% (I_C=0.1mA)	h_{FE} ± 1% (I_C=1mA)	h_{FE} ± 1% (I_C=10mA)	h_{FE} ± 1% (I_C=150mA)	h_{FE} ± 1% (I_C=100mA)	h_{FE} ± 1% (I_C=500mA)
1	Control	169	174	183	166	149	115
2		34	68	112	134	120	94
3		41	79	126	143	128	105
5		42	82	129	145	130	106
6		43	81	128	144	128	104
7		40	78	125	143	128	104
8							
9		47	84	128	142	127	101
11		52	90	135	148	132	108
12		42	76	121	138	123	99
13		50	87	131	147	131	107

Tested by: NG