Bendix
Aerospace Systems Division

LEAM FAILURE MODE EFFECT AND CRITICALITY ANALYSIS

NO.	REV. NO.
ATM 977	

PAGE 1 OF 29

DATE 2-15-71

This ATM documents the Failure Mode Effect and Criticality Analysis of the LEAM experiment. The analysis reflects data available at the PDR.

This preliminary ATM will be updated at CDR.

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LEAM Reliability
Project Engineer

1.0 GENERAL

A failure mode, effect and criticality analysis (FMECA) is a prime tool utilized in evaluation of the reliability of an experiment. Its main purpose is to determine those potential failure modes associated with the design, occurrance of which could result in experimental failure. In accomplishing this function, it is desirable to provide a ranking of the criticality of each potential failure mode such that those of most significance can be given most attention in further evaluation and development of the experiments design.

The analysis covered in this report is intended to discover critical failure areas and present a possible means of removing the failure from the system, either by design or operation. The analysis highlights any single point failures, that is, a failure that could fail the whole instrument, not just a small portion of it. The analysis is performed at two levels.

1. System level.
2. Block level.

For analysis at system level, a failure of a "Block" of the system is assumed and the effect of this failure is related to the system. For block level analysis, failure of a component part of the block is assumed and the effect of this failure is related to that block.

1.1 Criticality Ranking

The following four categories are used to identify the criticality of the failure.

CR1 - A failure that results in the loss of 100% of the expected data.

CR2 - A failure that results in the loss of more than 50% of the expected data but less than 100%.

CR3 - A failure that results in the loss of less than 50% of the expected data.

CR4 - A failure that results in no data loss.

1.2 Single Point Failures

Any failure that results in the loss of 50% or more of the expected data is defined as a single point failure. All single point failures fall into the criticality ranking 1 and 2. All the failures that fall into this category shall be reviewed and, if possible, corrective action or alternate mode of operation shall be instituted to minimize the loss. All single point failures are listed on page 6 and 7 , items 1 through 13.

1.3 Failure Probability

There are three factors contributing towards the failure of a part - open, short or drift. Each factor contributes to the overall failure rate and can be represented by the formula:

$$\lambda = \lambda \text{ open} + \lambda \text{ short} + \lambda \text{ drift}$$

In certain analysis, such as the failure mode and effects analysis, the catastrophic factor, opens and shorts are considered in the analysis. Drift, that is change due to life is not a factor in this type of analysis, although prolonged drift usually results in a catastrophic failure of the part.

The value of failure probability is calculated as follows:

Failure Probability = Q

$Q = 1 - e^{-\alpha \lambda T}$, where α is the percentage of this type of failure, (open or short)

λ is bits of failure rate (1 bit = 10^{-8} failures/hour)

T is time of operation (17520 hours)

Table I shows the listing of the type of component parts, and the probability of various types of failure modes.

1.4 System Level Analysis

Pages 8 through 22 show listings of assumed failure modes of blocks of the system and its effect on the system output.

1.5 Block Level Analysis

Pages 23 through 29 show listings of assumed failure modes of component piece parts of the block and its effect on the block output. For this portion of the analysis, failures of components parts are selected from the following list:

Type Part	Failure
Resistors	Opens
Capacitors	Shorts
Diodes, w/o Whiskers	Shorts
Diodes, w/ Whiskers	Opens and Shorts
Transistors, Power	Shorts
Transistors, All Others	Opens and Shorts
Inductors	Opens
Transformers, Power	Shorts
Transformers, All Others	Opens and Shorts

1.6 Conclusions

The failure modes, effects and criticality analysis, has shown that there are 13 single point failures. All of these failures are in the elements that are in "Reliability" series with the whole experiment. For instance, the power supply subsystem; if this fails the whole experiment is lost. One way to overcome this loss is to use redundant power supplies. However, this is impractical since this will add to the size and weight of the system. Also, the design goal power requirement of 3.0 watts will not be achieved. The transmitter circuit (output buffer) is another critical element. It would appear that it could easily be made redundant, however, digital circuits do not lend themselves readily to redundancy. All these factors will be considered when the system is re-evaluated in order to minimuze the failures and increase the overall reliability.

TABLE I. Component Parts and the Probability of Various Failure Modes

Type of Component Part	α	λ Failures per 10^8 Hours	Failure probability Q x 10^5
Ceramic Capacitors			
CKR Type	0.02*	0.2	.0679865
	0.3ϕ	0.2	1.01998
Temp. Compensated	0.05	1.0	.849925
	0.2ϕ	1.0	3.39979
Mica (low voltage)	0.05*	0.1	.0849366
	0.2ϕ	0.1	.339933
Parylene	0.05*	2.0	1.69985
	0.3ϕ	2.0	10.1994
Solid Tantalum	0.05*	0.05	.0424683
	0.25ϕ	0.05	.212342
Foil Tantalum	0.10*	2.0	3.39979
	0.1ϕ	2.0	3.39979
Wet Tantalum	0.05*	1.0	.849925
	0.2ϕ	1.0	3.39979
Diode Signal (w/whisker)	0.3*	0.3	1.52998
	0.4ϕ	0.3	2.03997
Diode Signal (w/o whisker)	0.01*	0.2	.033909
	0.4ϕ	0.2	1.35992
Diode Rectifier	0.05*	1.0	.849925
	0.5ϕ	1.0	8.49925
Diode Zeners, LVA	0.3*	2.0	1.01994
	0.4ϕ	2.0	1.35991

TABLE I (CONT.)

Type of Component Part	L1 α	λ Failures per 10^8 Hours	Failure probability Q x 10^{-5}
MED Logic	0.4	1.0	6.79997
MED Linear	0.3	1.0	5.0999
Relay	0.4*	2.0	13.5991
	0.4ϕ	2.0	13.5991
Thermistors	0.4*	5.0	33.994
Resistors (all types except precision ww)	0.05*	0.04	0.0339
Transistors, small	0.2*	1.0	3.39979
	0.2ϕ	1.0	3.39979
Transistors, power	0.05*	10	8.49953
	0.9ϕ	10	152.883
Transformers, small	0.50*		
	0.50ϕ		
Transformers, large	0.05*		
	0.05ϕ		
Inductors	0.90*		
Saturable Reactors	0.6*		
Magnetic Amplifier	0.5*		
	0.3ϕ		

L1 Approximate proportion that fall into each category of catastrophic failures

*OPEN ϕ SHORT

T = 17520 Hours

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

SYSTEM: LEAM	PREPARED BY: A. Lakhani		REV.
END ITEM: Leam Blocks	DWG NO.		PAGE 6 of 29
ASSY: Associated Sub-Blocks	DWG NO.		DATE 2/2/71

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY ICR
		ASSEMBLY	END ITEM		
1. Output Buffer	No output	No data out	Total loss of experiment	7.008	1
2. 330Ω Resistor R28	Open	No data out	Total loss of experiment	.03504	1
3. C19 Capacitor	Shorted	No data out	Total loss of experiment	.07008	1
4. Power Supply Subsystem	(a) Failure of ±5v output	No ±5v output	Total loss of experiment	--	1
	(b) Failure of ±12v output	No ±12v output	Total loss of experiment	--	1
	(c) Total failure of pwr. sol.	All power supply output fail	Total loss of experiment	2016.552	1
5. Squib Drive Subs	Squibs do not fire	Squib driver subsystem fails	Total loss of experiment	164.44	1
6. 25 KHz Oscillator	No output	Loss of control logic clocks	Total loss of experiment	151.723	1
7. Heater Control Subsystem	Inoperative	Loss of heater control operation	Total loss of experiment (In lunar night the foam epoxy will shrink and will crack boards, assembly and piece parts.	1123.032	1
8. Shift Clock and demand pulse receiver gate.	No output	Loss of shift register clock	Total loss of experiment	7.008	1
9. R25, R26 Resistor	Open	Loss of shift register clock	Total loss of experiment	.03504	1
10. C16, C17 Capacitor	Short	Loss of shift register clock	Total loss of experiment	.07008	1
11. Frame Mark pulse circuit	No output	Loss of frame mark pulses	Total loss of experiment	7.008	1

SYSTEM	PREPARED BY	REV.
LEAM	A. Lakhani	-
END ITEM	DWG NO.	PAGE 7 of 29
LEAM Blocks		
ASSY Associated Sub-Blocks	DWG NO.	DATE

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
12. Shift Clock and demand pulse circuitry	No output from gate G25 (signal 3513)	Loss of word 1 thru 5 shift register clocks	Loss of more than 50% of the experiment	7.008	2
13. Frame counter	Flip Flop CO inoperative	Loss of frame co nter data	Loss of more than 50% of the experiment	7.008	2

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

SYSTEM: Bendix LL	PREPARED BY: A. Lakhani		REV.
END ITEM: Central Electronics	DWG NO.		PAGE 8 of 29
ASSY: Data Mux. & Shift Clock Circuit	DWG NO.		DATE 2/2/71

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY Q x 10^{-5}	CRITICALITY CR
		ASSEMBLY	END ITEM		
Data Mux. Ckt.					
1. Word 1, 2 Gate	Incorrect Output	Word 1, 2 Output Fails	Loss of Word 1, 2	7.008	3
2. Word 3, 4 Gate	Incorrect Output	Word 3, 4 Output Fails	Loss of Word 3, 4	7.008	3
3. Word 5, 6 Gate	Incorrect Output	Word 5, 6 Output Fails	Loss of Word 5, 6	7.008	3
4. Word 7, 8 Gate	Incorrect Output	Word 7, 8 Output Fails	Loss of Word 7, 8	7.008	3
5. Word 9, 10 Gate	Incorrect Output	Word 9, 10 Output Fails	Loss of Word 9, 10	7.008	3
Shift Clock Ckt.					
6. Word 1, 2 Buffer Clock Gate	Incorrect Output	Loss of Word 1, 2, Shift Clk.	Loss of Word 1, 2	7.008	3
7. Word 3, 4 Buffer Clock Gate	Incorrect Output	Loss of Word 3, 4 Shift Clk.	Loss of Word 3, 4	7.008	3
8. Word 5, 6 Buffer Clock Gate	Incorrect Output	Loss of Word 5, 6 Shift Clk.	Loss of Word 5, 6	7.008	3
9. Word 7, 8 Buffer Clock Gate	Incorrect Output	Loss of Word 7, 8 Shift Clk.	Loss of Word 7, 8	7.008	3
10. Word 9, 10 Buffer Clock Gate	Incorrect Output	Loss of Word 9, 10 Shift Clk.	Loss of Word 9, 10	7.008	3

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

SYSTEM: LEAM	PREPARED BY: A. Lakhani		REV.
END ITEM: Central Electronics	DWG NO.	PAGE 9 of 29	
ASSY: Shift Register Ckt.	DWG NO.	DATE: 2/2/71	

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
11. Word 1, 2 Shift Register	No Output	Word 1, 2 Output Fails	Loss of Word 1, 2	140.160	3
12. Word 3, 4 Shift Register	No Output	Word 3, 4 Output Fails	Loss of Word 3, 4	140.160	3
13. Word 5, 6 Shift Register	No Output	Word 5, 6 Output Fails	Loss of Word 5, 6	140.160	3
14. Word 7, 8 Shift Register	No Output	Word 7, 8 Output Fails	Loss of Word 7, 8	140.160	3
15. Word 9, 10 Shift	No Output	Word 9, 10 Output Fails	Loss of Word 9, 10	140.160	3

SYSTEM	LEA	PREPARED BY	A. Lakha	REV.
END ITEM	Central Electronics	DWG NO.		PAGE 10 of 29
ASSY	Buffer Load Gates	DWG NO.		DATE

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
16. Front Film ID Buffer Load Gates	Incorrect Output	Front Film ID Signal(s) Incorrect	Loss of Front Film ID (1-4* Bits)	7.008	3
17. Front Film PHA Buffer Load Gate	Incorrect Output	Front Film PHA Signal(s) Incorrect	Loss of Front Film PHA (1-3 Bits)	7.008	3
18. Front Film Accum Buffer Load Gate	Incorrect Output	Front Film Accum. Signal(s) Incorrect	Loss of Front Film Accum. (1-3 Bits)	7.008	3
19. Rear Film ID Buffer Load Gate	Incorrect Output	Rear Film ID Signal(s) Incorrect	Loss of Rear Film ID (1-4 Bits)	7.008	3
20. Rear Film PHA Buffer Load Gates	Incorrect Output	Rear Film PHA Signal(s) Incorrect	Loss of Rear Film PHA (1-3 Bits)	7.008	3
21. Rear Film Accum. Buffer Load Gate	Incorrect Output	Rear Film Accum. Signal(s) Incorrect	Loss of Rear Accum. (1-3 Bits)	7.008	3
22. Front Collector ID Buffer Load Gate	Incorrect Output	Front Collector Signal(s)	Loss of Front Collector ID (1-4 Bits)	7.008	3
23. Mic PHA Buffer Load Gates	Incorrect Output	Mic Accum. Signal(s) Incorrect	Loss of Mic Accum (1-3 Bits)	7.008	3
24. Mic Accum. Buffer Load Gate	Incorrect Output	Mic Accum. Signal(s) Incorrect	Loss of Mic Accum. (1-3 Bits)	7.008	3
25. Rear Collector ID Buffer Load Gate	Incorrect Output	Rear Collector ID Signal(s) Incorrect	Loss of Rear Collector ID (1-4 Bits)	7.008	3
26. TOF Buffer Load Gates	Incorrect Output	TOF Signal(s) Incorrect	Loss of TOF (1-6 Bits)	7.008	3

SYSTEM	PREPARED BY	REV.
LEAM	A. Lakhani	-
END ITEM	DWG NO.	PAGE
Central Electronics		11 of 29
ASSY	DWG NO.	DATE
Buffer Load Gates		2/2/71

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY Q x 10^{-5}	CRITICALITY CR
		ASSEMBLY	END ITEM		
27. thru 37.	IDENTICAL TO 16 THRU 26 EXCEPT THAT THE FAILURE IS RELATED TO DUAL SENSOR 2				
38. Film ID (sen 2) Buffer Load Gates	Incorrect Output	Film ID Signal-Incorrect	Loss of Film ID (1-2 Bits)	7.008	3
39. Collector ID (Sen 3) Buffer Load Gate	Incorrect Output	Collector ID Signal Incorrect	Loss of Collector ID (1-2 Bits)	7.008	3
40. Film PHA (Sen 3) Buffer Load Gate	Incorrect Output	Film PHA Signal Incorrect	Loss of Film PHA (1-3 Bits)*	7.008	3
41. Film Accum (Sen 3) Buffer Load Gate	Incorrect Output	Film Accum. Signal Incorrect	Loss of Film Accum (1-3 Bits)	7.008	3
42. Noise Mic Accum (Sen 3) Buffer Load Gates	Incorrect Output	Noise Mic Accum. Signal Incorrect	Loss of Noise Mic Accum. (1-2 Bits)	7.008	3
43. Analog Data Sync (Sen 3) Buffer Load Gate	Incorrect Output	Analog Data Sync Signal	Loss of Analog Data Sync	7.008	3
44. Heater Status (Sen 3) Buffer Load Gate	Incorrect Output	Heater Status Signal Incorrect	Loss of Heater Status Signal	7.008	3
45. Main Mic PHA (Sen 3) Buffer Load Gate	Incorrect Output	Main Mic PHA Signal Incorrect	Loss of Main Mic PHA (1-3 Bits)	7.008	3
46. Main Mic Accum (Sen 3) Buffer Load Gates	Incorrect Output	Main Mic Accum. Signal Incorrect	Loss of Main Mic Accum (1-3 Bits)	7.008	3

* (1-3) is 1, 2, or 3.

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

SYSTEM LEA	PREPARED BY A. Lakhani		REV.
END ITEM Central Electronics	DWG NO.	PAGE 12 of 29	
ASSY Latch/Counter Ckt.	DWG NO.	DATE 2/2/71	

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
47. Front Film ID Latch	Incorrect Output	Front Film ID Signal Incorrect	Loss of Front Film ID (1-4 Bits)	7.008	3
48. Front Film PHA Counter					
(a) C401 Flip Flop	Incorrect Output	Front Film PHA Signal Inc.	Loss of Front Film PHA	7.008	3
(b) C402 Flip Flop	Incorrect Output	Front Film PHA Signal Inc.	Loss of 2 bits of Front Film PHA	7.008	3
(c) C403 Flip Flop	Incorrect Output	Front Film PHA Signal Inc.	Loss of 1 bit of Front Film PHA	7.008	3
49. Front Film Accum Counter					
(a) C404 Flip Flop	Incorrect Output	Front Film Accum. Signal Inc.	Loss of Front Film Accum.	7.008	3
(b) C405 Flip Flop	Incorrect Output	Front Film Accum. Signal Inc.	Loss of 2 bits of Front Film Accum.	7.008	3
(c) C406 Flip Flop	Incorrect Output	Front Film Accum. Signal Inc.	Loss of 1 bit of Front Film Accum.	7.008	3
50. Rear Film ID Latch	Incorrect Output	Rear Film ID Signal(s) Inc.	Loss of Rear Film (1-4 Bits)	7.008	3
51. Rear Film PHA Counter					
(a) C411 Flip Flop	Incorrect Output	Rear Film PHA Signal Inc.	Loss of Rear Film PHA	7.008	3
(b) C412 Flip Flop	Incorrect Output	Rear Film PHA Signal Inc.	Loss of 2 bits of Rear Film PHA	7.008	3
(c) C413 Flip Flop	Incorrect Output	Rear Film PHA Signal Inc.	Loss of 1 bit of Rear Film PHA	7.008	3
52. Rear Film Accum. Counter					
(a) C414 Flip Flop	Incorrect Output	Rear Film Accum. Signal Inc.	Loss of Rear Film Accum.	7.008	3
(b) C415 Flip Flop	Incorrect Output	Rear Film Accum. Signal Inc.	Loss of 2 bits of Rear Film Accum.	7.008	3
(c) C416 Flip Flop	Incorrect Output	Rear Film Accum. Signal Inc.	Loss of 1 bit of Rear Film Accum.	7.008	3

SYSTEM	PREPARED BY	REV.
LEA	A. Lakhani	
END ITEM: Central Electronics	DWG NO.	PAGE 13 of 29
ASSY: Latch/Counter Ckt.	DWG NO.	DATE: 2/2/71

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
53. Front Collector ID Latch	Incorrect Output	Front Collector Signal(s) Incorrect	Loss of Front Film Collector (1-4 Bits)	7.008	3
54. Mic PHA Counter					
(a) C433 Flip Flop	Incorrect Output	Mic PHA Signal Incorrect	Loss of Mic PHA	7.008	3
(b) C434 Flip Flop	Incorrect Output	Mic PHA Signal Incorrect	Loss of 2 bits of Mic PHA	7.008	3
(c) C435 Flip Flop	Incorrect Output	Mic PHA Signal Incorrect	Loss of 1 bit of Mic PHA	7.008	3
55. Mic Accum. Counter					
(a) C430 Flip Flop	Incorrect Output	Mic Accum. Signal Incorrect	Loss of Mic Accum.	7.008	3
(b) C431 Flip Flop	Incorrect Output	Mic Accum. Signal Incorrect	Loss of 2 bits of Mic Accum.	7.008	3
(c) C432 Flip Flop	Incorrect Output	Mic Accum. Signal Incorrect	Loss of 1 bit of Mic Accum.	7.008	3
56. TOF Counter					
(a) C421 Flip Flop	Incorrect Output	TOF Signal Incorrect	Loss of TOF	7.008	3
(b) C422 Flip Flop	Incorrect Output	TOF Signal Incorrect	Loss of 5 bits of TOF	7.008	3
(c) C423 Flip Flop	Incorrect Output	TOF Signal Incorrect	Loss of 4 bits of TOF	7.008	3
(d) C424 Flip Flop	Incorrect Output	TOF Signal Incorrect	Loss of 3 bits of TOF	7.008	3
(e) C425 Flip Flop	Incorrect Output	TOF Signal Incorrect	Loss of 2 bits of TOF	7.008	3
(f) C426 Flip Flop	Incorrect Output	TOF Signal Incorrect	Loss of 1 bit of TOF	7.008	3
57. THRU 66 SAME AS 47 THRU 56 EXCEPT THAT THE FAILURE IS RELATED TO DUAL SENSOR 2.					

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

SYSTEM LEAM	PREPARED BY A. Lakhani		REV.
END ITEM Central Electronics	DWG NO.	PAGE 14 of 29	
ASSY Sen. 3 Latch/Counter	DWG NO.	DATE	

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
67. Film ID Latch (Sen. 3)	Incorrect Output	Film ID Signal(s) Incorrect	Loss of Film IC (1-2 Bits)	7.008	3
68. Collector ID Latch (Sen. 3)	Incorrect Output	Collector ID Signal(s) Inc.	Loss of Collector ID (1-2 bits)	7.008	3
69. Film PHA Counter (Sen. 3)	Incorrect Output				
(a) C603 Flip Flop	Incorrect Output	Film PHA Signal Incorrect	Loss of Film PHA	7.008	3
(b) C604 Flip Flop	Incorrect Output	Film PHA Signal Incorrect	Loss of 2 bits of Film PHA	7.008	3
(c) C605 Flip Flop	Incorrect Output	Film PHA Signal Incorrect	Loss of 1 bit of Film PHA	7.008	3
70. Film Accum. Counter (Sen. 3)					
(a) C600 Flip Flop	Incorrect Output	Film Accum. Signal Inc.	Loss of Film Accum.	7.008	3
(b) C601 Flip Flop	Incorrect Output	Film Accum. Signal Inc.	Loss of 2 bits of Film Accum.	7.008	3
(c) C602 Flip Flop	Incorrect Output	Film Accum. Signal Inc.	Loss of 1 bit of Film Accum.	7.008	3
71. Noise Mic Accum Counter (Sen. 3)					
(a) C603 Flip Flop	Incorrect Output	Noise Mic Accum. Signal Inc.	Loss of Noise mic Accum.	7.008	3
(b) C631 Flip Flop	Incorrect Output	Noise Mic Accum. Signal Inc.	Loss of 1 bit of noise mic accum.	7.008	3

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

SYSTEM: LEAM	PREPARED BY: A. Lakha,		REV.
END ITEM: Central Electronics	DWG NO.		PAGE 15 of 29
ASS'Y: Sen. 3 Counter	DWG NO.		DATE

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
72. Analog Data Sync Ckt. (Sen. 3)	Incorrect Output	Loss of Analog Data Sync Signal		7.008	
73. Heater Status Ckt. (Sen. 3)	Incorrect Output	Loss of Heater Status Sig.	Status of the Heater Undeter.	7.008	3
74. Main Mic PHA Counter (Sen 3)					
(a) C623 Flip Flop	Incorrect Output	Main Mic PHA Sig. Incorrect	Loss of Main Mic PHA	7.008	3
(b) C624 Flip Flop	Incorrect Output	Main Mic PHA Sig. Incorrect	Loss of 2 bits of Main Mic PHA	7.008	3
(c) C625 Flip Flop	Incorrect Output	Main Mic PHA Sig. Incorrect	Loss of 1 bit of Main Mic PHA	7.008	3
75. Main Mic Accum. Counter (Sen 3)					
(a) C620 Flip Flop	Incorrect Output	Main Mic. Accum. Sig. Inc.	Loss of Main Mic. Accum.	7.008	3
(b) C621 Flip Flop	Incorrect Output	Main Mic. Accum. Sig. Inc.	Loss of 2 bits of Main Mic Accum.	7.008	3
(c) C622 Flip Flop	Incorrect Output	Main Mic. Accum. Sig. Inc.	Loss of 1 bit of Main Mic. Accum.	7.008	3

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

SYSTEM LEAM	PREPARED BY A. Lakhani		REV.
END ITEM Sens. Electronics	DWG NO.	PAGE 16 of 29	
ASSY Amplifier-Detector	DWG NO. Ckts.	DATE 2/12/71	

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
76. Front Film IC Pre-Amplifier Circuit	No Output	1/4 of Front Film ID Sig. Missiong	Loss of 1/4 of Front Film ID Incorrect TOF	19.4472	3
77. Front Film Analog Inhibit Circuit	No Output	1/4 of Front Film ID Sig. Missing	Loss of 1/4 of Front Film ID Incorrect TOF	19.4472	3
78. Front Film Tres-hold Det. Ckt.	No Output	1/4 of Front Film ID Sig. Missing	Loss of 1/4 of Front Film ID Incorrect TOF	83.5704	3
79. Front Film Sig. Inverter Gate	No Output	1/4 of Front Film ID Sig. Missing	Loss of 1/4 of Front Film ID Incorrect TOF	7.008	3
80. Front Film Logic Inhibit Gate	No Output	1/4 of Front Film ID Sig. Missing	Loss of 1/4 of Front Film ID Incorrect TOF	7.008	3
81. Front Film Summer Amplif.	No Output	Front Film PHA & Accum. Signals Missing	Loss of Front Film PHA & Accum.	6.72768	3
82. Summer Peak Detector	No Output	Front Film PHA & Accum. Signals Missing	Loss of Front Film PHA & Accum.	84.6216	3
83. Summer Threshold Detector	No Output	Front Film PHA & Accum. Signals Missing	Loss of Front Film PHA & Accum.	2.99592	3
84. Summer Signal Inverter GATE	No Output	Front Film PHA & Accum. Signals Missing	Loss of Front Film PHA & Accum.	7.008	3
85. Clock Sync Flip Flop	No Output	Front Film PHA & Accum. Signals Missing	Loss of Front Film PHA & Accum.	7.008	3

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LEAM	A. Lakhani	
END ITEM	DWG NO.	PAGE 17 of 29
Sen. Electronics		
ASSY	DWG NO.	DATE
Amplifier-Detector	Ckt.	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY Q x 10^{-5}	CRITICALITY CR
		ASSEMBLY	END ITEM		
86. Rear Film ID Preamplifier Ckt.	No Output	1/4 of Rear Film ID Sig. Inc.	Loss of 1/4 of Rear Film ID Incorrect TOF	19.4472	3
87. Rear Film Analog Inhibit Circuit	No Output	1/4 of Rear Film ID Sig. Inc.	Loss of 1/4 of rear Film ID Incorrect TOF	19.4472	3
88. Rear Film Treshold Detector Ckt.	No Output	1/4 of Rear Film ID Sig. Inc.	Loss of 1/4 of Rear Film ID Incorrect TOF	83.5704	3
89. Rear Film Signal Inverter Gate	No Output	1/4 of Rear Film ID Sig. Inc.	Loss of 1/4 of Rear Film ID Incorrect TOF	7.008	3
90. Rear Film Logic Inhibit Gate	No Output	1/4 of Rear Film ID Sig. Inc.	Loss of 1/4 of Rear Film ID Incorrect TOF	7.008	3
91. Rear Film Summer Amplifr.	No Output	Rear Film PHA & Accum. Signal Missing	Loss of Rear Film PHA & Accum.	6.72768	3
92. Summer Peak Detector	No Output	Rear Film PHA & Accum. Signal Missing	Loss of Rear Film PHA & Accum.	84.6216	3
93. Summer Threshold Detector	No Output	Rear Film PHA & Accum. Signal Missing	Loss of Rear Film PHA & Accum.	2.99592	3
94. Summer Signal Inverter Gate	No Output	Rear Film PHA & Accum. Signal Missing	Loss of Rear Film PHA & Accum.	7.008	3
95. Clock Sync Flip Flop	No Output	Rear Film PHA & Accum. Signal Missing	Loss of Rear Film PHA & Accum.	7.008	3

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
96. Front Collector ID Preamplifier	No Output	1/4 of Front Film & ID Signal Missing	Loss of 1/4 of Front Collector ID Incorrect TOF	19.4472	3
97. Front Collector Analog Inhibit Ckt.	No Output	1/4 of Front Film & ID Signal Missing	Loss of 1/4 of Front Collector ID Incorrect TOF	19.4472	3
98. Front Collector Threshold Det. Circuit	No Output	1/4 of Front Film & ID Signal Missing	Loss of 1/4 of Front Collector ID Incorrect TOF	83.5704	3
99. Front Collector Signal Inverter	No Output	1/4 of Front Film & ID Signal Missing	Loss of 1/4 of Front Collector ID Incorrect TOF	7.008	3
100. Front Collector Logic Inhibit Gate	No Output	1/4 of Front Film & ID Signal Missing	Loss of 1/4 of Front Collector ID Incorrect TOF	7.008	3
101. Mic Preampl.	No Output	Mic PHA & Accum. Signals Missing	Loss of Mic PHA & Accum.	37.3176	3
102. Band Pass Flt.	No Output	Mic PHA & Accum. Signals Missing	Loss of Mic PHA & Accum.	37.3176	3
103. Mic Peak Det.	No Output	Mic PHA & Accum. Signals Missing	Loss of Mic PHA & Accum.	37.3176	3
104. Mic Threshold Detector	No Output	Mic PHA & Accum. Signals Missing	Loss of Mic PHA & Accum.	37.3176	3
105. Mic Inverter Gates	No Output	Mic PHA & Accum. Signals Missing	Loss of Mic PHA & Accum.	7.008	3
106. Rear Collector ID Preamplifier	No Output	1/4 of Rear Collector ID Missing	Loss of 1/4 of Rear Collector ID	19.4472	3
107. Rear Collector Analog Inhibit Ckt.	No Output	1/4 of Rear Collector ID Missing	Loss of 1/4 of Rear Collector ID	19.4472	3

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Amplifier-Detector		

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
108. Rear Collector Threshold Detector	No Output	1/4 of Rear Collector ID Signal Missing	Loss of 1/4 of Rear Collector ID Loss of TOF	83.5704	3
109. Rear Collector Signal Inverter	No Output	1/4 of Rear Collector ID Signal Missing	Loss of 1/4 of Rear Collector ID. Loss of TOF	7.008	3
110. Rear Collector Logic Inhibit Gate	No Output	1/4 of Rear Collector ID Signal Missing	Loss of 1/4 of Rear Collector ID. Loss of TOF	7.008	3
111/TOF Circuit	No Output	Loss of TOF Signal	Loss of the measurement of transit time between the front and rear films		3
112. THRU 147. SAME AS 76 THRU 111 EXCEPT THAT THE FAILURE IS RELATED TO DUAL SENSOR 2					

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
148. Film ID Preamplifier (Sen. 3)	No Output	1/2 of Film ID Sig. Missing	Loss of 1/2 of Film ID	24.7032	3
149. Film Analog Inhibit Circuit (Sen. 3)	No Output	1/2 of Film ID S g. Missing	Loss of 1/2 of Film ID	24.7032	3
150. Film Threshold Detector (Sen. 3)	No Output	1/2 of Film ID Sig Missing	Loss of 1/2 of Film ID	24.7032	3
151. Film Signal Inverter (Sen. 3)	No Output	1/2 of Film ID Sig. Missing	Loss of 1/2 of Film ID	7.008	3
152. Film Logic Inhibit Gate (Sen. 3)	No Output	1/2 of Film ID Sig. Missing	Loss of 1/2 of Film ID	7.008	3
153. Collector ID Preamplifier (Sen. 3)	No Output	1/2 of Collector ID Sig. Ms.	Loss of 1/2 of Collector ID	24.7032	3
154. Collector Analog Inhibit Ckt. (Sen. 3)	No Output	1/2 of Collector ID Sig. Msg.	Loss of 1/2 of Collector ID	24.7032	3
155. Collector Threshold Det. (Sen. 3)	No Output	1/2 of Collector ID Sig. Msg.	Loss of 1/2 of Collector ID	7.00	3
156. Collector Sig. Inverter (Sen. 3)	No Output	1/2 of Collector ID Sig. Msg.	Loss of 1/2 of Collector ID	7.008	3
157. Collector Logic Inhibit Gate (Sen. 3)	No Output	1/2 of Collector ID Sig. Msg.	Loss of 1/2 of Collector Id	7.008	3
158. Film Summer Amplifier (Sen. 3)	No Output	Film PHA & Accum. Sig. Msg.	Loss of Film PHA & Accu.		3

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
159. Summer Peak Detector (Sen. 3)	No Output	Film PHA & Accu. Sig. Msg.	Loss of Film PHA & Accum.		3
160. Summer Threshold Detector (Sen. 3)	No Output	Film PHA & Accum. Sig. Msg.	Loss of Film PHA & Accum.		3
161. Summer Signal Inverter (Sen. 3)	No Output	Film PHA Accu. Sig. Msg.	Loss of Film PHA & Accum.	7.008	3
162. Clock Sync Flip Flop (Sen. 3)	No Output	Film PHA Accu. Sig. Msg.	Loss of Film PHA & Accum.	7.008	3
163. Noise Mic Preamplifier (Sen. 3)	No Output	Loss of Noise Mic Signal	Loss of Noise Mic Accum. Data	36.792	3
164. Band Pass Filter (Sen. 3)	No Output	Loss of Noise Mic Signal	Loss of Noise Mic Accum. Data		3
165. Noise Mic Peak Det. (Sen. 3)	No Output	Loss of Noise Mic Signal	Loss of Noise Mic Accum. Data		3
166. Noise Mic Threshold Det. (Sen 3	No Output	Loss of Noise Mic Signal	Loss of Noise Mic Accum. Data	42.048	3
167. Noise Mic Inverter Gates (Sen. 3)	No Output	Loss of Noise Mic Signal	Loss of Noise Mic Accum. Data	7.008	3
168. Main Mic Pre-Amplifier (Sen. 3)	No Output	Main Mic & PHA Accum. Sig. Missing	Loss of Main Mic PHA & Accum.	67.8024	3
169. Bank Pass Filter (Sen. 3)	No Output	Main Mic & PHA Accum. Sig. Missing	Loss of Main Mic PHA & Accum.		3

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

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END ITEM Sens. Electronics	DWG NO.	PAGE 22 of 29	
ASS'Y Amplifier-Detector	DWG NO.	DATE	

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^{-5}	CRITICALITY CR
170. Main Mic Peak Detector (Sen. 3)	No Output	Main Mic PHA & Accum. Signals Missing	Loss of Main Mic PHA & Accum. Data		3
171. Main Mic Threshold Detector	No Output	Main Mic PHA & Accum. Signals Missing	Loss of Main Mic PHA & Accum. Data	40.048	3
172. Main Mic Inverter Gates	No Output	Main Mic PHA & Accum. Signals Missing	Loss of Main Mic PHA & Accum. Data	7.008	3

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Heater Control		
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Component Parts		

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
1. Amplier A1	Inoperative	Loss of Automatic Mode	No Loss of Experiment	7.008	4
2. Transistor Q1	Open	Heater OFF all the Time	Total loss of experiment	3.504	1
	Short	Heater ON all th· Time	Excess power drain-No loss to the exper.	3.504	4
3. Transistor Q2	Open	Heater OFF all th· Time	Total loss of experiment	3.504	1
	Short	Heater ON all the Time	Excess power drain. No loss of experi.	3.504	4
4. Transistor Q3	Open	Heater ON all the Time	Excess power drain. No loss to the exper.	3.504	4
	Short	Will not be able to go to ON mode	No loss to the experiment	3.504	4
5. Transistor Q5	Open	Will not be able to turn heater OFF externally	No loss to the experiment	3.504	4
	Short	Heater OFF all the time	Total loss of experiment	3.504	1
6. Diode CR1	Open	Loss of automatic mode	no loss to the experiment	1.0512	4
7. Diode CR2	Open	Loss of automatic mode	No loss to the experiment	1.5768	4
8. Diode CR3	Open	Loss of automatic mode	No loss tothe experiment	1.5768	4
9. Diode CR4	Open	Loss of automatic Mode	No loss to the experiment	1.5768	4

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
10. Diode CR5	Open	Loss of Automatic mode	No loss to the experiment	1.5768	4
11. Diode CR6	Open	Loss of automatic mode	No loss to the experiment	1.5768	4
12. Diode CR7	Open	Loss of automatic mode	No loss to the experiment	1.5768	4
13. Diode CR8	Open	Loss of automatic mode	No loss to the experiment	1.5768	4
14. Diode CR9	Open	Loss of OFF mode	No loss to the experiment	1.5768	4
15. Diode CR10	Open	Loss of OFF mode	No loss to the experiment	1.5768	4
16. Diode CR11	Open	Loss of OFF mode	No loss to the experiment	1.5768	4
17. Diode CR12	Open	Loss of OFF Mode	No loss to the experiment	1.5768	4
18. Resistor R2	Open	Heater ON all the time	Excess power drain. No loss to the experiment	.03504	4
19. Resistor R3	Open	Heater ON all the time	Excess power drain. No loss to the experiment	.03504	4
20. Resistor R4	Open	Heater OFF all the time	Total loss of the experiment	.03504	1
21. Resistor R5	Open	Loss of automatic mode	No loss to the experiment	.03504	4
22. Resistor R6	Open	Loss of automatic mode	No loss to the experiment	.03504	4

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY Q x 10^{-5}	CRITICALITY CR
		ASSEMBLY	END ITEM		
23. Resistor R7	Open	Loss of automatic mode	No loss to the experiment	.03504	4
24. Resistor R8	Open	Loss of automatic mode	No loss to the experiment	.03504	4
25. Resistor R9	Open	Loss of automat c mode	No loss to the experiment	.03504	4
26. Resistor R10	Open	Loss of automatic Mode	No loss to the experiment	.03504	4
27. Resistor R11	Open	Loss of ON mode	No loss to the experiment	.03504	4
28. Resistor R12	Open	Loss of ON mode	No loss to the experiment	.03504	4
29. Resistor R13	Open	Loss of OFF mode	No loss to the experiment	.03504	4
30. Resistor R14	Open	Loss of ON Mode	No loss to the experiment	.03504	4
31. Resistor R15	Open	Loss of OFF mode	No loss to the experiment	.03504	4
32. Resistor R16	Open	Loss of ON and OFF mode	No loss to the experiment	.03504	4
33. Resistor R17	Open	Loss of automatic mode	No loss to the experiment	.03504	4
34. Resistor R18	Open	Loss of automatic mode	No loss to the experiment	.03504	4
35. Thermistor RT	Open	Loss of automatic mode	No loss to the experiment	.03504	4

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Component Parts		

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
36. Resistor R19	Open	Degrading Effect	Degradation in potential life	.03504	3
37. Resistor R20	Open	Loss of ON and OFF mode	No loss to the experiment (can go to automatic mode)	.03504	3
38. Capacitor C1	Short	Heater start mode undetermined	Inaccuracy in data	.07008	3
39. Capacitor C2	Short	Loss of automatic mode	No loss to the experiment	.07008	4
40. Capacitor C3	Short	Loss of automatic mode	No loss to the experiment	.07008	4
41. Capacitor C4	Short	Degrading effect	Degradation in potential life	.07008	3
42. Flip Flop Z1, Z3	Inoperative	Loss of ON and OFF mode	No loss to the experiment (can go to automatic mode)	.07008	4
43. Gate Z2	Inoperative	Loss of ON and OFF mode	No loss to the experiment(can go to automatic mode)	7.008	4

NOTE: The condition where heater is ON all the time, although no loss to the experiment, the potential life of the system is reduced due to the added heat. This could be avoided through operational sequence - however, diode coupling of operational power and survival power eliminates this possibility.

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25KHz Oscillator		
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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY ICR
		ASSEMBLY	END ITEM		
1. Transistor Q1	Open	Frequency accuracy degraded	Accuracy of output data degraded	3.504	1
2. Transistor Q2	Open	Loss of clock	Total loss of experiment	3.504	1
3. Transistor Q3	Open	Loss of clock	Total loss of experiment	3.504	1
4. Transistor Q4	Open	Loss of clock	Total loss of experiment	3.504	1
5. Transistor Q5	Open	Loss of clock	Total loss of experiment	3.504	1
6. Diode CR1	Open	Frequency Change	Inaccuracy in the output data	1.0512	3
7. Diode CR2	Open	Frequency Change	Inaccuracy in the output data	1.0512	3
8. Diode CR3	Open	Frequency Change	Inaccuracy in the output data	1.5768	3
9. Diode CR4	Open	Frequency Change	Inaccuracy in the output data	1.5768	3
10. Diode DR5	Open	Frequency Change	Inaccuracy in the output data	1.5768	3
11. Diode CR6	Open Short	No effect Frequency Accur. Degraded	No effect Accuracy of output data degrad.	1.5768 2.1024	4 3
12. Diode CR7	Open Short	No effect Frequency Accuracy Degrad.	No effect Accuracy of the output data degraded	1.5768 2.1024	4 3

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
13. Resistor R1	Open	No Output	Total loss of experiment	.03504	1
14. Resistor R2	Open	No Output	Total loss of experiment	003504	1
15. Resistor R3	Open	No Output	Total loss of experiment	.03504	1
16. Resistor R4	Open	No Output	Total loss of experiment	.03504	1
17. Resistor R5	Open	No Output	Total loss of experiment	.03504	1
18. Resistor R6	Open	No Output	Total loss of experiment	.03504	1
19. Resistor R7	Open	No Output	Total loss of experiment	.03504	1
20. Resistor R8	Open	No Output	Total loss of experiment	.03504	1
21. Resistor R9	Open	No Output	Total loss of experiment	.03504	1
22. Resistor R10	Open	No Output	Total Loss of experiment	.03504	1
23. Resistor R11	Open	No Output	Total loss of experiment	.03504	1
24. Capacitor C1	Short	No Output	Total loss of experiment	.876	1
25. Capacitor C2	Short	No Output	Total loss of experiment	.876	1
26. Capacitor C3	Short	Degradation in performance	Accuracy of the output data degraded	.07008	3

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

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ASSY Component Parts	DWG NO.	DATE	

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY CR
		ASSEMBLY	END ITEM		
27. Capacitor C5	Short	No Output	Total loss of experiment	.0438	1
28. Capacitor C6	Short	No Output	Total loss of experiment	.0438	1
29. MED Z1	Inoperative	No Output	Total loss of experiment	7.008	1