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.

This document has been revised to reflect the latest engineering changes as presented at the CDR of 14 June 1971. These changes include the following modifications:

(a) Addition of 1 zener diode, 1 resistor and 4 hex inverters to the VR/APM module.

(b) Deletion of 11 wet tantalum capacitors from the Inverter Module.

(c) Modification of the output Filter Module which includes the following:

(1) Reduction of 100 μh inductance coils to 10 μh's.

(2) Change the π type filter for the +29 V line which adds 2 wet slug capacitors in parallel.

Prepared by L. S. Moskowitz
L. S. Moskowitz
ALSEP Reliability Dept.

Approved by S. J. Ellison
S. J. Ellison
ALSEP Reliability Manager

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.

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 .999837 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.

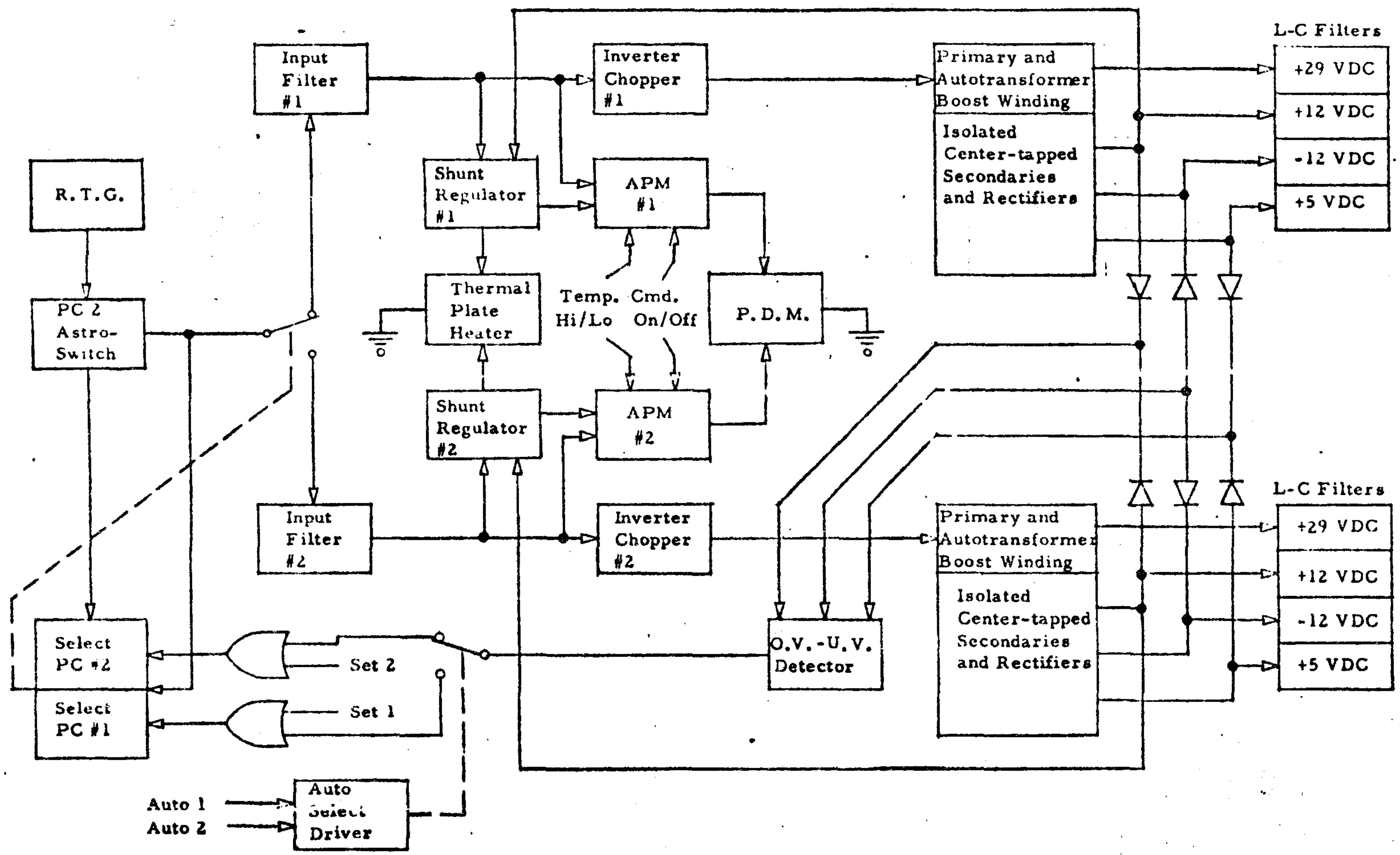

Figure 1

Block Diagram of the

Array E

Power Conditioning Unit

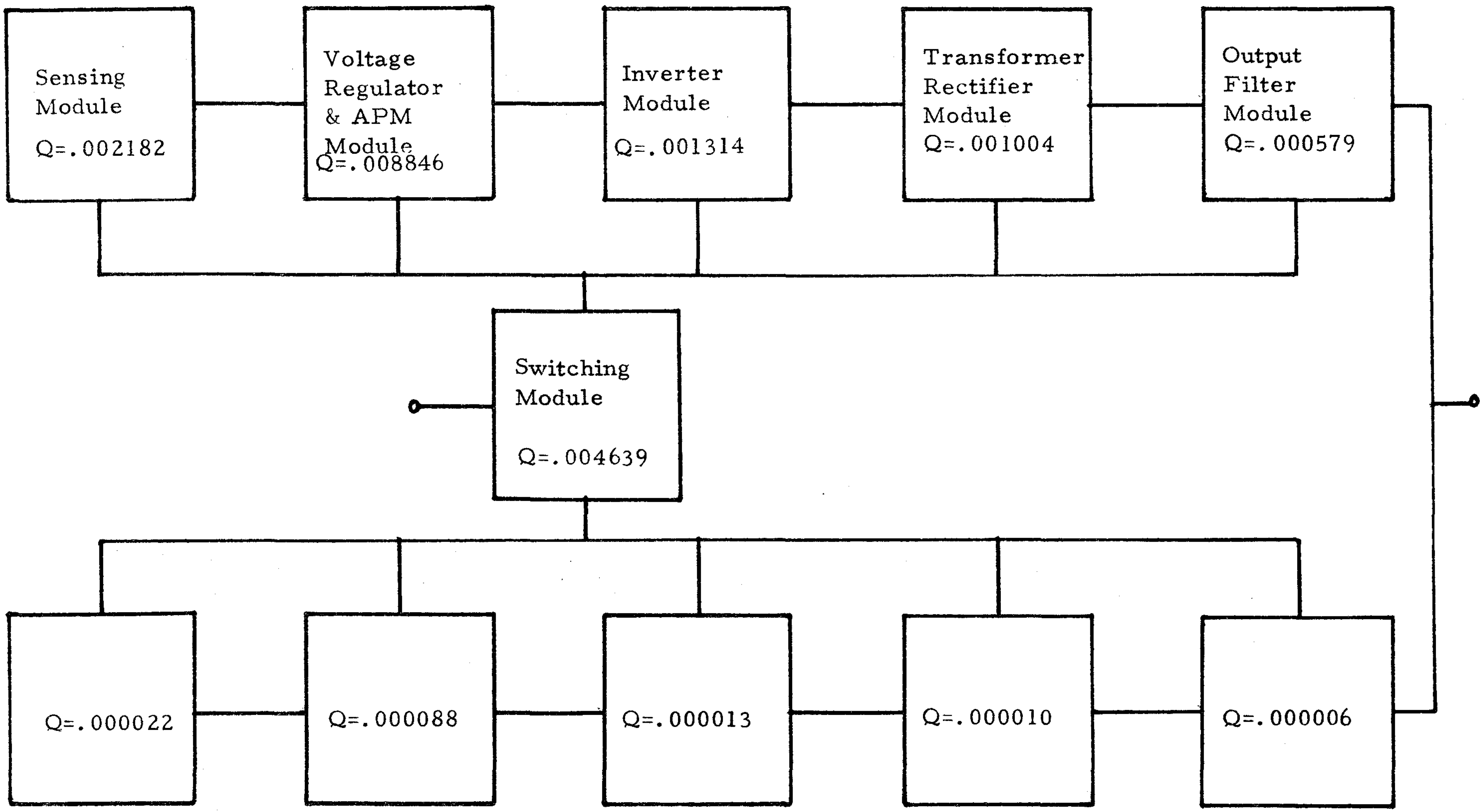

Figure 2 PCU Reliability Block Diagram

TABLE I

PROBABILITY FAILURE SUMMARY

Configuration	Q-Active	Q-Standby
Sensing Module	.002182	.000022
Voltage Regulator and APM Module	.008846	.000088
Inverter Module	.001314	.000013
Transformer Rectifier Module	.001004	.000010
Output Filter Module	.000579	.000006
	Q_1 = .013925	Q_2 = .000139
Switching Module	Q_S = .004639	

3.1 RELIABILITY CALCULATIONS

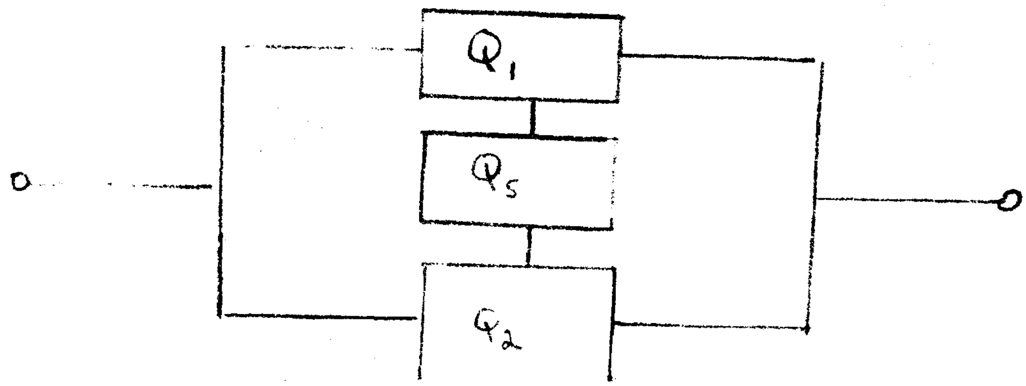

Figure 2 RELIABILITY MODEL

3.1.1

Q_1 = Probability Failure in Operation

Q_2 = Probability Failure in Standby

Q_S = Probability Failure in Switching

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

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

$$R_T = 1 - Q_T$$

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

3.1.2

$$R_T = 1 - Q_T$$

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

3.1.3

$$Q_2 = 1 - R_2$$

$$R_2 = 1 - Q_2$$

$$R_2 = 1 - Q_2$$

$$R_2 = .999861$$

$$Q_1 = .013925$$

$$Q_2 = .000139$$

$$Q_S = .004639$$

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

$$Q_T = \frac{(.013925)^2}{2} + \frac{(.013925)(.000139)}{2} +$$

$$(.013925)(.999861)(.004639)$$

$$Q_T = .000097 + .000001 + .000065$$

3.1.4

$$R_T = 1 - Q_T$$

$$R_T = 1 - .000163$$

$$R_T = .999837$$ 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.

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 satisified.

TABLE II

CRITICALITY RANKING CODE

Code	System Effect
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.

1

SYSTEM	PREPARED BY	NO.	REV.
ALSEP	L. Moskowitz	ATM952	A
END ITEM: PCU	DWG NO.	PAGE 11 of 39	
ASS'Y: VR/APM Module	DWG NO. 2349081-X	DATE 6-1-71	

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. 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 Collect-Emitter 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
	Base-Collector open Base-Emitter open	.00720	Shunt regulator can draw no current.	+12 Volt line increases until automatic switching to redundant PCU.	9.042	V
	1. 1 Q2		1. 1	1. 1		
	Base-Emitter short	.00337	Shunt regulator draws little current.	Voltage on regulator rises until automatic switching to redundant PCU.	3.734	V
	Collector-Emitter short Base-Collector short	.00337	Shunt regulator draws excessive current causing +12 volt line to drop.	Undervoltage detector circuit will automatically switch to redundant PCU.	3.734	V
	Base-Emitter open Collector-Base open	.00276	Shunt regulator draws no current.	Overvoltage condition will cause detector circuit to automatically switch to redundant PCU.	3.463	V
	1. 3 Q 9		1. 3	1. 3		
	Base-Emitter short	.00882	Shunt regulator draws no current	Voltage on regulator rises until O. V detector circuit switches to redundant PCU.	11.067	V
	Collector-Emitter short Base-Collector short	.00882	Regulator draws excessive current causing regulator voltage to drop.	Undervoltage detector circuit will automatically switch to redundant PCU.	11.067	V

SYSTEM	PREPARED BY	NO.	REV.
ALSEP	L. Moskowitz	ATM952	A
END ITEM PCU	DWG NO.	PAGE 12 of 39	
ASS'Y VR/APM Module	DWG NO. 2349081-X	DATE 6-1-71	

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
	Base-Emitter open Collector-Base open	.00721	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	1.4 Shunt regulator draws no current.	1.4 Voltage on shunt regulator increases until overvoltage detector circuit switches to redundant PCU.	29.167	V
	Collector-Emitter short Base-Collector short	.02324	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 Collector-Base open	.01899	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	1.5 Shunt regulator draws no current	1.5 Voltage on shunt regulator increases until overvoltage detector circuit switches to redundant PCU.	11.061	V
	Base-Collector short Collector Emitter short	.00882	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 Collector-Base open	.00721	Shunt regulator will draw no current.	Voltage on shunt regulator increases until overvoltage detector circuit switches to redundant PCU.	9.042	V

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 13 of 39	
ASS'Y VR/APM Module	DWG NO. 2349081-X	DATE 6-1-71	

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
	1.6 Q7 Base-Emitter short	.01249	1.6 Shunt regulator draws no current.	1.6 Overvoltage condition will cause detector circuit to switch to redundant PCU.	15.632	V
	Collector-Emitter short Base-Collector short	.01249	Regulator draws excessive current causing regulator voltage to drop.	Undervoltage detector circuit will automatically switch to redundant PCU.	15.632	V
	Base-Collector open Base-Emitter open	.01010	Shunt regulator draws no current	Voltage on regulator will rise until overvoltage detector circuit switches to redundant PCU.	12.771	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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 14 of 39	
ASS'Y VR/APM Module	DWG NO. 2349081-X	DATE 6-1-71	

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
	1.11 R6, R38, open short	.00121	1.11 Loss of frequency compensation. Shunt regulator would become irratic.	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 irratically. 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 Power Regulation	2.0 Q3		2.0	2.0		
	Base-Emitter short	.00882	Power dump on constantly.	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

5

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 15 of 39	
ASS'Y VR/APM Module	DWG NO. 2349081-X	DATE 6-1-71	

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 Q4		2.1	2.1		
	Collector-Base open	.00360	Cannot turn power dump on.	Command switch PCU's.	15.588	V
	Base-Emitter short	.00882				
	Collector-Base short	.00882	Power dump on constantly	Experiment ripple off sequence will occur. Command switch PCUs.	15.588	
	Emitter-Base open	.00360				
	2.2 Q5		2.2	2.2		
	Collector-Base open	.00993	Cannot turn power dump on.	Command switch PCU's.	40.379	VI
	Base-Emitter short	.02285				
	Collector-Base short	.02285	Power dump on constantly	Experiment ripple off sequence will occur. Command switch PCU's.	40.379	V
	Emitter-Base open	.00993				
	2.3 Q6		2.3	2.3		
	Base-Emitter short Collector-Base open	.01958	Cannot turn power dump on.	Command switch PCU's	24.564	VI
	Collector-Base short	.0161	Power dump on constantly	Experiment ripple off sequence will occur. Command switch PCU's	20.099	VI
	2.4 U1		2.4	2.4		
	Fails high	.01837	APM indicates reserve power. Power will be dumped at maximum level.	Experiment ripple off sequence will occur. Command switch PCU's	18.921	V
	Fails low	.03518	Cannot dump reserve power. Central Station would overheat.	Command switch PCU's	44,147	VI

SYSTEM	PREPARED BY	NO.	REV.
ALSEP	L. Moskowitz	ATM952	A
END ITEM	DWG NO.	PAGE 16 of 39	
PCU		DATE	
ASS'Y	DWG NO.	6-1-71	
VP/A/M Module	2349081-X		

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
	2.5 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

7

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 17 of 39	
ASS'Y VR/APM Module	DWG NO. 2349081-X	DATE 6-1-71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE			(α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
					ASSEMBLY	END ITEM		
	2.11	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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 18 of 39	
ASS'Y VR/APM Module	DWG NO. 2349081-X	DATE 6-1-71	

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
	2.23 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 turnQ5on. 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 Risistor pull up for U 3.	2.32 No system effect.	4.45	V
	2.33 R 30	open	.00396	2.33 Risistor 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	V

SYSTEM	PREPARED BY	NO.	REV.
ALSEP	L. Moskowitz	ATM952	A
END ITEM: PCU	DWG NO.	PAGE 19 of 39	
ASS'Y: VR/APM	DWG NO. 2349081-X	DATE 6-1-71	

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
	2.36	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 filtering effect.		No system effect.	0.28	VI
	2.39	C7	short, U2D	.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
	2.40	U2E	high	.05508	2.40	Could not command APM on.	2.40	Command switch PCU's	189.204	V
		U2B	low	.11016	2.40	Could not command				
		U2B	high	.05506		APM on at all times.		No system effect	189.204	VI
	2.41	U2D	high	.05508	2.41	Could not command APM off.	2.41	No system effect.	189.204	VI
		U2C	low	.11016						
		U2D	low	.05508		Could not command APM on.		Command switch PCU's	189.204	V
		U2C	high	.11016						
	2.42	VR5	short	.01893	2.42	Loss of + 5V line.	2.42	Switch PCU's.	23.749	V
		VR5	open	.01262		The +5 V line could increase to 6.1 volts.		Probably no effect.	15.733	VI
	2.43	R9	open	.00396	2.43	Loss of +5 V line.	2.43	Switch PCU's.	4.45	V

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 20 of 39	
ASS'Y Inverter Module	DWG NO. 2368161	DATE 6-1-71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE		(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁵	CRITICALITY
1.0 Inverter Module PCU I	1.0 C8		.00541	1.0 If capacitor opened, would lose some ripple filtering effect and inverter would shut down while switching PCU's.	1.0 Momentary power interrupt to transformer while switching PCUs.	2.61	VI
	1.1 C8		.00541	1.1 Loss of +16 v input I inverter.	1.1 Automatic PCU switching.	2.61	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	1.3 Switch to PCU 2.	2.792	V
	Emitter to base I	open	.00482	Oscillator may not start at low temperature of lunar night.			
	Emitter to base II	open	.00482				
	Emitter to base I	short	.01178	10K resistor limits current drag down to 3 milliamps.	No system effect	6.842	VI
	Emitter to base II	short	.01178				
	1.4 CR1	short	.02944	1.4 Put 5 milliamp on transformer secondary, would require 200 mils for transformer to become saturated. Capacitor on 16 v line would remove any AC ripple back to RTG.	1.4 No system effect.	8.540	VI
	1.5 CR1	open	.02944	1.5 Minor frequency superimposed on oscillator frequency.	1.5 No system effect.	8.540	VI

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 21 of 39	
ASSY. Inverter Module	DWG NO. 2368161	DATE 6-1-71	

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
	1.6 CR 3 short .00443	1.6 Excessive forward biasing voltatage 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 inproper 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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 22 of 39	
ASS'Y Inverter Module	DWG NO. 2368161	DATE 6-1-71	

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 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 toPCU 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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 23 of 39	
ASS'Y Inverter Module	DWG NO. 2368161	DATE 6-1-71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE				EFFECT OF FAILURE: ASSEMBLY		EFFECT OF FAILURE: END ITEM		FAILURE PROBABILITY $Q \times 10^5$	CRITICALITY
				(α)						
2.0 Inverter Module PCU 2	2.0	C20		.00541	2.0	If capacitor opened, would lose ripple filtering effects and inverter would shut down while switching PCU's.	2.0	Momentary power interrupt to transformer while switching PCUs.	2.61	VI
	2.1	C20		.00541	2.1	Loss of +16v input to inverter.	2.1	Automatic switching to PCU I.	2.61	V
	2.2	Q5, Q6			2.2	Oscillator off 50% of time.	2.2	Automatic switching to PCU I.	34.16	V
		Emitter to base	open	.0718						
		Collector to base	open	.0718						
		Emitter to base	short	.04170		Oscillator stops, drags +16v to ground.				
		Collector to base	short	.04170						
	2.3	Q2			2.3	Ocsillator may not start at low temperature of lunar night.	2.3	Switch to PCU I.	2.792	V
		Emitter to base I	open	.00482						
		Emitter to baseII	open	.00482				No system effect.	6.842	VI
		Emitter to base I	short	.01178		10Kohn resistor limits current drag down to 3 milliamps.				
		Emitter to baseII	short	.01178						
	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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 24 of 39	
ASS'Y Inverter Module	DWG NO. 2368161	DATE 6-1-71	

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. c	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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 25 of 39	
ASS'Y Inverter Module	DWG NO. 2368161	DATE 6-1-71	

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
	2.12 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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 26 of 39	
ASS'Y SWITCHING MODULE	DWG NO. 2368161	DATE 6-1-71	

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
1.0 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 1.	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

SYSTEM	PREPARED BY	NO.	REV.
ALSEP	L. Moskowitz	ATM952	A
END ITEM: PCU	DWG NO.	PAGE 27 of 39	
ASS'Y: SWITCHING MODULE	DWG NO.: E 2368161	DATE: 6-1-71	

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 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 occured	1.7 Still have automatic switching capability.	2.1472	VI
2.0 Auto 1, Auto 2 Select Circuit	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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 28 of 39	
ASS'Y SWITCHING MODULE	DWG NO. 2368161	DATE 6-1-71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁵	CRITICALITY
	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 -12 Volt Detector Circuit	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 VR1 Short .1107	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 overvoltage, undervoltage condition. Would require sending a command to switch PCU's.	14.888	VI

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 29 of 39	
ASS'Y SWITCHING MODULE	DWG NO. 2368161	DATE 6-1-71	

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
	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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 30 of 39	
ASS'Y SWITCHING MODULE	DWG NO. 2368161	DATE 6-1-71	

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
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

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 Regulator I internal dump C1 C4, L2	1.0 C3, C1, 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, C1 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 APM 1 EXT. Dump	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.	5.262	V
	2.3 C2 Open	.0292	2.3 No effect	2.3 No system effect	2.5052	VI
3.0 PCU I + 29V line	3.0 C5, C6, C7, C4 Short	.2815	3.0 Lose +29V line for PCU I.	3.0 Switch to PCU 2.	2.645	V
	3.1 C5, C6, C7, C4 Open	2.5485	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.	23.815	VI
	3.2 L3 Open	.3157	332 Loss of +29V output line for PCU I.	3.2 Would switch to PCU 2.	2.9741	V

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

SYSTEM	PREPARED BY	NO.	REV.
ALSEP ARRAY E	L. Moskowitz	ATM952	A
END ITEM	DWG NO.	PAGE 32 of 39	
PCU			
ASS'Y	DWG NO.	DATE	
OUTPUT FILTER	2368183	6-1-71	

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE — ASSEMBLY	EFFECT OF FAILURE — END ITEM	FAILURE PROBABILITY $Q \times 10^{5}$	CRITICALITY
	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 PCU I +12V line	4.0 C9, C8 Short .4400	4.0 Loss of +12V line for PCU I	4.0 Switch to PCU 2.	3.4318	V
	4.1 C9, 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 C11, C10 Short .5166	5.0 Loss of -5V output line for PCU I.	5.0 Switch to PCU 2.	5.0110	V
	5.1 C11, 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

SYSTEM	PREPARED BY	NO.	REV.
ALSEP ARRAY E	L. Moskowitz	ATM952	A
END ITEM	DWG NO.	PAGE 33 of 39	
PCU			
ASS'Y	DWG NO. 2368183	DATE 6-1-71	
OUTPUT FILTER			

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
6.0 PCU I -12V line	6.0 C13, C12	Short .3456	6.0 Loss of -12V output line for PCU I.	6.0 Switch to PCU 2.	5.0110	V
	6.1 C13, 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 C15, C14	Short .686	7.0 Lose capability to dump excessive reserve power internally to PCU.	7.0 Requires switching to PCU I.	5.928	V
	7.1 C15, C14	Open .075	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.	0.6587	VI
	7.2 L7	Short .0144	7.2 No appreciable effect. Loss of ripple dampening effect.	7.2 No system effect.	0.3153	VI
	7.3 L7	Open .1296	7.3 Could not dump excess reserve power internally.	7.3 Would require switching to PCU I.	2.8383	V
8.0 APM 2 External Dump	8.0 L12	Open .1296	8.0 Loss of external power dump for PCU 2.	8.0 Switch to PCU I.	2.8383	V
	8.1 L12	Short .0144	8.1 No appreciable effect. Loss of ripple dampening effect.	8.1 No system effect in that excessive current should not damage dump resistors.	0.3153	VI
	8.2 C23	Short .2628	8.2 Would be unable to use APM 2 ext. dump.	8.2 Would switch to redundant PCU.	5.262	VI
	8.3 C23	Open .0292	8.3 No effect.	8.3 No system effect	2.5052	V

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
9.0 PCU 2 -12V line	9.0 C17, C16	Short .4539	9.0 Loss of -12V output line for PCU II.	9.0 Switch to PCU I.	3.6265	V
	9.1 C17, 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 C19, C18	Short .5166	10.0 Loss of +5V output line for PCU II.	10.0 Switch to PCU I.	5.0110	V
	10.1 C19, C18	Open .0574	10.1 Loss of some voltage ripple filtering capability.	10.1 No system effect. If ripple becomes excessive can switch to PCU I.	0.5567	VI
	10.2 L9	Open .3054	10.2 Loss of +5 volt output line for PCU 2.	10.2 Switch to PCU I.	2.9625	V
	10.3 L9	Short .0574	10.3 No appreciable effect.	10.3 No system effect. If ripple becomes excessive, can switch to PCU I.	0.3291	VI
11.0 PCU 2 +12V line	11.0 C21, C20	Short .4400	11.0 Loss of +12V output line for PCU II.	11.0 Switch to PCU I.	3.4318	V
	11.1 C21, C20	Open .0488	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.	.3813	VI

SYSTEM ALSEP ARRAY E	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 35 of 39	
ASS'Y OUTPUT FILTER	DWG NO. 2368183	DATE 6-1-71	

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
	11.2 L10 Open .3600	11.2 Loss of +12V output line for PCU I.	11.2 Switch to PCU I.	2.808	V
	11.3 L10 Short .0400	11.3 No appreciable effect. Loss of some ripple dampening effect.	11.3 No system effect. If ripple becomes excessive, switch to PCU I.	0.3120	VI
12.0 PCU 2 +29V line	12.0 C22, C24, C25, C26 Short .2815	12.0 Loss of +29 volt output line for PCU 2	12.0 Switch to PCU I.	.2815	V
	12.1 C22, C24, C25, C26 Open 2.5485	12.1 Loss of some voltage ripple filtering.	12.1 No system effect. If ripple becomes excessive, switch to PCU I.	23.815	VI
	12.2 L11 Open .3157	12.2 Loss of +29V output line for PCU 2.	12.2 Switch to PCU I.	2.9741	V
	12.3 L11 Short .0315	12.3 No appreciable effect. Loss of some ripple dampening effect.	12.3 No system effect. If ripple becomes excessive, switch to PCU I.	0.3293	VI

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 36 of 39	
ASS'Y SENSING MODULE	DWG NO. 2368151	DATE 6-1-71	

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
1.0 RTG Supply Voltage Sensing Filter and TM Signals	1.0 L1, L2 Short C1, C2, C3, C4 Short VR1, VR2, VR3 Short	.02988 .0343	1.0 Loss of some ripple filtering capability Loss of one RTG Voltage TM status If VR1 or VR2 shorts, lose one voltage TM for PCU 1. If VR3 shorts lose voltage TM for PCU 2.	1.0 No system effect No significant system effect. Still have RTG input current status.	1.4148	VI
	1.1 L1, C1, C2 Open L2, C3, C4 VR1, VR2, VR3 Open	.2728	1.1 Loss of either or both RTG Voltage TM signals for one PCU. No effect on PCU	1.1 No significant system effect. Still have RTG input current status. Damage could occur to MUX during RTG open condition.	6.0124	VI
	1.2 R3, R8 Open R4, R9 R11, R12	.36914	1.2 Loss of one RTG TM Status. There are two TM status signals for PCU I and one for PCU 2.	1.2 No significant system effect	8.1355	VI
2.0 Inverter oscillator Transformer status	2.0 CR1, CR2, CR3, CR4 Short T1, T2 Open CR9, CR10, CR11, CR12 Short T7, T8 Open	2.014 .9769 2.014 .9767	2.0 Erratic RTG input current TM indication from one winding of inverter transformer. False indication of RTG input power.	2.0 Some current data would be indicated by TR 2 TM. No system effect.	159.612	VI
	2.1 CR5, CR6, CR7, CR8 Open T3, T4 Short CR13, CR14, CR15, CR16 Short T5, T6 Open	.9769 2.014 2.014 .9769	2.1 Erratic reserve power current TM indication from second winding of inverter transformer. False indication of reserve power.	2.1 Some reserve power would be indicated by TR I TM. No system effect.	159.612	VI
	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

SYSTEM ALSEP	PREPARED BY L. Moskowitz	NO. ATM952	REV. A
END ITEM PCU	DWG NO.	PAGE 37 of 39	
ASS'Y SENSING MODULE	DWG NO. 2368151	DATE 6-1-71	

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
	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 Relay Switching Circuit	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 redunancy. 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

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
1.0 DC-DC Converter PCU I	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 I.	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 I.	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 I	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 I.	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 I.	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

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁵	CRITICALITY
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