SUMMARY REPORT

THE NEUTRON MONITORING SYSTEM (NMS)

ELECTRICAL CIRCUIT ISOLATION TEST

T.C. McClellan — DATE 3-7-88
T.C. MCCLELLAN, RESPONSIBLE ENGINEER

W.C. Boehm — DATE 3-7-88
W.C. BOEHM, PRINCIPAL ENGINEER
VERIFIER

Clark F. Canham — DATE 3-7-88
C.F. CANHAM, MANAGER
PLANT ELECTRONIC SERVICES

DRF A00-03209

ABSTRACT

Tests were performed to demonstrate the ability of a fuse, resistor - divider network and zener diode to provide electrical isolation between safety function trip signals and non-safety computer and recorder signals. The resistor - divider, fuse and zener diode (on the output of an operational amplifier) met the requirement of providing isolation of the trip signal from faults at the computer and recorder connections. The tests performed demonstrate that under all credible faults at the connections to the computer or the recorder, there is no adverse affect on the trip signal.

1.0 INTRODUCTION

This report is an evaluation and discussion of the tests performed on an interface isolation circuit configuration used in the Average Power Range Monitoring subsystem of the Neutron Monitoring System.

This high resistance - fuse network isolates Average Power Range Monitor signal voltages to the trip circuits from the voltages sent to computer and recorder interfaces. The voltage source is an averaging operational amplifier that averages the inputs from the Local Power Range Monitors and produces a voltage proportional to reactor power.

These interface circuits are resistive voltage divider configurations. One circuit provides a 0 - 160 millivolt signal to the computer; a second circuit provides a 0 - 1 volt signal to the recorder.

2.0 BACKGROUND

The Neutron Monitoring System and the Average Power Range Monitoring System circuits used to isolate the non-safety functions from the safety trip function has come under question by the NRC. The NRC questioned the adequacy of resistors and fuses as isolation devices, and requested that their performance be demonstrated by test.

This circuit design dates from the Neutron Monitoring System design for the BWR/3s in the 1970s. As such there are more than 250 reactor-years of operating experience in the USA with these circuits without reports or evidence of generic faults.

The design of these circuits is rational and practical, rather than required by some standard or regulation. The initial design preceded the guidelines and standards now applied. However the design recognized the need for isolation between the output signals from the operational amplifier. This design achieved the isolation with an established circuit, ie, the voltage divider of resistors, the use of a fuse and where practical, the use of a zener diode. This design is a simple circuit that was readily analyzed to show it to be effective in all reasonable failure modes. This effectiveness has been demonstrated under the tests performed for this report.

3.0 RESULTS

The Neutron Monitoring System isolation circuits have been tested under a variety of faults to demonstrate that the trip signal is protected per the requirements of IEEE 384-1977, Criteria for Independence of Class IE Equipment and Circuits.

The fuses in the isolation circuits opened promptly (less than 2 milliseconds) under the application of fault voltages at the output terminals to the computer or the recorder interfaces.

During fuse opening time and for short circuit and low level fault conditions which may not cause the fuses to open, the high resistance in the voltage divider protects the trip signal and the operational amplifier. These resistors are the 10.7K (R7) or the 9K (R9 + R10), as shown in Figure 4.1. This protection is demonstrated by the small changes in the output of the operational amplifier (to the trip circuits) when fault simulations were applied at the output connections to the computer or the recorder.

4.0 THE CIRCUIT

4.1 Neutron Monitoring System Elementary

The circuit tested is outlined on a typical elementary diagram, Power Range Neutron Monitoring System, 807E163TY, sheet 12, attached. The dc amplifier, Z32, drawing 225A6679BB, is a prepackaged, encapsulated operational amplifier, input supply voltage filter capacitors, and an adjustment resistor. The amplifier specifications are shown on drawing 174B9091. Its specifications include a high gain, high input impedance and a low output impedance. The remaining components - input resistor, feedback resistor, voltage divider resistors, zener diode and fuses - are defined by auxiliary unit, Z31, drawing 112D1907, and the averaging card, Z30, 136B2158.

The circuit function is to average the input voltages from 22 (typically) local power range monitors, and provide an average power range monitor signal to the trip circuits, computer and recorder. In addition, the computer and recorder signals are isolated from the trip signal by a resistive voltage divider and fuse circuits.

4.2 Test Circuit

The equivalent circuit tested is shown on Figure 4.1, Test Specimen Schematic Diagram. This circuit is the functional equivalent of the partial circuit high-lighted on the elementary diagram, 807E163TY, Sheet 12. The key portions of the circuits performing the isolation function are shown in Figure 4.2 and Figure 4.3.

4.3 Circuit Operation

Figure 4.2 is a voltage divider of resistors and a 1/32 ampere fuse providing a 0 to -160 mvolt signal to the computer. The fuse is designed to open in 5 seconds at 200% of its rated current (drawing 209A5156P005). The 174 ohm resistor to common requires 10.875 Vdc to conduct this 200% current. This electrical path to common, having the lowest resistance will be the route of any overcurrent faulted condition. The fuse opening time decreases with increased overcurrent.

Figure 4.3 is a voltage divider of resistors, a zener diode across the low resistor (1K) and a 1/32 ampere fuse providing a 0 to -1 volt signal to the recorder. The fuse characteristic is the same as for the fuse used in Figure 4.2. The zener diode conducts most of the current in order to allow the fuse to open when required. In Figure 4.2, the 174 ohm resistor allows sufficient current to flow to open the fuse when required. In the circuit represented on Figure 4.3, the resistors are higher values, so a zener was used in the design to allow the fuse clearing current to flow when external voltage faults occur. A small positive voltage across the zener diode will cause forward conduction current to flow until the fuse blows. Approximately -11 volts across the zener diode will cause maximum rated current to flow through the zener (approximately 90 mA) which will be sufficient to blow the fuse.

4.4 Circuit Faults

An open circuit in the high resistor (10.7K or 9K) has no effect on the output of the operational amplifier trip signal.

A short circuit to common in the output of the operational amplifier will cause a downscale trip. This short circuit would have no effect on the input signals because of the high resistance path through the feedback resistor (1 megohm) and the high input resistance (499K + 499K). This is demonstrated by the tests in Section 5.0 on the 10 Kohm voltage divider which provided isolation. Two megohms (1M + 0.499M + 0.499M) provides even greater isolation.
The operational amplifier design includes internal short circuit protection. The output merely clamps to zero and returns to normal when the fault is removed.

An open circuit between the voltage divider of resistors has no effect on the trip signal, although the signal to the computer or recorder would be lost.

A short circuit to common between the voltage divider of resistors also has no effect on the trip signal because of the high resistance path provided by the 10.7K or 9K resistors. The signal to the computer or recorder would be lost.

Protection against the misapplication of voltages to the computer or the recorder connections is provided by the voltage divider and fuse circuits as discussed in 5.0, THE TESTS. The maximum credible voltage that could be applied is 120 Vac, RMS, which has peak values of +170 V, -170 V.

5.0 THE TESTS

5.1 Baseline Functional Test

An initial functional test on the NMS isolation circuit was performed to adjust and measure the amplifier offset (balance), to adjust and measure the amplifier gain, and to measure the outputs to the trip circuits, the computer and the recorder. The zero offset and the gain were slightly out-of-tolerance, but these were judged to be acceptable for this test of the isolation function.

5.2 Acceptance Criteria

For all simulated faults the acceptance criteria are:

The fuse opens prior to damage or failure of the operational amplifier. The trip output signal is not affected or returns to normal after the fuse opens.

The output signal is degraded sufficiently to cause the safety action (a trip or alarm).

Failure or permanent damage to the operational amplifier without causing the fuses to open is unacceptable.

5.3 170 Volt Transient Tests

Refer to Figure 4.1.

An 8 microfarad capacitor charged to +170 Vdc and to -170Vdc was used to provide the transient signal into test point 1 (signal output to the computer) and into test point 2 (signal output to the recorder). This 170 Vdc simulates the peak value of 120 Vac inadvertently and transiently applied at the non-safety related interfaces to the computer and recorder. A transient recorder was used to record the plus/minus 15 Vdc supply voltage, the 2.5 Vdc input voltage and the three output voltages (trip, computer, recorder).

The 1/32 ampere fuse protected the operational amplifier. It opened without damaging or failing the the operational amplifier. The change at the trip output was an approximate -0.05 volt spike. The effect of this spike on the trip output depends on the trip setpoints and signal level at the time of the transient. It could cause a trip if the input signal was already sufficiently close to the trip point.

The input signal and plus/minus 15 Vdc supply voltage were unaffected.

Thus the fuses, resistors and zener diode isolated the computer and the recorder, and protected the safety-related trip signal.

5.4 120 Vac Tests

Refer to Figure 4.1.

These tests simulate the inadvertent application of 120 Vac to the computer output or the recorder output. The 120 Vac was supplied from a variac through a mercury switch to the test point.

When the voltage was connected to the computer output, the fuse opened immediately. The input signal, output signal and 15 Vdc supply voltage were unaffected.

When the voltage was connected to the recorder output, the fuse opened promptly, and the zener diode (VR1) short circuited. All of the monitored test points, except the computer output, varied during the fuse clearing period and then returned to normal. The input signal changed about +0.2 volts, and the output signal changed about -1 volt. These changes would cause a trip if the signal was already sufficiently close to the trip point. The shorted zener diode did not affect the output signal because the remaining resistance of 9K (R9 + R10) does not load the operational amplifier sufficiently to cause signal degradation.

Thus the fuses, resistors and zener diode isolated the computer and the recorder, and protected the output trip signal.

5.5 Special Tests

These tests were performed to show the effects on the operational amplifier output signal as follows:

a) during the fuse clearing period,

b) the degree of isolation provided by the resistor R7, 10.7K, when the fuse does not clear,

c) when the low resistance path to common (R8 or VR1 & R11) fails to an open condition.

Testing was performed with the test circuit conditioned the same as for the previous tests. The tests (on Figure 4.1) consisted of the following:

- o 5 Vac applied at test point E (computer output),
- o -20 volt step at test point 1 (computer output),
- o +20 volt step at test point 1,
- o -15 volt step at test point 2 (recorder output),
- o -20 volt step at test point 2,
- o +300 Vdc at test point E with R8 open to common,
- o -300 Vdc at test point E with R8 open to common.

The low resistance path of VR1 and R11 at test point F is demonstrated by similarity to the circuit with test point E.

The lower voltages (5 Vac, +20, -20, -15) were selected to monitor circuit performance without stressing the components, to demonstrate fuse clearing time at these voltage levels, and to demonstrate the low output impedance of the operational amplifier. The 300 Vdc was selected to demonstrate isolation and protection of the operational amplifier output by the 9K or 10.7K resistors alone.

The 5 Vac signal at test point E (computer output) yielded a very small change (0.2 mVac) in the output trip signal. Similarly the step voltages yielded no changes at the output trip signal. This indicates that the effective output impedance of the operational amplifier is very low, as expected.

For the -20 volt step at the computer output the fuse opened in 1.8 milliseconds; for the +20 volt step the fuse opened in 1.6 milliseconds. The fuse overload current was approximately 370% for both cases. For the -15 volt step and -20 volt step at the recorder output, the fuse opened in 1.5 milliseconds. This indicates, at a reduced voltage, the ability of the 1/32 ampere fuse, resistor divider and zener diode to provide isolation and protection for the trip output.

For the +300 Vdc and -300 Vdc applied at test point E (computer output) with R8 open to common, the input signal and the 15 Vdc supply voltage were unaffected.

The trip output changed by less than ±5 mvolts for +300 Vdc and -300 Vdc. The relatively small changes demonstrate the capability of the circuit to withstand a fuse fault and open circuit in the low resistance path to common in the voltage divider. These small changes also demonstrate the very low dynamic output impedance of the operational amplifier and the associated feedback circuit.

5.6 Final Baseline Functional Test

The results of the final functional test were the same as the initial functional test. This indicates that the test circuit was not adversely affected by the fault signal simulations.

6.0 REFERENCES

Letter R. Artigas to Ashok C. Thadani, Subject: "Meeting Results - NRC and GE Review of the Neutron Monitoring System Interface Isolation", September 21, 1987.

NEDO-10139, Compliance of Protection Systems to Industry Criteria, June 1970.

General Electric drawings:

209A5156
209A6112
225A6679BB
136B2158
112D1907
807E163TY
174B9091

Design Record File A00-03209, NMS Isolation Circuits

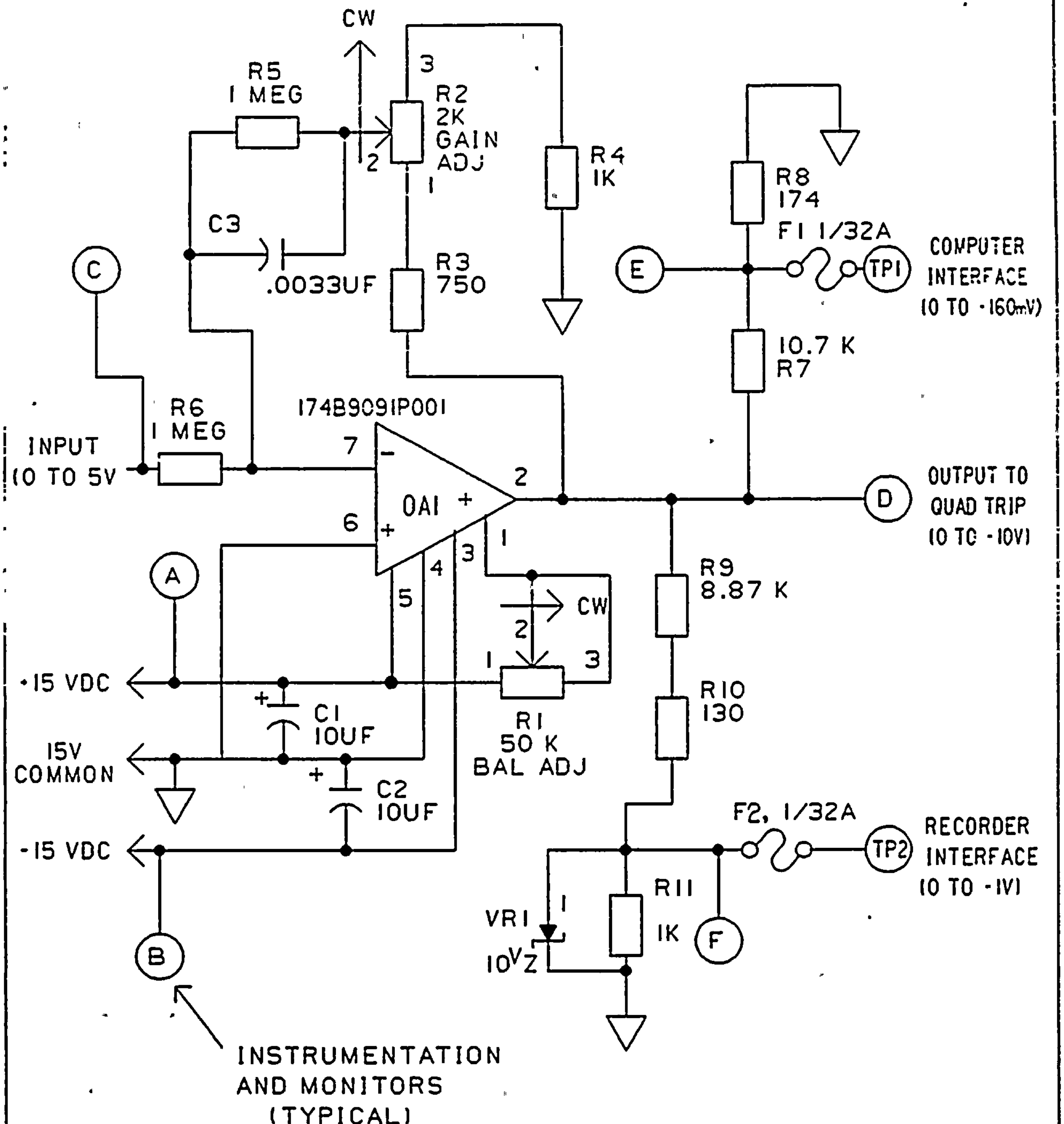


FIGURE 4.1

TEST SPECIMEN SCHEMATIC DIAGRAM

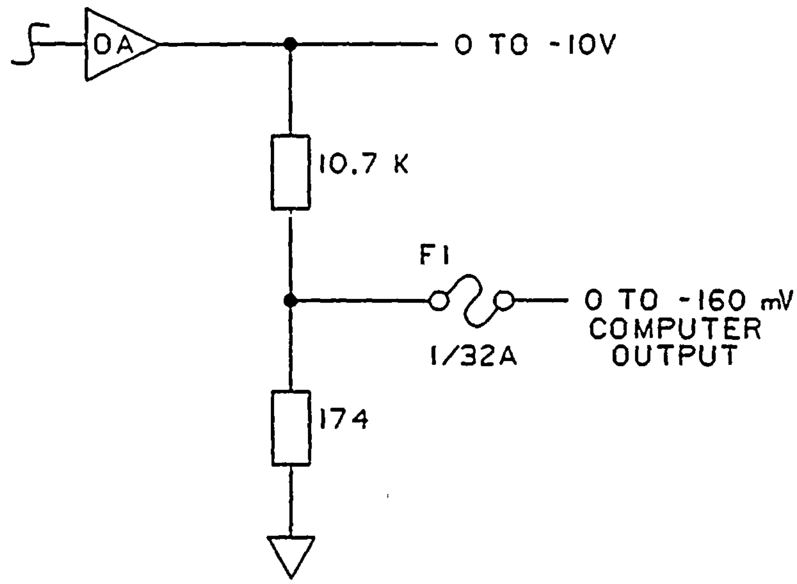


FIGURE 4.2

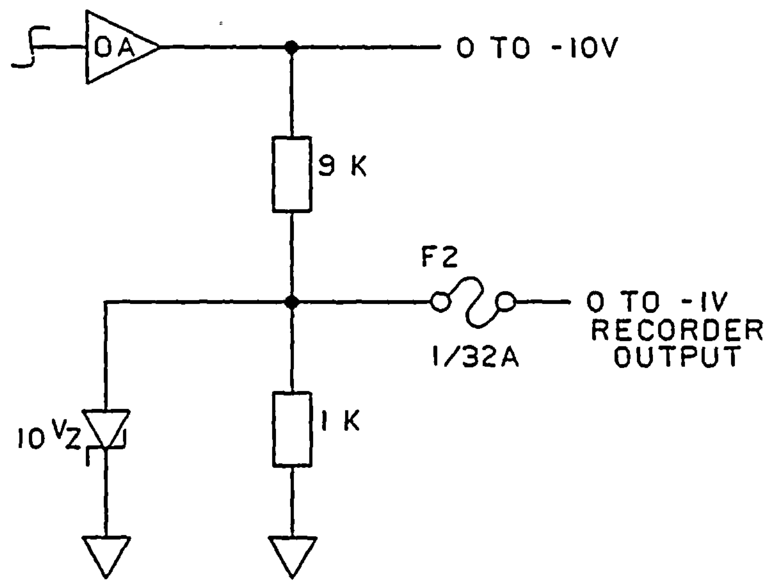


FIGURE 4.3

GENERAL ELECTRIC

209A5156

CONT ON SHEET F SH NO. 2

REV NO. 81234

209A5156

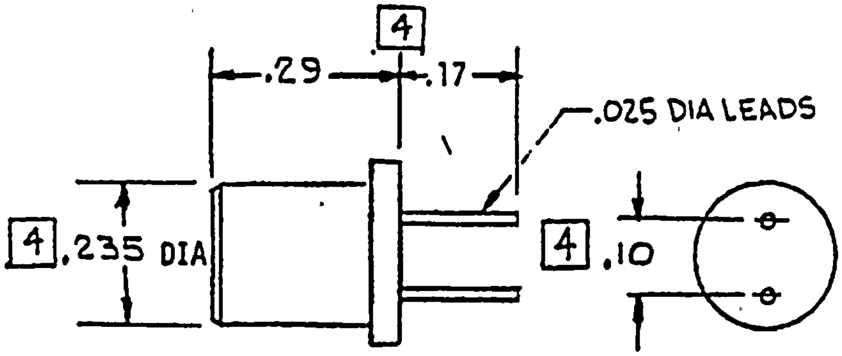
CONT ON SHEET F SH NO. 2

TITLE

FUSE, SUBMINIATURE (PLUG IN FOR PCB)

FIRST MADE FOR

REVISIC



SPECIFICATIONS:

TIME/CURRENT CHARACTERISTICS: WITHIN 1% AQL PER MIL-STD-105, INSPEC.LEVEL II

BLOWING CHARACTERISTICS:

PERCENT OF RATING	BLOW TIME
100%	4 HR. MIN.
200%	5 SEC. MAX.

VOLTAGE RATING: 125V

FUSE HOLDERS (IF REQUIRED):

FRONT PANEL: CAT NO. 282001 (LITTELFUSE)
REAR PANEL: CAT NO. 282002 (LITTELFUSE)

PART NO	AMP RATING	VENDOR CAT NO
5	1/32	272.031
7	1/16	272.062

>00107904

4 NJ72802

AS MANUFACTURED BY: LITTELFUSE INC.
OR ENGINEERING APPROVED EQUIV.

PRINTS T-

MADE BY W Cauley AUG 7 '68

ISSUED Ted [illegible] AUG 14-68

APPROVALS C A von Damm 8-7-68

NEBO DIV OR DEPT.

SAN JOSE, CALIF. LOCATION

209A5156

CONT ON SHEET F SH NO. 2

FF-803-WF (2-68)

CODE IDENT N

K-190-MM

EIS IDENT: DIODE

GENERAL ELECTRIC

209A6112

CONT ON SHEET SH NO.

C | REV NO. 11

209A6112

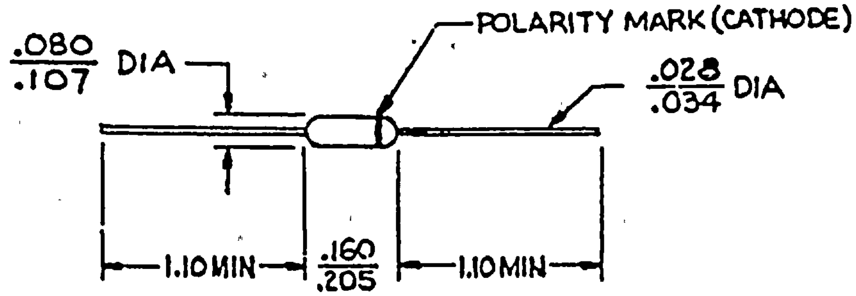
CONT ON SHEET SH NO.

TITLE PURCHASED PART

DIODE, ZENER, 1 WATT, 5%

FIRST MADE FOR STANDARDS

CLASS 2 FSC 5961-63/8



SPECIFICATIONS

POWER RATE: 1 WATT (DERATE 6.67M W/°C ABOVE 50°C)
JUNCTION AND STORAGE TEMP: −65°C TO +200°C
TEMP COEFFICIENT: .09%/°C MAX
PACKAGE: "SURMETIC" STYLE SILICONE POLYMER THERMOSETTING PLASTIC OR GLASS.
TOLERANCE: ±5%

11 MARKINGS: MEET MIL-STD-202C METHOD 215 RESISTANCE TO SOLVENTS
NOTE: FABRICATE AND TEST TO MIL-STD-750B, METHOD 1038.

PT NO	JEDEC NO	V_{ZT}	I_{ZT}	Z_{ZT}
14	1N4729A	3.6 V	69 MA	10 Ω
15	1N4730A	3.9	64	9
		4.3		
		4.7		
18	1N4733A	5.1	49	7
19	1N4734A	5.6	45	5
20	1N4735A	6.2	41	2
21	1N4736A	6.8	37	3.5
		7.5		
23	1N4738A	8.2	31	4.5
24	1N4739A	9.1	28	5.0
25	1N4740A	10	25	7.0
		11		
27	1N4742A	12	21	9
		13		
29	1N4744A	15 V	17 MA	14 Ω

PT NO	JEDEC NO	V_{ZT}	I_{ZT}	Z_{ZT}
30	1N4745A	16 V	16 MA	16 Ω
31	1N4746A	18	14 MA	20
32	1N4747A	20	12.5	22
33	1N4748A	22	11.5	23
34	1N4749A	24	10.5	25
35	1N4750A	27	9.5	35
36	1N4751A	30	8.5	40
37	1N4752A	33	7.5	45
		36		
		39		
40	1N4755A	43	6.0	70
		47		
42	1N4757A	51	5.0MA	95 Ω
		56		
		62		
48	1N4763A	91 V	2.8MA	250 Ω

AS MFG BY: SARKS-TARZIAN, FAIRCHILD, MOTOROLA, SIEMENS, INTERNATIONAL RECT CORP, UNITRODE, GEN SEMICOND IND, OR ENGINEERING APPROVED EQUIV.

REVISIONS

11 | R. WILKINS 12-9-?? | NE 97257 | CHK'D BY: V. BURT

10 | W.B. WALDROP 7/?/77 | NE 84358

040E

212B

016A

041G

PRINTS TO

MADE BY RP Kidwell 31 OCT 68 | APPROVALS C. A. von Damm 10-31-68 | NPD SAN JOSE | 209A6112

ISSUED Ted Burke NOV 6 68

CONT ON SHEET SH NO. CODE IDENT NO.

CHKD BY: C. HUDSON MAR 31 CI 15

EIS 18

GENERAL ELECTRIC

225A6679BB

CONT ON SHEET SH NO

C | ØI

225A6679BB

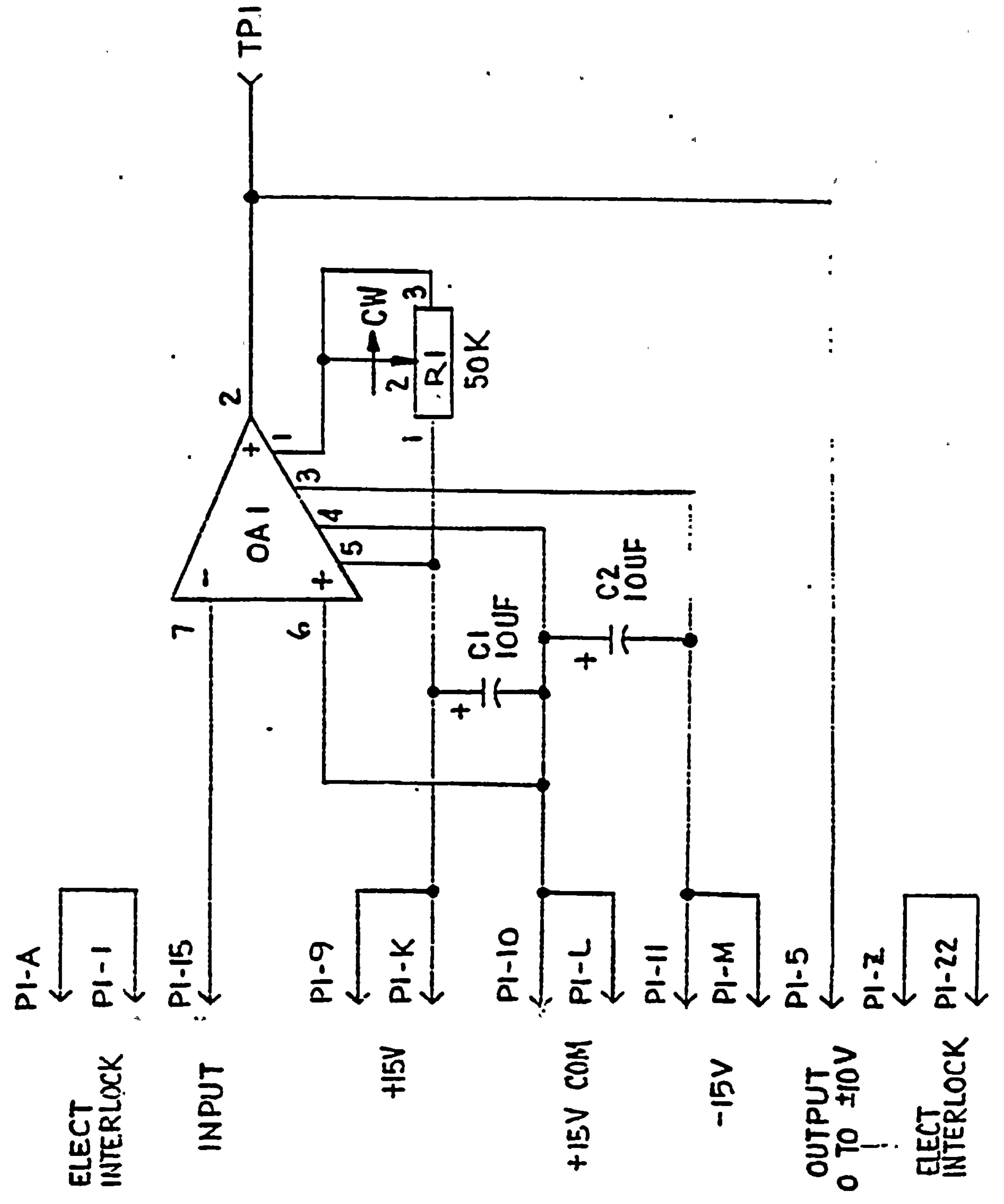
CONT ON SHEET SH NO.

TITLE SCHEM DIAG

D.C. AMPLIFIER

FIRST MADE FOR GEN USE

FCF 136B3107BB



REVISIONS
1 J. VASQUEZ 9-8-79 CATEGORY III CHG ADDED ICEF COPY CHK D.D. HOWLEY D.H.
236K
212A
212B
PRINTS TO

MADE BY F.P. KIDWELL 4MAR74

ISSUED K.SUMMERS 7-74

APPROVALS MAR 2 '74 J. KWIGN

NED

SAN JOSE

DIV OR DEPT.

LOCATION

225A6679BB

CONT ON SHEET SH NO.

PRINTED IN U.S.A.

CODE IDENT N.

EIS IDENT: AMPLIFIER

GENERAL ELECTRIC

174B9091

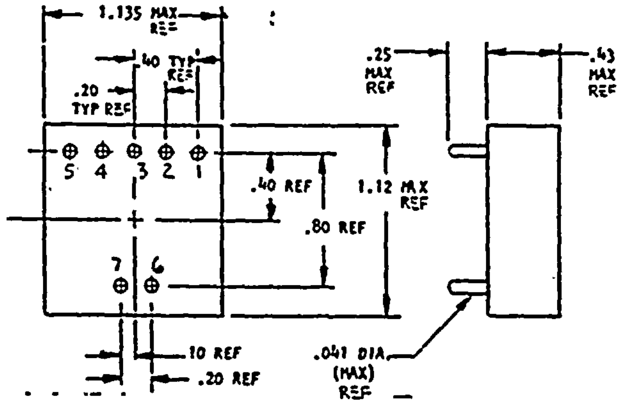
AMPLIFIER

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES | SURFACES ✓

FIRST MADE FOR STANDARDS

PURCHASED PART — CLASS 2

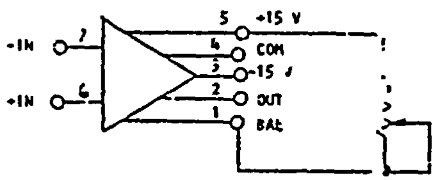
FSC 5820-CO/8



BOTTOM VIEW

ELECTRICAL SPECIFICATIONS:

OUTPUT VOLTAGE AND CURRENT:	±10V & 20 MA ±12V & 6 MA (MIN)
SUPPLY VOLTAGE AND FULL LOAD CURRENT:	±15V & 30 MA (MAX)
INPUT BIAS CURRENT (EITHER TERMINAL:	50 nA (MAX) @ 25°C
INPUT VOLTAGE OFFSET AND BALANCE:	±5 mV (MAX) USING A 50K BALANCE POT
OVERLOAD RESPONSE:	AMPLIFIER OUTPUT SHALL NOT EXHIBIT HOOKING CHARACTERISTICS (180° REVERSAL IN PHASE) WHEN SUBJECTED TO AN INPUT TRANSIENT +15 V MAX AND 1 MS TIME CONSTANT SUPERIMPOSED UPON ±10 VDC DIFFERENTIAL INPUTS.
VOLTAGE GAIN (OPEN LOOP):	85 dB
FREQUENCY RESPONSE (UNITY GAIN):	1 MHz (TYP)
STABILITY:	5 20 dB/DECADE MAX ROLL-OFF SLOPE TO AT LEAST UNITY GAIN FREQUENCY.
COMMON MODE VOLTAGE:	±10V
ENVIRONMENT:	OPERATING: 0-60°C TEMP AND 0-90% REL HUMIDITY STORAGE: -55°C TO +100°C TEMP INPUT BIAS CURRENT VS. TEMP: 1nA/°C INPUT BIAS CURRENT VS. TIME: 20nA/30 DAYS OFFSET VOLTAGE VS. TEMP: 50 uV/°C OFFSET VOLTAGE VS. TIME: 100uV/30 DAYS
SLEW RATE:	1V/u SEC (MIN)



WIRING DIAGRAM

(EXTERNAL BIAS POTENTIOMETER SUPPLIED BY USER)

NOTES:

5
1. DELETED
2. DELETED
3. DELETED

PART NO	CAT. NO	VENDOR
1	A2635	INTECH INC
	ZEL1ACM467	ZELTEX

REVISIONS

5	F. GARCIA	EK	3 — PT. NO. 2 ADDED W&L 7/1/74
ADDED SH.2 NJ29558			4 — DELETE ... ADD ZELTEX CAT NO. ...
CHK.BY: K.REDDICK			1 — ADD WIRING DIAG. 9-1-72
			2 — D. WOOLLEY
			NE48312

PRINTS TO: 040E | 243A | 212B | 015A | 429F | 429G | 041G | 038A | 427A | 430A

MAY 7, 1971 — May 20-71 — 5/10/71 — NC & I — SAN JOSE — 174B9091 — CONT ON SHEET 2 — SH NO 1

>DD437285 — CI

January 28, 1988

DOCKET NO(S). 50-410

DISTRIBUTION w/o encl
Docket File w/encl
PDI-1 Rdg.
CVogan
MHaughey

SUBJECT: NIAGARA MOHAWK POWER CORPORATION
Nine Mile Point Nuclear Station, Unit 2

The following documents concerning our review of the subject facility are transmitted for your information.

- ☐ Notice of Receipt of Application, dated ________.
- ☐ Draft/Final Environmental Statement, dated ________.
- ☐ Notice of Availability of Draft/Final Environmental Statement, dated ________.
- ☐ Safety Evaluation Report, or Supplement No.________ dated ________.
- ☐ Environmental Assessment and Finding of No Significant Impact, dated ________.
- ☐ Notice of Consideration of Issuance of Facility Operating License or Amendment to Facility Operating License, dated ________.
- ☐ Bi-Weekly Notice; Applications and Amendments to Operating Licenses Involving No Significant Hazards Considerations, dated ________ *[see page(s)]* ________.
- ☐ Exemption, dated ________.
- ☐ Construction Permit No. CPPR-________, Amendment No. ________ dated ________.
- ☐ Facility Operating License No. ________, Amendment No. ________ dated ________.
- ☐ Order Extending Construction Completion Date, dated ________.
- ☐ Monthly Operating Report for ________ transmitted by letter dated ________.
- ☐ Annual/Semi-Annual Report- ________ ________ transmitted by letter dated ________.

XOTHER: Bi-weekly Notice covering period through January 13, 1988. Expiration date for hearing requests and comments; February 12, 1988.

Office of Nuclear Reactor Regulation

Enclosures:
As stated

cc:

OFFICE	PDI-1						
SURNAME	CVogan						
DATE	1/28/88						

NRC FORM 318 (10/80) NRCM 0240

OFFICIAL RECORD COPY

[illegible]

[illegible]

[illegible]

[illegible]

September 2, 1987

DOCKET NO(S). 50-410

DISTRIBUTION w/o encl
√Docket File w/encl
PDI-1 Rdg.
CVogan
MHaughey

See Attached List of Addressees

SUBJECT: NIAGARA MOHAWK POWER CORPORATION
Nine Mile Point Nuclear Station, Unit No. 2

The following documents concerning our review of the subject facility are transmitted for your information.

- [ ] Notice of Receipt of Application, dated ____________.
- [ ] Draft/Final Environmental Statement, dated __________.
- [ ] Notice of Availability of Draft/Final Environmental Statement, dated ___________.
- [ ] Safety Evaluation Report, or Supplement No.__________________ dated __________.
- [ ] Environmental Assessment and Finding of No Significant Impact, dated ___________.
- [ ] Notice of Consideration of Issuance of Facility Operating License or Amendment to Facility Operating License, dated __________.
- [ ] Bi-Weekly Notice; Applications and Amendments to Operating Licenses Involving No Significant Hazards Considerations, dated __________ *[see page(s)]* ________________.
- [ ] Exemption, dated __________.
- [ ] Construction Permit No. CPPR-___________, Amendment No. ____________ dated __________.
- [ ] Facility Operating License No. ___________, Amendment No. ___________ dated _________.
- [ ] Order Extending Construction Completion Date, dated __________.
- [ ] Monthly Operating Report for ________________ transmitted by letter dated _________.
- [ ] Annual/Semi-Annual Report- ____ ________________________ transmitted by letter dated _________.

X OTHER: Bi-Weekly notice covering period through August 26, 1987. Expiration date for hearing requests and comments; September 25, 1987.

Office of Nuclear Reactor Regulation

Enclosures:
As stated

cc: See next page

OFFICE	PDI-1 Rdg						
SURNAME	CVogan						
DATE	9/3/87						