



**Aerospace
Systems Division**

**Array E PCU Failure Modes,
Effects and Criticality Analysis**

ATM 952

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This ATM documents the Failure Modes, Effect and Criticality Analysis on the Bendix designed Power Conditioning Unit for the Array E ALSEP System. 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. The VR/APM module remains as presented for the PDR since the latest engineering drawing is unavailable. The documentation for this module will be revised as engineering data becomes available.

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1.0 INTRODUCTION

The results of the preliminary Failure Modes, Effects and Criticality Analysis for the ALSEP Array E PCU are documented in this report. The present DVT and planned flight designs retain most of the basic design concepts which have resulted in 100% success on all previous arrays plus the following new features:

1. Complete Redundancy (except switching module)
2. Automatic Power Mangement
3. PCU I Switchback Capability
4. Improved Methods of Heat Sinking

2.0 CIRCUIT DESCRIPTION

Figure 1 presents a Functional Block Diagram of the Power Conditioning Unit. The redundant circuits are in power standby.

2.1 SWITCHING CIRCUIT

Output voltages are monitored by this circuit. In the event that a serious undervoltage or overvoltage condition should arise, this circuit would automatically switch power to the redundant unit.

2.2 INVERTER MODULE

The Inverter Module converts the prime 16 VDC power from the RTG to regulated dc outputs for the autotransformer as required.

2.3 SHUNT REGULATOR MODULE

The shunt regulator regulates the +12 VDC output of the PCU by altering the voltage from the RTG to maintain regulation of the +12VDC output which is nearly a fixed load of insignificant magnitude when compared to the 29 VDC line output.

2.4 AUTOMATIC POWER MANGAEMENT

The automatic power management (APM) circuit provides for internal or external dumping of excess reserve power.



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2.5 TRANSFORMER RECTIFIER MODULE

The output of the DC to DC converter are developed and rectified into the specific voltages needed throughout the ALSEP System by the transformer Rectifier Module.

2.6 OUTPUT FILTERS

The PCU output filters consist of a π type L-C filter for each output power line. Additional filtering is provided on each input and output line to reduce electromagnetic interference.

2.7 SENSING MODULE

The PCU sensing module provides filtering and TM status of RTG input voltage and current. This circuit also monitors the reserve power status and provides for PCU switching in event of unstable condition.

3.0 RELIABILITY PREDICTION

The reliability prediction for the Power Conditioning Unit operating in standby redundant configuration is calculated to be .999834 for launch, deployment and two years of lunar operation. The predicted reliability exceeds the specified goal of .98900 as stated in ATM 889, Section 4.2

Figure 2 shows the various modules which comprise the PCU and the Q's calculated for each module. The Q's for the redundant side of the PCU are calculated using the concept of standby redundancy. The Q's are based on a required two year operating life for the PCU.

The failure probability for each functional component identified in Figure 2 are tabulated in Table I. The probability failures shown represent composite totals derived from the part application stress ratios of each electronic piece part modified by the failure mode apportionment.

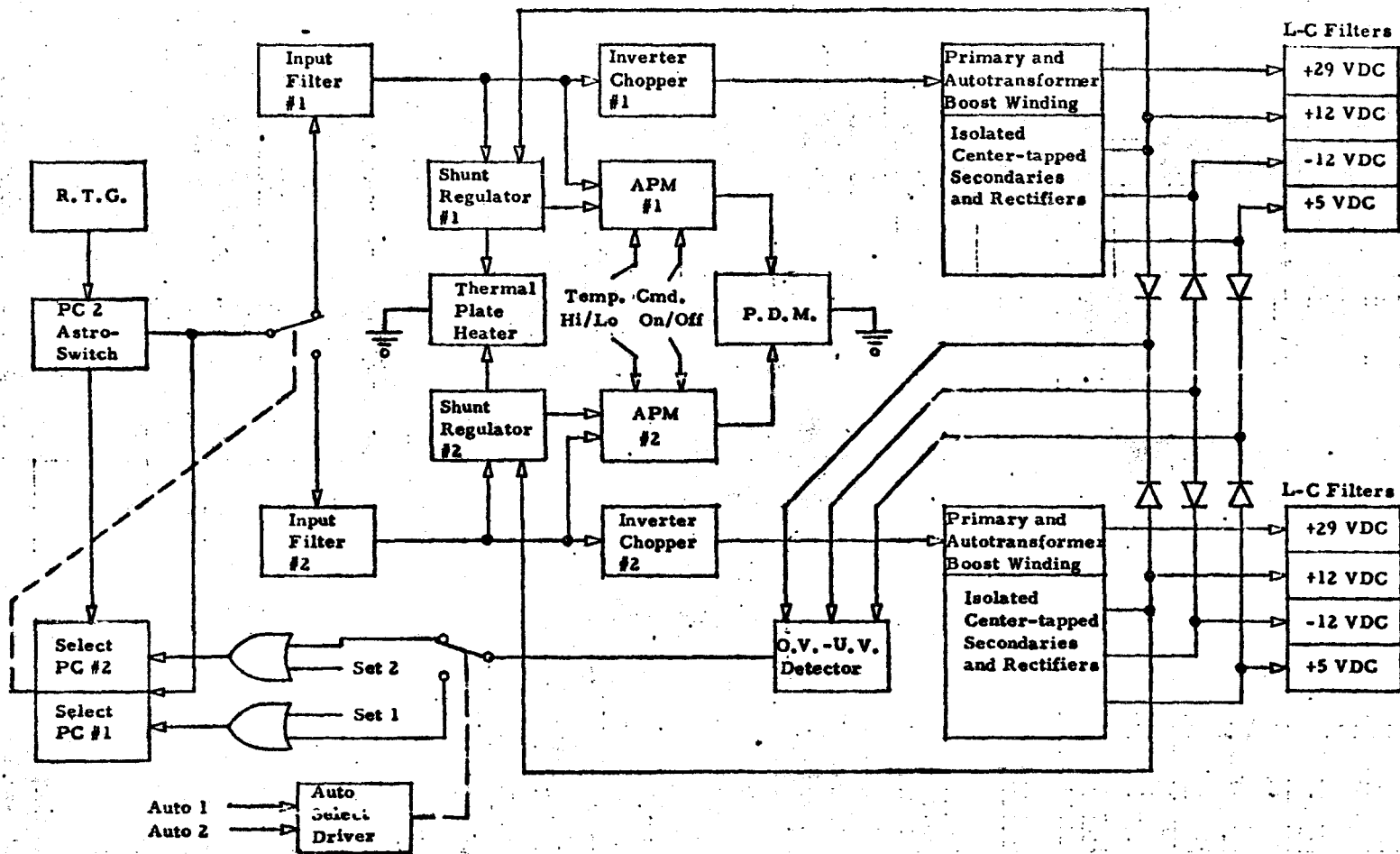


Figure 1
Block Diagram of the
Array E
Power Conditioning Unit

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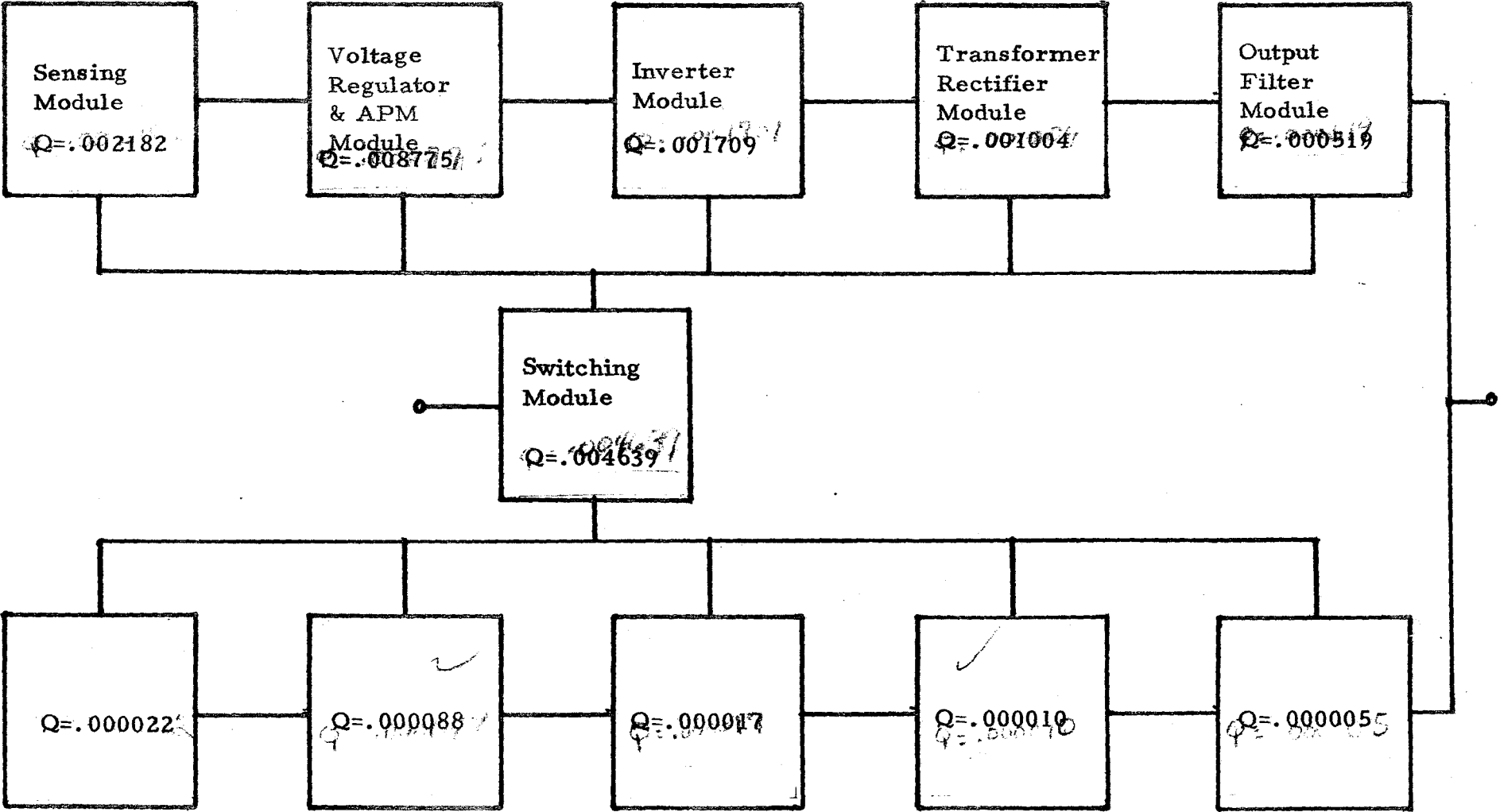


Figure 2 PCU Reliability Block Diagram



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TABLE I
PROBABILITY FAILURE SUMMARY

<u>Configuration</u>	<u>Q-Active</u>	<u>Q-Standby</u>
Sensing Module	.002182	.000022
Voltage Regulator and APM Module	.008775	.000088
Inverter Module	.001709	.000017
Transformer Rectifier Module	.001004	.000010
Output Filter Module	.000519	.000005
	$Q_1 = .014189$	$Q_2 = .000142$
Switching Module	$Q_S = .004639$	



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3.1 RELIABILITY CALCULATIONS

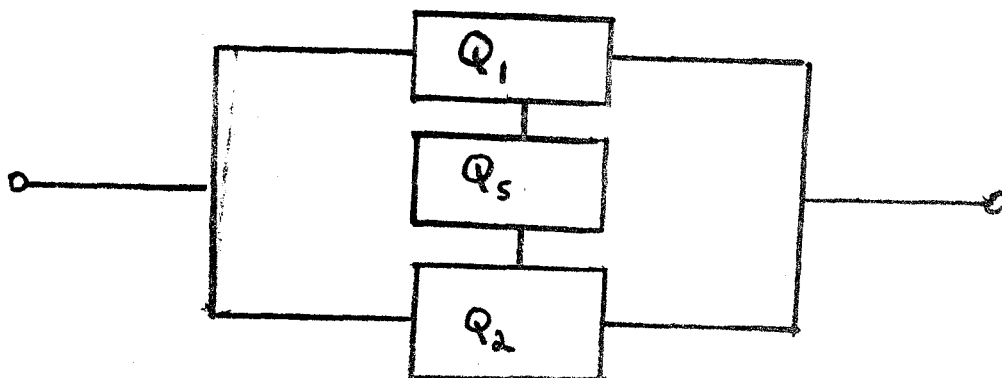


Figure 2 RELIABILITY MODEL

3.1.1

Q_1 = Probability Failure in Operation

Q_2 = Probability Failure in Standby

Q_S = Probability Failure in Switching

$$Q_T = \frac{Q_1 \cdot Q_1}{2} + \frac{Q_1 \cdot Q_2}{2} + Q_1 R_2 Q_S$$

$$Q_T = \frac{Q_1^2}{2} + \frac{Q_1 \cdot Q_2}{2} + Q_1 R_2 Q_S$$

$$R_T = 1 - Q_T$$

$$R_T = 1 - \frac{Q_1^2}{2} - \frac{Q_1 \cdot Q_2}{2} - Q_1 R_2 Q_S$$



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3.1.2

$$R_T = 1 - Q_T$$

$$R_T = 1 - \left(\frac{Q_1^2}{2} - \frac{Q_1 \cdot Q_2}{2} - Q_1 R_2 Q_S \right) \quad \text{Reliability Equation for PCU}$$

3.1.3

$$Q_2 = 1 - R_2$$

$$R_2 = 1 - Q_2$$

$$R_2 = 1 - Q_2$$

$$R_2 = .999858$$

$$Q_1 = .014189$$

$$Q_2 = .000142$$

$$Q_S = .004639$$

$$Q_T = \frac{(Q_1)^2}{2} + \frac{Q_1 \cdot Q_2}{2} + Q_1 \cdot R_2 \cdot Q_S$$

$$Q_T = \frac{(.014189)^2}{2} + \frac{(.014189)(.000142)}{2} +$$

$$(.014189)(.99985)(.004639)$$

$$Q_T = .000100 + .0000009 + .000065$$



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3.1.4

$$R_T = 1 - Q_T$$

$$R_T = 1 - .000166$$

$$R_T = .999834 \text{ Reliability, Redundant for full mission}$$

4.0 FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS

The failure mode and effects analysis for the PCU are documented in the following FMECA worksheets: These worksheets describe the functional failure modes and the resultant effect. Each identified failure mode is apportioned to a functional circuit and the criticality of each failure is weighted to the failure probability of each circuit reflected by the identified line item. The failure criticality ranking lists the system criticality effect as defined in Table II.

The format of the FMECA analysis is designed to provide the reader with a narrative description of the varying types of failures that could occur, combined with the resultant performance characteristics. This information is useful to system support in performing fault isolation should any anomaly occur.

There are no single point failures in the Array E PCU. Those parts which could be considered single point failures only in the remotest sense of the word are the power switching relay in the switching module and the relay in the sensing module. Both relays are double pole - double throw which cause system failure only in the event that both wiper arms of either relay broke off through mechanical damage.

The failure probability figures were derived from the environmental stress data contained in ATM 957, the PCU Parts Application Analysis. ATM 605A was used to derive the component α apportionments (open, short, etc.) Some failure modes, such as drift of a resistor do not, to a degree, affect the operation of the circuit. 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 unity.



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5.0 RELIABILITY ASSESSMENT

The purpose of performing a reliability prediction and failure mode analysis is to identify inherent design weaknesses. From the results of this analysis it has been concluded that single point failure modes have been eliminated from the PCU design and that the reliability and design objectives have been fully satisfied.

TABLE II

CRITICALITY RANKING CODE

<u>Code</u>	<u>System Effect</u>
I.	Loss of system
II.	Loss of system control
III.	Loss of one experiment
IV.	Loss of housekeeping channel(s)
V.	Loss of redundant element
VI.	Degradation of a redundant element.

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS						VR/APM Module	2349081-X	6-1-71
PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY Q x 10 ⁵	CRITICALITY			
		ASSEMBLY	END ITEM					
1.0 Voltage Regulator	1.0 Q1	1.0	1.0					
	Base-Emitter short .00882	Shunt regulator draws no current.	+12 Volt line increases until automatic switching to redundant PCU.	11.067	V			
	Base-Collector short .00882	Shunt regulator draws excessive current causing +12 volt line to drop.	Undervoltage detector circuit will automatically switch to redundant PCU.	11.067	V			
	Collect-Emitter short .00882							
	Base-Collector open .00720	Shunt regulator can draw no current.						
	Base-Emitter open .00720							
	1.1 Q2	1.1	1.1	9.042	V			
	Base-Emitter short .00337	Shunt regulator draws little current.	+12 Volt line increases until automatic switching to redundant PCU.					
	Collector-Emitter short .00337	Shunt regulator draws excessive current causing +12 volt line to drop.						
	Base-Collector short .00337		1.1					
	Base-Emitter open .00276	Shunt regulator draws no current.	Voltage on regulator rises until automatic switching to redundant PCU.	3.734	V			
	Collector-Base open .00276							
	1.3 Q9	1.3	1.3	3.734	V			
	Base-Emitter short .00882	Shunt regulator draws no current	Undervoltage detector circuit will automatically switch to redundant PCU.					
Collector-Emitter short .00882	Regulator draws excessive current causing regulator voltage to drop.	Overvoltage condition will cause detector circuit to automatically switch to redundant PCU.	3.463	V				
Base-Collector short .00882								
		1.3	11.067	V				
			11.067	V				

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITICALITY
		ASSEMBLY	END ITEM		
	Base-Emitter open .00721 Collector-Base open	Shunt regulator draws no current.	Regulator voltage will increase until overvoltage detector circuit switches to redundant PCU.	9.042	V
1.4 Q8	Base-Emitter short .02324	Shunt regulator draws no current.	Voltage on shunt regulator increases until overvoltage detector circuit switches to redundant PCU.	29.167	V
	Collector-Emitter short .02324 Base-Collector short	Shunt regulator draws excessive current causing regulator voltage to drop.	Undervoltage detector circuit will automatically switch to redundant PCU.	29.167	V
	Base-Emitter open .01899 Collector-Base open	Shunt regulator draws no current. Regulator voltage rises.	Overvoltage detector circuit will automatically switch to redundant PCU.	23.827	V
1.5 Q9	Base-Emitter short .00882	Shunt regulator draws no current	Voltage on shunt regulator increases until overvoltage detector circuit switches to redundant PCU.	11.061	V
	Base-Collector short .00882 Collector Emitter short	Shunt regulator draws excessive current causing regulator voltage to drop	Undervoltage detector circuit will automatically switch to redundant PCU.	11.067	V
	Base-Emitter open .00721 Collector-Base open	Shunt regulator will draw no current.	Voltage on shunt regulator increases until overvoltage detector circuit switches to redundant PCU.	9.042	V

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^3$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
	1.6 Q7 Base-Emitter short .01249 Collector-Emitter short .01249 Base-Collector short .01249 Base-Collector open .01010 Base-Emitter open .01010	1.6 Shunt regulator draws no current. Regulator draws excessive current causing regulator voltage to drop. Shunt regulator draws no current	1.6 Overvoltage condition will cause detector circuit to switch to redundant PCU. Undervoltage detector circuit will automatically switch to redundant PCU. Voltage on regulator will rise until overvoltage detector circuit switches to redundant PCU.	15.632 15.632 12.771	V V V
	1.7 R1, R3, R7, R27 short .0006292	1.7 Improper D. C. bias	1.7 Will cause undervoltage condition and automatic switching to redundant PCU.	0.789	V
	1.8 R1, R3, R7, R27 open .00421	1.8 Improper D. C. bias	1.8 Will cause overvoltage condition and automatic switching to redundant PCU.	5.282	V
	1.9 R14, R2, R39 R32, R29, R31 short .000936	1.9 Improper D. C. bias	1.9 Will cause overvoltage condition and automatic switching to redundant PCU.	1.194	V
	1.10 R14, R2, R39 R32, R29, R31 open .00626	1.10 Improper D. C. bias	1.10 Will result in undervoltage condition and automatic switching to redundant PCU.	7.923	V

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
2.0 Power Regulation	1.11 R6, R38, open short .00121	1.11 Loss of frequency compensation. Shunt regulator would become erratic.	1.11 Either overvoltage or undervoltage detector circuit would switch to redundant PCU. Faults signal would probably be sensed by O. V. circuit because of 300 millisecond time delay of U. V detector circuit.	1.518	V
	1.12 C1, C2, C5 short .00057	1.12 Voltage regulator turns on prematurely.	1.12 Undervoltage	0.707	V
	1.13 C1, C2, C5 open .00005	1.13 Regulator out of regulation because of lack of frequency compensation feedback.	1.13 Either overvoltage or undervoltage detector circuit switches to redundant PCU. Fault would probably be sensed by O. V. detector circuit because of 300 millisecond delay time of U. V. detector circuit.	0.069	V
	1.14 VR 1 short .01893	1.14 Loss of regulator voltage reference	1.14 Regulator would operate irrationally. Detector circuit would switch PCU's	23.749	V
	1.15 VR 1 open .01262	1.15 Excessive voltage supplied to Emitter Base junction of Q1. Transistor junction would break down.	1.15 Detector circuit would switch to redundant PCU.	15.733	V
	2.0 Q3 Base-Emitter short .00882	2.0 Power dump on constantly.	2.0 Experiment ripple off sequence will occur. Command switch PCU's.	22.134	V
	Collector-base short .00882				
	Collector-Base open .00360				
	Emitter-Base open .00360	Cannot turn power dump on.	Command switch PCU's.	9.042 VI	VI

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
	2.1 Q4	2.1 Cannot turn power dump on. Power dump on constantly	2.1 Command switch PCU's. Experiment ripple off sequence will occur. Command switch PCUs.	15.588	V
	Collector-Base open .00360				
	Base-Emitter short .00882			15.588	
	Collector-Base short .00882				
	Emitter-Base open .00360	2.2 Cannot turn power dump on. Power dump on constantly	2.2 Command switch PCU's. Experiment ripple off sequence will occur. Command switch PCU's.	40.379	VI
	2.2 Q5				
	Collector-Base open .00993			40.379	V
	Base-Emitter short .02285				
	Collector-Base short .02285	2.3 Cannot turn power dump on. Power dump on constantly	2.3 Command switch PCU's Experiment ripple off sequence will occur. Command switch PCU's	24.564	VI
	Emitter-Base open .00993				
	2.3 Q6			20.099	VI
	Base-Emitter short .01958				
	Collector-Base open .0161	2.4 APM indicates reserve power. Power will be dumped at maximum level. Cannot dump reserve power. Central Station would overheat.	2.4 Experiment ripple off sequence will occur. Command switch PCU's Command switch PCU's	18.921	V
	2.4 U1				
	Fails high .01837			44.147	VI
	Fails low .03518				

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITICALITY
		ASSEMBLY	END ITEM		
	2.5 U3 fails low .121128	2.5 Would provide false TM status. Would ripple experiments off.	2.5 Command switch PCU's,	136.269	V
	U3 fails high .05192	Could not ripple experiments off in low reserve power state.	Command switch PCU's.	58.41	V
	2.6 U2C fails high .00538	2.6 Could not command power dump on.	2.6 If central station overheated, command switch PCU's.	6.146	VI
	U2C fails low .012747	Power dump would be on at all times.	Could generate experiment ripple off sequence. Command switch PCU's	14.3402	V
	2.7 U2B fails high .00538	2.7 APM commanded on at all times. Cannot Command if off.	2.7 No appreciable system effect.	6.146	VI
	U2B fails low .012747	Could not command APM on.	Command switch PCU's.	14.3402	VI
	2.8 U2A fails high .00538	2.8 Could not switch APM on.	2.8 Command switch PCU's.	6.146	V
	U2A fails low .012747	Could not switch APM off.	No appreciable system effect.	14.3402	VI
	2.9 S1 fails closed .00455	2.9 Can not switch APM on.	2.9 Command switch PCU's.	10.243	VI
	2.10 S1 fails open .00455	2.10 APM on continuously.	2.10 No system effect.	10.243	VI

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)			EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
				ASSEMBLY	END ITEM		
	2.11 R16	open	.00396	2.11 Improper regulator temperature. TM. would indicate no temp	2.11 No system effect	4.45	VI
	2.12 R33	open	.00396	2.12 Improper regulator temperature. TM. would indicate no temp.	2.12 No system effect.	4.45	VI
	2.13 R35	open	.00396	2.13 Could not generate ripple off signal	2.13 Power would drop generating automatic switch command to redundant PCU.	4.45	V
	2.14 R12	open	.00396	2.14 APM would remain off	2.14 Central Station could overheat requiring command switching to redundant PCU.	4.45	V
	2.15 R 21	open	.00396	2.15 APM would stay on constantly	2.15 No system effect	4.45	VI
	2.16 R22	open	.00396	2.16 Would be unable to turn power dump on	2.16 Central station could overheat requiring command switching to redundant PCU.	4.45	V
	2.17 R8	open	.00396	2.17 Power dump would be on at all times	2.17 Could generate experiment ripple off signal. Could command switch PCU's	4.45	VI
	2.18 R9	open	.00396	2.18 Lose current pull up for U1.	2.18 No system effect.	4.45	VI
	2.19 R10	open	.00396	2.19 APM always on	2.19 No system effect.	4.45	VI
	2.20 R 23	open	.00396	2.20 Q3 would turn on hard	2.20 No system effect.	4.45	VI
	2.21 R 11	open	.00396	2.21 Could never turn APM on	2.21 Could cause central station to overheat resulting in command switching PCU's.	4.45	V
	2.22 R 28	open	.00396	2.22 Q4 would turn on hard	2.22 No system effect.	4.45	VI

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PART/COMPONENT SYMBOL	FAILURE MODE (α)			EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
				ASSEMBLY	END ITEM		
	2.23 R19, R4	open	.00396	2.23 No APM temp. TM status.	2.23 Loss of housekeeping data.	4.45	VI
	2.24 R 25	open	.00396	2.24 Incorrect APM temp. TM status	2.24 Incorrect housekeeping data.	4.45	VI
	2.25 R13	open	.00396	2.25 Cannot turn APM on.	2.25 Central Station could overheat requiring command switching of PCU's	4.45	V
	2.26 R5	open	.00396	2.26 Leakage current from Q4 would try to turn Q5 on. In Q5 comes on, APM is on.	2.26 No system effect.	4.45	---
	2.27 R17	open	.00396	2.27 APM dumps power real hard.	2.27 No system effect.	4.45	---
	2.28 R 20	open	.00396	2.28 No APM power TM.	2.28 Loss of housekeeping data.	4.45	---
	2.29 R 26	open	.00396	2.29 Incorrect APM power TM.	2.29 Incorrect housekeeping data.	4.45	---
	2.30 R 40	open	.00396	2.30 Would cause U 3 to generate ripple off signal.	2.30 Command switch PCU's.	4.45	V
	2.31 R 36	open	.00396	2.31 Prevent U3 from generating ripple off signal.	2.31 Command switch PCU's.	4.45	VI
	2.32 R 37	open	.00396	2.32 Resistor pull up for U 3.	2.32 No system effect.	4.45	V
	2.33 R 30	open	.00396	2.33 Resistor pull up.	2.33 No system effect.	4.45	VI
	2.34 R 34	open	.00396	2.34 Loss of APM CMD status TM.	2.34 Loss of housekeeping data.	4.45	VI
	2.35 R 41	open	.00396	2.35 Pull down resistor.	2.35 No system effect.	4.45	✓

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PART/COMPONENT SYMBOL	FAILURE MODE (α)			EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
				ASSEMBLY	END ITEM		
	2.36 C3	short	.001224	2.36 APM stays on.	2.36 No system effect.	1.37	VI
	C3	open	.00014	APM will start switching.	Command switch PCU's.	0.16	V
	2.37 C4	open	.00025	2.37 Loss of some signal filtering.	2.37 No system effect.	0.28	VI
	C4	short	.002205	Incorrect APM power TM.	Incorrect housekeeping data.	2.47	V
	2.38 C6	short	.002205	2.38 Will generate ripple off command.	2.38 Command switch PCU's.	2.47	V
	C6	open	.00025	Will lose some fileteing effect.	No system effect.	0.28	VI
	2.39 C7	short	.001224	2.39 Cannot command APM on.	2.39 Command switch PCU's.	1.37	V
	C7	open	.00014	Slow rise time for APM to come on.	No system effect.	0.16	VI

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^3$	CRITICALITY
		ASSEMBLY	END ITEM		
1.0 Inverter Module PCU I	1.0 C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16 Open .06492	1.0 If one capacitor opens would loose some ripple filtering effect. If 4 or more capacitors open, inverter would shut down while switching PCU's.	1.0 Momentary power interrupt to transformer while switching PCUs.	31.32	VI
	1.1 C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16 Short .06492	1.1 Loss of +16 v input I inverter.	1.1 Automatic PCU switching.	31.32	V
	1.2 Q3, Q4	1.2 Oscillator off 50% of time.	1.2 Automatic switching to PCU 2.	34.16	V
	Emitter to base open .01718 Collector to base open .01718 Emitter to base short .04170 Collector to base short .04170	Oscillator stops, drags 16v to ground.			
	1.3 Q1	1.3 Oscillator may not start at low temperature of lunar night.	1.3 Switch to PCU 2.	2.792	V
	Emitter to base I open .00482 Emitter to base II open .00482 Emitter to base I short .01178 Emitter to base II short .01178	10K resistor limits current drag down to 3 milliamps.	No system effect	6.842	VI
	1.4 CRI short .02944	1.4 Put 5 milliamp on transformer secondary, would require 200 mils for transformer to become saturated.	1.4 No system effect.	8.540	VI
		Capacitor on 16 v line would remove any AC ripple back to RTG.			
	1.5 CRI open .02944	1.5 Minor frequency superimposed on oscillator frequency.	1.5 No system effect.	8.540	VI

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
	1.6 CR 3 short .00443	1.6 Excessive forward biasing voltage would be applied to base-emitted junction of Q3, Q4. Could cause transistor breakdown	1.6 Would automatically switch to PCU 2	2.286	V
	1.7 CR3 open .00443	1.7 Oscillator would not be properly biased	1.7 Would automatically switch to PCU 2	2.286	V
	1.8 C3 short .00380	1.8 Cause improper biasing of oscillator	1.8 Would automatically switch to PCU 2	1.102	V
	1.9 R11 open .00577	1.9 No base current to Q3, Q4	1.9 Would automatically switch to PCU 2	1.671	V
	1.10 C1 short .00271	1.10 No effect once inverter has been started. If shorts prior to initiation of inverter, may not be able to start PCU I	1.10 No system effect	0.786	VI
	1.11 C1 open .00030	1.11 No effect once inverter has been started. If opens prior to initiation of inverter may not be able to start PCU I	1.11 No system effect	0.0873	VI

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITICALITY
		ASSEMBLY	END ITEM		
	1.12 R1 open .00450	1.12 Minor frequency superimposed on oscillator frequency	1.12 No system effect.	0.303	VI
	1.13 R 3, R5, R7 open .01258	1.13 Loss of oscillator	1.13 Automatic switching to PCU 2	2.894	V
	1.14 T1 Primary windings or Secondary winding open .006038	1.14 Loss of inverter.	1.14 Automatic switching to PCU 2	17.517	V
	1.15 T1 Primary windings or secondary windings short .006038	1.15 The 10 KHz frequency would become unstable.	1.15 Automatic switching to PCU 2	17.517	V

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^3$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
2.0 Inverter Module PCU 2	2.0 C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28 open .06492	2.0 If one capacitor opened, would lose some ripple filtering effect. If 4 or more capacitor open inverter would shut down while switching PCU's.	2.0 Momentary power interrupt to transformer while switching PCUs.	31.32	VI
	2.1 C17, C18, C19, C20, C22, C23, C24, C25, C26, C27, C28 short .06492	2.1 Loss of +16v input to inverter.	2.1 Automatic switching to PCU I.	31.32	V
	2.2 Q5, Q6 Emitter to base open .0718 Collector to base open .0718 Emitter to base short .04170 Collector to base short .04170	2.2 Oscillator off 50% of time. Oscillator stops, drags +16v to ground.	2.2 Automatic switching to PCU I.	34.16	V
	2.3 Q2 Emitter to base I open .00482 Emitter to base II open .00482 Emitter to base I short .01178 Emitter to base II short .01178	2.3 Oscillator may not start at low temperature of lunar night. 10Kohn resistor limits current drag down to 3 milliamps.	2.3 Switch to PCU I. No system effect.	2.792 6.842	V VI
	2.4 CR 2 short .02944	2.4 Puts 5 milliamps across transformer secondary. Would require minimum 200 milliamps to saturate core. Capacitors on +16v line would remove any AC ripple back to RTG.	2.4 No system effect.	8.540	VI
	2.5 CR2 open .02944	2.5 Minor secondary frequency imposed on 10 KHz frequency.	2.5 No system effect.	8.540	VI

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
2.6	2.6 CR4 short .00443	2.6 Excessive forward biasing voltage would be applied to base emitter junction of Q5, Q6. Could cause transistor breakdown.	2.6 Would automatically switch to PCU I.	2.286	VI
	2.7 CR4 open .00443	2.7 Oscillator would not be properly biased for on state.	2.7 Would automatically switch to PCU I.	2.286	V
	2.8 C4 short .00380	2.8 Improper biasing of oscillator.	2.8 Would automatically switch to PCU I.	1.102	V
	2.9 R 12 open .00577	2.9 No base current to Q5, Q6.	2.9 Would automatically switch to PCU I.	1.671	V
	2.10 C2 short .00271	2.10 No effect once inverter has been started. If shorts prior to initiation of inverter, may not be able to start PCU II.	2.10 Probably no system effect. Would start PCU I.	0.786	V
	2.11 C2 open .00030	2.11 No effect once inverter has been started. If opens prior to initiation of inverter, may not be able to start PCU II.	2.11 No system effect.	0.873	VI

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^3$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
	2.12 R2 open .00450	2.12 Minor frequency superimposed on oscillator frequency	2.12 No system effect	0.303	VI
	2.13 R4, R6, R8 open .01258	2.13 Loss of oscillator	2.13 Would automatically switch to PCU I	2.894	V
	2.14 Primary winding or secondary winding opens. .006038	2.14 Loss of inverter	2.14 Automatic switching to PCU I	17.517	V
	2.15 Primary winding or secondary winding shorts. .006038	2.15 The 10KHZ frequency would become unstable.	2.15 Degraded mode would automatically switch back to PCU I	17.517	V

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^3$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
1.0 Command Set PCU 1 and PCU 2 Circuit	1.1 Q1, Q6 Emitter to Base Short .1107	1.1 PCU 1 Command select relay driving transistor	1.1 Constant command select of PCU I. May lose capability of command switching to PCU 2. Auto 2 command would not automatically switch to PCU 2 IF PCUI became faulty.	37.564	VI
	1.2 Q1, Q6 Base to collector Base to emitter VR2 Open .0225 Open .0225 Short .1107	1.2 PCU 1 command select relay driving transistor	1.2 Could not command switch to PCU I.	15.344	VI
	1.3 Q2, Q7 Emitter to Base Short .1107	1.3 Command select relay input inverting transistors	1.3 Constant command select of PCU 2. May lose capability of command switching to PCU 1. Auto 1 command would not automatically switch to PCU I if PCU II became faulty.	37.567	V
	1.4 Q2, Q7 Base to collector Base to emitter VR3 Open .0225 Open .0225 Short .1107	1.4 PCU 2 command select relay input inverting transistors	1.4 Could not command switch to PCU II.	15.344	VI
	1.5 CR3, CR4 Short .00464 Open .00464	1.5 Voltage blocking diodes in event RTG becomes shorted.	1.5 Loss of line protection. Loss of ability to command select PCU 1 or PCU 2.	1.573 1.573	VI

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (OL)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^3$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
2.0 Auto 1, Auto 2 Select Circuit	1.6 R5, R6, R9, R10, R11, R12, R13, R15, R18, R19 Open .0410	1.6 Biasing resistors for transistors Q1, Q2, Q6, Q7	1.6 Erratic regulation. Automatic switching to redundant PCU	14.000	VI
	1.7 C1, C2 Short .0096	1.7 Loss of command switching to PCU side on which short occurred	1.7 Still have automatic switching capability.	2.1472	VI
	2.0 Q3, Q4 Emitter to Collector Short .1291 Base to Collector Open .0263 Base to emitter Open .0263	2.0 Auto 1 and Auto 2 inverting transistors	2.0 Loss of automatic switching capability. Can still switch by command.	57.448	VI
	2.1 Q5 Emitter to Collector Short .0266 Base to Emitter Open .0054 Base to Collector Open .0054	2.1 Auto 1 and Auto 2 relay driver.	2.1 Premature setting of automatic switching relay. Loss of redundant automatic switching capability.	8.4539 3.454	V VI
	2.2 R7, R8 Short .00071 Open .00824	2.2 Current Limiting	2.2 Loss of one side of PCU gate switching capability.	2.6037	VI

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^3$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
3.0 +12 Volt Detector Circuit	2.3 R 17, R18, R21, R22 Open .0164	2.3 Loss of R17, R18 automatic switching capability, or automatic switching	2.3 Could no longer depend on automatic switching. Would still be able to switch PCU's by command.	5.5992	VI
	2.4 R3, R4, R21, R15, R16 Open .000928	2.4 Loss or degradation of Auto switching TM status	2.4 No effect on system operation	4.1994	VI
	2.5 K1 Shorted contact .10786 Open contact .16868	2.5 Loss of all PCU switching	2.5 System would have to operate with previously energized PCU.	87.580	V
	3.0 Emitter to Collector Short .1272	3.0 Premature switching of PCU's.	3.0 Reduces system to single PCU.	41.228	V
	3.1 Q8, Q9 Emitter to Base Open .0259 Collector to Base Open .0259	3.1 Failure of PCU's to switch on +12 undervoltage condition	3.1 Loss of +12 volt overvoltage detection	16.841	VI
	3.2 Q11A, Q11B Emitter to Collector Short .04596	3.2 Would not be able to turn Q8 or Q9 on in event of 12V undervoltage or overvoltage condition.	3.2 Would not automatically switch PCU's in event of +12V over-voltage, undervoltage condition. Would require sending a command to switch PCU's.	14.888	VI
	VR1 Short .1107				

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
	3.3 Q11A, Q11B Emitter to Base Open .0093 Collector to Base Open .0093	3.3 Lose ability to turn Q8, Q9 on during faulty voltage condition	3.3 Command switch from faulty to redundant PCU.	5.994	VI
	3.4 C4 Short .0048	3.4 Cannot furnish sufficient base drive to transistor Q11A. Cannot automatically switch PCU's during +12V overvoltage condition	3.4 Command switch from faulty to redundant PCU.	1.0736	VI
	3.5 C4 Open .0048	3.5 Loss of time delay capability. Temporary spike may cause switching of PCU's.	3.5 No system effect. Can command switch PCU's.	1.0736	VI
	3.6 CR9 Short .0706 Open .0706	3.6 Loss of reference voltage. Would result in loss of +12 volt Detector Circuit.	3.6 Command switch from faulty to redundant PCU.	45.827	VI
	3.7 R24, R25, R27, R28, R33, R34, R35, R37, R38 Open .03608	3.7 Improper biasing of +12 volt fault detector transistors.	3.7 Detector circuit may switch prematurely if biasing resistor opens.	11.692	VI

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
4.0 +5V Fault Detector Signal	4.0 Q14A Shorts Emitter to Collector .1254	4.0 Would result in premature switching to redundant PCU.	4.0 Would operate in redundant PCU mode of operation. Loss of +5 volt detector circuit.	7.3481	V
	4.1 Q14A Emitter to base Open .0015 Collector to base Open .0015	4.1 Faulty +5 volt signal would not cause automatic switching of PCU's.	4.1 Could command switch to redundent PCU.	4.410	VI
	4.2 R40, R41, R42, R43 Open .06415	4.2 Would preclude automatic switching in event of faulty 5 volt signal.	4.2 Could command switch PCU's in the event of open condition.	.3808	VI
5.0 -12V Fault Detector Signal	5.0 Q12A Short Collector to Emitter .2114	5.0 Would lose ability to automatically switch PCU's in event of faulty -12 volt signal.	5.0 Could command switch to redundant PCU.	8.4774	VI
	5.1 Q12A Emitter to Base Open .0430 Collector to Base Open .0430	5.1 Would result in non switching to redundant PCU.	5.1 Would operate in redundant PCU mode of operation.	3.47	V
	5.2 R44, R45, R46, R47 Open .0698	5.2 If one of the biasing resistors opened, premature switching of PCU's would occur.	5.2 Would operate in redundant mode of operation in event open caused premature switching or could attempt command switch back of PCU's.	2.802	V

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
1.0 Regulator I internal dump C3, C4, L2	1.0 C3, C4	Short .686	1.0 Lose capability to dump excessive reserve power internally to PCU.	1.0 Requires switching to redundant PCU.	5.928 V
	1.1 C3, C4	Open .075	1.1 Loss of some ripple filtering capability.	1.1 No system effect in that excessive current should not damage dump resistors.	0.6587 VI
	1.2 L2	Short .0144	1.2 No appreciable effect. Loss of ripple damping effect.	1.2 No System effect.	0.3153 V
	1.3 L2	Open .1296	1.3 Could not dump excess power internally	1.3 Would require switching to redundant PCU.	2.8383 V
	2.0 L1	Open .1296	2.0 Loss of external power dump for PCU I	2.0 Switch to redundant PCU.	2.8383 V
	L1	Short .0144	2.1 No appreciable effect. Loss of ripple damping effect.	2.1 No system effect in that excessive current should not damage dump resistors.	0.3153 VI
	2.2 C2	Short .2628	2.2 Would be unable to use APM I ext. dump.	2.2 Would switch to redundant PCU.	2.5052 V
	2.3 C2	Open .0292	2.3 No effect	2.3 No system effect	5.262 VI
	3.0 C5, C6	Short .0563	3.0 Lose +29V line for PCU I.	3.0 Switch to PCU 2.	0.529 V
	3.1 C5, C6	Open .5077	3.1 Loss of some ripple filtering capability.	3.1 No system effect in that voltage ripple should not be excessive. In event that voltage ripple is excessive can switch to PCU 2.	4.763 VI
2.0 APM I EXT. Dump	3.2 L3	Open .3157	332 Loss of +29V output line for PCU I.	3.2 Would switch to PCU 2.	2.9741 V
3.0 PCU I + 29V line					

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PART/COMPONENT SYMBOL	FAILURE MODE (α)		EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
			ASSEMBLY	END ITEM		
4.0 PCU I +12V line	3.3 L3	Short . 0315	3.3 Loss of some ripple filtering Capability on +12V line.	3.3 No system effect in that voltage ripple should not be excessive. In event that voltage ripple is excessive, would switch to PCU 2.	0.3293	VI
	4.0 C7, C8	Short . 4400	4.0 Loss of +12V line for PCU I	4.0 Switch to PCU 2.	3.4318	V
	4.1 C7, C8	Open . 0488	4.1 Loss of some ripple filtering capability.	4.1 No system effect in that voltage ripple should not be excessive. In event ripple becomes excessive can switch to PCU 2.	0.3813	VI
	4.2 L4	Open . 3600	4.2 Loss of +12 volt output line for PCU I.	4.2 Would switch to PCU 2.	2.808	V
	4.3 L4	Short . 0400	4.3 No appreciable effect. Loss of some ripple damping effect.	4.3 No system effect in that voltage ripple should not be excessive. In event ripple becomes excessive, can switch to PCU 2.	0.3120	VI
5.0 PCU I +5V line	5.0 C9, C10	Short . 5166	5.0 Loss of +5V output line for PCU I.	5.0 Switch to PCU 2.	5.0110	V
	5.1 C9, C10	Open . 0574	5.1 Loss of some voltage ripple filtering capability	5.1 No system effect in that voltage ripple should not be excessive. In event ripple becomes excessive can switch to PCU 2.	0.5567	VI
	5.2 L5	Open . 3054	5.2 Loss of +5 volt output line for PCU I.	5.2 Would switch to PCU 2.	2.9625	V
	5.3 L5	Short . 0339	5.2 No appreciable effect. Loss of some ripple damping effect.	5.3 No system effect in that voltage ripple should not be excessive. In event ripple becomes excessive can switch to PCU 2.	0.3291	VI

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY Q x 10 ⁻³	CRITIC- ALITY
		ASSEMBLY	END ITEM		
6.0 PCU I -12V line	6.0 C11, C12 Short .3456	6.0 Loss of -12V output line for PCU I.	6.0 Switch to PCU 2.	5.0110	V
	6.1 C11, C12 Open .0384	6.1 Loss of some voltage ripple filtering.	6.1 No system effect in that voltage ripple should not be excessive. In event ripple becomes excessive can switch to PCU 2.	0.5567	VI
	6.2 L6 Open .3054	6.2 Loss of -12 volt output line for PCU I.	6.2 Would switch to PCU 2.	2.9625	V
	6.3 L6 Short .0339	6.3 No appreciable effect. Loss of some damping effect.	6.3 No system effect in that voltage ripple should not be excessive. In event ripple becomes excessive can switch to PCU 2.	0.3291	VI
7.0 Regulator 2 internal dump	7.0 C13, C14 Short .5255	7.0 Lose capability to dump excessive reserve power internally to PCU.	7.0 Requires switching to PCU I.	5.2656	V
	7.1 C13, C14 Open .0583	7.1 Loss of some ripple filtering capability.	7.1 No system effect in that excessive current should not be great enough to damage dump resistors.	0.5850	VI
	7.2 L7 Short .0328	7.2 No appreciable effect. Loss of ripple dampening effect.	7.2 No system effect.	0.329	VI
	7.3 L7 Open .2858	7.3 Could not dump excess reserve power internally.	7.3 Would require switching to PCU I.	2.964	V
	8.0 L12 Open .8532	8.0 Loss of external power dump for PCU 2.	8.0 Switch to PCU I.	2.961	V
8.0 APM 2 External Dump	8.1 L12 Short .0948	8.1 No appreciable effect. Loss of ripple dampening effect.	8.1 No system effect in that excessive current should not damage dump resistors.	0.329	VI
	8.2 C23 Short .2628	8.2 Would be unable to use APM 2 ext. dump.	8.2 Would switch to redundant PCU.	2.328	VI
	8.3 C23 Open .0292	8.3 No effect.	8.3 No system effect	2.5052	V

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
9.0 PCU 2 -12V line	9.0 C15, C16 Short .4539	9.0 Loss of -12V output line for PCU II.	9.0 Switch to PCU I.	3.6265	V
	9.1 C15, C16 Open .0504	9.1 Loss of some voltage ripple filtering	9.1 No system effect in that voltage ripple should not be excessive. In event ripple becomes excessive can switch to PCU I.	0.4029	VI
	9.2 L8 Open .3710	9.2 Loss of -12 volt output line for PCU 2.	9.2 Switch to PCU I.	2.9644	V
	9.3 L8 Short .0412	9.3 No appreciable effect. Loss of some ripple dampening effect.	9.3 No system effect in that voltage ripple should not be excessive. In event ripple becomes excessive, can switch to PCU I.	0.3293	VI
10.0 PCU 2 +5V line	10.0 C17, C18 Short .4539	10.0 Loss of +5V output line for PCU II.	10.0 Switch to PCU I.	3.6256	V
	10.1 C17, C18 Open .0504	10.1 Loss of some voltage ripple filtering capability.	10.1 No system effect. If ripple becomes excessive can switch to PCU I.	0.4029	VI
	10.2 L9 Open .3710	10.2 Loss of +5 volt output line for PCU 2.	10.2 Switch to PCU I.	2.9644	V
	10.3 L9 Short .0412	10.3 No appreciable effect.	10.3 No system effect. If ripple becomes excessive, can switch to PCU I.	0.3293	VI
11.0 PCU 2 +12V line	11.0 C19, C20 Short .0574	11.0 Loss of +12V output line for PCU II.	11.0 Switch to PCU I.	0.5567	V
	11.1 C19, C20 Open .5166	11.1 Loss of some voltage ripple filtering capability.	11.1 No system effect in that ripple voltage should not be excessive. In event ripple becomes excessive, switch to PCU I.	5.0110	VI

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-3}$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
12.0 PCU 2 +29V line	11.2 L10 Open . 2710	11.2 Loss of +12V output line for PCU I.	11.2 Switch to PCU I.	2.9625	V
	11.3 L10 Short . 0304	11.3 No appreciable effect. Loss of some ripple dampening effect.	11.3 No system effect. If ripple becomes excessive, switch to PCU I.	0.3291	VI
	12.0 C21, C22 Short . 2707	12.0 Loss of +29 volt output line for PCU 2	12.0 Switch to PCU I.	5.9287	V
	12.1 C21, C22 Open . 0300	12.1 Loss of some voltage ripple filtering.	12.1 No system effect. If ripple becomes excessive, switch to PCU I.	0.6587	VI
	12.2 L11 Open . 1296	12.2 Loss of +29V output line for PCU 2.	12.2 Switch to PCU I.	2.8383	V
	12.3 L11 Short . 0144	12.3 No appreciable effect. Loss of some ripple dampening effect.	12.3 No system effect. If ripple becomes excessive, switch to PCU I.	0.3153	VI

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PART/COMPONENT SYMBOL	FAILURE MODE (α)		EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-3}$	CRITIC- ALITY
			ASSEMBLY	END ITEM		
1.0 RTG Supply Voltage Sensing Filter and TM Signals	1.0 L1, L2	Short .02988	1.0 Loss of some ripple filtering capability	1.0 No system effect	1.4148	VI
	C1, C2, C3, C4	Short .0343	Loss of one RTG Voltage TM status	No significant system effect.		
	VR1, VR2, VR3	Short	If VR1 or VR2 shorts, lose one voltage TM for PCU 1. If VR3 shorts lose voltage TM for PCU 2.	Still have RTG input current status.		
	1.1 L1, C1, C2	Open .2728	1.1 Loss of either or both RTG Voltage TM signals for one PCU.	1.1 No significant system effect. Still have RTG input current status.	6.0124	VI
	L2, C3, C4		No effect on PCU	Damage could occur to MUX during RTG open condition.		
	VR1, VR2, VR3	Open	1.2 Loss of one RTG TM Status. There are two TM status signals for PCU 1 and one for PCU 2.	1.2 No significant system effect	8.1355	VI
	1.2 R3, R8	Open .36914				
	R4, R9					
	R11, R12					
	2.0 CR1, CR2, CR3, CR4	Short 2.014	2.0 Erratic RTG input current TM	2.0 Some current data would be		
	T1, T2	Open .9769	indication from one winding of inverter transformer. False indication of RTG input power.	indicated by TR 2 TM. No system effect.	159.612	VI
	CR9, CR10, CR11, CR12	Short 2.014				
T7, T8	Open .9767					
2.1 CR5, CR6, CR7, CR8	Open .9769	2.1 Erratic reserve power current TM	2.1 Some reserve power would be			
T3, T4	Short 2.014	indication from second winding of inverter transformer. False indication of reserve power.	indicated by TR 1 TM. No system effect.	159.612	VI	
CR13, CR14, CR15, CR16	Short 2.014					
T5, T6	Open .9769					
2.2 R1, R14, R5, R13	Open .0219	2.2 Loss of 10 K HZ signal from one winding of transformer	2.2 Second winding TM status would indicate some status.	7.9459	VI	

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
3.0 Relay Switching Circuit	2.3 R6 Open .0038	2.3 Loss of reserve power B status	2.3 No system effect. Still have Reserve Power A	1.5108	VI
	2.4 R7, C5 R10, C6 Open .00295 Open .00295	2.4 Loss of one reserve power status.	2.4 No system effect, redundant reserve power status.	1.7787	VI
	3.0 K1 Short .4570 Open .4570	3.0 Would switch to side with shorted contacts. Open condition would preclude switching to one side of relay.	3.0 Loose PCU redundancy. ALSEP would have to operate with one PCU.	86.83	V
	3.1 R15 Open .0091	3.1 Would result in loss in one side of relay.	3.1 Loose PCU redundancy ALSEP would have to operate with one PCU.	0.8788	V
	CR17 CR18 Short .0127 Short .0127	Short out one coil of relay. Can't switch PCU's.	ALSEP would have to operate with one PCU.	1.3995	V
	CR17 CR18 Open .0127 Open .0127	Loss of relay driver transistor negative spike protection.	Could switch PCU's one time. Would probably damage transistor driver in process.	1.3995	V

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
1.0 DC-DC Converter PCU 1	1.0 CR1, CR2 Open .0642	1.0 If either diode opens, would result in intermittent +29V being supplied in 50M second intervals from PCU 1.	1.0 Would require switching to PCU 2.	24.515	V
	1.1 CR1, CR2 Short .0642	1.1 If either diode shorts would result in loss of diode isolation protection.	1.1 No system effect.	24.515	VI
2.0 DC-DC Converter PCU 2	2.0 CR1, CR2 Open .0642	2.0 If either diode opens, would result in intermittent +29V being supplied in 50M second increments from PCU 2.	2.0 Would require switching to PCU 1.	24.515	V
	2.1 CR1, CR2 Short .0642	2.1 If either diode shorts, would result in loss of diode isolation protection.	2.1 No system effect	24.515	VI
3.0 DC-DC Converter PCU 1	3.0 CR5, CR6, CR7, CR8, CR9, CR10 Open .1787	3.0 Any open would result in intermittent +5V+12V, or -12V supply from transformer T1 of PCU 1.	3.0 Would require switching to PCU 2.	68.263	V
	3.1 CR5, CR6, CR7, CR8, CR9, CR10 Short .1787	3.1 Diode short would result in loss of diode isolation protection for the associated power line.	3.1 No system effect	68.263	VI
4.0 DC-DC Converter PCU 2	4.0 CR11, CR12, CR13, CR14, CR15, CR16 Open .1787	4.0 Any open would result in intermittent +5V, +12V, or -12V supply from transformer T2 of PCU 2.	4.0 Would require switching to PCU 1.	68.263	V
	4.1 CR11, CR12, CR13, CR14, CR15, CR16 Short .1787	4.1 Any open would result in intermittent +5V, +12V or -12V supply from transformer T2 of PCU 2.	4.1 No system effect	68.263	VI

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PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITIC- ALITY
		ASSEMBLY	END ITEM		
5.0 Fault Signal output PCU I	5.0 CR17, CR18, CR19 Open .3495	5.0 Would not supply signal to Detector circuit.	5.0 Probably not require switching PCU's as other two signals could indicate faulty signal and switch PCU's.	3.858	VI
	5.1 CR17, CR18, CR19 Short .3495	5.1 Short would result in loss of diode protection to output lines.	5.1 No system effect.	3.853	VI
6.0 Fault signal output PCU II	6.0 CR20, CR21, CR22 Open .3495	6.0 Would not supply signal to detector circuit.	6.0 Probably not require switching PCU's as other two signals could indicate faulty signal and could switch PCU's.	3.853	VI
	6.1 CR20, CR21, CR22 Short .3495	6.1 Short would result in loss of diode protection to output lines.	6.1 No system effect.	3.853	VI