ESA-QCA00107T-C

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european space research and technology centre

Components Division
Laboratory Support Group

RADIATION ANALYSIS

REPORT NUMBER

RA 070

Part Type : **Integrated Circuit**

Type No : **M 54 HC 00**

Manufacturer : **ST**

Project : **Soho**

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Content:

1. Introduction.

Due to the unknown radiation performance of these parts, the radiation effects were investigated.

Marking: M54HC00D

Date code: 9123

Manufacturer: ST

Case: Ceramic Dual-in-line

The parts were serialized at ESTEC.

Sample identification and test results can be found in the appendix, while this section describes radiation source and conditions and includes a discussion on the test results.

2. Aims and objectives.

The aim of the test was investigate the electrical performance under total dose radiation conditions.
The objective of the work was to build and design biasing circuitry, expose the samples to ionizing radiation and perform subsequent full parametric DC test.

3.The radiation source and dosimetry.

The 1460 Curie Co-60 facility in ESTEC was used for exposing the samples to ionizing radiation (1.25 MeV gamma radiation). The dose rate can be varied by placing the samples at different distance from the Co-60 pellets.
The dose rate chosen for the radiation in this test was 158.3 rad/min (H2O) for all devices up to a dose of 20k rad and 209 rad/min from 20 to 50k rad.

The dose was monitored by a Ionex Dosemaster equipped with a 0.6 cc ion probe placed at the same distance from the Co-60 source as the samples. The Ionex Dosemaster is calibrated to +/- 0.5 %.

Time schedule on 9 juli: 10.40 from 0k Rad to 10k Rad
12.20 from 10k Rad to 20k Rad
14.50 from 20k Rad to 50k Rad

4.The electrical measurements.

The electrical measurements were performed at ESTEC on the Tektronix S-3275 general purpose tester.

5.The biasing circuitry and sample allocation.

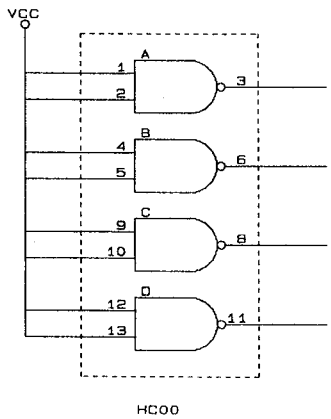
Due to an uncertainty of exactly what bias condition would be worst case, 3 different sets of conditions were applied with Vcc = 6V.

- Condition A, wherby all inputs are tied to Vcc and the outputs are left floating.
- Condition B, whereby the inputs of the gates are tied to ground or VCC and the outputs are tied to VCC or Ground with a 2Kohm load.
- Condition C, whereby a 100kHz generator with 50% duty cycle is tied to one side of each gate, the other side to Vcc and the outputs are tied to Vcc/2 with a 2Kohm load.

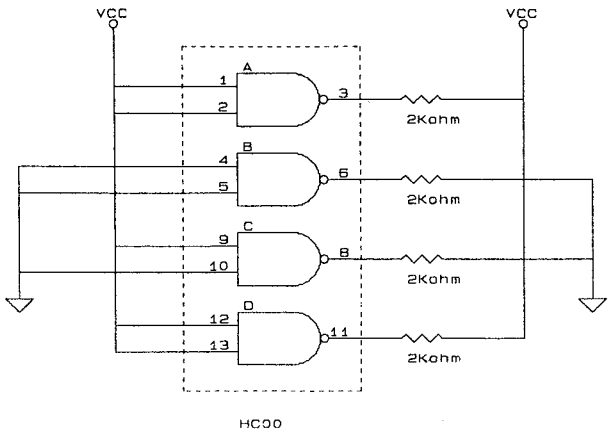
Condition A is used for devices 1 & 2, Condition B for 3 & 4 and Condition C for 5 & 6.

The biasing circuitry is shown below and on the next page.

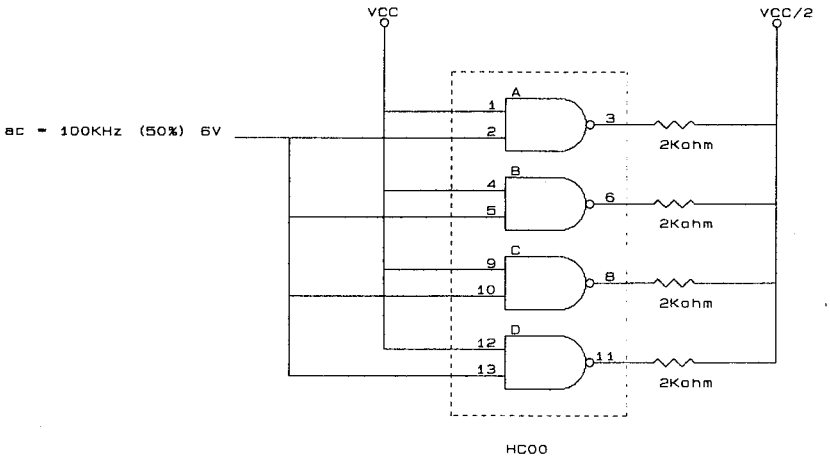
Condition "A"



Condition "B"



Condition "C"



6. The test sequence and test data limits.

ESA/SCC Detail Specification No. 9201/105 is used to test the ST devices.
Characterisation is performed at 25°C.

Table of performed tests:

VTHN	Threshold Voltage N-Channel
VTHP	Threshold Voltage P-Channel
VIC+	Input Clamp Voltage (+)
VIC-	Input Clamp Voltage (-)

at 2.0V

VOL	Output voltage at low current
VOH	Output voltage at low current
TPHL	Propagation Delay High to Low
TPLH	Propagation Delay Low to High
TTHL	Transition Time High to Low
TTLH	Transition Time Low to High
	Functional tests

at 4.5V

VOL1	Output voltage at low current
VOH1	Output voltage at low current
VOL2	Output voltage at high current
VOH2	Output voltage at high current
TPHL	Propagation Delay High to Low
TPLH	Propagation Delay Low to High
TTHL	Transition Time High to Low
TTLH	Transition Time Low to High
	Functional tests

at 6.0V

VOL1	Output voltage at low current
VOH1	Output voltage at low current
VOL2	Output voltage at high current
VOH2	Output voltage at high current
IILL	Input leakage to ground with all inputs low
IILH	Input leakage to ground with all inputs high
IIHL	Input leakage to Vcc with all inputs low
IIHH	Input leakage to Vcc with all inputs high
IDD1	Quiescent Supply current with all inputs low
IDD2	Quiescent Supply current with all inputs high
TPHL	Propagation Delay High to Low
TPLH	Propagation Delay Low to High
TTHL	Transition Time High to Low
TTLH	Transition Time Low to High
	Functional tests

7. Test results.

All raw data is stored on disk at ESTEC for any future requirement for further data analysis.
As can be derived from this data (partly in the appendix), the only failing parameters are V_{THP}, IDD1 and IDD2. See pages 6 to 7.
V_{THN} can also be found in that data.

V_{THP}, IDD1 and IDD2 showed a great dependency on the bias conditions, under which the devices were irradiated.

Graphic presentation of the measured values of all devices for both IDD1 and IDD2 is on page 8 and 9.

Considering the large amount of test data generated from the electrical measurements, only the full test data of device 1 with a radiation dose of 50k Radiation with no anneal time are given in the appendix at pages 10 to 14.

The increase of IDD1 - Quiescent current with all inputs low - causes a positive vertical shift of the step function of V_{THP}.
Depending on the value of IDD1 V_{THP} can be measured positive or negative.

8. Conclusion.

- V_{THP} failed on device 1 to 5.
  IDD1 failed on all devices.
  IDD2 failed on devices 3 and 4.
  After 718 hour anneal time IDD1 was out of specification on devices 1 to 5 and IDD2 was out of specification on devices 3 and 4.
  All devices recovered significantly and will probably come within specifications with time.
- Other parameters were hardly affected during radiation.
- The bias condition of the devices under test has a great impact on the sensitivity to total dose of ionizing radiation.

In view of the test results the ST M54HC00 is considered to be sensitive to the total dose of ionizing radiation.

9. Appendix

Device M 54HC00 HCMOS QUAD 2-INPUT NAND GATES
Manufacturer ST Date 9 jul 91
Lot 9123

Threshold Voltage N-channel A1: -450.mV <--> -1.45 V

Radiation dose

Ser.	0k	10k	20k	50k	50k 16 h ann.	50k 718 h
1	-1.12 V	-1.12 V	-1.28 V	-1.28 V	-1.11 V	-1.13 V
2	-1.12 V	-1.12 V	-1.13 V	-1.13 V	-1.11 V	-1.10 V
3	-1.13 V	-1.12 V	-1.12 V	-1.13 V	-1.10 V	-1.11 V
4	-1.18 V	-1.11 V	-1.13 V	-1.12 V	-1.10 V	-1.11 V
5	-1.13 V	-1.13 V	-1.12 V	-1.24 V	-1.11 V	-1.25 V
6	-1.13 V	-1.11 V	-1.11 V	-1.36 V	-1.15 V	-1.13 V

Threshold Voltage P-channel A1: 450.mV <--> 1.35 V

Radiation dose

Ser.	0k	10k	20k	50k	50k 16 h ann.	50k 718 h
1	589.MV	-576.MV *	-785.MV *	-785.MV *	-725.MV *	750.MV
2	598.MV	-21.6MV *	-720.MV *	-780.MV *	-725.MV *	820.MV
3	591.MV	660.MV	-680.MV *	-750.MV *	-690.MV *	875.MV
4	593.MV	670.MV	-670.MV *	-735.MV *	-685.MV *	880.MV
5	588.MV	670.MV	720.MV	-675.MV *	825.MV	850.MV
6	592.MV	675.MV	730.MV	855.MV	860.MV	850.MV

Device M 54HC00 HCMOS QUAD 2-INPUT NAND GATES
Manufacturer ST Date 9 jul 91
Lot 9123

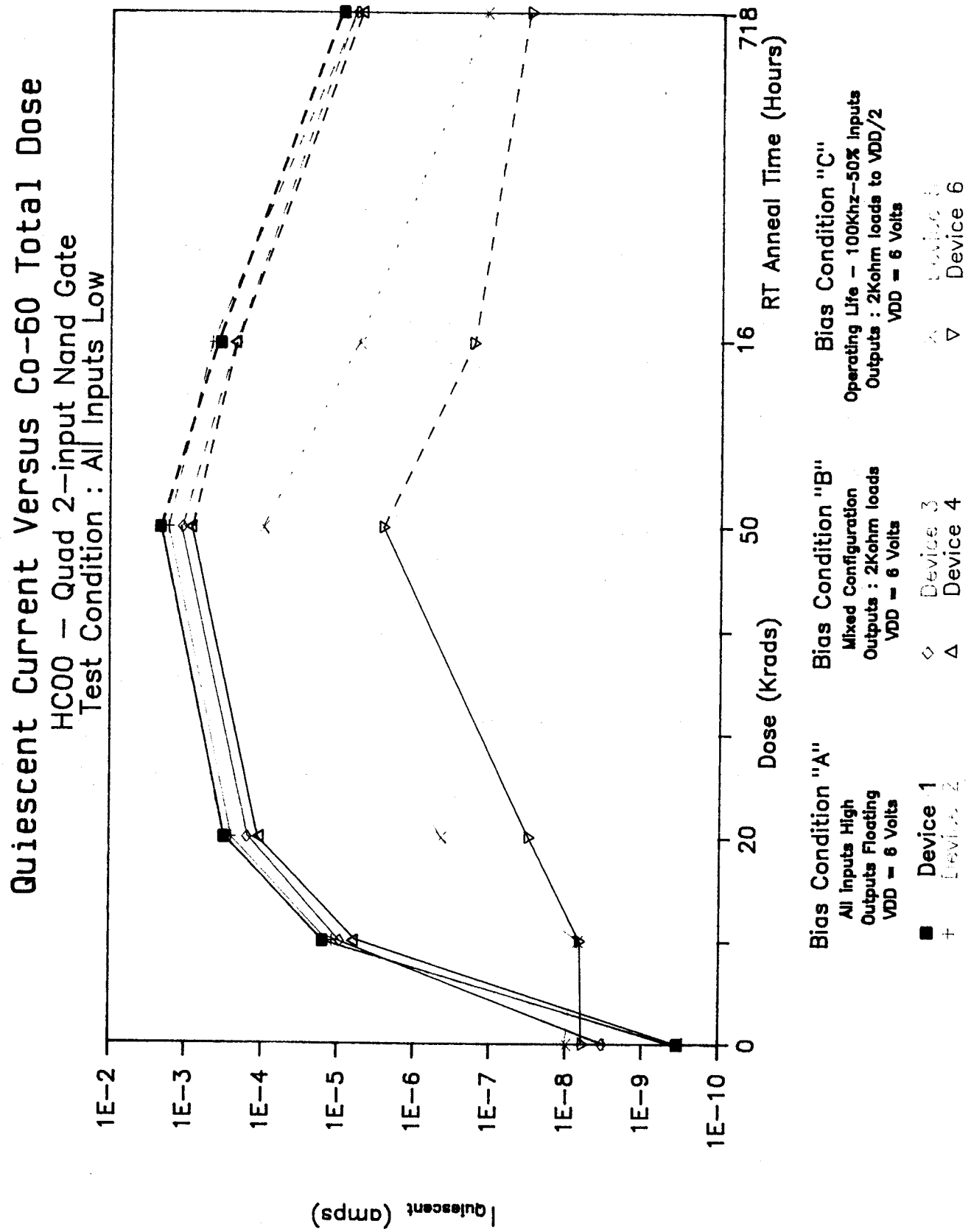
Quiescent Current with all inputs low (limit = 100nA)

	Radiation dose					
Ser.	0k	10k	20k	50k	50k 16 h ann.	50k 718 h
1	350.0PA	16.00UA *	2.160MA *	2.160MA *	351.5UA *	9.700UA *
2	3.150NA	12.60UA *	257.5UA *	1.690MA *	442.0UA *	6.550UA *
3	3.350NA	9.400UA *	159.5UA *	1.115MA *	215.5UA *	6.400UA *
4	350.0PA	6.400UA *	113.0UA *	875.0UA *	226.0UA *	5.600UA *
5	-9.55NA	-6.80NA	431.5NA *	96.50UA *	5.200UA *	120.0NA *
6	5.800NA	-6.40NA	30.40NA	2.540UA *	160.0NA *	30.35NA

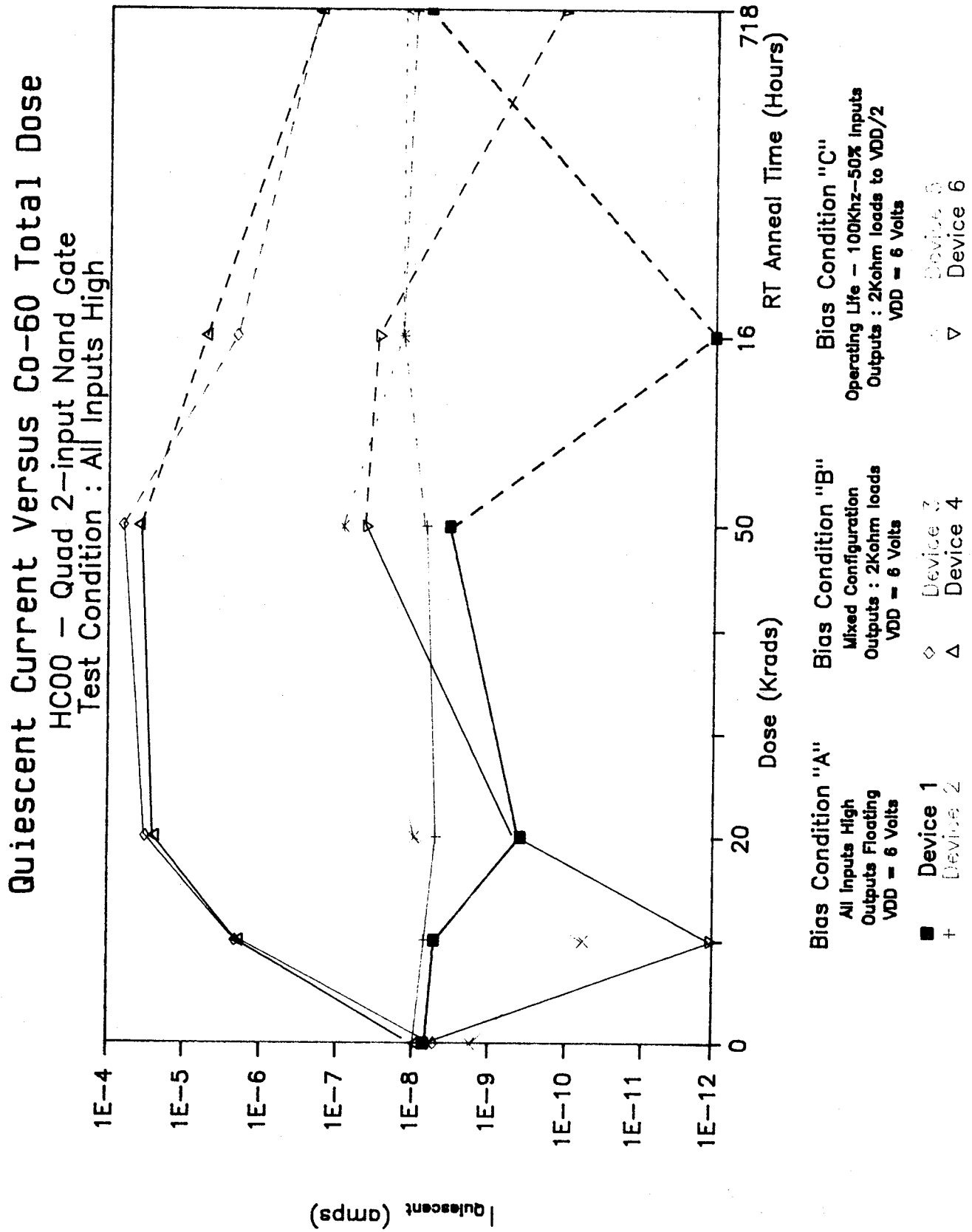
Quiescent Current with all inputs high (limit = 100nA)

	Radiation dose					
Ser.	0k	10k	20k	50k	50k 16 h ann.	50k 718 h
1	-6.400NA	-4.80NA	3.150NA	3.15NA	0.000 A	6.200NA
2	-8.850NA	-6.45NA	4.600NA	-6.40NA	12.80NA	9.600NA
3	-4.800NA	2.085UA *	32.00UA *	64.35UA *	2.075UA *	192.0NA *
4	8.550NA	1.920UA *	24.80UA *	39.95UA *	5.200UA *	176.0NA *
5	1.550NA	-50.0PA	8.800NA	80.00NA	12.80NA	12.85NA
6	-6.450NA	0.000 A	350.0PA	38.10NA	25.55NA	-100.PA

Graphic plot of the **Quiescent Current** with all inputs low.



Graphic plot of the **Quiescent Current** with all inputs high.



M 54HC00 HCMOS QUAD 2-INPUT NAND GATES

MANUFACTURER	ST	DATE	09 JUL 91
SERIAL	1	TIME	17:17:03
LOT	9123	RADIATION DOSE	50K

CURRENT: -10.0UA - 10.0UA LIMITS ACTUAL

THRESHOLD VOLTAGE N-CHANNEL A1: -450.MV <--> -1.45 V -1.28 V
THRESHOLD VOLTAGE P-CHANNEL A1: 450.MV <--> 1.35 V -785.MV <==

	VIC-		VIC+	
LIMIT	400.MV	<-->	900.MV	ABSOLUTE LEVELS
CURRENT	100.UA		100.UA	
A1	-629.MV		663.MV	
A2	-629.MV		663.MV	
A3	-630.MV		668.MV	
A4	-629.MV		663.MV	
B1	-629.MV		667.MV	
B2	-630.MV		663.MV	
B3	-629.MV		675.MV	
B4	-629.MV		668.MV	

VCC : 2.00 V

	VOL	VOH
LIMIT	100.MV	1.90 V
CURRENT	20.0UA	-20.0UA
Y1	2.80MV	1.97 V
Y2	2.95MV	1.96 V
Y3	2.75MV	1.96 V
Y4	2.80MV	1.97 V

M 54HC00 HCMOS QUAD 2-INPUT NAND GATES

MANUFACTURER	ST	DATE	09 JUL 91
SERIAL	1	TIME	17:17:05
LOT	9123	RADIATION DOSE	50K

VCC : 2.00 V PROPAGATION DELAYS

	TPHL A	TPLH	TPHL B	TPLH
LIMIT	90.0NS	90.0NS	90.0NS	90.0NS
Y1	18.3NS	22.8NS	17.9NS	22.3NS
Y2	18.4NS	23.7NS	19.3NS	23.8NS
Y3	18.2NS	22.7NS	18.7NS	23.9NS
Y4	18.4NS	23.8NS	18.7NS	23.5NS

	TTHL	TTLH
LIMIT	75.0NS	75.0NS
Y1	10.5NS	14.0NS
Y2	11.0NS	15.0NS
Y3	11.5NS	15.0NS
Y4	12.0NS	15.0NS

400.MV IS ADDED TO VOL1 AND 400.MV IS DEDUCTED FROM VOH1

VIL 300.MV VIH 1.50 V VOL 500.MV VOH 1.50 V

FUNCTIONAL TEST PASSED ** TOTAL ERRORS : 1 **

M 54HC00 HCMOS QUAD 2-INPUT NAND GATES

MANUFACTURER	ST	DATE	09 JUL 91
SERIAL	1	TIME	17:17:06
LOT	9123	RADIATION DOSE	50K

VCC : 4.50 V

	VOL1	VOH1	VOL2	VOH2
LIMIT	100.MV	4.40 V	260.MV	3.98 V
CURRENT	20.0UA	-20.0UA	4.00MA	-4.00MA
Y1	2.00MV	4.49 V	104.MV	4.36 V
Y2	1.90MV	4.48 V	102.MV	4.35 V
Y3	2.20MV	4.48 V	101.MV	4.35 V
Y4	2.35MV	4.49 V	102.MV	4.36 V

VCC : 4.50 V PROPAGATION DELAYS

	TPHL A	TPLH	TPHL B	TPLH
LIMIT	18.0NS	18.0NS	18.0NS	18.0NS
Y1	8.35NS	9.00NS	7.80NS	8.75NS
Y2	8.00NS	9.15NS	8.75NS	9.55NS
Y3	7.80NS	8.75NS	8.15NS	9.30NS
Y4	7.90NS	9.45NS	8.20NS	9.40NS

	TTHL	TTLH
LIMIT	15.0NS	15.0NS
Y1	5.00NS	5.50NS
Y2	5.50NS	6.00NS
Y3	6.00NS	6.50NS
Y4	6.00NS	7.00NS

400.MV IS ADDED TO VOL1 AND 400.MV IS DEDUCTED FROM VOH1

VIL 900.MV VIH 3.15 V VOL 500.MV VOH 4.00 V

FUNCTIONAL TEST PASSED ** TOTAL ERRORS : 0 **

M 54HC00 HCMOS QUAD 2-INPUT NAND GATES

MANUFACTURER	ST	DATE	09 JUL 91
SERIAL	1	TIME	17:17:09
LOT	9123	RADIATION DOSE	50K

VCC : 6.00 V

	VOL1	VOH1	VOL2	VOH2
LIMIT	100.MV	5.90 V	260.MV	5.48 V
CURRENT	20.0UA	-20.0UA	5.20MA	-5.20MA
Y1	2.10MV	5.98 V	107.MV	5.84 V
Y2	2.10MV	5.97 V	106.MV	5.84 V
Y3	2.15MV	5.97 V	104.MV	5.84 V
Y4	2.10MV	5.98 V	105.MV	5.85 V

INPUT-LEAKAGE CURRENT LIMIT : 50.0NA

PIN	IILL	IILH	IIHL	IIHH
A1	0.00 A	-400.PA	1.60NA	1.40NA
A2	0.00 A	-100.PA	1.15NA	600.PA
A3	-400.PA	550.PA	1.00NA	1.00NA
A4	100.PA	100.PA	150.PA	0.00 A
B1	-150.PA	0.00 A	0.00 A	750.PA
B2	250.PA	0.00 A	150.PA	0.00 A
B3	50.0PA	150.PA	400.PA	800.PA
B4	0.00 A	0.00 A	350.PA	350.PA

QUIESCENT CURRENT - ALL INPUTS HIGH : 3.150NA LIMIT : 100.NA
QUIESCENT CURRENT - ALL INPUTS LOW : 2.160MA LIMIT : 100.NA <==

M 54HC00 HCMOS QUAD 2-INPUT NAND GATES

MANUFACTURER	ST	DATE	09 JUL 91
SERIAL	1	TIME	17:17:14
LOT	9123	RADIATION DOSE	50K

VCC : 6.00 V PROPAGATION DELAYS

	TPHL A	TPLH	TPHL B	TPLH
LIMIT	15.0NS	15.0NS	15.0NS	15.0NS
Y1	6.55NS	8.65NS	6.20NS	8.30NS
Y2	6.30NS	8.60NS	6.95NS	9.10NS
Y3	6.55NS	7.75NS	6.75NS	8.20NS
Y4	6.70NS	8.20NS	6.85NS	8.25NS

	TTHL	TTLH
LIMIT	13.0NS	13.0NS
Y1	3.50NS	5.00NS
Y2	4.50NS	6.00NS
Y3	4.00NS	6.00NS
Y4	4.00NS	6.50NS

400.MV IS ADDED TO VOL1 AND 400.MV IS DEDUCTED FROM VOH1

VIL 1.20 V VIH 4.20 V VOL 500.MV VOH 5.50 V

FUNCTIONAL TEST PASSED ** TOTAL ERRORS : 1 **