Bendix
Aerospace
Systems Division

ALSEP Array E - Signal Conditioning Circuits Reliability and Failure Mode, Effects and Critical Analysis	NO. ATM 999	REV. NO.
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This ATM documents the Failure Modes, Effects and Criticality Analysis on the Signal Conditioning Circuit. The analysis reflects analysis on those parts which are presently planned to be used in final flight configuration.

This document is prepared in accordance with the requirements of Section 5.2 of the Reliability Program Plan for Array E, ALSEP-RA-08, Bendix document number BSR 3024 dated 11-30-70.

From the results of the analysis described herein, it has been concluded that the reliability and design objectives have been fully satisfied.

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1.0 INTRODUCTION

The results of the Reliability Prediction and the Failure Mode, Effects and Criticality Analysis for ALSEP-E, Signal Conditioning Circuit is documented in this report.

2.0 CIRCUIT DESCRIPTION

The Signal Conditioning Board consists of 3 hot temperature sensor amplifiers and reference voltage follower and 3 cold temperature sensor supplies the reference voltage to the 6 amplifiers. Also included on the Signal Conditioning Board are voltage monitor resistors, T/M bias resistors and calibration resistors.

The T/M bias resistors on the Interface Module Board are also included in this FMECA.

3.0 RELIABILITY PREDICTION

The reliability prediction for the Signal Conditioning Circuit is .995361 for no failure. This reliability is based on a time span covering launch, deployment and two years of lunar operation. Figure 1 defines the Signal Conditioning Circuit Reliability Block Diagram. The probability of failure for each block is also identified in Figure 1. The probability of failure shown represents the composite totals derived from the parts application stress ratios of each electronic piece part modified by the failure mode apportionment.

3.1 RELIABILITY CALCULATIONS

3.1.1 Q_T = probability of failure of processing all experimental data

$$Q_4 = (Q_{41})(Q_{42})(Q_{43})$$

$$Q_6 = (Q_{61})(Q_{62})(Q_{63})$$

$$Q_T = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$$

$R_T = 1 - Q_T$ = reliability of processing all experimental data

3.1.2 $Q_4 = (.001111)\,(.001111)\,(.001111)$

$Q_4 = 1.371 \times 10^{-9}$

$Q_6 = (.001111)\,(.001111)\,(.001111)$

$Q_6 = 1.371 \times 10^{-9}$

$Q_T = .002955 + .000628 + .000528 + 1.37 \times 10^{-9} + .000528 + 1.37 \times 10^{-9}$

$Q_T = .004639$

$R_T = 1 - .004639$

$R_T = .995361$

4.0 FAILURE MODES, EFFECTS & CRITICALITY ANALYSIS

The failure mode and effects analysis for the Signal Conditioning Circuits is documented in Table I. Table I delineates the failure modes at the piece part level.

The failure probabilities reflects the identified line item. The format of Table I is designed to provide the reader with a narrative description of the varying types of failure that could occur, combined with the resultant performance characteristics. This information is useful to system support in performing fault isolation should any anomaly occur. None of the voltage monitor and T/M temperatur sensors are critical failure mode items. The Hot Temperature Sensor and Cold Temperature are triple redundant.

The failure probability figures were derived using the data obtained in Table I. ATM 605A was used to derive the component α's (open, short, drift, etc. apportionment). Some failure modes, such as drift of a resistor in a digital circuit, do not effect the operation. The failure modes which do not affect the operation are not included in the FMECA. For this reason, the sum of α's for some circuit/function items do not equal one.

In Table I, when the effect of failure on the system is termed "output slightly erroneous", the digital value received on the ground can be adjusted to the correct value. This can be done by observing how the failure or drift has affected the calibration signals.

The Signal Conditioning circuits are ranked according to Criticality Ranking which rates the effect on mission success. The higher the criticality ranking number the lesser the effect on mission success.

CRITICALITY RANKING

I. Loss of system

II. Loss of system control

III. Loss of one experiment

IV. Loss of housekeeping channel

V. Loss of redundant element

VI. Degradation of a redundant element

Only catagory IV applies to the Signal Conditioning circuits.

5.0 SUMMARY

The purpose of performing a reliability prediction and failure mode analysis is to identify inherent design weaknesses. From the results of these analyses, it has been concluded the reliability and design objectives have been fully satisfied.

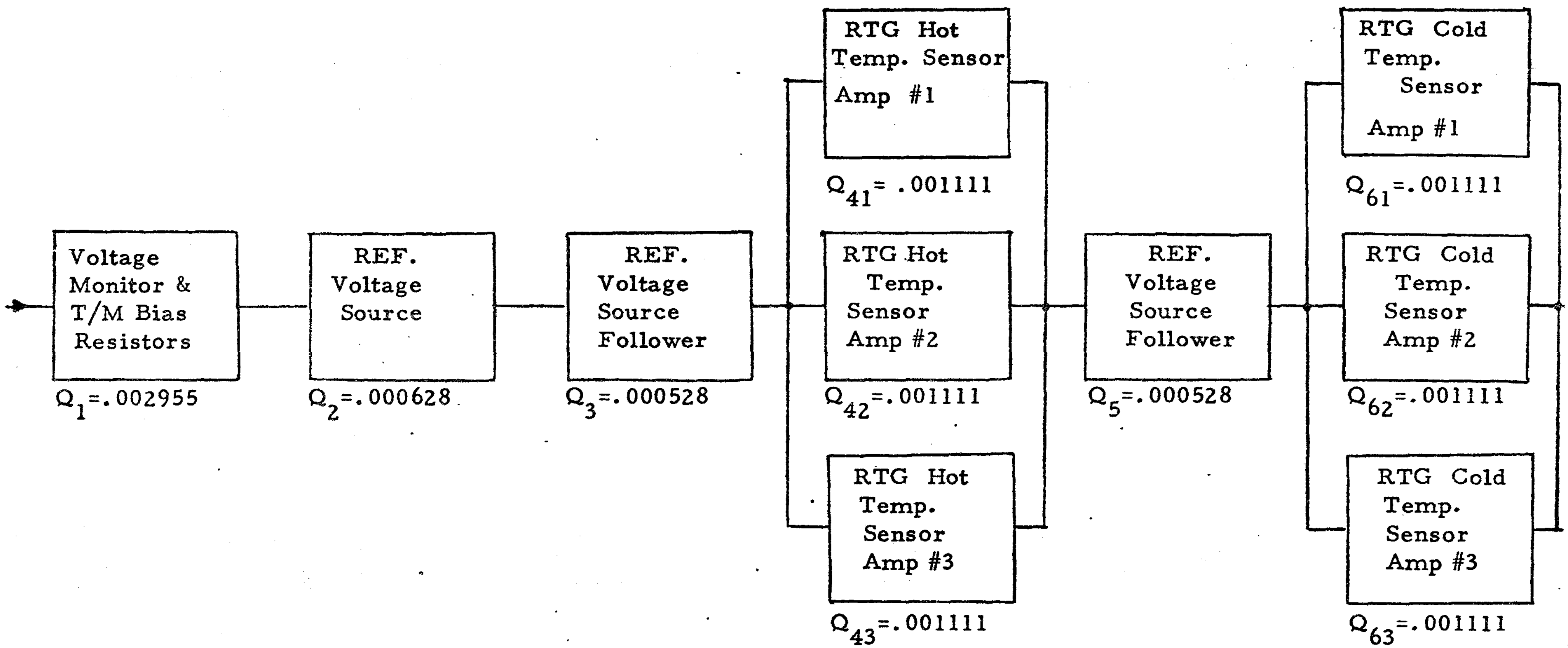

Figure 1 SIGNAL CONDITIONING CIRCUIT RELIABILITY BLOCK DIAGRAM

TABLE 1

SYSTEM	PREPARED BY	NO.	REV.
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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
1.0 Signal Conditioning Board	.162		RTG Cold #1, #2, #3 are three redundant outputs. If one out of three units work, the information gets through	#3 #2 #1 111.1, 111.1, 111.1	IV
1.1 RTG Cold #3 #2 #1 AR11 AR6 AR2 AR12 AR7 AR3 R49 R27 R14 R50 R28 R15 R51 R29 R16 R52 R30 R17 R53 R31 R18 R54 R32 R19 C33 C19 C4 C34 C20 C5 C35 C21 C7 C36 C22 C8 C37 C23 C9	1.1A AR12, AR7, AR3 Fails Inoperative AR11, AR6, AR2 Fails Inoperative R51, R29, R16 Fails Open R50, R28, R15 Fails Open	1.1A #1 Output Op. Amp AR3 Fails ± saturation #2 Output Op. Amp AR7 Fails ± saturation #3 Output Op. Amp AR12 Fails ± saturation	1.1A #1 RTG Cold #1 Fails in ± saturation voltage out #2 RTG Cold #2 Fails in ± saturation voltage out #3 RTG Cold #3 Fails in ± saturation voltage out		
	1.1B R54, R32, R19 Fails Open	1.1B #1 Output Op. Amp AR3 Fails + saturation #2 Output Op. Amp AR7 Fails + saturation #3 Output Op. Amp AR12 Fails + saturation	1.1B #1 RTG Cold #1 Fails in + saturation #2 RTG Cold #2 Fails in + saturation #3 RTG Cold #3 Fails in + saturation		
	1.1C C33, C19, C4 Fails Short C34, C20, C5 Fails Short C35, C21, C7 Fails Short C36, C22, C8 Fails Short C37, C23, C9 Fails Short	1.1C #1 Output Op. Amp AR3 Fails - saturation #2 Output Op. Amp AR7 Fails - saturation #3 Output Op. Amp AR12 Fails - saturation	1.1C #1 RTG Cold #1 Fails in - saturation #2 RTG Cold #2 Fails in - saturation #3 RTG Cold #3 Fails in - saturation		
	1.1D R53, R31, R18 Fails Open, Drift R49, R27, R14 Fails Open Drift R52, R30, R17 Fails Open Drift R50, R28, R15 Fails Drift R51, R29, R16 Fails Drift R54, R32, R19 Fails Drift AR11, AR6, AR2 Fails Drift AR12, AR7, AR3 Fails Drift	1.1D #1 Output Op Amp AR3 Fails in Drift #2 Output Op. Amp AR7 Fails in Drift #3 Output Op, Amp AR7 Fails in Drift	1.1D #1 RTG Cold #1 Fails in Drift #2 RTG Cold #2 Fails in Drift #3 RTG Cold #3 Fails in Drift		

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q × 10⁵	CRITICALITY
1.1 RTG Cold	1.1D C33, C19, C4 Fails Drift C34, C20, C5 C35, C21, C7 C36, C22, C8 C37, C23, C9	1.1D #1 Output Op. Amp AR3 Fails in Drift #2 Output Op. Amp AR7 Fails in Drift #3 Output Op. Amp AR7 Fails in Drift	1.1D #1 RTG Cold #1 Fails in Drift #2 RTG Cold #2 Fails in Drift #3 RTG Cold #3 Fails in Drift		
1.2 Low Temp Voltage Source AR10 R47 R48 R67 C29 C30	1.2A .077 ___ ___AR11 Fails Inoperative	1.2A #1 Output Op. Amp AR3 Fails ± saturation #2 Output Op. Amp AR7 Fails ± saturation #3 Output Op. Amp AR12 Fails ± saturation	1.2A #1 RTG Cold #1 Fails ± saturation #2 RTG Cold #2 Fails ± saturation #3 RTG Cold #3 Fails ± saturation	52.8	IV
	1.2B R47 Fails Open C29 Fails Short C30 Fails Short	1.2B #1 Output Op. Amp AR3 Fails + saturation #2 Output Op. Amp AR7 Fails + saturation #3 Output Op. Amp AR12 Fails + saturation	1.2B #1 RTG Cold #1 Fails + saturation #2 RTG Cold #2 Fails + saturation #3 RTG Cold #3 Fails + saturation		
	1.2C R67 Fails Open R48 Fails Open	1.2C #1 Output Op. Amp AR3 Fails - saturation #2 Output Op. Amp AR7 Fails - saturation #3 Output Op. Amp AR12 Fails - saturation	1.2C #1 RTG Cold #1 Fails - saturation #2 RTG Cold #2 Fails - saturation #3 RTG Cold #3 Fails - saturation		

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁻⁵	CRITICALITY
1.2 RTG Cold	1.2D AR10 Fails Drift R47 Fails Drift R48 Fails Drift R67 Fails Drift C29 Fails Drift C30 Fails Drift	1.2D #1 Output Op. Amp AR4 Fails Drift #2 Output Op. Amp AR8 Fails Drift #3 Output Op. Amp AR8 Fails Drift	1.2D #1 RTG Cold #1 Fails Drift #2 RTG Cold #2 Fails Drift #3 RTG Cold #3 Fails Drift		
1.3 VOLTAGE REFERENCE U1 R7 R8 R9 R26 C15 C16	1.3A .092 U1 Fails Inoperative	1.3A Output Voltage Regulator Fails in Saturation or Zero Volts Out	1.3A 6 - RTG Hot and Cold Temp Sensors Fail ± Saturation	62.8	IV
	1.3B R7 Fails Open R8 Fails Open C15 Fails Short	1.3B Output Voltage Regulator Fails ≤ 2V Volts Out	1.3B 6 - RTG Hot and Cold Temp Sensors Fail + Saturation		
	1.3C R9 Fails Open C16 Fails Short	1.3C Output Voltage Regulator Fails +12 Volts Out	1.3C 6 - RTG Hot and Cold Temp. Sensors Fail - Saturation		
	1.3D U1 Fails Drift R7 Fails Drift R8 Fails Drift R9 Fails Drift R26 Fails Drift C16 Fails Drift C15 Fails Drift	1.3D Output Voltage Regulator Fails Drift	1.3D 6 - RTG Hot and Cold Temp. Sensors Fail Drift		

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^5	CRITICALITY
1.4 RTG Hot #3 #2 #1 AR13 AR8 AR4 AR14 AR9 AR5 R55 R33 R20 R56 R34 R21 R57 R35 R22 R58 R36 R23 R59 R37 R24 R60 R38 R25 C38 C24 C10 C39 C25 C11 C40 C26 C12 C41 C27 C13 C42 C28 C14	1.4A .162 AR14, AR9, AR5 Fails Inoperative AR13, AR8, AR4 Fails Inoperative R57, R35, R22 Fails Open R56, R34, R21 Fails Open	1.4A #1 Output Op Amp AR 5 Fails ± saturation #2 Output Op Amp AR9 Fails ± saturation #3 Output Op Amp AR14 Fails ± saturation	1.4A #1 RTG Hot #1 Fails ± saturation #2 RTG Hot #2 Fails ± saturation #3 RTG Hot #3 Fails ± saturation	#3 #2 #1 111.1, 111.1, 111.1	IV
	1.4B R60, R38, R25 Fails Open	1.4B #1 Output Op Amp AR5 Fails + saturation #2 Output Op Amp AR9 Fails + saturation #3 Output Op Amp AR14 Fails + saturation	1.4B #1 RTG Hot #1 Fails + saturation #2 RTG Hot #2 Fails + saturation #3 RTG Hot #3 Fails + saturation		
	1.4C C38, C24, C10 Fail Open C39, C25, C11 Fail Open C40, C26, C12 Fail Open C41, C27, C13 Fail Open C42, C28, C14 Fail Open	1.4C #1 Output Op Amp AR5 Fails - saturation #2 Output Op Amp AR9 Fails - saturation #3 Output Op Amp AR14 Fails - saturation	1.4C #1 RTG Hot #1 Fails - saturation #2 RTG Hot #2 Fails - saturation #3 RTG Hot #3 Fails - saturation		
	1.4D R55, R33, R20 Fails Open, Drift R58, R36, R23 Fails Open, Drift R59, R37, R24 Fails Open, Drift R60, R38, R25 Fails Drift R56, R34, R21 Fails Drift R57, R35, R22 Fails Drift AR13, AR8, AR4 Fails Drift AR14, AR9, AR5 Fails Drift C38, C24, C10 Fails Drift C39, C25, C11 Fails Drift C40, C26, C12 Fails Drift C41, C27, C13 Fails Drift C42, C28, C14 Fails Drift	1.4D #1 Output Op Amp AR5 Fails in Drift #2 Output Op Amp AR9 Fails in Drift #3 Output Op Amp AR14 Fails in Drift	1.4D #1 RTG Hot #1 Fails Drift #2 RTG Hot #2 Fails Drift #3 RTG Hot #3 Fails Drift		

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
1.5 High Temp Voltage Source AR1 R10 R11 R12 R13 C1 C6	1.5A AR1 Fails Inoperative	.077	1.5A #1 Output Op Amp AR5 Fails ± saturation #2 Output Op Amp AR9 Fails ± saturation #3 Output Op Amp AR14 Fails ± saturation	1.5A #1 RTG Hot #1 Fails ± saturation #2 RTG Hot #2 Fails ± saturation #3 RTG Hot #3 Fails ± saturation	52.8	IV
	1.5B R10 Fail Open R11 Fail Open C1 Fail Short C6 Fail Short		1.5B #1 Output Op Amp AR5 Fails + saturation #2 Output Op Amp AR9 Fails + saturation #3 Output Op Amp AR14 Fails + saturation	1.5B #1 RTG Hot #1 Fails + saturation #2 RTG Hot #2 Fails + saturation #3 RTG Hot #3 Fails + saturation		
	1.5C R12 Fail Open R13 Fail Open		1.5C #1 Output Op Amp AR5 Fails - saturation #2 Output Op Amp AR9 Fails #3 Output Op Amp AR14 Fails	1.5C #1 RTG Hot #1 Fails - saturation #2 RTG Hot #2 Fails - saturation #3 RTG Hot #3 Fails - saturation		
	1.5D AR1 Fails Drift R10 Fails Drift R11 Fails Drift R12 Fails Drift R13 Fails Drift C1 Fails Drift C6 Fails Drift		1.5D #1 Output Op Amp AR5 Fails Drift #2 Output Op Amp AR9 Fails Drift #3 Output Op Amp AR14 Fails Drift	1.5D #1 RTG Hot #1 Fails Drift #2 RTG Hot #2 Fails Drift #3 RTG Hot #3 Fails Drift		

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE ASSEMBLY	EFFECT OF FAILURE END ITEM	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
1.6 + 5V Measure R70 R71	1.6A R71 Fails Open	.011	1.6A Voltage Divider R70, R71 reads zero volts	1.6A +5V measure reads 0 volts instead of 4.17 volts	7.3	IV
	1.6B R71 Fail Drift R70 Fail Drift		1.6B Voltage Divider R70, R71 Fails in Drift	1.6B +5V measure Fails in Drift		
	1.6C R70 Fails Open		1.6C Voltage Divider R70, R71 Fails to divide 5V to 4.17V	1.6C +5V measure reads 5 volts instead of 4.17 volts		
1.7 Temp Sensor RT1 R68	1.7A RT1 Fails Open	.082	1.7A RT1 and R68 Voltage Divider Fails	1.7A Int. Temp. T/M Fails with 0 volts out	56.3	IV
	1.7B RT1 Fails Drift R68 Fails Drift		1.7B RT1 and R68 Voltage Divider Fails Drift	1.7B Int. Temp. T/M Fails in Drift		
	1.7C R68 Fails Open		1.7C RT1 and R15 Voltage Divider Fails with $V_{out} = V_{source}$	1.7C Int. Temp. T/M Fails with $V_{out} = V_{source}$		
1.8 T/M Bias Resistors R61 R62 R69	1.8A R61 Fails Open R62 Fails Open R69 Fails Open	.016	1.8A T/M Bias Resistor Fail causes $V_{out} = V_{source}$	1.8A T/M Bias Resistor Fail with T/M Voltage = V_{source}	11.2	IV
	1.8B R61 Fails Drift R62 Fails Drift R69 Fails Drift		1.8B T/M Bias Resistor Fail by giving wrong calibration	1.8B T/M Bias Resistor Fail with T/M Voltage out of calibration		
1.9 T/M Bias Resistors R39 R40 R41 R42 R43 R44	1.9A R39 Fails Open R40 Fails Open R41 Fails Open R42 Fails Open R43 Fails Open R44 Fails Open	.043	1.9A Bias Resistor for T/M causes $V_{out} = 0V$	1.9A T/M Bias Resistor Fail with T/M Voltage = 0V	29.7	IV

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^5	CRITICALITY
	1.9B R39 Fails Drift R40 Fails Drift R41 Fails Drift R42 Fails Drift R43 Fails Drift R44 Fails Drift		1.9B Bias Resistor for T/M caused V_{out} to lose calibration	1.9B T/M Bias Resistor Fail with T/M Voltage out of calibration		
1.10 Cal. Resistors R3 R4 R5 R6	1.10A R3 Fails Open	.021	1.10A Voltage Divider Resistor Fail causing V_{out} = 0V	1.10A High Cal and Low Cal Fail with V_{out} = 0V	14.4	IV
	1.10B R3 Fails Drift R4 Fails Drift R5 Fails Drift R6 Fails Drift		1.10B Voltage Divider Resistor Fail causing V_{out} to lose calibration	1.10B High Cal and Low Cal Fail with V_{out} of calibration		
	1.10C R4 Fails Open R5 Fails Open		1.10C Voltage Divider Resistor Fail causing V_{out} = 6.4V	1.10C High Cal and Low Cal Fail, High Cal = 6.4V, Low Cal = 0V		
	1.10D R6 Fails Open		1.10D Voltage Divider Resistor Fail causing V_{out} = 6.4V	1.10D High Cal and Low Cal Fail, High Cal = 6.4V, Low Cal = 6.4V		
1.11 +29 V Measure R63 R64 VR2	1.11A R63 Fails Open	.046	1.11A Voltage Divider R63 and R64 Fail V_{out} = 0	1.11A +29V measure Fails causing V_{out} = 0	31.5	IV
	1.11B R64 Fails Open		1.11B Voltage Divider Fails V_{out}=6.8V	1.11B +29V measure Fails causing V_{out} = 6.8V		
	1.11C R63 Fails Drift R64 Fails Drift		1.11C Voltage Divider Fails V_{out} out of calibration	1.11C		

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^5	CRITICALITY
1.12 -12 V Measure R46 R68 VR3	1.12A R66 Fails Open	.046	1.12A Voltage Divider R46, R66 Fail V_{out} = +6.8V	1.12A -12V measure Fails causing V_{out} = 6.8V	31.4	IV
	1.12B R46 Fails Drift R66 Fails Drift		1.12B Voltage Divider R46, R66 Fail due to lose calibration	1.12B -12V measure Fails causing V_{out} to be out of calibration		
	1.12C R46 Fails Open		1.12C Voltage Divider R46, R66 Fail V = -.7V	1.12C -12V measure Fails causing V_{out} = -.7V		
	1.12D VR3 Fails Short		1.12D Voltage Divider R46, R66 Fail V = 0V	1.12D -12V measure Fails V_{out} = 0V		
	1.12E VR3 Fails Drift		1.12E Might effect Voltage Divider if $V_Z \leq$ 4V	1.12E -12V measure might Fail if $V_Z \leq$ 4V		
1.13 +12 V Measure R45 R65	1.13A R65 Fails Open	.011	1.13A Voltage Divider R45, R65 Fail V_{out} = 12V	1.13A +12V measure Fails with V_{out}=12V	7.3	IV
	1.13B R45 Fails Drift R65 Fails Drift		1.13B Voltage Divider R45, R65 Fail due to lose of calibration	1.13B +12V measure Fails due to lose calibration		
	1.13C R45 Fails Open		1.13C Voltage Divider R45, R65 Fail V_{out} = 0	1.13C +12V measure Fails V_{out} = 0V		
1.14 + 5V Measure R1 R2 VR1	1.14A R1 Fails Open R2 Fails Open 1.14B VR1 Fails Short	.051	1.14A +5V is not measured 1.14B +5V is not measured	1.14A +5V measure Fails with V_{out} = 0 1.14B +5V measure Fails with V_{out} = 0	34.9	IV

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^5$	CRITICALITY
2.1 T/M Bias Resistors R41, R42, R43 R44, R45, R46 R47, R48, R49 R50, R51, R52 R53, R54, R55 R56	2.1A R41-R56 Fail Open 2.1B R41-R56 Fail Drift	.104	2.1A Lose T/M Temp. Signals 2.1B Lose calibration of T/M Temp. Signals	2.1A Lose T/M Temp. Signals 2.1B Lose calibration of T/M Temp. Signals	71.50	IV