PPM-93-62

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Paramax Systems
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PARAMAX
A Unisys Company

Memorandum

PPM-93-062

DATE: June 15, 1993
TO: A. Sharma/311.0
FROM: K. Sahu/300.1
SUBJECT: Radiation Report on TRMM/GPEP
Part No. MQ80386-20 (80386 µP)
Control No. 7387

cc: B. Fafaul/311.1
Library/300.1 ✓

A radiation evaluation was performed on MQ80386-20 (Microprocessor) to determine the total dose tolerance of these parts. A brief summary of the test results is provided below. For detailed information, refer to Tables I through VI and Figure 1.

The total dose testing was performed using a cobalt-60 gamma ray source. During the radiation testing, four parts were irradiated under bias (see Figure 1 for bias configuration), and one part was used as a control sample. The total dose radiation levels were 2.5, 5 and 7.5 krads*. After 7.5 krads, parts were annealed at 25°C in five steps: 48 hours, 168 hours (cumulative), 330 hours (cumulative), 525 hours (cumulative) and 1200 hours (cumulative). The dose rate was between 0.04 and 0.06 krads/hour, depending on the total dose level (see Table II for radiation schedule). After each radiation exposure and annealing treatment, parts were electrically tested according to the test conditions and the specification limits** listed in Table IIIa and IIIb. These tests included four functional tests, three at 8 MHz and one at 16 MHz. Functional vactors for this testing were obtained from Intel and consist of 374 vector files with approximately 888,450 test vectors. Details of functional test conditions and procedure are provided in Table IV.

All five parts passed initial (pre-rad) electrical tests. All four irradiated parts passed all electrical tests at each irradiation level up to and including the 5-krad irradiation. After the 7.5-krad irradiation, all four irradiated parts failed all four functional tests and a number of VOH and VOL tests. All parts continued to fail all four functional tests and a number of VOH and VOL tests throughout all subsequent annealing steps.

Table V provides a summary of the functional test results, as well as the mean and standard deviation values for each parameter after different irradiation exposures and annealing steps. For more details on the functional test procedures and test results, refer to Table VI.

Any further details about this evaluation can be obtained upon request. If you have any questions, please call me at (301) 731-8954.

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*The term rads, as used in this document, means rads(silicon). All radiation levels cited are cumulative.

**These are manufacturers' non-irradiated data specification limits. No post-irradiation limits were provided by the manufacturer at the time these tests were performed.

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TABLE I. Part Information

Generic Part Number:	80386
Part Number:	MQ80386-20*
TRMM/GPEP Control Number:	7387
Charge Number:	C33213
Manufacturer:	Intel
Lot Date Code:	9048
Quantity Tested:	5
Serial Numbers of Radiation Samples:	761, 762, 764, 765
Serial Number of Control Sample:	760
Part Function:	Microprocessor
Part Technology:	CHMOS IV
Package Style:	164-pin Flat Pack
Test Equipment:	S-50
Test Engineer:	J. Lander

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* No radiation tolerance/hardness was guaranteed by the manufacturer for this part.

TABLE II. Radiation Schedule for 80386

EVENTS	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	03/22/93
2) 2.5 KRAD IRRADIATION (0.06 KRADS/HOUR)	03/29/93
POST-2.5 KRAD ELECTRICAL MEASUREMENT	03/31/93
3) 5 KRAD IRRADIATION (0.06 KRADS/HOUR)	03/31/93
POST-5 KRAD ELECTRICAL MEASUREMENT	04/02/93
4) 7.5 KRAD IRRADIATION (0.04 KRADS/HOUR)	04/02/93
POST-7.5 KRAD ELECTRICAL MEASUREMENT	04/05/93
5) 48 HOUR ANNEALING @25°C (#1)	04/05/93
POST-48 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/07/93
6) 168 HOUR ANNEALING @25°C (#2)	04/07/93
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/12/93
7) 330 HOUR ANNEALING @25°C (#3)	04/12/93
POST-330 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/19/93
8) 525 HOUR ANNEALING @25°C (#4)	04/20/93
POST-525 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/27/93
9) 1200 HOUR ANNEALING @25°C (#5)	04/27/93
POST-1200 HOUR ANNEAL ELECTRICAL MEASUREMENT	05/27/93

ALL ELECTRICAL MEASUREMENTS WERE PERFORMED AT 25°C.

PARTS WERE IRRADIATED AND ANNEALED UNDER BIAS; SEE FIGURE 1.

Table IIIa. MQ80386-20 Test Attributes

FUNCTIONAL TESTS 1/,2/

Test Name	VCC	VIL	VIH	CONDITIONS	PINS	LIMITS
Functional # 1	4.75V	0.80V	4.75V	Freq = 8.0MHz	All Pins	VOL≤1.5V , VOH≥1.5V
Functional # 2	5.25V	0.00V	2.00	Freq = 8.0MHz	All Pins	VOL≤1.5V , VOH≥1.5V
Functional # 3	5.00V	0.00V	5.00V	Freq = 16.0MHz	All Pins	VOL≤1.5V , VOH≥1.5V
Functional # 4	5.00V	0.00V	5.00V	Freq = 8.0MHz	All Pins	VOL≤1.5V , VOH≥1.5V

D.C. PARAMETRICS

Test Name	VCC	VIL	VIH	CONDITIONS	PINS	LIMITS
(Output Low Voltage) VOL1 VOL2 VOL3	4.75V 4.75V 4.75V	0.00V 0.00V 0.00V	4.75V 4.75V 4.75V	IOL = +4.0mA IOL = +4.0mA IOL = +5.0mA	A2-A31 D0-D31 Other Outputs	≥0.00V , ≤0.45V
(Output High Voltage) VOH1 VOH2 VOH3	4.75V 4.75V 4.75V	0.00V 0.00V 0.00V	4.75V 4.75V 4.75V	IOH = -1.0mA IOH = -1.0mA IOH = -0.9mA	A2-A31 D0-D31 Other Outputs	≥2.40V , ≤4.75V
IIH1 (Input HIGH Leakage)	5.25V	0.00V	5.25V	Vin = VCC	All Input Pins Except : BS16#, PEREQ, BUSY#, ERROR#	≥-0.00µA , ≤+15.0µA
IIH2 (Input HIGH Leakage)	5.25V	0.00V	5.25V	Vin = VCC	PEREQ	≥-0.00µA , ≤+200µA
IIL1 (Input LOW Leakage)	5.25V	0.00V	5.25V	Vin = GND	All Input Pins Except : BS16#, PEREQ, BUSY#, ERROR#	≥-15.0µA , ≤+0.00µA
IIL2 (Input LOW Leakage)	5.25V	0.00V	5.25V	Vin = GND	BS16#, BUSY# and ERROR#	≥-400µA , ≤+0.00µA
IOZH (ILO High) (Output Leakage)	5.25V	0.00V	5.25V	Vout = 5.25V	Hi-Z Output Pins	≥-15.0µA , ≤+15.0µA
IOZL (ILO Low) (Output Leakage)	5.25V	0.00V	5.25V	Vout = 0.45V	Hi-Z Output Pins	≥-15.0µA , ≤+15.0µA
ICC @ 8MHZ 3/ (Dynamic Vcc Current)	5.25V (CPU running at 8MHz)	0.00V	5.25V	CLK2 = 16MHz	VCC Pin	≥+0.0mA , ≤+230mA
ICC1 @ 16MHZ (Dynamic Vcc Current)	5.25V (CPU running at 16MHz)	0.00V	5.25V	CLK2 = 32MHz	VCC Pin	≥+0.0mA , ≤+460mA
ICC2 @ 20MHZ (Dynamic Vcc Current)	5.25V (CPU running at 20MHz)	0.00V	5.25V	CLK2 = 40MHz	VCC Pin	≥+0.0mA , ≤+550mA

COMMENTS AND EXCEPTIONS

(1) Functional Vectors obtained from Intel Corp. consist of 374 Vector Files with approximately 888,450 Test Vectors. For details of functional test conditions and procedures, see Table IV.

(2) VIL & VIH tests are performed GO/NOGO during Functional #1 & #2, respectively.

(3) Limit for ICC @ 8MHZ was estimated from ICC1 @ 16MHZ since it was not specified by the Mfr.

Table IIIb. MQ80386-20 Timing Test Attributes 1/

Timing Parameter Description	Symbol	Specification Limit	Actual Value used during Functional # 3 @ 16 MHz	Actual Value used during Functional # 4 @ 8 MHz
CLK2 Period	t1	≥ 25nS	31.0nS	62.5nS
CLK2 High Time @ (Vcc-0.8V)	t2b	≥ 5nS	5.0nS	10.0nS
CLK2 Low Time @ 0.8V	t3b	≥ 5nS	5.0nS	10.0nS
CLK2 Fall Time	t4	≤ 8nS	3.5nS	3.5nS
CLK2 Rise Time	t5	≤ 8nS	3.5nS	3.5nS
NA# Setup Time	t15	≥ 9nS	44.0nS	17.0nS
NA# Hold Time	t16	≥ 14nS	14.0nS	18.0nS
BS16# Setup Time	t17	≥ 13nS	44.0nS	17.0nS
BS16# Hold Time	t18	≥ 21nS	23.0nS	28.0nS
READY# Setup Time	t19	≥ 12nS	13.0nS	15.0nS
READY# Hold Time	t20	≥ 4nS	45.0nS	5.0nS
D0-D31 Setup Time	t21	≥ 11nS	13.0nS	15.0nS
D0-D31 Hold Time	t22	≥ 6nS	45.0nS	95.0nS
HOLD Setup Time	t23	≥ 17nS	18.0nS	20.0nS
HOLD Hold Time	t24	≥ 5nS	45.0nS	5.0nS
RESET Setup Time	t25	≥ 12nS	13.0nS	15.0nS
RESET Hold Time	t26	≥ 4nS	45.0nS	75.0nS
NMI, INTR Setup Time	t27	≥ 16nS	44.0nS	17.0nS
NMI, INTR Hold Time	t28	≥ 16nS	18.0nS	18.0nS
PEREQ, ERROR#, BUSY# Setup Time	t29	≥ 14nS	13.0nS	15.0nS
PEREQ, ERROR#, BUSY# Hold Time	t30	≥ 5nS	45.0nS	10.0nS

1/ AC Parameters were tested GO/NOGO during functional tests #3 and #4 using the "Gross" Timing Parameters shown above.

Table IV. Functional Test Conditions and Procedures 1/,2/,3/,4/,5/

Functional Test Number	Vcc Voltage	Input Low Voltage (VIL)	Input High Voltage (VIH)	Frequency (MHz)	Pattern File Block Size
#1	4.75V	0.80V	4.75V	8.0 MHz	1
#2	5.25V	0.00V	2.00V	8.0 MHz	1
#3	5.00V	0.00V	5.00V	16.0 MHz	15
#4	5.00V	0.00V	5.00V	8.0 MHz	15

Notes

1/ Vcc Supply Voltage: This parameter is the operating DC supply voltage. This device is rated at 5.00V +/- 5% (i.e, 4.75V to 5.25V)

2/ Input LOW Voltage (VIL): This parameter is the maximum voltage level at the inputs that can be interpreted as a logical LOW or '0'. The value of 0.00V or GND is usually called a 'Hard' Zero.

3/ Input HIGH Voltage (VIH): This parameter is the minimum voltage level at the inputs that can be interpreted as a logical HIGH or '1'. The value of 4.75V or VCC is usually called a 'Hard' One.

4/ Test Frequency (MHz): This parameter is the input Clock rate at which the part is being tested. The Clock cycle lasts for 125 nS at 8-MHz and 62.5 nS at 16-MHz.

5/ Pattern File Block Size: It is neccessary to describe how the functional tests are being performed before explaining this parameter. The four (4) functional tests verify different characteristics of the device-under-test (DUT). The purpose of functional #1 and #2 is to test the VIL and VIH parameters, respectively. These parameters are tested separately. The functional tests #3 and #4 verify full functionality of the DUT at 16-MHz and 8-MHz, respectively. A full functional test consists of 374 pattern vector files. These pattern files contain a total of 888,452 functional test vectors. The DUTs are tested using groups of 15 files at a time. These groups are called 'Blocks of files'. After every block is completed, it is then determined if the testing will continue to the next block of 15 files. When the DUT fails any vector file, it is neccessary to abort the testing of the following vector files of the same functional test, because the results are no longer meaningful.

For the case of functional #1 and #2, only one (1) pattern is tested because our only interest is in the ability of the part to detect VIL & VIH voltages. On the other hand, for functional #3 and #4 (full functionals), the block size is set to 15 pattern files at a time. The functional testing will stop if the DUT fails any test vector in any of those pattern files. These pattern files contain different numbers of vectors. Some files contain approximately 100 to 1000 vectors, but others could have from 2000 to 5000 vectors. A part is considered a failure even if it only fails one single test vector. The location of the failed vector within the pattern file does not provide enough data to determine the severity of the failure, or as a way to compare one part to another. This means that it is very difficult to determine if any functional recovery from irradiation is observed.

TABLE V: Summary of Electrical Measurements After Total Dose Exposures and Annealing for MQ80386-20 1/

		Spec. Lim./2		Total Dose Exposure (TDE) (krads)								Anneal 1		Anneal 2		Anneal 3		Anneal 4		Anneal 5	
				Initial		2.5		5		7.5		48 hrs. @25°C		168 hrs @25°C		330 hrs @25°C		525 hrs @25°C		1200 hrs @25°C	
Parameters		min	max	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
FUNC1, 8 MHz, 4.75 V				PASS		PASS		PASS		FAIL		1P3F		1P3F		1P3F		1P3F		1P3F	
FUNC2, 8 MHz, 5.25 V				PASS		PASS		PASS		FAIL		FAIL		FAIL		FAIL		FAIL		FAIL	
FUNC3, 16 MHz, 5.00 V				PASS		PASS		PASS		FAIL		FAIL		FAIL		FAIL		FAIL		FAIL	
FUNC4, 8 MHz, 5.00 V				PASS		PASS		PASS		FAIL		FAIL		FAIL		FAIL		FAIL		FAIL	
VOL1*	mV	0	450	89.5	9.3	89.1	8.4	88.7	7.8	FAIL		FAIL		FAIL		FAIL		FAIL		FAIL	
VOL2*	mV	0	450	117	1.6	117	1.5	117	1.9	FAIL		FAIL		FAIL		FAIL		FAIL		FAIL	
VOL3*	mV	0	450	111	12	111	11	111	12	FAIL		FAIL		FAIL		FAIL		FAIL		FAIL	
VOH1	V	2.4	4.75	4.71	0	4.71	0	4.71	0	FAIL		FAIL		4.67	.42	4.71	0	4.71	0	4.67	.42
VOH2*	V	2.4	4.75	3.23	.03	3.23	.03	3.25	.03	FAIL		FAIL		FAIL		FAIL		FAIL		FAIL	
VOH3*	V	2.4	4.75	4.71	0	4.71	0	4.71	0	FAIL		FAIL		FAIL		FAIL		FAIL		FAIL	
IIH1	uA	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IIH2	uA	0	200	52.2	.77	52.7	.68	53.3	.70	55.4	.55	54.9	.74	54.3	.74	54.4	.58	54.5	.52	54.5	.65
IIL1	uA	-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IIL2	uA	-400	0	-101	31	-100	31	-100	31	-101	31	-100	31	-99	31	-100	31	-100	31	-100	31
IOZH	uA	-15	15	0	0	0	0	0	0	0	0	**	**	0	0	0	0	0	0	0	0
IOZL	uA	-15	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ICC 8MHZ	mA	0	230	91.0	3.8	91.7	2.8	93.4	2.3	96.4	4.1	95.9	3.4	95.5	4.2	98.0	4.6	98.1	7.8	98.7	5.1
ICC16MHZ	mA	0	450	150	6.2	142	6.3	151	8.2	156	8.2	159	7.0	156	8.7	149	15	157	3.5	156	3.7
ICC20MHZ	mA	0	550	186	3.0	190	5.0	190	2.3	190	7.5	191	9.4	192	4.4	189	3.1	187	5.9	190	3.3

1/ The mean and standard deviation values were calculated over the four parts irradiated in this testing. The control sample remained constant throughout the testing and is not included in this table.

2/ These are manufacturers' non-irradiated data sheet specification limits. No post-irradiation limits were provided by the manufacturer at the time the tests were performed.

*After 7.5 krads, all parts failed a number of VOH and VOL tests. These failures were due to the output pins not being in the anticipated state due to functional failures of the parts.

**No reliable data were available at this point.

Radiation-sensitive parameters were VOL1, VOL2, VOL3, VOH2 and VOH3.

Table VI. RADIATION FAILURE SUMMARY

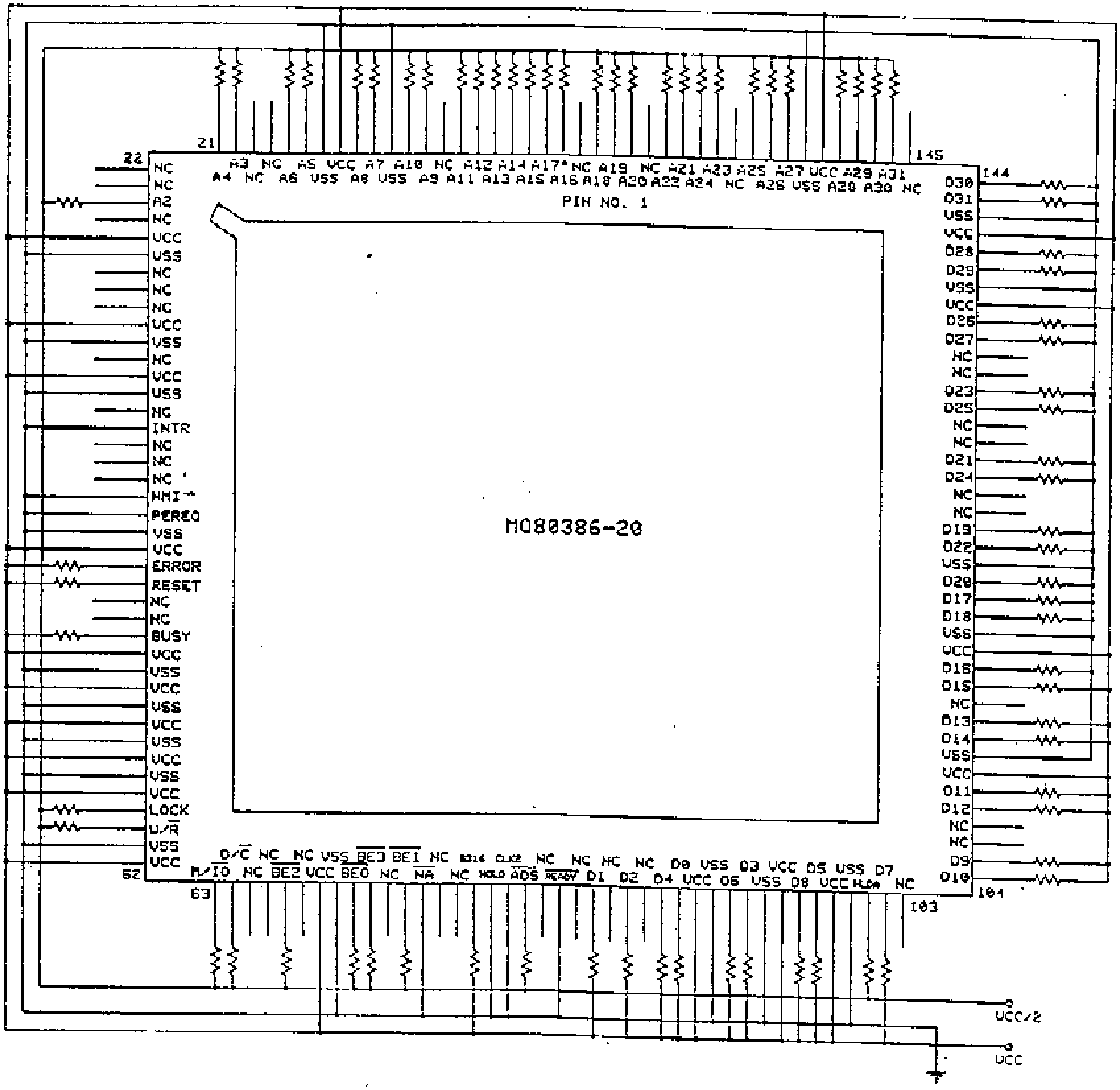
			1ST FAILING VECTOR FILE ENCOUNTERED AT			
TEST NAME	FAILURE DESCRIPTION 1/		F1	F2	F3	F4 2/
Post 7.5Krads Electrical Measurements	S/N : 761	Failed 4 functional tests and 119 DC tests.	* NOT AVAILABLE *			
	S/N : 762	Failed 4 functional tests and 103 DC tests.	* NOT AVAILABLE *			
	S/N : 764	Failed 4 functional tests and 78 DC tests.	* NOT AVAILABLE *			
	S/N : 765	Failed 4 functional tests and 72 DC tests.	* NOT AVAILABLE *			
48 Hrs Annealing #1 Electrical Measurements	S/N : 761	Failed 4 functional tests and 150 DC tests.	1	1	3	1
	S/N : 762	Failed 4 functional tests and 103 DC tests.	1	1	8	1
	S/N : 764	Failed 4 functional tests and 80 DC tests.	1	1	2	1
	S/N : 765	Failed 3 functional tests and 72 DC tests.	PASS	1	8	1
168 Hrs Annealing #2 Electrical Measurements	S/N : 761	Failed 4 functional tests and 103 DC tests.	1	1	1	1
	S/N : 762	Failed 4 functional tests and 102 DC tests.	1	1	8	1
	S/N : 764	Failed 4 functional tests and 80 DC tests.	1	1	1	1
	S/N : 765	Failed 3 functional tests and 72 DC tests.	PASS	1	8	1
330 Hrs Annealing #3 Electrical Measurements	S/N : 761	Failed 4 functional tests and 103 DC tests.	1	1	6	1
	S/N : 762	Failed 4 functional tests and 105 DC tests.	1	1	9	1
	S/N : 764	Failed 4 functional tests and 75 DC tests.	1	1	9	1
	S/N : 765	Failed 3 functional tests and 52 DC tests.	PASS	1	9	2
525 Hrs Annealing #4 Electrical Measurements	S/N : 761	Failed 4 functional tests and 102 DC tests.	1	1	6	1
	S/N : 762	Failed 4 functional tests and 103 DC tests.	1	1	15	1
	S/N : 764	Failed 4 functional tests and 75 DC tests.	1	1	9	1
	S/N : 765	Failed 3 functional tests and 44 DC tests.	PASS	1	9	1
1200 Hrs Annealing #5 Electrical Measurements	S/N : 761	Failed 4 functional tests and 101 DC tests.	1	1	9	1
	S/N : 762	Failed 4 functional tests and 102 DC tests.	1	1	73	1
	S/N : 764	Failed 4 functional tests and 99 DC tests.	1	1	21	1
	S/N : 765	Failed 3 functional tests and 16 DC tests.	PASS	1	156	9

Notes

1/ The failing DC tests were VOH and VOL tests. The tests are performed by using a functional pattern to bring the outputs to the correct logic state. When outputs are not able to reach the expected logic state, the part fails the VOH and VOL tests.

2/ This indicates whether the part failed the 1st vector file, or 2nd ... or the last one (374th) for each of the four functional test F1, F2, F3 and F4. e.g. For functional test #3, SN 765 failed the 8th vector file after 48 Hrs of annealing. However on annealing for 1200 Hrs, the part failed at vector file No. 156, indicating that it passed all other vector files 1 through 155. This indicates that a significant recovery took place for this functional test. However, no significant recovery was observed for functional test #2 and #4. The capability of the test program to determine which vector file is the first one to fail during each functional test was added after the first annealing. These results are therefore not available for post 7.5 Krad radiation exposure.

Figure 1. Radiation Bias Circuit for 80386



All resistor values = 2.2 kOhms ± 10%, 1/4 W

Vcc = +5.0 VDC ± 2.5 VDC