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NUCLEAR EFFECTS ANALYSIS D1-S-1800 AERIAL RADIAC SYSTEM AN/ADR---ETC(U)
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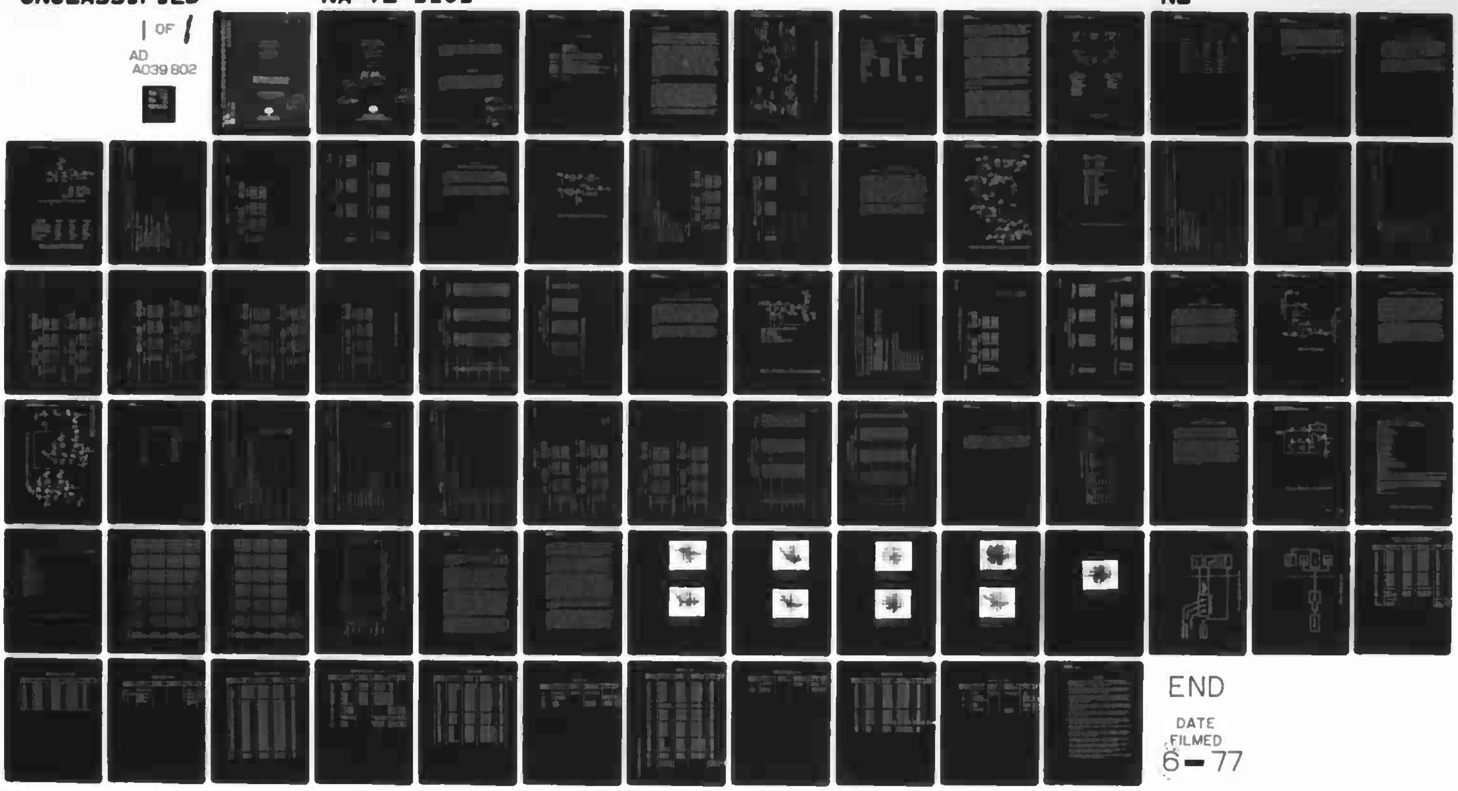

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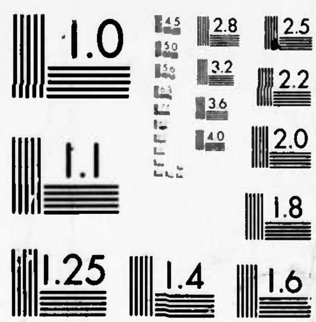

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PRELIMINARY REPORT

NUCLEAR EFFECTS ANALYSIS

D1-S-1800

AERIAL RADIAC SYSTEM

AN/ADR-6(XE-4)(V)

Los Angeles Division
North American Rockwell

(14) NA-72-1101

SERIAL NO. 2

(9) PRELIMINARY REPORT,

(6) NUCLEAR EFFECTS ANALYSIS

D1-S-1800

AERIAL RADIAC SYSTEM

AN/ADR-6(XE-4)(V).

Prepared by

NUCLEONICS GROUP

WE Arthur

W.E. Arthur, Program Manager
Aerial Radiac System Program

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FOREWORD

This document was prepared under U.S. Army Contract DAAB07-72-C-0202 to document the analysis of the effects of neutrons and a pulsed gamma-ray exposure on the Aerial Radiac System. This analysis, while preliminary, indicates that the system as designed is capable of operating within specification after exposure to the nuclear environment of EL-CP5073-0002A.

INTRODUCTION

In addition to certain performance and environmental requirements, delineated in EL-CP5073-0001B, the Aerial Radiac System is required to perform after being exposed to the nuclear effects environment specified in EL-CP5073-0002A. The verification of these environments will be by test during the engineering development phase of the basic contract. Until these tests are conducted the design of the system to meet those requirements is by circuit analysis, parts selection, and component testing.

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BASIC DESCRIPTION

This preliminary report summarizes the analysis effort performed to date on the Aerial Radiac System (ARS) to assure proper ARS operation following exposure to nuclear radiation ~~(Reference 12)~~. To facilitate the analysis effort, the ARS has been subdivided into several subcircuits ~~(Figure 1)~~. Each subcircuit will be analyzed and/or tested to assure proper performance following exposure to radiation at specification level.

The ARS is used to measure ground dose radiation level (Rads/hr). ~~(Refer to Figure 1)~~. The Power Supplies convert aircraft 28 volts dc to regulated +15 and -15 volts dc and -1000 volts dc. Gamma dose rate is measured by the Photomultiplier Tube and converted to a voltage level by a log amplifier. This voltage when scaled by EMAX in the subtractor circuit becomes the air dose level. The Ground Dose Computer provides the ground dose level by combining a signal proportional to the altitude as furnished by a radar altimeter with the air dose level signal. The ground dose level signal is displayed, recorded and/or can be telemetered. A self test feature is also provided. By activating self test, a light which simulates gamma radiation is generated in the Self Test Device Driver resulting in a test level air dose signal. At the same time, an altitude signal is generated from the radar altimeter. The resulting ground dose level is monitored by the Self Test Comparator illuminating either a Go or No-Go light. An alarm system is provided for crew safety. When the selected air dose level is exceeded, the alarm is automatically activated.

ANALYSIS

Nominal component values will be used to determine initial circuit values. Several potentiometers are used throughout the ARS circuitry to minimize the effect of differences in component values from nominal. Therefore, only component value changes following radiation expsure will be considered in this report. The components listed in Table 1 were selected from the ARS Parts List (Attachment 1) as being most sensitive to radiation damage or response. The following guidelines will be used in evaluating or modeling component parts parameters. Test data will be used for the 5 types of integrated circuits. Since the Motorola MC1558G is similar to the uA741 operational amplifiers, test data for the uA741 will be used. References providing IC Radiation Response Data include the North American Rockwell Reports (References 1,2,3), a Martin Marietta Report (Reference 4), as well as a Northrop Report (Reference 5).

Neutron degradation for the log amplifier is included as an appendix to this report. The photomultiplier and high voltage supply will be tested. Transistors will reflect degraded gain after exposure to the

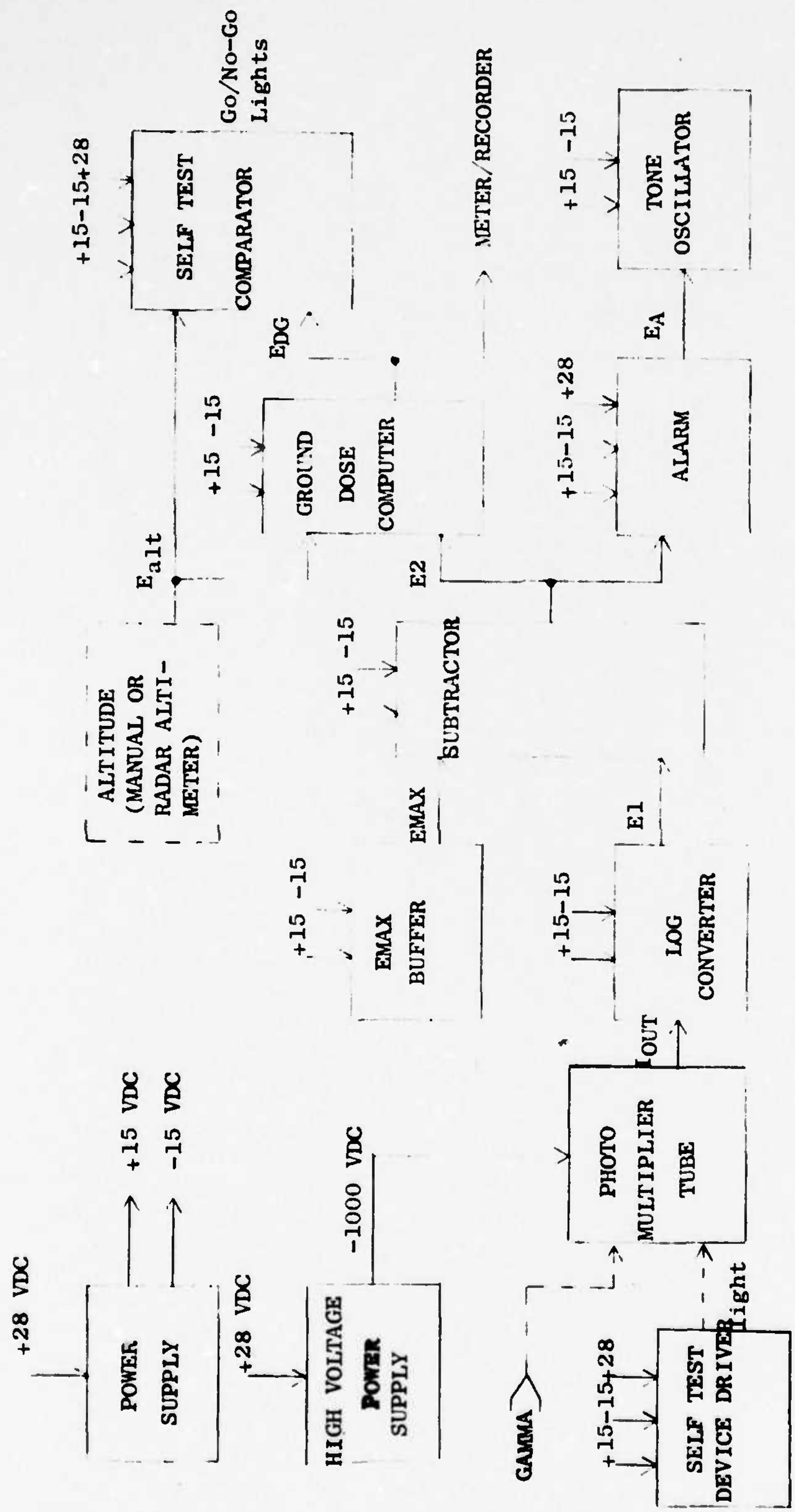


Figure 1. Function Flow Block Diagram of the Aerial Radiac System

Table 1. ARS Radiation Sensitive Components

Description	Military Part No.	Vendor	Vendor Part Number
I.C. Op-Amp		Motorola	MC1558G
I.C. Volt Reg.		Fairchild	U5R7723312
I.C. Volt Reg.		Motorola	MC1569R
I.C. Volt Reg.		Motorola	MC1563R
I.C. Current Amp.		Nat. Semicon	LH0002H
Log Module		Teledyne/Philbrick	700695
Photomultiplier		RCA	4516
High Voltage Supply		Technetics	N9567-114
Transistor	JAN2N2219A	QPL	
Transistor	JAN2N2222A	QPL	
Transistor	JAN2N2369A	QPL	
Transistor	JAN2N3019	QPL	
FET	JAN2N4857	QPL	
Diode	JAN1N4148	QPL	
Diode	JAN1N4249	QPL	
Diode	JAN1N4942	QPL	
Zener Diode	JAN1N753A	QPL	
Zener Diode	JAN1N964B	QPL	
Relay		Teledyne	412T-26
Relay		Teledyne	411D-26
Relay		Teledyne	412D-26

neutron environment. Either the NR method (Reference 6) or TREE technique (Reference 7) will be used to predict the gain degradation. The FET (alarm circuit) will not reflect degradation at specification levels (References 8,9). Diode response to radiation are also minimal (Reference 7). The diodes and transistors used in the relays will be treated as separate and discrete parts.

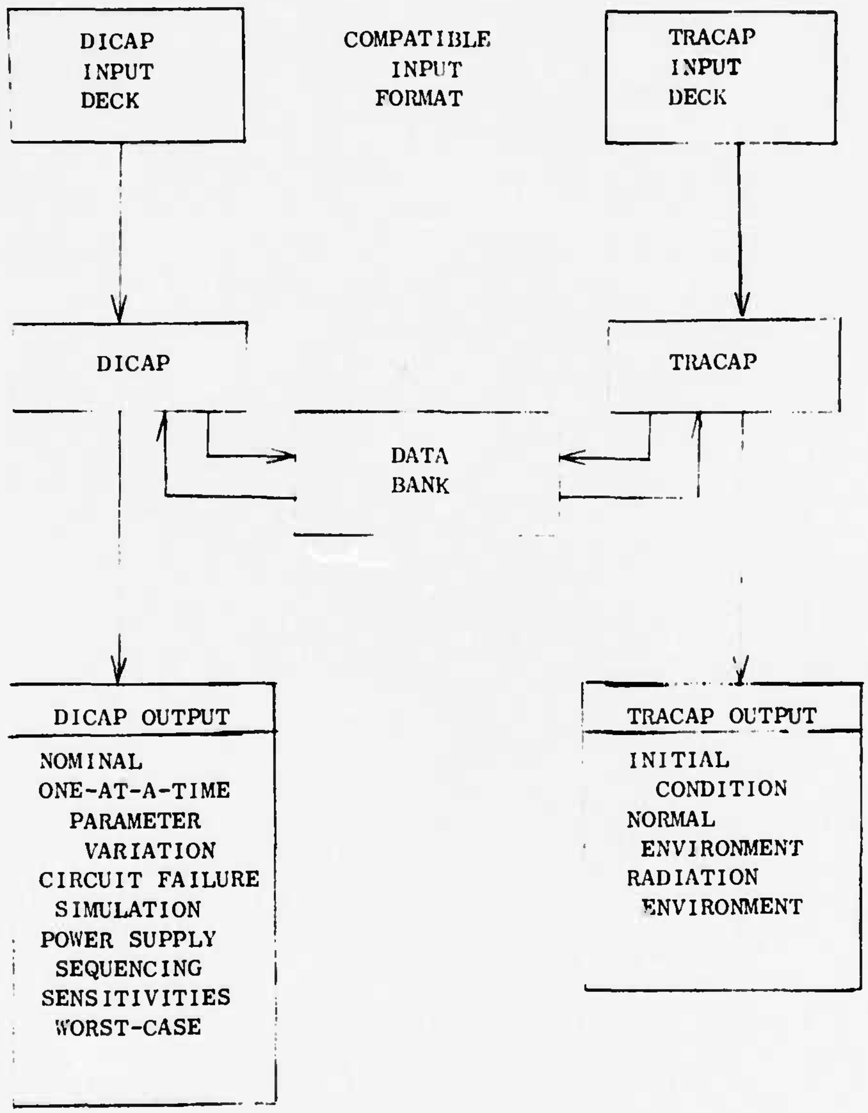
System performance following exposure to neutron fluence has been analyzed using DICAP (Reference 10) or hand analysis. Subcircuits not included in the present analysis will be analyzed or tested at a later date. DICAP is a part of the computer aided circuit analysis programs SYSCAP (System of Circuit Analysis programs). SYSCAP encompasses static and dynamic, linear and nonlinear analysis. The program is available at Control Data Corporation Data Centers with the CDC 6600 Computer. The SYSCAP structure is diagrammed in Figure 2. The static (DC) analysis program, DICAP, and the dynamic (transient) analysis program, TRACAP, are each large, complex overlay programs that execute separately.

SYSCAP performs a lumped-parameter, linear and nonlinear analysis of complex electronic networks. The circuit to be analyzed is mathematically modeled as a system of nodes interconnected by circuit elements, driven by signal sources and power supplies. The circuit elements which form the basic analysis set are resistors, capacitors, inductors, diodes, transistors, linear transformers, and operational amplifiers. DICAP and TRACAP use a nodal equation formulation of the electronic network problem. Both programs write these equations automatically and solve them using a sparse matrix solving routine. These equations are solved using an iterative technique that is continued until the non linear side conditions have been satisfied.

Results of the DICAP and Hand Analysis are shown on appendices to this report. Table 2 lists each subcircuit and corresponding appendix number. Test data on the log module is also included.

Gamma Ray Dose Rate

All of the ARS subcircuits were not analyzed for prompt gamma effects. In general, prompt gamma will not cause permanent damage (Reference 7). Although transient upsets are expected at radiation levels greater than 5×10^7 rads/seconds, recovery is expected within a few hundred microseconds (References 1,7). The subcircuit time constant will prolong the transient upset into the millisecond range. However, since the ARS responds to the rate of exposure, correct information will resume following the transient upset. Testing will be used to verify that components do not fail. The subtractor subcircuit was analyzed for transient upset at specification level. The prompt gamma prediction technique in Reference 1 was used. The TESS (Reference 11) computer analysis program was used to perform the analysis. As expected the output saturated for approximately 40 microseconds, decayed rapidly until 60 microseconds, then slowly for 3 milliseconds. The detailed analysis is presented in Appendix 8.



NR/SYSCAP STRUCTURE

Figure 2

Table 2

Subcircuit	Type Analysis	Method	Appendix
EMAX Buffer	Neutron	DICAP	1
Subtractor	Neutron	DICAP	2
Ground Dose Computer	Neutron	DICAP	3
Self Test Device Driver	Neutron	DICAP	4
Alarm	Neutron	Hand Analysis	5
Self Test Comparator	Neutron	DICAP	6
Log Module	Neutron	Test Data	7
Subtractor	Gamma Rate	TESS	8
Various	Gamma Rate	Test Data	9

The TESS computer program was developed by TRW System Group, Redondo Beach, California, and is available through Control Data Corporation. It is designed to perform large scale, nonlinear circuit analysis. The program performs Transient, DC, and AC analysis. Extensive use of state-of-the-art programming techniques, sophisticated list processing techniques and sparse matrix schemes allow rapid analysis of large problems with minimum memory core usage. The transient and DC portions are very similar to the widely available SCEPTRE program. The TESS program was selected because of the transient radiation response feature of the operational amplifier model.

Portions of the ARS have been tested in prompt gamma environment. No failures were observed. Details of these tests are included in Appendix 9.

Appendix 1

EMAX BUFFER CIRCUIT NEUTRON FLUENCE ANALYSIS

The EMAX Buffer subcircuit of the ground dose computer module in the Aerial Radiac System has been analyzed for neutron fluence. The SYSCAP DICAP computer program was used to perform the analysis. The DICAP schematic is shown in figure 1-1. This subcircuit is used to generate EMAX, a constant voltage used as a reference by the subtractor subcircuit. The two zener diodes (1N753A) are used for temperature compensation. The non-inverting input to the operational amplifier (1/2 MC1558) is variable through potentiometer R24. The output at Node 6 (EMAX) must remain within 8 millivolts following neutron fluence.

The circuit parameters affected by neutron fluence are the operational amplifier parameters only. Based on available neutron test data on operational amplifiers, the data at specification level in Table 1-1 is used for neutron degradation. The DICAP input data is shown in Table 1-2. A summary of the analysis is shown in Table 1-3. The output voltage at node 6 varies from nominal by less than a millivolt. This is within the design tolerance of 8 millivolts.

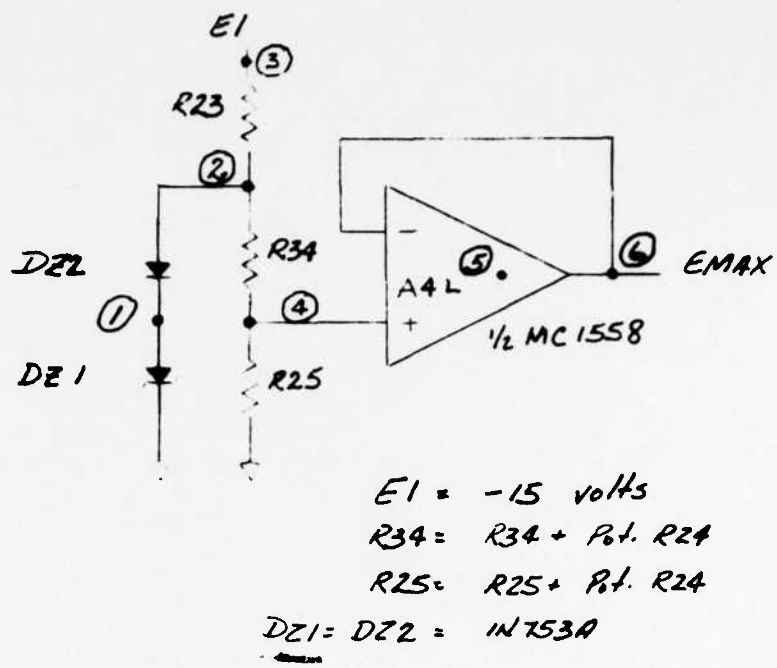


Figure 1-1. DICAP Schematic of EMAX Buffer Subcircuit

Parameter	Nominal	Minimum	Maximum
Input Resistance	1 Meg.	500 K	1 Meg.
Input Offset Current	40 Na.	10 Na	70 Na
Input Offset Voltage	3 MV	1 MV	5 MV
Input Bias Current	300 Na	100 Na	500 Na
Common Mode Voltage	0.	0.	0.
Gain	200000.	50000.	200000.
Output Impedance	75 ohms	75 ohms	75 ohms
V out high	13.V	12 V	14.V
V out low	-13.V	-12 V	-14.V

Table 1-1. Operational Amplifier MC1558 Parameters
Degraded For Specification Level Neutron Fluence

Table 1-2. DICAP FREE FORM INPUT DATA

```
DICAP CONTROL CARD - W/C ALL,NODES=6

    EMAX BUFFER CIRCUIT

    DZ1(A1,C0)NOM
    .63G,1.76,73N,80M,6.2,20M,6.65

    DZ2(A2,C1)NOM
    .63G,1.76,73N,80M,6.2,20M,6.65

    R23(3,2)I,1K,-0,+0

    R25(4,0)I,7.99K,-0,+0

    R34(2,4)I,3.9K,-0,+0

    E1(+3,-0)-15,-14.6MIN,-15MAX,S=1,-0,+0
    FINIS

            SPECIAL
```

Table 1-2. OPERATIONAL AMPLIFIER DATA (CONT.)

OPAMP NUMBER 1

NA= 6 NB= 4 NC= 6 ND= 0 NF= 5

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER		NOMINAL	MINIMUM	MAXIMUM
RNA	1	4.41176E+05	2.27273E+05	4.38596E+05
RNB	1	5.76923E+05	2.77778E+05	5.81395E+05
DIVO	1	3.00000E-03	1.00000E-03	5.00000E-03
IBC	1	3.00000E-07	1.00000E-07	5.00000E-07
VOFF	1	0.	0.	0.
GAIN	1	2.00000E+05	5.00000E+04	2.00000E+05
VOUT	1	7.50000E+01	7.50000E+01	7.50000E+01
VPH	1	1.30000E+01	1.20000E+01	1.40000E+01
VLL	1	-1.30000E+01	-1.20000E+01	-1.40000E+01

TABLE 1-3

SUMMARY OF WORST CASE NODE VOLTAGES

NODE NAME	NOMINAL VALUE (VOLTS)	MINIMUM VALUE (VOLTS)	MAXIMUM VALUE (VOLTS)
NODE 1	-5.90608E+00	-5.90608E+00	-5.90608E+00
NODE 2	-1.18122E+01	-1.18122E+01	-1.18122E+01
NODE 3	-1.49968E+01	-1.49968E+01	-1.49968E+01
NODE 4	-7.93503E+00	-7.93780E+00	-7.93826E+00
NODE 5	-8.01301E+00	-7.96278E+00	-8.06324E+00
NODE 6	-7.93499E+00	-7.93476E+00	-7.93522E+00

SUMMARY OF WORST CASE AUXILIARY SOLUTIONS

SOLUTION NAME	NOMINAL VALUE	MINIMUM VALUE	MAXIMUM VALUE
DZ1 IDZ	-2.19128E-03	-2.19123E-03	-2.19133E-03
DZ1 VDZ	5.90608E+00	5.90608E+00	5.90608E+00
DZ2 IDZ	-2.19128E-03	-2.19123E-03	-2.19133E-03
DZ2 VDZ	5.90608E+00	5.90608E+00	5.90608E+00
R23 IR	-3.18466E-03	-3.18465E-03	-3.18466E-03
R25 IR	-9.93496E-04	-9.93467E-04	-9.93525E-04
R34 IR	-9.93366E-04	-9.93308E-04	-9.93424E-04

Appendix 2

SUBTRACTOR CIRCUIT NEUTRON FLUENCE ANALYSIS

The subtractor subcircuit of the detector module in the Aerial Radiac System has been analyzed for neutron fluence. The SYSCAP DICAP computer program was used to perform the analysis. The DICAP schematic is shown in figure 2-1. This subcircuit is used to shift the voltage level from the log converter module (E1) by the negative of EMAX. The output voltage at node 5 (E02) must remain within 50 millivolts of the nominal.

The circuit parameters affected by specification level neutron fluence are operational amplifier parameters only. The DICAP input data is shown in Table 2-1. A summary of the analysis is shown in Table 2-2. The output voltage at node 5 varies from nominal by -4 millivolts to +12 millivolts. This is within the design tolerance of 50 millivolts.

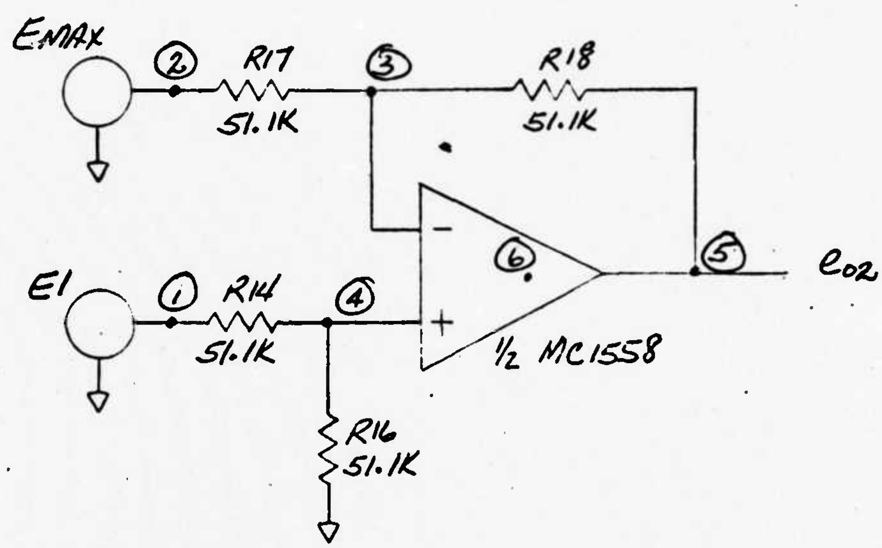


Figure 1-1. DICAP Schematic of Subtractor Subcircuit

Table 2-1. DICAP FREE FORM INPUT DATA

```
DICAP CONTROL CARD - W/C ALL,NODES=6

    SUBTRACTOR SUBCIRCUIT OF DETECTOR MODULE
    *OP AMP IS ONE-HALF OF MC1558

    E1(+1,-0)-4,-0,+0,RS=1,-0,+0

    EMAX(+2,-0)-8,-0,+0,RS=1,-0,+0

    R14(1,4)51.1K,-0,+0

    R17(2,3)51.1K,-0,+0

    R18(3,5)51.1K,-0,+0

    R1(4,0)51.1K,-0,+0
    FINIS

            SPECIAL

        OPAMP NUMBER 1

                  NA=  3     NB=  4     NC=  5     ND=  0     NF=  6

                  NOMINAL   RIN= 1.00E+06          DICO= 4.00E-08
                  MINIMUM   RIN= 5.00E+05          DICO= 1.00E-08
                  MAXIMUM   RIN= 1.00E+06          DICO= 7.00E-08
```

PARAMETER		NOMINAL	MINIMUM	MAXIMUM
RNA	1	4.41176E+05	2.27273E+05	4.38596E+05
RNB	1	5.76923E+05	2.77778E+05	5.81395E+05
DIVO	1	3.00000E-03	1.00000E-03	5.00000E-03
IBC	1	3.00000E-07	1.00000E-07	5.00000E-07
VOFF	1	0.	0.	0.
GAIN	1	2.00000E+05	5.00000E+04	2.00000E+05
ROUT	1	7.50000E+01	7.50000E+01	7.50000E+01
VUL	1	1.30000E+01	1.20000E+01	1.40000E+01
VLL	1	-1.30000E+01	-1.20000E+01	-1.40000E+01

Table 2-2. SUMMARY OF WORST CASE NODE VOLTAGES

NODE NAME	NOMINAL VALUE (VOLTS)	MINIMUM VALUE (VOLTS)	MAXIMUM VALUE (VOLTS)
NODE 1	-3.99996E+00	-3.99996E+00	-3.99996E+00
NODE 2	-7.99988E+00	-7.99988E+00	-7.99988E+00
NODE 3	-2.00032E+00	-1.99611E+00	-2.00454E+00
NODE 4	-2.00330E+00	-2.00109E+00	-2.00552E+00
NODE 5	4.00792E+00	4.00397E+00	4.01654E+00
NODE 6	-2.07831E+00	-2.02610E+00	-2.13053E+00

Appendix 3

GROUND DOSE COMPUTER CIRCUIT NEUTRON FLUENCE ANALYSIS

The ground dose computer subcircuit of the ground dose computer board in the Aerial Radiac System has been analyzed for neutron fluence. The SYSCAP DICAP computer program was used to perform the analysis. The DICAP schematic is shown in figure 3-1. This subcircuit is used to convert air dose to ground dose. The altitude signal (Ealt) from the manual selector switch or radar altimeter is shown as E4. The operational amplifiers A3L and A3H buffer and limit the altitude signal. Operational amplifier A2L serves as the subtractor circuit which scales the altitude signal and adds a constant to form the air ground correction factor (AGCF). The AGCF signal is then buffered by operational amplifier A2H. The air dose signal (E2) is added to the AGCF signal in operational amplifier A1L. This signal output is limited by the diodes and buffered by A1H. The output E_{DG} (voltage at node 24) is the ground dose signal. This signal is also telemetered through operational amplifier A4H. The ground dose signal must remain within 0.33 volts of the nominal output voltage.

The circuit parameters affected by specification level neutron fluence are op amp (MC1558) parameters only. The DICAP input data is shown in Table 3-1. A summary of the analysis is shown in Table 3-2. The ground dose voltage E_{DG} (node 24) varies from nominal by -117 millivolts to +124 millivolts. This is within the design tolerance of 330 millivolts.

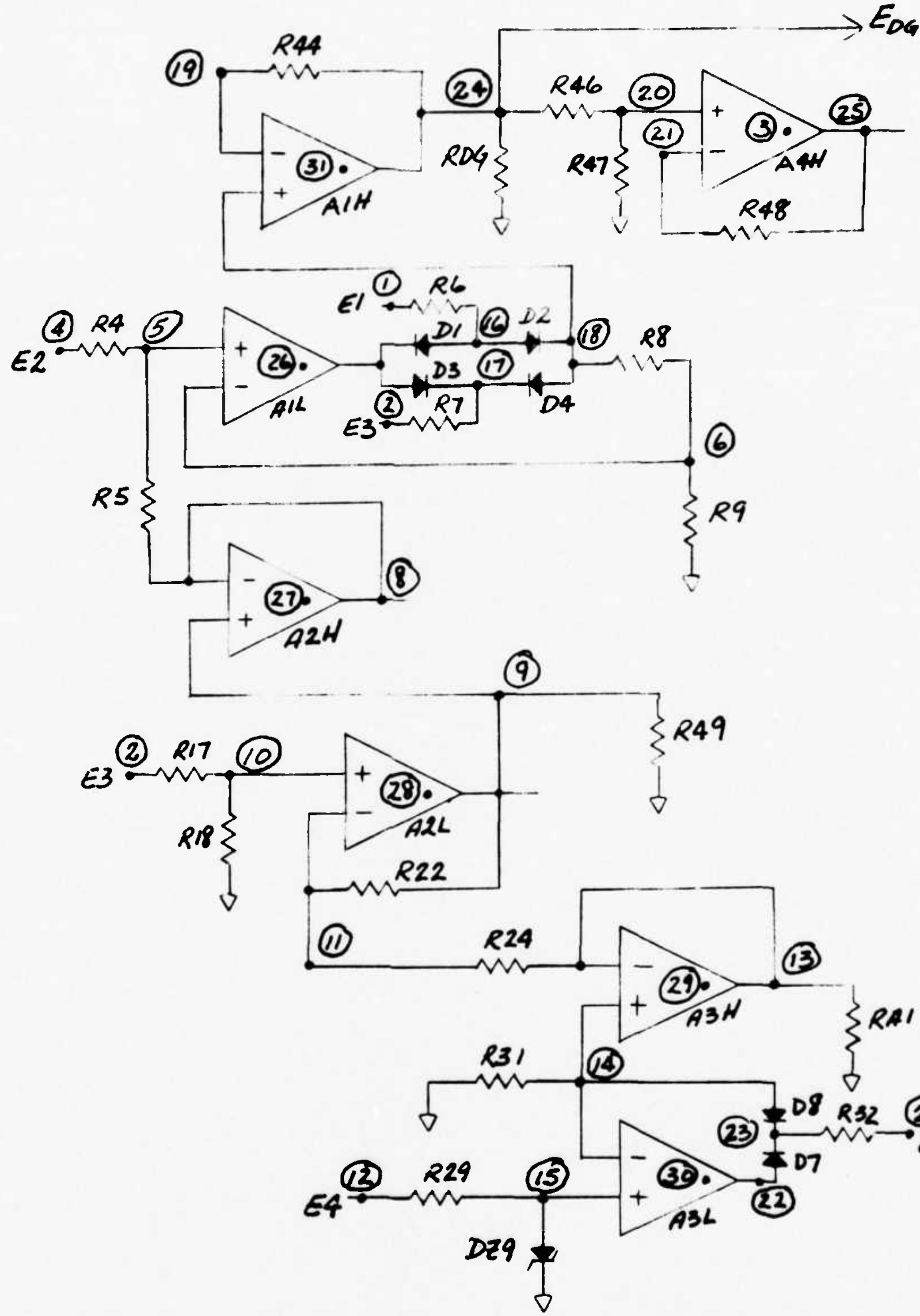


Figure 3-1. DICAP Schematic of the Ground Dose Computer Subcircuit

DICAP Designation		Circuit Designation
E1	=	15 volts
E2	=	air dose
E3	=	-15 volts
E4	=	altitude

All operational amplifiers are MC1558
Diodes are 1N4148
Zener Diode is 1N964B

R44	=	R36
R46	=	R32
R47	=	R33
R48	=	R31
R4	=	R4 + Pot. R3
R49	=	R30
R22	=	R19
R17	=	R17 + Pot. R16
R24	=	R20 + Pot. R21
R31	=	R27 + R28
R32	=	R29
D7	=	CRS
D8	=	CR6
DZ9	=	CR7
R29	=	R26

Figure 3-1. DICAP Schematic of the Ground Dose Computer Subcircuit (Cont'd)

```
**********************************************************************************
*                                                                                *
*                    Table 3-1.  DICAP FREE FORM INPUT DATA                      *
*                                                                                *
**********************************************************************************

DICAP CONTROL CARD - W/C ALL.NODES=31

     AERIAL RADIAC GROUND DOSE COMPUTER
     *OP AMPS ARE MC1558
     *DIODES ARE NOT DEGRADED

     DZ9(A15.C0)
     2MEG.1.14.9.4P.74M.13.9.5M.13

     D1(A16.C7)
     46.1.67.20P.3.100..01.10
```

Table 3-1. DIGAP FREE FORM INPUT DATA (CONT.)

```
D2(D16.C18)01
D3(D7.C17)01
D6(D1[illegible].C17)01
D7(D22.C23)01
D8(D14.C23)01
S1(+1.-6)15.-2.+2.PS=1.-0.+0
S2(+4.-0)4.0[illegible].4.004MIN.4.016MAX.PS=1.-0.+0
S3(+2.-0)-15.-2.+2.PS=1.-0.+0
S4(+12.-5)-.[illegible].-5.+5.PS=1.-0.+0
S5(4.5)10.4K.-[illegible].+0
S6(5.8)10K.-0.+[illegible]
S7(9.[illegible])150K.-[illegible].+[illegible]
S17(2.1[illegible])75.7K.-[illegible].+[illegible]
S18(1[illegible].[illegible])[illegible]K.-0.+0
S22(11.[illegible])10K.-[illegible].+0
[illegible](1[illegible].13)3[illegible].[illegible].-[illegible].+[illegible]
```

Table 3-1. DICAP FREE FORM INPUT DATA (CONT.)

```
R22(12.[illegible])10K,-0,+0
[illegible]6(1.16)14.3K,-0,+[illegible]
[illegible]7(17.2)4.7[illegible]EG,-0,+[illegible]
[illegible]8(13.6)2[illegible].7K,-0,+[illegible]
[illegible]([illegible].0)10K ,-0,+0
[illegible](24.20)51.1K,-0,+[illegible]
[illegible].7(2[illegible].0)31.1K ,-0,+0
[illegible](13.24)[illegible] ,-0,+[illegible]
[illegible](21.25)24.9K,-0,+0
[illegible](24.[illegible])3K ,-[illegible],+[illegible]
[illegible](13.0)5K,-0,+0
[illegible]32(23.21)1[illegible] ,-[illegible],+0
[illegible]31(14,0)13.32[illegible],-0,+0
FINIS
            SPECIAL
```

OPERATIONAL AMPLIFIER DATA

OPAMP NUMBER 1

NA= 6 NB= 5 NC= 7 ND= 0 NF= 26

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 1	4.41176E+05	2.27273E+05	4.38596E+05
RNB 1	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 1	3.00000E-03	1.00000E-03	5.00000E-03
IBC 1	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 1	0.	0.	0.
GAIN 1	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 1	7.50000E+01	7.50000E+01	7.50000E+01
VUL 1	1.30000E+01	1.20000E+01	1.40000E+01
VLL 1	-1.30000E+01	-1.20000E+01	-1.40000E+01

OPAMP NUMBER 2

NA= 8 NB= 9 NC= 8 ND= 0 NF= 27

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 2	4.41176E+05	2.27273E+05	4.38596E+05
RNB 2	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 2	3.00000E-03	1.00000E-03	5.00000E-03
IBC 2	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 2	0.	0.	0.
GAIN 2	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 2	7.50000E+01	7.50000E+01	7.50000E+01
VUL 2	1.30000E+01	1.20000E+01	1.40000E+01
VLL 2	-1.30000E+01	-1.20000E+01	-1.40000E+01

Table 3-1. DICAP INPUT DATA (CONT.)

OPAMP NUMBER 3

NA= 11 NB= 10 NC= 9 ND= 0 NF= 28

NOMINAL	RIN= 1.00E+06		DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05		DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06		DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 3	4.41176E+05	2.27273E+05	4.38596E+05
RNB 3	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 3	3.00000E-03	1.00000E-03	5.00000E-03
IBC 3	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 3	0.	0.	0.
GAIN 3	2.00000E+05	5.00000E+04	2.00000E+05
POUT 3	7.50000E+01	7.50000E+01	7.50000E+01
VUL 3	1.30000E+01	1.20000E+01	1.40000E+01
VLL 3	-1.30000E+01	-1.20000E+01	-1.40000E+01

OPAMP NUMBER 4

NA= 13 NB= 14 NC= 13 ND= 0 NF= 29

NOMINAL	RIN= 1.00E+06		DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05		DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06		DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 4	4.41176E+05	2.27273E+05	4.38596E+05
RNB 4	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 4	3.00000E-03	1.00000E-03	5.00000E-03
IBC 4	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 4	0.	0.	0.
GAIN 4	[illegible]	5.00000E+04	2.00000E+05
POUT 4	[illegible]	7.50000E+01	7.50000E+01
[illegible]	[illegible]	1.20000E+01	1.40000E+01
[illegible]	[illegible]	-1.20000E+01	-1.40000E+01

OPAMP NUMBER 5

NA= 14 NB= 15 NC= 22 ND= 0 NF= 30

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 5	4.41176E+05	2.27273E+05	4.38596E+05
RNB 5	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 5	3.00000E-03	1.00000E-03	5.00000E-03
IBC 5	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 5	0.	0.	0.
GAIN 5	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 5	7.50000E+01	7.50000E+01	7.50000E+01
VHI 5	1.30000E+01	1.20000E+01	1.40000E+01
VLI 5	-1.30000E+01	-1.20000E+01	-1.40000E+01

OPAMP NUMBER 6

NA= 19 NB= 18 NC= 24 ND= 0 NF= 31

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 6	4.41176E+05	2.27273E+05	4.38596E+05
RNB 6	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 6	3.00000E-03	1.00000E-03	5.00000E-03
IBC 6	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 6	0.	0.	0.
GAIN 6	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 6	7.50000E+01	7.50000E+01	7.50000E+01
VHI 6	1.30000E+01	1.20000E+01	1.40000E+01
VLI 6	-1.30000E+01	-1.20000E+01	-1.40000E+01

OPAMP NUMBER 7

NA= 21 NB= 20 NC= 25 ND= 0 NF= 3

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER		NOMINAL	MINIMUM	MAXIMUM
ONA	7	4.41176E+05	2.27273E+05	4.38596E+05
BWP	7	5.76923E+05	2.77778E+05	5.81395E+05
DIVO	7	3.00000E-03	1.00000E-03	5.00000E-03
IBC	7	3.00000E-07	1.00000E-07	5.00000E-07
VOFF	7	0.	0.	0.
GAIN	7	2.00000E+05	5.00000E+04	2.00000E+05
ROUT	7	7.50000E+01	7.50000E+01	7.50000E+01
VHH	7	1.30000E+01	1.20000E+01	1.40000E+01
VLL	7	-1.30000E+01	-1.20000E+01	-1.40000E+01

Table 3-1. DICAP INPUT DATA (CONT.)

TABLE 3-2

SUMMARY OF WORST CASE NODE VOLTAGES

NODE NAME	NOMINAL VALUE (VOLTS)	MINIMUM VALUE (VOLTS)	MAXIMUM VALUE (VOLTS)
NODE 1	1.49992E+01	1.46992E+01	1.52992E+01
NODE 2	-1.49985E+01	-1.46985E+01	-1.52984E+01
NODE 3	1.52425E+00	1.41345E+00	1.65086E+00
NODE 4	4.00771E+00	4.00370E+00	4.01571E+00
NODE 5	9.45973E-01	9.13337E-01	9.90570E-01
NODE 6	9.48958E-01	9.14755E-01	9.85351E-01
NODE 7	3.11619E+00	2.99889E+00	3.24249E+00
NODE 8	-1.99670E+00	-1.93738E+00	-2.05602E+00
NODE 9	-1.99971E+00	-1.94239E+00	-2.05703E+00
NODE 10	-1.75126E+00	-1.71549E+00	-1.78782E+00
NODE 11	-1.74825E+00	-1.71124E+00	-1.78527E+00
NODE 12	-8.00000E-01	-7.60000E-01	-8.40000E-01
NODE 13	-7.91306E-01	-7.46643E-01	-8.35969E-01
NODE 14	-7.94310E-01	-7.51645E-01	-8.37871E-01
NODE 15	-7.97313E-01	-7.56648E-01	-8.38874E-01
NODE 16	3.87141E+00	3.75462E+00	3.99670E+00
NODE 17	2.68[illegible]33E+00	2.56436E+00	2.80481E+00
NODE 18	3.20202E+00	3.08675E+00	3.32573E+00
NODE 19	3.20600E+00	3.08774E+00	3.32887E+00
NODE 20	1.59926E+00	1.53843E+00	1.66379E+00
NODE 21	1.60225E+00	1.53942E+00	1.66878E+00
NODE 22	-6.56[illegible]5E-01	-6.10335E-01	-7.03968E-01
NODE 23	-1.44137E+00	-1.39658E+00	-1.48746E+00
NODE 24	3.20515E+00	3.08789E+00	3.32902E+00
NODE 25	1.60648E+00	1.54587E+00	1.67270E+00
NODE 26	8.70964E-01	7.88328E-01	9.68061E-01
NODE 27	-2.07471E+00	-1.96739E+00	-2.18202E+00
NODE 28	-1.82626E+00	-1.74049E+00	-1.91202E+00
NODE 29	-8.69308E-01	-7.68147E-01	-9.61971E-01
NODE 30	-8.72311E-01	-7.69160E-01	-9.63383E-01
NODE 31	3.12701E+00	2.96174E+00	3.31138E+00

TABLE 3-2 (Cont'd)

SUMMARY OF WORST CASE AUXILIARY SOLUTIONS

SOLUTION NAME	NOMINAL VALUE	MINIMUM VALUE	MAXIMUM VALUE	STRESS RATIO
DZ[illegible] IDZ	-[illegible].40000E-12	-9.40000E-12	-9.40000E-12	NSL
DZ[illegible] VDZ	7.97313E-01	7.56648E-01	8.38874E-01	NSL
D1 ID	6.92852E-04	6.49539E-04	7.13479E-04	NSL
D1 VD	-7.55215E-01	-7.52943E-01	-7.57211E-01	NSL
D2 ID	9.94985E-05	9.51318E-05	1.02126E-04	NSL
D2 VD	-6.69390E-01	-6.67870E-01	-6.70971E-01	NSL
D3 ID	4.57629E-07	4.32147E-07	4.87814E-07	NSL
D3 VD	-4.35857E-01	-4.33369E-01	-4.38630E-01	NSL
D4 ID	3.30278E-06	3.23215E-06	3.36949E-06	NSL
D4 VD	-5.21682E-01	-5.20743E-01	-5.22550E-01	NSL
D7 ID	1.29636E-03	1.25852E-03	1.33394E-03	NSL
D7 VD	-7.94889E-01	-7.83489E-01	-7.96242E-01	NSL
D8 ID	5.93327E-05	5.60584E-05	6.26528E-05	NSL
D8 VD	-6.47264E-01	-6.44789E-01	-6.49638E-01	NSL

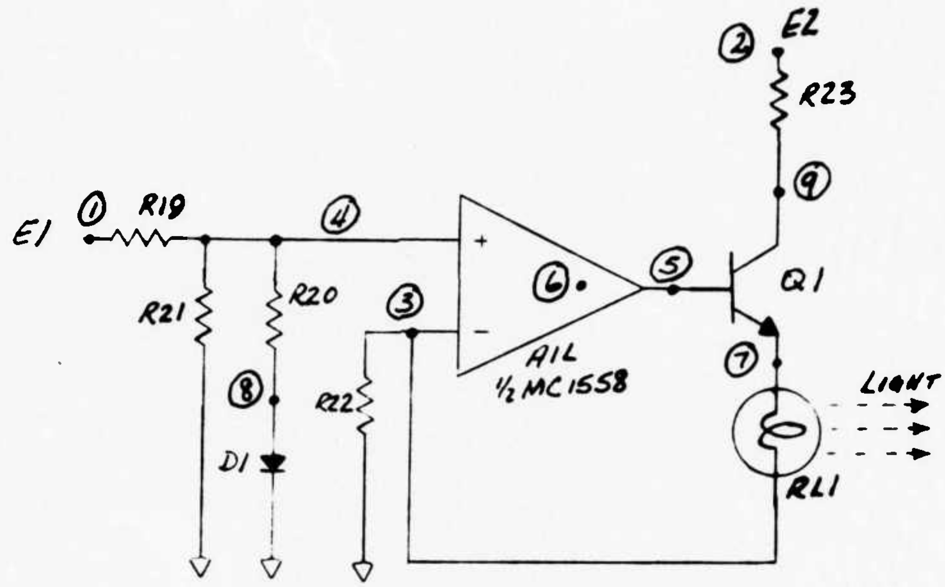
NOTE - N/A INDICATES STRESS RATIO IS NOT APPLICABLE.
NSL INDICATES NO STRESS LIMITS WERE SPECIFIED.

Appendix 4

SELF TEST DEVICE DRIVER CIRCUIT NEUTRON FLUENCE ANALYSIS

The Self Test Device Driver subcircuit of the detector module in the Aerial Radiac System has been analyzed for neutron fluence. The SYSCAP DICAP computer program was used to perform the analysis. The DICAP schematic is shown in figure 4-1. This subcircuit is used to generate a light to activate the photomultiplier tube during self test. The input signal, +15 volts, is applied through the detector switch to node 1. Diode CR1 is used for temperature compensation at the non-inverting input of the operational amplifier. The lamp (RL1) is simulated by a 100 ohm resistor. The current through the light bulb is maintained at approximately 10 ma. The design tolerance of the current through the lamp is ± 0.5 ma.

The circuit parameters affected by specification level neutron fluence are the operational amplifier parameters and transistor gain. The transistor gain is degraded to 20 from a typical value of 200. The DICAP input data is shown in Table 4-1. A summary of the analysis is shown in Table 4-2. The current (RL1 IR) through the lamp varies from nominal by -19 μa and +2 μa. This is within the design tolerance of 500 μa.



E1 = 15 volts from Detector Test
E2 = 28 volts
Q1 = 2N2222A
D1 = CR1 = 1N4249
RL1 = I1 = Incandescent Lamp

Figure 4-1. DICAP Schematic of Self Test Device Driver Subcircuit

Table 4-1. DICAP FREE FORM INPUT DATA

```
DICAP CONTROL CARD - W/C ALL,NODES=9

     SELF TEST DEVICE DRIVER CIRCUIT

     Q1,NPN(B5,C9,E7)         MIN
     7.5G,.6G,200,-16.27M,-.2358,-1.155,-1.981,0.0955,90.9,1.336,
     31.6P,1.4,75,1.336,31.6P,1.4,6
     7.5G,.6G,20.,-16.27M,-.2358,-1.155,-1.981, .0955,90.9,1.336,
     31.6P,1.4,75,1.336,31.6P,1.4,6

     D1(A8,C0)
     1.5G,2.41,.34U,.059,1000,10,10


     E1(+1,-0)15,14.6MIN,15MAX,RS=1,-0,+0

     E2(+2,-  0)28,22MIN,30MAX,RS=1,-0,+0

     R19(1,4)11.7K,-0,+0

     R20(4,8)500,-0,+0

     R21(4,0)10K,-0,+0

     R22(3,0)100,-0,+0

     R23(2,9)1.5K,-0,+0

     RL1(7,3)I,100,-0,+0
     FINIS

               SPECIAL
```

Table 4-1. OPERATIONAL AMPLIFIER DATA (CONT.)

OPAMP NUMBER 1

NA= 3 NB= 4 NC= 5 ND= 0 NF= 6

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 1	4.41176E+05	2.27273E+05	4.38596E+05
RNB 1	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 1	3.00000E-03	1.00000E-03	5.00000E-03
IBC 1	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 1	0.	0.	0.
GAIN 1	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 1	7.50000E+01	7.50000E+01	7.50000E+01
VUL 1	1.30000E+01	1.20000E+01	1.40000E+01
VLL 1	-1.30000E+01	-1.20000E+01	-1.40000E+01

TABLE 4-2

SUMMARY OF WORST CASE NODE VOLTAGES

NODE NAME	NOMINAL VALUE (VOLTS)	MINIMUM VALUE (VOLTS)	MAXIMUM VALUE (VOLTS)
NODE 1	1.49988E+01	1.45988E+01	1.49988E+01
NODE 2	2.79895E+01	2.19895E+01	2.99901E+01
NODE 3	1.05234E+00	1.03304E+00	1.05434E+00
NODE 4	1.04936E+00	1.03206E+00	1.04940E+00
NODE 5	2.80109E+00	2.76157E+00	2.80518E+00
NODE 6	9.74350E-01	9.24307E-01	1.03689E+00
NODE 7	2.10470E+00	2.06610E+00	2.10870E+00
NODE 8	5.05760E-01	5.03948E-01	5.05765E-01
NODE 9	1.22775E+01	6.24758E+00	1.51871E+01

SUMMARY OF WORST CASE AUXILIARY SOLUTIONS

SOLUTION NAME	NOMINAL VALUE	MINIMUM VALUE	MAXIMUM VALUE
Q1 ID1	-3.16000E-11	-3.15998E-11	-3.16611E-11
Q1 ID2	1.05236E-02	1.03306E-02	1.05436E-02
Q1 VCB	9.47639E+00	3.44240E+00	1.24255E+01
Q1 VEB	-6.96383E-01	-6.95470E-01	-6.96477E-01
D1 ID	1.08719E-03	1.05622E-03	1.08727E-03
D1 VP	-5.05760E-01	-5.03948E-01	-5.05765E-01
RL1 IR	1.05236E-02	1.03306E-02	1.05436E-02

Appendix 5

ALARM CIRCUIT NEUTRON FLUENCE ANALYSIS

A partial hand analysis for neutron fluence has been completed on the Alarm subcircuit of the Aerial Radiac System. The circuit schematic is shown in figure 5-1. The DA Alarm Set is used to select the level (in Rads/Hr) that the alarm will be activated. This voltage to operational amplifier A2H is compared with the air dose level (E02) in operational amplifier A2L. Capacitor C5 is used to filter out noise and provide a slight time delay to reduce relay chatter. Since operational amplifier A2L is in open-loop configuration, its output will be either plus or minus saturation. Relay K1 must activate when A2L is in plus saturation.

The specification level neutron fluence will induce changes in the operational amplifiers and in the gain of the transistor in Relay K1. Gain changes in the operational amplifiers will not affect circuit operation. Offset voltage changes will affect the alarm activate level. However, a shift of a few millivolts is not significant when considering the wide range of the alarm set level. Based on data from the manufacturer, the transistor in relay K1 is similar to 2N2222A. Based on prediction techniques, the transistor gain will degrade to 50% of its original value, sufficient for proper transistor action.

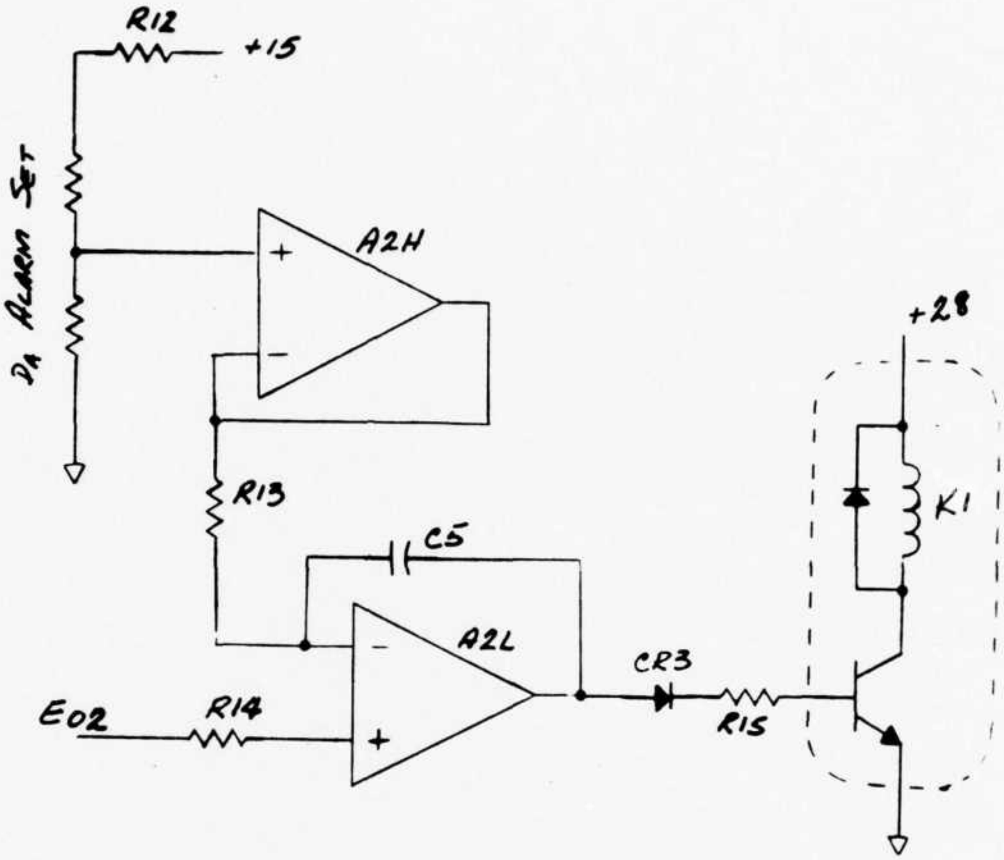


Figure 5-1. Alarm Schematic

Appendix 6

SELF TEST COMPARATOR CIRCUIT NEUTRON FLUENCE ANALYSIS

The Self Test Comparator subcircuit in the Aerial Radiac has been analyzed for neutron fluence. The SYSCAP DICAP computer program was used to perform the analysis. The DICAP schematic is shown in Figure 6-1. When Self Test is activated, 28 volts is applied to this subcircuit and E_{DG} (Ground Dose) is computed through the Self Test Device Driver subcircuit and E_{ALT} is generated. E_{DG} is 3.3 volts $\pm$10% and E_{ALT} is -0.8 $\pm$20%. The operational amplifiers A1H and A1L must sense voltage errors greater than 330 millivolts. A2H and A2L must sense voltage errors greater than 160 millivolts. If both voltages are within tolerance, all operational amplifiers will saturate in the plus state, CR9 will conduct current causing Q1 (2N2219A) to saturate and Relay K1 will activate resulting in a GO light. If any condition is out of tolerance, Q1 will not conduct and the No Go light will remain on.

The circuit parameters affected by specification level neutron fluence are the operational amplifier (MC1558) parameters and transistor gain. The transistor gain is degraded to 20 from a typical value of 200. The degradation is greater than either prediction technique. The DICAP input data is shown in Table 6-1. The tolerance on the Ground Dose Computer E_{DG} is $\pm$5% (from appendix 3) and on the altitude signal $\pm$5%. The relay K1 is simulated, for the purposes of this analysis, by 1500 ohms. The results of the analysis is shown in Table 6-2. The voltage at node 19 varies from 6.60 to 6.69 volts, sufficient to keep Q1 in saturation. The current through RK1 varies from 14.59 ma to 19.94 ma, indicating Relay K1 is turned on.

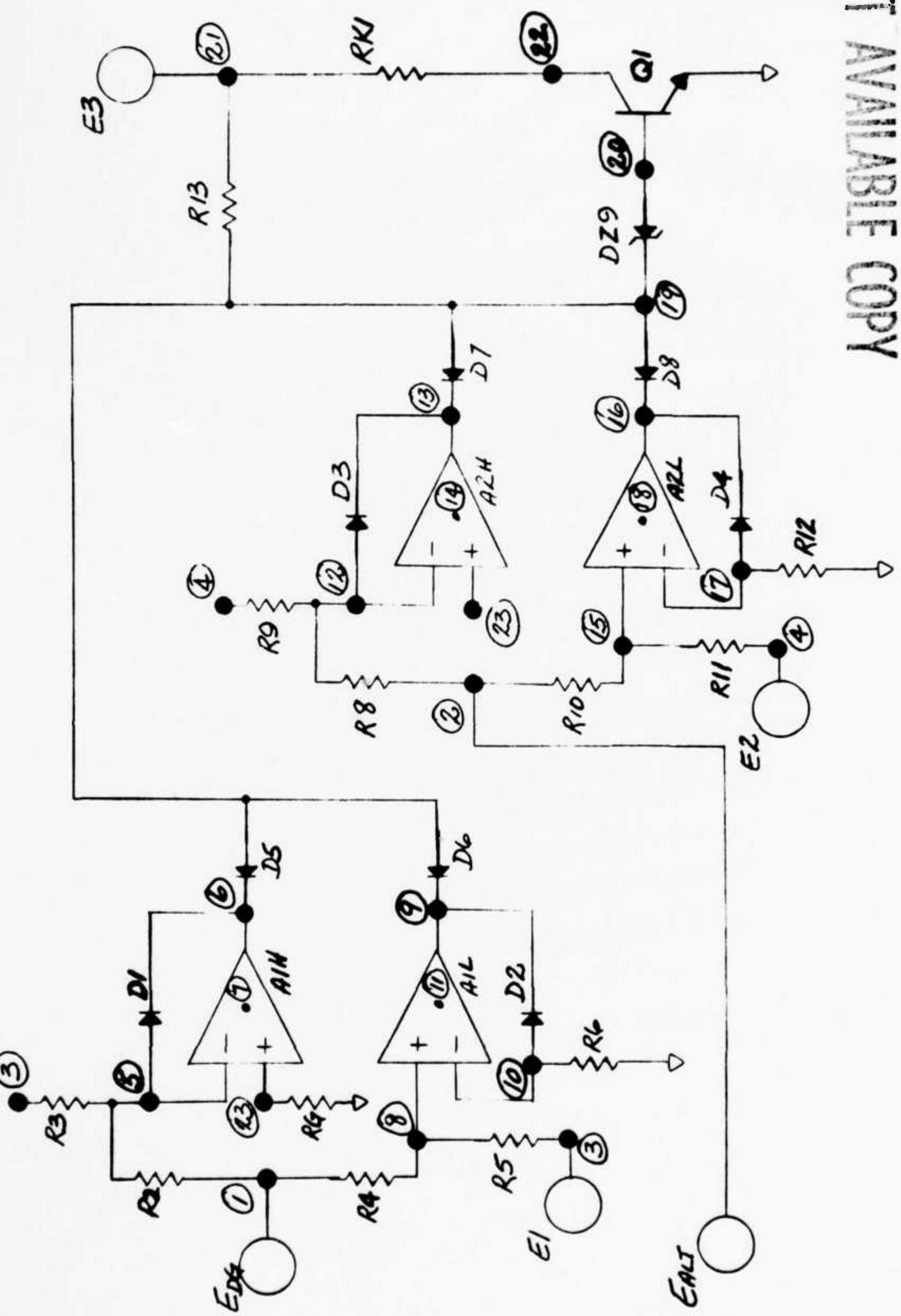


Figure 6-1. DICAP Schematic of Self Test Comparator Subcircuit

DICAP Component Designation and Parts List Equivalent

DICAP	PARTS LIST
R2	R2 + Pot. R1
R4	R4 + Pot. R1
R8	R8 + Pot. R7
R10	R10+ Pot. R7
D1	1N4148
D2	1N4148
D3	1N4148
D4	1N4148
D5	1N4148
D6	1N4148
D7	1N4148
D8	1N4148
D29	1N753A
RK1	Relay K1

All op amps are 1/2 MC1558

Table 6-1. DICAP FREE FORM INPUT DATA

```
DICAP CONTROL CARD - W/C ALL,NODES=23

     SELF TEST COMPARATOR

     01.NPN(A20.C22.E0)IC.MIN
     7.56..66.200.-16.270.-.2358.-1.155.-1.991,0.0955.90.9.1.336.
     31.6P.1.4.75.1.336.31.6P.1.4.6
     7.36..66.20..-16.270.-.2358.-1.155.-1.981. .0955.90.9.1.336.
     31.6P.1.4.75.1.336.31.6P.1.4.6

     D1(25.C6)NOP
     46.1.67.22P.3.100..01.10
```

```
*******************************************************************************
*                                                                             *
*           Table 6-1. DICAP FREE FORM INPUT DATA (CONT.)                     *
*                                                                             *
*******************************************************************************

     D2(A10,C9)D1

     D3(A12,C13)D1

     D4(A17,C16)D1

     D5(A19,C6)D1

     D6(A19,C9)D1

     D7(A19,C13)D1

     D8(A19,C16)D1

     D79(A20,C19)T,NOM
     .636,1,74,73M,30M,6,2,20M,6,65

     EDG(+1,-0)3,3,-5,+5,RS=1,-0,+0

     EALT(+2,-0)-,8,-5,+5,RS=1,-0,+0
```

Table 6-1. DICAP FREE FORM INPUT DATA (CONT.)

```
F1(+3.-0)-15.-2.+2.PS=1.-0.+0
F2(+4.-0)15.-2.+2.PS=1.-0.+0
F3(+21.-0)29.22(IN.30MAX.PS=1.-0.+0
R2(1.5)36.3K
R4(1.8)22.7K
R3(3.5)150K
R5(3.3)150K
R6(13.0)21K
R17(21.10)1.3.2K
R9(5.12)150K
R8(7.12)6.40K
R10(2.16)16.44K
R11(4.15)150K
R12(17.0)8.25K
CK1(21.22)1.1500
R6(23.0)1M
```

Table 6-1 (cont'd)

OPAMP NUMBER 1

```
NA= 5     NB= 23     NC= 6     ND= 0     NF= 7

NOMINAL   RIN= 1.00E+06          DICO= 4.00E-08
MINIMUM   RIN= 5.00E+05          DICO= 1.00E-08
MAXIMUM   RIN= 1.00E+06          DICO= 7.00E-08
```

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 1	4.41176E+05	2.27273E+05	4.38596E+05
RNB 1	5.76923E+05	2.77778E+05	5.81395E+05
DIVD 1	3.00000E-03	1.00000E-03	5.00000E-03
IBC 1	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 1	0.	0.	0.
GAIN 1	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 1	7.50000E+01	7.50000E+01	7.50000E+01
VUL 1	1.30000E+01	1.20000E+01	1.40000E+01
VLL 1	-1.30000E+01	-1.20000E+01	-1.40000E+01

OPAMP NUMBER 2

```
NA= 10    NB= 8      NC= 9     ND= 0     NF= 11

NOMINAL   RIN= 1.00E+06          DICO= 4.00E-08
MINIMUM   RIN= 5.00E+05          DICO= 1.00E-08
MAXIMUM   RIN= 1.00E+06          DICO= 7.00E-08
```

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 2	4.41176E+05	2.27273E+05	4.38596E+05
RNB 2	5.76923E+05	2.77778E+05	5.81395E+05
DIVD 2	3.00000E-03	1.00000E-03	5.00000E-03
IBC 2	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 2	0.	0.	0.
GAIN 2	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 2	7.50000E+01	7.50000E+01	7.50000E+01
VUL 2	1.30000E+01	1.20000E+01	1.40000E+01
VLL 2	-1.30000E+01	-1.20000E+01	-1.40000E+01

Table 2.1 (cont'd)

OPAMP NUMBER 3

NA= 12 NB= 23 NC= 13 ND= 0 NE= 14

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 3	4.41176E+05	2.27273E+05	4.38596E+05
RNB 3	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 3	3.00000E-03	1.00000E-03	5.00000E-03
IBC 3	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 3	0.	0.	0.
GAIN 3	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 3	7.50000E+01	7.50000E+01	7.50000E+01
VUL 3	1.30000E+01	1.20000E+01	1.40000E+01
VLL 3	-1.30000E+01	-1.20000E+01	-1.40000E+01

OPAMP NUMBER 4

NA= 17 NB= 15 NC= 16 ND= 0 NE= 18

NOMINAL	RIN= 1.00E+06	DICO= 4.00E-08
MINIMUM	RIN= 5.00E+05	DICO= 1.00E-08
MAXIMUM	RIN= 1.00E+06	DICO= 7.00E-08

PARAMETER	NOMINAL	MINIMUM	MAXIMUM
RNA 4	4.41176E+05	2.27273E+05	4.38596E+05
RNB 4	5.76923E+05	2.77778E+05	5.81395E+05
DIVO 4	3.00000E-03	1.00000E-03	5.00000E-03
IBC 4	3.00000E-07	1.00000E-07	5.00000E-07
VOFF 4	0.	0.	0.
GAIN 4	2.00000E+05	5.00000E+04	2.00000E+05
ROUT 4	7.50000E+01	7.50000E+01	7.50000E+01
VUL 4	1.30000E+01	1.20000E+01	1.40000E+01
VLL 4	-1.30000E+01	-1.20000E+01	-1.40000E+01

TABLE 6-2

SUMMARY OF WORST CASE NODE VOLTAGES

NODE NAME	NOMINAL VALUE (VOLTS)	MINIMUM VALUE (VOLTS)	MAXIMUM VALUE (VOLTS)
NODE 1	3.29980E+00	3.13480E+00	3.46480E+00
NODE 2	-7.99000E-01	-7.59797E-01	-8.39804E-01
NODE 3	-1.49998E+01	-1.46999E+01	-1.52998E+01
NODE 4	1.49998E+01	1.46998E+01	1.52998E+01
NODE 5	-2.63052E-01	-7.25529E-02	-4.52235E-01
NODE 6	1.35320E+01	1.21497E+01	1.49142E+01
NODE 7	-2.25763E-01	-4.55273E-02	-4.09576E-01
NODE 8	2.65610E-01	8.04929E-02	4.50712E-01
NODE 9	1.35331E+01	1.21708E+01	1.48954E+01
NODE 10	2.00072E-03	-4.15000E-03	1.67448E-02
NODE 11	3.95314E-02	-9.58422E-02	2.60944E-01
NODE 12	-1.44689E-01	-9.31735E-02	-1.95867E-01
NODE 13	1.32052E+01	1.21903E+01	1.44002E+01
NODE 14	-1.58690E-01	-5.34307E-02	-2.39623E-01
NODE 15	1.53556E-01	9.75173E-02	2.03589E-01
NODE 16	1.33132E+01	1.21997E+01	1.44267E+01
NODE 17	-1.05401E-04	2.14554E-03	-1.91096E-03
NODE 18	-1.02190E-02	1.11435E-01	-8.70290E-02
NODE 19	6.68048E+00	6.60672E+00	6.69811E+00
NODE 20	7.51753E-01	7.21387E-01	7.57539E-01
NODE 21	2.79788E+01	2.19835E+01	2.99772E+01
NODE 22	6.77398E-02	6.51202E-02	1.10327E-01
NODE 23	-6.66386E-13	-2.52054E-13	-1.68952E-12

TABLE 6-2 (cont'd)

SUMMARY OF WORST CASE AUXILIARY SOLUTIONS

SOLUTION NAME	NOMINAL VALUE	MINIMUM VALUE	MAXIMUM VALUE	STRESS RATIO
D1 ID1	8.12634E-03	2.12271E-03	8.96849E-03	NSL
D1 ID2	2.68417E-02	1.67910E-02	2.90302E-02	NSL
D1 VF3	-6.84013E-01	-6.29371E-01	-6.88653E-01	NSL
D1 VF4	-7.51753E-01	-7.21387E-01	-7.57539E-01	NSL
D79 ID7	-2.59735E-03	-1.87381E-03	-2.84089E-03	NSL
D79 VD7	5.92872E+00	5.88524E+00	5.94066E+00	NSL
D1 ID	-2.00000E-11	-2.00000E-11	-2.00000E-11	NSL
D1 VD	1.37950E+01	1.22237E+01	1.53664E+01	NSL
D2 ID	-2.00000E-11	-2.00000E-11	-2.00000E-11	NSL
D2 VD	1.35311E+01	1.21725E+01	1.48896E+01	NSL
D3 ID	-2.00000E-11	-2.00000E-11	-2.00000E-11	NSL
D3 VD	1.34399E+01	1.22846E+01	1.45953E+01	NSL
D4 ID	-2.00000E-11	-2.00000E-11	-2.00000E-11	NSL
D4 VD	1.33133E+01	1.22002E+01	1.44264E+01	NSL
D5 ID	-2.00000E-11	-1.99992E-11	-2.00022E-11	NSL
D5 VD	6.85149E+00	5.45164E+00	8.30747E+00	NSL
D6 ID	-2.00000E-11	-1.99992E-11	-2.00022E-11	NSL
D6 VD	6.35261E+00	5.47267E+00	8.28866E+00	NSL
D7 ID	-2.00000E-11	-1.99992E-11	-2.00023E-11	NSL
D7 VD	6.61477E+00	5.49222E+00	7.79344E+00	NSL
D8 ID	-2.00000E-11	-1.99992E-11	-2.00023E-11	NSL
D8 VD	6.63271E+00	5.50156E+00	7.81998E+00	NSL
Q1 IC	1.66074E-02	1.45943E-02	1.99389E-02	NSL
D79 IZT	-2.59736E-03	-1.87382E-03	-2.84090E-03	NSL
R41 IR	1.96074E-02	1.45943E-02	1.99389E-02	NSL
R13 IR	2.59736E-03	1.87381E-03	2.84089E-03	NSL

NOTE - N/A INDICATES STRESS RATIO IS NOT APPLICABLE.
NSL INDICATES NO STRESS LIMITS WERE SPECIFIED.

Appendix 7

LOG MODULE NEUTRON FLUENCE TEST RESPONSE

The Log Module subcircuit in the Detector Module of the ARS has been tested for neutron fluence degradation. The Log Module converts the output current of the Photomultiplier Tube to a corresponding voltage level. The test was conducted at the Northrop Reactor using the TRIGA MARK F dry exposure room with the 1/4" boral shield and 2.3" lead shield in position around the exposure room window. The shift in output voltage level at various fluence is shown in the attached Table 7-1.

Table 7-1. Log Module Neutron Test Data

Measured Current Input	Pre Neutron Test	4.80 X 10^{11}n/cm^2	1.07 X 10^{12}n/cm^2	8.83 X 10^{12}n/cm^2
1 X 10^{-9} amps	+8.17 volts	+8.09 volts	+8.14 volts	+8.30 volts
1 X 10^{-8}	+6.11	+6.03	+6.05	+6.10
1 X 10^{-7}	+4.00	+3.91	+3.93	+3.90
1 X 10^{-6}	+1.89	+1.81	+1.83	+1.76
1 X 10^{-5}	-0.22	-0.28	-0.27	-0.35

Appendix 8

SUBTRACTOR CIRCUIT PROMPT GAMMA RESPONSE

The subtractor subcircuit of the detector module in the Aerial Radiac System has been analyzed for prompt gamma radiation. The TESS computer program was used to perform the analysis. The TESS schematic is shown in Figure 8-1. This subcircuit is used to shift the voltage level from the log converter module (E1) by the negative of EMAX. The output voltage (VRL) must return to nominal within a reasonable time.

The circuit parameters affected by specification level prompt gamma are the op-amp transient response. The transient response is shown in reference 1. The op-amp model and other TESS input data is shown in Table 8-1. The standard uA741 model was used to simulate the MC1558 op-amp. The initial page of the tabulated output is shown in Table 8-2 and final value in Table 8-3. The prompt gamma was initiated at time 5.E-06. At time 3.23E-03 VRL has returned to nominal. The graphical output is shown in Figure 8-2. The response goes to negative 13.5 volts, then positive to 13.5 volts for 40 microseconds. The response then returns to 5 volts and slowly returns to +4 volts. However, within the anticipated operational use of the ARS, transient upsets of a few milliseconds are tolerable. It should be noted that the extended response time is due to circuit, not component response.

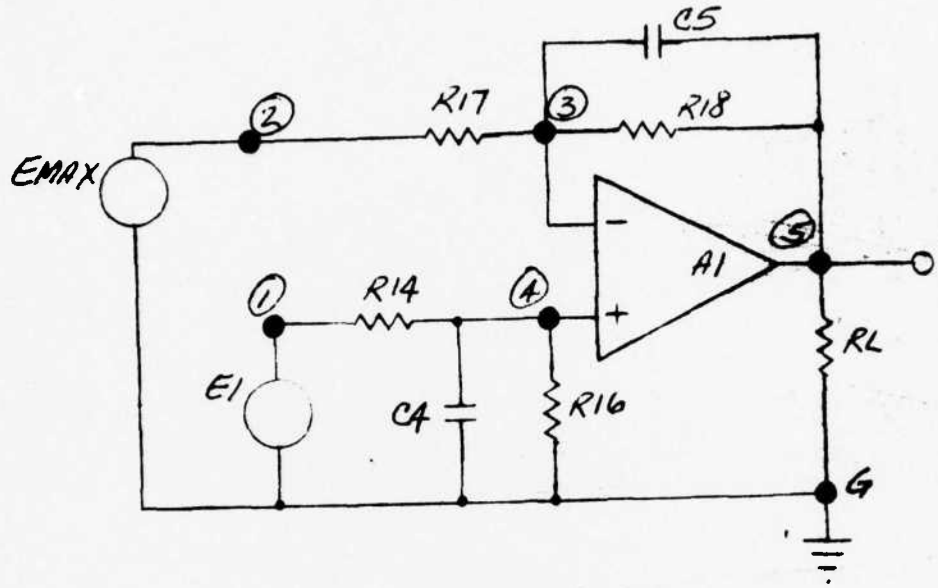


Figure 8-1. TESS Schematic of Subtractor Subcircuit

```
MODEL UA741(TEMP)(A-B-C-G)
UA741 MODEL    SCEPTRE-BOWERS   (MODIFIED)
UNITS-OHMS.VOLTS.AMPS.FARADS.HENRIES.SECONDS
ELEMENTS
EOS.1-A=5.E-3
E2 .G-2=O1(VC1)
E3 .G-4=TABLE1(VC2)
E4 .7-G=TABLE2(VJP)
ER .5-6=PER
C1 .1-B=2.E-12
C2 .3-G=3.E-11
C3 .5-G=3.E-11
C4 .C-B=1.E-11
R1 .1-B=4.E6
R2 .2-3=1.E3
R3 .4-5=9.65E8
R4 .C-7=175.
R5 .B-7=0.1
JB1.A-G=1.E-7
JB2.B-G=1.1E-7
JP .6-G=PJP
DEFINED PARAMETERS
P1=1.E-13
PSW=FUNCTION SWITCH(TS.P1)
PER=O2(4.3E-11.TABLE3(TIME))
PJP=O2(1.E-15.TABLE4(TIME))
FUNCTIONS
O1(A)=(A)
O2(A.B)=(A*B
TABLE1=-1.,-[illegible]5.67E-2.-5.67E-2.-5.67E-2.5.67E-2,5.67E-2.4.,5.67E-2.5.,1.
TABLE2=-1.,-14.,-1.E-4.-14.,1.E-4.14.,1.,14.
TABLE3=0.0.5.0E-6.0.5.01E-06.1.0E8.7.49E-6.1.0E8.7.5E-6.0.1.E-2.0
TABLE4=0.0,5.6E-6.0.5.61E-6.1.0E8.7.49E-6.1.0E8.7.50E-6.0.1.0E-2.0
TS
0.,5.E-6.5.E-6.5.E-6.5.E-6.5.01E-6.5.01E-6,5.01E-6.5.01E-6.
5.6E-6.5.6E-6.5.6E-6.5.6E-6.5.61E-6.5.61E-6,5.61E-6,5.61E-6.
7.49E-6.7.49E-6.7.49E-6.7.49E-6.7.5E-6.7.5E-6,7.5E-6.7.5E-6.
1.E-2.1.E-2.1.E-2
OUTPUTS
PSW
VC1.VC2.VC3.VC4.PLOT
```

Table 8-1. TESS uA741 Op Amp Model Input Data

```
TRANSIENT ANALYSIS OF SUBTRACTOR CIRCUIT USING TESS COMPUTER PROGRAM
ELEMENTS
A1.3-4-5-G=MODEL UA741
R17.2-3=51100
R14.1-4=51100
R18.3-5=51100
R16.4-G=51100
RL.5-G=5000
E1.G-1=-[illegible]
EMAX.G-2=-8
C4.4-G=.01E-06
C5.3-5=.01E-06
OUTPUTS
VC4.VC5.VRL.PLOT
INITIAL CONDITIONS
VC1A1=-3.28916E-05
VC2A1=-3.28918E-05
VC3A1=-2.97323E-05
VC4A1=-1.66629E-01
VC4=-2.0[illegible]
VC5=-5.99972E+0[illegible]
RUN CONTROLS
STOP TIME=3.E-3
MINIMUM STEP SIZE=1.E-20
INTEGRATION ROUTINE=GEAR
END

SYSTEM NOW ENTERING SIMULATION
```

Table 8-1. (Continued) TESS Subtractor Circuit Input Data

TRANSIENT ANALYSIS [illegible]

TRANSIENT ANALYSIS OF [illegible] CIRCUIT USING TESS COMPUTER PROGR

TIME	0.	1.47431E-12	2.94862E-12	8.84587E-12	1.47431E-11	3.83321E-11
PSWA1	3.00000E-[illegible]	1.47431E-12	5.89724E-12	5.89724E-12	2.35890E-11	2.35890E-11
VC1A1	-3.28016E-05	[illegible]	-2.60315E-05	-2.79788E-05	-2.79739E-05	-2.79756E-05
VC2A1	-3.28019E-05	-3.28917E-05	-3.28916E-05	-3.28913E-05	-3.28909E-05	-3.28895E-05
VC3A1	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05
VC4A1	-1.60640E-01	[illegible]	-1.60640E-01	-1.60640E-01	-1.60640E-01	-1.60640E-01
VC4	[illegible]	[illegible]	-2.00281E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00
VC5	[illegible]	[illegible]	-5.99972E+00	-5.99972E+00	-5.99972E+00	-5.99972E+00
VRL	[illegible]	[illegible]	4.00188E+00	4.00128E+00	4.00188E+00	4.00188E+00
TIME	[illegible]	2.51633E-10	6.28956E-10	1.00548E-09	2.51517E-09	4.02487E-09
PSWA1	[illegible]	[illegible]	3.77424E-10	1.50969E-09	1.50969E-09	6.03878E-09
VC1A1	-2.78935E-05	-2.78435E-05	-2.76766E-05	-2.75497E-05	-2.63889E-05	-2.71118E-05
VC2A1	[illegible]	-3.28762E-05	-3.28516E-05	-3.28266E-05	-3.27186E-05	-3.26147E-05
VC3A1	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05
VC4A1	[illegible]	-1.60640E-01	-1.60640E-01	-1.60640E-01	-1.60640E-01	-1.60639E-01
VC4	-2.00281E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00
VC5	-5.99972E+00	-5.99972E+00	-5.99972E+00	-5.99972E+00	-5.99972E+00	-5.99972E+00
VRL	[illegible]	4.00188E+00	4.00188E+00	4.00188E+00	4.00188E+00	4.00128E+00
TIME	1.61024E-08	4.02575E-08	6.44126E-08	1.61033E-07	2.57654E-07	6.44135E-07
PSWA1	2.41551E-08	2.41551E-08	9.66204E-08	9.66204E-08	3.86482E-07	3.86482E-07
VC1A1	-2.68399E-05	-2.76273E-05	-2.74581E-05	-2.89702E-05	-3.03088E-05	-3.22223E-05
VC2A1	-3.19348E-05	-3.07750E-05	-3.00065E-05	-2.94396E-05	-2.99151E-05	-3.18266E-05
VC3A1	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05	-2.97323E-05
VC4A1	-1.60639E-01	-1.60639E-01	-1.60639E-01	-1.60639E-01	-1.60639E-01	-1.60639E-01
VC4	[illegible]	-2.00281E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00
VC5	-5.99972E+00	-5.99972E+00	-5.99972E+00	-5.99972E+00	-5.99972E+00	-5.99973E+00
VRL	[illegible]	4.00188E+00	4.00128E+00	4.00129E+00	4.00188E+00	4.00189E+00
TIME	2.57654E-06	4.12247E-06	5.00000E-06	5.00000E-06	5.00000E-06	5.00000E-06
PSWA1	[illegible]	8.77529E-07	1.00000E-13	2.69025E-14	4.30860E-14	4.30860E-14
VC1A1	-3.28737E-05	-3.28667E-05	-3.28632E-05	-2.20521E-04	-5.69740E-04	-1.30576E-03
VC2A1	-3.28522E-05	[illegible]	[illegible]	-3.28637E-05	-3.28639E-05	-3.28644E-05
VC3A1	-2.97325E-05	-2.97327E-05	-2.97324E-05	-2.97328E-05	-2.97328E-05	-2.97328E-05
VC4A1	[illegible]	[illegible]	-1.60641E-01	-1.60604E-01	-1.60534E-01	-1.60387E-01
VC4	[illegible]	[illegible]	-2.00281E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00
VC5	[illegible]	[illegible]	[illegible]	-5.99979E+00	-5.99979E+00	-5.99979E+00
VRL	[illegible]	[illegible]	[illegible]	4.00176E+00	4.00141E+00	4.00068E+00

TRANSIENT ANALYSIS RESULTS

TRANSIENT ANALYSIS OF SUBTRACTOR CIRCUIT USING TESS COMPUTER PROGR

TIME	9.99227E-05	1.19964E-04	1.69503E-04	2.19041E-04	2.58579E-04	3.63745E-04
PSWA1	2.00419E-05	4.95381E-05	4.95381E-05	4.95381E-05	1.01166E-04	1.01166E-04
VC1A1	2.09146E-04	1.99171E-04	1.77994E-04	1.58752E-04	1.41287E-04	1.10559E-04
VC2A1	2.08180E-04	1.99207E-04	1.78028E-04	1.58782E-04	1.41314E-04	1.10581E-04
VC3A1	-3.40657E-05	-3.39044E-05	-3.35236E-05	-3.31777E-05	-3.28627E-05	-3.23113E-05
VC4A1	-1.81176E-01	-1.80410E-01	-1.78604E-01	-1.76964E-01	-1.75475E-01	-1.72856E-01
VC4	-1.99664E+00	-1.99709E+00	-1.99[illegible]11E+00	-1.99894E+00	-1.99963E+00	-2.00067E+00
VC5	-6.57946E+00	-6.55409E+00	-6.50763E+00	-6.46170E+00	-6.41994E+00	-6.34629E+00
VPI	4.59223E+00	4.54620E+00	4.51470E+00	4.46792E+00	4.42545E+00	4.35073E+00
TIME	5.72077E-04	6.73243E-04	7.98257E-04	9.23272E-04	1.04829E-03	1.17330E-03
PSWA1	1.01166E-04	1.25014E-04	1.25014E-04	1.25014E-04	1.25014E-04	1.25014E-04
VC1A1	6.48352E-05	4.78907E-05	3.10494E-05	1.77991E-05	7.42346E-06	-6.70793E-07
VC2A1	6.48400E-05	4.79029E-05	3.10590E-05	1.78066E-05	7.42928E-06	-6.65236E-07
VC3A1	-3.14931E-05	-3.11846E-05	-3.08819E-05	-3.06436E-05	-3.04571E-05	-3.03116E-05
VC4A1	-1.68960E-01	-1.67517E-01	-1.66083E-01	-1.64954E-01	-1.64071E-01	-1.63382E-01
VC4	-2.00181E+00	-2.00213E+00	-2.00239E+00	-2.00257E+00	-2.00267E+00	-2.00273E+00
VC5	-6.23626E+00	-6.19541E+00	-6.15474E+00	-6.12270E+00	-6.09759E+00	-6.07797E+00
VPI	4.23951E+00	4.19833E+00	4.15738E+00	4.12516E+00	4.09902E+00	4.08024E+00
TIME	1.51590E-03	1.73348E-03	1.95107E-03	2.16865E-03	2.38624E-03	2.66928E-03
PSWA1	2.17584E-04	2.17584E-04	2.17584E-04	2.17584E-04	2.83040E-04	2.83040E-04
VC1A1	-1.48845E-05	-2.00723E-05	-2.34814E-05	-2.57024E-05	-2.71373E-05	-2.82835E-05
VC2A1	-1.48822E-05	-2.00708E-05	-2.34804E-05	-2.57018E-05	-2.71369E-05	-2.82833E-05
VC3A1	-3.00560E-05	-2.99628E-05	-2.99015E-05	-2.98615E-05	-2.98357E-05	-2.98151E-05
VC4A1	-1.62172E-01	-1.61730E-01	-1.61440E-01	-1.61251E-01	-1.61128E-01	-1.61031E-01
VC4	-2.00278E+00	-2.00280E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00	-2.00281E+00
VC5	-6.04347E+00	-6.03088E+00	-6.02260E+00	-6.01720E+00	-6.01371E+00	-6.01093E+00
VPI	4.04567E+00	4.03306E+00	4.02477E+00	4.01937E+00	4.01588E+00	4.01309E+00
TIME	3.23536E-03					
PSWA1	2.83040E-04					
VC1A1	-2.93221E-05					
VC2A1	-2.93121E-05					
VC3A1	-2.97945E-05					
VC4A1	-1.60943E-01					
VC4	-2.00281E+00					
VC5	-6.00851E+00					
VPI	4.01057E+00					

Table 8-3. TESS Tabulated Output - Time 9.99E-05 to 3.23E-03

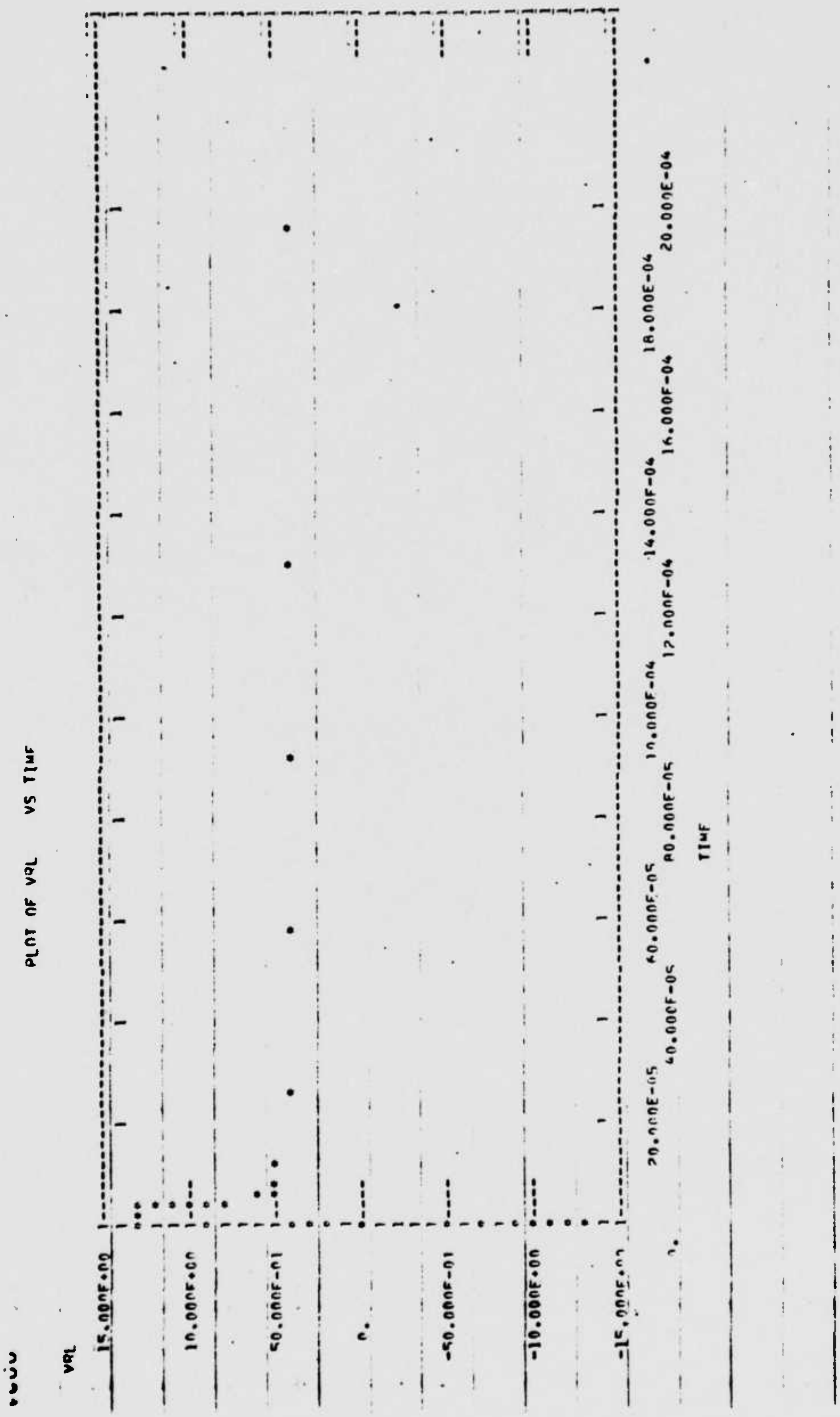


Figure 8-2. TESS Output Plot - VRL vs. Time

Appendix 9

TESTING OF AERIAL RADIAC SYSTEM TO PROMPT GAMMA

The Aerial Radiac System (breadboard model) was exposed to prompt gamma ray irradiation using the Feketron Model 705 flash x-ray machine at the Northrop Corporate Laboratories. These design tests were scheduled to locate potential susceptibilities of the ARS electronic components to this environment. The test data can be extrapolated to the specification level.

The ARS modules which were irradiated were placed in front of the flash x-ray target at a distance as close as physical limitations would permit. As a matter of convenience no special test fixtures were constructed. Instead, the computer/power supply (CPS) box, which contains three of the electronic circuit cards, was used as its own test fixture by employing its existing connectors and test point facilities. For each of the test points monitored (e_{03}, e_{ALT_1}, e_{ALT_2}, +15, -15, e_{02}, and H.V.), the selector switch on the CPS was placed in the proper position and then the signal was delivered from the test point jack to oscilloscope by means of a coaxial cable. The e_{02} and high voltage (H.V.) signals originate from circuitry within the Detector Module (DM), but these are also accessible at the test point jack.

Dose rates received by the breadboard components were limited by the physical proximity of the circuit cards to the x-ray target. The Power Supply board (+15), which was at the rear of the CPS, received a dose rate of 4 X 10^8 Rads(Si)/second and the Ground Dose (D_G) board, at the front of the CPS received 7.3 X 10^8 Rads(Si)/second. These levels were calculated from the average of four thermal luminescent detector (TLD) readings on each board. The Detector Module received two dose rates: one at 1.6 X 10^8 Rads(Si)/second and the other at 1.3 X 10^{10} Rads(Si)/second. For the high level, the scintillator end of the DM was placed flat on the X-ray target. Since the TLD's on the DM were placed external to its case, the actual level received internally may have been attenuated slightly. It was approximated that the High Voltage unit received about 5 X 10^9 Rads(Si)/second since it is placed about four inches behind the scintillator.

Figure 9-10 shows the test set-up used on the CPS module. The DM was disconnected from the system and the e_{02} input to the CPS was grounded. The CAI module, which control power to the system, and the +28 volt power supply were located out of range of the X-ray beam. A Textronix 556 oscilloscope was used in the control room to monitor the signals from the test point jack. After each shot, the test point selector switch and/or the manual altitude switch were rotated to a new position. The TLD's were exposed only once on the first shot and then removed.

Figures 9-1 through 9-6 show the responses obtained for the CPS tests. Except for e_{03} (Figure 9-1), all the operational amplifier outputs respond quite similarly. The difference in e_{03} may be attributed to the fact that this particular signal path consists of an adder stage for which one input is the output of another op-amp (e_{ALT2}). Not only do these motorola MC1558G dual op-amps behave like 741 types in general, but even more like their single counterpart, the MC1741G (Reference 3).

Figures 9-5 and 9-6 show the transients which occur on the +15 and -15 volt power supply lines. It can be assumed that these transients are produced only by the output regulators, MC1569R and MC1563R since they are isolated from the rest of the power supply components by large filter capacitors. Although the 1569 (+) and the 1563 (-) are not identical regulators, they are designed to track temperature identically and, as would be expected, their radiation responses are similar. For both, a small damped sinusoid rides on the quiescent level for a few microseconds.

Figures 9-7, 9-8, and 9-9 show the effect of prompt gamma radiation on Detector Module signals, e_{02} and high voltage. The e_{02} signal is the final output signal from circuitry consisting of three stages in cascade. The output current of the photomultiplier tube (PMT) is converted to voltage by the log module and then level shifted and filtered by an op-amp subtractor stage. Except for the absence of top end saturation, the e_{02} response is the typical 741 op-amp response. Since the maximum bandwidth of the 4351 log module is less than 200 KHz, it may be assumed that most of the fast response that the PMT produces in following the 30 nanosecond gamma pulse is lost in the following two stages. It can be seen that the final value of e_{02} after the pulse is slightly higher than its initial value (Figure 9-8). This can be attributed to a short term increase in PMT dark current. Observation of e_{02} on a digital voltmeter showed a gradual decrease to normal dark current level over a five minute interval.

The response of the high voltage power supply was measured by using the H.V. sample test point (5.8 volts = 1000 volts). At approximately 5×10^9 Rads(Si)/second, the higher voltage drops about 350 volts for 15 microseconds.

The tests performed here show that no catastrophic failures occurred to ARS components at the dose rate levels obtained. All the radiation responses observed consist mainly of brief (50 μs) perturbations from normal voltage levels. The magnitude (under saturation voltage) and time duration of an operational amplifier's output transient has, in general, been found to be directly proportional to dose rate. Extrapolation of present data to higher dose rates does not present a problem to the ARS since it has relatively slow time constants. Although the circuitry of the CAI module was not tested at this time, the only uncertainty within it is the LH0002H integrated circuit and this will be tested at a later date.

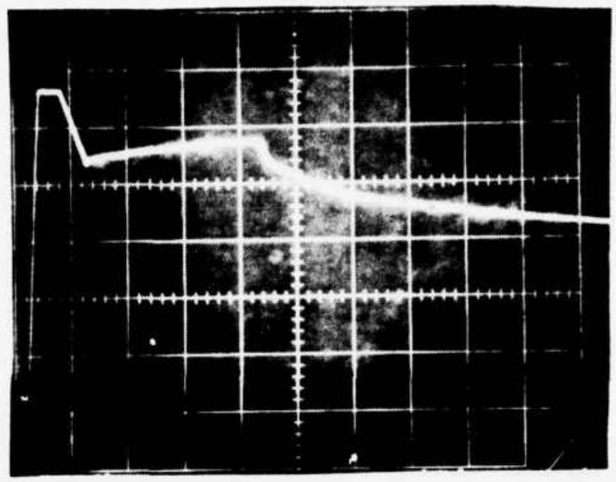


Figure 1: e_{03} response ($e_{02}=0$, $e_{alt}=0$)

H: 10 microseconds/division
V: 5 volts/division
Dose Rate: 7.3 X 10^8 Rads(Si)/second

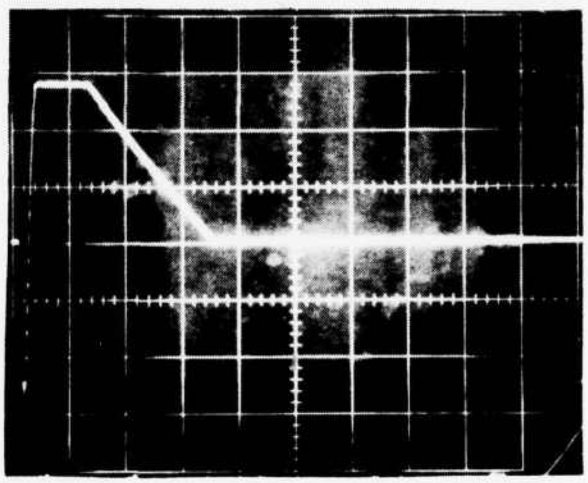


Figure 2: e_{alt} response ($e_{alt}=0$)

H: 10 microseconds/division
V: 5 volts/division
Dose Rate: 7.3 X 10^8 Rads(Si)/second

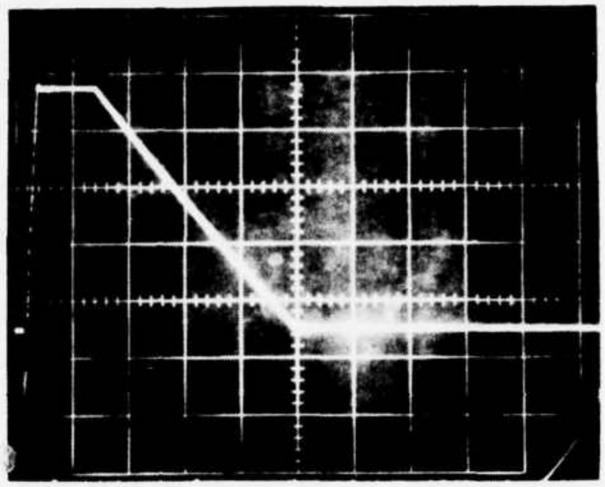


Figure 3: e_{alt_1} response (e_{alt}=-8V)
H: 10 microseconds/division
V: 5 volts/division
Dose Rate: 7.3 X 10^8 Rads(Si)/second

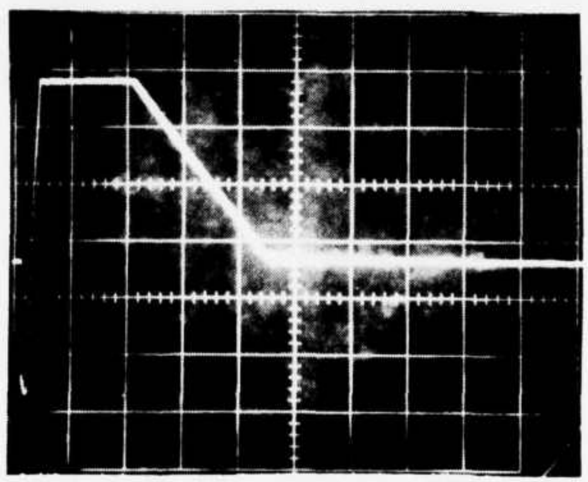


Figure 4: e_{alt_2} response (e_{alt_1}=0V)
H: 10 microseconds/division
V: 5 volts/division
Dose Rate: 7.3 X 10^8 Rads(Si)/second

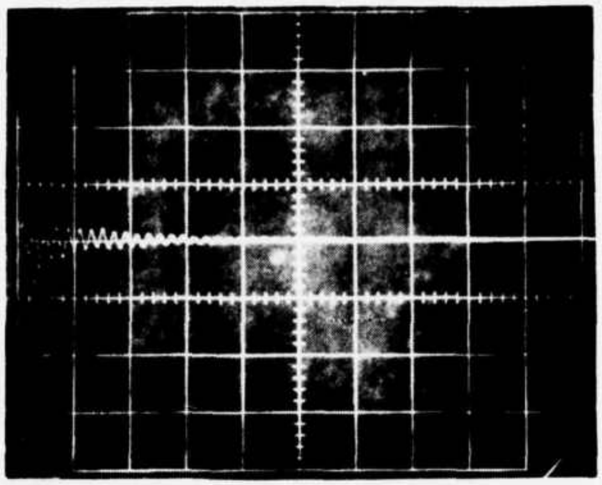


Figure 5: +15V response
H: 1 microsecond/division
V: 5 volts/division
Dose Rate: 4.0 X 10^8 Rads(Si)/second

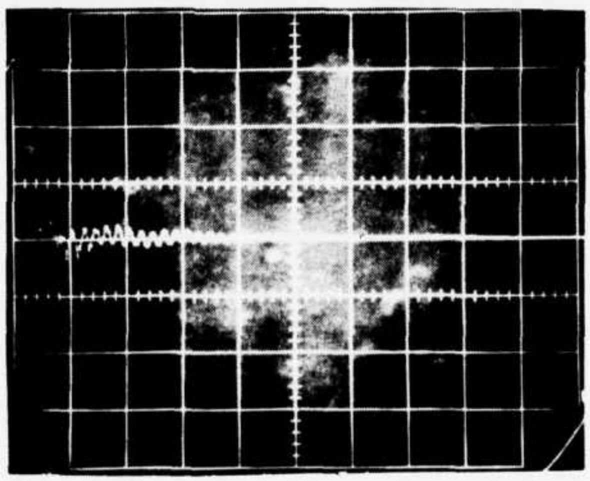


Figure 6: -15V response
H: 1 microsecond/division
V: 5 volts/division
Dose Rate: 4.0 X 10^8 Rads(Si)/second

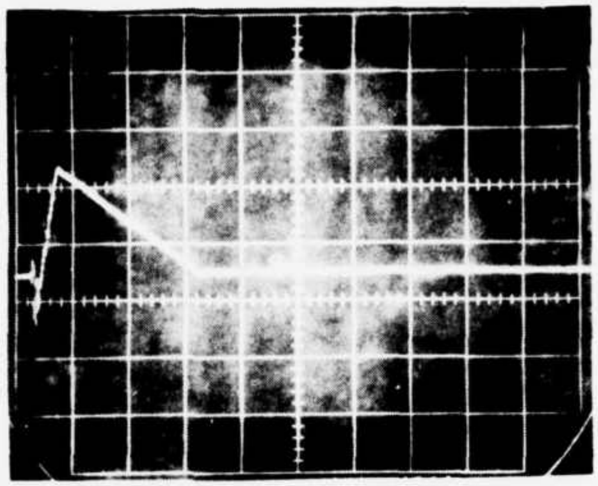


Figure 7: e_{02} response (15)

H: 5 microseconds/division
V: 5 volts/division
Dose Rate: 1.6 X 10^8 Rads(Si)/second

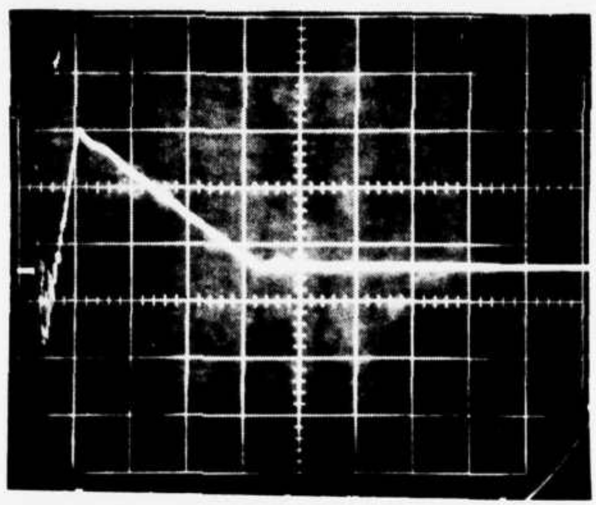


Figure 8: e_{02} response (at target)

H: 5 microseconds/division
V: 5 volts/division
Dose Rate: 1.3 X 10^{10} Rads(Si)/second

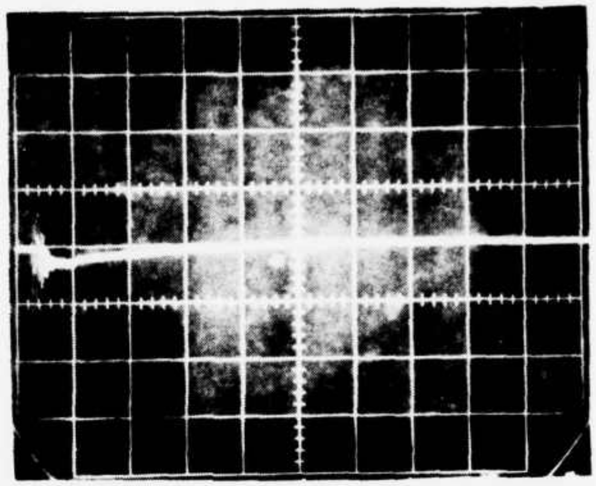


Figure 9: High Voltage Response (-5.8V sample)
H: 5 microseconds/division
V: 5 volts/division
Dose Rate: 5 X 10^9 Rads(Si)/second

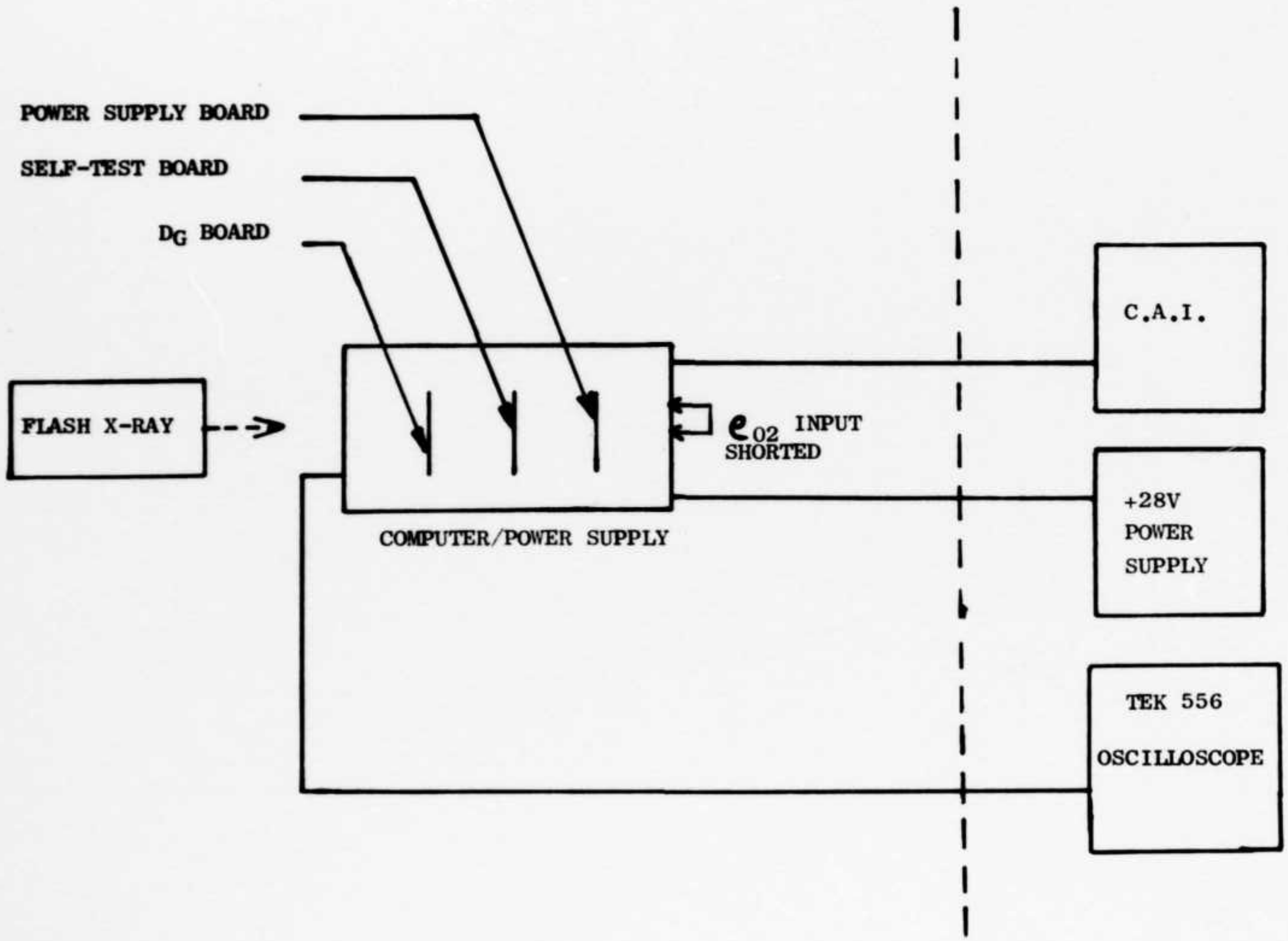


Figure 10: COMPUTER/POWER SUPPLY TEST SET-UP

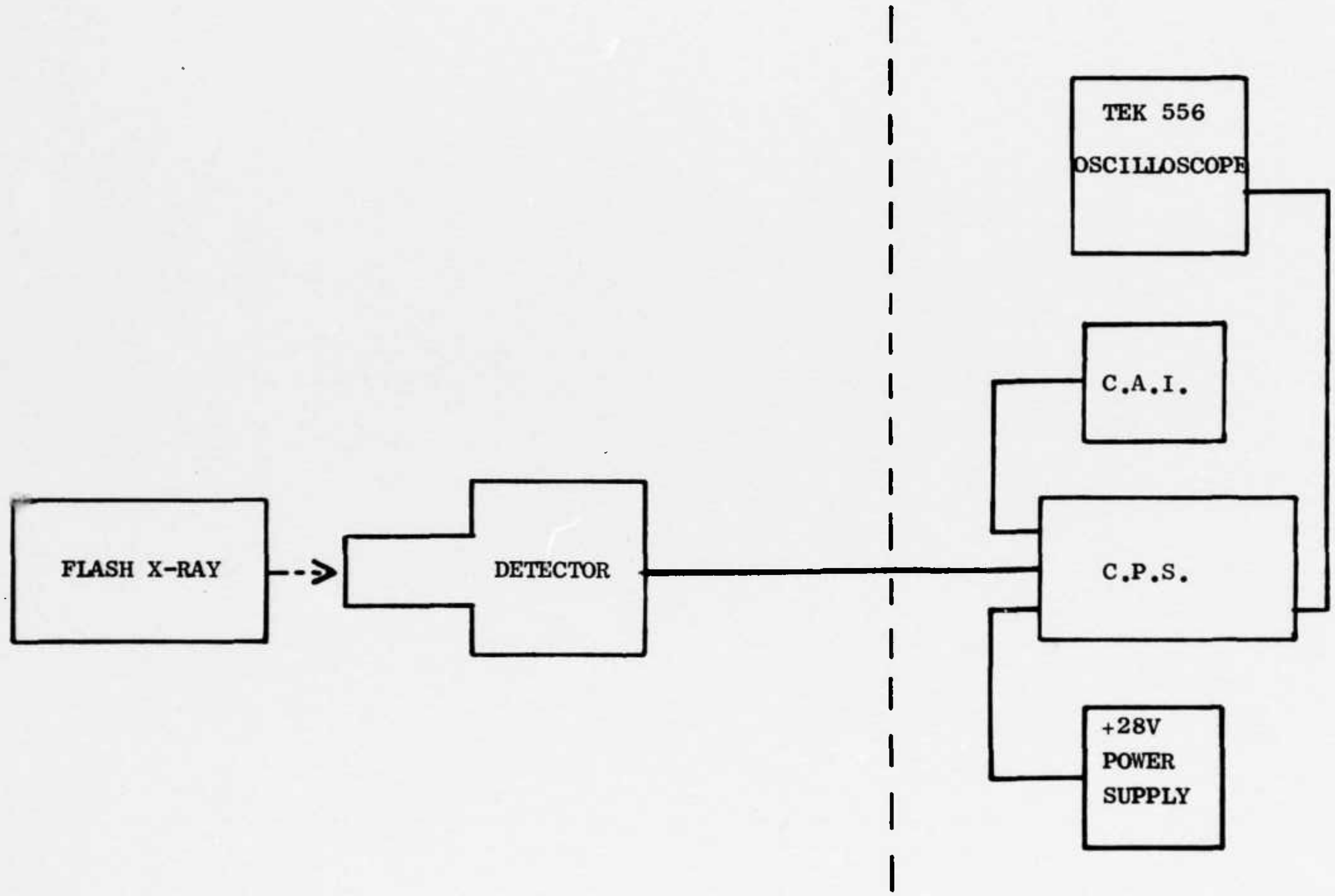


FIGURE 11: DETECTOR TEST SET-UP

ATTACHMENT 1. AERIAL RADIAC SYSTEM PARTS LIST
DETECTOR MODULE, LOG CONVERTER BOARD

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART ≠
R_{14}	Resistor	RN55D5112F	MIL-R-10509F	QPL	
R_{15}	Resistor	RN55D1652F	MIL-R-10509F	QPL	
R_{16}	Resistor	RN55D2052F	MIL-R-10509F	QPL	
R_{17}	Resistor	RN55D5112F	MIL-R-10509F	QPL	
R_{18}	Resistor	RN55D5112F	MIL-R-10509F	QPL	
R_{19}	Resistor	RN55D1072F	MIL-R-10509F	QPL	
R_{20}	Resistor	RN55D4990F	MIL-R-10509F	QPL	
R_{21}	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_{22}	Resistor	RN55D1000F	MIL-R-10509F	QPL	
R_{24}	Resistor	RN55D4222F	MIL-R-10509F	QPL	
R_{23}	Resistor	RCR20G152JM	MIL-R-39008	QPL	
C_1	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_2	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_4	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_5	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_6	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_7	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_8	Capacitor	CK05BX103K	MIL-C-11015	QPL	
Q_1	Transistor	JAN2N2222A	MIL-S-19500/255	QPL	
CR_1	Diode	JAN1N4249	MIL-S-19500/286	QPL	
CR_2	Zener Diode	JAN1N753A	MIL-S-19500/127	QPL	
CR_3	Zener Diode	JAN1N753A	MIL-S-19500/127	QPL	
A_1	I.C. OP-AMP			Motorola	MC1558G
RT_1	Thermistor			Fenwal	LB21J1
Log Mod.	Log. Mod			Teledyne/ Philbrick	700695

DETECTOR MODULE, RESISTOR BOARD

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
R_1	Resistor	RCR20G106JM	MIL-R-39008	QPL	
R_2	Resistor	RN60D2003F	MIL-R-10509F	QPL	
R_3	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_4	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_5	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_6	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_7	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_8	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_9	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_{10}	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_{11}	Resistor	RN55D1003F	MIL-R-10509F	QPL	
R_{12}	Resistor	RN55D9312F	MIL-R-10509F	QPL	
R_{13}	Resistor	RN55D6981F	MIL-R-10509F	QPL	
C_9	Capacitor	CK05BX103K	MIL-C-11015	QPL	

DETECTOR MODULE, CHASSIS

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
P.M.T.	Photomultiplier			R.C.A	4516
H.V. Supply	High Voltage Supply			Technetics	N9567-11
I_1	Incandescent Lamp			Lamps Inc.	679AS15
K_1	Reed Relay			Electronic Applications Co.	1C24A

GROUND DOSE COMPUTER BOARD

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
R_1	Potentiometer	RTR22DX102M	MIL-R-39015	QPL	
R_3	Potentiometer	RTR22DX102M	MIL-R-39015	QPL	
R_{11}	Potentiometer	RTR22DX201M	MIL-R-39015	QPL	
R_{14}	Potentiometer	RTR22DX201M	MIL-R-39015	QPL	
R_{16}	Potentiometer	RTR22DX103M	MIL-R-39015	QPL	
R_{21}	Potentiometer	RTR22DX502M	MIL-R-39015	QPL	
R_{24}	Potentiometer	RTR22DX202M	MIL-R-39015	QPL	
R_2	Resistor	RN55D9091F	MIL-R-10509F	QPL	
R_4	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_5	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_6	Resistor	RN55D1432F	MIL-R-10509F	QPL	
R_8	Resistor	RN55D2372F	MIL-R-10509F	QPL	
R_9	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_{10}	Resistor	RN55D1402F	MIL-R-10509F	QPL	
R_{12}	Resistor	RN55D8450F	MIL-R-10509F	QPL	
R_{13}	Resistor	RN55D1182F	MIL-R-10509F	QPL	
R_{15}	Resistor	RN55D2941F	MIL-R-10509F	QPL	
R_{17}	Resistor	RN55D6812F	MIL-R-10509F	QPL	
R_{18}	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_{19}	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_{20}	Resistor	RN55D3482F	MIL-R-10509F	QPL	
R_{22}	Resistor	RN55D4991F	MIL-R-10509F	QPL	
R_{23}	Resistor	RN55D1001F	MIL-R-10509F	QPL	
R_{25}	Resistor	RN55D6491F	MIL-R-10509F	QPL	
R_{26}	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_{27}	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_{28}	Resistor	RN55D3321F	MIL-R-10509F	QPL	
R_{29}	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_{30}	Resistor	RN55D1503F	MIL-R-10509F	QPL	
R_{31}	Resistor	RN55D2492F	MIL-R-10509F	QPL	
R_{32}	Resistor	RN55D5112F	MIL-R-10509F	QPL	
R_{33}	Resistor	RN55D5112F	MIL-R-10509F	QPL	
R_{34}	Resistor	RN55D3401F	MIL-R-10509F	QPL	
R_{35}	Resistor	RCR07G153JM	MIL-R-39008	QPL	
R_{36}	Resistor	RCR07G911JM	MIL-R-39008	QPL	
C_1	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_2	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_3	Capacitor	CK05BX103K	MIL-C-11015	QPL	

GROUND DOSE COMPUTER BOARD (continued)

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
C_4	Capacitor	CK05BX222K	MIL-C-11015	QPL	
C_5	Capacitor	CK05BX222K	MIL-C-11015	QPL	
C_6	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_7	Capacitor	CK05BX103K	MIL-C-11015	QPL	
CR_1	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_2	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_3	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_4	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_5	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_6	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_7	Zener Diode	JAN1N964B	MIL-S-19500/117	QPL	
A_1	I.C. OP-AMP			Motorola	MC1558G
A_2	I.C. OP-AMP			Motorola	MC1558G
A_3	I.C. OP-AMP			Motorola	MC1558G
A_4	I.C. OP-AMP			Motorola	MC1558G
S_1	Rotary Switch		MIL-S-3786/20	Grayhill	50MY29010-1-2N
S_2	Rotary Switch		MIL-S-3786/20	Grayhill	50MY29010-1-2N
K_1	Relay		MIL-R-5757	Teledyne	412D-26
K_2	Relay		MIL-R-5757	Teledyne	412D-26
K_3	Relay		MIL-R-5757	Teledyne	412D-26

SELF TEST BOARD

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
R_1	Potentiometer	RTR22DX502M	MIL-R-39015	QPL	
R_7	Potentiometer	RTR22DX102M	MIL-R-39015	QPL	
R_{14}	Potentiometer	RTR22DX102M	MIL-R-39015	QPL	
R_2	Resistor	RN55D3652F	MIL-R-10509F	QPL	
R_3	Resistor	RN55D1503F	MIL-R-10509F	QPL	
R_4	Resistor	RN55D2492F	MIL-R-10509F	QPL	
R_5	Resistor	RN55D1503F	MIL-R-10509F	QPL	
R_6	Resistor	RN55D2102F	MIL-R-10509F	QPL	
R_8	Resistor	RN55D6491F	MIL-R-10509F	QPL	
R_9	Resistor	RN55D1503F	MIL-R-10509F	QPL	
R_{10}	Resistor	RN55D8661F	MIL-R-10509F	QPL	
R_{11}	Resistor	RN55D1503F	MIL-R-10509F	QPL	
R_{12}	Resistor	RN55D8251F	MIL-R-10509F	QPL	
R_{15}	Resistor	RN55D1001F	MIL-R-10509F	QPL	
R_{13}	Resistor	RCR20G822JM	MIL-R-39008	QPL	
C_1	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_2	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_3	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_4	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_5	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_6	Capacitor	*CK05BX101K*	MIL-C-11015	QPL	
CR_1	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_2	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_3	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_4	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_5	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_6	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_7	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_8	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_9	Zener Diode	JAN1N753A	MIL-S-19500/127	QPL	

SELF TEST BOARD

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
Q_1	Transistor	JAN2N2219A	MIL-S-19500/251		
A_1	I.C. OP-AMP			Motorola	MC1558G
A2	I.C. OP-AMP			Motorola	MC1558G
K_1	Relay		MIL-R-5757	Teledyne	411D-26
K2	Relay		MIL-R-5757	Teledyne	411D-26
K_3	Relay		MIL-R-5757	Teledyne	412D-26

POWER SUPPLY BOARD

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
R_1	Resistor	RW70U1R00F	MIL-R-26E	QPL	
R_2	Resistor	RN55D1072F	MIL-R-10509F	QPL	
R_3	Resistor	RN55D6811F	MIL-R-10509F	QPL	
R_7	Resistor	RN55D2262F	MIL-R-10509F	QPL	
R_9	Resistor	RN55D6811F	MIL-R-10509F	QPL	
R_{10}	Resistor	RN55D6811F	MIL-R-10509F	QPL	
R_{12}	Resistor	RN55D2262F	MIL-R-10509F	QPL	
R_4	Resistor	RCR07G512JM	MIL-R-39008	QPL	
R_5	Resistor	RCR07G331JM	MIL-R-39008	QPL	
R_6	Resistor	RCR20G2R7JM	MIL-R-39008	QPL	
R_{13}	Resistor	RCR20G2R7JM	MIL-R-39008	QPL	
R_8	Potentiometer	RTR22DX102M	MIL-R-39015	QPL	
R_{11}	Potentiometer	RTR22DX102M	MIL-R-39015	QPL	
C_1	Capacitor	CSR13G156KM	MIL-C-39003	QPL	
C_3	Capacitor	CSR13F685KM	MIL-C-39003	QPL	
C_4	Capacitor	CSR13F226KM	MIL-C-39003	QPL	
C_7	Capacitor	CSR13F226KM	MIL-C-39003	QPL	
C_8	Capacitor	CSR13F226KM	MIL-C-39003	QPL	
C_{11}	Capacitor	CSR13F226KM	MIL-C-39003	QPL	
C_2	Capacitor	CK05BX471K	MIL-C-11015	QPL	
C_5	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_6	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_9	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_{10}	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_{12}	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_{13}	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_{14}	Capacitor	CK05BX104K	MIL-C-11015	QPL	
CR_1	Diode	JAN1N4148	MIL-S-19500/116	QPL	
CR_2	Diode	JAN1N4942	MIL-S-19500/359	QPL	
CR_3	Diode	JAN1N4942	MIL-S-19500/359	QPL	
CR_4	Diode	JAN1N4942	MIL-S-19500/359	QPL	
CR_5	Diode	JAN1N4942	MIL-S-19500/359	QPL	
CR_6	Zener Diode	JAN1N3034B	MIL-S-19500/115	QPL	
CR_7	Zener Diode	JAN1N3034B	MIL-S-19500/115	QPL	
Q_2	Transistor	JAN2N3019	MIL-S-19500/391	QPL	
Q_3	Transistor	JAN2N3019	MIL-S-19500/391	QPL	
Q_4	Transistor	JAN2N2369A	MIL-S-19500/317	QPL	
A_1	I.C. Volt Reg.			Fairchild	U5R7723
A_2	I.C. Volt Reg.			Motorola	MC1569R
A_3	I.C. Volt Reg.			Motorola	MC1563R

POWER SUPPLY BOARD (continued)

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
T_1	Transformer		MIL-T-27C, TF5RX09ZZ	Zenith Transformer	WE-2417
$H.S._1$	Heat Sink			Thermalloy	6168C
$H.S._2$	Heat Sink			Thermalloy	6168C

ALARM/OSCILLATOR BOARD

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
R_3	Resistor	RN55D1872F	MIL-R-10509F	QPL	
R_4	Resistor	RN55D6811F	MIL-R-10509F	QPL	
R_5	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_6	Resistor	RN55D2492F	MIL-R-10509F	QPL	
R_8	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_9	Resistor	RN55D8451F	MIL-R-10509F	QPL	
R_{12}	Resistor	RN55D6981F	MIL-R-10509F	QPL	
R_{13}	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_{14}	Resistor	RN55D1002F	MIL-R-10509F	QPL	
R_7	Resistor	RCR07G565JM	MIL-R-39008	QPL	
R_{11}	Resistor	RCR07G752JM	MIL-R-39008	QPL	
R_{15}	Resistor	RCR07G512JM	MIL-R-39008	QPL	
R_{16}	Resistor	RCR07G564JM	MIL-R-39008	QPL	
C_1	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_2	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_5	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_6	Capacitor	CK05BX103K	MIL-C-11015	QPL	
C_7	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_8	Capacitor	CK05BX104K	MIL-C-11015	QPL	
C_3	Capacitor	M39022/9-C129P	MIL-C-39022/9B	Com.Research	E12A503FSW
C_4	Capacitor	M39022/9-C129P	MIL-C-39022/9B	Com.Research	E12A503FSW
CR_1	Diode	JAN1N4148	MIL-S-19500/385	QPL	
CR_2	Diode	JAN1N4148	MIL-S-19500/385	QPL	
CR_3	Diode	JAN1N4148	MIL-S-19500/385	QPL	

ALARM/OSCILLATOR BOARD

SCHEMATIC DESIGNATION	DESCRIPTION	MILITARY PART NO.	MILITARY SPECIFICATION	VENDOR	VENDOR PART #
Q_1	F.E.T.	JAN2N4857	MIL-S-19500/385	QPL	
A_1	I.C. Op-Amp			Motorola	MC1558G
A_2	I.C. Op-Amp			Motorola	MC1558G
A_3	I.C. Current Amp			Nat.Semicon	LH0002
K_1	Relay			Teledyne	412T-26
K_2	Relay			Teledyne	412D-26
T_1	Transformer		MIL-T27C, TF4RX13YY	U.T.C.	DO-T34

REFERENCES

1. NA-72-638; Computer Circuit Analysis of the TREE Response of IC Operational Amplifiers; October 2, 1972; B-1 Division, North American Rockwell Corporation, Los Angeles, California.

2. TFD-72-1257; Summary of Component Radiation Tests Performed During Fiscal Year 1972; November 2, 1972; B-1 Division, North American Rockwell Corporation, Los Angeles, California.

3. NA-71-755; Preliminary Report Gamma Radiation Test and Evaluation of Integrated Circuit Type High Performance Operational Amplifiers; August 13, 1971; B-1 Division, North American Rockwell Corporation, Los Angeles, California.

4. CREG 70-2; Semiconductor Evaluation, Screening, and Nuclear Hardness Assurance; March 1970; Orlando Division, Martin Marietta Corporation, Orlando, Florida.

5. DASA 2616, NCL 70-77R; Radiation Effects on MSI/LSI Electronic Devices and Circuits; July 1971; Northrop Corporate Laboratories, Hawthorne, California.

6. NA-71-289; B-1 Nuclear Radiation Hardening Design Guidelines and Analysis Requirements; Revised March 24, 1972; B-1 Division, North American Rockwell Corporation, Los Angeles, California.

7. DASA 1420; TREE Handbook; September 1969; Battelle Memorial Institute, Columbus, Ohio.

8. B. Buchanan, etal, "Comparison of the Neutron Radiation Tolerance of Bipolar and Junction Field Effect Transistors," IEEE Proceedings, Vol. 55, No. 12, December 1967.

9. W. Shedd, etal, "Radiation Effects on Junction Field Effect Transistors", IEEE Transactions NS-16, No. 6, December 1969.

10. Pub. No. D0001359012; SYSCAP Series DICAP (Preliminary); September 1970; Control Data Corporation, Minneapolis, Minnesota.

11. Pub. No. 86615900; TESS User Information Manual; November 1972; Control Data Corporation, Minneapolis, Minnesota.

12. EL-CP5073-0002A, Nuclear Requirements For Aerial Radiac Set AN/ADR-6 (   ) (V), 1 March 1971 (Confidential).

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