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Radiation Design Criteria Handbook

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CALIFORNIA INSTITUTE OF TECHNOLOGY
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16. Abstract

This handbook provides radiation design criteria for electronic parts applications in space environments. The data was compiled from the Mariner/Jupiter Saturn 1977 (MJS'77) electronic parts radiation test program. In this program selected radiation-sensitive device types were exposed to radiation environments compatible with the MJS'77 requirements under suitable bias conditions. A total of 189 integrated circuits, transistors, and other semiconductor device types were tested up to 1.5×10^5 rads(Si) generated from steady electron beam and Co^{60} sources.

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Radiation Design Criteria Handbook

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August 1, 1976

PREFACE

The work described in this report was performed by the Astrionics Division of the Jet Propulsion Laboratory.

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INDEX OF TEST DEVICE TYPES[a]

Bipolar Transistors

Device	Vendor	Page	Device	Vendor	Page
2N918	MOT	16	2N3805	FAS	85
2N930	TIX	17	2N4044	CTI	86
2N2060	TIX	18	2N5087	CTI	88
2N2222	MOT	19	KD6001	KMC	88
2N2222	TIX	22	MQ2219	MOT	89
2N2369	CTI	44	MQ2905	MOT	93
2N2369	MOT	46	MQ3467	MOT	98
2N2484	CTI	47	MQ3725	MOT	102
2N2484	TIX	49	PA7443	RAY	106
2N2605	CTI	53	SA2267	RAY	111
2N2605	TIX	54	14BB101	SOD	112
2N2658	SOD	55	96SV131	SOD	114
2N2857	MOT	58	3029-201-1	RAY	115
2N2880	SOD	59	3029-202-1	RAY	117
2N2907	MOT	62	SDT3303	SOD	118
2N2907	TIX	66	SDT3304	SOD	120
2N2920	TIX	69	SDT3323	SOD	122
2N2946	TIX	72	SDT3403	SOD	125
2N2975	FAS	72	SDT4905	SOD	126
2N3057	RAY	74	SDT5553	SOD	128
2N3251	MOT	76	SDT5553	SOD (IRAN)	136
2N3350	TIX	77	SDT8805	SOD	139
2N3440	RCA	78	SE7056	NSC	139
2N3497	MOT	78	SQ1079	MOT	140
2N3499	MOT	79	SS3137	MOT	141
2N3501	MOT	79			
2N3637	MOT	80			
2N3742	MOT	85			

[a]See Appendix A for vendor identification code.

JFET's

Device	Vendor	Page	Device	Vendor	Page
2N2605	CTI	144	2N4393	SIL	149
2N2608	SIL	144	2N4416	SIL	150
2N3066	SIL	145	2N4856	SIL	150
2N3331	SIL	145	2N4856	TIX	151
2N3382	SIL	146	2N4858	TIX	151
2N3686	SOD	146	2N5196	SIL	152
2N3824	CTI	147	2N5520	SIL	153
2N4093	SIL	147	2N5556	MOT	154
2N4391	SIL	148	2N5906	SIL	154
2N4392	SIL	149	VCR3P	SIL	155

Integrated Circuits

AD550	ADI	156	HA2700	HAR (TO-99)	177
DAC-01	PMI	158	ICL8007	INL	179
DG125	SIL	159	ICL8018	INL	181
DG129	SIL	160	ICL8038	INL	183
DG129	SIL (IRAN)	161	LM101	NSC	184
DG133	SIL	161	LM101	NSC (IRAN)	186
DG133	SIL (IRAN)	163	LM102	NSC (unhardened)	187
DG141	SIL	164	LM102	NSC (hardened)	187
DG141	SIL (IRAN)	165	LM103	NSC	188
DG181	INL	165	LM105	NSC (unhardened)	188
DG181	SIL	166	LM105	NSC (hardened)	189
DGM111	SIL	168	LM106	NSC	189
HA2520	HAR	170	LM108	NSC (unhardened)	190
HA2600	HAR	172	LM108	NSC (hardened)	191
HA2620	HAR	173			
HA2700	HAR (flatpack)	175			

Integrated Circuits (contd)

Device	Vendor	Page	Device	Vendor	Page
LM111	NSC (unhardened)	193	LM139	NSC (hardened)	206
LM111	NSC (IRAN)	194	LM139	SGN	208
LM124	NSC (unhardened)	194	LM139	TIX	209
LM124	NSC (hardened)	197	LM710	NSC	211
LM139		198	LM723	NSC	212
LM139	NSC (unhardened)	201	MIC236	MOT	213
			MIC336	MOT	213

Zener Diodes

.4M4.7AZ1	MOT	218	1N4891	DIK	222
.4M5.1AZ1	MOT	218	1N4895	DIK	223
1N829	MOT	219	1N4907	MOT	223
1N935	MOT	219	FCT1121	FAS	224
1N945	MOT	220	LVA3100	TRW	224
1N4569	DIK	220	MZ827	MOT	225
1N4572	DIK	221	UZ8770	UTR	225
1N4577	MOT	221	UZ8775	UTR	226
1N4581	DIK	222			

Constant Current Diodes

1N5288	MOT	227	1N5297	MOT	228
1N5290	MOT	227	1N5300	MOT	228

Diodes and Rectifiers

1N4148	GEC	229	MV1404	MOT	231
1N5711	HPA	229	UTR4320	UTR	231
BC997	TIX	230	2N1878	UTR	232
FJT1100	FAS	230			

Capacitors

Device	Vendor	Page	Device	Vendor	Page
B11B	CRC	233			

Resistors

CDP16-01-103G	DAL	234	LDP16-01-153G	DAL	237
CDP16-01-104G	DAL	234	SDP16-02-473J	DAL	237
CDP16-01-223J	DAL	235	MG720	CAD	238
CDP16-01-563J	DAL	235	MG750	CAD	238
CDP16-01-683J	DAL	236	MM125	CAD	239
CDP18-02-393K	DAL	236	MS176	CAD	239

Optical Devices

TIL23	TIX	240	TIL601	TIX	240
TIL24	TIX	240	LS600	TIX	240

CMOS

CD4001	RCA	270	CD4028	RCA	287
CD4002	RCA	271	CD4029	RCA	288
CD4006	RCA	272	CD4030	RCA	291
CD4011	RCA	273	CD4031	RCA	292
CD4012	RCA	274	CD4035	RCA	293
CD4013	RCA	275	CD4040	RCA	295
CD4014	RCA	277	CD4042	RCA	296
CD4015	RCA	278	CD4043	RCA	297
CD4016	RCA	279	CD4047	RCA	298
CD4017	RCA	280	CD4049	RCA	302
CD4019	RCA	281	CD4050	RCA	303
CD4021	RCA	283	CD4051	RCA	304
CD4023	RCA	284	CD4052	RCA	305
CD4025	RCA	285	CD4053	RCA	306
CD4027	RCA	286			

ABSTRACT

This handbook provides radiation design criteria for electronic parts applications in space environments. The data was compiled from the Mariner/Jupiter Saturn 1977 (MJS'77) electronic parts radiation test program. In this program selected radiation-sensitive device types were exposed to radiation environments compatible with the MJS'77 requirements under suitable bias conditions. A total of 189 integrated circuits, transistors, and other semiconductor device types were tested up to 1.5×10^5 rads(Si) generated from steady electron beam and Co^{60} sources.

I. INTRODUCTION

In situ measurements of the Jovian trapped radiation were made by Pioneer 10 in December 1973 and by Pioneer 11 in December 1974. These measurements revealed a potentially hazardous environment for MJS'77 spacecraft electronics. During 1974 the MJS'77 project carried out an intensive study of the charged particles environment derived from those measurements and the effects of this environment on both spacecraft equipment and the Jupiter encounter aspects of the MJS mission. From this study the Mariner/Jupiter Saturn 1977 Radiation Control Requirements Document (PD 618-229, dated July 14, 1975) was developed. One of the requirements set forth is that the electronic piece parts used in the spacecraft perform within acceptable limits during and after Jupiter encounter and at Saturn. Because of resource limitations, the investigations were conducted with maximum use of existing literature and test results, limiting the JPL radiation test effort to known or suspected problem devices where adequate test data was not available.

This handbook is a summary of applicable data resulting from the MJS'77 radiation test effort. The information, presented according to device type (see Index, page), is intended to be useful to the engineer for circuit design. A complete detailed history file of the test results has been maintained and is available (contact: A. Stanley in the Parts Radiation Group of JPL Section 365).

In applying the data contained in the handbook, the user should be aware of inherent limitations; i.e., the data is intended as a guide and is valid only for the specific manufacturer's device at the stated conditions. When applying the data to circuit designs, the user is cautioned regarding extrapolation to lower fluences, different energies and different bias conditions. Device degradation is sensitive to measurement and bias conditions during irradiation. Also, different date codes may reflect process changes which could change the device sensitivity to radiation damage.

The radiation environments were in accordance with PD 618-229, using electrons from a Dynamitron at energies from 2 to 2.5 MeV, electrons from a Van de Graff generator at 3 and 5.5 MeV, and a cobalt 60 gamma source. The Dynamitron was used in those tests wherein the radiation source is not identified.

The major device types and features of the method used in presenting test results are given herein. Whenever deviations from this form occur because of the nature of the data or results obtained, they are further described for the specific device or parameters involved.

Data from different test runs of a given device parameter was combined where the tests and measurements were carried out under similar conditions. The data for the following test runs was combined for a given device type:

(1) Same bias conditions during irradiation.

(2) Same bias conditions during measurement of parameters.

(3) Same fluence.

(4) Characterization, non-lot screen and lot screen runs.

(5) 2 to 2.5 MeV electron energy data (if other energies were used it will be so stated).

(6) V_{CE} (saturated) for transistors.

(7) V_{CE} (not saturated) for transistors.

(8) Same manufacturer.

(9) Hardened devices.

(10) Unhardened devices.

A sample sheet is given in Fig. 1, with the major features indicated. An explanation of those features is given below.

(1) An outlier is here defined as a data point which does not fall within 3σ of the mean value of that parameter at the lowest value of the independent variable (i.e., lowest value of the collector current I_C or fluence, where the parameter is measured as a function of I_C or fluence, respectively).

DEVICE TYPE AND MANUFACTURER

BIAS CONDITIONS DURING RADIATION AS PER RTR

BIAS CONDITIONS DURING MEASUREMENTS

SAMPLE SIZE

σ = STANDARD DEVIATION DEFINED IN TEXT

PARTS RADIATION CHARACTERIZATION (SEE TEXT)

DEVICE TYPE: 2N2060 TEXAS INSTRUMENTS PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(hFE)	5×10¹²	VCE=0V, VC=7V,	VCE=7V, IC=0.01mA	12	0.101	0.377	0.035	0.296	0.394	
↓	1×10¹³	BASE OPEN	↓	12	0.250	0.850	0.049	0.733	0.975	
Δ(hFE)	5×10¹²		VCE=7V; IC=0.1mA	12	0.0356	0.135	0.0104	0.102	0.143	
↓	1×10¹³		↓	12	0.0871	0.354	0.0191	0.233	0.306	
Δ(hFE)	5×10¹²		VCE=7V, IC 1mA	12	0.0107	0.0324	0.0030	0.0316	0.042	
↓	1×10¹³	↓	↓	12	0.054	0.0637	0.0005	0.063	0.0214	

AGS

Fig. 1. Sample sheet

Once established as an outlier in this way, it is considered an outlier for all other values of the independent variable.

(2) The data is calculated both with and without outliers whenever they exist.

(3) The standard deviation σ is approximated by the following expression:

$$\sigma \approx \left(\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n - 1} \right)^{1/2}$$

where n is the number of data points, $\bar{x}$ is the mean value of the set of data points, and x_i is a measured value of the parameter. This gives an unbiased approximation of σ, including cases where the sample size (n) is small.[1]

(4) The parts radiation characterization number evaluates the parts in accordance with criteria from Section VIII of PD 618-229. These criteria are repeated here.

Insensitive to radiation; no special attention required.

Insensitive to radiation except for high-precision applications. The application and degree of sensitivity are specified.

Sensitive to radiation, resulting in significant degradation of device parameters. A radiation screening or shielding program is required if a reasonable design safety margin is lacking.

The device undergoes catastrophic change and is no longer functional.

[1] See Ref. 1.

For transistors, in addition to the tabulated information, graphs are included giving $\Delta(1/h_{FE})$ as a function of collector current. In these graphs, only those calculated excluding the outliers are plotted. The outliers are indicated on the graphs (wherever dual populations occur, both are plotted).

II. USE OF THE RADIATION HANDBOOK IN CIRCUIT DESIGN

The data contained in the Radiation Handbook should be used when performing worst case analysis of electronic circuitry. If parts data does not appear in this handbook, then estimates must be made by Section 365. The data shows permanent damage to semiconductors in a radiation environment. The rate of impinging radiation or radiation flux should also be considered as this can cause a noise effect produced by the impinging particles on semiconductor devices. In addition, it should also be pointed out that low-energy electrons may be deposited and collected by electronic circuitry which can cause a buildup of voltages across high resistance circuits.

The worst case analysis is performed by degrading first for temperature and life (aging) and then for radiation to obtain the final degraded value. The following sections describe the method of calculating degradation.

A. BIPOLAR TRANSISTORS

The current gain of a transistor is determined as described in the following diagram:

Subsystem requirement	Minimum gain at 25°C, at I_C	h_{FE} example 50
↓	↓	↓
Circuit requirement h_{FE}, I_C	Derate for temperature 0.9% per °C	38
↓	↓	↓
	Life derating 25%	28.5
↓	↓	↓
Minimum h_{FE} requirement	Radiation derating	$1/h_{FE}$=0.03
↓	↓	↓
	Predicted gain	15
↓	↓	

Compare requirements with predictions and if there are problems, identify and study solutions.

The radiation derating is determined by the radiation damage coefficient $\Delta(1/h_{FE})$, which is a result of parts testing. The equation for h_{FE} degradation is

$$\Delta\frac{1}{h_{FE}} = \frac{1}{h_{FE(final)}} - \frac{1}{h_{FE(initial)}}$$

where

(1) $h_{FE(final)}$ is the predicted gain to be applied to the circuit.

(2) $h_{FE(initial)}$ is the gain <u>after</u> degrading for temperature and life as per the MJS' 77 Radiation Controls Requirements. Document 618-229, Appendix D (set forth herein as Appendix B).

(3) $\Delta(1/h_{FE})$ is the radiation degradation constant which is found in the handbook for each part and is a function of collector current I_C, radiation fluence, and bias conditions during irradiation. For instance, a 2N2222A device may have the following conditions for which the $h_{FE(final)}$ must be calculated at $I_C = 60\,\mu a$ ($V_{CE} = 8$ V):

$$h_{FE(initial)} = 100 \text{ after degrading for temperature and life}$$

$$\Delta\frac{1}{h_{FE}} = 0.425; \text{ mean plus } 3\sigma \text{ at radiation electron fluence of } 5 \times 10^{12} \text{ e/cm}^2$$

$$\Delta\frac{1}{h_{FE}} = \frac{1}{h_{FE(final)}} - \frac{1}{h_{FE(initial)}}$$

or,

$$\frac{1}{h_{FE(final)}} = \Delta\frac{1}{h_{FE}} + \frac{1}{h_{FE(initial)}}$$

$$h_{FE(final)} = \frac{1}{\Delta\frac{1}{h_{FE}} + \frac{1}{h_{FE(initial)}}}$$

$$h_{FE(final)} = \frac{1}{0.425 + \frac{1}{100}}$$

$$= 0.425 + 0.01$$

$$= 0.435$$

$$h_{FE(final)} = \frac{1}{0.435}$$

$$= 2.3 \text{ which is severe degradation in the worst case}$$

Under the conditions of $I_C = 20$ mA, $V_{CE} = 20$ V, $h_{FE(initial)} = 100$ and at a fluence of 5×10^{12} e/cm^2

$$\Delta \frac{1}{h_{FE}} = 0.00441,$$

using the mean + 3σ value, then $h_{FE(final)}$ will be

$$h_{FE(final)} = \frac{1}{(0.00441) + \frac{1}{h_{FE(initial)}}}$$

$$= \frac{1}{0.00441 + 0.01} = \frac{1}{0.01441}$$

$$= 69.4$$

This demonstrates that radiation has a much greater influence on transistor performance at very low I_C; therefore, low I_C applications should be avoided in radiation environments. In power devices this might be interpreted to mean that no problems exist, but it is really the emitter current density that determines the radiation damage. Therefore, power devices will also degrade severely if the emitter current density is low.

The above calculation can be made using Table 1 by going to $\Delta(1/h_{FE}) = 0.00441$ and $h_{FE} = 100$ and interpolating to find $h_{FE(final)} = 69$. In all cases, the h_{FE} of outliers or mavericks must either be considered or screened out of lots to be used in hardware expected to encounter radiation environment.

Table 1. Determination of final beta, given initial beta and damage factor

(based on $\Delta 1/\beta = 1/\beta - 1/\beta o$)

$\Delta 1/\beta$ \ βo	10	12	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	110	120	130	140	150	170	200	250	300	350	400
.0005	9.95	11.9	14.9	19.8	24.7	29.6	34.4	39.2	44.1	48.8	53.3	58.1	62.9	67.6	72.5	76.9	81.3	86.2	90.9	95.2	104	114	122	132	139	156	182	222	263	294	333
.0007	9.93	11.9	14.9	19.7	24.6	29.4	34.1	38.9	43.7	48.3	52.9	57.5	61.7	66.7	71.4	75.8	80.0	84.8	89.3	93.5	102	111	119	128	135	152	175	212	250	278	313
.001	9.90	11.9	14.8	19.6	24.4	29.2	33.8	38.5	43.1	47.6	52.1	56.6	61.0	65.4	69.9	74.1	78.1	82.6	87.0	90.9	99.0	107	115	124	130	145	167	200	233	256	286
.0015	9.85	11.8	14.7	19.4	24.1	28.7	33.2	37.7	42.2	46.5	51.8	55.0	59.2	63.4	67.6	71.4	75.2	79.4	83.3	87.0	94.3	102	109	116	122	135	154	182	208	227	250
.002	9.80	11.7	14.6	19.2	23.8	28.3	32.7	37.0	41.3	45.5	49.5	53.6	57.5	61.4	65.4	69.0	72.5	76.3	80.0	83.3	90.1	96.8	103	110	115	127	143	167	189	204	222
.0025	9.76	11.7	14.5	19.0	23.5	27.9	32.2	36.4	40.5	44.4	48.3	52.2	55.9	59.6	63.3	66.7	69.9	73.5	76.9	80.0	86.2	92.3	98.0	104	109	119	133	154	172	185	200
.003	9.71	11.6	14.3	18.9	23.3	27.5	31.7	35.7	39.7	43.5	47.2	50.8	54.4	57.9	61.4	64.5	67.6	70.9	74.1	76.9	82.6	88.2	93.5	99.0	103	112	125	143	159	170	182
.0035	9.66	11.5	14.3	18.7	23.0	27.2	31.2	35.1	38.9	42.6	46.1	49.5	52.9	56.2	59.5	62.5	65.4	68.5	71.4	74.1	79.4	84.8	89.3	94.3	98.0	106	118	133	147	156	167
.004	9.62	11.5	14.1	18.5	22.7	26.8	30.7	34.5	38.2	41.7	45.1	48.4	51.6	54.7	57.8	60.6	63.3	66.2	69.0	71.4	76.3	81.1	85.5	90.1	93.8	101	111	125	137	145	154
.005	9.52	11.3	13.9	18.2	22.2	26.1	29.9	33.3	36.8	40.0	43.1	46.2	49.0	51.9	54.6	57.1	59.5	62.1	64.5	66.7	70.9	75.0	78.7	82.6	85.7	91.7	100	111	121	127	133
.006	9.43	11.2	13.8	17.9	21.7	25.4	28.9	32.3	35.5	38.5	41.3	44.1	46.7	49.3	51.8	54.1	56.2	58.5	60.6	62.5	66.2	69.8	73.0	76.3	79.0	84.0	90.9	100	108	112	118
.007	9.35	11.1	13.6	17.5	21.3	24.8	28.1	31.3	34.3	37.0	39.7	42.3	44.6	47.0	49.3	51.3	53.2	55.2	57.1	58.8	62.1	65.2	68.0	70.9	73.2	77.5	83.3	90.9	97.1	101	105
.008	9.26	11.0	13.4	17.2	20.8	24.2	27.4	30.3	33.1	35.7	38.2	40.5	42.7	44.9	47.0	48.8	50.5	52.4	54.1	55.6	58.5	61.2	63.7	66.2	68.2	71.9	76.9	83.3	88.5	91.7	95.2
.009	9.17	10.8	13.2	16.9	20.4	23.6	26.6	29.4	32.1	34.5	36.8	39.0	41.0	42.9	44.8	46.5	48.1	49.8	51.3	52.6	55.3	57.7	60.0	62.1	63.8	67.1	71.4	76.9	81.3	84.0	87.0
.010	9.09	10.7	13.0	16.7	20.0	23.1	26.0	28.6	31.1	33.3	35.5	37.5	39.4	41.2	42.9	44.4	45.9	47.4	48.8	50.0	52.4	54.5	56.5	58.5	60.0	62.9	66.7	71.4	75.2	77.5	80.0
.011	9.01	10.6	12.9	16.4	19.6	22.6	25.3	27.7	30.1	32.3	34.3	36.1	37.4	39.5	41.1	42.6	43.4	45.3	46.5	47.6	49.7	51.2	53.5	55.3	56.5	59.2	62.5	66.7	69.9	71.9	74.1
.012	8.93	10.5	12.7	16.1	19.2	22.1	24.7	27.0	29.2	31.3	33.1	34.9	36.5	38.1	39.5	40.8	42.0	43.3	44.4	45.5	47.4	49.2	50.8	52.4	53.6	55.9	58.8	62.5	65.4	47.1	69.0
.013	8.85	10.4	12.6	15.9	18.9	21.6	24.1	26.3	28.4	30.3	32.1	33.7	35.2	36.6	38.0	39.2	40.3	42.5	42.6	43.5	45.3	47.0	48.3	49.8	50.8	52.9	55.6	58.8	61.4	62.9	64.5
.014	8.77	10.3	12.4	15.6	18.5	21.1	23.5	25.6	27.6	29.4	31.1	32.6	34.0	35.1	36.6	37.7	38.8	39.8	40.8	41.7	43.3	44.8	46.1	47.4	48.3	50.3	52.6	55.6	57.8	59.2	60.6
.015	8.70	10.1	12.2	15.4	18.2	20.7	23.0	25.0	26.9	28.6	30.1	31.6	32.9	34.1	35.3	36.4	37.3	38.3	39.2	40.0	41.5	42.9	44.1	45.3	46.2	47.9	50.0	52.6	54.6	55.9	57.1
.017	8.62	10.0	12.0	14.9	17.5	19.9	21.9	23.8	25.5	27.0	28.4	29.7	30.9	32.0	33.0	33.9	34.7	35.6	36.4	37.0	38.3	39.5	40.5	41.5	42.2	43.7	45.5	47.6	49.3	50.3	51.3
.020	8.33	9.67	11.5	14.3	16.7	18.8	20.6	22.2	23.7	25.0	26.2	27.3	28.3	29.2	30.0	30.8	31.5	32.2	32.8	33.3	34.4	35.3	36.1	36.9	37.5	38.6	40.0	41.7	42.9	43.7	44.4
.025	8.00	9.23	10.9	13.3	15.4	17.2	18.7	20.0	21.2	22.2	23.2	24.0	24.7	25.5	29.6	26.7	27.2	27.7	28.2	28.6	29.3	30.0	30.6	31.2	31.6	32.4	33.3	34.5	35.3	35.8	36.4
.030	7.69	8.82	10.3	12.5	14.3	15.8	17.1	18.2	19.2	20.0	20.8	21.4	22.0	22.6	23.1	23.5	23.9	24.3	24.7	25.0	25.6	26.1	26.5	27.0	27.3	27.9	28.6	29.4	29.9	30.4	30.8
.035	7.41	8.48	9.83	11.8	13.3	14.6	15.8	16.7	17.5	18.2	18.7	19.3	19.8	20.3	22.8	21.0	21.4	21.7	22.0	22.2	22.7	23.0	23.4	23.8	24.0	24.5	25.0	25.6	26.1	26.4	26.7
.040	7.14	8.11	9.38	11.1	12.5	13.6	14.6	15.4	16.1	16.7	17.2	17.6	18.0	18.4	18.8	19.0	19.3	19.6	19.8	20.0	20.4	20.7	21.0	21.2	21.4	21.8	22.2	22.7	23.1	23.3	23.5
.050	6.67	7.50	8.57	10.0	11.1	12.0	12.7	13.3	13.9	14.3	14.7	15.0	15.3	15.6	15.8	16.0	16.2	16.4	16.5	16.7	16.9	17.2	17.3	17.8	17.6	17.9	18.2	18.5	18.8	18.9	19.1
.060	6.25	6.98	7.89	9.09	10.0	10.7	11.3	11.8	12.2	12.5	12.8	13.0	13.3	13.5	13.6	13.8	13.9	14.1	14.2	14.3	14.5	14.6	14.8	14.9	15.0	15.2	15.4	15.6	15.8	15.9	16.0
.070	5.88	6.52	7.32	8.33	9.09	9.71	10.1	10.5	10.8	11.1	11.3	11.5	11.7	11.8	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.8	12.9	13.0	13.0	13.2	13.3	13.5	13.6	13.7	13.8
.080	5.56	6.12	6.82	7.69	8.33	8.85	9.21	9.52	9.8	10.0	10.2	10.3	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.1	11.2	11.3	11.4	11.5	11.5	11.6	11.8	11.9	12.0	12.1	12.1
.090	5.26	5.77	6.38	7.14	7.69	8.13	8.42	8.70	8.9	9.09	9.25	9.38	9.49	9.59	9.68	9.76	9.68	9.89	9.95	10.0	10.1	10.2	10.2	10.3	10.3	10.4	10.5	10.6	10.7	10.8	10.8
.100	5.00	5.45	6.00	6.67	7.14	7.52	7.81	8.00	8.2	8.33	8.46	8.57	8.67	8.75	8.83	8.89	8.95	9.00	9.05	9.09	9.17	9.23	9.29	9.34	9.28	9.44	9.52	9.62	9.68	9.72	9.76

The above discussion applies to transistor h_{FE} when the transistor is not saturated and when it is saturated. The saturated h_{FE}, however, will be much lower because the I_B must be greater to lower the saturation V_{CE}. If, in switching applications, the $V_{CE(sat)}$ must be very small, then the designer must expect very low resultant h_{FE} due to low initial h_{FE} and allowances for mavericks.[2] With regard to I_{CBO}, V_{BE}, and $V_{BE(sat)}$, degrade for temperature and life and then add additional degradation due to radiation in accordance with this handbook for the part in question, being careful to select the appropriate bias conditions, measurement conditions and radiation fluence. In all cases, the $\overline{X} + 3\sigma$ values should be used in the addition. Designers should allow for I_{CBO} as high as 100 μa, ΔV_{BE} as high as 0.2 V and $\Delta V_{CE(sat)}$ as high as 0.2 V.

B. JFET's

The radiation-sensitive parameters of JFET devices are the leakage current I_{GSS} and noise characteristics. In applying this handbook, the radiation degradation in I_{GSS} should be added to the effects of temperature. The noise in the device increases considerably while it is irradiated but will probably return to close to original noise characteristic when radiation ceases (i.e., radiation flux effect). If temperature-degraded I_{GSS} was calculated to be 0.5 nA at $V_{GS} = 4$ V, $V_{DS} = O_V$, radiation fluence $= 5 \times 10^{12}$ e/cm^2, and a handbook value of 0.1 nA, then the total would be 0.6 nA.

In N-channel JFET's there is a channeling effect which can cause very large leakage currents. With no radiation screening controls, this current (I_{GSS}) could be as high as 100 nA.

C. DIODES, RECTIFIERS, AND ZENER DIODES

In most applications, diodes and rectifiers do not degrade sufficiently to provide much concern. However, in applications where the circuit is particularly sensitive to forward or reverse characteristics due to circuit efficiency, extra care must be taken in the selection of devices with

[2] Devices that are significantly more sensitive to radiation than the others.

minimum degradation. In these sensitive cases, the degradation is added to the parameter degradation with temperature. The parameters in question are V_F and I_R. ΔV_F usually changes by less than 50 mV in the MJS Jupiter environment. I_R changes by less than 10 μA. In the case of sensitive or precision applications of Zener diodes, V_z does vary with radiation and must be accounted for by adding ΔV_z due to radiation. ΔV_z is less than 5 mV in Zeners less than 15 volts; it is less than 20 mV in Zeners less than 30 volts.

D. LINEAR IC

The primary parameters of interest are V_{OS}, I_{OS}, I_{BIAS}, VOL, and these are highly influenced by a radiation environment. The degradation values listed in this handbook are changes or delta values due to radiation effects. These changes should be added to the other changes due to temperature effects. As a summary of these degradations, refer to Appendix C.

E. CMOS

The predominant parameters of interest in radiation are:

(1) Propagation delay, which increases with radiation.

(2) Device power consumption, which increases with radiation.

(3) OFF leakages in multiplexers, which increase with radiation.

(4) r_{ds} ON resistance, which increases with radiation.

(5) Noise margin, which increases with radiation.

The effects of radiation are added after the effects of temperature and life are determined.

To improve the response of CMOS to radiation, better process controls must be instituted unless the degradation can be tolerated in the design. Radiation data should be taken on samples of all wafers of parts to be used in radiation environment. Refer to the data in this handbook on parts that have been tested.

III. IRRADIATE-ANNEAL (IRAN) SCREENING

An extensive investigation of irradiation-anneal (IRAN) screening against total dose radiation effects was carried out as part of a program to harden the Mariner Jupiter/Saturn spacecraft against the Jupiter radiation belts. The method consists of irradiating semiconductor devices with cobalt-60 to a suitable total dose under representative bias conditions and separating the undesired tail of the distribution from the bulk of the parts by means of a predetermined acceptance limit. The acceptable devices are then restored to their preirradiation condition by annealing them at an elevated temperature.

Irradiate-anneal is the only known 100% radiation screen [illegible] [illegible]t mavericks. In general, this should be supplemented by a qualification test based on a diffusion-metallization lot, in which a few samples are irradiated to a total dose in excess of the project requirements. Failure to pass this test implies lot jeopardy and an extension of the delivery period by many months.

Since the lot screening method imposed intolerable time constraints, it was hoped that the irradiate-anneal technique might be employed to predict the radiation behavior of each device in a quantitative manner so that even lots of marginal radiation quality might be utilized at a somewhat lower yield. This requirement imposes far more severe constraints on the retracking of electrical parameters after the first and second irradiation than the elimination of mavericks.

A. DEVICE TYPES

IRAN was considered for device types that were determined to be more radiation-sensitive than allowable by the circuit and shielding analyses. However, such screening methods work only when the devices show a significantly varied response to a radiation exposure. The devices consist of linear bipolar devices, analog switches, n-channel JFETs, and bipolar transistors. The primary cause of radiation damage induced in these devices by ionizing radiation is the formation of inversion layers due to the

accumulation of positive charges in the silicon oxide insulator near the silicon-silicon oxide interface. This depends on the quality of the oxide, which is to a large extent an uncontrolled process variable.

Devices that are generically extremely sensitive to ionizing radiation (e.g., MOS devices) are poor candidates for the IRAN technique and must be shielded. An additional reason for excluding MOS devices is the difficulty of annealing out the radiation-induced interface states except at much higher temperatures. The important LM108 operational amplifier was excluded, because it had been possible to harden this device against ionizing radiation.

All n-channel JFETs with a lightly doped base region are likely to develop sizable gate leakage currents and were therefore considered to be candidates for IRAN. It was considered preferable to redesign circuits, so that bipolar transistors could operate with minimum dc current gain rather than resort to IRAN.

B. PROGRAM CONSTRAINTS

The original requirement imposed on the devices was to survive a total dose of 125 krad (Si). This was later decreased to 60 krad (Si) as the result of a more precise definition of the Jovian radiation belt. For reliability reasons, a ceiling of 150°C was imposed on the annealing temperature of the devices. It was later discovered that this temperature is inadequate for complete annealing of all surface effects. Burn-in temperatures up to 300°C have been successfully employed in many high reliability programs, but this requires device construction analysis and thermal stress analysis for each device type before procurement. Such an investigation was ruled out because of timing constraints. The devices are annealed in an inert atmosphere for 96 hours. Experiments showed that longer annealing times did not cause any additional annealing.

High-temperature annealing was considered to be unnecessary for the JFETs. In these devices only the leakage currents are affected by the ionizing radiation. These are easily controlled and not significant in those devices that pass the IRAN acceptance criteria.

C. EXPERIMENTAL INVESTIGATION

A series of investigations was carried out in order to obtain the following information:

(1) What is the optimum dose for screening? Too low a dose may not reproduce the surface effects that cause degradation at higher doses; whereas too high a dose degrades the devices unnecessarily. The onset of surface effects caused by inversion layers depends on the impurity concentration in the silicon as well as the composition of the oxide at the silicon interface and can therefore not be uniquely determined.

(2) What acceptance criteria can be applied? Unless there is complete retracking of all devices on reirradiation, the acceptance criteria must be considerably more tightly specified than the worst case conditions required by the application. On the other hand, tight specifications may cause severe yield penalties.

(3) What is the annealing behavior? Do all the parameters anneal completely or is there some residual radiation damage? Are there indications of anomalous annealing?

(4) Do the parameters retract on reirradiation or do they exhibit memory effects? Do any of the devices show anomalous properties that could not have been predicted from the results of the first irradiation?

A series of experiments was conducted on each device type under consideration for IRAN. Non-flight parts had previously been exposed to 2.5 MeV electrons up to 10^{13} e/cm^2. These devices were annealed for 96 hours at 150°C approximately two to three months after the initial exposures. Most parameters annealed back to acceptable specification levels, but others did not return to their preirradiation values. Since high-energy electrons can induce a significant amount of displacement damage, it was decided to carry out additional experiments using a cobalt-60 source. The devices were irradiated to a total dose of either 50 or 125 krad(Si), annealed at 150°C for 96 hours and subsequently reirradiated with 2.5-MeV electrons, making measurements at four radiation levels from 5×10^{11} to 5×10^{12} e/cm^2.

D. IRAN TEST DEVICES

Only the flight device types listed in Table 2 were subjected to IRAN; the other device types tested were unsuitable for IRAN. The degradation that these devices will experience on reirradiation in the Jupiter environment is indicated as a function of fluence in separate tables following the normal radiation properties. After annealing, the dc parameters of all devices were remeasured to the original specification limits with the following exceptions:

NSC LM101, I_B increased from 75 to 100 nA

NSC LM111, I_B increased from 100 to 400 nA

I_{OS} increased from 10 to 25 nA

Table 2. Device type subject to IRAN

Device type	IRAN total dose, krad (Si)	Acceptance criteria	Annealing
2N4856	60	I_{GSS} at V_{GS} = -20V < 500pA	None
2N5196	60	I_{GSS} at V_{GS} = -10V < 100pA	None
2N5520	60	I_{GSS} at V_{GS} = -10V < 100pA	None
2N5556	60	I_{GSS} at V_{GS} = -15V < 250pA	None
DG129	50	I_S (off) < 3nA	96 hr at 150°C
DG133	50	I_S (off) < 3nA	96 hr at 150°C
DG141	50	I_S (off) < 5nA	96 hr at 150°C
LM101	125	ΔV_{OS} < 0.7mV, ΔI_{OS} < 2.5nA, ΔI_B < 60nA	96 hr at 150°C
LM111	50	I_{OS} < 20nA, V_{OS} < 3mV, I_B < 1μA	96 hr at 150°C
SDT5553	5	h_{FE} at I_C = 0.15mA > 8	96 hr at 150°C

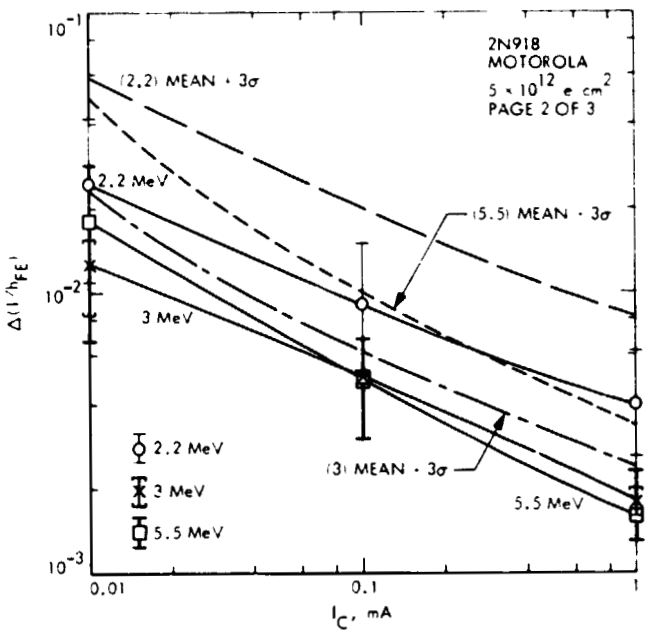
IV. TEST DEVICE TYPES DATA SHEETS

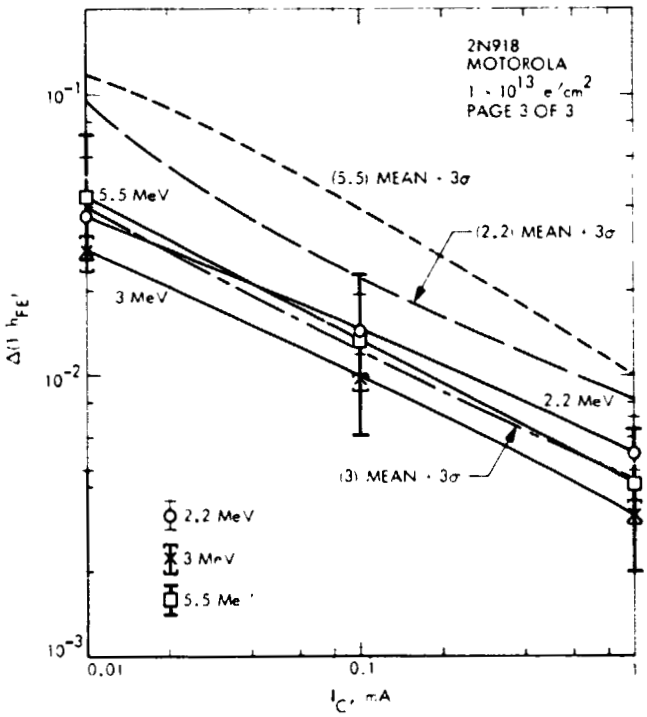
A. BIPOLAR TRANSISTORS

2N918, Motorola

DEVICE TYPE: 2N918 MOTOROLA PAGE 1 OF 3 3

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm^2	MeV	BIAS: IBRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^{12}	2.2	[illegible]	Vce 5V.	6	0.0248	0.0415	0.011	0.0479	0.0594	
		3	[illegible] 5V, BASE GND	Ic = 0.01mA	3	0.0126	0.0156	0.0083	0.0203	0.0241	
		5.5			3	0.0178	0.0284	0.0067	0.0395	0.0504	
	1×10^{13}	[illegible]			6	0.0373	0.0605	0.0046	0.0766	0.0963	
		3			3	0.028	0.0317	0.0236	0.0362	0.0423	
		5.5			3	0.0432	0.0722	0.0259	0.0937	0.119	
Δ(1/hFE)	5×10^{12}	2.2		Vce 5V, Ic 0.1mA	6	0.0091	0.015	0.005	0.0165	[illegible]	
		3			3	0.0050	0.0053	0.0046	0.0058	0.0062	
		5.5			3	0.0050	0.0068	0.003	0.0089	[illegible]	
	1×10^{13}	[illegible]			6	0.0144	0.0175	0.012	0.0197	[illegible]	
		3			3	0.0098	0.0103	0.0088	0.0115	[illegible]	
		5.5			3	0.0134	0.0228	0.0061	0.0305	0.039	
Δ(1/hFE)	5×10^{12}	[illegible]		Vce 5V, Ic 1mA	6	0.004	0.0062	0.0026	0.0068	0.0082	
		3			3	0.0018	0.002	0.0016	0.0022	0.0024	
		5.5			3	0.0016	0.0023	0.0013	0.0028	0.0034	
[illegible]	1×10^{13}	2.2			6	0.0053	0.0071	0.0046	0.0072	0.0082	
		3			3	0.0036	0.0036	0.0029	0.0039	[illegible]	
		5.5			3	0.0041	0.0064	0.002	0.0085	[illegible]	



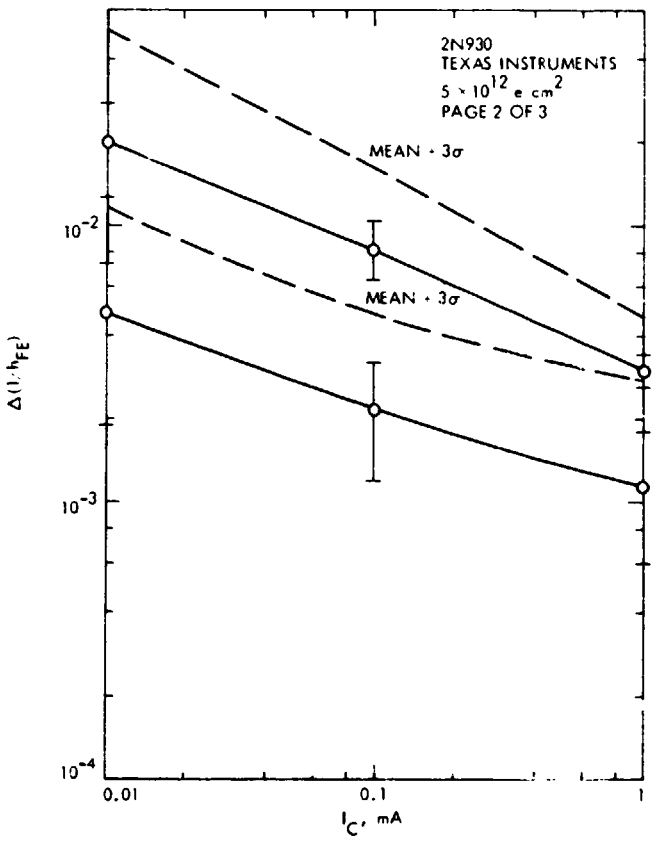


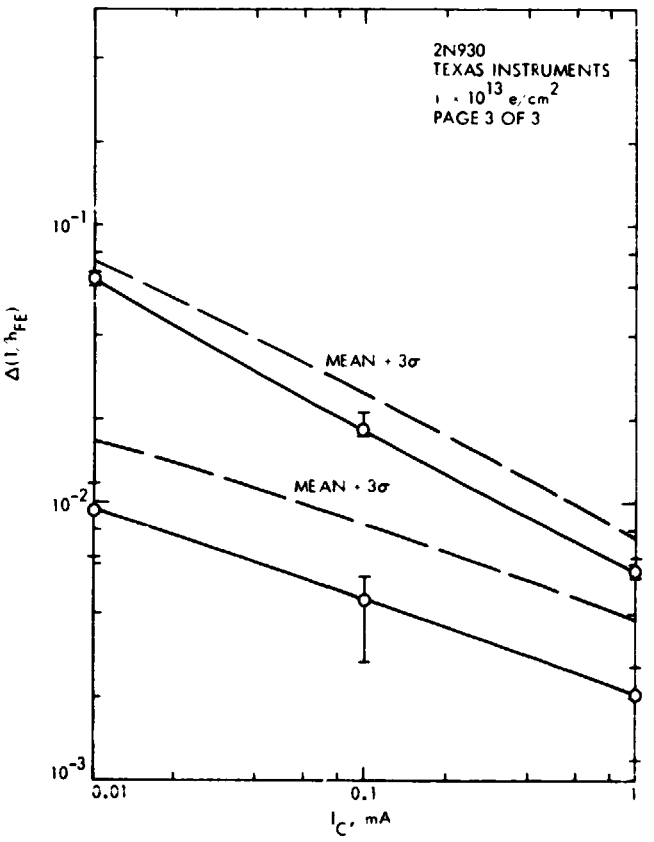
2N930, Texas Instruments

DEVICE TYPE: 2N930 TEXAS INSTRUMENTS PAGE 1 of 3 3

Parameter	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/hFE)	5×10¹²	VCE .3V	IC=0.01mA	6 HIGH POP	0.02	0.0274	0.0026	0.0409	0.0514	
		IC 0.01mA	VCE = .3V	4 LOW POP	0.0095	0.0073	0.0019	0.0088	0.0125	
	1×10¹³			2 HIGH POP	0.0645	0.0663	0.0626	0.0687	0.0723	
				4 LOW POP	0.0945	0.0118	0.0068	0.0140	0.0162	
Δ(1/hFE)	5×10¹²		IC=0.01mA	6*	0.00897	0.0274	0.0019	0.0285	0.0378	
	1×10¹³		VCE .3V	6*	0.0278	0.0663	0.0064	0.0847	0.113	
Δ(1/hFE)	5×10¹²		IC=0.1mA	2 HIGH POP	0.00825	0.0101	0.0064	0.0135	0.0161	
			VCE = .3V	4 LOW POP	0.0015	0.0032	0.0010	0.00371	0.00479	
	1×10¹³			2 HIGH POP	0.0188	0.0201	0.0174	0.0226	0.0245	
				4 LOW POP	0.0045	0.0055	0.0027	0.00205	0.00833	
Δ(1/hFE)	5×10¹²		IC=0.1mA	6*	0.0042	0.0101	0.0012	0.0110	0.0145	
	1×10¹³		VCE = .3V	6*	0.00825	0.0201	0.0027	0.0242	0.0317	
Δ(1/hFE)	5×10¹²		IC=1mA	2 HIGH POP	0.0030	0.0034	0.0026	0.0041	0.0047	
			VCE = .3V	4 LOW POP	0.0015	0.0018	0.0006	0.00225	0.0028	
	1×10¹³			2 HIGH POP	0.00595	0.0064	0.0055	0.0022	0.0079	
				4 LOW POP	0.0021	0.0026	0.0012	0.0033	0.0040	
Δ(1/hFE)	5×10¹²		IC=1mA	6*	0.0018	0.0034	0.0006	0.0039	0.0050	
	1×10¹³		VCE .3V	6*	0.0034	0.0064	0.0012	0.0025	0.0096	

* BOTH POPULATIONS COMBINED



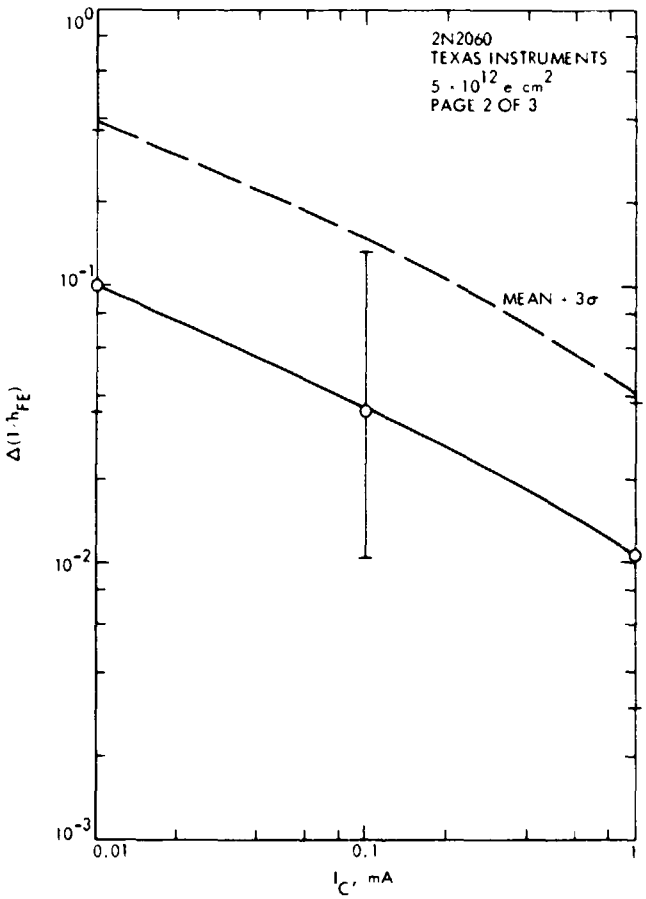


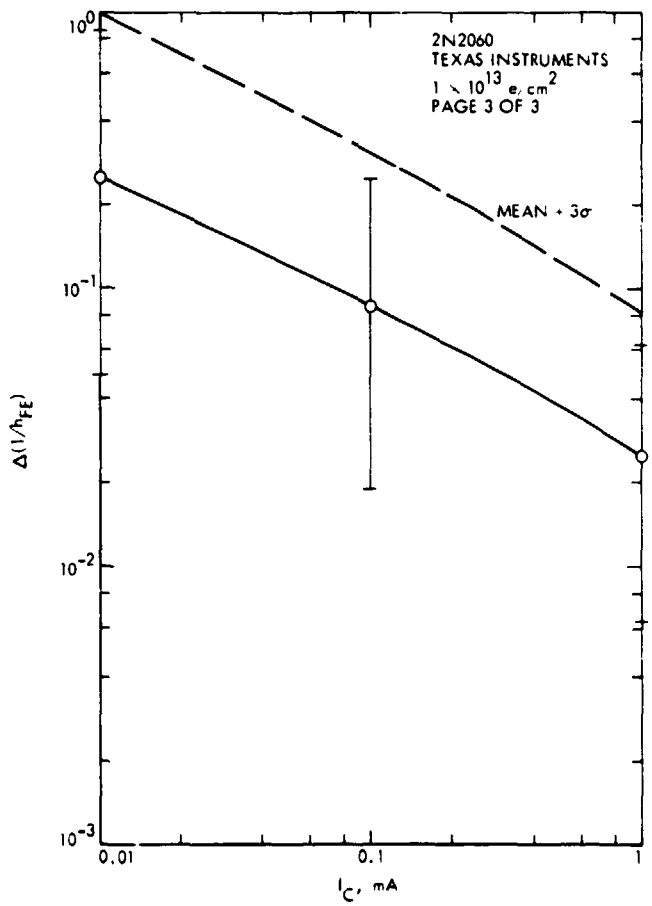
2N2060, Texas Instruments

DEVICE TYPE: 2N2060 TEXAS INSTRUMENTS PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VCE=0V, IC=7V,	VCE=7V, IC=0.01mA	12	0.101	0.377	0.035	0.296	0.394	
	1×10¹³	BASE OPEN		12	0.250	0.850	0.049	0.733	0.975	
Δ(1/hFE)	5×10¹²		VCE=7V, IC=0.1mA	12	0.0356	0.135	0.0104	0.107	0.143	
	1×10¹³			12	0.0871	0.254	0.0171	0.233	0.306	
Δ(1/hFE)	5×10¹²		VCE=7V, IC=1mA	12	0.0107	0.0387	0.0030	0.0316	0.042	
	1×10¹³			12	0.0254	0.0637	0.0065	0.063	0.0841	

AGS





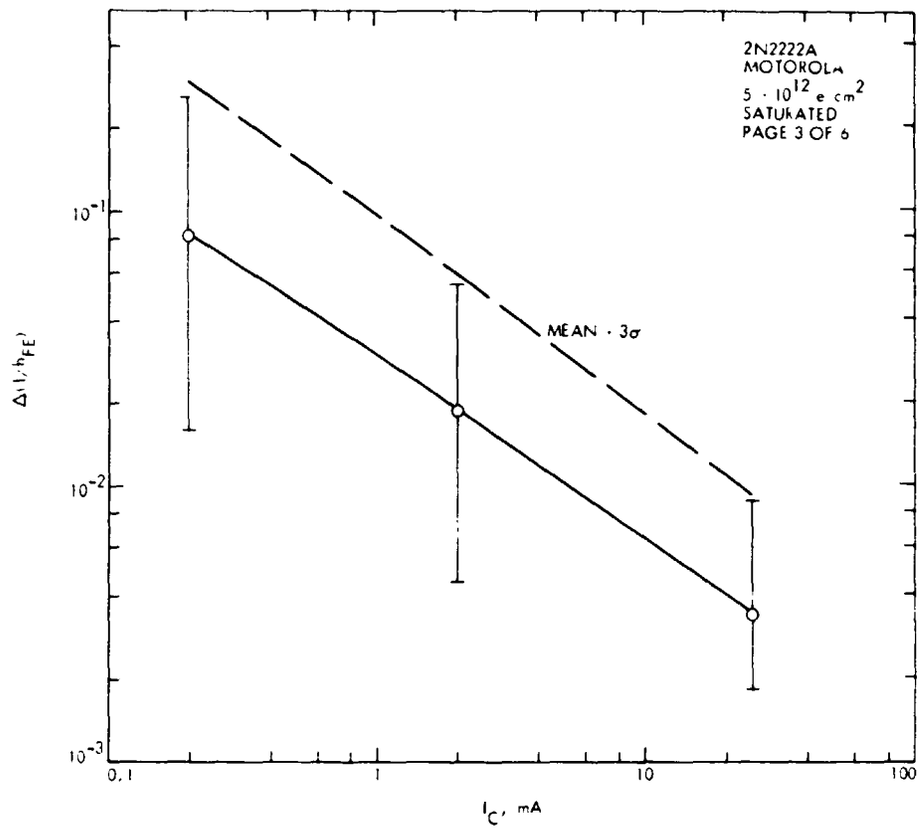
2N2222, Motorola

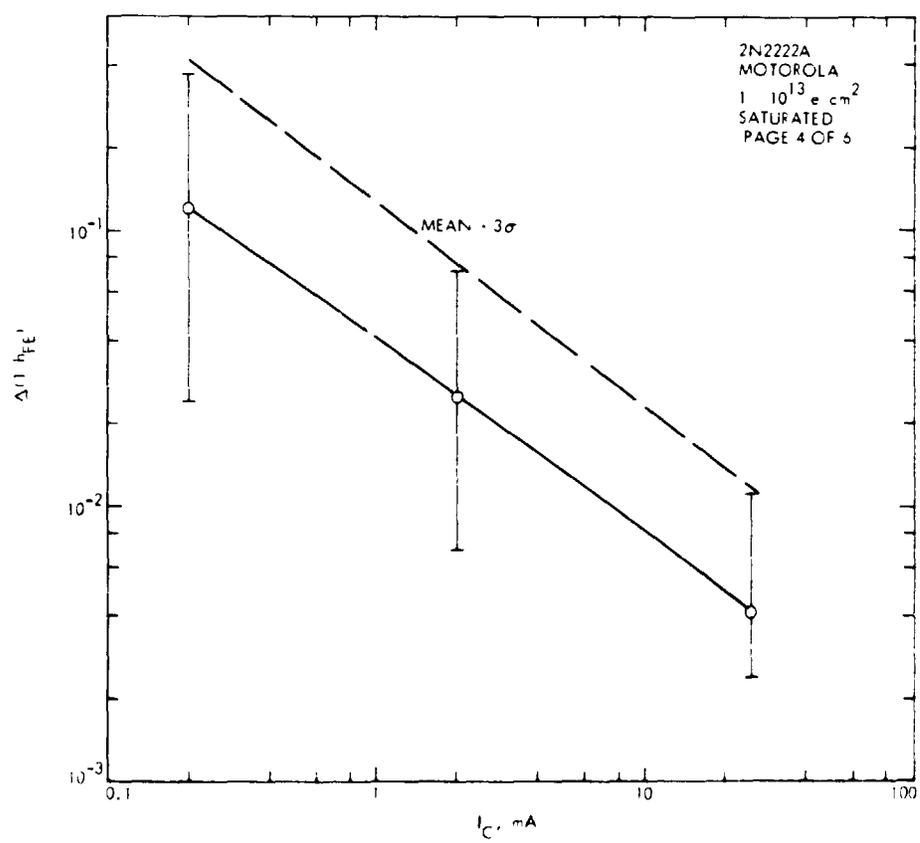
DEVICE TYPE: 2N2222 MOTOROLA PAGE 1056 3

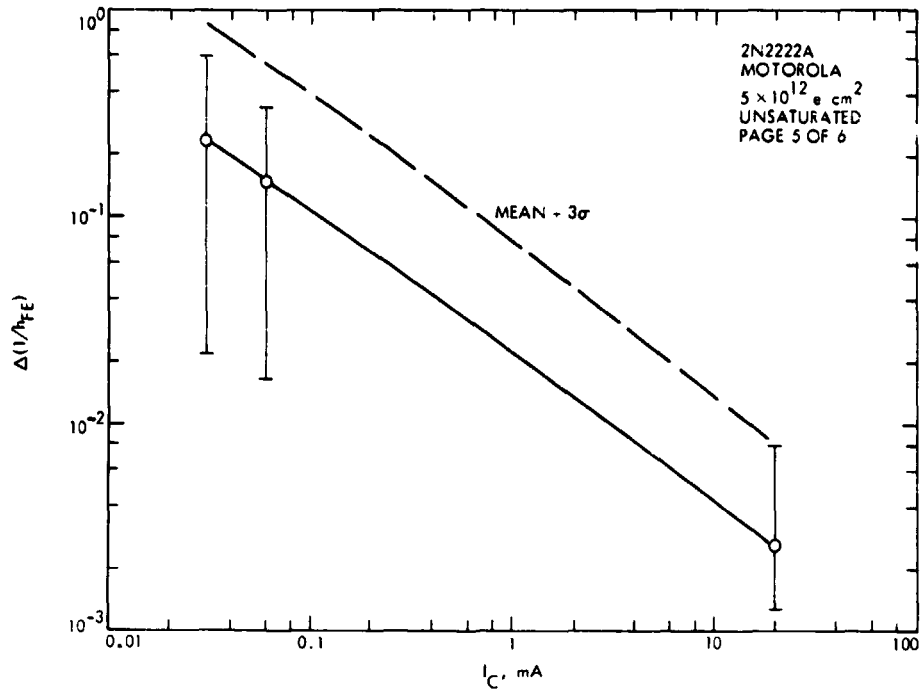
Parameter	Fluence	Operating Point Bias: Irrad.	Operating Point Bias: Meas.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/hFE)	5×10^{12}	$V_C = 40V$, $V_E = 0V$, $V_B = 0V$	$V_{CE} = 0.1V$, $I_C = 200\mu A$	12	.0813	.2647	.016	.222	.292	
↓	1×10^{13}	↓	↓	12	.12	.3748	.024	.32	.419	
Δ(1/hFE)	5×10^{12}		$V_{CE} = 0.12V$, $I_C = 2mA$	12	.0187	.054	.0045	.0454	.0588	
↓	1×10^{13}		↓	12	.025	.072	.007	.0594	.0766	
Δ(1/hFE)	5×10^{12}		$V_{CE} = 0.26V$, $I_C = 25mA$	12	.00338	.0088	.0018	.0074	.00902	
↓	1×10^{13}		↓	12	.00415	.0112	.0024	.00906	.015	
Δ(1/hFE)	5×10^{12}		$V_{CE} = 20V$, $I_C = 30\mu A$	12	.233	.6162	.0223	.64	.851	
↓	1×10^{13}		↓	12	0.413	1.233	0.0456	1.2	1.59	
Δ(1/hFE)	5×10^{12}		$V_{CE} = 8V$, $I_C = 60\mu A$	12	.149	.4425	.0169	.419	.549	
↓	1×10^{13}		↓	12	.23	.763	.0349	.691	.922	
Δ(1/hFE)	5×10^{12}		$V_{CE} = 20V$, $I_C = 20mA$	12	.00262	.008	.0013	.00631	.00815	
↓	1×10^{13}	↓	↓	12	.00376	.0097	.0022	.00803	.0102	
AGS										

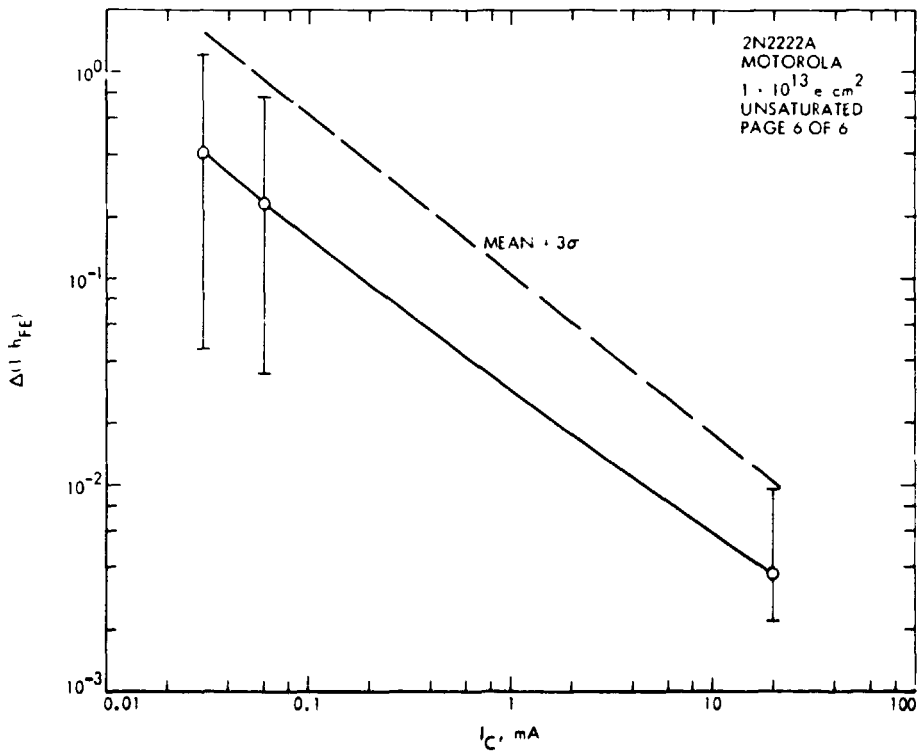
DEVICE TYPE: 2N2222 MOTOROLA PAGE 2056 3

Parameter	Fluence	Operating Point BIAS: IRRAD.	Operating Point BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
ICBO (nA)	5×10^{12}	$V_C = 60V$		3 *	0.853	1.2	0.46	1.6	1.97	
		$V_E = 0V$		5	2,800	14,000	0.42	15,300	21,600	
↓	1×10^{13}	$V_B = 0V$		3 *	0.773	1.3	0.02	2.11	2.78	
				5	3,500	17,500	0.02	19,200	27,000	
IEBO (nA)	5×10^{12}			3 *	2.52	7	0.12	10.3	14.2	
				5	9,610	48,000	0.12	52,500	74,000	
↓	1×10^{13}	↓		3 *	0.223	0.46	0.04	0.653	.868	
				5	28,000	140,000	0.04	153,000	216,000	
*	OUTLIER	POPULATION		2						


2N2222A
MOTOROLA
5 · 10^12 e cm^2
SATURATED
PAGE 3 OF 6
MEAN · 3σ
10^-1
10^-2
10^-3
0.1
1
10
100
I_C, mA


2N2222A
MOTOROLA
1 10^13 e cm^2
SATURATED
PAGE 4 OF 6
MEAN · 3σ
10^-1
10^-2
10^-3
0.1
1
10
100
I_C, mA


2N2222A
MOTOROLA
5 × 10^12 e cm^2
UNSATURATED
PAGE 5 OF 6
MEAN + 3σ
Δ(1/h_FE)
10^0
10^-1
10^-2
10^-3
0.01
0.1
1
10
100
I_C, mA


2N2222A
MOTOROLA
1 · 10^13 e cm^2
UNSATURATED
PAGE 6 OF 6
MEAN + 3σ
Δ(1/h_FE)
10^0
10^-1
10^-2
10^-3
0.01
0.1
1
10
100
I_C, mA

2N2222, Texas Instruments

Texas Instruments initiated a process change in 1972 affecting the oxide passivation layer. As a result, the data for both the tables and graphs will be grouped as follows:

Parameter	Group	Date code range
$\Delta(1/h_{FE})$	1	1971 - 1972
	2	1973
	3	1974 - 1975
I_{CBO} and I_{EBO}	1	1972
	2	1973 - 1975

The performance of this type of device at a $V_{CE} \geqq 0.12$ volts is very unpredictable. The test results are questionable because the test instrumentation did not use separate voltage and current probes. Any small change in V_{CE} will cause a very large change in the gain at this operating point. Consequently, separate graphs were used for $V_{CE} = 0.1$ and 0.12 V if there was more than one value of V_{CE} at a given current level in order to prevent overlap of the data due to large error bars.

DEVICE TYPE: 2N2222 TEXAS INSTRUMENTS PAGE 1 of 37 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
1971-1972	C/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/DEF)	5×10¹¹	C 40V.	Ic=0.2mA, Vce=0.2V	9	0.0015	0.0046	0.00021	0.0047	0.0063	
	1.25×10¹²	VE, B GND		9	0.0034	0.0120	0.00076	0.0112	0.0151	
	2.5×10¹²			9	0.0077	0.0316	0.0019	0.0277	0.0377	
	5×10¹³		Ic=0.2mA, Vce=0.1V	11	0.0399	0.1460	0.0010	0.1377	0.1865	
			Ic=0.2mA, Vce=0.2V	9	0.0207	0.0936	0.0038	0.0825	0.1134	
	1×10¹³		Ic=0.2mA, Vce=0.1V	11	0.0777	0.2659	0.0015	0.2562	0.3455	
Δ(1/DEF)	5×10¹¹		Ic=2mA, Vce=0.23V	9	0.00054	0.0017	0.000033	0.0019	0.0026	
	1.25×10¹²			9	0.0012	0.0043	0.000041	0.0041	0.0056	
	2.5×10¹²			9	0.0027	0.0106	0.00015	0.0093	0.0127	
	5×10¹²		Ic=2mA, Vce=0.12V	11	0.0116	0.0300	0.0040	0.0278	0.0389	
			Ic=2mA, Vce=0.23V	9	0.0060	0.0254	0.0014	0.0224	0.0306	
	1×10¹³		Ic=2mA, Vce=0.12V	11	0.0179	0.0520	0.0010	0.0536	0.0715	
Δ(1/DEF)	5×10¹¹		Ic=25mA, Vce=0.34V	9	0.000034	0.00044	0	0.00035	0.00047	
	1.25×10¹²			9	0.000087	0.00029	0.000078	0.00028	0.00037	
	2.5×10¹²			9	0.00015	0.0005	0.000029	0.00048	0.00065	
	5×10¹²		Ic=25mA, Vce=0.26V	11	0.0024	0.0056	0.0002	0.0062	0.0082	
			Ic=25mA, Vce=0.34V	9	0.00054	0.0033	0.000047	0.0026	0.0037	
	1×10¹³		Ic=25mA, Vce=0.26V	11	0.0037	0.0092	0.0001	0.0099	0.0130	
Δ(1/hFE)	5×10¹²		Ic=30μA, Vce=20V	11	0.1033	0.4638	0.0007	0.4021	0.5515	
	1×10¹³			11	0.2334	0.9467	0.0020	0.8409	1.1447	

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Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
1971-1972	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VC = 40V.	IC = 60μA, VCE 8V	11	0.0714	0.[illegible]8	0.0006	0.[illegible]671	0.3650	
↓	1×10¹³	VE VB = GND	↓	11	0.1604	0.5788	0.0016	0.5538	0.7504	
Δ(1/hFE)	5×10¹²		IC = 20mA, VCE 20V	11	0.0019	0.0051	0.0002	0.0054	0.0072	
↓	1×10¹³	↓	↓	11	0.0034	0.0085	[illegible]	[illegible]	0.0120	

DEVICE TYPE: 2N2222 TEXAS INSTRUMENTS PAGE 3 of 37

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
1973	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	VC = 40V;	IC = 0.2mA	19	0.0165	0.115	-0.0227	0.0966	0.1367	
	1.25×10¹²	VE = VB = GND	VCE = 0.12V	19	0.0119	0.0699	-0.001	0.0532	0.0738	
	2.5×10¹²			19	0.0052	0.0546	-0.0187	0.0420	0.0604	
↓	5×10¹²		↓	19	0.0160	0.0496	0.0013	0.0415	0.0543	
Δ(1/hFE)	5×10¹¹		IC 2mA, VCE 0.12V	19	0.0089	0.0814	-0.0621	0.0575	0.0817	
	1.25×10¹²			19	0.0087	0.0351	-0.0068	0.0402	0.0560	
	2.5×10¹²			19	0.0023	0.0326	-0.0260	0.0465	0.0687	
↓	5×10¹²		↓	19	0.0113	0.0615	-0.0174	0.0565	0.0790	
Δ(1/hFE)	5×10¹¹		IC 25mA, VCE 0.26V	19	0.00006	0.00043	-0.0030	0.0017	0.0025	
	1.25×10¹²			19	0.00049	0.00084	-0.00083	0.0012	0.0015	
	2.5×10¹²			18	0.00088	0.0015	0.00049	0.0014	0.0016	
	↓			19*	0.0010	0.0035	0.00049	0.0023	0.0030	
↓	5×10¹²		↓	19	0.0013	0.0024	0.00081	0.0022	0.0026	
Δ(1/hFE)	5×10¹¹		IC 60μA, VCE 20V	19	0.0029	0.0084	0.00048	0.0074	0.0096	
	1.25×10¹²			19	0.0052	0.0102	0.0022	0.0107	0.0134	
	2.5×10¹²			18	0.0080	0.0134	0.0047	0.0132	0.0159	
	↓			19*	0.0089	0.0252	0.0047	0.0183	0.0230	
↓	5×10¹²	↓	↓	18	0.0112	0.0225	0.0063	0.0188	0.0225	
				19*	0.0127	0.0386	0.0063	0.0222	0.0345	

* OUTLIERS INCLUDED

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Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
1973	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	Vc=40V; Ve=Va GND	Ic=1mA Vce=20V	19	0.0012	0.0022	0.00060	0.0022	0.0027	
	1.25×10¹²			18	0.0016	0.0031	0.0011	0.0028	0.0034	
				19*	0.0019	0.0069	0.0011	0.0046	0.0059	
	2.5×10¹²			18	0.0025	0.0035	0.0015	0.0038	0.0044	
				19*	0.0028	0.0068	0.0015	0.0051	0.0062	
	5×10¹²			17	0.0034	0.0049	0.0023	0.0049	0.0057	
				19*	0.0040	0.0109	0.0023	0.0081	0.0101	
Δ(1/hFE)	5×10¹¹		Ic=20mA Vce=20V	18	0.00027	0.00037	0.00018	0.00039	0.00045	
				19*	0.00045	0.0036	0.00018	0.0020	0.0027	
	1.25×10¹²			19	0.00048	0.00074	0.00028	0.00068	0.00078	
	2.5×10¹²			19	0.0007	0.0013	0.00036	0.0011	0.0013	
	5×10¹²			19	0.0011	0.0020	0.0006	0.0018	0.0022	

* OUTLIER INCLUDED

DEVICE TYPE: 2N2222 TEXAS INSTRUMENTS PAGE 5 of 37

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
1974-1975	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	Vce=0.5V,	Ic=0.05mA, Vce=0.5V	6	0.00087	0.0012	0.0006	0.0014	0.0017	
	1.25×10¹²	Ic 0.05mA		6	0.0012	0.0016	0.0008	0.0018	0.0021	
	2.5×10¹²			6	0.0019	0.0024	0.0012	0.0027	0.0031	
	5×10¹²			6	0.0032	0.0038	0.0022	0.0044	0.0050	
Δ(1/hFE)	5×10¹¹		Ic=0.1mA, Vce=0.5V	6	0.00048	0.0009	0	0.00107	0.0014	
	1.25×10¹²			6	0.00098	0.0014	0.0006	0.0015	0.0015	
	2.5×10¹²			6	0.0014	0.0016	0.0010	0.0018	0.00206	
	5×10¹²			6	0.0025	0.0031	0.0018	0.0044	0.0039	
Δ(1/hFE)	5×10¹¹	Vc=40V, Ve=Va GND	Ic=0.2mA, Vce=0.12V	13	0.0539	0.1450	-0.0304	0.1668	0.2233	
	1×10¹²		Ic=0.2mA, Vce=0.2V	6	0.0041	0.0066	0.0026	0.0071	0.0086	
	1.25×10¹²		Ic=0.2mA, Vce=0.12V	13	0.0344	0.0860	-0.0030	0.0889	0.1177	
	2.5×10¹²			13	0.0272	0.0911	-0.0439	0.1138	0.1571	
			Ic=0.2mA, Vce=0.2V	6	0.0088	0.0136	0.0061	0.0145	0.0173	
	5×10¹²		Ic=0.2mA, Vce=0.12V	13	0.0384	0.0851	0.0108	0.0750	0.1233	
Δ(1/hFE)	5×10¹¹	Vce=0.5V,	Ic=0.5mA, Vce=0.5V	6	0.00043	0.0006	0.0004	0.0006	0.00068	
	1.25×10¹²	Ic=0.05mA		6	0.0006	0.0008	0.0004	0.00085	0.00098	
	2.5×10¹²			6	0.00107	0.0012	0.0010	0.0013	0.0014	
	5×10¹²			6	0.0016	0.0018	0.0012	0.00203	0.0023	

DEVICE TYPE: 2N2222 TEXAS INSTRUMENTS PAGE 6 of 37

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
1974-1975	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	Ic:40V, Ve-Vb GND	Ic:2mA, Vce:0.12V	13	0.0163	0.0366	-0.0181	0.0516	0.0692	
	↓	Vce:0.5V, Ic:0.05mA	Ic:2mA, Vce 0.5V	6	0.00027	0.00035	0.0001	0.00045	0.00055	
	1×10¹²	Vc:40V, Ve Vb:GND	Ic:2mA, Vce:0.2V	6	0.0019	0.0031	0.0012	0.0035	0.0038	
	1.25×10¹²	↓	Ic 2mA, Vce 0.12V	13	0.0180	0.0375	-0.0068	0.0475	0.0623	
	↓	Vce 0.5V, Ic:0.05mA	Ic:2mA, Vce 0.5V	6	0.00038	0.0005	0.0002	0.00061	0.00072	
	2.5×10¹²	Ic:40V, Ve Vb GND	Ic:2mA, Vce:0.12V	13	0.0151	0.0351	-0.0197	0.0540	0.0735	
			Ic 2mA, Vce 0.2V	6	0.0046	0.0060	0.0035	0.0066	0.0077	
	↓	Vce 0.5V, Ic:0.05mA	Ic:2mA, Vce:0.5V	6	0.00066	0.00075	0.0004	0.00084	0.00095	
	5×10¹²	Vc:40V, Ve:Vb:GND	Ic 2mA, Vce 0.12V	13	0.0153	0.0316	-0.0040	0.0426	0.0562	
↓	↓	Vce 0.5V, Ic:0.05mA	Ic 2mA, Vce:0.5V	6	0.00099	0.0013	0.0007	0.0014	0.0016	
Δ(1/hFE)	5×10¹¹	Vc:40V, Ve:Vb:GND	Ic:25mA, Vce:0.26V	10	0.00032	0.00057	0.00045	0.00065	0.00082	
	1×10¹²		Ic:25mA, Vce:0.34V	6	0.0014	0.0022	0.0008	0.0023	0.0028	
	1.25×10¹²		Ic:25mA, Vce 0.26V	13	0.00063	0.00104	0.00025	0.0012	0.0015	
	2.5×10¹²		↓	13	0.0010	0.00160	0.0009	0.0019	0.0024	
	↓		Ic:25mA, Vce:0.34V	6	0.0029	0.0044	0.0021	0.0047	0.0056	
↓	5×10¹²		Ic:25mA, Vce:0.26V	13	0.0015	0.0022	0.0005	0.0027	0.0033	
Δ(1/hFE)	5×10¹¹		Ic:0.06mA, Vce:20V	15	0.0053	0.0095	0.2013	0.0102	0.0126	
	1.25×10¹²		↓	13	0.0096	0.0162	0.0023	0.0185	0.0230	
	2.5×10¹²		↓	13	0.0141	0.0250	-0.0049	0.0341	0.0412	
↓	5×10¹²	↓	↓	13	0.0197	0.0570	0.0025	0.0481	0.0623	

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Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
1974-1975	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	Vc -40V,	Ic 1mA, Vce:20V	13	0.0017	0.0031	0.0010	0.0031	0.0038	
	1.25×10¹²	Vc Vb GND		13	0.0028	0.0045	0.0009	0.0052	0.0061	
	2.5×10¹²			13	0.0130	0.0366	0.0014	0.0423	0.0570	
↓	5×10¹²		↓	13	0.0054	0.0084	0.0021	0.0101	0.0124	
Δ(1/hFE)	5×10¹¹		Ic 20mA, Vce 20V	10	0.00033	0.0005	0.00010	0.0006	0.00074	
	1.25×10¹²			13	0.00060	0.0014	0.00012	0.0011	0.0014	
	2.5×10¹²			13	0.0009	0.0014	0.00022	0.0017	0.0020	
↓	5×10¹²	↓	↓	13	0.0013	0.0019	0.0004	0.0023	0.0029	

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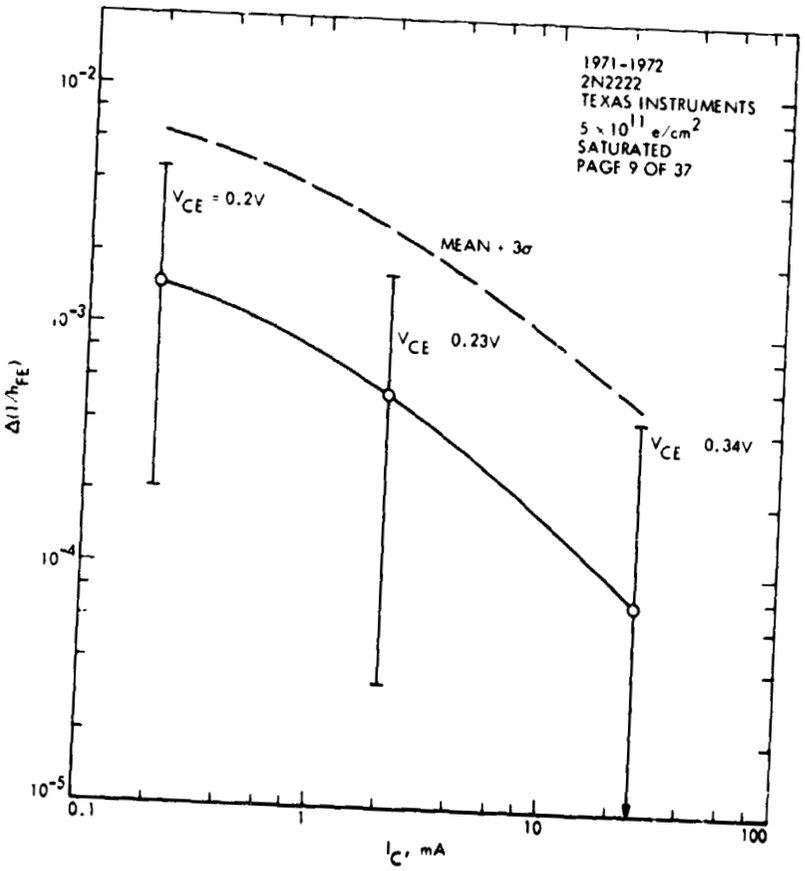
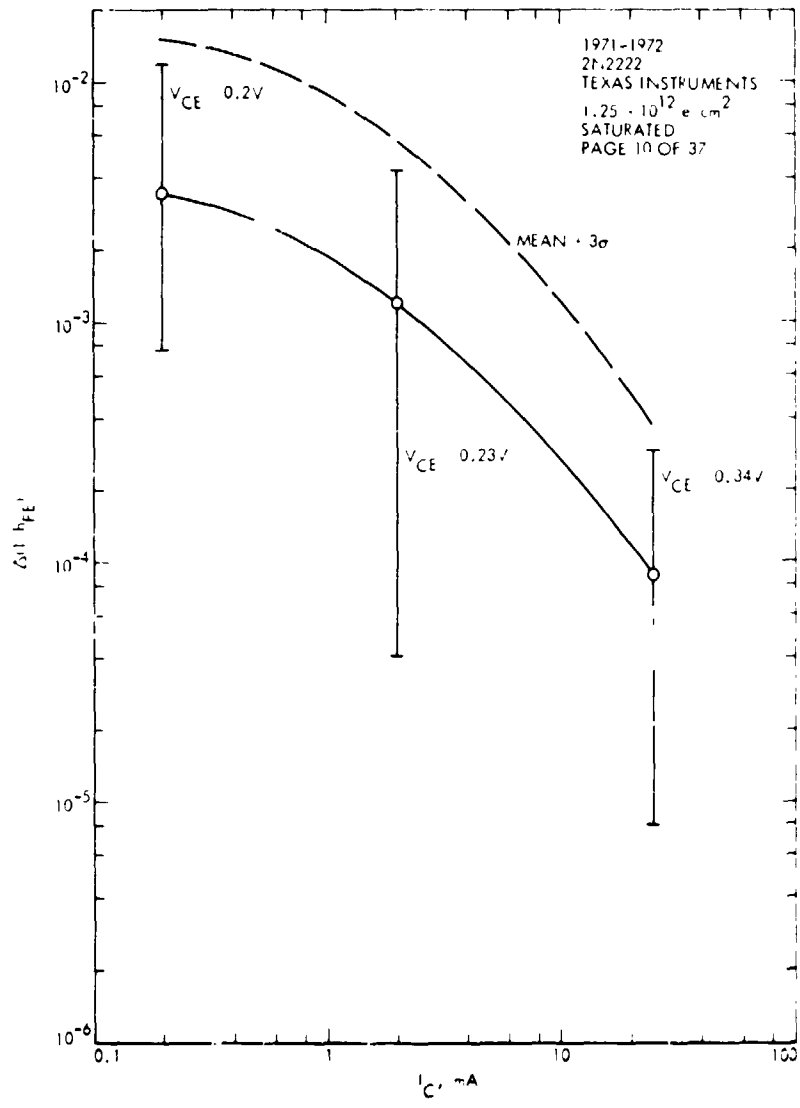
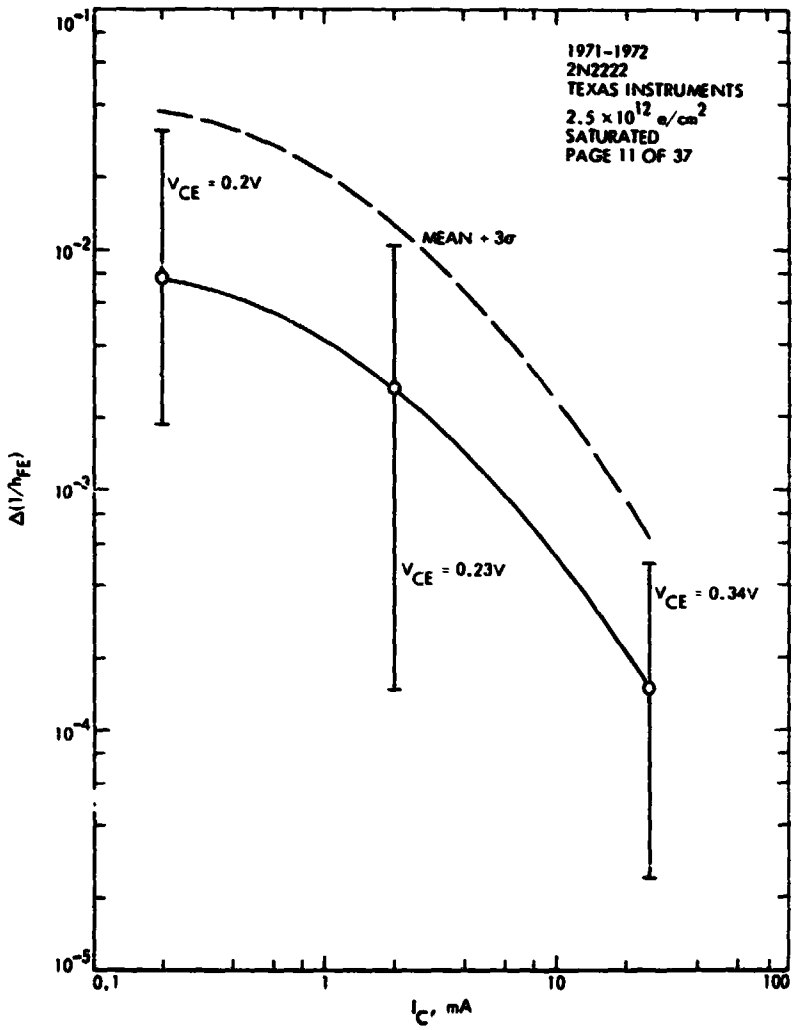
Parameter	Fluence	Operating Point:		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accep. Reject Criteria
1972	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ICBO (nA)	5×10¹²	VC: 60V	VCB: 60V	5	0.30	0.50	0.20	[illegible]	0.68	
↓	1×10¹³	VE, VB: GND	↓	4	0.40	0.60	0.20	0.71	0.86	
	↓	↓		5*	14.22	72	2.26	28.8	110.8	
IEBO (nA)	5×10¹²		VEB: 4V	5	1.19	1.80	0.15	2.44	3.06	
↓	1×10¹³	↓	↓	5	1.18	1.80	0.02	2.56	3.24	
1973-1975										
ICBO (nA)	5×10¹¹	VC: 15V	VCB: 15V	24	0.0388	[illegible]	0.0100	0.135	0.183	
↓	1.25×10¹²	VE, VB: GND	↓	24	0.0357	[illegible]	0.0050	0.133	0.182	
	2.5×10¹²			24	0.0363	0.245	0.0100	0.134	0.183	
↓	5×10¹²	↓	↓	24	0.0378	0.245	0.0070	0.139	0.190	

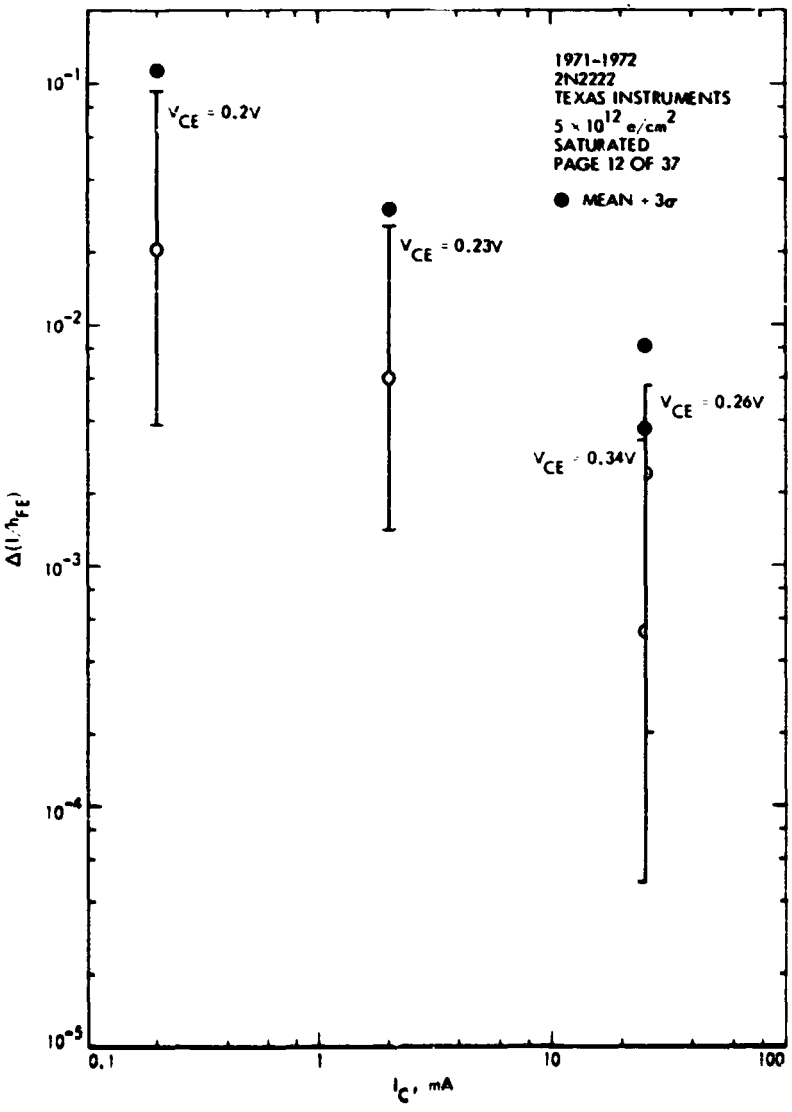
* OUTLIER INCLUDED

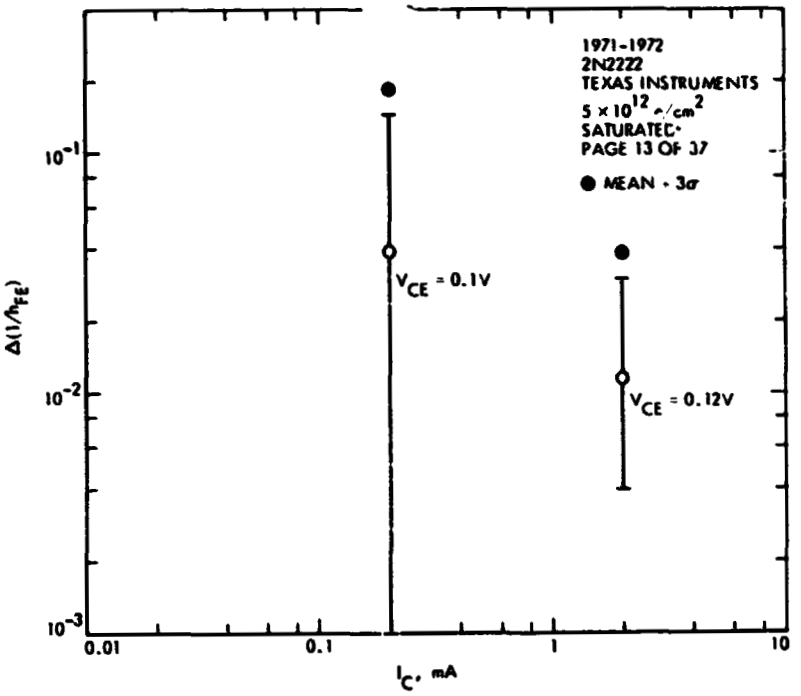


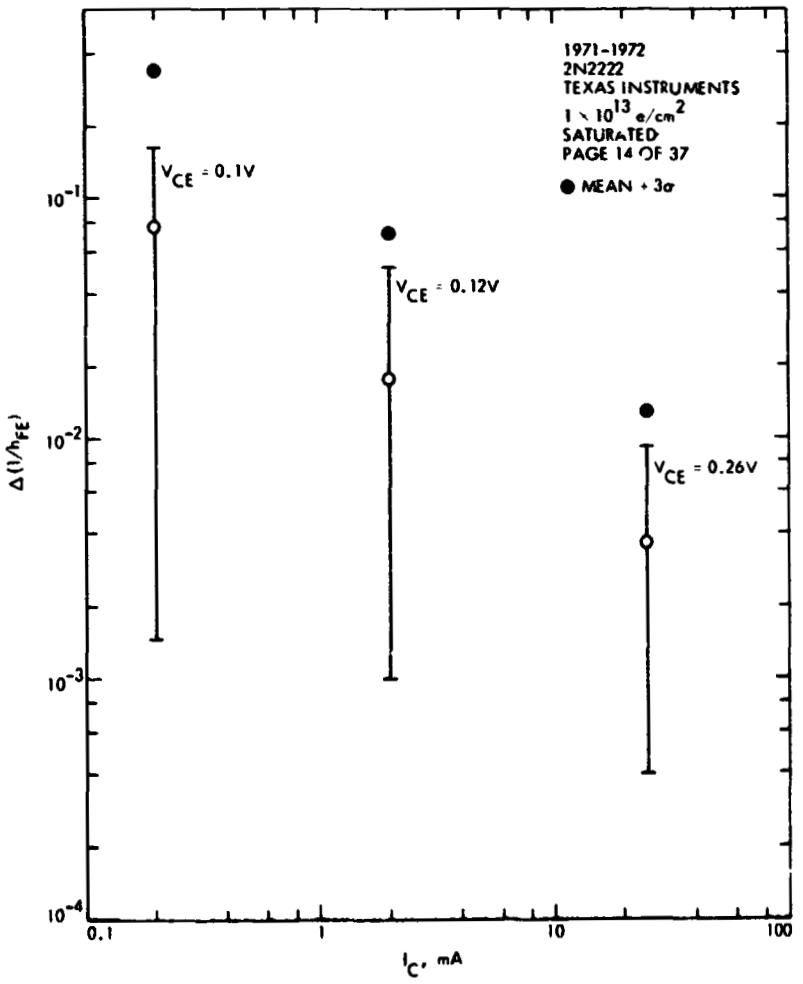
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

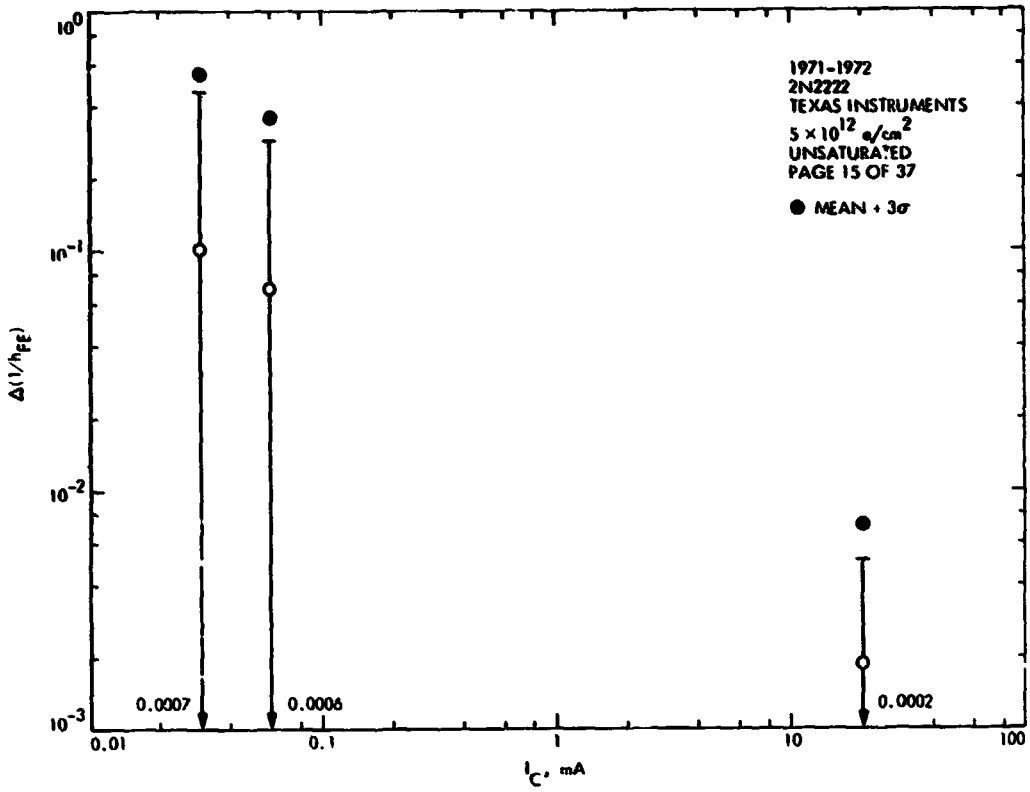

1971-1972
2N2222
TEXAS INSTRUMENTS
1.25 · 10^12 e cm^2
SATURATED
PAGE 10 OF 37
MEAN + 3σ
V_CE 0.2V
V_CE 0.23V
V_CE 0.34V
10^-2
10^-3
10^-4
10^-5
10^-6
0.1
1
10
100
I_C, mA

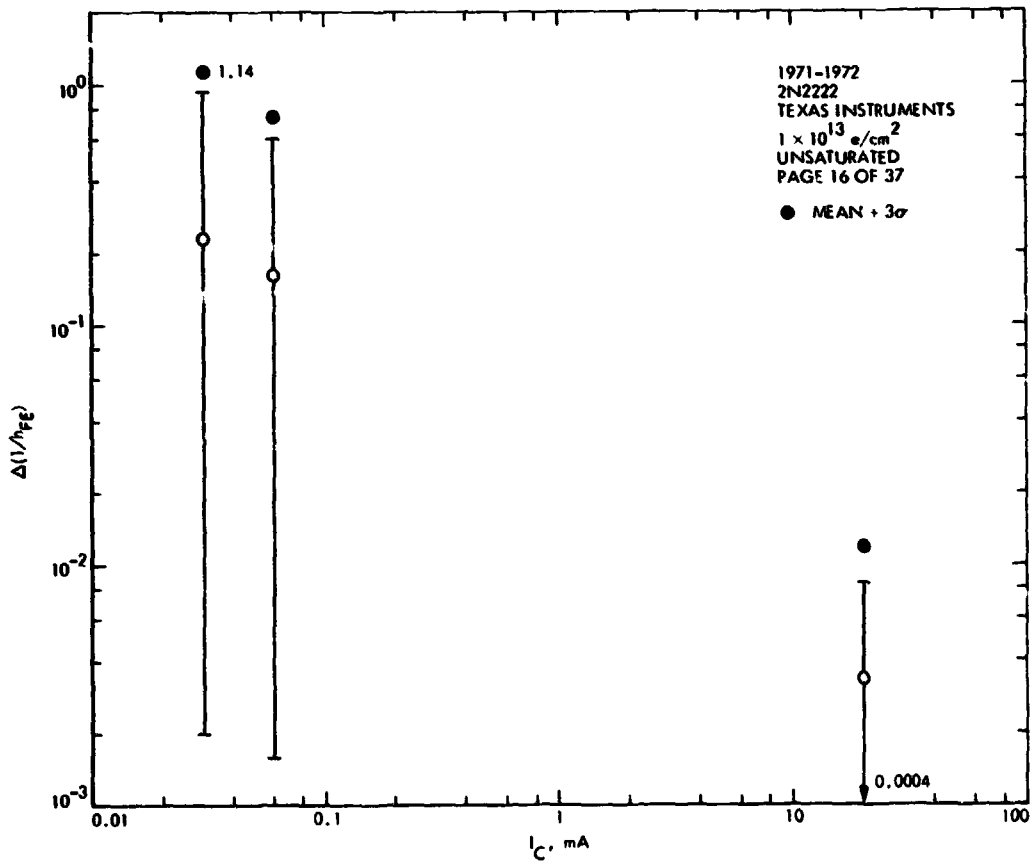

1971-1972
2N2222
TEXAS INSTRUMENTS
2.5 × 10^12 e/cm^2
SATURATED
PAGE 11 OF 37
V_CE = 0.2V
MEAN + 3σ
V_CE = 0.23V
V_CE = 0.34V
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
10^-5
0.1
1
10
100
I_C, mA

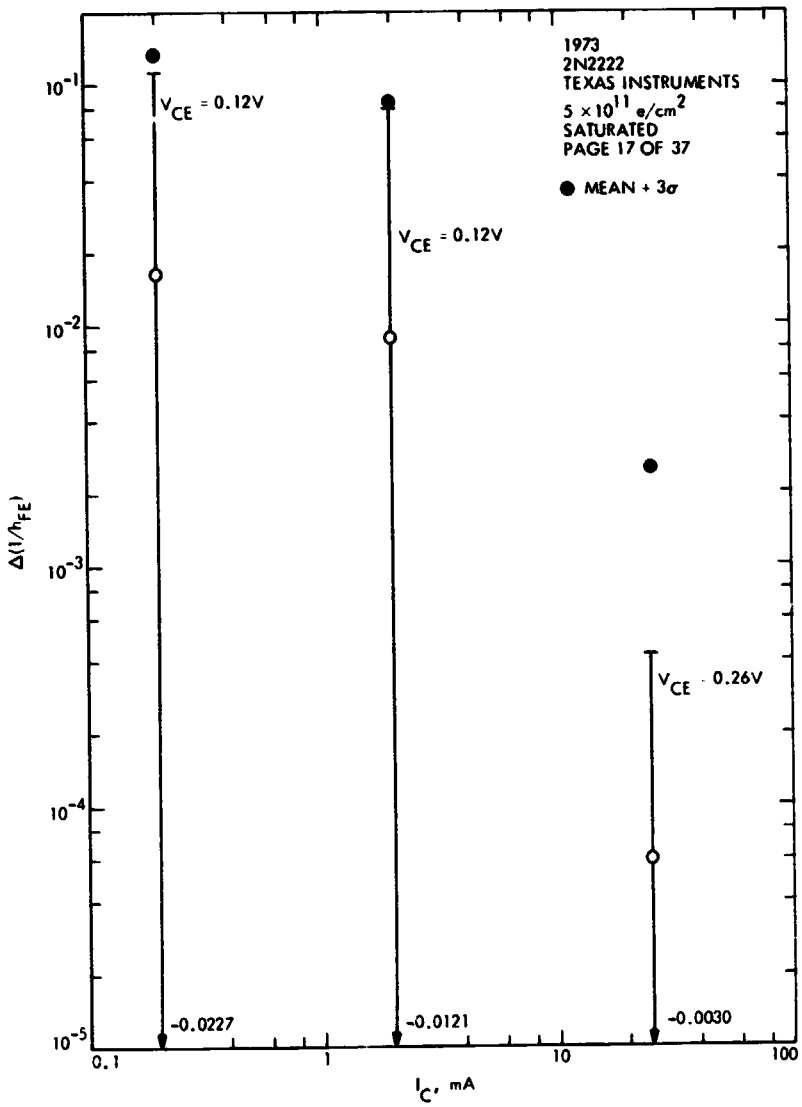

1971-1972
2N2222
TEXAS INSTRUMENTS
5 × 10^12 e/cm^2
SATURATED
PAGE 12 OF 37
● MEAN + 3σ
V_CE = 0.2V
V_CE = 0.23V
V_CE = 0.26V
V_CE = 0.34V
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
10^-5
0.1
1
10
100
I_C, mA

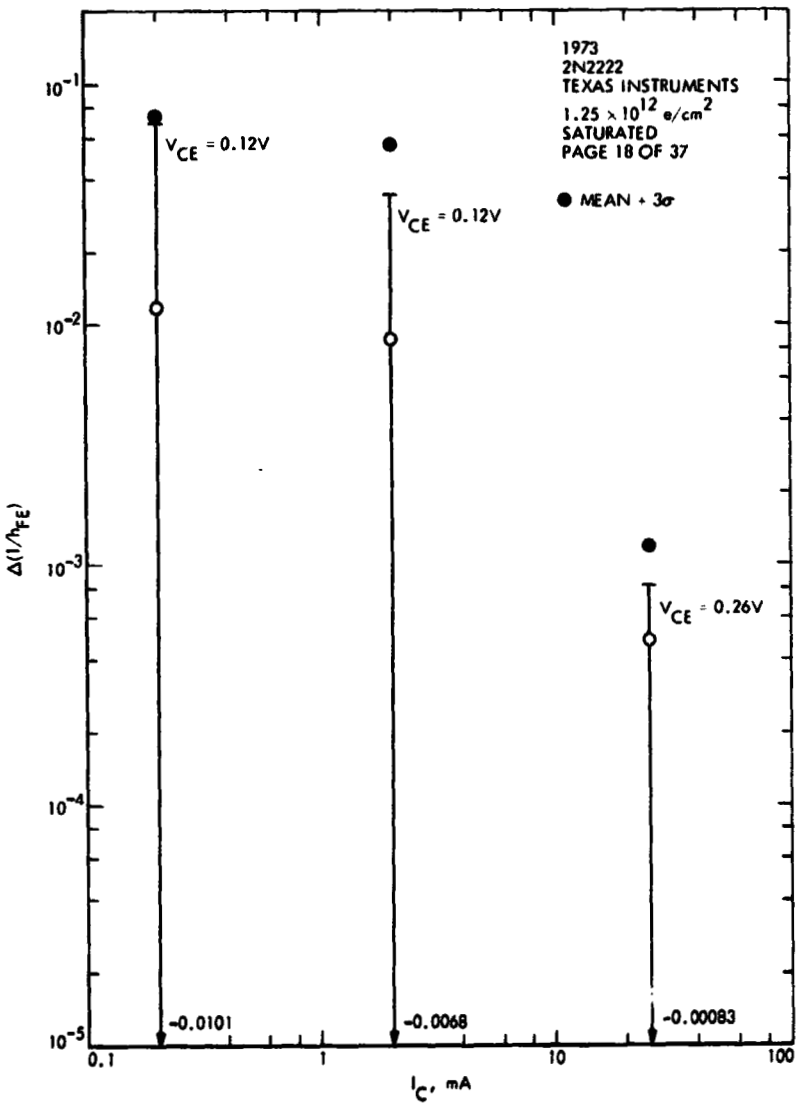

1971-1972
2N2222
TEXAS INSTRUMENTS
5 × 10^12 e/cm^2
SATURATED
PAGE 13 OF 37
● MEAN + 3σ
V_CE = 0.1V
V_CE = 0.12V
Δ(1/h_FE)
10^-1
10^-2
10^-3
0.01
0.1
1
10
I_C, mA

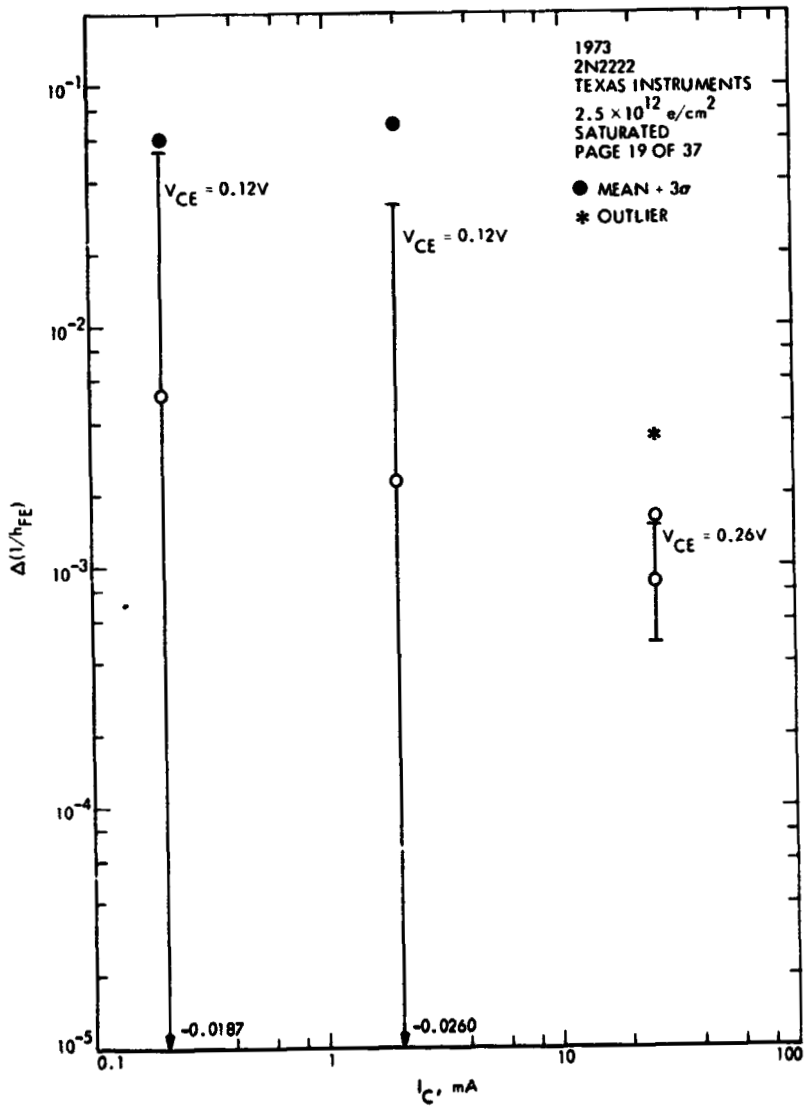

1971-1972
2N2222
TEXAS INSTRUMENTS
1 × 10^13 e/cm^2
SATURATED
PAGE 14 OF 37
● MEAN + 3σ
V_CE = 0.1V
V_CE = 0.12V
V_CE = 0.26V
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
0.1
1
10
100
I_C, mA

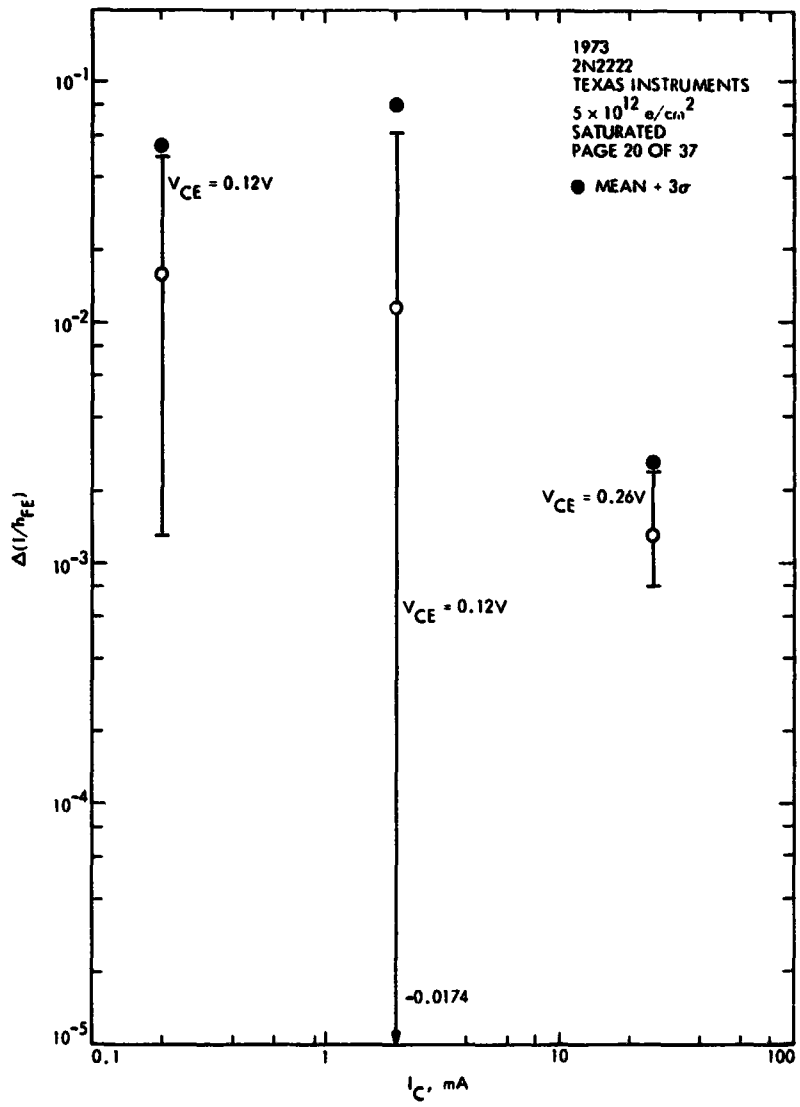

1971-1972
2N2222
TEXAS INSTRUMENTS
5 × 10^12 e/cm^2
UNSATURATED
PAGE 15 OF 37
● MEAN + 3σ
0.0007
0.0006
0.0002
Δ(1/h_FE)
I_C, mA

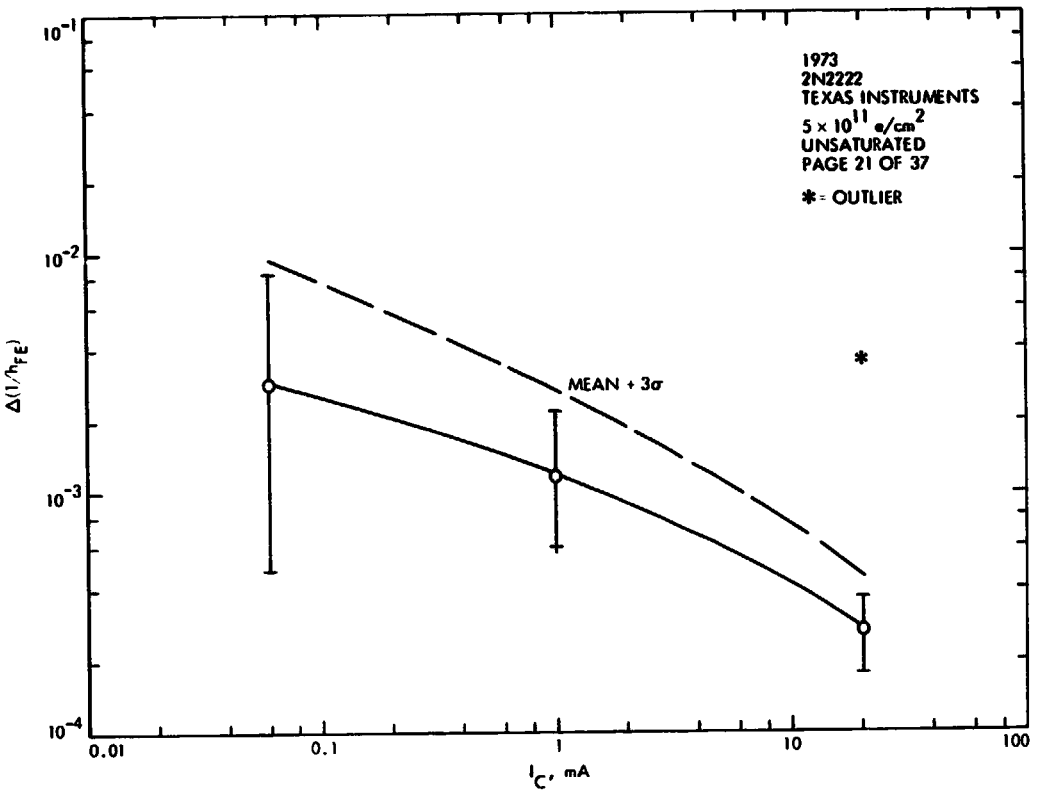

1.14
1971-1972
2N2222
TEXAS INSTRUMENTS
1 × 10^13 e/cm^2
UNSATURATED
PAGE 16 OF 37
● MEAN + 3σ
0.0004
Δ(1/h_FE)
I_C, mA

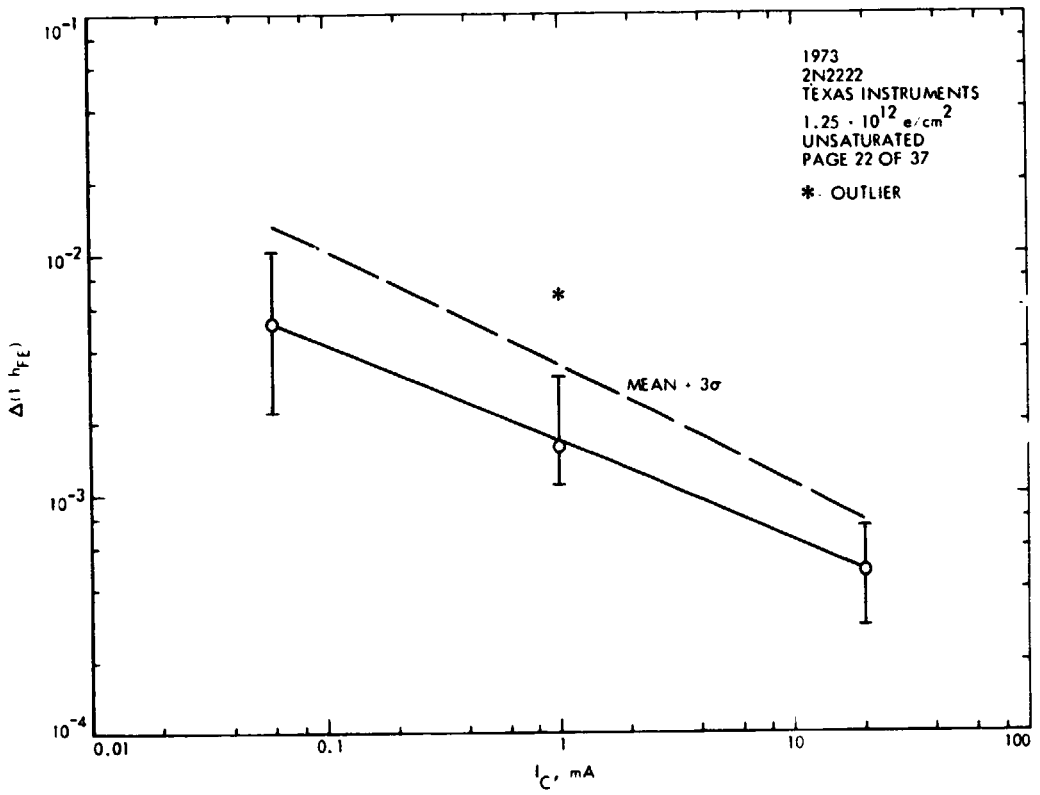

1973
2N2222
TEXAS INSTRUMENTS
5 × 10^11 e/cm^2
SATURATED
PAGE 17 OF 37
● MEAN + 3σ
V_CE = 0.12V
V_CE = 0.12V
V_CE = 0.26V
-0.0227
-0.0121
-0.0030
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
10^-5
0.1
1
10
100
I_C, mA

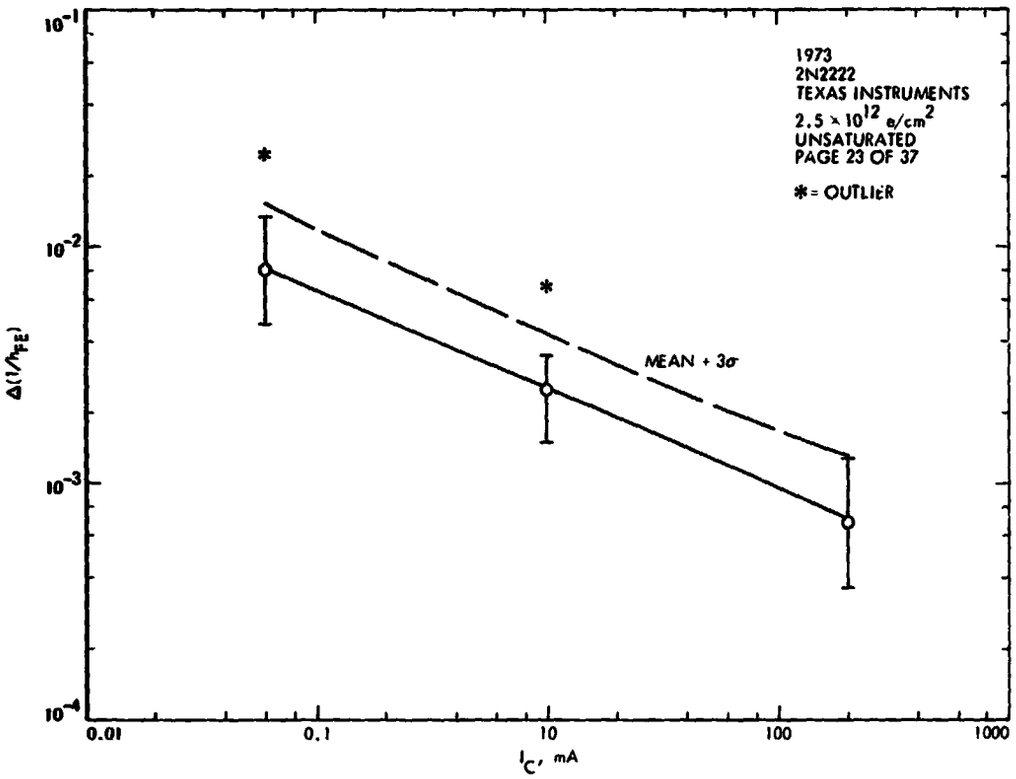

1973
2N2222
TEXAS INSTRUMENTS
1.25 × 10^12 e/cm^2
SATURATED
PAGE 18 OF 37
● MEAN + 3σ
V_CE = 0.12V
V_CE = 0.12V
V_CE = 0.26V
-0.0101
-0.0068
-0.00083
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
10^-5
0.1
1
10
100
I_C, mA

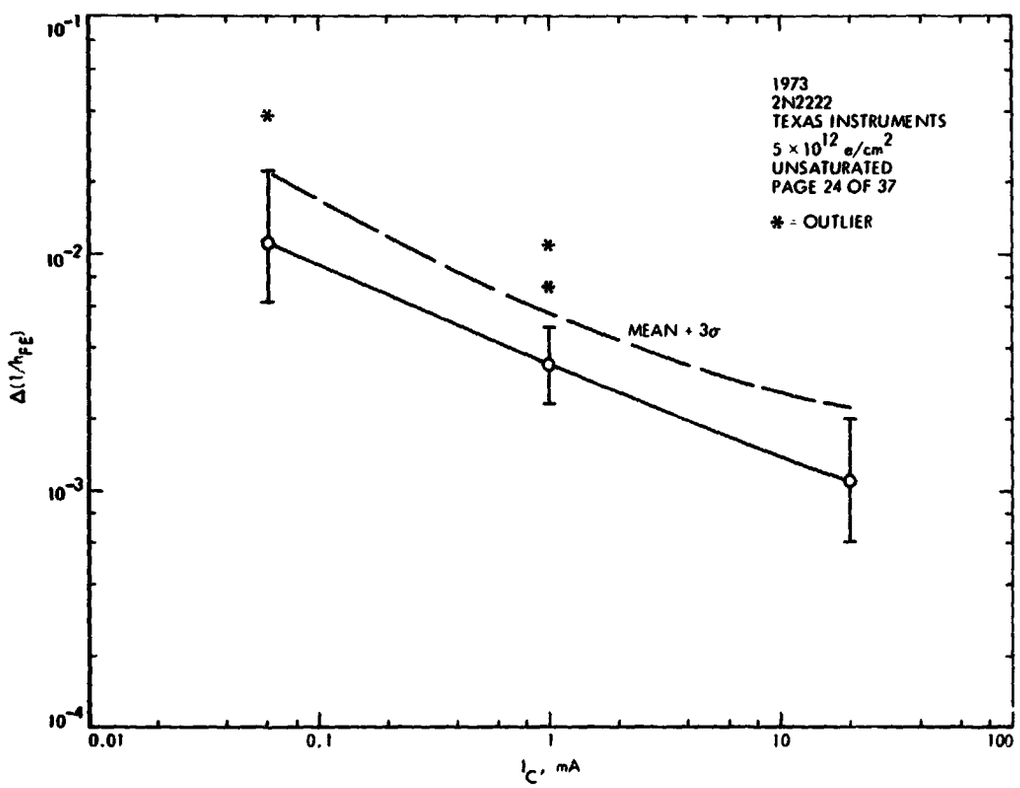

1973
2N2222
TEXAS INSTRUMENTS
2.5 × 10^12 e/cm^2
SATURATED
PAGE 19 OF 37
● MEAN + 3σ
✱ OUTLIER
V_CE = 0.12V
V_CE = 0.12V
V_CE = 0.26V
-0.0187
-0.0260
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
10^-5
0.1
1
10
100
I_C, mA

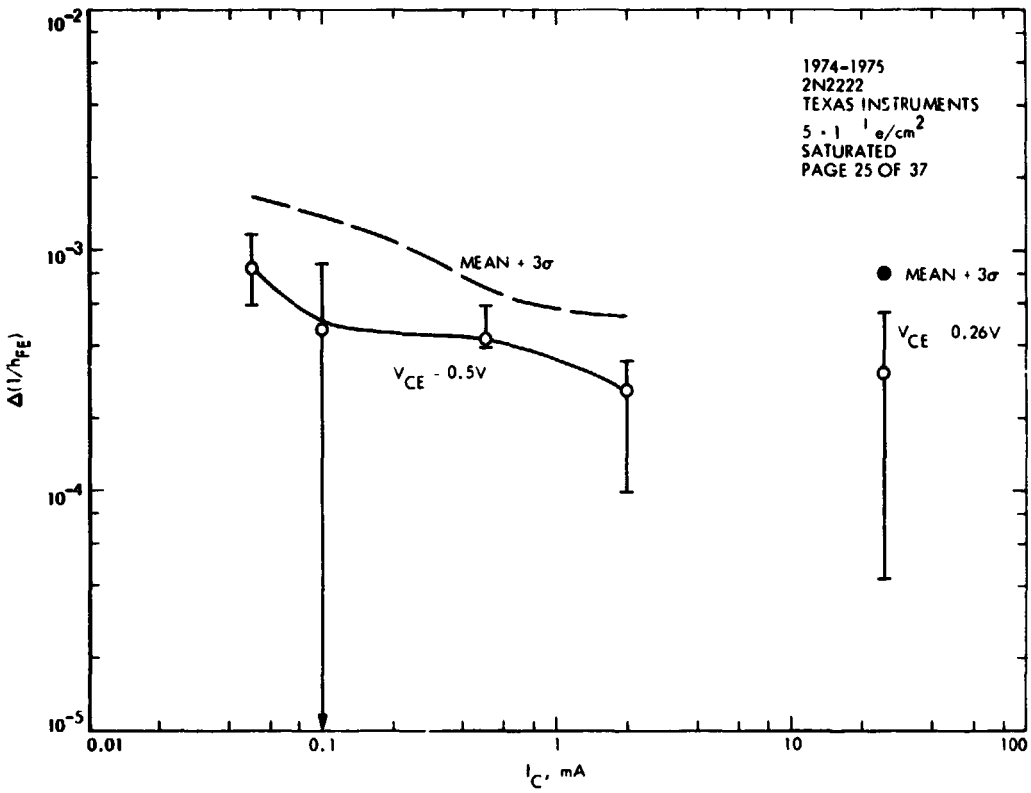

1973
2N2222
TEXAS INSTRUMENTS
5 x 10^12 e/cm^2
SATURATED
PAGE 20 OF 37
● MEAN + 3σ
V_CE = 0.12V
V_CE = 0.12V
V_CE = 0.26V
-0.0174
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
10^-5
0.1
1
10
100
I_C, mA

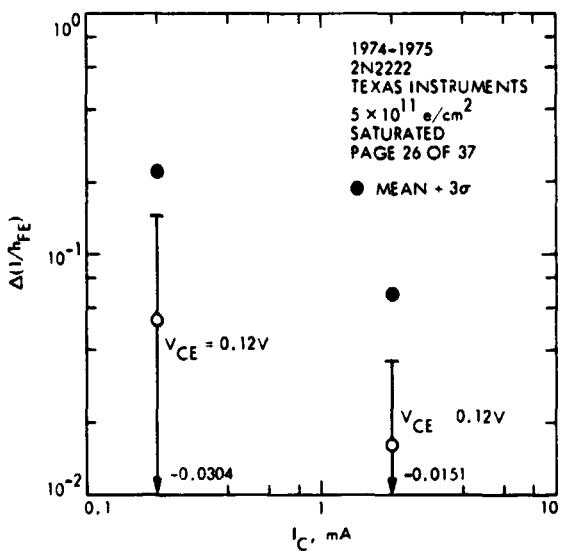

1973
2N2222
TEXAS INSTRUMENTS
5 × 10^11 e/cm^2
UNSATURATED
PAGE 21 OF 37
* = OUTLIER
MEAN + 3σ
Δ(1/h_FE)
I_C, mA
10^-1
10^-2
10^-3
10^-4
0.01
0.1
1
10
100

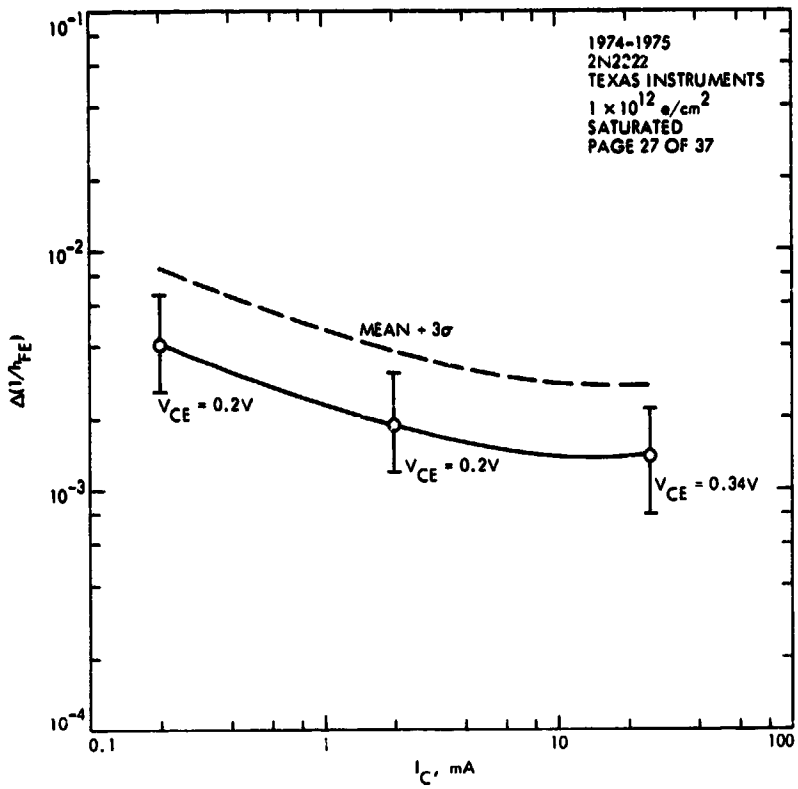

1973
2N2222
TEXAS INSTRUMENTS
1.25 · 10^12 e/cm^2
UNSATURATED
PAGE 22 OF 37
* · OUTLIER
MEAN + 3σ
Δ(1/h_FE)
I_C, mA
10^-1
10^-2
10^-3
10^-4
0.01
0.1
1
10
100

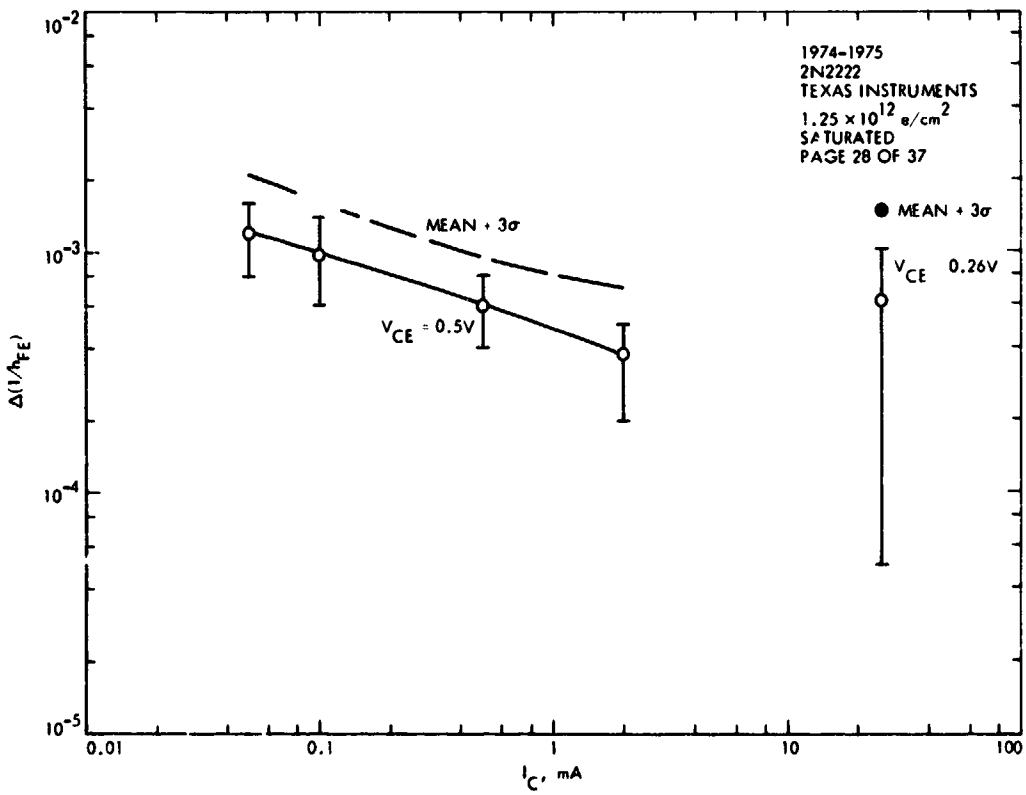

1973
2N2222
TEXAS INSTRUMENTS
2.5 × 10^12 e/cm^2
UNSATURATED
PAGE 23 OF 37
* = OUTLIER
MEAN + 3σ
Δ(1/h_FE)
I_C, mA
10^-1
10^-2
10^-3
10^-4
0.01
0.1
10
100
1000

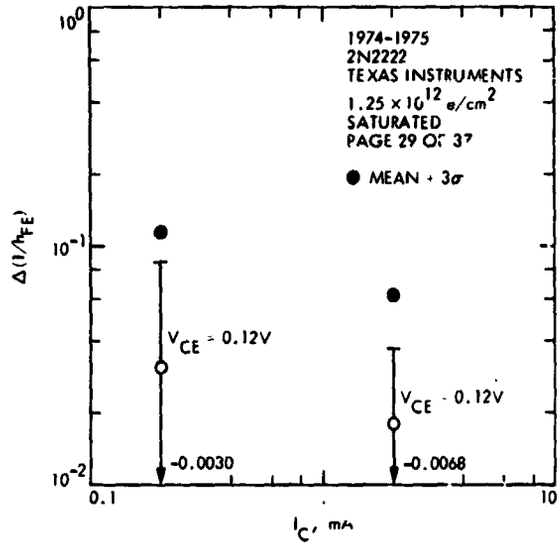

1973
2N2222
TEXAS INSTRUMENTS
5 × 10^12 e/cm^2
UNSATURATED
PAGE 24 OF 37
* = OUTLIER
MEAN + 3σ
Δ(1/h_FE)
I_C, mA
10^-1
10^-2
10^-3
10^-4
0.01
0.1
1
10
100

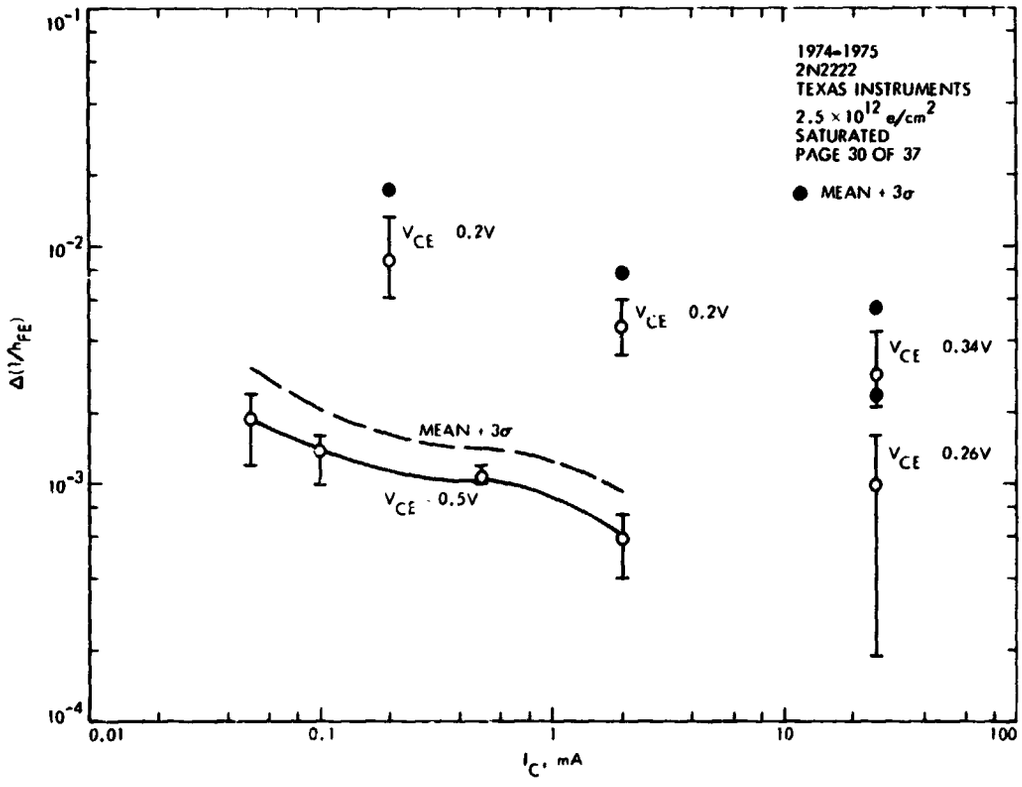

1974-1975
2N2222
TEXAS INSTRUMENTS
5 · 1 ¹ e/cm²
SATURATED
PAGE 25 OF 37
MEAN + 3σ
MEAN + 3σ
V_CE - 0.5V
V_CE 0.26V
Δ(1/h_FE)
I_C, mA


1974-1975
2N2222
TEXAS INSTRUMENTS
5 × 10¹¹ e/cm²
SATURATED
PAGE 26 OF 37
MEAN + 3σ
V_CE = 0.12V
V_CE 0.12V
-0.0304
-0.0151
Δ(1/h_FE)
I_C, mA


1974-1975
2N2222
TEXAS INSTRUMENTS
1 × 10^12 e/cm^2
SATURATED
PAGE 27 OF 37
MEAN + 3σ
V_CE = 0.2V
V_CE = 0.2V
V_CE = 0.34V
Δ(1/h_FE)
I_C, mA
10^-1
10^-2
10^-3
10^-4
0.1
1
10
100


1974-1975
2N2222
TEXAS INSTRUMENTS
1.25 × 10^12 e/cm^2
SATURATED
PAGE 28 OF 37
MEAN + 3σ
MEAN + 3σ
V_CE = 0.5V
V_CE 0.26V
Δ(1/h_FE)
I_C, mA
10^-2
10^-3
10^-4
10^-5
0.01
0.1
1
10
100





REPRODUCIBILITY OF THE
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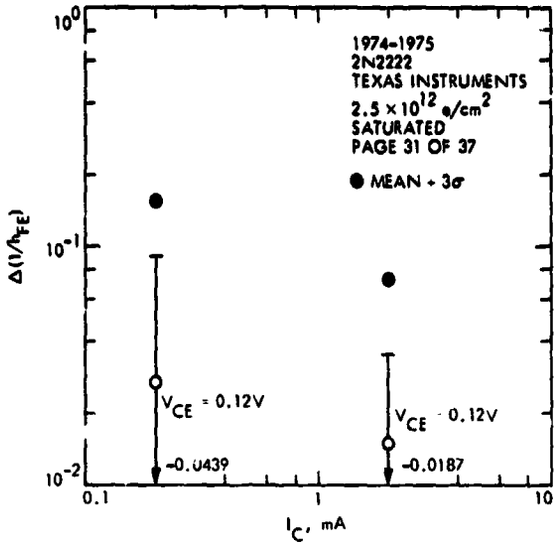
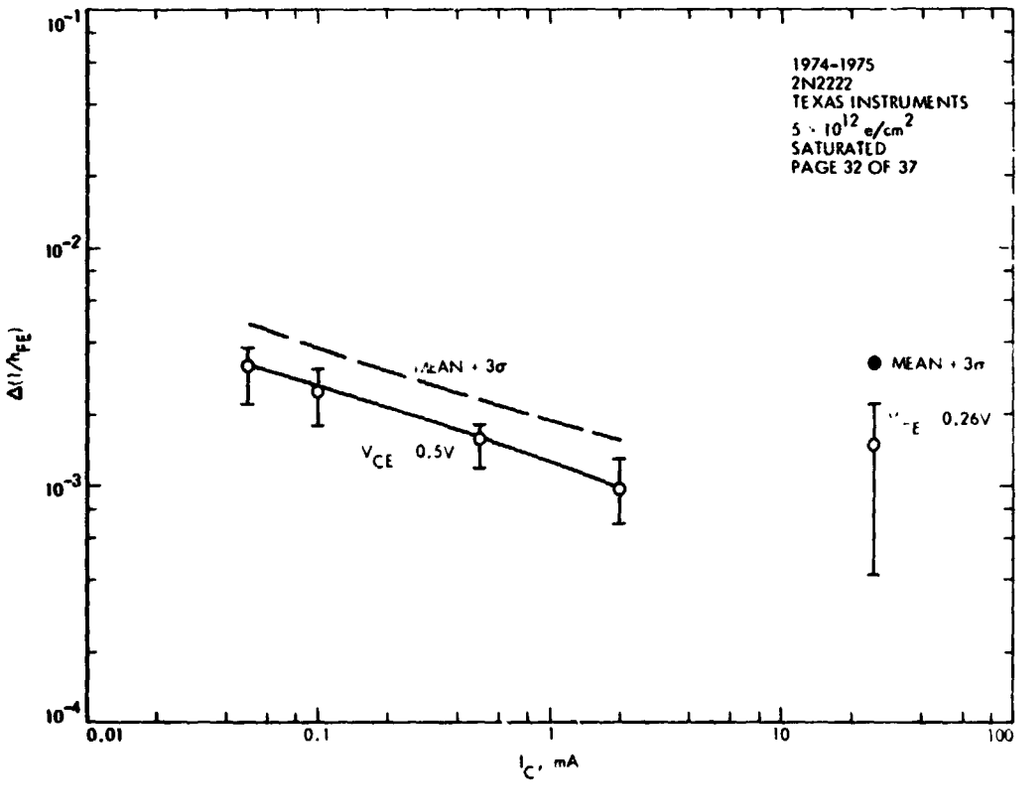
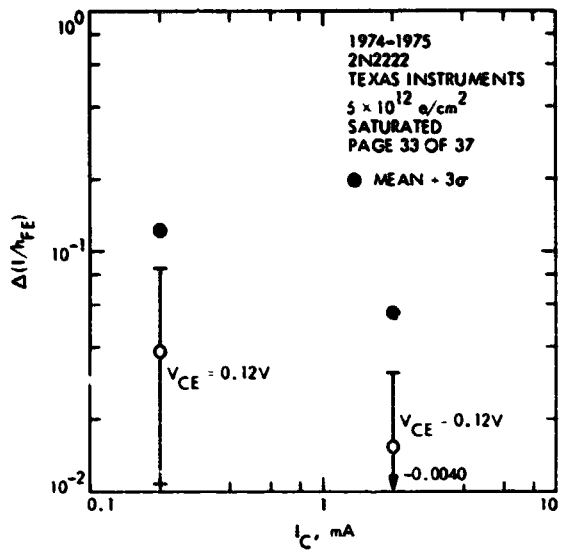
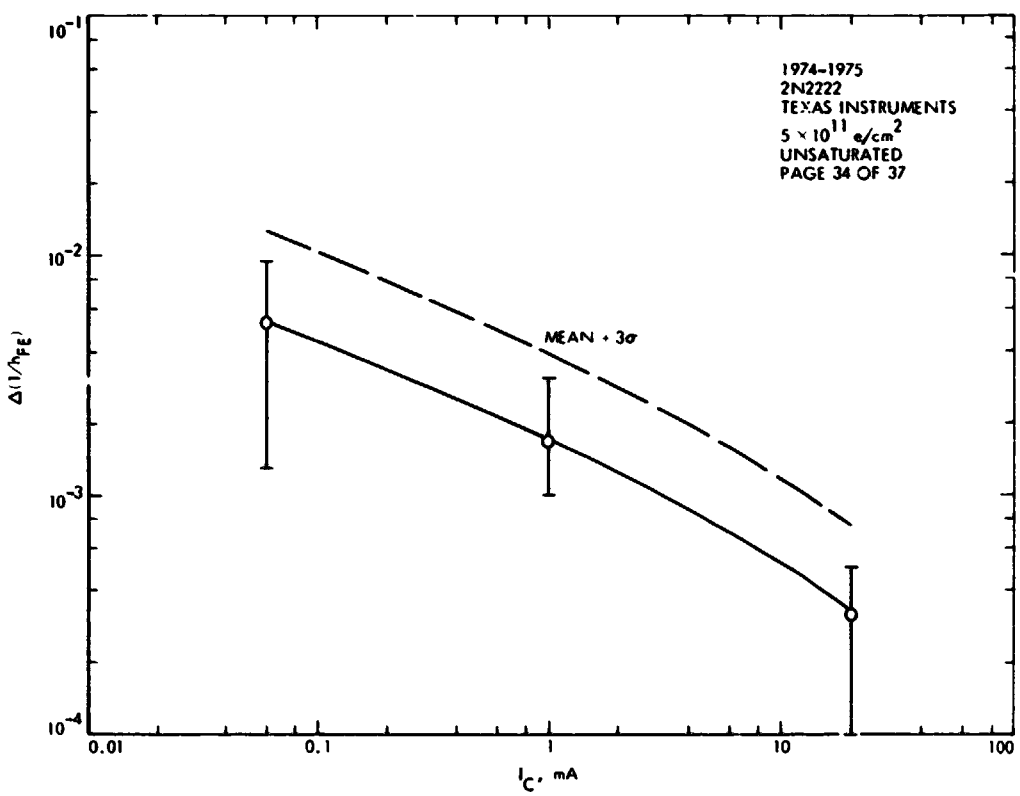
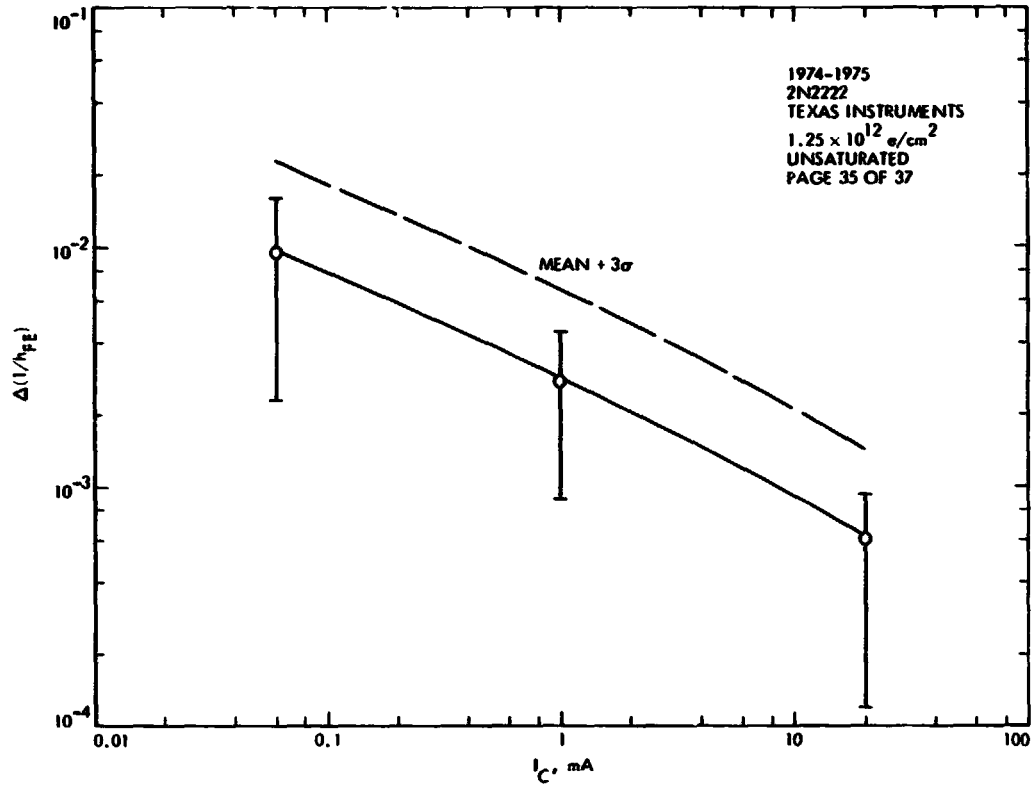
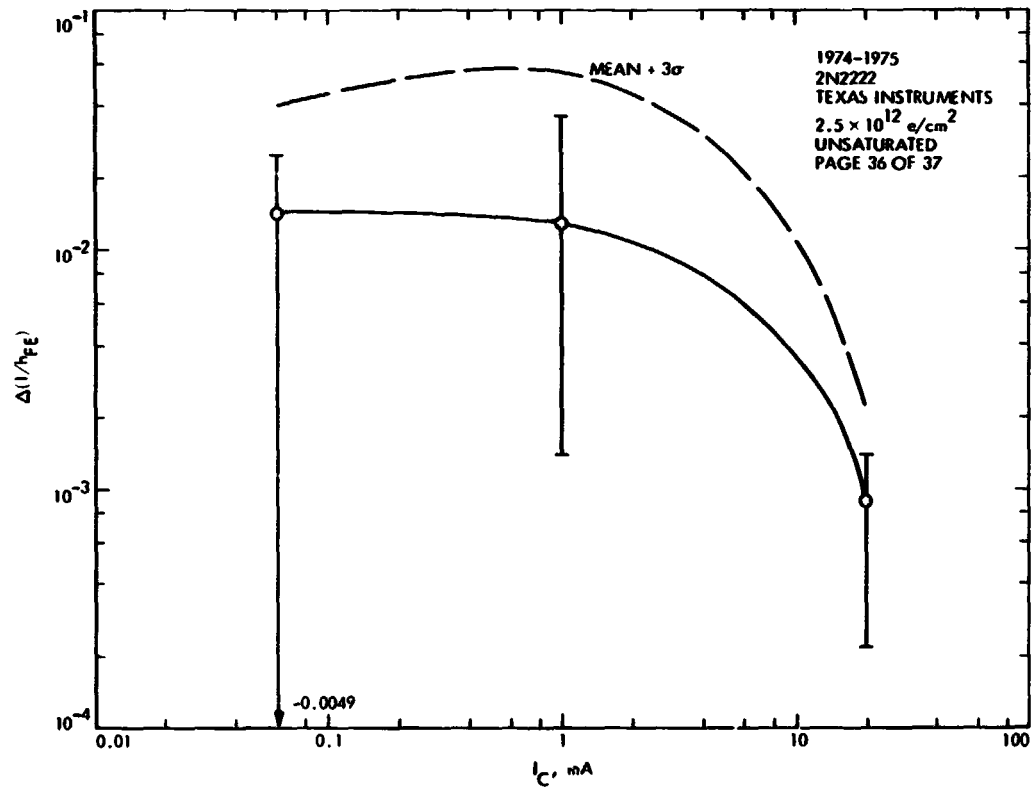

1974-1975
2N2222
TEXAS INSTRUMENTS
2.5 × 10^12 e/cm^2
SATURATED
PAGE 31 OF 37
● MEAN + 3σ
Δ(1/h_FE)
V_CE = 0.12V
-0.0439
V_CE = 0.12V
-0.0187
I_C, mA

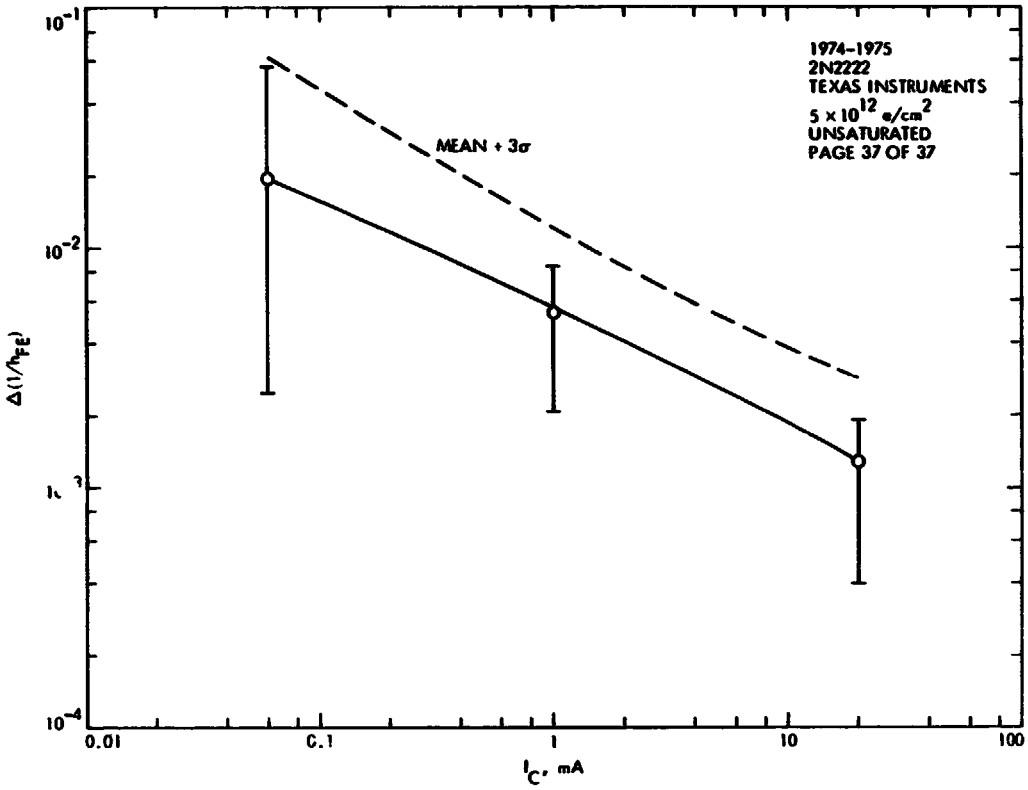

1974-1975
2N2222
TEXAS INSTRUMENTS
5 × 10^12 e/cm^2
SATURATED
PAGE 32 OF 37
MEAN + 3σ
V_CE 0.5V
● MEAN + 3σ
V_CE 0.26V
Δ(1/h_FE)
I_C, mA


1974-1975
2N2222
TEXAS INSTRUMENTS
5 × 10^12 e/cm^2
SATURATED
PAGE 33 OF 37
MEAN + 3σ
Δ(1/hFE)
VCE = 0.12V
VCE = 0.12V
-0.0040
IC, mA


1974-1975
2N2222
TEXAS INSTRUMENTS
5 × 10^11 e/cm^2
UNSATURATED
PAGE 34 OF 37
MEAN + 3σ
Δ(1/hFE)
IC, mA


1974-1975
2N2222
TEXAS INSTRUMENTS
1.25 × 10^12 e/cm^2
UNSATURATED
PAGE 35 OF 37
MEAN + 3σ
Δ(1/h_FE)
I_C, mA


1974-1975
2N2222
TEXAS INSTRUMENTS
2.5 × 10^12 e/cm^2
UNSATURATED
PAGE 36 OF 37
MEAN + 3σ
-0.0049
Δ(1/h_FE)
I_C, mA

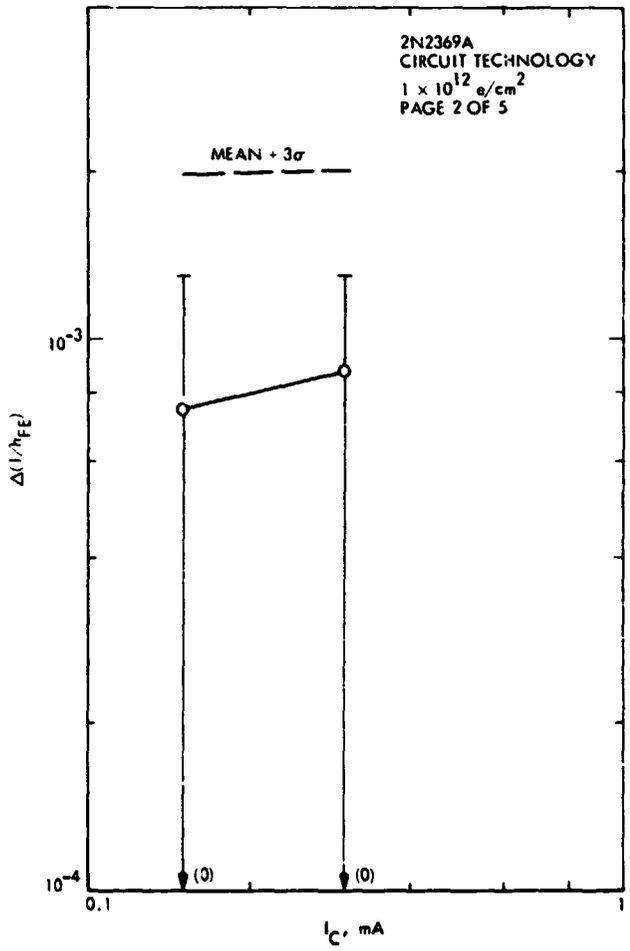


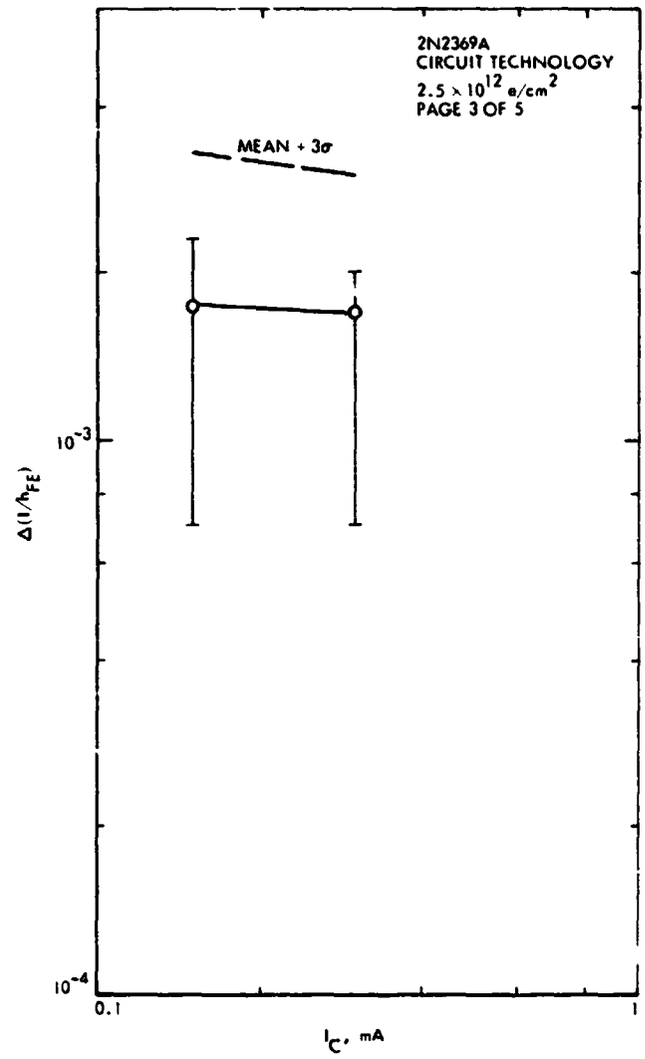
2N2369, Circuit Technology

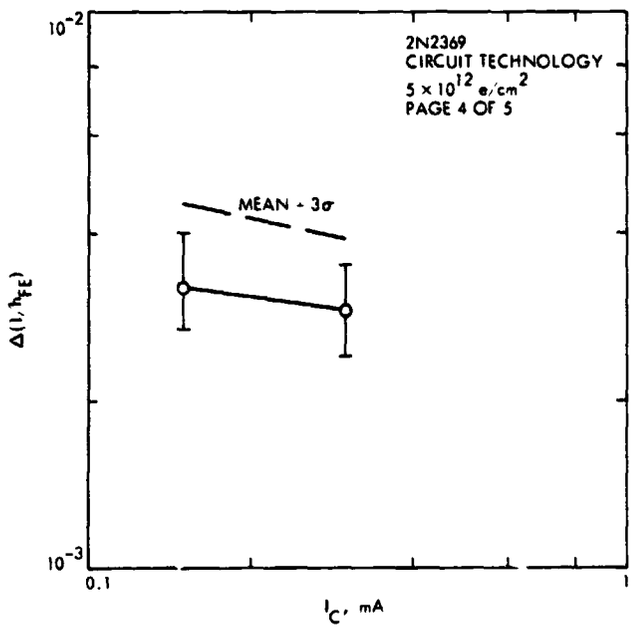
DEVICE TYPE: 2N2369 CTI PAGE 1 of 5 3

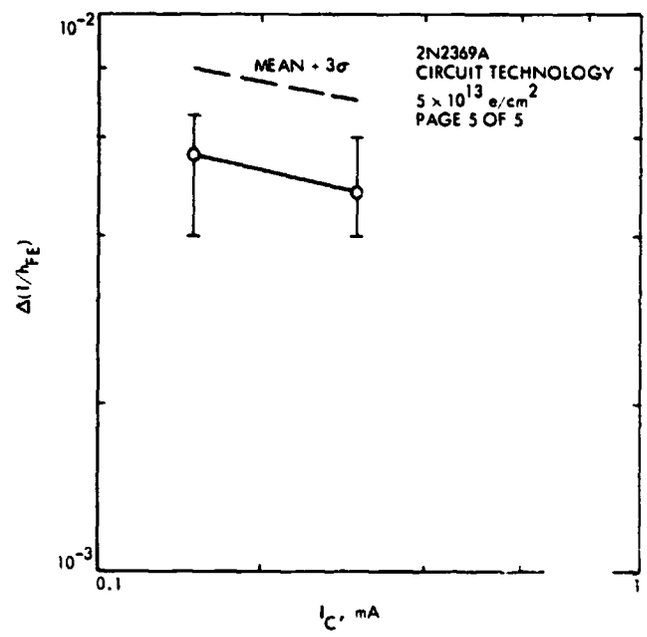
Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	1×10^12	VCE=5V; IC=150μA	VCE=5V; IC=150μA	8	0.00125	0.0013	0	0.00158	0.00199	
	2.5×10^12			8	0.00175	0.0023	0.0007	0.0028	0.0033	
	5×10^12			8	0.0032	0.0040	0.0027	0.0041	0.0045	
	5×10^13			8	0.0056	0.0066	0.0040	0.0072	0.0080	
Δ(1/hFE)	1×10^12		VCE=5V; IC=300μA	8	0.0008	0.0013	0	0.0017	0.0020	
	2.5×10^12			8	0.0017	0.0020	0.0007	0.0025	0.0030	
	5×10^12			8	0.0029	0.0035	0.0024	0.0036	0.0039	
	5×10^13			8	0.0048	0.0060	0.0040	0.0063	0.0070	

A65


2N2369A
CIRCUIT TECHNOLOGY
1 × 10^12 e/cm^2
PAGE 2 OF 5
MEAN + 3σ
10^-3
10^-4
Δ(1/h_FE)
(0)
(0)
0.1
1
I_C, mA


2N2369A
CIRCUIT TECHNOLOGY
2.5 × 10^12 e/cm^2
PAGE 3 OF 5
MEAN + 3σ
10^-3
10^-4
Δ(1/h_FE)
0.1
1
I_C, mA

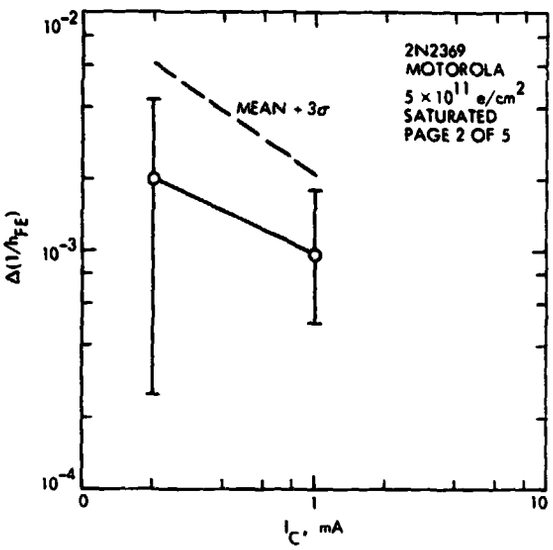

2N2369
CIRCUIT TECHNOLOGY
5 × 10^12 e/cm^2
PAGE 4 OF 5
MEAN + 3σ
10^-2
10^-3
Δ(1/h_FE)
0.1
1
I_C, mA

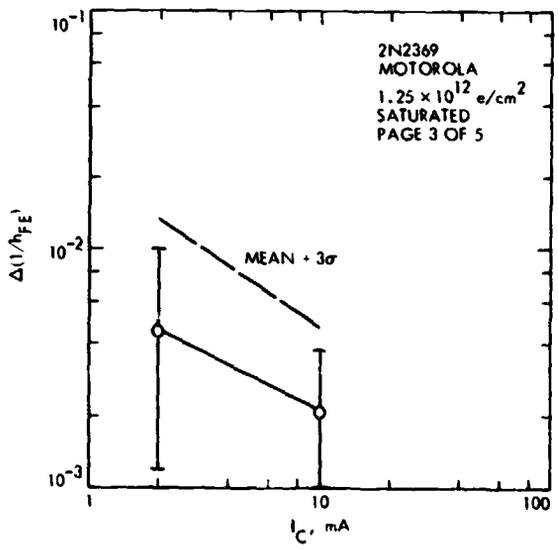

2N2369A
CIRCUIT TECHNOLOGY
5 × 10^13 e/cm^2
PAGE 5 OF 5
MEAN + 3σ
10^-2
10^-3
Δ(1/h_FE)
0.1
1
I_C, mA

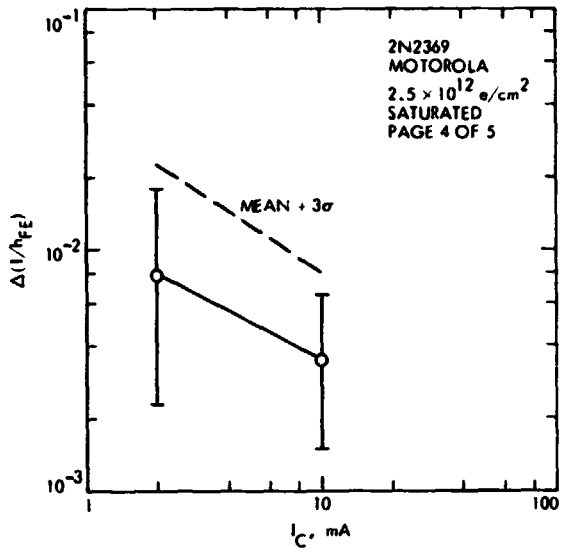
2N2369, Motorola

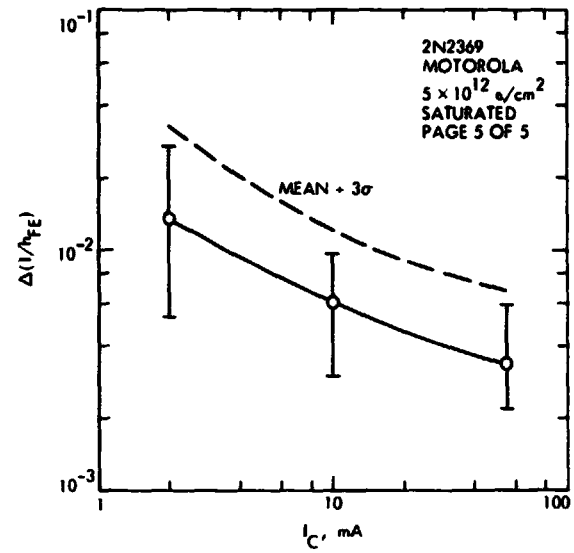
DEVICE TYPE: 2N2369 MOTOROLA PAGE 1 OF 5 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	Vce 5V, Ic: 0	Ic: 2mA; Vce 5V	12	0.0025	0.0112	0.0005	0.0084	0.0114	
	1.25×10¹²			12	0.0043	0.0100	0.0012	0.0099	0.0126	
	2.5×10¹²			12	0.0074	0.0172	0.0020	0.0167	0.0213	
	5×10¹²			12	0.0132	0.0257	0.0040	0.0248	0.0306	
Δ(1/hFE)	5×10¹¹		Ic: 2mA; Vce = 0.4V	12	0.0020	0.0045	0.0005	0.0047	0.0061	
	1.25×10¹²			12	0.0046	0.0100	0.0012	0.0105	0.0134	
	2.5×10¹²			12	0.0079	0.0180	0.0023	0.0178	0.0228	
	5×10¹²			12	0.0137	0.0270	0.0053	0.0269	0.0335	
Δ(1/hFE)	5×10¹¹		Ic: 10mA, Vce = 0.4V	12	0.0007	0.0018	0.0005	0.0017	0.0021	
	1.25×10¹²			12	0.0021	0.0048	0.0010	0.0039	0.0047	
	2.5×10¹²			12	0.0035	0.0065	0.0015	0.0065	0.0080	
	5×10¹²			12	0.0061	0.0097	0.0030	0.0103	0.0124	
Δ(1/hFE)	5×10¹²		Ic: 55mA, Vce = 0.4V	12	0.0034	0.0059	0.0022	0.0056	0.0068	





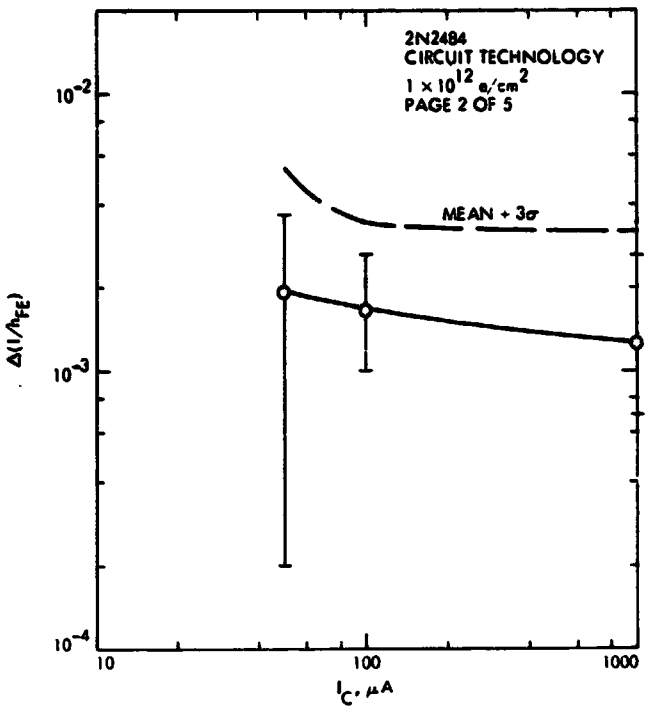


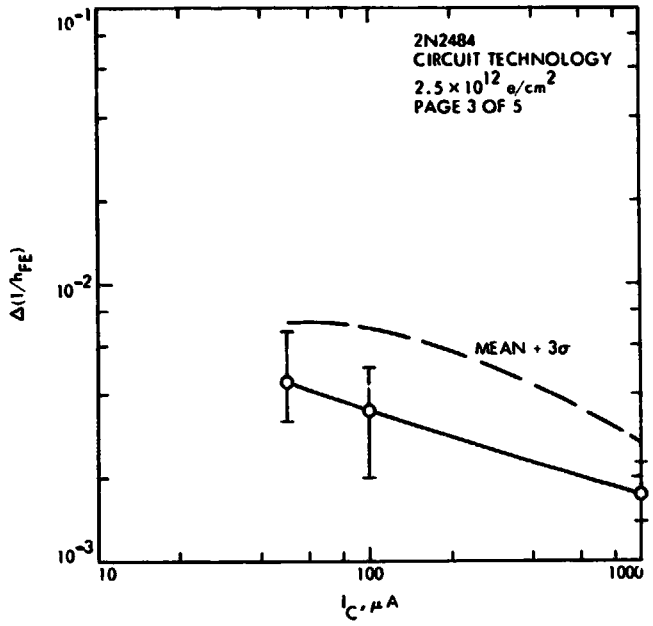


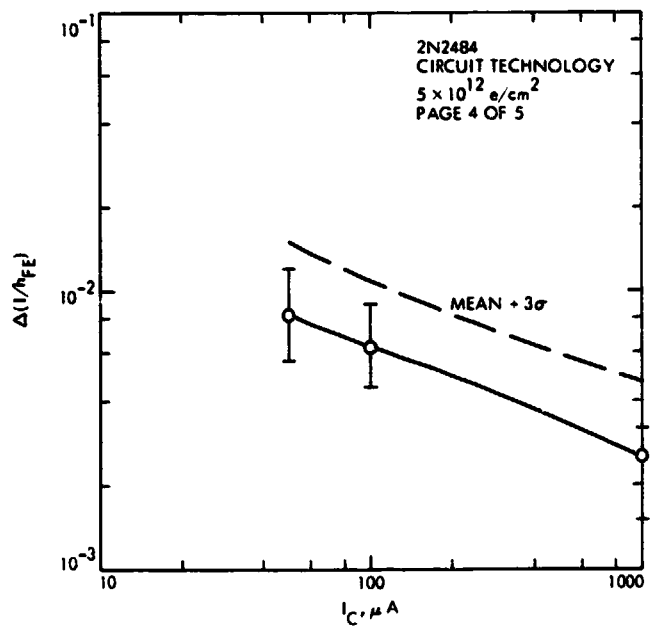
2N2484, Circuit Technology

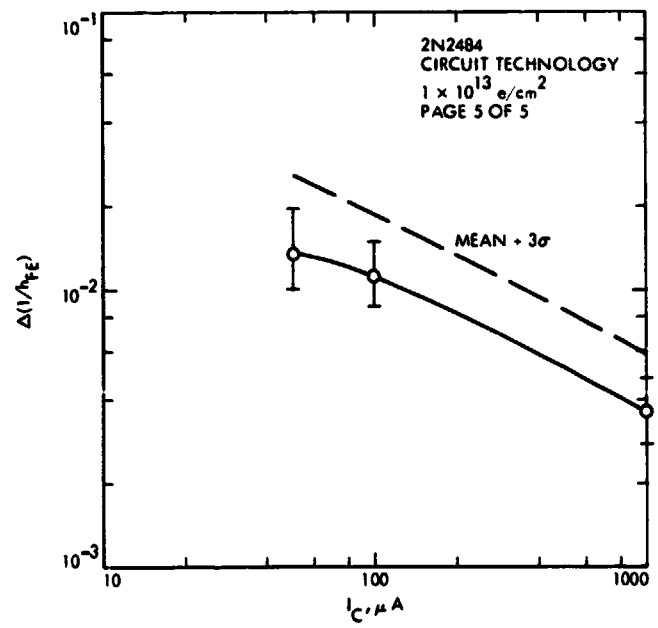
DEVICE TYPE: 2N2484 CTI PAGE 1 of 5 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/h_FE)	1×10^12	BIAS: IRRAD	BIAS: MEAS	6	0.00193	0.0036	0.0002	0.00422	0.00536	
		VCE = 6V	VCE = 6V							
	2.5×10^12	IC = 50μA	IC = 50μA	6	0.00451	0.0068	0.0032	0.00718	0.00898	
	5×10^12	↓	↓	6	0.00817	0.012	0.0056	0.0127	0.015	
↓	1×10^13	↓	↓	6	0.0135	0.0196	0.0102	0.0215	0.0254	
Δ(1/h_FE)	1×10^12	VCE = 6V	VCE = 6V	6	0.001168	0.0026	0.001	0.00287	0.00397	
		IC = 50μA	IC = 100μA							
	2.5×10^12	↓	↓	6	0.0035	0.005	0.002	0.00573	0.00685	
	5×10^12			6	0.00622	0.009	0.0045	0.00944	0.0111	
↓	1×10^13	↓	↓	6	0.0112	0.015	0.0089	0.0162	0.0187	
Δ(1/h_FE)	1×10^12	VCE = 6V	VCE = 6V	6	0.00127	0.002[illegible]	0.0007	0.00268	0.00339	
		IC = 50μA	IC = 1mA							
	2.5×10^12	↓	↓	6	0.00175	0.0023	0.0019	0.00293	0.00377	
	5×10^12			6	0.00255	0.0034	0.0015	0.00397	0.00469	
↓	1×10^13	↓	↓	6	0.00377	0.0048	0.0028	0.00526	0.0060	


2N2484
CIRCUIT TECHNOLOGY
1 × 10^12 e/cm^2
PAGE 2 OF 5
MEAN + 3σ
Δ(1/h_FE)
10^-2
10^-3
10^-4
10
100
1000
I_C, μA


2N2484
CIRCUIT TECHNOLOGY
2.5 × 10^12 e/cm^2
PAGE 3 OF 5
MEAN + 3σ
Δ(1/h_FE)
10^-1
10^-2
10^-3
10
100
1000
I_C, μA

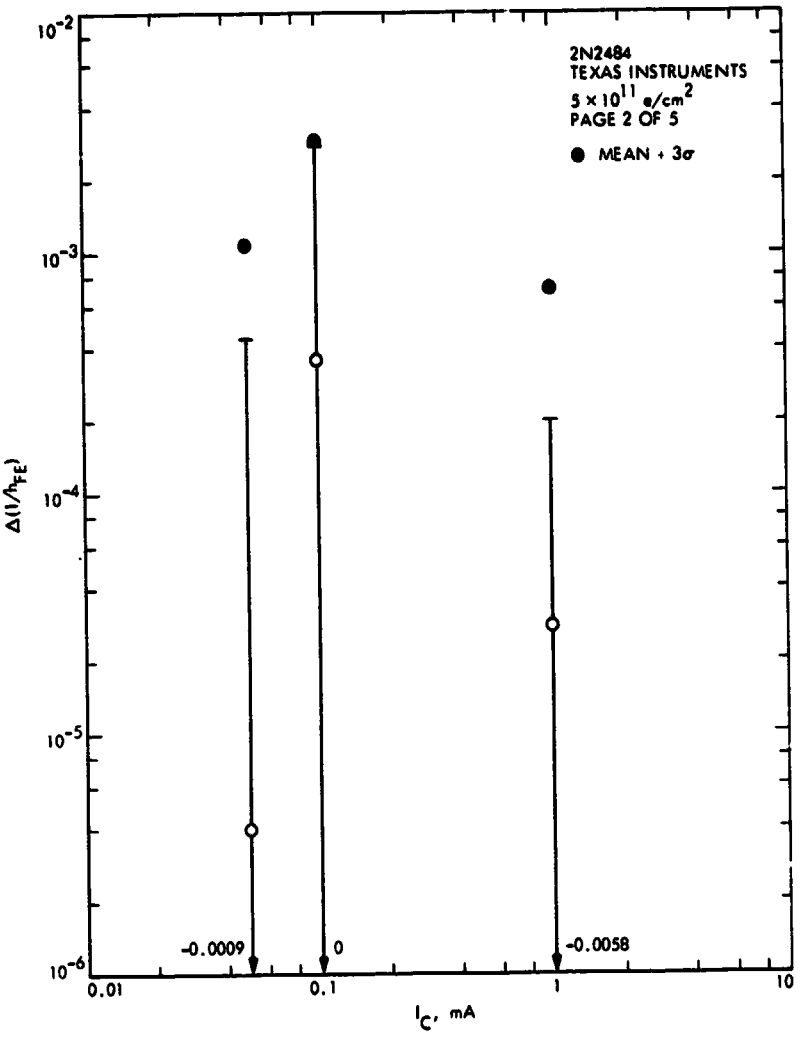

2N2484
CIRCUIT TECHNOLOGY
5 × 10^12 e/cm^2
PAGE 4 OF 5
MEAN + 3σ
Δ(1/h_FE)
10^-1
10^-2
10^-3
10
100
1000
I_C, μA

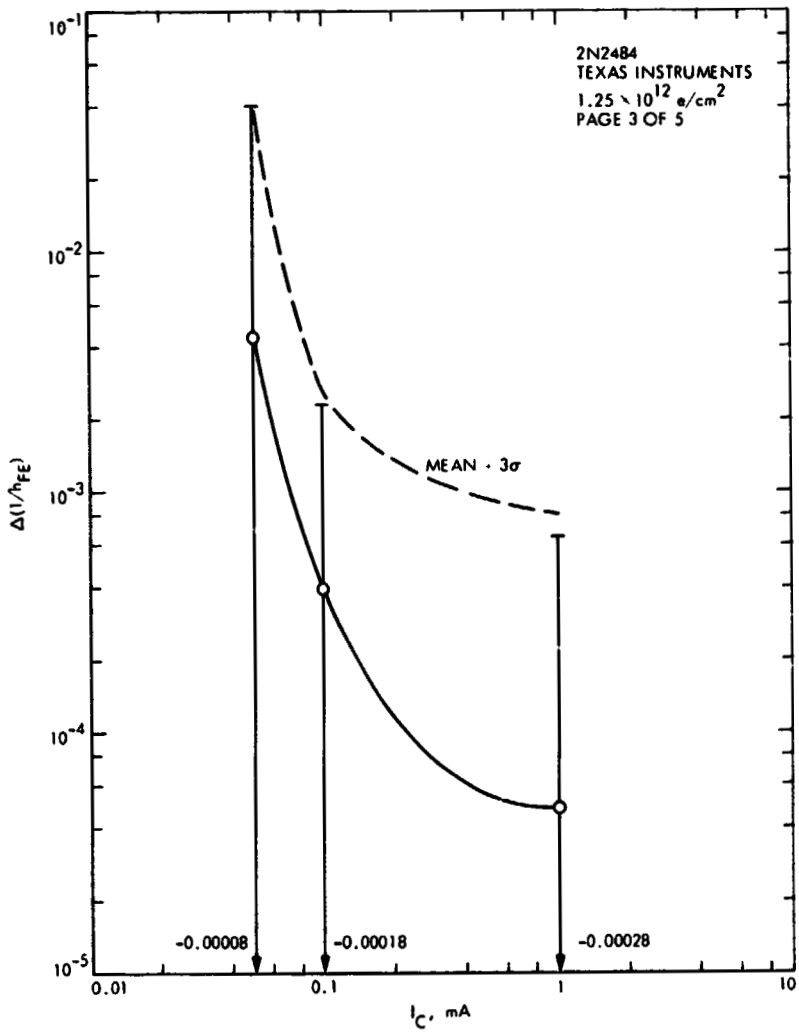

2N2484
CIRCUIT TECHNOLOGY
1 × 10^13 e/cm^2
PAGE 5 OF 5
MEAN + 3σ
Δ(1/h_FE)
10^-1
10^-2
10^-3
10
100
1000
I_C, μA

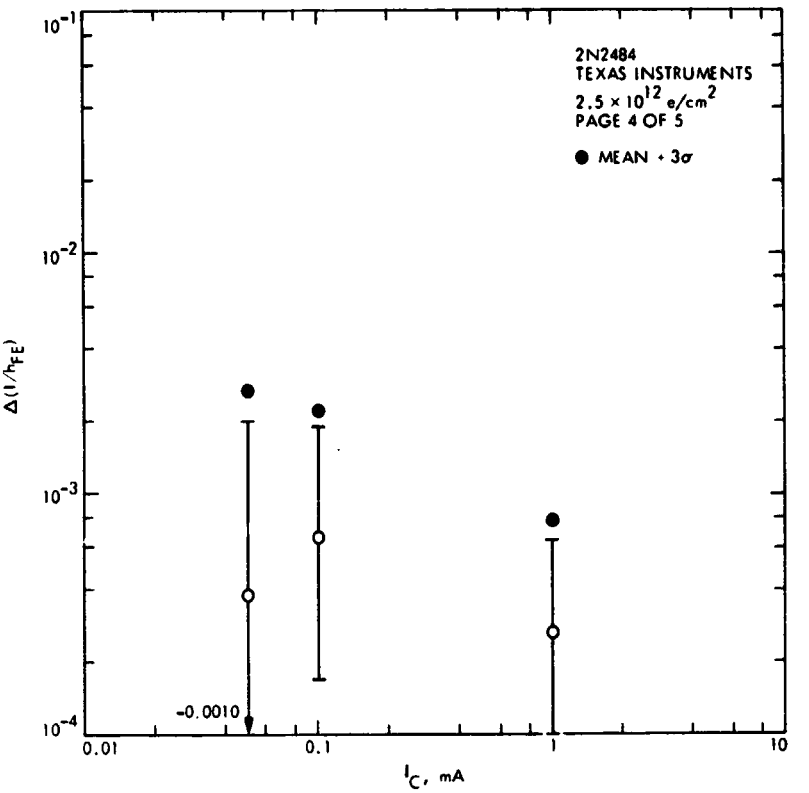
2N2484, Texas Instruments

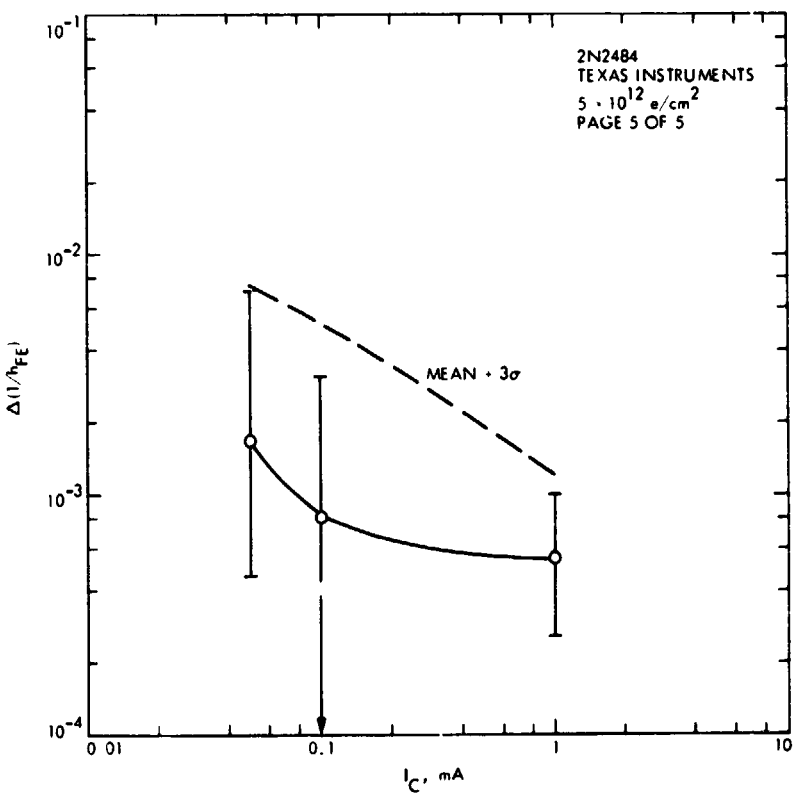
DEVICE TYPE: 2N2484 TEXAS INSTRUMENTS PAGE 1 of 5 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	VCE=6V, IC=0	IC=50μA, VCE=6V	10	0.00004	0.00049	-0.0009	0.00033	0.0011	
	1.25×10¹²			10	0.0054	0.0406	-0.00008	0.0298	0.0426	
	2.5×10¹²			10	0.00038	0.0030	-0.0010	0.0020	0.0027	
	5×10¹²			10	0.0017	0.0070	0.0004	0.0056	0.0075	
Δ(1/hFE)	5×10¹¹		IC=100μA, VCE=6V	10	0.00036	0.0028	0	0.0021	0.0029	
	1.25×10¹²			10	0.00039	0.0023	-0.0008	0.0018	0.0025	
	2.5×10¹²			10	0.00046	0.0019	-0.0017	0.0017	0.0022	
	5×10¹²			10	0.00082	0.0031	-0.0026	0.0032	0.0051	
Δ(1/hFE)	5×10¹¹		IC=1mA, VCE=6V	10	0.00038	0.0002	-0.00058	0.00049	0.00022	
	1.25×10¹²			10	0.00048	0.00065	-0.00078	0.00056	0.00081	
	2.5×10¹²			10	0.00037	0.00065	-0.0001	0.00062	0.00079	
	5×10¹²			10	0.00056	0.0009	-0.0026	0.0010	0.0012	
Δ(1/hFE)	5×10¹¹		IC=10mA, VCE=1V	10	-0.0030	-0.005	-0.0123	0.0071	0.0122	
	1.25×10¹²			10	0.0034	0.0130	-0.0005	0.0102	0.0137	
	2.5×10¹²			10	0.00341	0.0030	-0.0010	0.0026	0.0037	
	5×10¹²			10	0.0049	0.0070	-0.0010	0.0083	0.0100	
ICBO (nA)	5×10¹¹	VCB=30V	VCB 30V	11	0.0239	0.148	0.0020	0.111	0.154	
	1.25×10¹²	EMITTER OPEN		11	0.0351	0.215	0.004	0.158	0.220	
	2.5×10¹²			11	0.0461	0.245	0.001	0.186	0.256	
	5×10¹²			11	0.073	0.255	0.001	0.263	0.359	


2N2484
TEXAS INSTRUMENTS
5 × 10^11 e/cm^2
PAGE 2 OF 5
MEAN + 3σ
Δ(1/h_FE)
10^-2
10^-3
10^-4
10^-5
10^-6
-0.0009
0
-0.0058
0.01
0.1
1
10
I_C, mA


2N2484
TEXAS INSTRUMENTS
1.25 × 10^12 e/cm^2
PAGE 3 OF 5
MEAN + 3σ
-0.00008
-0.00018
-0.00028
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
10^-5
0.01
0.1
1
10
I_C, mA

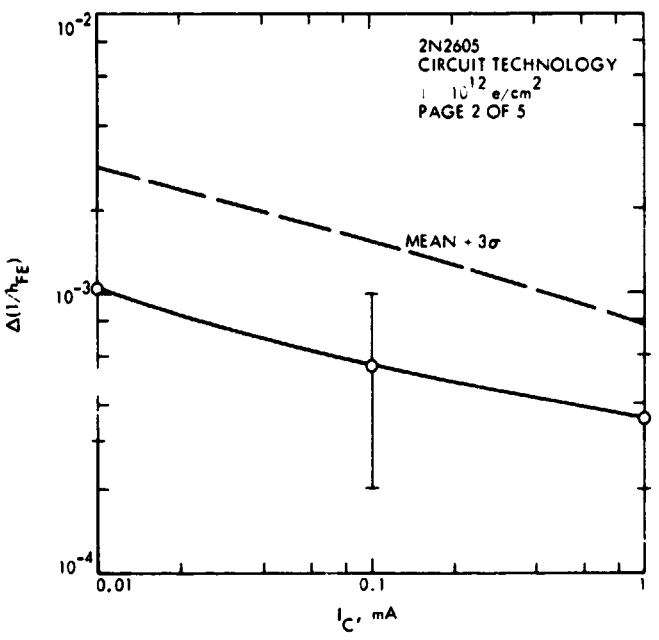

2N2484
TEXAS INSTRUMENTS
2.5 × 10^12 e/cm^2
PAGE 4 OF 5
● MEAN + 3σ
-0.0010
Δ(1/hFE)
IC, mA

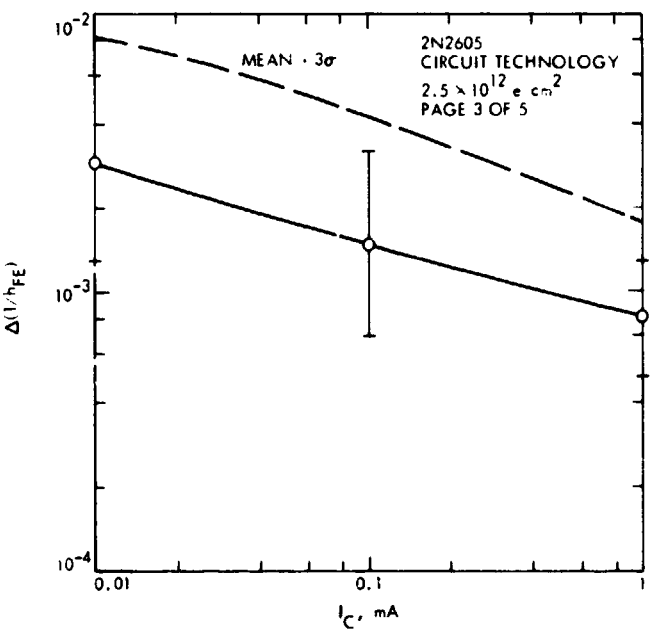

2N2484
TEXAS INSTRUMENTS
5 × 10^12 e/cm^2
PAGE 5 OF 5
MEAN + 3σ
Δ(1/hFE)
IC, mA

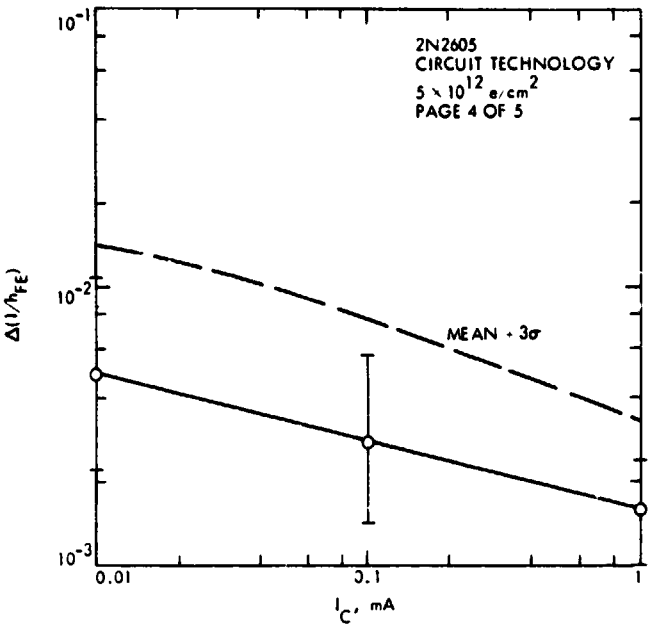
2N2605, Circuit Technology

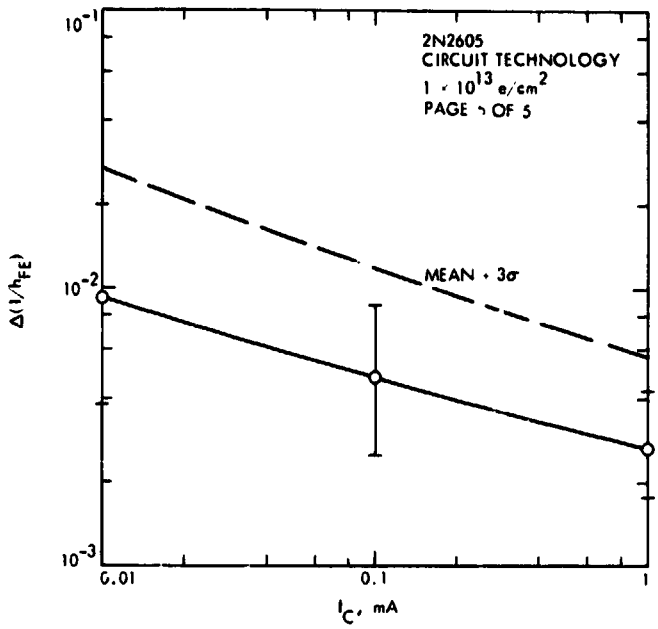
DEVICE TYPE: 2N2605 CTI PAGE 1 of 5 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	1×10¹²	VCE=6V; IC=0.01mA	VCE=6V; IC=0.01mA	8	0.00103	0.0020	0.0003	0.0022	0.0028	
	2.5×10¹²			8	0.0029	0.0060	0.0013	0.0064	0.0082	
	5×10¹²			8	0.0049	0.0110	0.0022	0.0110	0.0141	
	1×10¹³			8	0.0092	0.0200	0.0038	0.0212	0.0272	
Δ(1/hFE)	1×10¹²		VCE=6V; IC=0.1mA	8	0.00055	0.0010	0.0002	0.0012	0.0015	
	2.5×10¹²			8	0.0015	0.0032	0.0007	0.0033	0.0042	
	5×10¹²			8	0.0028	0.0057	0.0014	0.0060	0.0076	
	1×10¹³			8	0.0043	0.0087	0.0025	0.0095	0.0118	
Δ(1/hFE)	1×10¹²		VCE=6V; IC=1mA	8	0.00036	0.0006	0.0002	0.0006	0.00078	
	2.5×10¹²			8	0.00083	0.0013	0.0005	0.0015	0.0018	
	5×10¹²			8	0.0016	0.0024	0.0010	0.0027	0.0033	
	1×10¹³			8	0.0027	0.0043	0.0018	0.0047	0.0057	
VCE(SAT) (V)	1×10¹²		IC=0.1mA;	8	0.0320	0.0334	0.0312	0.0336	0.0343	
	2.5×10¹²		IB=0.05mA	8	0.0340	0.0365	0.0322	0.0371	0.0387	
	5×10¹²			8	0.0389	0.0434	0.0347	0.0456	0.0489	
	1×10¹³			8	0.0462	0.0531	0.0386	0.0578	0.0636	







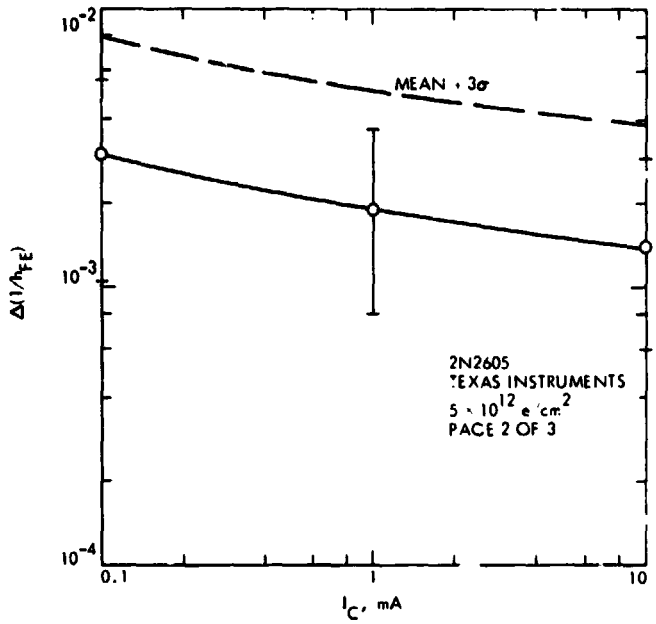


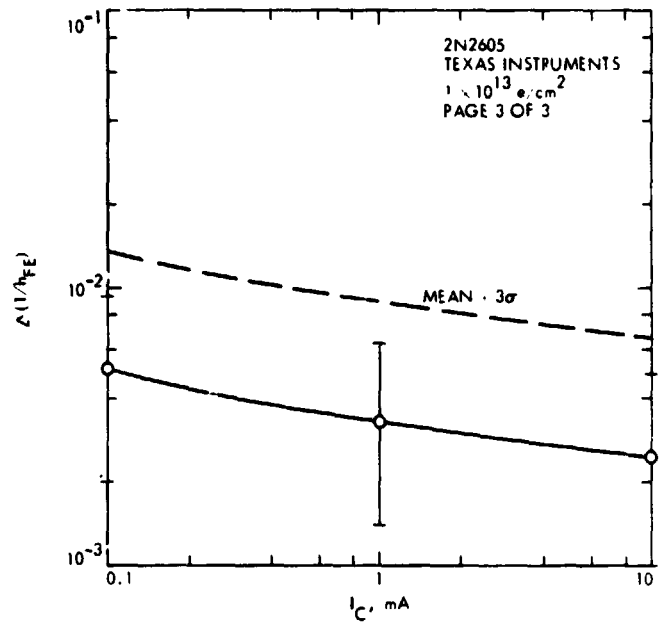
2N2605, Texas Instruments

DEVICE TYPE: 2N2605 TEXAS INSTRUMENTS PAGE 1 of 3 — 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^12	VCE=15V, IC=0.1mA	VCE 2V, IC=0.1mA	6	0.0030	0.0056	0.0011	0.0063	0.0079	
↓	1×10^13		↓	6	0.0052	0.0094	0.0020	0.0108	0.0137	
Δ(1/hFE)	5×10^12		VCE 2V, IC=1mA	6	0.0019	0.0037	0.0008	0.0040	0.0051	
↓	1×10^13		↓	6	0.0033	0.0063	0.0014	0.0070	0.0089	
Δ(1/hFE)	5×10^12		VCE 2V, IC=10mA	6	0.0014	0.0029	0.0006	0.0031	0.0039	
↓	1×10^13	↓	↓	6	0.0025	0.0049	0.0010	0.0053	0.0067	

ACS





2N2658, Solitron

DEVICE TYPE: 2N2658 SOLITRON PAGE 1 OF 3

Parameter	Fluence	MeV	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reje Criteria
	e/cm²		BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^12	2.5	VC: 40V, VE: 0V,	IC: 1mA; VCE: 40V	6*	0.0762	0.1160	0.0442	0.138	0.160	
		3	IC: 1mA		2	0.109	0.1411	0.0767	0.200	0.246	
		5.5			2	0.0797	0.1176	0.0417	0.187	0.241	
	1×10^13	2.5			6*	0.131	0.1901	0.0687	0.227	0.275	
		3			2	0.1165	0.1771	0.1527	0.199	0.216	
		5.5			2	0.141	0.1454	0.1369	0.153	0.159	
Δ(1/hFE)	5×10^12	2.5	VCE: 3V, IC: 5mA	IC: 5mA; VCE: 3V	3	0.00067	0.0002	0	0.0030	0.00411	
	1.25×10^13				3	0.0014	0.0024	0.0008	0.0051	0.00410	
	2.5×10^13				3	0.0032	0.0044	0.0020	0.0056	0.0068	
	5×10^13				3	0.0151	0.0160	0.0138	0.0175	0.0186	
Δ(1/hFE)	5×10^12	2.5	VC: 40V; VE 0V	IC: 10mA, VCE: 40V	6*	0.0169	0.0255	0.0099	0.0294	0.0357	
	1×10^13	2.5	IC: 1mA		6*	0.0283	0.0354	0.0188	0.0429	0.0502	
		3			2	0.0551	0.0682	0.0419	0.0922	0.111	
		5.5			2	0.0449	0.0482	0.0415	0.0543	0.05911	
Δ(1/hFE)	5×10^12	2.5		IC: 50mA; VCE: 10V	6*	0.0059	0.0085	0.0037	0.0100	0.0120	
	1×10^13	2.5			6*	0.0095	0.0120	0.0068	0.0138	0.0160	

* OUTLIER POPULATION = 1

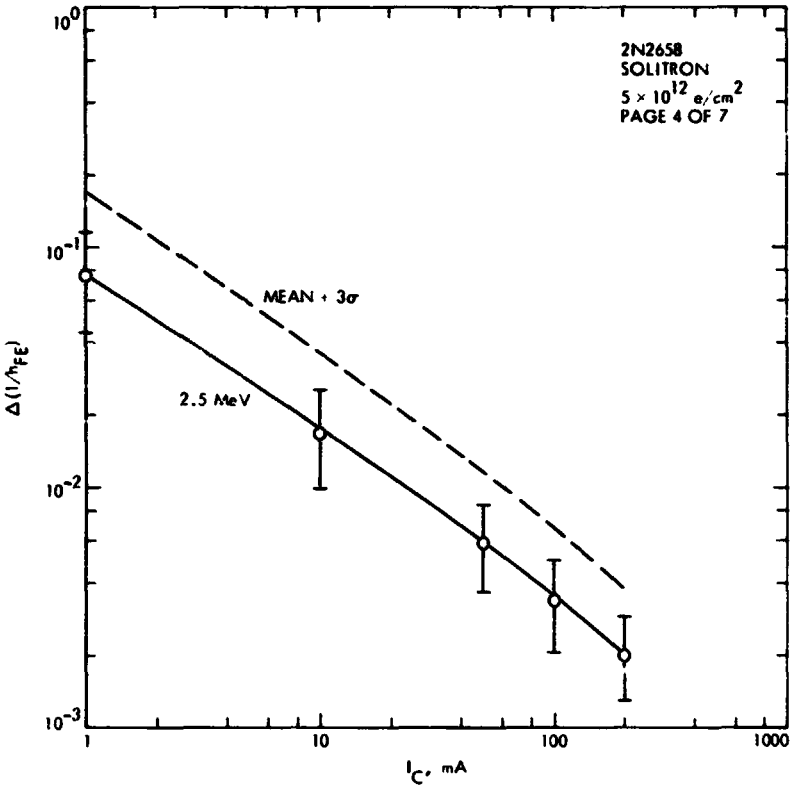
THE OUTLIERS SHOW NO RADIATION DAMAGE AND HAVE BEEN EXCLUDED FROM THE 3σ CALCULATIONS.

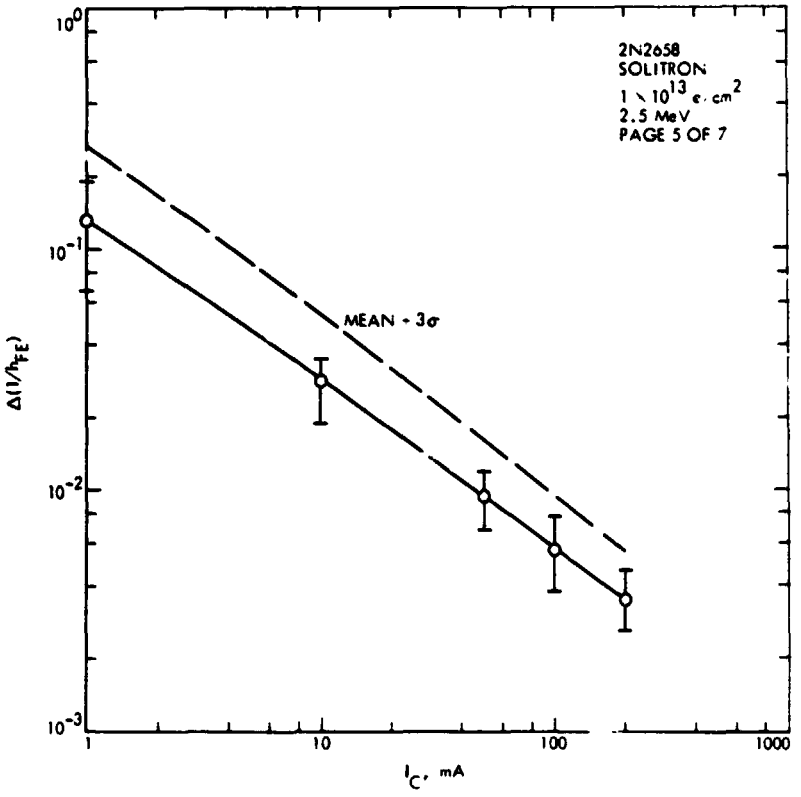
DEVICE TYPE: 2N2658 SOLITRON PAGE 2 of 7

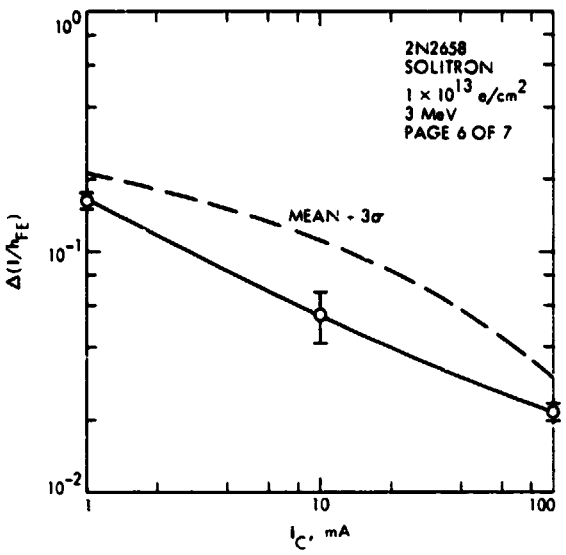
Parameter	Fluence e/cm²	Dev	Operating Point BIAS: IRRAD.	Operating Point BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
ΔIB(DEL)	5×10³	3	Ic -10V Ic 0	Ic 10mA Vce 10V	12**	0.0239	0.0250	0.0221	0.0006	0.0016	
	1×10⁴	3	Ic 10mA		12**	0.0257	0.0277	0.0238	0.0083	0.0096	
		3		Ic 10mA Vce -40V	2	0.0117	0.0135	0.0099	0.0108	0.0123	
		5.5			2	0.0114	0.0115	0.0114	0.0118	0.0120	
ΔIB(DEL)	5×10¹³	3		Ic 10mA Vce -10V	12**	0.0030	0.0037	0.0023	0.0032	0.0038	
	1×10¹⁴	3			12**	0.0055	0.0046	0.0046	0.0059	0.0066	
Vce(sat)(V)	5×10¹³	3.5		Ic 10mA Ib 1mA	7	0.0547	0.0786	0.0310	0.0887	0.1060	
	1×10¹⁴	3.5			7	0.0702	0.0820	0.0311	0.1260	0.1480	
Vce(sat)(V)	5×10¹³	3		Ic 10mA Ib 10mA	7	0.0724	0.0854	0.0618	0.0876	0.0946	
	1×10¹⁴	3			7	0.0755	0.0865	0.0586	0.0990	0.1110	
Vce(sat)(V)	5×10¹³	5.5		Ic 10mA Ib 10mA	7	0.0968	0.1130	0.0851	0.1130	0.1210	
	1×10¹⁴	5.5			7	0.0997	0.1179	0.0824	0.1150	0.1280	
									±2σ	±3σ	
ΔVBE(V)	5×10¹³	3		Ic 1mA Vce -40V	2	17.25	18.9	15.6	21.92	24.25	
									12.58	10.25	
		5.5			2	15.35	16.9	13.8	19.73	21.83	
									10.97	8.77	
** OTHER 2 PHOTOVOLTS											
THE OTHERS SHOW NO RADIATION DAMAGE AND HAVE BEEN EXCLUDED FROM THE											
	3σ		CALCULATIONS.								

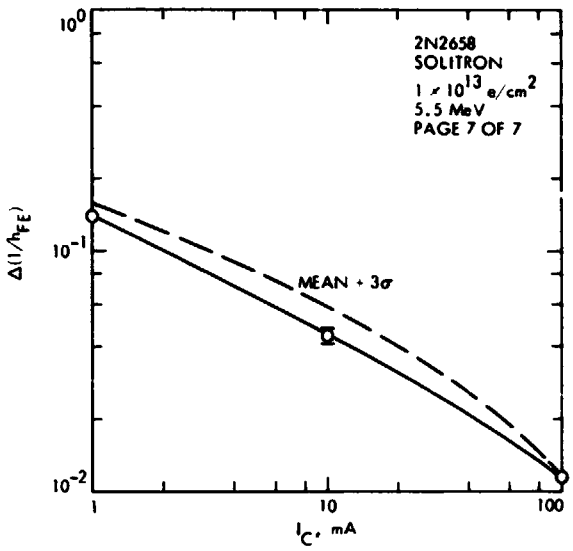
DEVICE TYPE: 2N2658 SOLITRON PAGE 3 of 7

Parameter	Fluence e/cm²	Dev	Operating Point BIAS: IRRAD.	Operating Point BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
									-2σ	-3σ	
ΔVBE(V)	1×10¹⁴	3	Ic -40V Ic 1mA	Ic 1mA, Vce 40V	2	12.4	16.7	8.1	22.71	29.52	
									32	-4.57	
		5.5			2	13.1	15.7	10.5	20.45	24.13	
									5.75	2.07	
ΔVBE(V)	1×10¹⁴	3		Ic 10mA Vce 40V	2	5.0	10.0	0	17.14	26.31	
									-9.4	-16.31	
		5.5			2	0	0	0	0	0	
									0	0	
ΔIBS(nA)	5×10¹³	3		Ic 10mA Vce 40V	2	-20.0	0	-40.0	36.57	104.85	
									-76.57	-104.85	
		5.5			2	-20	10	10	10	-10	
									40	40	
ICBO(nA)	5×10¹³		Ic 10V Ib 0 Ie GND	VCB [illegible] V	3	[illegible]	0.50	[illegible]	[illegible]	[illegible]	
	1×10¹⁴				3	0.191	[illegible]	[illegible]	[illegible]	[illegible]	
	2×10¹⁴				3	8.743	16.00	[illegible]	23.[illegible]	30.4	
	5×10¹⁴				3	1230.7	1800	840	2254	2737	


2N2658
SOLITRON
5 × 10^12 e/cm^2
PAGE 4 OF 7
MEAN + 3σ
2.5 MeV
Δ(1/h_FE)
I_C, mA
10^0
10^-1
10^-2
10^-3
1
10
100
1000


2N2658
SOLITRON
1 × 10^13 e/cm^2
2.5 MeV
PAGE 5 OF 7
MEAN + 3σ
Δ(1/h_FE)
I_C, mA
10^0
10^-1
10^-2
10^-3
1
10
100
1000

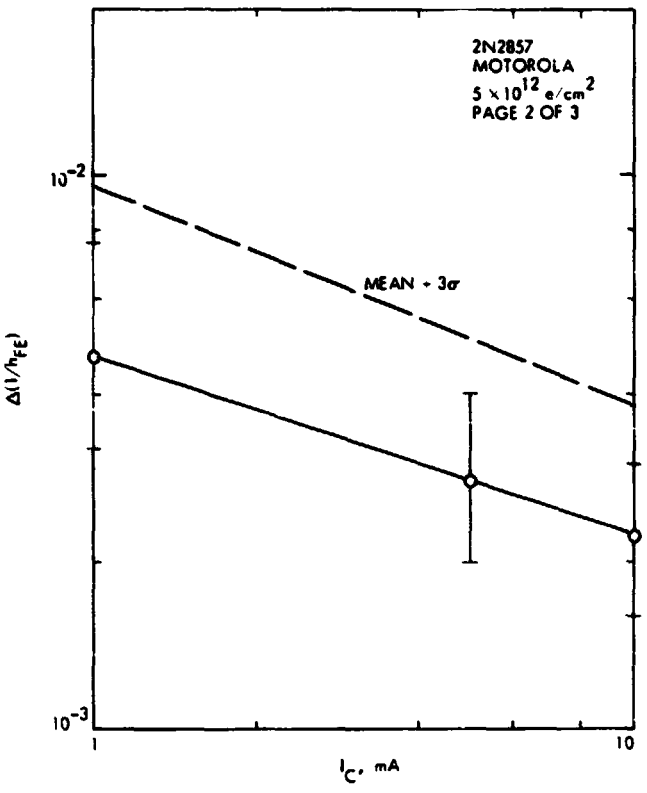


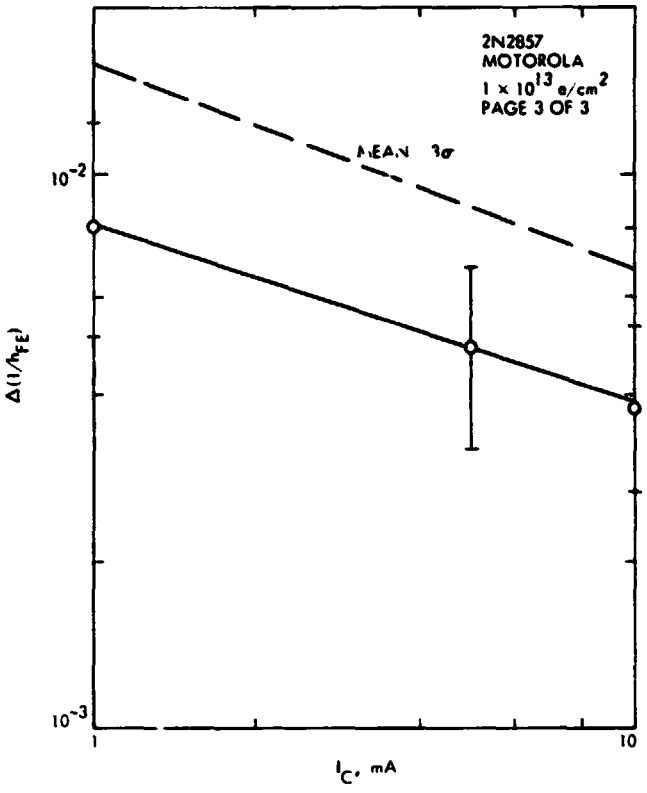


2N2857, Motorola

DEVICE TYPE: 2N2857 MOTOROLA PAGE 1 OF 3 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IBRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^12	IC = 5V, VE = 0	VCE = 5V; IC = 1mA	6	0.00468	0.0075	0.0032	0.00789	0.0095	
↓	1×10^13	VB = 0	↓	6	0.00817	0.0125	0.0052	0.0139	0.0160	
Δ(1/hFE)	5×10^12		VCE = 5V; IC = 5mA	6	0.00382	0.0040	0.0020	0.00123	0.00493	
↓	1×10^13		↓	6	0.00492	0.0068	0.0032	0.00754	0.00885	
Δ(1/hFE)	5×10^12		VCE 5V; IC = 10mA	6	0.0022	0.0030	0.0016	0.00372	0.00381	
↓	1×10^13	↓	↓	6	0.0038	0.0053	0.0027	0.00573	0.0067	

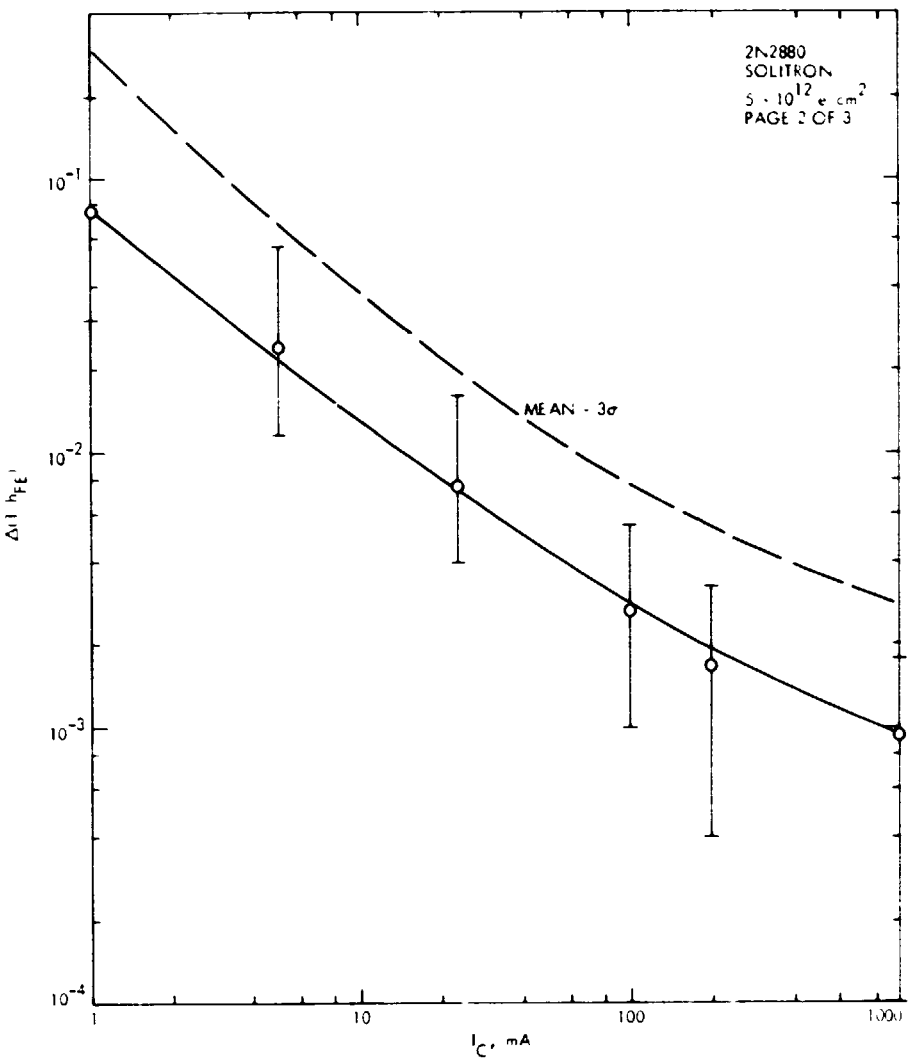


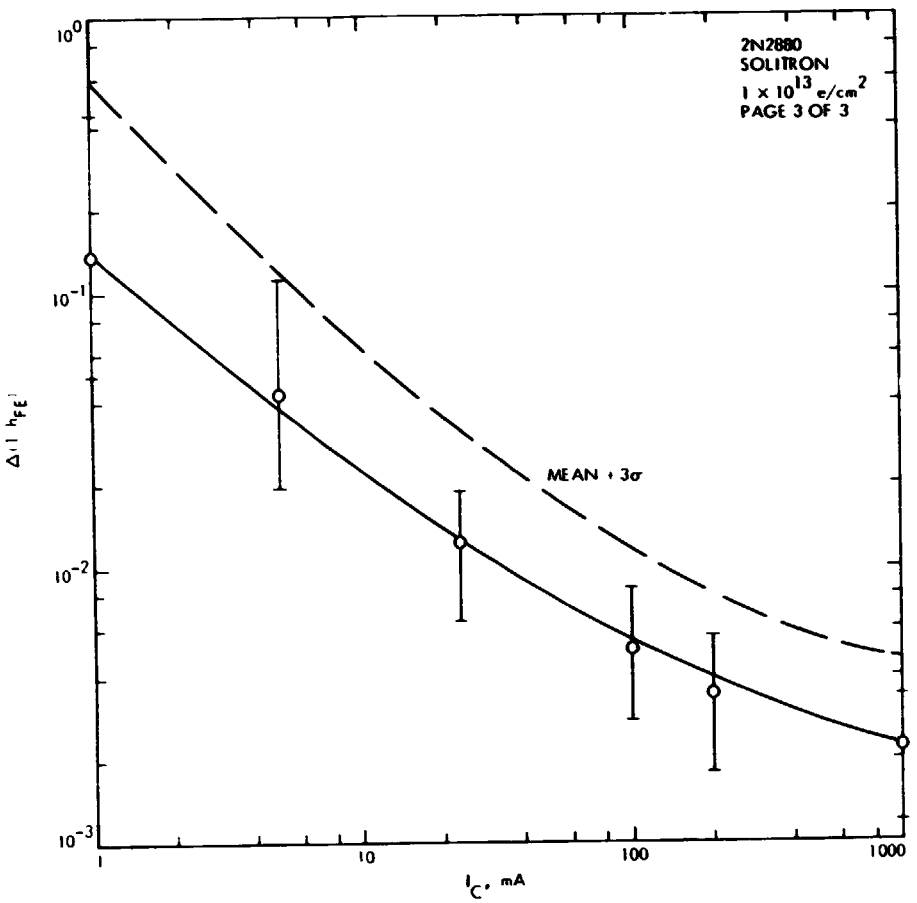


2N2880, Solitron

DEVICE TYPE: 2N2880 SOLITRON PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS : IRRAD.	BIAS : MEAS.							
Δ(1/hFE)	5 × 10^12	VC = 10V, VE = 0V	VCE = 4V, IC = 1mA	6	.0756	.2003	.0305	.203	.266	
↓	1 × 10^13	IC = 1mA	↓	6	.137	.4268	.056	.431	.578	
Δ(1/hFE)	5 × 10^12		VCE = 4V, IC = 23mA	6	.00785	.0163	.004	[illegible]	.0211	
↓	1 × 10^13		↓	6	.0122	.0192	.0065	[illegible]	.0254	
Δ(1/hFE)	5 × 10^12		VCE = 2V, IC = 1A	6	.00095	.0018	.0001	.00222	.00283	
↓	1 × 10^13		↓	6	.00222	.0034	.0012	.00375	.00452	
Δ(1/hFE)	5 × 10^12		VCE = 2V, IC = 100mA	6	.0027	.0055	.001	.00587	.00745	
↓	1 × 10^13		↓	6	.00505	.0084	.0028	.0.898	.011	
Δ(1/hFE)	5 × 10^12		VCE = 2V, IC = 50A	6	.0245	[illegible]	.0.16	.0577	.0743	
↓	1 × 10^13		↓	6	.0427	.112	.0.96	.114	.15	
Δ(1/hFE)	5 × 10^12		VCE = 2V, IC = 200mA	6	.0017	.0033	.0004	.00375	.00478	
↓	1 × 10^13		↓	6	.00347	.0057	.0018	.00622	.0076	
VCE(SAT)(V)	5 × 10^12		IC = 5A; IB = 500mA	6	0.644	0.987	0.504	0.991	1.16	
↓	1 × 10^13	↓	↓	6	0.712	1.3	0.513	1.3	1.59	
hFE										


2N2880
SOLITRON
5 · 10^12 e/cm^2
PAGE 2 OF 3
MEAN - 3σ
10^-1
10^-2
10^-3
10^-4
Δ(1/h_FE)
1
10
100
1000
I_C, mA


2N2880
SOLITRON
1 × 10^13 e/cm^2
PAGE 3 OF 3
MEAN + 3σ
10^0
10^-1
10^-2
10^-3
Δ(1/h_FE)
1
10
100
1000
I_C, mA

2N2907, Motorola

DEVICE TYPE: 2N2907 Motorola PAGE 1 of 9 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/h_FE)	5×10¹²	BIAS: IRRAD.	BIAS: MEAS.	5	0.00038	0.002	0.0002	0.00233	0.00306	
		Collector: 62V	Ic: 36μA							
↓	1×10¹³	Emitter-Base: GND	VCE: 62V	5	0.00184	0.0042	0.0005	0.00966	0.00608	
Δ(1/h_FE)	5×10¹²	Collector: 62V	Ic: 2mA	5	0.00178	0.0025	0.001	0.00301	0.00362	
		Emitter: GND	VCE: 0.62V							
↓	1×10¹³	Base = GND		5	0.0042	0.0059	0.003	0.00642	0.00753	
Δ(1/h_FE)	5×10¹²	Collector: 62V	Ic: 10mA	5	0.00066	0.001	0.0004	0.0011	0.00135	
		Emmitter-GND	VCE: 0.2V							
↓	1×10¹³	Base = GND		5	0.0013	0.0021	0.0009	0.00228	0.00277	
Δ(1/h_FE)	5×10¹²	Collector = 62V	Ic: 40mA	5	0.00064	0.0011	0.0003	0.00127	0.00158	
		Emmitter: GND	VCE: 0.3V							
↓	1×10¹³	Base: GND		5	0.00088	0.0016	0.0006	0.0018	0.00215	
Δ(1/h_FE)	5×10¹²	Collector: 62V	Ic = 20mA	5	0.00024	0.0004	0.0001	0.000608	0.000742	
		Emitter: GND	VCE: 20V							
↓	1×10¹³	BASE: GND		5	0.00049	0.0008	0.0001	0.001	0.00125	
KGS										

DEVICE TYPE: 2N2907 Motorola PAGE 2 of 9 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/h_FE)	5×10¹²	BIAS: IRRAD.	BIAS: MEAS.	5	0.00022	0.0005	0	0.000678	0.000904	
		Collector: 62V	Ic: 5mA							
↓	1×10¹³	Emitter: Base: GND	VCE: 10V	5	0.0006	0.001	0.0003	0.00115	0.00142	
VCE(sat) (V)	0	Collector: 62V	Ic: 10mA	5	0.037	0.046	0.03			
		Emmitter: GND	IB: 1mA							
	5×10¹²	BASE = GND		5	0.041	0.049	0.036	0.051	0.056	
↓	1×10¹³	↓	↓	5	0.044	0.053	0.039	0.547	0.06	
VCE(sat) (V)	0	Collector: 62V	Ic: 10mA	5	0.0548	0.065	0.047			
		Emitter: GND	IB: 0.5mA							
	5×10¹²	BASE: GND		5	0.0604	0.07	0.055	0.0734	0.799	
↓	1×10¹³	↓	↓	5	0.064	0.074	0.058	0.0775	0.0842	
VCE(sat) (V)	0	Collector 0V	Ic: 100mA	5	0.132	0.182	0.098			
		Emitter = GND	IB: 5mA							
	5×10¹²	BASE: GND		5	0.138	0.188	0.105	0.205	0.239	
	1×10¹³			5	0.141	0.191	0.108	0.208	0.241	
↓		↓	↓							

DEVICE TYPE: 2N2907 Motorola PAGE 3 of 9 3

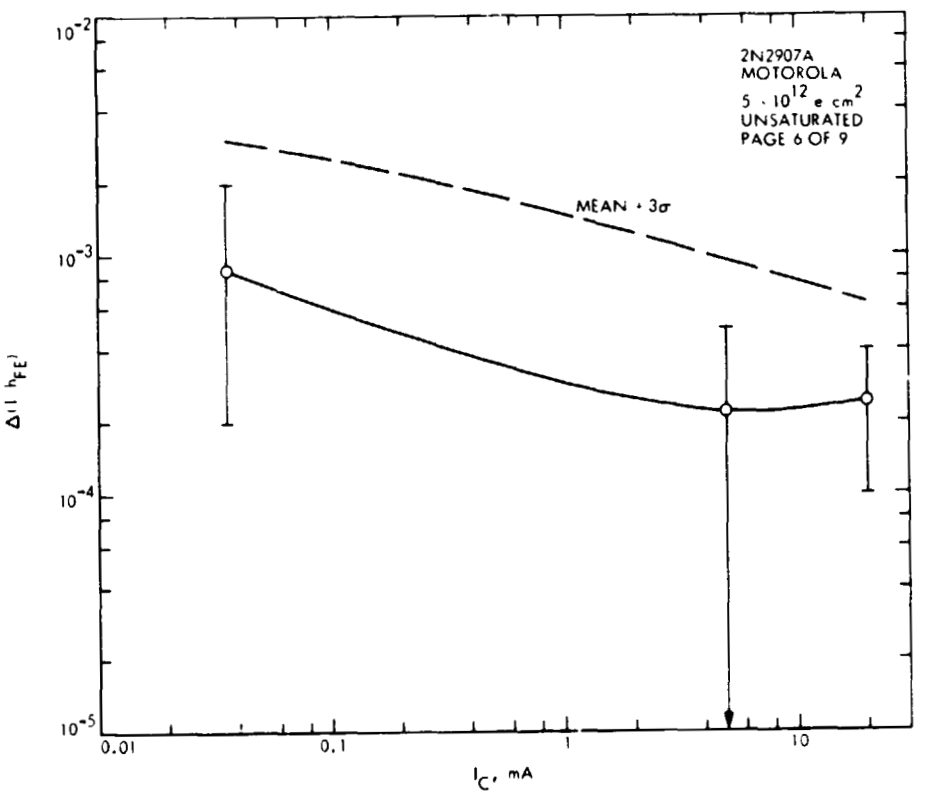
Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
$V_{BE(sat)}$ (V)	0	BIAS: IRRAD.	BIAS: MEAS.	5	0.725	0.735	0.719			
		Collector 12V	I_C = 10mA							
	5×10^{12}	Emitter = GND	I_B = 1mA	5	0.723	0.73	0.716	0.74	0.742	
		BASE = GND								
	1×10^{13}			5	0.719	0.723	0.709	0.735	0.744	
$V_{BE(sat)}$ (V)	0	Collector = 12V	I_C = 100 mA	5	0.843	0.854	0.839			
		Emitter = GND	I_B = 10 mA							
	5×10^{12}	BASE = GND		5	0.847	0.851	0.84	0.856	0.86	
	1×10^{13}			5	0.841	0.849	0.827	0.858	0.867	
$V_{BE(sat)}$ (V)	0	Collector = 12V	I_C = 10 mA	5	0.709	0.717	0.704			
		Emitter = GND	I_B = 0.5 mA							
	5×10^{12}	BASE = GND		5	0.715	0.719	0.709	0.722	0.726	
	1×10^{13}			5	0.707	0.717	0.695	0.724	0.732	

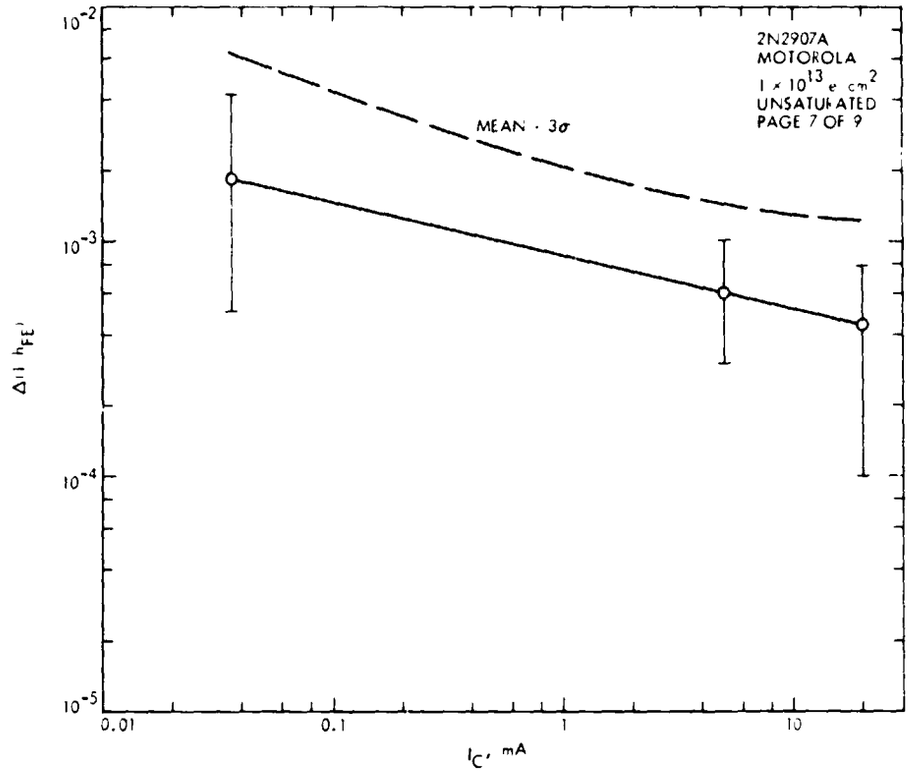
DEVICE TYPE: 2N2907 Motorola PAGE 4 of 9 3

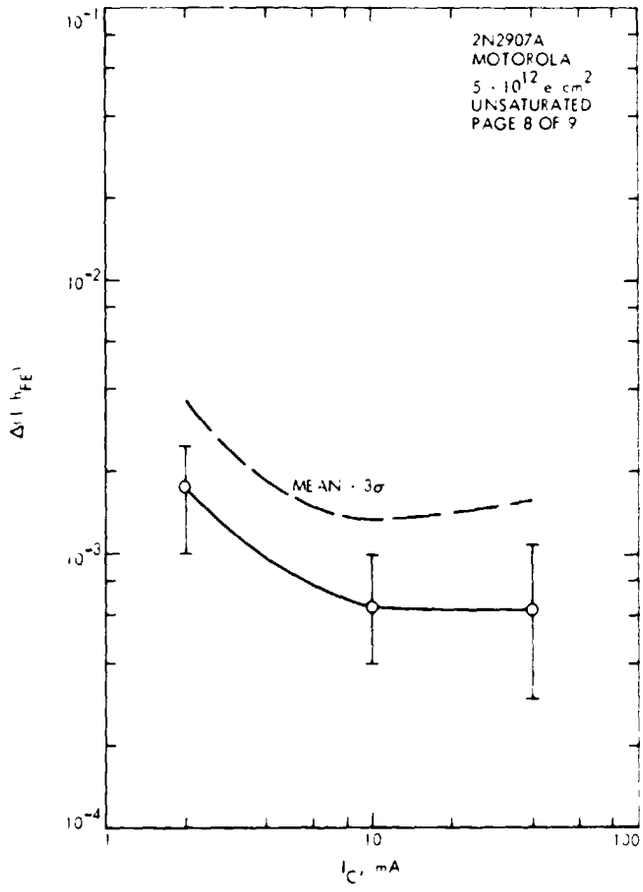
Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
$V_{BE(sat)}$ (V)	0	BIAS: IRRAD.	BIAS: MEAS.	5	0.821	0.83	0.818			
		Collector = 12V	I_C = 100 mA							
	5×10^{12}	Emitter = GND	I_B = 5 mA	5	0.83	0.838	0.824	0.84	0.846	
		BASE = GND								
	1×10^{13}			5	0.821	0.832	0.819	0.836	0.843	
I_{CBO} (nA)		Collector = 50V	V_{CB} = 50V							
		Emitter = 0V								
	5×10^{12}	BASE = 0V		4*	0.27	0.38	0.22	0.419	0.493	
	1×10^{13}			4*	0.325	0.49	0.23	0.498	0.585	
	* Outlier. One (Calculations done with outliers excluded.)									
I_{CBO} (nA)		Collector = 50V	V_{CB} = 50V							
		Emitter = 0V								
	5×10^{12}	BASE = 0V		5**	1.06	4.2	0.22	4.57	6.33	
	1×10^{13}			5**	1.18	9.6	0.23	5.01	6.92	
	** Calculations done with outliers included.									

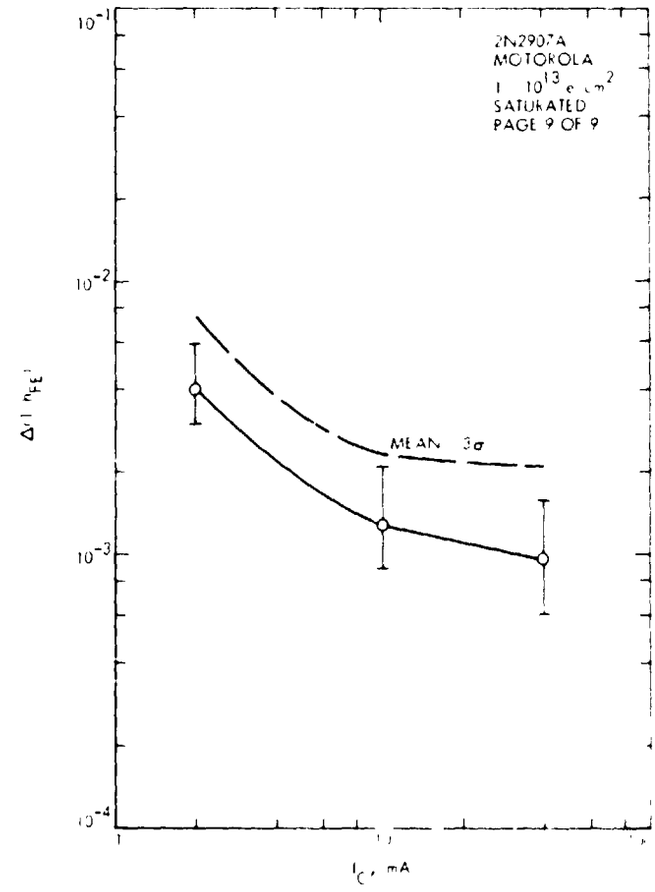
DEVICE TYPE: 2N2907 Motorola PAGE 6 of 9 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
I_{EBO} (nA)		BIAS: IRRAD. Collector = 50V Emitter = 0V BASE = 0V	BIAS: MEAS. V_{EB} = 35V							
	5×10^{12}			5	0.17	0.22	0.12	0.257	0.301	
	1×10^{13}			5	0.186	0.22	0.13	0.3	0.314	




2N2907A
MOTOROLA
1 × 10^13 e cm^2
UNSATURATED
PAGE 7 OF 9
MEAN - 3σ
Δ(1/h_FE)
I_C, mA


2N2907A
MOTOROLA
5 · 10^12 e cm^2
UNSATURATED
PAGE 8 OF 9
MEAN - 3σ
Δ(1/h_FE)
I_C, mA


2N2907A
MOTOROLA
1 · 10^13 e cm^2
SATURATED
PAGE 9 OF 9
MEAN - 3σ
Δ(1/h_FE)
I_C, mA

2N2907, Texas Instruments

DEVICE TYPE: 2N2907 TEXAS INSTRUMENTS PAGE 1 of 9 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
Δ(1/hFE)	1×10¹²	VC = 12V,	IC = 2mA, VCE = 0.23V	5	0.00051	0.0015	0.00006	0.0017	0.0023	
	2.5×10¹²	VE = VB GND		5	0.0013	0.0040	0.0003	0.0045	0.0061	
	5×10¹²		IC = 2mA, VCE = 0.12V	4	0.0018	0.0035	0.0011	0.0041	0.0052	
	1×10¹³			4	0.0040	0.0077	0.0024	0.0090	[illegible]	
Δ(1/hFE)	1×10¹²		IC = 10mA, VCE = 0.3V	5	0.00038	0.0012	0	0.0013	[illegible]	
	2.5×10¹²			5	0.00092	0.0027	0.0002	0.0030	0.0041	
	5×10¹²		IC = 10mA, VCE = 0.2V	4	0.0008	0.0011	0.0007	0.0012	0.0014	
	1×10¹³			4	0.0014	0.0019	0.001[illegible]	0.0021	0.0025	
Δ(1/hFE)	1×10¹²		IC = 10mA, VCE = 0.36V	5	0.00036	0.0011	0	0.0013	0.0018	
	2.5×10¹²			5	0.0009	0.0025	0.0002	0.0028	0.0038	
	5×10¹²		IC = 10mA, VCE = 0.3V	3*	0.0009	0.0013	0.0006	0.0016	0.0019	
	1×10¹³			4	0.0014	0.0022	0.0011	0.0025	0.0030	
Δ(1/hFE)	5×10¹²		IC = 36 μA	4	0.0019	0.0025	0.0016	0.0027	0.0031	
	1×10¹³		VCE = 10V	4	0.0037	0.0042	0.0032	0.0046	0.0051	
Δ(1/hFE)	5×10¹²		IC = 5mA	4	0.00035	0.0005	0.0002	0.0004	0.0005	
	1×10¹³		VCE = 10V	4	0.0013	0.0016	0.0011	0.0018	0.0020	
Δ(1/hFE)	5×10¹²		IC = 20mA	4	0.00043	0.0006	0.0003	0.00068	0.00080	
	1×10¹³		VCE = 20V	4	0.00083	0.0010	0.0007	0.0011	0.0012	

* NEGATIVE OUTLIER EXCLUDED FROM 3σ MEASUREMENT

DEVICE TYPE: 2N2907 TEXAS INSTRUMENTS PAGE 2 of 9

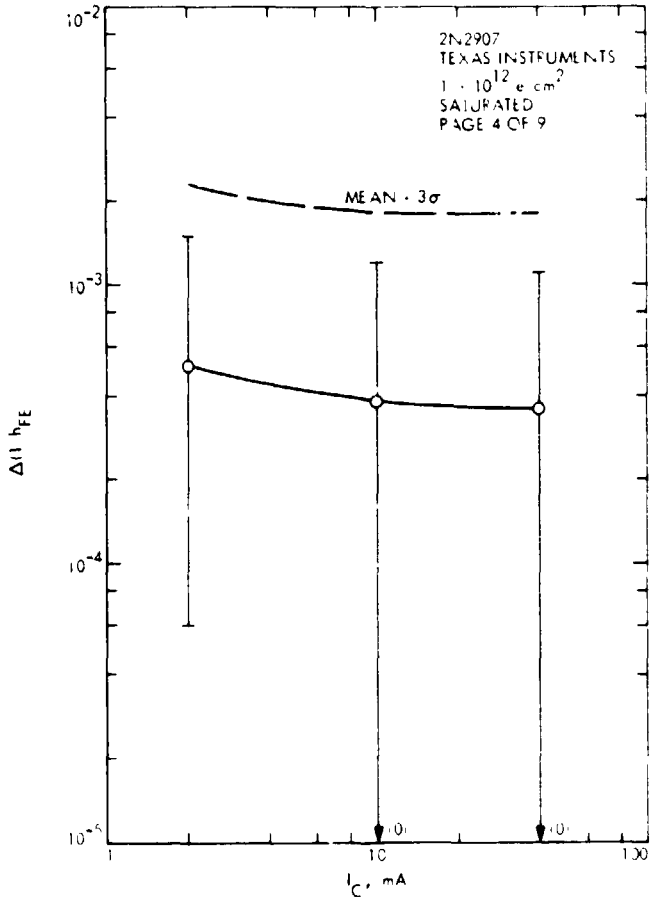
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
VCE (SAT)	5×10¹²	VC = 12V, VE = VB = GND	IC = 10mA, IB = 1mA	4	0.0458	0.053	0.041	0.0560	0.0661	
(V)	1×10¹³			4	0.049	0.057	0.044	0.0602	0.0658	
VCE (SAT)	5×10¹²		IC = 10mA, IB = 0.5mA	4	0.0623	0.072	0.055	0.0764	0.0835	
(V)	1×10¹³			4	0.0665	0.078	0.058	0.0832	0.0915	
VC (SAT)	5×10¹²		IC = 100mA, IB = 5mA	4	0.161	0.83	0.149	0.190	0.216	
(V)	1×10¹³			4	0.166	0.192	0.153	0.201	0.219	
								±2σ	±3σ	
ΔVBE (SAT)	5×10¹²		IC = 10mA, IB = 1mA	4	-0.005	0.003	-0.011	0.0083	0.0150	
(V)								-0.013	-0.0250	
	1×10¹³			4	0.0010	0.012	-0.005	0.0165	0.0213	
								-0.0155	-0.0203	
ΔVBE (SAT)	5×10¹²		IC = 100mA, IB = 10mA	4	-0.0027	0.003	-0.007	0.0065	0.0111	
(V)								-0.012	-0.0166	
	1×10¹³			4	0	0.011	-0.008	0.0159	0.0238	
								-0.0159	-0.0238	
ΔVBE (MAX)	5×10¹²		IC = 10mA, IB = 0.5mA	4	-0.0005	0.002	-0.003	0.0036	0.0057	
(V)								-0.0046	-0.0067	
	1×10¹³			4	-0.0035	0.0010	-0.0070	0.0296	0.0461	
								-0.0416	-0.0241	

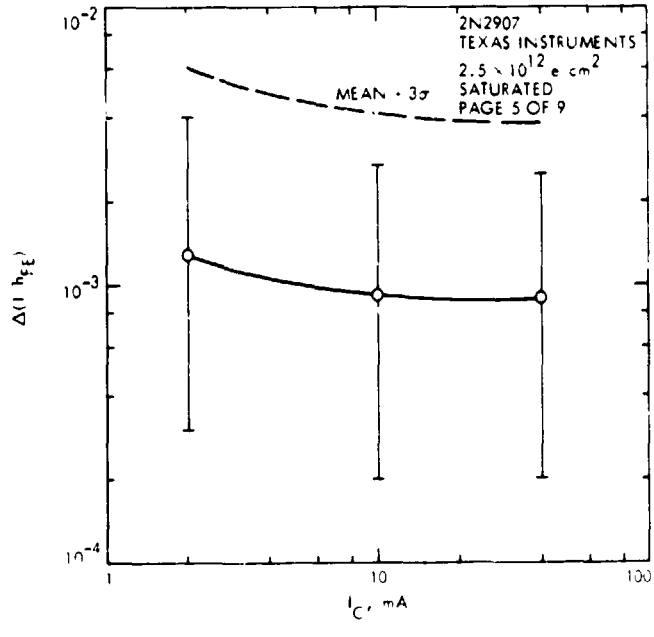
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

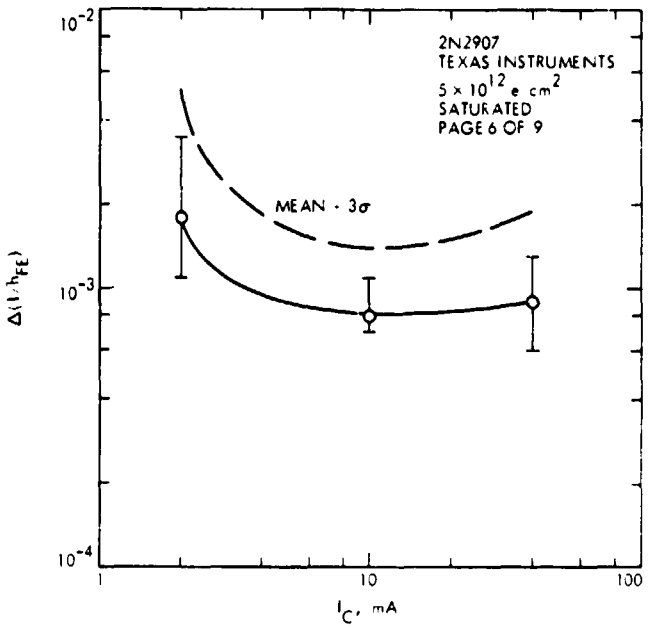
DEVICE TYPE: 2N2907 TEXAS INSTRUMENTS PAGE 5 of 9

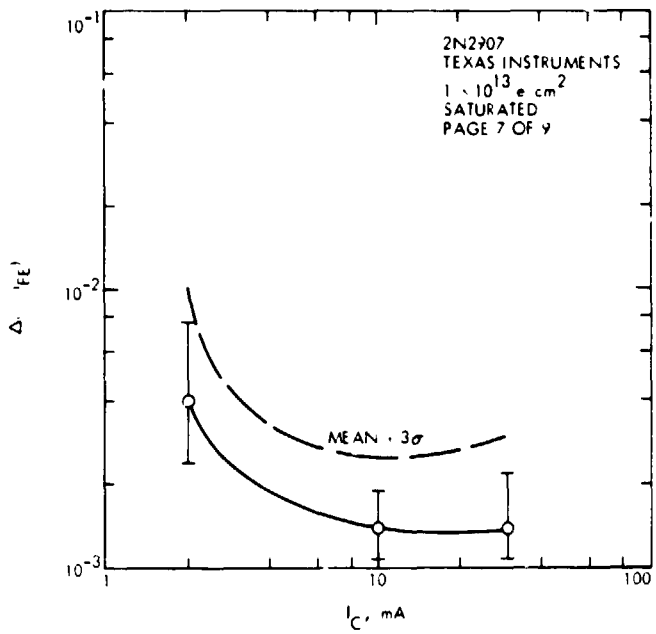
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVBE (INT)	5×10¹²	VC=12V, VE=VB=GND	IC=100mA, IB=5mA	4	0.0055	0.0140	0	0.0178	0.0240	
(V)	↓	↓	↓					-0.0068	-0.0130	
↓	1×10¹³	↓	↓	4	0.0007	0.006	-0.002	0.0082	0.0120	
↓	↓	↓	↓					-0.0067	-0.0105	
								+2σ	+3σ	
ICBO (nA)	5×10¹²	VC=50V, VE=VB=0	VCB=50V	4	0.24	0.38	0.12	0.509	0.643	
↓	↓	↓	↓	5*	1.95	8.8	0.12	9.61	13.4	
↓	1×10¹³	↓	↓	4	0.268	0.42	0.14	0.555	0.698	
↓	↓	↓	↓	5*	2.67	12.3	0.14	13.4	18.8	
IEBO (pA)	5×10¹²	↓	VEB=3.5V	5	48.2	78	25	92.3	114	
↓	1×10¹³	↓	↓	5	56	91	28	109	136	

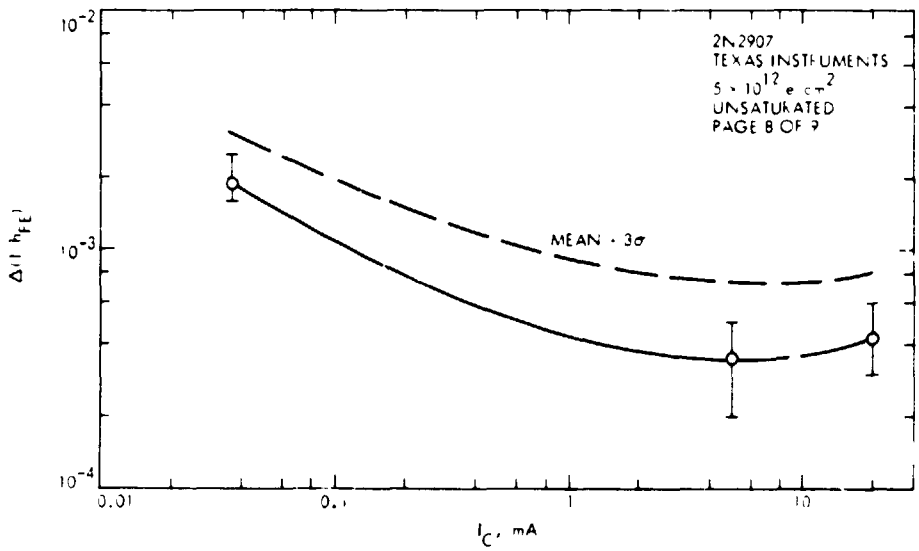
* OUTLIERS INCLUDED

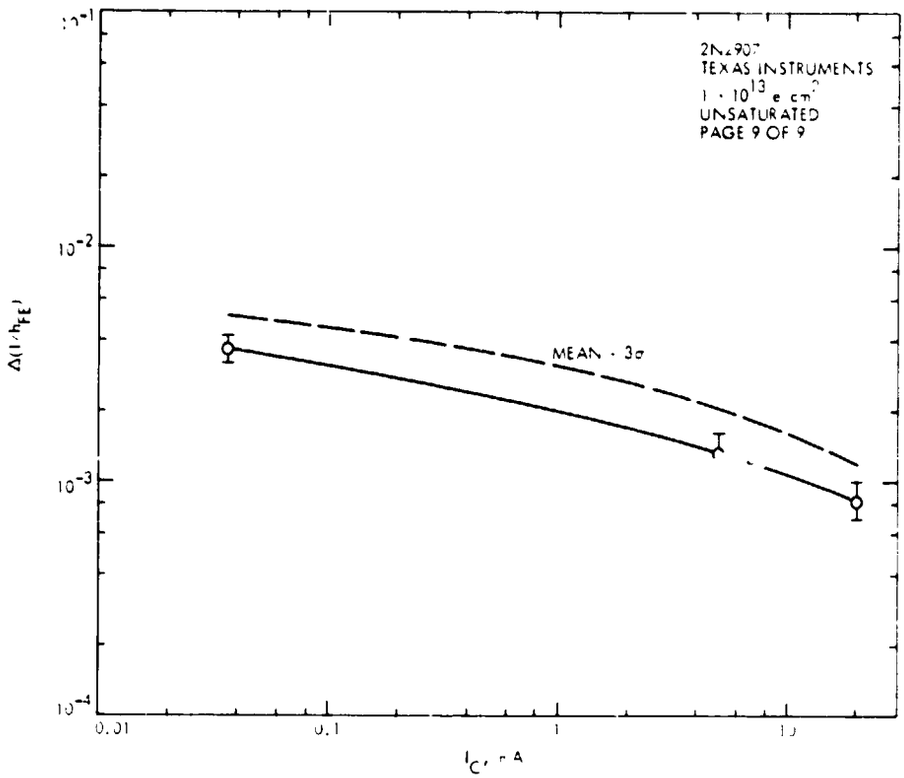





2N2907
TEXAS INSTRUMENTS
5 × 10^12 e cm^2
SATURATED
PAGE 6 OF 9
MEAN + 3σ
Δ(1/hFE)
10^-2
10^-3
10^-4
1
10
100
IC, mA


2N2907
TEXAS INSTRUMENTS
1 × 10^13 e cm^2
SATURATED
PAGE 7 OF 9
MEAN + 3σ
10^-1
10^-2
10^-3
1
10
100
IC, mA


2N2907
TEXAS INSTRUMENTS
5 × 10^12 e cm^2
UNSATURATED
PAGE 8 OF 9
MEAN + 3σ
Δ(1/hFE)
10^-2
10^-3
10^-4
0.01
1
10
IC, mA



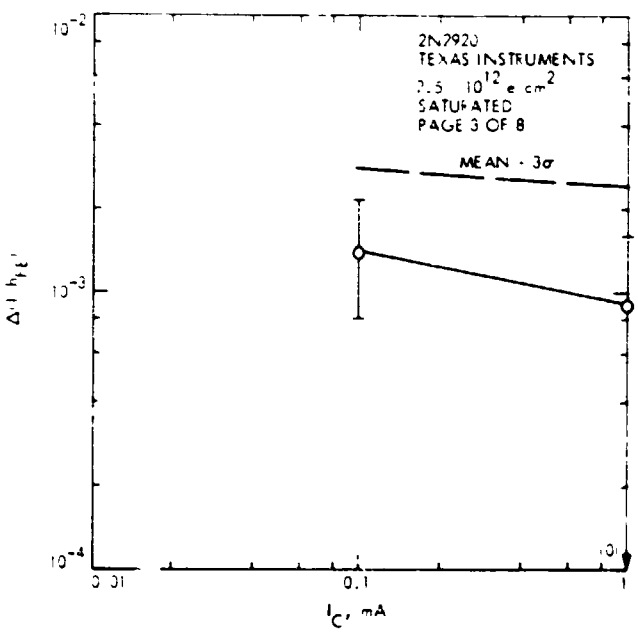
2N2920, Texas Instruments

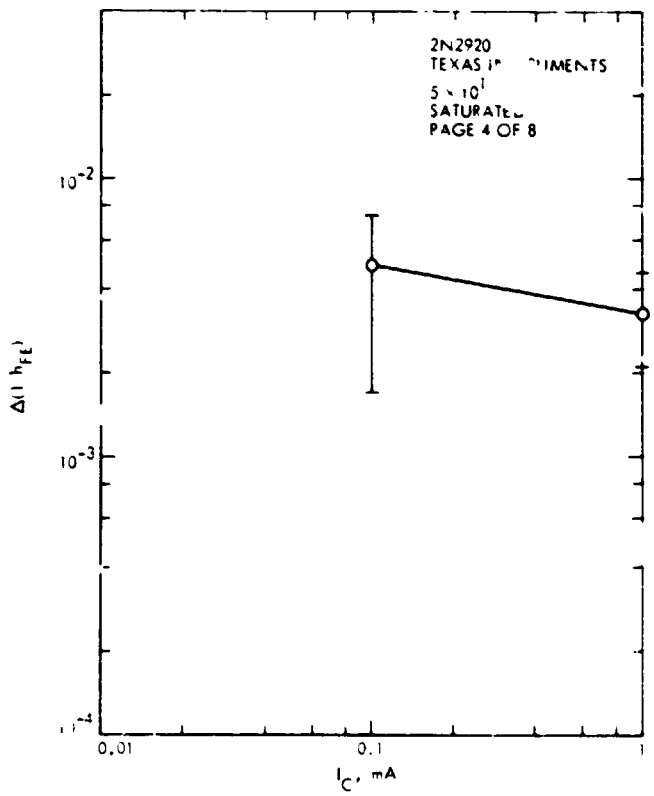
DEVICE TYPE: 2N2920 TEXAS INSTRUMENTS PAGE 1 of 8

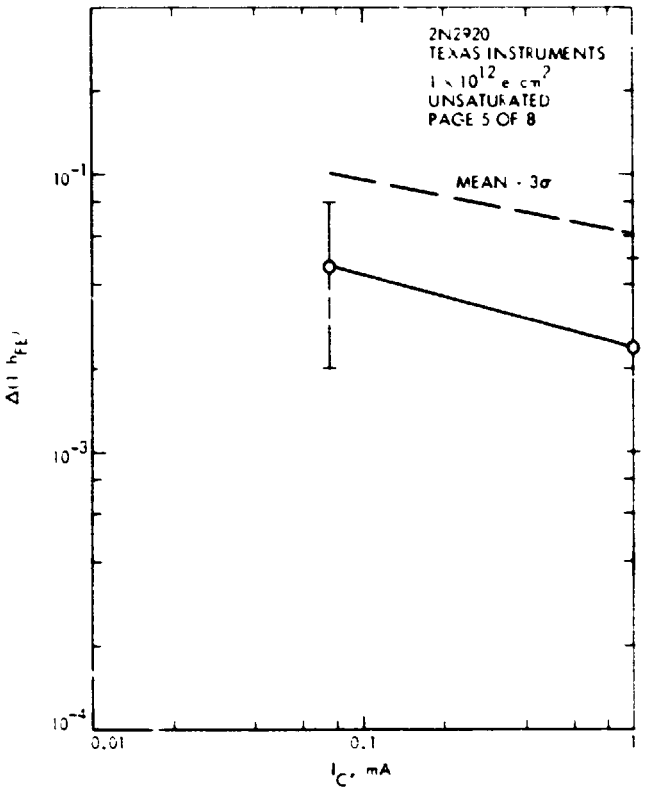
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	B ASS MEAS.							
Δ(1/hFE)	2.5×10^12	IC 30V, IB=VE=0	IC 0.1mA, VCE=0.2V	12	0.0014	0.0022	0.0008	0.0024	0.0028	
↓	5×10^12		↓	12	0.0019	0.0[illegible]4	0.0017	0.0092	0.0114	
Δ(1/hFE)	2.5×10^12		IC 1mA, VCE=0.2V	12	0.00091	[illegible]	0	0.0019	0.0024	
↓	5×10^12	↓	↓	12	0.0033	0.0046	0.0021	0.0054	0.0063	
Δ(1/hFE)	[illegible]	VCE 8V, IC=75μA	IC 75μA, VCE 8V	2	0.00047	0.0008	0.0002	0.0008	0.0010	
	2.5×10^12			12	0.00098	0.0015	0.0004	0.0017	0.0020	
	5×10^12			8 [illegible]	0.0017	0.0020	0.0013	0.0021	0.0023	
	↓			4 [illegible]	0.0107	0.0133	0.0070	0.0160	0.0187	
	1×10^13			8 [illegible]	0.0096	0.0185	0.0056	0.0178	0.0230	
↓	↓	↓	↓	4 [illegible]	0.0914	0.1230	0.0687	[illegible]	0.1700	
Δ(1/hFE)	[illegible]		IC 1mA, VCE 8V	[illegible]	[illegible]	0.0005	0.0001	0.0009	0.0011	
	2.5×10^12			[illegible]	[illegible]	0.0007	[illegible]	[illegible]	0.0023	
	5×10^12			[illegible]	0.0006	0.0008	0.0004	0.0089	[illegible]	
	↓			4 [illegible]	[illegible]	0.0050	0.0030	0.0059	0.0067	
	1×10^13			8 [illegible]	0.0035	0.0061	[illegible]	0.0060	0.0073	
↓	↓	↓	↓	4 [illegible]	0.0201	0.0[illegible]	[illegible]	[illegible]	[illegible]	

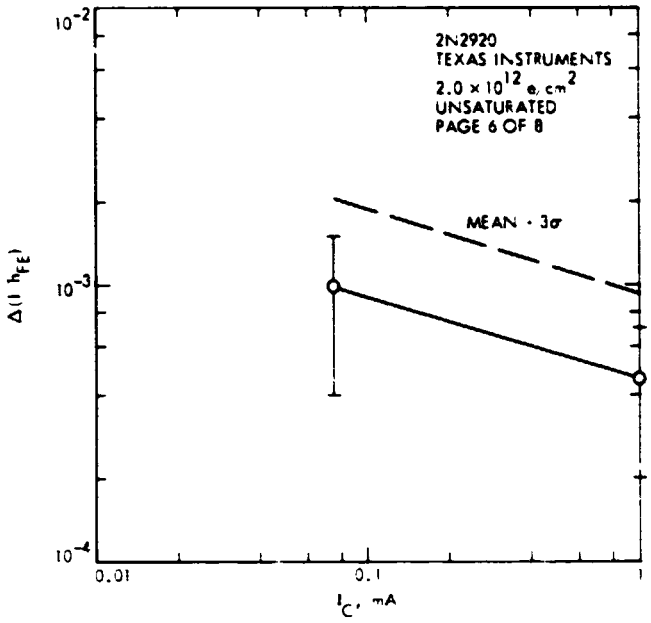
DEVICE TYPE: 2N2920 TEXAS INSTRUMENTS PAGE 2 of 8 3

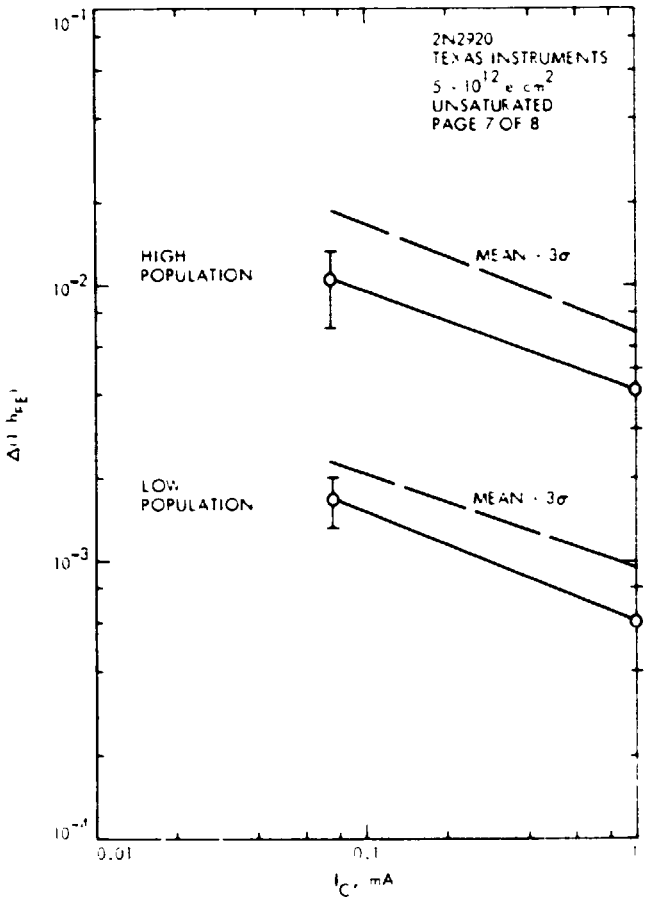
Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
$\Delta h_{FE}^1/h_{FE}^2$	5×10^{12}	V_{CE}=8V, I_C=25μA	V_{CE}=8V, I_C=25μA	6	1.150	1.975	0.477	2.14	2.63	
								0.157	-0.339	
	1×10^{13}			6	1.07	1.315	0.935	1.35	1.48	
								0.834	0.704	
$\Delta h_{FE}^1/h_{FE}^2$	5×10^{12}		V_{CE}=8V, I_C=1mA	6	1.36	2.907	0.266	3.09	3.96	
								-0.371	-1.24	
	1×10^{13}			6	1.14	1.564	0.735	1.69	1.97	
								0.585	0.308	

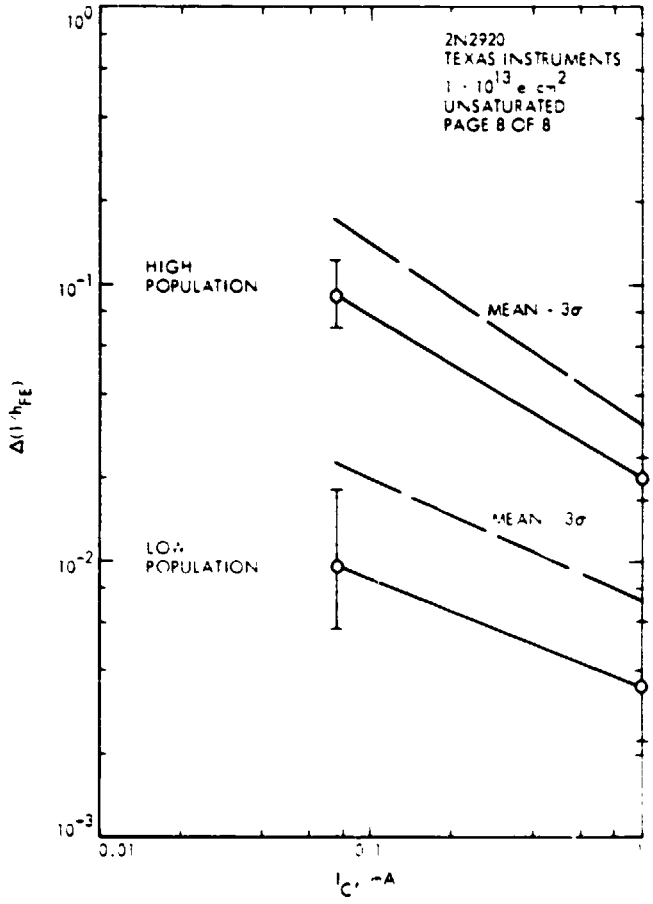





2N2920
TEXAS INSTRUMENTS
1 × 10^12 e cm^-2
UNSATURATED
PAGE 5 OF 8
MEAN - 3σ
Δ(1/h_FE)
I_C, mA


2N2920
TEXAS INSTRUMENTS
2.0 × 10^12 e cm^-2
UNSATURATED
PAGE 6 OF 8
MEAN - 3σ
Δ(1/h_FE)
I_C, mA


2N2920
TEXAS INSTRUMENTS
5 × 10^12 e cm^-2
UNSATURATED
PAGE 7 OF 8
HIGH POPULATION
MEAN - 3σ
LOW POPULATION
MEAN - 3σ
Δ(1/h_FE)
I_C, mA


2N2920
TEXAS INSTRUMENTS
1 × 10^13 e cm^-2
UNSATURATED
PAGE 8 OF 8
HIGH POPULATION
MEAN - 3σ
LOW POPULATION
MEAN - 3σ
Δ(1/h_FE)
I_C, mA

2N2946, Texas Instruments

DEVICE TYPE: 2N2946 TEXAS INSTRUMENTS PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
VEC (SAT)	5x10¹		IB = -1.44mA	6	1.74	1.87	1.64	1.94	2.04	
(mV)	1.25x10²			6	1.76	1.87	1.66	1.94	2.04	
	2.5x10²			6	1.78	1.89	1.69	1.96	2.04	
↓	5x10¹²		↓	6	1.81	1.91	1.73	1.96	2.03	
ICEO (nA)	5 [illegible]	VB=5V, VC=0	VB=5V, VC=0	5	9.99μA	25.97μA	0.024	37.40μA	51.1μA	
	1.25x10¹²	VE = -7.12V	VE = -7.12V	5	0.0362	0.0760	0.0100	0.0964	0.126	
	2.5x10¹²			5	0.133	0.270	0.034	0.316	0.408	
↓	5x10¹²	↓	↓	5	0.455	1.28	0.091	1.509	2.035	

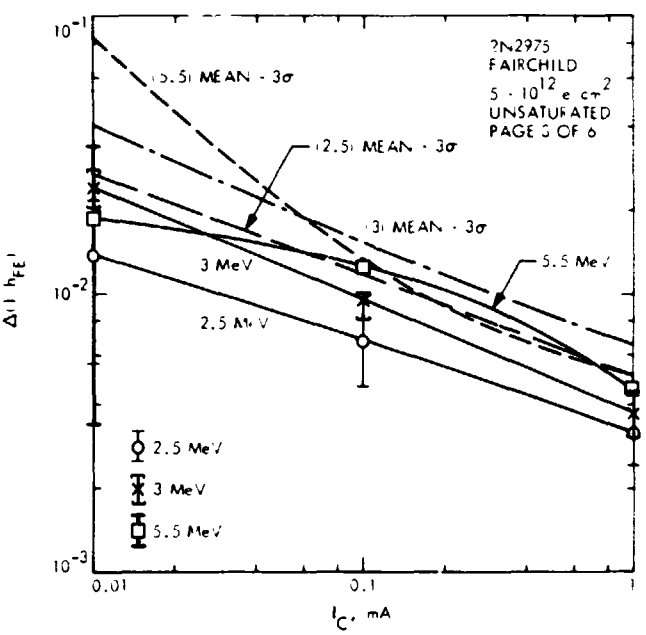
2N2975, Fairchild Semiconductor

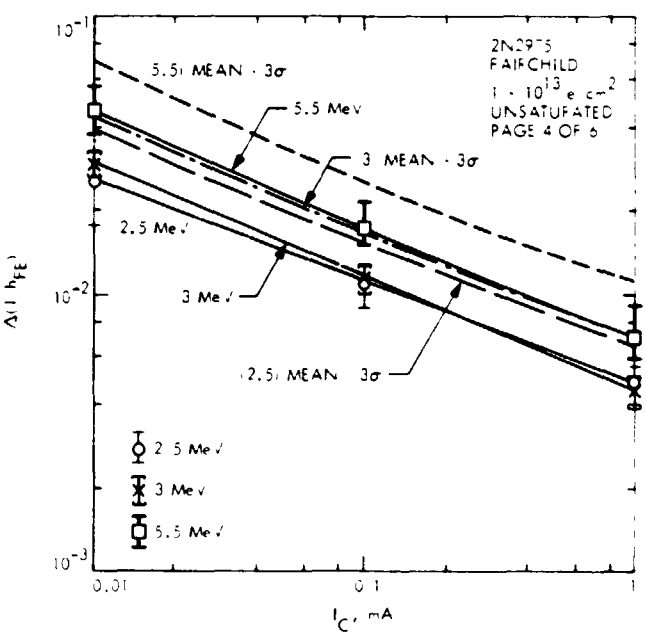
DEVICE TYPE: 2N2975 FAIRCHILD SEMICONDUCTOR PAGE 1 of 6 3

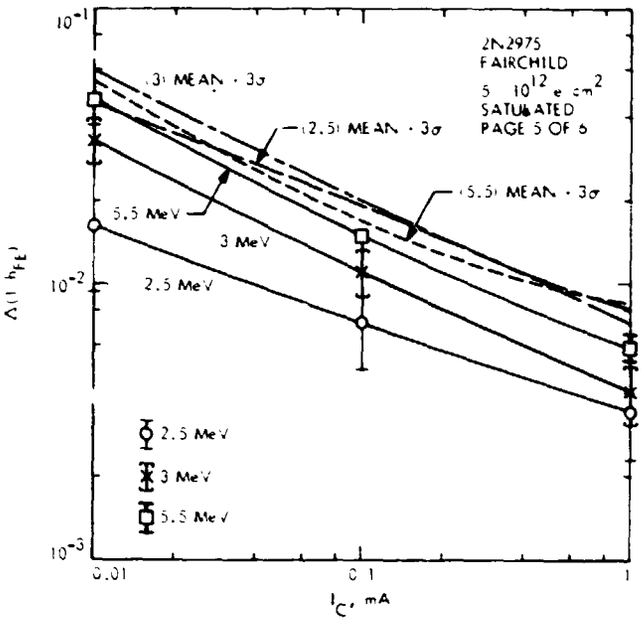
Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	MeV	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5x10¹²	2.5	VCE=5V, 6V,	VCE=5.6V, IC=10μA	12	0.0138	0.0218	0.0056	0.0227	0.0272	
		3	IC=10μA		2	0.0244	0.0281	0.0206	0.035	0.0403	
	↓	5.5			2	0.0189	0.0343	0.0034	0.0625	0.0844	
	1x10¹³	2.5			2	0.0258	0.0326	0.0176	0.0346	0.0390	
		3			2	0.0297	0.0329	0.0264	0.0388	0.0434	
↓	↓	5.5		↓	4	0.0455	0.0565	0.0375	0.0614	0.0694	
Δ(1/hFE)	5x10¹²	2.5		VCE=5.6V, IC=100μA	12	0.0067	0.0101	0.0046	0.0101	0.0118	
		3			2	0.0095	0.0109	0.0081	0.0135	0.0154	
	↓	5.5			2	0.0125	0.0127	0.0123	0.0131	0.0133	
	1x10¹³	2.5			12	0.0112	0.0128	0.0090	0.0139	0.0153	
		3			2	0.0114	0.0126	0.0101	0.0149	0.0167	
↓	↓	5.5		↓	4	0.0173	0.0213	0.0151	0.0228	0.0256	
Δ(1/hFE)	5x10¹²	2.5		VCE=5.6V, IC=1mA	12	0.0031	0.0043	0.0024	0.0044	0.0050	
		3			2	0.0027	0.0044	0.003	0.0057	0.0067	
	↓	5.5			2	0.0045	0.0046	0.0043	0.0049	0.0051	
	1x10¹³	2.5			12	0.0049	0.0055	0.0039	0.0060	0.0065	
		3			2	0.0045	0.0051	0.0039	0.0062	0.0071	
↓	↓	5.5	↓	↓	4	0.0070	0.0091	0.0059	0.0099	0.0113	

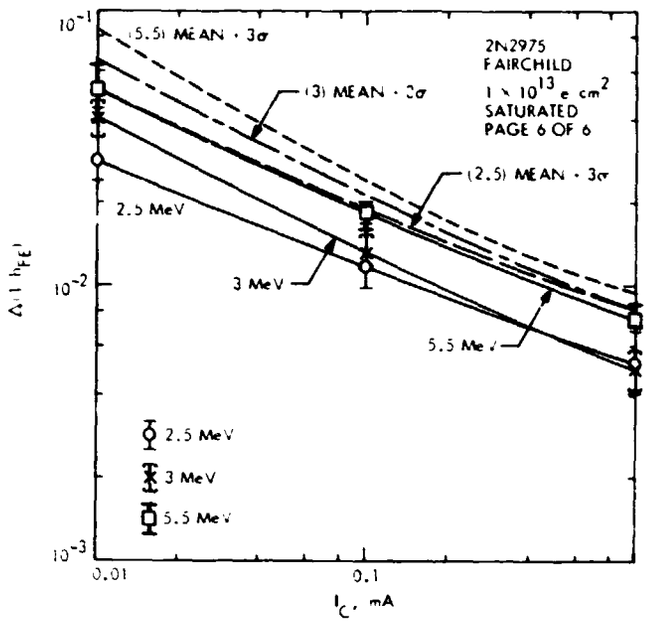
DEVICE TYPE: 2N2975 FAIRCHILD SEMICONDUCTOR Page 3 of 6

Parameter	Fluence e/cm²	MeV	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/hFE)	5×10¹²	2.5	VCE 5V, IC=10μA	VCE=.35V, IC=10μA	12	0.0164	0.0383	0.0094	0.0356	0.0452	
		3			2	0.0336	0.0378	0.0273	0.0512	0.0601	
		5.5			2	0.0471	0.0489	0.0452	0.0523	0.0549	
	1×10¹³	2.5			12	0.0288	0.0413	0.0233	0.0435	0.0509	
		3			2	0.0411	0.047	0.0351	0.0579	0.0663	
		5.5			4	0.0521	0.0637	0.0394	0.0744	0.0856	
Δ(1/hFE)	5×10¹²	2.5		VCE=.35V, IC=10μA	12	0.0074	0.0146	0.0048	0.0139	0.0172	
		3			2	0.0112	0.0133	0.0091	0.0171	0.0201	
		5.5			2	0.015	0.0155	0.0145	0.0164	0.0171	
	1×10¹³	2.5			12	0.0119	0.0167	0.0098	0.0167	0.0191	
		3			2	0.0134	0.0153	0.0115	0.0188	0.0215	
		5.5			4	0.0184	0.0203	0.0159	0.022	0.0238	
Δ(1/hFE)	5×10¹²	2.5		VCE=.35V, IC=1mA	12	0.0035	0.0060	0.0023	0.0059	0.0072	
		3			2	0.0041	0.005	0.0031	0.0067	0.0081	
		5.5			2	0.0059	0.0065	0.0053	0.0076	0.0085	
	1×10¹³	2.5			12	0.0053	0.0070	0.0041	0.0073	0.0083	
		3			2	0.005	0.0058	0.0042	0.0073	0.0084	
		5.5			4	0.0076	0.0085	0.007	0.0087	0.0095	
ICBO (nA)	5×10¹²	2.5	VCB=20V,	VCB=20V	11	1.820	15.8	0.0120	11.4	16.1	
	1×10¹³	2.5	VCB=20V		11	19.9	174	0.0860	125	178	





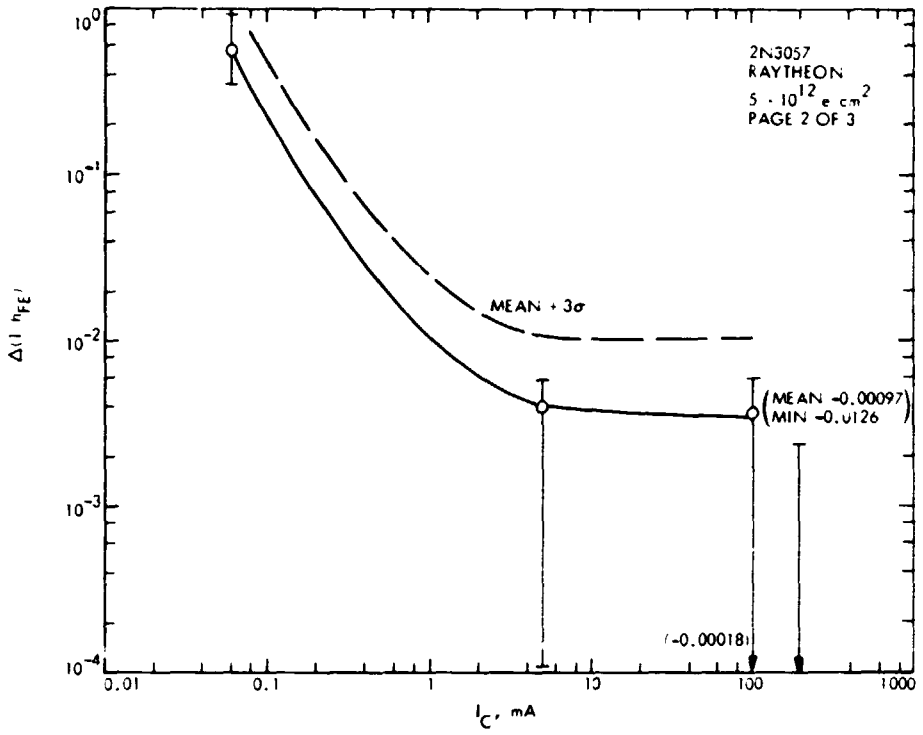


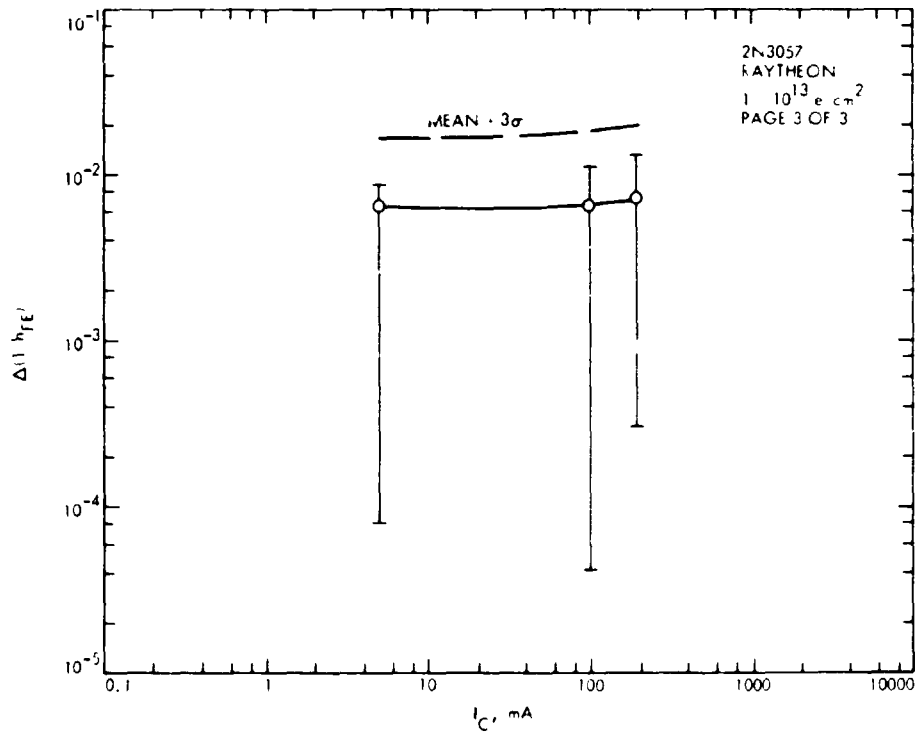


2N3057, Raytheon

DEVICE TYPE: 2N3057 RAYTHEON PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^12	VCE=0.25V, IC=0mA	VCE=0.25V, IC=5mA	6	0.0040	0.0057	0.00011	0.0080	0.0101	
↓	1×10^13	↓	↓	6	0.0065	0.0089	0.00008	0.0132	0.0165	
Δ(1/hFE)	5×10^12		VCE=0.25V, IC=100mA	6	0.0036	0.0059	0.00018	0.0081	0.0104	
↓	1×10^13		↓	6	0.0067	0.0115	0.00004	0.0146	0.0185	
Δ(1/hFE)	5×10^12		VCE=0.25V, IC=190mA	6	0.0087	0.0124	0.0126	0.0106	0.0163	
↓	1×10^13	↓	↓	6	0.0072	0.0134	0.0003	0.0160	0.0204	
Δ(1/hFE)	5×10^11	VCB=60V,	VCE=1V, IC=60μA	6	0.0122	0.0202	0.0058	0.0232	0.0287	
	1.25×10^12	VEB=0V		6	0.0392	0.0552	0.0225	0.0623	0.0814	
	2.5×10^12			6	0.153	0.242	0.0908	0.264	0.320	
↓	5×10^12		↓	6	0.566	0.9753	0.3592	0.998	1.21	
ICBO (nA)	5×10^11		VCB=60V	6	0.157	0.3	0.125	0.297	0.367	
	1.25×10^12			6	0.187	0.38	0.13	0.377	0.472	
	2.5×10^12			6	0.288	0.47	0.17	0.501	0.607	
↓	5×10^12	↓	↓	6	0.558	0.8	0.28	0.951	1.5	


2N3057
RAYTHEON
5 · 10^12 e cm^2
PAGE 2 OF 3
MEAN + 3σ
(MEAN -0.00097)
(MIN -0.0126)
(-0.00018)
Δ(1/h_FE)
I_C, mA

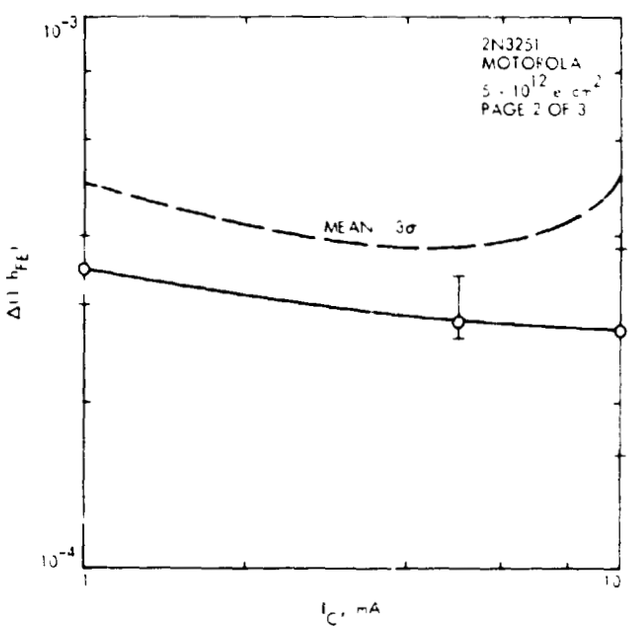

2N3057
RAYTHEON
1 10^13 e cm^2
PAGE 3 OF 3
MEAN + 3σ
Δ(1/h_FE)
I_C, mA

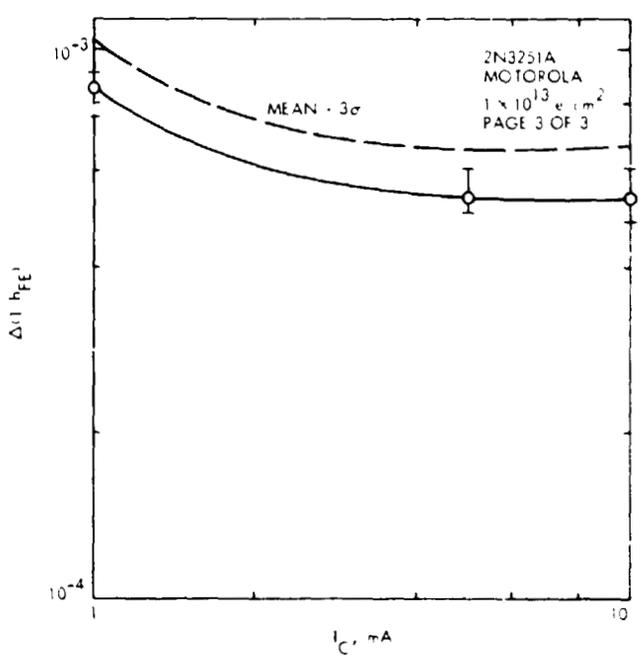
2N3251, Motorola

DEVICE TYPE: 2N3251 MOTOROLA PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VC=10V, VE=VB=0	VCE=10V, IC=1mA	5	0.00035	0.0004	0.0003	0.00045	0.0005	
↓	1×10¹³	↓	↓	5	0.00085	0.0009	0.00075	0.00099	0.00106	
Δ(1/hFE)	5×10¹²	↓	VCE=10V, IC=5mA	5	0.00028	0.00034	0.00026	0.00035	0.00038	
↓	1×10¹³	↓	↓	5	0.00053	0.00060	0.0005	0.00061	0.00065	
Δ(1/hFE)	5×10¹²	↓	VCE=10V, IC=10mA	5	0.00027	0.00038	0.00016	0.00042	0.00050	
↓	1×10¹³	↓	↓	5	0.00053	0.0006	0.00048	0.00062	0.0006[illegible]	

AGS

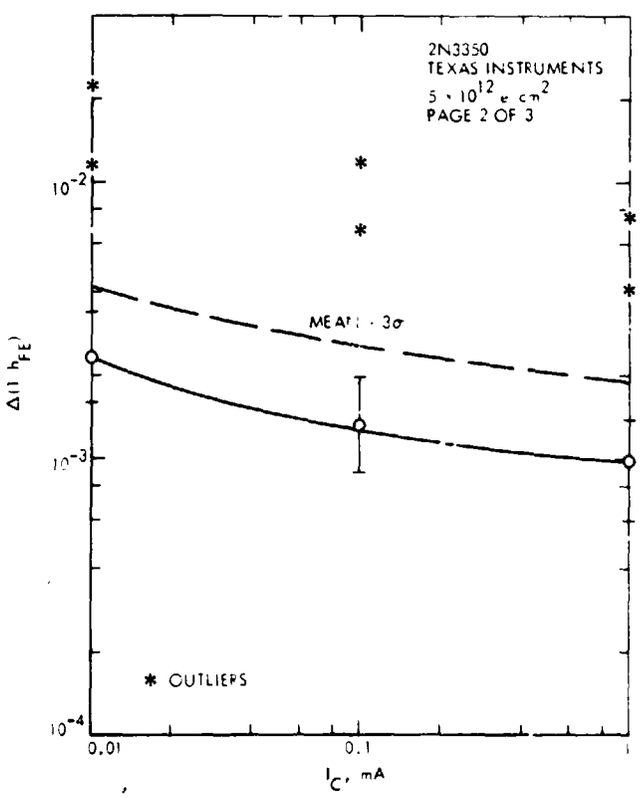


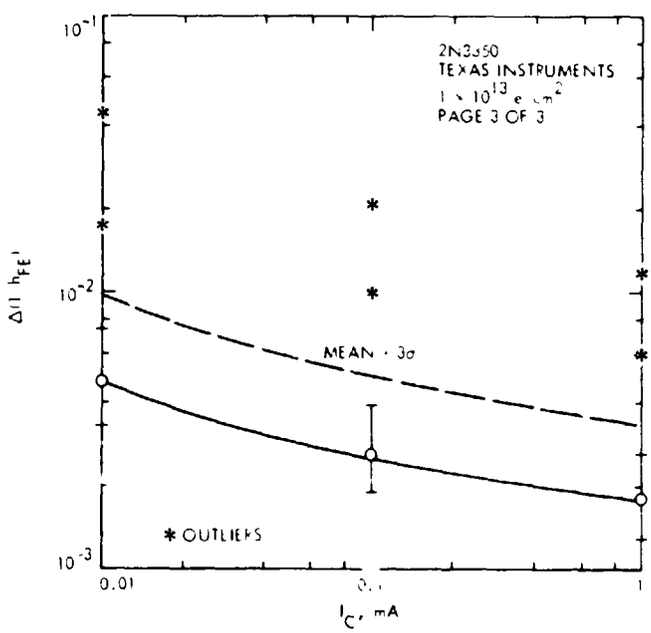


2N3350, Texas Instruments

DEVICE TYPE: 2N3350 TEXAS INSTRUMENTS PAGE 1 of 3 3

Parameter	e/cm² Fluence	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/hFE)	5×10¹²	VCE=0.5V; IC=100μA	VCE=0.5V; IC=0.01mA	10*	0.00239	0.0034	0.0016	0.00366	0.00432	
↓	1×10¹³	↓	↓	10*	0.00483	0.0073	0.0033	0.00816	0.00983	
Δ(1/hFE)	5×10¹²		VCE=0.5V; IC=0.1mA	10*	0.00132	0.0020	0.0003	0.00217	0.00266	
↓	1×10¹³		↓	10*	0.00266	0.0039	0.0019	0.00425	0.00504	
Δ(1/hFE)	5×10¹²		VCE=0.5; IC=1mA	10*	0.00099	0.0014	0.00060	0.00164	0.00196	
↓	1×10¹³	↓	↓	10*	0.00181	0.0026	0.0013	0.00286	0.00339	
		*OUTLIER POPULATION		2						
	OUTLIERS INCLUDED									
Δ(1/hFE)	5×10¹²		VCE=0.5V; IC=0.01mA	12	0.0047	0.0226	0.0016	0.0173	0.0236	
↓	1×10¹³		↓	12	0.0093	0.0456	0.0033	0.0335	0.0457	
Δ(1/hFE)	5×10¹²		VCE=0.5V; IC=0.1mA	12	0.0034	0.0121	0.0009	0.0109	0.0147	
↓	1×10¹³		↓	12	0.0048	0.0211	0.0019	0.0160	0.0216	
Δ(1/hFE)	5×10¹²		VCE=0.5V; IC=1mA	12	0.0018	0.0075	0.0006	0.0057	0.0079	
↓	1×10¹³	↓	↓	12	0.0030	0.0118	0.0013	0.0091	0.0122	





2N3440, RCA

DEVICE TYPE: 2N3440 RCA PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	Ic=1mA, VCE=10V	Ic=1mA, VCE=10V	4	0.00055	0.001	0.0002	0.0012	0.0015	
↓	1×10¹³	↓	↓	4	0.0010	0.002	0.0004	0.0024	0.0030	

2N3497, Motorola

DEVICE TYPE: 2N3497 MOTOROLA Pg 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ICBO	5×10¹¹	VCB = -60V	VCB = -60V	4	0.458	0.57	0.35	0.625	0.784	
	↓	VEB = 0						0.24	0.131	
	1.25×10¹²			4	0.458	0.56	0.38	0.624	0.708	
	↓							0.291	0.207	
	2.5×10¹²			4	0.468	0.56	0.39	0.622	0.699	
	↓							0.313	0.236	
	5×10¹²			4	0.6	0.77	0.48	0.845	0.967	
↓	↓	↓	↓					0.355	0.233	
Δ(1/hFE)	5×10¹¹	VCB = -60V	Ic = 15μA,	4	0.00005	0.0002	0	0.00025	0.00035	
	1.25×10¹²	VEB = 0	VCE = -60V	4	0.00075	0.0004	0.0002	0.00047	0.00056	
	2.5×10¹²			4	0.0016	0.0008	0.0006	0.0085	0.0095	
↓	5×10¹²	↓	↓	4	0.00153	0.0017	0.0014	0.0018	0.0020	

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2N3499, Motorola

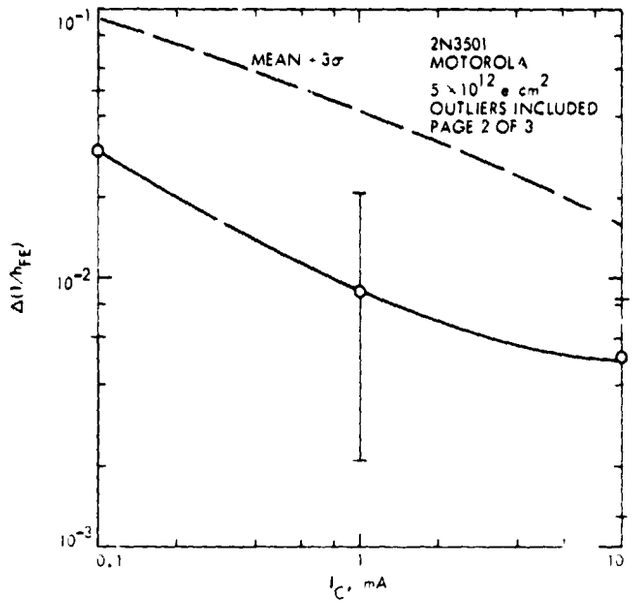
DEVICE TYPE: 2N3499 MOTOROLA PAGE 1 of 1 3

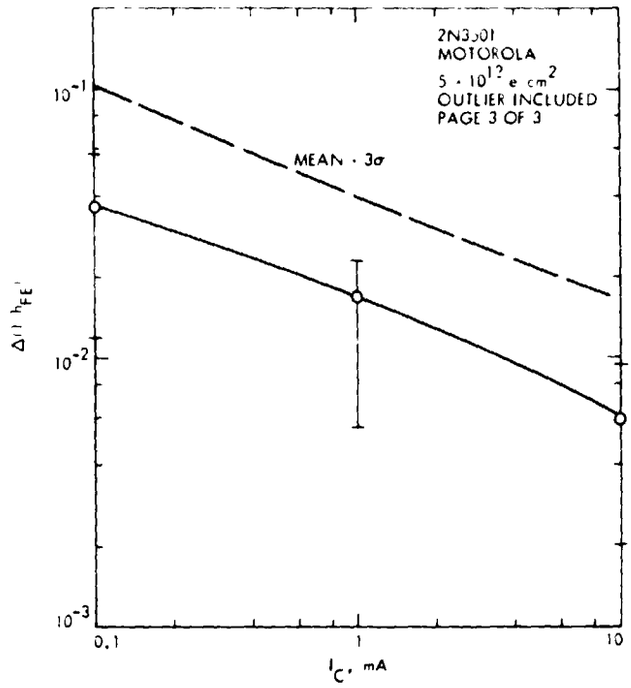
Parameter	e/cm² Fluence	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
$V_{CE(SAT)}$ (V)	0	V_C=20V; V_C-V_B=0	I_C=50mA;	6	0.0702	0.0752	0.0636			
	5×10^{12}		I_B=5mA	6	0.0748	0.0825	0.0637	0.0876	0.0941	
	1×10^{13}			6	0.0795	0.0855	0.0702	0.0940	0.1010	
$V_{CE(SAT)}$ (V)	0		I_C=100mA;	6	0.1010	0.1070	0.09[illegible]			
	5×10^{12}		I_B=10mA	6	0.1050	0.1111	0.0948	0.1180	0.1250	
	1×10^{13}			6	0.1090	0.1168	0.0991	0.1230	0.1290	
$V_{CE(SAT)}$ (V)	0		I_C=200mA	6	0.1520	0.1586	0.1410			
	5×10^{12}		I_B=20mA	6	0.1550	0.1[illegible]0	0.1426	0.1700	0.1770	
	1×10^{13}			6	0.1590	0.1659	0.1469	0.1740	0.1810	

2N3501, Motorola

DEVICE TYPE: 2N3501 MOTOROLA PAGE 1 of 3 3

Parameter	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
$\Delta(1/h_{FE})$	5×10^{12}	V_C=50V; V_E=0V,	V_{CE}=50V, I_C=0.1mA	3	0.0396	0.0496	0.0060	0.0730	0.0956	
	1×10^{13}	I_C=0.1mA		3	0.0369	0.0570	0.0120	0.0826	0.1050	
$\Delta(1/h_{FE})$	5×10^{12}		V_{CE}=50V, I_C=1mA	3	0.0089	0.0210	0.0021	0.0289	0.0405	
	1×10^{13}			3	0.0170	0.0233	0.0055	0.0368	0.0468	
$\Delta(1/h_{FE})$	5×10^{12}		V_{CE}=50V, I_C=10mA	3	0.0050	0.0086	0.0013	0.0125	0.0160	
	1×10^{13}			3	0.0059	0.0094	0.0020	0.0139	0.0171	
I_{CBO} (nA)	5×10^{12}	V_C=50V; V_E-V_B=0	V_{CB}=50V	3	24.4	45.0	0.20	69.6	82.2	
	1×10^{13}			3	67.1	115	0.34	186	246	





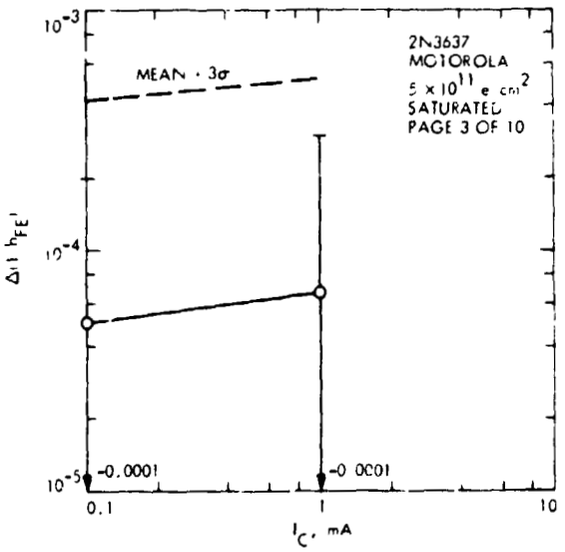
2N3637, Motorola

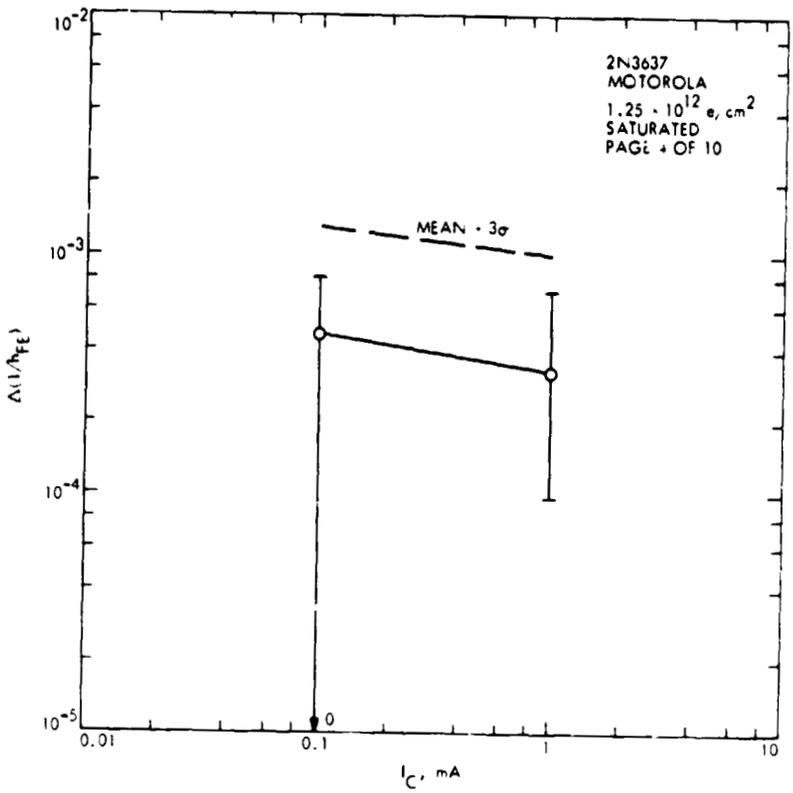
DEVICE TYPE: [illegible] 3

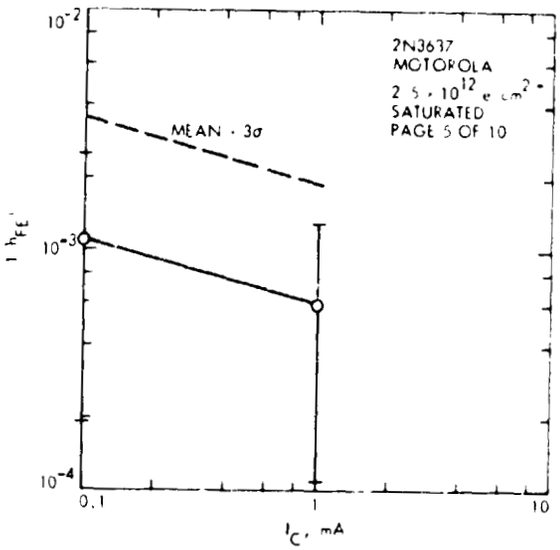
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean -2σ	Accept Reject Criteria
	[illegible]	BIAS: 1GRAD.	BIAS: MEAS.							
[illegible]	[illegible]	[illegible]	I_C 10mA, V_{CE} 1V	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]	[illegible] mA		6	[illegible]	[illegible]	0	[illegible]	[illegible]	
	[illegible]			6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]			6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		I_C 10mA, V_{CE} 1V	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]			6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]			6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]			6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		I_C 10mA, V_{CE} [illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]			6	[illegible]	[illegible]	0	[illegible]	[illegible]	
	[illegible]			6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]		I_C [illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]		I_C 10mA, V_{CE} [illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]		I_C 10mA, V_{CE} [illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
			I_C 10mA, V_{CE} [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]		I_C [illegible] 30V	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]			6	[illegible]	[illegible]	0	[illegible]	[illegible]	
	[illegible]		I_C [illegible] 30V	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
			I_C 10mA, V_{CE} 30V	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
			I_C 1mA, V_{CE} 30V	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

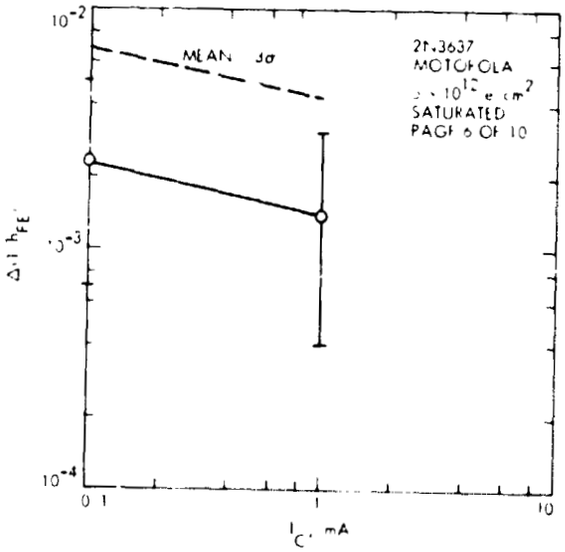
DEVICE TYPE: 2N 3637 MOTOROLA PAGE 2 OF 10

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	1×10¹³	VCE 100V,	IC 1mA, VCE 100V	6	0.0013	0.0016	0.0012	0.0017	0.0019	
↓	↓	IC = 0.1mA	IC 1mA, VCE 100V	6	0.0008	0.0010	0.0007	0.0011	0.0012	
Δ(1/hFE)	5×10¹²	↓	IC 10mA, VCE 100V	6	0.0008	0.0007	0.0014	0.0018	0.0028	
↓	↓		IC 10mA, VCE 100V	6	0.0004	0.0006	0.0003	0.0006	0.0007	
↓	1×10¹³	↓	IC 10mA, VCE 100V	6	0.0002	0.0010	0.0010	0.0021	0.0031	
↓	↓	↓	IC 10mA, VCE 100V	6	0.0007	0.0009	0.0006	0.0009	0.0010	
ICBO(nA)	5×10	BIASED INPUT:	VCB = 103V	7	38.4	30	1.4	207.5	282.1	
↓	1.5×10¹²	VCE 120V, OFF STATE		7	25.9	40	1.5	126.8	177.3	
↓	5×10¹²	IC 400μA, ON STATE		7	25	35	1.7	124.4	170.9	
↓	5×10¹²	98.5% DU CYCLE	↓	7	59.1	100	2.0	325.0	457.6	









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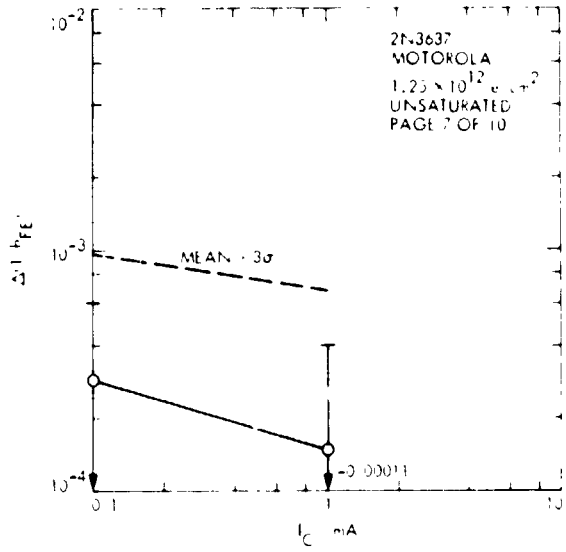
ORIGINAL PAGE IS POOR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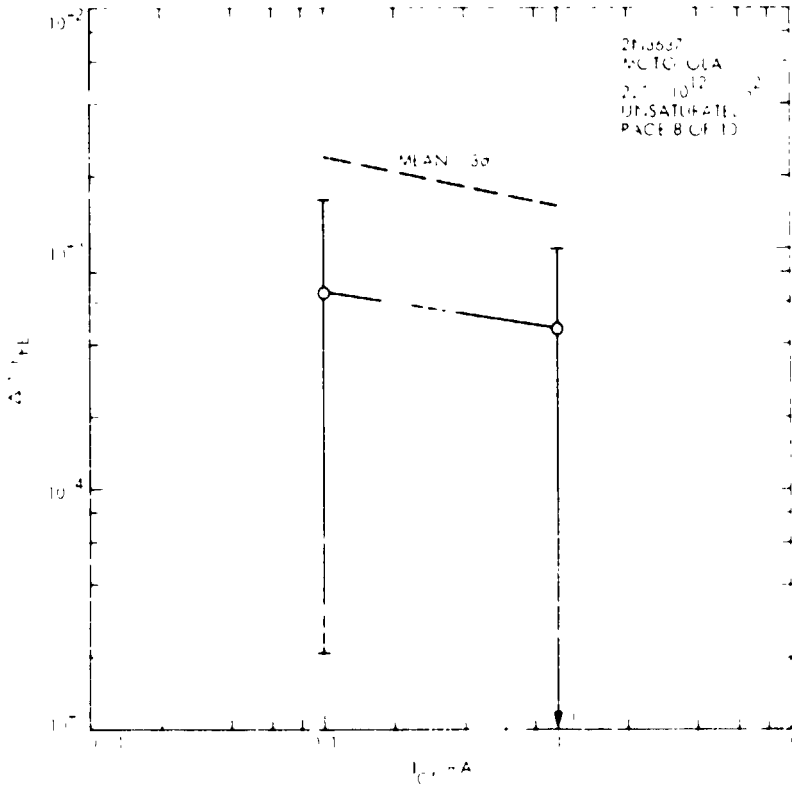
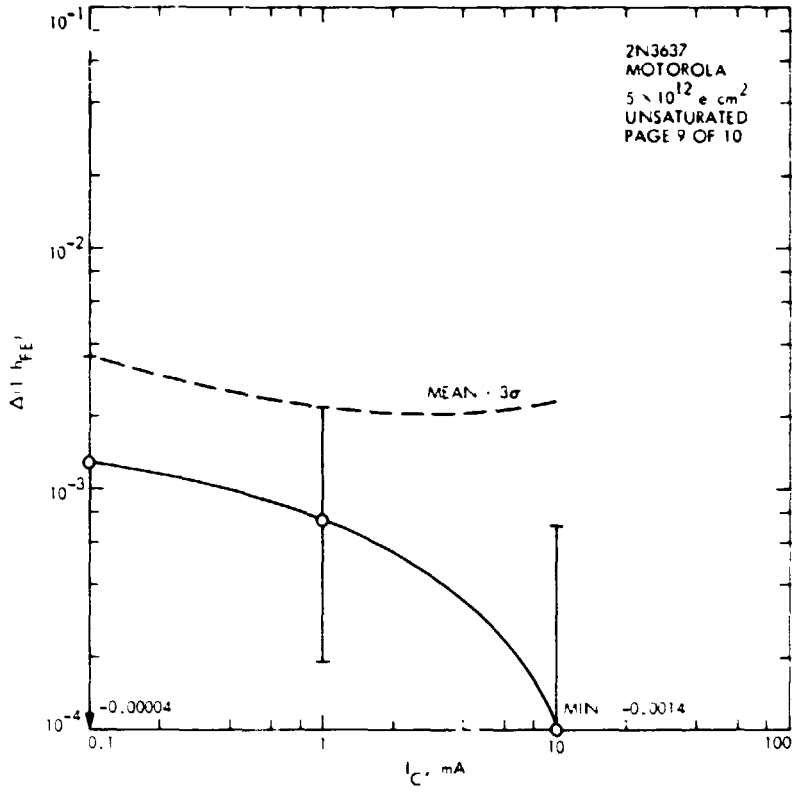
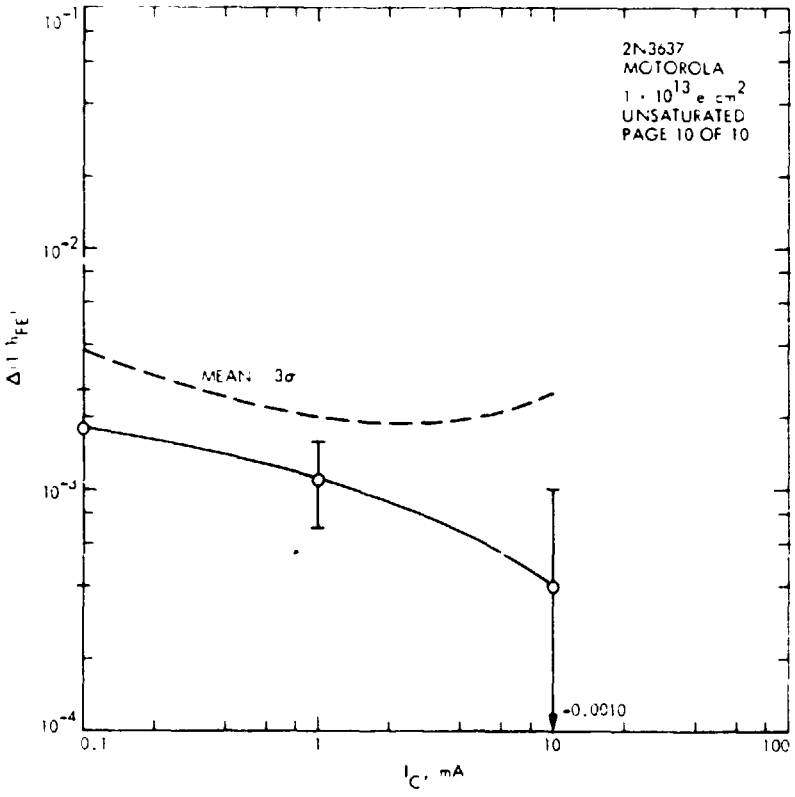
MOTOROLA
UNSATURATED
PAGE 7 OF 10
MEAN + 3σ
10^{-2}
10^{-3}
10^{-4}
0.1
1
10
I_C mA


2N3637
MOTOROLA
UNSATURATED
PAGE 8 OF 10
MEAN + 3σ
10^{-2}
10^{-4}


2N3637
MOTOROLA
5 × 10^12 e cm^2
UNSATURATED
PAGE 9 OF 10
MEAN + 3σ
-0.00004
MIN -0.0014
Δ(1/h_FE)
I_C, mA


2N3637
MOTOROLA
1 × 10^13 e cm^2
UNSATURATED
PAGE 10 OF 10
MEAN + 3σ
-0.0010
Δ(1/h_FE)
I_C, mA

2N3742, Motorola

DEVICE TYPE: 2N3742 MOTOROLA PAGE 1 of 1 3

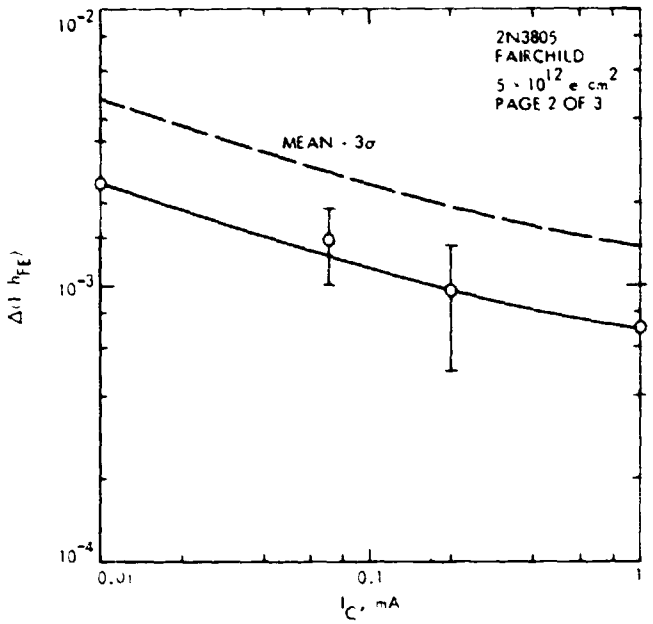
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	1×10¹¹	VCE=12V,	VCE=12V;	4	0.0186	0.0582	0.002	0.0232	0.100	
	2.5×10¹¹	IC=0.25mA	IC=0.25mA	4	0.103	0.386	0.0024	0.481	0.669	
	5×10¹¹			4	0.219	0.8331	0.0048	1.04	1.45	
	1×10¹²			4	0.335	1.267	0.0104	1.58	2.2	
	5×10¹²			6	0.94	2.553	0.1217	2.74	3.63	
ABS	1×10¹³			6	1.03	2.692	0.2054	2.85	3.75	

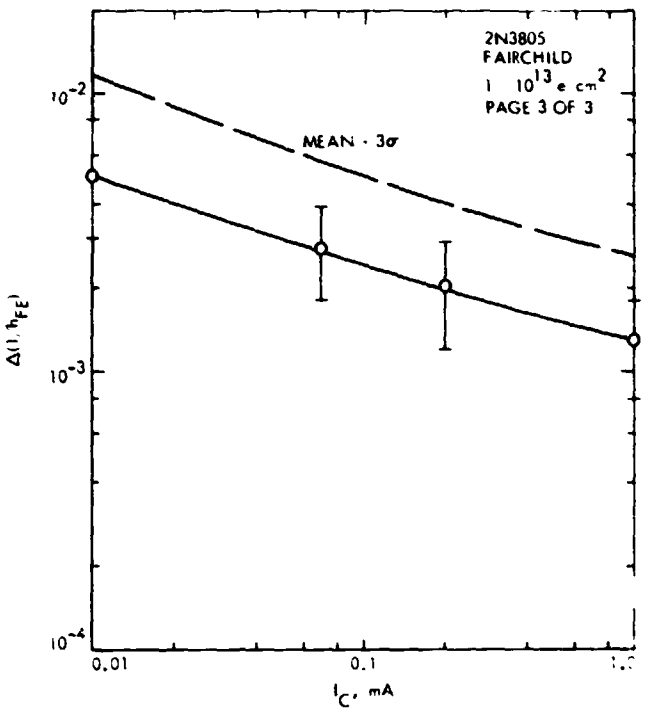
2N3805, Fairchild Semiconductor

DEVICE TYPE: 2N3805 DUAL FAIRCHILD SEMICONDUCTOR PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VC=16V, VE=0	VCE 16V; IC=1mA	6	0.00235	0.0033	0.0015	0.00358	0.00479	
	1×10¹³	VB=0		6	0.00523	0.0081	0.0030	0.0098	0.0[illegible]	
Δ(1/hFE)	5×10¹²		VCE=6V; IC=20μA	6	0.00147	0.0090	0.0010	0.0022	0.00269	
	1×10¹³			6	0.00382	0.0035	0.0018	0.0047	0.0056	
Δ(1/hFE)	5×10¹²		VCE=6V; IC=200μA	6	0.00097	0.0014	0.0005	0.0017	0.0020	
	1×10¹³			6	0.00205	0.0029	0.0016	0.0036	0.0043	
Δ(1/hFE)	5×10¹²		VCE=16V; IC=1mA	6	0.00072	0.0010	0.0004	0.0021	0.0016	
	1×10¹³			6	0.0033	0.0018	0.0008	0.0022	0.0027	
ICBO(1)A	5×10¹²	VCB=18V; VE=0	VCB=18V	4	0.273	0.330	0.175	0.412	0.490	
		VB=0		6*	2.05	10.0	0.125	5.90	13.8	
	1×10¹³			4	3.3	4.4	1.25	5.86	7.14	
				6*	45.3	245	1.25	241	339	

* OUTLIERS INCLUDED



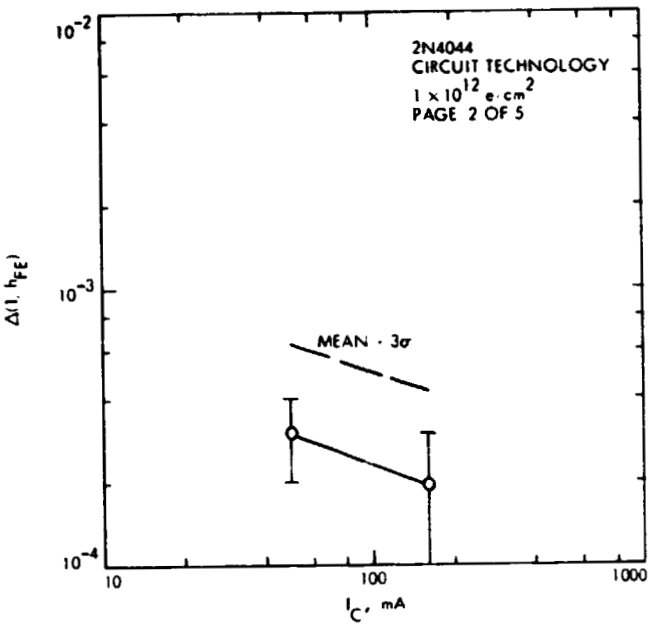


2N4044, Circuit Technology

DEVICE TYPE: 2N4044 C.I.I. PAGE 1 of 5 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	1×10^12	VCE = 6V	IC = 50 μA	8	0.00031	0.0004	0.0002	0.00051	0.00061	
	2.5×10^12	IC 50 μA	VCE 6V	8	0.00054	0.0007	0.0003	0.00082	0.00096	
	5×10^12			8	0.00084	0.0012	0.0004	0.0013	0.0016	
	1×10^13			8	0.00125	0.0018	0.0009	0.0019	0.0225	
Δ(1/hFE)	1×10^12		IC = 160 μA	8	0.0002	0.0003	0.0001	0.00035	0.00043	
	2.5×10^12		VCE 6V	8	0.0004	0.0007	0.0003	0.00066	0.00079	
	5×10^12			8	0.0005	0.0008	0.0005	0.00081	0.00825	
	1×10^13			8	0.00089	0.0012	0.0005	0.0014	0.0017	
								± 2σ	± 3σ	
hFE1/hFE2	1×10^12		IC1 = 50 μA	8	0.885	0.95	0.82	1.01	1.07	
			IC2 = 160 μA					0.76	0.697	
	2.5×10^12		VCE = 6V	8	0.876	0.97	0.8	1.01	1.07	
								0.745	0.697	
	5×10^12			8	0.855	0.97	0.72	1.0	1.08	
								0.707	0.633	
	1×10^13			8	0.801	0.88	0.75	0.925	0.976	
								0.718	0.6666	

AE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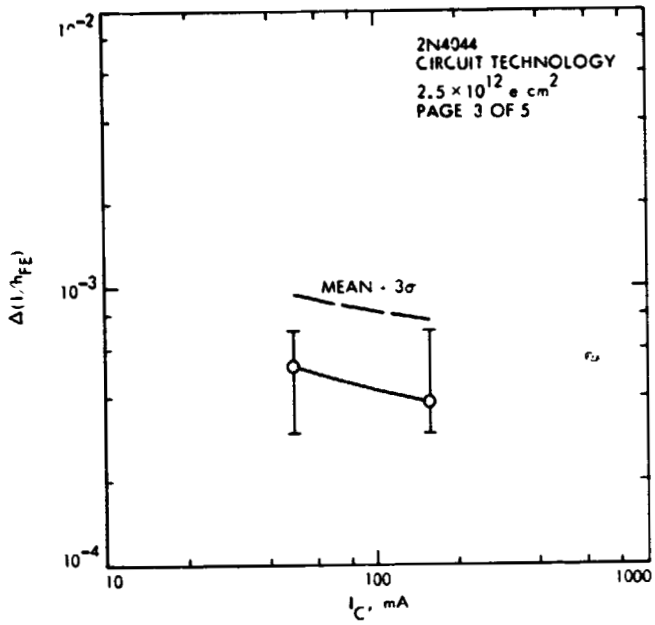
CIRCUIT TECHNOLOGY
1 × 10^12 e·cm^2
PAGE 2 OF 5
MEAN + 3σ
Δ(1/hFE)
IC, mA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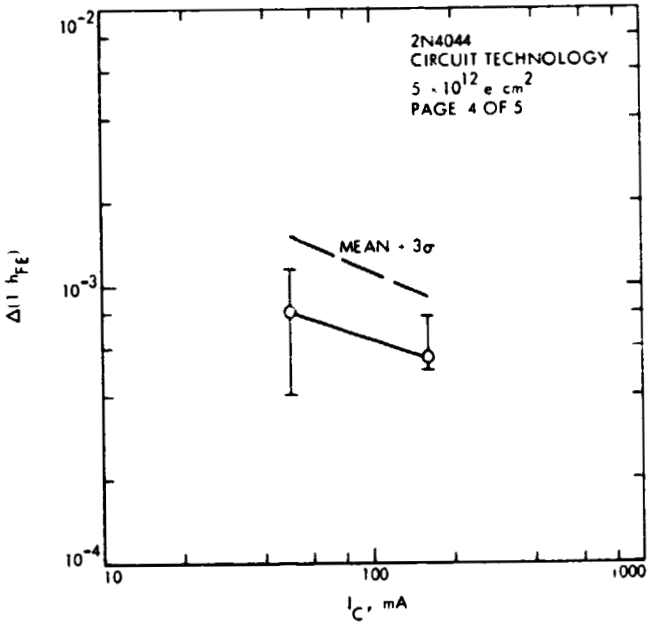
PAGE 3 OF 5
MEAN + 3σ
Δ(1/hFE)
IC, mA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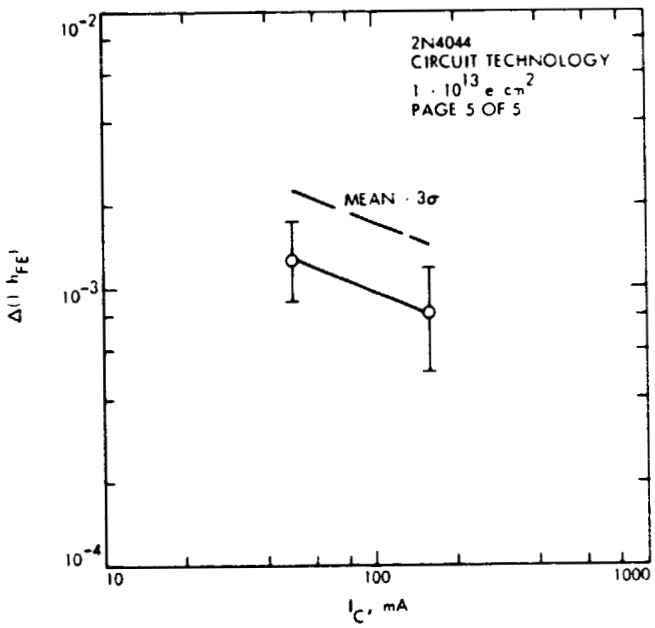
CIRCUIT TECHNOLOGY
5 × 10^12 e cm^2
PAGE 4 OF 5
MEAN + 3σ
Δ(1/hFE)
IC, mA


2N4044
CIRCUIT TECHNOLOGY
1 × 10^13 e cm^2
PAGE 5 OF 5
MEAN + 3σ
Δ(1/hFE)
IC, mA

2N5087, Circuit Technology

DEVICE TYPE: 2N5087 CTI PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	1×10¹²	VCE=6V, IC=70μA	VCE=6V, IC=70μA	8	0.00056	0.0009	0.0001	0.0011	0.0014	
	2.5×10¹²			8	0.0013	0.0022	0.0004	0.0025	0.0031	
	5×10¹²			8	0.0021	0.0042	0.0005	0.0045	0.0057	
	1×10¹³			8	0.0038	0.0082	0.0014	0.0080	0.0101	

KD6001, KMC Semiconductor

DEVICE TYPE: KD6001 KMC PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VCE=5V, IC=1mA	VCE=5V, IC=1mA	6	0.0117	0.014	0.009	0.0162	0.0184	
	1×10¹³			6	0.0207	0.025	0.018	0.0267	0.0293	

MQ2219, Motorola

DEVICE TYPE: MQ2219 MOTOROLA PAGE 1 of 10 3

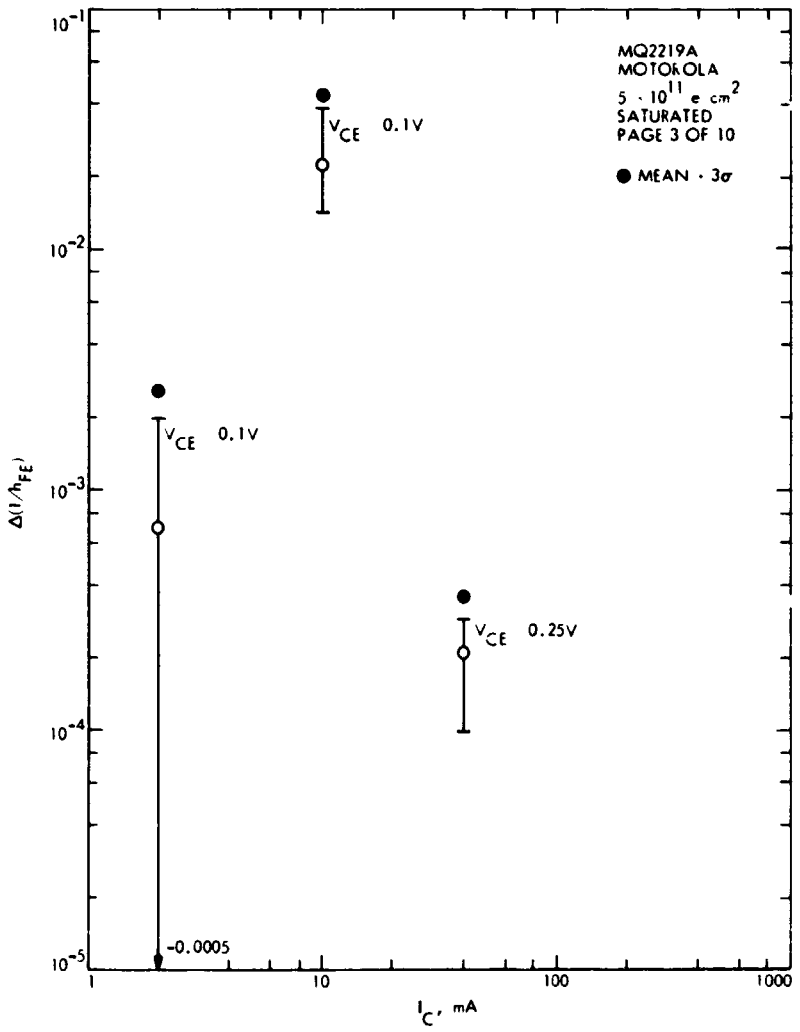
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	VCE = 9V, VBE = 0	IC = 10mA; VCE = 0.1V	20	0.0009	0.0020	0.0005	0.0020	0.0026	
	1.25×10¹²			20	0.0027	0.0045	0.0015	0.0062	0.0050	
	2.5×10¹²			20	0.0057	0.0079	0.0040	0.0079	0.0090	
	5×10¹²			16	0.0107	0.0145	0.0085	0.0142	0.0160	
Δ(1/hFE)	5×10¹¹		IC = 10mA, VCE = 0.1V	20	0.0204	0.0392	0.0140	0.0365	0.0435	
	1.25×10¹²			19	0.0297	0.0441	0.0074	0.0489	0.0584	
				20*	0.0342	0.1180	0.0074	0.0778	0.0996	
	2.5×10¹²			20	0.0342	0.0480	0.0210	0.0541	0.0641	
	5×10¹²			16	0.0418	0.0594	0.0323	0.0610	0.0705	
Δ(1/hFE)	5×10¹¹		IC = 40mA; VCE = 0.25V	20	0.00021	0.00038	0.00028	0.00031	0.00036	
	1.25×10¹²			20	0.00042	0.00064	0.00028	0.00058	0.00079	
	2.5×10¹²			20	0.0008	0.0015	0.0004	0.0011	0.0013	
	5×10¹²			16	0.0025	0.0015	0.0006	0.0016	0.0017	
Δ(1/hFE)	5×10¹¹		IC = 10mA; VCE = 2.4V	20	0.0062	0.0010	0.0035	0.0016	0.0021	
	1.25×10¹²			20	0.0012	0.0030	0.0054	0.0057	0.0086	
	2.5×10¹²			20	0.0026	0.0038	0.0039	0.0047	0.0057	
	5×10¹²			16	0.0019	0.0065	0.0037	0.0066	0.0074	

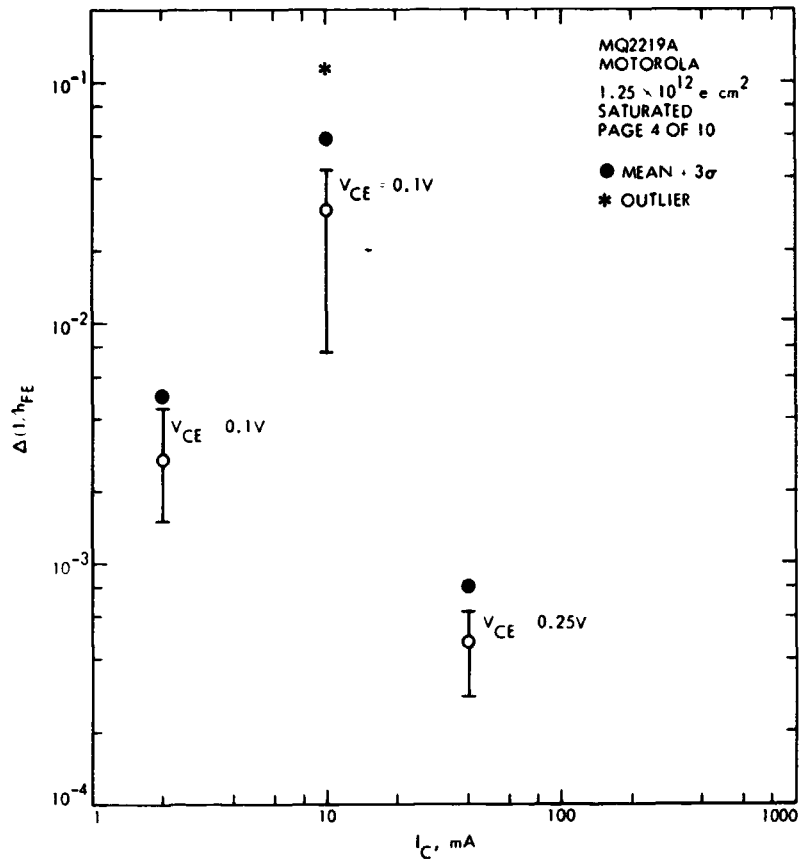
* OUTLIER INCLUDED

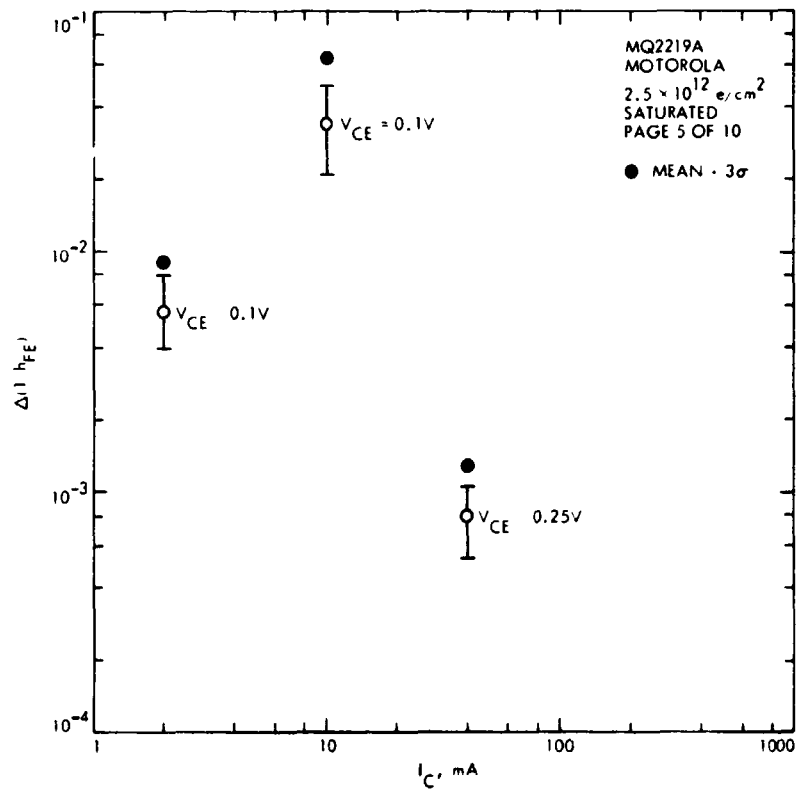
DEVICE TYPE: MQ2219 MOTOROLA PAGE 2 of 10

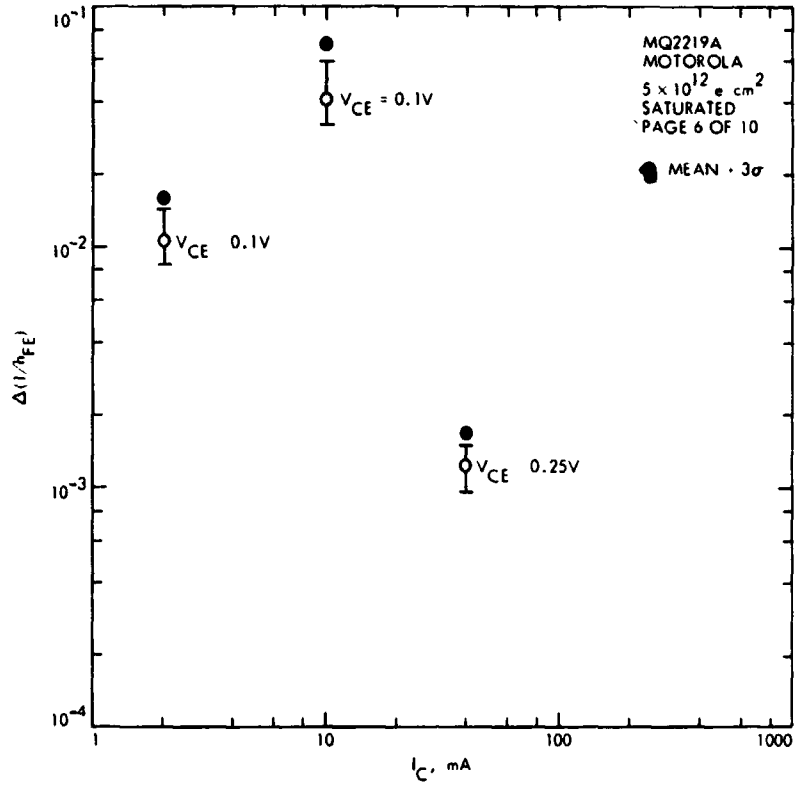
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	VCE = 9V, VBE = 0	IC = 10mA, VCE = 2.4V	18	0.00036	0.0006	0.0001	0.00063	0.00077	
				20*	0.00069	0.0039	0.0001	0.0022	0.0030	
	1.25×10¹²			20	0.00083	0.0012	0.0006	0.0012	0.0014	
	2.5×10¹²			20	0.0015	0.0021	0.0011	0.0021	0.0024	
	5×10¹²			16	0.0023	0.0028	0.0017	0.0029	0.0030	
Δ(1/hFE)	5×10¹¹		IC = 40mA, VCE = 2.4V	20	0.00028	0.00039	0.00016	0.00040	0.00048	
	1.25×10¹²			20	0.00052	0.0007	0.00033	0.00075	0.00087	
	2.5×10¹²			20	0.0008	0.0011	0.00054	0.0011	0.0013	
	5×10¹²			16	0.0011	0.0014	0.00087	0.0015	0.0017	

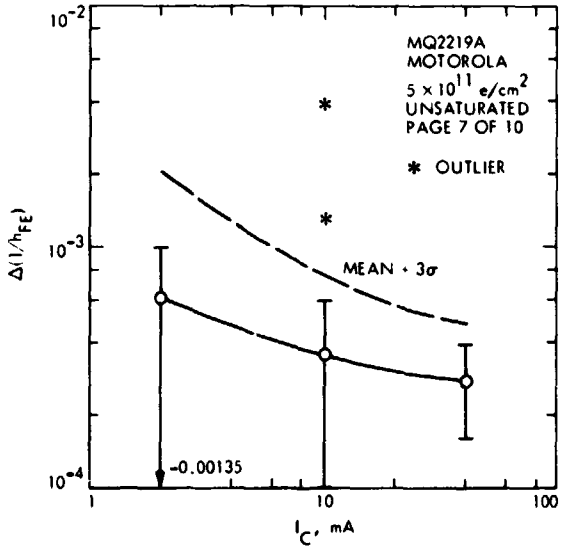
* OUTLIERS INCLUDED

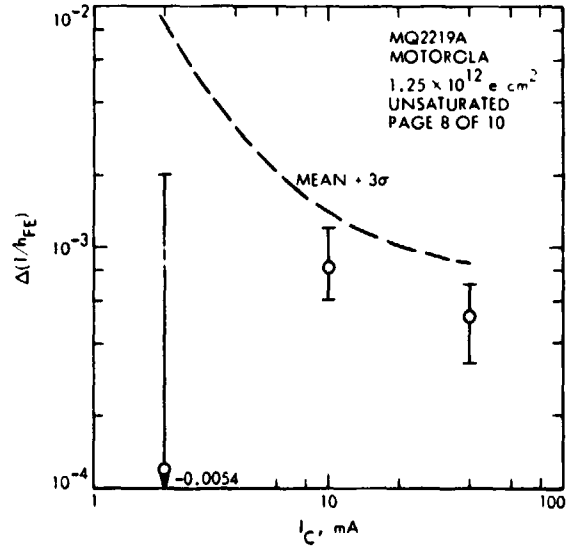

MQ2219A
MOTOROLA
5 · 10^11 e cm^2
SATURATED
PAGE 3 OF 10
● MEAN · 3σ
V_CE 0.1V
V_CE 0.1V
V_CE 0.25V
-0.0005
Δ(1/h_FE)
10^-1
10^-2
10^-3
10^-4
10^-5
1
10
100
1000
I_C, mA


MQ2219A
MOTOROLA
1.25 × 10^12 e cm^2
SATURATED
PAGE 4 OF 10
● MEAN + 3σ
✱ OUTLIER
V_CE = 0.1V
V_CE 0.1V
V_CE 0.25V
Δ(1/h_FE)
I_C, mA
10^-1
10^-2
10^-3
10^-4
1
10
100
1000

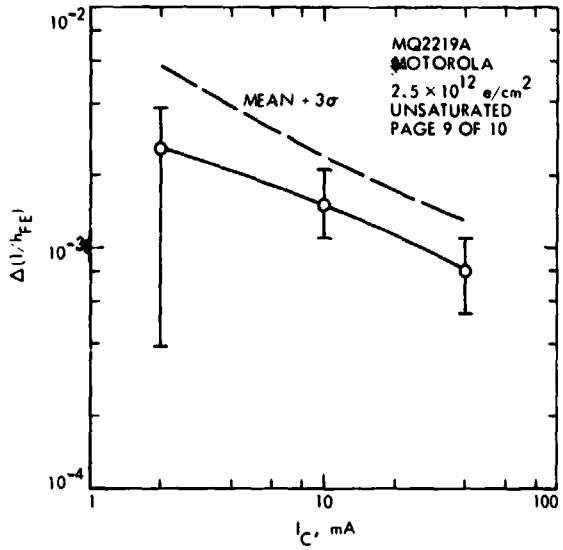

MQ2219A
MOTOROLA
2.5 × 10^12 e/cm^2
SATURATED
PAGE 5 OF 10
● MEAN + 3σ
V_CE = 0.1V
V_CE 0.1V
V_CE 0.25V
Δ(1/h_FE)
I_C, mA
10^-1
10^-2
10^-3
10^-4
1
10
100
1000

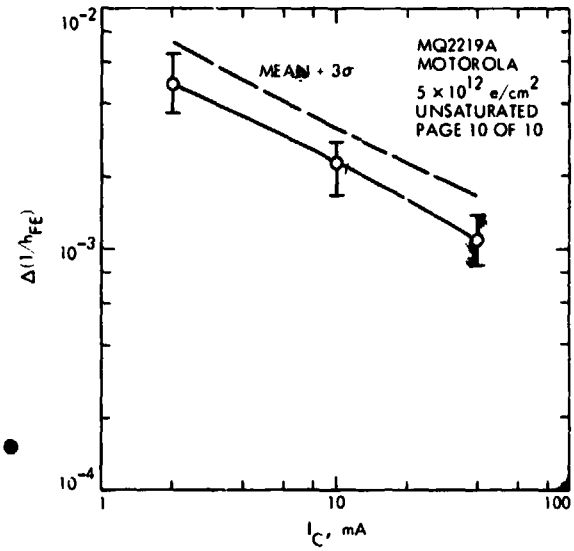






REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR





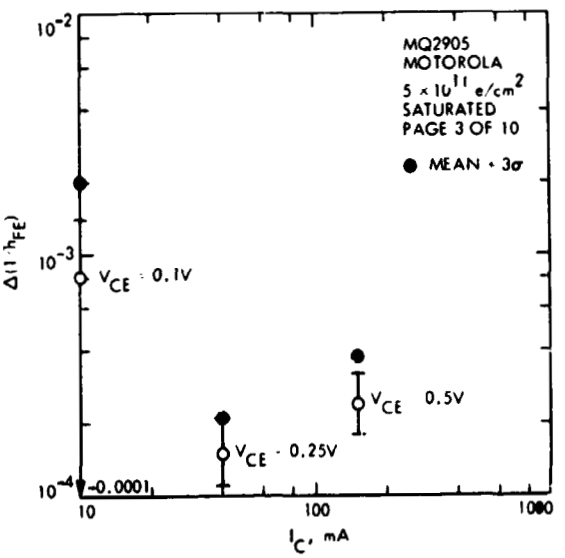
MQ2905, Motorola

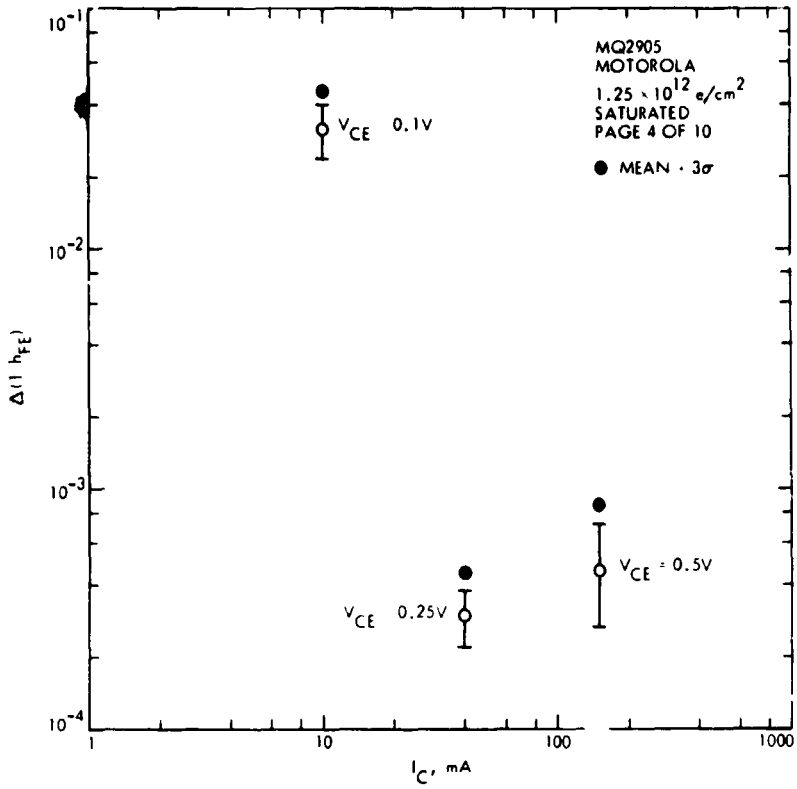
DEVICE TYPE: MQ 2905 MOTOROLA PAGE 1 of 10 3

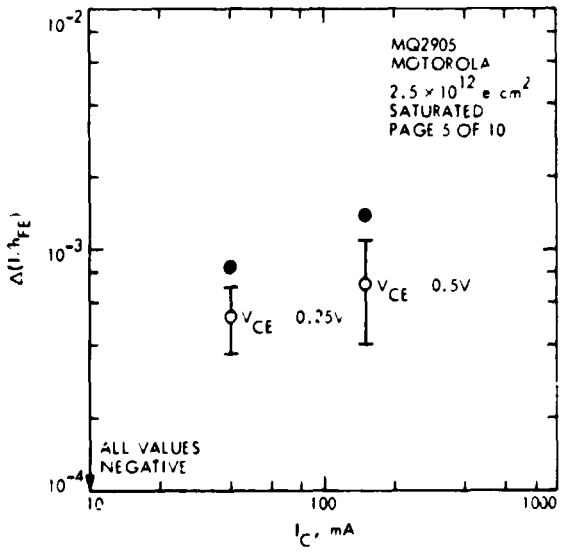
Parameter	Fluence	Operating Point			Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.		BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	VCE=5V	VBE=0	IC=10mA VCE 0.1V	16	0.0081	0.0014	-0.0008	0.0016	0.0020	
	1.25×10¹²				20	0.0343	0.0402	0.0242	0.0417	0.0462	
	2.5×10¹²				20	0.0047	-0.0032	-0.0029	-0.0038	-0.0010	
	5×10¹²				20	0.0406	0.0522	0.0312	0.0527	0.0588	
Δ(1/hFE)	5×10¹¹			IC=10mA VCE=0.25V	16	0.00015	0.00021	0.00011	0.00019	0.00021	
	1.25×10¹²				20	0.0030	0.0038	0.0022	0.0034	0.0045	
	2.5×10¹²				20	0.0053	0.0072	0.0037	0.0074	0.0085	
	5×10¹²				20	0.0011	0.0014	0.0006	0.0015	0.0017	
Δ(1/hFE)	5×10¹¹			IC=150mA VCE 0.5V	16	0.0024	0.0032	0.0018	0.0034	0.0038	
	1.25×10¹²				20	0.0046	0.0022	0.0027	0.0074	0.0086	
	2.5×10¹²				20	0.0023	0.0011	0.0041	0.0062	0.0014	
	5×10¹²				20	0.0013	0.0019	0.0009	0.0020	0.0024	
Δ(1/hFE)	5×10¹¹			IC=10mA VCE=2.1V	16	0.0033	0.0067	[illegible]	0.0068	0.0085	
	1.25×10¹²				20	0.0027	0.0010	-0.0037	0.0062	0.0032	
	2.5×10¹²				20	0.0097	0.0013	0.0057	0.0015	0.0018	
	5×10¹²				19	0.0016	0.0020	0.0013	0.0021	0.0024	
					20*	0.0018	0.0040	0.0013	0.0028	0.0035	
AGS											
	* OUTLIER INCLUDED										

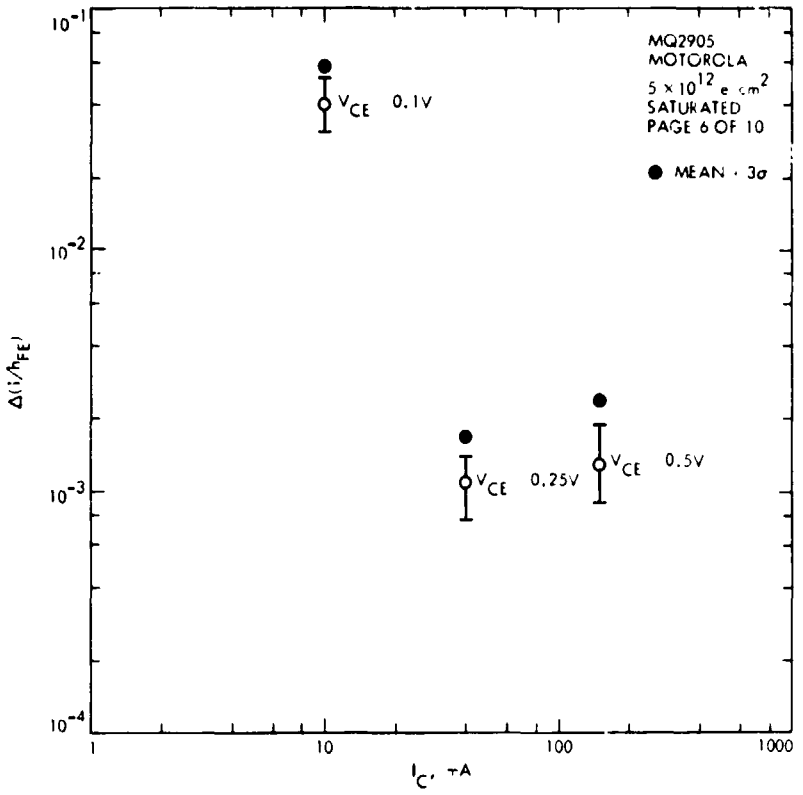
DEVICE TYPE: MQ 2905 MOTOROLA PAGE 3 of 10

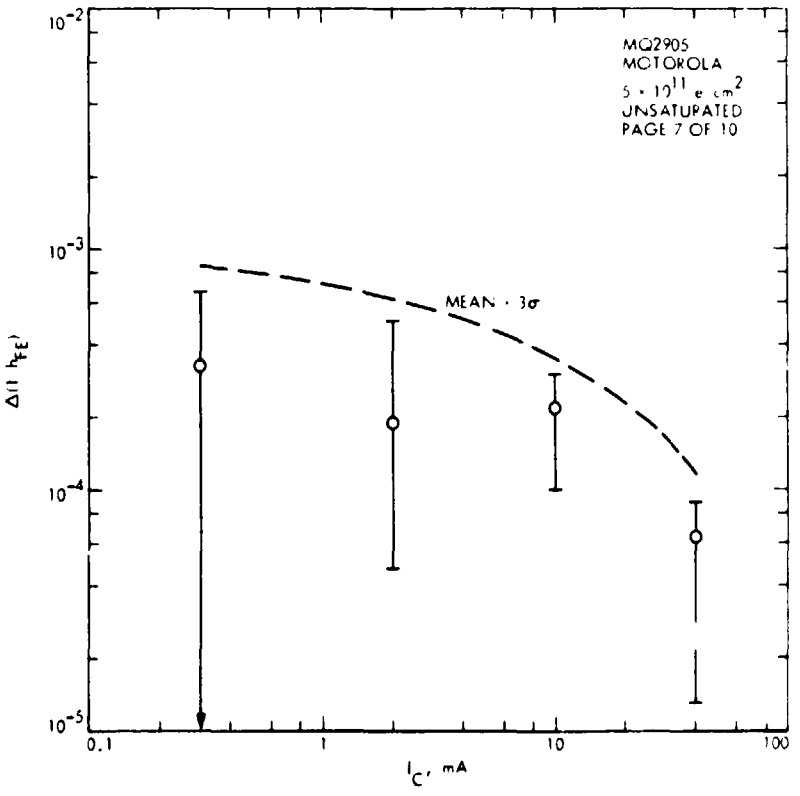
Parameter	Fluence	Operating Point			Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.		BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	VCE: 5V	VBE: 0	IC: 2mA; VCE: 2.4V	16	0.00019	0.0005	0.00004	0.00045	0.00058	
	1.25×10¹²				20	0.00026	0.00045	0.0001	0.00056	0.00071	
	2.5×10¹²				20	0.00048	0.0010	0.0014	0.0014	0.0019	
	5×10¹²				20	0.0010	0.0013	0.0006	0.0014	0.0016	
Δ(1/hFE)	5×10¹¹			IC: 10mA; VCE: 2.4V	16	0.00022	0.0003	0.0001	0.00033	0.00038	
	1.25×10¹²				20	0.00009	0.0005	0.0001	0.00051	0.00062	
	2.5×10¹²				20	0.00043	0.0006	0.0003	0.00064	0.00078	
	5×10¹²				20	0.00071	0.0010	0.0005	0.0005	0.00105	
Δ(1/hFE)	5×10¹¹			IC: 40mA; VCE: 2.4V	16	0.00064	0.00089	0.00043	0.00098	0.00112	
	1.25×10¹²				20	0.00016	0.00019	0.00011	0.0002	0.00020	
	2.5×10¹²				20	0.00024	0.00031	0.00016	0.00035	0.00036	
	5×10¹²				20	0.00048	0.00057	0.00036	0.0006	0.00065	

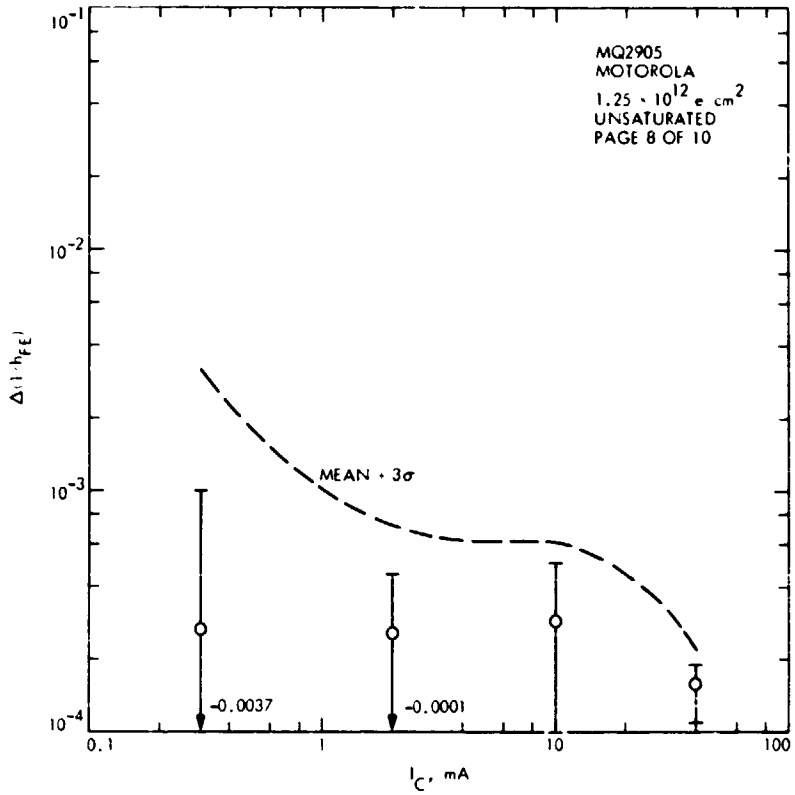


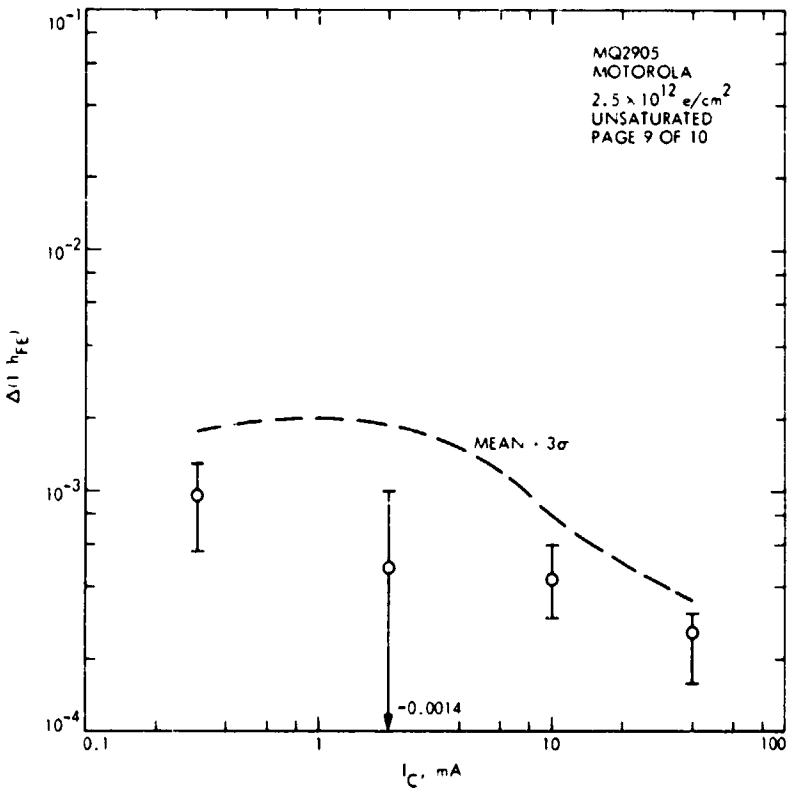

MQ2905
MOTOROLA
1.25 × 10^12 e/cm^2
SATURATED
PAGE 4 OF 10
● MEAN · 3σ
V_CE 0.1V
V_CE 0.25V
V_CE = 0.5V
Δ(1/h_FE)
I_C, mA

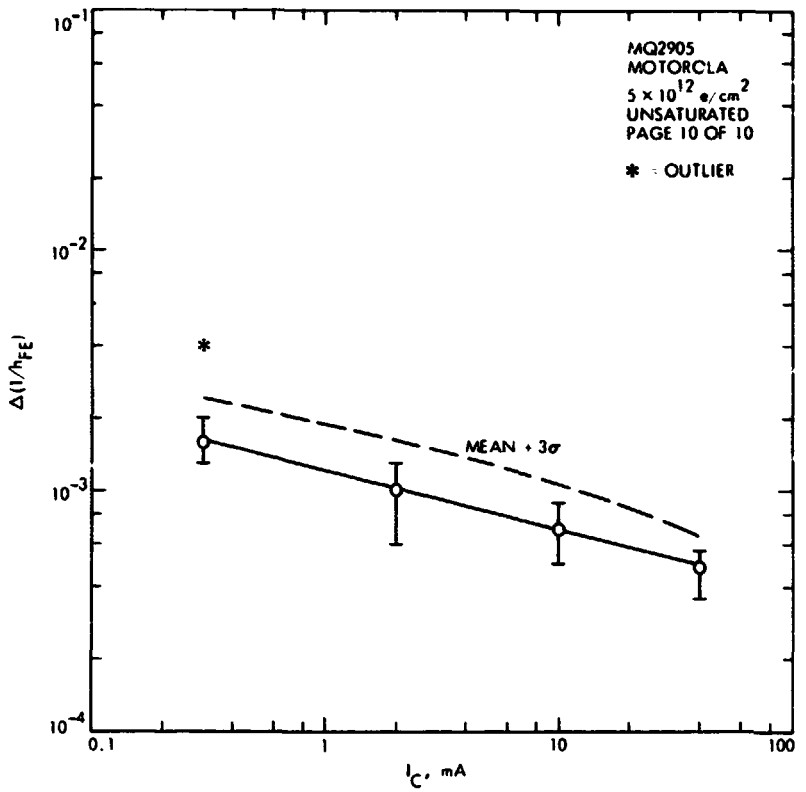

MQ2905
MOTOROLA
2.5 × 10^12 e cm^2
SATURATED
PAGE 5 OF 10
V_CE 0.25V
V_CE 0.5V
ALL VALUES
NEGATIVE
Δ(1/h_FE)
I_C, mA


MQ2905
MOTOROLA
5 × 10^12 e cm^2
SATURATED
PAGE 6 OF 10
MEAN · 3σ
V_CE 0.1V
V_CE 0.25V
V_CE 0.5V
Δ(1/h_FE)
I_C, mA


MQ2905
MOTOROLA
5 × 10^11 e cm^2
UNSATURATED
PAGE 7 OF 10
MEAN · 3σ
Δ(1/h_FE)
I_C, mA


MQ2905
MOTOROLA
1.25 × 10^12 e cm^2
UNSATURATED
PAGE 8 OF 10
MEAN + 3σ
-0.0037
-0.0001
Δ(1/h_FE)
I_C, mA


MQ2905
MOTOROLA
2.5 × 10^12 e/cm^2
UNSATURATED
PAGE 9 OF 10
MEAN + 3σ
-0.0014
Δ(1/h_FE)
I_C, mA



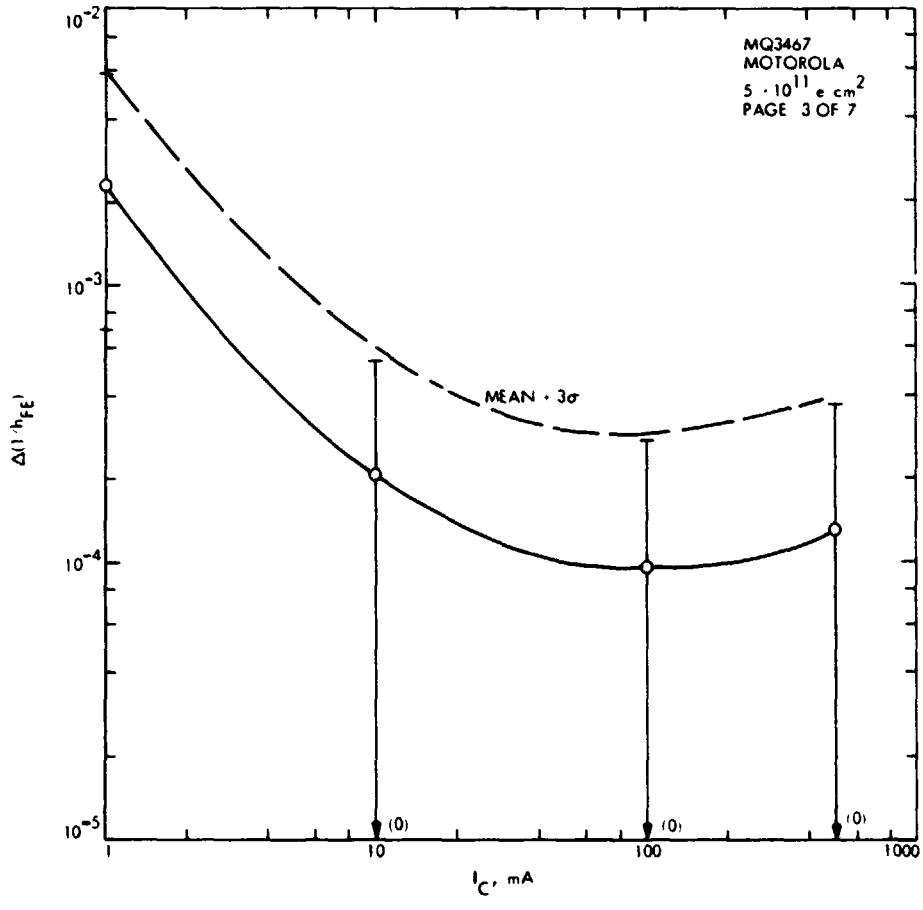
MQ3467, Motorola

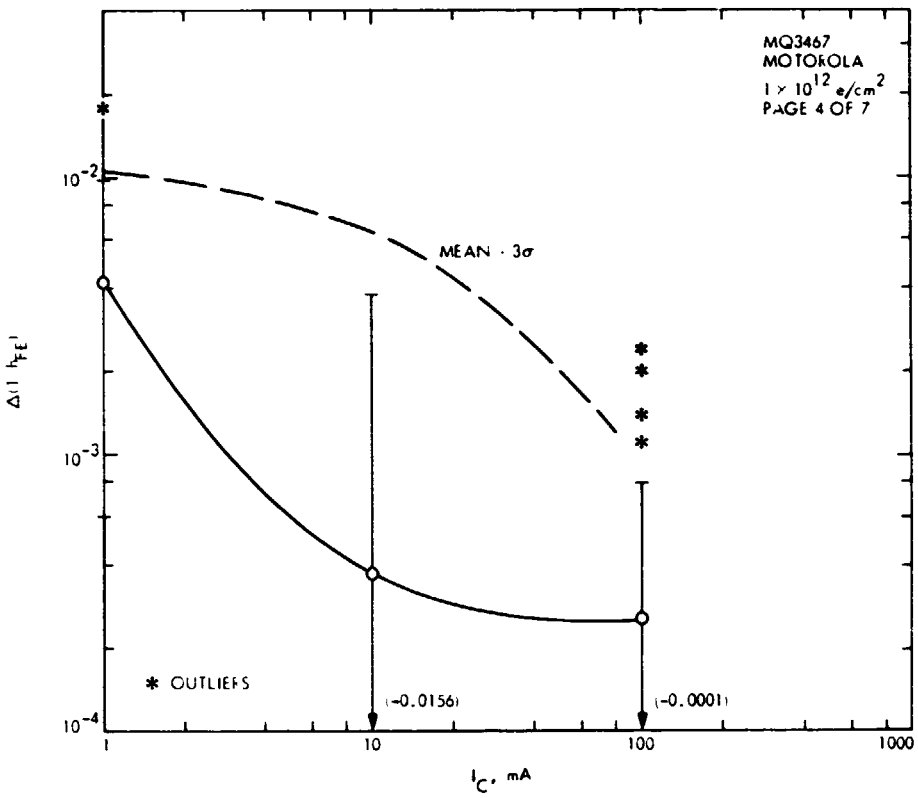
DEVICE TYPE: MQ3467 MOTOROLA PAGE of 7 3

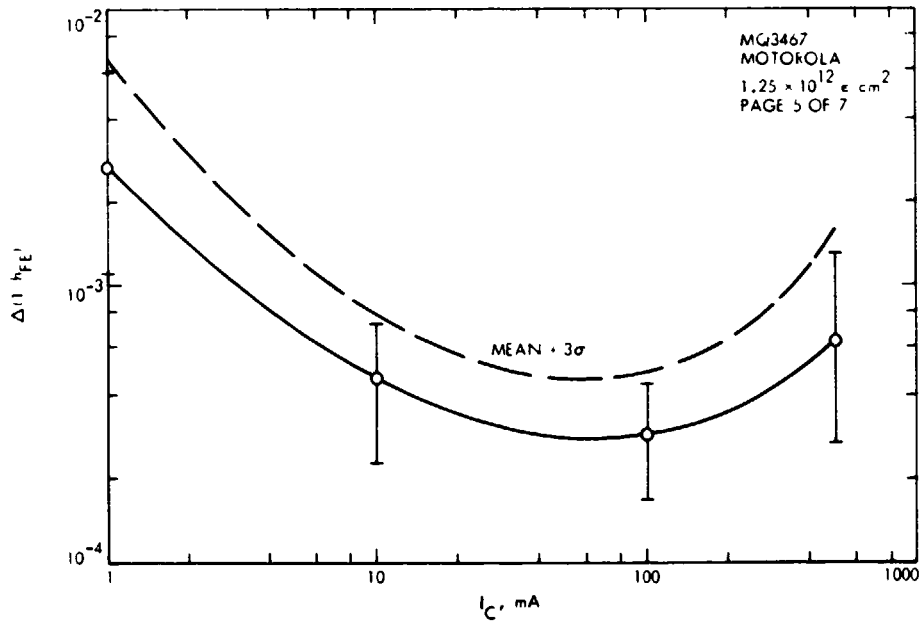
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^11	VC = 40V;	VCE = 0.2V; IC = 1mA	23	0.0023	0.0058	0.00026	0.0049	0.0062	
	1×10^12	VE VB = GND		68	0.0042	0.0099	0.0006	0.0082	0.0101	
	↓			69*	0.0044	0.0179	0.0006	0.0095	0.0121	
	1.25×10^12			23	0.0027	0.0059	0.0011	0.0055	0.0069	
	2.5×10^12			91	0.0048	0.0114	0.0005	0.0102	0.0129	
	↓			93*	0.0052	0.0365	0.0005	0.0139	0.0182	
	5×10^12			23	0.0041	0.0075	0.0017	0.0073	0.0089	
	1×10^13			15	0.0068	0.0078	0.0052	0.0083	0.0091	
Δ(1/hFE)	5×10^11		VCE = 0.3V; IC = 10mA	23	0.00021	0.00054	0	0.00048	0.00060	
	1×10^12			71	0.00038	0.0038	-0.0156	0.0045	0.00666	
	1.25×10^12			23	0.00047	0.00073	0.00023	0.00070	0.00082	
	2.5×10^12			93	0.00079	0.0054	-0.0162	0.0017	0.0067	
	↓			94*	0.00087	0.0084	-0.0162	0.0051	0.0072	
	5×10^12			23	0.0013	0.0019	0.00087	0.0019	0.0022	
Δ(1/hFE)	5×10^11		VCE 0.4V; IC = 100mA	23	0.00009	0.00038	0	0.00022	0.00029	
	1×10^12			62	0.00026	0.00008	-0.0001	0.00065	0.00085	
	↓			71*	0.00049	0.0042	-0.0001	0.0019	0.0026	
	1.25×10^12			23	0.00038	0.0004	0.00017	0.0042	0.0049	
	2.5×10^12			83	0.00053	0.0013	0	0.0014	0.0013	
	↓			94*	0.00073	0.0051	0	0.0022	0.0038	
	5×10^12			23	0.00087	0.0012	0.00052	0.0012	0.0014	

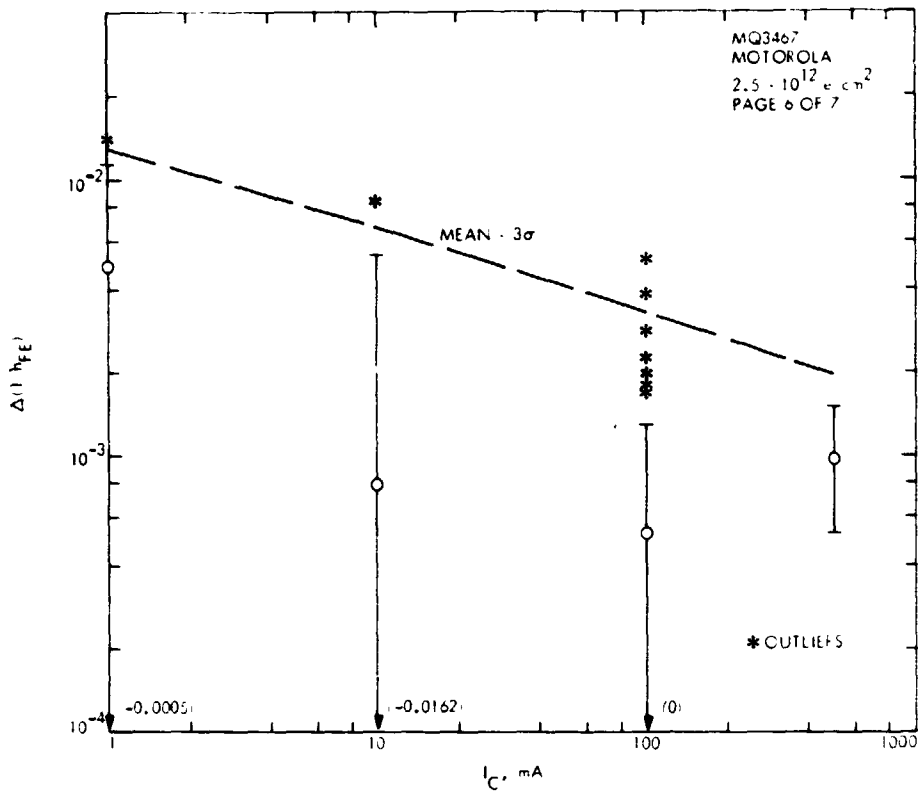
DEVICE TYPE: MQ3467 MOTOROLA PAGE 2 of 7

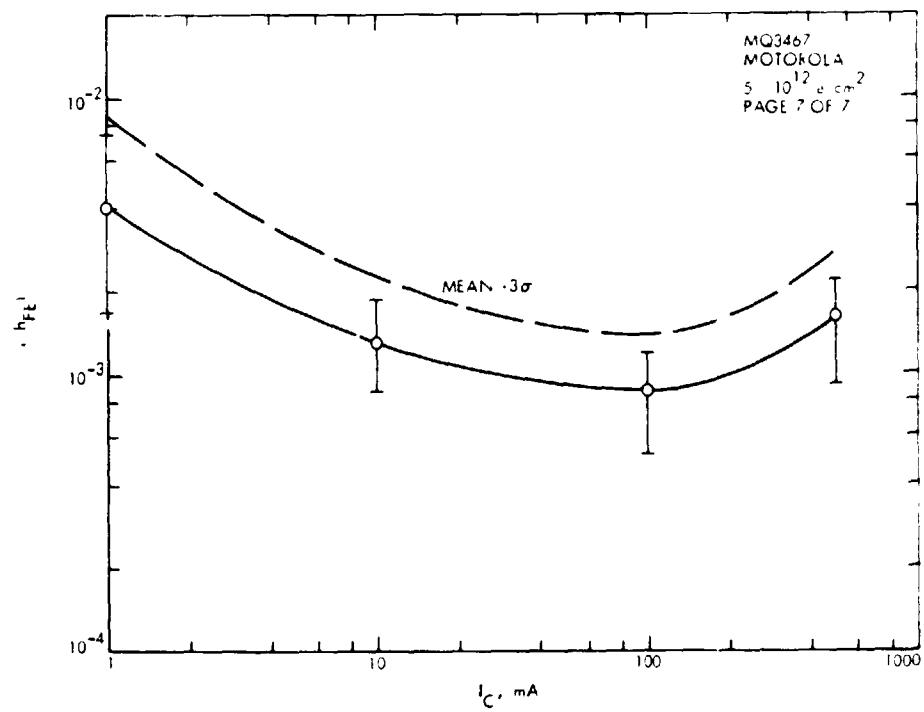
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	VC = 40 V;	VCE = 0.6V, IC = 500mA	23	0.00013	0.00037	0	0.00031	0.00046	
	1.25×10¹²	VE = VB = GND		23	0.00063	0.0013	0.00022	0.0012	0.0015	
	2.5×10¹²			23	0.00097	0.0015	0.00052	0.0016	0.0019	
	5×10¹²			23	0.00160	0.0022	0.00091	0.0024	0.0028	




MQ3467
MOTOROLA
1 × 10^12 e/cm^2
PAGE 4 OF 7
MEAN + 3σ
* OUTLIERS
(-0.0156)
(-0.0001)
Δ(1/h_FE)
I_C, mA


MQ3467
MOTOROLA
1.25 × 10^12 e/cm^2
PAGE 5 OF 7
MEAN + 3σ
Δ(1/h_FE)
I_C, mA


MQ3467
MOTOROLA
2.5 · 10^12 e cm^-2
PAGE 6 OF 7
MEAN - 3σ
* OUTLIERS
-0.0005
-0.0162
(0)
Δ(1/h_FE)
10^-2
10^-3
10^-4
1
10
100
1000
I_C, mA


MQ3467
MOTOROLA
5 10^12 e cm^-2
PAGE 7 OF 7
MEAN -3σ
1/h_FE
10^-2
10^-3
10^-4
1
10
100
1000
I_C, mA

MQ3725, Motorola

DEVICE TYPE: MQ3725 MOTOROLA PAGE 1 of 9 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	Ic=40V, Ve=Vb=GND	Ic=1mA, Vce=0.2V	24	0.0015	0.0238	0.00074	0.0039	0.0050	
	1×10¹²			68	0.0210	0.0787	0.0163	0.0616	0.0818	
	1.25×10¹²			24	0.0019	0.0122	0.0011	0.0112	0.0143	
	2.5×10¹²			92	0.0656	0.2323	0.0163	0.1990	0.2660	
	5×10¹²			24	0.0303	0.0468	0.0078	0.0436	0.0553	
	1×10¹³			20	0.0516	0.1000	0.0380	0.0843	0.101	
Δ(1/hFE)	5×10¹¹	Ic=40V, Ve=Vb=GND	Ic=10mA, Vce=0.3V	24	0.00073	0.0017	0.00006	0.0016	0.0020	
	1×10¹²			68	0.0064	0.0142	0.0004	0.0143	0.0182	
	1.25×10¹²			24	0.0017	0.0044	0.0009	0.0041	0.0052	
	2.5×10¹²			92	0.0151	0.0424	0.0016	0.0401	0.0526	
	5×10¹²	Ic=30V, Ve=Vb=GND	Ic=10mA, Vce=0.16V	16	0.0091	0.0196	0	0.0217	0.0280	
		Ic=30V, Ve=Vb=GND	Ic=10mA, Vce=0.3V	24	0.0062	0.0139	0.0031	0.0128	0.0161	
	1×10¹³	Ic=30V, Ve=Vb=GND	Ic=10mA, Vce=0.16V	16	0.0141	0.0294	0.0034	0.0272	0.0337	
Δ(1/hFE)	5×10¹¹	Ic=40V, Ve=Vb=GND	Ic=100mA, Vce=0.1V	24	0.00043	0.0011	0.00021	0.00098	0.0013	
	1×10¹²			68	0.0020	0.0037	0.00061	0.0038	0.0047	
	1.25×10¹²			24	0.00087	0.0022	0.00048	0.0020	0.0025	
	2.5×10¹²			92	0.0039	0.0086	0.00081	0.0088	0.0113	
	5×10¹²	Ic=30V, Ve=Vb=GND	Ic=100mA, Vce=0.2V	15	0.0036	0.0068	0	0.0075	0.0095	
				16*	0.0062	0.0151	0	0.0273	0.0328	
		Ic=40V, Ve=Vb=GND	Ic=100mA, Vce=0.1V	24	0.0023	0.0051	0.0014	0.0046	0.0058	
ABS	1×10¹³	Ic=30V, Ve=Vb=GND	Ic=100mA, Vce=0.2V	16	0.0106	0.0427	0	0.0320	0.0428	

* OUTLIER INCLUDED

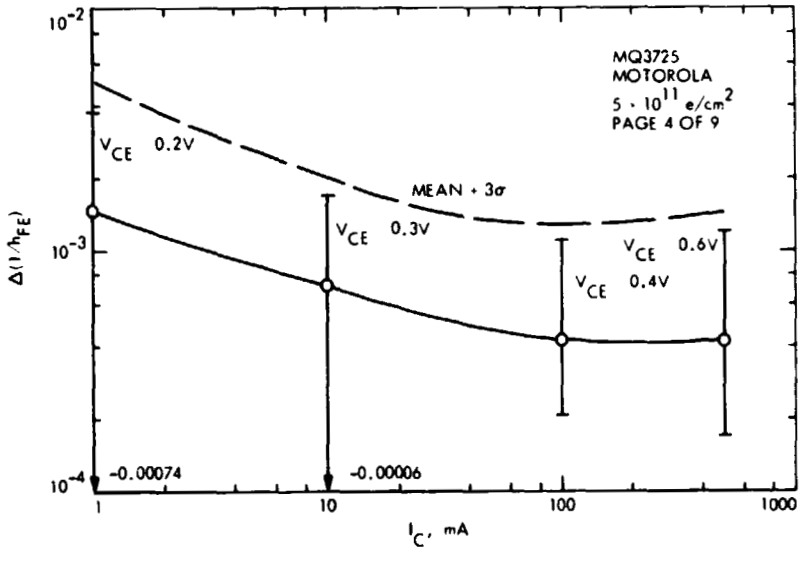
DEVICE TYPE: MQ3725 MOTOROLA PAGE 2 of 9

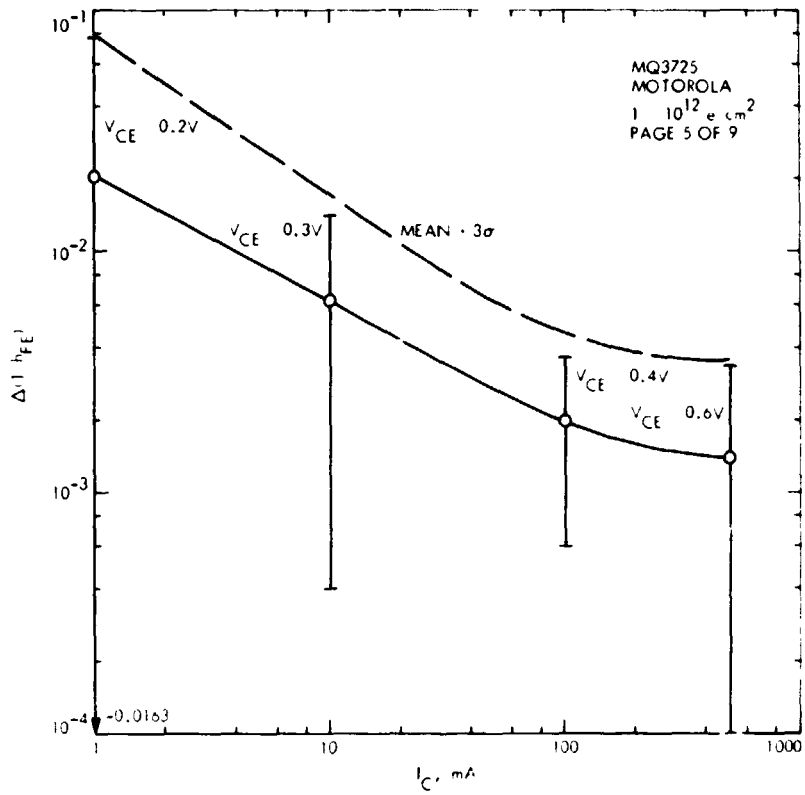
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹¹	Ic=40V, Ve=Vb=GND	Ic=500mA, Vce=0.6V	24	0.00042	0.0012	0.00017	0.0011	0.0014	
	1×10¹²			68	0.0014	0.0034	0.0001	0.0029	0.0036	
	1.25×10¹²			24	0.00078	0.0023	0.00033	0.0021	0.0028	
	2.5×10¹²			92	0.0024	0.0051	0.00058	0.0049	0.0062	
	5×10¹²	Ic=30V, Ve=Vb=GND	Ic=500mA, Vce=0.5V	16	0.0023	0.0036	0.0018	0.0034	0.0040	
		Ic=40V, Ve=Vb=GND	Ic=500mA, Vce=0.6V	24	0.0018	0.0045	0.00098	0.0042	0.0054	
	1×10¹³	Ic=30V, Ve=Vb=GND	Ic=500mA, Vce=0.5V	16	0.0038	0.0058	0.0029	0.0056	0.0066	
								±2σ	±3σ	
ΔVce(sat) (V)	5×10¹²	Ic=30V, Ve=Vb=GND	Ic=100mA, Ib=10mA	16	0.0038	0.0050	0.0020	0.0055	0.0063	
								0.0021	0.0013	
	1×10¹³			16	0.0054	0.0080	0.0040	0.0075	0.0085	
								0.0034	0.0024	
ΔVce(sat) (V)	5×10¹²		Ic=500mA, Ib=50mA	16	0.0118	0.0170	0.0060	0.0191	0.0228	
								0.0045	0.0085	
	1×10¹³			16	0.0134	0.0190	0.0070	0.0210	0.0248	
								0.0058	0.0019	
ΔVbe(sat) (V)	5×10¹²		Ic=100mA, Ib=10mA	16	0.0011	0	0.0040	0.0012	0.0023	
								0.0033	0.0044	
	1×10¹³			16	0.00116	0.0010	0.0050	0.0019	0.0027	
								0.00046	0.00061	

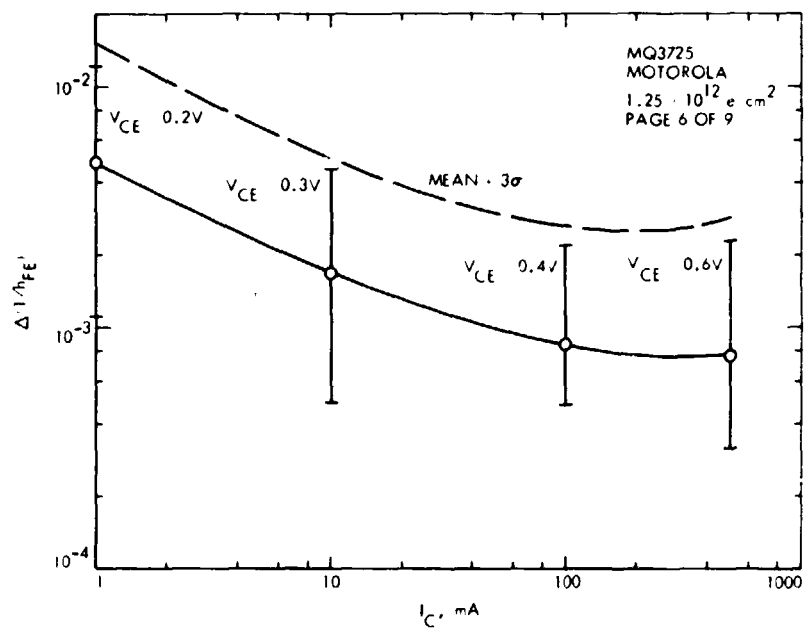
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

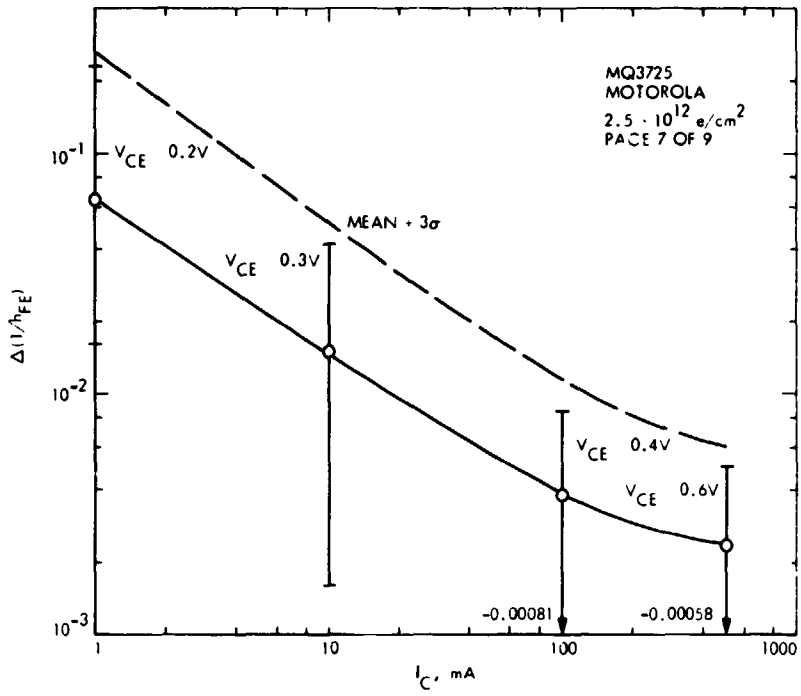
DEVICE TYPE: MQ3725 MOTOROLA PAGE 3 of 9

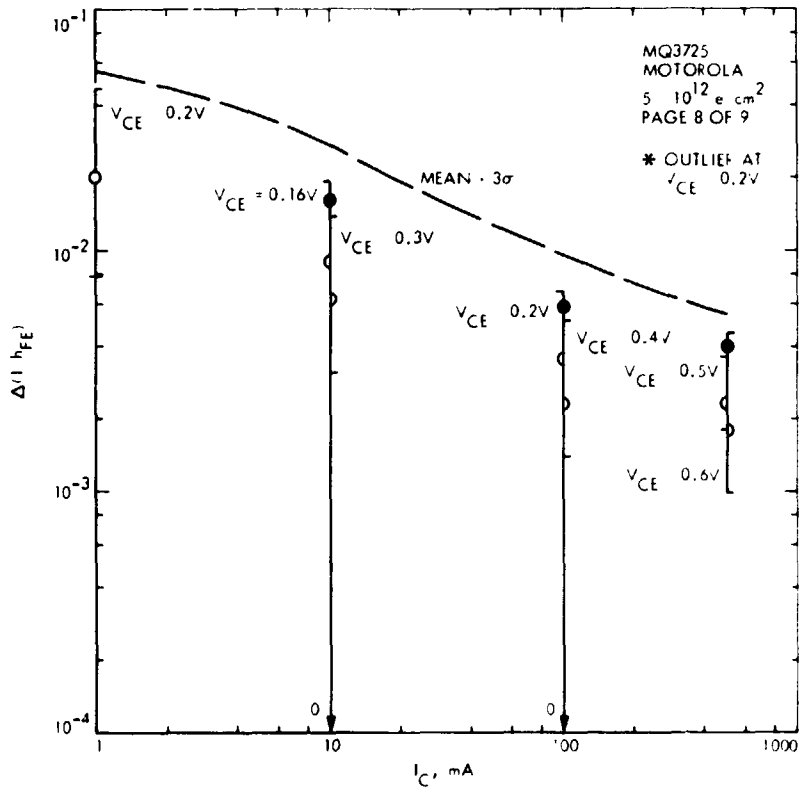
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔVBE (SAT)	5×10¹²	VC: 30V, VE VB GND	IC: 500mA, IB: 50mA	16	0.0044	0.0080	0	0.0087	0.0111	
(V)	↓							0	-0.0022	
↓	1×10¹³	↓	↓	16	0.0042	0.0080	-0.0010	0.0092	0.0116	
↓	↓							-0.00078	0.0033	
								+2σ	+3σ	
ICBO (nA)	5×10¹²		VCB = 30V	16	235	360	190	359	421	
↓	1×10¹³	↓	↓	16	311	525	210	533	643	

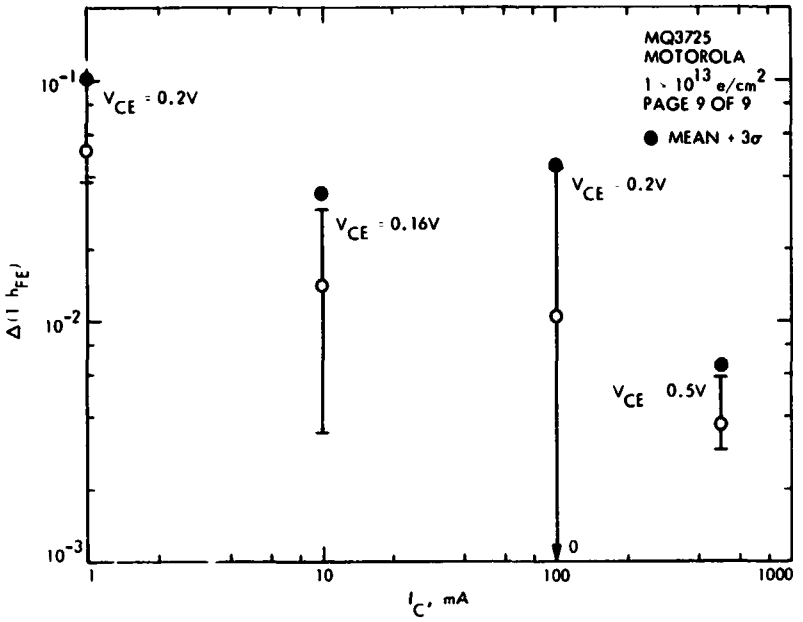



MQ3725
MOTOROLA
1 10^12 e cm^2
PAGE 5 OF 9
V_CE 0.2V
V_CE 0.3V
MEAN · 3σ
V_CE 0.4V
V_CE 0.6V
-0.0163
Δ(1/h_FE)
I_C, mA


MQ3725
MOTOROLA
1.25 · 10^12 e cm^2
PAGE 6 OF 9
V_CE 0.2V
V_CE 0.3V
MEAN · 3σ
V_CE 0.4V
V_CE 0.6V
Δ(1/h_FE)
I_C, mA


MQ3725
MOTOROLA
2.5 · 10^12 e/cm^2
PAGE 7 OF 9
MEAN + 3σ
VCE 0.2V
VCE 0.3V
VCE 0.4V
VCE 0.6V
-0.00081
-0.00058
Δ(1/hFE)
IC, mA


MQ3725
MOTOROLA
5 10^12 e cm^2
PAGE 8 OF 9
* OUTLIER AT
VCE 0.2V
MEAN · 3σ
VCE 0.2V
VCE = 0.16V
VCE 0.3V
VCE 0.2V
VCE 0.4V
VCE 0.5V
VCE 0.6V
0
0
Δ(1 hFE)
IC, mA



PA7443, Raytheon

DEVICE TYPE: PA7443 RAYTHEON PAGE 10 of 9 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VCE:0.5V; IC:0.5mA	IC:0.5mA; VCE:0.1V	80	0.0140	0.0226	0.0005	0.0215	0.0252	
↓	↓			81*	0.0141	0.0272	0.0005	0.0231	0.0261	
	1×10¹³			80	0.0207	0.0312	0.0114	0.0299	0.0346	
↓	↓	↓	↓	81*	0.0210	0.0366	0.0114	0.0306	0.0354	
Δ(1/hFE)	5×10¹¹	VCE:30V; VCE:VBE:0.1V	IC:1mA; VCE:0.2V	20	0.00338	0.00369	0.00285	0.00385	0.00459	
↓	1×10¹²			72	0.00387	0.0062	0.0013	0.00608	0.00719	
	1.25×10¹²			20	0.00441	0.00633	0.00178	0.00684	0.00816	
	2.5×10¹²			92	0.0073	0.0122	0.00304	0.0114	0.0134	
	5×10¹²			20	0.0087	0.0117	0.0050	0.0121	0.0138	
↓	1×10¹³	↓	↓	20	0.0133	0.0159	0.0112	0.0154	0.0165	
Δ(1/hFE)	5×10¹²	VCE:0.5V; IC:0.5mA	IC:5mA; VCE:0.16V	80	0.0073	0.0133	0.0002	0.0120	0.0141	
↓	↓			81*	0.0074	0.0150	0.0002	0.0124	0.0149	
	1×10¹³			80	0.0099	0.0159	0.0019	0.0150	0.0176	
↓	↓	↓	↓	81*	0.0100	0.0183	0.0019	0.0154	0.0182	
Δ(1/hFE)	5×10¹¹	VCE:30V; VCE:VBE:0.1V	IC:10mA; VCE:0.3V	20	0	0.0010	-0.00078	0.00085	0.0013	
↓	1×10¹²			72	0.00125	0.0026	0.0007	0.0028	0.0033	
	1.25×10¹²			20	0.00092	0.00217	0.00033	0.0021	0.0027	
	2.5×10¹²			92	0.00285	0.0057	0.00027	0.0051	0.00635	
↓	5×10¹²	↓	↓	20	0.00259	0.0042	0.0011	0.0040	0.0047	

* OUTLIER INCLUDED

DEVICE TYPE: PA7413 RAYTHEON PAGE 2 of 9

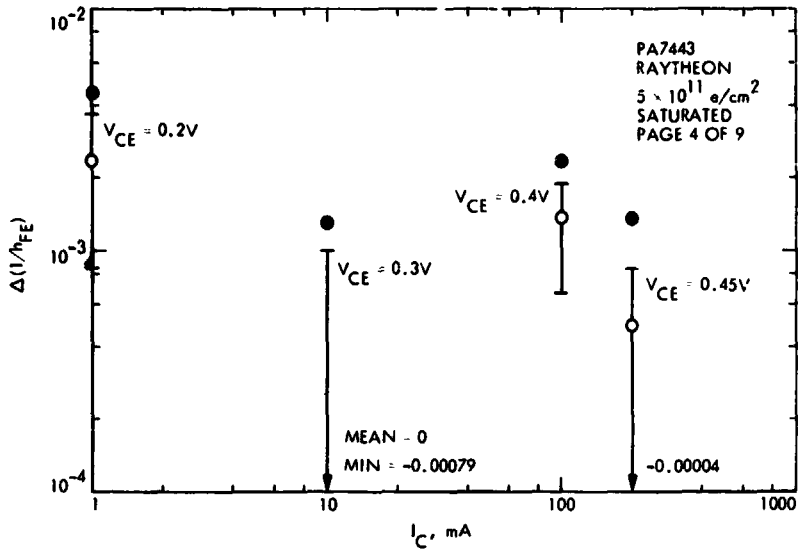
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VCE 0.5V, IC 0.5mA	IC:50mA; VCE=0.5V	80	0.0026	0.0052	0.0002	0.0046	0.0066	
	↓			81*	0.0038	0.0146	0.0002	0.0061	0.0077	
	1×10¹³			79	0.0033	0.0053	0.0014	0.0051	0.0060	
↓	↓	↓	↓	81*	0.0034	0.0080	0.0014	0.0056	0.0066	
Δ(1/hFE)	5×10¹¹	VC:30V, VE VB GND	IC:100mA; VCE=0.5V	20	0.0014	0.0019	0.0006	0.0023	0.0026	
	1×10¹²			72	0.0010	0.0021	0.0006	0.0037	0.0051	
	1.25×10¹²			20	0.0020	0.0025	0.0007	0.0029	0.0033	
	2.5×10¹²			91	0.0022	0.0051	0.0031	0.0044	0.0056	
	↓			92*	0.0022	0.0058	0.0031	0.0045	0.0056	
↓	5×10¹²	↓	↓	20	0.0030	0.0038	0.0019	0.0041	0.0046	
Δ(1/hFE)	5×10¹²	VCE 0.5V, IC:0.5mA	IC:170mA; VCE=0.5V	81	0.0030	0.0060	0.0004	0.0062	0.0078	
	1×10¹³			80	0.0036	0.0066	0	0.0063	0.0077	
↓	↓	↓	↓	81*	0.0036	0.0080	0	0.0065	0.0080	
Δ(1/hFE)	5×10¹¹	VC:30V, VE VB GND	IC:200mA; VCE=0.5V	20	0.0005	0.0038	0.0004	0.0011	0.0014	
	1×10¹²			72	0.0058	0.0143	0.0103	0.0063	0.0078	
	1.25×10¹²			20	0.0012	0.0016	0.0030	0.0027	0.0025	
	2.5×10¹²			90	0.0035	0.0135	0.0054	0.0103	0.0137	
	↓			92*	0.0039	0.0133	0.0054	0.0124	0.0167	
↓	5×10¹²	↓	↓	20	0.0023	0.0035	0.0014	0.0038	0.0046	

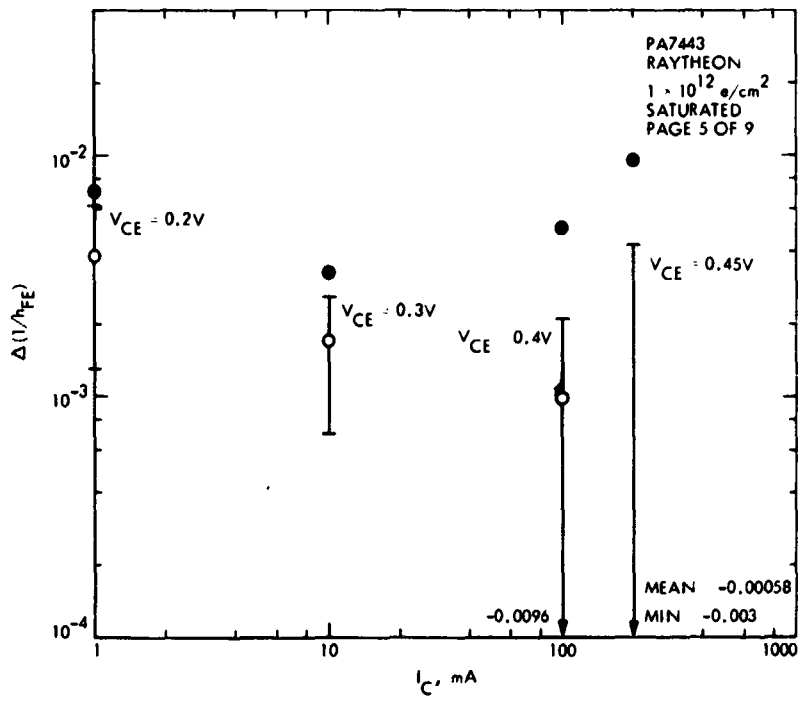
*OUTLIER INCLUDED

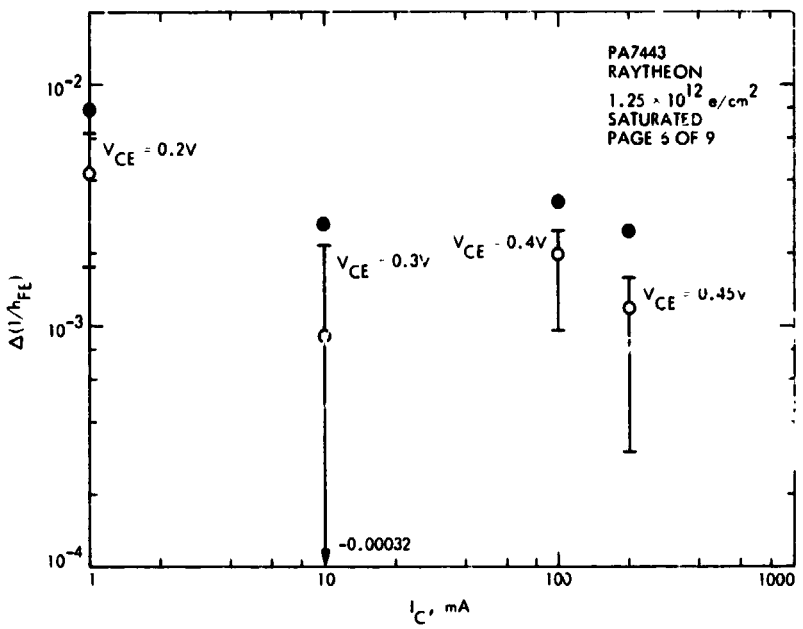
DEVICE TYPE: PA7413 RAYTHEON PAGE 3 of 9

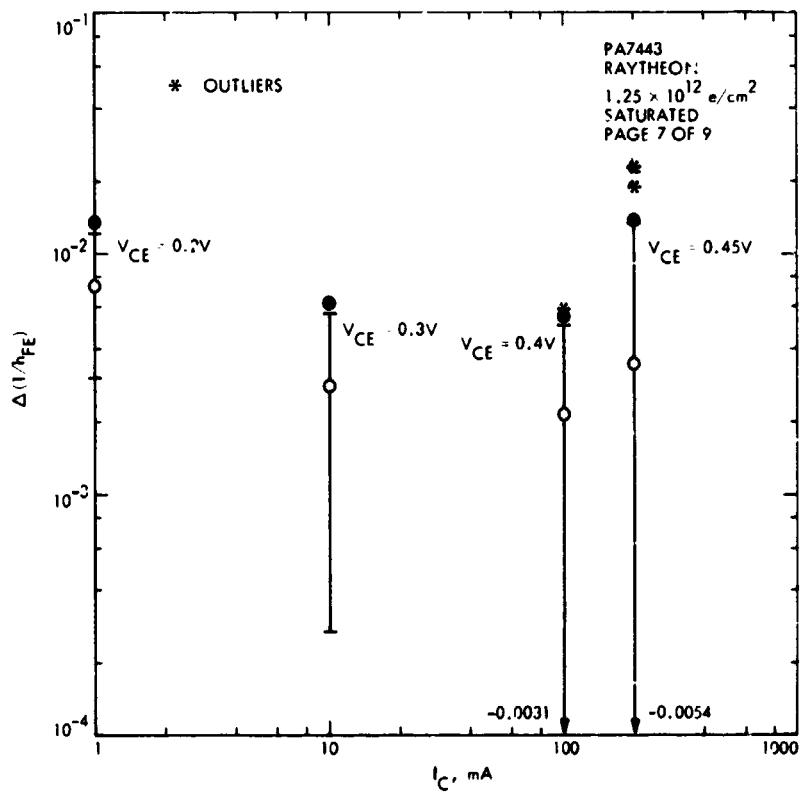
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VCE=0.5V,	IC=0.25mA; VCE=0.5V	80	0.0117	0.0192	0.0010	0.0174	0.0203	
	↓	IC=0.5mA		81*	0.0119	0.0223	0.0010	0.0180	0.0210	
	1×10¹³			80	0.0172	0.0265	0.0100	0.0241	0.0276	
↓	↓	↓	↓	81*	0.0174	0.0324	0.0100	0.0250	0.0289	

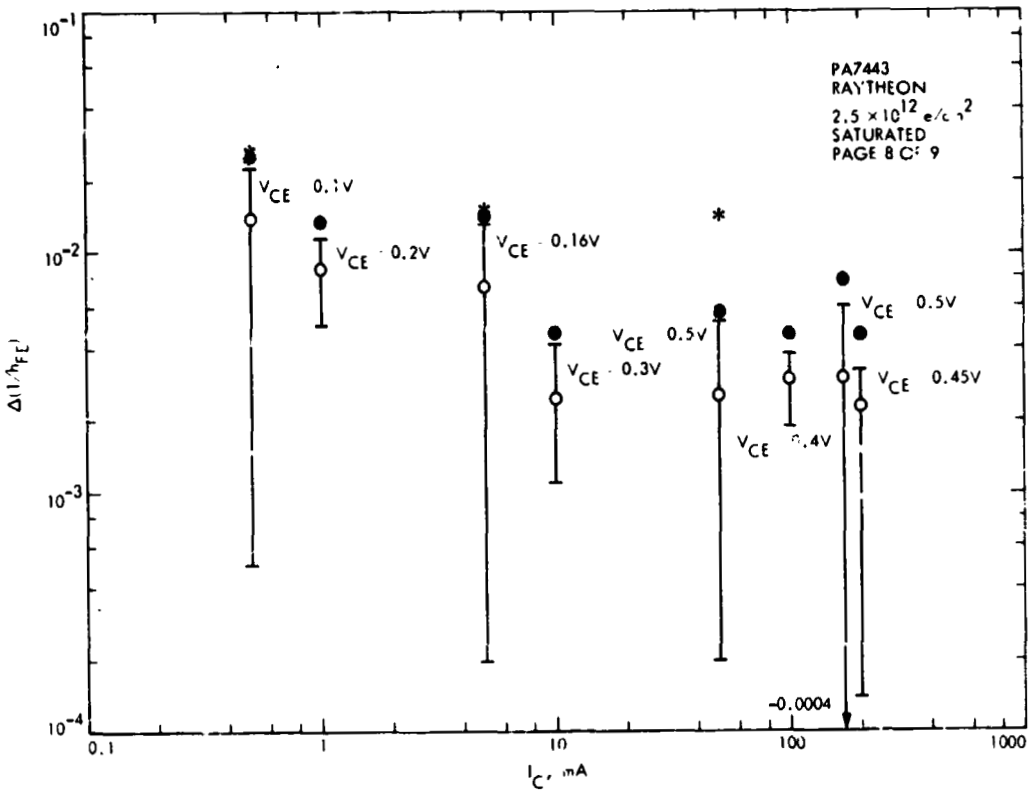
* OUTLIER INCLUDED

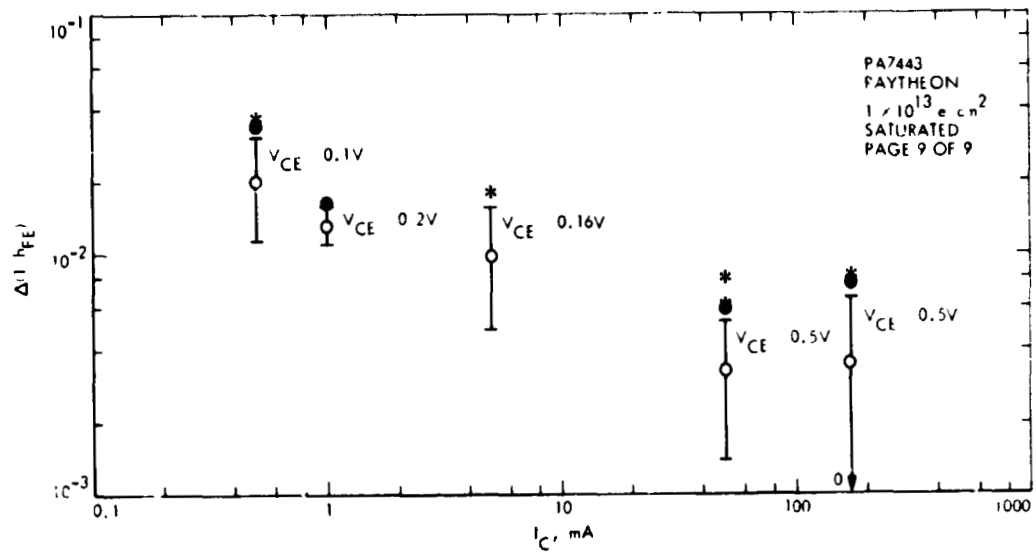

PA7443
RAYTHEON
5 × 10^11 e/cm^2
SATURATED
PAGE 4 OF 9
V_CE = 0.2V
V_CE = 0.3V
V_CE = 0.4V
V_CE = 0.45V
MEAN - 0
MIN = -0.00079
-0.00004
Δ(1/h_FE)
10^-2
10^-3
10^-4
1
10
100
1000
I_C, mA


PA7443
RAYTHEON
1 × 10^12 e/cm^2
SATURATED
PAGE 5 OF 9
V_CE = 0.2V
V_CE = 0.3V
V_CE 0.4V
V_CE = 0.45V
MEAN -0.00058
MIN -0.003
-0.0096
Δ(1/h_FE)
10^-2
10^-3
10^-4
1
10
100
1000
I_C, mA


PA7443
RAYTHEON
1.25 × 10^12 e/cm^2
SATURATED
PAGE 5 OF 9
V_CE = 0.2V
V_CE = 0.3V
V_CE = 0.4V
V_CE = 0.45V
-0.00032
Δ(1/h_FE)
I_C, mA


* OUTLIERS
PA7443
RAYTHEON
1.25 × 10^12 e/cm^2
SATURATED
PAGE 7 OF 9
V_CE = 0.2V
V_CE = 0.3V
V_CE = 0.4V
V_CE = 0.45V
-0.0031
-0.0054
Δ(1/h_FE)
I_C, mA

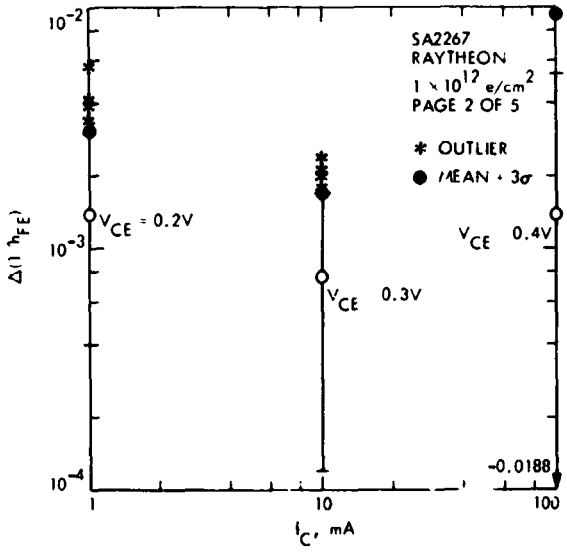

PA7443
RAYTHEON
2.5 × 10^12 e/cm^2
SATURATED
PAGE 8 OF 9
VCE 0.1V
VCE 0.2V
VCE 0.16V
VCE 0.3V
VCE 0.5V
VCE 0.4V
VCE 0.5V
VCE 0.45V
-0.0004
Δ(1/hFE)
IC, mA

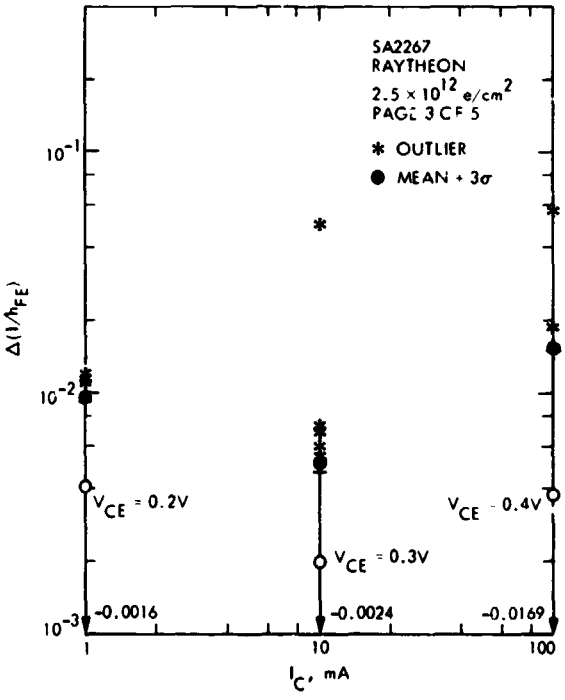

PA7443
RAYTHEON
1 × 10^13 e/cm^2
SATURATED
PAGE 9 OF 9
VCE 0.1V
VCE 0.2V
VCE 0.16V
VCE 0.5V
VCE 0.5V
0
Δ(1/hFE)
IC, mA

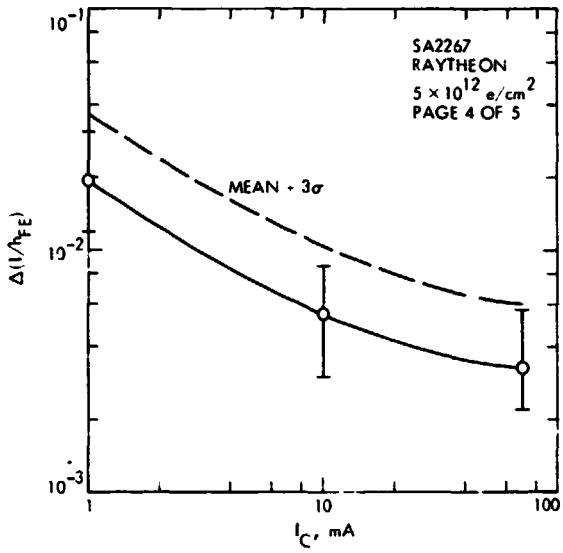
SA2267, Raytheon

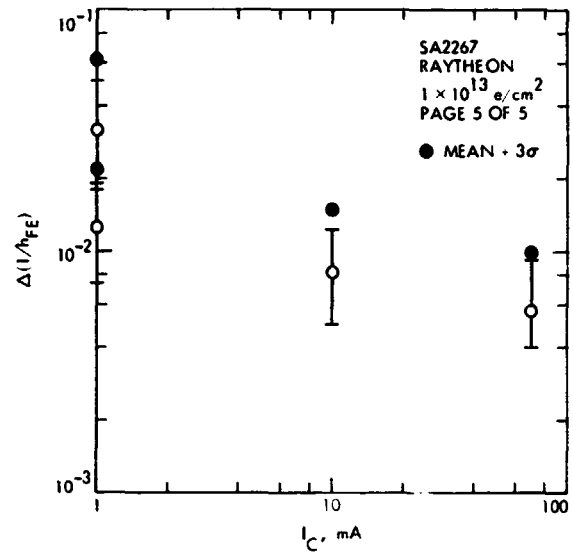
DEVICE TYPE: SA 2267 RAYTHEON PAGE 1 of 5 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
Δ(1/hFE)	1×10¹²	Vce .3V, Ic 0	Ic=1mA, Vce 0.2V	119	0.0014	0.0030	0.0004	0.0025	0.0031	
↓	↓		↓	124*	0.0015	0.0057	0.0004	0.0031	0.0039	
	2.5×10¹²			119	0.0041	0.0092	0.0016	0.0078	0.0096	
	↓		↓	124*	0.0044	0.0121	0.0016	0.0080	0.0113	
	5×10¹²		Ic 1mA, Vce 0.1V	24	0.0199	0.0310	0.0120	0.0314	0.0371	
	1×10¹³		↓	24	0.0323	0.0510	0.0190	0.0526	0.0607	
↓			Ic=1mA, Vce 0.2V	20	0.0125	0.0181	0.0074	0.0189	0.0220	
Δ(1/hFE)	1×10¹²		Ic=10mA, Vce=0.3V	119	0.00077	0.0017	0.00012	0.0014	0.0017	
↓	↓		↓	123*	0.00083	0.0024	0.0003	0.0016	0.0020	
	2.5×10¹²			119	0.0020	0.0047	0.0024	0.0041	0.0052	
	↓		↓	124*	0.0026	0.0509	0.0024	0.0117	0.0163	
	5×10¹²		Ic 10mA, Vce 0.2V	24	0.0055	0.0087	0.0030	0.0088	0.0105	
↓	1×10¹³		↓	24	0.0082	0.0124	0.0050	0.0127	0.0150	
Δ(1/hFE)	5×10¹²		Ic 10mA, Vce 0.3V	24	0.0033	0.0057	0.0022	0.0051	0.0060	
↓	1×10¹³		↓	24	0.0057	0.0082	0.0040	0.0084	0.0098	
Δ(1/hFE)	1×10¹²		Ic 1mA, Vce 0.4V	123	0.0044	0.0053	-0.0188	0.0068	0.0095	
↓	2.5×10¹²			121	0.0038	0.0051	-0.0169	0.0116	0.0154	
↓	↓	↓	↓	123*	0.0044	0.0580	-0.0169	0.0121	0.0235	
* OUTLIERS	INCLUDED									





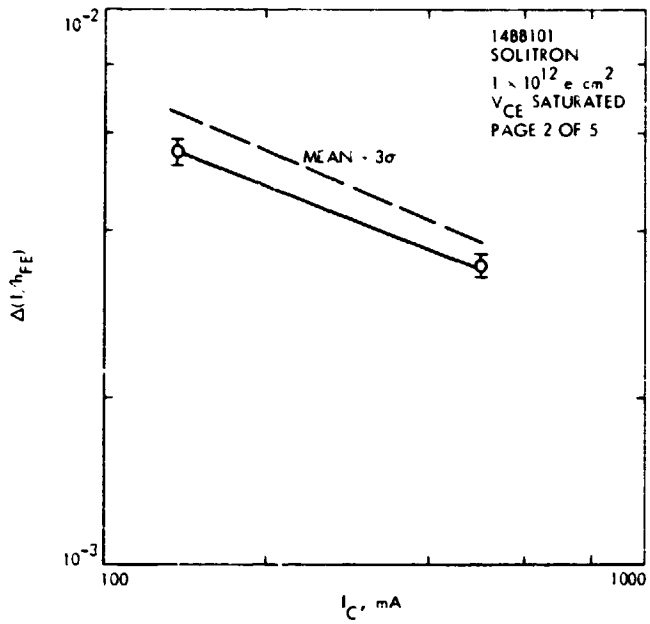


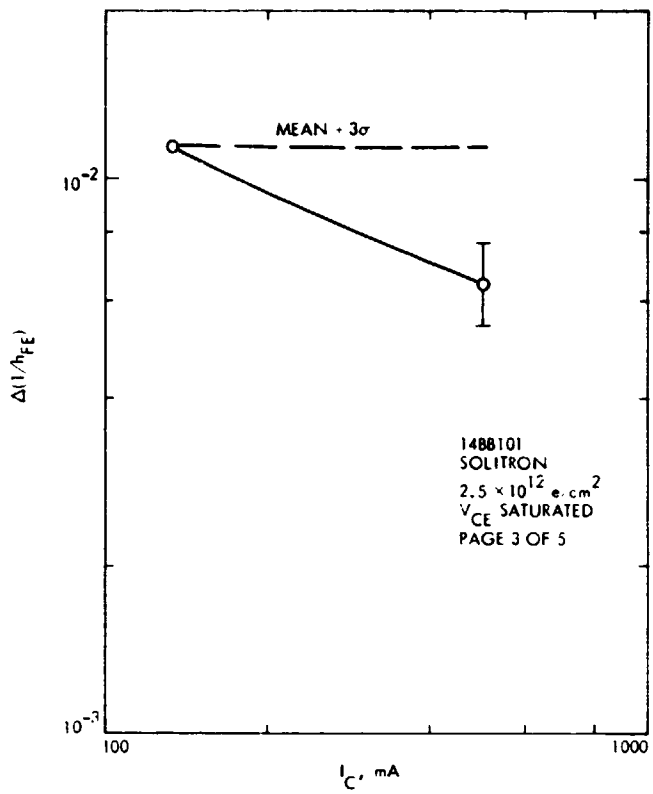


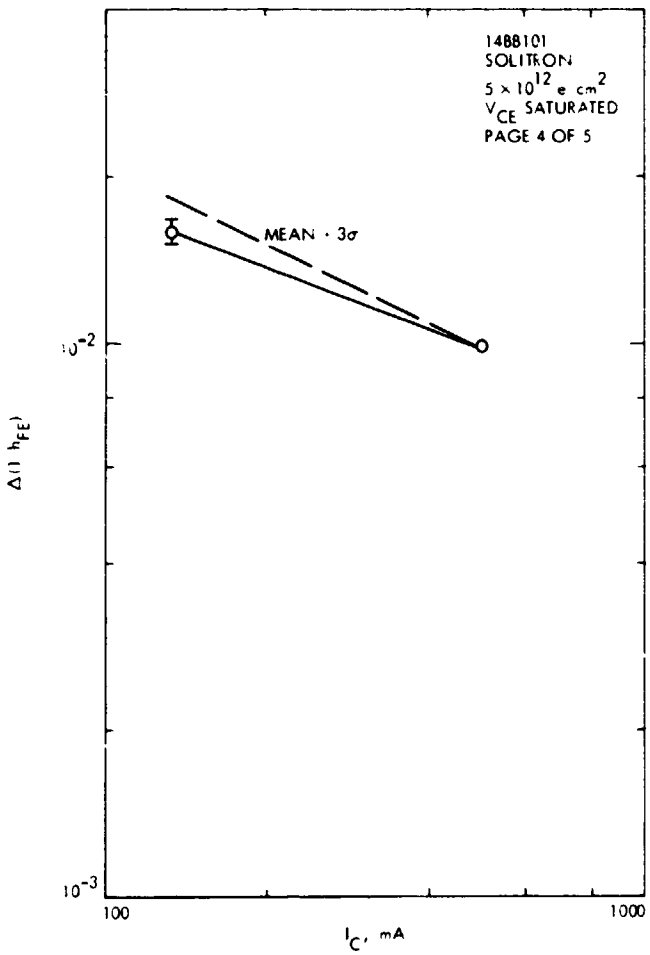
14BB101, Solitron

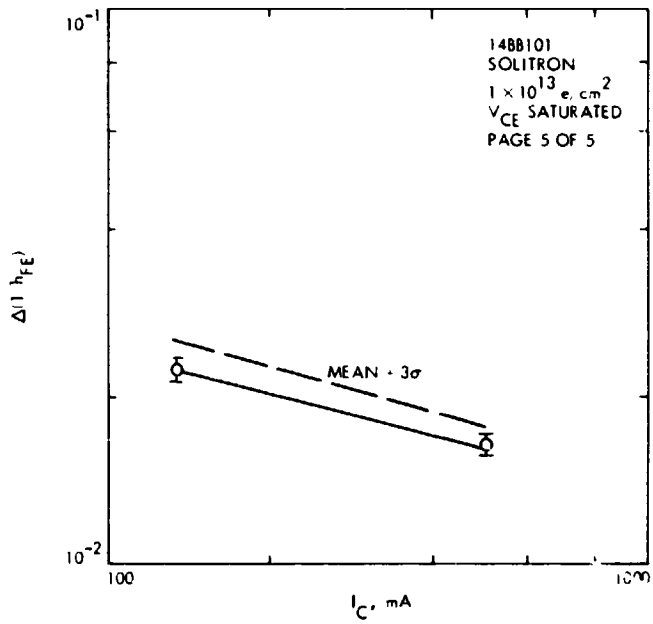
DEVICE TYPE: 14BB101 SOLITRON PAGE 1 of 5 3

Parameter	ℓ/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/h_FE)	1×10^12	BIAS: IRRAD	BIAS: MEAS	2	0.0056	0.0058	0.0054	0.00617	0.00695	
		VCE = 0.1V	VCE = 0.1V							
	2.5×10^12	IC = 133mA	IC = 133mA	2	0.0115	0.015	0.0115	0.0115	0.0115	
	5×10^12			2	0.0159	0.0165	0.0154	0.0175	0.0183	
	1×10^13			2	0.0227	0.0231	0.0223	0.0238	0.0244	
Δ(1/h_FE)	1×10^12	VCE = 0.1V	VCE = 0.1V	2	0.0035	0.0036	0.0034	0.00378	0.00392	
		IC = 133mA	IC = 500mA							
	2.5×10^12			2	0.00655	0.0077	0.0054	0.0098	0.0114	
	5×10^12			2	0.0101	0.0101	0.01	0.0102	0.0103	
	1×10^13			2	0.0167	0.0168	0.0165	0.0171	0.0173	
Δ(1/h_FE)	1×10^12	VCE = 0.1V	VCE = 75V	2	0.0024	0.002	0.0028	0.00353	0.0041	
		IC = 133mA	IC = 375mA							
	2.5×10^12			2	0.0044	0.0045	0.0039	0.00581	0.00652	
	5×10^12			2	0.00635	0.0068	0.0059	0.00762	0.00826	
	1×10^13			2	0.00975	0.0096	0.0085	0.0106	0.0114	


14BB101
SOLITRON
1 × 10^12 e cm^2
V_CE SATURATED
PAGE 2 OF 5
MEAN + 3σ
Δ(1/h_FE)
10^-2
10^-3
100
1000
I_C, mA


MEAN + 3σ
14BB101
SOLITRON
2.5 × 10^12 e.cm^2
V_CE SATURATED
PAGE 3 OF 5
Δ(1/h_FE)
10^-2
10^-3
100
1000
I_C, mA

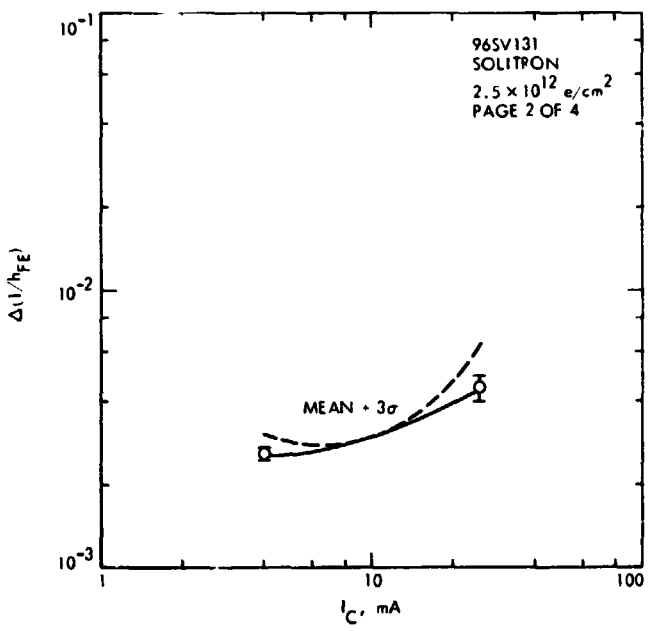

14BB101
SOLITRON
5 × 10^12 e cm^2
V_CE SATURATED
PAGE 4 OF 5
MEAN + 3σ
Δ(1 h_FE)
10^-2
10^-3
100
1000
I_C, mA

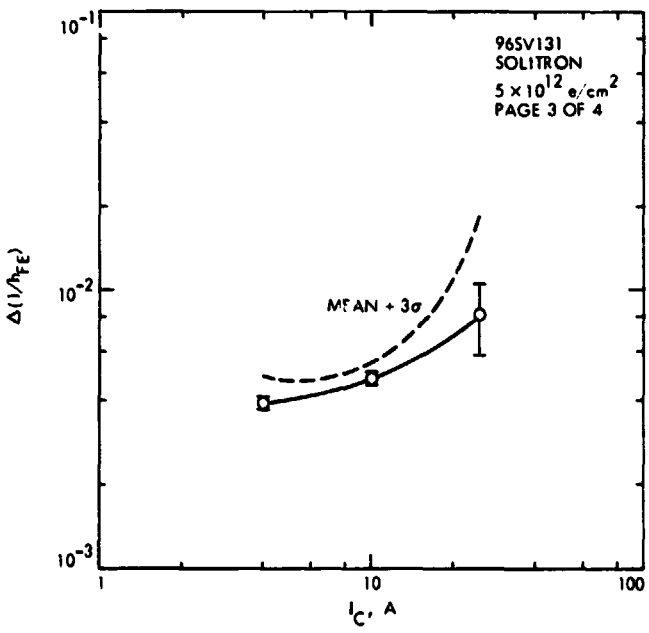

14BB101
SOLITRON
1 × 10^13 e, cm^2
V_CE SATURATED
PAGE 5 OF 5
MEAN + 3σ
Δ(1 h_FE)
10^-1
10^-2
100
I_C, mA

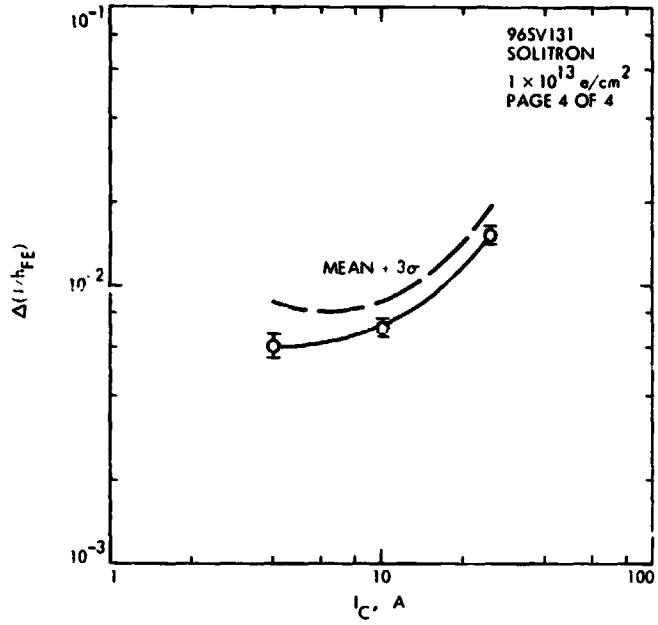
96SV131, Solitron

DEVICE TYPE: 96SV131 SOLITRON PAGE 1 of 4 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +1σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	2.5×10¹²	VCE=20V; VE=0V	VCE=0.5V; IC=4A	2	0.0026	0.0027	0.0025	0.0029	0.0030	
↓	5×10¹²	VB - GND thru	↓	2	0.0039	0.0041	0.0037	0.0045	0.0048	
↓	1×10¹³	4Ω RESISTOR	↓	2	0.0061	0.0067	0.0055	0.0078	0.0087	
Δ(1/hFE)	2.5×10¹²		VCE=0.5V; IC=10A	2	0.0029	0.0029	0.0029	0.0029	0.0029	
↓	5×10¹²		↓	2	0.0048	0.0049	0.0046	0.0052	0.0054	
↓	1×10¹³		↓	2	0.0071	0.0075	0.0067	0.0082	0.0088	
Δ(1/hFE)	2.5×10¹²		VCE=0.5V; IC=25A	2	0.0055	0.0059	0.0050	0.0067	0.0074	
↓	5×10¹²		↓	2	0.0082	0.0105	0.0058	0.0148	0.0181	
↓	1×10¹³		↓	2	0.0153	0.0162	0.0143	0.0179	0.0193	
VCE(SAT)(V)	0		IC=40A; IB=1A (Pulsed)	2	0.163	0.165	0.160			
↓	2.5×10¹²		↓	2	0.172	0.172	0.172	0.172	0.172	
↓	5×10¹²		↓	2	0.177	0.178	0.176	0.180	0.181	
↓	1×10¹³		↓	2	0.185	0.185	0.184	0.186	0.187	
VCE(SAT)(V)	0		IC=10A; IB=1A	2	0.53	0.53	0.53			
↓	2.5×10¹²		↓	2	0.558	0.560	0.555	0.565	0.568	
↓	5×10¹²		↓	2	0.578	0.580	0.575	0.585	0.588	
↓	1×10¹³	↓	↓	2	0.600	0.610	0.600	0.619	0.626	
ICER (nA)	2.5×10¹²	VE=0V, VC=60V;	VCE=60V,	1	8.5	8.5	8.5	8.5	8.5	
	5×10¹²	BASE: GND thru	RBE=4Ω	1	82	82	82	82	82	
	1×10¹³	4Ω RES		1	240	240	240	240	240	







3029-201-1, Raytheon

DEVICE TYPE: 3029-201-1 Raytheon PAGE 1 of 5 3

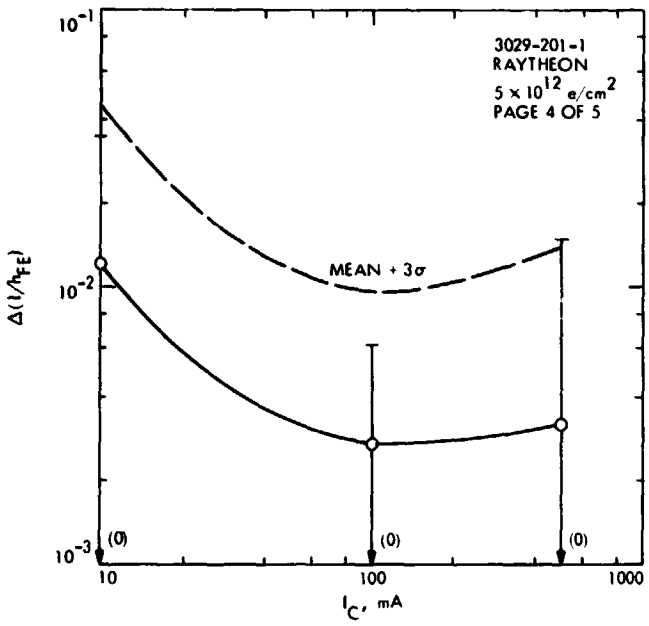
Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ(1/hFE)	5×10^12	BIAS: 1RAD.	BIAS: MEAS.	24	0.0122	0.0342	0	0.355	0.971	
↓		Collector: 30V	IC: 10mA							
↓	1×10^13	Emitter=Base=GND	VCE: 0.1V	24	0.0156	0.0399	0.0012	0.0421	0.0553	
Δ(1/hFE)	5×10^12	Collector=30V	IC=100mA	24	0.00228	0.00662	0	0.00712	0.00928	
		Emitter: GND	VCE: 0.18V							
↓	1×10^13	Base: GND		24	0.00378	0.0088	0.00006	0.00985	0.0129	
Δ(1/hFE)	5×10^12	Collector=30V	IC: 500mA	24	0.00318	0.0198	0	0.0106	0.0143	
↓		Emitter = GND	VCE: 0.5V							
↓	1×10^13	BASE: GND		24	0.00335	0.0198	0	0.0115	0.0153	
VCE(sat) (V)	0	Collector=30V	IC= 100mA	24	0.115	0.127	0.1			
		Emitter= GND	IB= 10mA							
↓	5×10^12	BASE: GND	↓	24	0.117	0.127	0.101	0.132	0.14	
↓	1×10^13	↓	↓	24	0.117	0.127	0.101	0.133	0.142	

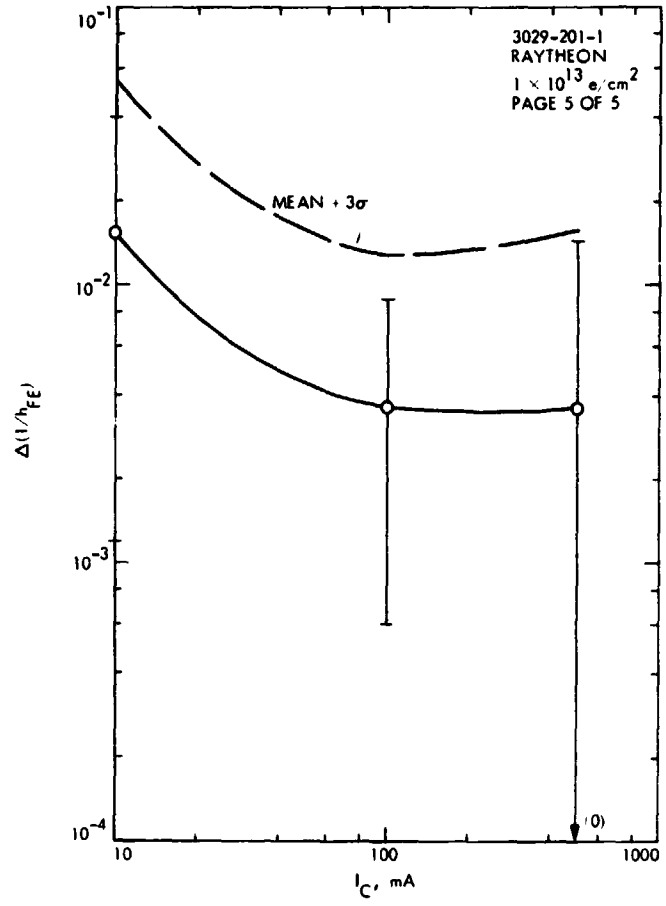
DEVICE TYPE: 3029-201-1 RAYTHEON PAGE 2 of 5 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
VCE(sat) (V)	0	BIAS: IRRAD.	BIAS: MEAS.	24	0.34	0.412	0.301			
		Collector: 30V	IC: 500mA							
	5×10¹²	Emitter - GND	IB: 50 mA	24	0.347	0.372	0.314	0.376	0.39	
		BASE: GND								
↓	1×10¹³		↓	24	0.398	0.373	0.315	0.378	0.393	
VBE(sat) (V)	0	Collector: 30V	IC: 100 mA	24	0.669	0.679	0.659			
		Emitter: GND	IB: 10mA							
	5×10¹²	BASE: GND		24	0.667	0.676	0.652	0.679	0.685	
↓	1×10¹³	↓	↓	24	0.666	0.674	0.656	0.675	0.68	
VBE(sat) (V)	0	Collector: 30V	IC: 500mA	24	0.731	0.742	0.72			
		Emitter: GND	IB: 50mA							
	5×10¹²	BASE - GND		24	0.732	0.733	0.719	0.75	0.763	
↓	1×10¹³	↓	↓	24	0.729	0.739	0.721	0.74	0.743	

DEVICE TYPE: 3029-201-1 Raytheon PAGE 3 of 5 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
ICBO		BIAS: IRRAD.	BIAS: MEAS.							
		Collector: 30V	VCB: 30V							
	5×10¹²	Emitter: GND		4 *	0.91μA	1.2μA	0.72μA	1.38μA	1.61μA	
		BASE: GND								
↓	1×10¹³		↓	4*	3.3μA	4.6μA	3.2μA	5μA	5.64μA	
* High Population.										
ICBO		Collector: 30V	VCB: 30V							
		Emitter: GND								
	5×10¹²	BASE: GND		8**	1.49nA	1.8nA	1.3nA	1.8nA	1.95nA	
↓	1×10¹³	↓	↓	8**	2.36nA	3nA	2nA	3nA	3.35nA	
** Low Population.										
ICBO		Collector: 30V	VCB: 30V							
		Emitter GND								
	5×10¹²	BASE: GND		12 ⊗	304nA	1200nA	1.3nA	1230nA	1700nA	
↓	1×10¹³	↓	↓	12 ⊗	1290nA	4600nA	2nA	4970nA	6830nA	
⊗ Both populations combined.										

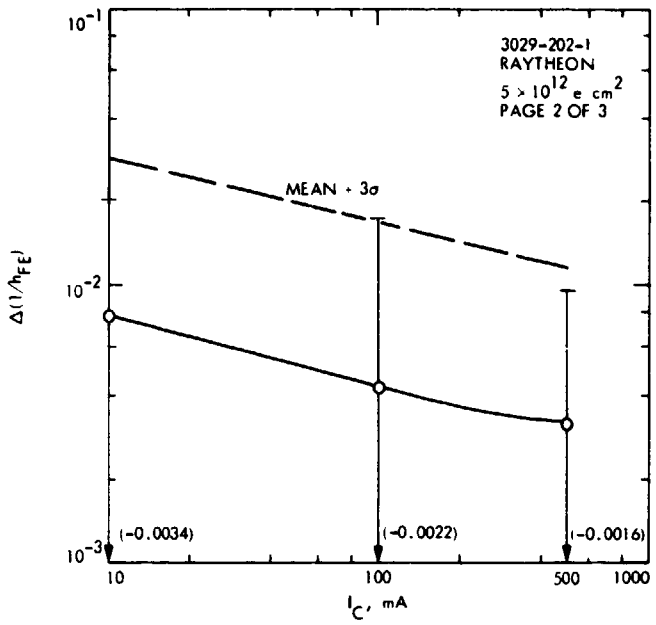


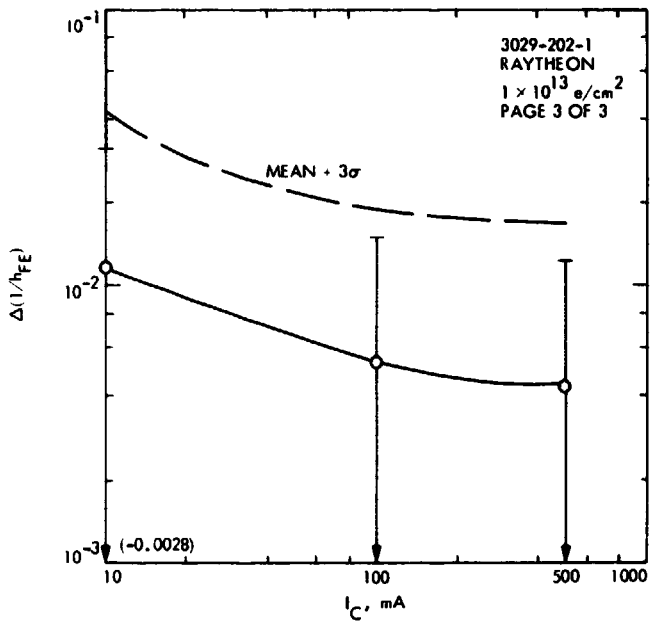


3029-202-1, Raytheon

DEVICE TYPE: 3029-202-1 RAYTHEON PAGE 1 of 3 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^12	VCE=30V, IC=IB=0	VCE=0.16V; IC=10mA	24	0.0028	0.0205	-0.0034	0.0222	0.0294	
↓	1×10^13		↓	24	0.0118	0.0316	-0.0028	0.0332	0.0438	
Δ(1/hFE)	5×10^12		VCE=0.2V; IC=100mA	24	0.0043	0.0179	-0.0022	0.0126	0.0168	
↓	1×10^13		↓	24	0.0053	0.0151	-0.0037	0.0147	0.0194	
Δ(1/hFE)	5×10^12		VCE=0.5V; IC=500mA	24	0.0032	0.0096	-0.0016	0.0080	0.0119	
↓	1×10^13		↓	24	0.0044	0.0123	-0.002	0.0128	0.0170	
VCE(SAT)(V)	5×10^12		IC=100mA, IB=10mA	24	0.133	0.150	0.118	0.147	0.153	
↓	1×10^13		↓	24	0.136	0.153	0.125	0.151	0.158	
VCE(SAT)(V)	5×10^12			24	0.1601	0.1667	0.1658	0.1666	0.1669	
↓	1×10^13		↓	24	0.1660	0.1667	0.1516	0.1666	0.1669	
VCE(SAT)(V)	5×10^12		IC=500mA, IB=50mA	24	0.304	0.336	0.277	0.335	0.351	
↓	1×10^13		↓	24	0.306	0.339	0.278	0.338	0.355	
VBE(SAT)(V)	5×10^12			24	0.722	0.727	0.718	0.727	0.729	
↓	1×10^13		↓	24	0.721	0.726	0.718	0.726	0.729	
ICEO(nA)	5×10^12		VCE=30V	12	15.7	35	11	28.5	34.9	
	1×10^13	↓		12	27.4	82	13	65.1	84.0	





SDT3303, Solitron

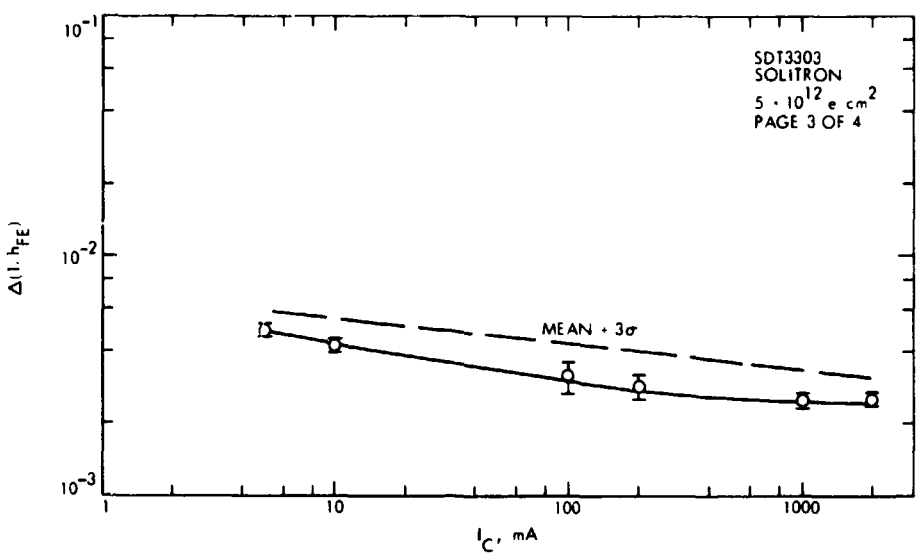
DEVICE TYPE: SDT 3303 SOLITRON PAGE 1 of 4 — 3

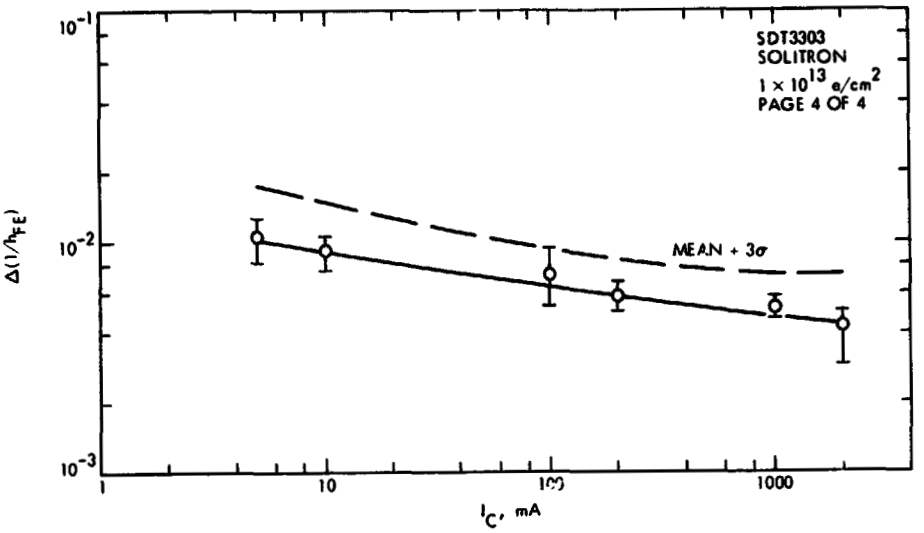
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^12	VC=30V, VE=0	IC=5mA, VCE=2V	3	0.00487	0.0052	0.00416	0.00548	0.00578	
↓	1×10^13	VB=0	↓	3	0.0107	0.0126	0.0082	0.0152	0.0174	
Δ(1/hFE)	5×10^12		IC 10mA, VCE 2V	3	0.00433	0.0045	0.0040	0.00491	0.0052	
↓	1×10^13		↓	3	0.00933	0.0105	0.0075	0.0125	0.0142	
Δ(1/hFE)	5×10^12		IC=100mA, VCE=2V	3	0.0032	0.0036	0.0027	0.00412	0.00452	
↓	1×10^13		↓	3	0.0071	0.0094	0.0053	0.0113	0.0134	
Δ(1/hFE)	5×10^12		IC 300mA, VCE=2V	3	0.00287	0.0032	0.0025	0.00357	0.00392	
↓	1×10^13		↓	3	0.00587	0.0067	0.0050	0.00757	0.0094	
Δ(1/hFE)	5×10^12		IC=1A, VCE=2V	3	0.0025	0.0027	0.0023	0.0029	0.0031	
↓	1×10^13		↓	3	0.0052	0.0058	0.0047	0.0063	0.0069	
Δ(1/hFE)	5×10^12		IC=2A, VCE=5V	3	0.0025	0.0027	0.0024	0.00285	0.00302	
↓	1×10^13		↓	3	0.0043	0.0050	0.0039	0.0067	0.0074	
VCE(sat)	5×10^12		IC=2A, IB=0.2A	3	0.350	0.409	0.267	0.513	0.594	
↓	1×10^13	↓	↓	3	0.397	0.494	0.293	0.598	0.699	

MOS

DEVICE TYPE: SDT 3303 SOLITRON PAGE 2 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
V_{BE} (SAT)	5×10^{12}	V_C=30V; V_E=0	I_C=.2A; I_B=0.2A	3	0.964	0.993	0.936	1.020	1.050	
↓	1×10^{13}	V_B=0	↓	3	0.967	0.992	0.936	1.020	1.050	
I_{CEO} (nA)	5×10^{12}	V_{CE}=30V,	V_{CEO}=30V	3	928	2600	41	3830	5070	
↓	1×10^{13}	BASE OPEN	↓	3	877μA	2050μA	540	3090μA	4470μA	

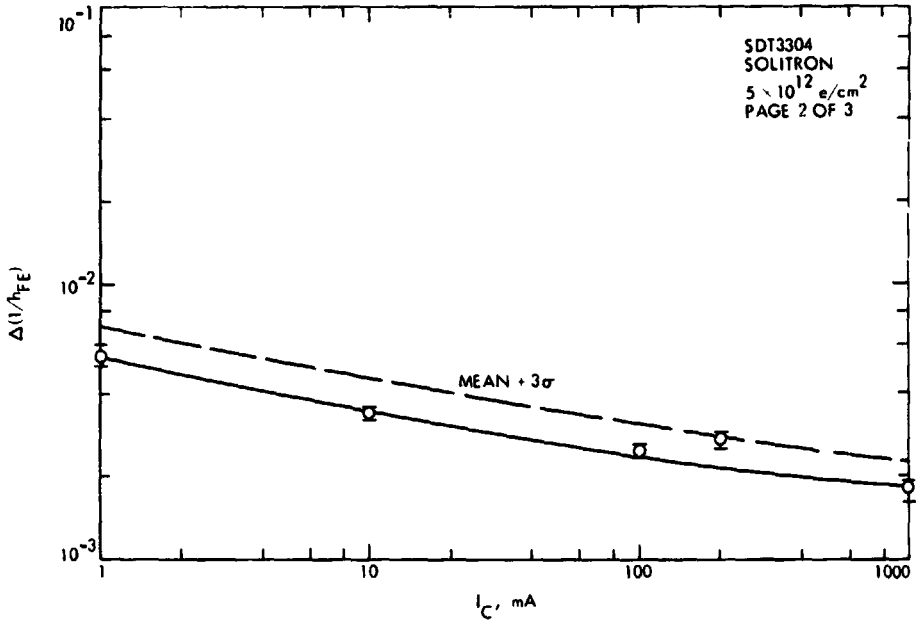


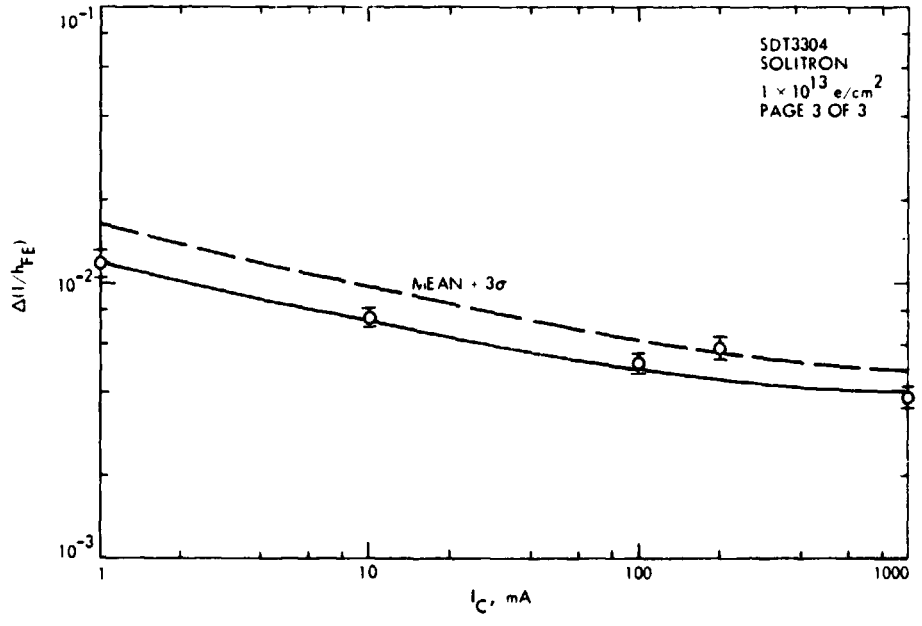


SDT3304, Solitron

DEVICE TYPE: SDT 3304 SOLITRON PAGE 1 of 3 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: 1 RAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10^12	VC = 30V; VE = 0	VCE = 30V; IC = 1mA	3	0.00553	0.0060	0.0050	0.00654	0.00704	
↓	1×10^13	VB = 0	↓	3	0.0121	0.0130	0.0105	0.0150	0.0164	
Δ(1/hFE)	5×10^12		VCE = 30V; IC = 10mA	3	0.00347	0.0036	0.0033	0.00377	0.00392	
↓	1×10^13		↓	3	0.0076	0.0081	0.0070	0.00871	0.00927	
Δ(1/hFE)	5×10^12		VCE = 30V; IC = 100mA	3	0.0025	0.0026	0.0023	0.00285	0.00303	
↓	1×10^13		↓	3	0.00523	0.0055	0.0047	0.00616	0.00662	
Δ(1/hFE)	5×10^12		VCE = 3V; IC = 200mA	3	0.00273	0.0029	0.0025	0.00315	0.00336	
↓	1×10^13		↓	3	0.00587	0.0064	0.0053	0.00687	0.00752	
Δ(1/hFE)	5×10^12		VCE = 30V; IC = 1A	3	0.0018	0.0019	0.0016	0.00215	0.00232	
↓	1×10^13	↓	↓	3	0.00397	0.0042	0.0036	0.00461	0.00493	
ICEO (nA)		VCE = 30V;	VCEO = 30V							
↓	5×10^12	BASE OPEN		3	66	106	34	139	176	
↓	1×10^13	↓	↓	3	3730	7200	1540	9810	12800	
NGS										


SDT3304
SOLITRON
5 × 10^12 e/cm^2
PAGE 2 OF 3
MEAN + 3σ
Δ(1/h_FE)
10^-1
10^-2
10^-3
1
10
100
1000
I_C, mA


SDT3304
SOLITRON
1 × 10^13 e/cm^2
PAGE 3 OF 3
MEAN + 3σ
Δ(1/h_FE)
10^-1
10^-2
10^-3
1
10
100
1000
I_C, mA

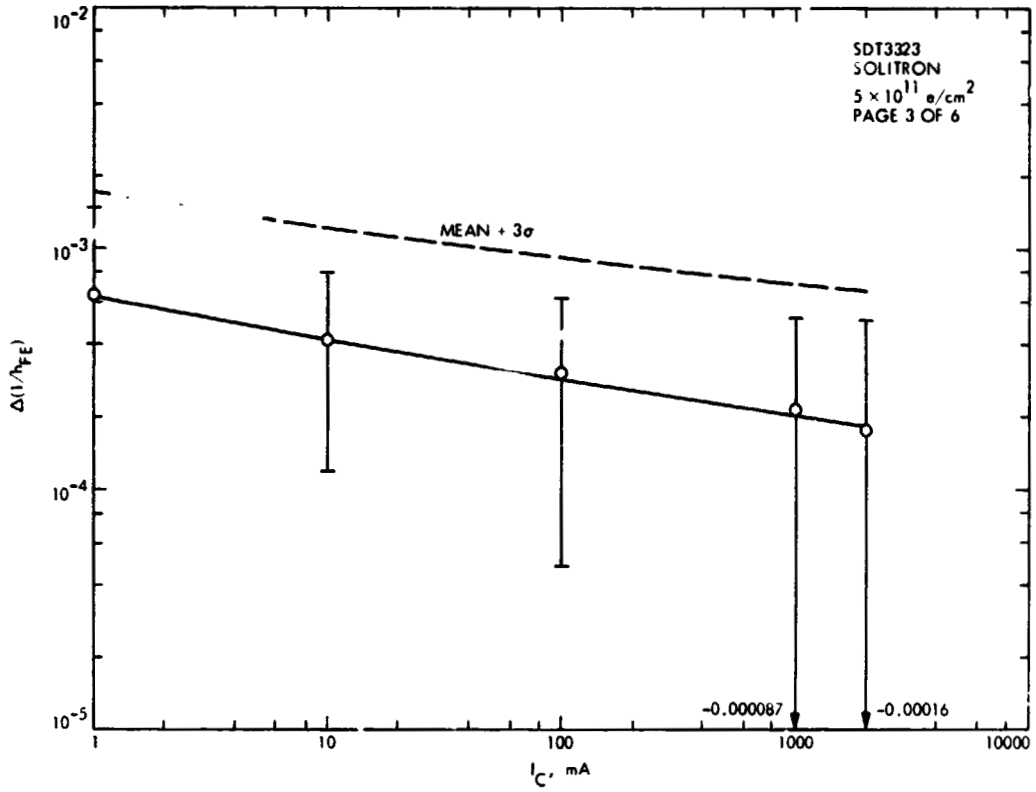
SDT3323, Solitron

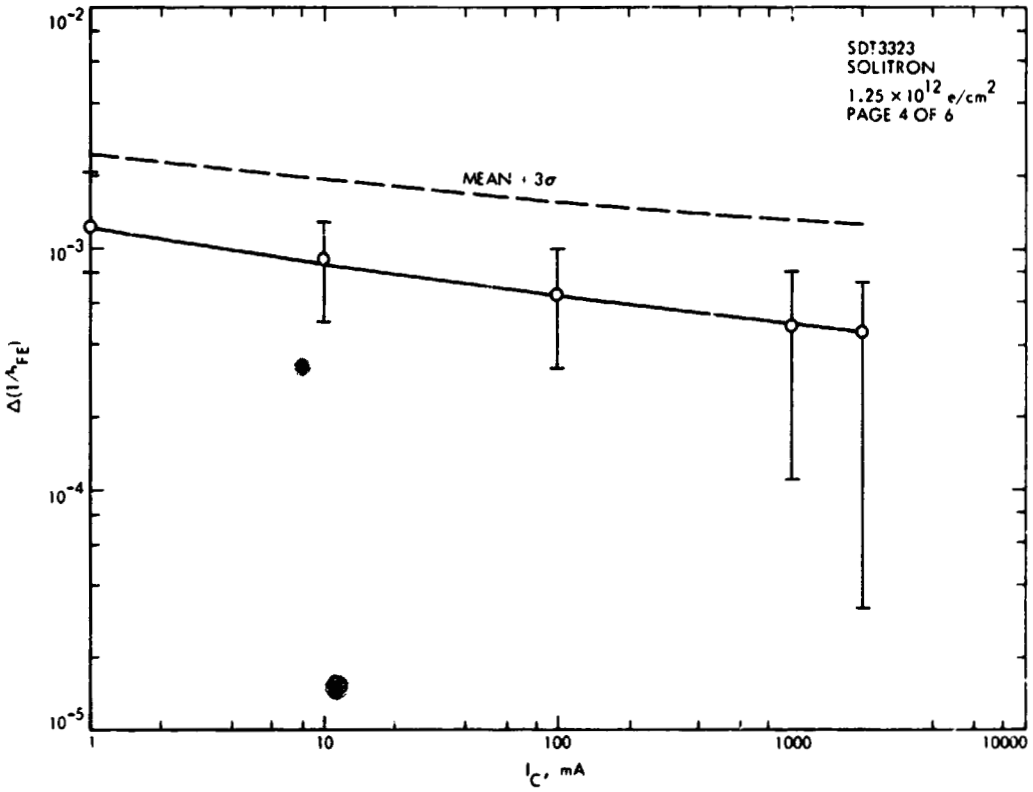
DEVICE TYPE: SDT3323 SOLITRON PAGE 1 of 6 3

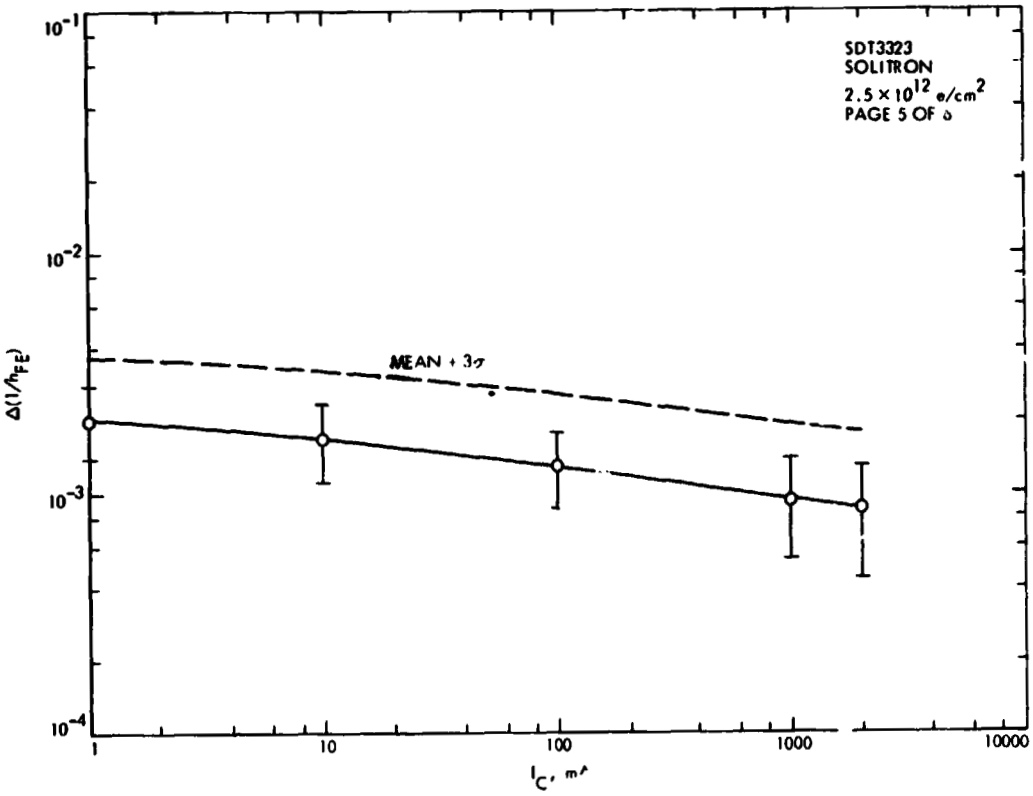
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5x10¹¹	VCE = 30V,	IC = 1mA,	8	0.00065	0.0015	0.0004	0.0014	0.0018	
	1.25x10¹²	BASE = GND	VCE = 5V	8	0.0025	0.0021	0.0008	0.0021	0.0025	
	2.5x10¹²			8	0.0028	0.0028	0.0014	0.0032	0.0037	
	5x10¹²			8	0.0040	0.0054	0.0029	0.0058	0.0067	
Δ(1/hFE)	5x10¹¹		IC = 10mA;	8	0.00043	0.00078	0.00012	0.00053	0.0012	
	1.25x10¹²		VCE = 2V	8	0.00093	0.0013	0.0005	0.0016	0.0020	
	2.5x10¹²			8	0.0017	0.0024	0.0011	0.0027	0.0032	
	5x10¹²			8	0.0032	0.0049	0.0023	0.0049	0.0057	
Δ(1/hFE)	5x10¹¹		IC = 100mA	8	0.00031	0.00063	0.00008	0.00076	0.00099	
	1.25x10¹²		VCE = 2V	8	0.00067	0.0010	0.00032	0.0013	0.0015	
	2.5x10¹²			8	0.0013	0.0018	0.00086	0.0020	0.0024	
	5x10¹²			8	0.0024	0.0033	0.0017	0.0037	0.0043	
Δ(1/hFE)	5x10¹¹		IC = 1A	8	0.00022	0.00052	-0.00087	0.0007	0.00094	
	1.25x10¹²		VCE = 2V	8	0.00049	0.0008	0.00011	0.0011	0.0015	
	2.5x10¹²			8	0.00084	0.0014	0.00054	0.0016	0.0020	
	5x10¹²			8	0.0018	0.0026	0.0013	0.0029	0.0034	
Δ(1/hFE)	5x10¹¹		IC = 2A	8	0.00018	0.00051	-0.0006	0.00062	0.00091	
	1.25x10¹²		VCE = 5V	8	0.00046	0.00073	0.00032	0.0010	0.0013	
	2.5x10¹²			8	0.00087	0.0013	0.00045	0.0015	0.0018	
	5x10¹²			8	0.0016	0.0022	0.0011	0.0026	0.0030	

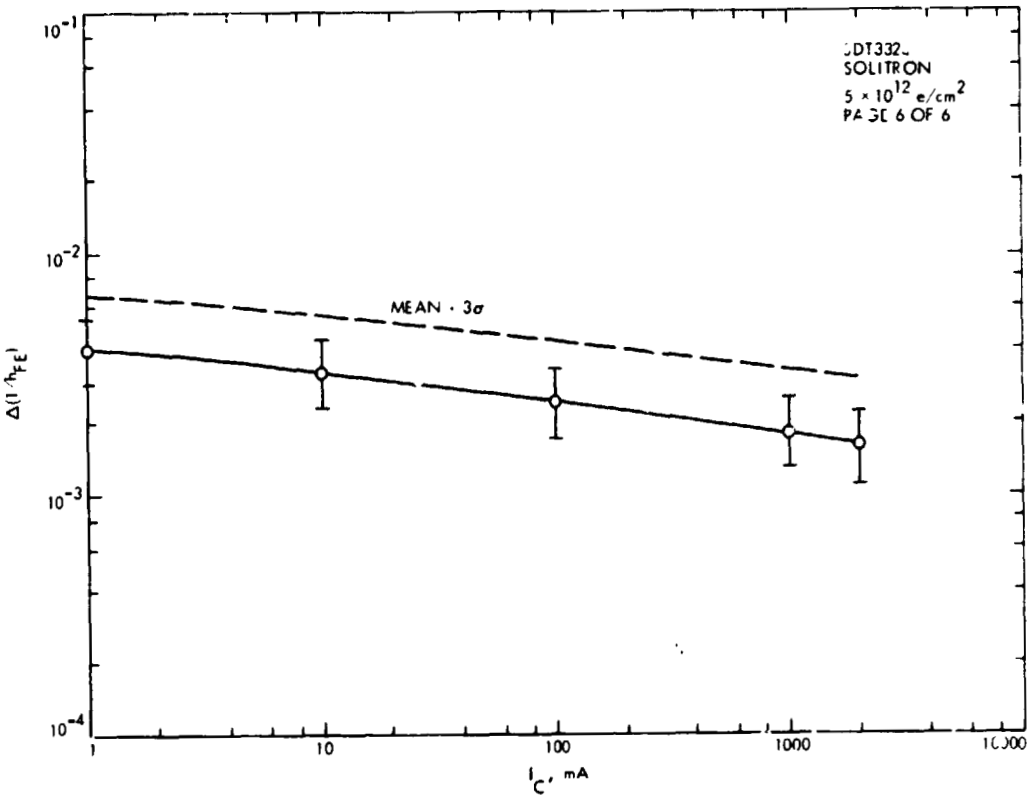
DEVICE TYPE: SDT3323 SOLITRON PAGE 2 of 6

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ICEO (nA)	5x10¹¹	VCE = 30V	VCEO = 30V	5	4.95	21.5	0.47	23.5	32.8	
	1.25x10¹²	BASE = OPEN		5	4.83	20	0.62	21.8	30.3	
	2.5x10¹²			5	8.28	18	1.9	21.7	28.4	
	5x10¹²			5	1207	4600	16.5	5139	7105	


SDT3323
SOLITRON
5 × 10^11 e/cm^2
PAGE 3 OF 6
MEAN + 3σ
-0.000087
-0.00016
Δ(1/h_FE)
I_C, mA


SDT3323
SOLITRON
1.25 × 10^12 e/cm^2
PAGE 4 OF 6
MEAN + 3σ
Δ(1/h_FE)
I_C, mA





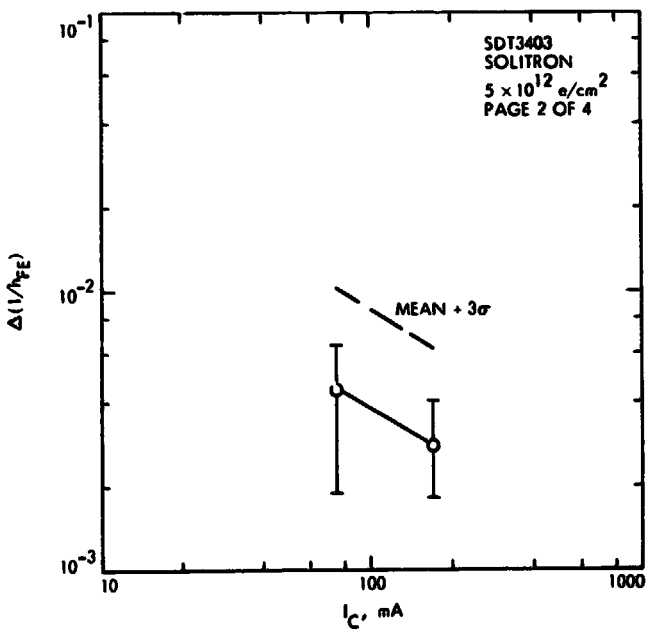
REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

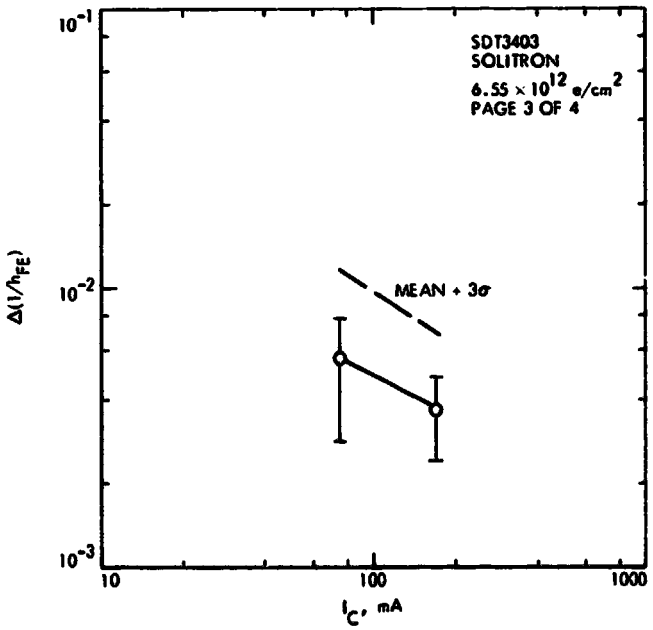
SDT3403, Solitron

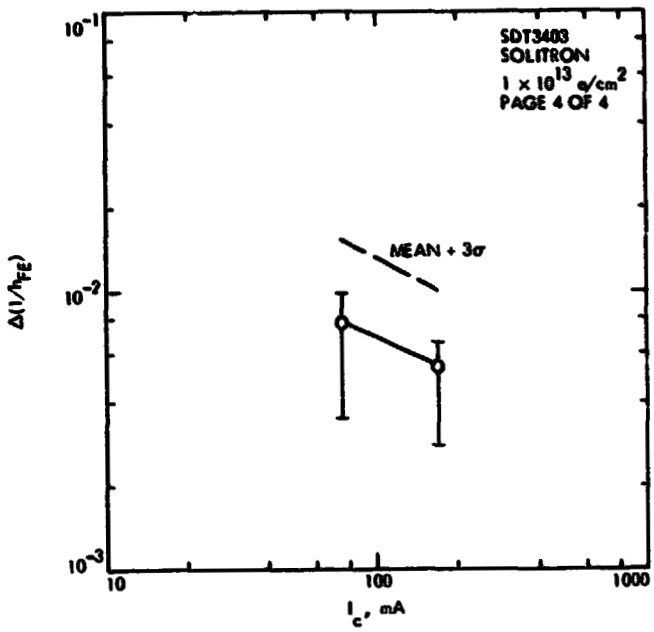
DEVICE TYPE: SDT 3403 SOLITRON PAGE 1 of 4 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean 1σ	Mean 2σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: 100 RAD.							
Δ(1/hFE)	5×10¹²	VCE=1V, IC=25mA	VCE=1V, IC=25mA	5	0.0045	0.0064	0.0019	0.0084	0.0103	
↓	6.55×10¹²	↓	↓	5	0.0056	0.0078	0.0038	0.0097	0.0116	
↓	1×10¹³	↓	↓	5	0.0078	0.0098	0.0035	0.0129	0.0154	
Δ(1/hFE)	5×10¹²		VCE=1V, IC=120mA	5	0.0038	0.0041	0.0018	0.0051	0.0063	
↓	6.55×10¹²		↓	5	0.0032	0.0048	0.0024	0.0058	0.0069	
↓	1×10¹³	↓	↓	5	0.0054	0.0066	0.0038	0.0085	0.0100	

AES





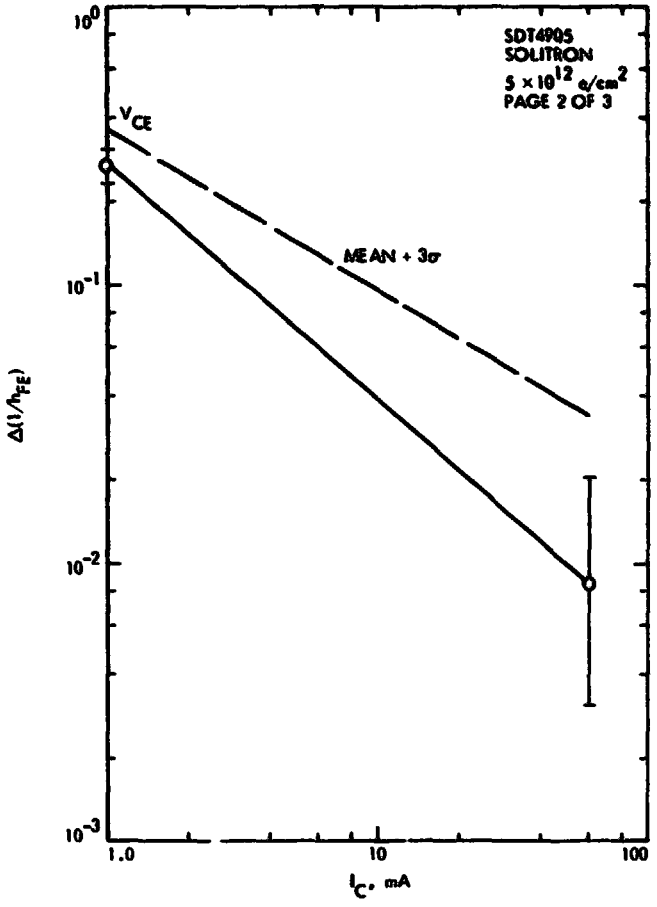


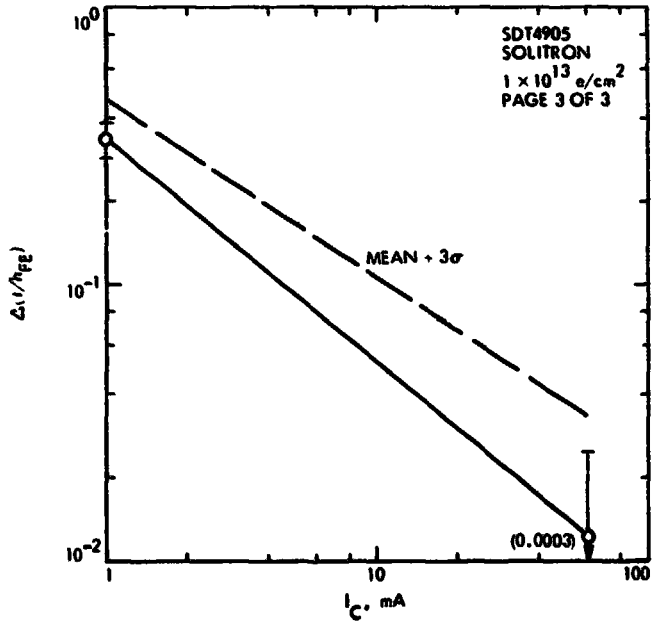
SDT4905, Solitron

DEVICE TYPE: SDT 4905 SOLITRON PAGE 1 of 3 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5x10^12	VCE=15V; Tc=20mA	VCE=30V; Tc=1mA	5	0.271	0.3024	0.2348	0.329	0.358	
↓	1x10^13	↓	↓	5	0.336	0.3831	0.2852	0.422	0.460	
Δ(1/hFE)	5x10^12		VCE=7V; Tc=40mA	5	0.0085	0.0207	0.0031	0.0256	0.0341	
↓	1x10^13	↓	↓	5	0.0123	0.0249	0.0003	0.0300	0.0388	

AGS


SDT4905
SOLITRON
5 × 10^12 e/cm^2
PAGE 2 OF 3
V_CE
MEAN + 3σ
Δ(1/h_FE)
10^0
10^-1
10^-2
10^-3
1.0
10
100
I_C, mA


SDT4905
SOLITRON
1 × 10^13 e/cm^2
PAGE 3 OF 3
MEAN + 3σ
(0.0003)
Δ(1/h_FE)
10^0
10^-1
10^-2
1
10
100
I_C, mA

SDT5553, Solitron

DEVICE TYPE: SDT 5553 SOLITRON PAGE 1 of 11 4

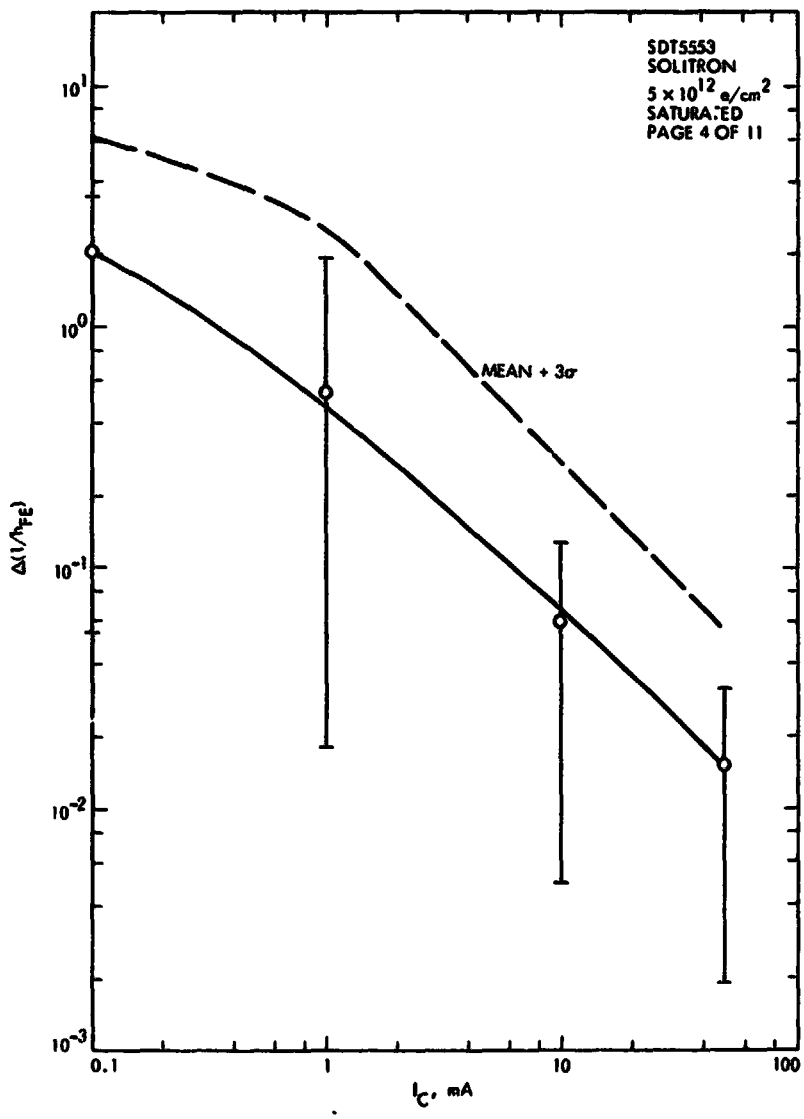
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5x10¹²	VCE=20V; VCE=6V;	VCE=0.5V; IC=10mA	6	1.591	3.487	0.0538	4.545	6.499	
↓	1x10¹³	IC=0.1mA	↓	6	1.9769	4.1167	0.103	5.3542	8.0399	
Δ(1/hFE)	5x10¹²		VCE=0.5V; IC=1mA	6	0.5928	1.932	0.018	1.992	2.7214	
↓	1x10¹³		↓	6	0.3856	0.8158	0.030	1.0265	1.3469	
Δ(1/hFE)	5x10¹²		VCE=0.5V; IC=10mA	6	0.0594	0.1024	0.005	0.169	0.2338	
↓	1x10¹³		↓	6	0.0726	0.1437	0.0085	0.1981	0.2519	
Δ(1/hFE)	5x10¹²		VCE=0.5V; IC=50mA	6	0.015	0.0314	0.0019	0.0414	0.0545	
↓	1x10¹³		↓	6	0.0206	0.0385	0.0034	0.0521	0.0679	
Δ(1/hFE)	5x10¹²		VCE=20V; IC=0.1mA	6	6.2089	9.8307	0.0499	13.6229	17.905	
↓	1x10¹³		↓	6	15.622	33.8257	0.0889	49.9466	65.8862	
Δ(1/hFE)	5x10¹²		VCE=20V; IC=1mA	6	0.2699	0.608	0.017	0.8051	1.0787	
↓	1x10¹³		↓	6	0.3446	0.7522	0.0291	0.9517	1.2953	
Δ(1/hFE)	5x10¹²		VCE=20V; IC=10mA	6	0.0465	0.0989	0.0045	0.1330	0.1762	
↓	1x10¹³		↓	6	0.0610	0.1361	0.0072	0.1827	0.2136	
Δ(1/hFE)	5x10¹²		VCE=20V; IC=50mA	6	0.0144	0.0305	0.0017	0.0403	0.0530	
↓	1x10¹³	↓	↓	6	0.0195	0.0373	0.0030	0.0507	0.0663	

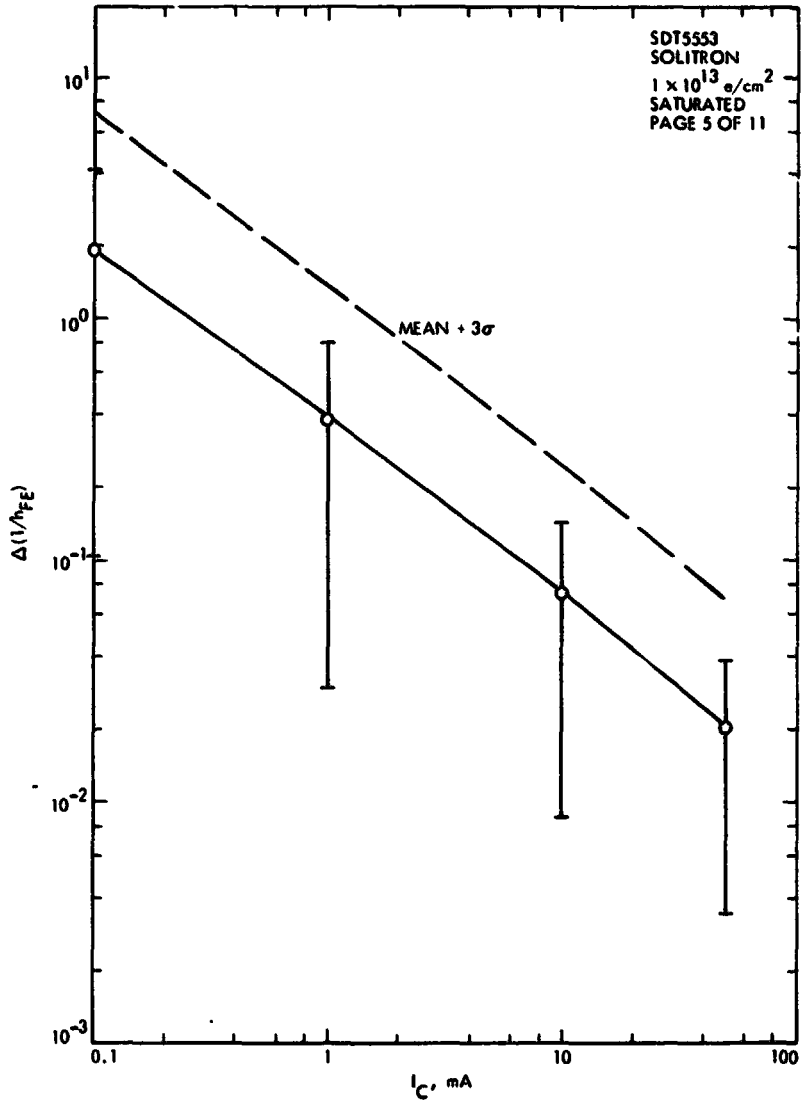
DEVICE TYPE: SDT 5553 SOLITRON PAGE 1 of 11

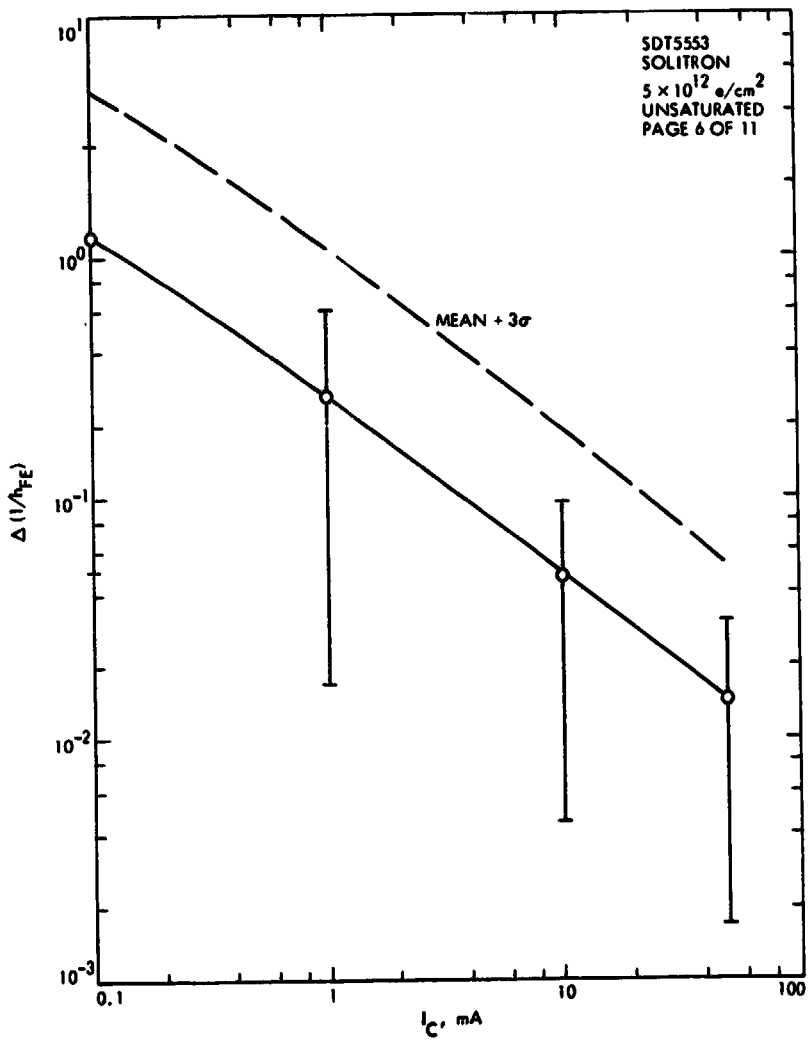
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5x10¹²	VC=20V; VE=GND	VCE=1.2V; IC=0.2mA	6	0.4009	0.891	0.037	1.0913	1.4345	
↓	1x10¹³	IC=0.1mA	↓	6	0.4994	0.9078	0.0644	1.1692	1.5041	
Δ(1/hFE)	5x10¹¹	VCE=20V; IC=0	VCE=0.5V; IC=100mA	4	0.0004	0.0008	0.0001	0.0010	0.0013	
↓	↓		↓	5*	0.0013	0.0051	0.0001	0.0055	0.0076	
	1.25x10¹²			4	0.0008	0.0013	0.0004	0.0017	0.0022	
	↓			5*	0.0009	0.0017	0.0004	0.0021	0.0026	
	2.5x10¹²			4	0.0016	0.0028	0.0007	0.0034	0.0043	
	↓			5*	0.0052	0.0097	0.0007	0.0214	0.0286	
	5x10¹³			4	0.0037	0.0066	0.0014	0.0084	0.0107	
↓	↓		↓	5*	0.0024	0.0073	0.0014	0.0299	0.0406	
Δ(1/hFE)	5x10¹¹		VCE=1V; IC=400mA	4	-0.0002	0	-0.0004	0.0001	0.0002	
↓	↓			5*	-0.00006	0.0008	-0.0004	0.0009	0.0014	
	1.25x10¹²			4	0.0001	0.0005	-0.0003	0.0008	0.0011	
	↓			5*	0.0007	0.0032	-0.0003	0.0035	0.0049	
	2.5x10¹²			3	0.0007	0.0013	0	0.0021	0.0028	
	↓			4*	0.0021	0.0062	0	0.0076	0.0094	
	5x10¹²			4	0.0021	0.0041	0.0006	0.0050	0.0065	
↓	↓	↓	↓	5*	0.0036	0.0084	0.0006	0.0105	0.0140	
	* OUTLIER INCLUDED									

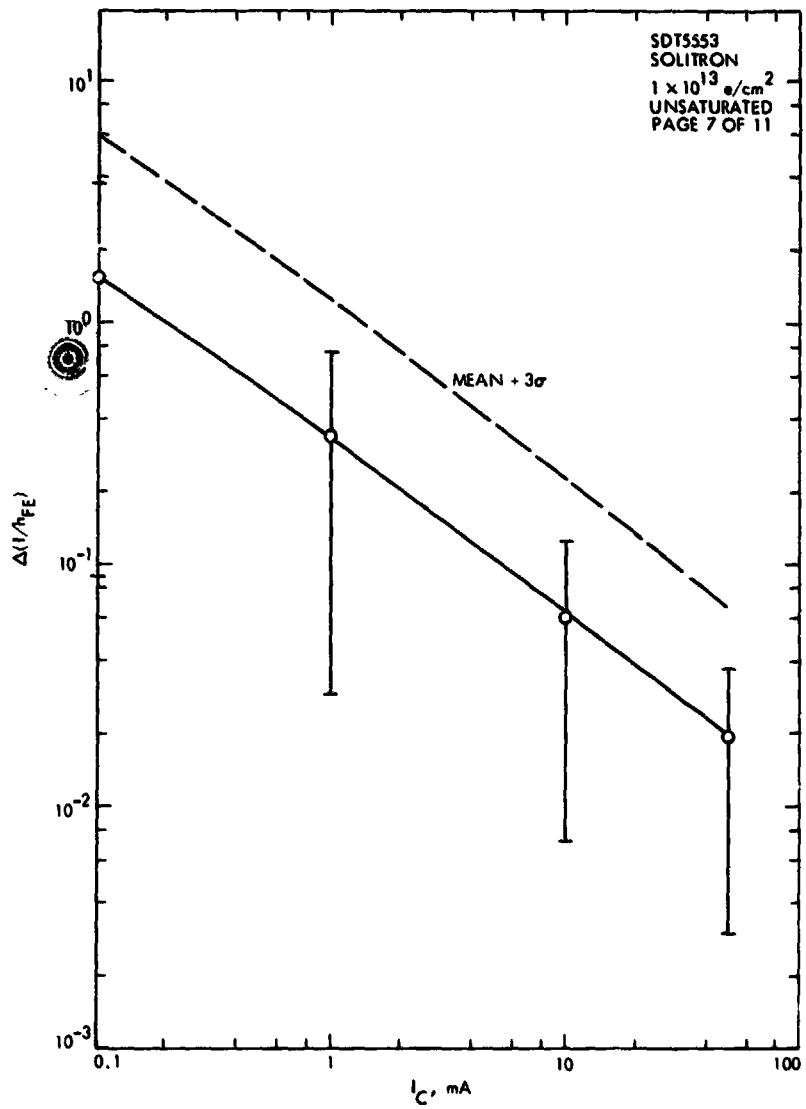
DEVICE TYPE: SDT 5553 Sa, -80N PAGE 3 of 11

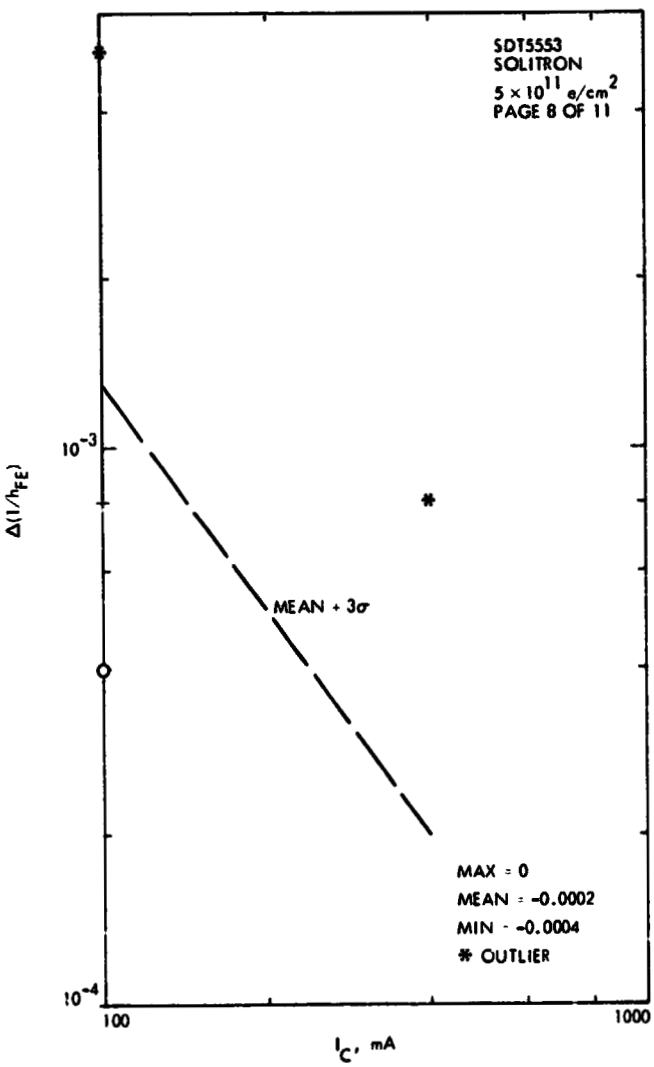
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean 125°	Mean 195°	Accept Reject Criteria
	e/cm²	BIAS: 1RAD.	BIAS: 0RAD.							
Δ(1/hFE)	1×10¹¹	VCE=1.20V;	VCE=1.20V;	2	0.0031	0.0048	0.0020	0.0074	0.0095	
	↓	IC=0.25mA	IC=0.25mA	3*	0.0020	0.0044	0.0020	0.0300	0.0360	
	2.5×10¹¹	↓	↓	2	0.0051	0.0076	0.0032	0.0116	0.0147	
	↓			3*	0.0763	0.2182	0.0032	0.3220	0.4419	
	5×10¹¹			2	0.0092	0.0132	0.0052	0.0305	0.0362	
	↓			3*	0.2182	0.6363	0.0052	0.9423	1.3044	
	1×10¹²			9	1.538	4.3022	0.0092	4.8852	6.5596	
	2.5×10¹²			5	3.3968	5.857	0.0852	7.6282	9.7459	
	rad (Si)									
Δ(1/hFE)	5×10³	VCE=12V; IC=0.5mA	VCE=12V; IC=0.5mA	39	0.0042	0.0387	0.00033	0.0190	0.0263	
↓	↓	↓	↓	44*	0.0647	1.63	0.00033	0.491	0.704	
VCE (sat)(V)	5×10¹²	VCE=20V; VC=0	IC=500mA; IC=50mA	6	0.134	0.175	0.114	0.178	0.201	
↓	1×10¹³	IC=0.1mA	↓	6	0.142	0.181	0.119	0.184	0.220	
VBE(sat) (V)	5×10¹²	↓	IC=250mA; IC=25mA	6	0.0932	0.112	0.079	0.116	0.178	
↓	1×10¹³	↓	↓	6	0.100	0.124	0.084	0.172	0.141	
ICEO (nA)	5×10¹²	VCB=12.6V; VC=0V	VCB=12.6V	4	1210	4900	240	6020	8120	
↓	↓	↓	↓	6*	1890	4900	2	4970	6890	
	1×10¹³			4	4010	6000	540	8870	11300	
	↓			6*	2840	6000	3	8100	10700	
	* OUTLIER INCLUDED									

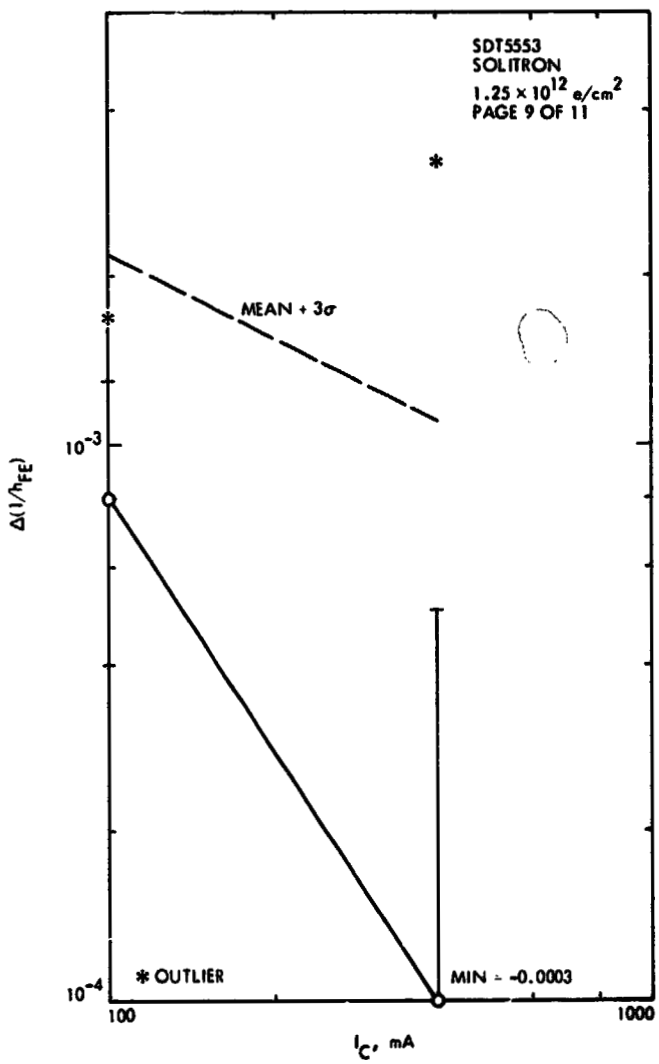

SDT5553
SOLITRON
5 × 10^12 e/cm^2
SATURATED
PAGE 4 OF 11
MEAN + 3σ
Δ(1/h_FE)
10^1
10^0
10^-1
10^-2
10^-3
0.1
1
10
100
I_C, mA

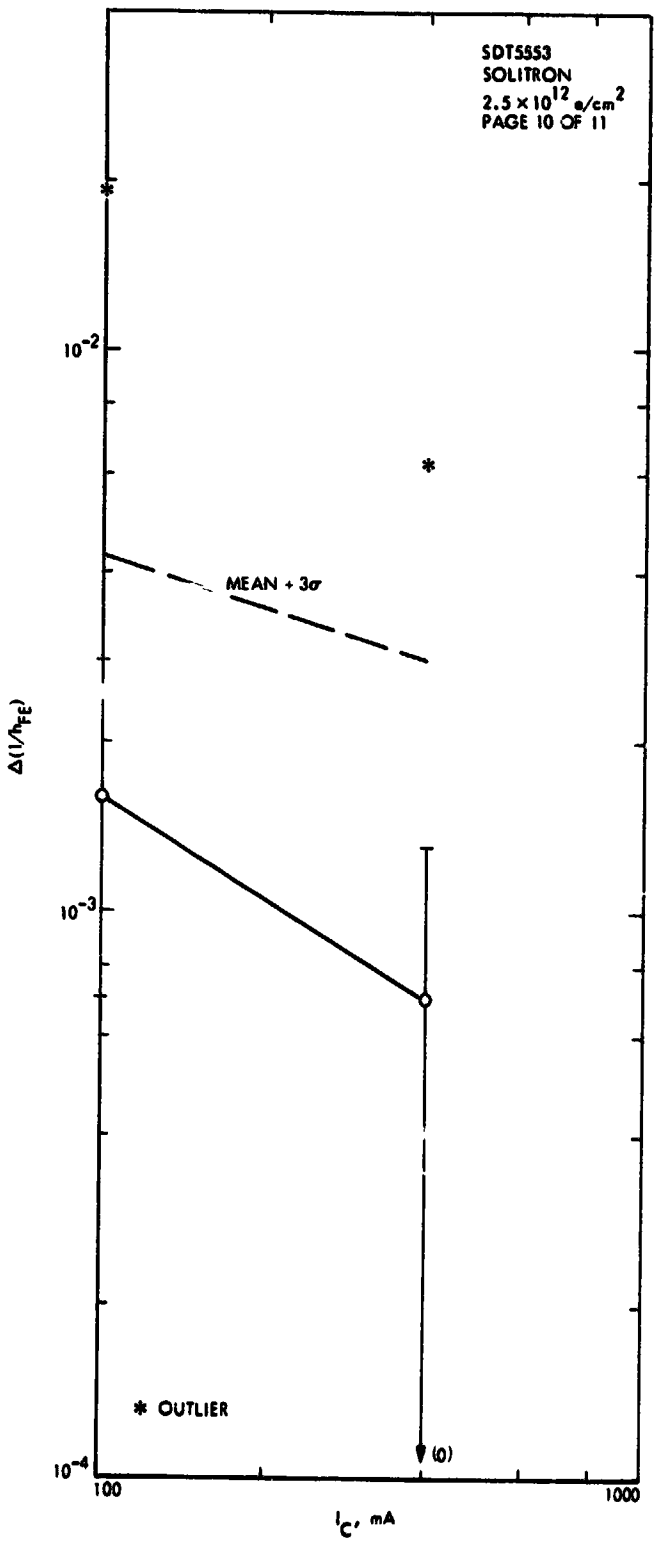

SDT5553
SOLITRON
1 × 10^13 e/cm^2
SATURATED
PAGE 5 OF 11
MEAN + 3σ
Δ(1/h_FE)
10^1
10^0
10^-1
10^-2
10^-3
0.1
1
10
100
I_C, mA

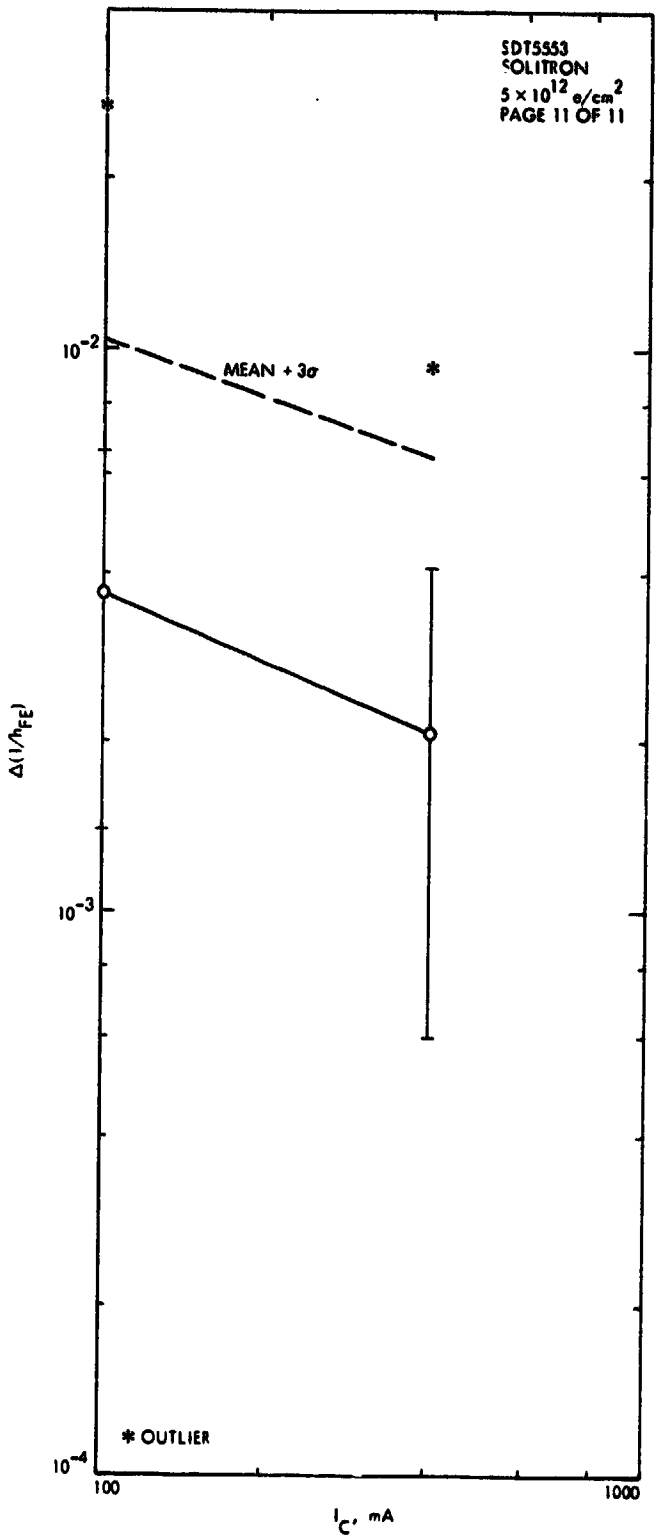

SDT5553
SOLITRON
5 × 10^12 e/cm^2
UNSATURATED
PAGE 6 OF 11
MEAN + 3σ
Δ(1/h_FE)
10^1
10^0
10^-1
10^-2
10^-3
0.1
1
10
100
I_C, mA


SDT5553
SOLITRON
1 × 10^13 e/cm^2
UNSATURATED
PAGE 7 OF 11
MEAN + 3σ
Δ(1/h_FE)
10^1
10^0
10^-1
10^-2
10^-3
0.1
1
10
100
I_C, mA


SDT5553
SOLITRON
5 × 10^11 e/cm^2
PAGE 8 OF 11
MEAN + 3σ
MAX = 0
MEAN = -0.0002
MIN = -0.0004
* OUTLIER
Δ(1/hFE)
10^-3
10^-4
100
1000
IC, mA


SDT5553
SOLITRON
1.25 × 10^12 e/cm^2
PAGE 9 OF 11
MEAN + 3σ
* OUTLIER
MIN = -0.0003
Δ(1/hFE)
10^-3
10^-4
100
1000
IC, mA


SDT5553
SOLITRON
2.5 × 10^12 e/cm^2
PAGE 10 OF 11
MEAN + 3σ
Δ(1/h_FE)
10^-2
10^-3
10^-4
* OUTLIER
(0)
100
1000
I_C, mA

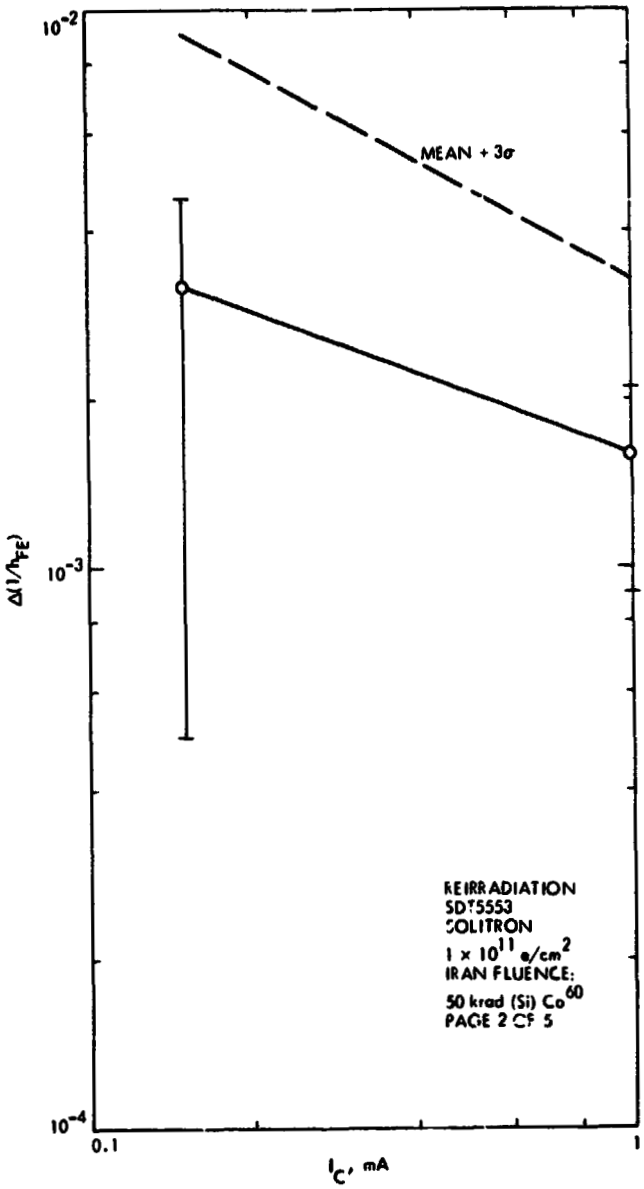

SDT5553
SOLITRON
5 × 10^12 e/cm^2
PAGE 11 OF 11
MEAN + 3σ
Δ(1/h_FE)
10^-2
10^-3
10^-4
* OUTLIER
100
1000
I_C, mA

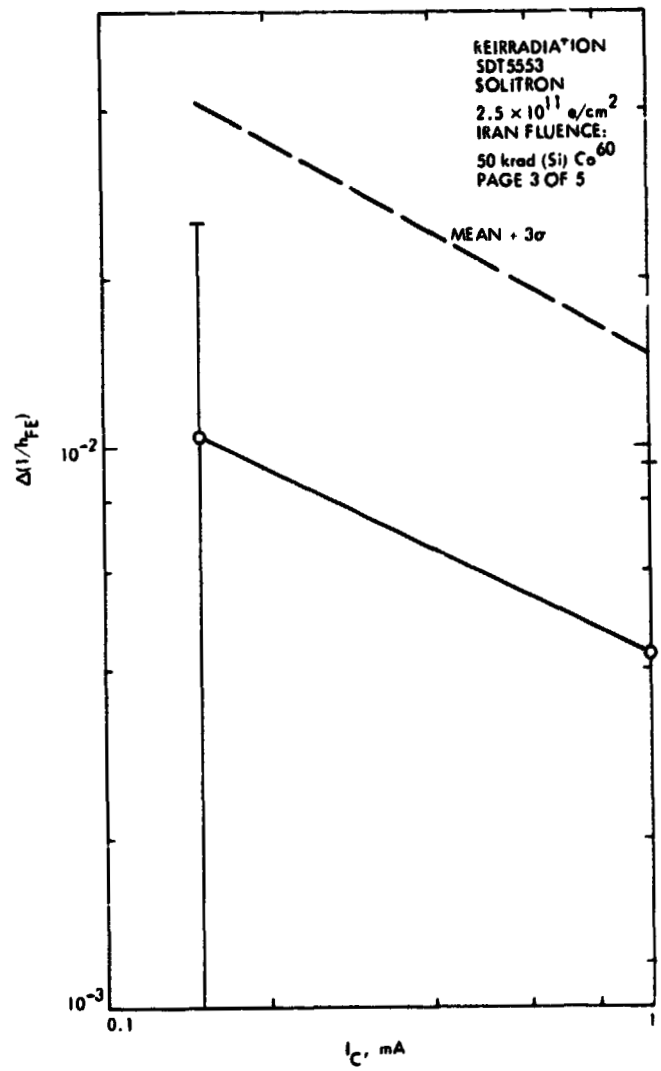
SDT5553, Solitron (IRAN reirradiation)

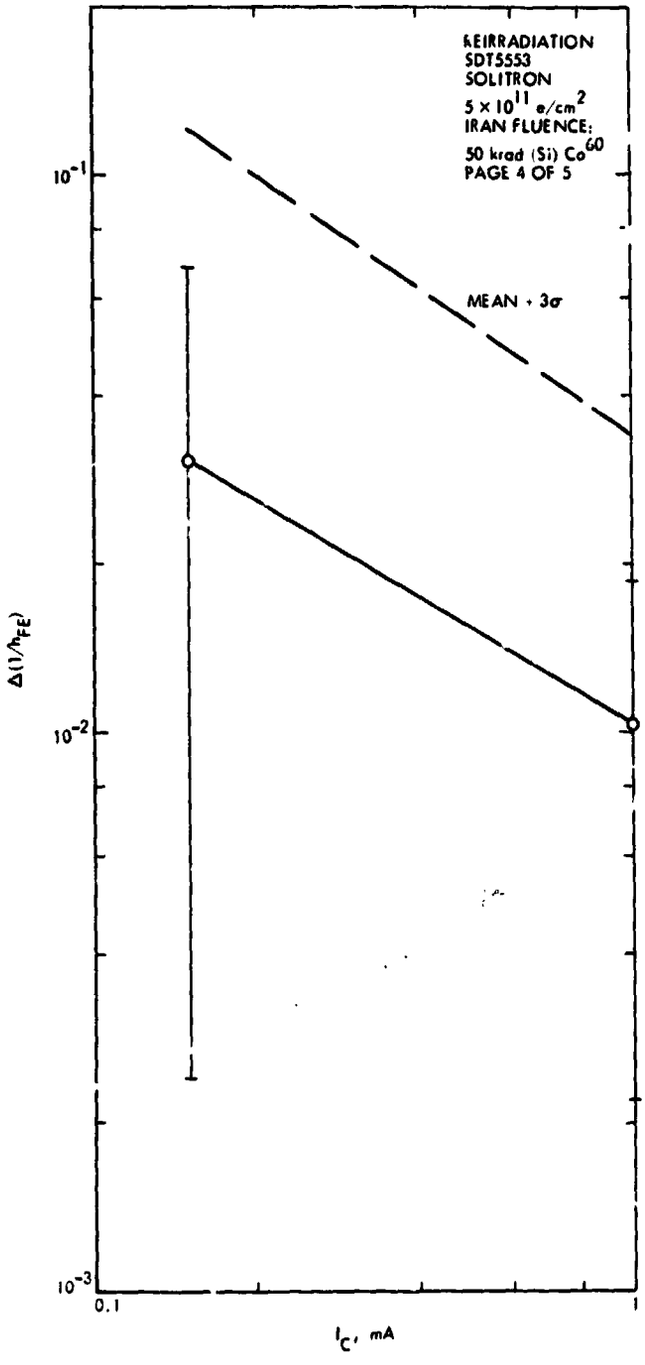
DEVICE TYPE: SDT5553 SOLITRON PAGE 1 of 5 IRAN FLUENCE 50Krad(Si) Co^{60} 4 IRAN

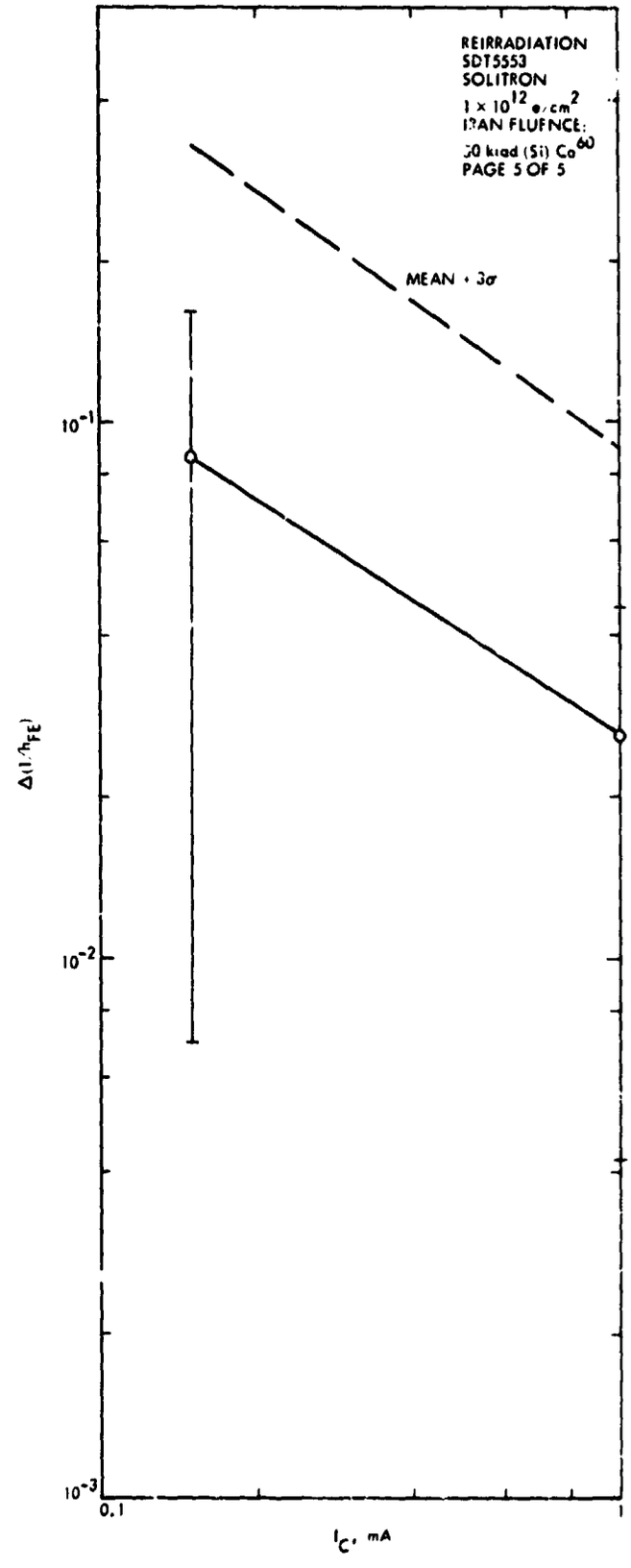
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	1x10¹¹	VCE = 1.24V;	VCE = 1.24V;	4	0.0032	0.0046	0.0005	0.0071	0.0091	h_{FE} > 8
	2.5x10¹¹	IC = 0.15mA	IC = 0.15mA	4	0.0105	0.0253	0.0010	0.0312	0.0415	
	5x10¹¹			4	0.0308	0.0693	0.0024	0.0916	0.1220	
	1x10¹²			4	0.0873	0.1610	0.0070	0.2533	0.3349	
Δ(1/hFE)	1x10¹¹		VCE = 12V;	4	0.0016	0.0021	0.0008	0.0027	0.0033	
	2.5x10¹¹		IC = 1mA	4	0.0043	0.0083	0.0012	0.0113	0.0142	
	5x10¹¹			4	0.0129	0.0158	0.0022	0.0261	0.0340	
	1x10¹²			4	0.0364	0.0450	0.0042	0.0687	0.0899	

A65


10^{-2}
10^{-3}
10^{-4}
$\Delta(1/h_{FE})$
MEAN + 3σ
REIRRADIATION
SDT5553
SOLITRON
1×10^{11} e/cm^2
IRAN FLUENCE:
50 krad (Si) Co^{60}
PAGE 2 OF 5
0.1
1
I_C, mA


REIRRADIATION
SDT5553
SOLITRON
2.5×10^{11} e/cm^2
IRAN FLUENCE:
50 krad (Si) Co^{60}
PAGE 3 OF 5
MEAN + 3σ
10^{-2}
10^{-3}
$\Delta(1/h_{FE})$
0.1
1
I_C, mA


REIRRADIATION
SDT5553
SOLITRON
5 × 10^11 e/cm^2
IRAN FLUENCE:
50 krad (Si) Co^60
PAGE 4 OF 5
MEAN + 3σ
10^-1
10^-2
10^-3
Δ(1/h_FE)
0.1
1
I_C, mA


REIRRADIATION
SDT5553
SOLITRON
1 × 10^12 e/cm^2
IRAN FLUENCE:
50 krad (Si) Co^60
PAGE 5 OF 5
MEAN + 3σ
10^-1
10^-2
10^-3
Δ(1/h_FE)
0.1
1
I_C, mA

SDT8805, Solitron

DEVICE TYPE: SDT 8805 SOLITRON PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: 1 RAD.	BIAS: MEAS.							
Δ(1/hFE)	12.5K	UNPOWERED	Ic=200mA; Vce=1V	4	0.00042	0.00056	0.00035	0.00064	0.00075	
	31.3K			4	0.00058	0.00086	0.00043	0.00096	0.0012	
	62.5K			4	0.00083	0.0013	0.00061	0.0014	0.0017	
	125K			4	0.0011	0.0018	0.00078	0.0020	0.0025	

AGS

SE7056, National Semiconductor

DEVICE TYPE: SE 7056 NSC PAGE 1 of 1 3

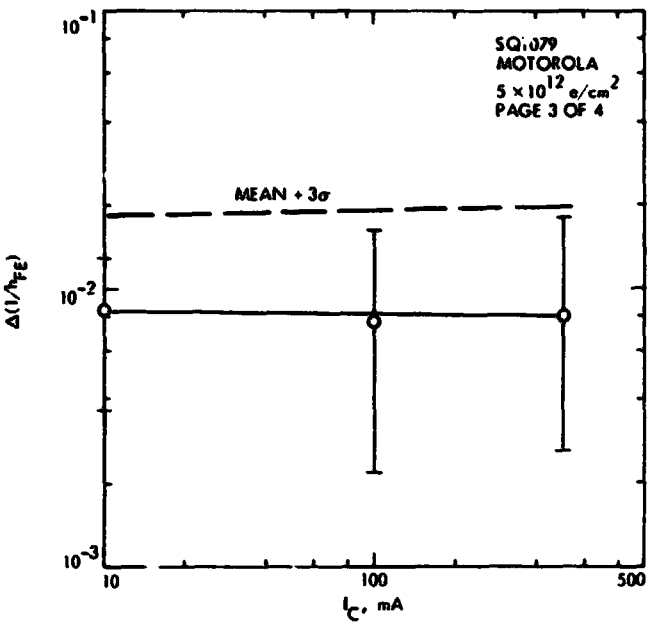
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
Δ (1/hFE)	5×10^{11}	VCE = 124V	Ic = 0.15mA;	6	0.0011	0.0020	-0.0013	0.0036	0.0048	
	1×10^{12}	Ic = 0.15mA	VCE = 124V	6	0.0023	0.0034	-0.0013	0.0060	0.0078	
	2.5×10^{12}			4	0.0041	0.0045	0.0040	0.0046	0.0049	
	5×10^{12}			10	0.0076	0.0107	-0.0033	0.0158	0.0200	
	1×10^{13}			4	0.0148	0.0173	0.0131	0.0188	0.0208	

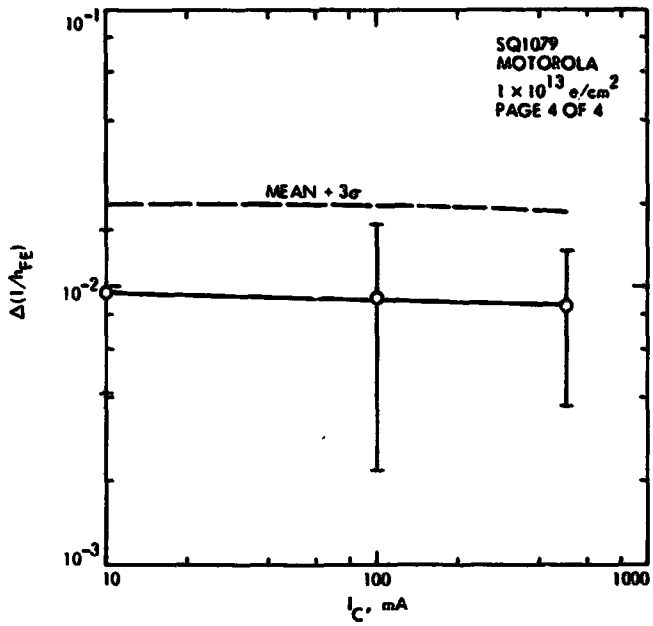
AGS

SQ1079, Motorola

DEVICE TYPE: SQ1079 MOTOROLA			PAGE 1 of 4						3
Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	5×10¹²	VCE = 30V; VCB = 0	VCE = 0.1V; IC = 10mA	12	0.00845	0.0130	0.0037	0.0159	0.0187	
↓	1×10¹³	VEB = 0	↓	12	0.00968	0.0163	0.0042	0.0161	0.0194	
Δ(1/hFE)	5×10¹²		VCE = 0.1V; IC = 100mA	12	0.00767	0.0163	0.0022	0.0159	0.0193	
↓	1×10¹³		↓	12	0.00947	0.0169	0.0022	0.0167	0.0203	
Δ(1/hFE)	5×10¹²		VCE = 0.5V; IC = 500mA	12	0.00793	0.0180	0.0036	0.0175	0.0212	
↓	1×10¹³		↓	12	0.00872	0.0138	0.0038	0.0153	0.0186	
VCE(sat) (V)	0		IC = 100mA; IB = 10mA	12	0.149	0.170	0.127			
	5×10¹²		↓	12	0.152	0.169	0.131	0.177	0.189	
↓	1×10¹³			12	0.153	0.171	0.133	0.178	0.190	
VCE(sat)(V)	0		IC = 500mA; IB = 50mA	12	0.421	0.443	0.382			
	5×10¹²		↓	12	0.432	0.448	0.397	0.463	0.479	
↓	1×10¹³		↓	12	0.435	0.449	0.405	0.463	0.477	
VBE(sat)(V)	0		IC = 100mA; IB = 10mA	12	0.672	0.682	0.664			
	5×10¹²			12	0.668	0.676	0.660	0.677	0.682	
↓	1×10¹³		↓	12	0.668	0.677	0.650	0.683	0.691	
VBE(sat)(V)	0		IC = 500mA; IB = 50mA	12	0.746	0.756	0.736			
As	5×10¹²			12	0.745	0.752	0.739	0.753	0.757	
↓	1×10¹³	↓	↓	12	0.745	0.752	0.739	0.752	0.756	

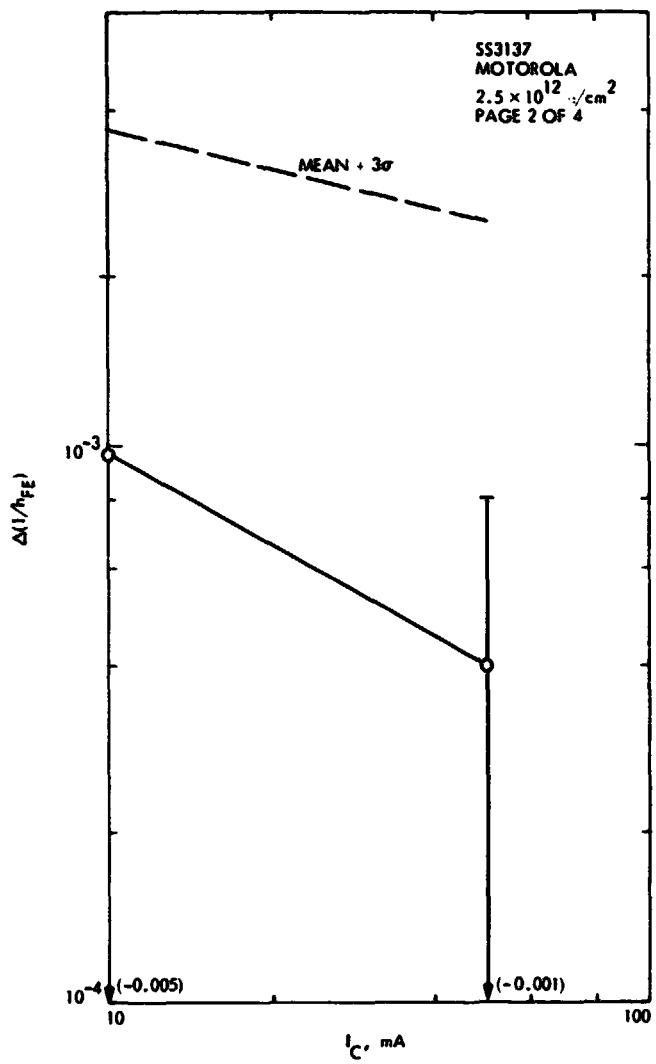
DEVICE TYPE: SQ1079 MOTOROLA			PAGE 2 of 4						3
Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
ICBO (nA)	0	VCE = 30V; VEB = 0	VCB = 30V	12	6.42	7.8	4.8			
↓	5×10¹²	VEB = 0	↓	12	6.35	9.1	5.0	8.6	9.22	
↓	1×10¹³	↓	↓	12	6.58	11.5	4.8	10.5	12.5	

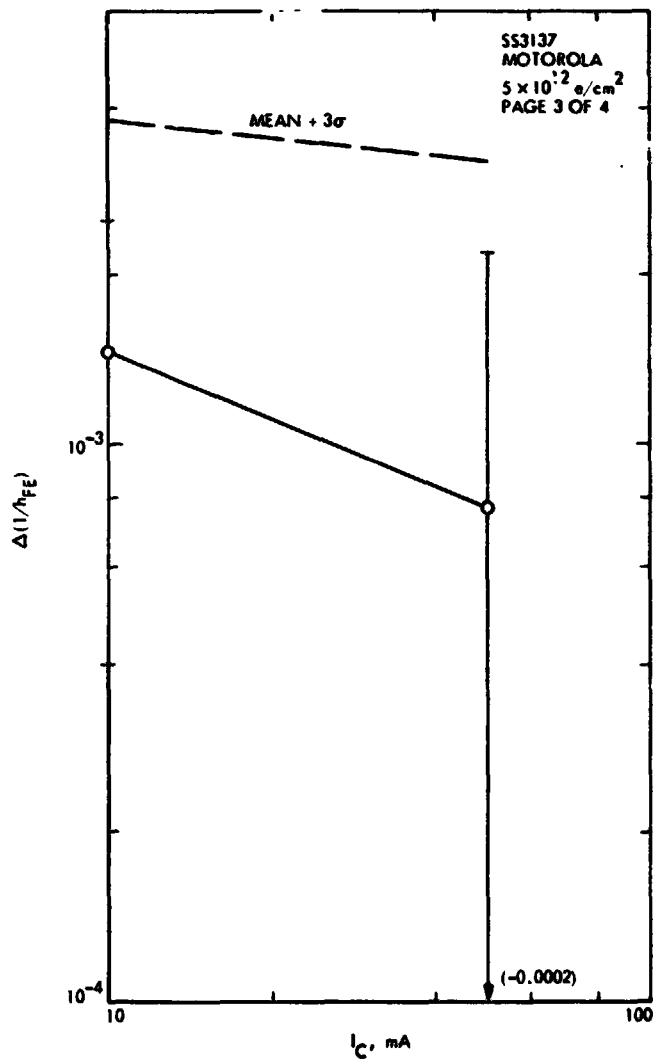


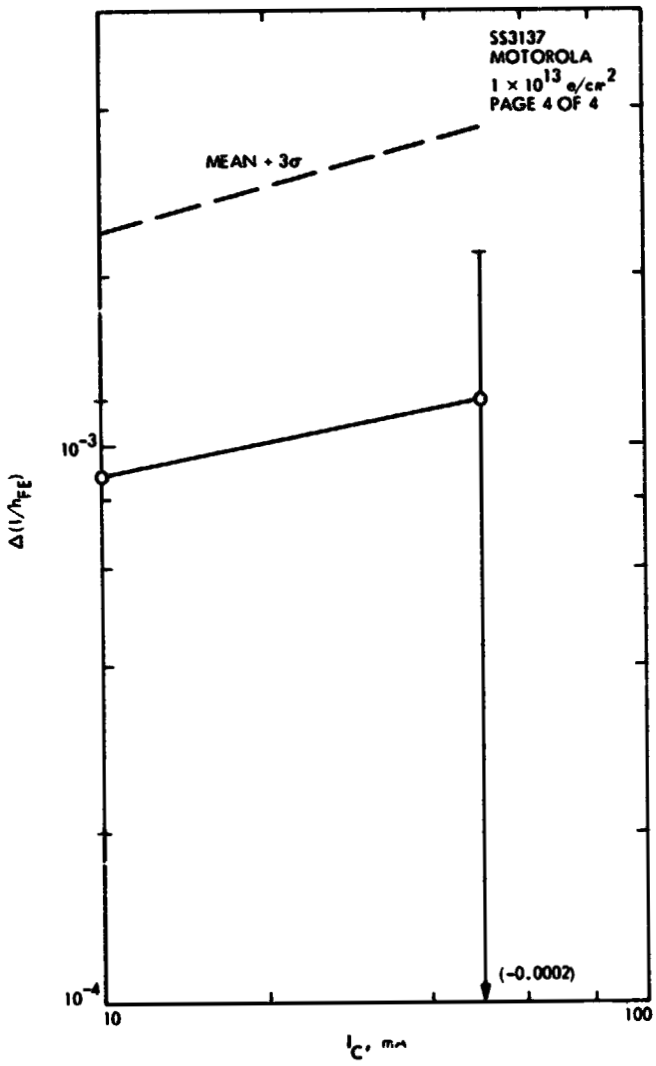


SS3137, Motorola

DEVICE TYPE: SS3137 MOTOROLA			PAGE 1 OF 4							3
Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ(1/hFE)	2.5×10^12	VC = 50V;	VCE = 1V; IC = 10mA	6	0.00097	0.0020	-0.0005	0.0028	0.0037	
	5×10^12	B-E-GND		6	0.0014	0.0025	0.0001	0.0030	0.0038	
	1×10^13			6	0.00088	0.0040	0.0002	0.0019	0.0029	
Δ(1/hFE)	2.5×10^12		VCE = 1V;	6	0.0004	0.0008	-0.001	0.0018	0.0026	
	5×10^12		IC = 50mA	6	0.00077	0.0022	-0.0002	0.0024	0.0032	
AVG	1×10^13			6	0.0012	0.0022	-0.0002	0.0029	0.0037	


SS3137
MOTOROLA
2.5 × 10^12 e/cm^2
PAGE 2 OF 4
MEAN + 3σ
10^-3
10^-4
(-0.005)
(-0.001)
10
100
Δ(1/h_FE)
I_C, mA


SS3137
MOTOROLA
5 × 10^12 e/cm^2
PAGE 3 OF 4
MEAN + 3σ
10^-3
10^-4
(-0.0002)
10
100
Δ(1/h_FE)
I_C, mA


SS3137
MOTOROLA
1 × 10^13 e/cm^2
PAGE 4 OF 4
MEAN + 3σ
10^-3
10^-4
Δ(1/h_FE)
(-0.0002)
10
100
I_C, mA

B. JFETs

2N2608, Circuit Technology

DEVICE TYPE: 2N2608 CIRCUIT TECHNOLOGY PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
IGSS (nA)	5×10¹²	VGS = 12V;	VGS = 4V, VDS = 0	7	0.09	0.098	0.084	0.101	0.107	
↓	↓	VDS = 5V	↓	8*	0.111	0.216	0.084	0.232	0.272	
	1×10¹³			7	0.101	0.122	0.082	0.135	0.151	
↓	↓		↓	8*	0.401	2.5	0.082	2.1	2.95	
ID (OFF)	5×10¹²		VGS = 12V, VDS = 5V	7	0.0649	0.069	0.058	0.0726	0.0764	
↓	↓		↓	8*	0.104	0.38	0.058	0.327	0.437	
	1×10¹³			7	0.159	0.17	0.14	0.18	0.19	
↓	↓		↓	8*	0.559	3.2	0.14	2.07	3.76	
rDS (ON)	5×10¹²	↓	VGS = 0; I = 1μA	8	53.6	58	50	59.6	62.5	
↓	1×10¹³	↓	↓	8	53	58	49	59.2	62.4	

2N2608, Siliconix

DEVICE TYPE: 2N2608 SILICONIX PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
IGSS (nA)	5×10¹²	VGS = 12V	VGS = 4V, VDS = 0V	6	-.447	-.18	-.72	-.038	.167	
↓	1×10¹³	VDS = 5V ↓	↓	6	-1.57	-.2	-3.8	1.4	2.83	
ID (OFF)	5×10¹²		VDS = 0V, I = 1μA	6	.52	.85	.3	.916	1.11	
↓	1×10¹³		↓	6	1.45	3.4	0.4	3.83	5.02	
rDS (ON)	5×10¹²		VGS = 12V, VDS = 5V	6	1,580	2,000	1,200	2,100	2,350	
↓	1×10¹³	↓	↓	6	1,300	1,600	900	1,840	2,100	

2N3066, Siliconix

DEVICE TYPE: 2N3066 SILICONIX PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
IGSS (nA)	5x10¹²	VGS = -8V; VDS = 0	VGS = -8V; VDS = 0	9	0.0225	0.04	0.0089	0.0529	0.0672	
↓	1x10¹³	↓	↓	9	0.119	0.14	0.0235	0.38	0.51	
								±2σ	±3σ	
Δ VP (mV)	5x10¹²		VGS = 10V; ID = 10μA	9	-1.1	-0.7	-2.0	-0.1	0.3	
↓	↓	↓	↓					-2.1	-2.6	
	1x10¹³			9	-1.7	-0.9	-5.0	1.0	2.4	
↓	↓	↓	↓					-4.5	-5.9	

2N3331, Siliconix

DEVICE TYPE: 2N3331 SILICONIX PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVP (mV)	5x10¹²	VGS = +15V;	VDS = 15V	9	1.7	17	-7.6	20.2	29.5	
	↓	VDS = -15V	ID = 10μA					-16.8	-26	
↓	1x10¹³	↓	↓	9	1.1	18	-12.5	20.6	30.3	
								-18.3	-28.1	
								+2σ	+3σ	
IGS (nA)	5x10¹²		VDS = 0;	8	-2.26	0.49	-6.5	2.8	5.59	
↓	↓		VGS = +15V	9*	-4.26	0.49	-15.5	5.7	10.6	
	1x10¹³			8	-1.09	0.73	-3.66	2.05	3.62	
↓	↓		↓	9*	-1.61	0.73	-5.8	2.69	4.84	
IDS(OFF)	5x10¹²		VDS = 15V;	9	0.861	1.9	0.205	1.91	2.43	
(nA)	1x10¹³		VGS = +15V	9	1.78	6.1	0.27	5.34	7.11	
IDSS (mA)	5x10¹²		VDS = -15V;	9	6.37	8.5	5.6	8.3	9.32	
↓	1x10¹³	↓	VGS = 0	9	6.37	8.5	5.6	8.3	9.32	

* OUTLIERS INCLUDED

2N3382, Siliconix

DEVICE TYPE: 2N3382 SILICONIX PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
I_D(OFF)(nA)	5x10¹²	V_{GS}=7V; V_{DS}=3V	V_{GS}=7V; V_{DS}=-3V	6	0.111	0.3	0.028	0.215	0.417	
↓	1x10¹³	↓	↓	6	0.322	0.75	0.1	0.851	1.62	
ΔR(on)(Ω)	5x10¹²		V_{GS}=0; I_D=0.15mA	6	146	231	84	252	304	
↓	1x10¹³		↓	6	148	233	84	252	304	
ΔVp (mV)	5x10¹²		V_{DS}=-3V; I_D=1μA	6	-0.5	3.0	-3.0	4.5	7.0	
↓	↓							-5.5	-8.0	
↓	1x10¹³		↓	6	-12.0	79	-156	142.7	220.1	
↓	↓	↓	↓					-166.7	244.1	

NS

2N3686, Solitron

DEVICE TYPE: 2N3686 SOLITRON PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
gm(μmhos)	5x10¹²	V_{DS}=10V; I_D=200μA	V_{DS}=10V; I_D=200μA	3	1060	1110	980	921	852	
↓	1x10¹³		↓	3	1060	1120	990	990	864	
								+2σ	+3σ	
I_D(OFF)(nA)	5x10¹²		V_{DS}=10V, V_{GS}=-15V	3	0.061	0.142	0.020	0.201	0.271	
↓	1x10¹³		↓	3	0.507	1.3	0.1	1.88	2.52	
Noise Voltage	5x10¹²		V_{DS}=10V; I_D=200μA	3	2.13	2.30	2.00	2.44	2.59	
(nV)	1x10¹³		F=30KHz	3	2.20	2.30	2.10	2.40	[illegible]	
	rad(Si)									
I_G(pA)	625K		V_{DS}=10V;	5	30	38	24	42.2	48.4	
↓	312K		I_{DS}=200μA	5	24.2	29	21	32.1	36.1	
	625K			5	22.2	26	20	27.2	29.7	
↓	125K	↓	↓	5	50	65	45	66.9	75.3	

NS

2N3824, Circuit Technology

DEVICE TYPE: 2N3824 C.T.I. Page 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
I_{GSS} (nA)	5×10¹²	VGS=-12V; VDS=0	VGS=-12V; VDS=0	8	0.223	0.56	0.02	0.506	0.648	
↓	1×10¹³		↓	8	0.941	1.37	0.09	1.83	2.28	
I_D(off)(nA)	5×10¹²		VGS=-12V; VDS=5V	8	0.179	0.56	0.08	0.493	0.65	
↓	1×10¹³		↓	8	0.611	0.93	0.36	1.01	1.22	
r_{DS}(on)(Ω)	5×10¹²		VGS=0; ID=1μA	8	16.9	18	16	18.2	18.8	
↓	1×10¹³		↓	8	16.6	17	16	17.7	18.2	

NGS

2N4093, Siliconix

DEVICE TYPE: 2N4093 Siliconix Page 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
I_D(off)	5×10¹²	VDS=0V;	VDS=5V;	6	0.1070	0.1800	0.0200	0.2140	0.2670	
(nA)	1×10¹³	ID 100μA	VGS=-15V	6	0.4630	0.8900	0.0500	1.2000	1.5600	
r_{DS}(on)	5×10¹²		VGS=0V;	6	42.1	62.74	28.18	68.2	81.2	
(Ω)	1×10¹³	↓	ID=100μA	6	42.2	62.95	28.26	68.3	81.4	
	Dose									
	rad(si)									
I_{GSS}(pA)	60K	VGS=-20V	VGS=-20V	5	1650	2590	1280	2710	3250	
	70.5K	VDS=0V	VDS=0V	5	2600	3600	2130	3780	4360	
	91.3K			5	11800	24000	4800	26400	33700	
	122.5K			5	103,000	240,000	20,000	269,000	361,000	
↓	185K	↓	↓	5	1020,000	2180,000	182,000	2490,000	3300,000	

NGS

2N4391, Siliconix

DEVICE TYPE: 2N4391 SILICONIX PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
$I_D(OFF)$(nA)	5×10¹²	VDS = 20V	VDS = 20V	5	4.38	5.7	1.5	7.68	8.33	
↓	1×10¹³	VGS = -15V	VGS = -15V	5	18.0	24.2	8.9	29.6	35.5	
$V_{DS(on)}$(mV)	5×10¹²		I_D = 10μA	5	0.186	0.21	0.16	0.225	0.244	
↓	1×10¹³		↓	5	0.182	0.21	0.16	0.22	0.24	
$r_{DS(on)}$(Ω)	5×10¹²			5	18.6	21	16	22.5	24.4	
↓	1×10¹³		↓	5	18.2	21	16	22	24	
								±2σ	±3σ	
ΔVP (mV)	5×10¹²		VDS = 20V;	5	11.4	29	2.0	32.1	42.5	
↓	↓		I_D = 10μA					-9.3	-19.7	
↓	1×10¹³		↓	5	9.6	17	3.0	20.6	26.2	
↓	↓							-1.4	-7.0	
								±2σ	±3σ	
C_{rss}(pF)	5×10¹²	↓	VDS = 0;	5	2.65	2.71	2.56	2.78	2.84	
↓	1×10¹³	↓	VGS = 15V	5	2.74	2.92	2.62	3.0	3.13	
I_{GSS} (nA)	rad(Si)									
SCREENED	60K	VGS = -20V;	VGS = -20V	3	0.34	0.36	0.33	0.375	0.392	
UNSCREENED		VDS = 0	VDS = 0	2	0.805	0.89	0.72	1.05	1.17	
SCREENED	225K	↓	↓	3	0.73	0.82	0.67	0.889	0.968	
UNSCREENED				2	1.21	1.32	1.10	1.52	1.68	
SCREENED	91.3K			3	1.25	1.36	1.16	1.45	1.55	
NG UNSCREENED		↓	↓	2	2.15	2.30	2.0	2.57	2.79	

DEVICE TYPE: 2N4391 SILICONIX PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.							
I_{GSS}(nA)										
SCREENED	1.22.5K	VGS = -20V;	VGS = -20V;	3	2.37	2.60	2.20	2.80	2.99	
UNSCREENED	↓	VDS = 0V	VDS = 0V	2	4.25	4.50	4.00	4.9	5.31	
SCREENED	185K	↓	↓	3	6.03	6.50	5.80	6.84	7.25	
UNSCREENED	↓			2	10.9	11.5	10.2	12.7	13.6	

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

2N4392, Siliconix

DEVICE TYPE: 2N4392 SILICONIX PAGE 1 of 1 — 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.							
I_{GSS} (nA)	60K	V_{GS}=-20V; V_{DS}=0V	V_{GS}=-20V, V_{DS}=0V	5	0.821	1.5	0.485	1.64	2.05	
	22.5K			5	1.5	2.32	1.05	2.48	2.97	
	91.3K			5	2.45	4.5	1.2	4.96	6.22	
	122.5K			5	6.09	13.8	2.25	15.1	19.7	
	e/cm²									
	5×10^{12}	V_{DS}=5V; V_{GS}=-10V	V_{GS}=-15V, V_{DS}=5V	6	7.64	28.5	0.068	22.3	40.1	
	rad (Si)									
	185K	V_{GS}=-20V; V_{DS}=0V	V_{GS}=-20V; V_{DS}=0V	5	20.7	60.0	5.5	65.3	82.7	
	e/cm²									
	1×10^{13}	V_{DS}=5V; V_{GS}=-10V	V_{GS}=-15V; V_{DS}=5V	6	58.1	248	4.2	249	345	
$r_{DS(on)}$ (Ω)	5×10^{12}		V_{DS}=-5V;	6	36.7	50	30	53	61.2	
	1×10^{13}		V_{GS}=0V; I_D=1μA	6	38.3	50	30	58	67.1	

ΔGS.

2N4393, Siliconix

DEVICE TYPE: 2N4393 SILICONIX PAGE 1 of 1 — 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
I_D(off) (nA)	5×10^{12}	V_{DS}=20V;	V_{DS}=20V	6	2.33	2.86	1.7	3.25	3.71	
	1×10^{13}	V_{GS}=-15V	V_{GS}=-15V	6	10.9	13.0	7.7	14.9	16.9	
I_{DSS} (mA)	5×10^{12}		V_{DS}=20V	6	14.8	21	8	24.2	29	
	1×10^{13}		V_{GS}=0	6	14.8	21	8	24.2	29	
								±2σ	±3σ	
ΔV_P (mV)	5×10^{12}		V_{DS}=10V;	6	-1.6	0	-10	6.4	10.5	
			I_D=10μA					-9.8	-13.9	
	1×10^{13}			6	-1.6	0	-10	6.4	10.5	
								-9.8	-13.9	
$V_{GS(on)}$(mV)	5×10^{12}		V_{GS}=0	6	5.7	7.6	4.7	8.0	9.2	
			I_D=100μA					3.4	2.2	
	1×10^{13}			6	5.6	7.5	4.7	7.8	8.9	
								3.4	2.1	
								+2σ	+3σ	
$r_{DS(on)}$(Ω)	5×10^{12}		V_{GS}=0	6	56.8	76	47	77.8	91.3	
	1×10^{13}		I_D=100μA	6	55.8	75.4	46	78.9	90.4	
	rad(Si)									
I_{GSS} (pA)	60K	V_{GS}=-20V;	V_{GS}=-20V	5	4820	6900	2800	7960	9530	
	22.5K	V_{DS}=0	V_{DS}=0V	5	7330	9250	4400	11000	12800	
	91.3K			5	22500	29300	12800	34900	41100	
	122.5K			5	93400	132000	46000	158000	192000	
	185K			5	698000	980000	340000	1180000	1440000	

2N4416, Siliconix

DEVICE TYPE: 2N4416 SILICONIX PAGE 1 of 1 — 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean 2σ	Mean 3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
gm (μmhos)	5×10¹²	VDS = 10V;	VDS = 10V	6	3540	3767	3000	3050	0810	
	1×10¹³	VGS = 0V	ID = 2.5mA	6	3260	3767	2000	1900	1260	
								+2σ	+3σ	
Ciss (pF)	5×10¹²		VDS = 15V; VGS = 0V	6	3.44	3.58	3.35	3.61	3.70	
	1×10¹³		f = 1 MHz	6	3.83	5.84	3.14	5.83	6.83	
								-2σ	-3σ	
Crss (pF)	5×10¹²		VDS = 0V; VGS = 5V	6	1.04	1.073	0.995	0.984	0.955	
	1×10¹³		f = 1 MHz	6	1.016	1.084	1.011	1.01	0.978	
	Dose rad (Si)									
IGSS (pA)	12.5K	VDS = 10V;	VDS = 10V;	5	101	120	51	158	186	
	31.3K	IDS = 2.5mA	IDS = 2.5mA	5	144	184	90	250	303	
	62.5K			5	295	400	67	560	686	
	125K			5	983	1380	222	1930	2400	

NOS

2N4856, Siliconix

DEVICE TYPE: 2N4856 SILICONIX PAGE 1 of 1 — 3

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
IGSS (nA)	60K		VGS = -20V;	VGS = -20V;	201	0.401	0.816	0.141	0.681	0.821	
			VDS = 0V	VDS = 0V	221*	0.478	2.206	0.141	1.07	1.36	
	70.5K				5	0.906	0.980	0.860	0.995	1.039	
	91.3K				5	0.627	0.760	0.405	0.968	1.149	
	122.5K				5	2.452	2.620	2.330	2.672	2.882	
	185K				5	10.62	14.70	8.20	15.62	18.13	
ID (OFF) (nA)		5×10¹²	VDS = 12V,	VDS = 12V, VGS = 17V	4	4.35	10	2.2	11.87	15.67	
			VGS = -17V		5*	105.48	510	2.2	552.29	783.95	
		1×10¹³			4	43.83	138.0	11.1	167.11	232.2	
					5*	425.06	1950.0	11.1	2133.5	2982.7	

NOS

* OUTLIER INCLUDED

2N4856, Texas Instruments

DEVICE TYPE: 2N4856 TEXAS INSTRUMENTS PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
$I_{DS(OFF)}$	5×10¹²	V_{DS}=0V; V_{GS}=-30V	V_{DS}=0V; V_{GS}=-30V	5	-27.3	-2.0	-56.0	65.1	84.0	
(nA)	1×10¹³	↓	↓	5	-135	-41	-240	284	359	
I_{GSS} (nA)	5×10¹²	↓	V_{GS}=-30V; V_{DS}=0	6	8.95	11.5	5.5	13.6	16.0	
↓	1×10¹³	↓	↓	6	55.3	72.0	34.0	87.6	104	

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2N4858, Texas Instruments

DEVICE TYPE: 2N4858 TEXAS INSTRUMENTS PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
$I_{G(OFF)}$(nA)	5×10¹²	V_{DS}=0, V_{GS}=-6.7V	V_{DS}=0, V_{GS}=-6.7V	5	0.325	0.67	0.042	0.834	1.09	
↓	1×10¹³		↓	5	1.78	4.1	0.22	4.91	6.47	
$I_{D(OFF)}$(nA)	5×10¹²		V_{DS}=10V; V_{GS}=-17V	5	0.348	0.54	0.12	0.721	0.907	
↓	1×10¹³		↓	5	1.34	2.35	0.28	3.21	4.15	
$I_{D(OFF)}$(μA)	5×10¹²		V_{DS}=-10V; V_{GS}=-17V	5	0.096	0.195	0.011	0.249	0.325	
↓	1×10¹³		↓	5	0.574	1.35	0.085	1.58	2.09	
$r_{DS(on)}$(Ω)	5×10¹²		V_{GS}=0; I_D=0.3mA	5	42.1	48.1	35.97	51.6	56.4	
↓	1×10¹³	↓	↓	5	42.3	47.95	35.8	52.3	52.3	

A8

2N5196, Siliconix

3

DEVICE TYPE: 2N5196 SILICONIX PAGE 1 of 2

Parameter	[illegible]		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	[illegible]		BIAS: 1 BRAD.	BIAS: MEAS.							
I_{GSS} (nA)	60K		V_{GS} = 10V, V_{DS} = 0V	V_{GS} = -10V, V_{DS} = 0V	125	0.0125	0.029	0.002	0.0274	0.0348	0.1
					148*	0.0316	1.583	0.002	0.29[illegible]	0.42[illegible]	
	720K				10	0.0613	0.082	0.042	0.0846	[illegible]	
	913K				10	0.0775	0.118	0.055	0.123	0.145	
	1225K				10	0.110	0.182	0.070	0.197	0.241	
	185K				10	0.292	0.530	0.145	0.619	[illegible]	
		5×10^{12}	V_{GS} = -10V; V_{DS} = 0V	V_{GS} = -10V; V_{DS} = 10V	10	0.128	0.170	0.08	0.193	0.225	
		1×10^{13}			10	0.559	1.1	0.18	1.11	1.39	
I_{DSS_1} (nA)		5×10^{12}		V_{GS} = 0V; V_{DS} = 10V	6	1.96	2.5	1.1	3.0	3.5	
		1×10^{13}			6	1.94	2.5	1.1	2.95	3.45	
I_{DSS_2} (nA)		5×10^{12}			6	1.95	2.5	[illegible]	2.99	3.51	
		1×10^{13}			6	1.92	2.5	[illegible]	2.96	3.48	
									±2σ	±3σ	
I_{DSS_1}/I_{DSS_2}		5×10^{12}			6	1.01	1.033	[illegible]	1.04	1.06	
									0.977	0.963	
		1×10^{13}			6	1.01	1.086	0.980	1.09	1.12	
									0.939	0.902	
									-2σ	-3σ	
V_{GS_1} (V)		5×10^{12}		V_{DS} = 10V; I_D = 300μA	6	-0.943	-0.482	-1.23	-1.48	-1.75	
		1×10^{13}			6	-0.942	-0.478	-1.229	-1.48	-1.75	

* OUTLIERS INCLUDED

AGS

DEVICE TYPE: 2N5196 SILICONIX PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 BRAD.	BIAS: MEAS.							
V_{GS_2} (V)	5×10^{12}	V_{DS} = 10V; V_{GS} = 10V	V_{DS} = 10V; I_D = 300μA	6	-0.944	-0.483	-1.299	-1.48	-1.75	
	1×10^{13}			6	-0.944	-0.486	-1.227	-1.48	-1.75	
$V_{GS_1}-V_{GS_2}$ (V)	5×10^{12}			6	0.001	0.0045	-0.0026	-0.0042	-0.0067	
	1×10^{13}			6	0.0016	0.0078	-0.002	-0.0067	-0.0109	
g_{m_1}	5×10^{12}			6	0.0051	0.0054	0.0048	0.0047	0.0045	
	1×10^{13}			6	0.0050	0.0054	0.0048	0.0047	0.0045	
g_{m_2}	5×10^{12}			6	0.0051	0.0054	0.0048	0.0047	0.0046	
	1×10^{13}			6	0.0051	0.0053	0.0048	0.0047	0.0045	
								±2σ	±3σ	
g_{m_1}/g_{m_2}	5×10^{12}			6	0.995	1.01	0.9897	1.01	1.02	
								0.978	0.[illegible]70	
	1×10^{13}			6	0.997	1.01	0.9804	1.02	1.03	
								0.973	0.962	
								±2σ	±3σ	
Noise Voltage (nV)	5×10^{12}		V_{DS} = 1.5V; I_D = 90μA	12	18.3	26.0	12.0	26.2	32.1	
	1×10^{13}		WC = 300Hz	12	24.0	30.0	19.0	31.4	35.2	

2N5520, Siliconix

DEVICE TYPE: 2N5520 SILICONIX PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Base	5x10¹²	VDS = 5V;	VDS = 5V; ID = 250μA	12	4.75	6.0	3.40	6.47	7.34	
Voltage (V)	1x10¹³	ID = 250μA	f = 300 Hz	12	5.69	6.8	3.60	7.74	8.77	
								-2σ	-3σ	
gm₁ and gm₂	5x10¹²		VDS = 5V; ID = 250μA	12	652	700	610	585	552	
(μmhos)	1x10¹³			12	688	740	646	618	583	
VGS₁ (V)	5x10¹²			6	1.49	2.23	0.759	0.423	-0.11	
↓	1x10¹³			6	1.49	2.23	0.758	0.42	-0.113	
VGS₂ (V)	5x10¹²			6	1.49	2.23	0.756	0.422	-0.111	
↓	1x10¹³			6	1.49	2.23	0.755	0.421	-0.12	
								±2σ	±3σ	
VDS (mV)	5x10¹²		VDS = 5V;	6	0.983	3.8	-1.1	4.79	6.69	
↓			VGS = 0V					-2.82	-4.73	
	1x10¹³			6	0.70	2.9	-2.8	6.02	8.69	
								-4.62	-7.09	
								+2σ	+3σ	
IDSS (mA)	5x10¹²			12	2.39	3.70	1.10	4.16	5.04	
↓	1x10¹³	↓	↓	12	2.39	3.75	1.10	4.17	5.06	

AS

DEVICE TYPE: 2N5520 SILICONIX PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.							
IGSS (nA)	60K	VGS = -10V; VDS = 0V	VGS = -10V; VDS = 0V	10	0.065	0.078	0.052	0.0822	0.0908	
	225K			10	0.114	0.138	0.085	0.151	0.169	
	91.3K			10	0.161	0.195	0.120	0.210	0.235	
	122.5K	↓	↓	10	0.274	0.330	0.204	0.370	0.418	
	e/cm²									
	5x10¹²	VDS = 5V; ID = 250μA	VDS = 5V; ID = 250μA	12	0.221	1.28	0.0055	1.17	1.64	
	rad (Si)									
	185K	VGS = -10V; VDS = 0V	VGS = -10V; VDS = 0V	10	0.691	0.940	0.505	0.987	1.140	
	e/cm²									
↓	1x10¹³	VDS = 5V; ID = 250μA	VDS = 5V; ID = 250μA	12	6.00	50	0.0139	36.6	51.9	

2N5556, Motorola

DEVICE TYPE: 2N5556 MOTOROLA PAGE 1 of 1 — 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
gm (μmhos)	5×10¹²	VDS=9V;	VDS=9V,	6	1910	2111	1744	1570	1410	
↓	1×10¹³	ID=0.5mA	ID=0.5mA	6	1920	2122	1716	1590	1430	
								+2σ	+3σ	
IDSS (mA)	5×10¹²		VDS=9V;	6	1.68	2.34	0.75	3.13	3.86	
↓	1×10¹³	↓	VGS=0V	6	1.65	2.31	0.75	3.11	3.83	
	rad(Si)									
IGSS (nA)	60K	VGS=-15V	VGS=-15V;	70	0.0207	0.2190	-0.010	0.1836	0.2395	
	↓	VDS=0V	VDS=0V	96	4.09	86.54	-0.010	30.7	43.9	
	225K			4	0.196	0.278	0.150	0.311	0.368	
	91.3K			4	0.312	0.420	0.188	0.549	0.668	
	122.5K	↓	↓	4	0.588	0.950	0.280	1.150	1.490	
	5×10¹² e/cm²	VDS=9V, ID=0.5mA	VDS=9V, ID=0.5mA	6	0.0507	0.112	0.03	0.111	0.142	
	rad(Si)									
	185K	VGS=15V, VDS=0V	VGS=15V, VDS=0V	4	1.320	2.342	0.480	2.920	3.270	
↓	1×10¹³ e/cm²	VDS=9V, ID=0.5mA	VDS=9V, ID=0.5mA	6	0.5	2.1	0.11	2.07	2.85	
Noise	5×10¹²		VDS=9V, ID=0.5mA	6	34.3	36.0	32.0	37.6	39.2	
Voltage (nV)	1×10¹³		10 Hz	6	39.3	46.0	34.0	48.7	53.4	
Noise	5×10¹²		VDS=9V, ID=0.5mA	6	29.2	27.0	19.0	30.4	33.5	
Voltage (nV)	1×10¹³		100 Hz	6	20.2	32.0	11.0	34.9	39.2	
AG Noise	5×10¹²		VDS=9V, ID=0.5mA	6	10.1	12.0	8.0	13.1	14.6	
Voltage (nV)	1×10¹³	↓	1 KHz	6	11.2	12.0	9.0	13.8	15.2	

2N5906, Siliconix

DEVICE TYPE: 2N5906 SILICONIX PAGE 1 of 1 — 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
IGS (nA)	5×10¹²	VDS=15V, ID=50μA	VDS=15V, ID=50μA	11	0.0467	0.032	0.011	0.0816	0.0945	
↓	1×10¹³		↓	11	0.0692	0.105	0.043	0.124	0.121	
VGS (V)	5×10¹²		VDS=15V, ID=50μA	11	1.18	2.011	0.573	2.35	2.94	
↓	1×10¹³		↓	11	1.18	2.014	0.573	2.35	2.94	
GFS (μmhos)	5×10¹²		VDS 15V, ID=50μA	11	116	125	108.25	126	131	
↓	1×10¹³	↓	↓	11	115	125	108.13	126	131	
AG										

VCR3P, Siliconix

DEVICE TYPE: VCR3P SILICONIX PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	/Mean/ $\pm\sigma$	/Mean/ $\pm\sigma$	Accept Reject Criteria
	e/cm^2	BIAS: IRRAD.	BIAS: MEAS.							
I_D (mA)	5×10^{12}	$V_{DS}=0$, $V_{GS}=-1.5V$	$V_{DS}=0.1V$, $V_{GS}=0$	6	-1.08	-0.88	-1.32	1.48	1.69	
↓	1×10^{13}		↓	6	-1.09	-0.90	-1.33	1.49	1.69	
I_D (mA)	5×10^{12}		$V_{DS}=0.1V$; $V_{GS}=1.5V$	6	-0.668	-0.54	-0.82	0.906	1.03	
↓	1×10^{13}		↓	6	-0.682	-0.55	-0.83	0.919	1.04	
I_D (mA)	5×10^{12}		$V_{DS}=0.1V$; $V_{GS}=3V$	6	-0.271	-0.13	-0.41	0.453	0.545	
↓	1×10^{13}		↓	6	-0.276	-0.132	-0.415	0.462	0.555	
I_D (mA)	5×10^{12}		$V_{DS}=-0.1V$, $V_{GS}=0$	6	1.05	1.29	0.85	1.46	1.67	
↓	1×10^{13}		↓	6	1.06	0.86	1.3	1.48	1.69	
I_D (mA)	5×10^{12}		$V_{DS}=-0.1V$; $V_{GS}=1.5V$	6	0.645	0.790	0.520	0.869	0.981	
↓	1×10^{13}		↓	6	0.652	0.80	0.520	0.884	1.0	
I_D (mA)	5×10^{12}		$V_{DS}=-0.1V$; $V_{GS}=3V$	6	0.245	0.400	0.098	0.441	0.538	
↓	1×10^{13}	↓	↓	6	0.247	0.40	0.10	0.441	0.538	

NS

C. INTEGRATED CIRCUITS

AD550, Analog Devices

The data presented are device linearity deltas; i.e., the effects of LSB current changes are subtracted out of the data. For total error for any given bit, the ΔI_{LSB} must be multiplied by the bit weighting and added to the value shown in the data. Parameter ΔV_{BE} was not stable due to servo loop biasing and collector-base leakage current problems. Parameters ΔV_{BE} and $\Delta(1/B)$ are for the DUT reference transistor.

DEVICE TYPE: AD550 ANALOG DEVICES PAGE 2 of 4 — 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	#/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔI_{LSB}	2.5×10¹²	I_{REF} = 0.125 mA	I_{REF} = 0.125 mA	5	-0.146	-0.11	-0.21	-0.0678	-0.0987	
(μA)	↓	EMITTER RES @ 15V	EMITTER RES @ 15V					-0.2242	-0.9633	
	5×10¹²	V+ = 5V, ALL CURRENT	V+ = 5V	5	-0.274	-0.18	-0.42	-0.0858	0.0338	
	↓	SWITCHES IN DUT						-0.4592	-0.6618	
	1×10¹³	ABS OFF, OUTPUT 1KΩ		5	-0.456	-0.27	-0.57	-0.2128	-0.0912	
	↓	to GND						-0.1892	-0.8308	
ΔI_{BIT3}	2.5×10¹²			5	-0.012	0.04	-0.13	0.1276	0.1974	
(μA)	↓							-0.1516	-0.2214	
	5×10¹²			5	0.012	0.05	-0.03	0.0726	0.1029	
	↓							-0.0486	-0.0789	
	1×10¹³			5	0.030	0.08	-0.02	0.11	0.15	
	↓							-0.05	-0.09	
ΔI_{BIT2}	2.5×10¹²			5	-0.050	0.09	-0.33	0.2795	0.4444	
(μA)	↓							-0.3796	-0.5444	
	5×10¹²			5	-0.020	0.07	-0.17	0.1774	0.2761	
	↓							-0.2174	-0.3161	
	1×10¹³			5	-0.044	0.03	-0.11	0.0928	0.1612	
	↓							-0.1808	-0.2492	

DEVICE TYPE: AD550 ANALOG DEVICES PAGE 3 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔI_{BIT}	2.5×10^{12}	I_{REF} = 0.125 mA	I_{REF} = 0.125 mA	5	-0.012	+0.20	-0.17	0.2922	0.4413	
(μA)	↓	EMITTER RES. @ -15V	EMITTER RES. @ -15V					-0.3162	-0.4683	
	5×10^{12}	V+ = 5V; ALL CURRENT	V+ = 5V	5	-0.082	+0.15	-0.30	0.3078	0.5027	
	↓	SWITCHES IN DUT ARE						-0.4718	-0.6667	
	1×10^{13}	OFF, OUTPUT 1KΩ to		5	-0.412	-0.03	-1.22	0.5372	1.0118	
	↓	GND.						-1.3612	-1.8358	
ΔI_L (nA)	2.5×10^{12}			5	1.2032	2.8	0.70	2.9994	3.3975	
	↓							-0.5930	-1.4911	
	5×10^{12}			5	2.4432	6.406	0.20	7.1444	9.495	
	↓							-2.258	-4.6086	
	1×10^{13}			5	12.973	45.906	2.30	50.067	68.614	
	↓							-24.121	-42.668	
ΔV_{BE}	2.5×10^{12}			5	+0.53	+2.01	-1.12	3.23	4.58	
(mV)	↓							-2.17	-3.52	
	5×10^{12}			5	+0.56	+2.05	-1.16	3.06	4.31	
	↓							-1.94	-3.19	
	1×10^{13}			5	+0.68	+1.93	-0.19	2.22	2.99	
	↓	↓	↓					-0.86	-1.63	

DEVICE TYPE: AD550 ANALOG DEVICES PAGE 4 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
$\Delta(1/\beta)$	2.5×10^{12}	I_{REF} = 0.125 mA	I_{REF} = 0.125 mA	5	6.21	7.79	3.40	9.83	11.64	
($\times10^{-4}$)	↓	EMITTER RES. @ -15V	EMITTER RES. @ -15V					2.59	0.78	
	5×10^{12}	V+ = 5V, ALL CURRENT	V+ = 5V	5	10.0	12.2	5.62	15.32	17.98	
	↓	SWITCHES IN DUT						4.68	2.02	
	1×10^{13}	ARE OFF; OUTPUT 1KΩ		5	15.5	18.6	9.05	23.48	26.87	
↓	↓	to GND	↓					7.92	4.13	

DAC-01, Precision Monolithics

DEVICE TYPE: DAC-01 PMI 1 of 2 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
Bipolar Zero	5×10¹¹	V=±15V	L1, L2, L3, L4	3	-0.0667	-0.0532	-0.0994	-0.0408	-0.0274	
Scale Offset	↓		0 1 1 1					-0.0879	-0.106	
(+) (V)	1×10¹²			3	-0.0983	-0.0692	-0.1219	-0.0417	-0.0179	
	↓							-0.152	-0.179	
	2.5×10¹²			3	-0.113	-0.222	-0.1942	0.0595	0.146	
	↓							-0.286	-0.373	
	5×10¹²			6	-0.0562	0.1227	-0.2960	0.259	0.417	
	↓							-0.372	-0.53	
	1×10¹³			3	0.0525	0.1945	-0.115	0.365	0.521	
↓	↓	↓	↓					-0.26	-0.416	
Δ										
Bipolar Zero	5×10¹¹		L1, L2, L3, L4	3	0.0653	0.0778	0.0518	0.0913	0.104	
Scale Offset	↓		1 0 0 0					0.0392	0.0262	
(-) (V)	1×10¹²			3	0.0657	0.1202	0.0101	0.176	0.231	
	↓							-0.0444	-0.0994	
	2.5×10¹²			3	0.11	0.1912	0.0211	0.281	0.366	
	↓							-0.0605	-0.146	
	5×10¹²			6	0.049	0.2803	-0.1276	0.366	0.525	
	↓							-0.268	-0.427	
	1×10¹³			3	-0.0292	0.1147	-0.1238	0.224	0.351	
↓	↓	↓	↓					-0.282	-0.409	
NGS										

DEVICE TYPE: DAC-01 PMI 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
Δ	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
Full Scale	5×10¹¹	V=±15V	L1, L2, L3, L4	3	-0.0787	-0.0625	-0.0893	-0.0568	-0.0459	
Voltage (Vss)	↓		0 0 0 0					-0.1	-0.111	
(+) (V)	1×10¹²			3	-0.111	-0.087	-0.1265	-0.0689	-0.048	
	↓							-0.152	-0.123	
	2.5×10¹²			3	-0.135	-0.051	-0.2123	0.0268	0.108	
	↓							-0.297	-0.377	
	5×10¹²			6	-0.0883	0.0766	-0.3116	0.204	0.35	
	↓							-0.38	-0.526	
	1×10¹³			3	-0.164	0.1313	-0.6492	0.683	1.11	
↓	↓	↓	↓					-1.01	-1.43	
Δ										
Full Scale	5×10¹¹		L1, L2, L3, L4	3	0.0549	0.0679	0.0405	0.0825	0.0962	
Voltage (Vss)	↓		1 1 1 1					0.0274	0.0137	
(-) (V)	1×10¹²			3	0.0809	0.1058	0.0505	0.137	0.165	
	↓							0.0248	-0.0033	
	2.5×10¹²			3	0.0912	0.1739	-0.0003	0.266	0.354	
	↓							-0.0831	-0.171	
	5×10¹²			6	0.0321	0.2202	-0.1413	0.345	0.502	
	↓							-0.281	-0.438	
	1×10¹³			3	-0.0771	0.0888	-0.2085	0.226	0.378	
↓	↓	↓	↓					-0.38	-0.532	

DG125, Siliconix

DEVICE TYPE: DG 125 SILICONIX PAGE 1 of 2 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: 1 RAD.	BIAS: MEAS.							
IS(OFF)(nA)		S=10V; D=-10V; VEE=-20V; VCC=10V; VL=4.5V								
	0	IN1,IN2,IN3=0V(OFF)	VS=-10V; VD=10V	6	0.150	0.280	0.060			
	5x10¹²	IN4,IN5=4V(ON)	VIN=4.1V	6	0.740	2	0.290	2	2.62	
	1x10¹³	IN=0V(OFF)		6	1.06	1.70	0.70	2	2.47	
IS(OFF)(nA)	0	IN=4V(ON)	VS=-10V; VD=10V	6	0.158	0.260	0.090			
	5x10¹²		VIN=4.1V	6	1.15	2.10	0.460	2.64	3.38	
	1x10¹³			6	1.58	2.25	1.10	2.33	2.70	
ID(OFF)(nA)	0	IN=0V(OFF)	VD=-10V; VS=10V;	6	0.15	0.24	0.11			
	5x10¹²		VIN=4.1V	6	4.45	8.30	1.70	10.40	13.30	
	1x10¹³			6	6.53	10	4.40	10.50	12.50	
ID(OFF)(nA)	0	IN=4V(ON)	VD=10V; VS=10V	6	0.145	0.240	0.110			
	5x10¹²		VIN=4.1V	6	4.32	8.30	0.84	10.50	13.20	
	1x10¹³			6	6.05	9.80	4.20	10.20	12.30	
ID(on)+IS(on) (nA)	0	IN=0V(OFF)	VD=10V; IS=0	6	-0.237	-0.140	-0.320			
	5x10¹²		VIN=0.5V	6	0.560	1	-0.070	1.42	1.84	
	1x10¹³			6	1.33	2.60	0.40	3.02	3.87	

DEVICE TYPE: DG 125 SILICONIX PAGE 2 of 2 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: 1 RAD.	BIAS: MEAS.							
IN(on)+IS(on) (nA)		S=-10V; D=-10V; VEE=-20V; VCC=10V; VL=4.5V								
	0	IN1,IN2,IN3=0V(OFF)	VD=10V; IS=0	6	-0.222	-0.120	-0.280			
	5x10¹²	IN1,IN2,IN3=4V(ON)	VIN=0.5V	6	0.657	1.20	-0.040	1.63	2.12	
	1x10¹³	IN=4V(ON)		6	1.33	2.50	0.50	2.87	3.64	
rDS(on)-(Ω)	0	IN=0V(OFF)	VD=-10V; IS=-1mA	6	18.9	21.1	17.5			
	5x10¹²		VIN=0.5V	6	23	32	15.3	38.3	45.9	
	1x10¹³			6	376	555.7	104.6	737	917	
rDS(on)-(Ω)	0	IN=4V(ON)	VD=10V; IS=-1mA	6	18.8	20.5	16.7			
	5x10¹²		VIN=0.5V	6	33.4	58.5	5.7	77.5	99.6	
	1x10¹³			6	463	658.9	280.8	767	918	
rDS(on)(Ω)	0	IN=0V(OFF)	VD=10V; IS=1mA	6	6.12	6.30	5.90			
	5x10¹²		VIN=0.5V	6	7.23	7.70	7	7.78	8.05	
	1x10¹³			6	7.75	8.70	7	9.42	10.30	
rDS(on)(Ω)	0	IN=4V(ON)	VD=10V; IS=1mA	6	6.35	7.10	5.80			
	5x10¹²		VIN=0.5V	6	8.83	11.40	6.70	12.60	14.50	
	1x10¹³			6	8.72	10.90	5.20	12.70	14.70	

DG129, Siliconix

DEVICE TYPE: DG 129 SILICONIX PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	|Mean/ +σ|	|Mean/ +σ|	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
		D=S=10V; VB=0V; VCC=12V, VEE=-18V								
I_S(off)(nA)	5×10¹²	IN=0V	VS=10V, VD=10V	11	-1.05	-0.68	-1.5	1.66	1.97	
↓	1×10¹³	↓	VIN=0.8V	11	-2.25	-1.6	-3.1	3.16	3.62	
I_S(off)(nA)	50K rad	IN=+4V		95	0.2201	0.71	0	0.8177	1.1165	
	5×10¹²			10	-12.5	-15	-23	22.15	24.46	
↓	1×10¹³	↓	↓	10	-53.1	-44	-70	68.69	76.49	
I_D(off)(nA)	5×10¹²	IN=0V	VD=10V; VS=-10V;	11	-1.01	-0.61	-1.5	1.68	2.01	
↓	1×10¹³	↓	VIN=0.8V	11	-2.22	-1.6	-3.0	3.16	3.68	
I_D(off)(nA)	100K rad	IN=+4V		16	0.854	1.5	0.118	1.82	2.31	
	5×10¹²			10	-19.5	-14	-25	27.17	31.01	
↓	1×10¹³	↓	↓	10	-58.3	-47	-74	80.83	92.09	
								mean +3σ	mean +3σ	
I_S(on)+I_D(on)	5×10¹²	IN=0V	VD=VS=-10V	11	0.484	0.72	0.32	0.734	0.855	
(nA)	1×10¹³	↓	VIN=2.5V	11	0.754	1.1	0.57	1.15	1.34	
I_S(on)+I_D(on)	5×10¹²	IN=4V		10	0.76	2.50	0.41	2.03	2.66	
(nA)	1×10¹³	↓	↓	10	1.37	5.00	0.60	3.99	5.23	

DEVICE TYPE: DG 129 SILICONIX PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
		D=S=10V; VB=0V; VCC=12V, VEE=-18V								
r_{DS} (ON)	5×10¹²	IN=0V	VD=10V; IS=10mA	11	27.41	33.10	24.2	33.49	36.53	
(Ω)	1×10¹³	↓	VIN=2.5V	11	27.19	31.1	24.3	32	34.4	
r_{DS} (ON)	5×10¹²	IN=+4V		11	26.3	34.1	9.98	38.2	44.2	
(Ω)	1×10¹³	↓	↓	11	26.0	32.3	9.98	32.8	43.7	

DG129, Siliconix, IRAN reirradiation

IRAN Reirradiation

DEVICE TYPE: DG129 Siliconix pg 1 of 1 IRAN Fluence 50krad(Si) Co^{60} 3 IRAN

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Is(off)	.4×10¹¹	D:S=10V; IN=4V	Vs=10V; VD=10V	23	142.0	240.0	98.0	219.0	257.0	≤3 nA
(pA)	↓	VR=0V; VCC=12V	VIN=0.8V							
		VEE=18V								
	1.2×10¹²			23	251.0	330.0	175.0	344.0	390.0	
	↓									
	2.4×10¹²			23	584.0	865.0	290.0	958.0	1150.0	
	↓									
	4×10¹²			23	1290.0	2100.0	510.0	2340.0	2870.0	
↓	↓	↓	↓							↓

AGS

DG133, Siliconix

DEVICE TYPE: DG133 SILICONIX PAGE 1 of 4 3

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	/Mean/ +2σ/	/Mean/ +3σ/	Accept Reject Criteria
	rad(Si)	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
			D=S=10V, VR=0V								
			VEE=-18V; VCC=+12V								
Is(OFF)(nA)		5×10¹²	IN=0V	VS=10V; VD=-10V	6	-0.732	-0.30	-1.5	1.85	2.41	
↓		1×10¹³	↓	VIN=0.8V	6	-2.22	-0.90	-5.0	5.95	7.81	
Is(OFF)(nA)	50K		IN=-4V		91	0.0747	0.34	-0.16	0.352	0.491	
	100K				8	0.9025	1.25	0.62	1.38	1.62	
		5×10¹²			6	-7.83	-7.0	-8.7	9.28	9.96	
↓		1×10¹³	↓	↓	6	-26.9	-19.0	-30.5	35.6	39.9	
Is(OFF)(nA)		5×10¹²	IN=0V	VS=-10V; VD=10V	6	-0.612	-0.22	-1.4	1.69	2.22	
↓		1×10¹³	↓	VIN=-0.8V	6	-1.23	-0.4	-3.8	3.77	5.04	
Is(OFF)(nA)		5×10¹²	IN=-4V		6	-7.22	-6.4	-8.0	8.56	9.23	
↓		1×10¹³	↓	↓	6	-26.6	-18.5	-32	37.7	43.2	
Is(ON)+Id(ON)		5×10¹²	IN=0V	VD=VS=-10V;	6	0.27	0.38	0.13	0.431	0.51	
(nA)		1×10¹³	↓	VIN=-0.5V	6	0.54	0.9	0.2	0.985	1.21	
Is(ON)+Id(ON)		5×10¹²	IN=-4V		6	0.453	0.52	0.27	0.576	0.687	
(nA)		1×10¹³	↓	↓	6	0.883	1.2	0.74	1.23	1.4	

AGS

DEVICE TYPE: DG133 Siliconix PAGE 2 of 4 3

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
$r_{DS(on)}$ (Ω)	0	BIAS: IRRAD. D=S=10V	BIAS: MEAS. VD=10V	6	26.8	27.8	25.4			
	5×10^{12}	VGEX=-18V; VCC=+10V	IS=-10mA	6	27.2	28.2	26.3	28.8	29.5	
		VR=0V	VIN=2.5V							
	1×10^{13}	IN¹=0V(on)		6	27.1	29.0	23.8	31	33	
$r_{DS(on)}$ (Ω)	0	IN²=+4V(on)	VD=10V IS=-10mA	6	26.7	27.7	26			
	5×10^{12}		VIN=2.5V	6	28.3	30.5	26.5	31.1	32.9	
	1×10^{13}			6	28.3	29.8	26.7	30.6	31.7	

DEVICE TYPE: DG133 SILICONIX PAGE 3 of 4 3

*Parameter	Fluence e/cm²	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / MEAN -2σ	Mean +3σ / MEAN -3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
$I_{DS(OFF)}$ 10⁻⁹A	0	D=S=10V; IK=0V; VCE=+12V; VCX=-18V; IN¹=0V(on)	VD=+10V; IN¹=0V	6	1640	2500	1110			
	1×10^{13}			6	27.8	41.6	11.8	3.37		
$I_{DS(OFF)}$ 10⁻⁹A	0	IN²=+4V(on)	VD=+10V; IN²=+4V	6	2680	10000	830			
	1×10^{13}			6	3.22	5.30	2.20	0.306		
$I_{DS(OFF)}$ 10⁻⁹A	0		VD=-10V; IN¹=0V	6	2210	3530	1250			
	1×10^{13}			6	29.7	43.5	13.5	3.86		
$I_{DS(OFF)}$ 10⁻⁹A	0		VD=-10V; IN²=+4V	6	1420	2000	900	654		
	1×10^{13}			6	2.65	4.20	1.90	0.399		
V_{IN}(min)(V)	0		VD=-10V; IN¹=0V	6	1.49	1.52	1.46	MEAN +2σ	MEAN +3σ	
	1×10^{13}			6	1.53	1.56	1.49	1.59	1.62	
V_{IN}(min)(V)	0		VD=-10V; IN²=+4V	6	1.57	1.96	1.46			
	1×10^{13}			6	1.52	1.54	1.48	1.57	1.59	
V_{IN}(max)(V)	0		VD=+10V; IN¹=0V	6	1.61	1.70	1.54			
	1×10^{13}			6	1.69	1.75	1.61	1.82	1.88	
V_{IN}(max)(V)	0		VD=10V; IN²=+4V	6	1.59	1.64	1.53			
	1×10^{13}			6	1.66	1.69	1.59	1.74	1.79	

* MEASURED AT END OF EXPERIMENT

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

DEVICE TYPE: DG133 SILICONIX PAGE 4 of 4 3

*Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ / Mean -2σ	Mean -3σ / Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
V_{IN}(max)(V)	0	D=S=+10V; V_{CC}=0V	V_D=-10V; IN^1=0V	6	1.96	2.14	1.78			
↓	1×10^{13}	V_{CC}=+12V; V_{EE}=-18V	↓	6	1.57	1.59	1.53	1.51	1.48	
		IN^1=0V OFF								
V_{IN}(max)(V)	0	IN^2=+4V ON	V_D=-10V; IN^2=+4V	6	2.02	2.46	1.74			
↓	1×10^{13}		↓	6	1.54	1.57	1.45	1.44	[illegible]	
V_{IN}(max)(V)	0		V_D=-10V; IN^1=0V	6	2.66	3.06	2.03			
↓	1×10^{13}		↓	6	1.68	1.76	1.58	1.52	1.44	
V_{IN}(max)(V)	0		V_D=-10V; IN^2=+4V	6	2.88	3.97	1.96			
↓	1×10^{13}	↓	↓	6	1.64	1.68	1.56	1.54	1.48	

* MEASURED AT END OF EXPERIMENT

DG133, Siliconix, IRAN reirradiation

IRAN Reirradiation

DEVICE TYPE: DG133 Siliconix pg 1 of 1 IRAN Fluence 50 krad (Si) Co^{60} 3 IRAN

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
I_S (off)	$.5\times10^{12}$	D=S=10V; I_N=4V	V_S=10V; V_D=-10V	12	36.4	56.0	17.3	60.9	73.1	<3nA
(pA)	↓	V_R=0V; V_{CC}=12V	V_{IN}=0.8V							
		V_{EE}=-18V								
	1.25×10^{12}			12	319.0	410.0	115.0	507.0	601.0	
	↓									
	2.39×10^{12}			12	684.0	930.0	146.0	1180.0	1430.0	
	↓									
	5×10^{12}			12	2040.0	2750.0	263.0	3690.0	4510.0	
↓	↓	↓	↓							

AGS

DG141, Siliconix

DEVICE TYPE: DG141 SILICONIX PAGE 1 OF 2 3

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
			D-S=10V, VR=0V								
			VEE=-18V, VCC=12V								
$I_{S(OFF)}$ (nA)		5×10^{12}	IN=0V	VS=10V, VD=-10V	6	2.48	3.9	1.5	4.18	5.02	
↓		1×10^{13}	↓	VIN=0.8V	6	6.27	7.3	4.7	8.34	9.38	
$I_{S(OFF)}$ (nA)	50K		IN=+4V	↓	29	0.368	0.910	0.135	0.821	1.018	
↓		5×10^{12}	↓	↓	6	51.7	63	40	69.2	78	
	125K				7	2.15	3.0	0.46	3.75	4.55	
↓		1×10^{13}	↓	↓	6	154	200	46	270	327	
$I_{D(OFF)}$ (nA)		5×10^{12}	IN=0V	VD=10V; VS=-10V	6	2.42	3.9	1.5	4.17	5.05	
		1×10^{13}	↓	VIN=0.8V	6	6.93	12	4.5	12.3	15.1	
$I_{D(OFF)}$ (nA)		5×10^{12}	IN=+4V	↓	6	42.8	51	34	56.1	62.7	
↓		1×10^{13}	↓	↓	6	141	160	120	171	186	
$I_{S(ON)}+I_{D(ON)}$ (μA)		5×10^{12}	IN=0V	VD=VS=-10V	6	0.295	0.37	0.20	0.42	0.485	
		1×10^{13}	↓	VIN=2.5V	6	0.60	0.77	0.42	0.855	0.983	
$I_{S(ON)}+I_{D(ON)}$ (nA)		5×10^{12}	IN=+4V	↓	6	0.537	0.67	0.33	0.79	0.917	
		1×10^{13}	↓	↓	6	1.21	1.6	0.77	1.9	2.27	

DEVICE TYPE: DG141 SILICONIX PAGE 2 OF 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
		D-S=10V, VR=0V								
		VEE=-18V, VCC=12V								
$r_{DS(ON)}$ (Ω)	5×10^{12}	IN=0V	VD=10V, IS=-10mA	6	8.25	9.1	7.3	9.71	10.4	
	1×10^{13}	↓	VIN=2.5V	6	8.38	9.1	7.3	10.1	10.9	
$r_{DS(ON)}$ (Ω)	5×10^{12}	IN=+4V	↓	6	7.8	8.1	7.3	8.42	8.73	
	1×10^{13}	↓	↓	6	7.85	8.2	7.1	8.5	8.83	

DG141, Siliconix, IRAN reirradiation

IRAN Reirradiation

DEVICE TYPE: DG141 Siliconix page 1 of 1 IRAN Fluence 50 krad (Si) Co^{60} 3 IRAN

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	|Mean| +2σ	|Mean| +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
I_S (off)	$.5\times10^{12}$	D:S:10V; IN:4V	V_S=10V; V_D=10V	11	0.324	0.48	0.086	0.568	0.687	45nA
(nA)	↓	V_{RS}=10V; V_{CC}=12V	V_{IN}=0.8V							
		V_{EE}=-18V								
	1.25×10^{12}			11	0.729	1.2	0.115	1.31	1.6	
	↓									
	2.5×10^{12}			11	1.57	2.8	0.215	2.72	3.35	
	↓									
	5×10^{12}			11	3.09	5.3	0.41	5.87	7.27	
	↓	↓	↓							↓

A/S

DG181, Intersil

DEVICE TYPE: DG181 INTERSIL PAGE 1 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	|Mean| +2σ	|Mean| +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS							
		S_1=10K to -10V		* ALL DEVICES LATCHED IN OFF POSITION						
		S_2=10K to +10V		** ONE DEVICE LATCHED IN OFF POSITION						
		D_1, D_2=300Ω to GND		*** ONE DEVICE LATCHED IN ON POSITION						
		V_{CC}=+5V, V_{EE}=-15V		OTHERS LATCHED IN OFF POSITION						
		V_{IN}=+5V, V_D=GND								
I_S(OFF)	2.5×10^{11}	V_{IN}=5V	V_S=10V, V_D=-10V	4	-0.093	-0.015	-0.027	0.0301	0.0356	
(nA)	5×10^{11}		V_{CC}=10V; V_{EE}=-10V	4	-0.0403	-0.025	-0.05	0.0622	0.0731	
	* 1×10^{12}		V_{IN}=3V	4	-0.097	-0.046	-0.14	0.180	0.222	
	** 2.5×10^{12}	↓		4	-1.15mA	-1.1mA	-1.2mA	1.27mA	1.32mA	
I_D(OFF)	2.5×10^{11}	V_{IN}=0		6	-0.0417	-0.008	-0.16	0.158	0.217	
(nA)	** 5×10^{11}			6	-0.0223	-0.023	-0.034	0.0344	0.04[illegible]	
	* 1×10^{12}			6	-0.0517	-0.042	-0.06	0.0671	0.0749	
	*** 2.5×10^{12}	↓	↓	6	-1.06mA	-1mA	-1.1mA	1.13mA	1.17mA	
$I_{D(OFF)}$	2.5×10^{11}	V_{IN}=5V	V_S=10V, V_D=10V	4	0.033	-0.031	-0.036	0.0373	0.0395	
(nA)	5×10^{11}		V_{CC}=10V, V_{EE}=-20V	4	-0.05	-0.042	-0.062	0.0682	0.0723	
	* 1×10^{12}		V_{IN}=3V	4	-0.135	-0.11	-0.17	0.188	0.214	
	*** 2.5×10^{12}	↓		4	-1.0mA	-1.0mA	-1.0mA	1mA	1mA	
I_D (OFF)	2.5×10^{11}	V_{IN}=0		6	-0.0202	-0.012	-0.032	0.0353	0.0428	
(nA)	** 5×10^{11}			6	-0.0402	-0.034	-0.048	0.0516	0.0574	
	* 1×10^{12}			6	-0.0517	-0.042	-0.06	0.0671	0.0749	
	*** 2.5×10^{12}	↓	↓	6	-1mA	-1mA	-1mA	1mA	1mA	

DEVICE TYPE: DG181 INIT. RSIL PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
		S₁=10KΩ to -10V								
		S₂=10KΩ to +10V								
		D₁=D₂=3000Ω to GND								
		Vcc=+15V; Vee=-15V								
		V₁=+5V; V₂=GND								
$I_{S(on)}+I_{D(on)}$	2.5×10¹¹	V_{IN}=5V	$V_D=V_S$=-7.5V	4	1.92	4.5	0.07	6.32	8.52	
(nA)	5×10¹¹		V_{IN}=0.8V	4	0.513	0.7	0.4	0.782	0.925	
	1×10¹²			4	-0.013	0.006	-0.05	0.0382	0.0638	
	2.5×10¹²			4	0.25	0.3	0.2	0.33	0.375	
$I_{S(on)}+I_{D(on)}$	2.5×10¹¹	V_{IN}=0		6	0.0847	0.1	0.074	0.104	0.113	
	5×10¹¹			6	0.208	0.38	-0.03	0.521	0.677	
	1×10¹²			6	0.0505	0.07	-0.034	0.0856	0.103	
	2.5×10¹²			6	0.257	0.3	0.21	0.324	0.358	
$r_{DS(on)}$	2.5×10¹¹	V_{IN}=5V	V_D=-7.5V; I_D=10mA	4	32.5	42.5	25.5	46	55.2	
(Ω)	5×10¹¹		V_{IN}=0.8V	4	41	70	30.9	79.7	99	
	1×10¹²			4	26.9	30.9	21.8	34.4	38.2	
	2.5×10¹²			4	28.7	29.9	27.7	30.7	31.6	
$r_{DS(on)}$	2.5×10¹¹	V_{IN}=0		6	25	27.5	23.4	28.8	30.5	
(Ω)	5×10¹¹			6		748.2	25.3	1100	1390	
	1×10¹²			6	748	748	748	748	748	
	2.5×10¹²			6	29.7	33.1	27.1	34.4	36.7	

DG181, Siliconix

DEVICE TYPE: DG181 SILICONIX PAGE 1 of 3 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	|Mean| +2σ	|Mean| +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
		S₁=S₂=10K to -10V								
		D₁=D₂=3000Ω to GND								
		Vcc=+15V; Vee=-15V								
		V₁=+5V; V₂=GND								
I_B (OFF)	2.5×10¹¹	V_{IN}=5V	V_S=-10V; V_D=-10V,	6	-0.187	-0.12	-0.213	0.265	0.305	
(nA)	5×10¹¹		Vcc=+10V, Vee=-20V	6	-0.288	-0.18	-0.316	0.425	0.494	
	1×10¹²		V_{IN}=3V	6	-0.523	-0.316	-0.68	0.763	0.882	
	2.5×10¹²			6	-2.88	-1.7	-5.6	5.76	7.19	
I_S (OFF)	2.5×10¹¹	V_{IN}=0V		4	-0.133	-0.09	-0.16	0.201	0.235	
(nA)	5×10¹¹			4	-0.163	-0.11	-0.21	0.254	0.300	
	1×10¹²			4	-0.243	-0.16	-0.31	0.382	0.452	
	2.5×10¹²			4	-0.54	-0.28	-1.24	1.01	1.25	
I_S (OFF)	4.5×10¹³	V_{IN}=0V	V_S=10V, V_D=-10V	4	-4290	-57	-13000	16100	22100	
(nA)	1×10¹³		Vcc=10V, Vee=-20V	4	-9270	-1900	-16,000	23800	31100	
			V_{IN}=2V							
I_S (OFF)	4.5×10¹³	V_{IN}=+1V		4	-2840	-53	-8000	9940	13500	
(nA)	1×10¹³			4	-8970	-1900	-22000	27100	30[illegible]	
I_D (OFF)	2.5×10¹¹	V_{IN}=5V	V_S=-10V, V_D=10V	6	0.152	0.036	-0.056	0.0598	[illegible]	
(nA)	5×10¹¹		Vcc=10V, Vee=-20V	6	-0.09	-0.07	-0.11	0.121	[illegible]	
	1×10¹²		V_{IN}=3V	6	0.22	0.17	0.27	0.298	[illegible]	
	2.5×10¹²			6	3.46	0.084	-1.15	1.65	2.05	

DEVICE TYPE: DG181 SILICONIX PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	|Mean| / σ	|Mean| / σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
		S1=S2=5 to 10V								
		D1=D2=300Ω to GND								
		Vcc=15V, Vee=-15V								
		VA=-5V, VB=GND								
I_D(OFF)	2.5×10¹¹	VIN=0	VS=10V, VD=10V	4	-0.0295	-0.026	-0.032	0.0355	0.0385	
(μA)	5×10¹¹		Vcc=10V, Vee=-10V	4	-0.0503	-0.041	-0.064	0.0721	0.083	
	1×10¹²		VIN=3V	4	-0.0938	-0.065	-0.12	0.145	0.171	
	2.5×10¹²			4	-0.159	-0.095	-0.21	0.057	0.326	
I_D(OFF)	2.5×10¹³	VIN=0	VS=10V, VD=10V;	4	-0.605	-0.2	-1.7	2.07	2.8	
(nA)	1×10¹³		Vcc=10V, Vee=-2V	4	-1.39	-0.61	-3.0	3.63	4.74	
			VIN=2V							
I_S(OFF)	2.5×10¹²	VIN=-4V		4	-5.58	-3.5	-9.5	11.0	13.7	
(nA)	1×10¹³			4	-29.3	-25	-38	46.2	47.1	
								mean/σ	mean/σ	
I_S(on)-I_D(on)	2.5×10¹¹	IN=5V	VD=VS=-7.5V,	6	0.0237	0.065	-0.01	0.0297	0.108	
(μA)	5×10¹¹		VIN=0.8V	6	0.0326	0.09	-0.006	0.104	0.14	
	1×10¹²			6	0.062	0.14	0.005	0.164	0.216	
	2.5×10¹²			6	0.118	0.25	-0.02	0.332	0.439	
I_S(on)-I_D(on)	2.5×10¹³	VIN=-4V		4	0.0385	0.05	0.028	0.0568	0.059	
(μA)	5×10¹³			4	0.0785	0.065	0.03	0.0785	0.096	
	1×10¹⁴			4	0.103	0.14	0.07	0.169	0.20	
	2.5×10¹⁴			4	0.548	0.67	0.44	0.772	0.82	

DEVICE TYPE: DG181 SILICONIX PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	|Mean| / σ	|Mean| / σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
		S1=S2=10 to 10V								
		D1=D2=300Ω to GND								
		Vcc=15V, Vee=-15V								
		VA=-5V, VB=GND								
I_S(on)-I_D(on)	4.5×10¹²	VIN=0	VD=VS=-7.5V;	4	-3270	-1.3	-10,000	12400	17000	
(nA)	1×10¹³		VIN=0.8V	4	-15,700	-690	-35,000	44100	58400	
								mean/σ	mean/σ	
I_S(on)-I_D(on)	4.5×10¹²	VIN=-4V		4	-548	-7.1	-1700	1020	1800	
(nA)	1×10¹³			4	2783	6700	210	8510	11,100	
r_{DS}(ON)	2.5×10¹¹	VIN=5V	VD=-7.5V;	6	24.2	26.3	21.9	26.3	28.9	
(Ω)	5×10¹¹		IS=10mA	6	29.9	33.6	28.5	33.2	35.6	
	1×10¹²		VIN=0.8V	6	31.5	41.1	24.9	44	50.2	
	2.5×10¹²			6	24.2	26.1	22.2	26.8	28.[illegible]	
r_{DS}(ON)	2.5×10¹¹	VIN=-4V		4	24.9	26.3	23.4	22.3	28.6	
(Ω)	5×10¹¹			4	27.1	28.5	26.4	29	30	
	1×10¹²			4	26.7	28.1	25.6	28.8	29.7	
	2.5×10¹²			4	26.5	28	25.9	28.5	28.5	
r_{DS}(ON)	4.5×10¹²	VIN=0		4	13.4	14.5	12.6	15	15.8	
(Ω)	1×10¹³			4	13.3	14.4	12.3	15	15.9	
	[illegible]	VIN=-4V		4	14.3	14.8	13.2	15.7	16.5	
	[illegible]			4	14.1	14.6	13.3	15.2	15.8	

DGM111, Siliconix

DEVICE TYPE: DGM111 SILICONIX PAGE 1 of 4 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
		S-D = -10V; Vcc = 15V								
		VL = 4.5V; VEE = -15V								
Is (OFF)	5×10¹²	VIN = 4V	VS = -10V, VD = 10V	9	1.38	2.0	0.9	2.13	2.51	
(nA)	1×10¹³	↓	Vcc = 15V; VEE = -15V	9	2.86	4.2	1.8	4.65	5.54	
			VIN = 4.1V							
Is (OFF)	5×10¹²	VIN = 0		9	98.1	160	12	213	271	
(nA)	1×10¹³	↓		9	151	250	55	300	374	
ID (OFF)	5×10¹²	VIN = 4V		9	0.818	1.1	0.6	1.2	1.37	
(nA)	1×10¹³	↓		9	1.24	1.5	0.78	1.75	2.01	
ID (OFF)	5×10¹²	VIN = 0		9	94.6	160	12	202	255	
(nA)	1×10¹³	↓ ↓	↓	9	165	295	56	331	413	
ID (OFF)	5×10¹¹	PASSIVE	VS = GND, Vcc = 15V	8	0.0323	0.044	0.033	0.0463	0.0508	
(nA)	1×10¹²		VD = 10V thru 5KΩ	8	0.0628	0.085	0.04	0.0979	0.116	
	2.5×10¹²		VEE = 15V, VL = 5V	8	0.121	0.181	0.05	0.226	0.279	
↓	5×10¹²	↓	VIN = 4.1V, VREF = 0V	8	0.216	0.32	0.099	0.391	0.419	

DEVICE TYPE: DGM 111 SILICONIX PAGE 2 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
		D = 10V; S = GND; VL = 5V								
		VEE = -15V; Vcc = 15V								
IL (OFF)	5×10¹¹	VIN = 4.1V	VS = GND; VD = 10V	8	0.0225	0.029	0.013	0.0328	0.0388	
(nA)	1×10¹²		Vcc = 15V, VEE = -15V	8	0.0314	0.042	0.017	0.0486	0.0573	
	1.5×10¹²		VIN = 4.1V	4	0.0253	0.031	0.023	0.033	0.0386	
	2.5×10¹²			18	0.24	0.56	0.049	0.586	0.759	
	5×10¹²			18	0.917	3	0.049	3.24	4.4	
↓	1×10¹³	↓		10	5.49	7.5	3.4	8.9	10.6	
ID (OFF)	5×10¹¹	VIN = 0.5V		8	0.0115	0.018	0.005	0.0202	0.0245	
(nA)	1×10¹²			8	0.0144	0.022	0	0.0286	0.0358	
	1.5×10¹²			4	0.0005	0.004	0.003	0.0063	0.0092	
	2.5×10¹²			18	0.0406	0.082	0.007	0.0903	0.115	
	5×10¹²			18	0.105	0.15	0.058	0.16	0.187	
↓	1×10¹³	↓ ↓	↓	10	0.18	0.31	0.012	0.345	0.427	
		S-D = -10V, Vcc = 15V								
		VEE = -15V, VL = 4.5V								
Is(on)-Is(on)	5×10¹²	VIN = 4V	VD = VS = 10V	9	0.269	0.6	-0.01	0.697	0.911	
(nA)	1×10¹³	↓	Vcc = 15V, VEE = -15V	9	1.17	1.8	0.19	2.32	2.9	
			VIN = 0.5V							
Is(on)-Is(on)	5×10¹²	VIN = 0		9	0.531	1.25	-0.11	1.49	1.98	
(nA)	1×10¹³	↓ ↓	↓	9	1.78	3.2	0.22	3.87	4.91	

DEVICE TYPE: DGM 111 SILICONIX PAGE 3 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
		S=GND, VGG=-15V								
		VEE=15V, VCC=+15V								
$r_{DS(ON)}$	5×10¹	V_{IN}=+1V	V_D=10V, I_S=1mA	9	67.8	79	58	83.2	91	
(Ω)	1×10¹³	↓	VEE=15V, VCC=15V	9	70.3	81	61	84.4	91.4	
			V_{IN}=0.5V							
$r_{DS(ON)}$	5×10¹²	V_{IN}=0	↓	9	59.7	64	56	65.10	68.5	
(Ω)	1×10¹³	↓	↓	9	64.2	68	59	70.4	73.4	
$r_{DS(ON)}$	5×10¹¹	PASSIVE	I_S=GND, VCC=15V	8	95.1	100.5	90	102	105	
(Ω)	1×10¹²	↓	V_D=10V, R_{DRAIN}=5KΩ	8	108	120	100.5	123	131	
↓	2.5×10¹²	↓	VEE=15V, V_{IN}=0.5V	8	141	175	121	180	200	
↓	5×10¹²	↓	↓	8	199	277.5	152.5	289	334	
$r_{DS(ON)}$	5×10¹¹	D=10V, S=GND, VG=-5V	VS=GND, VD=+10V	8	83.24	96.65	78.20	93.34	98.37	
(Ω)	1×10¹²	VEE=15V, VCC=15V	V_{IN}=0.5V	8	86.15	96.37	80.27	92.52	103.21	
↓	1.5×10¹²	V_{IN}=+1.1V	↓	4	109.38	100	102.5	124.5	132.1	
↓	2.5×10¹²	↓	↓	18	108.08	179	86.47	159.61	185.38	
↓	5×10¹²	↓	↓	18	138.02	310	98.82	254.64	312.95	
↓	1×10¹³	↓	↓	10	295.1	827.5	102.0	792.3	1048.9	

DEVICE TYPE: DGM 111 SILICONIX PAGE 4 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
$r_{DS(ON)}$	5×10¹¹	D=0V, S=GND, VG=-5V	VS=GND, VD=+10V	8	96.2	112.5	86.5	111.85	119.68	
(Ω)	1×10¹²	VEE=15V, VCC=15V	V_{IN}=0.5V	8	105.1	115.8	106.23	110.25	112.2	
↓	1.5×10¹²	V_{IN}=0.5V	↓	4	194.0	214.5	177.5	228.3	245.4	
↓	2.5×10¹²	↓	↓	18	196.26	1910.0	214.0	1236.7	2223.8	
↓	5×10¹²	↓	↓	18	2544.5	5512.0	635	6456.7	7862.8	
↓	1×10¹³	↓	↓	10	543.2	838	280.5	906.3	1082.8	

HA2520, Harris

DEVICE TYPE: HA 2520 HARRIS PAGE 1 of 4 FLATPACK ANG. TO-99 3

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rads	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)		5×10¹¹	IN± = 100K to GND		6	0.494	0.635	0.247	0.781	0.924	
			V± = ±15V						0.207	0.0636	
		1.25×10¹²	10KΩ FEEDBACK		6	1.22	1.352	1.159	1.37	1.45	
									1.07	0.981	
	50K				6	1.2845	1.668	0.832	1.924	2.241	
									0.685	0.338	
		2.5×10¹²			6	1.87	2.238	1.644	2.31	2.54	
									1.42	1.20	
		5×10¹²			14	1.68	2.98	-0.153	3.75	4.79	
									0.398	-1.44	
	125K				6	1.889	3.907	-1.91	6.100	8.206	
									-2.312	-4.428	
	150K				3	1.147	1.651	0.693	2.109	2.590	
									0.185	-0.296	
		1×10¹³			8	1.3	3.128	-1.229	4.5[illegible]	6.14	
									-1.83	-3.55	
ΔVos (mV)		5×10¹¹	Vs = ±15V	500Ω OUTPUT LOAD	3	0.872	1.118	0.672	1.32	1.55	
									0.423	0.198	
		1×10¹²			3	1.69	2.259	1.385	2.68	3.18	
									0.692	0.196	
		2.5×10¹²			3	2.99	3.766	2.49	4.35	5.23	
									1.63	0.943	
		5×10¹²			3	3.99	4.299	3.615	4.68	5.02	
									3.3	2.95	

DEVICE TYPE: HA2520 HARRIS PAGE 2 of 4

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rads	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIos (nA)		5×10¹¹	IN± = 100K to GND		6	1.33	3.65	-2.72	6.21	8.65	
			V± = ±15V						-3.54	-5.98	
		1.25×10¹²	10KΩ FEEDBACK		6	1.45	5.65	-6.92	11.0	15.8	
									-8.1	-12.9	
	50K				6	-8.54	5.83	-21.41	12.75	23.40	
									-29.83	-40.48	
		2.5×10¹²			6	1.18	7.69	-6.23	13.2	19.2	
									-10.8	-16.8	
		5×10¹²			14	-3.87	20.17	-32.27	24.8	39.1	
									-32.5	-46.9	
	125K				6	-13.83	-1.95	-22.53	0.963	8.36	
									-28.62	-36.02	
	150K				3	-2.64	2.19	-10.17	10.57	17.17	
									-15.85	-22.46	
		1×10¹³			8	-11.8	50.19	-49.28	50.0	80.9	
									-73.7	-105.0	
ΔIos (nA)		5×10¹¹	Vs = ±15V	500Ω OUTPUT LOAD	3	-3.18	0.3	-9.16	7.23	12.4	
									-13.6	-18.8	
		1×10¹²			3	-3.55	-0.57	-7.76	3.94	7.69	
									-11.0	-14.8	
		2.5×10¹²			3	-6.08	-3.2	-11.2	2.8	7.25	
									-15.0	-19.4	
		5×10¹²			3	-9.84	-3.25	-17.93	5.06	12.5	
									-24.7	[illegible]	

DEVICE TYPE: HA-2520 HARRIS PAGE 3 of 4

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	rad(Si)	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔIB (nA)		5×10⁴	INT: 100K to GND		6	96.5	104.95	87.8	108.0	114.0	
		↓	VT: ±15V						85.0	79.3	
		1.25×10⁴	10KΩ FEEDBACK		6	222.0	231.6	222.5	242	252	
		↓							202	192	
	50K				6	205.3	316.6	83.0	363.3	442.4	
	↓								47.2	-31.9	
		2.5×10⁴			6	359	385.5	326.7	403	425	
		↓							315	293	
		5×10⁴			14	372	584.7	141.8	205	822	
		↓							32.9	-1628.0	
	125K				6	348.0	446.3	265.5	495.8	569.6	
	↓								200.3	126.5	
	150K				3	223.6	328.5	116.3	435.8	541.9	
	↓								11.4	-92.8	
		1×10⁵			8	382	468.4	186.1	729	86.2	
		↓							34.9	-134	
ΔIB (nA)		5×10⁴	VS = ±15V	500Ω OUTPUT LOAD	3	103	116.4	82.4	140	159	
		↓							66.7	48.3	
		1.25×10⁴			3	196	223	155.6	267	302	
		↓							125	89.3	
		2.5×10⁴			3	396	450.6	322.8	528	594	
		↓							264	198	
		5×10⁴			3	613	680.5	510.6	793	883	
		↓							433	343	

DEVICE TYPE: HA-2520 HARRIS PAGE 4 of 4

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	rad(Si)	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
SLEW RATE		5×10⁴	CIRCUIT DEPENDENT	8V OUT 2.5 DIV	3	108	125	100	77.5	65	
RISE (V/μsec)		1×10⁵	VENDOR'S SPEC	cycle, square wave	3	108	125	105	77.5	65	
SLEW RATE		5×10⁴			3	139	167	125	90	66	
FALL (V/μsec)		1×10⁵			3	139	167	125	90	66	
OPEN LOOP GAIN	50K		INT: 100K to GND	20mA LOAD	6	78.85	81.06	77.66	76.38	75.14	
(dB)		5×10⁴	VS ±15V		3	75.33	78.41	73.16	69.85	67.10	
	125K		10KΩ FEEDBACK		6	74.73	76.05	73.26	71.84	70.39	
		1×10⁵		↓	3	FAILED	74.90	FAILED			
		1×10⁶		1.5mA LOAD	2	72.04	72.23	71.84			
Δ OPEN LOOP	50K			20mA LOAD	6	-5.16	-3.3	-7.3	-7.9	-9.2	
GAIN (dB)		5×10⁴			3	-7.87	-6.6	-9.2	-10.5	-11.8	
	125K				6	-8.9	-8.0	-10.5	-10.9	-11.8	
		1×10⁵			3	FAILED	-10.10	FAILED			
									(mean/[illegible])	(mean/[illegible])	
PHASE SHIFT		2.5×10⁴	VS = ±15V		5	-2.76°	-2.6°	-3.0°	3.62°	3.3°	
		5×10⁴			5	-2.8°	-2.6°	-3.0°	3.62°	3.77°	
		1×10⁵			5	-2.82°	-2.6°	-3.0°	3.18°	3.36°	

HA2600, Harris

DEVICE TYPE: HA2600 HARRIS PAGE 1 of 3 — 3

Parameter	Fluence	Operating Point			Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.		BIAS: MEAS.							
ΔVos (mV)	1.25×10¹²	IN⁺: 100K to GND			4	0.0175	0.02	0.01	0.0275	0.0325	
		V±: ±15V							0.0075	0.0025	
	5.2 A rad	10KΩ FEEDBACK			6	0.1583	0.2790	0.028	0.3184	0.4435	
									-0.0318	-0.1267	
	2.5×10¹²				4	0.045	0.06	0.01	0.065	0.075	
									0.025	0.015	
	5×10¹²				16	-0.030	0.307	-1.403	0.741	1.13	
									-0.805	-1.19	
	625K rad				9	0.458	2.073	-0.366	2.1467	2.9911	
									-1.2307	-2.0751	
	1×10¹³				15	0.672	3.433	-0.155	2.78	3.84	
									-1.44	-2.49	
ΔIos (nA)	1.25×10¹²				4	0.838	3	-1.3	5.41	7.7	
									-3.74	-6.02	
	50K rad				6	7.98	14.44	0.02	18.923	24.344	
									-2.963	-8.434	
	2.5×10¹²				4	0.87	3.38	-1.34	5.97	8.51	
									-4.23	-6.77	
	5×10¹²				15	-5.810	22.08	-37.303	27.1	43.6	
									-38.8	-55.3	
	625K rad				9	4.217	35.97	-22.33	41.857	60.677	
									-33.413	-52.243	

DEVICE TYPE: HA2600 HARRIS PAGE 2 of 3

Parameter	Fluence	Operating Point			Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.		BIAS: MEAS.							
ΔIos (nA)	1×10¹³	IN⁺: 100K to GND			15	0.681	46.07	-31.364	46.6	62	
		V±: ±15V, 10KΩ FEEDBACK							-30.2	-60.6	
									+2σ	+3σ	
ΔIb (nA)	1.25×10¹²				4	0.673	1.21	0.28	1.46	1.85	
	50K rad				6	6.548	10.055	3.575	10.987	13.210	
	2.5×10¹²				4	0.875	1.62	0.04	2.03	2.6	
	5×10¹²				15	5.83	102.35	-0.86	32.3	53	
	625K rad				9	8.159	92.74	-4.88	43.58	61.215	
	1×10¹³				15	10.5	48.78	0.3371	40.3	55.1	
									-2σ	-3σ	
Sw. Rate (V/μsec) Rise	5×10¹²	CIRCUIT DEFINED		8V INPUT, 2.5°b	3	6.8	7	6.7	6.15	6.28	
	1×10¹³	IN VERTICAL SPEC.		1 Duty Cycle 2g pulse	2	5.8	6.3	5.3	4.39	3.68	
Sw. Rate (V/μsec) Fall	5×10¹²				3	7.9	8.3	7.7	7.21	6.86	
	1×10¹³				2	7	7.7	6.3	5.00	4.03	
Open Loop Gain (dB)	50K rad	IN⁺: 100K to GND		20mA load	6	104.5	119.4	100.8	89.85	82.52	
	2.5×10¹²	V±: ±15V; 10KΩ			3	101.13	102.8	99.4	97.73	96.03	
	5×10¹²	FEEDBACK			3	100.2	101.6	98.4	96.23	95.29	
	625 K rad				6	103.1	120	98.34	86.97	78.60	
	1×10¹³				3	98.6	99.8	97.0	95.22	94.22	

DEVICE TYPE: HA 2600 HARRIS PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean −2σ	Mean −3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
Δ OPEN LOOP	50 K rad	IN± = 100K to GND	2mA LOAD	6	-5.33	-4.2	-6.6	-7.5	-8.6	
GAIN (dB)	2.5×10¹²	V± = ±15V, 10KΩ		3	-1.07	-0.6	-1.6	-2.1	-2.6	
	5×10¹²	FEEDBACK		3	-2.0	-1.2	-2.8	-3.6	-4.4	
↓	125 K rad	↓	↓	6*						
		* FAILED								

HA2620, Harris

DEVICE TYPE: HA2620 HARRIS PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)	50 K rad	IN± = 100K to GND		6	-.0598	0.117	0.03	0.1292	0.1639	
	↓	V± = ±15V						-0.0095	-0.0442	
	5×10¹²	10KΩ FEEDBACK		6	-1.83	0.043	-3.656	0.82	2.15	
	↓							-4.48	-5.81	
	150 K rad			10	0.073	1.867	-1.76	1.810	2.674	
	↓							-1.664	-2.533	
	1×10¹³			6	-1.69	0.019	-3.498	0.83	2.09	
↓	↓							-4.21	-5.47	
ΔIos (nA)	50 K rad			6	-1.0788	2.25	-6.68	5.683	9.0641	
	↓							-7.841	-11.222	
	5×10¹²			5	-2.42	0.82	-9.62	6.9	11.5	
	↓							-11.7	-16.3	
	5×10¹²			6*	27.1	174.63	-9.62	172	244	
	↓							-118	-190	
	150 K rad			10	-10.222	-0.050	-27.1	8.119	17.29	
	↓							-28.56	-37.73	
	1×10¹³			6	-2.84	0.78	-13.12	8.0	13.4	
↓	↓	*OUTLIER INCLUDED (MAY HAVE BEEN CAUSED BY MEASUREMENT ERROR)						-13.7	-19.1	
								+2σ	+3σ	
ΔIB (nA)	50 K rad			6	2.975	4.915	0.44	6.1235	7.7727	
	5×10¹²			6	22.1	58.2	-2.45	62.6	82.9	
	150 K rad			10	2.167	5.94	-0.74	6.858	9.204	
↓	1×10¹³	↓		6	26.2	58.1	3.41	63.6	82.4	

DEVICE TYPE: HA2620 HARRIS PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean 2σ	Mean 3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
SLEW RATE	2.5×10¹²	V± = ±10V	V± = ±10V gain=10	9	26.5	29.6	22.2	22.3	20.2	
RISE (V/μsec)	5×10¹²		OUTPUT SWING = 5V	9	26.1	28.6	21.3	21.5	19.2	
↓	1×10¹³			9	25.7	27.6	20.6	21.1	18.8	
SLEW RATE	2.5×10¹²			9	-25.4	-21.9	-27.6	-28.6	-30.2	
FALL (V/μsec)	5×10¹²			9	-25.2	-21.2	-26.7	-28.6	-30.2	
↓	1×10¹³	↓	↓	9	-24.6	-19.9	-26.2	-28.6	-30.6	
OPEN LOOP GAIN	2.5×10¹²	SUPPLY VOLTAGE	$R_L = \infty$	3	104.9	110.0	95.4	84.9	74.96	
(dB)	5×10¹²	±15V	↓	3*						
OPEN LOOP GAIN	2.5×10¹²		2mA LOAD	6*						
Δ OPEN LOOP	2.5×10¹²		$R_L = \infty$	3	-6.73	-1.0	-15.8	-22.6	-30.6	
GAIN (dB)	5×10¹²		↓	3*						
↓	2.5×10¹²	↓	2mA LOAD	6*						
LARGE SIGNAL	2.5×10¹²	V± = ±10V	V± = ±10V	3	757	809.3	683.2	625.5	559.6	
BANDWIDTH	5×10¹²		OUT. VOLTAGE SWING	3	707	769.6	615.5	545.0	463.9	
(KHz)	1×10¹³	↓	= MAX = ~15V	3	716	780.1	602.6	519.3	421.2	
		* FAILED								

DEVICE TYPE: HA2620 HARRIS PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
SMALL SIGNAL	2.5×10¹²	V± = ±10V	V± = ±10V	6	27	29.3	22.2	21.2	18.3	
BANDWIDTH	5×10¹²		OUT. VOLTAGE SWING	6	27.2	29.3	25.1	23.7	21.8	
(MHz)	1×10¹³	↓	10mV	6	26.6	29	21.9	20.8	17.9	

HA2700, Harris, Flatpack

DEVICE TYPE: HA2700 HARRIS FLATPACK PAGE 1 of 4 — 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / −2σ	Mean +3σ / −3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔVos (mV)	5×10¹¹	IN± = 100K to GND		25	0.183	0.469	0.001	0.441	0.520	
		V± = ±15V						−0.076	0.205	
	1.25×10¹²	100KΩ FEEDBACK		25	0.564	1.41	0.001	1.323	1.777	
								−0.144	−0.628	
	2.5×10¹²			43	1.623	3.84	0.001	3.753	4.79	
								−0.407	−1.45	
				45*	2.022	11.40	0.001	5.96	7.92	
								−1.91	−3.88	
	5×10¹²			40 $	4.66	8.94	−0.003	9.48	11.89	
								−0.165	−2.58	
				45*$	5.25	15.4	−0.003	11.67	14.87	
								−1.18	−4.39	
	1×10¹³			20	8.51	15.3	4.04	13.70	16.29	
								3.32	0.707	
ΔIos (nA)	5×10¹¹			24	−0.431	0.16	−1.36	0.468	0.917	
								−1.33	−1.78	
				25*	−0.726	0.16	−7.8	2.35	3.89	
								−3.8	−5.34	
	1.25×10¹²			24	−0.908	1.31	−4.37	1.47	2.66	
								−3.28	−4.47	
				25*	−1.23	1.31	−9.04	2.77	4.76	
								−5.23	−7.23	

AG

*OUTLIERS INCLUDED $ ERRATIC DEVICE OUTPUT - VALID DATA IMPOSSIBLE TO OBTAIN ON 2 DEVICES

DEVICE TYPE: HA2700 HARRIS FLATPACK PAGE 2 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / −2σ	Mean +3σ / −3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔIos (nA)	2.5×10¹²	IN± = 100K to GND		41	−1.44	1.71	−6.02	2.17	[illegible]	
		V± = ±15V						−5.06	−6.86	
		100KΩ FEEDBACK		45*	−1.44	8.34	−12.24	5.28	8.64	
								−8.15	−11.51	
	5×10¹²			40 $	−4.20	3.81	−9.79	2.31	5.57	
								−10.71	−13.96	
				45*$	−4.22	17.79	20.31	7.82	13.84	
								−16.26	−22.28	
	1×10¹³			20	−5.97	14.39	−15.89	10.21	18.29	
								−22.14	−30.63	
ΔIb (nA)	5×10¹¹			24	−0.510	3.06	−5.82	3.94	6.17	
								−1.96	−7.19	
				25*	0.012	12.53	−5.82	6.81	10.21	
								−6.78	−10.12	
	1.25×10¹²			25	−1.05	16.07	−5.81	8.07	12.93	
								−10.37	−15.23	
	2.5×10¹²			45	1.34	15.81	−6.60	11.60	16.72	
								−8.91	−14.03	
	5×10¹²			45$	9.40	32.50	−7.1	26	34.3	
								−7.2	−15.5	
	1×10¹³			20	21.79	45.62	−3.59	45.65	52.58	
								−2.06	−13.97	

*OUTLIERS INCLUDED $ ERRATIC DEVICE OUTPUT - VALID DATA IMPOSSIBLE TO OBTAIN ON 2 DEVICES.

DEVICE TYPE: HA2700 HARRIS FLAT PACK PAGE 3 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean −2σ	Mean −3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
OPENLOOP GAIN	2.5×10¹²	IN± = 100K to GND	AVERAGED OVER	4	96.6	102.8	83.6	70.8	57.9	
(dB)	5×10¹²	V± = ±15V	+10V to −10V SWING	4**						
↓	1×10¹³	10KΩ FEEDBACK	RL = ∞	4**						
OPENLOOP GAIN	5×10¹¹		2mA LOAD	4	108.8	110	102.3	106.5	105.4	
(dB)	1.25×10¹²			4	99.65	101.2	98.4	97.3	96.2	
	2.5×10¹²			8**						
	5×10¹²			8**	**	CATASTROPHIC REDUCTION OF				
↓	1×10¹³		↓	4**		OUTPUT VOLTAGE SWING IN				
						NEGATIVE DIRECTION				
OPENLOOP GAIN	2.5×10¹²		5mA LOAD	4**						
(dB)	5×10¹²			4**						
↓	1×10¹³	↓	↓	4**						
OPENLOOP GAIN	5×10¹¹		−10V 2mA LOAD	16	108.45	115.9	103.7	103.4	100.4	
(dB)	↓		+10V	16	108.6	114	102.5	102.1	98.9	
	1.25×10¹²		−10V	16	101.9	107.9	93.6	92.5	87.8	
	↓		+10V	16	101.1	106	94.9	94.1	90.6	
	2.5×10¹²		−10V	16*	96	100.4	87.5	88.2	84.4	
	↓		+10V	16	92.3	99.6	83.2	83.1	78.5	
	5×10¹²		−10V	16**	88.1	92.7	82.4	79.4	75	
↓	↓	↓	+10V ↓	16⊖	84	90	77.4	75.2	70.8	

* 4 DEVICES FAILED ** 9 DEVICES FAILED ⊖ 6 DEVICES FAILED

DEVICE TYPE: HA2700 HARRIS FLATPACK PAGE 4 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean −2σ	Mean −3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
ΔOPENLOOP	2.5×10¹²	IN± = 100K to GND	AVG. OVER RL = ∞	4	−22.25	−10.4	−34.0	−48.7	−61.9	
GAIN (dB)	5×10¹²	V± = ±15V	+10V to −10V ↓	4**	** CATASTROPHIC REDUCTION OF OUTPUT					
		10KΩ FEEDBACK	SWING		VOLTAGE SWING IN NEGATIVE DIRECTION					
ΔOPENLOOP	5×10¹¹		2mA LOAD	4	−9.08	−7.4	−12.6	−13.9	−16.3	
GAIN (dB)	1.25×10¹²			4	−18.18	−14.8	−23.1	−25.2	−28.7	
↓	2.5×10¹²	↓	↓	8**						
ΔOPENLOOP	5×10¹¹		−10V 2mA LOAD	15	−5.9	−2.7	−10.3	−12.3	−12.5	
GAIN (dB)				16#	−6.7	−2.7	−19.0	−14.5	−18.4	
	↓		+10V	16	−4.93	−1.1	−7.1	−8.9	−10.8	
	1.25×10¹²		−10V	16	−14.3	−6.6	−31.1	−22.2	−33.7	
	↓		+10V	16	−12.5	−8.7	−18.1	−18.2	−21.1	
	2.5×10¹²		−10V	16*	FAILED	FAILED	−29.0			
	↓		+10V	16	−20.9	−9.6	−26.7	−25.8	−34.2	
	5×10¹²		−10V	16**						
↓	↓		+10V ↓	16⊖	FAILED	FAILED	−41.0			
* 4 DEVICES FAILED		** 9 DEVICES FAILED	⊖ 6 DEVICES FAILED		# OUTLIER INCLUDED					
								+2σ	+3σ	
ΔSUPPLY	2.5×10¹²			4	83.25	120	66	133.6	158.7	
CURRENT (mA)	5×10¹²			4	102.25	162	66	203.8	251.6	
↓	1×10¹³	↓		4	96.75	165	49	195.6	245	

HA2700, Harris, TO-99 + DIP

DEVICE TYPE: HA2700 HARRIS TO-99 + DIP PAGE 1 of 4 3

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)		5×10¹¹	IN±: 100K to GND		14	0.0916	0.208	0.05	0.181	0.226	
			V±: ±15V						0.0023	-0.0423	
		1.25×10¹²	10 KΩ FEEDBACK		14	0.217	0.486	0.096	0.435	0.544	
									-0.00058	-0.109	
	50K				6	0.171	0.285	0.134	0.285	0.342	
									0.0572	0.00032	
		25×10¹²			25	0.342	0.684	0.111	0.619	0.803	
									0.0354	-0.118	
					26*	0.367	0.978	0.111	0.758	0.953	
									-0.0238	-0.219	
		5×10¹³			26	0.786	2.2	0.201	1.83	2.35	
									-0.257	-0.779	
	150K				5	0.245	0.356	0.067	0.475	0.591	
									0.014	-0.101	
		1×10¹³			12	0.991	1.915	0.33	1.92	2.39	
									0.0616	-0.403	
ΔIos (nA)		5×10¹¹			14	-0.[illegible]	0.34	-0.5	0.355	0.583	
									-0.559	-0.787	
		1.25×10¹²			14	-0.218	0.94	-1.91	1.18	1.88	
									-1.62	-2.36	
	50K				6	0.28	1.32	-0.61	1.57	2.21	
									-1.01	-1.65	
	* OUTLIER INCLUDED										

DEVICE TYPE: HA2700 HARRIS TO-99 + DIP PAGE 2 of 4

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIos (nA)		25×10¹²	IN±: 100K to GND		26	-0.263	2.04	-3.21	1.97	3.09	
			V±: ±15V						-2.5	-3.61	
		5×10¹³	10KΩ FEEDBACK		26	-0.476	2.88	-4.02	2.86	4.53	
									-3.82	-5.48	
	150K				5	0.332	1.46	-0.28	1.88	2.65	
									-1.21	-1.99	
		1×10¹³			12	-0.42	4.4	-2.35	3.63	5.66	
									-4.47	-6.5	
ΔIB (nA)		5×10¹¹			14	-0.646	-0.45	-1.89	1.04	1.89	
									-2.34	-3.18	
		1.25×10¹²			14	-1.06	4.25	-4.66	4.15	6.75	
									-6.27	-8.87	
		25×10¹²			26	-2.76	8.83	-8.85	5.41	9.5	
									-10.9	-15.0	
		5×10¹³			25	-4.16	5.735	-11.85	5.11	9.74	
									-13.4	-18.1	
					26*	-3.44	14.69	-11.84	8.27	14.1	
									-15.2	-21.0	
	150K				5	-3.22	-1.61	-4.66	-0.63	0.66	
									-5.81	-7.10	
		1×10¹³			12	-11.3	-4.73	-22.04	-1.66	3.14	
									-20.9	-25.	
	* OUTLIER INCLUDED										

DEVICE TYPE: HA2700 HARRIS TO-99 & DIP PAGE 3 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
OPEN LOOP GAIN	2.5×10¹²		$R_L = \infty$	3	114.2	115.8	113	111.3	109.9	
(dB)	5×10¹²		↓	3	112	115	109.8	106.6	103.9	
↓	1×10¹³		↓	9	103.6	109.2	97.8	96.4	92.9	
OPEN LOOP GAIN	5×10¹¹		2 mA LOAD	4	116.5	118.8	115.4	113.3	111.7	
(dB)	1.25×10¹²		↓	4	112.6	114.4	111	109.5	107.9	
↓	2.5×10¹²		↓	4	108.4	109.2	106.6	106	104.8	
↓	5×10¹²		↓	4	103.4	107	100.4	97.96	95.25	
↓	1×10¹³		↓	6	99	101.2	94.2	93.7	91.1	
OPEN LOOP GAIN	2.5×10¹²		4 mA LOAD	6	108.0	114.8	101.8	95.5	89.3	
(dB)	5×10¹²		↓	6	105.9	113	99.6	93.7	87.7	
↓	1×10¹³		↓	6	105.6	119	96.4	88.4	79.8	
OPEN LOOP GAIN	1×10¹³		5 mA L[illegible]	6	98.8	101.4	93	92.4	89.3	
(dB)										
Δ OPEN LOOP	2.5×10¹²		$R_L = \infty$	3	-2.53	-1.8	-3.2	-3.9	-4.6	
GAIN (dB)	5×10¹²		↓	3	-4.73	-4.0	-5.2	-6.02	-6.7	
↓	1×10¹³		↓	3	-9.3	-8.4	-9.8	-10.9	-11.8	
Δ OPEN LOOP	5×10¹¹		2 mA LOAD	4	-2.0	-0.8	-4.2	-5.1	-6.7	
GAIN (dB)	1.25×10¹²		↓	4	-5.9	-4.4	-9.0	-10.1	-12.3	

DEVICE TYPE: HA2700 HARRIS TO-99 & DIP PAGE 4 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
Δ OPEN LOOP	2.5×10¹²		2 mA LOAD	4	-10.1	-7.0	-13.4	-15.7	-18.5	
GAIN (dB)	5×10¹²		↓	4	-15.1	-12.8	-19.6	-21.3	-24.4	
Δ OPEN LOOP	2.5×10¹²		4 mA LOAD	6	-4.1	-2.0	-5.6	-7.2	-8.7	
GAIN (dB)	5×10¹²		↓	6	-6.2	-4.6	-7.6	-8.8	-10.1	
↓	1×10¹³		↓	6	-9.9	-8.4	-11.0	-11.8	-12.8	
								+2σ	+3σ	
SLEW RATE	2.5×10¹²		8V INPUT: 2±%	2	5	5	5	5	5	
RISE (V/μsec)	5×10¹²		duty cycle sq. pulse	2	5	5	5	5	5	
↓	1×10¹³		INPUT PULSE. tf = tr²	2	5	5	5	5	5	
			2 μsec							
SLEW RATE	2.5×10¹²		↓	2	8.3	8.3	8.3	8.3	8.3	
FALL (V/μsec)	5×10¹²		↓	2	9.5	10	[illegible]	10.9	11.6	
↓	1×10¹³		↓	2	10	10	[illegible]	10	10	

ICL8007, Intersil

DEVICE TYPE: ICL8007 INTERSIL PAGE 1 of 4 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)	2.5×10¹²	POWER SUPPLY: ±15V	Vc± = ±15V	3	6.01	9.51	4.21	16.1	15.1	
	↓	IN+ = +4V						-0.053	-3.08	
	5×10¹²	OUTPUT SHORTED		3	6.84	15.3	2.53	21.5	28.8	
	↓	TO IN⁻						-7.81	-15.1	
	1×10¹³	↓		3	14.3	274.2	39.22	383	502	
	↓	↓						-96.8	-217	
	2.5×10¹³	POWER SUPPLY OFF		3	3.46	9.5	0.22	13.9	19.2	
	↓	↓						-7.02	-12.3	
	5×10¹³			3	0.718	1.22	0.432	1.59	2.03	
	↓							-0.158	-0.595	
	1×10¹⁴			3	1.34	2.036	0.813	2.6	3.23	
	↓	↓						0.082	-0.597	
ΔVOB (mV)	5×10¹¹	IN±: 1MΩ to GAIN		6	0.289	0.847	-0.018	0.906	1.21	
	↓	1000pF BYPASS CAP						-0.328	-0.636	
	1.25×10¹²	Vt = ±15V		6	0.56	1.03	0.207	1.11	1.38	
	↓	10K FEEDBACK						0.011	-0.263	
	2.5×10¹²			6	-4.096	0.607	-8.67	2.72	6.12	
	↓							-10.9	-14.3	
	5×10¹²			6	-16.28	1.04	-36.99	15.4	31.2	
	↓	↓	↓					-47.9	-63.7	

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DEVICE TYPE: ICL 8007 INTERSIL PAGE 2 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIos (nA)	5×10¹¹	IN±: 1MΩ TO GAIN		6	-0.008	0.039	-0.071	0.067	0.105	
	↓	1000pF BYPASS CAP						-0.083	-0.121	
	1.25×10¹²	Vt = ±15V		6	-0.002	0.038	-0.07	0.074	0.113	
	↓	10K FEEDBACK						-0.079	-0.117	
	2.5×10¹²			6	-0.054	0.043	-0.20	0.121	0.208	
	↓							-0.228	-0.315	
	5×10¹²			6	-0.203	-0.112	-0.225	-0.069	-0.002	
	↓							-0.337	-0.403	
ΔIB (nA)	5×10¹¹		COMMON MODE	6	0.017	0.076	-0.028	0.087	0.123	
	↓		VOLTAGE = 0					-0.054	-0.089	
	1.25×10¹²			6	0.0026	0.026	-0.019	0.037	0.054	
	↓							-0.031	-0.048	
	2.5×10¹²			6	0.032	0.110	-0.009	0.118	0.161	
	↓							-0.053	-0.096	
	5×10¹²			6	0.110	0.148	0.059	0.165	0.197	
	↓	↓	↓					0.035	0.003	
ΔIA (pA)	2.5×10¹²	POWER SUPPLY: ±15V	COMMON MODE	3	0.025	5.7	-3.15	8.8	14.7	
	↓	IN+: +4V	VOLTAGE = 0					-9.7	-14.6	
	5×10¹²	OUTPUT SHORTED		3	4.21	5.235	3.25	6.20	7.19	
	↓	TO IN⁻						2.22	1.23	
	1×10¹³			3	23.2	71.6	-8.5	108	151	
	↓	↓	↓					-61.9	-104	

DEVICE TYPE: ICL 8007 INTERSIL PAGE 3 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔIo (pA)	2.5x10¹²	POWER SUPPLY OFF	COMMON MODE VOLTAGE = 0	3	0.492	2.275	-0.5	3.16 -2.16	5.13 -4.15	
	5x10¹²			3	0.367	1.08	-0.516	1.87 -1.85	2.8 -2.78	
	1x10¹³			3	-1.9	0.9	-5.25	4.99 -8.79	8.44 -12.2	
	2.5x10¹²	POWER SUPPLY = ±15V IN+ = +4V	COMMON MODE VOLTAGE +8V	3	6.18	20.5	-1.45	30.9 -18.5	43.3 -30.9	
	5x10¹²	OUTPUT SHORTED TO IN⁻		3	26	45.3	6.7	64.6 -2.6	83.9 -31.9	
	1x10¹³			3	21.7	64.1	-10.6	98.3 -55	[illegible]	
	2.5x10¹²	POWER SUPPLY OFF		3	9.23	18.3	0.5	[illegible]	45.4 -27.9	
	5x10¹²			3	14.1	20.6	[illegible]	[illegible]	36.1 -7.95	
	1x10¹³			3	5.7	10.05	-1.7	18.6 -7.18	25 -13.6	
	2.5x10¹²	POWER SUPPLY = ±15V IN+ = +4V OUTPUT SHORTED TO IN⁻	COMMON MODE VOLTAGE -8V	3	-13.4	0.7	-41.25	34.8 -61.6	58.9 -85.7	

DEVICE TYPE: ICL 8007 INTERSIL PAGE 4 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔIo (pA)	5x10¹²	POWER SUPPLY = ±15V IN+ = +4V	COMMON MODE VOLTAGE -8V	3	-4.88	15.2	-38.7	54 -63.7	83.4 -93.1	
	1x10¹³	OUTPUT SHORTED TO IN⁻		3	-14.1	10.3	-52.8	53.7 -82	87.6 -116	
	2.5x10¹²	POWER SUPPLY OFF		3	-3.88	3.8	-19.1	14.4 -32.1	26 -43.8	
	5x10¹²			3	-6.1	4.94	-14.4	13.8 -26	23.7 -35.9	
	1x10¹³			3	-12.2	3.25	-22.4	15.5 -35.9	26.3 -48.7	
SUPPLY CURRENT (mA)	2.5x10¹²	POWER SUPPLY = ±15V IN+ = +4V	V+ = +15V	3	3.27	3.6	[illegible]	3.88 2.66	4.18 2.35	
	5x10¹²	OUTPUT SHORTED TO IN⁻		3	3.67	4.2	3.1	4.28 3.06	4.58 2.75	
	1x10¹³			3	3.23	3.5	2.8	3.99 2.47	4.37 2.1	
	2.5x10¹²	POWER SUPPLY OFF		3	3.43	3.6	3.2	3.85 3.02	4.06 2.81	
	5x10¹²			3	3.4	3.6	[illegible]	[illegible] 2.8	4.19 2.61	
	2.5x10¹²			3	3.3	3.5	3	3.83 2.77	4.09 2.51	

ICL3018, Intersil

The data presented are device linearity deltas; i.e., the effects of LSB current changes are subtracted out of the data. For total error for any given bit, the ΔI_{LSB} must be multiplied by the bit weighting and added to the value shown in the data. Parameter ΔV_{BE} was not stable due to servo loop biasing and collector-base leakage current problems. Parameters ΔV_{BE} and Δ(I/B) are for the DUT reference transistor.

DEVICE TYPE: ICL 8018 INTERSIL PAGE 2 of 4 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔI_{LSB} (μA)	2.5×10^{12}	I_{REF} = 0.125 mA	I_{REF} = 0.125 mA	14	-0.0158	+0.02	-0.09	0.0516	0.0853	
	↓	EMITTER RES. @ 75V	EMITTER RES. @ -5V					-0.0832	-0.1169	
	5×10^{12}	V+ = 5V ALL CURRENT	V+ = 5V	14	-0.1633	+0.02	-1.29	0.5605	0.9224	
	↓	SWITCHES IN DUT ARE						-0.8871	-1.249	
	1×10^{13}	OFF. OUTPUT 1KΩ to		14	-6.745		-8.53	-2.576	-0.4912	
↓	↓	GND.						-10.91	-12.999	
ΔI_{BIT3} (μA)	2.5×10^{12}			14	+0.0075	+0.03	-0.01	0.0383	0.0537	
	↓							-0.0233	-0.0387	
	5×10^{12}			14	0	+0.09	-0.05	0.0688	0.1032	
	↓							-0.0688	-0.1032	
	1×10^{13}			14	+0.0483	1.15	-1.62	1.4479	2.1477	
↓	↓							-1.3513	-2.0511	
ΔI_{BIT2} (μA)	2.5×10^{12}			14	+0.0392	+0.09	-0.01	0.1625	0.1679	
	↓							-0.0466	-0.0895	
	5×10^{12}			14	+0.0183	+0.16	-0.29	0.2519	0.3687	
	↓							-0.2153	-0.3321	
	1×10^{13}			14	-0.4083	1.39	-4.60	2.5879	4.086	
↓	↓	↓	↓					-3.4045	-4.9026	
OES.										

DEVICE TYPE: ICL 8018 INTERSIL PAGE 3 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔI_{BIT}	2.5×10^{12}	I_{REF} = 0.125 mA	I_{REF} = 0.125 mA	14	+0.0908	+0.26	-0.02	0.2786	0.3725	
(μA)	↓	EMITTER RES. @ -15V	EMITTER RES. @ -15V					-0.097	-0.1909	
	5×10^{12}	V+ = 5V: ALL CURRENT	V+ = 5V	14	0.0633	+0.36	-0.46	0.4921	0.7065	
	↓	SWITCHES IN DUT						-0.3655	-0.5799	
	1×10^{13}	ARE OFF; OUTPUT 1KΩ		14	0.4883	5.51	-9.50	8.0971	11.9015	
↓	↓	to GND						-7.1205	-10.9249	
ΔI_L	2.5×10^{12}			14	+0.811	+1.70	+0.02	1.793	2.284	
(nA)	↓							-0.171	-0.662	
	5×10^{12}			14	30.83	295.0	0.40	206.25	293.96	
	↓							-144.59	-232.30	
	1×10^{13}			14	975.7	4605		3703.4	5062.3	
↓	↓							-1752.0	-3115.9	
ΔV_{BE} (mV)	2.5×10^{12}			14	-0.8309	2.30	-3.0	2.505	4.1728	
	↓							-4.1667	-5.8346	
	5×10^{12}			14	-0.97	2.2	-4.0	3.67	5.99	
	↓							-5.61	-7.93	
	1×10^{13}			14	-2.7	2.0	-6.0	2.1	6.48	
↓	↓	↓	↓					-7.5	-9.9	

DEVICE TYPE: ICL 8018 INTERSIL PAGE 4 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
$\Delta(1/\beta)$	2.5×10^{12}	I_{REF} = 0.125 mA	I_{REF} = 0.125	14	5.783	11.9	0.90	14.125	18.296	
($\times10^{-4}$)	↓	EMITTER RES. @ -15V	EMITTER RES. @ -15V					-2.559	-6.73	
	5×10^{12}	V+ = 5V: ALL CURRENT	V+ = 5V	14	12.933	17.1	6.6	20.71	24.60	
	↓	SWITCHES IN DUT						5.155	[illegible]	
	1×10^{13}	ARE OFF; OUTPUT 1KΩ		14	68.483	94.2		102.39	119.36	
↓	↓	to GND	↓					34.57	17.62	

ICL8038, Intersil

DEVICE TYPE: ICL 8038 INTERSIL PAGE 1 OF 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -3σ	Mean +3σ -3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
ΔSupply	5x10¹²	VIN = GND	10KHz : 30V	6	-0.05	0	-0.1	0.0595	0.1143	
Current(mA)	↓		VIN = 0.5V					-0.1595	-0.2143	
	1x10¹³			6	-0.0333	0	-0.1	0.0699	0.1215	
↓	↓		↓					-0.1366	-0.1882	
ΔSupply	5x10¹²		VIN = 1.75V	6	-0.0833	0	-0.2	0.0623	0.1424	
Current(mA)	↓							-0.2338	-0.3091	
	1x10¹³			6	-0.0333	0	-0.2	0.1299	0.2116	
↓	↓		↓					-0.1966	-0.2782	
ΔSupply	5x10¹²		VIN = -3.0V	6	-0.0333	0	-0.1	0.0699	0.1215	
Current(mA)	↓							-0.1366	-0.1882	
	1x10¹³			6	-0.0333	0	-0.1	0.0699	0.1215	
↓	↓		↓					-0.1366	-0.1882	
ΔSupply	5x10¹²		VIN = 0V	6	-0.0666	0	-0.1	0.0366	0.0882	
Current(mA)	↓							-0.1699	-0.2215	
	1x10¹³			6	-0.03	0	-0.1	0.0595	0.1143	
↓	↓		↓					-0.1595	-0.2143	
ΔFrequency	5x10¹²		VIN = 0.5V	6	-0.03	-0.026	-0.034	-0.0229	-0.0184	
Out (KHz)	↓							-0.0370	-0.0415	
	1x10¹³			6	-0.026	0.033	-0.046	0.0337	0.0628	
↓	↓	↓	↓					-0.0852	-0.1148	

DEVICE TYPE: ICL 8038 INTERSIL PAGE 2 OF 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.							
ΔFrequency	5x10¹²	VIN = GND	10KHz : 30V	6	-0.0036	0.111	-0.035	0.1091	0.1605	
Out (KHz)	↓		VIN = 1.75V					-0.1165	-0.1679	
	1x10¹³			6	-0.0106	0.1040	-0.046	0.1050	0.1628	
↓	↓		↓					-0.1263	-0.1842	
ΔFrequency	5x10¹²		VIN = -3.0V	6	-0.0168	0.008	-0.051	0.0248	0.0457	
Out (KHz)	↓							-0.0585	-0.0794	
	1x10¹³			6	-0.024	-0.004	-0.036	0.0046	0.0189	
↓	↓		↓					-0.0526	-0.0669	
ΔFrequency	5x10¹²		VIN = 0V	6	-0.0206	-0.009	-0.029	-0.0062	0.0009	
Out (KHz)	↓							-0.035	-0.0420	
	1x10¹³			6	-0.026	0.010	-0.037	0.0222	0.0381	
↓	↓		↓					-0.0414	-0.0573	
ΔVout(V)	5x10¹²			6	0	0	0	0	0	
↓	1x10¹³	↓	↓	6	0	0	0	0	0	

LM101, National Semiconductor

DEVICE TYPE: LM101 NSC. PAGE 1 of 4 3

Parameter	Fluence e/cm²	Bias: Irradiation	Operating Point	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔVos (mV)		50K	IN±: 100K TO GND; VE: ±10V, 10K FEEDBACK	6	-0.216	-0.103	-0.612	0.105	0.287	
			0.1μF BETWEEN BALANCE & COMP.					-0.635	-0.808	
	5x10¹²			6	2.02	6.22	0.085	6.35	8.52	
								-2.31	-4.47	
		125K		49*	0.297	4.078	-10.38	4.7	2.41	
								-4.11	-4.81	
	1x10¹³			6	3.75	9.28	0.348	9.25	12.7	
								-2.24	-5.24	
ΔVos (mV)	1x10¹²		IN SITU MEAS. WITH BEAM ON AT 5x10⁹ e/cm²/sec.	3	0.146	0.277	0.024	0.399	0.526	
								-0.107	-0.284	
	2x10¹²			3	0.328	0.553	0.068	0.817	1.06	
								-0.161	-0.405	
	5x10¹²			3	2.54	5.41	0.738	7.56	10.1	
								-2.48	-4.99	
	1x10¹³			3	5.02	9.28	2.38	12.5	16.2	
								-2.44	-6.17	

65 * 8 OUTLIERS INCLUDED

DEVICE TYPE: LM101 NSC. PAGE 2 of 4

Parameter	Fluence e/cm²	Bias: Irradiation	Operating Point	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔIos (nA)		50K	IN±: 100K to GND, VE: ±15V, 10K FEEDBACK	6	0.068	4.95	-3.6	5.84	8.72	
								-5.72	-8.61	
	5x10¹²		0.1μF BETWEEN BALANCE & COMP.	6	-25.7	19.6	-102.3	60.1	106.0	
								-114.0	-158.0	
		125K		49*	-0.633	33.84	-39.23	7.09	11.0	
								-8.96	-12.2	
	1x10¹²			6	-27.2	74.7	-215.8	172	271	
								-226	-326	
ΔIos (nA)	1x10¹²		IN SITU MEAS. WITH BEAM ON AT 5x10⁹ e/cm²/sec	3	5.63	18.3	-1.1	22.6	38.6	
								-16.3	-27.3	
	2x10¹²			3	3.13	6.8	1.1	9.5	12.7	
								-3.23	-6.41	
	5x10¹²			3	-20.6	16	-71.5	70.4	116	
								-112	-157	
	1x10¹³			3	-69.7	17.4	-188.5	143	250	
								-283	-389	

* 7 OUTLIERS INCLUDED

DEVICE TYPE: LM101 NSC PAGE 3 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRADIATION						-2σ	-3σ	
ΔIB (nA)		50K	IN± - 100K to GND; V± = ±15V	6	-13.6	2.49	-35	10.7	22.8	
			10K FEEDBACK					-37.9	-50	
	5x10¹²		0.1μF BETWEEN BALANCE & COMP.	6	57.2	80.1	42.1	85	99	
								29.3	15.4	
		125K		497**	41.5	78.8	15.3	64.4	75.9	
								18.5	6.96	
	1x10¹³			6	94.3	119.5	76.5	124	138	
								64.9	50.2	
DIFF. SURGE	5x10¹²			10	7.28	12.75	4.0	12.9	15.7	
OUTPUT CURRENT								1.68	-1.12	
I₁ AND I₂				12*	8.44	15.0	4.0	15.9	19.6	
(μA)								0.987	-2.74	
	1x10¹³			10	7.05	13.5	3.5	13.8	17.1	
								0.33	-3.63	
				12*	8.79	18.0	3.5	19.0	24.0	
								-1.37	-6.45	
								+2σ	+3σ	
SLEW RATE	5x10¹²		8V INPUT 2-5% DUTY	3	0.333	0.56	0.19	0.73	0.83	
RISE (V/μSEC)	1x10¹³		CYCLE SQ. PULSE	3	0.237	0.4	0.14	0.52	0.66	
FALL (V/μSEC)	5x10¹²			3	0.66	1.25	0.28	1.7	2.21	
	1x10¹³			3	0.53	1.0	0.2	1.37	1.78	

* INCLUDES CURRENT BULGE; UNSTABLE CONDITION ** ONE OUTLIER INCLUDED

DEVICE TYPE: LM101 NSC PAGE 4 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
OPEN LOOP GAIN	5x10¹²	Vs = ±15V	RL = ∞	3	98.1	100	95.4	93.3	90.9	
(dB)	1x10¹³			3*	FAILED	95.8	FAILED			
OPEN LOOP GAIN	5x10¹²		RL = 2.5K	6	99.2	108.8	92.6	86.8	80.6	
(dB)	1x10¹³			6*	FAILED	103	FAILED			
ΔOPEN LOOP	5x10¹²		RL = ∞	3	-7.3	-6.0	-10.0	-11.95	-14.3	
GAIN (dB)	1x10¹³			3*	FAILED	FAILED	-16.4			
ΔOPEN LOOP	5x10¹²		RL = 2.5K	6	-7.5	-3.8	-12.4	-14.5	-17.9	
GAIN (dB)	1x10¹³			6*	FAILED	FAILED	-20.0			

* ONE DEVICE FAILED; LATCHED TO SUPPLY

LM101, National Semiconductor, IRAN reirradiation

IRAN REIRRADIATION

DEVICE TYPE: LM101 NSC PAGE 1 of 2 IRAN FLUENCE 125K rad (Si) Co^{60} 3 IRAN

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)	5×10¹¹	IN± = 100K LOGND		37	0.0512	1.351	-0.713	0.571	0.830	
	↓	V± = ±15V						-0.468	-0.728	
	1.25×10¹²	10KΩ FEEDBACK		37	0.0997	0.849	-0.117	0.384	0.526	
	↓							-0.184	-0.326	
	2.5×10¹²			36	0.312	0.851	0.045	0.663	0.838	
								-0.039	-0.214	
				37*	0.362	2.155	0.045	1.059	1.408	
	↓							-0.336	-0.685	
	5×10¹²			37	2.189	7.289	-3.693	6.785	9.083	
↓	↓							-2.407	-4.705	
ΔIos (nA)	5×10¹¹			36	-0.273	0.66	-1.54	0.516	0.910	
								-1.262	-1.456	
				37*	-0.098	6.2	-1.54	2.168	3.30	
	↓							-2.364	-3.50	
	1.25×10¹²			37	-0.441	0.84	-1.55	0.781	1.39	
	↓							-1.662	-2.27	
	2.5×10¹²			36	-0.58	4.5	-4.11	1.91	3.16	
								-3.07	-4.32	
				37*	-1.79	4.5	-45.38	13.14	20.61	
								-16.72	-24.19	
	5×10¹²			37	-3.73	-3.32	-10.51	2.17	5.22	
↓	↓	↓						-10.03	-13.08	
	* OUTLIERS INCLUDED									

IRAN REIRRADIATION

DEVICE TYPE: LM101 NSC PAGE 2 of 2 IRAN FLUENCE 125K rad (Si) Co^{60} IRAN

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIB (nA)	5×10¹¹	IN± = 100K LOGND		37	16.29	24.93	2.22	27.04	32.4	
	↓	V± = ±15V						5.54	0.162	
	1.25×10¹²	10KΩ FEEDBACK		37	33.73	51.9	17.92	55.06	65.72	
	↓							12.41	1.75	
	2.5×10¹²			37	57.41	87.36	29.19	93.70	111.85	
	↓							21.11	2.96	
	5×10¹²			37	97.43	145.12	5.58	162.54	195.09	
↓	↓	↓						32.33	-0.222	

LM102, National Semiconductor, unhardened

DEVICE TYPE: LM102 NSC (UNHARDENED) PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)	5x10¹²	IN = 100K to GND	Vs = ±15V	3	-1.13	1.4	-2.9	3.37	5.62	
		V± = ±15V; Bal = 30pF						-5.63	-7.88	
		to 8; Out = 10Meg to		4*	-4.1	1.4	-1.3	8.3	14.5	
		IN.						-16.5	-22.7	
	1x10¹³			3	-2.93	0.9	-5.7	3.92	7.35	
								-9.79	-13.2	
				4*	-9.9	0.9	-30.8	18.5	32.7	
								-38.3	-52.5	
ΔIB (nA)	5x10¹²			4	-5.9	-3.5	-7.16	-2.61	-0.967	
								-9.9	-10.8	
	1x10¹³			4	-17.5	-8.99	-27.91	-1.4	6.61	
								-33.6	-41.6	

* OUTLIER INCLUDED

LM102, National Semiconductor, hardened

DEVICE TYPE: LM102 (HARDENED) NSC PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)	5x10¹²	IN = 100K to GND	Vs = ±12V	6	2.48	4.22	0.78	5.06	6.36	
		V± = ±12V						-0.109	-1.4	
	9.18x10¹²			6	2.53	4.1	0.66	5.03	6.29	
								0.0259	-1.23	
	1x10¹³			6	2.51	4.06	0.61	5.01	6.26	
								0.00628	-1.24	
ΔIB (nA)	5x10¹²			6	-6.01	-5.106	-7.605	-3.98	-2.96	
								-8.04	-9.05	
	9.18x10¹²			6	-11.9	-10.25	-14.46	-8.4	-6.62	
								-15.4	-17.2	
	1x10¹³			6	-12.8	-11.12	-15.52	-9.1	-7.31	
								-16.5	-18.4	

LM103, National Semiconductor

DEVICE TYPE: LM103 NSC PAGE 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -3σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔVz (mV)	5×10¹²	IR = 10 μA	IZ = 0.01mA	3	0.90	2.9	-0.2	4.37 / -2.57	6.10 / -4.30	
	1×10¹³			3	2.57	6.8	-0.1	9.98 / -4.85	13.69 / -8.55	
ΔVz (mV)	5×10¹²		IZ = 0.1mA	3	4.87	5.5	3.9	6.57 / 3.17	7.42 / 2.32	
	1×10¹³			3	9.3	11.1	7.5	12.9 / 5.7	14.7 / 3.9	
ΔVz (mV)	5×10¹²		IZ = 1mA	3	15.5	19.6	12.4	22.9 / 8.2	26.6 / 4.5	
	1×10¹³			3	24.7	22.3	21.7	30.4 / 19.1	33.2 / 16.2	

LM105, National Semiconductor, unhardened

DEVICE TYPE: LM105 UNHARDENED NSC. PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	|Mean| +2σ	|Mean| +3σ	Accept Reject Criteria
	rad(Si) e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔLOAD REG. (mV)	5×10¹¹	CURRENT LIMIT = 100 Ω	VIN = 8.5V;	6	-1.73	0.10	-4.7	5.11	6.80	
	1.25×10¹²	REGULATED OUTPUT:	IL = 10mA	6	-5.00	-0.70	-18.6	18.54	25.31	
	50K	BOOSTER OUTPUT = ON;		6	0.10	6.4	-12.0	14.0	21.0	
	2.5×10¹²	VREG. INPUT = ON;		6	-6.28	-1.70	-20.1	20.36	27.15	
	100K	COMPENSATION SOLUTION		4	-14.7	11.0	-75.0	95.9	136.5	
	5×10¹²	47 pf to REG OUTPUT		9	-7.47	0	-22.3	20.26	26.66	
	1×10¹³			3	-5.9	-0.6	-9.7	15.4	20.1	
ΔLINE REG (mV)	5×10¹¹		VIN = 8.5V; IL = 5mA	6	-1.9	0.1	-5.3	5.68	7.57	
	1.25×10¹²		VOUT = 5V	6	-5.08	-0.6	-19.0	18.94	25.87	
	50K			6	-0.5	5.5	-11.9	14.1	21.0	
	2.5×10¹²			6	-6.85	-1.5	-20.6	20.88	27.90	
	100K			4	14.1	60.0	-15.0	78.5	110.7	
	5×10¹²			9	-7.37	0.30	-23.1	20.87	27.62	
	1×10¹³			9	-5.43	-0.50	-8.7	14.1	18.5	
ΔLINE REG (mV)	5×10¹¹		VIN = 40V; IL = 5mA	6	-1.60	1.0	-7.4	7.24	10.82	
	1.25×10¹²		VOUT = 5V	6	-1.32	1.0	-3.7	4.96	6.77	
	50K			6	0.9	6.0	-8.6	11.2	16.3	
	2.5×10¹²			6	-6.38	-0.4	-23.2	23.35	31.83	
	100K			4	-6.7	0	-18.0	23.5	32.0	
	5×10¹²			9	-6.1	-0.9	-22.4	19.35	25.97	
	1×10¹³			3	-3.43	-1.6	-4.5	6.62	8.22	

* VALUES REPRESENT THE CHANGE IN VOLTAGE PRODUCED BY IRRADIATION.

LM105, National Semiconductor, hardened

DEVICE TYPE: LM105 HARDENED NSC PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	/Mean/ +2σ	/Mean/ +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔLOAD REG.	5×10¹²	CURRENT LIMIT: 10Ω	VIN: 8.5V;	6	-1.65	-0.6	-2.5	2.92	3.55	
(mV)	1×10¹³	to REG. OUTPUT;	IL = 10mA	6	-2.97	-0.4	-4.7	5.98	7.48	
		BOOSTER OUTPUT: 0V								
ΔLINE REG.	5×10¹²	UNREG. INPUT: 0V	VIN = 8.5V;	6	-1.47	-0.5	-2.3	2.71	3.33	
(mV)	1×10¹³	COMPENSATION SWITCH IN	IL = 5mA	6	-2.52	1.4	-4.5	6.71	8.81	
		47pF to REG. OUTPUT								
ΔLINE REG.	5×10¹²	↓	VIN = 40V;	6	-0.567	7.9	-2.9	9.04	13.3	
(mV)	1×10¹³		IL = 5mA	6	-3.12	-0.7	-4.5	6.25	7.82	

* VALUES REPRESENT THE CHANGE IN VOLTAGE PRODUCED BY IRRADIATION.

LM106, National Semiconductor

DEVICE TYPE: LM106 NSC PAGE 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVOS (mV)	5×10¹²	V± = ±12V	VNULL = 0.7V	10	-0.0083	0.039	-0.047	0.05	0.0791	
	↓							-0.0666	-0.0957	
	1×10¹³			10	-0.0006	0.066	-0.053	0.0802	0.121	
↓	↓							-0.0814	-0.122	
ΔIOS (μA)	5×10¹²			10	0.185	1.59	-0.09	1.18	1.68	
	↓							-0.812	-1.31	
	1×10¹³			10	-0.003	0.2	-0.09	0.177	0.268	
↓	↓							-0.183	-0.274	
ΔIA (μA)	5×10¹²			4	0.843	1.28	0.48	1.57	1.94	
	↓							0.111	-0.255	
	1×10¹³			4	1.23	1.99	0.67	2.45	3.07	
↓	↓	↓	↓					0.0102	-0.601	

LM108, National Semiconductor, unhardened

DEVICE TYPE: LM108 NSC (UNHARDENED) PAGE 1 of 3 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos(mV)	2.5×10¹²	IN±1MΩ to GND	Rs = 50KΩ	8	-24.98	-8.07	-52.8	6.87	22.79	
	↓	100pF BYPASS CAP						-56.83	-78.75	
	5×10¹²	10K FEEDBACK		8	51.61	513.89	-495.5	924.6	1331.04	
	↓	COMB1: 100pF 608						-801.4	-1227.8	
	1×10¹³	COMB2: OPEN		8	161.18	502.89	-666.99	1650.5	895.17	
	↓	↓	↓					-328.14	-572.81	
ΔVos(mV)	2.5×10¹¹		Rs = 1MegΩ	4	0.045	0.08	0.018	0.102	0.131	
	↓							-0.013	-0.041	
	5×10¹¹			4	-0.056	0.023	-0.620	0.086	0.158	
	↓							-0.199	-0.270	
	1.25×10¹²			4	-0.162	-0.021	-0.242	0.041	0.143	
	↓							-0.365	-0.467	
	2.5×10¹²			22	-12.79	-1.36	-45.4	8.2	21.2	
	↓							-43.8	-56.8	
	5×10¹²			18	-135.17	524.7	-448.5	474.5	772.3	
	↓							-744.8	-1049.6	
	1×10¹³			18	89.62	500.9	-231.3	628.6	898.1	
	↓							-449.4	-718.9	
ΔIos(nA)	2.5×10¹¹			4	0.046	0.07	0.025	0.093	0.117	
	↓							-0.001	-0.025	
	5×10¹¹			4	0.172	0.275	0.108	0.322	0.397	
	↓	↓	↓					0.021	-0.054	

DEVICE TYPE: LM 108 NSC (UNHARDENED) PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIos(nA)	1.25×10¹²	IN±1MΩ to GND	Rs = 1MegΩ	4	0.615	0.981	0.421	1.13	1.39	
	↓	100pF BYPASS CAP						0.10	-0.16	
	2.5×10¹²	10K FEEDBACK		22	0.495	3.55	-2.73	4.39	6.34	
	↓	COMB1: 100pF 608						-3.40	-5.35	
	5×10¹²	COMB2 OPEN		18	-0.137	3.96	-3.607	4.06	6.02	
	↓							-3.79	-5.75	
	1×10¹³			18	0.135	9.0	-8.04	9.38	14.0	
	↓	↓	↓					-9.11	-13.7	
ΔIos(nA)	2.5×10¹¹			4	0.226	0.356	0.159	0.407	0.498	
	↓							0.045	-0.045	
	5×10¹¹			4	0.785	1.19	0.548	1.37	1.67	
	↓							0.195	-0.10	
	1.25×10¹²			4	2.23	3.28	1.67	3.70	4.43	
	↓							0.76	0.021	
	2.5×10¹²			22	3.93	9.5	0.52	8.80	11.04	
	↓							-0.94	-3.37	
	5×10¹²			17	-0.605	0.72	-3.14	1.47	2.50	
	↓							-2.68	-3.71	
				18*	0.253	10.84	-3.14	9.81	11.58	
	↓	↓	↓					-7.3	-11.08	

* OUTLYER INCLUDED

DEVICE TYPE: LM108 NSC (UNHARDENED) PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 BRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIB (nA)	1x10¹³	IN±: 1MΩ to GND	RS: 1 Meg Ω	17	-0.243	4.94	-0.29	6.08	9.04	
		1000pF BYPASS CAP						-6.57	-8.29	
		10K FEEDBACK		18**	-3.29	4.94	-5.[illegible]	23.31	36.61	
		COMP1 = 1000pF to 8'						-29.90	-43.20	
		COMP2 = OPEN								
SLEW RATE	5x10¹²		8V INPUT 25% duty	3*						
RISE (V/μsec)	1x10¹³		cycle; square pulse	3*	* FAILED					
SLEW RATE	5x10¹²			3*						
FALL (V/μsec)	1x10¹³			3*	* FAILED					
OPEN LOOP	2.5x10¹²	Vs = ±15V	2mA LOAD	3*						
GAIN	5x10¹²			3*	* FAILED					

** OUTLYER INCLUDED

LM108, National Semiconductor, hardened

DEVICE TYPE: LM108 (HARDENED) PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: 1 BRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)	5x10¹¹	IN± = 1MΩ to GND	1μF BYPASS	17	-0.0043	0.0380	-0.0460	0.0382	0.0596	
		V± = ±15V						-0.0470	-0.0685	
	1.25x10¹²	10KΩ FEEDBACK		27	0.0010	0.0890	-0.0790	0.0978	0.1462	
		COMP1 = 1000pF to 8						-0.0957	-0.1441	
	2.5x10¹²	COMP2 = OPEN		62	-0.0229	0.2160	-0.293	0.179	0.280	
								-0.225	-0.326	
	5x10¹²			62	-0.0621	0.329	-0.465	0.232	0.379	
								-0.356	-0.504	
	1x10¹³			35	-0.234	0.168	-0.732	0.242	0.480	
								-0.710	-0.948	
ΔIos (nA)	5x10¹¹			27	-0.0001	0.109	-0.066	0.063	0.0945	
								-0.063	-0.0948	
	1.25x10¹²			27	0.0068	0.108	-0.078	0.0868	0.1259	
								-0.0924	-0.1121	
	2.5x10¹²			62	0.0199	0.257	-0.198	0.159	0.228	
								-0.119	0.188	
	5x10¹²			62	0.0528	0.552	-0.310	0.359	0.5[illegible]	
								-0.254	-0.407	
	1x10¹³			35	0.1255	0.669	-0.542	0.671	0.943	
								-0.420	-0.682	

DEVICE TYPE: LM108 NSC (HARDENED) PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRADIATION						-2σ	-3σ	
ΔIB(nA)	5×10¹¹	IN± = 1MΩ to GND; 1μF BYPASS CAP		27	0.0792	0.626	-3.229	1.425	2.0986	
		V± = ±1[illegible]; 10KΩ [illegible]						-1.267	-[illegible]	
	1.25×10¹²	COMP1 = 1000pF to 8		25	0.5016	0.[illegible]4	0.262	0.835	1.002	
		COMP2 = OPEN						0.168	0.0011	
				27*	0.5881	1.773	0.262	1.294	1.646	
								-0.1173	-[illegible]	
	2.5×10¹²			60	1.335	2.51	0.584	2.261	2.724	
								0.4098	-0.053	
				62*	1.411	3.928	0.584	2.653	3.274	
								0.170	-0.451	
	5×10¹²			60	3.043	5.72	1.39	5.12	6.15	
								0.969	-0.0676	
				62*	3.212	8.876	1.39	5.98	7.369	
								0.44	-0.946	
	1×10¹³			35	7.114	12.69	3.04	12.27	14.85	
	* OUTLIERS INCLUDED							1.955	-0.624	
								+2σ	+3σ	
SLEW RATE	2.5×10¹²		8V INPUT;	2	0.122	0.133	0.111	0.153	0.169	
RISE (V/μsec)	5×10¹²		25% duty cycle	2	0.119	0.125	0.114	0.135	0.143	
	1×10¹³		SQUARE PULSE	2	0.109	0.114	0.103	0.124	0.132	
SLEW RATE	2.5×10¹²			2	0.135	0.140	0.129	0.150	0.158	
FALL (V/μsec)	5×10¹²			2	0.129	0.133	0.125	0.140	0.146	
	1×10¹³			2	0.120	0.124	0.116	0.131	0.137	

DEVICE TYPE: LM108 NSC (HARDENED) PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
OPEN LOOP GAIN	2.5×10¹²	Vs = ±15V	RL = ∞	33	116.853	129.127	106.927	103.462	96.767	
(dB)	5×10¹²			34	112.591	138.326	100.668	95.853	87.484	
	1×10¹³			34	101.629	116.482	89.6[illegible]	87.638	80.643	
OPEN LOOP GAIN	2.5×10¹²		RL = 5K	34	102.783	113.046	98.062	95.936	92.512	
(dB)	5×10¹²		2mA LOAD	34	98.831	119.789	93.552	88.970	84.040	
	1×10¹³			34	92.2[illegible]	111.222	85.057	80.558	74.706	
Δ OPEN LOOP	2.5×10¹²		RL = ∞	33	-0.119	11.4	-12.0	-11.3	-16.9	
GAIN (dB)	5×10¹²			34	-4.22	21.3	-22.9	-22.8	-32.1	
	1×10¹³			34	-15.2	6.3	-32.6	-31.6	-39.8	
Δ OPEN LOOP	2.5×10¹²		RL = 5K	34	-2.8	4.6	-6.1	-7.2	-9.4	
GAIN (dB)	5×10¹²		2mA LOAD	34	-6.7	11.4	-13.1	-16.2	-20.9	
	1×10¹³			34	-1[illegible]	2.8	-22.6	-25.9	-32.1	

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

LM111, National Semiconductor, unhardened

DEVICE TYPE: LM111 NSC UNHARDENED PAGE 1 of 2 3

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(S)	e/cm²	BIAS: IRRADIATION						-2σ	-3σ	
ΔIos (nA)	50K		V⁺=15V; IN⁺=GND	IN⁻=-130mV	181	-7.34	13.88	-52.14	8.27	16.1	
				OUTPUT=+15V					-22.9	-30.7	
		5x10¹²			6	-9.33	12.0	-43.0	33.8	55.4	
									-52.5	-74.1	
			OUTPUT=GND;	IN⁻=+50mV	5	[illegible]	9.0	-34.0	21.6	39.5	
									-49.6	-62.5	
	125K		OUTPUT=+15V;	IN⁻=-130mV	6	-37.9	36.8	-92.79	54.4	101	
									-130	-176	
		1x10¹³			6	17.5	55.0	-32.0	84.8	118	
									-49.8	-83.5	
			OUTPUT=GND;	IN⁻=+50mV	5	-23.4	14.0	-52.0	28.1	53.9	
									-74.9	-101	
ΔVos (mV)	50K		OUTPUT=+15V;	IN⁻=-130mV	180	0.835	1.764	-0.58	1.84	2.35	
									-0.175	-0.68	
		5x10¹²			6	1.38	2.0	[illegible]	2.36	2.85	
									0.408	-0.0792	
			OUTPUT=GND;	IN⁻=+50mV	5	0.04	0.2	-0.5	0.5	0.771	
									-0.58	-0.851	
	125K		OUTPUT=+15V;	IN⁻=-130mV	6	2.13	3.027	1.497	3.32	3.92	
									0.935	0.339	
		1x10¹³			6	2.75	3.7	1.4	4.28	5.05	
									1.22	0.452	
			OUTPUT=GND;	IN⁻=+50mV	5	0.16	0.5	-0.1	0.62	0.851	
									-0.3	-0.531	

DEVICE TYPE: LM111 NSC UNHARDENED PAGE 2 of 2

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(S)	e/cm²	BIAS: IRRADIATION						-2σ	[illegible]	
ΔIa (μA)	50K		IN⁺=GND; V⁺=+15V	IN⁻=-130mV	175	-0.344	-0.127	-0.492	-0.167	-0.078	
				OUTPUT=+15V					-0.521	-0.610	
					181*	-0.315	0.798	-0.492	0.056	0.241	
									-0.685	-0.871	
		5x10¹²			6	-0.992	-0.475	-1.302	-0.381	-0.0762	
									-1.6	-1.91	
			OUTPUT=GND;	IN⁻=+50mV	5	-0.895	2.574	-1.188	-0.42	-0.182	
									-1.37	-1.61	
	125K		OUTPUT=+15V;	IN⁻=-130mV	6	-0.742	-0.347	-1.108	-0.226	+0.031	
									-1.257	-1.515	
		1x10¹³			6	-1.1	-0.542	-1.569	-0.335	-0.0493	
									-1.87	-2.26	
			OUTPUT=GND;	IN⁻=+50mV	5	-1.02	-0.612	-1.389	-0.432	-0.138	
									-1.6	-1.9	
									+2σ	+3σ	
ISINK MAX (mA)		5x10¹²	PULSED BY 2KHz		5	0.032	0.05	0.0[illegible]	0.058	0.0711	
		125x10¹²	100mA OVERDRIVE;		2	0.075	0.09	0.06	0.117	[illegible]	
		25x10¹²	6mA SINK CURRENT		5	0.126	0.15	0.09	0.184	0.212	
		5x10¹²	10μsec PULSE		5	0.182	0.23	0.13	0.264	0.306	
* OUTLIERS INCLUDED											

LM111, National Semiconductor, IRAN reirradiation

IRAN REIRRADIATION

DEVICE TYPE: LM111 NSC. PAGE 1 of 1 IRAN FLUENCE 50Krad (Si)Co^{60} IRAN

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔVos (mV)	5×10¹¹	V± = 15V; IN⁺ = GND		12	0.800	1.338	0.290	1.568	1.953	<3mV
	1.25×10¹²	IN⁻ = -130mV		12	1.511	2.423	0.494	2.944	3.661	
	2.5×10¹²			12	2.393	3.783	0.488	4.815	6.027	
	5×10¹²			12	3.733	5.868	1.140	7.359	9.123	
								-2σ	-3σ	
ΔIos (nA)	5×10¹¹			12	-18.24	2.23	-30.89	-41.47	-5[illegible].09	<20nA
	1.25×10¹²			12	-42.23	-7.11	-77.83	-87.50	-110.14	
	2.5×10¹²			12	-80.58	-19.35	-136.24	-160.92	-201.09	
	5×10¹²			12	-132.31	-36.97	-219.35	-263.77	-329.50	
								±2σ	±3σ	
ΔIB (nA)	5×10¹¹			12	66.94	293.40	-163.50	401.62	568.96	<1μA
								-262.74	-435.08	
	1.25×10¹²			12	-48.00	188.45	-432.50	352.17	552.25	
								-448.17	-648.26	
	2.5×10¹²			12	-149.74	129.95	-495.5	261.12	466.95	
								-560.59	-966.02	
	5×10¹²			12	-136.29	280.95	-520.20	339.54	577.46	
								-612.12	-950.03	

LM124, National Semiconductor, unhardened

DEVICE TYPE: LM124 NSC (UNHARDENED) PAGE 1 of 5 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)	5×10¹¹	IN⁺ = 100K to GND	R₂ = 10K, V⁻ = 0	14	0.102	0.048	-0.358	0.135	0.254	
		10K FEEDBACK	V⁺ = 15V					-0.340	-0.459	
	1.25×10¹²	V⁺ = +15V		14	0.053	0.391	-0.593	0.543	0.787	
								-0.437	-0.681	
	2.5×10¹²			14	0.783	1.646	-0.497	1.998	2.600	
								-0.412	-1.014	
	5×10¹²			14	1.335	2.531	-0.442	3.113	4.001	
								-0.442	-1.331	
ΔVos (mV)	5×10¹²		R₂ = 10K; V⁻ = -15V	17	-4.502	-2.857	-10.67	0.488	2.983	
			V⁺ = +15V					-9.492	-11.99	
	1×10¹³			16*	-7.063	-5.278	-8.98	-4.83	-3.72	
								-9.30	-10.41	
ΔVos (mV)	5×10¹¹		R₂ = 1K, V⁻ = 15V	14	-0.144	0.030	-0.450	0.163	0.316	
			V⁺ = +15V					-0.450	-0.603	
	1.25×10¹²			14	0.010	0.360	-0.68	0.522	0.778	
								-0.502	-0.758	
	2.5×10¹²			14	0.677	1.57	-0.57	1.889	2.48	
								-0.491	-1.086	
	5×10¹²			14	1.261	3.17	-0.54	3.27	4.27	
								-0.746	-1.75	

* ONE DEVICE FAILED

DEVICE TYPE: LM124 NSC (UNHARDENED) PAGE 2 of 5

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIos(nA)	5×10¹¹	IN⁺=100K to GND	R2=10K, V⁻=0	14	0.711	7.14	-3.09	6.03	8.70	
	↓	10K FEEDBACK	V⁺=+15V					-4.61	-7.27	
	1.25×10¹²	V⁺=+15V		14	-1.01	13.18	-18.19	16.11	24.67	
	↓							-18.14	-26.70	
	2.5×10¹²			14	-5.62	19.83	-51.86	38.44	60.47	
	↓							-49.68	-71.71	
	5×10¹²			14	-12.26	29.28	-89.69	59.78	95.8	
↓	↓		↓					-84.3	-120.3	
ΔIos(nA)	5×10¹²		R2=10K, V⁻=-15V	17	-1.56	2.145	-26.17	11.23	17.62	
	↓		V⁺=+15V					-14.35	-20.75	
	1×10¹³			16*	-0.963	13.85	-9.67	10.85	16.76	
↓	↓		↓					-12.78	-18.68	
ΔIos(nA)	5×10¹¹		R2=1K; V⁻=-15V	14	1.283	5.70	-1.70	5.32	7.33	
	↓		V⁺=+15V					-2.73	-4.74	
	1.25×10¹²			14	-0.743	12.60	-17.1	15.66	23.86	
	↓							-17.14	-25.35	
	2.5×10¹²			14	-5.76	19.10	-49.90	36.75	58.30	
	↓							-48.46	-69.82	
	5×10¹²			14	-12.01	29.10	-87.30	57.41	92.11	
↓	↓	↓	↓					-81.42	-116.13	
	* ONE DEVICE FAILED									

DEVICE TYPE: LM124 NSC (UNHARDENED) PAGE 3 of 5

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIB(nA)	5×10¹¹	IN⁺=100K to GND	R2=10K; V⁻=0	14	-13.49	-11.67	-16.46	-10.40	-8.86	
	↓	10K FEEDBACK	V⁺=+15V					-16.57	-18.12	
	1.25×10¹²	V⁺=+15V		14	-28.84	-24.41	-35.91	-20.67	-16.58	
	↓							-37.01	-41.10	
	2.5×10¹²			14	-47.79	-35.57	-61.69	-30.06	-21.19	
	↓							-65.53	-74.39	
	5×10¹²			14	-74.91	-52.83	-97.32	-44.30	-28.97	
↓	↓		↓					-105.5	-120.8	
ΔIB(nA)	5×10¹²		R2=10K, V⁻=-15V	17	-10.75	4.81	-24.35	2.80	9.57	
	↓		V⁺=+15V					-24.30	-31.08	
	1×10¹³			17	-11.13	[illegible]	-42.5	18.50	33.52	
↓	↓		↓					-40.76	-55.58	
ΔIB(nA)	5×10¹¹		R2=1K, V⁻=-15V	14	-8.78	-6.90	-11.1[illegible]	-5.97	-4.60	
	↓		V⁺=+15V					-11.56	-12.96	
	1.25×10¹²			14	-23.87	-17.8	-31.40	-16.41	-12.67	
	↓							-31.37	-35.11	
	2.5×10¹²			14	-42.39	-30.80	-56.20	-25.85	-17.58	
	↓							-58.92	-67.19	
	5×10¹²			14	-67.93	-46.3	-90.6	-38.60	-23.93	
↓	↓	↓	↓					-97.26	-111.93	

DEVICE TYPE: LM124 NSC (UNHARDENED) PAGE 4 of 5

Parameter	Fluence	Operating Point				Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.		BIAS: MEAS.						-2σ	-3σ	
ΔOUTPUT	5×10¹¹	IN+: 10K to GND		IN-: -1.2V, IN+: 0		14	-0.0013	-0.0011	-0.0022	-0.0005	-0.0002	
CURRENT SINK	↓	10K FEEDBACK								-0.0020	-0.0024	
(mA)	1.25×10¹²	V+ = +15V				14	-0.0028	-0.0022	-0.0032	-0.0015	-0.0024	
	↓									-0.0031	-0.0033	
	2.5×10¹²					14	-0.0050	-0.0051	-0.0062	-0.0050	-0.0047	
	↓									-0.0063	-0.0066	
	5×10¹²					22	-0.0077	-0.0050	-0.0091	-0.0047	-0.0032	
	↓									-0.0106	-0.0121	
	1×10¹³					8	-0.0109	-0.0060	-0.0140	-0.0050	-0.0030	
↓	↓			↓						-0.0169	-0.0198	
ΔOUTPUT	5×10¹¹			IN-=0; IN+=1.2V		14	-0.0011	0	-0.0022	-0.0007	-0.0004	
CURRENT SOURCE	↓									-0.0022	-0.0017	
(μA)	1.25×10¹²					14	-0.0019	0	-0.0030	-0.0004	-0.0002	
	↓									-0.0033	-0.0041	
	2.5×10¹²					14	-0.0026	0	-0.0040	-0.0007	-0.0006	
	↓									-0.0045	-0.0054	
	5×10¹²					21	-0.0030	0	-0.0050	-0.0004	-0.0021	
										-0.0064	-0.0081	
						22*	-0.0023	0.0110	-0.0050	0.0044	0.0077	
	↓									-0.0082	-0.0106	
	1×10¹³					8	-0.0003	0.0110	-0.0040	0.0091	0.0139	
↓	↓	↓		↓						-0.0098	-0.0147	
	* OUTLIER INCLUDED											

DEVICE TYPE: LM124 NSC (UNHARDENED) PAGE 5 of 5

Parameter	Fluence	Operating Point				Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.		BIAS: MEAS.								
OPEN LOOP GAIN	2.5×10¹²	V+ = +15V		2mA LOAD +10V		8	99.03	100.0	97.22	97.51	96.25	
(dB)	5×10¹²			SWING		8	99.30	100.9	98.06	97.09	96.87	
	1×10¹³			↓		8	95.37	97.07	93.16	92.40	90.91	
	2.5×10¹²			-10V SWING		8	104.60	106.02	102.47	102.24	101.07	
	5×10¹²					8	96.22	99.18	91.05	91.35	88.82	
	1×10¹³			↓		8	83.69	84.45	82.60	82.31	81.62	
	2.5×10¹²			20V PEAK to PEAK		8	103.05	103.75	102.21	101.76	101.62	
	5×10¹²					8	98.27	100.25	95.56	95.44	94.03	
↓	1×10¹³			↓		8	87.62	88.39	86.02	85.86	84.99	
ΔOPEN LOOP	2.5×10¹²			+10V SWING		8	-0.57	0.65	-1.22	-2.55	-3.53	
GAIN (dB)	5×10¹²					8	-0.30	0.99	-1.22	-2.34	-3.36	
	1×10¹³			↓		8	-4.23	-0.99	-7.74	-8.96	-11.33	
	2.5×10¹²			-10V SWING		8	-1.80	0	-3.55	-4.59	-5.99	
	5×10¹²					8	-10.19	-6.84	-14.97	-15.23	-18.49	
	1×10¹³			↓		8	-22.20	-20.59	-24.09	-25.28	-26.54	
	2.5×10¹²			20V PEAK to PEAK		8	-1.99	0.63	-4.01	-4.86	-6.45	
	5×10¹²					8	-6.77	-4.09	-10.01	-11.0	-13.12	
↓	1×10¹³	↓		↓		8	-17.42	-14.94	-20.46	-21.05	-22.86	

LM124, National Semiconductor, hardened

DEVICE TYPE: LM124 HARDENED NSC PAGE 1 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔVos (mV)	5×10¹²	IN⁻=100K to GND, IN⁺=15V, OUT=100K to IN⁻		19	-1.039	-0.0965	-2.895	-0.0406	0.2587	
								-3.238	-4.0323	
	1×10¹³			19	-4.019	-2.080	-7.082	-0.438	1.353	
								-7.601	-9.392	
ΔIos (nA)	5×10¹²			19	-2.565	6.04	-9.26	6.054	10.363	
								-11.184	-15.484	
	1×10¹³			19	-1.778	15.34	-13.6	15.147	23.161	
								-18.704	-22.17	
ΔIB (nA)	5×10¹²			19	-143.5	-136.3	-152.99	-132.91	-122.6	
								-154.10	-159.4	
	1×10¹³			19	-253.7	-242.8	-262.6	-242.3	-236.6	
								-265.2	-270.9	
Output Current Sink (mA)	5×10¹²	IN⁻=100K to GND, IN⁺=15V, OUT=100K to IN⁻	IN⁻=1.2V, IN⁺=GND, OUT SWITCH=+5V	7	-0.0057	-0.0037	-0.0183	-0.0011	0.0011	
								-0.0103	-0.0126	
	1×10¹³			7	-0.0110	-0.0080	-0.0148	0.0041	-0.0007	
								0.0178	-0.0212	
Output Current Source (mA)	5×10¹²		IN⁻=GND, IN⁺=1.2V, OUT SWITCH=GND	7	-0.0041	0	-0.0010	0.0016	0.0011	
								-0.0017	-0.0020	
	1×10¹³			7	-0.0012	-0.0010	0.0000	-0.0003	0.0001	
								-0.0022	-0.0027	

DEVICE TYPE: LM124 NSC (HARDENED) PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
OPEN LOOP GAIN (dB)	2.5×10¹²	V+=+15V	2mA LOAD +10V	8	98.12	100.0	97.07	96.18	95.20	
	5×10¹²		SWING	8	96.60	100.0	94.85	93.21	91.52	
	1×10¹³			8*						
	2.5×10¹²		-10V SWING	8	97.95	98.79	97.38	96.88	96.35	
	5×10¹²			8	86.15	87.95	84.71	83.83	82.82	
	1×10¹³			8*						
	2.5×10¹²		20V PEAK TO PEAK	8	98.88	100.0	97.72	97.31	96.53	
	5×10¹²			8	90.14	91.70	88.88	88.32	87.41	
	1×10¹³			8*						
Δ OPEN LOOP GAIN (dB)	2.5×10¹²		+10V SWING	8	-0.065	1.62	-1.07	-1.78	-2.63	
	5×10¹²			8	-1.59	1.62	-2.88	-4.85	-6.48	
	2.5×10¹²		-10V SWING	7**	-7.23	-6.25	-8.64	-8.91	-9.75	
	5×10¹²			7**	-19.05	-17.25	-19.74	-20.70	-21.53	
	2.5×10¹²		20V PEAK TO PEAK	8	-4.10	-3.10	-5.07	-5.36	-5.99	
	5×10¹²			8	-12.84	-11.40	-13.51	-14.37	-15.13	

* FAILED

** NO PRETEST MEASUREMENT GIVEN FOR ONE DEVICE

LM139, National, Signetics, and Texas Instruments

The data presented herein represents eight radiation tests for various vendors and date codes using different bias and measurement conditions. In all cases, two sections (of the four-section device type) were tested. Device failure is defined as saturation of the null amplifier during dc measurements; i.e., the device output is latched to the positive supply voltage. Table 3 is a summary of the number of failures versus fluence for the various experimental conditions and device lots.

National Semiconductor made various attempts to harden the LM139 with only partial success. Several radiation tests were performed on these experimental devices, but only one lot (E2035, tested 11-25-75) was available for flight use and consequently included herein.

Table 3. LM139 quad comparator radiation test summary

Test date	Manufacturer	Process	Date code	Supply voltage, V	Null voltage, V	Bias condition during irradiation: Input No.	Input Condition	Outputs	No. of Devices	Failures at fluence levels[a]: 2.5×10^{11} e/cm^2	5×10^{11} e/cm^2	1×10^{12} e/cm^2	1.25×10^{12} e/cm^2	2.5×10^{12} e/cm^2	5×10^{12} e/cm^2	1×10^{13} e/cm^2
12/20/74	NSC	Standard	406	+5	+1.4	1-	+50 mV	On	6	-	-	-	-	-	0	1
						1+	Gnd									
						2-	-130 mV	Off	6	-	-	-	-	-	0	1
						2+	Gnd									
3/20/75	NSC	Standard	402	+15	+0.7	1-	+50 mV	On	3	0	0	0	-	-	-	-
			and			1+	Gnd									
			502			2-	-130 mV	Off	3	0	0	2	-	-	-	-
						2+	Gnd									
4/16/75	NSC	(LM339) Standard	403	+15	+0.7	1-	+50 mV	On	6	-	0	0	-	0	1	-
						1+	Gnd									
						2-	Gnd	Off	6	-	0	3	-	6	6	-
						2+	+50 mV									
11/7/75	NSC	Standard	406	+15	+0.7	1-	+50 mV	On	3	-	0	-	0	0	0	-
						1+	Gnd									
						2-	Gnd	Off	3	-	0	-	0	3	3	-
						2+	+50 mV									
11/6/75	NSC	Standard	406	+15	+0.7	1-	b	50% duty	3	-	0	-	0	0	0	-
						1+		~pulse								
						2-	b	56 μs	3	-	0	-	0	3	3	-
						2+		pulse								
11/6/75	NSC	Standard	406	+15 (during meas)	+0.7	1-	open	passive[c]	3	-	0	-	0	0	0	-
						1+										
						1-	open	passive[c]	3	-	0	-	0	0	0	-
						1+										
11/25/75	NSC	Hardened	Lot - E2035	+15	+0.7	1-	+50 mV	On	3	-	0	-	0	0	0	-
						1+	Gnd									
						2-	Gnd	Off	3	-	0	-	0	0	3	-
						2+	+50 mV									
7/3/75	SGN	Standard	7437	+15	+0.7	1-	+50 mV	On	5	-	0	0	-	0	0	-
						1+	Gnd									
						2-	Gnd	Off	5	-	0	0	-	0	5	-
						2+	+50 mV									

[a] Null amplifier saturated during dc measurements for one or more parameters.

[b] Input (1-) - 0 to 100 mV, 50% duty cycle. Input (1+) = 50 mVdc.
Input (2-) - 0 to 100 mV, 56 μs pulse every 3 s.
Input (2+) - 50 mV dc.

[c] No supply voltage applied during irradiation.

Conclusions reached were as follows:

(1) The LM139 type device is very sensitive to radiation damage.

(2) The devices biased "off" during radiation are more sensitive to degradation than devices biased "on" during irradiation.

(3) Device degradation may vary significantly between different date codes.

(4) The degradation for the devices pulsed at 50% duty cycle is comparable to the devices biased "on" during radiation.

(5) The degradation for the devices pulsed at 56μ sec every 3 sec is comparable to the devices biased "off" during irradiation.

(6) The parameter degradation of the devices irradiated passively was slightly worse than the devices biased "on" during irradiation.

(7) The hardened National Semiconductor devices, using the same bias conditions, did not fail until 5×10^{12} e/cm^2, whereas the standard devices failed at 2.5×10^{12} e/cm^2. The hardened devices showed significantly greater degradation in sink current than the unhardened devices.

(8) The low failure rate for the 12/20/74 test was due to use of a supply voltage of 5 instead of 15 volts.

LM139, National Semiconductor, unhardened

DEVICE TYPE: LM139 NSC UNHARDENED PAGE 1 of 11 4

Parameter	Fluence e/cm²	Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔVos (mV)	2.5×10¹¹	15	+0.7	-130mV	OFF	3	-0.1	-0.08	-0.12	-0.06	-0.04	
				GND						-0.14	-0.16	
		15	+0.7	+50mV	ON	3	-0.033	0	-0.07	0.037	0.072	
				GND						-0.104	-0.137	
	5×10¹¹	15	+0.7	-130mV	OFF	3	-0.427	-0.19	-0.70	-0.087	0.34	
				GND						-0.94	-1.20	
		15	+0.7	GND	OFF	9	1.68	8.35	-3.63	8.72	12.24	
				+50mV						-5.36	-8.88	
		15	+0.7	+50mV	ON	12	-0.052	0.31	-0.3	0.23	0.37	
				GND						-0.34	-0.48	
		15	+0.7		50% duty cycle @ 100Hz	3	0.1	0.2	0	0.3	0.4	
										-0.1	-0.2	
		15	+0.7		56μsec pulse	3	0.5	0.6	0.4	0.7	0.8	
										0.3	0.2	
		15	+0.7	PASSIVE		6	-0.55	-0.1	-0.8	-0.017	0.249	
										-1.08	-1.35	
	1×10¹²	15	+0.7	-130mV	OFF	3*						
				GND			* OUTPUT LATCHED TO POSITIVE SUPPLY					
		15	+0.7	GND	OFF	6**	OUTPUT LATCHED TO POSITIVE SUPPLY					
				+50mV			ON 3 DEVICES					
		15	+0.7	+50mV	ON	8**	-0.038	0.18	-0.18	0.24	0.58	
				GND						-0.32	-0.45	
AGS												
										** 1 OUTLIER EXCLUDED		

DEVICE TYPE: LM139 NSC UNHARDENED PAGE 2 of 11

Parameter	Fluence e/cm²	Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔVos (mV)	1.25×10¹²	15	+0.7	GND	OFF	3	38.97	49.41	32.6	57.2	66.3	
				+50mV						20.7	11.6	
		15	+0.7	+50mV	ON	3	-0.67	-0.40	-1.0	-0.056	0.25	
				GND						-1.28	-1.58	
		15	+0.7		50% duty cycle @ 100Hz	3	0	0.4	-0.2	0.69	1.04	
										-0.69	-1.04	
		15	+0.7		56μsec Pulse	3	47.6	71	28.4	90.8	116.4	
										4.3	-17.3	
		15	+0.7	PASSIVE		6	-0.38	0.5	-0.8	0.58	1.07	
										-1.35	-1.83	
	2.5×10¹²	15	+0.7	GND	OFF	9*	* ALL DEVICES LATCHED TO POSITIVE SUPPLY					
				+50mV								
		15	+0.7	+50mV	ON	9	-0.206	1.34	-2.0	1.88	2.92	
				GND						-2.29	-3.33	
		15	+0.7		50% duty cycle @ 100Hz	3	-0.1	0.5	-0.6	1.01	1.57	
										-1.21	-1.77	
		15	+0.7		56μsec pulse	3**	** WILL NOT NULL					
		15	+0.7	PASSIVE		6	-0.017	1.5	-1.0	2.013	3.03	
										-2.05	-3.06	
	5×10¹²	5	+1.4	-130mV	OFF	6	0.432	1.33	-0.05	1.64	2.25	
				GND						-0.78	-1.39	
		5	+1.4	+50mV	ON	6	10.4	43.7	-2.67	45.8	63.5	
				GND						-25.1	-42.8	

DEVICE TYPE: LM139 NSC UNHARDENED PAGE 3 of 11

Parameter	Fluence	Operating Point: Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²											
ΔVos(mV)	5×10¹²	15	+0.7	GND	OFF	9*	* ALL DEVICES LATCHED TO POSITIVE SUPPLY					
				+50mV								
		15	+0.7	+50mV	ON	9	-0.316	3.72	-3.8	3.58	5.65	
				GND						-4.3	-6.28	
		15	+0.7		50% duty cycle @ 120Hz	3	-0.37	0.6	-1.3	1.53	2.48	
										-2.27	-3.22	
		15	+0.7		56μsec pulse	3**	** WILL NOT ANNEAL					
		15	+0.7	PASSIVE		6	0.92	4.7	-6.4	9.04	13.1	
										-7.2	-11.3	
	1×10¹³	5	+1.4	-130mV	OFF	6**	1.13	4.10	0.08	4.49	6.17	
				GND						-2.24	-3.92	
		5	+1.4	+50mV	ON	6**	15.4	49.8	0.32	56.3	76.7	
				GND						-25.4	-45.9	
						** ONE DEVICE LATCHED TO POSITIVE SUPPLY						
ΔIos(nA)	2.5×10¹¹	15	+0.7	-130mV	OFF	3	-0.87	-0.8	-1.0	-0.164	-0.58	
				GND						-1.1	-1.2	
		15	+0.7	+50mV	ON	3	-0.163	0.1	-1.1	0.165	1.30	
				GND						-1.9	-2.56	
	5×10¹¹	15	+0.7	-130mV	OFF	3	2.1	-0.6	-3.4	0.22	2.1	
				GND						-4.9	-6.3	
		15	+0.7	GND	OFF	9	-0.56	2.4	-5.0	4.26	6.67	
				+50mV						-5.37	-7.78	

DEVICE TYPE: LM139 NSC UNHARDENED PAGE 4 of 11

Parameter	Fluence	Operating Point: Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²											
ΔIos(nA)	5×10¹¹	15	+0.7	+50mV	ON	12	-0.48	3.1	-6.0	3.88	6.06	
				GND						-4.83	-7.01	
		15	+0.7		50% duty cycle @ 120Hz	3	-0.67	1.0	-4.0	5.11	7.99	
										-6.44	-9.33	
		15	+0.7		56μsec pulse	3	-1.5	1.0	-3.5	3.08	5.37	
										-6.08	-8.37	
		15	+0.7	PASSIVE		6	9.05	12	7	12.57	14.33	
										5.53	3.77	
	1×10¹²	15	+0.7	-130mV	OFF	3*						
				GND			* OUTPUT LATCHED TO POSITIVE SUPPLY					
		15	+0.7	GND	OFF	6**	** 3 DEVICES LATCHED TO POSITIVE SUPPLY					
				+50mV								
		15	+0.7	+50mV	ON	8**	1.99	5.5	-3.7	8.98	12.5	
				GND		** 1 OUTLIER EXCLUDED				-5	-8.5	
	1.25×10¹³	15	+0.7	GND	OFF	3	96.7	131	58	170.1	206.7	
				+50mV						23.3	13.4	
		15	+0.7	+50mV	ON	3	-8.0	-3	-16	6	13	
				GND						-22	-29	
		15	+0.7		50% duty cycle @ 120Hz	3	3.67	4.0	3.0	4.82	5.10	
										2.51	1.93	
		15	+0.7		56μsec pulse	3	123.8	158.5	87	178.1	234.3	
										53.5	12.4	
		15	+0.7	PASSIVE		6	14	23	7	26.9	33.3	
										1.1	-5.36	

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

DEVICE TYPE: LM139 NSC UNHARDENED PAGE 5 of 11

Parameter	Fluence	Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN-PUT	Output	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²											
ΔIos (nA)	2.5×10¹²	15	+0.7	GND	OFF	9*	* ALL DEVICES LATCHED TO POSITIVE SUPPLY					
		15	+0.7	+50mV	ON	9	-0.18	23.6	-34	43.3 / -43.6	65 / -65.3	
		15	+0.7	GND	50% duty cycle 60Hz	3	3.67	10.0	2.4	7.73 / -0.467	9.78 / -2.54	
		15	+0.7		50μsec pulse	3**	** WILL NOT NULL					
		15	+0.7	PASSIVE		6	34.4	68	17.6	71.6 / -2.71	90.2 / -21.3	
	5×10¹²	5	+1.4	-130mV GND	OFF	6	7.65	34	-9.6	39.5 / -24.2	55.5 / -40.2	
		5	+1.4	+50mV GND	ON	6	47.35	200.1	-11.5	222.5 / -127.8	310 / -215.3	
		15	+0.7	GND +50mV	OFF	9*	ALL DEVICES LATCHED TO POSITIVE SUPPLY					
		15	+0.7	+50mV GND	ON	9	10.7	51.5	-42.5	68.4 / -47	92.2 / -75.9	
		15	+0.7		50% duty cycle 60Hz	3	32	41	25	52.9 / 11.1	63.3 / 0.677	
		15	+0.7		50μsec pulse	3**	** WILL NOT NULL					
		15	+0.7	PASSIVE		6	106.3	197	50	222.5 / -9.84	280.6 / -67.7	

DEVICE TYPE: LM139 NSC UNHARDENED PAGE 6 of 11

Parameter	Fluence	Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN-PUT	Output	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²											
ΔIos (nA)	1×10¹³	5	+1.4	-130mV GND	OFF	6*	15.2	58.2	-9.1	60.0 / -36.6	92.8 / -62.4	
		5	+1.4	+50mV GND	ON	6*	58.4	333.1	-72	378.1 / -261.4	538 / -421.3	
						* ONE DEVICE LATCHED TO POSITIVE SUPPLY						
ΔIB (nA)	2.5×10¹¹	15	+0.7	-130mV GND	OFF	3	4.87	11.1	0.8	15.8 / -6.1	21.3 / -11.6	
		15	+0.7	+50mV GND	ON	3	2.47	9.1	-2	14.2 / -7.3	20 / -15.1	
	5×10¹¹	15	+0.7	-130mV GND	OFF	3	29.3	43.1	13.6	59 / -0.36	73.9 / -15.2	
		15	+0.7	GND +50mV	OFF	9	0.49	5.3	-36	69.9 / -68.9	104.6 / -103.6	
		15	+0.7	+50mV GND	ON	12	2.39	56	-36.5	65.3 / -60.5	96.7 / -92	
		15	+0.7		50% duty cycle 60Hz	3	70	86	58	98.8 / 41.2	113.3 / 26.7	
		15	+0.7		50μsec pulse	3	66.3	82	56	93.9 / 38.7	107.7 / 24.9	
		15	+0.7	PASSIVE		6	63.8	78	47	80.6 / 37	104.1 / 23.6	

DEVICE TYPE: LM139 NSC UNHARDENED PAGE 7 of 11

Parameter	Fluence	OPERATING POINT: Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²									-2σ	-3σ	
ΔIB (nA)	1x10¹²	15	+0.7	-130mV	OFF	3*						
				GND			*OUTPUT LATCHED TO POSITIVE SUPPLY					
		15	+0.7	GND	OFF	6**	**3 DEVICES LATCHED TO POSITIVE SUPPLY					
				+50mV								
		15	+0.7	+50mV	ON	9	-6.69	103.6	-87.6	114.8	175.5	
				GND						-128.2	-188.9	
	1.25x10¹²	15	+0.7	GND	OFF	3	167.9	185	140	216.7	241.1	
				+50mV						119.2	94.8	
		15	+0.7	+50mV	ON	3	116.7	146	98	168.1	193.8	
				GND						65.2	37.5	
		15	+0.7		50% duty	3	176.7	218	147	250.5	287.4	
					cycle @ 100Hz					102.8	65.9	
		15	+0.7		56μsec	3	219.3	239	200	258.3	277.8	
					pulse					180.3	160.8	
		15	+0.7	PASSIVE		6	183.7	222	124	222.3	36.6	
										95	50.7	
	2.5x10¹²	15	+0.7	GND	OFF	9*	*ALL DEVICES LATCHED TO POSITIVE					
				+50mV			SUPPLY					
		15	+0.7	+50mV	ON	9	5.69	285	-221.5	407.4	608.3	
				GND						-396	-596.9	
		15	+0.7		50% duty	3	334.3	400	290	450.4	508.4	
					cycle @ 100Hz					218.3	160.3	
		15	+0.7		56μsec	3**	**WILL NOT NULL					
					PULSE							

DEVICE TYPE: LM139 NSC UNHARDENED PAGE 8 of 11

Parameter	Fluence	OPERATING POINT: Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²									-2σ	-3σ	
ΔIB (nA)	2.5x10¹²	15	+0.7	PASSIVE		6	385.7	470	263	566.3	656.5	
										205.1	114.8	
	5x10¹²	5	+1.4	-130mV	OFF	6	291.2	412.5	219.6	438.6	512.3	
				GND						143.8	70	
		5	+1.4	+50mV	ON	6	279.3	359.9	167.2	426.5	500.1	
				GND						132.1	58.5	
		15	+0.7	GND	OFF	9*	*ALL DEVICES LATCHED TO POSITIVE					
				+50mV			SUPPLY					
		15	+0.7	+50mV	ON	9	111.8	1333.3	-406.9	1277	1860	
				GND						-1053.5	-1636	
		15	+0.7		50% duty	3	532.3	610	486	667.7	735.4	
					cycle @ 100Hz					397	329.3	
		15	+0.7		56μsec	3**	**WILL NOT NULL					
					pulse							
		15	+0.7	PASSIVE		6	665.2	718	598	748.1	789.6	
										582.2	540.7	
	1x10¹³	5	+1.4	-130mV	OFF	6**	486.8	654.8	403.1	686.5	786.3	
				GND						287.1	187.3	
		5	+1.4	+50mV	ON	6**	498.9	595.7	431.7	667.7	752.1	
				GND						330.1	245.7	
						** ONE DEVICE LATCHED TO POSITIVE SUPPLY						

DEVICE TYPE: LM139 NSC PAGE 9 of 11

Parameter	Fluence	Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	OPERATING POINT: Bias Condition During Trend. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²											
OUTPUT SINK	25×10¹¹	15	1.5	-30mV GND	OFF	3	10.34	11.14	9.29	8.44	7.49	
CURRENT (mA)	↓	15	1.5	+30mV GND	ON	3	10.26	11.04	9.23	8.40	7.47	
	5×10¹¹	15	1.5	-30mV GND	OFF	3	9.63	10.54	8.47	7.51	6.46	
		15	1.5	GND +30mV	OFF	9	11.0	18.57	7.18	2.58	*	
		15	1.5	+30mV GND	ON	12	10.58	12.38	6.82	3.39	*	
		15	1.5		50% duty cycle	3	14.68	19.92	10.63	5.17	0.41	
		15	1.5		50 μsec pulse	3	15.75	20.14	12.56	7.90	3.97	
	↓	15	1.5	PASSIVE		6	15.30	18.57	12.71	9.80	7.05	
	1×10¹²	15	1.5	-30mV GND	OFF	3**	7.74	2.36	7.12	5.99	5.[illegible]	
		15	1.5	GND +30mV	OFF	9**	** 4 DEVICES FAILED					
		15	1.5	+30mV GND	ON	12	8.24	13.43	5.31	3.43	1.02	
		15	1.5		50% duty cycle	3	10.28	14.2	7.12	3.07	*	
		15	1.5		50 μsec pulse	3	11.27	14.86	8.96	4.97	1.83	
	↓	15	1.5	PASSIVE		6	10.26	13.5	7.43	[illegible].71	1.99	
	2.5×10¹²	15	1.5	GND +30mV	OFF	9	ALL DEVICES LATCHED TO POSITIVE SUPPLY					
		15	1.5	+30mV GND	ON	9	5.42	8.82	3.34	1.23	0.04	
		15	1.5		50% duty cycle	3	6.55	9.02	1.47	1.95	*	
		15	1.5		50 μsec pulse	3	WILL NOT NULL					
↓	↓	15	1.5	PASSIVE		6	6.03	8.57	3.67	1.66	*	
	* VALUE CHANGED SIGN											
	** 1 DEVICE FAILED											

DEVICE TYPE: LM139 NSC PAGE 10 of 11

Parameter	Fluence	Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	OPERATING POINT: Bias Condition During Trend. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²											
OUTPUT SINK	5×10¹²	15	1.5	GND +30mV	OFF	9	ALL DEVICES LATCHED TO POSITIVE SUPPLY					
CURRENT (mA)	↓	15	1.5	+30mV GND	ON	9	3.72	6.52	1.90	0.79	*	
		15	1.5		50% duty cycle	3	3.68	4.86	2.56	1.37	0.24	
		15	1.5		50 μsec pulse	3	WILL NOT NULL					
↓	↓	15	1.5	PASSIVE		6	2.93	4.04	1.59	0.74	*	
OUTPUT SINK	2.5×10¹¹	15	1.5	-30mV GND	OFF	3	-0.49	-0.26	-0.65	-0.90	-1.10	
CURRENT (mA)	↓	15	1.5	+30mV GND	ON	3	-0.63	-0.60	-0.68	-0.72	-0.76	
	5×10¹¹	15	1.5	-30mV GND	OFF	3	-1.28	-1.10	-1.47	-1.65	-1.84	
		15	1.5	GND +30mV	OFF	9	-2.62	-1.54	-4.87	-5.28	-6.32	
		15	1.5	+30mV GND	ON	12	-2.22	-0.48	-5.01	-4.86	-6.17	
		15	1.5		50% duty cycle	3	-4.74	-4.53	-5.15	-5.45	-5.82	
		15	1.5		50 μsec pulse	3	-4.88	-4.21	-5.66	-6.04	-7.37	
	↓	15	1.5	PASSIVE		6	-4.71	-4.12	-5.57	-6.08	-6.76	
	1×10¹²	15	1.5	-30mV GND	OFF	3**	-2.8	-2.78	-2.82	-2.86	-2.88	
		15	1.5	GND +30mV	OFF	9**	** 4 DEVICES FAILED					
		15	1.5	+30mV GND	ON	12	-4.56	-2.59	-10.08	-7.05	-6.20	
		15	1.5		50% duty cycle	3	-9.15	-8.06	-10.87	-12.16	-13.07	
		15	1.5		50 μsec pulse	3	-9.36	-7.81	-10.22	-12.04	-13.18	
↓	↓	15	1.5	PASSIVE		6	-9.25	-8.63	-10.88	-11.6	-12.5	
	* VALUE CHANGED SIGN											
	** 1 DEVICE FAILED											

DEVICE TYPE: LM139 NSC PAGE 11 of 11

Parameter	Fluence	OPERATING POINT: Bias Condition During Meas. Supply Volt (V)	Null Volt (V)	Bias Condition During Irrad. IN- IN+	Output	Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²											
ΔOUTPUT SINK	2.5x10¹²	15	1.5	GND +50mV	OFF	9	ALL DEVICES LATCHED TO POSITIVE SUPPLY					
CURRENT (mA)		15	1.5	+50mV GND	ON	9	-7.95	-5.29	-14.47	-15.30	-19.01	
		15	1.5		50% DUTY [illegible]	3	-12.88	-10.71	-16.05	-18.49	-21.3	
		15	1.5		56 μsec PULSE	3	WILL	NOT	NULL			
		15	1.5	PASSIVE		6	-13.98	-12.26	-14.64	-15.74	-16.[illegible]	
	5x10¹²	15	1.5	GND +50mV	OFF	9	ALL DEVICES LATCHED TO POSITIVE SUPPLY					
		15	1.5	+50mV GND	ON	9	-9.71	-4.51	-18.17	-19.59	[illegible]	
		15	1.5		50% DUTY [illegible]	3	-15.75	-12.62	-20.21	-23.68	-27.65	
		15	1.5		56 μsec PULSE	3	WILL	NOT	NULL			
		15	1.5	PASSIVE		6	-17.06	-14.6	-18.65	-20.06	-21.56	

LM139, National Semiconductor, hardened

DEVICE TYPE: LM139 HARDENED NSC PAGE 1 of 3 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos (mV)	5x10¹¹	Vs = +15V	VNULL = +0.7V	3	-0.13	-0.1	-0.2	-0.018	0.0378	
		IN⁻ = +50mV	Vs = +15V					-0.249	-0.307	
	1.25x10¹²	IN⁺ = GND		3	-0.4	-0.4	-0.4	-0.4	-0.4	
		OUTPUT = ON						-0.4	-0.4	
	2.5x10¹²			3	-0.9	-0.6	-1.2	-0.3	0	
								-1.5	-1.8	
	5x10¹²			3	-0.83	-0.6	-1.2	-0.19	0.131	
								-1.48	-1.8	
	5x10¹¹	IN⁻ = GND		3	0.1	0.5	-0.7	1.49	2.18	
		IN⁺ = +50mV						-1.29	-1.98	
	1.25x10¹²	OUTPUT = OFF		3	0.97	1.2	0.8	0.38	1.59	
								0.55	0.34	
	2.5x10¹²			3	11.8	20.4	3.0	29.2	37.9	
								-5.6	-14.3	
	5x10¹²			3*	* FAILED					
ΔIos (nA)	5x10¹¹	Vs = +15V		3	-0.67	0	-1.0	0.488	1.07	
		IN⁻ = +50mV						-1.82	-2.4	
	1.25x10¹²	IN⁺ = GND		3	-4.1	-1.0	-9.0	4.49	8.78	
		OUTPUT = ON						-12.69	-16.98	
	2.5x10¹²			3	-16.7	-8	-26	1.37	10.39	
								-34.7	-43.7	
	5x10¹²			3	-28	-16	-44	0.84	15.3	
								-56.8	-71.3	

DEVICE TYPE: LM139 HARDENED NSC PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIOS (nA)	5×10¹¹	VS = +15V	VNULL = +0.7V	3	-25.3	-19	-31	-13.3	-7.25	
	↓	IN⁻ = GND	VS = +15V					-37.4	-43.4	
		1.25×10¹²	IN⁺ = +50mV	3	-6.67	-2	-11	2.35	6.86	
		↓	OUTPUT = OFF					-15.7	-20.2	
		2.5×10¹²		3	51.7	66	38	79.7	93.7	
		↓						23.6	7.63	
↓		5×10¹²	↓	3*	* FAILED					
Δ+IB (nA)	5×10¹¹	VS = +15V		3	98.3	118	87	132.5	149.6	
		↓	IN⁻ = +50mV					64.1	47	
		1.25×10¹²	IN⁺ = GND	3	204.3	248	181	280	312.9	
		↓	OUTPUT = ON					128.6	96.8	
		2.5×10¹²		3	288.3	344	260	380.8	433	
		↓						191.9	144	
		5×10¹²		3	353.7	403	325	439.5	482.4	
		↓	↓					267.8	224.9	
		5×10¹¹	IN⁻ = GND	3	99.3	119	89	133.4	150.5	
		↓	IN⁺ = +50mV					65.3	48.2	
		1.25×10¹²	OUTPUT = OFF	3	209.3	256	180	291	331.9	
		↓						127.6	86.8	
		2.5×10¹²		3	321.3	369	280	411	455.8	
		↓						231.7	186.8	
↓		5×10¹²	↓	3*	* FAILED					

DEVICE TYPE: LM139 HARDENED NSC PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
OUTPUT SINK	5×10¹¹	VS = +15V	VS = +15V	3	6.92	7.3	6.37	5.94	5.46	
CURRENT (mA)	1.25×10¹²	IN⁻ = +50mV	VNULL = 1.5V	3	4.55	4.85	4.00	3.60	3.12	
	2.5×10¹²	IN⁺ = GND		3	3.33	3.64	2.87	2.52	2.11	
	5×10¹²	OUTPUT = ON		3	2.65	2.90	2.31	2.04	1.73	
	5×10¹¹	IN⁻ = GND		3	6.97	7.39	6.36	5.89	5.35	
	1.25×10¹²	IN⁺ = +50mV		3	4.56	4.86	3.96	3.52	3.00	
	2.5×10¹²	OUTPUT OFF		3	3.33	3.65	2.84	2.47	2.03	
↓	5×10¹²			3*	[illegible]		* 2 DEVICES	FAILED		
ADJUST SINK	5×10¹¹	VS = +15V		3	-4.49	-4.15	-4.82	-5.16	-5.50	
CURRENT (mA)	1.25×10¹²	IN⁻ = +50mV		3	-6.86	-6.38	-7.19	-7.70	8.13	
	2.5×10¹²	IN⁺ = GND		3	-8.08	-7.59	-8.33	-8.93	9.35	
	5×10¹²	OUTPUT = ON		3	-8.23	-8.33	-7.06	-9.47	-10.84	
	5×10¹¹	IN⁻ = GND		3	4.49	-4.11	-4.86	-5.24	-5.62	
	1.25×10¹²	IN⁺ = +50mV		3	-6.90	-6.4	-7.26	-7.79	-8.23	
	2.5×10¹²	OUTPUT OFF		3	-8.12	-7.61	-8.[illegible]	-9.01	-9.46	
↓	5×10¹²		↓	3*			* 2 DEVICES	FAILED		

LM139, Signetics

DEVICE TYPE: LM139 SIGNETICS PAGE 1 of 3 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVos(mV)	5×10¹¹	Vs = +15V	VBULL = +0.7V	5	0.1	1.5	-0.9	1.92	2.82	
	↓	IN⁻ = +50mV	Vs = +15V					-1.72	-2.62	
	1×10¹²	IN⁺ = GND		5	3.62	19.7	-0.9	21.6	30.6	
	↓	OUTPUT = ON						-14.4	-23.4	
	2.5×10¹²			5	-5.2	-0.2	-21.9	13.5	22.8	
	↓							-23.9	-33.2	
	5×10¹²			5	-5.58	-1.3	-21.9	12.7	21.8	
	↓	↓						-23.8	-33	
	5×10¹¹	IN⁻ = GND		5	1.36	4.1	0.1	4.5	6.07	
	↓	IN⁺ = +50mV						-1.78	-3.35	
	1×10¹²	OUTPUT = OFF		5	2.14	6.5	-0.4	7.33	9.92	
	↓							-3.05	-5.64	
	2.5×10¹²			5	127.6	232.1	9.8	312.5	412.4	
	↓							-62.3	-157.2	
↓	5×10¹²	↓		5*	* WILL NOT SINK CURRENT					
ΔIos(nA)	5×10¹¹	Vs = +15V		5	-2.34	1.7	-10.8	7.39	12.3	
	↓	IN⁻ = +50mV						-12.1	-16.9	
	1×10¹²	IN⁺ = GND		5	-0.84	3.2	-2.4	3.75	6.04	
	↓	OUTPUT = ON						-5.43	-7.72	
	2.5×10¹²			5	-4.28	11.3	-17.2	16.4	26.8	
	↓							-25	-35.3	
	5×10¹²			5	-5.78	14.8	-17.7	19.1	31.5	
↓	↓	↓	↓					-30.6	-43.0	

DEVICE TYPE: LM139 SIGNETICS PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIos(nA)	5×10¹¹	Vs = +15V	VBULL = +0.7V	5	1.32	4.9	-1.3	6.61	9.25	
	↓	IN⁻ = GND	Vs = +15V					-3.97	6.61	
	1×10¹²	IN⁺ = +50mV		5	2.66	12.7	-3.9	16	22.7	
	↓	OUTPUT = OFF						-10.7	-17.4	
	2.5×10¹²			5	26.4	54.9	8.3	68.3	89.2	
	↓							-15.6	-36.5	
↓	5×10¹²	↓		5*	* WILL NOT SINK CURRENT					
ΔIB(nA)	5×10¹¹	Vs = +15V		4**	23.6	39.4	14.3	47.4	59.3	
	↓	IN⁻ = +50mV						-0.22	-12.1	
	1×10¹²	IN⁺ = GND		4**	53.9	91.3	27.3	117.5	149.2	
	↓	OUTPUT = ON						-9.66	-41.4	
	2.5×10¹²			4**	123.9	209.7	54.1	286.9	368.3	
	↓							-39.0	-120.5	
	5×10¹²			4**	200.6	322.1	89.3	443.6	565.1	
	↓	↓						-42.4	-163.9	
	5×10¹¹	IN⁻ = GND		5	47.7	139.7	14	53.1	205.7	
	↓	IN⁺ = +50mV						-57.7	-110.3	
	1×10¹²	OUTPUT = OFF		5	101.3	280.1	26	310.9	415.6	
	↓							-108.2	-213	
	2.5×10¹²				200	444.1	58.9	515.9	623.8	
	↓							-115.8	-223.7	
↓	5×10¹²	↓	↓	5*	* WILL NOT SINK CURRENT					
			** ONE DEVICE WILL NOT SINK CURRENT							

DEVICE TYPE: LM139 SIGNETICS PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean −2σ	Mean −3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
OUTPUT SINK CURRENT (mA)	5×10¹¹	VS = +15V	VS = +15V	5	20.58	22.3	16.3	15.5	12.9	
	1×10¹²	IN⁻ = +50mV	VNULL = 1.5V	5	19.9	21.9	15.8	14.7	12.1	
	2.5×10¹²	IN⁺ = GND		5	18.74	20.9	14.8	13.6	11.0	
	5×10¹²	OUTPUT = ON		5	17.84	20.5	13.9	12.5	9.8	
	5×10¹¹	IN⁻ = GND		5	20.64	22.4	16.2	15.4	12.7	
	1×10¹²	IN⁺ = +50mV		5	19.86	22.0	15.7	14.6	12.0	
	2.5×10¹²	OUTPUT = OFF		5	18.8	21.0	14.9	13.7	11.1	
	5×10¹²			5	0.08	0.089	0.072	0.063	0.055	
ΔOUTPUT SINK CURRENT (mA)	5×10¹¹	VS = +15V		5	-0.86	-0.5	-2.1	-2.27	-2.96	
	1×10¹²	IN⁻ = +50mV		5	-1.56	-0.9	-3.3	-3.62	-4.65	
	2.5×10¹²	IN⁺ = GND		5	-2.72	-1.8	-4.6	-5.15	-6.37	
	5×10¹²	OUTPUT = ON		5	-3.62	-2.1	-5.6	-6.55	-8.02	
	5×10¹¹	IN⁻ = GND		5	-0.82	-0.5	-2.1	-2.31	-3.0	
	1×10¹²	IN⁺ = +50mV		5	-1.6	-0.9	-3.3	-3.63	-4.65	
	2.5×10¹²	OUTPUT = OFF		5	-2.76	-1.8	-4.7	-5.35	-6.65	
	5×10¹²			5	-21.5	-16.6	-23.1	-26.9	-29.7	

LM139 (LM2901), Texas Instruments

DEVICE TYPE: LM139 (LM2901) TEXAS INSTRUMENTS PAGE 1 of 3 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ −2σ	Mean +3σ −3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔVos (mV)	5×10¹¹	VS = +15V	VNULL = +0.7V	3	-0.067	0	-0.1	0.019	0.107	
		IN⁻ = +50mV	VS = +15V					-0.182	-0.240	
	1.25×10¹²	IN⁺ = GND		3	-0.43	-0.3	-0.7	0.029	0.259	
		OUTPUT = ON						-0.815	-1.13	
	2.5×10¹²			3	-1.03	-0.8	-1.5	-0.23	0.179	
								-1.84	-2.25	
	5×10¹²			3	-1.99	-1.5	-2.5	-0.91	-0.39	
								-2.96	-3.47	
	5×10¹¹	IN⁻ = GND		3	0.27	0.4	0.2	0.498	0.613	
		IN⁺ = +50mV						0.036	-0.08	
	1.25×10¹²	OUTPUT = OFF		3	0.77	1.2	0.4	1.57	1.98	
								-0.04	-0.15	
	2.5×10¹²			3	1.67	2.5	0.7	3.48	4.39	
								-0.49	-1.06	
	5×10¹²			3	2.9	3.9	1.9	4.9	5.9	
								0.90	-0.1	
ΔIos (nA)	5×10¹¹	VS = +15V		3	-11.7	-1.0	-19	7.24	16.7	
		IN⁻ = +50mV						-30.6	-40	
	1.25×10¹²	IN⁺ = GND		3	-26.7	8	-48	33.9	64.2	
		OUTPUT = ON						-87.2	-117.5	
	2.5×10¹²			3	-39	38	-86	95.4	162.7	
								-173.4	-240.7	

DEVICE TYPE: LM139 (LM2901) TEXAS INSTRUMENTS PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔIos (nA)	5×10¹²	Vs: ±15V, IN⁻: +50mV	VNULL: +0.7V	3	-69	71	-150	124.5	286.2	
	↓	IN⁺: GND, OUTPUT: ON	Vs: ±15V					-312.5	-434.2	
	5×10¹¹	IN⁻: GND		3	20.3	95	49	116.7	132.9	
	↓	IN⁺: +50mV						-23.97	0.79	
	1.25×10¹²	OUTPUT: OFF		3	233	269	185	319.5	362.8	
	↓							146.5	103.2	
	2.5×10¹²			3	514.3	538	500	555.6	576.3	
	↓							473	452.4	
	5×10¹²			3	-846.3	-744	-1030	-502.5	-368.1	
↓	↓	↓						-1165	-1324	
ΔIB (nA)	5×10¹¹	VS: ±15V		3	154.3	183	105	240.2	283.1	
	↓	IN⁻: +50mV						68.5	25.6	
	1.25×10¹²	IN⁺: GND		3	374	460	231	623.4	748.1	
	↓	OUTPUT: ON						124.6	-0.069	
	2.5×10¹²			3	678.3	854	371	1208	1473	
	↓							145.1	-620.5	
	5×10¹²			3	985.3	1285	458	1902	2360	
	↓							69.1	-389	
	5×10¹¹	IN⁻: GND		3	209	242	144	321.6	377.9	
	↓	IN⁺: +50mV						96.4	40.1	
	1.25×10¹²	OUTPUT: OFF		3	569.3	669	372	911	1082	
↓	↓	↓	↓					227.5	56.6	

DEVICE TYPE: LM 2901 (LM139) T.I. PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔIB (nA)	2.5×10¹²	VS: ±15V	VNULL: +0.7V	3	1085	1270	725	1709	2020	
	↓	IN⁻: GND	VS: ±15V					461.4	150	
	5×10¹²	IN⁺: +50mV		3	1661	1896	1204	2454	2850	
↓	↓	OUTPUT: OFF	↓					869	473	
								-2σ	-3σ	
OUTPUT SINK	5×10¹¹	VS: ±15V	VS: ±15V	3	18.85	20.48	17.96	16.02	14.61	
CURRENT (mA)	1×10¹²	IN⁻: +50mV	VNULL = 1.5V	3	15.42	18.28	13.14	10.19	7.57	
	2.5×10¹²	IN⁺: GND		3	11.79	16.16	8.56	3.94	0.019	
	5×10¹²	OUTPUT: ON		3	9.08	14.86	5.51	*	*	
	5×10¹¹	IN⁻: GND		3	18.9	19.96	18.06	16.97	16.0	
	1×10¹²	IN⁺: +50mV		3	15.33	17.51	13.24	11.42	9.47	
	2.5×10¹²	OUTPUT: OFF		3	11.51	14.98	8.99	5.29	2.18	
↓	5×10¹²			3	8.23	13.56	5.29	0.31	*	
			*VALUE CHANGES SIGN							
OUTPUT SINK	5×10¹¹	VS: ±15V		3	-2.79	-2.16	-3.94	-4.79	-5.79	
CURRENT (mA)	1×10¹²	IN⁻: +50mV		3	-6.21	-4.46	-8.76	-10.23	-12.98	
	2.5×10¹²	IN⁺: GND		3	-9.84	-6.58	-13.34	-16.62	-20.00	
	5×10¹²	OUTPUT: ON		3	-12.56	-7.88	-16.39	-21.20	-25.51	
	5×10¹¹	IN⁻: GND		3	-3.18	-2.39	-4.14	-4.95	-5.84	
	1×10¹²	IN⁺: +50mV		3	-6.75	-4.84	-9.09	-11.06	-13.22	
	2.5×10¹²	OUTPUT: OFF		3	-10.57	-7.37	-13.84	-17.04	-20.48	
↓	5×10¹²		↓	3	-13.35	-8.80	-17.04	-21.23	-25.92	

LM710, National Semiconductor

DEVICE TYPE: LM710 NSC PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRADIATION								
ΔVos(mV)	2.5×10¹²	V⁻=-6V, V⁺=12V	IN⁻=-130mV	2	0.035	0.05	0.02	0.0774	0.0986	
		Vnull=0.7V						-0.0074	-0.0386	
	2.5×10¹²		IN⁻=+50mV	2	-0.105	-0.06	-0.15	0.0323	0.0859	
								-0.242	-0.296	
	5×10¹²		IN⁻=-130mV	2	0.07	0.08	0.06	0.0983	0.112	
								0.0417	0.0276	
	5×10¹²		IN⁻=+50mV	2	-0.1	-0.05	-0.15	0.0414	0.112	
								-0.241	-0.312	
	5×10¹²	Vnull=1.5V	IN⁻=-130mV	3	-0.02	-0.005	-0.033	0.005	0.0175	
								-0.045	-0.0525	
	5×10¹²		IN⁻=+50mV	3	-0.283	0.019	-0.392	0.3924	0.5582	
								-0.586	-0.8149	
	8.2×10¹²		IN⁻=-130mV	3	-0.0226	-0.011	-0.036	0.0024	0.0150	
								-0.0478	-0.0604	
	8.2×10¹²		IN⁻=+50mV	3	-0.473	0.008	-0.461	0.3970	0.6494	
								-0.8918	-0.9641	
	1×10¹³	Vnull=0.7V	IN⁻=-130mV	2	0.115	0.12	0.11	0.129	0.136	
								0.101	0.0938	
	1×10¹³		IN⁻=+50mV	2	-0.09	-0.03	-0.15	0.0797	0.165	
								-0.516	-0.345	
	1×10¹³	Vnull=1.5V	IN⁻=-130mV	3	-0.02	-0.009	-0.028	-0.0023	0.0095	
								-0.0396	-0.195	
Ass	1×10¹³		IN⁻=+50mV	3	-0.1683	0.023	-0.515	0.4281	0.7264	
								-0.7648	-1.0631	

DEVICE TYPE: LM710 NSC PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRADIATION								
ΔIos(μA)	2.5×10¹²	V⁻=-6V, V⁺=12V	IN⁻=-130mV	2	0.2	0.3	0.1	0.483	0.604	
		Vnull=0.7V						-0.083	-0.024	
	2.5×10¹²		IN⁻=+50mV	2	-0.4	-0.1	-0.7	0.449	0.823	
								-1.25	-1.67	
	5×10¹²		IN⁻=-130mV	2	0.2	0.4	0	0.766	1.06	
								-0.366	-0.669	
	5×10¹²		IN⁻=+50mV	2	-0.65	-0.3	-1.0	0.34	0.830	
								-1.64	-2.13	
	5×10¹²	Vnull=1.5V	IN⁻=-130mV	3	-0.27	-0.23	-0.30	-0.1978	-0.1618	
								-0.3401	-0.3781	
	5×10¹²		IN⁻=+50mV	3	-1.4233	-0.02	-3.69	2.5051	4.4624	
								-5.3518	-7.3116	
	8.2×10¹²		IN⁻=-130mV	3	-0.3266	-0.26	-0.36	0.2111	0.1534	
								-0.4421	-0.4988	
	8.2×10¹²		IN⁻=+50mV	3	-1.77	-0.39	-4.47	2.9068	5.2453	
								-6.4469	-8.7853	
	1×10¹³	Vnull=0.7V	IN⁻=-130mV	2	0.35	0.6	0.1	1.06	1.41	
								-0.357	-0.711	
	1×10¹³		IN⁻=+50mV	2	-0.8	-0.5	-1.1	0.0485	-1.65	
								0.429	-0.07	
	1×10¹³	Vnull=1.5V	IN⁻=-130mV	3	-0.4133	-0.34	-0.49	-0.2633	-0.1881	
								-0.5634	-0.6384	
	1×10¹³		IN⁻=+50mV	3	-1.8933	-0.43	-4.80	3.175	5.7103	
								-6.9624	-8.9970	

DEVICE TYPE: LM710 NSC PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRADIATION								
ΔIB (μA)	2.5×10¹²	V⁻=-6V, V⁺=+12V	IN⁻=-130mV	2	1.3	1.4	1.2	1.583	1.724	
		VOUT=0.7V						1.0171	0.3757	
	2.5×10¹²		IN⁻=+50mV	2	1.5	1.6	1.4	1.783	1.924	
								1.21	1.0757	
	5×10¹²		IN⁻=-130mV	2	1.8	2.0	1.6	2.366	2.619	
								1.234	0.9514	
	5×10¹²		IN⁻=+50mV	2	1.85	1.9	1.8	1.991	2.066	
								1.109	1.638	
	5×10¹²	VOUT=1.5V	IN⁻=-130mV	3	-0.633	2.91	-4.51	5.5414	8.6088	
								-6.908	-9.8250	
	5×10¹²		IN⁻=+50mV	3	-2.883	-1.68	-5.18	1.0746	-1.0858	
								-6.86	-8.8525	
	8.2×10¹²		IN⁻=-130mV	3	-1.1733	2.36	-4.59	4.9473	8.0077	
								-7.294	-10.354	
	8.2×10¹²		IN⁻=+50mV	3	-3.0266	-2.28	-6.19	0.815	3.0359	
								-8.168	-10.285	
	1×10¹³	VOUT=0.7V	IN⁻=-130mV	2	2.5	2.6	2.4	2.783	2.924	
								2.217	2.0757	
	1×10¹³		IN⁻=+50mV	2	2.7	2.7	2.7	2.7	2.7	
								2.7	2.7	
	1×10¹³	VOUT=1.5V	IN⁻=-130mV	3	-1.416	2.13	-3.32	4.759	7.369	
								-7.677	-10.187	
	1×10¹³		IN⁻=+50mV	3	-3.9966	-2.55	-6.75	0.7743	3.1547	
								-8.7626	-11.521	

LM723, National Semiconductor

DEVICE TYPE: LM723 NSC PAGE 1 of 1 .3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVOUT (mV)	5×10¹²	VIN=+15V, VOUT=+12V	VIN=+15V, VOUT=12V	3	-1.67	1	-3	2.95	5.26	
		ILOAD=15mA	ILOAD=15mA					-6.29	-8.59	
	1×10¹³			3	-4.67	-3	-6	-1.61	-0.0841	
								-7.72	-7.25	
ΔVOUT (mV)	5×10¹²		VIN=30V, VOUT=28V	3	2	1.3	-4	21.1	30.6	
			ILOAD=3mA					-17.1	-26.6	
	1×10¹³			3	0	1.3	-8	22.7	34.1	
								-22.7	-34.1	
ΔVREF (mV)	5×10¹²		VIN=+15V, VOUT=12V	3	2.87	6.8	0.9	9.68	13.09	
			ILOAD=15mA					-3.95	-7.35	
	1×10¹³			3	3.00	7.2	-0.3	10.67	14.49	
								-4.66	-8.49	
ΔLINE REG (%)	5×10¹²	VIN=+12V	VIN=12 to 15V,	3	-0.00066	0.0297	0.0219	0.0533	0.0803	
		VOUT=+5V	VOUT=5V, ILOAD=50mA					-0.0546	-0.0816	
	1×10¹³	ILOAD=1mA		3	0.019	0.0277	0	0.0404	0.0547	
								-0.0166	-0.0309	
ΔLOAD REG (%)	5×10¹²		VIN=+15V, VOUT=+5V	3	-0.0192	-0.0138	-0.0219	-0.0099	-0.0052	
			ILOAD=1mA min					-0.0285	-0.0331	
	1×10¹³		50mA max	3	0.0145	0.0257	0.0059	0.0498	0.0675	
								-0.0207	-0.0385	

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

MIC236, Motorola

DEVICE TYPE: MIC 236 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔREF. BAL. (mV)	5x10¹²	Vcc = -6V		7	1.73	2.8	0.6	3.35 / 0.109	4.16 / -0.701	
ΔREF. SIG. BAL. (mV)	5x10¹²			7	0.6	0.9	0.3	1.0 / 0.2	1.2 / 0.0	
% DET. SENSITIVITY	5x10¹²			7	0.686	4.8	0.0	4.31 / -2.94	6.13 / -4.76	

NS

MIC336, Motorola

DEVICE TYPE: MIC 336 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔREF. BAL. (mV)	5x10¹²	Vcc = -6V		16	0.156	0.5	-0.4	0.698 / -0.385	0.968 / -0.656	
ΔREF. SIG. BAL. (mV)	5x10¹²			16	0.175	0.5	-0.3	0.651 / -0.301	0.889 / -0.539	
% DET. SENSITIVITY	5x10¹²			16	0.888	7.1	0	5.74 / -3.96	8.16 / -6.99	

NS

D. ZENER DIODES

The radiation analysis carried out by General Electric largely from neutron data indicated potential shifts in Zener voltage sufficient to cause problems in some applications. Electron irradiation at 2.2 MeV caused relatively minor shifts in the Zener voltage at fluences up to 1×10^{13} e/cm^2. Additional measurements were therefore carried out with 3 and 5.5 MeV electrons using the high voltage VandeGraaff at Notre Dame University.

The Zener voltage was determined both before and after radiation at a fixed current level by means of in situ measurements. This made it possible to determine the radiation-induced change in the Zener voltage to an accuracy of ±1 mV by relatively simple means. The experiment lasted less than one half hour and the radiation-induced thermal heating is not significant, so that thermal changes during the time of the experiment may be ignored. The absolute value of the Zener voltage, which is a strong function of the Zener current, has been determined to an accuracy of about ±10 mV.

The results of the measurements are summarized in Table 4. It may be noted that the majority of the devices tested do not change by more than the experimental error at a fluence of 5×10^{12} e/cm^2 for all energies up to 5.5 MeV. Three device types showed a significant linear change in Zener voltage with electron energy, as shown in Fig. 2. One of the device types indicated a positive voltage shift, whereas the other two indicated a negative voltage shift. These changes are attributed to bulk radiation damage.

Some devices of the 1N829 showed changes as great as 12 mV, whereas the remainder stayed within ±1 mV. The anomalously large changes were not energy-dependent, and are therefore considered to be due to a surface ionization effect.

Very few of the Unitrode U28770 and U28775 high voltage Zener diodes were available for testing, and these showed shifts from -14 to -120 mV. The 14-mV value is within experimental error. In cases where very few devices were available, devices were first irradiated to a fluence of 1×10^{13} e/cm at 2.2 MeV and then reirradiated at a later data with 3.0

Table 4. Electron radiation effects in Zener and reference diodes

Device type	Manufacturer	V_Z, V	I_Z, mA	Max. ΔV_Z at 5×10^{12} e/cm^2, mV	Electron energy range, MeV
Devices with Zener voltage change within measurement accuracy of ±1 mV					
1N945 TC Zener	MOT	11.7	7.5	-1	2.2 - 5.5
1N4569 TC ref. diode	DIK	6.4	0.5	-2	2.2, 5.5
1N4572 TC ref. diode	DIK	6.4	1.0	-1.9	2.2 - 5.5
1N4577 TC ref. diode	MOT	6.4	2.0	0	2.2
1N4895A TC Zener (ultrastable)	DIK	6.35	7.5	-1	2.2, 5.5
MZ827 TC Zener	MOT	6.2	7.5	-1	2.2 - 5.5
.4M4.7AZ1 non-comp. Zener	MOT	4.7	5	+2	2.2 - 5.5
.4M5.1AZ1 non-comp. Zener	MOT	5.1	5	±1	2.2 - 5.5
Devices with Zener voltage change within measurement accuracy of ±1 mV, but with mavericks showing greater energy-independent change					
1N829 TC Zener	MOT	6.2	5.5	-2 -12[a]	2.2 - 5.5
Devices with linear Zener voltage change with energy					
1N935 TC ref. diode	MOT	9.0	1.0, 7.5	-ve (see Fig. 2)	2.2 - 5.5
1N4907 TC ref. diode	MOT	12.8	2	-ve (see Fig. 2)	2.2 - 5.5
FCT1121 TC ref. diode	FAS	6.8	0.1	+ve (see Fig. 2)	2.2 - 5.5

[a]Maverick.

Table 4 (contd)

Device type	Manufacturer	V_Z, V	I_Z, mA	Max. ΔV_Z at 5×10^{12} e/cm^2, mV	Electron energy range, MeV
Devices with significant Zener voltage change measured only at 2.2 MeV					
1N4581 TC ref. diode	DIK	6.6	4.0	-4	2.2
1N4891 TC ref. diode (ultrastable)	DIK	6.4	2.0	-12	2.2
			7.5	-8	
High surge non-compensated Zeners					
UZ8770	UTR	70	0.05	+14	2.2
UZ8775	UTR	75	0.1	+220	2.2 - 5.5

or 5.5 MeV electrons. No conclusions could be drawn from the data obtained from the second irradiation, primarily because most of the Zener voltage shifts were within experimental error.

An attempt was made to measure changes in the temperature coefficient of the temperature-compensated (TC) Zener diodes produced by a fluence of 1×10^{13} e/cm^2 at energies of 2.2, 3.0 and 5.5 MeV. These measurements could not be carried out in situ and were therefore subject to many systematic errors. The main conclusion is that the pre-irradiation temperature coefficient of different devices of one type varies within one order of magnitude, whereas the radiation-induced changes are less than 50% of the initial value. The temperature coefficient from -50 to +25°C decreases with radiation, whereas the temperature coefficient from 25°C to 75°C increases with radiation. No correlation with electron energy could be detected.

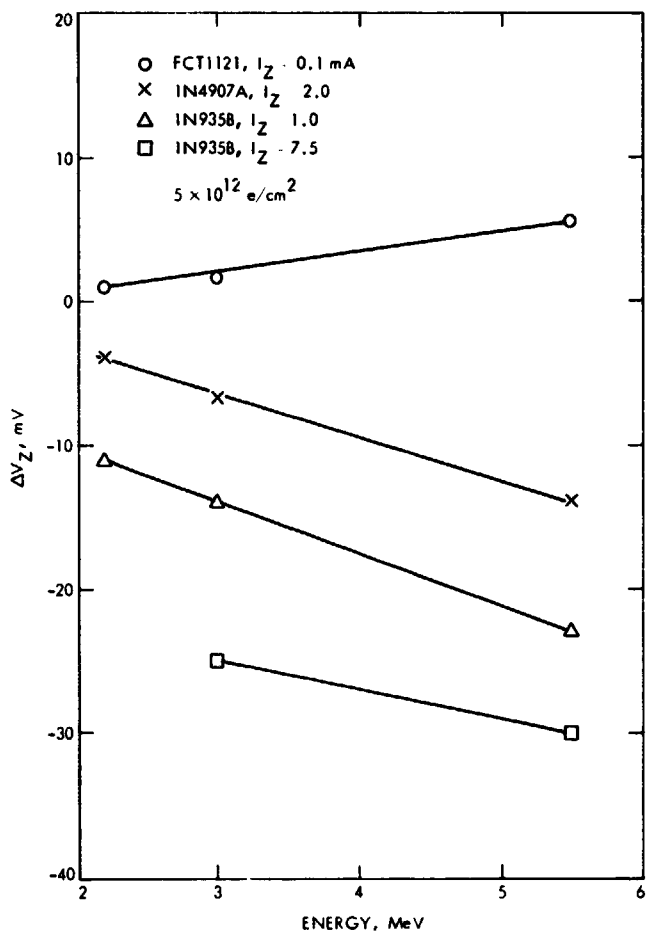

Fig. 2. Zener voltage change with energy

.4M4.7AZ1, Motorola

DEVICE TYPE: .4M4.7AZ1 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point Bias: IRRAD.	Operating Point Bias: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔVz(mV)	2.2	5×10¹²	Iz = 5mA	Iz = 5mA	3	-0.167	-0.1	-0.2	-0.05	0.0065	
		↓							-0.28	-0.34	
		1×10¹³			3	-0.13	-0.1	-0.2	-0.018	0.040	
									-0.25	-0.31	
ΔVz(mV)	3.0	5×10¹²			3	1	3	-1	5	7	
		↓							-3	-5	
		1×10¹³			3	-1	0	-2	1	2	
									-3	-4	
ΔVz(mV)	5.5	5×10¹²			4	0.5	2	-1	3.08	4.37	
		↓							-2.08	-3.37	
		1×10¹³			4	1.25	2	0	3.16	4.12	
									-0.66	-1.62	

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.4M5.1AZ1, Motorola

DEVICE TYPE: .4M5.1AZ1 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point Bias: IRRAD.	Operating Point Bias: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔVz(mV)	2.2	5×10¹²	Iz = 5mA	Iz = 5mA	3	0.467	0.5	0.4	0.58	0.64	
		↓							0.35	0.29	
		1×10¹³			3	0.5	0.5	0.5	0.5	0.5	
									0.5	0.5	
ΔVz(mV)	3.0	5×10¹²			3	1	2	0	3	4	
		↓							-1	-2	
		1×10¹³			3	0.33	1	-1	2.64	3.80	
									-1.98	-3.13	
ΔVz(mV)	5.5	5×10¹²			4	-0.75	0	-2	1.16	2.12	
		↓							-2.66	-3.62	
		1×10¹³			4	-0.25	0	-1	0.75	1.25	
									-1.25	-1.75	

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1N829, Motorola

DEVICE TYPE: 1N829 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ −2σ	Mean +3σ −3σ	Accept Reject Criteria
ΔVz (mV)	2.2	5×10¹²	Iz @ TC = 0	Iz @ TC = 0	3	-3.867	-0.40	-10.7	7.97	13.89	
									-15.70	-21.66	
		1×10¹³			3	-7.033	-0.90	-19.1	13.87	24.32	
									-27.93	-38.38	
ΔVz (mV)	3	5×10¹²			2	-1.0	0	-2.0	1.83	3.24	
									-3.83	-5.24	
		1×10¹³			2	-2.0	-1.0	-3.0	0.83	2.24	
									-4.83	-6.24	
ΔVz (mV)	5.5	5×10¹²			3	-5.33	-2.0	-12.0	6.21	11.99	
									-16.88	-22.65	
		1×10¹³			3	-8.67	-3.0	-20.0	10.26	20.78	
									-28.30	-38.11	

1N935, Motorola

DEVICE TYPE: 1N935 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ −2σ	Mean +3σ −3σ	Accept Reject Criteria
ΔVz (mV)	2.2	5×10¹²	Iz = 1mA	Iz = 1mA	3	-10.7	-7.8	-13.1	-5.33	-2.64	
									-16.07	-18.76	
		1×10¹³			3	-20.07	-13.8	-25.1	-8.57	-2.32	
									-31.57	-37.32	
ΔVz (mV)	3.0	5×10¹²		Iz = 1mA	3	-12.67	-11	-14	-9.6	-8.1	
									-15.7	-17.2	
		1×10¹³			3	-18.67	[illegible]	-21	-13.6	-11.1	
									-23.7	-26.2	
ΔVz (mV)		5×10¹²		Iz = 7.5mA	3	-19.3	-16	-25	-9.5	-4.5	
									-28.2	-34.1	
		1×10¹³			3	-22	-24	-37	-15	-7.99	
									-43	-50	
ΔVz (mV)	5.5	5×10¹²		Iz = 1mA	3	-20.67	-17	-25	-12.6	-8.5	
									-28.7	-32.8	
		1×10¹³			3	-30.3	-26	-37	-18.6	-12.8	
									-42.1	-47.9	
ΔVz (mV)		5×10¹²		Iz = 7.5mA	3	-26	-18	-30	-12.1	-5.2	
									-39.9	-46.8	
		1×10¹³			3	-40	-32	-47	-24.9	-17.4	
									-55.1	-62.6	

1N945, Motorola

DEVICE TYPE: 1N945 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean −3σ / −2σ	Mean +2σ / +3σ	Accept Reject Criteria
ΔVz(mV)	2.2	5×10¹²	Iz = 7.5 mA	Iz = 7.5mA	3	-0.067	0	-0.1	0.049 / -0.18	0.107 / -0.24	
		1×10¹³			3	-0.1	-0.1	-0.1	-0.1	-0.1	
ΔVz(mV)	3.0	5×10¹²			1	-1	-1	-1	-1	-1	
		1×10¹³			1	-1	-1	-1	-1	-1	
ΔVz (mV)	5.5	5×10¹²			1	-1	-1	-1	-1	-1	
		1×10¹³			1	0	0	0	0	0	

AGS

1N4569, Dickson

DEVICE TYPE: 1N4569 DICKSON PAGE 1 of 1 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / −2σ	Mean +3σ / 3σ	Accept Reject Criteria
ΔVz(mV)	2.2	5×10¹²	Iz @ TC = 0	Iz @ TC = 0	3	-0.067	1.3	-1.8	3.10 / -3.23	4.68 / -4.81	
		1×10¹³			3	-0.60	0.70	-2.4	2.60 / -3.82	4.23 / -5.43	
ΔVz(mV)	3.0	5×10¹²			2	-1.0	0	-2.0	1.83 / -3.83	3.24 / -5.24	
		1×10¹³			2	-2.0	-1.0	-3.0	1.83 / -4.83	-2.24 / -6.24	
ΔVz(mV)	5.5	5×10¹²			3	-1.3	-1	-2	-0.18 / -2.79	0.40 / -3.07	
		1×10¹³			3	-2.67	-2	-4	-0.36 / -4.98	0.80 / -6.13	

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1N4572, Dickson

DEVICE TYPE: 1N4572 DICKSON PAGE 1 of 1 — 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔVz (mV)	2.2	5×10¹²	Iz = 1mA	Iz = 1mA	3	-1	-0.40	-1.90	0.59	1.38	
									-2.59	-3.38	
		1×10¹³			3	-1.53	-0.70	-2.70	0.55	1.54	
									-3.61	-4.66	
ΔVz (mV)	3.0	5×10¹²			2	-0.50	0	-1	0.91	1.62	
									-1.91	-2.62	
		1×10¹³			2	-1.5	-1	-2	-0.086	0.62	
									-2.91	-3.62	
ΔVz (mV)	5.5	5×10¹²			2	-1.5	-1	-2	-0.086	0.62	
									-2.91	-3.62	
		1×10¹³			2	-2	-1	-3	0.83	2.24	
									-4.83	-6.24	

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1N4577, Motorola

DEVICE TYPE: 1N4577 MOTOROLA PAGE 1 of 1 — 2

Parameter	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔVz (mV)	5×10¹²	Iz = 2 mA		3	-0.04	0	-0.1	0.0658	0.1187	
								-0.1458	-0.1987	
	1×10¹³			3	-0.2	0	-0.4	0.2	0.4	
								-0.6	-0.8	

1N4581, Dickson

DEVICE TYPE: 1N4581 DICKSON PAGE 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -3σ	Mean +3σ -3σ	Accept Reject Criteria
	e/cm²	BIAS: 1RAD.	BIAS: MEAS.							
ΔVz	5×10¹²	Iz = 4mA	Iz = 4mA	3	-0.3	-0.2	-0.1	-0.0999	0	
(mV)	↓							-0.500	-0.600	
	1×10¹³			3	-0.767	-0.5	-1.0	-0.333	-0.046	
↓	↓	↓	↓					-1.699	-1.5246	

1N4891, Dickson

DEVICE TYPE: 1N4891 DICKSON PAGE 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -3σ	Mean +3σ -3σ	Accept Reject Criteria
	e/cm²	BIAS: 1RAD.	BIAS: MEAS.							
ΔV:	5×10¹²	Iz = 2mA	Iz = 2mA	3	-0.8666	-0.6	-1.0	-0.4047	-0.1238	
(mV)	↓							-1.3285	-1.5524	
	1×10¹³			3	-1.333	-1.0	-1.70	-0.6309	-0.2797	
↓	↓		↓					-2.0357	-2.3868	
ΔVz	5×10¹²		Iz = 2.5mA	3	-0.7	-0.6	-0.8	-0.4999	-0.3999	
(mV)	↓							-0.9000	-1.000	
	1×10¹³			3	-1.2666	-1.1	-1.4	-0.9641	-0.8054	
↓	↓	↓	"					-1.5721	-1.7349	

1N4895, Dickson

DEVICE TYPE: 1N4895 DICKSON PAGE 1 of 1 2

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	MeV	BIAS: IRRAD.	BIAS: MEAS.							
ΔVz	5x10¹²	2.2	Iz = 25 mA	Iz = 25 mA	1	-0.3	-0.3	-0.3	-0.3	-0.3	
(mV)	1x10¹³	2.2			1	-0.9	-0.9	-0.9	-0.9	-0.9	
ΔVz	5x10¹²	55			1	-1	-1	-1	-1	-1	
(mV)	1x10¹³	55			1	-4	-4	-4	-4	-4	

1N4907, Motorola

DEVICE TYPE: 1N4907 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	MeV	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔVz (mV)	2.2	5x10¹³	Iz = 2mA	Iz 2mA	3	-4	-2	-8	2.93	6.39	
									-10.93	-14.39	
		1x10¹³			3	-2.67	-4	-14	3.35	8.86	
									-18.68	-24.19	
ΔVz (mV)	3.0	5x10¹²			3	-7	-6	-9	-3.54	-1.80	
									-10.46	-12.20	
		1x10¹³			3	-12	-11	-13	-10	-9	
									-14	-15	
ΔVz (mV)	5.5	5x10¹²			4	-14.25	-9	-23	-1.88	4.30	
									-26.62	-32.80	
		1x10¹³			4	-22.75	-14	-33	-6.80	1.17	
									-38.70	-46.67	

FCT1121, Fairchild Semiconductor

DEVICE TYPE: FCT 1121 FAIRCHILD SEMICONDUCTOR PAGE 1 of 1 — 2

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	MeV	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔVz (mV)	2.2	5x10¹²	Iz = 0.1 mA	Iz = 0.1 mA	3	0.1	0.4	-0.1	0.63 / -0.43	0.89 / -0.69	
		1x10¹³			3	0.2	0.6	0	0.89 / -0.49	1.24 / -0.84	
ΔVz (mV)	3.2	5x10¹²			2	1.95	4	-0.1	9.75 / -3.85	10.65 / -6.75	
		1x10¹³			2	2	5	-1	10.49 / -6.49	14.23 / -10.23	
ΔVz (mV)	5.5	5x10¹²			2	5.5	7.0	4.0	9.7 / 1.3	11.9 / -1.86	
		1x10¹³			2	5	6	4	7.8 / 2.2	9.2 / 0.76	

LVA3100, TRW

DEVICE TYPE: LVA3100 TRW PAGE 1 of 1 — 2

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²		BIAS: IRRAD.	BIAS: MEAS.							
Noise Voltage (μV rms)	5x10¹²		Iz = 400 μA	Iz = 400 μA, 10 Hz	3	0.2233	0.30	0.14	0.3837	0.4639	
	1x10¹³			Noise μVrms Per Point Circle Full Scale	3	0.2366	0.34	0.13	0.4467	0.5517	
Noise Voltage (μVrms)	5x10¹²			Iz = 400 μA, 1 KHz	3	0.21666	0.29	0.13	0.3283	0.4591	
	1x10¹³			Noise μVrms Per Pt Circle Full Scale	3	0.2183	0.29	0.13	0.3809	0.4622	
Bandpass Noise Output R.M.S. (mVrms)	5x10¹²			5 Hz to 100 KHz	3	15.23	22.6	10.0	28.36	34.93	
	1x10¹³				3	15.23	23.2	9.4	29.52	36.66	

MZ827, Motorola

DEVICE TYPE: MZ827 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point Bias: 1RAD.	Operating Point Bias: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
									-2σ	-3σ	
ΔVz (mV)	2.2	5x10⁹	Iz - 7.5mA	Iz - 2.5mA	3	0	0	0	0	0	
									0	0	
		1x10¹³			3	0	0	0	0	0	
									0	0	
ΔVz (mV)	3.0	5x10⁹			3	-1	-1	-1	-1	-1	
									-1	-1	
		1x10¹³			3	-0.67	0	-1	0.49	1.07	
									-1.82	-2.40	
ΔVz (mV)	5.5	5x10⁹			4	-0.25	0	-1	0.75	1.25	
									-1.25	-1.75	
		1x10¹³									

NGS

UZ8770, Unitrode

DEVICE TYPE: UZ8770 UNITRODE PAGE 1 of 1 2

Parameter	Fluence e/cm²	Fluence MeV	Operating Point Bias: 1RAD.	Operating Point Bias: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
ΔVz	5x10⁹	2.2	Iz = 50μA	Iz = 50μA ±.01%	1	14	14	14	14	14	
(mV)	1x10¹³	2.2			1	190	190	190	190	190	
ΔVz	5x10¹²	5.5			1	-20	-20	-20	-20	-20	
(mV)	1x10¹³	5.5			1	-20	-20	-20	-20	-20	

NGS

UZ8775, Unitrode

DEVICE TYPE: UZ8775 UNITRODE PAGE 1 of 1 2

Parameter	Fluence MeV	Fluence e/cm²	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
ΔVz (mV)	2.2	5×10¹²	Iz = 0.1 mA	Iz = 0.1 mA	3	14.67	17.0	13.0	15.83	20.9	
									10.5	5.-1	
		1×10¹³			3	15.07	22	8	29.86	36.95	
									1.28	-5.62	
ΔVz (mV)	3.0	5×10¹²			2	0	0	0	0	0	
									0	0	
		1×10¹³			2	-15	-10	-20	-0.858	6.21	
									-29.14	-36.21	
ΔVz (mV)	5.5	5×10¹²			2	105	220	-10	530.3	592.9	
									-220.3	-382.9	
		1×10¹³			2	155	310	0	593.4	812.6	
									-283.4	-502.6	

E. CONSTANT CURRENT DIODES

1N5288, Motorola

DEVICE TYPE: 1N 5288 Motorola PAGE 1 of 1

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
ΔIpeak (mA)	5x10¹²	V=6V	V=6V	3	0.000667	0	0.002	0.00161 -0.00298	0.0028 -0.0045	
	1x10¹³			3	0	0	0	0	0	
								0	0	

AGS

1N5290, Motorola

DEVICE TYPE: 1N 5290 Motorola PAGE 1 of 1

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.							
ΔIpeak (mA)	5x10¹²	V=4V	V=4V	0	0	0	–	0	0	
	1x10¹³			0	0	0	0	0	0	
								0	0	

AGS

1N5297, Motorola

DEVICE TYPE: 1N 5297 Motorola Page 1 of 1

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
Δ[illegible] (mA)	5x10¹²	V=5V	V=5V	3	-0.00667	0	-0.02	0.0164	0.026	
								-0.0248	-0.0413	
	1x10¹³			3	-0.00667	0	-0.02	0.0164	0.026	
								-0.0298	-0.0413	

AGS

1N5300, Motorola

DEVICE TYPE: 1N 5300 MOTOROLA Page 1 of 1

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
		BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
Δ[illegible] (mA)	5x10¹²	V=6V	V=6V	3	-0.00333	0	-0.01	0.00821	0.014	
								-0.0149	-0.0207	
	1x10¹³			3	-0.00333	0	-0.01	0.00821	0.014	
								-0.0149	-0.0207	

AGS

F. DIODES AND RECTIFIERS

1N4148, GE

DEVICE TYPE: 1N 4148 G.E. Pg. 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔIR (nA)	5x10¹²	VR=15V	VR=15V	6	0.383	0.6	0.2	0.704	0.864	
								0.0629	-0.0923	
	1x10¹³			6	0.933	2	0.5	2.06	2.63	
								-0.196	-0.76	
ΔIF (nA)	5x10¹²		VF=0.15V	6	0.833	10	-4	11.2	16.4	
								-9.55	-14.7	
	1x10¹³			6	-5.83	6	-18	6.97	13.4	
								-18.6	-25	

NGS

1N5711, Hewlett-Packard

DEVICE TYPE: 1N5711 HPA PAGE 1 of 1 2

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	Ma	BIAS: IRRAD.	BIAS: MEAS.							
ΔVF (mV)	5x10¹²	3	IF = 0.45mA	IF = 0.45mA	3	-0.0333	0.6	-0.7	1.22	1.92	
		5.5			3	-0.967	0.9	-1.0	-0.851	-0.983	
	1x10¹³	3			3	0.267	1.0	-0.6	1.88	2.69	
		5.5			3	-1.03	-0.9	-1.3	-0.571	-0.341	

NG

BC997, Texas Instruments

DEVICE TYPE: BC 997 Texas Instruments Pg. 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔI leakage (nA)	5x10¹²	VR=-2V	VR=2V; acc.±5%	24	-0.383	-0.2	-0.7	-0.103	0.0328	
								-0.664	-0.805	
	1x10¹³			24	-0.442	-0.2	-0.8	-0.153	-0.0080	
								-0.73	-0.874	

AGS

FJT1100, Fairchild Semiconductor

DEVICE TYPE: FJT 1100 Fairchild semiconductor Pg. 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔI Rg (nA)	5x10¹²	VR=10V	VR=10V	3	0.006	0.008	0.004	0.01	0.012	
								0.002	0	
	1x10¹³			3	0.003	0.011	-0.004	0.0181	0.0256	
								-0.0121	-0.0196	

AGS

MV1404, Motorola

DEVICE TYPE: MV1404 MOTOROLA PAGE 1 of 1 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ΔLEAKAGE	5×10¹²	VR = 10V	VR = 4.5V; ACC. ±3%	6	0.178	0.28	0.04	0.355	0.443	
CURRENT	↓							0.001%	-0.0863	
(nA)	1×10¹³			6	0.2	0.3	0.03	0.412	0.517	
	↓							-0.0117	-0.117	
	5×10¹²		VR = 8.5V; ACC. ±3%	6	0.143	0.3	-0.2	0.537	0.734	
	↓							-0.251	-0.448	
	1×10¹³			6	0.0833	0.33	-0.3	0.56	0.796	
	↓							-0.383	-0.619	
ΔDIODE	5×10¹²		VR = 1.5V; f = 1MHz	6	1.53	3.8	-7	9.96	14.2	
CAPACITANCE	↓		ACC. ± 3%					-6.89	-11.1	
(pF)	1×10¹³			6	1.58	3.7	-6.5	9.55	13.5	
	↓							-6.38	-10.4	
	5×10¹²		VR = 8.5V; f = 1MHz	6	0.2	0.6	-0.1	0.751	1.03	
	↓		ACC. ± 3%					-0.351	-0.627	
	1×10¹³			6	0.0833	0.5	-0.3	0.6020	0.898	
	↓							-0.459	-0.731	
NCS										

UTR4320, Unitrode

DEVICE TYPE: UTR4320 UNITRODE PAGE 1 of 1 2

Parameter	Fluence		Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	MeV	BIAS: IRRAD.	BIAS: MEAS.							
VF (mV)	5×10¹²	3	IF = 50mA	IF = 50mA	3	670	675.6	667.3	680	684	
		5.5			3	677	684.4	667.8	694	702	
	1×10¹³	3			3	670	675.6	667.5	679	684	
		5.5			3	677	684.1	667.4	694	702	
VF (mV)	1×10¹³	3		IF = 100mA	3	708	713	705	717	721	
		5.5			3	730	734	705	749	763	
VF (mV)	1×10¹³	3		IF = 200mA	3	760	764	756	768	772	
		5.5			3	778	801	758	821	849	
VF (mV)	1×10¹³	3		IF = 500mA	3	845	871	832	890	912	
		5.5			3	859	894	833	922	954	
VF (mV)	1×10¹³	3		IF 1A	3	882	891	865	911	925	
		5.5			3	922	969	892	1000	1050	
VF (mV)	1×10¹³	3		IF = 2A	3	947	960	922	991	1010	
		5.5			3	1000	1060	970	1100	1160	
NCS											

2N1878, Unitrode

DEVICE TYPE: 2N1878 UNITRODE Pg. 1 of 1 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ΔV Gate Voltage	5x10¹²	Anode V = 50V;	Anode V = 50V;	3	-0.072	-0.015	-0.108	0.0279	0.0278	
(V)		$I_F = I_G = 0$	$R_L = 500\Omega$;					-0.172	-0.222	
	1x10¹³		$R_G = 560\Omega$	3	-0.426	-0.125	-0.553	0.00876	0.226	
								-0.861	-1.08	
ΔI_G	5x10¹²			3	0.127	0.19	0.04	0.282	0.36	
Gate Current								-0.0287	-0.106	
(mA)	1x10¹³			3	0.557	0.7	0.29	1.02	1.25	
								0.0944	-0.137	

C 68

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

G. CAPACITORS

B11B, Component Research, Teflon capacitors

DEVICE TYPE: B11B TEFLON CAPACITORS COMPONENT RESEARCH PAGE 1 of 1 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
0.02 μF										
Δ CAPACITANCE	5×10¹²	VC = 10V		6	-5	0	-10	5.95	11.4	
(pF)	↓							-11.0	-21.4	
	1×10¹³			6	-3.33	10	-10	13	21.2	
	↓							-19.7	-27.8	
0.05 μF										
Δ CAPACITANCE	5×10¹²			6	11.7	20	0	26.7	34.2	
	↓							-3.39	-10.9	
	1×10¹³			6	-1.67	10	-10	18	27.8	
	↓	↓						-21.3	-31.2	
AGS										

H. RESISTORS

CDP16-01-103G, Dale Electronics

DEVICE TYPE: CDP 16-01-103G Dale Electronics pg lot 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
100K± 5%	e/cm²	BIAS: 1 RAD.	BIAS: MEAS.					-2σ	-3σ	
ΔDC Resistance										
(KΩ)	5×10^{12}	15VDC Across Res.		16	0.00128	0.0076	-0.0018	0.00642	0.00928	
								-0.00405	-0.00671	
	1×10^{13}			16	0.00101	0.0068	-0.002	0.0062	0.0088	
								-0.00418	-0.00677	

NGS

CDP16-01-104G, Dale Electronics

DEVICE TYPE: CDP 16-01-104G Dale Electronics pg lot 1

Parameter	e/cm² Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
100K± 2%		BIAS: 1 RAD.	BIAS: MEAS.					-2σ	-3σ	
ΔDC Resistance										
(KΩ)	5×10^{12}	15VDC Across Res.		16	-0.0114	0.026	-0.024	0.0108	0.022	
								-0.0336	-0.0447	
	1×10^{13}			16	-0.0079	-0.011	-0.029	-0.00883	-0.00427	
								-0.0271	-0.0316	

NGS.

CDP16-01-223J, Dale Electronics

DEVICE TYPE: CDP 16-01-223J Dale Electronics pg 1 of 1 — 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
22K±5%	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ADC Resistance										
(KΩ)	5×10¹²	15VDC across Res.		16	0.002	0.007	-0.007	0.00845	0.0117	
	↓							-0.00445	-0.00767	
	1×10¹³			16	0.00221	0.006	-0.013	0.00756	0.0102	
	↓							-0.00294	-0.00557	

AQ

CDP16-01-563J, Dale Electronics

DEVICE TYPE: CDP 16-01-563J Dale Electronics pg 1 of 1 — 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
56K±5%	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ADC Resistance										
(KΩ)	5×10¹²	15VDC across Res.		16	0.00369	0.001	-0.011	0.00265	0.00578	
	↓							-0.01	-0.0132	
	1×10¹³			16	-0.00658	-0.004	-0.013	-0.0015	0.00102	
	↓							-0.0116	-0.0141	

AQ

CDP16-01-683J, Dale Electronics

DEVICE TYPE: CDP 16-01-683J Dale Electronics pg1 of 1 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
68K±5%	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ADC Resistance										
(KΩ)	5×10¹²	15VDC ACROSS RES.		16	-0.0109	0.0	-0.070	0.0257	0.0438	
								-0.0464	-0.0644	
	1×10¹³			16	-0.00963	0.0	-0.077	0.027	0.0453	
								-0.0463	-0.0646	

AGS

CDP18-02-393K, Dale Electronics

DEVICE TYPE: CDP 18-02-393K Dale Electronics pg1 of 1 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
39K±10%	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ADC Resistance										
(KΩ)	5×10¹²	15VDC ACROSS RES.		34	-0.00798	0.023	-0.021	0.0104	0.0197	
								-0.0264	-0.0356	
	1×10¹³			34	0.0461	2.014	-0.026	0.742	1.09	
								-0.649	-0.997	

AGS

LDP16-01-153G, Dale Electronics

DEVICE TYPE: LDP 16-01-153G DALE ELECTRONICS 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
15K±5%	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ADC Resistance (KΩ)	5×10¹²	15VDC, Across Res.		16	0.0039	0.0050	0.0020	0.0019 0.0086	0.0017 0.0125	
	1×10¹³			16	0.0053	0.0080	0.0090	0.0015 0.0090	0.0007 0.0109	

AGS

SDP16-02-473J, Dale Electronics

DEVICE TYPE: SDP 16-02-473T Dale Electronics pg 1 of 1 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
47K±5%	e/cm²	BIAS: IRRAD.	BIAS: MEAS.							
ADC Resistance (KΩ)	5×10¹²	15VDC across Res.		29	0.00183	0.025	-0.003	0.012 -0.00833	0.0171 -0.0134	
	1×10¹³			29	0.000862	0.025	-0.003	0.0111 -0.00935	0.0162 -0.0145	

AGS

MG720, Caddock Electronics

DEVICE TYPE: MG720 CADDOCK Electronics pg1of1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
20mΩ	e/cm²	Bias: Irrad.	Bias: Meas.					-2σ	-3σ	
ΔDC Resistance	5X10¹²	V=3000V		5	-0.002	0.0	-0.01	0.0069	0.0114	
(mΩ)								-0.0109	-0.0154	
	1X10¹³			5	0	0	0	0	0	
								0	0	

MG750, Caddock Electronics

DEVICE TYPE: MG750 Caddock Electronics pg1of1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
20mΩ	e/cm²	Bias: Irrad.	Bias: Meas.					-2σ	-3σ	
ΔDC Resistance	5X10¹²	I_C: 12μA		5	0.18	0.3	0.0	0.399	0.509	
(mΩ)								-0.0391	-0.149	
	1X10¹³			5	0	0	0	0	0	
								0	0	
	1.5X10¹³			5	0.04	0.2	0.0	0.219	0.308	
								-0.139	-0.228	

MM125, Caddock Electronics

DEVICE TYPE: MM125 Caddock Electronics pg 1 of 1 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
ADC Resistance	5×10¹²	I = 0.15mA		5	-0.0126	0.0	-0.054	0.0339	0.0572	
(KΩ)	↓	↓						-0.0591	-0.0324	
↓	1×10¹³	↓		5	0.0016	0.046	-0.03	0.0567	0.0[illegible]	
↓	↓	↓						-0.0535	-0.081	

AGS

MS176, Caddock Electronics

DEVICE TYPE: MS176 Caddock Electronics pg 1 of 1 1

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	e/cm²	Bias: Irrad.	Bias: Meas.					-2σ	-3σ	
ADC Resistance	5×10¹²	No Voltage Applied		4	0.5	1.0	0.0	1.65	2.23	
(Ω)	↓	↓						-0.655	-1.23	
↓	1×10¹³	↓		4	1.25	2.0	0.0	3.16	4.12	
↓	↓	↓						-0.665	-1.62	

AGS

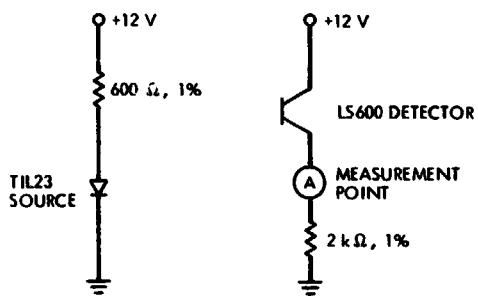
I. OPTICAL DEVICES

The Texas Instruments Types TIL23 and TIL24 light sources and types TIL601 and LS600 light detectors were evaluated in the JPL Dynamitron using a 2.5-MeV electron beam. Two of the tests used a 0.32-cm (1/8-in.) spacing between the source and detector in order to evaluate the spacecraft usage conditions. Three tests used a spacing of 20 cm (8 in.) in order to allow shielding and consequently evaluation of the source or detector separately. In addition, various angles were used during irradiation in order to reduce the amount of shielding caused by the lens material. All of the devices were measured in situ, within a period of 5 minutes, with the beam off.

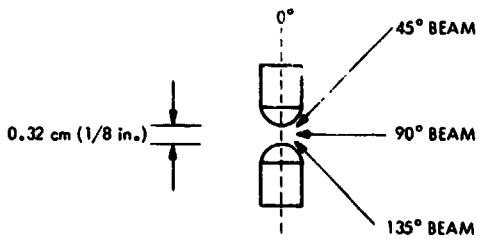
1. Tests Using 0.32-cm (1/8-in.) Space

Test results using a 0.32-cm (1/8-in.) space between the light source and detector with both device types irradiated at the same time unshielded were as follows:

Test No. 1. Four TIL23 light sources and four LS600 light detectors were tested on April 15-29, 1975. The test circuit is shown below:



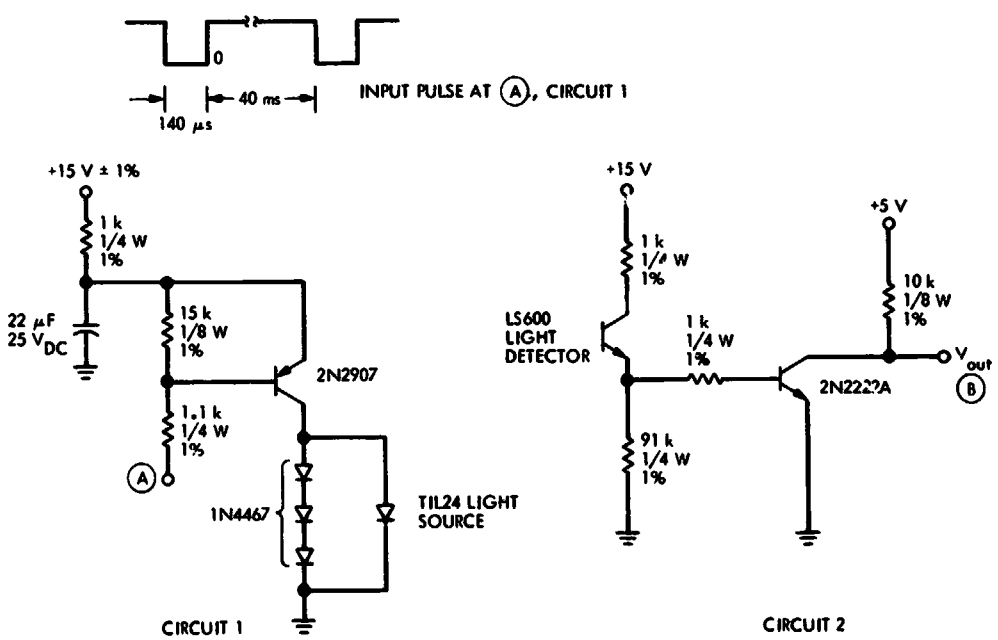
Due to the close spacing between the TIL23 source and LS600 detector and the presence of the glass window, there is an undetermined amount of shielding of the device from the electron beam. Consequently, exposures at a number of incidence angles for the electron beam were used (i.e., 45, 90, and 135°), as shown below, during the test.



Device S/N	Current measured at point Ⓐ, μA (Φ - fluence, e/cm^2; ϕ = flux, e/cm^2/s)							Beam Angle, deg	Date, 1975
	$\Phi = 0$, $\phi = 0$	$\Phi = 1 \times 10^{12}$, $\phi = 1 \times 10^9$	Δ, %	$\Phi = 2.5 \times 10^{12}$, $\phi = 1.5 \times 10^9$	Δ, %	$\Phi = 5 \times 10^{12}$, $\phi = 2.5 \times 10^9$	Δ, %		
12	350	213	-39	120	-66	55	-84	45	4-15
1	470	390	-17	320	-32	234	-50	135	4-16
2	282	205	-27	134	-53	75	-73	45	4-16
3	60	213	-28	0.36[a]	a	19	-68	90	4-29

[a]Data invalid; the device accidentally pulled out of position during irradiation.

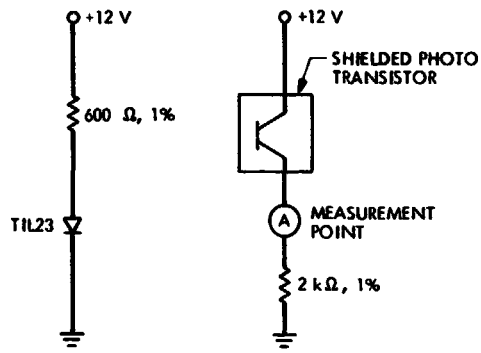
Test No. 2. Four LS600 light detectors and four TIL24 light sources were exposed on January 22, 1975, to the electron beam at a 60° angle (see Fig. 3). The fluence was 5×10^{12} and 1×10^{13} e/cm^2 with a flux rate of 2.5×10^9 e/cm^2/s. There was no significant change in the output level as measured at point Ⓑ for any of the devices tested. Although the test devices were undoubtedly severely degraded (as indicated from previous test experience), there was still sufficient pulsed output after radiation exposure to trigger the 2N2222A transistor "on," therefore maintaining a constant output at point Ⓑ. The test circuit is shown below:



2. Tests Using 20-cm (8-in.) Space

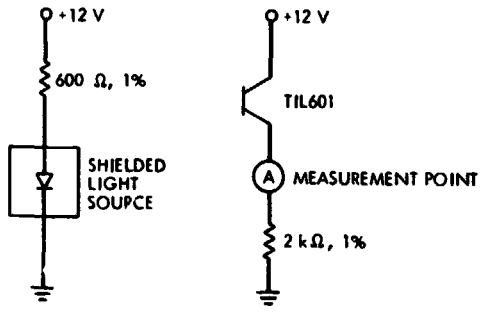
Test results using 20 cm (8 inch) of spacing between the light source and detector with one of the device types shielded during irradiation were as follows:

Test No. 1. Four TIL23 light sources were exposed to the electron beam at an angle of 45 deg as shown in Fig. 4 with the detector shielded. The test circuit is shown below:



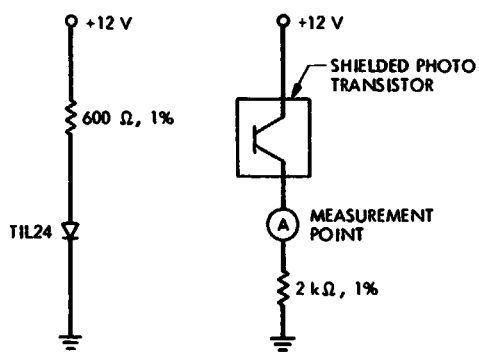
Device S/N	TIL23 output voltage measured at point Ⓐ, mV (Φ = fluence, e/cm^2; ϕ = flux, e/cm^2/s)				
	$\Phi = 0$, $\phi = 0$	$\Phi = 5 \times 10^{12}$, $\phi = 3.6 \times 10^9$	Δ, %	$\Phi = 1 \times 10^{13}$, $\phi = 3.6 \times 10^{19}$	Δ, %
5	0.240	0.014	-94.2	0.004	-98.3
6	0.360	0.022	-94.0	0.006	-98.3
7	0.140	0.014	-90.0	0.005	-96.4
8	1.900	0.116	-94.0	0.038	-98.0

Test No. 2. Four TIL601 light detectors were exposed on January 22, 1975, to the electron beam at a 45-deg angle as shown in Fig. 4 with the light source shielded. The test circuit is shown below:



Device S/N	TIL601 current measured at point Ⓐ, nA (Φ = fluence, e/cm^2; ϕ = flux, e/cm^2/s)				
	$\Phi = 0$, $\phi = 0$	$\Phi = 5 \times 10^{12}$, $\phi = 3.6 \times 10^9$	Δ, %	$\Phi = 1 \times 10^{13}$, $\phi = 3.6 \times 10^{19}$	Δ, %
1	250.0	129.0	-48.4	38.0	-85.0
2	96.0	19.2	-80.0	8.0	-91.7
3	160.0	65.0	-59.4	19.0	-88.1
4	112.0	78.0	-30.4	53.0	-52.7

Test No. 3. Four TIL24 light sources were exposed to the electron beam at an angle of 45 deg as shown in Fig. 4 with the detector shielded. The test circuit is shown below:



Device S/N	TIL24 voltage measurement at point Ⓐ, mV (Φ = fluence, e/cm^2; ϕ = flux, e/cm^2/s)				
	$\Phi = 0$, $\phi = 0$	$\Phi = 5 \times 10^{12}$, $\phi = 3.6 \times 10^9$	Δ, %	$\Phi = 1 \times 10^{13}$, $\phi = 3.6 \times 10^9$	Δ, %
1	0.318	0.047	-85.2	0.015	-95.3
2	0.218	0.010	-95.4	0.003	-98.6
9	0.384	0.030	-92.2	0.009	-97.7
10	3.000	0.208	-93.1	0.016	-99.5

3. Conclusions

(1) These types of optical devices are very sensitive to radiation-induced damage.

(2) The light sources are more sensitive to radiation damage than the detectors.

(3) There is increased light scatter due to the degraded source lens.

(4) There is more apparent degradation with 20-cm (8-in.) spacing between the source and detector than with 0.32-cm (1/8-in.) spacing because the light from the source decreases as the square of the distance from the detector, and any increase in light scatter will exhibit more effect as the distance is increased.

4. Test Conditions

The device shown in Fig. 3 was irradiated with the axis of the electron beam at 60 deg to the axis of the device as shown in the diagram in order to avoid the glass lid.

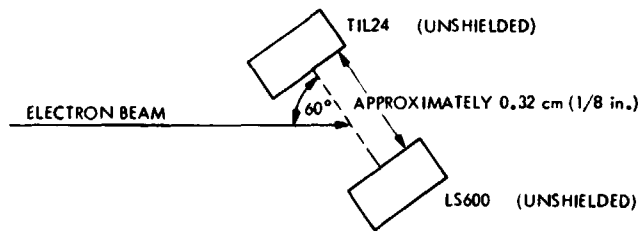


Fig. 3. Flux angle, electron beam at 60 deg

No other components of the experiment were changed. A cosine variation in fluence with incident angle was used. The Faraday cup readings of fluence were thus twice the fluence required (i.e., 10^{13} and 2×10^{13} e/cm^2). The effective value of the fluence on the device was obtained as of these values (i.e., 5×10^{12} and 10^{13} e/cm^2). This was done by using a time exposure twice as long rather than doubling the flux rate. Thus the effective flux rate at the device was one-half that in the test requirements.

The device shown in Fig. 4 was irradiated with the axis of the electron beam at 45 deg to the axis of the device as shown in the diagram in order to avoid the glass lid.

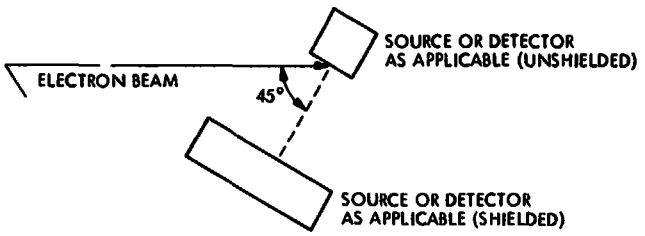


Fig. 4. Flux angle, electron beam at 45 deg

A cosine variation in fluence with incident angle was used. The Faraday cup readings of fluence were thus 1.4 times the fluence required (i.e., 0.707×10^{12} and 1.41×10^{13} e/cm^2). The effective value of the fluence on the device was obtained as 0.707 of these values (i.e., 5×10^{12} and 10^{13} e/cm^2). This was done by using a time exposure 1.4 times as long rather than increasing the flux rate. Thus the effective flux rate at the device is 0.707 times that in the test requirements.

J. CMOS

Large quantities of CMOS devices comprising 28 different logic functions are used in the spacecraft. Devices fabricated by the standard commercial process could not withstand a dose of 150 krad(Si) under normal bias conditions due to shift of the n-channel gate turn-on voltage toward O V accompanied by a large increase in the supply current. By reducing the gate oxide annealing temperature (Ref. 2) it was found possible to fabricate devices that were still functional after irradiation to 150 krad(Si) though somewhat degraded in the device characteristics. A program was developed to monitor the radiation properties of the production line that included wafer lot sampling of changes in the quiescent supply current, test pattern sampling, and final device parameter characterization. All irradiations were carried out under representative usage bias conditions using a cobalt-60 source.

The four basic CMOS failure modes in an ionizing radiation environment have been identified by Burghard and Gwyn (Refs. 3 and 4) with their associated causes as follows:

(1)	Failure to switch	-	$\lvert V_{Tn}\rvert \downarrow$	$\lvert V_{TP}\rvert \uparrow$
(2)	Excessive leakage	-	$\lvert V_{Tn}\rvert \downarrow$	
(3)	Speed reduction	-	$\lvert V_{TP}\rvert \uparrow$	
(4)	Noise immunity	-	$\lvert V_{TN}\rvert \downarrow$	$\lvert V_{TP}\rvert \uparrow$

The arrows indicate a decrease or increase in $\lvert V_T\rvert$.

1. Gate Turn-on Voltage

Three to five test pattern dice were selected at random from each metallization lot. The test pattern dice contain individual N- and P-channel transistors and MOS capacitors. Measurement of I_{DS} versus V_{GS} of the two transistors was made before and after a dose of 1.15×10^5 rad(Si). A typical set of curves is shown in Fig. 5. The results for the N-channel transistor are particularly striking. The true gate turn-on voltage V_{Tn} at low currents is less than 1 V before irradiation and shifts to -0.6 V at 150 krad. At higher current levels V_{Tn} stays well above zero, as shown in Fig. 6, and does not shift significantly after irradiation (see Fig. 7).

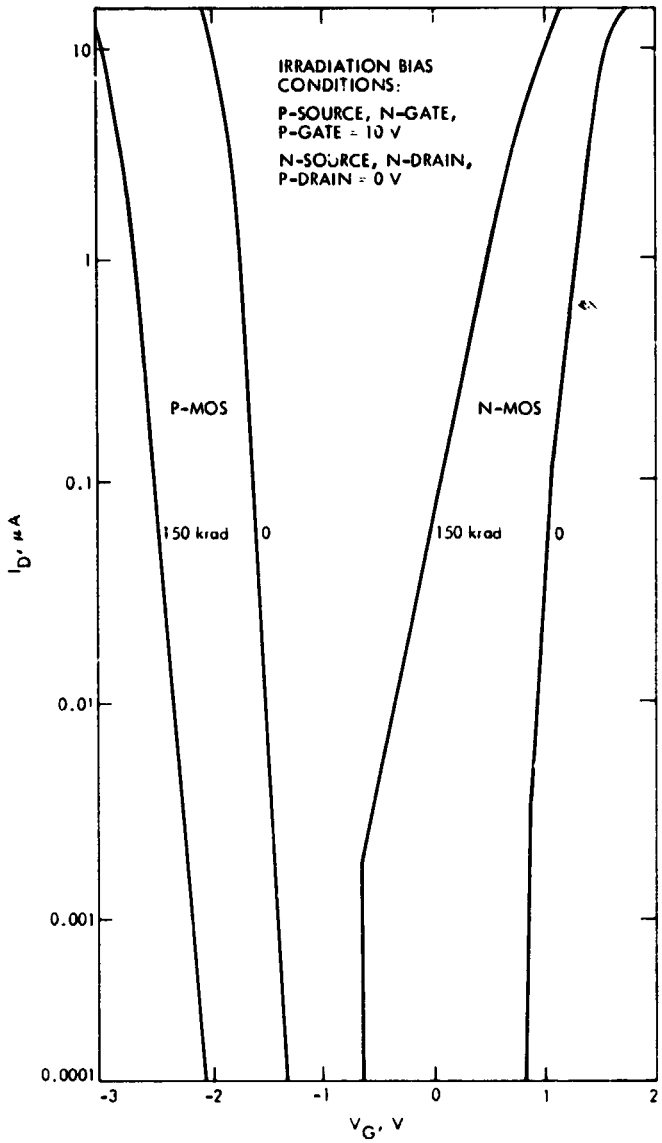


Fig. 5. N- and P-channel gate drive transfer characteristics

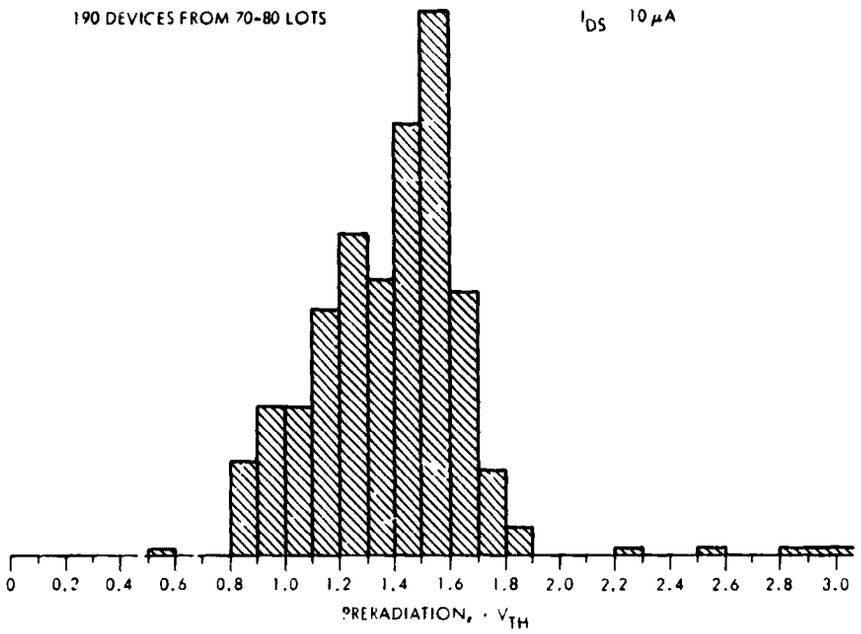


Fig. 6. Threshold voltage of N-channel transistor on test pattern TA 6372, 950°C gate oxide anneal in forming gas, preradiation

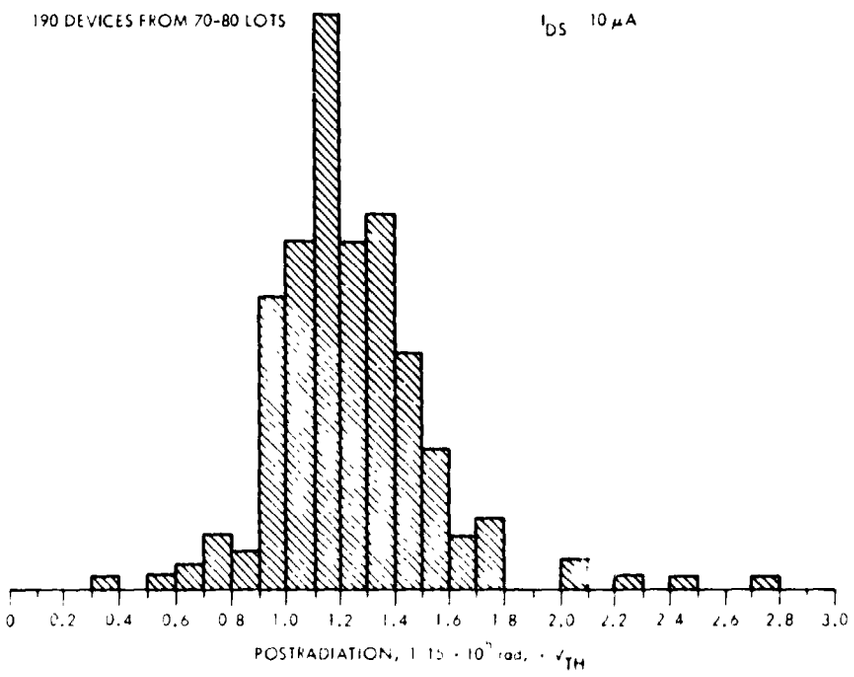


Fig. 7. Threshold voltage of N-channel transistor on test pattern TA 6372, 950°C gate oxide anneal in forming gas, postradiation

On the other hand, V_{TP} at 10 μA shows a bimodal distribution after irradiation, which may explain the lack of control of the propagation time (see Figs. 8 and 9). The distribution in the relative shift in the gate turn-on voltages is shown in Fig. 10.

The gate turn-on voltage is the most direct way of radiation-screening CMOS devices. However, the approach adopted in the MJS project was to monitor the quiescent supply current, which is related to V_{Tn} at low currents but does not control V_{Tp}. Moreover, there is no correlation in the behavior of these two parameters, since V_{Tn} at 150 krad(Si) is primarily a function of radiation induced oxide states, whereas V_{Tp} is a function of radiation-induced interface states.

The gate turn-on voltage V_T is the parameter directly affected by ionizing radiation. The V_T is, however, a transistor parameter, not a circuit parameter. The transfer characteristics of any CMOS circuit allow considerable shift in V_{Tm} or V_{Tp} before the circuit function ceases. The V_{Tn} may even cross O V and be slightly negative before functional failure occurs.

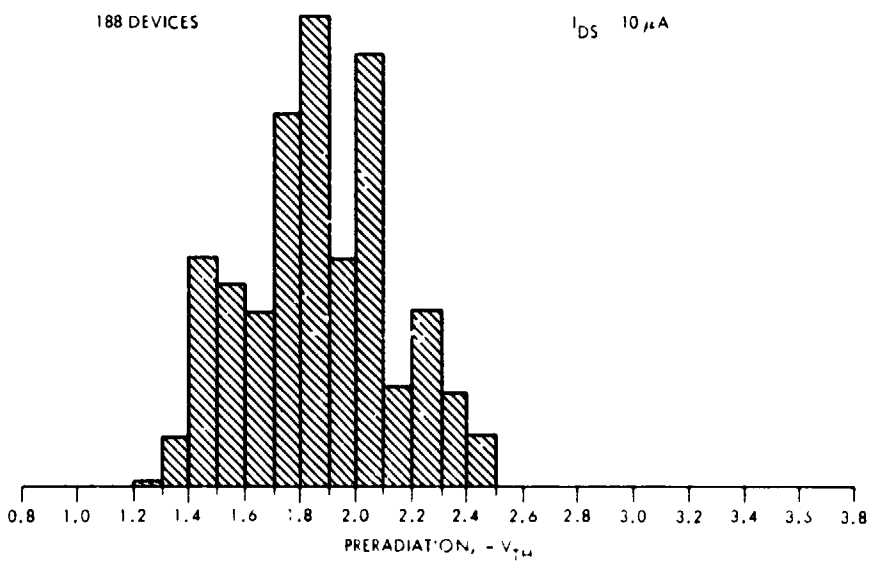


Fig. 8. Threshold voltage of P-channel transistor on test pattern TA 6372, 950°C gate oxide anneal in forming gas, preradiation

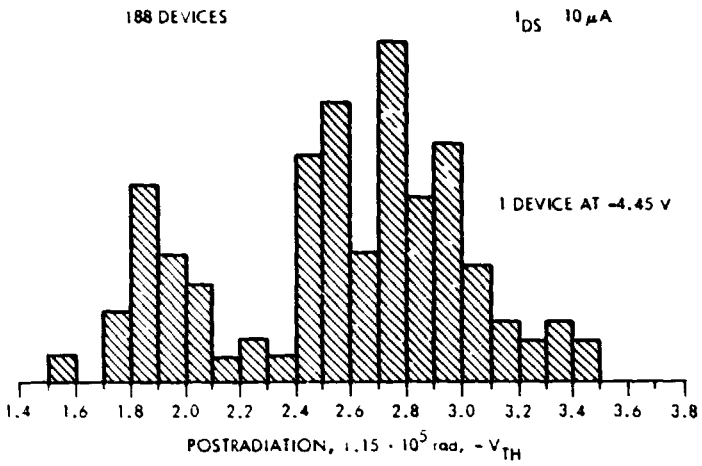


Fig. 9. Threshold voltage of P-channel transistor on test pattern TA 6372, 950°C gate oxide anneal in forming gas, postradiation

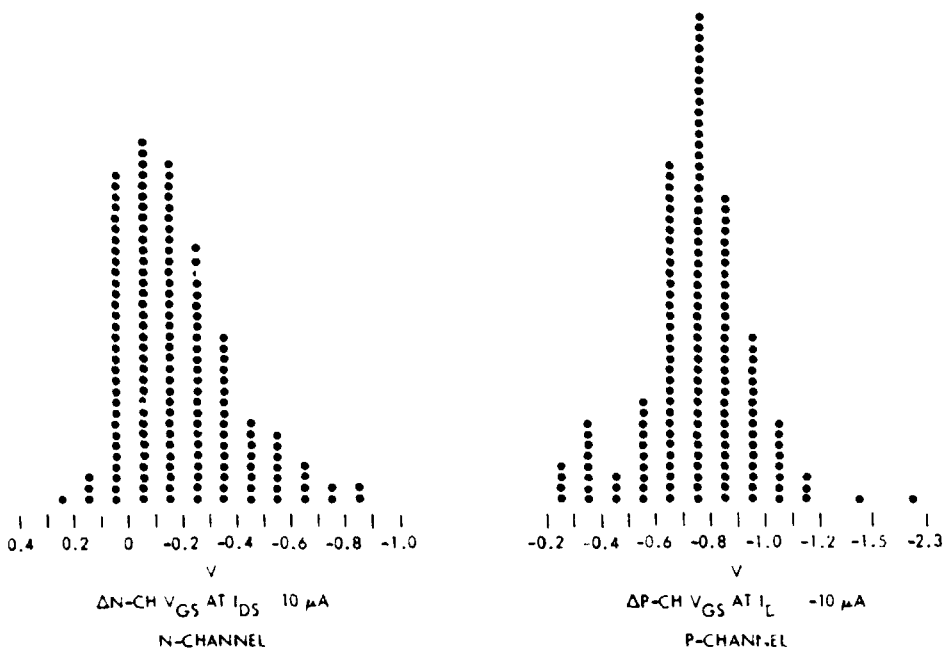


Fig. 10. Distribution of ΔV_{GS} at I_{DS} after 1.5×10^{15} rad(Si)

2. Wafer Screening of I_{SS}

Wafer screening consisted of irradiating five circuit devices or seven in the case of the three multiplexers from each wafer that would be used for the JPL product. The quiescent supply current I_{SS} was measured with all input terminals to ground and with all input terminals connected to 10 V. Rejection was based on an I_{SS} measurement after 150 krad(Si). The rejection criteria are given in Table 5. These criteria have considerable margin to functional failure.

The rejection rate at 150 krad was less than 10% for some simple circuits (gates and flipflops) and greater for complex and large-area circuits (counters, shift registers, multiplexers and buffers). More than 2700 wafers have now been screened in this manner.

The test dice were not specially screened for I_{SS} before irradiation. As indicated in Fig. 11, 75% of the devices (Group 1) had leakage currents below 1 nA, another 20% (Group 2) possessed greater leakage currents, but sufficiently low to pass the JPL specifications, whereas the remaining 5% (Group 3) would have been rejected in pre-irradiation screening. The post-irradiation data for Group 1 (Fig. 12) shows a reasonable Gaussian distribution, but with the rejection limit set so as to cause a 12% rejection rate. The more than 10,000-fold increase in I_{SS} appears to be the best that can be achieved on this type with the modified annealing process, and is attributed to the shift in V_{Tn} toward O V. Group 2, with marginal pre-irradiation properties produced a post-irradiation yield of only 66% (see Figs. 13 and 14).

A preliminary study on the variation of I_{SS} over a given wafer after irradiation indicates a tight distribution in some wafers, while other wafers exhibit a great deal of variability. This is in agreement with the general lot variability of the product observed during radiation screening.

The distribution of I_{SS} has been analyzed for a number of different device types and for both forming gas and nitrogen annealing. The results for the CD4052 and CD4049 are shown in Figs. 15 through 22. The data indicates a number of bimodal distributions caused by lack of process control, but that nitrogen annealing offers a substantially better product. The data that has been analyzed in this manner is summarized in Table 6.

Table 5. Rejection criteria for RCA CMOS wafer radiation screening

Type	I_{SS} (post-radiation), μA	I_{L1}	I_{L2}
CD 4001	> 2.5 μA		
4002	2.5		
4006	30		
4011	2.5		
4012	2.5		
4013	7.5		
4014	50		
4015	50		
4016	7.5		
4017	50		
4019	7.5		
4021	50		
4023	2.5		
4025	2.5		
4027	7.5		
4028	7.5		
4029	50		
4030	5.0		
4031	100		
4035	50		
4040	50		
4042	25		
4043	25		
4047	50		
4049	7.5		
4050	7.5		
4051	50	100 nA	>3μA/100 μA
4052	50	100 nA	100 nA
4053	50	100 nA	100 nA

I_{SS} is quiescent supply current measured with all inputs low (I_{SS1}) and all inputs high (I_{SS2}).

I_L is off-leakage current through all transmission gates (switches) in parallel. I_{L1} is measured with all switch inputs high (10 V) and the switch common to ground through the current meter. I_{L2} is measured with the switch common high and all switch inputs to ground through the current meter.

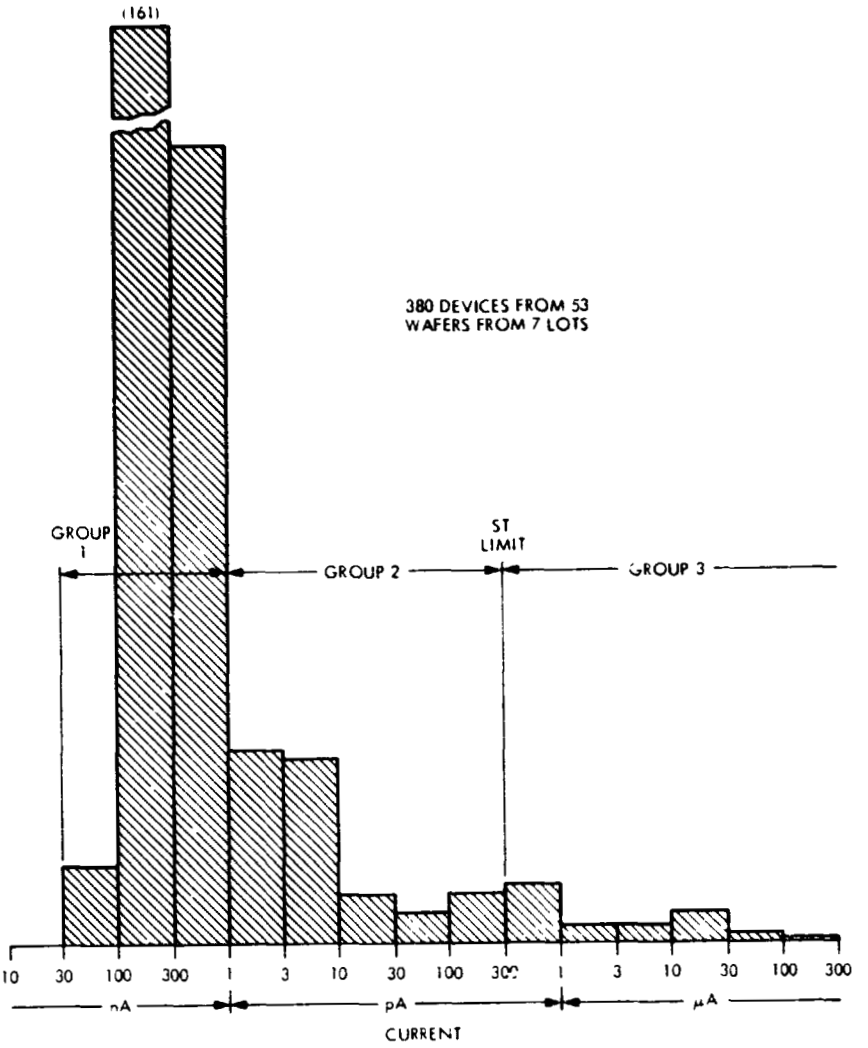


Fig. 11. RCA CD4006, preradiation, I_{SS1}

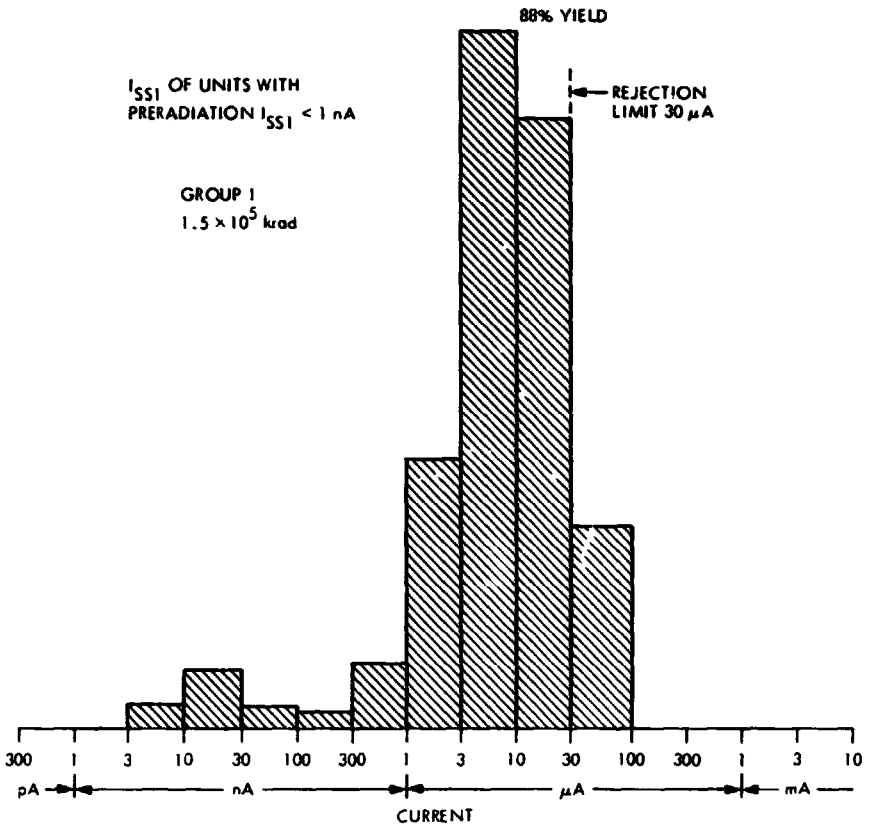


Fig. 12. RCA CD4006, postradiation I_{SS1} of units with preradiation I_{SS1} < 1 mA

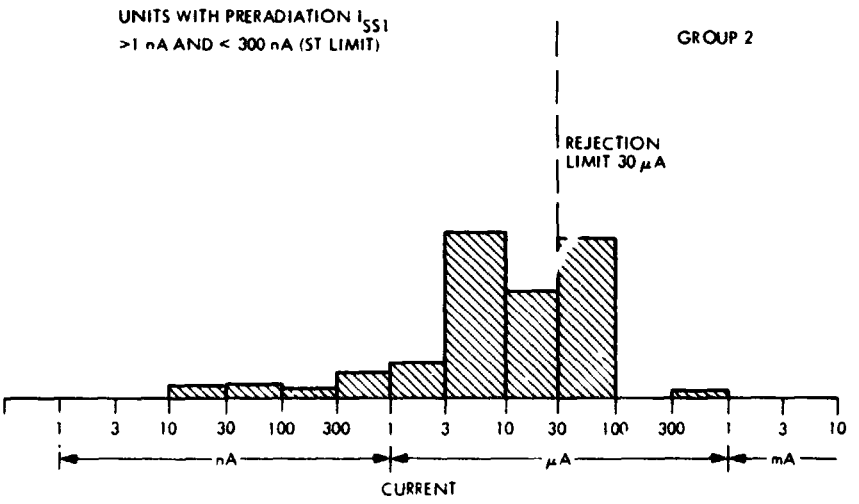


Fig. 13. RCA CD 4006, preradiation, group 2

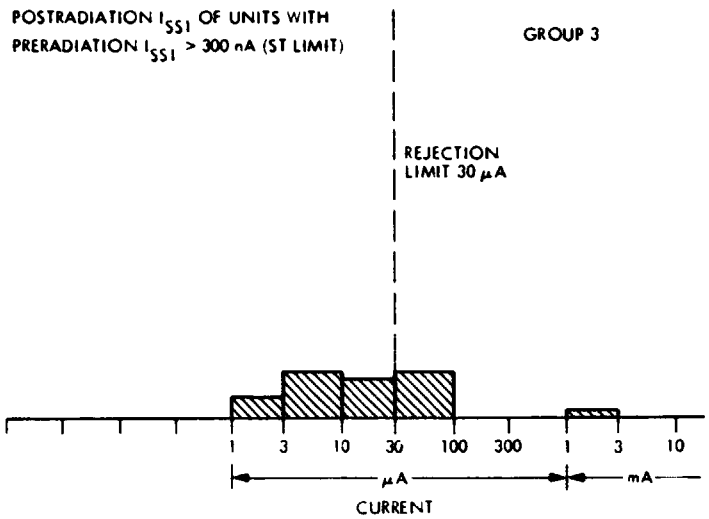


Fig. 14. RCA CD4006, group 3

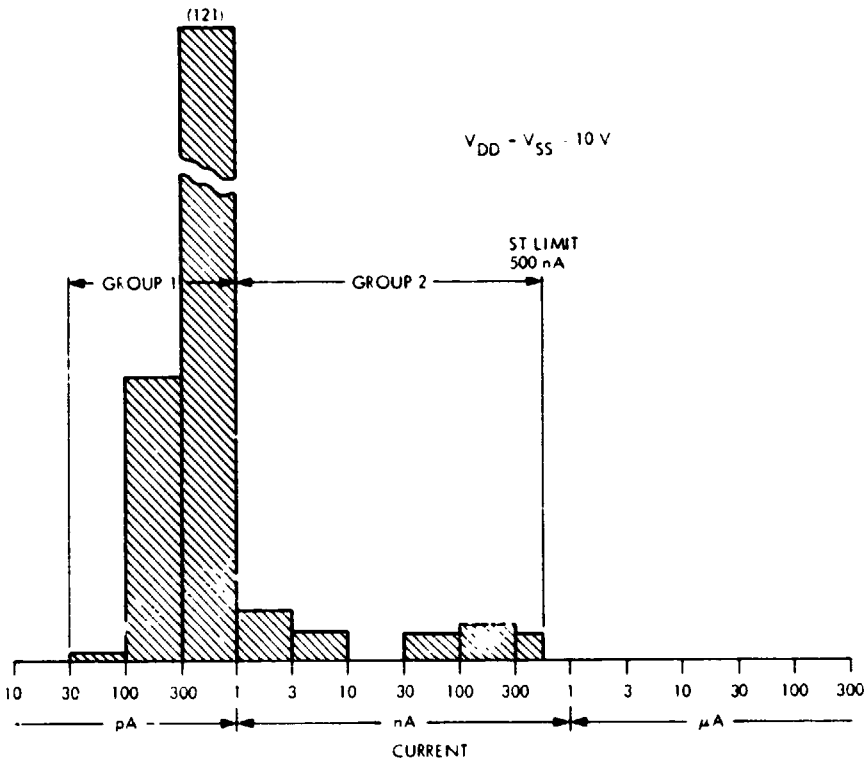


Fig. 15. Preradiation I_{SS} current of CD4052A multiplexers with 950°C gate oxide anneal in forming gas

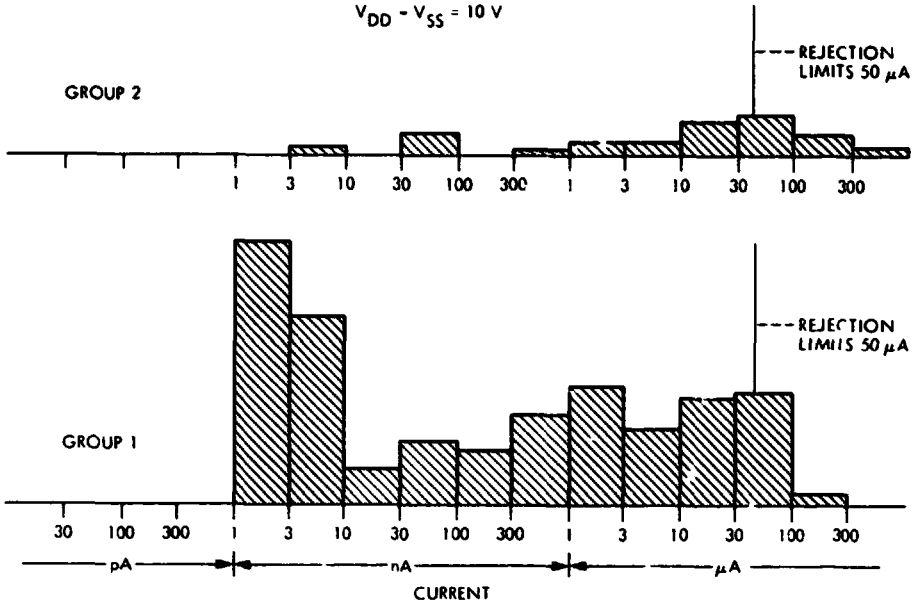


Fig. 16. Postradiation I_{SS} current of CD4052A multiplexers with 950°C gate oxide anneal in forming gas

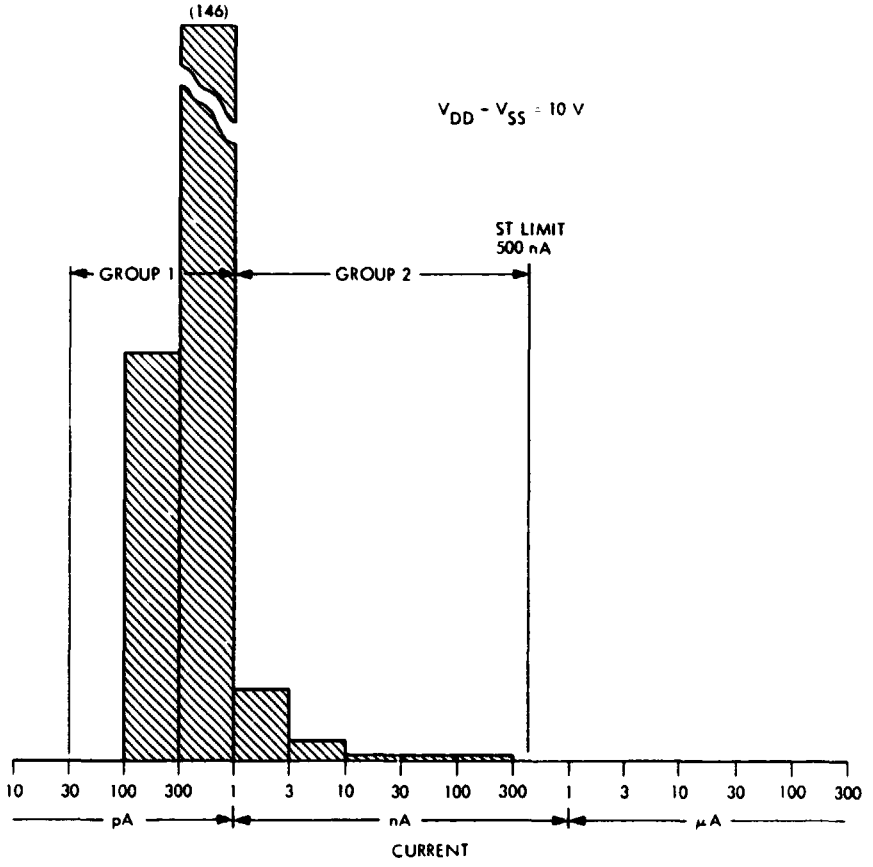


Fig. 17. Preradiation I_{SS} current of CD4052A multiplexers with 950°C gate oxide anneal in nitrogen

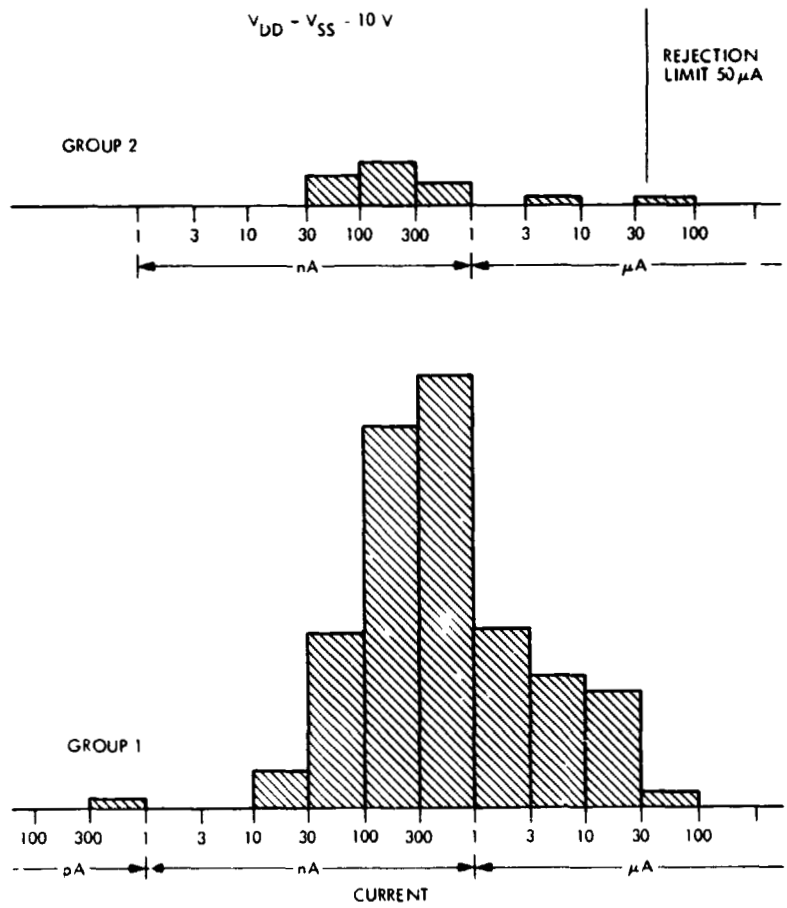


Fig. 18. Postradiation I_{SS} current of CD4052A multiplexers with 950°C gate oxide anneal in nitrogen

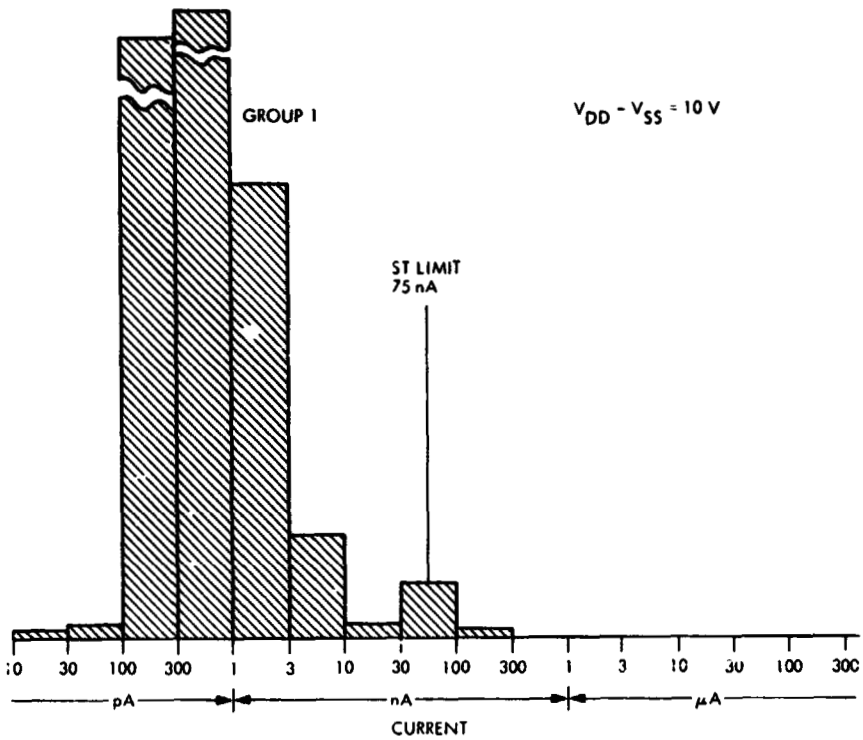


Fig. 19. Preradiation I_{SS} current of CD4049 with 950°C gate oxide anneal in forming gas

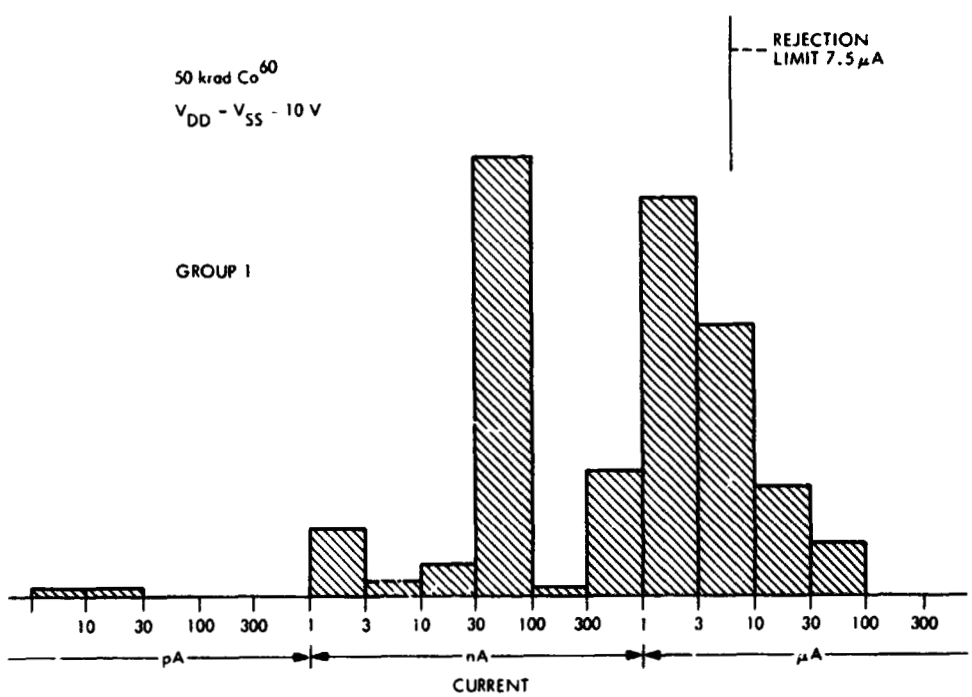


Fig. 20. Postradiation I_{SS} current of CD4049 with 950°C gate oxide anneal in forming gas

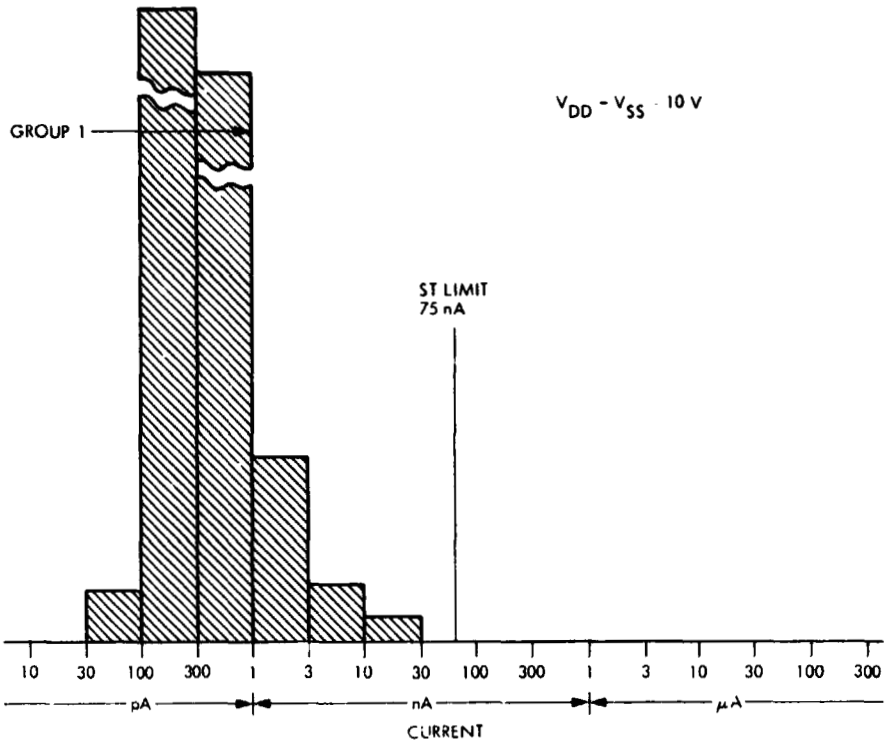


Fig. 21. Preradiation I_{SS} current of CD4049 with 950°C gate oxide anneal in nitrogen

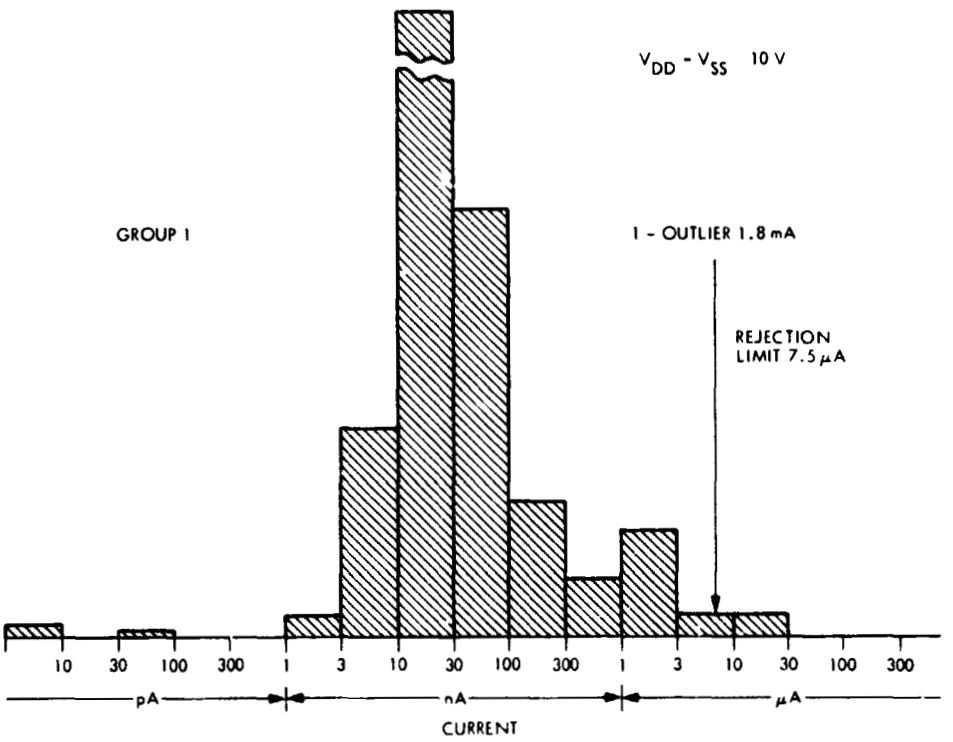


Fig. 22. Postradiation I_{SS} current of CD4049 with 950°C gate oxide anneal in nitrogen

Table 6. Analysis of I_{SS} data

Device type	Function	Annealing gas	Distribution	Peak of prime devices	Other peaks, μA	Rejection limit, μA
CD4006	18-stage shift register	Forming gas	Gaussian	10 μA		30
CD 4019	Quad And-Or gate	Forming gas	Gaussian	5 nA		7.5
		Nitrogen	Gaussian	20 nA		7.5
CD 4027	Dual flipflop	Forming gas	Gaussian	20 nA		7.5
CD 4029	Up/down counter	Forming gas	Bimodal	50 nA	20	50
		Nitrogen	Bimodal	5 nA 50 nA	2	50
CD 4049	Hex-buffer	Forming gas	Bimodal	50 nA	2	7.5
		Nitrogen	Quasi-Guassian	20 nA	2	7.5
CD 4052	Multiplexer	Forming gas	Bimodal	3 nA	2 30	50
		Nitrogen	Gaussian	500 nA		50

It is evident that the rejection limits do remove lots with lack of surface control. The rejection limits were chosen to screen out wafers with catastrophic devices or with I_{SS} higher than acceptable to the project systems designers. The yield figures of the wafer screening program are summarized in Table 7.

Increases in I_{SS} are a problem for the user (subsystem designer) only when the total for a subsystem exceeds the current available for the power supply, or when the subsystem power limitation is exceeded. Therefore, it is the average of the increases that is of interest, not the individual increases in I_{SS}. All the RCA CMOS that will be supplied are from wafers whose test samples had a post-150 krad I_{SS} of less than 100 times the 25°C specification limit- ST 11868 or MIL-STD-38510 or equivalent (see Table 5).

Table 7. CMOS wafer screening summary

2793 wafers radiated (over 200 lots) 2162 wafers accepted (77.4%) Forming gas vs N_2, anneal			
	Wafers accepted	Wafers radiated	Accepted, %
Forming gas	1049	1406	74.6
Nitrogen[a]	1078	1296	83.2

[a]Excluding 5 bad lots at beginning of N_2 anneal

In many cases the post-rad I_{SS} was much less than 100 times the specification limit. Therefore, the total post-150 krad I_{SS} for a subsystem should not exceed 100 times the sum of the specification limits for each device in the subsystem. The above statement should be true even though the wafer screening does not guarantee that every device will have a post-rad I_{SS} less than the 100 × limit, because of the averaging effect. It should be pointed out that 100 times the sum of the specification limits for each device in the subsystem cannot be used to establish the maximum current required from the power supply since this is quiescent current. The operating current of the subsystem will be higher because it is proportional to the clock or operating frequencies of the subsystem.

3. Transmission Gate Leakage

The multiplexers CD4051, CD4052, and CD4053 were subjected to an additional screen. The off leakage current through all transmission gates in parallel was required to be less than 100 nA measured with all switch inputs at 10 V and the outputs at ground (I_{L1}), and less than 100 nA for the CD 4052 and CD4053, and 3 μA for the CD4051, with all switch outputs at 10 V and the inputs at ground (I_{L2}). This resulted in a yield of about 50% for these device types.

The design requirements for I_{L2} in the CD4051 are more lenient than in the other multiplexers in this project. The 3 μA criterion for I_{L2} of the CD4051 was necessary to get any yield from the early production of these

devices. In subsequent forming gas lots I_{L2} dropped below 1μA typically, and when the gate oxide anneal was changed to nitrogen, I_{L2} dropped below 100 nA typically. The 3μA screening rejection criterion was reduced to 100 nA for the nitrogen annealed product.

Figures 23 and 24 show the distribution of the I_{L2} leakage current before and after irradiation, respectively, for devices annealed in forming gas. It may be seen that prime pre-irradiation devices show a bimodal distribution after irradiation, resulting in a high yield loss. This problem was solved by switching to nitrogen annealing. The pre-irradiation distribution (Fig. 25) was the same as before, but the post-irradiation data (Fig. 26) shows a more Gaussian distribution, though with a few outliers beyond 1 μA. The I_{SS} data for the same devices, shown in Figs. 15 through 18, exhibits a very similar behavior.

The I_LTG of the flight multiplexers is not expected to exceed the values in Table 5 for forming gas-annealed product or 40 nA for nitrogen-annealed product at 150 krads. Most of the 4051 product will be forming

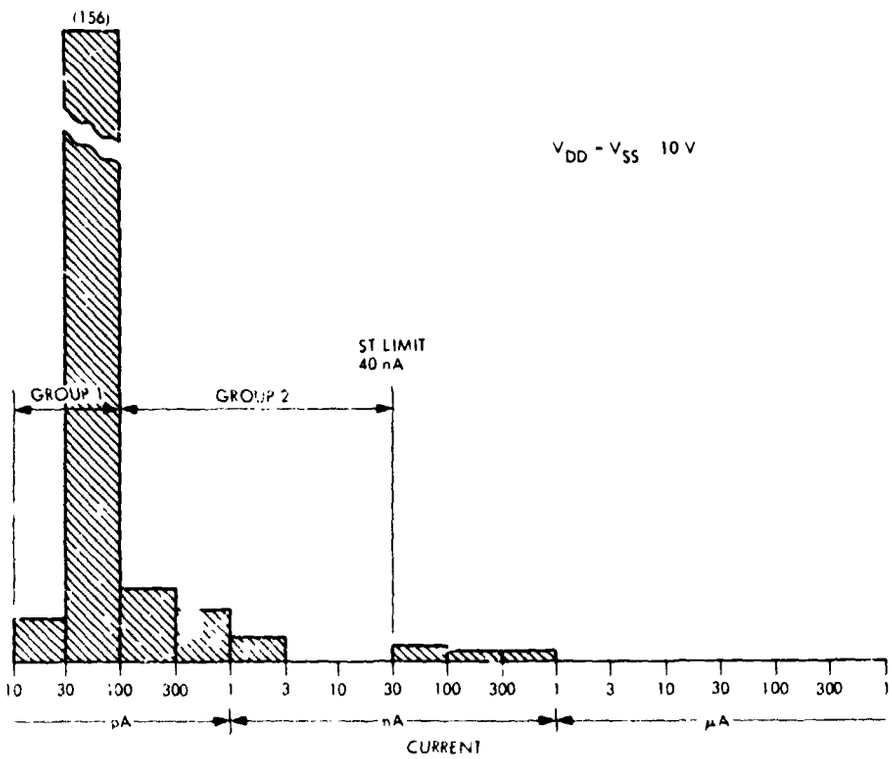


Fig. 23. Pr radiation switch leakage current I_{L2} of CD4052A multiplexers with 950°C forming gas

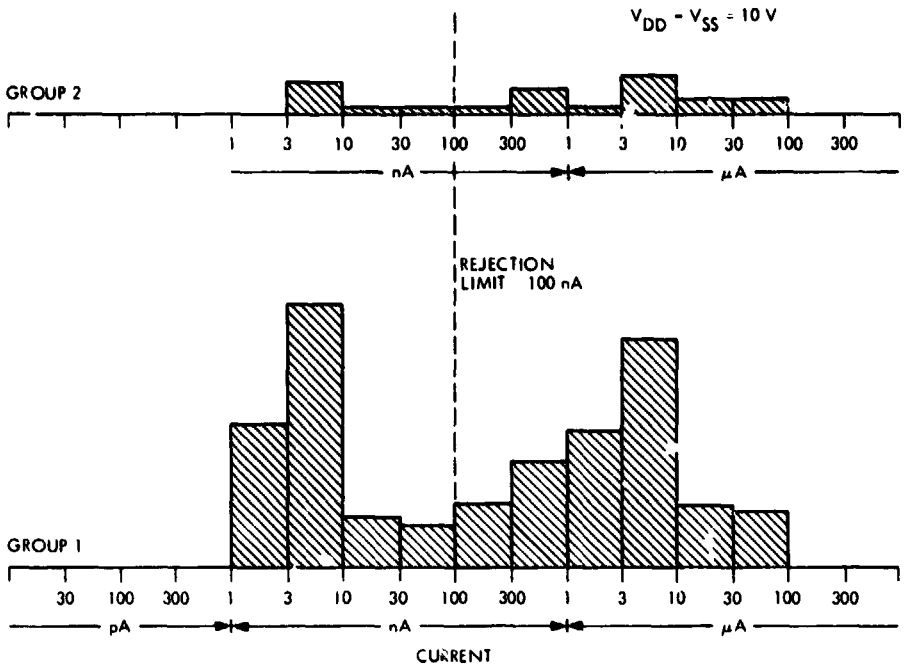


Fig. 24. Postradiation switch leakage current I_{L2} of CD4052A multiplexers with 950°C gate oxide anneal in forming gas

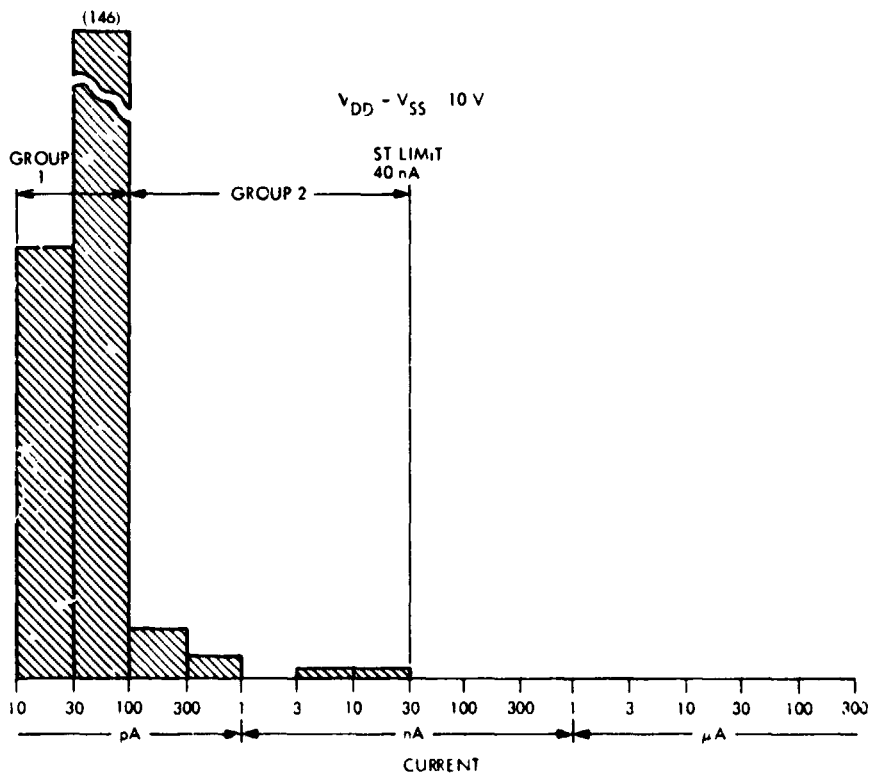


Fig. 25. Preradiation switch leakage current I_{L2} of CD4052A multiplexers with 950 gate oxide anneal in nitrogen

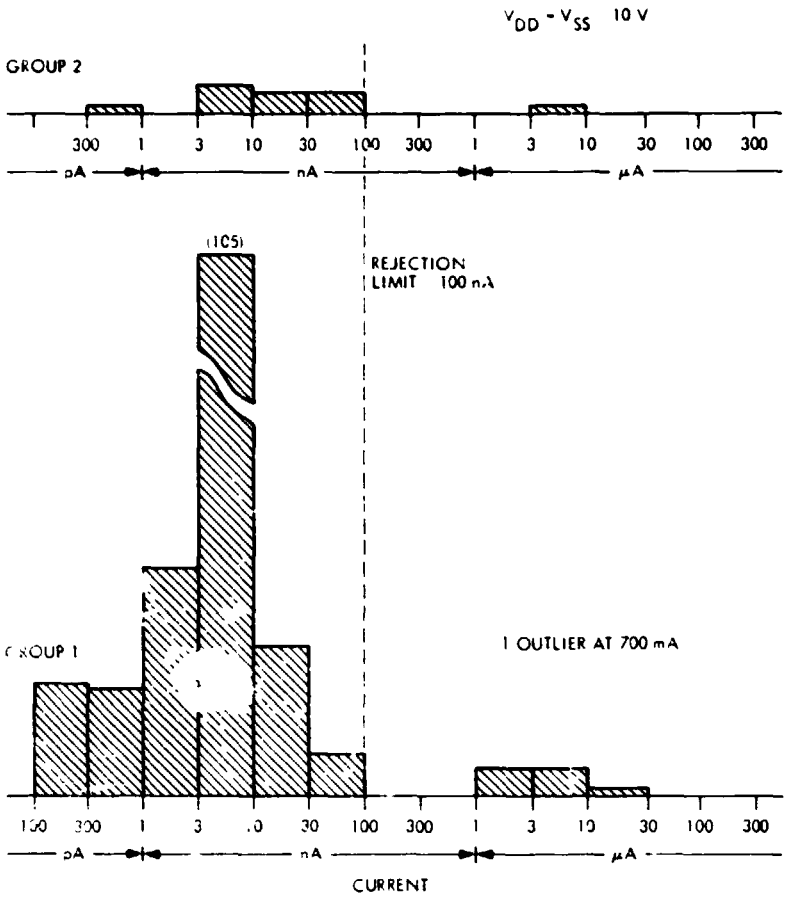


Fig. 26. Postradiation switch leakage current I_{L2} of CD4052A multiplexers with 950°C gate oxide anneal in nitrogen

gas-annealed. The 4052 product will be a combination of forming gas- and nitrogen-annealed devices, and the 4053 product will be entirely nitrogen-annealed.

4. Multiplexer On-Resistance

The on-resistance of the multiplexers increases less than 5% at 75 krads and 10% at 150 krads.

5. Propagation Time

A complete electrical characterization of some of the CMOS devices was carried out for JPL at the Naval Research Laboratory using an EH4600 series computer-controlled test system at a total dose of 7.5×10^4 and 1.5×10^5 rad(Si). The parameters tested and some typical results are

shown in Table 8. It may be noted that radiation causes a significant increase in the propagation time. It was established that there is no correlation between the radiation effects on propagation delay and quiescent supply current I_{SS}.

Table 8. CMOS radiation characterization data at 150 krad(Si)

Tests (At V_{DD} = 10 V)		4011	4029	4035	4050
1. Functional (go/no go) $V_0 < 5$ V = "0" $V_0 > 5$ V = "1"			All passed		
2. DC margin (go/no go) $V_0 < 1$ V = "0" $V_0 > 9$ V = "1"			All passed		
3. Δt_{PLH} (%) 30 pF load	Average	26.9[a]	13.8[b]	48.8[c]	10.6[d]
	Maximum	30	37	55	18
3a. Δt_{PLH} (%) 30 pF load	Average		26[e]		
	Maximum		37		
4. Δt_{PHL} (%) 30 pF load	Average	6.2[a]	28.2[b]	32.8[c]	35.6[d]
	Maximum	8.8	31	37	50
4a. Δt_{PHL} (%) 30 pF load	Average		19[e]		
	Maximum		33		
5. ΔV drop in output transistors at minimum source/sink current specified in RCA manual		N-CH < 0.1	V < 0.1	< 0.1	< 0.1
		P-CH < 0.1	V < 0.1	~0.1	< 0.1
6. Range of maximum quiescent supply current Δ	from:	56X	250X	23X	25X
	to:	4700X	9800X	3300X	3400X

[a]Propagation time measurement from pin 2 to pin 3 (in to out).

[b]Propagation time measurement from pin 15 to pin 6 (CL. to Q_1).

[c]Propagation time measurement from pin 6 to pin 1 (CL. to Q_1).

[d]Propagation time measurement from pin 3 to pin 2 (in to out).

[e]Propagation time measurement from pin 15 to pin 7 (CL. to carry out).

A more detailed analysis was carried out on additional measurements made at the Hughes (Fullerton) Facility (see Table 9). The propagation time after irradiation appears to be within the JPL specification limits, but the data shows large increases in propagation time. These are primarily influenced by outliers whose change may be up to one order of magnitude worse than the mean.

6. Dose Rate and Annealing Effects

Srour (Ref. 5) recently reviewed experimental observations on dose-rate dependence of the shift in V_T in MOS devices. The dependence is a function of the dose rate, the bias conditions during radiation and also the nature of the gate oxide. Srour irradiated N- and P-channel transistors on a commercial CMOS inverter using a Co^{60} source at rates of 0.23 and 22 rad(Si)/s. He observed a marked rate effect. Annealing the devices at room temperature for 140 hours (the time it takes to perform an irradiation to 1.2×10^5 rads at a rate of 0.23 rad/s) following a higher ionization rate irradiation brought the high and low dose-rate results into agreement.

Yamakawa (Ref. 6) measured rate effects in I_{SS} of CMOS devices with a 950°C gate-oxide anneal temperature at 113 and 7.6 rad/s at a total dose of 1.5×10^5 rad(Si). The bias conditions were as described in the wafer screen. The two dose rates represent the screening conditions and the Jovian radiation environment respectively. There was a strong annealing effect after radiation, but no rate effect could be detected. Additional experiments on the propagation time showed no annealing for several days. in agreement with the hypothesis that the propagation time is governed by interface states.

7. Conclusions

The radiation resistance of CMOS devices with a gate oxide annealing temperature of 950°C appears to be adequate for the MJS project, because the devices will be exposed to a total dose of less than 1.25×10^5 krad and because no severe constraints have been imposed on the quiescent supply current.

Preliminary data indicate that the substitution of forming gas by nitrogen in the gate oxide annealing step has a very beneficial effect on

Table 9. Propagation time

Device type	Parameter	Capacitance CL, pF	Propagation time, ns					
			Specified limit	Mean		Max.		Δ Max.
				Pre-irradiate	1.5×10^5 rad	Pre-irradiate	1.5×10^5 rad	
CD4019	t_{PLH}	32		46.1	54.3	70.0	91.0	27
		51	125	56.9	62.2	78.0	102	27
	t_{PHL}	32		64.7	86.1	76.0	102.0	28
		51	125	73.4	96.6	86.0	116.0	30
CD4025	t_{PLH}	31		48.9	64.7	52	70	18
		53	65	70.3	94	74	102	30
	t_{PHL}	31		39.2	44	48	54	21
		53	55	51	58.6	62	72	30
CD4027	t_{PLH}	30		81.5	85.6	116	94	16
		50	120	92.9	99	134	108	16
	t_{PHL}	30		66.5	76.5	88	90	16
		50	160	79.2	106	91.8	106	19
CD4029	t_{PLH}	31		236	249	280	400	120
		51	260	260	273	330	440	140
	t_{PHL}	31		221	241	280	470	190
		51	260	242	262	320	520	220

Table 9 (contd)

Device type	Parameter	Capacitance CL, pF	Propagation time, ns					
			Specified limit	Mean		Max		Δ Max.
				Pre-irradiate	1.5×10^5 rad	Pre-irradiate	1.5×10^5 rad	
CD4051	t_{PLH}	30		72.0	73.4	90	90	12
		51	400	74.6	75	80	92	10
	t_{PHL}	30		205	207	218	245	45
		51	1000	208	209	222	248	45
CD4052	t_{PLH}	31		193	224	330	375	60
		52	400	198	229	335	380	70
	t_{PHL}	31		395	395	570	520	55
		52	1000	467	464	720	650	40

reducing the post-radiation quiescent supply current and transmission gate leakage currents of the multiplexers and on producing a more homogeneous product.

The wafer screening of I_{SS} is expensive but necessary in view of the lack of safety margin shown in the distribution, the presence of outliers and bimodal distributions. For future programs, radiation screening of N-channel and P-channel test transistors associated with each wafer should be considered, since the absolute values of post-irradiation V_{Tn} and V_{Tp} are more fundamental parameters directly related to oxide and interface states. At present V_{Tp} is not screened, and this produces a barely tolerable variation in the propagation time. In future programs other process controls involving capacitor measurements should be considered in direct collaboration with the manufacturers. Such controls have been described in a paper by Gregory (Ref. 4).

Finally, any future programs with a radiation environment in excess of that encountered by MJS or with more stringent design requirements must use the radiation hard dry gate oxide process developed at RCA, Somerville, with DNA support, or equivalent, since the 950°C annealed process cannot survive a total dose much greater than 1.5×10^5 rad(Si).

CD4001, RCA

DEVICE TYPE: CD4001 RCA 950°C ANNEAL IN NITROGEN PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_T (V)	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-CHANNEL	0	V_{DD} = 10V,	I_{SS} = 20μA, V_{DD} = 10V	10	1.29	1.34	1.23	1.37	1.41	
		ALL INPUTS = 10V						1.21	1.17	
	7.5×10^4			9	0.19	0.43	-0.2	*0.729	*1.0	
								-0.356	-0.627	
	1.5×10^5			10	-0.337	-0.29	-0.39	-0.27	-0.237	
								-0.404	-0.437	
P-CHANNEL	0		I_{DD} = 10μA, V_{DD} = 10V	10	-1.87	-1.73	-1.96	-1.72	-1.64	
								-2.03	-2.11	
	7.5×10^4			9	-1.47	0.01	-2.22	*0.609	*1.65	
								-3.56	-4.60	
	1.5×10^5			10	0.107	0.15	0.07	0.168	0.199	
								0.0459	0.0153	
T_{PHL} (ns)	0		V_{DD} = 10V, C_L = 30pF	10**	56.6	63.9	52.0	61.5	63.9	
								51.8	49.4	
	7.5×10^4			9**	83.7	267	55.1	*210	*273	
								-42.9	-106	
	1.5×10^5			10**	61.8	66.8	57.3	66.4	68.8	
								57.1	54.8	

ONE DEVICE FAILED
* 8 MEASUREMENTS TAKEN ON EACH DEVICE

DEVICE TYPE: CD4001 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
T_{PHL} (ns)	0	V_{DD} = 10V	V_{DD} = 10V, C_L = 30pF	10**	33.6	49.4	24.8	43.2	47.9	
		ALL INPUTS = 10V						24.1	19.4	
	7.5×10^4			9**	31.3	111.0	21.2	*59.7	*73.9	
								2.97	-11.2	
	1.5×10^5			10**	26.0	36.9	18.9	33.5	37.2	
								18.6	14.9	

* ONE DEVICE FAILED
** 8 MEASUREMENTS TAKEN ON EACH DEVICE

CD4002, RCA

DEVICE TYPE: CD 4002 R.C.A. 950°C. ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_T (V)	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-CHANNEL	0	VDD=10V;	ISS=10μA; VDD=10V	10	1.2	1.41	-0.06	2.09	2.53	
		ALL INPUTS=10V						0.309	-0.136	
	7.5x10⁴			10	1.03	1.22	-0.14	1.85	2.26	
								0.203	-0.209	
	1.5x10⁵			10	1.02	1.21	-0.12	1.83	2.23	
								0.215	-0.188	
P-CHANNEL	0		IDD=10μA; VDD=10V	10	-1.43	-0.13	-1.67	-0.59	-0.052	
								-2.37	-2.84	
	7.5x10⁴			10	-1.96	-0.06	-2.32	-0.64	0.056	
								-3.3	-3.97	
	1.5x10⁵			10	-2.26	-0.08	-2.73	-0.63	0.118	
								-3.84	-4.63	
TPLH (nS)	0		VDD=10V; CL=30pf	10*	51.4	52.5	43.3	58	61.4	
								44.7	41.4	
	7.5x10⁴			10*	59.1	69.1	50.1	67.3	71.5	
								50.8	46.7	
	1.5x10⁵			10*	72.1	555.3	57.5	182	237	
								-37.8	-92.8	

* 80 MEASUREMENTS TAKEN ON 10 DEVICES

DEVICE TYPE: CD 4002 R.C.A PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (nS)	0	VDD=10V;	VDD=10V; CL=30pf	10*	39.2	43.5	34.3	43.3	45.4	
		ALL INPUTS=10V						35.1	33	
	7.5x10⁴			10*	42.2	433.1	37.5	135	178	
								-40.2	-83.9	
	1.5x10⁵			10*	45.7	49.7	41	49.6	51.5	
								41.8	39.8	

* 80 MEASUREMENTS TAKEN ON 10 DEVICES

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

CD4006, RCA

DEVICE TYPE: CD 4006 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_T (V)	rad(Si)	Bias: Irrad.	Bias: Meas.					-2σ	-3σ	
N-Channel	0	VDD=10V,	I_{SS}=-10μA	10	1.42	1.48	1.32	1.54	1.6	
		ALL INPUTS=10V	VDD=10V					1.3	1.24	
	7.5×10^4			9	1.15	1.39	0.87	1.54	1.73	
								0.77	0.528	
	1.5×10^5			10	0.892	1.3	0.59	1.49	1.79	
								0.294	-0.0052	
P-Channel	0		I_{DD}=10μA	10	-1.84	-1.75	-2.03	-1.65	-1.55	
			VDD=10V					-2.03	-2.13	
	7.5×10^4			9	-2.38	-1.5	-3.03	-1.5	-1.05	
								-3.27	-3.71	
	1.5×10^5			10	-2.72	-1.55	-3.55	-1.58	-1.01	
								-3.85	-4.42	
TPLH(ns)	0		VDD=10V, CL=30pf	10*	138	168	114.9	160	172	
			CLOCK IN TO Qn					115	104	
	7.5×10^4			9*	148	180	126	175	189	
								121	108	
	1.5×10^5			10*	157	201	133	186	201	
								128	113	
NOTES										
* 6 MEASUREMENTS TAKEN ON EACH DEVICE										

DEVICE TYPE: CD 4006 RCA Page 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	Bias: Irrad.	Bias: Meas.							
TLPH(ns)	0	VDD=10V,	VDD=10V, CL=30pf	10*	128	145	109.9	143	151	
		ALL INPUTS=10V	CLOCK IN TO Qn					112	105	
	7.5×10^4			9*	139	164	115.9	161	172	
								117	106	
	1.5×10^5			10*	151	180	125	174	186	
								127	116	
* 6 MEASUREMENTS TAKEN ON EACH DEVICE										

CD4011, RCA

DEVICE TYPE: CD4011 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 OF 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
VT (V)	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
n Channel	0	VDD = +10V	ISS = 10μA	10	1.23	1.26	1.19	1.28	1.31	
	↓	All inputs = 10V	VDD = 10V					1.17	1.14	
	7.5 x 10⁴			10	0.789	0.96	0.67	0.982	1.08	
	↓							0.596	0.5	
	1.5 x 10⁵			9	0.499	0.74	0.37	*0.735	*0.853	
↓	↓		↓					0.262	0.114	
P Channel	0		IDD = 10μA	10	-1.81	-1.74	-1.94	-1.68	[illegible]	
	↓		VDD = 10V					-1.94	-2.2	
	7.5 x 10⁴			10	-2.28	-2.14	-2.41	-2.11	-2.22	
	↓							-2.40	-2.54	
	1.5 x 10⁵			9	-2.59	-2.41	-2.7	*-2.40	*-2.30	
↓	↓		↓					-2.78	-2.88	
TPHL (ns)	0		VDD = 10V,		* 40.3	41.6	[illegible]	45.2	[illegible]	
	↓		CL 30 PF,					[illegible]	[illegible]	
	7.5 x 10⁴		INPUT A or B to	10**	46.4	55.0	41.2	52.0	[illegible]	
	↓		output Y.					[illegible]	[illegible]	
	1.5 x 10⁵			9**	51.2	60.5	45.6	*57.8	*61.1	
↓	↓	↓	↓					44.6	41.4	

* ONE DEVICE FAILED

NOTE ** 8 MEASUREMENTS TAKEN ON EACH DEVICE

DEVICE TYPE: CD4011 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (ns)	0	VDD = +10V	VDD 10V,	10**	32.1	42.4	22.7	40.7	44.9	
	↓	All inputs = 10V	CL = 30 PF,					23.5	9.2	
	7.5 x 10⁴		INPUT A or B to	10**	33.4	44.1	24.0	42.5	47.1	
	↓		output Y					24.2	19.6	
	1.5 x 10⁵			9**	34.2	45.5	24.1	*44.3	*49.3	
↓	↓	↓	↓					24.1	19	

* ONE DEVICE FAILED

** 8 MEASUREMENTS TAKEN ON EACH DEVICE

CD4012, RCA

PAGE 1 OF 2

DEVICE TYPE: CD 4012 R.C.A. 950° C ANNEAL IN NITROGEN 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	Bias: Irrad.	Bias: Meas.					-2σ	-3σ	
VT (V) N-Channel	0	VDD=10V; ALL INPUTS=10V	IDS=-10μA; VDD=10V	10	1.11	1.24	0.87	1.36	1.49	
								0.863	0.739	
	2.5x10⁴			10	0.639	0.78	0.45	0.957	0.966	
								0.421	0.312	
	1.5x10⁵			10	0.332	0.54	0.09	0.635	0.786	
								0.0294	-0.122	
P Channel	0		IDS=-10μA; VDD=10V	10	-1.81	-1.63	-2.09	-1.54	-1.4	
								-2.08	-2.22	
	2.5x10⁴			10	-1.91	-0.78	-2.26	-1.09	-0.612	
								-2.74	-3.15	
	1.5x10⁵			10	-2.07	-1.92	-2.32	-1.85	-1.74	
								-2.3	-2.41	
TPLH (nS)	0		VDD=10V; CL=30pF	10*	31.5	42.7	27	37.9	41	
								25.1	22	
	2.5x10⁴			10*	33.1	40.5	26.1	38.8	41.6	
								22.5	24.7	
	1.5x10⁵			10*	33.7	42.5	28.8	39.2	42	
								22.3	25.5	

N/S

* 80 MEASUREMENTS TAKEN ON 10 DEVICES

PAGE 2 OF 2

DEVICE TYPE: CD 4012 RCA

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	Bias: Irrad.	Bias: Meas.					-2σ	-3σ	
TPHL (nS)	0	VDD=10V; ALL INPUTS=10V	VDD=10V; CL=30pF	10*	49.1	62.2	40	58.4	63	
								39.8	35.2	
	2.5x10⁴			10*	46.3	58.5	35.5	55	59.5	
								37.6	33.2	
	1.5x10⁵			10*	44.7	57	36.5	53.2	57.5	
								36.2	31.9	

* 80 MEASUREMENTS TAKEN ON 10 DEVICES

CD4013, RCA

PAGE 1 of 4

DEVICE TYPE: CD4013 RCA 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_T (V)	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-CHANNEL	0	V_{DD} = 10V	I_{SS} = -10μA	5	1.62	1.63	1.61	1.64	1.65	
		ALL INPUTS = 10V	V_{DD} = 10V					1.61	1.6	
	2.5×10^4			5	1.23	1.25	1.2	1.27	1.29	
								1.19	1.17	
	1.5×10^5			5	0.926	0.95	0.9	0.967	0.98	
								0.89	0.872	
P-CHANNEL	0		I_{DD}: 10μA	5	-2.08	-2.07	-2.09	-2.07	-2.06	
			V_{DD}: 10V					-2.09	-2.1	
	2.5×10^4			5	-2.24	-2.22	-2.25	-2.21	-2.2	
								-2.26	-2.28	
	1.5×10^5			5	-2.3	-2.28	-2.31	-2.28	-2.26	
								-2.33	-2.34	
T_{PLH} (ns)	0		V_{DD}=10V; C_L=30pF	5*	81.9	92	77	93	98.6	
			(A, CLOCK INPUT					70.8	65.2	
	2.5×10^4		TO Qn)	5*	83	92.9	76.6	95.9	102	
								70	63.6	
	1.5×10^5			5*	81.2	92	76.5	92.5	98.2	
								69.8	64.2	
	* 10 MEASUREMENTS		TAKEN ON 5	DEVICES						

ACS

PAGE 2 of 4

DEVICE TYPE: CD4013 RCA

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
T_{PLH} (ns)	0	V_{DD} = 10V	V_{DD}=10V; C_L=30pF	5*	130	134	125	136	139	
		ALL INPUTS = 10V	(B, CLOCK INPUT					124	121	
	2.5×10^4		TO $\overline{Q}$n)	5*	128	133	122.9	135	139	
								121	118	
	1.5×10^5			5*	127	132	121.9	133	136	
								121	118	
T_{PLH} (ns)	0		V_{DD}=10V; C_L=30pF	5	71.2	73.8	68.5	76	78.4	
			(C, SET TO Qn)					66.4	64.1	
	2.5×10^4			5	70.7	73.3	68	75.4	77.8	
								66	63.7	
	1.5×10^5			5	70.2	72.6	67.7	75.7	77	
								65.7	63.4	
T_{PLH}(ns)	0		V_{DD}=10V; C_L=30pF	5*	56.6	59.1	53	60.7	62.7	
			(D, RESET TO $\overline{Q}$n)					52.5	50.5	
	2.5×10^4			5*	56.3	58.7	52.7	60.5	62.5	
								52.2	50.2	
	1.5×10^5			5*	55.9	58.7	52.5	60	62.1	
								51.7	49.7	
	* 10 MEASUREMENTS		TAKEN ON 5	DEVICES						

DEVICE TYPE: CD4013 RCA PAGE 3 of 4

Parameter	Fluence rad(Si)	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
TPHL (ns)	0	VDD: 10V ALL INPUTS = 10V	VDD: 10V; CL: 30pF (A, CLOCK INPUT TO Qn)	5*	103	107.9	99.9	108 / 98.4	111 / 96	
	2.5×10^4			5*	100	105	97	105 / 95.4	107 / 93.1	
	1.5×10^5			5*	98.7	101.9	96	102 / 95	104 / 93.1	
TPHL (ns)	0		VDD: 10V; CL: 30pF (B, CLOCK INPUT TO $\overline{Q}$n)	5*	115	117	109.9	121 / 109	124 / 106	
	7.5×10^4			5*	113	116.9	107.9	120 / 107	123 / 104	
	1.5×10^5			5*	112	116.9	106.9	119 / 106	122 / 103	
TPHL (ns)	0		VDD: 10V, CL: 30pF (C, SET TO Qn)	5	104	106	99.9	110 / 98.2	113 / 95.3	
	7.5×10^4			5	102	104	98	107 / 95.8	110 / 93	
	1.5×10^5			5	101	103	98	105 / 95.8	108 / 93.4	

* 10 MEASUREMENTS MADE ON 5 DEVICES

DEVICE TYPE: CD 4013 RCA PAGE 4 of 4

Parameter	Fluence rad(Si)	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
TPHL (ns)	0	VDD: 10V; ALL INPUTS: 10V	VDD: 10V; CL: 30pF (D, RESET TO Qn)	5*	123	126.9	119	127 / 118	130 / 116	
	7.5×10^4			5*	121	126	116.9	127 / 115	130 / 113	
	1.5×10^5			5*	[illegible]	123.9	116.9	125 / 116	128 / 113	

* 10 MEASUREMENTS TAKEN ON 5 DEVICES

CD4014, RCA

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DEVICE TYPE: CD4014 RCA 950°C ANNEAL IN FORMING GAS

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_T (V)	rad (Si)	BIAS: 1 RAD.	BIAS: MEAS.					-2σ	-3σ	
N-Channel	0	VDD = 10V;	ISS = -10μA	10	1.49	1.55	1.41	1.58	1.63	
		ALL INP. TO 10V	VDD = 10V					1.39	1.35	
	7.5×10^4			10	1.49	1.55	1.41	1.58	1.63	
								1.39	1.34	
	1.5×10^5			10	1.55	1.63	1.47	1.66	1.71	
								1.44	1.39	
P Channel	0		IDD = 10μA	10	-1.7	-1.56	-1.87	-1.48	-1.37	
			VDD = 10V					-1.91	-2.02	
	7.5×10^4			10	-2.02	-0.75	-2.34	-1.1	-0.639	
								-2.95	-3.41	
	1.5×10^5			10	-2.37	-0.75	-2.71	-1.21	-0.633	
								-3.52	-4.1	
TPLH (nS)	0		VDD = 10V, CL = 30pf	10*	168	199.9	143.9	195	209	
			CLOCK IN TO Qn					141	127	
	7.5×10^4			10*	178	206.9	152	207	221	
								150	135	
	1.5×10^5			10*	195	236	163	230	247	
								160	143	

* 30 MEASUREMENTS TAKEN ON 10 DEVICES

DEVICE TYPE: CD 4014 RCA — PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: 1 RAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (nS)	0	VDD = 10V;	VDD = 10V, CL = 30pf	10*	142	166.9	121.9	164	175	
		ALL INP. TO 10V	CLOCK IN TO Qn					120	109	
	7.5×10^4			10*	151	175.9	132	172	183	
								129	118	
	1.5×10^5			10*	163	[illegible]	138.9	192	207	
								134	119	

* 30 MEASUREMENTS TAKEN ON 10 DEVICES

CD4015, RCA

PAGE 1 OF 2

DEVICE TYPE: CD4015 RCA 950°C ANNEAL IN FORMING GAS 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_t (V)	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-Channel	0	V_{DD} = 10V;	I_{SS} = -10mA	10	1.41	1.64	0.98	1.79	1.99	
		All inputs = 10V	V_{DD} = 10V					1.03	0.835	
	7.5×10^4			10	1.32	1.6	0.95	1.69	1.88	
								0.942	0.754	
	1.5×10^5			10	1.26	1.58	0.94	1.66	1.87	
								0.854	0.651	
P-Channel	0		I_{DD} = +10mA	10	-2.0	-1.25	-2.55	-1.02	0.533	
			V_{DD} = 10V					-2.97	-3.46	
	7.5×10^4			10	-2.44	-1.21	-3.15	-1.08	-0.42	
								-3.79	-4.46	
	1.5×10^5			10	-2.72	-1.19	-3.6	-1.03	-0.179	
								-4.42	-5.26	
TPLH (nS)	0		V_{DD} = 10V;	10 *	141	182	103	183	204	
			C_L = 30pF					98.4	77.2	
	7.5×10^4		CLOCK IN TO Q₀	10 *	160	217	22.9	221	251	
								98.4	62.9	
	1.5×10^5			10 *	183	256	126.9	255	291	
								110	74.1	

AC: * 80 MEASUREMENTS TAKEN ON 10 DEVICES

PAGE 2 of 2

DEVICE TYPE: CD4015 RCA

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (nS)	0	V_{DD} = 10V;	V_{DD} = 10V;	10 *	131	163	112	162	177	
		All inputs = 10V	C_L = 30pF					100	85.1	
	7.5×10^4		CLOCK IN TO Q₀	10 *	141	175	119	172	187	
								111	95.5	
	1.5×10^5			10 *	149	185	122.9	181	197	
								116	99.9	

* 80 MEASUREMENTS TAKEN ON 10 DEVICES

C-4

CD4016, RCA

DEVICE TYPE: CD4016 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: 1RAD.	BIAS: MEAS.					-2σ	-3σ	
VT (V)	0	VDD: 10V	ISS: 10mA; VDD: 10V	10	1.18	1.22	1.13	1.23	1.26	
N CHANNEL		ALL INPUTS: 10V						1.13	1.10	
	7.5×10^4			10	1.21	1.26	1.15	1.27	1.31	
								1.15	1.11	
	1.5×10^5			10	1.26	1.34	1.20	1.34	1.38	
								1.19	1.15	
P CHANNEL	0		IDD 10mA; VDD 10V	10	-1.65	-1.57	-1.76	-1.54	-1.48	
								-1.76	-1.82	
	7.5×10^4			10	-1.96	-1.87	-2.07	-1.85	-1.79	
								-2.07	-2.13	
	1.5×10^5			10	-2.18	-2.11	-2.34	-2.05	-1.98	
								-2.32	-2.38	
TPLH (ns)	0		VDD: 10V, CL: 30pF	10*	12.7	39.5	9.8	24.7	30.6	
			(SWITCH INPUT TO					0.742	-5.24	
	7.5×10^4		SWITCH OUTPUT)	10*	11.4	13.1	0.3	15.4	17.4	
								7.47	5.49	
	1.5×10^5			10*	12.6	13.7	11.2	13.8	14.3	
								11.4	10.8	
* 40 MEASUREMENTS TAKEN ON			10 DEVICES							

DEVICE TYPE: CD4016 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: 1RAD.	BIAS: MEAS.					-2σ	-3σ	
TPLH (ns)	0	VDD = 10V.	VDD: 10V; CL: 30pF	10*	22.2	44.6	19.6	32.6	37.8	
		ALL INPUTS: 10V	(CONTROL INPUT TO					11.9	6.67	
	7.5×10^4		SWITCH OUTPUT)	10*	21.8	23.6	20.5	23.4	24.2	
								20.2	19.4	
	1.5×10^5			10*	22.9	24.7	21.5	24.4	25.2	
								21.4	20.6	
TPHL (ns)	0		VDD: 10V; CL: 30pF	10*	11.1	33.5	9.0	20.6	25.4	
			(SWITCH INPUT TO					1.58	-3.18	
	7.5×10^4		SWITCH OUTPUT)	10*	10.3	11.7	0.1	14.0	15.8	
								6.67	4.84	
	1.5×10^5			10*	10.9	12.2	9.9	12.5	13.3	
								9.22	8.39	
TPHL (ns)	0		VDD: 10V, CL: 30pF	10*	15.5	29.0	13.5	21.8	24.9	
			(CONTROL INPUT TO					9.26	6.12	
	7.5×10^4		SWITCH OUTPUT)	10*	15.4	16.8	14.0	16.7	17.4	
								14.1	13.4	
	1.5×10^5			10*	16.1	17.7	14.5	17.6	18.3	
								14.7	14.0	
* 40 MEASUREMENTS TAKEN ON 10 DEVICES										

CD4017, RC[redacted]

DEVICE TYPE: CD4017 RCA 250°C ANNEAL IN NITROGEN GAS PAGE 1 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
V_T (V)	0	V_{DD} = 10V;	I_{DD} = -10μA	10	1.94	2.08	1.61	2.21	2.34	
N-CHANNEL		ALL INPUTS = 10V	V_{DD} = 10V					1.67	1.54	
	2.5×10⁴			10	1.45	1.56	1.34	1.59	1.65	
								1.32	1.25	
	1.5×10⁵			10	1.21	1.3	1.12	1.35	1.42	
								1.06	0.982	
P-CHANNEL	0		I_{DD} = 10μA	10	-2.32	-2.2	-2.49	-2.12	-2.03	
			V_{DD} = 10V					-2.51	-2.61	
	2.5×10⁴			10	-2.49	-2.37	-2.7	-2.28	-2.18	
								-2.7	-2.8	
	1.5×10⁵			10	-2.53	-2.39	-2.75	-2.3	-2.19	
								-2.76	-2.87	
T_{PLH} (ns)	0		V_{DD}=10V; C_L=30pF	10*	315	406	241.9	380	413	
			(A, CLOCK INPUT					250	217	
	2.5×10⁴		TO Qa)	10*	323	430	229.9	397	433	
								249	212	
	1.5×10⁵			10*	329	463	245.9	409	450	
								248	208	
NOTE	* 100 MEASUREMENTS		TAKEN ON	10 DEVICES						

DEVICE TYPE: CD4017 RCA PAGE 2 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
T_{PLH} (ns)	0	V_{DD} = 10V	V_{DD}=10V; C_L=30pF	10	155	171.9	148	171	179	
		ALL INPUTS = 10V	(B, CLOCK INPUT					138	130	
	2.5×10⁴		TO CARRY OUTPUT)	10	155	173.9	148	173	182	
								138	129	
	1.5×10⁵			10	156	175	149	174	183	
								139	130	
T_{PLH} (ns)	0		V_{DD}=10V; C_L=30pF	10*	284	391	150.9	391	445	
			(C, RESET TO					176	122	
	2.5×10⁴		Qn)	10*	285	393.9	148	396	452	
								173	117	
	1.5×10⁵			10*	286	393.9	148	398	453	
								174	118	
T_{PHL} (ns)	0		V_{DD}=10V; C_L=30pF	10**	204	268	175	244	264	
			(A, CLOCK INPUT					164	144	
	2.5×10⁴		TO Qn)	10**	200	261	170	237	256	
								162	143	
	1.5×10⁵			10**	199	258	171	236	254	
								163	145	
	* 90	MEASUREMENTS	TAKEN ON	10 DEVICES						
	** 100	MEASUREMENTS	TAKEN ON	10 DEVICES						

DEVICE TYPE: CD4017 RCA PAGE 3 of 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (ns)	0	VDD=10V;	VDD=10V, CL=30pF	10	171	189	163	188	196	
		ALL INPUTS=10V	(B, CLOCK INPUT					155	146	
	7.5×10^4		TO CARRY OUTPUT)	10	172	192	164.9	190	199	
								154	145	
	1.5×10^5			10	174	194	166	193	202	
								156	146	
TPHL (ns)	0		VDD=10V, CL=30pF	10*	219	291	180	261	282	
			(C, RESET TO					176	155	
	7.5×10^4		0V)	10*	209	278.9	175.9	249	269	
								169	148	
	1.5×10^5			10*	204	268.9	175	243	262	
								166	147	
	* 50 MEASUREMENTS TAKEN ON 10 DEVICES									

CD4019, RCA

DEVICE TYPE: CD4019 RCA 350°C ANNEAL IN FORMING GAS PAGE 1 of 4 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
VT (V)	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-CHANNEL	0	VGS=10V;	IDS=10μA, VDD=10V	9	1.66	1.82	1.17	2.11	2.34	
		ALL INPUTS=10V						1.2	0.98	
	7.5×10^4			8	1.58	1.75	1.15	*2.03	*2.26	
								1.12	0.90	
	1.5×10^5			9	1.6	1.87	1.1	2.13	2.39	
								1.07	0.83	
P-CHANNEL	0		IDD=10μA, VGS=10V	9	-2.23	-1.25	-2.68	-1.28	-0.80	
								-3.19	-3.66	
	7.5×10^4			8	-2.55	-1.23	-3.08	*1.11	*0.40	
								-3.98	-4.69	
	1.5×10^5			9	-2.88	-1.2	-3.55	-1.13	-0.25	
								-4.62	-5.50	
TPLH (ns)	0		VDD=10V, CL=30pF	9**	60.8	64.8	54	65.5	67.9	
			(INPUTS A TO					56.1	53.7	
	7.5×10^4		ASSOCIATED OUTPUT	8**	63.7	68.5	57	*68.9	*71.5	
			YD)					58.5	55.9	
	1.5×10^5			9**	67	72.1	59.2	72.9	75.8	
								61.1	58.2	
A6. * ONE DEVICE FAILED										
** 4 MEASUREMENTS TAKEN ON EACH DEVICE										

DEVICE TYPE: CD4019 RCA PAGE 2 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean 125°C -2σ	Mean 125°C -3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.							
TPLH (nS)	0	VDD: 10V;	VDD: 10V; CL: 30pF	9**	63.2	66.4	58.3	62.2	69.1	
		ALL INPUTS: 10V	INPUTS KA TO					59.3	57.3	
	7.5×10^4		ASSOCIATED OUTPUT	8**	66.9	70.3	59.9	*71.1	*73.8	
			Yn)					60.6	58	
	1.5×10^5			9**	69.7	74.5	63.9	75.2	77.9	
								64.2	61.9	
TPLH (nS)	0		VDD: 10V; CL: 30pF	9**	57.4	63.4	50.4	63.6	66.7	
			INPUTS B TO					51.2	48.1	
	7.5×10^4		ASSOCIATED OUTPUT	8**	59.7	65	53	*65.5	*68.4	
			Yn)					53.9	50.9	
	1.5×10^5			9**	62.7	68.3	55	68.8	71.9	
								56.6	53.5	
TPLH (nS)	0		VDD: 10V, CL: 30pF	9**	58.9	63.7	54.1	63.8	66.3	
			INPUTS KB TO					54	51.5	
	7.5×10^4		ASSOCIATED OUTPUT	8**	61.9	67	57	*67.1	*69.7	
			Yn)					56.6	54	
	1.5×10^5			9**	65.5	71.1	59.4	71.5	74.5	
								59.5	56.5	

* ONE DEVICE FAILED
** 4 MEASUREMENTS TAKEN ON EACH DEVICE

DEVICE TYPE: CD4019 RCA PAGE 3 of 4 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean 125°C -2σ	Mean 125°C -3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.							
TPHL (nS)	0	VDD: 10V;	VDD: 10V; CL: 30pF	9**	98.9	118	77.6	117.5	126.8	
		ALL INPUTS: 10V	INPUTS A TO					80.3	71	
	7.5×10^4		ASSOCIATED OUTPUT	8**	108.7	120.9	99	*120.5	*126.4	
			Yn)					97	91.1	
	1.5×10^5			9**	123.7	143.9	108.9	141.3	150.1	
								106.1	97.3	
TPHL (nS)	0		VDD: 10V; CL: 30pF	9**	107.1	135	96	125	133.9	
			INPUTS KB TO					89.3	80.3	
	7.5×10^4		ASSOCIATED OUTPUT	8**	115.6	133	101.9	*129.4	*136.2	
			Yn)					101.9	95	
	1.5×10^5			9**	131	152.9	115.9	150.8	160.7	
								111.2	101.3	
TPHL (nS)	0		VDD: 10V; CL: 30pF	9**	93.4	121.9	60.4	127.9	145.1	
			INPUTS B TO					59	41.8	
	7.5×10^4		ASSOCIATED OUTPUT	8**	101.9	126	69.2	*136.2	*153.4	
			Yn)					67.6	50.4	
	1.5×10^5			9**	118.4	147	77.2	148.4	164.9	
								87.4	71.8	

* ONE DEVICE FAILED
** 4 MEASUREMENTS TAKEN ON EACH DEVICE

DEVICE TYPE: CD4019 RCA PAGE 4 of 4

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (ns)	0	VDD = 10V	VDD = 10V; CL = 30pF	9**	92.6	119	70.5	119	132.2	
		ALL INPUTS = 10V	(INPUTS Kb to					66.2	53	
	2.5×10^4		ASSOCIATED OUTPUT	8**	103.9	118	77.5	*122.1	*131.3	
			Yn)					85.6	76.4	
	1.5×10^5			9**	118.5	145	98	140.6	151.6	
								96.5	85.5	

* ONE DEVICE FAILED
** 4 MEASUREMENTS TAKEN ON EACH DEVICE

CD4021, RCA

DEVICE TYPE: CD4021 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean -2σ	Mean +3σ	Accept Reject Criteria
VT (V)	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-CHANNEL	0	VDD = 10V	ISS = -10μA	10	1.396	1.65	-0.31	2.6	3.20	
		ALL INPUTS = 10V	VDD = 10V					0.192	-0.41	
	7.5×10^4			9	1.28	1.61	-0.34	*2.51	*3.13	
								0.043	-0.57	
	1.5×10^5			5	1.15	1.58	-0.3	**2.77	**3.58	
								-0.47	-1.28	
P-CHANNEL	0		IDD = 10μA	10	-1.61	0.14	-1.98	-0.35	0.27	
			VDD = 10V					-2.86	-3.49	
	7.5×10^4			9	-2.04	0.13	-2.61	*-0.24	*0.66	
								-3.84	-4.74	
	1.5×10^5			5	-2.62	0.08	-3.47	**0.45	**1.98	
								-5.69	-6.23	
TPLH (ns)	0		VDD = 10V; CL = 30pF	10*	184	222.9	150	230.5	253.7	
			(CLOCK INPUT TO Qn)					137.6	114.4	
	7.5×10^4			9*	200.2	241.9	169	*250	*274.9	
								150.4	125.5	
	1.5×10^5			5*	218	259.9	166.9	**289.6	**325	
								146.4	110.6	

* ONE DEVICE FAILED
** 5 DEVICES FAILED
* 3 MEASUREMENTS TAKEN ON EACH DEVICE

DEVICE TYPE: CD4021 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (ns)	0	VDD = 10V	VDD = 10V, C_L = 30pf	10*	158.3	173.9	136	183.6	196.2	
		ALL INPUTS = 10V	CLOCK INPUT TO 0V					133.1	120.4	
	2.5x10⁴			9*	175.1	191	152.9	*203.2	*217.2	
								146.9	132.9	
	1.5x10⁵			5*	215.5	243	173.9	**241	**303.4	
								156.8	127.5	

* ONE DEVICE FAILED
** 5 DEVICES FAILED
* 3 MEASUREMENTS TAKEN ON EACH DEVICE

CD4023, RCA

DEVICE TYPE: CD 4023 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
VT (V)	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-CHANNEL	0	VDD = 10V,	I_{DD} = -10μA	9	1.4	1.55	1.29	1.6	1.7	
		ALL INPUTS = 10V	VDD = 10V					1.2	1.1	
	7.5x10⁴			8	0.683	0.79	0.62	*0.817	*0.884	
								0.548	0.481	
	1.5x10⁵			9	0.377	0.46	0.21	0.546	0.616	
								0.207	0.137	
P-CHANNEL	0		I_{DD} = 10μA	9	-1.98	-1.76	-2.15	-1.68	-1.54	
			VDD = 10V					-2.28	-2.42	
	7.5x10⁴			8	-2.61	-2.51	-2.73	*-2.45	*-2.36	
								-2.78	-2.86	
	1.5x10⁵			9	-3.06	-2.95	-3.21	-2.89	-2.8	
								-3.24	-3.32	
TPLH (nS)	0		VDD = 10V, C_L = 30pf	9**	48.1	56.5	41.1	54.8	58.2	
								41.4	38.1	
	7.5x10⁴			8**	52.5	66.3	50.7	*65.2	*69	
								42.9	46	
	1.5x10⁵			9**	67.8	93.9	58.6	79.4	86	
								55.6	49.5	

* ONE DEVICE FAILED
AC ** 9 MEASUREMENTS TAKEN ON EACH DEVICE

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

DEVICE TYPE: CD 4023 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.							
TPHL(nS)	0	VDD=10V	VDD=10V, CL=30pF	9**	43.8	50.6	34.8	51.8	55.7	
		ALL INPUTS=10V						35.8	31.8	
	7.5x10^4			8**	45.5	54.1	36.1	*54.3	*58.7	
								36.8	32.4	
	1.5x10^5			9**	53.1	444.3	37.9	142	186	
								-35.4	-79.7	

* ONE DEVICE FAILED

** 9 MEASUREMENTS TAKEN ON EACH DEVICE

CD4025, RCA

DEVICE TYPE: CD 4025 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
VT(V)	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.							
N-Channel	0	VDD=10V,	ICS=10μA; VDD=10V	4	1.33	1.36	1.31	1.37	1.39	
		ALL INPUTS=10V						1.28	1.26	
	7.5x10^4			4	1.06	1.09	1.03	1.12	1.15	
								1	0.925	
	1.5x10^5			4	1.01	1.05	0.96	1.1	1.15	
								0.923	0.878	
P-Channel	0		IDD=1CμA; VDD=10V	4	-1.81	-1.75	-1.86	-1.72	-1.67	
								-1.91	-1.96	
	7.5x10^4			4	-2.33	-2.24	-2.37	-2.21	-2.15	
								-2.44	-2.5	
	1.5x10^5			4	-2.66	-2.53	-2.73	-2.47	-2.38	
								-2.84	-2.93	
TPLH(nS)	0		VDD=10V; CL=30pF	4*	72.9	98	62.5	89.6	98	
								56.2	47.8	
	7.5x10^4			4*	88.1	103	70.5	109	119	
								67.6	57.3	
	1.5x10^5			4*	101	113	76.6	115	122	
								86.4	79.4	

NOS * 36 MEASUREMENTS TAKEN ON 4 DEVICES

DEVICE TYPE: CD4025 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	Rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (ns)	0	VDD=10V; ALL INPUTS=10V	VDD=10V, CL=30pF	4*	52.4	60.6	41.7	61.9	66.7	
								43	38.2	
	2.5x10^4			4*	54.7	66.8	42.4	66	71.7	
								43.3	37.7	
	1.5x10^5			4*	58.9	70.5	42.3	70.3	75.9	
								47.6	41.9	
* 36 MEASUREMENTS TAKEN ON 4 DEVICES										

CD4027, RCA

PAGE 1 of 2

DEVICE TYPE: CD4027 RCA 950°C ANNEAL IN FORMING GAS 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
VT (V)	Rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N CHANNEL	0	VDD=10V, ALL INPUTS=10V	IDD=10μA, VDD=10V	10	1.38	1.50	0.86	1.68	1.84	
								1.07	0.91	
	1.5x10^5			10	1.11	1.42	-0.17	2.16	2.69	
								0.0547	-0.471	
P CHANNEL	0		IDD=10μA, VDD=10V	10	-1.92	-1.8	-2.05	-1.77	-1.69	
								-2.07	-2.15	
	1.5x10^5			10	-2.48	-1.68	-2.76	-1.64	-1.22	
								-3.30	-3.74	
TPLH (ns)	0		VDD=10V, CL=30pF (CLOCK TO Q)	10*	95.5	119.0	74.5	115.0	134.0	
								76.5	62.1	
	1.5x10^5			10*	105.0	126	82	123	132	
								87.5	78.6	
TPLH (ns)	0		VDD=10V, CL=30pF (SET TO Q)	10*	94.7	115.9	72.8	114	124	
								75.2	65.5	
	1.5x10^5			10*	104	126	77.5	124	133	
								85.1	75.5	
TPLH (ns)	0		VDD=10V, CL=30pF (CLOCK TO $\overline{Q}$)	10*	168	189.9	150	182	186	
								148	139	
	1.5x10^5			10*	182	208	155	207	219	
		* 20 MEASUREMENTS TAKEN ON 10 DEVICES						158	145	

DEVICE TYPE: CD4027 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPLH (ns)	0	VDD=10V, ALL INPUTS=10V	VDD=10V, CL=30pF (RESET TO Q̄)	10*	74.1	106.9	64.6	84.3	104.0	
								53.8	43.7	
	1.5x10^5			10*	87.3	112	67.5	111	123	
								63.2	51.1	
TPHL (ns)	0		VDD=10V, CL=30pF (CLOCK TO Q)	10*	116	134	104	130	137	
								102	94.7	
	1.5x10^5			10*	128	141	113	142	150	
								114	107	
TPHL (ns)	0		VDD=10V; CL=30pF (RESET TO Q)	10*	153	175	136.9	172	181	
								134	125	
	1.5x10^5			10*	174	198	150.9	196	207	
								152	141	
TPHL (ns)	0		VDD=10V, CL=30pF (CLOCK TO Q̄)	10*	156	185	136.9	178	190	
								133	121	
	1.5x10^5			10*	171	199.9	147	193	204	
								149	138	
TPHL (ns)	0		VDD=10V; CL=30pF (SET TO Q̄)	10*	155	184	138	177	189	
								132	120	
	1.5x10^5			10*	171	201	148	193	205	
		*20 MEASUREMENTS TAKEN ON 10 DEVICES						148	136	

CD4028, RCA

DEVICE TYPE: CD4028 R.C.A. 950°C ANNEAL IN FORMING GAS PAGE 1 OF 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
VT (V)	rad(Si)	Bias: Irrad.	Bias: Meas.					2σ	-3σ	
N-Channel	0	VDD=10V, ALL INPUTS=10V	ISS=-10μA VDD=10V	9	1.84	1.96	1.73	1.98	2.05	
								1.69	1.62	
	7.5x10^4			9	1.84	1.99	1.36	2.21	2.4	
								1.46	1.28	
	1.5x10^5			9	1.97	2.15	1.5	2.34	2.53	
								1.6	1.41	
P-Channel	0		IDD=10μA VDD=10V	9	-2.65	-2.03	-2.9	-2.14	-1.88	
								-3.17	-3.42	
	7.5x10^4			9	-3.11	-1.7	-3.5	-2.01	-1.47	
								-4.2	-4.75	
	1.5x10^5			9	-3.48	-1.87	-3.87	-2.24	-1.62	
								-4.72	-5.34	
TPLH (ns)	0		VDD=10V; CL=30pF input RBS and monostable	9*	134	152	114.9	152	161	
								116	107	
				9**	74	93.9	63.4	89.6	92.4	
								58.4	50.6	
	7.5x10^4			9*	153	170	131	173	183	
								133	123	
				9**	85.7	103	63.3	110	122	
								61.8	49.9	
ACC	* 36 MEASUREMENTS TAKEN ON 9 DEVICES									
	** 27 MEASUREMENTS TAKEN ON 9 DEVICES									

DEVICE TYPE: CD4028 RCA PAGE 2 of 2

Parameter	Fluence rad (Si)	Operating Point: Bias: Irrad.	Operating Point: Bias: Meas.	Sample size	Mean	Max.	Min.	Mean +2σ / −2σ	Mean +3σ / −3σ	Accept Reject Criteria
TPLH (nS)	1.5x10^5	VDD=10V; ALL INPUTS=10V	VDD=10V; CL=30pF; Input ALL pulsed	9*	174	194	147	197	209	
								150	158	
				9**	96.8	114.9	70.8	119	130	
								74.8	63.8	
TPHL (nS)	0			9*	115	134	100.9	132	140	
								99	90.8	
				9**	78.3	104	63.9	104	117	
								52.2	39.2	
	7.5x10^4			9*	123	141	102.9	140	148	
								105	96.8	
				9**	93.9	116.9	70.8	123	138	
								64.8	50.2	
	1.5x10^5			9*	131	150	113.9	149	158	
								112	103	
				9**	109	134	77.5	138	152	
								80	65.5	

* 36 MEASUREMENTS TAKEN ON 9 DEVICES
** 27 MEASUREMENTS TAKEN ON 9 DEVICES

CD4029, RCA

DEVICE TYPE: CD4029 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 of 5 3

Parameter	Fluence rad (Si)	Operating Point: Bias: Irrad.	Operating Point: Bias: Meas.	Sample size	Mean	Max.	Min.	Mean +2σ / −2σ	Mean +3σ / −3σ	Accept Reject Criteria
VT (V) N-CHANNEL	0	VDD=10V; ALL INPUTS=10V	ID=10μA; VDD=10V	10	1.84	1.99	1.68	2.04	2.14	
								1.64	1.54	
	7.5x10^4			10	1.53	1.84	1.07	1.86	2.17	
								1.11	0.889	
	1.5x10^5			10	1.50	2.20	0.83	2.24	2.61	
								0.251	0.379	
P CHANNEL	0		ID=10μA; VDD=10V	10	-2.24	-1.89	-2.49	-1.86	-1.65	
								-2.63	-2.82	
	7.5x10^4			10	-2.77	-2.62	-3.05	-2.17	-1.87	
								-3.37	-3.67	
	1.5x10^5			10	-2.83	-0.1	-3.49	-0.767	0.266	
								-4.9	-5.93	
TPLH (nS)	0		VDD=10V; CL=30pF (COUNT UP CLOCK TO OUTPUT CL)	10*	177	220.9	150	205	218	
								150	137	
	7.5x10^4			10*	188	236	159.9	222	239	
								154	137	
	1.5x10^5			10*	200	277	169	246	269	
								154	131	

* 82 MEASUREMENTS TAKEN ON 10 DEVICES

DEVICE TYPE: CD4029 RCA PAGE 2 of 5

Parameter	Fluence rad (Si)	Operating Point Bias: Irrad.	Bias: Meas.	Sample size	Mean	Max.	Min.	Mean -3σ	Mean +3σ	Accept Reject Criteria
								-3σ	-3σ	
TPLH (ns)	0	VDD=10V,	VDD=10V; CL=30pF	10*	180	202	162.8	818	290	
		ALL INPUTS=10V	(COUNT DOWN					146	130	
	7.5x10^4		CLOCK TO OUTPUT	10*	213	1877	162	592	781	
			ON)					-166	-356	
	1.5x10^5			10*	204	288.9	171	255	280	
								153	128	
TPHL (ns)	0		VDD=10V; CL=30pF	10**	217	234.9	187	244	257	
			(PRESET ENABLE					191	177	
	7.5x10^4		TO OUTPUT ON)	10**	234	266	199.9	270	288	
								198	181	
	1.5x10^5			10**	251	314.9	213.9	300	325	
								201	176	
TPLH (ns)	0		VDD=10V; CL=30pF	10**	252	270	217.7	288	306	
			(COUNT UP, CLOCK					217	199	
	7.5x10^4		TO CARRY OUTPUT)	10**	285	310.9	248.9	323	347	
								247	228	
	1.5x10^5			10**	324	380.9	282	374	399	
								274	249	

* 80 MEASUREMENTS TAKEN ON 10 DEVICES
** 40 MEASUREMENTS TAKEN ON 10 DEVICES
*** 20 MEASUREMENTS TAKEN ON 10 DEVICES

DEVICE TYPE: CD4029 RCA PAGE 3 of 5

Parameter	Fluence rad (Si)	Operating Point Bias: Irrad.	Bias: Meas.	Sample size	Mean	Max.	Min.	Mean -3σ	Mean +3σ	Accept Reject Criteria
								-3σ	-3σ	
TPLH (ns)	0	VDD=10V	VDD=10V; CL=30pF	10**	182	199	155	205	216	
		ALL INPUTS=10V	(COUNT DOWN					159	148	
	7.5x10^4		CLOCK TO CARRY	10**	197	234.9	164	232	250	
			OUTPUT)					161	144	
	1.5x10^5			10**	215	281	173	268	295	
								161	134	
TPLH (ns)	0		VDD=10V; CL=30pF	10	268	292.9	226.9	299	315	
			(PRESET ENABLE					237	222	
	7.5x10^4		TO CARRY OUTPUT)	10	298	303	263	339	359	
								258	238	
	1.5x10^5			10	339	387	296	394	401	
								284	257	
TPHL (ns)	0		VDD=10V; CL=30pF	10*	134	152.9	113.9	167	168	
			(COUNT UP, CLOCK					111	99.6	
	7.5x10^4		TO OUTPUT ON)	10*	149	180.9	126	176	189	
								122	109	
	1.5x10^5			10*	170	210	145	202	218	
								138	123	

* 80 MEASUREMENTS TAKEN ON 10 DEVICES
** 20 MEASUREMENTS TAKEN ON 10 DEVICES

DEVICE TYPE: CD4029 RCA PAGE 4 of 5

Parameter	Fluence rad(Si)	Operating Point: Bias: Irrad.	Operating Point: Bias: Meas.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
TPHL (ns)	0	VDD = 10V	VDD=10V; CL=30pF	10*	132	157	112	156	168	
		ALL INPUTS = 10V	(COUNT DOWN)					108	96.3	
	2.5x10^4		CLOCK TO OUTPUT	10*	148	180	123.9	176	189	
			ON).					120	106	
	1.5x10^5			10*	169	206	[illegible]	200	216	
								138	123	
TPHL (ns)	0		VDD=10V; CL=30pF	10**	144	177	122.9	176	192	
			(PRESET ENABLE					112	96.6	
	2.5x10^4		TO OUTPUT ON)	10**	159	201.9	136	196	215	
								122	104	
	1.5x10^5			10**	181	236	154	228	252	
								134	111	
TPHL (ns)	0		VDD=10V; CL=30pF	10**	247	259	231.9	262	[illegible]	
			(COUNT UP, CLOCK					231	223	
	2.5x10^4		TO CARRY OUTPUT)	10**	266	282.9	243.9	290	302	
								241	229	
	1.5x10^5			10**	285	331	271	308	345	
								262	245	

* 30 MEASUREMENTS TAKEN ON 10 DEVICES
** 40 MEASUREMENTS TAKEN ON 10 DEVICES
*** 20 MEASUREMENTS TAKEN ON 10 DEVICES

DEVICE TYPE: CD4029 RCA PAGE 5 of 5

Parameter	Fluence rad(Si)	Operating Point: Bias: Irrad.	Operating Point: Bias: Meas.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
TPHL (ns)	0	VDD = 10V	VDD=10V; CL=30pF	10***	166	170	159	171	174	
		ALL INPUTS = 10V	(COUNT DOWN,					158	155	
	2.5x10^4		CLOCK TO CARRY	10***	178	189	176	190	195	
			OUTPUT)					167	162	
	1.5x10^5			10***	205	217.9	192	220	228	
								190	183	
TPHL (ns)	0		VDD=10V; CL=30pF	10	322	334.9	292.9	349	362	
			PRESET ENABLE					295	281	
	2.5x10^4		TO CARRY OUTPUT	10	347	370	318	383	402	
								310	292	
	1.5x10^5			10	379	447	347	437	460	
								321	292	

*** 20 MEASUREMENTS TAKEN ON 10 DEVICES

CD4030, RCA

PAGE 1 of 2

3

DEVICE TYPE: CD4030 RCA 950° ANNEAL IN NITROGEN

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	Rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-25	-35	
V_T (V)										
N-CHANNEL	0	VDD: 10V	IDD: 10μA; VDD: 10V	5	1.08	1.42	1.22	1.44	1.52	
		ALL INPUTS: 10V						1.12	1.04	
	7.5×10^4			5	1.04	1.19	0.99	1.21	1.27	
								0.862	0.782	
	1.5×10^5			5	0.868	1.09	0.78	1.13	1.26	
								0.607	0.477	
P CHANNEL	0		IDD: 10μA; VDD: 10V	5	-2.24	-2.01	-2.47	-1.88	-1.71	
								-2.59	-2.76	
	7.5×10^4			5	-2.44	-2.23	-2.66	-2.11	-1.95	
								-2.76	-2.82	
	1.5×10^5			5	-2.54	-2.36	-2.73	-2.26	-2.62	
								-2.82	-2.96	
TPLH (ns)	0		VDD: 10V, CL: 30pF	5*	43.1	68.6	19.5	80.2	99.5	
								5.51	-13.3	
	7.5×10^4			5*	44.5	71.1	20.6	83	102	
								5.98	-13.3	
	1.5×10^5			5*	45.4	72.0	21.2	84.5	104	
								6.32	-13.2	

AGS * 80 MEASUREMENTS TAKEN ON 5 DEVICES

PAGE 2 of 2

DEVICE TYPE: CD4030 RCA

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	Rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-25	-35	
TPHL (ns)	0	VDD: 10V	VDD: 10V; CL: 30pF	5*	54.6	69.8	46.9	64.4	69.3	
		ALL INPUTS: 10V						44.9	40.0	
	7.5×10^4			5*	53.6	70.3	45.1	64.8	70.1	
								42.4	36.8	
	1.5×10^5			5*	53	71	44	65.6	71.9	
								40.4	34.1	

* 80 MEASUREMENTS TAKEN ON 5 DEVICES

CD4031, RCA

DEVICE TYPE: CD4031 RCA 950°C ANNEAL IN FORMING GAS — PAGE 1 of 3 — 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_T (V)	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-CHANNEL	0	V_{DD} = 10V	I_{DS} = 10μA	10	1.26	1.3	1.21	1.33	1.36	
		ALL INPUTS = 10V	V_{DD} = 10V					1.19	1.15	
	7.5×10^4			9	0.60	1.07	-0.16	*1.42	*1.82	
								-0.22	-0.63	
	1.5×10^5			10	0.63	1.0	0.28	1.09	1.32	
								0.17	-0.06	
P-CHANNEL	0		I_{DD} = 10μA	10	-1.69	-1.64	-1.81	-1.58	-1.52	
			V_{DD} = 10V					-1.80	-1.86	
	7.5×10^4			9	-1.72	0.01	-2.33	*0.14	*1.02	
								-3.57	-4.50	
	1.5×10^5			10	-2.25	-0.07	-2.67	-0.67	0.12	
								-3.83	-4.62	
T_{PLH} (ns)	0		V_{DD}=10V, C_L=30pF	10	290.8	328.9	258	338.6	362.6	
			(CLOCK TO Q OUTPUT)					242.9	219	
	7.5×10^4			9	308.8	359	280	*357	*381.1	
								260.5	236.4	
	1.5×10^5			10	335.7	384.9	300	391.3	419.1	
								280	252.2	
	* ONE DEVICE FAILED									
AGS										

DEVICE TYPE: CD4031 RCA — PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
T_{PLH} (ns)	0	V_{DD} 10V	V_{DD}=10V, C_L=30pF	10	322	365	291	368.8	392.2	
		ALL INPUTS = 10V	(CLOCK TO $\overline{Q}$ OUTPUT)					275.1	251.7	
	7.5×10^4			9	332.1	379.9	304	*374.7	*396	
								289.5	268.2	
	1.5×10^5			10	343.4	391	310.9	396.2	422.6	
								290.5	264.1	
T_{PLH} (ns)	0		V_{DD}=10V, C_L=30pF	10	175.9	203.9	155	208.8	226.8	
			(CLOCK TO DELAYED					141.9	125	
	7.5×10^4		CLOCK OUTPUT)	9	185.7	224.9	160.9	*222.3	*240.6	
								149.2	130.9	
	1.5×10^5			10	195.9	233.9	171.9	239.3	[illegible]	
								152.6	130.9	
T_{PHL} (ns)	0		V_{DD}=10V, C_L=30pF	10	284.7	326	252.9	333.1	352.3	
			(CLOCK TO Q OUTPUT)					236.3	212	
	7.5×10^4			9	298.7	347.9	268.9	*346.1	*369.8	
								251.3	227.6	
	1.5×10^5			10	313.4	359	277.9	368.4	395.9	
								258.5	231	
	* ONE DEVICE FAILED									

DEVICE TYPE: CD4031 RCA PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (ns)	0	VDD=10V	VDD=10V; CL=30pF	10	223.5	256	194.9	265.1	285.9	
		ALL INPUTS=10V	(CLOCK TO Q OUTPUT)					181.8	161	
	2.5x10^4			9	234.9	275	208.9	*275.5	*295.8	
								194.2	173.9	
	1.5x10^5			10	253.1	291.9	222.9	292.2	322.2	
								207.1	184.1	
TPHL (ns)	0		VDD=10V; CL=30pF	10	255.1	306.9	220.9	309	336	
			(CLOCK TO DELAYED					201.3	174.3	
	2.5x10^4		CLOCK OUTPUT)	9	274.2	331	245	*323.1	*347.6	
								225.2	200.8	
	1.5x10^5			10	288.8	355	261	361.6	393.1	
								235.9	204.4	

* ONE DEVICE FAILED

CD4035, RCA

PAGE 1 OF 3

DEVICE TYPE: CD 4035 RCA. 950°C ANNEAL IN FORMING GAS 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
VT (V)	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-CHANNEL	0	VDD=10V;	IDD=10μA;	10	1.45	1.54	1.31	1.59	1.66	
		ALL INPUTS=10V	VDD=10V					1.32	1.25	
	2.5x10^4			10	1.55	1.68	1.32	1.79	1.91	
								1.31	1.19	
	1.5x10^5			10	1.44	1.59	1.14	1.79	1.87	
								1.15	1.01	
P-CHANNEL	0		IDD=+10μA	10	-1.87	-1.72	-2.01	-1.68	-1.58	
			VDD=10V					-2.07	-2.17	
	2.5x10^4			10	-3.08	-2.97	-3.2	-2.91	-2.83	
								-3.25	-3.34	
	1.5x10^5			10	-3.31	-2.94	-3.45	-3.01	-2.87	
								-3.61	-3.76	
TPLH (nS)	0	RN=RN/(INT MEM=ON)	VDD=10V; CL=10pF	10*	108	118	96	119	125	
								92.2	91.7	
		;NEG INPUT=ON		10*	146	162	129	161	169	
								130	122	
		;T/C INPUT=ON		10*	73.9	92.9	68.5	83.9	88.9	
								63.9	58	

* 10 MEASUREMENTS TAKEN ON 10 DEVICES

A65

DEVICE TYPE: CD 4035 R.C.A. PAGE 2 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPLH (nS)	7.5x10^4	VDD=10V; Clock input to Qn	VDD=10V; CL=10pf	10*	149	162	135	162	169	
								136	130	
		; Reset input to Qn		10*	201	238	177	230	244	
								172	158	
		; T/C input to Qn		10*	119	132	112	129	134	
								110	105	
	1.5x10^5	; Clock input to Qn		10*	159	171	143.9	172	179	
								147	140	
		; Reset input to Qn		10*	214	248.9	189	245	260	
								184	169	
		; T/C input to Qn		10*	129	140	120	138	142	
								120	115	
TPHL (nS)	0	; Clock input to Qn		10*	125	134	112	137	143	
								113	107	
		; Reset input to Qn		10*	149	168	131	168	177	
								130	120	
		; T/C input to Qn		10*	94.4	100.9	77.1	107	113	
								82.1	76	

* 40 MEASUREMENTS TAKEN ON 10 DEVICES

DEVICE TYPE: CD 4035 R.C.A. PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (nS)	7.5x10^4	VDD=10V; Clock input to Qn	VDD=10V; CL=10pf	10*	162	175.9	145.9	177	185	
								147	140	
		; Reset input to Qn		10*	198	236.9	171.9	232	248	
								165	149	
		; T/C input to Qn		10*	128	136	121.9	136	139	
								121	117	
	1.5x10^5	; Clock input to Qn		10*	165	177	149	180	188	
								150	142	
		; Reset input to Qn		10*	205	240.9	178	239	257	
								170	153	
		; T/C input to Qn		10*	136	142	129	143	147	
								129	125	

* 40 MEASUREMENTS TAKEN ON 10 DEVICES

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

CD4040, RCA

DEVICE TYPE: CD4040 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.							
VT (V)								-.25	-.35	
N CHANNEL	0	VDD: 10V	ISS: 10μA, VDD: 10V	6	1.57	1.74	0.98	2.16	2.45	
		ALL INPUTS: 10V						0.985	0.691	
	7.5×10^4			6	0.76	1.74	-0.1	2.65	3.59	
								-1.13	-2.07	
	1.5×10^5			6	0.795	2.01	-0.1	2.77	3.75	
								-1.18	-2.16	
P CHANNEL	0		IDD: 10μA, VDD: 10V	6	-1.96	-1.14	-2.32	-1.12	-0.682	
								-2.81	-3.23	
	7.5×10^4			6	-0.83	0.09	-2.63	1.83	3.31	
								-3.59	-4.97	
	1.5×10^5			6	-1.27	0.07	-3.05	1.73	3.24	
								-4.28	-5.78	
TPLH (ns)	0		VDD: 10V, CL: 30pF (CLOCK TO Q1)	6	168	186	152	191	203	
								144	132	
	7.5×10^4			6	192	223	171	227	245	
								156	138	
	1.5×10^5			6	219	260	192	265	288	
								172	149	

DEVICE TYPE: CD4040 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.							
TPLH (ns)	0	VDD: 10V,	VDD: 10V, CL: 30pF	6*	70.9	98.0	55.9	82.7	104	
		ALL INPUTS: 10V	(Qj TO Qj+1)					49.1	38.2	
	7.5×10^4			6*	94.5	125	69.7	125	140	
								64.3	49.2	
	1.5×10^5			6*	115	153	83	157	162	
								83.9	68.2	
TPHL (ns)	0		VDD: 10V, CL: 30pF (CLOCK TO Q1)	6	137	144	129	148	154	
								125	120	
	7.5×10^4			6	148	157	135	161	167	
								135	129	
	1.5×10^5			6	158	168	148	172	179	
								145	138	
TPHL (ns)	0		VDD: 10V, CL: 30pF (Qj TO Qj+1)	6*	50.5	63	37.5	61.1	66.3	
								39.9	34.6	
	7.5×10^4			6*	54.4	67.9	39.8	65.7	71.4	
								43	37.3	
	1.5×10^5			6*	57.8	73.3	41.5	70	76.2	
								45.5	39.3	

*6 MEASUREMENTS TAKEN ON 6 DEVICES.

CD4042, RCA

PAGE 1 OF 2

3

DEVICE TYPE: CD4042 RCA 950°C ANNEAL IN NITROGEN

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_T (V)	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-Channel	0	V_{DD} = 10V;	I_{SS} = -10μA;	4	1.17	1.42	0.95	1.57	1.77	
		All inputs = 10V	V_{DD} = 10V					0.776	0.577	
	7.5×10^4			4	0.738	0.99	0.27	1.39	1.71	
								0.0877	-0.237	
	1.5×10^5			4	0.523	0.64	0.4	0.745	0.857	
								0.3	0.188	
P-Channel	0		I_{DD} = -10μA;	4	-1.61	-1.25	-2.24	-0.738	-0.303	
			V_{DD} = 10V					-2.48	-2.91	
	7.5×10^4			4	-1.11	-0.13	-2.1	0.516	1.33	
								-2.74	-3.55	
	1.5×10^5			4	-1.1	-0.23	-2.07	0.435	1.2	
								-2.63	-3.39	
TPLH (nS)	0		V_{DD}=10V, C_L=30pf	4*	118	131	99.9	135	144	
			CLOCK IN TO Q_n →					99.9	91.1	
			CLOCK IN TO $\bar{Q}_n$ →	4*	170	196.9	150.9	195	207	
								146	134	
	7.5×10^4			4*	118	133	100.9	137	146	
								99.7	90.4	
				4*	173	201	152.9	198	211	
								147	135	

ALS * 30 MEASUREMENTS TAKEN ON 4 DEVICES

DEVICE TYPE: CD4042 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
(continued):	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPLH (nS)	1.5×10^5	V_{DD} = 10V;	V_{DD}=10V; C_L=30pf	4*	116	131	99.9	134	143	
		All inputs = 10V						98.2	89.2	
				4*	173	201.9	152.9	198	210	
								148	135	
TPHL (nS)	0		V_{DD}=10V; C_L=30pf	4*	131	145	120	147	155	
			CLOCK IN TO Q_n →					116	108	
			CLOCK IN TO $\bar{Q}_n$ →	4*	178	205	156	202	215	
								153	140	
	7.5×10^4			4*	134	147	120	151	159	
								117	108	
				4*	175	203	154	201	213	
								150	137	
	1.5×10^5			4*	133	147	119	151	159	
								116	107	
				4*	172	199	150.9	196	208	
								147	135	

* 30 MEASUREMENTS TAKEN ON 4 DEVICES

CD4043, RCA

DEVICE TYPE: CD 4043 RCA 950°C ANNEAL IN NITROGEN PAGE 1 OF 3 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
V_T (V)	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N-Channel	0	VDD=10V; All inputs=10V	ISS=-10μA; VDD=10V	10	1.3	1.5	0.84	1.69	1.89	
								0.898	0.7	
	7.5×10^4			10	1.08	1.4	0.54	1.58	1.83	
								0.585	0.336	
	1.5×10^5			10	0.867	1.05	0.32	1.31	1.53	
								0.425	0.204	
	3×10^5			5	0.568	0.8	0.26	0.936	1.12	
								0.201	0.0175	
P-Channel	0		IDD=+10μA; VDD=10V	10	-2.1	-1.28	-2.73	-1.13	-0.651	
								-3.06	-3.54	
	7.5×10^4			10	-1.99	-0.69	-2.9	-1.565	0.49	
								-3.42	-4.14	
	1.5×10^5			10	-1.96	-0.45	-2.95	-0.348	0.459	
								-3.58	-4.39	
	3×10^5			5	-2.01	-0.4	-2.96	0.0488	1.08	
								-4.06	-5.09	
TPLH (nS)	0		VDD=10V; CL=30pF	10*	78.2	103	69.2	98.7	109	
			SET OR RESET TO Qn					57.7	47.4	
			ENABLE IN TO Qn	10**	77.7	101.9	68.6	99.2	110	
								56.3	45.6	
* 80 MEASUREMENTS TAKEN ON 10 DEVICES										
** 40 MEASUREMENTS TAKEN ON 10 DEVICES										

DCS

DEVICE TYPE: CD 4043 RCA PAGE 2 OF 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPLH (nS)	7.5×10^4	VDD=10V; All inputs=10V	VDD=10V; CL=30pF	10*	75.8	106.9	67.5	94.7	104	
								56.9	47.5	
				10**	76.8	100.8	68	97.1	107	
								56.4	46.2	
	1.5×10^5			10*	142	157	128	156	164	
								128	120	
				10**	74.7	101.9	67.3	95	105	
								54.5	44.4	
	3×10^5			5*	69.2	79.8	64.6	76.5	80.2	
								61.9	58.2	
				5**	72	91	66.7	82.8	88.2	
								61.2	55.8	
TPHL (nS)	0		VDD=10V; CL=30pF	10*	144	157.9	131	158	166	
			SET OR RESET TO Qn					130	122	
			ENABLE IN TO Qn	10**	79.5	106.9	70.5	103	115	
								55.8	44	
	7.5×10^4			10*	143	157.9	129	158	165	
								128	121	
				10**	77.3	106	68	99.8	111	
								54.9	43.6	
* 8 MEASUREMENTS TAKEN ON EACH DEVICE										
** 4 MEASUREMENTS TAKEN ON EACH DEVICE										

DEVICE TYPE: CD 4043 RCA PAGE 3 of 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	Rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (nS)	1.5x10^4	VDD=10V;	VDD=10V; CL=30pF	10*	142	157	128	156	164	
		ALL INPUTS=10V						128	120	
				10**	74.7	101.9	67.3	95	105	
								54.5	44.4	
	3x10^5			5*	142	156	132	156	163	
								129	122	
				5**	69.2	75.9	65.5	76	79.4	
								62.4	59	

* 8 MEASUREMENTS TAKEN ON EACH DEVICE
** 4 MEASUREMENTS TAKEN ON EACH DEVICE

[illegible] MODES 6-10

CD4047, RCA

DEVICE TYPE: CD4047 RCA 250°C ANNEAL IN NITROGEN Page 1 of 8 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
IT (V)	Rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
N CHANNEL	0	VDD=10V;	IDD=10μA	9	.283	0.41	0.14	0.439	0.516	
		ALL INPUTS=10V	VDD=12V					0.128	0.051	
	7.5x10^4			9	0.484	0.81	0.07	1.11	1.462	
								-0.139	-0.45	
	1.5x10^5			9	0.459	0.69	-0.05	0.898	1.12	
								0.0199	-0.2	
P CHANNEL	0		IDD=10μA	9	-1.61	-1.52	-1.8	-1.45	-1.38	
			VDD=10V					-1.77	-1.84	
	7.5x10^4			9	-1.73	-1.63	-1.94	-1.56	-1.48	
								-1.9	-1.99	
	1.5x10^5			9	-1.77	-1.69	-1.96	-1.62	-1.54	
								-1.92	-2.0	
TPLH (nS)	0		VDD=10V, CL=30pF	9	275	344	240	337	368	
			(PIN 8 to 10)					213	182	
	7.5x10^4			9	274	338	240	333	360	
								214	185	
	1.5x10^5			9	272	334	239	330	359	
								213	184	

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

DEVICE TYPE: CD4047 RCA PAGE 2 of 8

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPLH (ns)	0	VDD: 10V.	VDD: 10V; CL: 30pF	9	161	187	149	184	196	
		ALL INPUTS: 10V	(PIN 8 to 13)					137	126	
	2.5×10^4			9	161	186	148	184	196	
								137	126	
	1.5×10^5			9	159	184	148	182	174	
								137	125	
TPLH (ns)	0		VDD: 10V; CL: 30pF	9	263	325	229	319	348	
			(PIN 6 TO 10)					207	179	
	2.5×10^4			9	263	318	229	315	342	
								210	183	
	1.5×10^5			9	261	317	229	314	341	
								209	182	
TPLH (ns)	0		VDD: 10V; CL: 30pF	9	152	170	141	169	178	
			(PIN 6 TO 13)					134	126	
	2.5×10^4			9	153	170	142	170	178	
								135	127	
	1.5×10^5			9	152	169	141	169	177	
								135	126	

DEVICE TYPE: CD4047 RCA PAGE 3 of 8

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPLH (ns)	0	VDD: 10V	VDD: 10V; CL: 30pF	9	233	290	199	288	315	
		ALL INPUTS: 10V	(PIN 4 TO 10)					178	151	
	2.5×10^4			9	232	288	199	286	313	
								178	151	
	1.5×10^5			9	231	286	198	285	312	
								177	150	
TPLH (ns)	0		VDD: 10V; CL: 30pF	9	126	145	114	145	154	
			(PIN 4 TO 13)					106	96.7	
	2.5×10^4			9	125	144	114	144	153	
								106	96.5	
	1.5×10^5			9	124	142	113	142	152	
								105	96	
TPLH (ns)	0		VDD: 10V; CL: 30pF	9	226	281	193	279	306	
			(PIN 5 TO 10)					172	145	
	2.5×10^4			9	224	279	193	278	304	
								171	144	
	1.5×10^5			9	222	277	192	275	302	
								169	143	

DEVICE TYPE: CD 4047 RCA PAGE 4 of 8

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPLH (ns)	0	VDD = 10V;	VDD = 10V; CL = 30pF	9	117	137	107	137	146	
		ALL INPUTS = 10V	(PIN 5 TO 13)					98.1	88.4	
	7.5×10^4			9	116	136	107	136	146	
								96.9	87.1	
	1.5×10^5			9	115	134	106	134	143	
								97	87.8	
TPLH (ns)	0		VDD = 10V; CL = 30pF	9	131	158	112	159	174	
			(PIN 9 TO 10)					102	88.1	
	7.5×10^4			9	133	158	115	159	172	
								107	93.7	
	1.5×10^5			9	133	159	116	159	172	
								107	94.3	
TPLH (ns)	0		VDD = 10V; CL = 30pF	9	131	151	117	151	161	
			(PIN 3 TO 11)					110	100	
	7.5×10^4			9	136	155	120	157	167	
								115	104	
	1.5×10^5			9	135	156	121	156	167	
								114	103	

DEVICE TYPE: CD 4047 RCA PAGE 5 of 8

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad (Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (ns)	0	VDD = 10V	VDD = 10V, CL = 30pF	9	244	300	216	296	322	
		ALL INPUTS = 10V	(PIN 8 to 11)					192	166	
	7.5×10^4			9	241	295	214	292	318	
								190	164	
	1.5×10^5			9	237	290	212	287	312	
								187	161	
TPHL (ns)	0		VDD = 10V; CL = 30pF	9	232	278	206	277	299	
			(PIN 6 TO 11)					187	165	
	7.5×10^4			9	230	276	205	275	298	
								185	162	
	1.5×10^5			9	227	272	203	271	293	
								182	160	
TPHL (ns)	0		VDD = 10V; CL = 30pF	9	203	249	179	248	270	
			(PIN 4 TO 11)					158	135	
	7.5×10^4			9	200	246	177	245	268	
								154	131	
	1.5×10^5			9	196	242	175	241	263	
								152	130	

DEVICE TYPE: CD4047 RCA PAGE 6 of 8

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TPHL (ns)	0	VDD = 10V	VDD=10V, CL=30pF	9	196	242	173	241	263	
	↓	ALL INPUTS=10V	(PIN 5 TO 11)					151	128	
	2.5×10⁴			9	193	238	172	237	259	
	↓							148	126	
	1.5×10⁵			9	189	234	170	233	254	
	↓		↓					146	125	
TPHL (ns)	0		VDD=10V, CL=30pF	9	92.1	113	87	114	123	
	↓		(PIN 12 TO 11)					79.8	71.1	
	2.5×10⁴			9	96.3	113	87	114	123	
	↓							78.2	69.2	
	1.5×10⁵			9	94.3	112	86	113	122	
	↓		↓					75.9	66.7	
TPHL (ns)	0		VDD=10V, CL=30pF	9	132	149	120	149	158	
	↓		(PIN 9 TO 10)					115	106	
	2.5×10⁴			9	134	149	121	150	158	
	↓							118	110	
	1.5×10⁵			9	130	148	119	148	157	
	↓	↓	↓					113	104	

DEVICE TYPE: CD4047 RCA PAGE 7 of 8

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.					-2σ	-3σ	
TIME CONSTANT	0	VDD: 10V	VDD: 10V, CL=30pF	9	2.62	2.722	2.588	2.71	2.75	
MULTIPLICATION	↓	ALL INPUTS: 10V	(MONOSTABLE PERIOD)					2.54	2.5	
FACTORS	2.5×10⁴			9	2.63	2.691	2.6	2.69	2.72	
	↓							2.57	2.54	
	1.5×10⁵			9	2.63	2.674	2.6	2.68	2.71	
	↓		↓					2.58	2.56	
	0		VDD: 10V, CL=30pF	9	4.59	4.612	4.522	4.64	4.67	
	↓		(ASTABLE PERIOD)					4.53	4.5	
	2.5×10⁴			9	4.59	4.612	4.55	4.63	4.65	
	↓							4.55	4.53	
	1.5×10⁵			9	4.6	4.626	4.577	4.63	4.65	
	↓		↓					4.57	4.55	
	0		VDD: 10V, CL=30pF	9	1.86	2.01	1.783	1.99	2.05	
	↓		(T1 PRIME PERIOD)					1.72	1.66	
	2.5×10⁴			9	1.87	1.982	1.81	1.98	2.03	
	↓							1.77	1.72	
	1.5×10⁵			9	1.89	1.972	1.82	2.0	2.05	
	↓	↓	↓					1.78	1.72	

DEVICE TYPE: CD 4047 RCA PAGE 8 of 8

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.							
TIME CONSTANT	0	VDD: 10V	VDD: 10V; C_L: 30pF	9	1.01	1.046	0.956	1.07	1.11	
MULTIPLICATION	↓	ALL INPUTS: 10V	(T1 PERIOD)					0.941	0.928	
FACTORS	7.5×10^4			9	0.991	1.032	0.922	1.05	1.09	
	↓							0.928	0.896	
	1.5×10^5			9	0.989	1.030	0.936	1.05	1.07	
	↓		↓					0.934	0.906	
	0		VDD: 10V; C_L: 30pF	9	1.21	1.252	1.184	1.25	1.27	
	↓		(T1 PERIOD)					1.17	1.15	
	7.5×10^4			9	1.23	1.28	1.204	1.28	1.3	
	↓							1.19	1.16	
	1.5×10^5			9	1.25	1.284	1.218	1.3	1.32	
↓	↓	↓	↓					1.2	1.18	

CD4049, RCA

PAGE 1 of 2

DEVICE TYPE: CD4049 RCA 950°C ANNEAL IN FORMING GAS 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
V_T (V)	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.							
N Channel	0	VDD: 10V	ISS: 10μA;	10	1.08	1.24	0.76	1.22	1.29	
	↓	All inputs: 10V	VDD: 10V					0.931	0.859	
	7.5×10^4			9	0.891	0.97	0.78	1.02	1.03	
	↓							0.762	0.698	
	1.5×10^5			10	0.821	0.96	0.65	1.01	1.1	
	↓		↓					0.654	0.565	
P Channel	0		IDD: 10μA	10	-1.57	-1.48	-1.76	-1.36	-1.26	
	↓		VDD: 10V					-1.78	-1.88	
	7.5×10^4			9	-2.01	-1.89	-2.35	-1.69	-1.53	
	↓							-2.34	-2.5	
	1.5×10^5			10	-2.09	-0.14	-2.71	-0.677	0.031	
	↓		↓					-3.51	-4.22	
TPLH (nS)	0		VDD: 10V;	10*	47.6	62.6	43.4	55.1	58.1	
	↓		C_L: 30pF					40.1	36.4	
	7.5×10^4			9*	50.7	74.3	45.9	62.2	67.6	
	↓							39.5	33.8	
	1.5×10^5			10*	54.0	94.9	47.8	71.1	77.7	
↓	↓	↓						36.9	28.2	
*6 MEASUREMENTS TAKEN ON EACH DEVICE										

DEVICE TYPE: CD4049 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.							
TPHL (nS)	0	VDD = 10V	VDD = 10V	10*	11.2	13.0	8.5	13.3	14.4	
		All inputs = 10V	CL = 30 pF					9.04	7.98	
	7.5x10^4			9*	11.5	13.5	8.8	13.5	14.6	
								9.38	8.24	
	1.5x10^5			10*	11.9	14.0	9.2	14.0	15.0	
								9.74	8.68	

* 6 MEASUREMENTS TAKEN ON EACH DEVICE

CD4050, RCA

DEVICE TYPE: CD4050 R.C.A. 950°C ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
VT (V)	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.							
N CHANNEL	0	VDD: 10V,	ISS: 10μA,	10	1.17	1.22	1.09	1.25	1.29	
		BLANKET: 10V	VDD: 10V					1.1	1.06	
	7.5x10^4			10	0.866	[illegible]	0.6[illegible]	0.983	1.07	
								0.748	0.511	
	1.5x10^5			10	0.64	1	0.45	0.772	1.14	
								0.506	0.142	
P CHANNEL	0		IDD: 10μA	10	-1.68	-1.54	-1.79	-1.52	-1.44	
			VDD: 10V					-1.83	-1.91	
	7.5x10^4			10	-2.26	-2.14	-2.57	-2.02	-1.9	
								-2.5	-2.62	
	1.5x10^5			10	-2.63	-2.48	-2.95	-2.36	-2.23	
								-2.89	-3.02	
TPLH (nS)	0		VDD=10V, CL=30pF	10*	43.6	51	37.4	49.6	52.5	
								37.7	34.7	
	7.5x10^4			10*	46.4	53.7	40.2	52.4	56.2	
								34.8	36.6	
	1.5x10^5			10*	48.2	55.6	41.6	55.6	59.2	
								41	37.2	

* 6 MEASUREMENTS TAKEN ON EACH DEVICE

AG5

DEVICE TYPE CD4050 R.C.A. PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
	rad(Si)	BIAS: IRRAD.	BIAS: MEAS.							
TPHL (ns)	0	VDD=10V	VDD=10V, CL=30pf	10*	24.4	35.2	18	31.7 7	35.1 13.3	
	7.5x10^4	ALL INPUT=10V		10*	28.6	45	21	37.2 18.9	43.1 14.1	
	1.5x10^5			10*	33.8	53	24.2	46.2 21.4	51.4 15.2	

* 10 MEASUREMENTS TAKEN ON EACH DEVICE

CD4051, RCA

Page 1 of 2

DEVICE TYPE: CD 4051 RCA 950°C ANNEAL IN FORMING GAS 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ -2σ	Mean +3σ -3σ	Accept Reject Criteria
VT(V)		BIAS: IRRAD.	BIAS: MEAS.							
N-Channel	0	VDD=10V ALL INPUTS=10V	ISS=10μA; VDD=10V	10	1.13	1.33	0.75	1.49 0.777	1.67 0.598	
	7.5x10^4			10	0.84	1.38	-0.31	2.1 -0.416	2.25 -1.04	
	1.5x10^5			10	0.898	1.48	-0.31	2.2 -0.409	2.86 -1.06	
P-Channel	0		ISS=+10μA VDD=10V	10	-2.35	-2.05	-2.92	-1.76 -2.94	-1.47 -3.24	
	7.5x10^4			10	-1.85	0.15	-2.75	0.283 -3.99	1.35 -5.06	
	1.5x10^5			10	-1.99	0.14	-2.99	0.29 -4.28	1.43 -5.42	
TPLH (ns)	0	VDD=10V; [illegible]	VDD=10V; CL=30pf	10*	172	298	76.6	292 51.5	352 -8.64	
		[illegible]		2*	209	412	149	332 85.1	394 23.4	
	7.5x10^4	[illegible]		10*	123	301.9	79.8	290 56	349 -2.13	
		[illegible]		10*	219	431.9	156	350 88	416 22.5	

* 30 MEASUREMENTS TAKEN ON 10 DEVICES

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

DEVICE TYPE: CD 4051 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
TPLH (nS)	1.5×10^5	VDD=10V; INPUT=0V	VDD=10V; CL=30pF	10*	180	324	92	305	367	
								56.4	-5.7	
		INPUT=10V		10*	230	457	161	373	444	
								87.9	16.7	
TPHL (nS)	0	INPUT=0V		10*	221	427	161	344	406	
								97.6	35.9	
		INPUT=10V		10*	187	314	106	298	354	
								76	20.4	
	7.5×10^4	INPUT=0V		10*	226	444	106.9	362	430	
								89.9	21.8	
		INPUT=10V		10*	187	314.9	106.9	296	351	
								78	23.5	
	1.5×10^5	INPUT=0V		10*	240	466	170	381	452	
								99	28.4	
		INPUT=10V		10*	193	336	111	310	368	
								76.9	18.6	

* 30 MEASUREMENTS TAKEN ON 10 DEVICES

CD4052, RCA

DEVICE TYPE: CD4052 RCA 950°C ANNEAL IN FORMING GAS Page 1 of 2 5

Parameter	Fluence	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
V_T (V)	rad(Si)									
N CHANNEL	0	VDD=10V	ISSR=10μA	8	1.34	1.41	1.26	1.46	1.52	
		ALL INPUTS=10V	VDD=10V					1.22	1.16	
	7.5×10^4			7	1.19	1.49	0.1	*2.34	*2.92	
								0.04	-0.53	
	1.5×10^5			8	1.27	1.57	-0.07	2.36	2.91	
								0.17	-0.38	
P-CHANNEL	0		IDD=10μA	8	-2.11	-2.01	-2.23	-1.97	-1.9	
			VDD=10V					-2.26	-2.33	
	7.5×10^4			7	-2.05	0.06	-2.48	*0.19	*0.75	
								-3.92	-4.86	
	1.5×10^5			8	-2.23	0.04	-2.67	-0.39	0.53	
								-4.07	-4.99	
TPLH (nS)	0		VDD=10V, CL=30pF	8*	182	204	79.5	294	350	
			(CONTROL INPUT					70.7	14.8	
	7.5×10^4		TO OUTPUT)	7*	188	280	91	*301	*357	
								76	19.8	
	1.5×10^5			8*	196	292.9	96	313	371	
								79.4	21	

* ONE DEVICE FAILED

* 16 MEASUREMENTS TAKEN ON EACH DEVICE

KGS

DEVICE TYPE: CD4052 RCA PAGE 2 of 2

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
	rad (Si)	BIAS: 1 RAD.	BIAS: MEAS.							
TPLH (ns)	0	VDD = 10V	VDD = 10V, CL = 30pF	8*	208	338.9	192.9	.381	.438	
		ALL INPUTS = 10V	(INHIBIT INPUT					155	98.7	
	2.5×10^4		TO OUTPUT)	7*	229	356.9	184	*409	*473	
								150	84.9	
	1.5×10^5			8*	291	.323	185.9	.427	.496	
								.154	.85.2	
TPHL (ns)	0		VDD = 10V, CL = 30pF	8**	197	281	108.9	.304	.357	
			(CONTROL INPUT					90.7	.325	
	2.5×10^4		TO OUTPUT)	7**	203	296.9	113.9	*312	*366	
								94.3	.329	
	1.5×10^5			8**	212	.313	119	.326	.383	
								92.3	40.2	
TPHL (ns)	0		VDD = 10V, CL = 30pF	8*	270	357.9	178	.413	.484	
			(INHIBIT INPUT					127	55.1	
	2.5×10^4		TO OUTPUT)	7*	283	376.9	169	*439	*517	
								127	48.9	
	1.5×10^5			8*	295	.393	171.9	.456	.537	
								134	50.1	

* ONE DEVICE FAILED
* 8 MEASUREMENTS TAKEN ON EACH DEVICE
** 16 MEASUREMENTS TAKEN ON EACH DEVICE

CD4053, RCA

DEVICE TYPE: CD4053 RCA 950°C ANNEAL IN FORMING GAS PAGE 1 of 2 3

Parameter	Fluence	Operating Point		Sample size	Mean	Max.	Min.	Mean +2σ / -2σ	Mean +3σ / -3σ	Accept Reject Criteria
VT (V)	rad (Si)	BIAS: 1 RAD.	BIAS: MEAS.							
N CHANNEL	0	VDD = 10V	ISS = 10μA,	9	1.08	1.51	-0.36	.2.39	.3.04	
		ALL INPUTS = 10V	VDD = 10V					-0.218	-0.869	
	2.5×10^4			9	0.893	1.56	-0.35	2.52	3.34	
								-0.735	-1.55	
	1.5×10^5			8	1.11	1.61	-0.1	*2.61	*3.36	
								-0.389	-1.14	
P CHANNEL	0		IDD = 10μA	9	-1.78	0.28	-2.47	0.249	1.26	
			VDD = 10V					-3.8	-4.82	
	2.5×10^4			9	-1.64	0.29	-2.63	1.05	2.4	
								-4.33	-5.68	
	1.5×10^5			8	-2.04	0.1	-2.87	*0.58	*1.89	
								-4.66	-5.97	
TPLH (ns)	0		VDD = 10V, CL = 30pF	9**	152.2	185.9	50.6	196.9	216.8	
			(INHIBIT INPUT TO					124	92.5	
	2.5×10^4		OUTPUT)	9**	147	170	115.9	174	188	
								120	106	
	1.5×10^5			8***	150	175.9	119	*179	*193	
								121	107	

* ONE DEVICE FAILED
** 54 MEASUREMENTS TAKEN ON 9 DEVICES
*** 48 MEASUREMENTS TAKEN ON 8 DEVICES

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DEVICE TYPE: CD4053 RCA PAGE 2 of 2

Parameter	Fluence rad(Si)	Operating Point: BIAS: IRRAD.	Operating Point: BIAS: MEAS.	Sample size	Mean	Max.	Min.	Mean +2σ	Mean +3σ	Accept Reject Criteria
								-2σ	-3σ	
TPLH (nS)	0	VDD = 10V	VDD = 10V; CL = 30pF	9**	153	250	48.9	257	310	
		ALL INPUTS = 10V	(CONTROL INPUTS					48.1	-418	
	2.5×10^4		TO OUTPUT)	9**	155	254.9	50.4	262	315	
								48.1	-5.39	
	1.5×10^5			8***	162	272.3	53.5	*276	*332	
								48.5	-8.29	
TPHL (nS)	0		VDD = 10V; CL = 30pF	9**	150	173.9	126	175	187	
			(INPUT INPUT TO					126	114	
	2.5×10^4		OUTPUT)	9**	136.3	152	102.9	160.7	172.9	
								112	99.8	
	1.5×10^5			8***	139	157.9	112	*165	*178	
								113	99.9	
TPHL (nS)	0		VDD = 10V; CL = 30pF	9**	161	252	56.5	264	315	
			(CONTROL INPUTS					58.1	6.77	
	2.5×10^4		TO OUTPUT)	9**	160	258.9	56.8	263	314	
								57.6	6.23	
	1.5×10^5			8***	171	278.9	60.1	*280	*334	
								61.7	7.17	

* ONE DEVICE FAILED

** 54 MEASUREMENTS TAKEN ON 9 DEVICES

*** 48 MEASUREMENTS TAKEN ON 8 DEVICES

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APPENDIX A

VENDOR IDENTIFICATION CODE

JPL alphabetical code	FSCM number	Vendor
ADI	24355	Analog Devices, Inc., Norwood, Mass
ANA	31855	Analog Technology Corporation
CAD	19647	Caddock Electronics, Div of Globe Union, Inc.
CRC	12517	Component Research Company, Inc.
CTI		Circuit Technology, Inc.
DAL	91637	Dale Electronics, Inc., Subs. of the Lionel Corporation
DIK	12954	Dickson Electronics Corporation
EXR	52063	Exar Integrated Systems, Inc.
FAS	07263	Fairchild Semiconductors, Div of Fairchild Camera and Instrument Corp.
GEC	09214	General Electric Company, Semiconductor Products Dept.
HAR	91417	Harris Semiconductor (Radiation, Inc.)
HON	91929	Honeywell, Inc., Microswitch Division
HPA	28480	Hewlett-Packard Company
INL	32293	Intersil Inc., Cupertino, Cal.
KMC	20754	KMC Semiconductor
MOT	14713	Motorola Semiconductor Products, Inc.
NSC	27014	National Semiconductor Corporation
PMI	06665	Precision Monolithics, Inc., Santa Clara, California

JPL alphabetical code	FSCM number	Vendor
RAY	49956	Raytheon Company
RCA	02735	RCA Corp., Solid State Division Somerville, N. J.
SET	14099	Semtech Corporation
SGN	18324	Signetics Corp., Subs. of Corning Glass Works
SIL	17856	Siliconix, Inc.
SOD	13327	Solitron Devices, Inc.
TIX	01295	Texas Instruments, Inc., Semiconductor Components Div.
TRW	01281	TRW Semiconductor, Inc., (PSI)
UTR	12969	Unitrode Corp.
WEC	05277	Westinghouse Electric Corp., Semiconductor Division

APPENDIX B

RECOMMENDED WORST-CASE ELECTRONIC DEVICE PARAMETER VARIATIONS

The purpose of this appendix is to provide recommendations to aid the circuit designer in the worst-case analysis of circuits. The worst case parameter variations contained in Tables B-1 through B-6 for transistors, resistors, fixed capacitors, diodes, TTL (transistor-transistor logic) and linear integrated circuits, and CMOS integrated circuits are recommendations only and not hard requirements.

These tables do not include radiation-induced degradation. Radiation degradation should be added to the variations in these tables on an individual part basis where part data is available. Estimates should be made otherwise. Section 153 should be contacted when the worst-case analysis is to be performed.

Table B-1. Worst-case parameter variations for transistors

As an aid to the circuit designer's worst-case analyses, the maximum expected parameter variations for system life and temperature are given. It is noted that all parameter changes are based on the specific value given in the application of JPL ST or manufacturer specifications, except for h_{FE}. For this parameter the variation is from the design value as established by appropriate design curves at 25°C and the design value of I_C. For the cases of saturated switches, the parameter changes of h_{FE} will be established from the minimum value specified in the manufacturer specifications, or ST. The data below applies to all transistors listed in the approved parts list.

Parameter	Variations	Conditions	Remarks
h_{FE}	0.9%/°C	For temperature	Change from design value mfr. spec.
	-25%	For life	
BV_{CBO}	-10%	For life and temperature	Change from min. value in mfr. spec.
BV_{EBO}	-10%	For life and temperature	Change from min. value in mfr. spec.
BV_{CEO}	-30%	For life and temperature	Change from min. value in mfr. spec.
$V_{CE(SAT)}$	+15%	For life	Change from max. value in mfr. spec.
	+0.2mV/°C	For temperature	
$V_{BE(SAT)}$	+15%	For life and temperature	Change from max. value in mfr. spec.
I_{CBO}	doubles every 10°C increase	For temperature	Change from max. value in mfr. spec. at 25°C
	+100%	For life	
I_{EBO}	doubles every 10%	For temperature	Change from max. value in mfr. spec. at 25°C
	+100%	For life	Added to temperature effects

Table B-1 (contd)

Parameter	Variations	Conditions	Remarks
I_{CES}	30X	For life and temperature	Change from max. value in mfr. spec.
t_r	+10%	For life and temperature	Change from max. value in mfr. spec.
t_d	+10%	For life and temperature	Change from max. value in mfr. spec.
t_s	+10%	For life and temperature	Change from max. value in mfr. spec.
t_f	+10%	For life and temperature	Change from max. value in mfr. spec.
C_{obo}	±5%	For life and temperature	Change from max. value in mfr. spec.
C_{ibo}	+5%	For life and temperature	Change from max. value in mfr. spec.
f_T	-25%	For life and temperature	Change from min. value in mfr. spec.

Table B-2. Worst-case parameter variations for resistors

Part description: General, class, type	Manufacturer	Manufacturer's type number	Tolerance, %	
			Purchase	Design[a, b]
Carbon comp.	ABC	RCR05	±5	±25
Carbon comp.	ABC	RCR07	±5	±25
Carbon comp.	ABC	RCR20	±5	±25
Precision WW	SHA	HR series	±0.1	±0.5
Metal film	MEP ANG	RNC55H	±1	±2.5
Metal film	MEP ANG	RNC60H	±1	±2.5
Power wirewound	DAL	RWR series	±1	±2.5
Metal glaze	CAD	MG, MH series	±1	±10
Metal glaze	CAD	MM series	±1	±10
Metal film fixtrim	ANG	IV-5	--	±1.5
HI RES (10^{12} ohms)	PYR	HR600	±5	±10
Ultra high res.	WEL	M51	±1	±5
Ultra high res.	WEL	MH51	±10	±15

[a]Design tolerance includes purchase, temperature, and end-of-life tolerances except where noted.

[b]Design tolerance does not include temperature and voltage coefficient effects for which the JPL ST or mfg. spec. should be consulted.

Table B-3. Worst-case parameter variations for fixed capacitors

Part description: General, class, type	Manufacturer	Manufacturer's type number	Tolerance, %	
			Purchase	Design[a]
Solid tantalum	SPR	CSR13 - KS	±10	±20
Ceramic	AUX	CKR05BX - KS	±10	±25
Ceramic	AUX	CKR06BX - KJ	±10	±25
Ceramic	AUX	CKR11BX - KR	±10	±25
Ceramic	AUX	CKR12BX - KR	±10	±25
Ceramic	AUX	CKR14BR - KR	±10	±30
Ceramic	AUX	CKR15BR - KR	±10	±30
Ceramic, temp. comp.	AUX	ML10 MC70 ML11 MC90	±5	±12
Ceramic, HV disc.	ERIE	800 series	±10	±17
Glass	CGW	CYFR series	±1	±2.1
Ceramic, CYL, AX.	AUX	HRMC 706A, 206A, 866A, 906A	TBD	TBD
Porcelain	VIT	VY series	TBD	TBD
Polysulfone	CRC	MP series	TBD	TBD
MICA	ELM	HRDM	TBD	TBD

[a]Design tolerance includes purchase, temperature, and end-of-life tolerances except where noted.

Table B-4. Worst-case parameter variations for diodes, Zener diodes

As an aid to the circuit designer's worst-case analyses, the maximum expected parameter variations for system life and temperature are given. It is noted that all parameter changes are based on the specific value given in the applicable manufacturer's specification or JPL ST.

Diodes			
Parameter	Variation	Conditions	Remarks
V_F	±10%	For life	Change from value in mfr. spec.
	+150 mV	For temperature	
C	+25%	For life and temperature	Change from value in mfr. spec.
t_r	+10%	For life and temperature	Change from value in mfr. spec.
I_R	10X	For life	Change from value in mfr. spec.
	(a)	For temperature	Change from value in mfr. spec.
B_V	-40%	For life and temperature	Change from value in mfr. spec.
Zener diodes			
V_{ZT}	±5%	For life and temperature	Added to tolerance in mfr. spec.
Z_{ZT}	+10%	For life and temperature	Change from value in mfr. spec.
T_C	+10%	For life and temperature	Change from value in mfr. spec.
I_R	30X	For temperature	Change from value in mfr. spec.
	10X	For life	
V_F	+10%	For life and temperature	Change from value in mfr. spec.

[a]Doubles for every 10°C increase in temperature.

Table B-4 (contd)

Voltage reference diode			
Parameter	Variation	Conditions	Remark
V_{ZT}	±2X	For life and temperature	Change to tolerance in mfr. spec.
I_R	30X	For temperature	Change from value in mfr. spec.
	10X	For life	
Z_{ZT}	+10%	For life and temperature	Change from value in mfr. spec.
Temp. Coef.	+10%	For life	Added to temperature coefficient for temperature variations

Note: Consult with part specialists on life stability factors.

Table B-5. Worst-case parameter variations for integrated circuits

As an aid to the circuit designer's worst-case analyses, the maximum expected parameter variations for system life and temperature are given. All parameter changes listed are based on the specific value given in the applicable JPL ST. The data below apply to all IC's listed in the approved parts list.

Parameter	Variations, %	Conditions
Digital IC's (TTL and low power TTL)		
$V_{OUT(0)}$	±15	Life and temperature
$V_{OUT(1)}$	±15	Life and temperature
$I_{IN(1)}$	±75	Life and temperature
$I_{IN(0)}$	±20	Life and temperature
$I_{OUT(1)}$	±20	Life and temperature
I_{OS}	±25	Life and temperature
T_{PDH}	±50	Life and temperature
T_{PDL}	±50	Life and temperature
I_{cc}	±25	Life and temperature
Clock pulse width	±50	Life and temperature
Linear IC's		
A_{VOL}	±40	Life and temperature
V_{OS}	±20	Life and temperature
I_{IN}	±30	Life and temperature
E_O	-10	Life and temperature
I_{BIAS}	+10	Life and temperature
$\Delta V_{OS}/\Delta T$	+40	Life and temperature
I_{OS}	+10	Life and temperature
I_{cc}	+20	Life and temperature
I_{EE}	+20	Life and temperature

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Table B-6. Worst-case parameter variations for CMOS integrated circuits

As an aid to the circuit designer's worst-case analyses, the maximum expected parameter variations for system life and temperature are given. All parameter changes listed are based on the specific value given in the applicable specification control drawing. The data below apply to all CMOS listed in the approved parts lists.

Parameter	Variations, % (life)	Variations, %/°C (temperature)	Remarks
$V_{OUT(0)}$	+5	+0.1	No DC load
$V_{OUT(1)}$	-1	-0.01	No DC load
$I_{OUT(1),\ (0)}$	±10	-0.5	
I_{SS}	±50	+10	Quiescent current
t_{PLH}, t_{PHL}	10	0.4	

APPENDIX C

PARAMETER VALUES OF IC TYPES REQUIRING RADIATION ACCEPTANCE PRIOR TO FLIGHT USE

The various approaches being used to establish radiation acceptability of certain IC types prior to flight use are the following:

(1) Use a modified or standard manufacturing process combined with a sample radiation test of each lot built.

(2) Irradiate/anneal (IRAN) all of the devices to be used.

(3) IRAN a sample from each lot. In this case, the devices subjected to IRAN as well as the lot balance are considered suitable for flight.

The starting values of the device parameters and the parameter changes due to the Jovian environment are related to the radiation acceptance approach employed. For the sake of completeness, IC's that were not radiation-screened but were used by the subsystems, are included.

All IC types (except CMOS) currently being subjected to one of the above approaches to establish radiation acceptability prior to flight use are listed in Table C-1 together with the specific parameters being controlled. Room temperature parameter values are given for the following cases.

Initial: Starting worst case values of parameters when the devices are supplied to JPL.

Post-IRAN: Worst case parameter values after devices have been subjected to IRAN. Hence, for devices subjected to IRAN, these would be the parameter values at the time of initial installation into flight hardware.

Post-Jupiter: Anticipated worst case parameter values after devices have been through the Jovian environment. Values are given for assumed doses of 12.5, 30, 60 and 125 krads.

Note that for some device types the parameter values may exceed the manufacturer's normally specified limit when the devices are initially installed. Subsystems requiring better parameter values than those in the table must

resort to shielding. Parameters other than those listed in the table may also be affected by radiation, but have not been identified via the GE circuit analyses as being critical to the applications and are not subject to control.

Table C-1. Worst-case parameter values of MJS'77 flight part integrated circuits

Part type	Manufacturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
AD550	ADI	ΔI_{LSB}	(μA)					0.3	0.6
		I_{BIT_1}	(μA)					0.5	0.7
		ΔI_{BIT_2}	(μA)					0.55	0.4
		ΔI_{BIT_3}	(μA)					0.25	0.15
		ΔI_L	(nA)					4	10
		ΔV_{BE}	(mV)					5	5
		$\Delta 1/h_{FE}$						1.2×10^{-3}	1.8×10^{-3}
DAC-01	PMI	Bipolar zero scale offset							
		ΔV_{0S10SF^+}	(mV)			-110	-180	-400	-530
		ΔV_{0S10SF^-}	(mV)			110	240	370	530
		Full-scale voltage							
		ΔV_{FS^+}	(mV)			-120	-180	-400	-530
		ΔV_{FS^-}	(mV)			100	170	360	510

Table C-1 (contd)

Part type	Manufacturer	Parameter controlled	Initial value	Post-IRAN	Post-Jupiter values			
					12.5 krad	30 krad	60 krad	125 krad
DG129	SIL	I_S, off (nA)	1	1	2	6	7.5	15[a]
DG133	SIL	I_S, off (nA)	1	1	2	6	7.5	15
DG141	SIL	I_S, off (nA)	3	3	5	15	30	60
DG181	SIL	I_S, off (nA)	1	-	0.5	1.0	7.5	Failed
		I_D, off (nA)	1	-	0.2	0.4	2.0	Failed
DGM111	SIL	I_S, off (nA)			-	-	-	30
		I_D, off (nA)[b]			-	-	-	260
		I_D, off (nA)[c]			0.05	0.06	0.8	5
		r_{DS}, on (ohms)[b]			-	-	-	100
		r_{DS}, on (ohms)[c]			120	250	250	1000

[a] 25 nA for nonscreened parts.

[b] S = D=-10 V.

[c] S = GND, D=10 V.

Table C-1 (contd)

Part type	Manu-facturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
		No-load conditions							
HA9-2520 HA2-2520	HAR	V_{OS}	(mV)	8		9	9.5	10.6	16.5
		ΔV_{OS}	(mV)			1	1.5	2.6	8.5
		I_{OS}	(nA)	25		33.7	41	66	75
		ΔI_{OS}	(nA)			8.7	16	41	50
		I_B	(nA)	200		315	460	650	1100
		ΔI_B	(nA)			115	260	450	900
		500-ohm output load							
		V_{OS}	(mV)	8 mV		9.6	11.2	13.1	16.5
		ΔV_{OS}	(mV)			1.6	3.2	5.1	8.5
		I_{OS}	(nA)	25 nA		45	45	66	75
		ΔI_{OS}	(nA)			20	20	41	50
		I_B	(nA)	200 nA		360	520	800	1100
		ΔI_B	(nA)			160	320	600	900
		A_{OL}, 2mA	(dB)			-	-	70	65

Table C-1 (contd)

Part type	Manu-facturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
HA9-2600	HAR	V_{OS}	(mV)	4			4.05	4.5	7.0
		ΔV_{OS}	(mV)				0.05	0.5	3.0
		I_{OS}	(nA)	10			18	35	75
		ΔI_{OS}	(nA)				8	25	65
		I_B	(nA)	10			12	24	75
		ΔI_B	(nA)				2	14	65
		A_{OL}, 2mA	(dB)					90	75
								50 krad	
HA9-2620 HA2-2620	HAR	V_{OS}	(mV)	4				4.2	10
		ΔV_{OS}	(mV)					0.2	6
		I_{OS}	(nA)	15				27	55
		ΔI_{OS}	(nA)					12	40
		I_B	(nA)	15				23	100
		ΔI_B	(nA)					8	85

Table C-1 (contd)

Part type	Manu-facturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
HA9-2620 HA2-2620 (contd)	HAR	A_{OL}, 2mA	(dB)					85	85
		Large signal bandwidth (kHz)						550	450
		Small signal bandwidth (MHz)						18	18
HA2-2700	Harris	V_{OS}	(mV)	3	3	3.4	4	5	8
		ΔV_{OS}	(mV)			0.4	1	2	5
		I_{OS}	(nA)	10	10	11	14	16	18
		ΔI_{OS}	(nA)			1	4	6	8
		I_B	(nA)	20	20	24	30	40	45
		ΔI_B	(nA)			4	10	20	25
		A_{OL}, 2mA	(dB)			110	100	90	80
HA9-2700	Harris	V_{OS}	(mV)	3		4	6	12	28
		ΔV_{OS}	(mV)			1	3	9.0	25
		I_{OS}	(nA)	10		12.0	13.1	20	30
		ΔI_{OS}	(nA)			2	3.1	10	20

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Table C-1 (contd)

Part type	Manufacturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
HA9-2700 (contd)	Harris	I_B	(nA)	20		32	40	45	60
		ΔI_B	(nA)			12	20	25	40
		A_{OL}, 2mA	(dB)			100	90	d	d
ICL8007AM	Intersil	V_{OS}	(mV)	20		21.3	21.4	35	Failed
		ΔV_{OS}	(mV)			1.3	1.4	15	Failed
		I_{OS}	(pA)	0.2		42	42	150	Failed
		I_B	(pA)	0.5		36	39	71	Failed
ICL8018 ICL8019 ICL8020	Intersil	ΔI_{LSB}	(μA)					0.12	1.3
		ΔI_{BIT_3}	(μA)					0.06	0.11
		ΔI_{BIT_2}	(μA)					0.17	0.37
		ΔI_{BIT_1}	(μA)					0.38	0.71
		ΔI_L	(nA)					2.3	294
		ΔV_{BE}	(mV)					6	8
		$\Delta 1/h_{FE}$						2×10^{-3}	2.5×10^{-3}

[d]Catastrophic reduction in output voltage swing in negative direction.

Table C-1 (contd)

Part type	Manu-facturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
ICL8038	Intersil	ΔV_{OUT}	(V)						0
		ΔFreq. out	(kHz)						0.2
LM101AF, LM101AH	NSC	V_{OS}	(mV)	2	2	3	4	5	12
		ΔV_{OS}	(mV)			1	2	3	10
		I_{OS}	(nA)	10	10	13	14	16	25
		ΔI_{OS}	(nA)			3	4	6	15
		I_B	(nA)	75	100	135	168	212	300
		ΔI_B	(nA)			35	68	112	200
							25 krad	50 krad	
LM101	NSC	V_{OS}	(mV)	2	None			2.8	10.6
		ΔV_{OS}						0.8	8.6
		I_{OS}	(nA)	10				18.8	168
		ΔI_{OS}	(nA)					8.8	158
		I_B	(nA)	75				125	151
		ΔI_B	(nA)					50	76

Table C-1 (contd)

Part type	Manu-facturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
LM102F	NSC	V_{OS}	(mV)	4					12
		ΔV_{OS}	(mV)						8
		I_B	(nA)	3					12
		ΔI_B	(nA)						9
LM103	NSC	ΔV_Z, 0.01 mA	(mV)						6.1
		ΔV_Z, 0.1 mA	(mV)						7.5
		ΔV_Z, 1.0 mA	(mV)						27
LM105	NSC	$\Delta Load_{REG}$	(mV)			7	25.5	28	140
		$\Delta Line_{REG}$	(mV)			11	26	32	112
LM106	NSC	V_{OS}	(mV)	3					3.1
		ΔV_{OS}	(mV)						0.1
		I_{OS}	(μA)	3					4.7
		ΔI_{OS}	(μA)						1.7
		I_B	(μA)	20					22
		ΔI_B	(μA)						2

Table C-1 (contd)

Part type	Manu-facturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
LM108AH (Hard)	NSC	V_{OS}	(mV)	0.9		1.0	1.1	1.35	1.65
		ΔV_{OS}	(mV)			0.1	0.2	0.45	0.75
		I_{OS}	(nA)	0.5		0.6	0.65	0.8	1.1
		ΔI_{OS}	(nA)			0.1	0.15	0.3	0.6
		I_B	(nA)	4.0		6	6	8.5	13
		ΔI_B	(nA)			2	2	4.5	9
		A_{OL}, 2 mA	(dB)			-	-	92	84
LM108 (Unhard)	NSC	V_{OS}	(mV)	2.0		2.3	2.5	59	1052
		ΔV_{OS}	(mV)			0.3	0.5	57	1050
		I_{OS}	(nA)	0.2		0.6	1.6	6.6	6.7
		ΔI_{OS}	(nA)			0.4	1.4	6.4	6.5
		I_B	(nA)	2.0		3.7	6.5	13.3	13.6
		ΔI_B	(nA)			1.7	4.5	11.3	11.6
		A_{OL}, 2 mA	(dB)			-	-	-	Failed

Table C-1 (contd)

Part type	Manufacturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
LM108H (Hardened)	NSC	V_{OS}	(mV)	2		2.1	2.2	2.5	2.8
		ΔV_{OS}	(mV)			0.1	0.2	0.5	0.8
		I_{OS}	(nA)	0.5		0.6	0.65	0.8	1.1
		ΔI_{OS}	(nA)			0.1	0.15	0.3	0.6
		I_B	(nA)	4		6	6	8.5	13
		ΔI_B	(nA)			2	2	4.5	9
		A_{OL}, 2 mA	(db)			—	—	92	84
LM108H[e] (Hardened lot C1233A)	NSC	V_{OS}	(mV)	2		2.1	2.2	3.4	3.4
		ΔV_{OS}	(mV)			0.1	0.2	1.4	1.4
LM111F LM111H (IRAN)	NSC	V_{OS}	(mV)	3	3	4.5	6	8	9
		$\lvert\Delta V_{OS}\rvert$	(mV)			1.5	3	5	6
		I_{OS}	(nA)	10	25	75	145	225	335
		$\lvert\Delta I_{OS}\rvert$	(nA)			50	120	200	310
		I_B	(nA)	100	400	700	1100	1250	1300
		ΔI_B	(nA)			300	700	850	900

[e]Other parameters are the same as for the hardened LM108.

Table C-1 (contd)

Part type	Manufacturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	50 krad	125 krad
LM111 (Non-IRAN)	NSC	V_{OS}	(mV)	3				5.5	8
		ΔV_{OS}	(mV)					2.5	4
		I_{OS}	(nA)	10				45	190
		ΔI_{OS}	(nA)					35	180
		I_B	(μA)	0.1				1.1	2.1
		ΔI_B	(μA)					1	2
								60 krad	
LM124F	NSC	V_{OS}	(mV)[f]	5		6	8	10	15
		ΔV_{OS}	(mV)			1	3	5	10
		I_{OS}	(nA)	30		45	69	110	150
		ΔI_{OS}	(nA)			15	30	80	120
		I_B	(nA)	150		210	270	350	450
		ΔI_B	(nA)			60	120	200	300
		I_{Sink}	(5K load)				No change		
		I_{Source}	(5K load)				No change		

[f] $V^+ = 15$ V, $V^- = 0$ V.

Table C-1 (contd)

Part type	Manufacturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
LM139 (Unhard)	NSC	V_{OS}, on	(mV)	5		5.5	7.0	9.0	12.0
		ΔV_{OS}, on	(mV)			0.5	2.0	4.0	7.0[g]
		V_{OS}, off	(mV)	5		17.5	Failed	Failed	Failed
		ΔV_{OS}, off	(mV)			12.5	Failed	Failed	Failed
		I_{OS}, on	(nA)	25		35	55	95	375
		ΔI_{OS}, on	(nA)			10	30	70	350
		I_{OS}, off	(nA)	25		35	Failed	Failed	Failed
		ΔI_{OS}, off	(nA)			10	Failed	Failed	Failed
		I_B, on	(nA)	100		210	400	750	2100
		ΔI_B, on	(nA)			110	300	650	2000
		I_B, off	(nA)	100		210	Failed	Failed	Failed
		ΔI_B, off	(nA)			110	Failed	Failed	Failed
		ΔI_{Sink}, on	(mA)			-7.0	-14	-22	-28
		ΔI_{Sink}, 50% duty cycle	(mA)			-6.0	-14	-22	-28
		ΔI_{Sink}, off	(mA)			-7.0	Failed	Failed	Failed

[g]Null voltage = 0.7 V.

Table C-1 (contd)

Part type	Manufacturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
LM139 (Unhard) Flight Lot 10145	NSC	V_{OS}, on	(mV)	5		5.3	5.5	5.6	6.0
		ΔV_{OS}, on	(mV)			0.3	0.5	0.6	1.0
		V_{OS}, off	(mV)	5		5.5	Failed	Failed	Failed
		ΔV_{OS}, off	(mV)			0.5	Failed	Failed	Failed
		I_{OS}, on	(nA)	25		28	34	47	105
		ΔI_{OS}, on	(nA)			3	9	22	80
		I_{OS}, off	(nA)	25		29	Failed	Failed	Failed
		ΔI_{OS}, off	(nA)			4	Failed	Failed	Failed
		I_B, on	(nA)	100		190	230	315	525
		ΔI_B, on	(nA)			90	130	215	425
		I_B, off	(nA)	100		160	Failed	Failed	Failed
		ΔI_B, off	(nA)			60	Failed	Failed	Failed
		ΔI_{Sink}, on	(mA)			-4	-7	-9	-11
		ΔI_{Sink}, off	(mA)			-4	Failed	Failed	Failed

Table C-1 (contd)

Part type	Manu-facturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
LM139 (Hard)	NSC	V_{OS}, on	(mV)	5		5.5	5.5	7	7
		ΔV_{OS}, on	(mV)			0.5	0.5	2	2
		V_{OS}, off	(mV)	5		7.2	7.2	45	Failed
		ΔV_{OS}, off	(mV)			2.2	2.2	40	Failed
		I_{OS}, on	(nA)	25		27.5	45	75	100
		ΔI_{OS}, on	(nA)			2.5	20	50	75
		I_{OS}, off	(nA)	25		70	70	125	Failed
		ΔI_{OS}, off	(nA)			45	45	100	Failed
		I_B, on	(nA)	100		250	420	550	600
		ΔI_B, on	(nA)			150	320	450	500
		I_B, off	(nA)	100		250	450	600	Failed
		ΔI_B, off	(nA)			150	350	500nA	Failed
		I_{Sink}, on	(mA)			5.4	3.0	2.0	1.7
		ΔI_{Sink}, on	(mA)			-5.5	-8.2	-9.4	-9.9
		I_{Sink}, off	(mA)			5.[illegible]	3.0	2.0	Failed
		ΔI_{Sink}, off	(mA)			-5.7	-8.3	-9.5	Failed

Table C-1 (contd)

Part type	Manufacturer	Parameter controlled		Initial value	Post-IRAN	Post-Jupiter values			
						12.5 krad	30 krad	60 krad	125 krad
LM710	NSC	V_{OS}	(mV)	2.0				2.1	2.6
		ΔV_{OS}	(mV)					0.1	0.6
		I_{OS}	(μA)	3.0				3.9	10.5
		ΔI_{OS}	(μA)					0.9	7.5
		I_B	(μA)	20.0				22.0	29.9
		ΔI_B	(μA)					2.0	9.9
LM723	NSC	ΔV_{out}	(mV)						31
		ΔV_{REF}	(mV)						1.1
		ΔLine Reg	(%)						0.09
		ΔLoad Reg	(%)						0.04

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