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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.

Prepared by

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Project Engineer



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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.



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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:

$$\lambda = \lambda$$
 open $+\lambda$ short $+\lambda$ 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.



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The value of failure probability is calculated as follows:

Failure Probability = Q

 $Q = I - e^{-\alpha \lambda} T$, 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	<u>Failure</u>
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



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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.



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

		$\lambda \\ \textbf{Failures}$	Failure prob- ability Q x 10 ⁵
Type of Component Part	α	per 10 ⁸ Hours	
Ceramic Capacitors			
CKR Type	0.02*	0.2	.0679865
Cliff Typo	0.3ϕ	0.2	1.01998
Temp. Compensated	0.05	1.0	. 849925
i cirip. Componibatoa	0.2φ	1.0	3.39979
Mica (low voltage)	0.05*	0.1	.0849366
111100 (1011 1010050)	0.2φ	0.1	.339933
Parylene	0.05*	2.0	1.69985
1 01) 10110	0.3ϕ	2.0	10.1994
Solid Tantalum	0.05*	0.05	.0424683
	0.25¢	0.05	.212342
Foil Tantalum	0.10*	2.0	3.39979
	0.1ϕ	2.0	3.39979
Wet Tantalum	0.05*	1.0	.849925
	0.2ø	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



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TABLE I (CONT.)

Type of Component Part	$^{ m L1}_{lpha}$	λ Failures per 10 ⁸ Hours	Failure prob- ability Q x 105
Type of Component Lait	<u> </u>	per 10 Hours	
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. 4 99 53
	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

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P	ART/COMPONENT	FAILURE MODE	EFFECT OF	The state of the s	FAILURE	CRITIC-
······································	SYMBOL	railure mode	ASSEMBLY	END ITEM	PROBABILITY Q × 10 ⁻⁵	ALITY CR
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 (b) Failure of ±12v output (c) Total failure of pwr. sol. 	No ±5v output No ±12v output All power supply output fail	Total loss of experiment Total loss of experiment Total loss of experiment	 2016.552	1 1 1
5.	Squib Drive Subs	Squibs do not fire	Squib driver subsystem fails	Total loss of experiment	164.44	1
6.	25 KHz Oscilla- tor	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	ŀ
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
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PART/COMPONENT SYMBOL	FAILURE MODE (α)	The second secon	F FAILURE END ITEM	FAILURE PROBABILITY Q × 10 ⁵	CRITIC- ALITY CRI
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 counter data	Loss of more than 50% of the experiment	7.008	2
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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT O	F FAILURE Glock Circuit END ITEM	FAILURE PROBABILITY Q × 10 ⁻⁵	CRITIC- ALITY CR
Data Mux. Ckt.		Pri de de Cari Pajor la Taliana de Cari Pajor	то от общенняю учения простед на постоя по постед на по	Q x 10 ^y	CR
1. Word 1, 2 Ga	ate Incorrect Output	Word 1, 2 Output Fails	Loss of Word 1, 2	7.008	3
2. Word 3, 4 Ga	ate Incorrect Output	Word 3, 4 Output Fails	Loss of Word 3, 4	7.008	3
3. Word 5, 6 Ga	ate Incorrect Output	Word 5, 6 Output Fails	Loss of Word 5, 6	7.008	3
4. Word 7, 8 Ga	ate Incorrect Output	Word 7, 8 Output Fails	Loss of Word 7, 8	7.008	3
5. Word 9, 10 C	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 Bu Clock Gate	uffer 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
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PART/COMPONENT SYMBOL	FAILURE MODE	A STATE OF THE PROPERTY OF THE	F FAILURE	FAILURE PROBABILITY Q × 10 ⁵	CRITIC-
DI MEXIL		ASSEMBLY	END ITEM	Q x 10 ⁻⁵	ALITY CR
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 Outpu t	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
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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

Buffer Load Gates EFFECT OF FAILURE PART/COMPONENT **FAILURE** CRITIC-FAILURE MODE PROBABILITY ALITY SYMBOL (oc) ASSEMBLY END ITEM Q x 105 16. Front Film ID Incorrect Output Front Film ID Signal(s) Incorrect Loss of Front Film ID (1-4* Bits) 7.008 3 Buffer Load Gates 17. Front Film PHA Incorrect Output Front Film PHA Signal(s) Incorrect Loss of Front Film PHA (1-3 Bits) 7.008 3 Buffer Load Cate 18. Front Film Incorrect Output Front Film Accum. Signal(s) Incorrect Loss of Front Film Accum. (1-3 Bits) 7.008 3 Accum Buffer Load Gate 19. Rear Film ID Incorrect Output Rear Film ID Signal(s) Incorrect Loss of Rear Film ID (1-4 Bits) Buffer Load 7.008 3 Gate 20. Rear Film PHA Incorrect Output Rear Film PHA Signal(s) Incorrect Loss of Rear Film PHA (1-3 Bits) Buffer Load 7.008 3 Gates 21. Rear Film Incorrect Output Rear Film Accum. Signal(s) Incorrect Loss of Rear Accum. (1-3 Bits) 7.008 Accum. Buffer 3 Load Gate 22. Front Collector Incorrect Output Front Collector Signal(s) Loss of Front Collector ID (1-4 Bits) ID Buffer 7.008 3 Load Gate 23. Mic PHA Buffer Incorrect Output Mic Accum. Signal(s) Incorrect Loss of Mic Accum (1-3 Bits) 7.008 Load Gates 3 24. Mic Accum. Incorrect Output Mic Accum. Signal(s) Incorrect Loss of Mic Accum. (1-3 Bits) 7.008 Buffer Load Gate 3 25. Rear Collector Incorrect Output Rear Collector ID Signal(s) Incorrect Loss of Rear Collector ID (1-4 Bits) ID Buffer Load 7.008 3 Gate 26. TOF Buffer Incorrect Output TOF Signal(s) Incorrect Loss of TOF (1-6 Bits) Load Gates 7.008 3

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ASSY Buffer Load Gates 2/2/71 FART/COMPONENT EFFECT OF FAILURE FAILURE CRITIC-FAILURE MODE PROBABILITY Q × 10⁻⁵ ALITY SYMBOL (ac) ASSEMBLY END ITEM 27. thru 37. IDENTICAL TO 16 THRU 26 EXCEPT THAT THE FAILURE IS RELATED TO DUAL SENSOR 2 Film ID (sen 2) Incorrect Output Film ID Signal-Incorrect Loss of Film ID (1-2 Bits) 7.008 3 Buffer Load Gates Collector ID Incorrect Output Collector ID Signal Incorrect Loss of Collector ID (1-2 Bits) 7.008 3 (Sen 3) Buffer Load Gate 40. Film PHA (Sen Incorrect Output Film PHA Signal Incorrect Loss of Film PHA (1-3 Bits)* 7.008 3 3) Buffer Load Gate 41. Film Accum Incorrect Output Film Accum. Signal Incorrect Loss of Film Accum (1-3 Bits) 7.008 3 (Sen 3) Buffer Load Gate 42. Noise Mic Incorrect Output Noise Mic Accum. Signal Incorrect Loss of Noise Mic Accum. (1-2 Bits) 7.008 3 Accum (Sen 3) Buffer Load Gates 43. Analog Data Incorrect Output Analog Data Sync Signal Loss of Analog Data Sync 7.008 3 Sync (Sen 3) Buffer Load Gate Heater Status Incorrect Output Heater Status Signal Incorrect Loss of Heater Status Signal 7.008 3 (Sen 3) Buffer Load Gate 45. Main Mic PHA Incorrect Output Main Mic PHA Signal Incorrect Loss of Main Mic PHA (1-3 Bits) 7.008 3 (Sen 3) Buffer Load Cate Main Mic Incorrect Output Main Mic Accum. Signal Incorrect Loss of Main Mic Accum (1-3 Bits) 7.008 3 Accum (Sen 3) Buffer Load Gates * (1-3) is 1, 2, $\frac{1}{3}$.

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PART/COMPONENT	54.0.055.446.05	EFFECT OF	FAILURE	FAILURE	CRITIC-
SYMBOL	FAILURE MODE (&)	ASSEMBLY	END ITEM	PROBABILITY Q × 10-5	ALITY CR
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.	17.008	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. Counte	T T T T T T T T T T T T T T T T T T T		• · ·		
(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
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PART/COMPONENT SYMBOL	FAILURE MODE (QC)	EFFECT O		FAILURE PROBABILITY Q × 10 ⁻⁵	CRITIC ALITY 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		, 			And Annual Control of the Control of
(a) C433 Flip Flop(b) C434 Flip Flop(c) C435 Flip Flop	Incorrect Output	Mic PHA Signal Incorrect Mic PHA Signal Incorrect Mic PHA Signal Incorrect	Loss of Mic PHA Loss of 2 bits of Mic PHA Loss of 1 bit of Mic PHA	7.008 7.008 7.008	3 3 3
55. Mic Accum. Counter					
(a) C430 Flip Flop(b) C431 Flip Flop(c) C432 Flip Flop	Incorrect Output	Mic Accum. Signal Incorrect Mic Accum. Signal Incorrect Mic Accum. Signal Incorrect	Loss of Mic Accum. Loss of 2 bits of Mic Accum. Loss of 1 bit of Mic Accum.	7.008 7.008 7.008	3 3 3
(a) C421 Flip Flop (b) C422 Flip Flop (c) C423 Flip Flop (d) C424 Flip Flop (e) C425 Flip Flop (f) C426 Flip Flop	Incorrect Output Incorrect Output Incorrect Output Incorrect Output Incorrect Output	TOF Signal Incorrect	Loss of TOF Loss of 5 bits of TOF Loss of 4 bits of TOF Loss of 3 bits of TOF Loss of 2 bits of TOF Loss of 1 bit of TOF	7.008 7.008 7.008 7.008 7.008 7.008	3 3 3 3 3
57. THRU 66 SAME	AS 47 THRU 56 EXCEPT THAT THE FAIL	URE IS RELATED TO DUAL SENSOR 2.		•	
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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

EFFECT OF FAILURE PART/COMPONENT FAILURE CRITIC-FAILURE MODE PROBABILITY Q × 105 ALITY CR SYMBOL (X) ASSEMBLY END ITEM 67. Film ID Latch Incorrect Output Film ID Signal(s) Incorrect Loss of Film IC (1-2 Bits) 7.008 3 (Sen. 3) 68. Collector ID Incorrect Output Collector ID Signal(s) Inc. Loss of Collector ID (1-2 bits) 7.008 3 Latch (Sen. 3) 69. Film PHA Counte Incorrect Output (Sen. 3) (a) C603 Flip Flop Incorrect Output Film PHA Signal Incorrect Loss of Film PHA 7,008 (b) C604 Flip Flop Incorrect Output Film PHA Signal Incorrect Loss of 2 bits of Film PHA 7.008 (c) C605 Flip Flop Incorrect Output Film PHA Signal Incorrect Loss of 1 bit of Film PHA 7.008 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 3 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 (b) C631 Flip Flop Incorrect Output Noise Mic Accum. Signal Inc. Loss of l bit of noise mic accum. 7.008

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

EFFECT OF FAILURE PART/COMPONENT FAILURE CRITIC-FAILURE MODE PROBABILITY Q x 10-5 SYMBOL. ALITY (OL) ASSEMBLY END ITEM 72. Analog Data Incorrect Output Loss of Analog Data Sync Signal 7.008 Sync Ckt. (Sen. 3) 73. Heater Status Incorrect Output Loss of Heater Status Sig. Status of the Heater Undeter. 7.008 3 Ckt. (Sen. 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) C62? Flip Flop Incorrect Output Main Mic. Accum. Sig. Inc. Loss of 1 bit of Main Mic. Accum. 7.008

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PART/COMPONENT		FAILURE MODE	EFFECT OF			CRITIC-	
contract scattered as	SYMBOL.	FAILURE MODE (CC)	ASSEMBLY	END ITEM	PROBABILITY Q × 10 ⁻⁵	ALITY CR	
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	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 Thresho Detector	ld 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	No Output	Front Film PHA & Accum. Signals Missing	Loss of Front Film PHA & Accum.	7.008	3	
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Amplifier-Detector Ckt.

PREPARED BY A. Lakhani DWG NO.

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	FAILURE MODE, EFFECT & CRI	TICALITY ANALYSIS WORKSHE	Sen. Electronics Applifier-Detector R. KO.	PAGE 17 DATE	of 29.
PART/COMPONENT SYMBOL	FAILURE MODE	EFFECT O	ment of the state	FAILURE PROBABILITY Q x 10 ⁵	CRITIC- ALITY
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	CR 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 Tres- hold 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 Thres- hold 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	FAILURE MODE	EFFECT OF	F FAILURE	FAILURE	CRITIC-
SYMBOL	(α)	ASSEMBLY	· END ITEM	PROBABILITY Q × 10	ALITY CR
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 Cl	No Output t.	1/4 of Front Fi:m & 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 Fit.	No Output	Mic PHA & Accum. Signals Missing	Loss of Mic PHA & Accum.	37. 3176	3
103. Mic Peak Det.	No Cutput	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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PART/COMPONENT SYMBOL	FAILURE MODE (α)	A STATE OF THE PROPERTY OF THE	F FAILURE END ITEM	FAILURE PROBABILITY Q × 10 ⁻⁵	CRITIC- ALITY CR
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 Collecto: 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. SAMI	AS 76 THRU 111 EXCEPT THAT THE FA	LURE IS RELATED TO DUAL SENSOR 2			
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	PART/COMPONENT	THE CHARLES AND AND THE CHARLES AND THE CHARLE	EFFECT OF FAILURE		FAILURE	CRITIC-
	SYMBOL	FAILURE MODE (CC)	ASSEMBLY	END ITEM	PROBABILITY Q x 105	ALITY CR
	148. Film ID Pre- amplifier (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 Cutput	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 Presmplifier (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 Thres- hold 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	ASSEMBLY	END ITEM	FAILURE PROBABILITY Q × 10 ⁻⁵	CRITIC ALITY CR
159. Summer Peak Detector (Sen. 3)	No Output	Film PHA & Accu. Sig. Mag.	Loss of Film PHA & Accum.	and the second s	3
160. Summer Thres- hold Detector (Sen. 3)	No Output	Film PHA & Ac um. 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. Mag.	Loss of Film PHA & Accum.	7. 008	3 .
163. Noise Mic Pre- amplifier (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
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PART/COMPONENT	CONTRACTOR OF THE STATE OF THE	EFFECT O	F FAILURE	FAIL LIDE	CDITIO
SYMBOL	FAILURE MODE (CL)	подосновного отправления подосности учественности подосности и подосн	END ITEM	FAILURE PROBABILITY Q × 10 ⁵	CRITIC - ALITY CR
176. Main Mic Peak Detector (Sen. 3)	No Output	Main Mic PHA & Accum. Signals Missing	Loss of Main Mic PHA & Accum. Data	The second secon	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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	PART/COMPONENT		NT	PAII 11 PE A 1 A PE	EFFECT OF FAILURE			FAILURE	CRITIC-
	VPICENTO TR	SÝMBOL.	THE OWNER OF THE OWNER, WHI	FAILURE MODE	(∞)	ASSEMBLY	END ITEM	PROBABILITY Q × 105	ALITY CR
	1.	Amplier	A1	Inoperative		Loss of Automatic Mode	No Loss of Experiment	7. 008	4
	2.	Transistor	Ωl	Open Short		Heater OFF all the Time Heater ON all the Time	Total loss of experiment Excess power drain-No loss to the exper.	3. 504 3. 504	1 4
	3.	Transistor	Q2	Open Short		Heater OFF all the Time Heater ON all the Time	Total loss of experiment Excess power drain. No loss of experi.	3. 504 3. 504	1 4
	4.	Transistor	Q3	Open Short		Heater ON all the Time Will not be able to go to ON mode	Excess power drain. No loss to the expe	r. 3.504 3.504	4
-	5.	Transistor	Q5	Open Short		Will not be able to turn heater OFF externally Heater OFF all the time	No loss to the experiment Total loss of experiment	3. 504 3. 504	4 1
	6.	Diode	CR1	Open		Loss of automatic mode	no loss to the experiment	1. 0512	4
	7.	Diode	CR2	Ope n		Loss of automatic mode	No loss to the experiment	1.5768	4
A CONTRACTOR	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
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PART/COMPONENT SYMBOL		FAILURE MODE		AND STREET AND TOTAL AND TOTAL STREET, TOTAL STREET, S	AND THE PROPERTY OF THE PROPER	FAILURE PROBABILITY	CRITIC-	
2736TO73500	JIMOUL	TO SHOW MANAGEMENT AND ADDRESS OF THE PARTY.	AL AND PROPERTY OF THE PARTY OF		ASSEMBLY	END ITEM	PROBABILITY Q × 10 ⁻⁵	CR
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
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FART/COMPONENT	FAILURE MODE	EFFECT O	F FAILURE	FAILURE	CRITIC-
SYMBOL NORTHWAY CONTRACTOR OF THE PROPERTY OF	CO.	ASSEMBLY	END ITEM	PROBABILITY Q × 10 ⁵	ALITY CR
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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PART/COMPONENT SYMBOL	FAILURE MODE (a)	EFFECT OI ASSEMBLY	F FAILURE "END ITÉM	FAILURE PROBABILITY Q × 10 ⁻⁵	CRITIC -
36. Resistor R19	Ореп	Degrading Effect	Degradation in potential life	. 03504	CR 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 Cl	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 could be avo	n where heater is ON all the time, although ded through operational sequence - howeve	no loss to the experiment, the potential life, diode coupling of operational power and s	of the system is reduced due to the added harvival power eliminates this possibility.	eat. This	
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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

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25KHz Oscillator

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Component Parts

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NACOPIC STREET	PART/COMPONENT		FAILURE MODE	EFFECT OF FAILURE		FAILURE	CRITIC-
	SYMBOL	THE STATE CONTRACTOR SHOWS SHOW THE STATE OF	is a continuous conti	ASSEMBLY	END ITEM	PROBABILITY Q x 10 ³	ALITY ICR
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
1	. Transistor Q5	Open		Loss of clock	Total loss of experiment	3.504	1
1	Diode CR	l Open		Frequency Change	Inaccuracy in the output data	1.0512	3
7	. Diode CR	2 Open		Frequency Change	Inaccuracy in the output data	1. 0512	3
8	B. Diode CR	3 Open		Frequency Change	Inaccuracy in the output data	1. 5768	3
_ !	Diode CR	4 Open		Frequency Change	Inaccuracy in the output data	1.5768 ,	3
	0. Diode DR	5 Open		Frequency Change	Inaccuracy in the output data	1. 5768	3
]	1. Diode CR	6 Open Short	·	No effect Frequency Accur. Degraded	No effect Accuracy of output data degrad.	1.5768 2.1024	4 3
	2. Diode CR	7 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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25 KHz Oscillator
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PART/COMPONENT	Paramer / Anthrough-Anthropy / Anthropy / Anthrough-Anthropy / Anthrough-Anthropy / Anthropy / Ant	EFFECT OF FAILURE		FAILURE	CRITIC-
SYMBOL.	FAILURE MODE (a)	ASSEMBLY CONTROL OF THE PROPERTY OF THE PROPER	END ITEM	FAILURE PROBABILITY Q × 10 ⁻⁵	ALITY CR
13. Resistor R1	Open	No Output	Total loss of experiment	. 03504	l
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 Cl	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
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25 KHz Oscillator
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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT O. ASSEMBLY	F FAILURE END ITEM	FAILURE PROBABILITY Q × 10 ⁻⁵	CRITIC- ALITY CR	
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	
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