Frederick Boden, 716

VOLUME I

FINAL REPORT

of

PHASE III

# A STUDY OF THE EFFECT OF SPACE RADIATION ON SILICON INTEGRATED MICROCIRCUITS

(10 April, 1967 to 9 April, 1968)

Contract No. NAS5-10308

Prepared by


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Columbus, Ohio 43201


for

National Aeronautics and Space Administration
Goddard Space Flight Center
Glenn Dale Road
Greenbelt, Maryland 20771

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Goddard Space Flight Center
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## SUMMARY

Ten types (approximately 500 individual units) of both analog and digital integrated circuits were exposed to 0.5, 1.0, and 1.5 MeV electrons. In addition, seven different "equivalent 962 circuits" were exposed to 1.5 MeV electrons. The effects of radiation were determined in terms of the device behavior from both in situ measurements and more comprehensive pre/post characterization measurements. The circuits were mounted on circuit boards and were swept with an electron beam from a Van de Graaff generator. The irradiation was continued until either 50 percent failures were observed or a fluence of $1 \times 10^{16}$ e/cm$^2$ was reached. The failure criterion for this program was any parameter exceeding the limit specified by the manufacturer. Each microcircuit type was represented by seven test groups. One test group was maintained as a control. The other six groups represented two different electrical conditions (biased and unbiased), irradiated at the three different energy levels. The biased groups contained ten samples and were powered continuously under irradiation. The unbiased groups contained five samples and were not powered under irradiation except for periodic pulsed measurements.

Generally, the purposes of this program were to obtain information that would give a better understanding of the effects of electron irradiation on semiconductor integrated circuits and to provide the necessary facts on which design decisions could be based. Specifically, the purposes of this program are:

(1) To display a significant amount of performance information, under electron irradiation, for the more common types of analog and digital microcircuits which will be usable for selection and design decisions for systems programmed for space missions

(2) To evaluate the magnitude of the effects resulting from electron irradiation at three different energies (0.5, 1.0, and 1.5 MeV)

(3) To determine which of the three energy levels will be most critical to the operation of the microcircuits

(4) To define the difference between the radiation response of electrically equivalent circuits which differ in method of isolation, topology, and/or processing techniques.

The results obtained during the program are completely applicable only to the specific circuits studied, and, although, generally applicable to the various classes of devices examined, are not necessarily applicable to the behavior of other specific devices from the same manufacturers.

## Effects Versus Microcircuit Class

The mode of failure for the amplifier circuits was attributed to four basic parameter changes: decreased transistor gain, increased input bias current, decrease in the maximum output-voltage swing, and increased offset voltage. These results are consistent with those changes observed in the second phase of this program. The parameter change or combination of changes that caused the first failure depended on the circuit type and the electron irradiation. Both permanent and temporary changes in output parameters were observed as a result of radiation. Permanent changes are defined as those changes in parameter values that were observed during as well as long after (4 weeks) irradiation. In contrast, temporary effects are defined as changes in measured parameters which recovered either during or after (at most 30 minutes) irradiation. The evidence seems to indicate that the temporary effects were, at least, initiated by surface damage. In some cases the changes occurred rapidly and at different exposure rates and, thus, the nature of the monitoring measurements did not preclude the possibility that some of the observed changes were initiated by rate effects.

Significant degradation of the open loop gain can be expected for amplifiers used in the space environment. In addition, the input bias current can be expected to increase resulting in a lower input impedance. The changes in input bias current also can result in large increases in offset voltage, unless the resistance from input to ground is low. For this reason, low balanced-input resistance from inputs to ground is desirable for stable operation under space radiation. Another method to avoid saturation of cascaded amplifier stages, resulting from increased offset voltage, is the use of ac coupling rather than dc coupling. Where large output signals are required, strong feedback is recommended in order to make maximum use of the amplifier output-swing capability while minimizing changes in offset voltage.

The principal mode of failure for the digital circuits is attributed to degradation of the output transistor. Decreases in transistor current gain coupled with increases in transistor saturation resistance resulted in increases in the output low voltage of the gates and flip-flops. These changes were accompanied by decreases in input drive current and increases in the propagation delay. Since the primary failure mode for the digital circuits was the increase in output low voltage, the longevity of these circuits under irradiation can be increased by decreasing the fan-out of the circuits. The radiation response of these circuits is, in general, consistent with, and similar to, the changes observed in Phase I and Phase II of this program.(1)

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(1) "A Study of the Effects of Space Radiation on Silicon Integrated Circuits", Phase I, June 26, 1964, to September 26, 1965, NAS5-3985, (AD 806799L); Phase II, June 29, 1965, to August 31, 1966, NAS5-9630.

## Effect of Electron Energy and Electrical Condition

The relative magnitude of the changes in parameter values that were permanent in nature were found to increase with electron energy. These results are similar to, and consistent with, results obtained for bipolar transistors.(2) Although, in the devices evaluated, the average degradation at the higher electron energies was more severe, temporary changes in parameter values were observed during some of the 0.5 MeV irradiation.

In some circuit types, no statistically significant differences were observed among the biased and unbiased test groups. However, in most cases the degradation among the unabiased circuits was more severe than among the powered circuits. This was especially true for the 1.5 MeV irradiations where significant degradation was observed. These results indicate that the degradation resulting from irradiation can be substantially reduced if power is dissipated in the microcircuit during irradiation.

## Equivalent 962 Circuits

The degradation observed for the "equivalent 962 circuits" was similar to the degradation observed for the other digital circuits tested. That is, the decreases in transistor current gain coupled with increased transistor saturation voltage caused increases in the output low voltage of these gates. The overall responses of the seven circuit types to electron irradiation were similar. However, significant differences in the magnitude of the changes in parameter values were observed. The differences in radiation response were most pronounced

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(2) "Space Radiation Equivalence for Effects on Transistors", by R. R. Brown and W. E. Horne prepared under NASA Contract No. NAS5-9578.

for the output low voltage where changes ranging from 17.4 percent to over 200 percent were observed for the biased samples.

The differences observed in radiation response did not correlate with the circuit topology. Circuits with almost identical topologies had different radiation responses, while circuits with dissimilar topologies tracked well during radiation. No improved radiation response was observed which could be attributed to the method of isolation. The differences observed in the radiation response of the seven "equivalent 962 circuits" are attributed to differences in processing techniques. Unfortunately, processing information is usually not available to the design engineer. Therefore, the design engineer would not be able to select one of several electrically equivalent circuits to best perform his function without some radiation test results.

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# INTRODUCTION

It is imperative that designers of space-flight systems use the most effective and reliable circuitry available. Component selection for space programs, however, must be made with due regard to the behavior of the components under their intended operating environment. Of particular importance is the radiation environment of space.

The use of silicon integrated circuits in electronic design offers many potential advantages. Included among these are high reliability, good performance, small size, low weight and low cost. Under contract with the Goddard Space Flight Center (Phase I - NAS5-9630 and Phase II - NAS5-3985 of this program), Battelle has studied the effects of electron radiation on many digital and analog circuit types representative of the prevalent integrated-circuit technology. As a result of these past studies for NASA, several questions have arisen concerning the radiation vulnerability of integrated circuits. First, it is not clear either from the literature or from Battelle's past studies what magnitude of effects can be expected for surface and bulk damage resulting from irradiation by electrons of various energies. Second, it is not readily apparent based on radiation effects data on transistors, that the radiation response of "electrically equivalent circuits" are necessarily similar.

In order for NASA to accumulate and maintain the required information upon which to base decisions on microcircuit-utilization and/or microcircuit-improvement efforts, it is necessary that simulated space-radiation-effects data be obtained which will resolve these questions. Studies of the space environment indicate that almost 90 percent of the electrons encountered in space have energies less than 3 MeV. The metal enclosure of microcircuit modules are such that electrons of energies less than 0.5 MeV will be effectively shielded from the microcircuits. Since performance data at an electron energy of 3 MeV are already available (NAS5-9630 and NAS5-3985), performance data at electron energies of 0.5, 1.0, and 1.5 MeV will provide necessary information to help establish the energy dependence of radiation degradation in microcircuits.

## Purpose

Very generally, the purposes of this program are to obtain information that will give a better understanding of the effects of electron irradiation on semiconductor integrated circuits and to provide the necessary facts on which design decisions can be based. Specifically the purposes of this program are:

(1) To display a significant amount of performance information, under electron irradiation, for the more common types of analog and digital microcircuits which will be usable for selection and design decisions for systems programmed for space missions

(2) To evaluate the magnitude of the effects resulting from electron irradiation at three different energies (0.5, 1.0, and 1.5 MeV)

(3) To determine which of the three energy levels will be most critical to the operation of the microcircuits

(4) To define the difference between the radiation response of electrically equivalent circuits that differ in method of isolation, topology, and processing techniques.

## Objectives

The available information, concerning integrated circuits previously irradiated, is contained in the reports published as a result of NASA contracts NAS5-3985 and NAS5-9630. These reports indicate that the major problem areas, caused by irradiation, in linear integrated circuits are excessive changes in offset voltage, decreases in gain and increases in input bias current; while problem areas for the digital circuits are decreases in output transistor gain resulting in changes in the output voltages of the one and zero logic states.

In order to evaluate the vulnerability of integrated circuits in the space environment, failure levels must be established. In this study the failure level is taken as that value of degradation in the parameter value which exceeds the manufacturer's specification. Thus the general objectives of this experiment are to establish failure modes and evaluate integrated-circuit performance in an electron-radiation environment as related to the performance requirements outlined by the manufacturers.

Specific experimental objectives are:

(1) Determine the modes and, possibly, the mechanisms of integrated-circuit failures that are observed because of the irradiation

(2) Establish with reasonable confidence the parametric changes due to radiation by characterizing each device before, during, and after the radiation exposure and then determine the following statistical characteristics:

(a) Initial means of the parameters

(b) Average parametric changes

(c) Standard deviations of the parametric mean changes

(d) Average percentage changes

(e) Interval estimates as percentages

(f) Percentage average changes

(g) The F-test

(h) The t-test.

(3) Compare the monitored parameter changes as a function of the three electron energies (0.5, 1.0, 1.5 MeV). Also determine whether one of the three energies will be the most critical to the operation of the selected circuits

(4) Establish whether biased or unbiased microcircuits will best survive the effects of electron radiation.

(5) Compare the responses of the electrically equivalent circuits as a function of method of isolation, topology, and/or processing techniques.

## EXPERIMENTAL PROCEDURE

### General

The overall program plan was divided into two essentially parallel tasks: the Fundamental Study and the Equivalent-Circuit Study. Flow-chart diagrams of both tasks are illustrated in Figures 1 and 2. As the figures indicate the two tasks are similar. Differences include the number of devices that were irradiated, the irradiation procedure, and the method of data analysis.

To determine the radiation sensitivity of the circuits, initial and final characterization were of primary importance. The parameters selected for measurement included those for which specifications were given by the device manufacturers. In addition, parameters were measured that could be related to component response to radiation. The nature and extent of the characterization is discussed in more detail in the section entitled "Characterization".

In addition to pre/post characterization, a selected number of output parameters were monitored during and immediately following radiation exposure. The parameters selected for monitoring were those parameters that would be most indicative of the electrical conditions of the microcircuits. To determine whether biased or unbiased circuits are more sensitive to radiation, the 15 devices selected for irradiation at each energy level were divided in two test groups. The biased test group contained ten devices while the unbiased group contained five. The radiation was periodically interrupted and measurements were made. Power-supply and input voltages were applied to the unbiased test group in the form of 10 to 100 $\mu$-second pulses and the output response of the circuits was photographed. Monitoring was continued for approximately 15 minutes after the final radiation exposure to determine the extent of radiation damage annealing at room temperature. Specific details concerning the monitoring of device parameters during irradiation are presented in the section titled "Monitoring During Irradiation".

As Figure 1 indicates, the circuits selected for the Fundamental Study were irradiated at the three energy levels (0.5, 1.0, and 1.5 MeV). Fifteen parts of each device type were irradiated at each electron energy. The treatment of the DTL962 circuits of the Equivalent-Circuit Study was different. As outlined by Figure 2, two units of each device type were irradiated at the three energy levels. The data, obtained during these irradiations, indicated

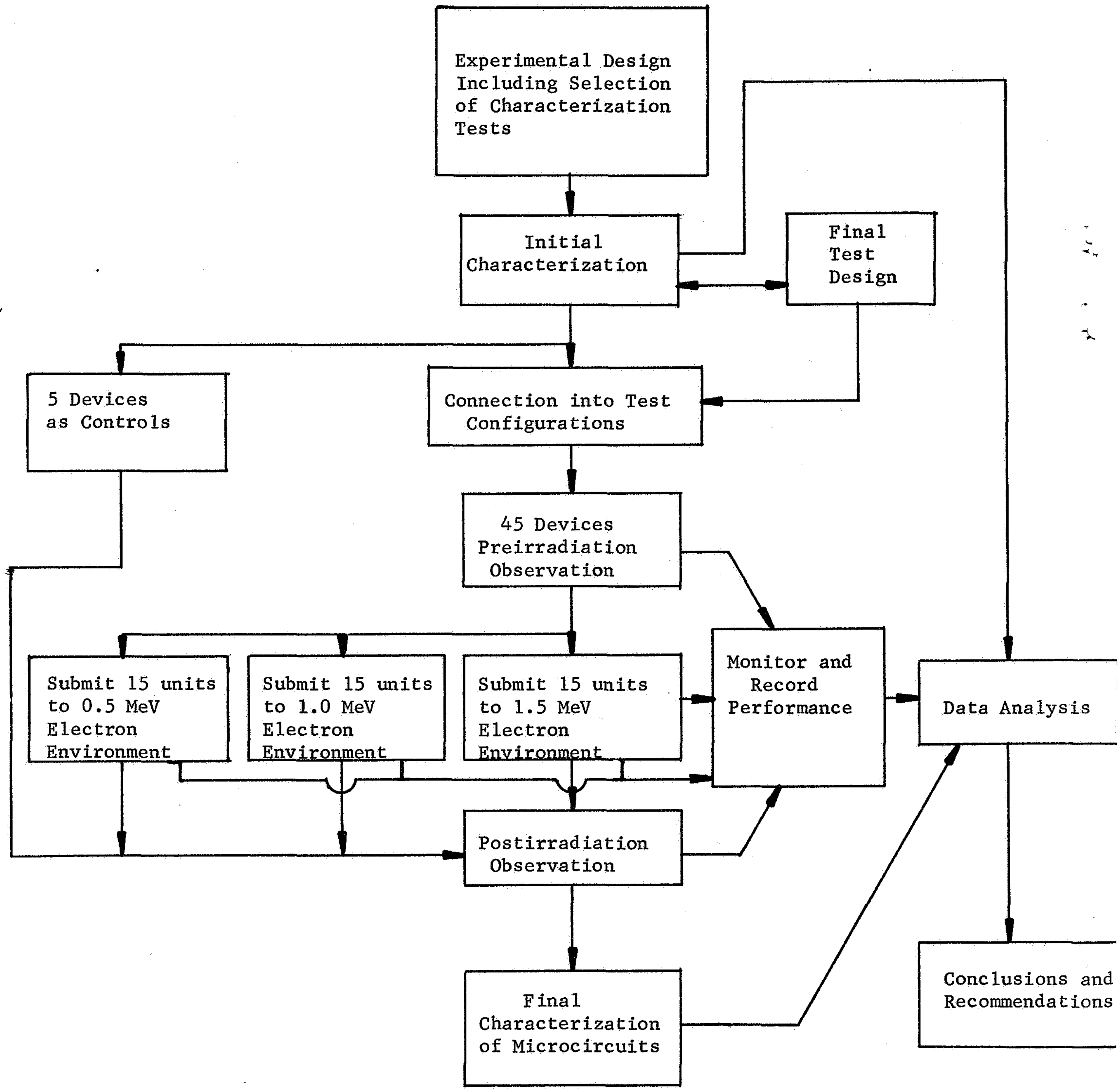



FIGURE 1. EXPERIMENTAL PLAN FOR FUNDAMENTAL STUDY

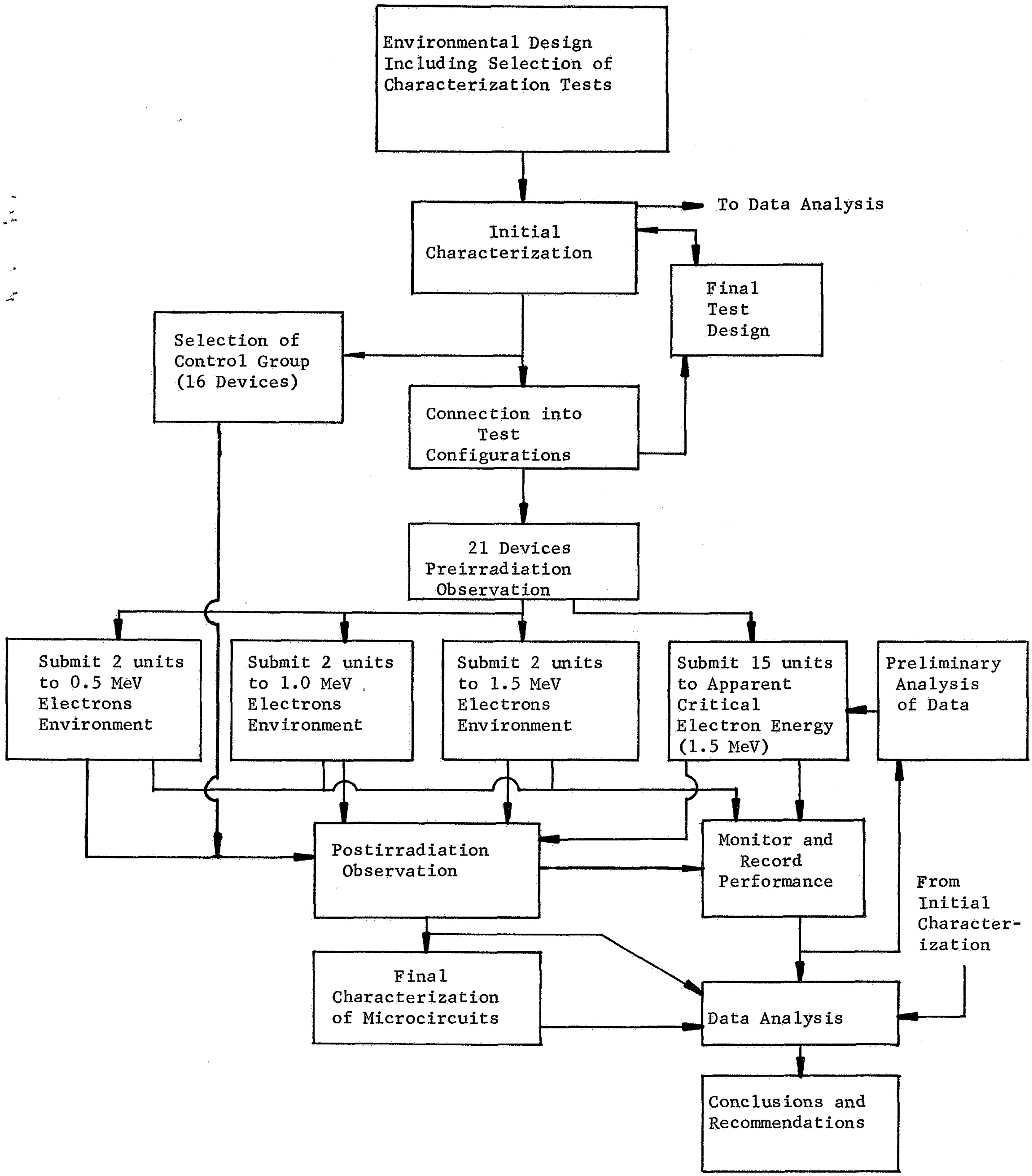



FIGURE 2. EXPERIMENTAL PLAN FOR THE EQUIVALENT-CIRCUIT STUDY

that irradiation damage was most pronounced at the 1.5 MeV electron energy. Therefore, fifteen units of each device type were subsequently irradiated at the 1.5 MeV electron energy.

The data, obtained from characterization measurements and monitoring during irradiation, were reduced with the aid of a digital computer. These data were subsequently analyzed in order to interpret the performance of the microcircuits under irradiation. The final products of these last steps appear in the sections entitled "Analysis of Test Data", "Results", and "Conclusions".

## Selection of Microcircuits

The analog and digital microcircuits that were used in the fundamental-study group are listed in Table 1. Analog and digital circuits of a substantial variety were observed so that a broad knowledge of the effects of space radiation on these types of microcircuits was obtained. The major criteria for selection were the circuit's potential use in future space missions and NASA's needs.

Operational amplifiers were selected as representitive of the analog circuits because of their wide range of applicability in electronic circuits and because a substantial variety of such microcircuits are commercially available. The digital circuits were selected in pairs, i.e., a gate and a flip-flop for each manufacturer and configuration selected. Since a majority of the systems using digital elements contain both gates and flip-flops, sufficient design information would not be provided if only the gates or only the flip-flops were studied. Power consumption was a major criterion for the selection of these microcircuits, since for circuits with reduced power requirements, the designer can increase the number or complexity of the electronic

TABLE 1. DEVICES USED IN THE FUNDAMENTAL STUDY

| Function | Part No. | Manufacturer | Comments |
|---|---|---|---|
| Operational Amplifier | $\mu$A709 | Fairchild | High gain amplifier. (This device type was studied under NAS5-9630). |
| Operational Amplifier | LM101 | National Semiconductor | High gain amplifier similar to $\mu$A709 and 807BE. |
| Operational Amplifier | 807BE | Amelco | High gain amplifier similar to $\mu$A709 and LM101. |
| Video Amplifier | SE501G | Signetics | Variable gain amplifier with adjustable bandwidth. Planned for use in John Hopkins University space probe. |
| Digital Gate | SN54L20 | Texas Instruments | $T^2L$ configuration designed for low power dissipation. |
| Digital Flip-Flop | SN54L71 | | |
| Digital Gate | LPDT$\mu$L9042 | Fairchild | DTL configuration designed for low power dissipation. |
| Digital Flip-Flop | LPDT$\mu$L9040 | | |
| Digital Gate | RD310 | Radiation, Inc. | DTL configuration with dielectric isolation. (Very similar to RD210 and RD221 studied under NAS5-9630) |
| Digital Flip-Flop | RD321 | | |

functions performed on a space mission with the same amount of available power. Both p-n junction isolated and dielectrically isolated microcircuits were selected. In considering the specimen types for this program it was felt that some part types that were evaluated in previous programs should be included in this program.

The circuits listed in Table 2 are the seven part types that constitute the equivalent-circuit group. This group contains both p-n junction isolated and dielectrically isolated circuits as well as circuits similar to those evaluated in previous programs.

## Test Groups

As indicated in Table 3, 50 units of each device type in the fundamental-study group were obtained. These devices were contributed to the program by the circuit manufacturers. After initial characterization, each set of fifty devices was divided into seven test groups. The first test group consisted of 5 units that comprised the control group (not irradiated). The next three groups of 10 units each were statically operated in the electron environment at electron energies of 0.5, 1.0, and 1.5 MeV, respectively. The remaining three groups of 5 units each were unbiased during irradiation. However, the samples were pulsed periodically with power-supply and input voltages and the output response was photographed.

For the equivalent-circuit-study group, 21 units of each device type were irradiated. Each set of 21 units was divided into five test groups. The first three groups consisted of 2 units each which were irradiated at the three energy levels. The remaining 15 units of each part type were irradiated

TABLE 2. DEVICES USED IN THE EQUIVALENT-CIRCUIT STUDY

| Function | Part No. | Manufacturer | Comments |
|---|---|---|---|
| Digital Gate | MC962 | Motorola | Junction isolated (B-3M NAS5-9630) |
| Digital Gate | PL962 | Philco | Junction isolated |
| Digital Gate | DTμL962 | Fairchild | Junction isolated (same family as DTμL930 NAS5-3985). |
| Digital Gate | SN15962 | Texas Instruments | Junction isolated |
| Digital Gate | RD242 | Radiation, Inc. | Dielectrically isolated |
| Digital Gate | SN1253 | Motorola | Dielectrically isolated |
| Digital Gate | (a) | Motorola | Dielectrically isolated (similar to SN1253; different circuit topology). |

(a) No Part Number was assigned to these particular devices. In the text, these devices are referred to as Motorola Dielectrically Isolated Circuits.

TABLE 3. TEST GROUPS

| Study Groups \ Energy Bias Condition | Number of Samples for Each Energy and Bias Condition | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0.5 MeV | | 1.0 MeV | | 1.5 MeV | | Unirradiated |
| | Biased | Unbiased | Biased | Unbiased | Biased | Unbiased | |
| Fundamental Study | 10 | 5 | 10 | 5 | 10 | 5 | 5 |
| Equivalent Circuit Study (Test Irradiations) | 2 | 0 | 2 | 0 | 2 | 0 | 0 |
| Equivalent Circuit Study (critical energy)(a) | 0 | 0 | 0 | 0 | 10 | 5 | 16 |

(a) The 1.5 MeV electron energy was determined to be the critical energy.

at the critical electron energy (1.5 MeV), similar to the irradiations of the fundamental-study group. In addition, four each of the DTμL962, PL962, MC962, and SN15962 circuits were procured. These samples were pooled and used as the control group (not irradiated). Table 3 summarizes the test groups for both the fundamental and equivalent circuit studies.

## Characterization

The characterization was a source of two types of data that serve the following purposes:

(1) To determine, for design and application use, the functional changes in device performance parameters that establish the failure modes due to radiation

(2) To determine the effects of radiation on the individual components within the integrated circuit by means of terminal measurements.

The characterization of microcircuits was intended to be an examination of the microcircuit's characteristics sufficient to describe the changes that are of engineering interest. Two general categories of parameters were measured: functional and nonfunctional. The functional parameters are those indicative of the system performance capability of the microcircuit function. An example of the functional-parameter measurements would be the static logic-voltage levels, logical 0 and 1 currents, transient parameters, dc offset, and cutoff frequency depending on the function of the microcircuit.

Nonfunctional parameters are those helpful to the isolation of specific functional changes. These parameters may consist of diode characteristics, transistor gain, or resistance. Nonfunctional parameters depend on the availability of essential internal elements at external terminals. Digital circuits were measured on Battelle's automatic data-taking system in groups of 50. The bias conditions for each parameter were adjusted for each device type that was processed. A total of 687 devices were characterized.

The plans for the characterization were developed in three sections similar to those used under Contract NAS5-9630 and NAS5-3985. The first section consists of a schematic of the circuit, circuit identification, and the parameters to be measured. The second section consists of a general view of the individual tests, including test conditions and comments of a general nature. Samples of this section are given in Figures 3, 4, and 5 for a gate, a flip-flop, and an amplifier, respectively. The third section consists of a detailed experimental procedure for each parameter measurement. All three parts of the characterization plans are presented in Appendix I, Volume II.

## Monitoring During Irradiation

In situ monitoring of selected parameters was used on all circuits to determine the effects of incident radiation and the degree of permanency of any deleterious effects that occurred. Parameters, of the biased group were monitored by a modified Hewlett Package Dymec Data acquisition system at Goddard Space Flight Center that also controlled the input voltages. Data was read automatically and recorded both on punched- and printed-paper tapes. Monitoring of the passively irradiated group was accomplished by gating on the supply and input voltages for short intervals of time (10 to 100 $\mu$sec) at predetermined fluence points. Data were displayed on a storage oscilloscope and either read directly or photographed.

CHARACTERIZATION PLAN

CIRCUIT TYPE: SN54L20

| BASIC CONDITIONS | NOTES |
|---|---|
| $V_{CC}$ = 5.0 volts on Pin 4<br>Ground Pin 11<br>Temperature 25 C | $V_{MIN\ ONE}$ = 2.40 volts<br>$V_{MAX\ ZERO}$ = 0.30 volts |

| PARAMETER | APP TEST | CONDITIONS |
|---|---|---|
| Output voltage levels<br>$V_{ONE}$, $V_{ZERO}$ | 1 | At fan-out of 10 ($R_L$ = 4 kΩ).<br>For $V_{OH}$, $V_{in}$ = 0.70 volts.<br>For $V_{OL}$, $V_{in}$ = 2.0 volts. |
| Input voltage levels<br>$V_{ONE}$, $V_{ZERO}$ | 2 | At fan-out of 1 ($R_L$ = 40 kΩ).<br>For $V_{IH}$, $V_{out}$ = 0.30 volts.<br>For $V_{IL}$, $V_{out}$ = 2.40 volts. |
| Input leakage current | 3 | Input voltage of 5 volts. |
| Input drive current | 4 | Input current with input connected to ground through 100 Ω. |
| Power supply current | 5 | Current required to supply gate at zero and one level. |
| Propagation delay | 6 | Average delay between input and output of gate while at fan-out of 10. |
| | | Engineer: LJP Date: July 15, 1967 |

FIGURE 3. SAMPLE CHARACTERIZATION PLAN FOR GATES

CHARACTERIZATION PLAN

CIRCUIT TYPE: LPDTμL 9040

| BASIC CONDITIONS | NOTES |
|---|---|
| $V_{CC}$ = 5 volts on Pin 14<br>Ground on Pin 7<br>Pin 11 open<br>Temperature 25 C | $V_{MAX\ ZERO}$ = 0.25 volts<br>$V_{MIN\ ONE}$ = 2.45 volts<br>Standard clock pulse: 4.5 volts<br>500 ns, 1 MHz |

| PARAMETER | APP TEST | CONDITIONS |
|---|---|---|
| Output_one voltage for Q and Q | 1 | At fan-out of 10 ($R_L$ = 4 kΩ). |
| Output_zero voltage for Q and Q | 1 | At fan-out of 10 ($R_L$ = 4 kΩ). |
| Input leakage current at $C_D$ | 2 | 5 volts at $C_D$ measure leakage to Pin 14. |
| Input zero current at $C_D$, $S_C$, CP | 3 | Current when the respective terminals are grounded. |
| Resistance | 4 | 15 kΩ resistor between Pins 5 and 14. |
| Propagation delay | 5 | Delay between input and output at fan-out of 10. |
| Minimum clock amplitude | 5 | Reduce clock amplitude until toggle action stops.<br>Engineer: LJP Date: July 20, 1967 |

FIGURE 4. SAMPLE CHARACTERIZATION PLAN FOR FLIP-FLOPS

CHARACTERIZATION PLAN

CIRCUIT TYPE: LM 101

| BASIC CONDITIONS | NOTES |
|---|---|
| -12 volts Pin 4<br>+12 volts Pin 7<br>Temperature 25 C | +5 volts Pin 4<br>-5 volts Pin 7 |

| PARAMETER | APP TEST | CONDITIONS |
|---|---|---|
| High gain mode<br>High gain mode (±5 volts) | 1 | Use triangular wave input. From $V_{in}$ versus $V_{out}$ plot obtain gain. Repeat same measurement at $V_{CC}$, $V_{BB}$ = ±5 volts. |
| Closed loop gain | 2 | Amplifier tied down to gain of 100. |
| Input offset voltage<br>Input offset voltage (±5 volts) | 2 | The output voltage at zero input divided by gain. Operated under closed-loop conditions (100). Repeat same measurement at $V_{CC}$, $V_{BB}$ = 5 volts. |
| Input bias current | 3 | Input to ground - open-loop configuration. Average sum of both input transistor bias currents. |
| ± Saturation voltage | 2 | Increase input voltage until output reaches saturation. Use closed-loop configuration. |
| Common mode rejection ratio | 4 | Amplifier tied down to gain of 100. Input signal was 1.0 volt rms at 100 Hz. CMRR measured in volts. |
| Input offset current | 5 | Open loop configuration. Difference between the input bias current of the two input transistors.<br><br>Engineer: LJP Date: Sept. 1, 1967 |

FIGURE 5. SAMPLE CHARACTERIZATION PLAN FOR AMPLIFIERS

Monitoring Gates

Figures 6 and 7 illustrate the general test configurations for the biased and unbiased gate circuits. Fifteen circuits of the same device type, ten biased and five unbiased, were mounted on each printed circuit card. Two cards placed end to end were irradiated simultaneously.

In the biased configuration, the input lead from each circuit was connected to a common input bus. The input-voltage level on the bus was controlled by the Dymec Data Acquisition System. The output of each circuit was connected to a specific input channel of the data system. Individual load resistors were connected from each circuit output to the positive voltage supply. The load resistors were chosen to represent the maximum permissible fan-out for each circuit type.

At selected electron fluences the radiation was interrupted for measurement. The circuit temperature was observed and sufficient time was allowed for the circuits to cool to room temperature (~25 C). The rise in circuit temperature was negligible at the low exposure rates, however, at the higher rates (approximately $10^{12}$ $e/cm^2 \cdot s$) the temperature of the circuits increased 5 to 10 C. After the temperature had stabilized, the data scan was initiated and the data were recorded.

During the first data scan, the circuit input voltages were maintained at the same level as they were during the irradiation (the maximum permissible voltage for a logic zero). The output-voltage level of each biased circuit was measured in turn. Channels 1 to 10 were allotted to the ten circuits on the top board in the radiation fixture. Channels 11 to 20 were allotted to the

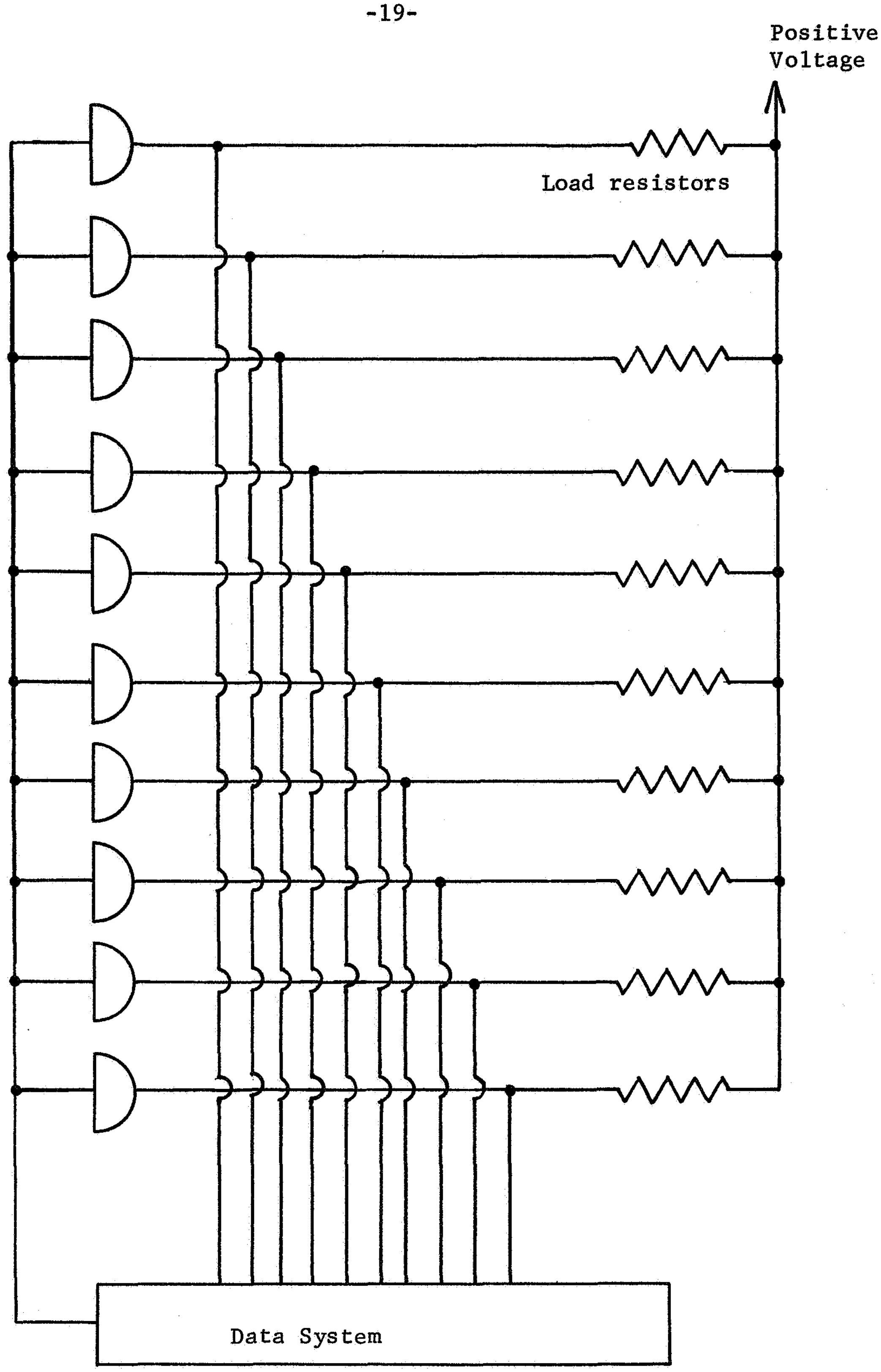



FIGURE 6. GENERAL TEST CONFIGURATION FOR BIASED GATE CIRCUITS

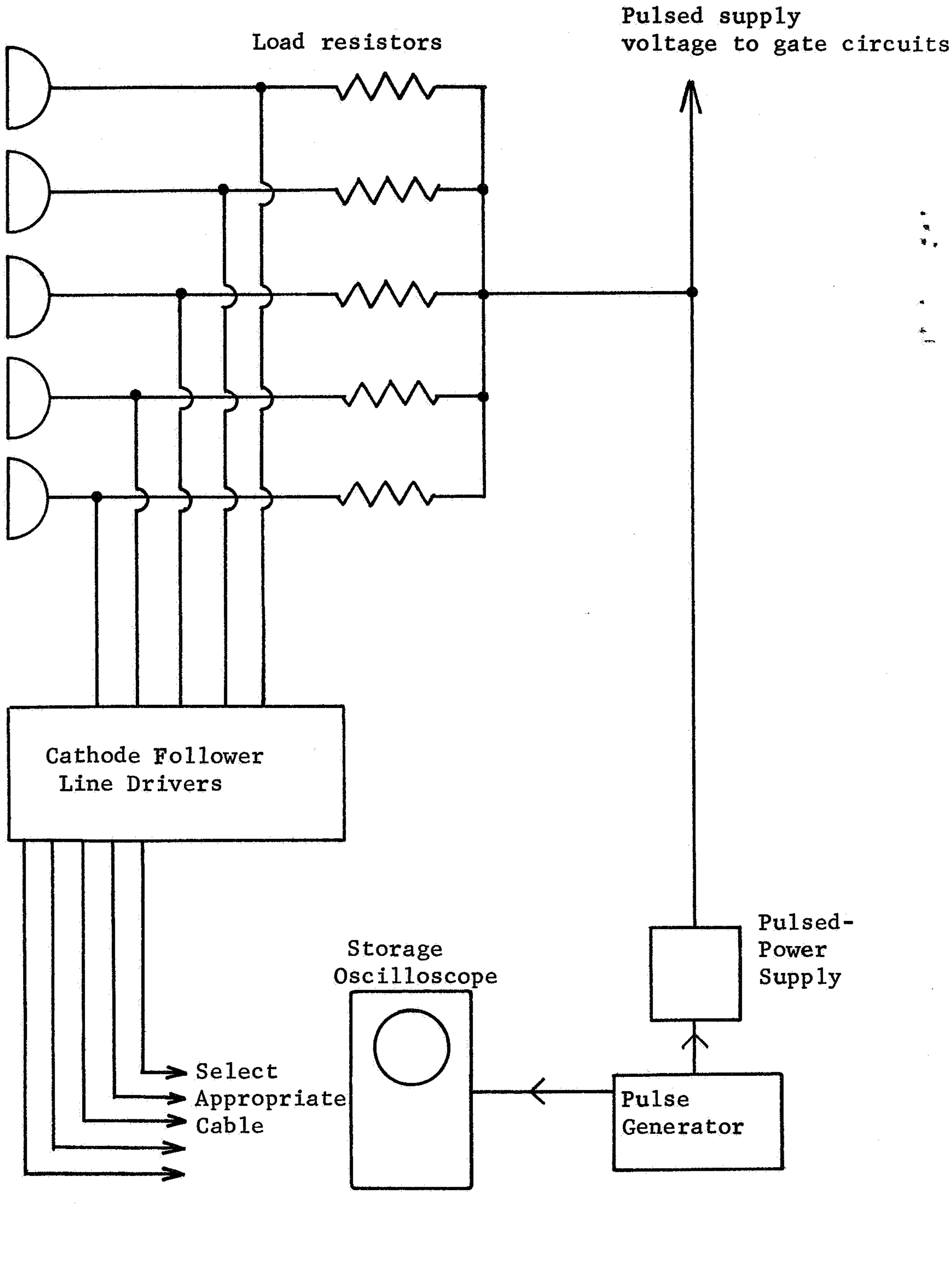



FIGURE 7. GENERAL TEST CONFIGURATION FOR UNBIASED GATE CIRCUITS

ten circuits on the lower board. At the completion of the first scan, the data system automatically applied the minimum permissible logic-one voltage to the integrated circuit. The system would again scan all operating-circuit outputs and record the data. Peripheral measurements (input-voltage levels, fluence, and power-supply voltages) were recorded on Channels 20 to 25. Thus it was possible to determine the circuit states regardless of integrated-circuit failure.

The output-voltage pulses from the unbiased group of gate circuits was displayed on a storage oscilloscope. A conventional cathode follower, located near the integrated circuits, served to isolate the circuits from the effects of long low-impedance coaxial lines. A pulsed-power supply, designed and contructed to provide single pulses of voltage, controlled in amplitude and duration, served to energize the integrated circuits. At specified fluence points, the single-pulse switch of the pulse generator was actuated. Two output pulses were obtained from the pulse generator. The first pulse was applied to the storage oscilloscope's external synchronization connection and served to initiate the oscilloscope trace. The second pulse, of preset duration, was applied to the input of the pulsed-power supply after being delayed. The delay permitted the waveform to be centered on the oscilloscope display. Logic inputs to the gates were left in an open-circuit condition corresponding to a logic one. Therefore, on the application of the supply voltage pulse, the circuit outputs would be at logic zero for the duration of the pulse. Load resistors, chosen to represent the maximum permissible fan-out simulated the effects of loading in an actual-application situation. As described earlier, the output voltage of the integrated circuits was displayed on a storage oscilloscope through the vacuum-tube line driver and approximately 40 feet of RC-58 coaxial cable. The display was stored on the oscilloscope for direct evaluation or a photographic record. The sequence was repeated for each of the five circuits on the card.

Input and power-supply voltages were set at the values specified during characterization. The specific test configurations may be found in Appendix II, Volume II, according to device type.

Monitoring Flip-Flops

Figures 8 and 9 illustrate the general test configuration for the biased and unbiased flip-flop circuits. Fifteen circuits of the same device type, ten operating and five nonoperating, were mounted on each printed-circuit card. Two cards placed end to end were irradiated simultaneously. Load resistors, chosen to represent the maximum permissible fan-out, were connected from both outputs on each circuit to the positive supply voltage.

In the operating configuration, a direct input lead from each circuit was connected to a manual switch at the data-system control panel. By means of the switch, the flip-flops could be reset. Connections were made from both Q and $\overline{Q}$ to the stationary contacts of relays of the data system. The movable contact from each relay was connected through the system patch panel to a specific data-input channel. Data-system Channels 1 through 10 were allotted to circuits on the upper board in the radiation fixture and Channels 11 through 20 were allotted to circuits on the lower board. The relay states were controlled by the data system.

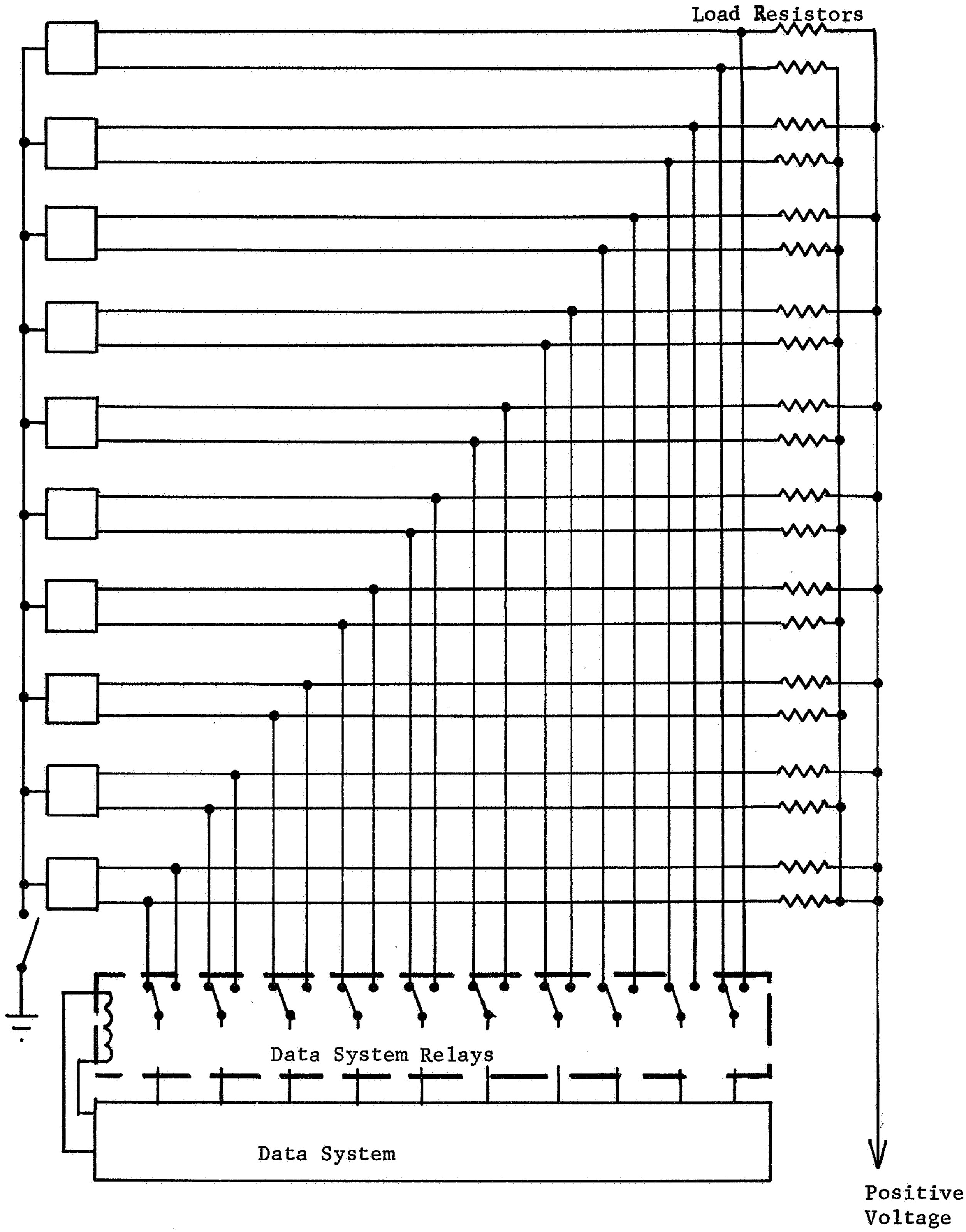



FIGURE 8. GENERAL TEST CONFIGURATION FOR THE BIASED FLIP-FLOP CIRCUITS

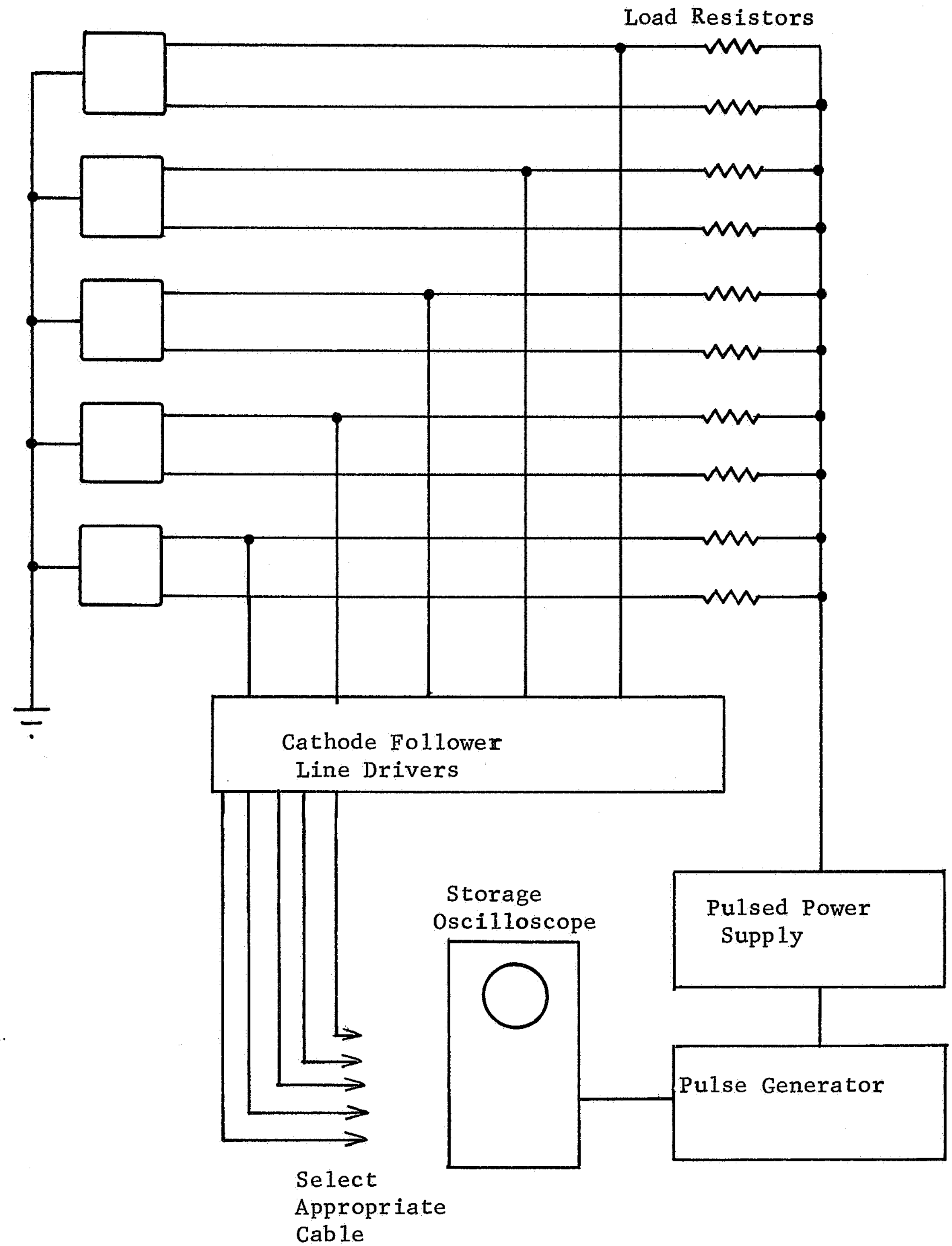



FIGURE 9. GENERAL TEST CONFIGURATION FOR THE UNBIASED FLIP-FLOP CIRCUIT

The measurement sequence at a specific fluence point was, in general, the same as that for the biased gate circuits. After the irradiation was interrupted and the temperature of the circuits returned to 25 C, the circuits were scanned to observe the logic state. The reset switch was operated as necessary to reset circuits that had been switched due to noise pulses. After it was determined that all circuits were in the proper state, the data scan was initiated and the output voltage level, at the one output, was recorded for each circuit. At the completion of the scan, the data system automatically shifted the other flip-flop outputs to the system data-input channels. Another data scan was initiated and the other logic-condition data were recorded.

The direct-set input on each flip-flop of the unbiased group was grounded to insure that the circuit would be in the same state each time that it was energized. Load resistors were connected from each output to the pulsed-supply voltage. The resistor values were selected to simulate maximum permissible fan-out. The output of each circuit was connected through a line driver to the storage oscilloscope. Operation of the pulsed data-collection system was exactly the same as that for the pulsed gates. The specific test configuration specifying input and power-supply voltages may be found in Appendix II, Volume II, according to device type.

Monitoring Operational Amplifiers

Figures 10 and 11 illustrate the general test configurations for the biased- and unbiased-operational-amplifier groups. Fifteen circuits of the same device type, ten biased and five unbiased, were mounted on each

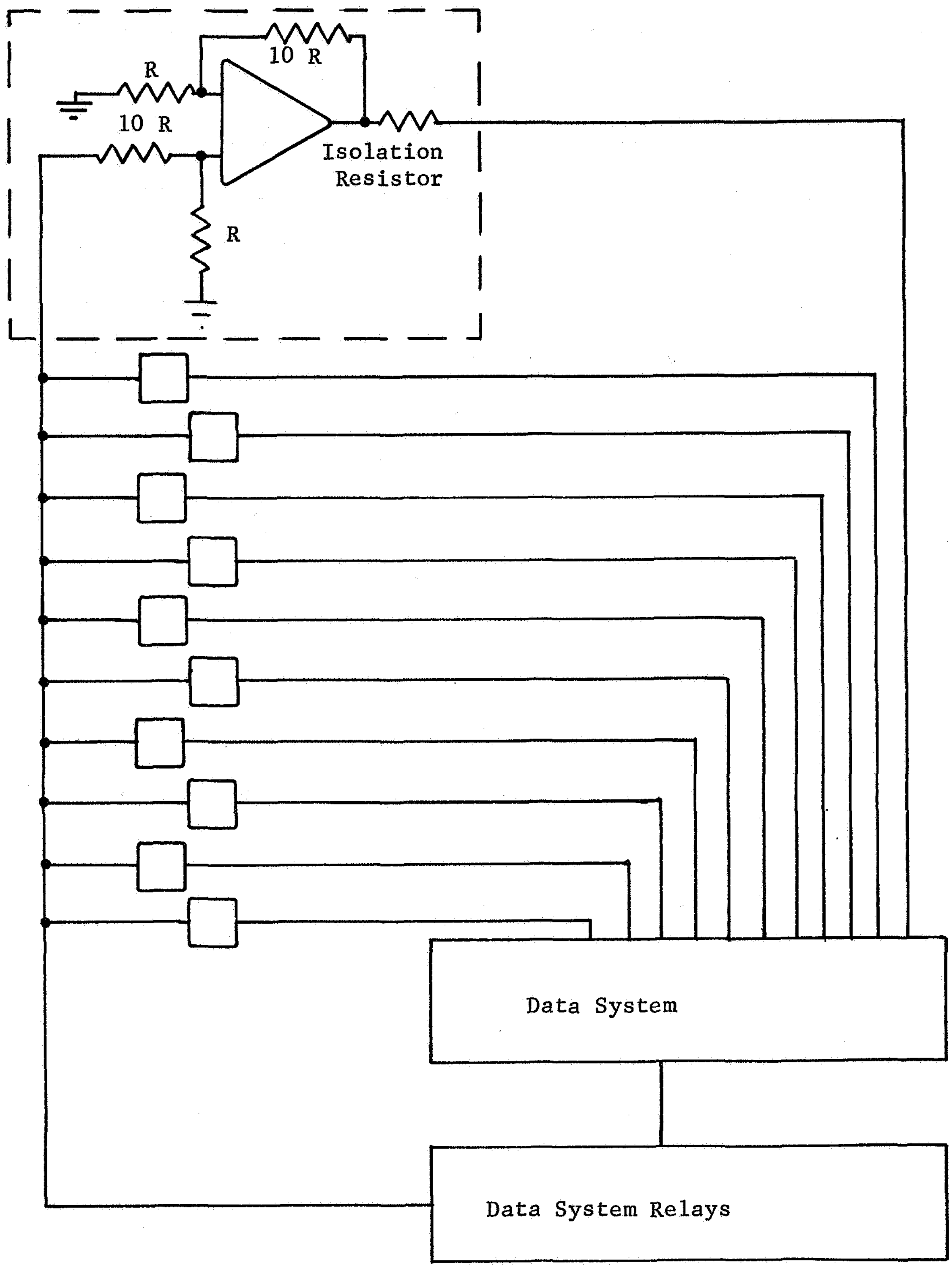



FIGURE 10. GENERAL TEST CONFIGURATION FOR THE BIASED OPERATIONAL AMPLIFIERS

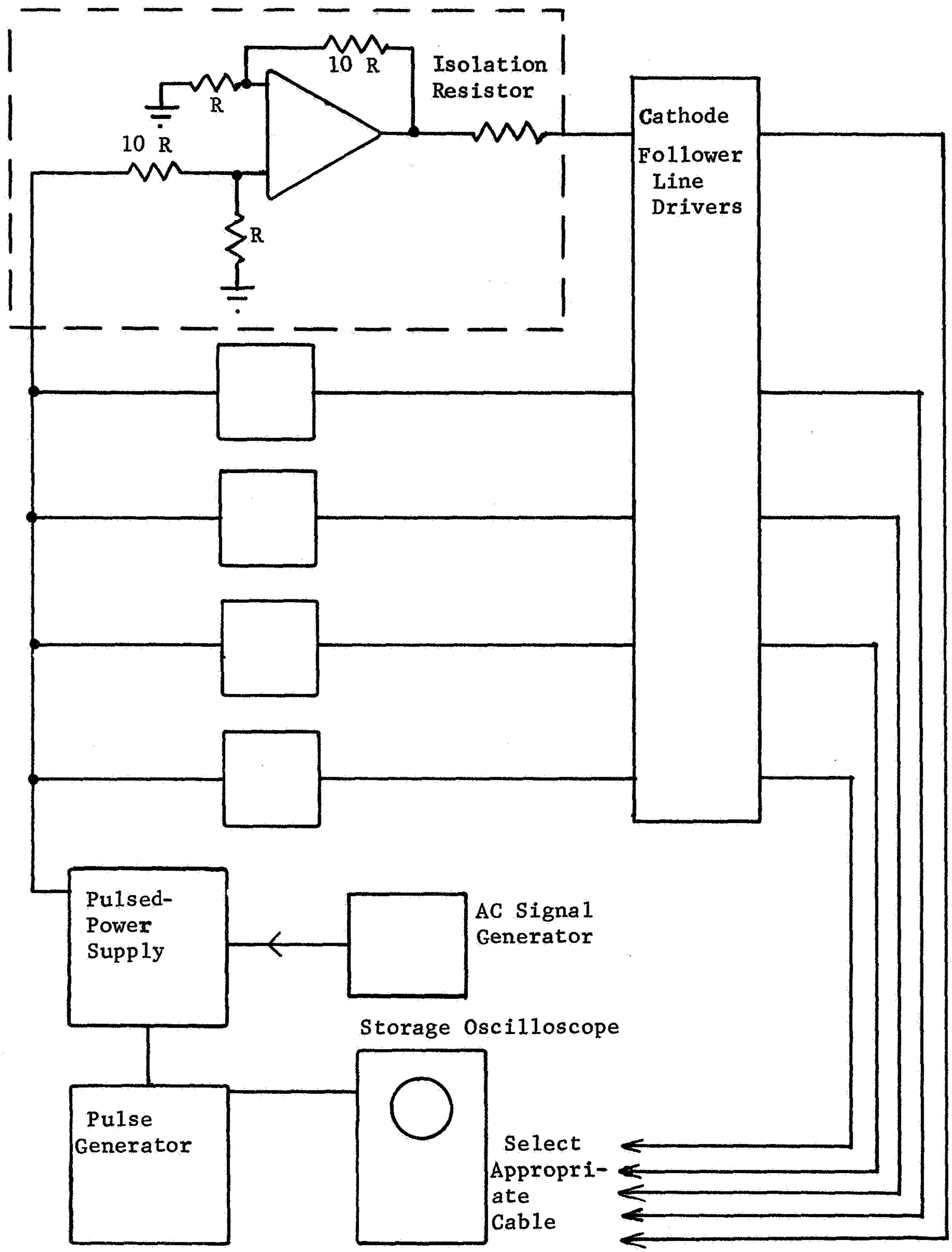



FIGURE 11. GENERAL TEST CONFIGURATION FOR THE UNBIASED OPERATIONAL AMPLIFIERS

printed-circuit board. Feedback resistors, selected for a circuit gain of 100, and stabilizing networks were mounted on the board in close proximity to the associated amplifier circuits. Series isolation resistors in the output lines served to eliminate detrimental effects due to output-line reactance. Forty-dB attenuators at the noninverting input of each amplifier circuit served to improve the signal-to-noise ratio of the input lines and also provided isolation between the individual amplifier circuits. The circuit configuration was identical in both the biased and unbiased conditions.

The input-output variables and the parameters measured are listed in Table 4. Four output parameters were chosen for measurement. A grounded-input condition was used to permit a convenient measurement of input offset voltage,

TABLE 4. OPERATIONAL-AMPLIFIER-MEASUREMENT CONDITIONS

| Scan | Input (at the amplifier) | Output | Parameter |
|---|---|---|---|
| 1 | Ground | Dc voltage | Offset voltage |
| 2 | +0.22 V | Dc voltage | Positive saturation |
| 3 | -0.22 V | Dc voltage | Negative saturation |
| 4 | 1 kHz sinusoid | Ac voltage | Circuit gain |
| During Irradiation | Ground | | |

an ac signal was applied for the gain measurement, and both positive and negative dc voltages provided a measurement of the saturation levels. Selection of the various input voltages was performed by programmable relays in the data system. Measurements were made in the same general manner as that for the gate circuits.

The same type of pulsed arrangement described previously was used to monitor the operational amplifiers which were unbiased during irradiation. A pulse generator furnished a synchronizing pulse to the storage oscilloscope and a delayed pulse, of preset duration, to the pulsed-power supply. Three coincident outputs were obtained from the pulsed-power supply. The first two were supply voltages (positive and negative) which were connected through coaxial cable to the $V_{CC}$, $V_{BB}$ inputs on the circuits. The third output, a gated, 10-kHz sinusoidal waveform, was connected through coaxial cable to the non-inverting input of the integrated circuits. The circuit outputs were displayed on the storage oscilloscope. From the photographs of the output waveforms, data on the closed-loop gain and offset voltage were obtained. Specific details of the circuit configuration of the operational amplifiers are contained in Appendix II, Volume II.

## Monitoring Video Amplifier

Figures 12 and 13 illustrate the test configuration for the biased and unbiased video amplifiers. The measurements made on these amplifiers were similar to those that were described for the operational amplifiers. The input lead from each circuit package was connected through a common input line to the programmable relays in the data system. The gain was determined by the integrated-circuit components and no external components were used. Series

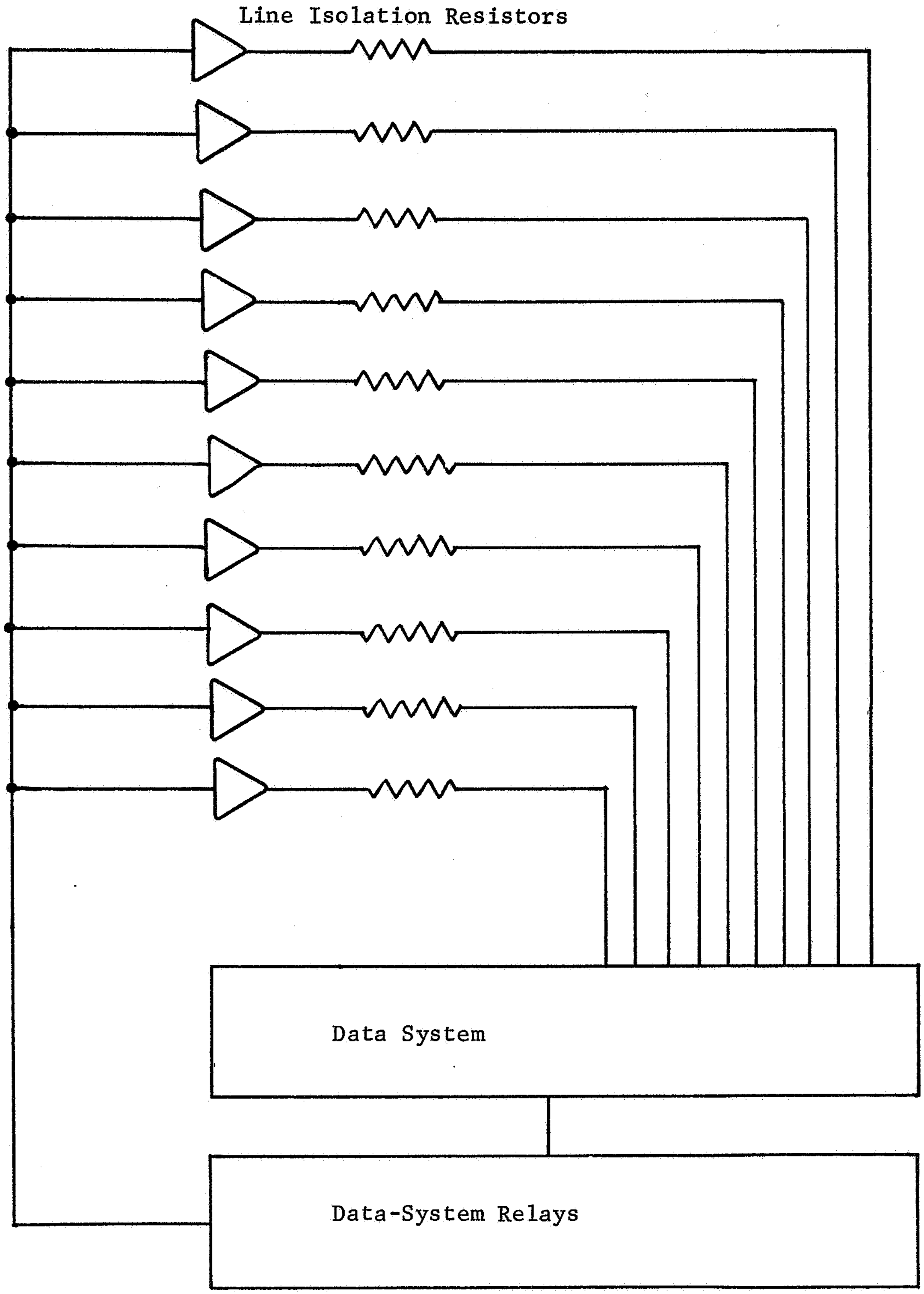



FIGURE 12. GENERAL TEST CONFIGURATION FOR THE BIASED VIDEO AMPLIFIERS

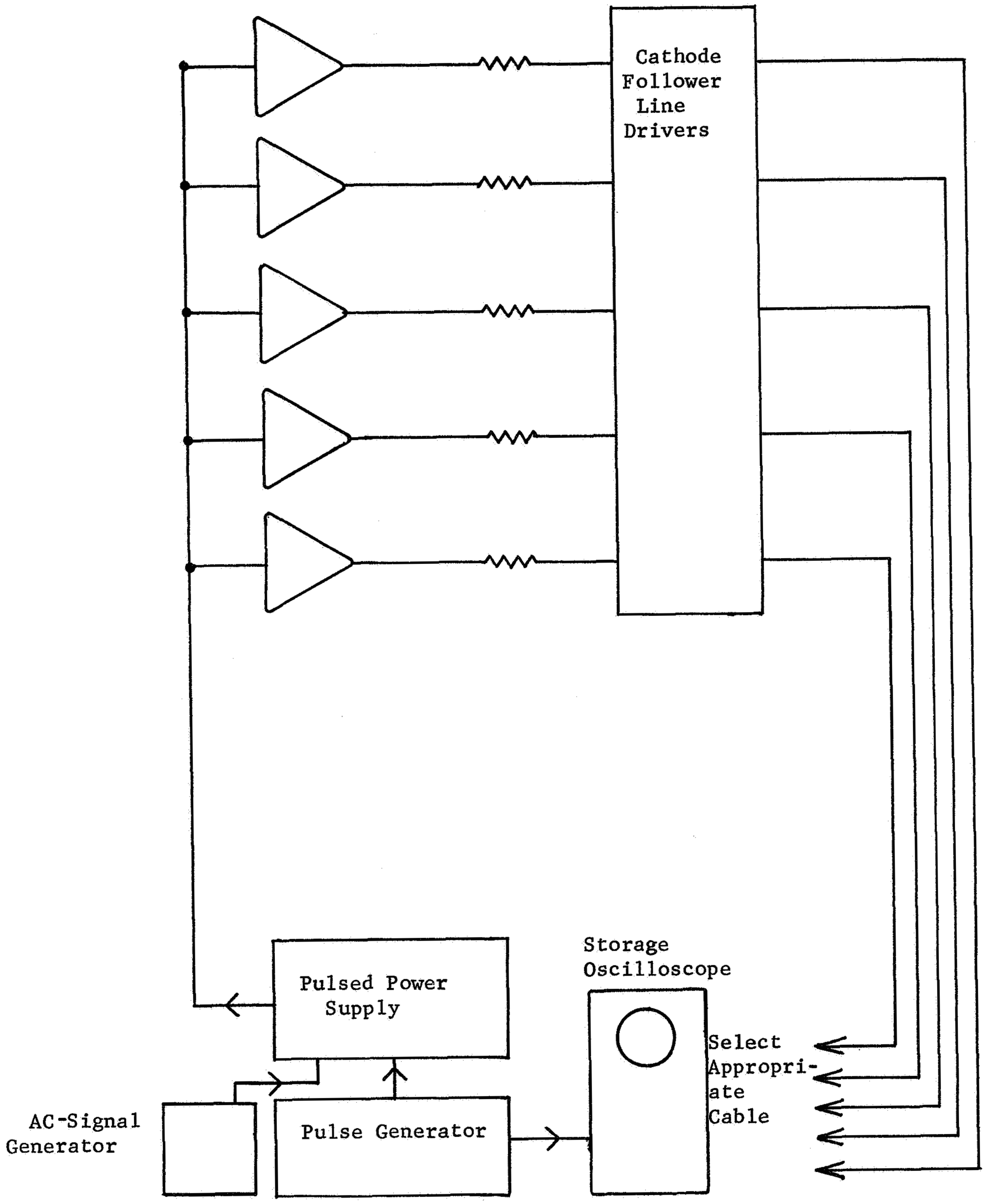



FIGURE 13. GENERAL TEST CONFIGURATION FOR THE UNBIASED VIDEO AMPLIFIERS

isolation resistors were mounted at the output of each circuit package to reduce the effects of line reactance. Operation of the data system, at each designated fluence point, was the same as that for the operational amplifiers. The input-output conditions and measurement sequence are contained in Table 5.

TABLE 5. VIDEO-AMPLIFIER MEASUREMENT CONDITIONS

| Scan | Input | Output | Parameter |
|---|---|---|---|
| 1 | Ac ground | Dc voltage | Output-voltage level |
| 2 | Dc ground | Dc voltage | Negative saturation |
| 3 | Positive 1 volt dc | Dc voltage | Positive saturation |
| 4 | 1 kHz sinusoid | Ac voltage | Circuit gain |
| During Irradiation | Ac ground | | |

The unbiased circuits were pulsed with positive 6 volts and gated 10-kHz sinusoidal pulses. From the photographs of the output waveform the gain and the dc output level were obtained. Additional details concerning radiation monitoring is presented in Appendix II, Volume II.

Radiation Monitoring Equipment

The equipment used for monitoring the powered devices is shown in Figure 14. From left to right on top of table are a ac voltmeter, a precision power supply, and two ac voltage generators. The two cabinets next to the table contain the data-acquisition system and power supplies. Next is an oscilloscope used to monitor the output of selected circuits while the electron beam was on.

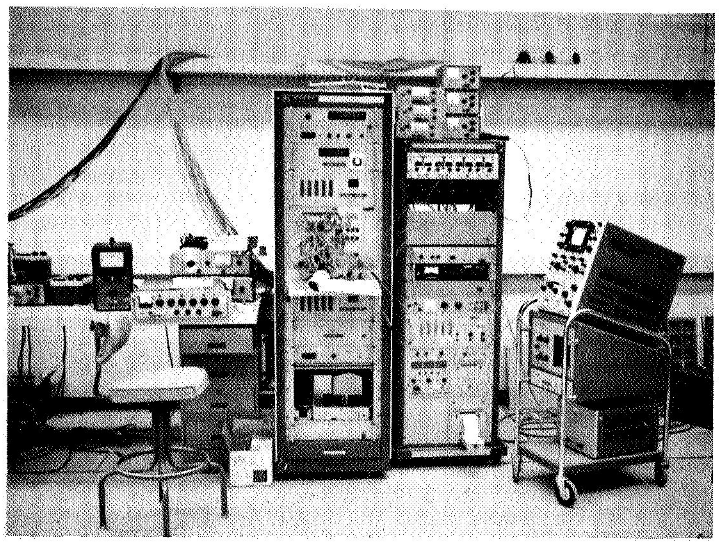


FIGURE 14. MONITORING EQUIPMENT USED FOR POWERED DEVICES DURING IRRADIATION

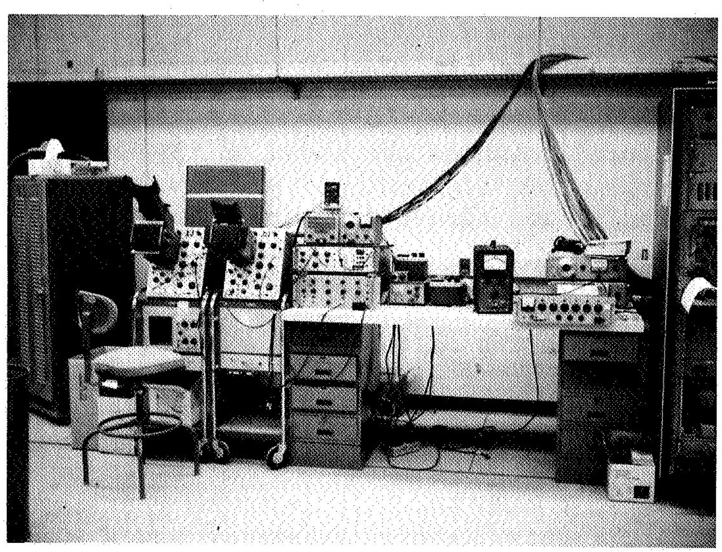


FIGURE 15. MONITORING EQUIPMENT USED FOR THE PASSIVELY IRRADIATED DEVICES DURING IRRADIATION

The data-acquisition system used for this experiment was the Dy-2010B manufactured by the Hewlett Packard Company. The system had been extensively modified by the Goddard Space Flight Center Radiation Effects Group for use in radiation experiments. The system, by means of a stepping scanner, samples up to 25 different dc or ac voltages. Six digits of information are provided by an integrating digital voltmeter that is the heart of the system. Two major modifications have enhanced the system's versatility for radiation experiments: (1) an additional scanner, capable of operation in several different modes is used to control an array of relays. The relay closures, accessible at a patch panel, permit system-controlled changes in circuit configuration and a variety of measurements to be made on each device, and (2) a patch panel was installed to facilitate changes in data channels, relay-contact closures, etc. The major advantage realized by the use of the data-acquisition system was the capability of measuring many devices in a short period of time. The punched-paper tape provided a convenient means of data storage for subsequent processing by computer.

The equipment used to monitor the unbiased circuits is shown in Figure 15. Two storage oscilloscopes are shown on the left side of the picture. The signal generators, pulse and sinusoidal, are located on the bench next to the oscilloscopes. The pulsed-power supplies were built on paper-phenolic boards and they may be seen on top of the sine-wave signal generators. The various power supplies are located on the center of the bench.

Figure 16a is a schematic diagram of the pulsed-power supply used in monitoring the unbiased circuits. Laboratory-bench power supplies were used for the positive and negative supply voltages. A pulse generator supplied the

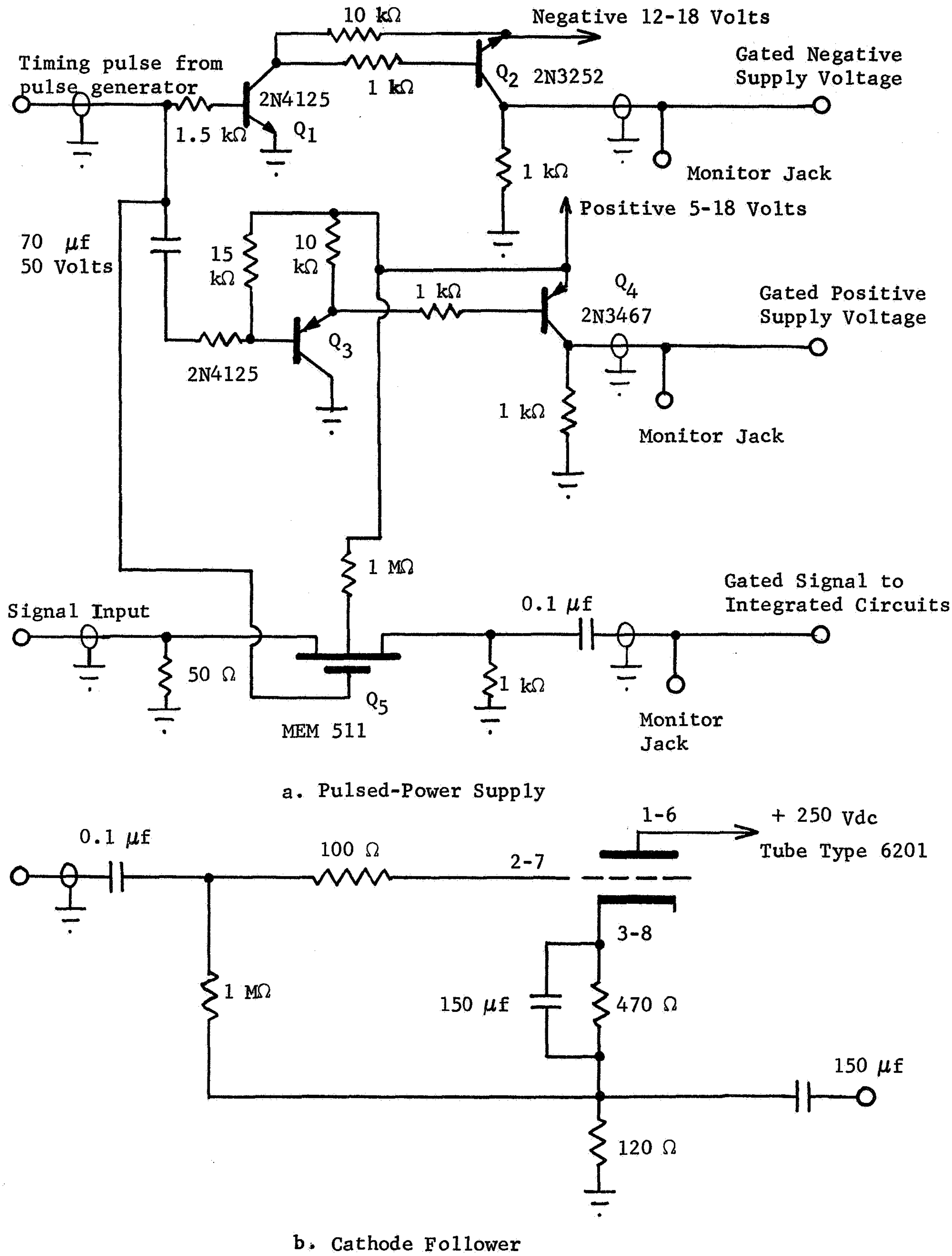



FIGURE 16. VACUUM TUBE CATHODE FOLLOWER AND TRANSISTORIZED PULSED-POWER-SUPPLY CIRCUITS

negative 15-volt input pulse. Transistor amplifiers $Q_1$ and $Q_2$ form the negative pulse section and $Q_3$, and $Q_4$ supply the positive output pulse. The positive and negative power supply voltages were adjusted as necessary to obtain the desired output-pulse amplitude. MOS transistor $Q_5$ served as a series gate for the 10-kHz sinusoid signal. The circuit components were mounted on paper-phenolic printed-circuit boards.

Figure 16b is a schematic diagram of the cathode follower line driver circuits. The passive components of the circuit were mounted in an aluminum chassis. Shielded tube sockets were used to mount the Type 6201 vacuum tubes. The circuit gain was 0.38.

Figure 17 is a photograph of the in situ radiation fixture. The two cylindrical objects at the center of the picture are the Faraday-cup dosimeters.

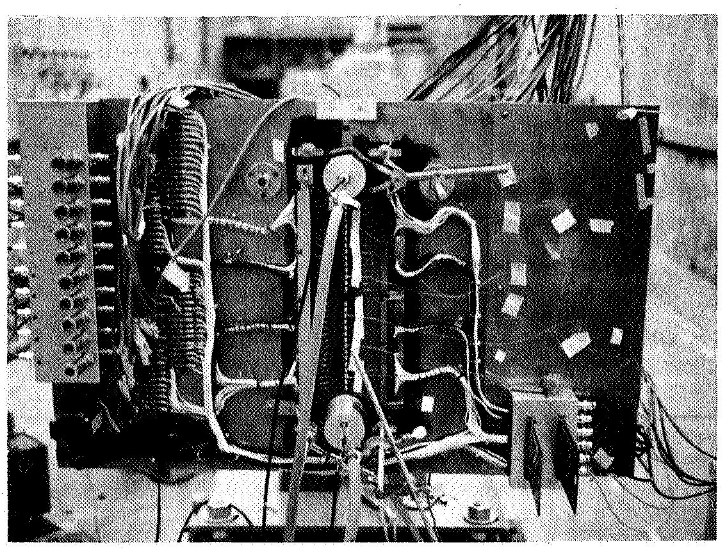
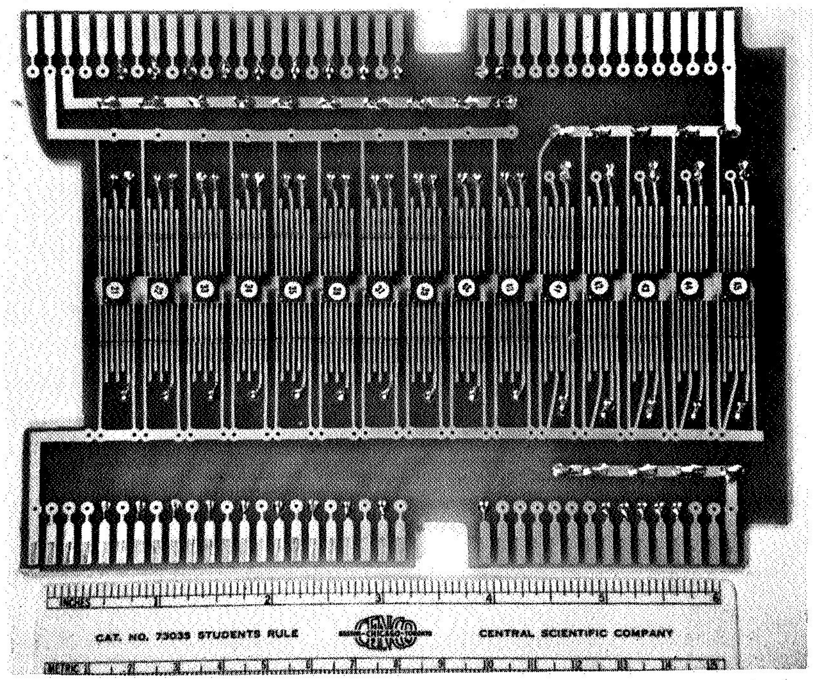


FIGURE 17. RADIATION FIXTURE MOUNTED TO VAN DE GRAAFF ACCELERATOR

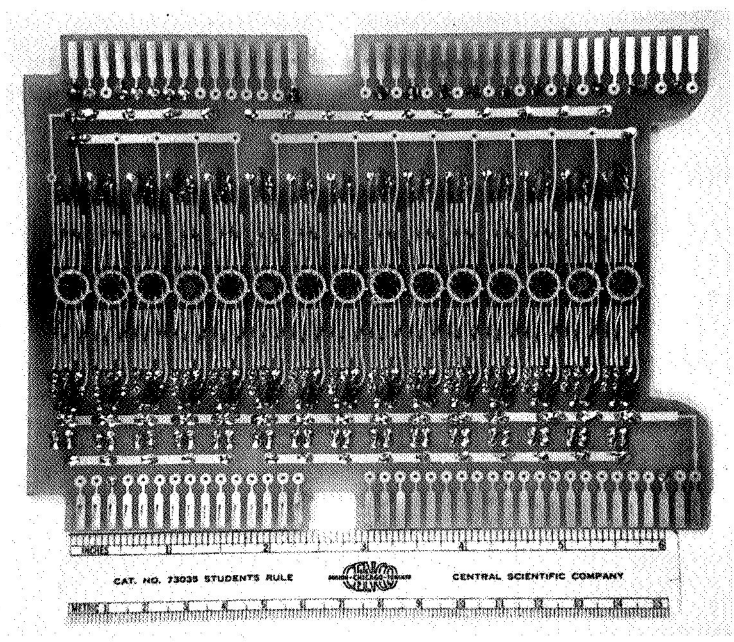
The integrated circuits, mounted on the printed-circuit cards, form a vertical line between the two cups. Connections to external equipment (data system, power supplies, etc.) were made from the terminal strips seen on the left side of the photograph through printed-circuit edge connectors to the integrated-circuit cards. Load resistors for the biased groups of integrated circuits were mounted on paper-phenolic boards shown in the lower right side of the photograph. Connections were made from the boards to appropriate points on the printed-circuit edge connectors.

The chassis containing the line drivers is mounted on the left side of the fixture. The RG-58 output cables to the storage oscilloscopes are visible at the extreme left of the photograph. Coaxial cable (RG 58 and RG 174) was used to connect the pulsed-power-supply outputs to the output terminals of the integrated circuits. The 3/8-inch aluminum main frame was bolted directly to the output horn of the Van de Graaff accelerator.

The circuits were mounted on type G-10-900 glass-epoxy circuit boards. Etched circuit patterns peculiar to each circuit type were designed to minimize the need for additional hand wiring. The integrated circuits were mounted in a line through the major axis of the board. Parallel gap welding was used to connect the circuit leads to the board. Edge patterns for external connections were designed to accommodate Amphenol Series 143 printed-circuit connectors. Figures 18a and b are photographs of typical boards.




a. Typical Digital-Circuit Board




b. Typical Amplifier-Circuit Board

FIGURE 18. TYPICAL TEST BOARDS FOR DIGITAL AND AMPLIFIER CIRCUITS

## Radiation Environment and Dosimetry

### Environment

The radiation environment chosen for these experiments was a 2-MeV Van de Graaff accelerator (High Voltage Engineering AN2000), located at the NASA-Goddard Space Flight Center Radiation Effects Laboratory. The beam was directed through a vertical scanner that magnetically sweeps the beam through a 10 degree arc maximum. This results in a 15-inch uniform sweep at the titanium window. The beam was swept linearly along the window at a 200-Hz rate. The electron energies were 0.5, 1.0, and 1.5 MeV with an energy spread at $\pm 2$ keV. Two vacuum-type Faraday cups, one at each extreme of the major beam scan, were used to provide a continuous check on beam uniformity. The beam current could be adjusted to obtain fluxes from $1 \times 10^7$ $e/cm^2 \cdot s$ to approximately $3 \times 10^{12}$ $e/cm^2 \cdot s$. The irradiations were done in air.

The temperature of the devices was continuously monitored from the beginning of the irradiation run in order to assure that the measurements were made at room temperature (25 C $\pm 3$ C). Six copper-Constantan thermocouple junctions were mounted on the integrated-circuit packages. The thermocouple leads were connected, through conventional ice-bath reference junctions to a Honeywell six-point recorder. The accuracy of the temperature determinations was at least $\pm 0.5$ C.

### Dosimetry

As stated previously, Faraday cups located on each extreme of the major beam sweep were used to monitor the electron beam. These cups provided a constant check on beam uniformity.

The Faraday cups were designed and constructed by the Radiation Effects Group at Goddard Space Flight Center. As shown in Figure 19 and Table 6, the aluminum outer shell contained the measuring cup inside a polystyrene insulator. The cup was manufactured from brass and had a carbon base. The window plate together with the 1-mil aluminum window provided an air-tight seal. The cup was evacuated to reduce errors caused by ionizing currents.

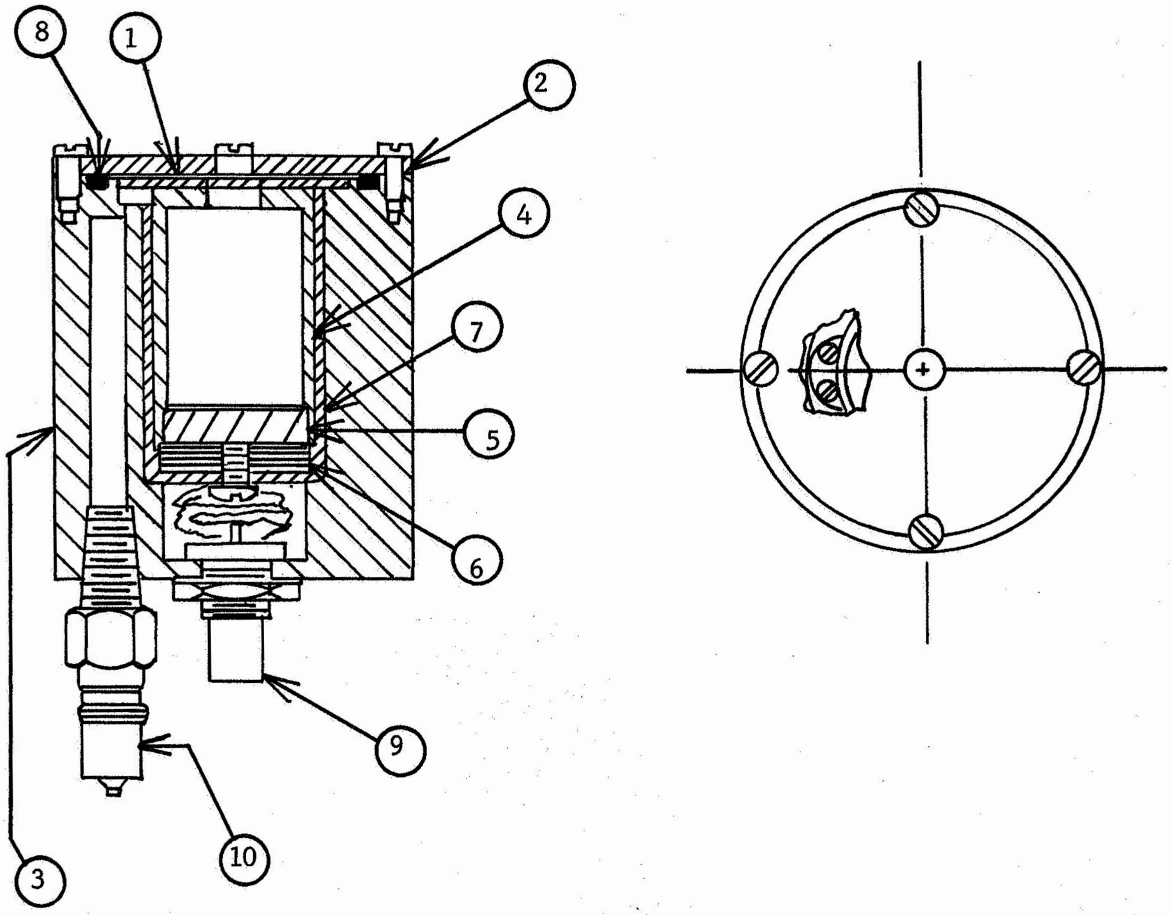
Fluence was determined by one of two methods. For fluxes less than $1 \times 10^9$ e/cm$^2\cdot$s, fluence was calculated by continuously monitoring the current from Faraday cup to ground and keeping an accurate measure of the exposure time. To determine the flux, the current (in amperes) was divided by the product of the area of the cup's window-plate aperture (in cm$^2$) and the charge per electron. For example

$$\frac{5 \times 10^{-10} \text{ ampere (coulomb/s)}}{3.16 \times 10^{-1} \text{ cm}^2 \times 1.6 \times 10^{-19} \text{ coulomb/electron}} = 1 \times 10^8 \text{ e/cm}^2\cdot\text{s},$$

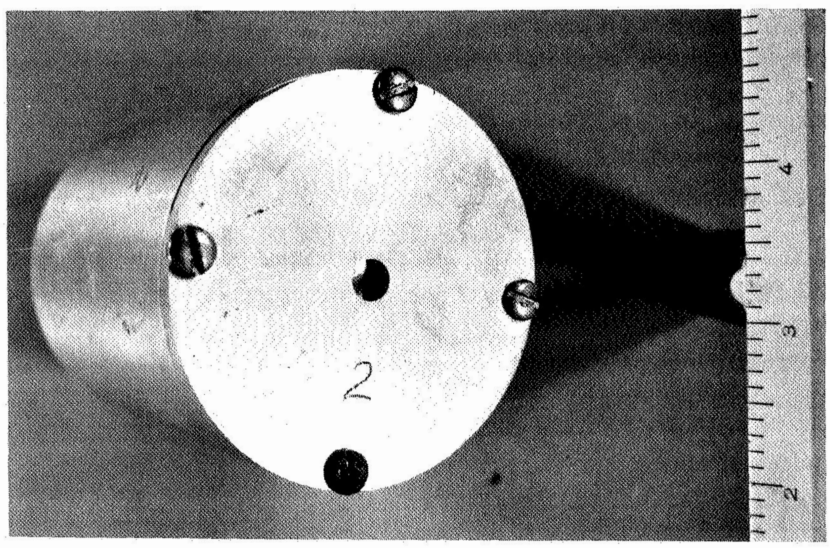
where the Faraday cup's aperture area = $3.16 \times 10^{-1}$ cm$^2$. For fluxes greater than $1 \times 10^9$ e/cm$^2\cdot$s a current integrator was used to integrate the Faraday-cup current and thus determine fluence. Selection of suitable integrator scales caused the instrument to operate with small increments of fluence, each of predetermined value. The number of increments was stored in an electromechanical counter. When the counter reached a preset number, the electron beam was automatically gated off.

## Irradiation Procedure

The irradiation procedure generally followed the steps that were outlined before the irradiations were started. Before the microcircuit specimens,




a. Schematic (See Table 6 for Parts Identification)




b.

FIGURE 19. FARADAY CUP, SCHEMATIC AND PHOTOGRAPH

TABLE 6. FARADAY CUP PART IDENTIFICATION
(See Figure 19)

Faraday-Cup Assembly[a]:

| | |
|---|---|
| 1 | - Spacer--aluminum 0.065 in. thick<br>Spacer aperture--0.375 in. diameter |
| 2 | - Window plate--aluminum 0.125 in. thick<br>Window plate aperture--0.250 in. diameter<br>Window--aluminum foil 0.001 in. thick |
| 3 | - Outer shell--aluminum 2.500 in. OD, 1.250 in. ID |
| 4,5,6 | - Measuring-cup--brass/carbon 1.125 in. OD, 1.018 in. ID<br>Measuring-cup aperture--0.375 in. diameter |
| 7 | - Insulating shell--polystyrene 1.250 in. OD, 1.125 in. ID |
| 8 | - "0" ring |
| 9 | - BNC and vacuum feedthrough |
| 10 | - Vacuum connection |

(a) Parts 3, 4, 5, 6, and 7 are concentric right cylinders.

test fixture, and measurement instrumentation were transported to the radiation-facility site (NASA-Goddard Space Flight Center) the experimental system was checked in the laboratory. Special emphasis was placed on checking all instrumentation to assure that everything was in proper working order.

The irradiation procedure followed at the radiation-facility site is outlined below:

(1) Place device test boards in test jig and connect thermocouples.

(2) Set all necessary voltages.

(3) Observe operation of the pulsed circuits in the static operating mode through the monitoring equipment.

(4) Convert pulsed circuits to pulsed operating mode and check operation.

(5) Check biased-circuit operation through monitoring equipment.

(6) Take initial pulsed-measurement pictures on samples to be irradiated.

(7) Start radiation at a flux of $10^7$ $e/cm^2 \cdot s$ for 100 seconds and increase flux periodically to a maximum value of $3 \times 10^{12}$ $e/cm^2 \cdot s$. Maintain the flux at least one order

of magnitude lower than the exposure. For example, at $10^{12}$ e/cm$^2$ of exposure the flux could be increased to $10^{11}$ e/cm$^2\cdot$s.

(8) Interrupt irradiation periodically for measurements. Make measurements on the biased circuits at a rate of two per decade at low fluences. At higher fluences, increase the rate of measurement to four per decade beginning at $10^{13}$ e/cm$^2$ and to ten per decade beginning at $10^{15}$ e/cm$^2$. Measure the pulsed circuits at $10^{11}$, $10^{13}$, $10^{14}$, $10^{15}$, $5 \times 10^{15}$ and $1 \times 10^{16}$ e/cm$^2$.

(9) Before recording measurements be sure circuits have cooled to within 3 C of room temperature.

(10) Irradiate until biased circuits exhibit 50 percent failures or $1 \times 10^{16}$ e/cm$^2$, whichever occurs first.

(11) Make measurements on biased and pulsed circuits after radiation has been terminated.

(12) Monitor biased circuits for about 15 minutes after radiation has been terminated.

(13) Convert pulsed circuits to static mode and observe through monitoring equipment.

(14) Disconnect power supplies and remove test boards from test fixture.

Observations that might be helpful in later data analysis were recorded in a logbook. A record was kept of the radiation flux. The fluence and the measured parameter values were recorded on the data tapes. Any deviations from the above radiation procedure are treated, for the individual device type, in the section entitled "Analysis of Data".

## ANALYSIS OF DATA

### General

The effects of 1.5, 1.0, and 0.5 MeV electron irradiation on the ten different circuit types of the fundamental study and the effects of 1.5 MeV electron irradiation on the seven types of 962 circuit of the equivalent-circuit study are presented in this section. These effects are presented in terms of the device behavior determined from both the in situ measurements and the more comprehensive pre/post characterization measurements. In this section the practical significance of the observed parametric changes is discussed. Attention is focused on salient features of the experimental results and on possible design steps to extend the period of device operation in the space environment. In addition, the test results are examined to gain further insight into the mechanisms of radiation degradation.

In the following analysis of part types it will be assumed that the reader is familiar (either through Battelle's 1965 report Contract No. NAS5-3985 or other sources) with the basic damage mechanisms and the changes that occur in monolithic circuits when exposed to electron radiation.

Due to the variety of circuits studied in this program, the discussion is broken down into three categories. The amplifier circuits are discussed first, followed by discussion of the digital circuits. These two groups make up the fundamental-study group. The digital circuits in the equivalent-circuit study are treated last. Before discussing the individual circuits in turn two comments are appropriate. First, the changes in parameters which were permanent[(3)] in nature were found to increase with electron energy. These results are similar to and consistent with results obtained for individual transistors. In should be noted, that the electron exposures quoted in this report are incident on the device package and <u>not</u> on the microcircuit chip itself. The exposure which is seen by the active devices on the microcircuit chip may be significantly smaller than the exposure measured outside the package. This is especially true for the irradiations with the 0.5 MeV electrons. Some specific results on package shielding can be found in a report titled "Space Radiation Equivalence for Effects on Transistors", by R. R. Brown and W. E. Horne prepared under NASA Contract No. NAS5-9578.

Second, all failures centered around the transistors. Whether the degradation was the result of (1) decreases in current gain, (2) increases in leakage current such that it becomes an appreciable part of the current being controlled in transistors operating at very low-current levels, or (3) the complete failure of specific active elements, the problem device is the transistor. In addition, the radiation response of the integrated circuits studied indicates that failure modes are possible which are related not only to the degradation of the individual active elements but also to the design of the integrated circuit. As a consequence, attempts at circuit hardening must not only be aimed at keeping the transistors in operating ranges for satisfactory performance but also must consider the interaction between components of a specific system.

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(3) Changes which were not permanent in nature were observed during some irradiations. These changes are discussed in the appropriate sections.

#

## Description of Data Summaries

To help clarify the detailed analysis and to make it easier to follow, a discussion on the format for the presentation of the summarized data in the "Results" section is presented below.

### Circuit Identification

The first page of each summary (see page 130) presents the test plan for each circuit type. Included on this page is the circuit identification, a schematic diagram, test conditions and measurement temperature, and the parameters measured during irradiation and pre/post characterization (the underlined parameters were measured in situ).

### In Situ Data

After the first page of each summary, the radiation response of the circuits is presented. These data are presented in the form of curves showing the measured-circuit parameter as a function of electron exposure. Curves are presented for both the biased and unbiased samples for the three electron energies used in the irradiations. Curves are included only for those cases in which a significant change in the parameter value was observed.

The curves, showing the response of the biased samples, were generated using a computer and a CALCOMP plotter. The mean value of each parameter with the minimum and maximum value observed at a particular fluence value are presented. The data taken immediately after the last exposure and the data taken 15 minutes after irradiation are superimposed on the last exposure value. The "post plus 15 minutes" data can be identified by the horizontal line drawn through the appropriate symbols. Table 7 gives a key for interpreting the symbols used for the curves of the biased microcircuits. Since only five circuits were irradiated under the unbiased condition, the response for each individual circuit is superimposed on the same curve.

TABLE 7. KEY USED IN PLOTTING RADIATION RESPONSE OF THE BIASED MICROCIRCUITS

| | |
|---|---|
| ⊕ | POST PLUS 15 MIN. |
| ✱ | MEAN |
| ⊙ | MAX |
| ⚠ | MIN |

## Characterization Data

Following the radiation-response curves, each summary contains a comparative tabular evaluation of the pre/post characterization measurements. The radiation-induced parametric changes for the device may be read directly from the tables. The data for parameter's are presented and partially analyzed one per column. Since the data were summarized by computer, the number of columns (or parameters) may vary from one to seven on a page, depending on how many columns of raw data were combined. At the top of each column is listed the parameter. In order to make circuit-by-circuit comparisons convenient, common symbols were used throughout the summaries. The symbols, to a limited extent, are consistent with those used in industry to denote microcircuit parameters. The symbols are limited because the computer prints only Arabic capital letters and no subscripts. Also, the symbols do not necessarily correspond to those used in the specific characterization plans of Appendix I

(Volume II) which more closely follow the industrial-type symbol. Listed immediately before the summarized results are the common symbols and an explanation of the parameter. To simplify the tables, the parameter values are listed in volts, amperes, ohms, and seconds.

The data summaries are broken down into eight groupings: the information pertaining to the biased and unbiased groups at the three electron energy levels; the F-test values; and the t-test values. To permit the necessary comparisons, the parameter changes are considered separately for each test group. The effects of the electrical condition during irradiation at the three electron energies are basically of interest, as are the changes in the nonirradiated control group in relation to the changes in the irradiated test groups.

For each test group, the following summarized information is provided:

(1) Number represents the number of data points considered in the mathematical analysis, except for calculation of the initial mean.

(2) Initial mean is the initial mean of the precharacterization values for devices belonging to that particular test group.

(3) Average change is the average change between pre/post characterization parameter values for the devices belonging to that particular test group.

(4) Standard deviation (STD) of the mean is a measure of the spread in parameter changes of the sample remaining in a particular test group.

(5) Average percent change is the average of the individual percent changes in parameter values for each of the samples within a particular test group. These data are thus "normalized" to fractional changes from initial instead of absolute changes.

(6) Interval estimate as percent is an estimate of the average change that might be seen for this parameter if additional samples were exposed to the same electron environment under the same test conditions. It should be realized that this estimate is based on the number of samples within a particular test group and on a predetermined confidence level. For this program, a 95 percent confidence level has been used. To summarize this in semiempirical form the interval estimate as a percent is the probability [X < percent average change < Y] = .95, where X and Y are the limits of the interval expressed as a percent.

(7) Percent average (AVE) change is the average change in parameter values expressed as a percent of the initial value. This value should fall within the interval estimate when expressed as a percent. It is not necessarily true, however, that the average percent change will fall within the interval estimate when it is expressed as a percent.

Below the information for each individual test group there are the results obtained from performing F-tests and t-tests.

The F-test, as used here, provides sufficient information to either accept or reject the hypothesis that the electron irradiation has not caused a significant change in a particular parameter value. This information is provided in the form of an F-value that is computed from the experimentally obtained parameter data. This hypothesis can be checked at any desired confidence level by referring to a standard F-table. The F-table is entered by selecting the desired confidence level and determining the degrees of freedom. If the F-value obtained in this manner from the standard F-table is less than the computed F-value reported in the data summaries, the hypothesis is rejected at the selected confidence level. F-tests were performed for all the samples irradiated at each energy with the control group, for all the biased samples with the control group, for all the unbiased samples with the control group.

To clarify the use of the F-test consider the F-value (for groups C, D, and G[4]) presented on page 144 for the μA709 concerning parameter measurements of the open-loop gain parameter. As shown in the data summary sheets, three groups and a total number of 20 samples are involved in the mathematical analysis. Locate an F-table which is for a 95 percent confidence level. A reference for this is the Handbook of Probability and Statistics with Tables, by Burington and May, reprinted 1958, page 278. To enter this F-table look for the F-value under the column headed by $m_1 = 2$ and in the row listed as $m_2 = 17$ ($m_1$ = number of groups minus one and $m_2$ = total number of samples minus the number of groups). The number is 3.59. Now compare 3.59 with the F-value reported on the data summary sheet for the open-loop gain of the μA709. It is

(4) See the data summary sheets for code used to define different groups.

seen that the computed F-value (Groups C, D, G), 32.3, is greater than the tabulated F-value, 3.59, and hence, we can reject the hypothesis that electron irradiation has not caused a significant change in the open-loop gain. In other words, we are 95 percent confident that, if units comparable to the ones used for this program are exposed to a 1.0 MeV electron flux for a total exposure of $1 \times 10^{16}$ e/cm$^2$, then a statistically significant change will occur in the open-loop gain due to the radiation.

The t-test as used here provides sufficient information to accept or reject the hypothesis that test groups being considered are not significantly different as a result of their exposure to the electron environment. This information is provided in the form of a t-value which is computed from the parameter data experimentally obtained from the samples being considered. This hypothesis also can be checked at any desired confidence level. Checking the hypothesis with the t-test is similar to the check of the F-test. Select a confidence level and determine the degrees of freedom (for this case the number of samples considered minus two). With this information locate the t-value in a standard t-table. If the located t-value is less than the computed t-value reported in the summaries then the hypothesis is rejected at the selected confidence level.

To illustrate the use of the t-test again refer to the μA709 data summary sheet for open-loop gain page 144. Consider the 1.0-MeV-irradiated biased group (C) and the control group (G). Since, in this case, the number of total samples is 15, the degrees of freedom are 15 minus 2 or 13. Now select a confidence level, say 99 percent. Usually the t-test is performed at a higher confidence level than the F-test. Locate a t-table or use the one on page 283 of the Handbook of Probability and Statistics with Tables which is referenced under the F-test discussion. Look under the column headed by 0.01 (1.00 minus 0.99) and in the row listed as 13 and find the t-value 3.012. Compare this value with that reported on the data summary sheet. For the open-loop gain of the μA709, it can be seen that the computed t-value, 6.14, for the C-G (1.0 MeV biased-control) group is greater than the tabulated t-value, 3.012. As a result, we can reject at the 99 percent confidence level the hypothesis that the biased samples were not significantly different from the control group as a result of irradiation with 1.0 MeV electrons. In other words we can say with 99 percent confidence that as a result of the irradiation, units comparable to the μA709 units used in this program, when exposed to $1 \times 10^{16}$ e/cm$^2$ (1.0 MeV), will show a statistically significant difference between the control group and the biased group.

In some cases the F-value and t-value printed in the data summaries is "IIIII" or "RRRRR". These symbols indicate that the standard deviation of the specific groups used in the mathematical analysis was zero and the F- and t-tests are invalid. It should be noted that both the F- and t-tests allow only their respective hypothesis to be checked for acceptance or rejection at a specific confidence level and nothing more than that can be said based on the results of such tests.

## Amplifier Circuits

### Introduction

The mode of failure for the amplifier circuits was attributed to four basic parameter changes: decreased transistor gain, increased input bias current, decrease in the maximum output-voltage swing, and increased offset voltage. These results are consistent with those changes observed in the second phase of this program. The parameter change or combination of changes that caused the first failure was dependent on the circuit type and the electron irradiation. Both permanent and temporary changes in output parameters were observed as a result of radiation. Permanent changes are defined as those changes in parameter values that were observed during as well as long after (4 weeks) irradiation. In contrast, temporary effects are defined as changes in measured parameters which recovered either during or after (at most 30 minutes) irradiation. The evidence seems to indicate that the temporary effects were, at least, initiated by surface damage. In some cases, the changes occurred rapidly and at different exposure rates and, thus, the nature of the monitoring measurements did not preclude the possibility that some of the observed changes were initiated by rate effects.

Significant degradation of the open-loop gain can be expected for amplifiers used in the space radiation environment. In addition, the input bias current can be expected to increase, resulting in a lower input impedance. The changes in input bias current can also result in large increases in offset voltage, unless the resistance from input to ground is low. For this reason, low balanced-input resistance from inputs to ground is desirable for stable operation under space radiation. Also to avoid saturation of cascaded amplifier stages resulting from increased offset voltage, use ac coupling rather than dc coupling. Where large output signals are required, strong feedback is recommended in order to make maximum use of the amplifier's output-voltage-swing capability while minimizing changes in offset voltage.

The failure criterion for this program was any parameter falling outside the limits specified by the manufacturer. Failure limits were specified in this manner to be compatible with the information supplied to design engineers by the manufacturers. Since no specification was given for the closed-loop-gain parameter, it was arbitrarily determined that a 10 percent decrease in closed-loop gain for the operational amplifiers ($\mu$A709, 807BE, and LM101) would be considered a failure. The closed-loop-gain failure level was set as a 25 percent decrease for the SE501G video amplifier.

Summary

The $\mu$A709 amplifier experienced its first failure after 5 x $10^{15}$ e/cm$^2$ (1.5 MeV), when the maximum output swing of a unbiased circuit decreased below $\pm$9.5 volts. No failures were observed among the biased samples at an exposure of 1 x $10^{16}$ e/cm$^2$ during either the 1.0 or 0.5 MeV irradiations. Changes of engineering significance included decreased open-loop gain, increases in input bias current, decreases in output voltage swing, and increased offset voltage.

The 807BE biased amplifiers were found to saturate after approximately 5 x $10^{12}$ e/cm$^2$ (1.5 MeV). These changes were temporary in nature and recovery was observed during continued irradiation. Only the biased samples were observed to saturate. With respect to permanent changes, the first failure was recorded after an exposure of 5 x $10^{15}$ e/cm$^2$ (1.5 MeV) when the output voltage swing of an unbiased 807BE amplifier had decreased below $\pm$9.5 volts. Significant changes were observed in the open-loop gain, input bias current, output voltage swing, and offset voltage similar to those of the $\mu$A709 circuits.

Temporary changes were also observed in the gain and the offset voltage of the LM101 circuits. These changes were observed during the 1.5 and 1.0 MeV irradiations in the exposure range of 2 x $10^{12}$ to 2 x $10^{14}$ e/cm$^2$. The offset voltage increased, and the gain decreased by approximately 10 percent for the biased samples. No changes were observed among the unbiased units. With respect to permanent changes, the LM101 behaved similar to both the μA709 and 807BE circuits. The first failure was recorded after 3 x $10^{15}$ e/cm$^2$ (1.5 MeV) when output voltage swing decreased below ±9.5 volts.

A decrease in closed-loop gain was the failure mode for the SE501G video amplifiers. The first failure was observed after 2 x $10^{15}$ e/cm$^2$ (1.5 MeV) when the closed-loop gain of some biased and unbiased samples decreased more than 25 percent. Changes of engineering significance included decreased closed-loop gain, output dc level, and transistor current gain.

Fairchild μA709

The μA709 is high-gain operational amplifier with junction isolation, fabricated on a silicon monolithic substrate by the Fairchild Planar epitaxial process. The circuits are designed to provide low offset, high input impedance, large input-common-mode range, and low power consumption over the full military temperature range (-55 C to +125 C). Typical open-loop gain and power consumption are 45,000 and 80 milliwatts ($V_{CC}$ = ±15 volts), respectively.

The principal failure mode for the μA709 circuits was a decrease in the output voltage swing below ±9.5 volts. The measurements taken during exposure showed significant decreases in the magnitude of the negative saturation voltage between 7-8 x $10^{15}$ e/cm$^2$ (1.5 MeV). No failures were recorded during the 1.0 and 0.5 MeV irradiations. Engineering significant changes were also observed in the open-loop gain, input offset voltage, and input bias current. The closed-loop gain (100) of these amplifiers remained constant (within 2 percent) during irradiation and no statistically significant changes were observed between the pre/post characterization data. The changes in the input offset currents were so erratic that no meaningful interpretation of the data was possible. The changes in the positive saturation voltage, common-mode rejection ratio, and resistance were small and not of engineering significance.

Tables 8 and 9 list the comparative percent average changes for the biased and unbiased $\mu$A709 circuits. No data is given for the 1.5-MeV irradiated unbiased group, since all five samples in this group were not functional after irradiation. The radiation response of the circuits are presented in Figures 34 through 43 in the "Results" section. Curves are presented only if measurable changes were observed. In cases where the plot of the data is not clear, the data is presented in tabular form.

An example of the degradation of the open-loop characteristics of these amplifiers after electron irradiation is shown in Figure 20. This figure shows the input-output voltage transfer characteristics of a typical irradiated and nonirradiated circuit (not the same circuit). These photographs in conjunction with the postirradiation measurements indicate that the open-loop voltage gain is severely degraded and the transfer characteristic is no longer linear. The nonlinearity in the transfer characteristic is more severe for negative voltages indicating nonsymmetric degradation of the amplifier. That is, the gain for negative voltages is less than for positive voltages. As Figure 20b indicates, the amplifier no longer has a well-defined saturation

TABLE 8. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE BIASED μA709 CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Open-Loop Gain | -75.7 | -48.2 | -8.8 |
| Closed-Loop Gain | N.S. | N.S. | N.S. |
| Input Offset Voltage | -334 | -55.6 | N.S. |
| Input Offset Current | N.S. | N.S. | N.S. |
| Positive Saturation Voltage | -8.2 | -5.7 | -0.5 |
| Negative Saturation Voltage | -16.9 | -2.5 | -0.2 |
| Input Bias Current | 690 | 439 | N.S. |
| Common Mode Rejection Ratio | N.S. | N.S. | N.S. |
| Resistance | 3.7 | N.S. | N.S. |
| Fluence to First Failure[(a)], e/cm$^2$ | $7 \times 10^{15}$ | $>1 \times 10^{16}$ | $>1 \times 10^{16}$ |
| Total Fluence, e/cm$^2$ | $8 \times 10^{15}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output voltage swing decreased below ±9.5 volts.

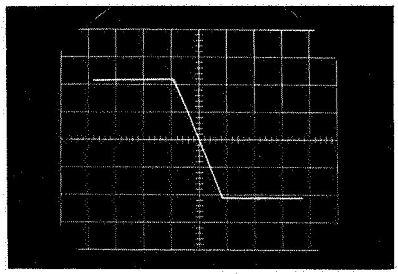
TABLE 9. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE UNIBASED μA709 CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Open-Loop Gain | (b) | -68.8 | -10.1 |
| Closed-Loop Gain | | N.S. | N.S. |
| Input Offset Voltage | | 438 | N.S. |
| Input Offset Current | | N.S. | N.S. |
| Positive Saturation Voltage | | -5.2 | -0.3 |
| Negative Saturation Voltage | | -16.2 | -0.2 |
| Input Bias Current | | 310 | 29.8 |
| Common Mode Rejection Ratio | | N.S. | N.S. |
| Resistance | 3.0 | N.S. | N.S. |
| Fluence to First Failure[a], $e/cm^2$ | $5 \times 10^{15}$ | $1 \times 10^{16}$ | $>1 \times 10^{16}$ |
| Total Fluence, $e/cm^2$ | $8 \times 10^{15}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

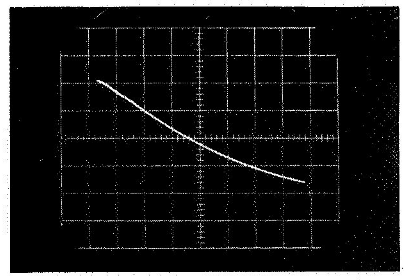
NOTE: N.S. = No statistically significant change.

(a) Circuit was not operational.

(b) All circuits in this group were not operational after irradiation.



a. Nonirradiated



b. Irradiated--1 x $10^{16}$ e/cm$^2$ (1.0 MeV)

Horizontal Scale: 5 V/cm

Vertical Scale: 5 V/cm

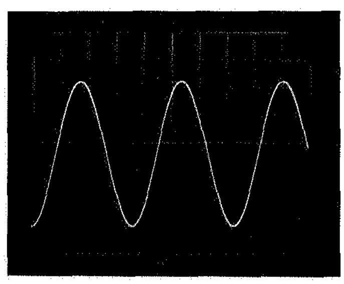
FIGURE 20. INPUT-OUTPUT VOLTAGE TRANSFER CHARACTERISTIC OF TYPICAL $\mu$A709 CIRCUITS

characteristic and has a reduced dynamic range. The magnitude of the negative saturation voltage had decreased from approximately -11.0 volts to approximately -7 volts. The data during irradiation indicates that the loss of the negative portion of the output response is an abrupt function of fluence. The abrupt failure of the output stage is not characteristic of the gradual decrease in voltage gain. Since the positive saturation voltage decreased very little, degradation to the lateral p-n-p level shifting transistor is believed to be responsible for the decreases in the magnitude of the negative saturation voltage observed for the biased samples and the complete failure of the five nonbiased samples (1.5 MeV irradiation).

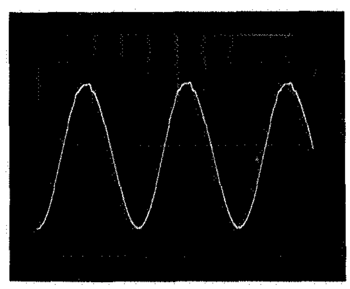
The degradation to the current gain of the input transistors is exemplified by the large increases in input bias current. These increases indicate the vulnerability of transistors operated at very low-current levels.

Increases were observed in the offset voltage. Changes in this parameter were varied; the general trend, however, was toward more positive voltages. The offset voltage was found to be rather stable under irradiation up to 3 x $10^{15}$ e/cm$^2$ (1.5 MeV) and 1 x $10^{16}$ e/cm$^2$ (1.0 MeV). The magnitude of the offset voltage of Sample 5 exhibited significant increases from 1 to 8 x $10^{15}$ e/cm$^2$ (0.5 MeV). The other circuits indicated no changes during the 0.5 MeV irradiation. Sample 5 had recovered to its preirradiation value when post-radiation measurements were made.

Significant increases in cross-over distortion were observed in all amplifiers irradiated with 1.5 MeV and 1.0 MeV. Figure 21 shows the output



a. Nonirradiated



b. Irradiated - 1 x $10^{16}$ (1.0 MeV

Vertical Scale: 0.5 V/cm

FIGURE 21. OUTPUT VOLTAGE OF TYPICAL $\mu$A709 CIRCUITS SHOWING CROSS-OVER DISTORTION

waveform of typical irradiated and nonirradiated circuits (not the same circuit). Both amplifiers are operating at a closed-loop gain of 100. The input was a 1-kHz sinusoidal signal. Since the cross-over distortion in these amplifiers is eliminated by negative feedback, decreases in the open-loop gain after irradiation reduces the effectiveness of this method for eliminating distortion. The characteristics of the distortion were similar in all 1.5 and 1.0 MeV irradiated circuits of which the output waveform shown in Figure 21b is representative. No quantitative measurements were made to determine the percent harmonic distortion, etc.

Tables 8 and 9 show that the degradation in the unbiased circuits was more severe than in the biased circuits for the circuits irradiated with 1.5 and 1.0 MeV electrons. No significant differences were observed between the 0.5 MeV irradiated biased and unbiased groups. The statistical analysis indicates with 99 percent confidence that, for the open-loop gain, the negative saturation voltage, and the offset voltage, there were statistically significant differences between the biased and unbiased samples that were irradiated by 1.0 MeV electrons. The complete failure of all five unbiased samples during the 1.5 MeV irradiations would indicate greater degradation to the unbiased samples.

Significant annealing was observed in the negative saturation voltages of the biased samples. This general behavior is exemplified by Sample 10 irradiated to $8 \times 10^{15}$ e/cm$^2$ (1.5 MeV). Immediately following exposure the negative saturation voltage had degraded from -10 to -3.25 volts. Fifteen minutes after exposure the saturation voltage had recovered to -4.73 volts. Three weeks after exposure (postirradiation characterization) the negative saturation voltage had recovered to -7.9 volts.

The degradation to the device parameters was found to increase with electron energy. The changes in device parameters were greater after $8 \times 10^{15}$ e/cm$^2$ at 1.5 MeV than after $1 \times 10^{16}$ e/cm$^2$ at 1.0 MeV. Only minor changes were observed during the irradiation with 0.5 MeV electrons.

The implications of these results to design engineers are that (1) stable operation of these amplifiers can be expected at closed-loop gains of at least 100 until failure of the output stage limits operation altogether, (2) the circuits should be energized during irradiation, (3) for maximum gain stability, the highest power supply voltages, compatible with the microcircuits and the system, should be used, and (4) the circuits are more sensitive to the higher energy electron irradiation.

The $\mu$A709 circuits were irradiated with 3.0 MeV electron during Phase II of this study. During these irradiations the biased circuits saturated at a relatively low electron fluence ($1 \times 10^{12}$ e/cm$^2$). During this third phase no saturation was observed during any of the irradiations. Since the Phase II irradiations were terminated at $1 \times 10^{13}$ e/cm$^2$, no comparisons of pre/post characterization data can be made with that data.

Amelco 807BE

The 807BE is a high-gain operational amplifier with junction isolation, fabricated on a silicon monolithic substrate using the planar-epitaxial process. The circuit is designed to provide low offset, high input impedance, high common-mode range and thermal stability over the full military temperature range. The nominal open-loop voltage gain is 60,000.

The effects observed during the irradiation of these circuits can be grouped into two categories. The first, represents those changes that were permanent; that is, changes which were observed both immediately following and long after irradiation. The second, represents the saturation of the biased amplifiers while the circuits were irradiated--a state from which they eventually recovered after the irradiation had been terminated. The saturation effect will be described first.

During the 1.5 and 1.0 MeV irradiation, after approximately 5 x $10^{12}$ e/$cm^2$, the biased 807BE amplifiers began to saturate in the negative direction. The irradiation was then interrupted and the saturated amplifiers were observed to recover in about 20 minutes after the radiation had been terminated. Irradiation was then continued at a lower exposure rate. About 30 minutes of irradiation at 1 x $10^8$ e/$cm^2$·s some amplifiers saturated. Since the amplifiers recovered after the electron beam had been temporarily interrupted and no permanent effects were observed, the irradiation was continued.

It was found that the time required for the amplifiers to recover from saturation decreased with increased exposure. As stated, about 20 minutes were required for recovery after the initial saturation. In contrast, after an exposure of 2 x $10^{15}$ e/$cm^2$ the circuits recovered almost immediately (less than 10 seconds).

As stated, only the powered circuits were observed to saturate. To test the hypothesis that the applied voltages were related to the observed saturation, the power supplies were turned off during an irradiation period. Immediately after the electron beam was turned off the circuits were energized. The circuits did not saturate. During the period that the circuits were saturated and while measurements were being made (electron beam off) the temporary removal of the power-supply voltages did not correct the situation, i.e., immediately after the reapplication of power the circuits were still saturated.

The behavior just described was observed during the 1.5 MeV and 1.0 MeV irradiations. During the 0.5 MeV irradiation the saturation of amplifiers was not observed until an exposure of $5 \times 10^{15}$ e/cm$^2$ and only two of the ten biased samples saturated at all. In all other respects the two saturated circuits (during 0.5 MeV irradiation) behaved like the circuits irradiated with 1.5 and 1.0 MeV electrons.

No model has been suggested to date to explain these observed effects, although the evidence would strongly indicate surface effects. Exposure rate could be a significant factor contributing to this effect. An attempt to isolate the problem area from the information generated for this program is not feasible because of the temporary nature of the observed effect and the nature of the data during the occurrence of the effect.

The permanent radiation effects (after the circuits had recovered from negative saturation) were observed to be decreases in the magnitude of the negative saturation voltage (maximum output-voltage swing) and increases in the offset voltage. The pre/post characterization measurements indicate changes of engineering significance in the open-loop gain, negative saturation voltage, offset voltage, and input bias current. The changes in the positive saturation voltage, closed-loop gain, and common mode rejection ratio were small and not of engineering significance. While changes in offset current were observed, the erratic nature of these changes precluded meaningful analysis of the data.

Tables 10 and 11 list the comparative percent average changes for the biased and unbiased 807BE circuits. These changes are given for the three energies used in the irradiations. The radiation response of the circuits is presented in Figures 45 through 57 in the "Results" section. Curves are presented only if significant changes were observed.

An example of the degradation of the open-loop amplifier characteristics is shown in Figure 22. This figure shows the input-output voltage transfer characteristics of a typical irradiated and nonirradiated circuit (not the same circuit). These photographs in conjunction with the pre/post characterization data indicate the degradation to the open-loop characteristic

a. Nonirradiated

b. Irradiated - 1 x $10^{16}$ (1.5 MeV)

Horizontal Scale: 5 V/cm

Vertical Scale: 5 V/cm

FIGURE 22. INPUT-OUTPUT VOLTAGE TRANSFER CHARACTERISTIC OF TYPICAL 807BE CIRCUITS

TABLE 10. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE BIASED 807BE CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Open-Loop Gain | -96.2 | -78.6 | N.S. |
| Closed-Loop Gain | -2.7 | N.S. | N.S. |
| Input Offset Voltage | 904 | 1040 | N.S. |
| Input Offset Current | N.S. | N.S. | -501 |
| Positive Saturation Voltage | -0.7 | N.S. | N.S. |
| Negative Saturation Voltage | -30.0 | -7.7 | N.S. |
| Input Bias Current | 1200 | 457 | 30 |
| Common Mode Rejection Ratio | N.S. | N.S. | N.S. |
| Fluence to First Failure, $e/cm^2$ | $7 \times 10^{15}$ [a] | $6 \times 10^{15}$ [a] | $6 \times 10^{15}$ [b] |
| Total Fluence, $e/cm^2$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant changes.

(a) Output voltage swing decreased below $\pm 9.5$ volts.

(b) Increase in the input offset voltage of 20 millivolts.

TABLE 11. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE UNBIASED 807BE CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Open-Loop Gain | -97.8 | -81.8 | -14.7 |
| Closed-Loop Gain | -4.3 | N.S. | N.S. |
| Input Offset Voltage | 1120 | 115 | N.S. |
| Input Offset Current | -784 | 674 | N.S. |
| Positive Saturation Voltage | -1.6 | N.S. | N.S. |
| Negative Saturation Voltage | -109 | N.S. | N.S. |
| Input Bias Current | 1040 | 64.2 | 53.8 |
| Common Mode Rejection Ratio | N.S. | N.S. | N.S. |
| Fluence to First Failure[a], $e/cm^2$ | $5 \times 10^{15}$ | $>1 \times 10^{16}$ | $>1 \times 10^{16}$ |
| Total Fluence, $e/cm^2$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output voltage swing decreased below $\pm 9.5$ volts.

due to the reduction of the gain of the active elements. Even though the average open-loop gain had degraded more than 90 percent, closed-loop operation at a gain of 100 was possible. The degradation of the input stage is characterized by the large increases in the input bias current. These large changes indicate the vulnerability of the input stage which is operated at low currents. The changes in offset voltage after irradiation are indicative of the circuit imbalance after irradiation, consistent with the severe degradation of the input stage.

The magnitude of the negative saturation voltage was found to decrease abruptly with increased electron fluence after a threshold exposure was reached. These changes indicate an abrupt failure of active elements in the circuit. Since the positive saturation decreased very little, degradation to the lateral p-n-p transistors of the output stage are believed to be responsible for these abrupt changes in the output voltage swing.

Generally, no significant differences were observed between biased and unbiased samples irradiated with 1.0 and 0.5 MeV electrons. The unbiased samples irradiated with 1.5 MeV electrons showed significantly greater degradation than the biased samples. The statistical analysis indicates, with 95 percent confidence, that for the closed-loop gain, input offset voltage, input offset current, and negative saturation voltage there were significant differences between the biased and unbiased samples. The degradation to the unbiased samples was so severe that three of the five samples irradiated with 1.5 MeV electrons could not be operated at all after irradiation. Significant annealing of the positive saturation voltage was observed for the biased samples. No annealing data are available for the unbiased samples, since the dynamic range was not measured in situ.

Generally the degradation of device parameters was found to increase with electron energy for both the biased and unbiased samples. As is evident from Tables 10 and 11 the degradation to the open-loop gain, positive and negative saturation voltages, and input bias current, was most severe as a result of irradiation with 1.5 MeV electrons.

The implications of these results to design engineers are that: (1) from the permanent damage point of view, stable operation of these amplifiers can be expected at gains of at least 100 until failure of the output stage limits operation altogether, (2) these amplifiers have a tendency toward negative saturation during electron irradiation, (3) for greater circuit longevity with respect to permanent degradation, the circuits should be biased under irradiation, (4) for maximum gain stability the highest supply voltages, compatible with the microcircuits and the system, should be used, and (5) the circuits are more sensitive to the higher energy electron irradiation.

National Semiconductor LM101

The LM101 is a high-gain general purpose operational amplifier with junction isolation, fabricated on a silicon monolithic substrate using the planar-epitaxial process. The circuit is designed to provide low offset, high input impedance, large common mode range, and low power consumption over the full military temperature range. Frequency compensation can be accomplished with a single 30 picofarad capacitor. Typical large-signal voltage gain and power-supply currents are 160,000 and 1.8 milliamperes respectively ($V_{CC}$ = ±20 volts).

The principal failure mode for the LM101 circuits varied with the electron energy. Irradiation with 1.5 MeV electrons resulted in a first failure after an exposure of 3 x $10^{15}$ e/cm$^2$ when a decrease in the output voltage swing below ±9.5 volts was observed. Measurements taken during exposure showed significant decreases in the positive saturation voltage between 2 to 5 x $10^{15}$ e/cm$^2$ (1.5 MeV). In addition, beginning at 2 x $10^{12}$ e/cm$^2$ during the 1.5 MeV irradiations, the closed-loop gain of the amplifiers began to decrease. Also changes in the offset voltage were recorded. By 2 x $10^{14}$ e/cm$^2$ the open-loop gain and offset voltage had recovered to preirradiation values. The changes in closed-loop gain during this period varied, but an average decrease of about 10 percent was observed.

The decrease in positive saturation voltage observed during the 1.5 MeV irradiation was also observed during the 1.0 MeV irradiation. The decreases were, however, less severe and only one unit had decreased below 9.5 volts after 1 x $10^{16}$ e/cm$^2$ (1.0 MeV). Changes in the closed-loop gain and offset voltage observed during the 1.5 MeV irradiation were also observed during the 1.0 MeV irradiation run. Changes in these parameters began at a fluence of 2 x $10^{12}$ e/cm$^2$ (1.0 MeV) and by a fluence of 5 x $10^{14}$ e/cm$^2$ (1.0 MeV) the circuits had returned to normal operation. The overall decrease in gain averaged about 10 percent. The decrease in the closed-loop gain was accompanied by large variations in offset voltage. The output offset voltage of one unit increased to over 4 volts at 2 x $10^{13}$ e/cm$^2$ (1.0 MeV) and was considered a failure (the failure level for the output offset voltage was set at ±2 volts). Changes in offset voltage in both positive and negative directions were recorded. These changes in gain and offset voltage were observed for only the biased circuits during both the 1.5 and 1.0 MeV irradiations.

During the 0.5 MeV irradiation the principal failure mode was the decrease in the closed-loop gain of over 10 percent. The closed-loop gain decreased for both the biased and unbiased samples. This decrease was caused by a decrease in the closed-loop bandwidth after irradiation. Some improvement in the bandwidth could be obtained by decreasing the compensation capacitor.

The pre/post characterization data indicated degradation of engineering significance in the open-loop gain, input bias current, positive saturation voltage, and power-supply current. Changes were observed in the offset voltage and the offset current of the amplifiers. While the changes in offset voltage varied, the general trend was toward the more negative voltages. Since the changes in both offset voltage and offset current were so erratic, no meaningful analysis of the data were possible. The degradation in closed-loop gain and negative saturation voltage was small and not of engineering significance.

Tables 12 and 13 list the comparative percent average changes for the biased and unbiased LM101 circuits. These changes are given for the three energies used in the irradiations. The radiation response of the circuits is presented in Figures 59 through 72 in the "Results" section. Curves are presented only if measurable changes were observed.

An example of the degradation of the open-loop characteristics of the amplifiers after irradiation is shown in Figure 23. This figure shows the input-output voltage transfer characteristics of a typical irradiated and nonirradiated circuit (not the same circuit). These photographs in conjunction with the post characterization data indicate the open-loop gain is severely degraded after irradiation. The open-loop gain was measured at power-supply voltages of ±12 and ±5 volts. The data indicate that the percent open-loop gain degradation is larger for the lower supply voltage, which is consistent with more severe degradation of transistor gain at low currents. The degradation of the current

TABLE 12. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE LM101 BIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Open-Loop Gain ($V_{CC}$ = ±12 V) | -79.0 | -67.0 | -59.7 |
| Closed-Loop Gain | -3.3 | N.S. | -5.2 |
| Input Offset Voltage ($V_{CC}$= ±12 V) | 515 | 245 | N.S. |
| Input Offset Current | N.S. | N.S. | N.S. |
| Positive Saturation Voltage | -10.4 | -1.8 | N.S. |
| Negative Saturation Voltage | N.S. | -2.0 | -0.5 |
| Input Bias Current | 592 | 537 | -16 |
| Power-Supply Current | -70 | -63 | -23 |
| Open-Loop Gain ($V_{CC}$ = ±5 V) | -83.1 | -74.7 | -71.6 |
| Input Offset Voltage ($V_{CC}$= ±5 V) | 487 | | N.S. |
| Fluence to First Failure, e/cm$^2$ | $3 \times 10^{15}$(a) | $7 \times 10^{12}$(b) | $7 \times 10^{15}$(c) |
| Total Fluence, e/cm$^2$ | $5 \times 10^{15}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Decrease in maximum output voltage below ±9.5 volts.

(b) Increase in input offset voltage above 20 millivolts.

(c) Closed-loop gain decreased by 10 percent.

TABLE 13. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE LM101 UNBIASED CIRCUITS

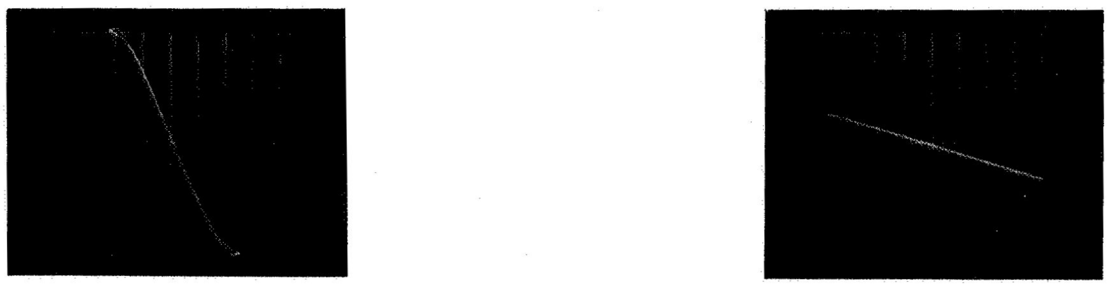
| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Open-Loop Gain ($V_{CC}$ = ±12 V) | -75.5 | -75.0 | -40.4 |
| Closed-Loop Gain | -5.1 | -1.8 | N.S. |
| Input Offset Voltage ($V_{CC}$= ±12 V) | N.S. | N.S. | N.S. |
| Input Offset Current | N.S. | N.S. | N.S. |
| Positive Saturation Voltage | -41.7 | -29.8 | N.S. |
| Negative Saturation Voltage | -2.7 | -2.0 | -1.1 |
| Input Bias Current | 607 | 664 | 100 |
| Power-Supply Current | -74.8 | -67.8 | -23.7 |
| Open-Loop Gain ($V_{CC}$ = ±5 V) | -80.8 | -77.5 | -38.5 |
| Input Offset Voltage ($V_{CC}$= ±5 V) | N.S. | N.S. | N.S. |
| Fluence to First Failure, e/cm$^2$ | >1 x $10^{15}$ (a) | 5 x $10^{15}$ (b) | 1 x $10^{16}$ (b) |
| Total Fluence, e/cm$^2$ | 5 x $10^{15}$ | 1 x $10^{16}$ | 1 x $10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Monitoring equipment failed during irradiation.

(b) Closed-loop gain decreased 10 percent.

gain of the input transistors is characterized by the large increases in the input bias current. These increases in bias current emphasize the vulnerability of transistors operated at low currents.



a. Nonirradiated

Horizontal Scale: 1 V/cm
Vertical Scale: 5 V/cm

b. Irradiated - $5 \times 10^{15}$ (1.5 MeV)

Horizontal Scale: 5 V/cm
Vertical Scale: 5 V/cm

FIGURE 23. INPUT-OUTPUT VOLTAGE TRANSFER CHARACTERISTIC OF TYPICAL LM101 CIRCUITS

The decrease in the positive saturation voltage was found to be a very abrupt function of the electron fluence. The indication is that these changes are caused by the complete failure of a circuit element rather than the gradual decrease in gain of the amplifier. Since the negative saturation voltage decreased very little, degradation to the lateral p-n-p transistor of the output stage is believed to be responsible for these abrupt decreases in output voltage swing.

With respect to the anomalous changes observed in the closed-loop voltage gain and offset voltage, all devices were affected to some degree in the $2 \times 10^{12}$ e/cm$^2$ to $2 \times 10^{14}$ e/cm$^2$ exposure range during both 1.5 and 1.0 MeV irradiations. The temperature did not vary from room temperature enough for attribution of these observations to changes in temperature. No model has been proposed to date to explain the behavior of these circuits. An attempt to isolate the source of the problem area is not feasible from the data available because of the temporary nature of the observed effect. It should be noted that this behavior was not observed among the unbiased circuits.

In general, no statistically significant differences were observed between the biased and unbiased samples for the 1.5 and 1.0 MeV irradiations. The only exception was the changes in positive saturation voltage. The statistical analysis indicates, with 99 percent confidence, that for the positive saturation voltage there were statistically significant differences between the biased and unbiased samples for both the 1.5 MeV and 1.0 MeV. Significant annealing of the positive saturation voltage was observed for the biased samples. No annealing data are available for the unbiased samples, since the dynamic range was not measured in situ.

Tables 12 and 13 indicate that the changes for the open-loop gain and the closed-loop gain at 0.5 MeV are greater for the biased circuits. For these parameters the statistical analysis indicates with 99 percent confidence that there were statistically significant differences between the biased and unbiased samples. Damage which is more severe under bias, as this seems to be, can often be correlated with surface effects.

The degradation of the device parameters was found to increase with electron energy. The changes to device parameters were similar after $5 \times 10^{15}$ $e/cm^2$ at 1.5 MeV and $1 \times 10^{16}$ $e/cm^2$ at 1.0 MeV. The changes observed after $1 \times 10^{16}$ $e/cm^2$ (0.5 MeV) were smaller than those observed at the higher energies, but significant degradation of the open-loop gain was observed after the 0.5 MeV irradiations.

The implications of these results to design engineers are that: (1) stable operation can be expected from these amplifiers at closed-loop gains of at least 100 until failure of the output stage limits operation altogether, (2) decreases in closed-loop gain on the order of 10 percent should be expected at relatively low exposures ($2 \times 10^{12}$ to $5 \times 10^{14}$ $e/cm^2$), (3) the circuits should be powered during irradiation, (4) for maximum gain stability, the highest supply voltages, compatible with the microcircuits and the system, should be used, and (5) the circuits are more sensitive to the higher energy irradiation.

Signetics SE501G

The SE501G is a general-purpose direct-coupled, wide-band amplifier with junction isolation fabricated within a monolithic silicon substrate by planar and epitaxial techniques. The circuit is designed to provide a number of externally variable feedback connections for variable voltage gain. A nominal voltage gain of 50 is specified with gain stability of ±2 dB over the full military temperature range.

The primary failure mode of the SE501G circuits under electron irradiation was the decrease in the closed-loop voltage gain below the failure level. It was arbitrarily determined that a 25 percent decrease in closed-loop gain would be considered a failure. Another output parameter that showed changes large enough to be of engineering significance was the output dc level. Changes in the positive and negative saturation voltages and the input dc level were not large enough to be of engineering significance. Tables 14 and 15 list the comparative percent average changes for the biased and unbiased SE501G circuits. These changes are given for the three electron energies used in the irradiations. The results of the measurements made during irradiation are presented in Figures 74 through 81 in the "Results" section. Changes in the output dc level and saturation voltages during the 0.5 MeV irradiation, and in the saturation voltages during the 1.5 MeV and 1.0 MeV irradiations were insignificant and are therefore not presented.

The changes in the closed-loop gain reflect the degradation of the transistors. Since negative feedback is used, the degradation of the transistors is much greater than is reflected by the changes in closed-loop gain. The dc operating point of the output transistor was also changed after radiation. These changes are reflected in the decrease observed in the output dc level.

TABLE 14. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE SE501G BIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Closed-Loop Gain | -24.9 | -21.1 | N.S. |
| Positive Saturation Voltage | -1.74 | -2.5 | N.S. |
| Negative Saturation Voltage | N.S. | N.S. | N.S. |
| Input Level Voltage | -1.5 | -1.2 | N.S. |
| Output Level Voltage | -10.3 | -9.5 | N.S. |
| Resistance | N.S. | N.S. | N.S. |
| Leakage Current | N.S. | N.S. | N.S. |
| $h_{FE}$ at $I_C$ = 50 $\mu$A | -78.9 | -73.1 | -50.4 |
| $V_{BE}$ at $I_C$ = 50 $\mu$A | N.S. | N.S. | N.S. |
| $h_{FE}$ at $I_C$ = 10 mA | -68.3 | -65.2 | -24.9 |
| $V_{BE}$ at $I_C$ = 10 mA | 3.7 | 3.7 | 0.5 |
| Gain Ratio = $\beta$ (10 mA)/$\beta$ (50 $\mu$A) | 48.4 | 25.3 | N.S. |
| Fluence to First Failure[(a)], e/cm$^2$ | $2 \times 10^{15}$ | $5 \times 10^{15}$ | $>1 \times 10^{16}$ |
| Total Fluence, e/cm$^2$ | $3 \times 10^{15}$ | $6 \times 10^{15}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Decrease in closed-loop gain by 25 percent.

TABLE 15. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE SE501G UNBIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Closed-Loop Gain | -37.0 | -30.9 | N.S. |
| Positive Saturation Voltage | -3.2 | -2.9 | N.S. |
| Negative Saturation Voltage | N.S. | N.S. | N.S. |
| Input Level Voltage | -2.3 | -2.1 | N.S. |
| Output Level Voltage | -14.2 | -12.8 | N.S. |
| Resistance | N.S. | N.S. | N.S. |
| Leakage Current | N.S. | N.S. | N.S. |
| $h_{FE}$ at $I_C$ = 50 $\mu$A | -78.7 | -75.0 | -44 |
| $V_{BE}$ at $I_C$ = 50 $\mu$A | N.S. | N.S. | N.S. |
| $h_{FE}$ at $I_C$ = 10 mA | -70.5 | -67.6 | -12.7 |
| $V_{BE}$ at $I_C$ = 10 mA | 4.7 | 3.9 | N.S. |
| Gain Ratio = $\beta$ (10 mA)/$\beta$ (50 $\mu$A) | 32.6 | 27.3 | 49.9 |
| Fluence to First Failure[(a)], e/cm$^2$ | $2 \times 10^{15}$ | $5 \times 10^{15}$ | $>1 \times 10^{16}$ |
| Total Fluence, e/cm$^2$ | $3 \times 10^{15}$ | $6 \times 10^{15}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Decrease in closed-loop gain by 25 percent.

Since these amplifiers are intended to be ac coupled, the changes in dc output level have relatively no effect on the other states used in a system. But the decrease in the dc level does decrease the maximum output voltage (dynamic range) of the amplifier. Since the negative saturation voltage does not change during irradiation, the decreases in the dc level voltage are reflected directly as decreases in dynamic range.

As shown in Tables 14 and 15, the changes in the unbiased samples were more severe than in the biased samples irradiated with 1.5 and 1.0 MeV electrons. The statistical analysis indicates at the 99 percent confidence level that for the voltage gain, positive saturation voltage[5], output dc level, and input dc level there were statistically significant differences between the biased and unbiased samples. The above statement applies to the circuits irradiated with the 1.5 and 1.0 MeV electrons. Only the differences noted for the closed-loop gain are of engineering significance. Since the biased circuits were irradiated with an ac ground at the input, these results indicate that operation under irradiation can significantly reduce the radiation damage. Although annealing was observed between the time the circuits were irradiated and post characterization measurements were made, the effect was not large enough to be of engineering significance.

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(5) For this parameter at 1.5 MeV the confidence level is 95 percent.

The degradation of the output parameters was found to increase with electron energy for both the biased and unbiased circuits. As Tables 14 and 15 indicate, no significant changes were observed for the 0.5 MeV irradiations. Voltage gain degradation of engineering significance was observed at $2 \times 10^{15}$ $e/cm^2$ during the 1.5 MeV electron irradiation while similar changes were observed at $5 \times 10^{15}$ $e/cm^2$ during the 1.0 MeV irradiations.

In addition to the output parameters of the amplifier, the current gain, $h_{FE}$, and the base emitter voltage, $V_{BE}$, of the output emitter follower transistor (Pins 5, 6, and 7) were characterized. These transistor parameters were measured at collector currents of 50 $\mu$A and 10 mA. Significant changes in the $h_{FE}$ parameter were noted at all energy levels. The changes in the $V_{BE}$ parameter were small and not of engineering significance. It is interesting to note that the decreases in gain are appreciably larger for the low-current measurements indicated by the increases in the gain ratio. These results are consistent with bulk damage effects. Thus, to minimize the radiation degradation, the transistors should be operated at the highest current level possible.

The implications of these results to design engineers are: (1) to obtain gain stability during irradiation, the circuits should be operated at the lowest possible closed-loop gain, (2) the circuits should be powered under irradiation, (3) the circuits are more sensitive to the higher energy electron irradiation. In addition, some decrease in degradation can be obtained by operating this circuit at the largest supply voltage compatible with the microcircuits and the system.

## Digital Circuits

### Introduction

The principal mode of failure for the digital circuits is attributed to degradation of the output transistor. Decreases in transistor current gain coupled with increases in transistor saturation voltage resulted in increases in the output low voltage of the gates and flip-flops. These changes were accompanied by decreases in input drive current and increases in the propagation delay. Since the primary failure mode for the digital circuits was the increase in output low voltage, the longevity of these circuits under irradiation can be increased by decreasing the fan-out of the circuits. The radiation response of these circuits is, in general, consistent with, and similar to the changes observed in Phase I and Phase II of this program.

The failure criterion, similar to that for the amplifier circuits, was any parameter exceeding the limits specified by the manufacturer. Failure limits were specified in this manner to be compatible with the information presently supplied to design engineers by the manufacturers.

### Summary

The LPDTμL9042 gates experienced first failure at a fluence of $1.4 \times 10^{16}$ e/cm$^2$ (1.5 MeV) when the output low voltage exceeded 0.25 volt. Temporary changes in the output low voltage were also observed. These temporary changes were observed during the 0.5 MeV irradiation in the exposure range of $5 \times 10^{12}$ e/cm$^2$ to $2 \times 10^{14}$ e/cm$^2$. The output low-level voltage of six of the ten biased samples increased and exceeded failure level. Both biased and unbiased samples were affected.

The changes in the LPDTμL9040 flip-flops were similar to those observed for the 9042 gates. The temporary anomalous behavior discussed for the 9042 gates was also observed for these circuits. Permanent changes in the output low voltage were observed at all energy levels. The first failure occurred after an exposure of $1 \times 10^{16}$ e/cm$^2$ (1.5 MeV).

The first failure for the SN54L71 gates occurred after an exposure of $1.9 \times 10^{16}$ e/cm$^2$ (1.5 MeV) when the output low voltage exceeded 0.30 volt. These changes were accompanied by increases in the propagation delay of the circuits. No failures were recorded after an exposure of $1 \times 10^{16}$ e/cm$^2$ at any of the three electron energy levels.

The primary failure mode of the RD310 gates was the increase in the output low-level voltage beyond 0.45 volt. First failure was recorded after an exposure of $5 \times 10^{14}$ e/cm$^2$ (1.5 MeV). Increases in the input-diode leakage current were also observed. Changes in the other parameters were small and not of engineering significance.

The RD321 circuits experienced first failure after an exposure of $2 \times 10^{15}$ e/cm$^2$ (1.5 MeV) when the output low-level voltage had increased beyond 0.45 volt. The post characterization measurements indicated that an additional failure mode was important. The flip-flops failed to respond to a standard clock pulse, i.e., would not change state, after irradiation. Since the circuits were not switched during irradiation, the fluence required to induce failures of this type was not determined. Changes of engineering significance were observed in the clocked input current, output high-level voltage and the input leakage current. The changes in drive currents and resistance were small and not significant.

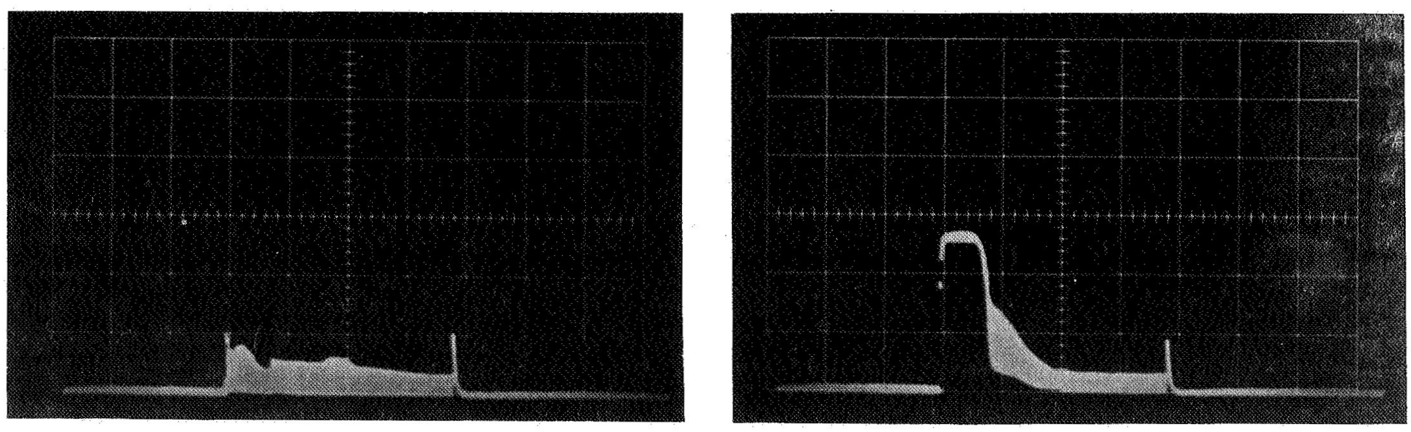
<u>Fairchild LPDTμL9042</u>

The LPDTμL9042 is a junction isolated DTL dual 4-input NAND/NOR gate. The circuit is fabricated on a silicon monolithic substrate using standard Fairchild Planar epitaxial process. The circuits are specifically designed for low power, medium speed application. The circuits are guaranteed to provide fan-outs of 10 in the full military temperature range. Typical propagation delay and power dissipation are 60 nanoseconds and less than 1 milliwatt, respectively.

The irradiation procedure for the 1.5 MeV irradiation was different than described previously. The circuits were irradiated to approximately $1 \times 10^{16}$ e/cm$^2$ and then taken out of the test jig. Two days later the circuits were reirradiated to an additional $1 \times 10^{16}$ e/cm$^2$. Thus, the total exposure was approximately $2 \times 10^{16}$ e/cm$^2$ at 1.5 MeV. The 1.0 MeV and 0.5 MeV irradiations were conducted to a total exposure of $1 \times 10^{16}$ e/cm$^2$ according to the outlined procedure.

The changes in the output low-level voltage, $V_{OL}$, were the most significant changes observed. During the second 1.5 MeV irradiation run the first failures ($V_{OL}$ exceeded 0.25 volt) were observed at a total exposure of $1.4 \times 10^{16}$ e/cm$^2$. No failures were observed during the 1.0 MeV irradiation run. In addition to the degradation of the $V_{OL}$ parameter, increases of engineering significance in the propagation delay (rise) were observed at the 1.5 and 1.0 MeV energies. The changes in the other parameters were not sufficiently large to be of engineering significance.

During the 0.5 MeV irradiation run, significant changes in the $V_{OL}$ and $V_{OH}$, parameters were observed at rather low exposures. Beginning at the exposure level of 5 x $10^{12}$ e/cm$^2$ the $V_{OL}$ parameter began to increase while the $V_{OH}$ parameter decreased. At 1 x $10^{13}$ e/cm$^2$ the $V_{OL}$ parameter for six of the ten biased samples had increased above the failure level. The pulsed devices also showed anomalous behavior at an exposure of 1 x $10^{13}$ e/cm$^2$. Figure 24 shows the output response of two unbiased circuits at 1 x $10^{13}$ e/cm$^2$. The outputs of all the biased samples were found to be oscillating at a high frequency. The irradiation of the devices was continued and, by an exposure of 2 x $10^{14}$ e/cm$^2$, all the devices (biased and pulsed) had resumed normal operation.



Vertical Scale: 1 V/cm

Horizontal Scale: 2 $\mu$s/cm

FIGURE 24. OUTPUT RESPONSE OF UNBIASED LPDT$\mu$L9042 CIRCUITS AT 1 x $10^{13}$ e/cm$^2$ (0.5 MeV)

At an exposure of $4 \times 10^{15}$ $e/cm^2$ (0.5 MeV), Sample 1 of the biased circuits failed and did not recover. Irradiation was terminated at $1 \times 10^{16}$ $e/cm^2$. Examination of Sample 1 after irradiation indicated development of a resistive path, between the input diodes and the substrate, that shunted the base current of the output transistor to ground. The circuit was not operational during postirradiation measurements. This isolated failure is not believed to be correlated to the unstable behavior described earlier. Except for Sample 1, no engineering significant permanent changes were observed between the pre/post characterization data for the 0.5 MeV irradiated circuits. While some minor changes in $V_{OL}$ and propagation delay (fall) occurred, conclusions cannot be drawn because of the large variation within the groupings.

Tables 16 and 17 list the comparative percent average changes for the biased and unbiased circuits. These changes are given for the three electron energies used in the irradiations. The results of the measurements made during irradiation are presented in Figures 83 through 90. The results from the first irradiation run at 1.5 MeV are presented in Figure 88 while Figure 89 represents results from the second 1.5 MeV run. The output high-level response is presented only for the 0.5 MeV irradiation run, since the observed changes in this parameter for the 1.5 and 1.0 MeV irradiations were not of engineering significance. In addition to the radiation-response curves, the raw in situ data is presented in tabular form for the 0.5 MeV irradiation run.

The permanent degradation in electrical parameters can be attributed principally to decreases in transistor gain. The decrease in gain is exemplified by the increases in the $V_{OL}$ parameter and the increase in the rise time of the output transistor. No significant differences, at the 95 percent confidence

TABLE 16. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE LPDTμL9042 BIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage | 295 | 36 | 4.9 |
| Output High Voltage | N.S. | N.S. | N.S. |
| Input Low Voltage | N.S. | -1.6 | N.S. |
| Input High Voltage | 1.0 | -2.0 | N.S. |
| Input Drive Current | -3.9 | -1.7 | N.S. |
| Input Leakage Current | N.S. | N.S. | N.S. |
| Diode Forward Voltage | -1.8 | 0.8 | N.S. |
| Resistance | 6.9 | N.S. | N.S. |
| Propagation Delay (Rise) | 214 | 22 | N.S. |
| Propagation Delay (Fall) | -4.0 | N.S. | 32.8 |
| Fluence to First Failure[a], e/cm$^2$ | $1.4 \times 10^{16}$ | $>1.0 \times 10^{16}$ | $5 \times 10^{12}$[b] |
| Total Fluence, e/cm$^2$ | $2 \times 10^{16}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low-level voltage exceeds 0.25 volt.

(b) Circuits recovered after further irradiation (see text).

TABLE 17. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE LPDTμL9042 UNBIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage | 131 | 26 | 2.1 |
| Output High Voltage | N.S. | N.S. | N.S. |
| Input Low Voltage | N.S. | -1.5 | N.S. |
| Input High Voltage | 4.0 | N.S. | N.S. |
| Input Drive Current | -2.6 | -1.9 | N.S. |
| Input Leakage Current | N.S. | N.S. | N.S. |
| Diode Forward Voltage | -2.0 | 0.8 | N.S. |
| Resistance | 5.6 | N.S. | N.S. |
| Propagation Delay (Rise) | 108 | 24.7 | N.S. |
| Propagation Delay (Fall) | -14.7 | N.S. | 14.8 |
| Fluence to First Failure[(a)], e/cm$^2$ | >2 x $10^{16}$ | >1 x $10^{16}$ | 1 x $10^{13}$[(b)] |
| Total Fluence, e/cm$^2$ | 2 x $10^{16}$ | 1 x $10^{16}$ | 1 x $10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low-level voltage exceeds 0.25 volt.

(b) Circuits recovered after further irradiation (see text).

level, were observed between the biased and unbiased test groups. No significant postirradiation annealing was observed in either the biased or unbiased circuits.

With reference to the anomalous effects observed during the 0.5 MeV irradiation of these circuits, all devices were affected to some degree in the $5 \times 10^{12}$ e/cm$^2$ to $2 \times 10^{14}$ e/cm$^2$ exposure range. The temperature of the devices did not vary from room temperature enough to attribute these observations to changes in temperature. No model has been proposed to date to explain the behavior of these circuits, although evidence would indicate that surface effects could be responsible for the observed behavior. Exposure rate cannot be overlooked as a significant factor in affecting this behavior. An attempt to isolate the source of the problem area is not feasible from the data taken because of the temporary nature of the effects observed.

The permanent degradation of device parameters was most severe for the 1.5 and 1.0 MeV irradiations. The observed changes in the $V_{OL}$ parameter up to $1 \times 10^{16}$ e/cm$^2$ were not significantly different for the 1.5 and 1.0 MeV irradiations.

The implications of these results to design engineers are: (1) the possibility of failure resulting from relatively low energy electrons should be considered even though the effects seem to be temporary in nature, (2) to obtain increased radiation longevity, the fan-out of the circuits should be decreased, and (3) the circuits are more sensitive, in terms of permanent degradation, to the higher energy electrons.

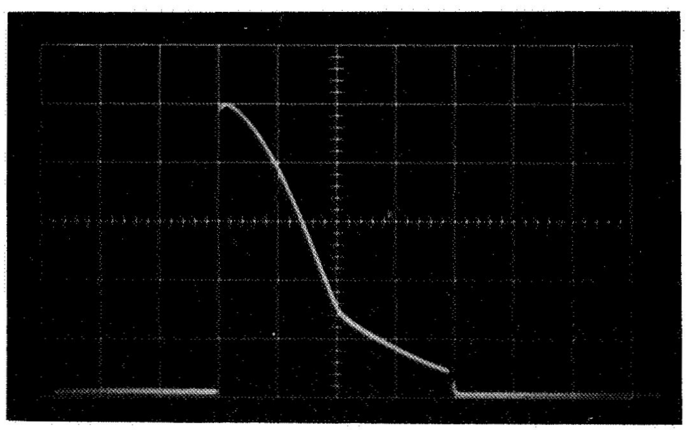
Fairchild LPDTμL9040

The LPDTμL9040 is a junction isolated DTL directly coupled, dual-rank flip-flop that can be operated in either the R-S or J-K mode. The circuit is fabricated with a silicon monolithic substrate using standard Fairchild Planar epitaxial process and is specifically designed for low-power, medium-speed application. The circuits are guaranteed to provide fan-outs of 10 in the full military temperature range. Typical binary clock rate and power dissipation are 2.5 megahertz and less than 4 milliwatts respectively.

The effects of radiation exposure on the LPDTμL9040 circuits are similar to, and consistent with, those observed for the LPDTμL9042 circuits. The changes in the output low-level voltages, $V_{OL}$ were the most significant changes observed. During the 1.5 MeV irradiation the $V_{OL}$ parameter for two unbiased circuits exceeded the failure level (0.25 volt) at an electron fluence of $1 \times 10^{16}$ e/cm$^2$. With the exception of these two units, no other failures were recorded during either the 1.5 MeV or the 1.0 MeV irradiations. Permanent changes in the $V_{OL}$ parameter were noted at all energy levels. The changes in the other parameters were not sufficiently large to be of engineering significance.

During the 0.5 MeV irradiation run significant changes in the $V_{OL}$ and $V_{OH}$ parameters were observed. Beginning at $5 \times 10^{12}$ e/cm$^2$ the $V_{OL}$ parameter began to increase significantly. Immediately after the irradiation had been terminated at $1 \times 10^{13}$ e/cm$^2$, the $V_{OL}$ parameter of these two circuits was near 5 volts. While the radiation was off, recovery in the output voltage was observed. The irradiation rate was then reduced to $1 \times 10^8$ e/cm$^2$·s and the circuits irradiated for 15 minutes. No increases in the output voltages were observed. Irradiation was then continued at an increased flux. By 2 x $10^{14}$ e/$cm^2$ all devices had resumed normal operation.

Only one of the unbiased circuits showed anomalous behavior at 1 x $10^{13}$ e/$cm^2$. Figure 25 is a photograph of the observed output response. No oscillation was observed at the output of the pulsed circuits. Except for slight increases in the $V_{OL}$ parameters, no statistically significant changes were observed between the pre/post characterization data for the 0.5 MeV irradiated circuits.



Vertical Scale: 1 V/cm
Horizontal Scale: 2 $\mu$s/cm

FIGURE 25. OUTPUT RESPONSE OF A UNBIASED LPDT$\mu$L9040 CIRCUIT AT 1 x $10^{13}$ e/$cm^2$ (0.5 MeV)

TABLE 18. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE LPDTμL9040 BIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage at Q | 122 | 26.2 | 3.1 |
| Output Low Voltage at $\overline{Q}$ | 68.2 | 22.7 | 3.1 |
| Output High Voltage at Q | N.S. | N.S. | N.S. |
| Output High Voltage at $\overline{Q}$ | N.S. | N.S. | N.S. |
| Input Current (CD) | 5.9 | 2.2 | N.S. |
| Input Current (SD) | 7.4 | N.S. | N.S. |
| Input Current (CP) | 6.6 | 1.3 | N.S. |
| Leakage Current (CD) | N.S. | 35 | N.S. |
| Resistance | 2.3 | 1.7 | N.S. |
| Propagation Delay (Rise) | -5.5 | 2.0 | N.S. |
| Propagation Delay (Fall) | 13 | N.S. | N.S. |
| Minimum Clock Amplitude | N.S. | N.S. | N.S. |
| Minimum Voltage at Cl | N.S. | N.S. | N.S. |
| Fluence to First Failure[(a)], $e/cm^2$ | $>1 \times 10^{16}$ | $>1 \times 10^{16}$ | $1 \times 10^{13}$[(b)] |
| Total Fluence, $e/cm^2$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low voltage exceeds 0.25 volt.

(b) Circuits recovered after further irradiation (see text).

TABLE 19. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE LPDTμ9040 UNBIASED CIRCUITS

| Description / Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage at Q | 176 | 32.5 | 3.3 |
| Output Low Voltage at $\overline{Q}$ | 210 | 33.9 | 2.0 |
| Output High Voltage at Q | N.S. | N.S. | N.S. |
| Output High Voltage at $\overline{Q}$ | N.S. | N.S. | N.S. |
| Input Current (CD) | 9.4 | 2.3 | N.S. |
| Input Current (SD) | 5.1 | N.S. | N.S. |
| Input Current (CP) | 9.1 | 2.4 | N.S. |
| Leakage Current (CD) | 27 | N.S. | 24.2 |
| Resistance | 1.7 | N.S. | N.S. |
| Propagation Delay (Rise) | -11.2 | N.S. | N.S. |
| Propagation Delay (Fall) | N.S. | N.S. | N.S. |
| Minimum Clock Amplitude | N.S. | N.S. | N.S. |
| Minimum Voltage at C1 | N.S. | N.S. | N.S. |
| Fluence to First Failure[a], $e/cm^2$ | $1 \times 10^{16}$ | $>1 \times 10^{16}$ | $5 \times 10^{12}$[b] |
| Total Fluence, $e/cm^2$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low voltage exceeds 0.25 volt.

(b) Circuits recovered after further irradiation (see text).

Tables 18 and 19 list the comparative percent average changes for the biased and unbiased circuits. These changes are given for the three electron energies used in the irradiations. The results of the measurements made during irradiation are presented in Figures 92 through 98. The output high-level response is presented only for the 0.5 MeV irradiation run, since no changes were observed in this parameter during the 1.5 and 1.0 MeV irradiations. In addition to the radiation response curves the raw in situ data is presented in tabular form for the 0.5 MeV irradiation run.

The permanent degradation in electrical parameters can be attributed to decreases in transistor gain. The changes observed were similar to those recorded for the LPDTμL9042 gates. The statistical analysis indicates that there were no significant differences between the circuits biased in one state only and the unbiased samples. Only slight recovery was observed in either the biased or unbiased samples.

The permanent degradation of device parameters was found to increase with electron energy for both the biased and unbiased circuits. The statistical analysis indicates, with 99 percent confidence, for permanent changes in the low-level output voltages at Q and $\overline{Q}$, input current at SD and CP, and propagation delay (rise) that there were statistically significant differences between the circuits irradiated at 1.5, 1.0, and 0.5 MeV.

The comments made for the LPDTμL9042 circuit concerning the anomalous behavior during the 0.5 MeV irradiations and the design steps for increasing survival ability in the radiation environment are also applicable for the LPDTμL9040 circuits.

Texas Instruments SN54L20

The SN54L20 is a p-n junction isolated TTL dual 4-input NAND gate. These circuits are fabricated on a single monolithic silicon chip using passivated epitaxial techniques. The circuits provide a fan-out of 10 in the full military temperature range and are intended for use in relatively high-speed, low-power systems. The typical propagation delay and power dissipation are 33 nanoseconds and 1 milliwatt, respectively.

The irradiation procedure for the 1.5 MeV irradiation was different than that described previously. The circuits were irradiated to $1 \times 10^{16}$ e/cm$^2$ and then taken out of the test jig. Two days later the circuits were reirradiated to an additional $1 \times 10^{16}$ e/cm$^2$. Thus, the total exposure was $2 \times 10^{16}$ e/cm$^2$ at 1.5 MeV. The 1.0 MeV and the 0.5 MeV irradiations were conducted to a total exposure of $1 \times 10^{16}$ e/cm$^2$ according to the outlined procedure.

The changes in the output low-level voltage, $V_{OL}$, were the most significant changes observed. During the second 1.5 MeV irradiation run the first failures ($V_{OL}$ exceeded 0.30 volt) were observed at a total exposure of $1.9 \times 10^{16}$ e/cm$^2$. No failures were observed during the 0.5 or 1.0 MeV irradiation runs.

In addition to the degradation of the $V_{OL}$ parameter, increases of engineering significance were observed in the propagation delay (rise) at the 1.5, 1.0, and 0.5 MeV electron energies and the propagation delay (fall) at the 1.5 MeV energy. No changes of engineering significance were observed in the other parameters. Tables 20 and 21 list the comparative percent average changes for the biased and unbiased SN54L20 circuits. Changes are given for the three electron energies used in the irradiations. The results of the measurements

TABLE 20. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE SN54L20 BIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage | 213 | 89.6 | 20.6 |
| Output High Voltage | N.S. | N.S. | N.S. |
| Input Low Voltage | -3.6 | N.S. | -2.4 |
| Input High Voltage | -5.3 | N.S. | -3.2 |
| Input Drive Current | -10.5 | -9.9 | -7.2 |
| Input Leakage Current | N.S. | N.S. | N.S. |
| Propagation Delay (Rise) | 105 | 69.8 | 36.6 |
| Propagation Delay (Fall) | 61 | N.S. | N.S. |
| Power-Supply Current (One) | -10 | N.S. | N.S. |
| Power-Supply Current (Zero) | -10 | N.S. | N.S. |
| Fluence to First Failure[a], e/cm$^2$ | $1.9 \times 10^{16}$ | $>1 \times 10^{16}$ | $>1 \times 10^{16}$ |
| Total Fluence, e/cm$^2$ | $2 \times 10^{16}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(c) Output low-level voltage exceeds 0.30 volt.

TABLE 21. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE SN54L20 UNBIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage | 455 | 87.6 | 14.6 |
| Output High Voltage | N.S. | N.S. | N.S. |
| Input Low Voltage | N.S. | -2.9 | N.S. |
| Input High Voltage | -4.4 | -4.5 | 3.4 |
| Input Drive Current | -8.13 | N.S. | N.S. |
| Input Leakage Current | N.S. | N.S. | N.S. |
| Propagation Delay (Rise) | 131 | 82.9 | N.S. |
| Propagation Delay (Fall) | 46.9 | N.S. | N.S. |
| Power-Supply Current (One) | -8.6 | -6.5 | N.S. |
| Power-Supply Current (Zero) | -8.6 | -6.3 | N.S. |
| Fluence to First Failure[(a)], e/cm$^2$ | $1.5 \times 10^{16}$ | $>1 \times 10^{16}$ | $>1 \times 10^{16}$ |
| Total Fluence, e/cm$^2$ | $2 \times 10^{16}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

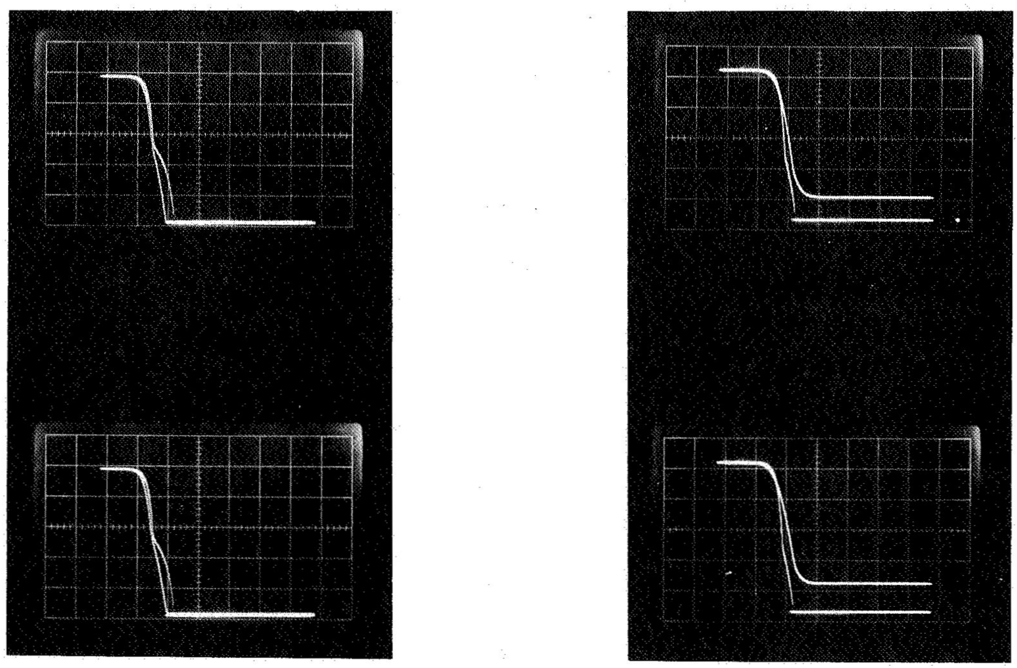
NOTE: N.S. = No statistically significant change.

(a) Output low voltage exceeds 0.30 volt.

made during irradiation are presented in Figures 100 through 106 in the "Results" section. Only the output low-level response is presented, since no changes of engineering significance were observed in the output high-level voltage.

The observed degradation of the $V_{OL}$ parameter may be attributed to decreases in transistor gain and increases in the $r_{sat}$ parameter. Since the drive to the gain stages of the gate circuits remains relatively constant during irradiation, the amount of current the gate can sink is roughly proportional to the square of the transistor current gain ($\beta^2$). This conclusion is reinforced by the circuit propagation delay increases and by the effects of changes in fan-out on a typical circuit voltage transfer characteristic. Figures 26a and 26b are double-exposure photographs comparing the input-output voltage transfer characteristics of typical irradiated and nonirradiated circuits (not the same circuit). The circuits whose waveforms appear in Figure 26a had an equivalent fan-out of one load. Figure 26b illustrates the effects of a fan-out of ten on the same circuits. As may be seen in the photographs, the circuits with a fan-out of one are operating normally while at a fan-out of ten, a significant increase in $V_{OL}$ is apparent.

Referring to Tables 20 and 21 the change in the unbiased circuits were, in general, similar to those observed in the biased circuits. However, statistically significant differences (at the 95 percent confidence level) in output low-level voltage, drive current and logic one power-supply current were observed between the 1.5 MeV biased and unbiased groups. Only the changes in the output low-level voltage are considered to be of engineering significance. The percent change in $V_{OL}$ was a factor of two greater in the 1.5 MeV unbiased group as compared to the biased group. These data suggest that annealing of radiation damage may occur in those circuits that are biased during radiation.



a. Fan-out = 1 b. Fan-out = 10

Vertical Scale: 1 V/cm

Horizontal Scale: 0.2 V/cm

FIGURE 26. VOLTAGE TRANSFER CHARACTERISTICS OF TYPICAL SN54L20 CIRCUITS

The parameter degradation appeared to be an increasing function of the electron energy for both the biased and unbiased group. The changes observed were greater for the 1.5 and 1.0 MeV groups than for the 0.5 MeV group. The observed increases in the output low voltage up to 1 x $10^{16}$ $e/cm^2$ were similar for the 1.5 MeV and 1.0 MeV irradiations.

The implications of these results to design engineers are: (1) to obtain increased radiation longevity, the fan-out of the circuits should be decreased, (2) the circuits should be powered during exposure, and (3) the circuits appear to be more sensitive to the higher energy electron irradiations.

Texas Instruments SN54L71

The SN54L71 is a junction isolated TTL, RS master-slave flip-flop. The circuits are intended for low-power and relatively high-speed applications. The circuits are designed to provide a fan-out of 10 in the full military temperature range. Typical clock rate and power dissipation are 3 megahertz and 3.8 milliwatts, respectively.

No circuit failures were observed during irradiation. However, changes of engineering significance did occur in the output low-level voltage at Q, $\overline{Q}$, and the propagation delay. The changes in the input, leakage, and power-supply currents were small and not of engineering significance. Tables 22 and 23 list the comparative percent average changes for the biased and unbiased SN54L71 circuits. The results of measurements made during irradiation are presented in Figures 108 through 114 in the "Results" section. The output high-level response is presented only for the 1.5 MeV irradiation range since the observed changes were not of engineering significance at the other electron energies.

TABLE 22. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE BIASED SN54L71 CIRCUITS

| Description Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage at Q | 111 | 55.6 | 17.4 |
| Output Low Voltage at $\overline{Q}$ | 82.9 | 46.9 | 12.9 |
| Output High Voltage at Q | N.S. | N.S. | N.S. |
| Output High Voltage at $\overline{Q}$ | N.S. | N.S. | N.S. |
| Input Current at $R_1$ | N.S. | -4.4 | -3.1 |
| Input Current at Preset | 3.7 | N.S. | -1.9 |
| Leakage Current at $R_1$ | -50.6 | N.S. | N.S. |
| Leakage Current at Preset | N.S. | N.S. | N.S. |
| Resistance | N.S. | N.S. | N.S. |
| Propagation Delay (Rise) | 20.8 | 23.2 | 12.1 |
| Propagation Delay (Fall) | 47.7 | 34.5 | 32.2 |
| Power-Supply Current | -7.01 | -5.6 | -3.69 |
| Fluence to First Failure[(a)], e/cm$^2$ | >1 x $10^{16}$ | >1 x $10^{16}$ | >1 x $10^{16}$ |
| Total Fluence, e/cm$^2$ | 1 x $10^{16}$ | 1 x $10^{16}$ | 1 x $10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low-level voltage exceeds 0.3 volt.

TABLE 23. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE UNBIASED SN54L71 CIRCUITS

| Description | Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|---|
| Output Low Voltage at Q | | 94.0 | 59.0 | 17.2 |
| Output Low Voltage at $\overline{Q}$ | | 96.7 | 61.7 | 16.7 |
| Output High Voltage at Q | | N.S. | N.S. | N.S. |
| Output High Voltage at $\overline{Q}$ | | N.S. | N.S. | N.S. |
| Input Current at $R_1$ | | -3.78 | N.S. | -3.9 |
| Input Current at Preset | | 58.7 | 22.8 | N.S. |
| Leakage Current at $R_1$ | | -54.4 | -46.2 | N.S. |
| Leakage Current at Preset | | N.S. | N.S. | N.S. |
| Resistance | | N.S. | N.S. | N.S. |
| Propagation Delay (Rise) | | 35.3 | 29.7 | 10.8 |
| Propagation Delay (Fall) | | 31.3 | 33.2 | 22.7 |
| Power-Supply Current | | -5.9 | -4.8 | -3.7 |
| Fluence to First Failure[a], $e/cm^2$ | | $>1 \times 10^{16}$ | $>1 \times 10^{16}$ | $>1 \times 10^{16}$ |
| Total Fluence, $e/cm^2$ | | $1 \times 10^{16}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low-level voltage exceeds 0.3 volt.

Table 22 shows that the degradation of output low-level voltage was not symmetric for the biased circuits. The changes in the output low-level voltage at Q were larger for all three electron energies. It is to be noted that the circuits were maintained in one state, i.e., Q was high and $\overline{Q}$ was low during irradiation. These results indicate that less severe degradation occurred in the more heavily conducting $\overline{Q}$ side of the flip-flop. These changes in the output low voltage are characteristic of decreases in the output-transistor current gain. The increases in the propagation delay also reflect the decrease in transistor current gain. The decrease in the leakage current at the preset terminal result from decreases in the inverse current gain of the input transistor.

One circuit, No. 4, of the 0.5 MeV group, failed to operate when post-irradiation measurements were made. The state of the circuit could not be changed with either a clock pulse or dc voltage at the set terminal. Investigation revealed a short circuit between the preset terminal and circuit common. The exposure at which failure occurred could not be determined since the circuits were not switched during irradiation.

It is interesting to observe in Tables 22 and 23 that differences of statistical and engineering significance existed between the $\overline{Q}$ low-level-voltage parameters for the biased and unbiased groups. It may be seen that the effects of radiation, on the heavily conducting $\overline{Q}$ $V_{OL}$ parameter, were less severe for the biased group. This fact strengthens the contention that the application of bias tends to reduce the deleterious effects of radiation.

The changes in output parameters appeared to be energy dependent and were observed to be progressively greater with increased electron energy.

The implications of these results to design engineers are: (1) to obtain increased radiation longevity, the fan-out of the circuits should be decreased, (2) the circuits should be powered during exposure, and (3) the circuits appear to be more sensitive to the higher energy electron irradiations.

Radiation Incorporated RD310

The RD310 is a dielectrically isolated DTL dual 4-input NAND/NOR gate. This circuit is fabricated on a single monolithic silicon chip using passivated epitaxial techniques and is intended for use in high-speed low-power systems. The circuits are designed to provide fan-outs of 5 in the full military temperature range. Typical propagation delay and power dissipation are 7 nanoseconds and 10 milliwatts, respectively.

The primary failure mode of the RD310 circuits under electron irradiation was the increase in the output low-level voltage beyond the specified limit of 0.45 volt. Figure 27 shows the input-output-voltage transfer characteristics of a typical irradiated and nonirradiated RD310 circuit (not the same circuit) photographed simultaneously. Figure 27a is at fan-out of 1 and Figure 27b is at fan-out of 5. The irradiated sample has the lower input threshold in both photographs. These photographs indicate that there is relatively no difference between the irradiated and control samples at fan-out of 1 whereas at fan-out of 5 the differences in voltage gain and $V_{OL}$ voltage are obvious. Another parameter which showed changes large enough to be of engineering significance was the input diode leakage current. Changes in the remaining parameters, specifically the output high-level voltage, were small and not of engineering significance. Tables 24 and 25 list the comparative percent average changes

TABLE 24. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE RD310 BIASED CIRCUITS

| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage | 175 | 195 | 25 |
| Output High Voltage | N.S. | N.S. | N.S. |
| Input Low Voltage | -4.7 | -5.0 | -2.5 |
| Input High Voltage | -4.9 | -5.2 | -3.0 |
| Input Drive Current | -1.3 | -2.0 | -2.0 |
| Input Leakage Current | 46 | 27 | N.S. |
| Diode Forward Voltage | 1.6 | 1.7 | .60 |
| Resistance | N.S. | N.S. | N.S. |
| Propagation Delay (Rise) | N.S. | N.S. | N.S. |
| Propagation Delay (Fall) | N.S. | N.S. | N.S. |
| Fluence to First Failure[a], $e/cm^2$ | $5 \times 10^{14}$ | $2 \times 10^{15}$ | $>1 \times 10^{16}$ |
| Total Fluence, $e/cm^2$ | $1 \times 10^{15}$ | $3 \times 10^{15}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

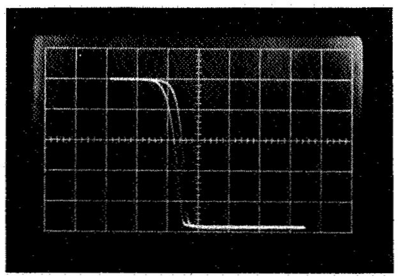
(a) Output low-level voltage exceeds 0.45 volt.

TABLE 25. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE RD310 UNBIASED CIRCUITS

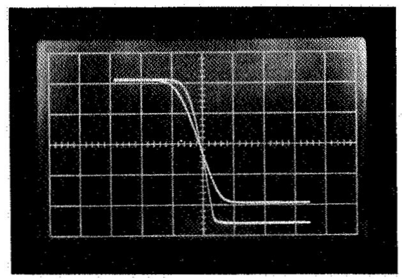
| Description \ Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage | 623 | 434 | 31 |
| Output High Voltage | N.S. | N.S. | N.S. |
| Input Low Voltage | -5.1 | -4.8 | -3.2 |
| Input High Voltage | -4.9 | -4.6 | -3.9 |
| Input Drive Current | -1.5 | -1.7 | -1.2 |
| Input Leakage Current | 64 | 184 | 33 |
| Diode Forward Voltage | 2.4 | 1.9 | 0.80 |
| Resistance | N.S. | N.S. | N.S. |
| Propagation Delay (Rise) | N.S. | N.S. | N.S. |
| Propagation Delay (Fall) | N.S. | N.S. | N.S. |
| Fluence to First Failure[a], e/cm$^2$ | $5 \times 10^{14}$ | $1 \times 10^{15}$ | $>1 \times 10^{16}$ |
| Total Fluence, e/cm$^2$ | $1 \times 10^{15}$ | $3 \times 10^{15}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low-level voltage exceeds 0.45 volt.



a. Fan-out = 1



Fan-out = 5

Vertical Scale: 1 V/cm
Horizontal Scale: 0.2 V/cm

FIGURE 27. INPUT-OUTPUT-VOLTAGE TRANSFER CHARACTERISTIC OF TYPICAL RD310 CIRCUITS

for the biased and unbiased RD310 circuits. Changes are given for the three electron energies used in the irradiations. The results of the measurements made during irradiation are presented in Figures 116 through 121 in the "Results" section. Only the output low-level response is presented, since no changes of engineering significance were observed in the output high-level voltage. Referring to Figure 116 the anomalous change in the output low-level response at $1 \times 10^{12}$ e/cm$^2$ is small (0.015 volt) and cannot be attributed to a specific mechanism.

The observed degradation in the $V_{OL}$ parameter can be attributed to decreases in transistor gain and increases in the $r_{sat}$ parameter. Since the base current of the gate remains relatively constant during radiation, the amount of current that the gate can sink is proportional to the current gain. Rough calculations indicate that approximately a factor of 2 decrease in gain was required to increase the $V_{OL}$ voltage to the failure level (0.45 volt).

Tables 24 and 25 indicate that the changes in the unbiased circuits were more severe than in the biased circuits at all energy levels. The statistical analysis indicates, with 99 percent confidence, that for the parameters of output low-level voltage, diode forward voltage, and input leakage current there were statistically significant differences between the biased and unbiased samples for the 1.5 MeV irradiations. With 95 percent confidence, for the parameters of output low-level voltage and diode forward voltage there were statistically significant differences between the biased and unbiased samples for the 1.0 MeV irradiations. Also, with a 95 percent confidence, for the parameter of input leakage current, there were statistically significant differences between the biased and unbiased samples for the 0.5 MeV irradiations. It should be pointed out that the biased circuits were irradiated with the output transistor turned off. These results indicate that operation can cause significant annealing of radiation-induced damage. This conclusion is enforced by the results of the dc operation and measurement of the $V_{OL}$ parameter made immediately after the radiation exposure was terminated. The dc measurements were significantly lower than the pulsed measurements. For example, the pulsed measurements after $3 \times 10^{15}$ e/cm$^2$ (1.0 MeV) indicated an average $V_{OL}$ = 1.9 volts while dc measurements, at approximately the same time, resulted in an average $V_{OL}$ = 1.1 volts.

The degradation of device parameters resulting from irradiation was found to increase with electron energy. Significant degradation was observed at $5 \times 10^{14}$ e/cm$^2$ for the 1.5 MeV electrons, while similar changes were observed at $1 \times 10^{15}$ e/cm$^2$ at the 1.0 MeV electron irradiations. Changes in parameter values occurred near $1 \times 10^{16}$ e/cm$^2$ for the 0.5 MeV electrons. These results may be roughly compared to Phase II's RD210 circuit (similar to RD310)[6] irradiated with 3.0 MeV electrons. The RD210 showed significant changes in the $V_{OL}$ parameter at an electron fluence of $4.15 \times 10^{14}$ e/cm$^2$.

The implications of these results to design engineers are: (1) to obtain increased radiation longevity, the fan-out of the circuits should be decreased, (2) the circuits should be powered under irradiation, and (3) the circuits are more sensitive to the higher-energy-electron irradiations. To take advantage of the additional base drive, the circuits should be operated at the largest supply voltage compatible with the microcircuits and the system.

Radiation Incorporated RD321

The RD321 is a dielectrically isolated, dual-pulse triggered binary. This circuit is a member of the 300 Series DTL circuits fabricated using passivated epitaxial techniques and is intended for use in high-speed low-power systems. The circuits are designed to provide a fan-out of 5 in the full military temperature range. The circuit will operate as a binary counter at speeds in excess of 20 MHz and typical power dissipation is 24 milliwatts.

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(6) The RD210 essentially has more gain in the output transistor and can drive a larger fan-out. The comparison here is carried out at full fan-out for both device types and hence it would require essentially the same percentage decrease in gain of the output transistor to achieve the defined failure threshold for the low-level output voltage.

The primary failure modes of the RD321 flip-flops were the increases observed in the output low-level voltage beyond the specified limit of 0.45 volt and the failure of the circuits to respond to a standard clock pulse (4.5 volts, 1 MHz, a 5 $\mu$sec pulse width), i.e., would not change state. Changes of engineering significance were also observed in the output high-level voltage, the clocked input current, and the input leakage current. The changes in resistance and the drive currents were small and not of engineering significance. Tables 26 and 27 list the comparative changes as a percent average change for the biased and unbiased RD310 circuits. These changes are given for the three electron energies used in the irradiations. The results of the measurements made during irradiation are presented in Figures 123 through 129 in the "Results" section. The output high-level response is presented only for the 1.5 MeV irradiation run since the observed changes were not of engineering significance for this parameter at the other electron energies.

Note in Table 26 that the degradation of the flip-flops was not symmetric for the biased circuits. That is, the changes in the output low-level voltage at the $\overline{Q}$ terminal were appreciably larger than at the Q terminal. In fact, the degradation of one side of the flip-flops which were irradiated with 1.0 and 1.5 MeV electrons was so severe that the circuits, when cross coupled and clocked, would not change state. The state of the flip-flop could be changed, however, by increasing $V_{CC}$ or by applying the proper dc voltages directly on the clocked input. Since the circuits were maintained in one state during the total radiation exposure, these change-of-state failures were not observed until post characterization data were obtained. For this reason the critical fluence for change-of-state failures was not determined. The data also indicate that there were cases where the output low-voltage levels had

TABLE 26. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE RD321 BIASED CIRCUITS

| Description Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage at Q | 127 | 73 | 9 |
| Output Low Voltage at $\overline{Q}$ | 601 | 319 | 12 |
| Output High Voltage at Q | -34 | -19 | N.S. |
| Output High Voltage at $\overline{Q}$ | N.S. | N.S. | N.S. |
| Input Current (RC) | N.S. | N.S. | N.S. |
| Input Current (RD) | -4 | -4 | -2 |
| Input Current (CP) | -16 | -14 | -5 |
| Leakage Current (RD) | 123 | 106 | N.S. |
| Resistance | 1.61 | 1.68 | N.S. |
| Propagation Delay (Rise) | (b) | (b) | N.S. |
| Propagation Delay (Fall) | (b) | (b) | N.S. |
| Fluence to First Failure[(a)], $e/cm^2$ | $2 \times 10^{15}$ | $9 \times 10^{15}$ | $>1 \times 10^{16}$ |
| Total Fluence, $e/cm^2$ | $3 \times 10^{15}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low-level voltage exceeds 0.45 volt.

(b) Could not be switched.

TABLE 27. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE RD321 UNBIASED CIRCUITS

| Description Energy | 1.5 MeV | 1.0 MeV | 0.5 MeV |
|---|---|---|---|
| Output Low Voltage at Q | 599 | 1450 | 16 |
| Output Low Voltage at $\overline{Q}$ | 724 | 1550 | 16 |
| Output High Voltage at Q | -35 | -28 | N.S. |
| Output High Voltage at $\overline{Q}$ | -16 | -25 | N.S. |
| Input Current (RC) | N.S. | N.S. | N.S. |
| Input Current (RD) | -3.6 | -4.5 | -2.3 |
| Input Current (CP) | -20 | -26 | -6 |
| Leakage Current (RD) | 106 | 82 | N.S. |
| Resistance | 1.78 | 1.90 | 1.14 |
| Propagation Delay (Rise) | (b) | (b) | N.S. |
| Propagation Delay (Fall) | (b) | (b) | N.S. |
| Fluence to First Failure[(a)], e/cm$^2$ | $1 \times 10^{15}$ | $2 \times 10^{15}$ | $>1 \times 10^{16}$ |
| Total Fluence, e/cm$^2$ | $3 \times 10^{15}$ | $1 \times 10^{16}$ | $1 \times 10^{16}$ |

NOTE: N.S. = No statistically significant change.

(a) Output low-level voltage exceeds 0.45 volt.

(b) Could not be switched.

not exceeded the failure level of 0.45 volt for circuits which would not switch. These results indicate that two failure modes are important. The first is the increase in the output low-level voltage, and the second is the failure of the flip-flops to respond to a standard clock pulse. These failure modes are the result of decreased transistor gain. In the first case the output transistor cannot be maintained in saturation while in the second case there is not enough gain to switch the circuit. The changes observed in the output high-level voltage and the clock input current are consistent with decreases in transistor gain. Increases in leakage currents are the result of softened diode reverse characteristics.

The changes to the output characteristics were most severe for the unbiased circuits at all energy levels. The statistical analysis indicates, with 98 percent confidence, for the low-level output Q voltage, high-level output $\overline{Q}$ voltage, and input current for the clock pulse that there were statistically significant differences between the samples biased in one state only and in the unbiased samples. With 99 percent confidence, for the low level Q and $\overline{Q}$ output voltage, high level $\overline{Q}$ output voltage, the current into the direct-reset input,(7) and the current into the clock-pulse input there were statistically significant differences between the biased and unbiased samples. Also, with a 99 percent confidence, for the low level Q and $\overline{Q}$ output voltages there were statistically significant differences between the biased and unbiased samples. It is interesting to compare the changes in the output characteristics at both Q and $\overline{Q}$ for the biased and unbiased circuits. The changes in unbiased circuits were approximately symmetrical between Q and $\overline{Q}$. However, the changes in the biased circuits were not symmetrical. If the flip-flops are considered

(7) For this parameter only the confidence level is 98 percent.

as two cross-coupled gates, these results would indicate that degradation is more severe for the gate that is maintained in the one state (output in high-voltage state) during irradiation. As expected, the increases in leakage currents were the only changes that were larger for the biased circuits because reverse-biased junctions are normally considered more sensitive to charge particle radiation.

The shift of output parameters was found to increase with electron energy for both the biased and unbiased devices. Degradation of engineering significance was observed at $1 \times 10^{15}$ e/cm$^2$ for the 1.5 MeV electrons while similar changes were observed at $2 \times 10^{15}$ e/cm$^2$ at the 1.0 MeV electron irradiation. Changes in parameter values occurred near $1 \times 10^{16}$ e/cm$^2$ for the 0.5 MeV electrons. In general, the RD321 flip-flops were insensitive to machine noise and did not reset during irradiation.

The implications of these results to design engineers are: (1) to obtain increased radiation longevity (output low-voltage failures), the fan-out of the circuits should be decreased, (2) the circuits should be powered under irradiation, (3) the largest power-supply voltage compatible with the microcircuits and the system should be used, and (4) the circuits are more sensitive to the higher energy electron irradiation.

## Equivalent 962 Circuits

The equivalent 962 circuits consisted of seven types of DTL NAND/NOR gates as listed in Table 2. The Fairchild, Motorola, Philco, and Texas Instrument 962 circuits are triple 3-input NAND/NOR gates. These circuits are fabricated on a single monolithic substrate using planar-epitaxial techniques. The active elements are isolated with diffused p-n junctions and diffused resistors are used throughout. The devices are gold doped to improve the switching time. Figures 28a, 28b, 28c, and 28d are photographs of the four-junction isolated circuits. All photographs in Figure 28 were taken at the same magnification. The Motorola SC1253, Motorola Dielectrically Isolated MD962 and the Radiation, Inc. RD242 circuits are also triple 3-input NAND/NOR gates. These circuits are fabricated by planar epitaxial techniques. The circuit elements are surrounded by moats of dielectric material that provide the interelement isolation. Nicrome thin-film resistors are used throughout and the devices are gold doped to improve the switching time. Figures 29a, 29b, 29c, and 29d are photographs of the three dielectrically isolated circuits. Figures 29a, 29b, and 29c are at the same magnification. The photograph in Figure 29d was taken at a lower magnification, so that the complete RD242 chip would be visible. As Figures 28 and 29 indicate the topology of the various circuits are quite different even though they are "electrically equivalent". A schematic diagram of a typical gate element is given in the "Results" section.

As stated previously, two samples of each 962 circuit were irradiated with 1.5, 1.0, and 0.5 MeV electrons to determine the critical energy. As a result of these test irradiations, it was decided to irradiate all the 962 circuits with 1.5 MeV electrons up to a total exposure of $6 \times 10^{15}$ e/cm$^2$. As with the other circuits in this program, the failure criterion was any parameter exceeding the limits specified by the manufacturer. Failure limits were specified in this manner to be compatible with the information presently supplied to the design engineers by the manufacturers.

The most significant changes that were observed as a result of the irradiation were the increases in the output low-level voltage. These changes

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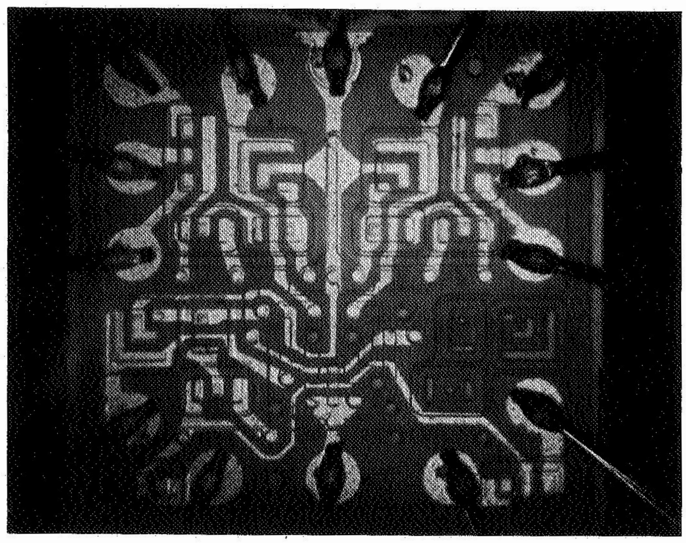
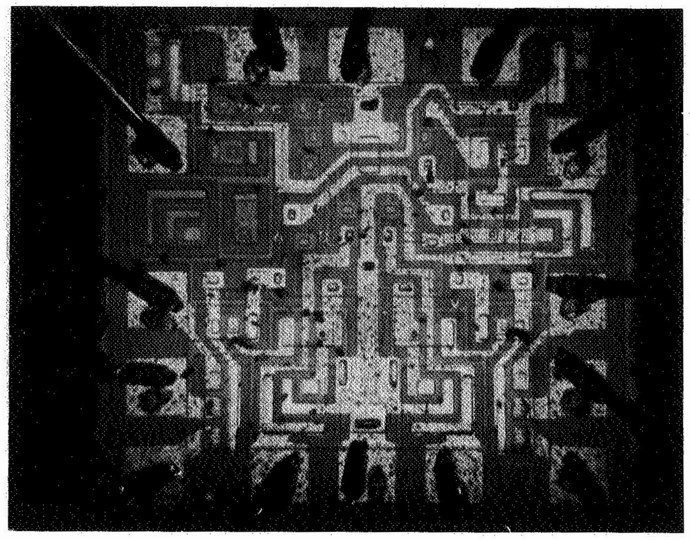
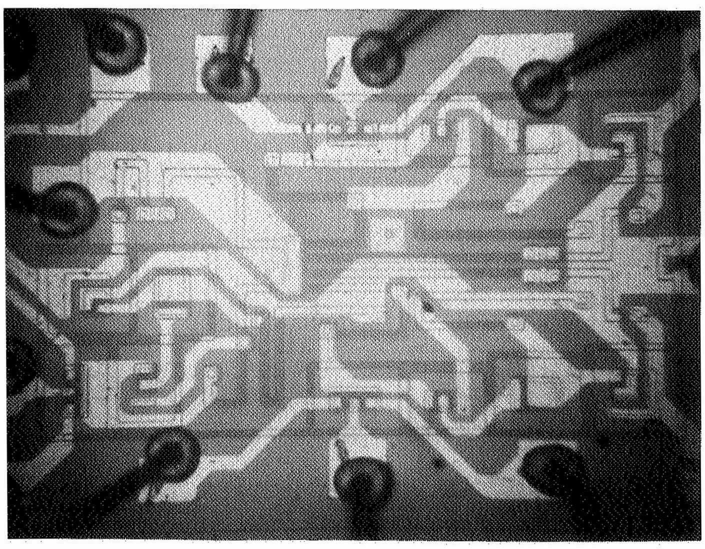


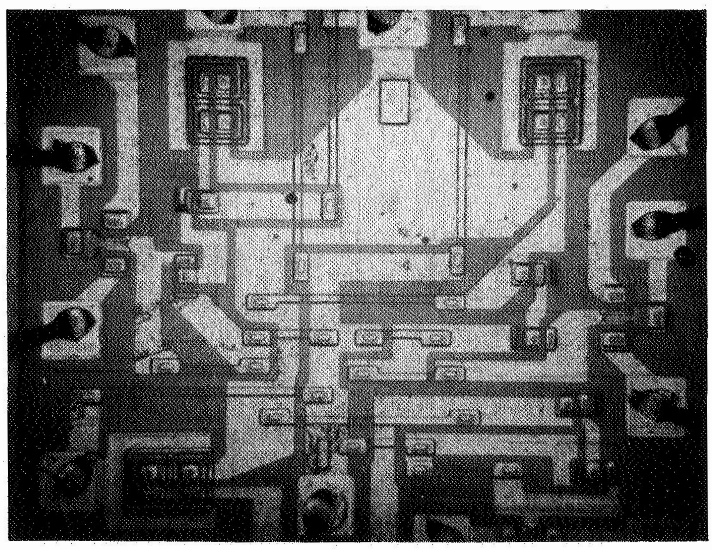
a. Philco 962



b. Fairchild 962

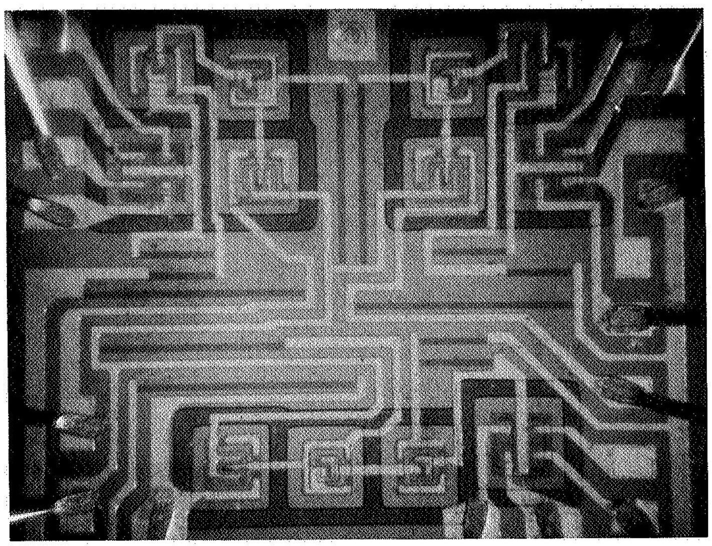


c. Texas Instrument 962

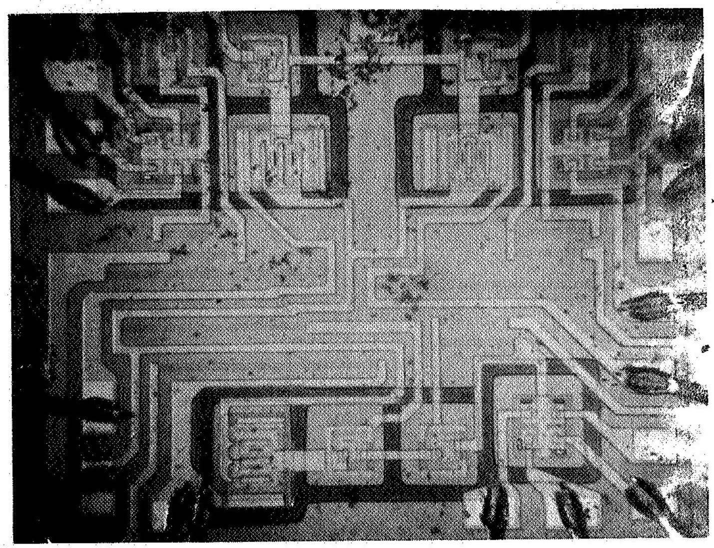


d. Motorola 962

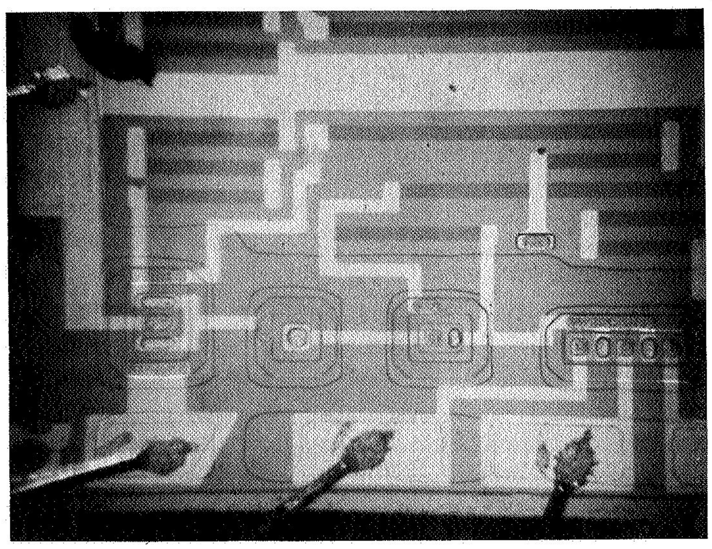
FIGURE 28. PHOTOGRAPHS OF THE JUNCTION-ISOLATED EQUIVALENT 962 CIRCUITS



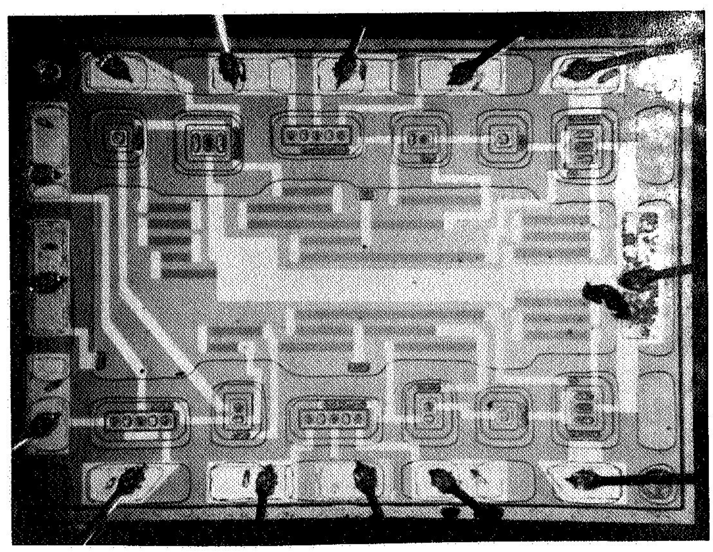
a. Motorola SC1253



b. Motorola Dielectrically Isolated Circuits



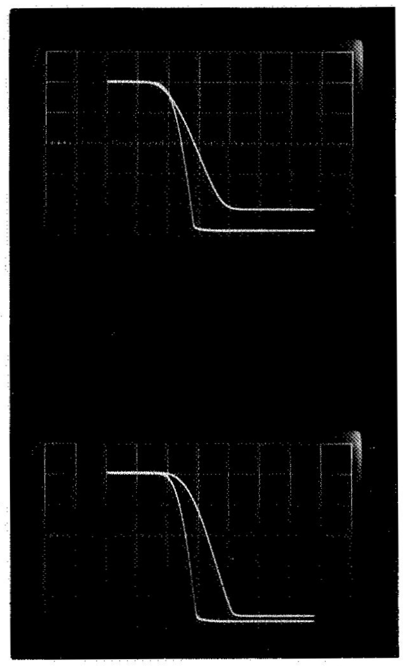
c. Radiation RD242 (same magnification as other circuits)



d. Radiation RD242 (lower magnification)

FIGURE 29. PHOTOGRAPHS OF THE DIELECTRICALLY ISOLATED CIRCUITS

are illustrated in Figure 30 which shows the input-output transfer characteristic of typical irradiated and nonirradiated circuits (not the same circuits) at full fan-out. The increases in output low-level voltage and the decrease in the dynamic voltage gain are apparent in the figure.



Horizontal Scale: 0.2 V/cm
Vertical Scale: 1.0 V/cm

FIGURE 30. INPUT-OUTPUT TRANSFER CHARACTERISTIC OF TYPICAL EQUIVALENT CIRCUITS

Tables 28 and 29 list the comparative percent average changes for the biased and unbiased equivalent 962 circuits. The percent average changes in the control samples are also tabulated in the comparison. The results of the measurements made during irradiation are presented in Figures 131 through 144 in the "Results" section. Only the output low-level response is presented, since no significant changes were observed in the output high-level voltage.

The observed degradation in the output low voltage can be attributed to decreases in transistor gain and increases in the $r_{sat}$ parameter. Since the drive to the gain stages of the gate circuits remains relatively constant during irradiation, the amount of current that the gate can sink is roughly proportional to the product of the current gains of the two transistors in the circuit. The observed increase in the propagation delay (rise) is consistent with the decrease in transistor current gain. The decreases in the propagation delay (fall) observed for all the gates (except the Motorola 962) is indicative of the decrease in the lifetime that results from irradiation. The changes in the output high voltage, the input levels, the input drive currents, and resistance were small and not of engineering significance. Although increases in leakage currents were observed for most of the circuits, the changes were erratic and no meaningful analysis of the data was possible.

Tables 28 and 29 indicate that the degradation of the output low voltage of the unbiased circuits was more severe than that of the biased circuits. The statistical analysis indicates, at the 90 percent confidence level, that the changes in the output low voltage were significantly different for the biased and unbiased circuits. In all the devices, larger average changes were observed in the unbiased samples. These results are similar to the observations made on the circuits in the fundamental study.

TABLE 28. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE BIASED EQUIVALENT 962 CIRCUITS[a]

| Parameter | 1[b] | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Output Low Voltage | 55 | 17.4 | 35.7 | 204 | 54.5 | 61.2 | 47.2 | 1.2 |
| Output High Voltage | N.S. | N.S. | 0.36 | -0.05 | N.S. | N.S. | N.S. | 0.09 |
| Input Low Voltage | 0.8 | N.S. | -0.6 | N.S. | 0.6 | -0.3 | -4.4 | -2.1 |
| Input High Voltage | -0.2 | N.S. | -0.4 | -0.3 | 1.1 | 0.6 | N.S. | -3.1 |
| Input Drive Current | N.S. | -4.2 | N.S. | N.S. | N.S. | -7.7 | N.S. | -1.7 |
| Input Leakage Current | 48.5 | N.S. | N.S. | 322 | N.S | -5.4 | N.S. | 6.0 |
| Resistance | 1.9 | N.S. | 1.8 | 0.9 | 1.4 | 1.4 | N.S. | 0.27 |
| Propagation Delay (Rise) | 1.3 | 1.5 | 11.1 | 3.1 | 12.5 | 5.7 | 13.9 | -3.7 |
| Propagation Delay (Fall) | -69 | -65 | -55 | -80 | -73 | N.S. | -70 | 18 |

NOTE: N.S. = No statistically significant change.

(a) These circuits were irradiated to $6 \times 10^{15}$ e/cm$^2$ (1.5 MeV).

(b) Code:
1 Fairchild DTL962
2 Motorola Dielectrically Isolated Circuits
3 Philco 962
4 Radiation RD242
5 Texas Instrument 962
6 Motorola 962
7 Motorola SC1253
8 Controls

TABLE 29. COMPARATIVE AVERAGE CHANGES IN PERCENT FOR THE UNBIASED EQUIVALENT 962 CIRCUITS[a]

| Parameter | 1[b] | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Output Low Voltage | 52 | 23.2 | 45.7 | 589 | 81.5 | 76.7 | 94.2 | 1.2 |
| Output High Voltage | N.S. | N.S. | 0.36 | -0.1 | N.S. | N.S. | N.S. | 0.09 |
| Input Low Voltage | N.S | N.S. | N.S. | N.S. | 0.5 | N.S. | -5.2 | -2.1 |
| Input High Voltage | 0.62 | N.S. | 0.5 | 0.04 | 2.0 | 0.9 | N.S. | -3.1 |
| Input Drive Current | N.S. | -12.3 | N.S. | N.S. | N.S. | -7.8 | -5.0 | -1.7 |
| Input Leakage Current | 85.5 | N.S. | 16 | 1770 | 110 | N.S. | N.S. | 6.0 |
| Resistance | 2.0 | N.S. | 1.4 | 1.3 | 1.5 | N.S. | N.S. | 0.27 |
| Propagation Delay (Rise) | 7.6 | 6.7 | 12.9 | 13.3 | 14.1 | 8.9 | 12.7 | -3.7 |
| Propagation Delay (Fall) | -62 | -67 | -59 | -62 | -74 | N.S. | -71 | 18 |

NOTE: N.S. = No statistically significant change.

(a) These circuits were irradiated to $6 \times 10^{15}$ e/cm$^2$ (1.5 MeV).

(b) Code:
1 Fairchild DTL962
2 Motorola Dielectrically Isolated Circuits
3 Philco 962
4 Radiation RD242
5 Texas Instrument 962
6 Motorola 962
7 Motorola SC1253
8 Controls

The overall responses of the circuits to electron irradiation were similar, as Tables 28 and 29 indicate. However, significant differences in the magnitude of these changes were observed among the circuit types. The differences in radiation response were most pronounced for the output low voltage as shown in Figure 31. Average increases ranging from 17.4 percent to over 200 percent were observed for the biased samples. The absolute average changes in output low voltage and an indication of the sample variance is shown in Figure 32.

The differences observed in the radiation response did not correlate with the circuit topology. Figure 31 shows the radiation response of the Fairchild 962 and Philco 962 circuits to be significantly different, even though the topologies of these two circuits are quite similar. The topology of the Motorola SC1253 and MD962 circuits shown in Figure 32 are identical, yet the radiation response is quite different. On the other hand, the radiation response of the Fairchild and Motorola 962 circuits tracked very well, yet the topology of the circuits is dissimilar.

No improved radiation response was observed which could be attributed to the method of isolation used. Figures 31 and 32 show that the radiation responses of the dielectrically isolated circuits were varied. The changes in the output low voltage of the SC1253 circuits tracked well with the other junction-isolated circuits while the Motorola Dielectrically Isolated Circuits showed the smallest changes. The largest changes in the output low voltage were observed for the RD242 circuits. It is of interest to note that the changes in the thin-film nicrome resistors (used on the dielectrically isolated circuits) were smaller than those observed for the diffused resistors that are used in the junction-isolated circuits. Since the changes in resistance are small, these differences are generally not of engineering significance.

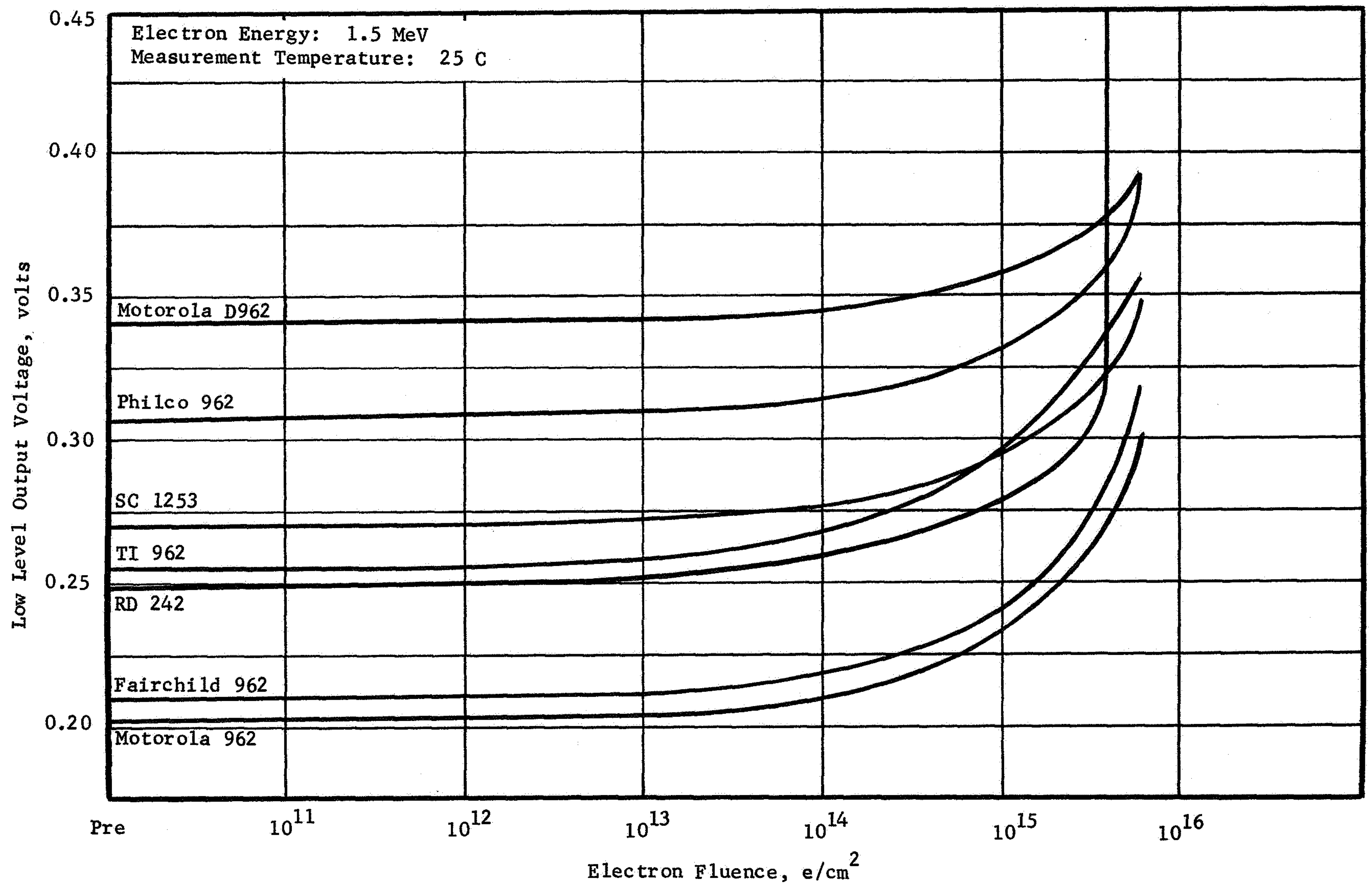



FIGURE 31. AVERAGE LOW-LEVEL OUTPUT RADIATION RESPONSE FOR THE SEVEN TYPES OF DTL 962 ELECTRICALLY EQUIVALENT CIRCUITS (BIASED SAMPLES)

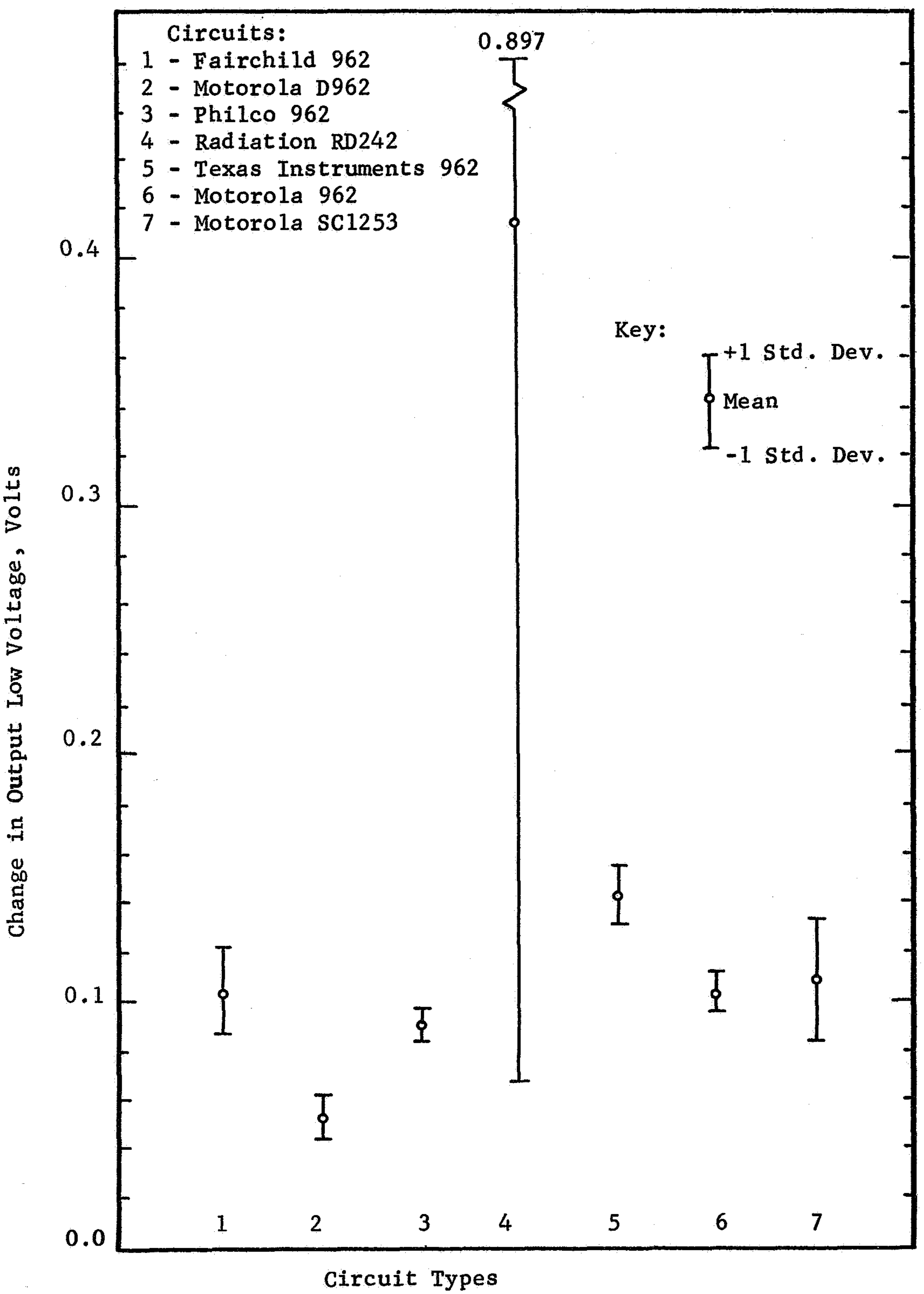



FIGURE 32. THE CHANGE IN OUTPUT LOW VOLTAGE DUE TO RADIATION AS A FUNCTION OF CIRCUIT TYPES

The differences observed in the radiation response of the seven equivalent 962 circuits are attributed to differences in the processing techniques used during fabrication. Processing techniques vary not only among manufacturers but also there are changes made by a given manufacturer as new fabrication technology is developed. Information concerning these changes is usually not made available to the design engineer. Fortunately, the changes in processing which improve the electrical properties of a microcircuit usually will improve the radiation response as well. Some design steps which have been shown to improve the radiation tolerance of microcircuits are:

(1) Circuit design changes that allow the microcircuit to function with lower transistor current gain

(2) Derating maximum fan-out specification

(3) Increasing the initial gain and the gain-bandwidth product of the transistors

(4) Changes in transistor geometry that improve the saturation resistance

(5) Gold doping of the active elements

(6) Improvements in the surface passivation technique.

The implications of these results to design engineers are: (1) the radiation response of electrically equivalent circuits may be significantly different depending on the specific processing techniques used during fabrication, (2) no correlation was found between the radiation response of these circuits and the circuit topology, and (3) no improved radiation response was observed which could be attributed to the method of isolation used.

## RESULTS

In this section, the effects of the radiation exposure on each of the ten device types in the fundamental study and the seven device types in the equivalent-circuit study are presented. The radiation response curves and tabular data summaries are intended to give a concise picture of the radiation-induced effects as determined from the in situ and characterization measurements. Comprehensive pre/post characterization data may be found in Appendix III (Volume II). The computer programs used for summarizing the characterization data as well as those used to reduce and plot the in situ data are presented in Appendix IV (Volume II).

A discussion of the data format has been presented at the beginning of the previous section "Analysis of Data".

The following are the symbols used in the tabular pre/post data summaries:

Amplifier Symbols

| | |
|---|---|
| CMRR | Common mode rejection ratio |
| GAIN C.L. | Closed-loop voltage gain |
| GAIN O.L. | Open-loop voltage gain |
| G(OL 5) | Open-loop voltage gain with supply voltages equal to 5 volts |
| GAIN RATIO | The ratio of H(FE) High to H(FE) Low |
| H(FE) HIGH | Transistor dc current gain at a collector current of 10 mA |
| H(FE) LOW | Transistor dc current gain at a collector current of 50 μA |
| I BIAS | Input bias current |
| I(CBO) | Transistor collector to base current with emitter open |
| I(CC) | Power-supply current |
| I O.S. | Input offset current |
| V(BE) HIGH | Transistor base to emitter voltage at a collector current of 10 mA |
| V(BE) LOW | Transistor base to emitter voltage at a collector current of 50 μA |
| V(D.C. IN) | Input voltage level |
| V(D.C. OUT) | Output voltage level |
| V O.S. | Input offset voltage |
| V(O.S. 5) | Input offset voltage with supply voltages equal to 5 volts |

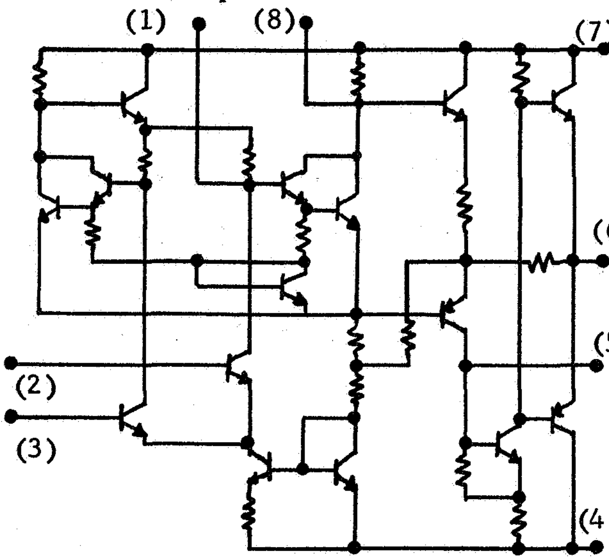
| | |
|---|---|
| V $SAT^+$ | Positive output saturation voltage |
| V $SAT^-$ | Negative output saturation voltage |

## Digital Circuit Symbols

| | |
|---|---|
| MIN CP AMP | Minimum clock pulse voltage for circuit operation |
| MIN V(C1) | Minimum voltage at CP terminal for circuit operation |
| MIN V(S1) | Minimum voltage at S1 terminal for circuit operation |
| I(CC) | Power-supply current |
| I(CC0) | Power-supply current with output at logic zero |
| I(CC1) | Power-supply current with output at logic one |
| I DRIVE | Input drive current |
| I(IN CP) | Input current at CP terminal |
| I(IN PSET) | Input current at preset terminal |
| I(IN RC) | Input current at RC terminal |
| I(IN RD) | Input current at RD terminal |
| I(IN SD) | Input current at SD terminal |
| I(IN R1) | Input current at R1 terminal |
| I(L CD) | Input leakage current at CD terminal |
| I LEAKAGE | Input-diode leakage current |
| I(L PSET) | Input leakage current at preset terminal |
| I(L RD) | Input leakage current at RD terminal |
| I(L R1) | Input leakage current at R1 terminal |
| T(DF) | Propagation delay fall |
| T(DR) | Propagation delay rise |

| | |
|---|---|
| V(BAR Q H) | $\overline{Q}$ terminal output voltage at logic one |
| V(BAR Q L) | $\overline{Q}$ terminal output voltage at logic zero |
| V(DF) | Input-diode forward voltage |
| V(IH) | Input voltage required for specified output logic-zero voltage |
| V(IL) | Input voltage required for specified output logic-one voltage |
| V(OH) | Output voltage with specified logic-zero voltage applied to input |
| V(OL) | Output voltage with specified logic-one voltage applied to input terminal |
| V(QH) | Q terminal output voltage at logic one |
| V(QL) | Q terminal output voltage at logic zero. |

Fairchild $\mu$A709




TEST CONDITIONS:

1. Pin 4, -12 volts.
2. Pin 7, +12 volts.
3. Temperature 25 C.

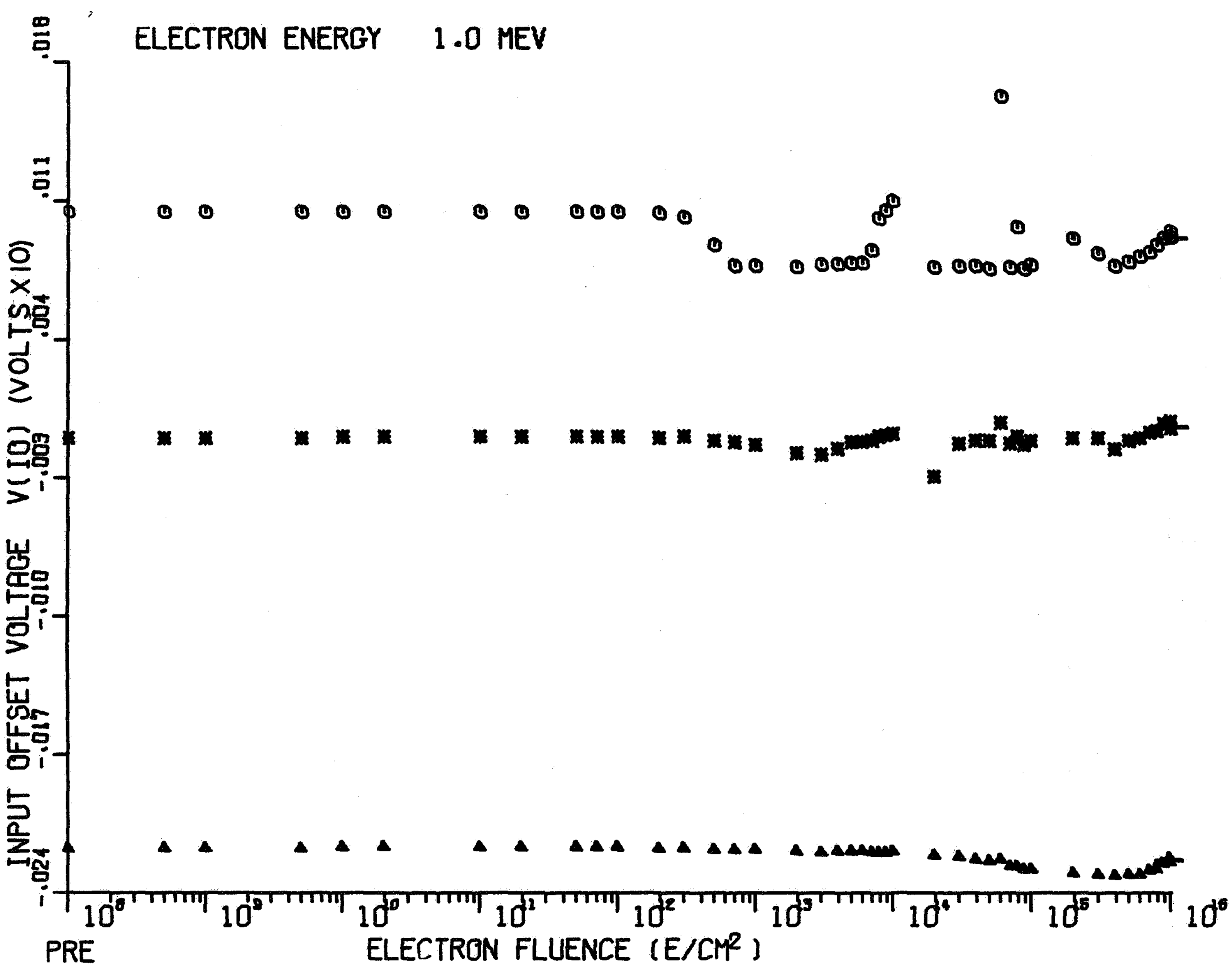
TEST PARAMETERS:

1. Open-loop gain.
2. Closed-loop gain.
3. Input offset voltage.
4. Input bias current.
5. + Saturation voltage.
6. - Saturation voltage.
7. Common mode rejection ratio.
8. Input offset current.
9. Resistance.

FIGURE 33. TEST PLAN FOR $\mu$A709 AMPLIFIER

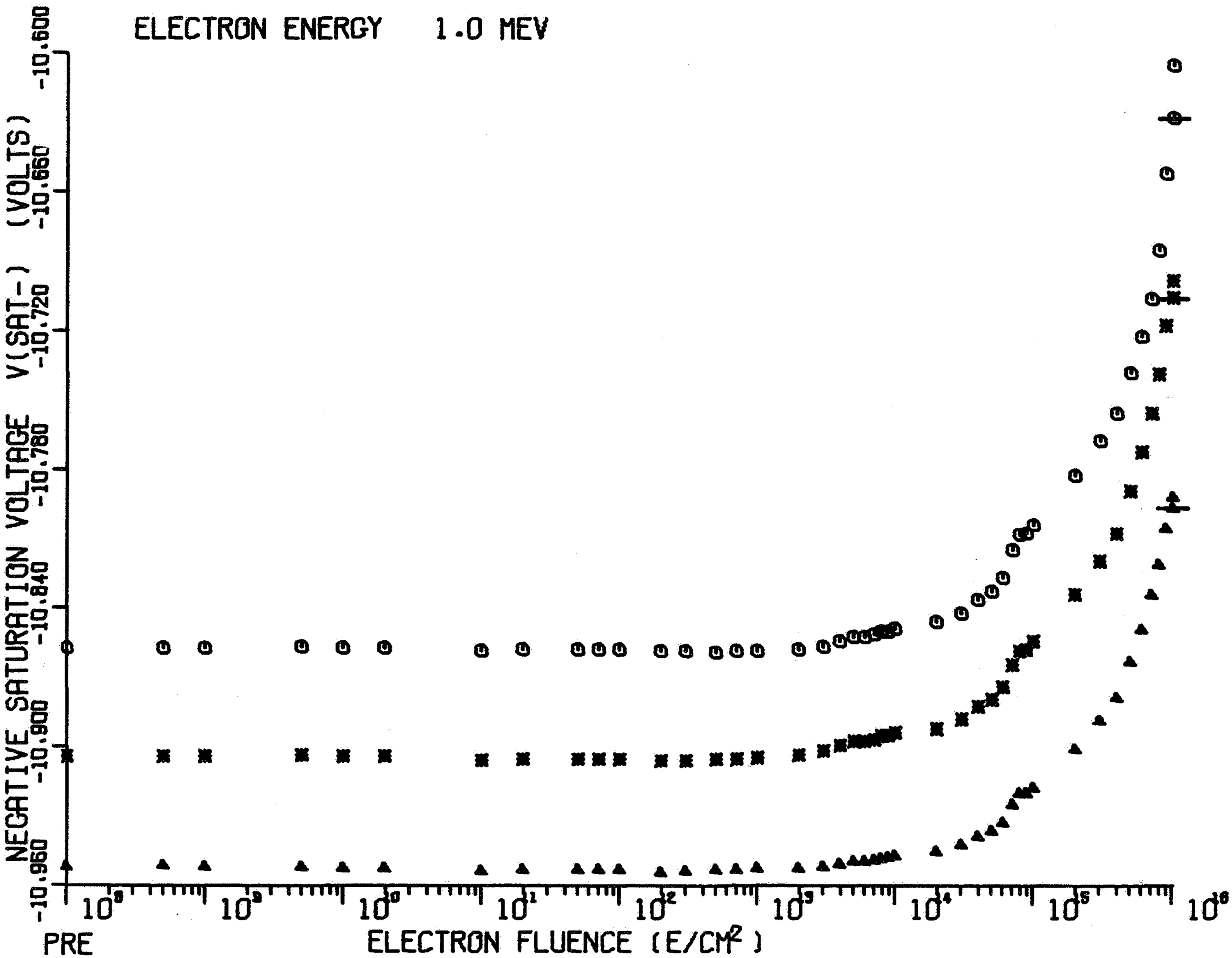
STATIC AC GAIN RADIATION RESPONSE FOR A709 AMPLIFIERS.
AC GAIN (A)
ELECTRON ENERGY 1.0 MEV

| FLUENCE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0. | 1.003360 | .983080 | 1.019430 | 1.008650 | .995650 | .997410 | .999470 | 1.010500 | .995570 | .991530 |
| 0.5E+09 | 1.003440 | .983140 | 1.019560 | 1.008760 | .995650 | .997430 | .999410 | .995850 | .996280 | .991530 |
| 0.1E+10 | 1.003460 | .983220 | 1.019450 | 1.008810 | .995640 | .997390 | .999430 | 1.010450 | .995680 | .991540 |
| 0.5E+10 | 1.003300 | .982560 | 1.010770 | 1.009100 | .988650 | .997780 | .998610 | 1.010370 | .987000 | .992030 |
| 0.1E+11 | 1.003540 | .969400 | 1.011620 | 1.009380 | .988380 | .997210 | .999410 | 1.010480 | .986840 | .992170 |
| 0.2E+11 | 1.003810 | .969660 | 1.011660 | .996040 | .996530 | .990260 | .999820 | 1.009910 | .986660 | .980460 |
| 0.1E+12 | 1.003680 | .970220 | 1.011720 | .996190 | .989230 | .990660 | .988290 | .996580 | .987520 | .980190 |
| 0.2E+12 | 1.003730 | .983110 | 1.010750 | .996360 | .989580 | .990590 | .988430 | 1.010560 | .986880 | .980330 |
| 0.5E+12 | 1.003340 | .982850 | 1.018630 | .995520 | .989150 | .990930 | .999190 | .996040 | .987700 | .991640 |
| 0.7E+12 | 1.003480 | .982990 | 1.018640 | .995530 | .995640 | .990530 | .988080 | .996530 | .995670 | .980090 |
| 0.1E+13 | 1.002870 | .969840 | 1.019290 | .995940 | .995620 | .996720 | .987720 | 1.010510 | .986830 | .991420 |
| 0.2E+13 | 1.002970 | .982670 | 1.018610 | 1.007970 | .994720 | .996810 | .998630 | 1.009710 | .994780 | .990770 |
| 0.3E+13 | 1.003130 | .982650 | 1.018570 | 1.007990 | .994820 | .996770 | .987850 | 1.010450 | .994790 | .990920 |
| 0.5E+13 | 1.003250 | .982490 | 1.018460 | 1.008060 | .995040 | .996710 | .998660 | 1.009910 | .994620 | .990890 |
| 0.7E+13 | 1.002780 | .982510 | 1.018240 | 1.007720 | .994550 | .996370 | .998550 | 1.009670 | .994180 | .990500 |
| 0.1E+14 | 1.002930 | .982560 | 1.018320 | 1.007900 | .994600 | .996720 | .998610 | 1.010100 | .994460 | .990700 |
| 0.2E+14 | 1.002800 | .982230 | 1.017960 | 1.007640 | .994550 | .996480 | .998430 | 1.010740 | .994140 | .990440 |
| 0.3E+14 | 1.003560 | .982540 | 1.018110 | 1.008010 | .994680 | .996540 | .998720 | 1.011380 | .994070 | .990790 |
| 0.4E+14 | 1.003720 | .982720 | 1.018330 | 1.007720 | .994890 | .996570 | .998480 | 1.011340 | .994320 | .990650 |
| 0.5E+14 | 1.003990 | .982990 | 1.018220 | 1.008070 | .994780 | .996930 | .998780 | 1.010870 | .994730 | .990790 |
| 0.6E+14 | 1.003990 | .982690 | 1.018490 | 1.008110 | .994680 | .997020 | .998630 | 1.011200 | .994620 | .990780 |
| 0.7E+14 | 1.004280 | .982760 | 1.018450 | 1.007980 | .995030 | .996830 | .998740 | 1.011000 | .994670 | .991020 |
| 0.8E+14 | 1.004410 | .982690 | 1.018540 | 1.007960 | .994950 | .996820 | .998830 | 1.010720 | .994880 | .990980 |
| 0.9E+14 | 1.004260 | .982710 | 1.018590 | 1.007990 | .994950 | .996880 | .999050 | 1.010470 | .995210 | .991000 |
| 0.1E+15 | 1.004160 | .983020 | 1.018390 | 1.008170 | .994960 | .996800 | .998980 | 1.010560 | .995110 | .991010 |
| 0.2E+15 | 1.003290 | .982870 | 1.018690 | 1.008050 | .995160 | .996990 | .998920 | 1.011330 | .992730 | .990930 |
| 0.3E+15 | 1.002780 | .982850 | 1.018130 | 1.008340 | .994710 | .997090 | .998890 | 1.009080 | .994510 | .990910 |
| 0.4E+15 | 1.002420 | .982820 | 1.018220 | 1.008160 | .994860 | .996800 | .998890 | 1.009140 | .994450 | .990810 |
| 0.5E+15 | 1.003380 | .982930 | 1.017950 | 1.008260 | .994770 | .996920 | .998760 | 1.008290 | .995180 | .991180 |
| 0.6E+15 | 1.002830 | .982670 | 1.018610 | 1.008160 | .995220 | .996900 | .999220 | 1.007930 | .995860 | .991100 |
| 0.7E+15 | 1.002360 | .982820 | 1.018450 | 1.007970 | .994880 | .996960 | .998920 | 1.009130 | .994300 | .991180 |
| 0.8E+15 | 1.002380 | .982700 | 1.018160 | 1.008010 | .994860 | .996980 | .998900 | 1.008550 | .994540 | .991050 |
| 0.9E+15 | 1.002480 | .982640 | 1.018330 | 1.007980 | .994750 | .996780 | .999050 | 1.008820 | .994380 | .990970 |
| 0.1E+16 | 1.002270 | .982720 | 1.018220 | 1.008000 | .994670 | .996810 | .998890 | 1.008700 | .994560 | .990960 |
| 0.2E+16 | 1.001660 | .982660 | 1.018050 | 1.007880 | .994740 | .996600 | .998940 | 1.007980 | .994400 | .991000 |
| 0.3E+16 | 1.001470 | .982160 | 1.017920 | 1.007460 | .994400 | .996430 | .998780 | 1.007410 | .994110 | .990590 |
| 0.4E+16 | 1.001590 | .982150 | 1.017820 | 1.007420 | .994350 | .996490 | .998640 | 1.007760 | .993350 | .990770 |
| 0.5E+16 | .999680 | .982160 | 1.017720 | 1.007030 | .994310 | .996100 | .998620 | 1.006910 | .993410 | .990620 |
| 0.6E+16 | .999550 | .982030 | 1.017500 | 1.006830 | .994130 | .996080 | .998670 | 1.005790 | .993420 | .990490 |
| 0.7E+16 | .999930 | .981610 | 1.017030 | 1.006400 | .993620 | .995610 | .998410 | 1.004820 | .992830 | .990070 |
| 0.8E+16 | .998700 | .981330 | 1.016890 | 1.005710 | .993300 | .995280 | .997910 | 1.003880 | .992280 | .989660 |
| 0.9E+16 | .997900 | .981100 | 1.016350 | 1.005310 | .993020 | .994630 | .997980 | 1.002170 | .991810 | .989570 |
| 0.1E+17 | .997310 | .980920 | 1.016120 | 1.004660 | .992500 | .994150 | .997690 | 1.000490 | .991370 | .989180 |
| 0.1E+17 | .997510 | .980880 | 1.016340 | 1.005130 | .992740 | .994620 | .997660 | 1.002180 | .991400 | .989270 |



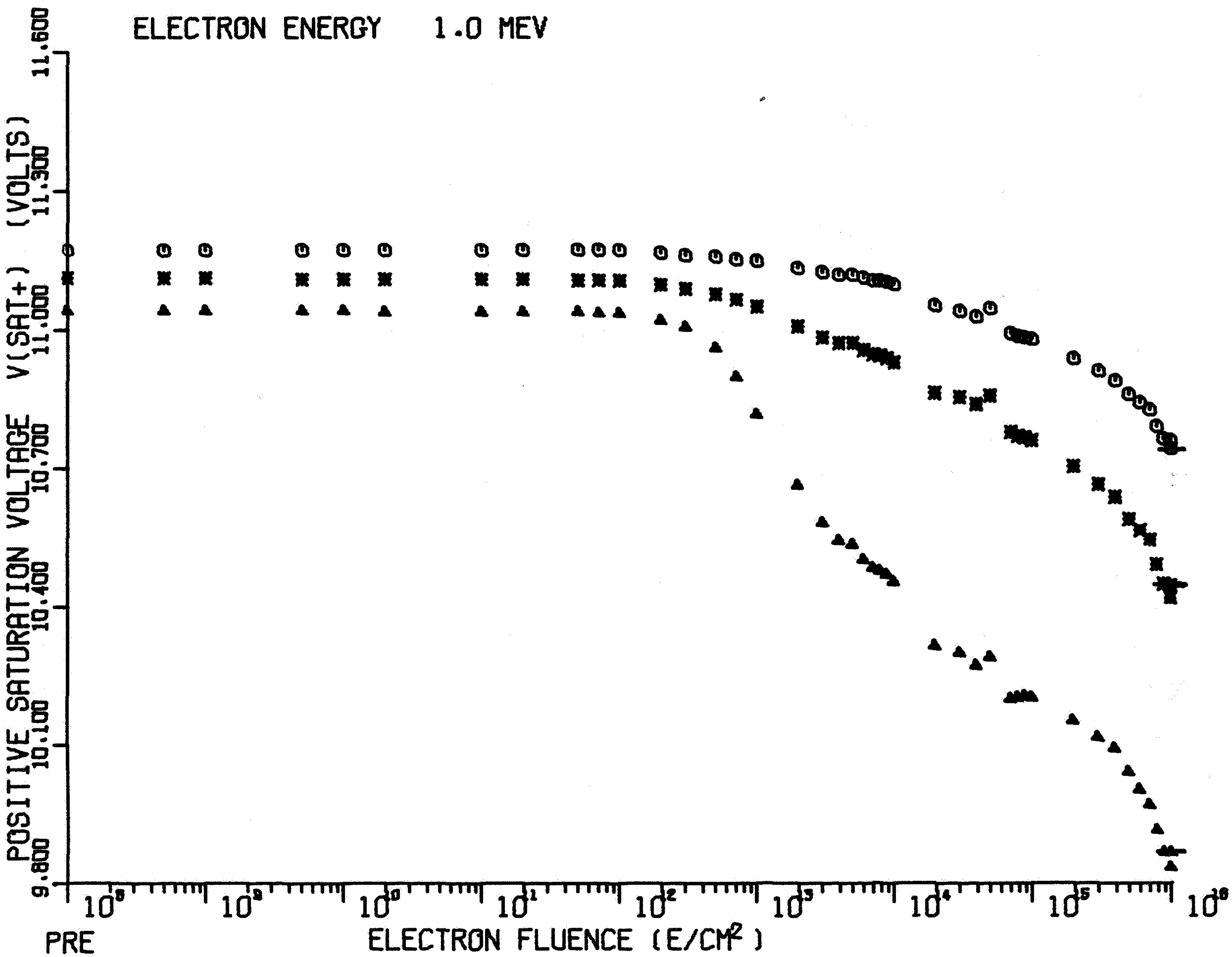

STATIC INPUT OFFSET VOLTAGE RADIATION RESPONSE FOR μA709 AMPLIFIERS.

FIGURE 34




STATIC NEGATIVE SATURATION VOLTAGE RADIATION RESPONSE FOR $\mu$A709 AMPLIFIERS

FIGURE 35




STATIC POSITIVE SATURATION VOLTAGE RADIATION RESPONSE FOR $\mu$A709 AMPLIFIERS.

FIGURE 36

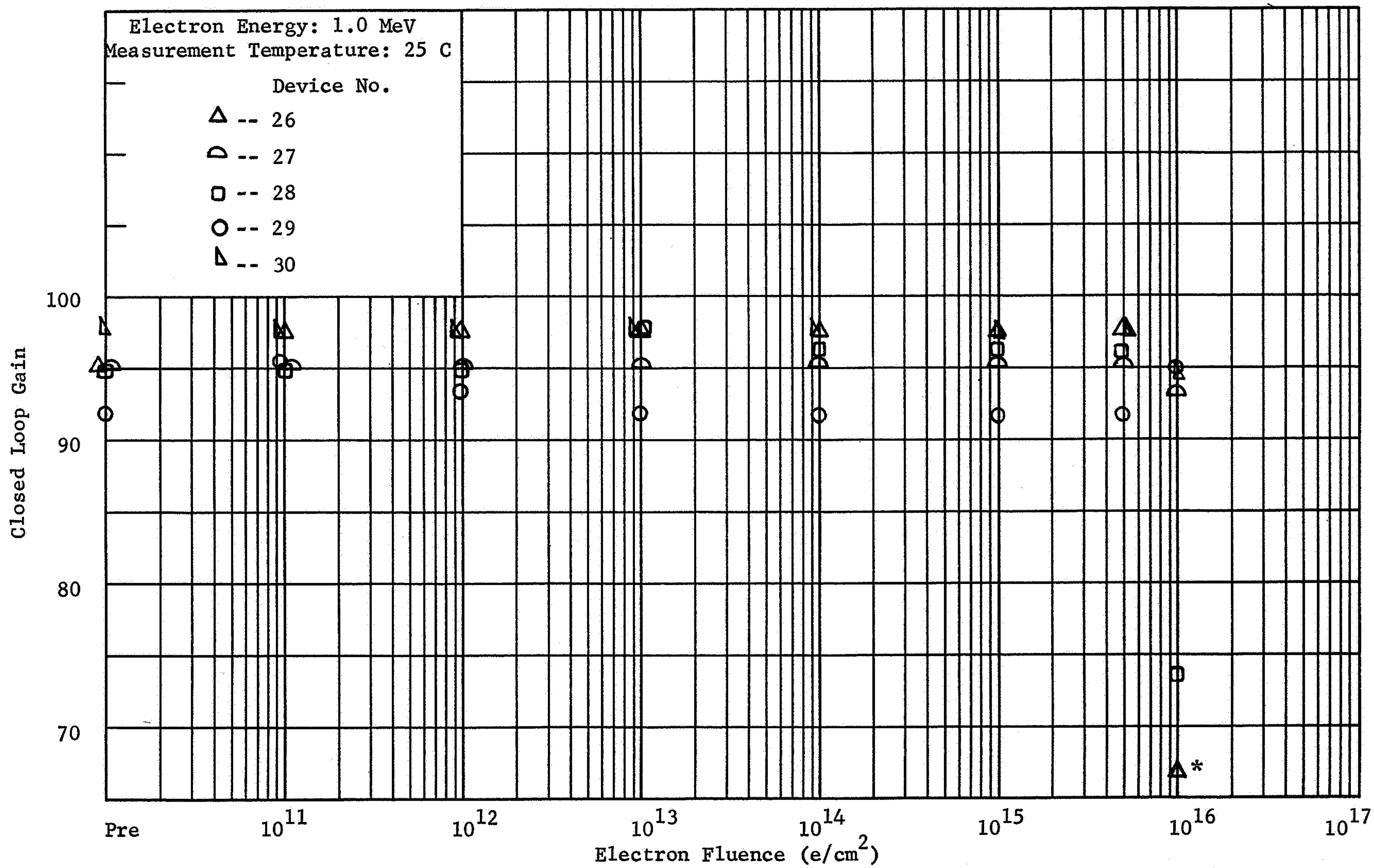



FIGURE 37. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF $\mu$A 709 AMPLIFIERS.

* Device in saturation for all input voltages.

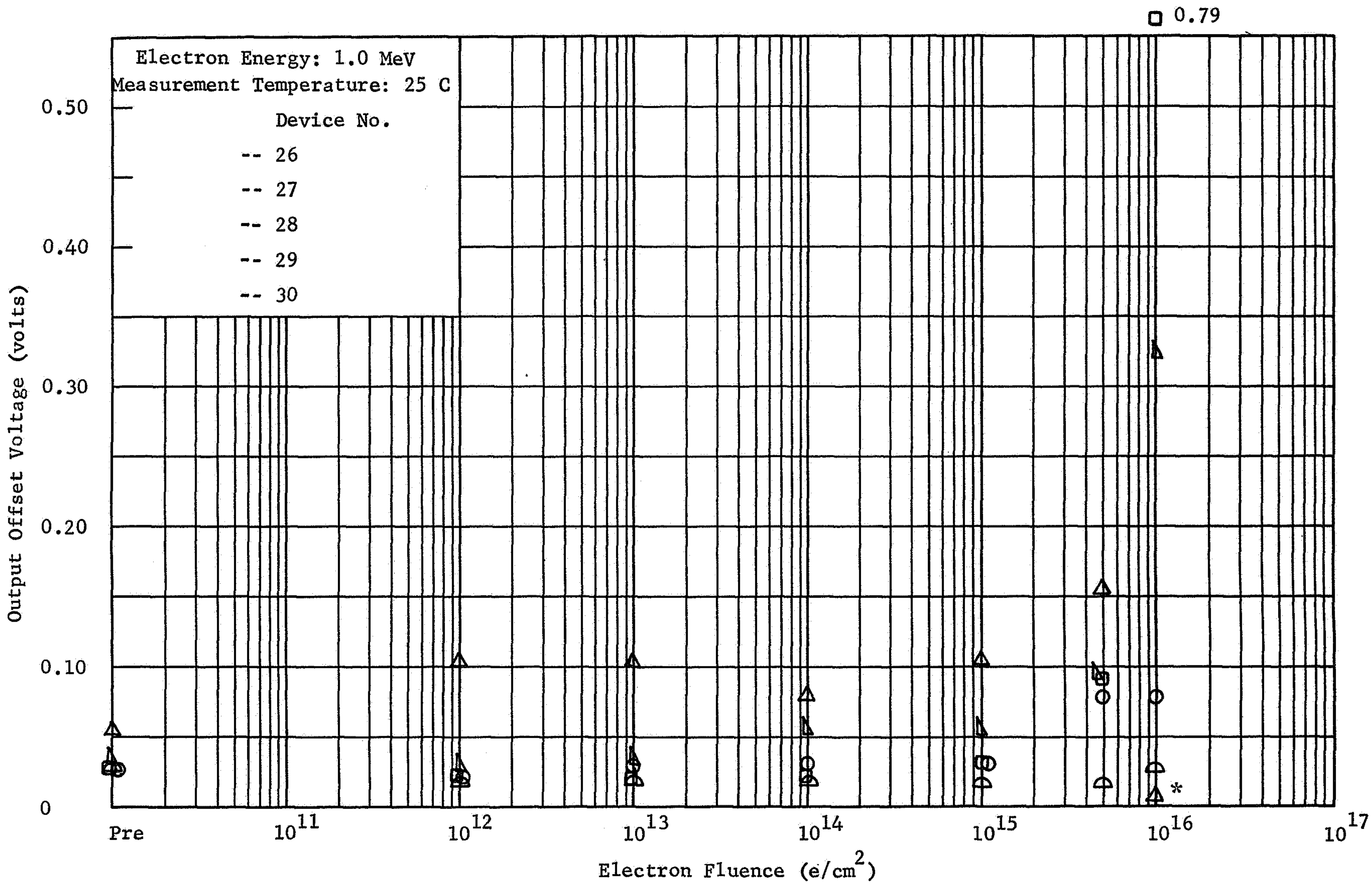
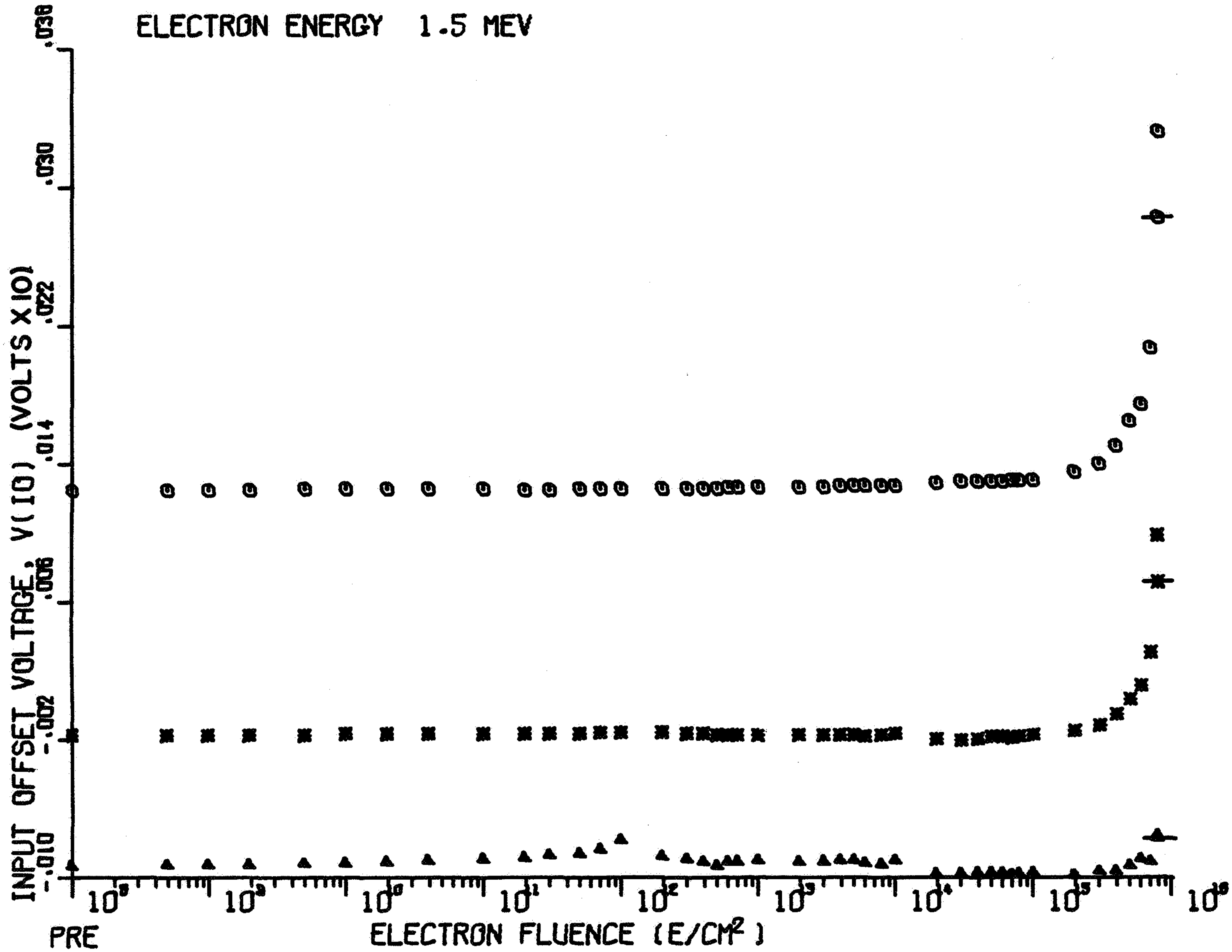



FIGURE 38. PULSED OUTPUT OFFSET VOLTAGE RESPONSE FOR $\mu$A 709 AMPLIFIERS.

* Device in saturation for all input voltages.

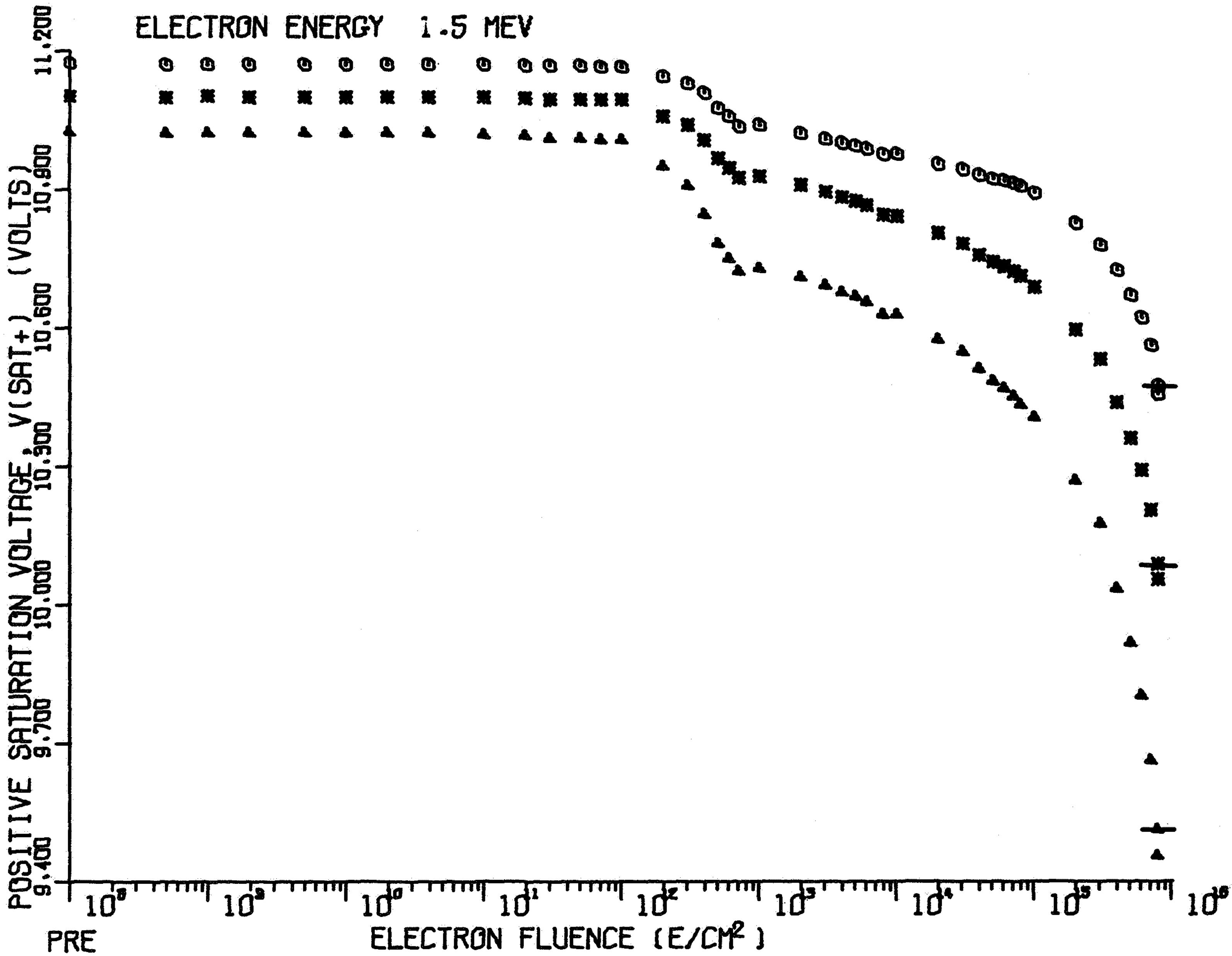
STATIC AC GAIN RADIATION RESPONSE FOR A709 AMPLIFIERS.
AC GAIN
ELECTRON ENERGY 1.5 MEV

| FLUENCE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0. | 1.055400 | 1.074600 | 1.028000 | 1.047500 | 1.077600 | 1.080500 | 1.041300 | 1.078400 | 1.049700 | 1.114600 |
| 0.5E+09 | 1.052600 | 1.074600 | 1.026600 | 1.045900 | 1.077400 | 1.078500 | 1.039100 | 1.078700 | 1.048300 | 1.115000 |
| 0.1E+10 | 1.054400 | 1.074200 | 1.025200 | 1.047000 | 1.075300 | 1.078200 | 1.040400 | 1.076700 | 1.047800 | 1.114800 |
| 0.2E+10 | 1.051600 | 1.072600 | 1.025700 | 1.043900 | 1.075800 | 1.075900 | 1.039100 | 1.077000 | 1.045900 | 1.113700 |
| 0.5E+10 | 1.051400 | 1.073400 | 1.024300 | 1.045600 | 1.075800 | 1.077200 | 1.039700 | 1.075500 | 1.044700 | 1.112800 |
| 0.1E+11 | 1.053100 | 1.071300 | 1.026200 | 1.043600 | 1.075300 | 1.078100 | 1.037600 | 1.077500 | 1.045000 | 1.114100 |
| 0.2E+11 | 1.052200 | 1.075100 | 1.025500 | 1.046800 | 1.076600 | 1.077700 | 1.040200 | 1.077800 | 1.047400 | 1.115400 |
| 0.4E+11 | 1.055100 | 1.073000 | 1.027900 | 1.045800 | 1.077800 | 1.078600 | 1.041100 | 1.077300 | 1.048000 | 1.116200 |
| 0.1E+12 | 1.052600 | 1.074700 | 1.026400 | 1.047400 | 1.075300 | 1.079100 | 1.039200 | 1.078700 | 1.048200 | 1.114500 |
| 0.2E+12 | 1.053000 | 1.074800 | 1.027800 | 1.046800 | 1.077700 | 1.077800 | 1.041200 | 1.077500 | 1.048800 | 1.115100 |
| 0.3E+12 | 1.054700 | 1.075800 | 1.028600 | 1.047700 | 1.078100 | 1.080400 | 1.041100 | 1.079500 | 1.049100 | 1.116800 |
| 0.5E+12 | 1.054800 | 1.073800 | 1.029600 | 1.046000 | 1.078300 | 1.079100 | 1.041800 | 1.078200 | 1.049000 | 1.114800 |
| 0.7E+12 | 1.056100 | 1.074400 | 1.031300 | 1.047000 | 1.077700 | 1.080900 | 1.042200 | 1.079700 | 1.049600 | 1.115000 |
| 0.1E+13 | 1.056400 | 1.075300 | 1.032600 | 1.048200 | 1.078200 | 1.080900 | 1.040700 | 1.080900 | 1.048300 | 1.117800 |
| 0.2E+13 | 1.055900 | 1.075800 | 1.030600 | 1.047900 | 1.079400 | 1.081900 | 1.041500 | 1.081300 | 1.049600 | 1.119200 |
| 0.3E+13 | 1.056600 | 1.076500 | 1.029300 | 1.048300 | 1.078200 | 1.080700 | 1.042100 | 1.078600 | 1.049000 | 1.119300 |
| 0.4E+13 | 1.054300 | 1.075900 | 1.028000 | 1.045600 | 1.078200 | 1.078300 | 1.040500 | 1.078600 | 1.048500 | 1.116300 |
| 0.5E+13 | 1.054600 | 1.076400 | 1.027900 | 1.046900 | 1.077200 | 1.077100 | 1.040700 | 1.077300 | 1.049300 | 1.116700 |
| 0.6E+13 | 1.060400 | 1.046800 | 1.034000 | 1.013000 | 1.043600 | 1.024000 | 1.018200 | 1.049700 | 1.015400 | 1.036400 |
| 0.7E+13 | 1.034500 | 1.047100 | 1.015700 | 1.016100 | 1.045200 | 1.023100 | 1.018000 | 1.048700 | 1.014700 | 1.035100 |
| 0.1E+14 | 1.055300 | 1.078500 | 1.030100 | 1.047900 | 1.079100 | 1.079000 | 1.042400 | 1.078500 | 1.051000 | 1.119200 |
| 0.2E+14 | 1.032800 | 1.079200 | 1.013400 | 1.050400 | 1.042600 | 1.023200 | 1.017900 | 1.049100 | 1.015200 | 1.036700 |
| 0.3E+14 | 1.057000 | 1.078000 | 1.030200 | 1.012500 | 1.043600 | 1.022600 | 1.017900 | 1.049100 | 1.015000 | 1.036200 |
| 0.4E+14 | 1.035200 | 1.048900 | 1.017800 | 1.017000 | 1.045500 | 1.024600 | 1.018200 | 1.085100 | 1.013100 | 1.034300 |
| 0.5E+14 | 1.036200 | 1.081000 | 1.014000 | 1.014100 | 1.044600 | 1.024000 | 1.018700 | 1.049100 | 1.054000 | 1.034800 |
| 0.6E+14 | 1.056200 | 1.044900 | 1.030900 | 1.013000 | 1.043600 | 1.023500 | 1.017100 | 1.084500 | 1.013300 | 1.035300 |
| 0.8E+14 | 1.034500 | 1.048800 | 1.016600 | 1.015200 | 1.045500 | 1.024700 | 1.017700 | 1.049800 | 1.015000 | 1.036100 |
| 0.1E+15 | 1.031500 | 1.079200 | 1.013700 | 1.049700 | 1.042500 | 1.021600 | 1.017600 | 1.047900 | 1.015400 | 1.036000 |
| 0.2E+15 | 1.056500 | 1.078000 | 1.025800 | 1.048100 | 1.079900 | 1.070900 | 1.042700 | 1.079800 | 1.050400 | 1.118500 |
| 0.3E+15 | 1.031700 | 1.078100 | 1.013600 | 1.014600 | 1.044500 | 1.023400 | 1.048500 | 1.081600 | 1.051800 | 1.031900 |
| 0.4E+15 | 1.056700 | 1.077900 | 1.029200 | 1.049300 | 1.080500 | 1.070100 | 1.044300 | 1.079600 | 1.051600 | 1.115200 |
| 0.5E+15 | 1.056900 | 1.078000 | 1.028800 | 1.048900 | 1.041000 | 1.021600 | 1.016600 | 1.047200 | 1.014600 | 1.037300 |
| 0.6E+15 | 1.056100 | 1.043300 | 1.030800 | 1.013600 | 1.044400 | 1.022900 | 1.018600 | 1.048200 | 1.054800 | 1.034000 |
| 0.7E+15 | 1.055700 | 1.044300 | 1.028400 | 1.012600 | 1.044800 | 1.022200 | 1.018300 | 1.082400 | 1.012100 | 1.033400 |
| 0.8E+15 | 1.030100 | 1.078300 | 1.013400 | 1.012800 | 1.044200 | 1.023800 | 1.018600 | 1.034300 | 1.011500 | 1.033500 |
| 0.1E+16 | 1.029900 | 1.043900 | 1.014000 | 1.014200 | 1.044200 | 1.022500 | 1.046800 | 1.044700 | 1.012200 | 1.034100 |
| 0.2E+16 | 1.030300 | 1.045100 | 1.014000 | 1.013700 | 1.044800 | 1.022300 | 1.047800 | 1.044500 | 1.013100 | 1.124200 |
| 0.3E+16 | 1.030700 | 1.079600 | 1.012800 | 1.012900 | 1.043700 | 1.023200 | 1.016800 | 1.044400 | 1.014000 | 1.033600 |
| 0.4E+16 | 1.030800 | 1.045100 | 1.032300 | 1.012500 | 1.042100 | 1.020700 | 1.015300 | 1.042300 | 1.013400 | 1.034300 |
| 0.5E+16 | 1.032900 | 1.046900 | 1.014400 | 1.014200 | 1.042300 | 1.020600 | 1.015300 | 1.039700 | 1.011700 | 1.032100 |
| 0.6E+16 | 1.064500 | 1.122100 | 1.062800 | 1.045100 | 1.125700 | 1.123200 | 1.088400 | 1.117500 | 1.092000 | 1.166700 |
| 0.7E+16 | 1.096500 | 1.122100 | 1.060800 | 1.089400 | 1.125900 | 1.112700 | 1.093500 | 1.129800 | 1.099200 | 1.173700 |
| 0.8E+16 | 1.101000 | 1.127100 | 1.040300 | 1.034600 | 1.136400 | 1.129200 | 1.107500 | 1.121800 | 1.110300 | 1.191700 |
| 0.8E+16 | 1.058200 | 1.125900 | 1.066200 | 1.101700 | 1.131900 | 1.130500 | 1.099900 | 1.115100 | 1.104600 | 1.184500 |



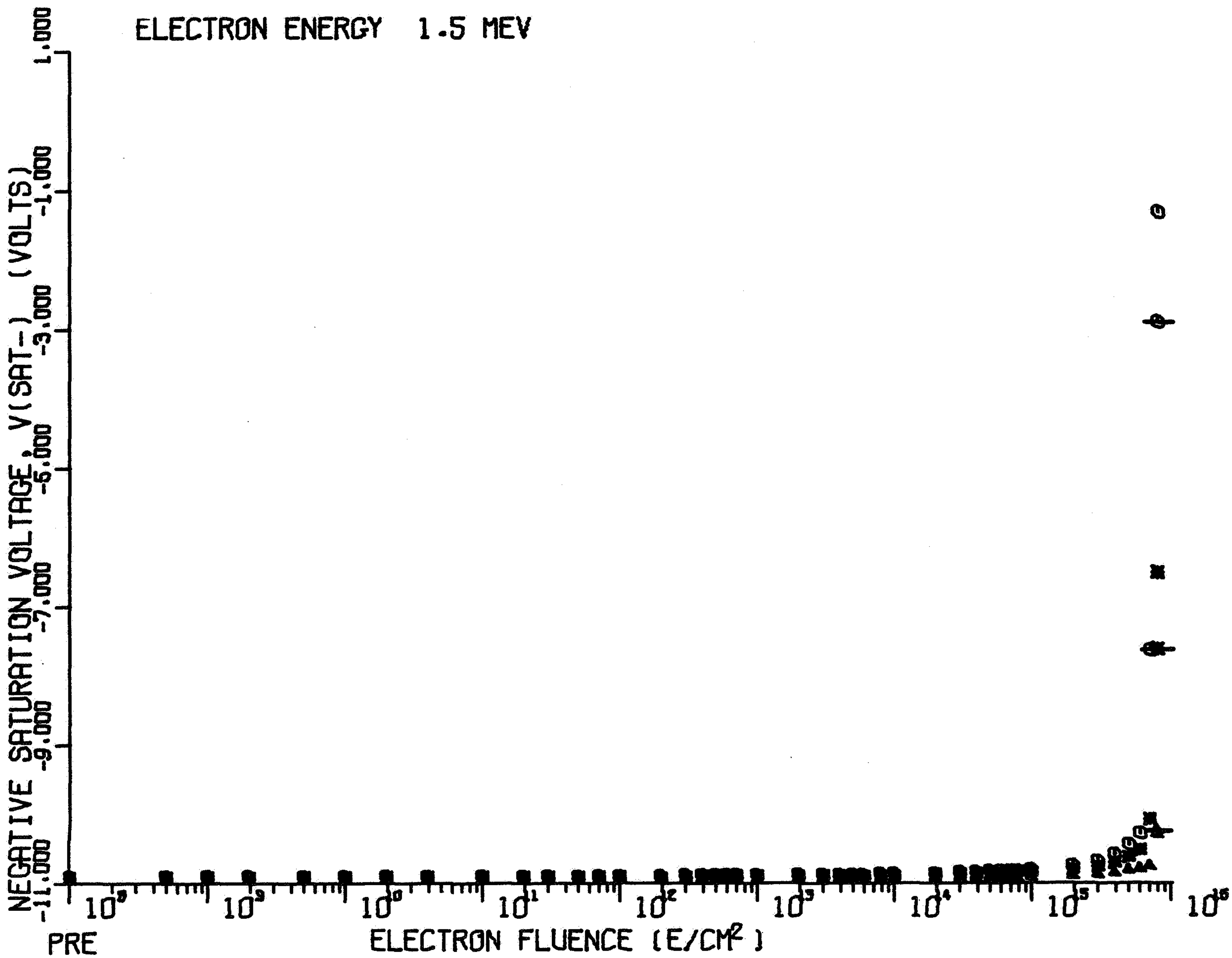

STATIC INPUT OFFSET VOLTAGE RADIATION RESPONSE FOR $\mu$A709 AMPLIFIERS.

FIGURE 39




STATIC POSITIVE SATURATION VOLTAGE RADIATION RESPONSE FOR $\mu$A709 AMPLIFIERS.

FIGURE 40




STATIC NEGATIVE SATURATION VOLTAGE RADIATION RESPONSE FOR $\mu$A709 AMPLIFIERS.

FIGURE 41

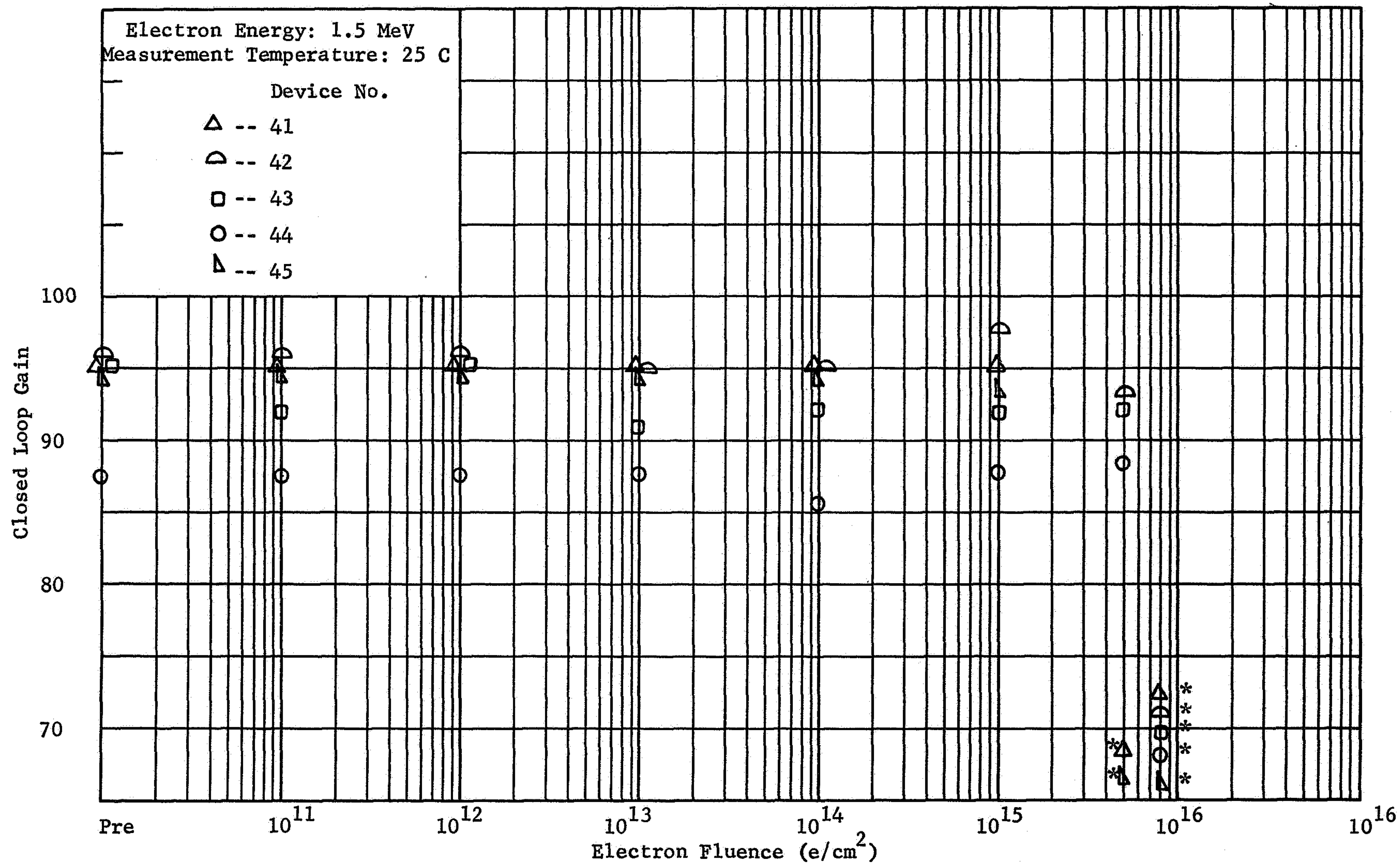



FIGURE 42. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF μA 709 AMPLIFIERS.

* Device in saturation for all input voltages.

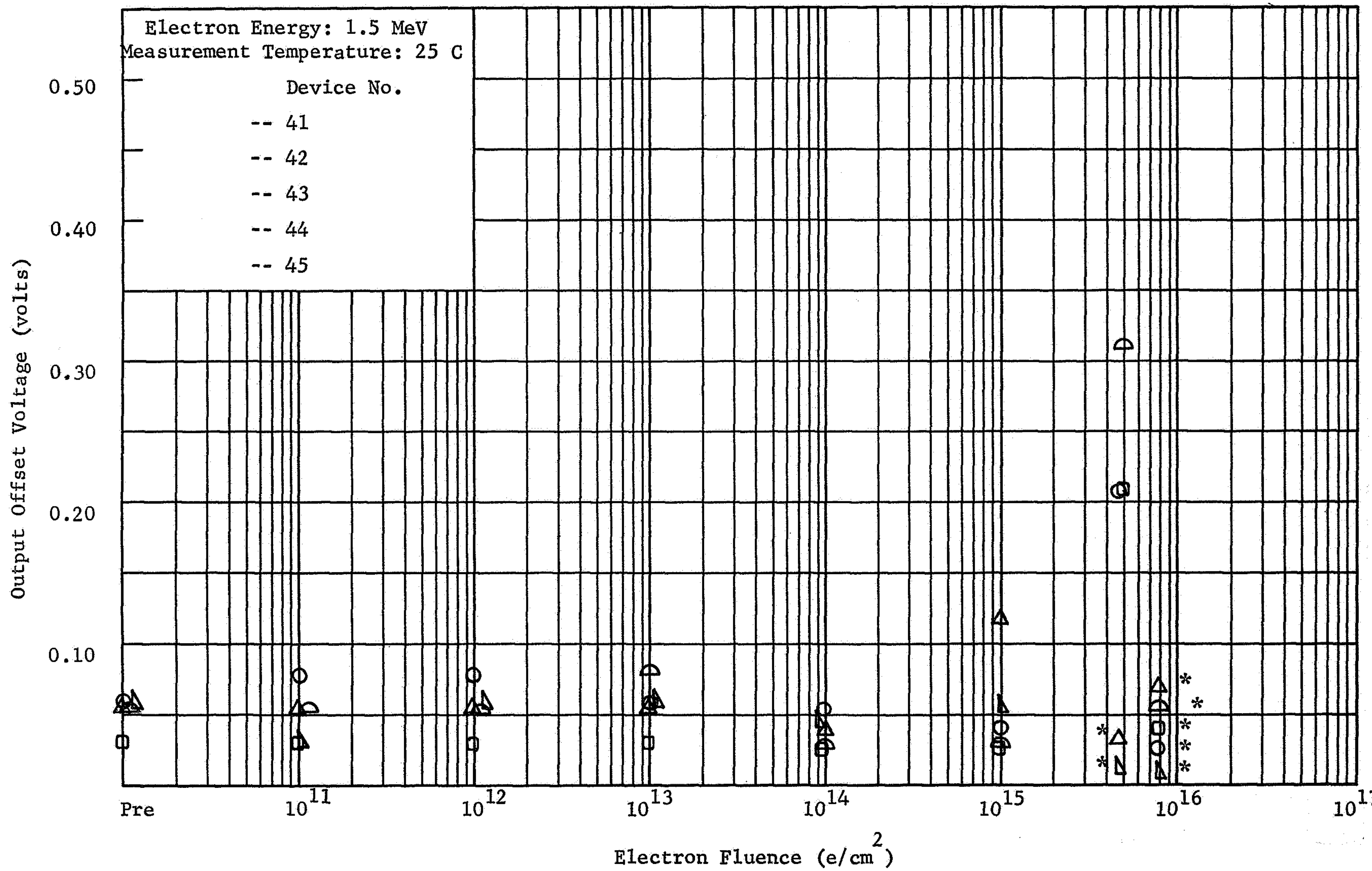



FIGURE 43. PULSED OUTPUT OFFSET VOLTAGE RESPONSE FOR μA 709 AMPLIFIERS.

* Device in saturation for all input voltages.

FAIRCHILD A709

| | GAIN O.L. | I O.S. | V SAT - | V SAT + | GAIN C.L. | V O.S. | I BIAS |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.328E+05 | -0.720E-08 | -0.110E+02 | 0.112E+02 | 0.990E+03 | -0.270E-03 | -0.418E-06 |
| AVERAGE CHANGE | -0.290E+04 | 0.148E-08 | 0.210E-01 | -0.510E-01 | 0. | -0.245E-04 | -0.490E-07 |
| STD OF MEAN | 0.150E+04 | 0.473E-08 | 0.738E-02 | 0.772E-01 | 0. | 0.105E-03 | 0.363E-07 |
| AVE PER CENT CHANGE | -0.901E+01 | 0.398E-01 | -0.191E+00 | -0.457E+00 | 0. | -0.148E+02 | 0.125E+02 |
| INTERVAL ESTIMATE | -0.121E+02 | 0.265E+02 | -0.143E+00 | -0.951E+00 | 0. | 0.370E+02 | 0.179E+02 |
| AS PER CENT | -0.556E+01 | -0.676E+02 | -0.238E+00 | 0.360E-01 | 0. | -0.189E+02 | 0.551E+01 |
| PER CENT AVE CHANGE | -0.883E+01 | -0.206E+02 | -0.191E+00 | -0.456E+00 | 0. | 0.908E+01 | 0.117E+02 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.327E+05 | -0.442E-07 | -0.110E+02 | 0.112E+02 | 0.990E+03 | -0.638E-03 | -0.369E-06 |
| AVERAGE CHANGE | -0.330E+04 | 0.244E-08 | 0.200E-01 | -0.300E-01 | 0. | -0.204E-04 | -0.110E-06 |
| STD OF MEAN | 0.145E+04 | 0.118E-07 | 0.100E-01 | 0.412E-01 | 0. | 0.242E-04 | 0.113E-06 |
| AVE PER CENT CHANGE | -0.102E+02 | 0.350E+01 | -0.182E+00 | -0.269E+00 | 0. | 0.208E+01 | 0.404E+02 |
| INTERVAL ESTIMATE | -0.156E+02 | 0.277E+02 | -0.688E-01 | -0.726E+00 | 0. | 0.561E+01 | 0.679E+02 |
| AS PER CENT | -0.458E+01 | -0.387E+02 | -0.294E+00 | 0.190E+00 | 0. | -0.107E+01 | -0.827E+01 |
| PER CENT AVE CHANGE | -0.101E+02 | -0.552E+01 | -0.182E+00 | -0.268E+00 | 0. | 0.227E+01 | 0.298E+02 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.335E+05 | 0.371E-07 | -0.110E+02 | 0.112E+02 | 0.990E+03 | -0.121E-03 | -0.354E-06 |
| AVERAGE CHANGE | -0.162E+05 | -0.297E-08 | 0.274E+00 | -0.636E+00 | -0.500E+00 | 0.672E-04 | -0.156E-05 |
| STD OF MEAN | 0.542E+04 | 0.878E-07 | 0.409E-01 | 0.227E+00 | 0.158E+01 | 0.191E-03 | 0.104E-05 |
| AVE PER CENT CHANGE | -0.478E+02 | 0.571E+01 | -0.249E+01 | -0.570E+01 | -0.505E-01 | -0.360E+01 | 0.444E+03 |
| INTERVAL ESTIMATE | -0.598E+02 | -0.177E+03 | -0.222E+01 | -0.714E+01 | -0.165E+00 | 0.574E+02 | 0.644E+03 |
| AS PER CENT | -0.367E+02 | 0.161E+03 | -0.275E+01 | -0.424E+01 | 0.637E-01 | -0.169E+03 | 0.229E+03 |
| PER CENT AVE CHANGE | -0.482E+02 | -0.800E+01 | -0.249E+01 | -0.569E+01 | -0.505E-01 | -0.556E+02 | 0.439E+03 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.319E+05 | -0.550E-07 | -0.110E+02 | 0.111E+02 | 0.990E+03 | 0.181E-03 | -0.515E-06 |
| AVERAGE CHANGE | -0.220E+05 | 0.192E-07 | 0.178E+01 | -0.576E+00 | -0.600E+01 | 0.791E-03 | -0.160E-05 |
| STD OF MEAN | 0.366E+04 | 0.196E-07 | 0.191E+01 | 0.899E-01 | 0.894E+01 | 0.503E-03 | 0.378E-06 |
| AVE PER CENT CHANGE | -0.692E+02 | -0.112E+03 | -0.162E+02 | -0.518E+01 | -0.606E+00 | -0.244E+02 | 0.353E+03 |
| INTERVAL ESTIMATE | -0.830E+02 | 0.930E+01 | 0.532E+01 | -0.619E+01 | -0.173E+01 | 0.920E+02 | 0.402E+03 |
| AS PER CENT | -0.545E+02 | -0.793E+02 | -0.377E+02 | -0.418E+01 | 0.516E+00 | 0.784E+03 | 0.219E+03 |
| PER CENT AVE CHANGE | -0.688E+02 | -0.350E+02 | -0.162E+02 | -0.518E+01 | -0.606E+00 | 0.438E+03 | 0.310E+03 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | 9 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.336E+05 | 0.233E-08 | -0.110E+02 | 0.112E+02 | 0.990E+03 | -0.201E-03 | -0.322E-06 |
| AVERAGE CHANGE | -0.255E+05 | -0.208E-07 | 0.186E+01 | -0.918E+00 | -0.800E+01 | 0.671E-03 | -0.222E-05 |
| STD OF MEAN | 0.311E+04 | 0.558E-07 | 0.143E+01 | 0.208E+00 | 0.753E+01 | 0.277E-03 | 0.527E-06 |
| AVE PER CENT CHANGE | -0.755E+02 | 0.683E+02 | -0.169E+02 | -0.823E+01 | -0.808E+00 | -0.111E+03 | 0.768E+03 |
| INTERVAL ESTIMATE | -0.823E+02 | -0.273E+04 | -0.766E+01 | -0.956E+01 | -0.135E+01 | -0.235E+03 | 0.807E+03 |
| AS PER CENT | -0.691E+02 | 0.947E+03 | -0.262E+02 | -0.669E+01 | -0.264E+00 | -0.433E+03 | 0.573E+03 |
| PER CENT AVE CHANGE | -0.757E+02 | -0.892E+03 | -0.169E+02 | -0.822E+01 | -0.808E+00 | -0.334E+03 | 0.690E+03 |

FAIRCHILD A709

| | GAIN O.L. | I O.S. | V SAT - | V SAT + | GAIN C.L. | V O.S. | I BIAS |
|---|---|---|---|---|---|---|---|
| 1.5 MEV UNBIASED-F | | | | | | | |
| NUMBER | 5 | 3 | 5 | 5 | 5 | 4 | 5 |
| INITIAL MEAN | 0.312E+05 | 0.646E-08 | -0.110E+02 | 0.111E+02 | 0.990E+03 | -0.183E-03 | -0.470E-06 |
| AVERAGE CHANGE | -0.312E+05 | 0.523E-08 | 0.170E+02 | -0.770E+00 | -0.989E+03 | 0.190E-01 | -0.201E-05 |
| STD OF MEAN | 0.240E+04 | 0.122E-06 | 0.408E+01 | 0.903E-01 | 0. | 0.202E-01 | 0.174E-06 |
| AVE PER CENT CHANGE | -0.100E+03 | -0.106E+03 | -0.155E+03 | -0.691E+01 | -0.999E+02 | 0.257E+04 | 0.452E+03 |
| INTERVAL ESTIMATE | -0.110E+03 | -0.459E+04 | -0.109E+03 | -0.792E+01 | -0.999E+02 | 0.716E+04 | 0.474E+03 |
| AS PER CENT | -0.904E+02 | 0.476E+04 | -0.201E+03 | -0.590E+01 | -0.999E+02 | -0.280E+05 | 0.382E+03 |
| PER CENT AVE CHANGE | -0.100E+03 | 0.810E+02 | -0.155E+03 | -0.691E+01 | -0.999E+02 | -0.104E+05 | 0.428E+03 |
| CONTROL-G | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.315E+05 | 0.240E-08 | -0.110E+02 | 0.111E+02 | 0.990E+03 | 0.514E-04 | -0.420E-06 |
| AVERAGE CHANGE | -0.880E+03 | -0.174E-07 | 0.200E-02 | 0.340E-01 | 0. | 0.166E-04 | -0.100E-07 |
| STD OF MEAN | 0.102E+04 | 0.509E-07 | 0.447E-02 | 0.548E-02 | 0. | 0.121E-04 | 0.561E-07 |
| AVE PER CENT CHANGE | -0.269E+01 | 0.225E+02 | -0.181E-01 | 0.305E+00 | 0. | 0.535E+01 | 0.483E+01 |
| INTERVAL ESTIMATE | -0.682E+01 | -0.336E+04 | 0.322E-01 | 0.244E+00 | 0. | 0.318E+01 | 0.190E+02 |
| AS PER CENT | 0.124E+01 | 0.191E+04 | -0.685E-01 | 0.366E+00 | 0. | 0.614E+02 | -0.142E+02 |
| PER CENT AVE CHANGE | -0.279E+01 | -0.723E+03 | -0.182E-01 | 0.305E+00 | 0. | 0.323E+02 | 0.238E+01 |
| F-TESTS | | | | | | | |
| GROUPS A-B-G | 0.464E+01 | 0.105E+01 | 0.115E+02 | 0.341E+01 | IIIII | 0.403E+00 | 0.288E+01 |
| GROUPS C-D-G | 0.323E+02 | 0.358E+00 | 0.573E+01 | 0.274E+02 | 0.301E+01 | 0.131E+02 | 0.750E+01 |
| GROUPS E-F-G | 0.203E+03 | 0.168E+00 | 0.951E+02 | 0.629E+02 | 0.605E+05 | 0.713E+01 | 0.560E+02 |
| GROUPS A-C-E-G | 0.937E+02 | 0.292E+00 | 0.125E+02 | 0.604E+02 | 0.846E+01 | 0.282E+02 | 0.266E+02 |
| GROUPS B-D-F-G | 0.192E+03 | 0.377E+00 | 0.675E+02 | 0.177E+03 | 0.609E+05 | 0.455E+01 | 0.111E+03 |
| GROUPS ALL | 0.902E+02 | 0.337E+00 | 0.892E+02 | 0.496E+02 | 0.368E+05 | 0.743E+01 | 0.230E+02 |
| T-TESTS | | | | | | | |
| GROUPS A-B | 0.492E+00 | -0.229E+00 | 0.221E+00 | -0.562E+00 | IIIII | -0.842E-01 | 0.160E+01 |
| GROUPS C-D | 0.214E+01 | -0.549E+00 | -0.260E+01 | -0.561E+00 | 0.196E+01 | -0.411E+01 | 0.890E-01 |
| GROUPS E-F | 0.358E+01 | -0.529E+00 | -0.109E+02 | -0.150E+01 | 0.286E+03 | -0.307E+01 | -0.872E+00 |
| GROUPS A-G | -0.269E+01 | 0.121E+01 | 0.524E+01 | -0.241E+01 | IIIII | -0.853E+00 | -0.164E+01 |
| GROUPS B-G | -0.305E+01 | 0.847E+00 | 0.367E+01 | -0.344E+01 | IIIII | -0.307E+01 | -0.177E+01 |
| GROUPS C-G | -0.614E+01 | 0.335E+00 | 0.146E+02 | -0.648E+01 | -0.694E+00 | 0.581E+00 | -0.325E+01 |
| GROUPS D-G | -0.124E+02 | 0.150E+01 | 0.209E+01 | -0.151E+02 | -0.150E+01 | 0.344E+01 | -0.930E+01 |
| GROUPS E-G | -0.169E+02 | -0.114E+00 | 0.287E+01 | -0.100E+02 | -0.233E+01 | 0.517E+01 | -0.919E+01 |
| GROUPS F-G | -0.259E+02 | 0.379E+00 | 0.935E+01 | -0.199E+02 | RRRRR | 0.214E+01 | -0.245E+02 |
| GROUPS A-C | 0.746E+01 | 0.160E+00 | -0.193E+02 | 0.772E+01 | 0.100E+01 | -0.133E+01 | 0.457E+01 |
| GROUPS A-E | 0.206E+02 | 0.126E+01 | -0.409E+01 | 0.123E+02 | 0.336E+01 | -0.741E+01 | 0.130E+02 |
| GROUPS C-E | 0.471E+01 | 0.522E+00 | -0.353E+01 | 0.290E+01 | 0.308E+01 | -0.567E+01 | 0.161E+01 |
| GROUPS B-D | 0.106E+02 | -0.164E+01 | -0.207E+01 | 0.123E+02 | 0.150E+01 | -0.360E+01 | 0.844E+01 |
| GROUPS B-F | 0.222E+02 | -0.540E-01 | -0.934E+01 | 0.167E+02 | RRRRR | -0.215E+01 | 0.205E+02 |
| GROUPS D-F | 0.471E+01 | 0.266E+00 | -0.759E+01 | 0.341E+01 | 0.246E+03 | -0.206E+01 | 0.221E+01 |

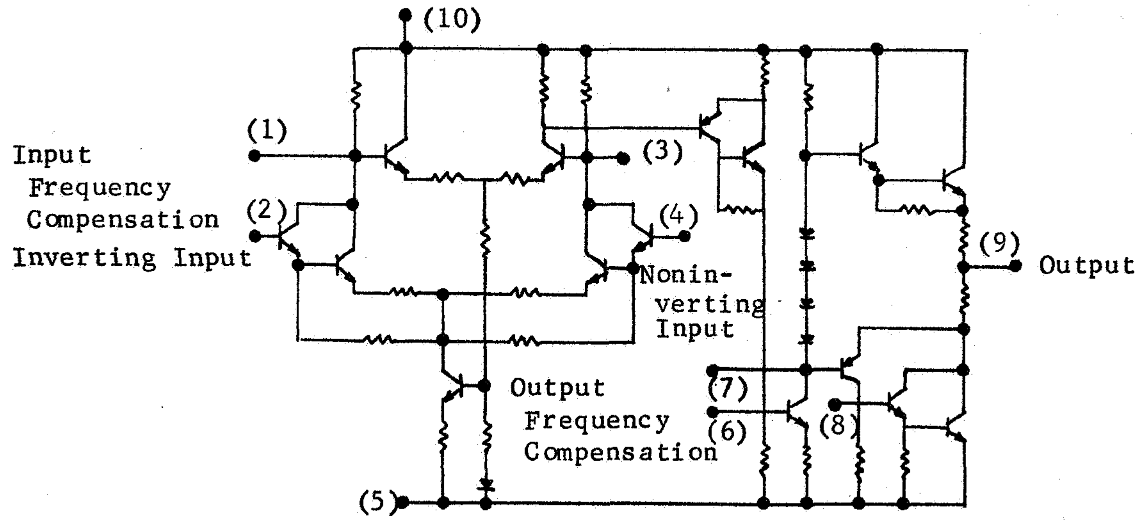
FAIRCHILD A709

| | CMRR | RESISTANCE |
|---|---|---|
| **0.5 MEV BIASED-A** | | |
| NUMBER | 10 | 10 |
| INITIAL MEAN | 0.589E-03 | 0.958E+04 |
| AVERAGE CHANGE | -0.119E-02 | 0.111E+03 |
| STD OF MEAN | 0.254E-03 | 0.296E+02 |
| AVE PER CENT CHANGE | -0.206E+03 | 0.118E+01 |
| INTERVAL ESTIMATE | -0.233E+03 | 0.938E+00 |
| AS PER CENT | -0.172E+03 | 0.138E+01 |
| PER CENT AVE CHANGE | -0.203E+03 | 0.116E+01 |
| **0.5 MEV UNBIASED-B** | | |
| NUMBER | 5 | 5 |
| INITIAL MEAN | 0.500E-03 | 0.104E+05 |
| AVERAGE CHANGE | -0.102E-02 | 0.130E+03 |
| STD OF MEAN | 0.552E-03 | 0.400E+02 |
| AVE PER CENT CHANGE | -0.238E+03 | 0.123E+01 |
| INTERVAL ESTIMATE | -0.340E+03 | 0.770E+00 |
| AS PER CENT | -0.661E+02 | 0.172E+01 |
| PER CENT AVE CHANGE | -0.203E+03 | 0.125E+01 |
| **1.0 MEV BIASED-C** | | |
| NUMBER | 10 | 10 |
| INITIAL MEAN | 0.597E-03 | 0.939E+04 |
| AVERAGE CHANGE | -0.114E-02 | 0.516E+03 |
| STD OF MEAN | 0.403E-03 | 0.506E+03 |
| AVE PER CENT CHANGE | -0.190E+03 | 0.586E+01 |
| INTERVAL ESTIMATE | -0.240E+03 | 0.164E+01 |
| AS PER CENT | -0.144E+03 | 0.934E+01 |
| PER CENT AVE CHANGE | -0.192E+03 | 0.549E+01 |
| **1.0 MEV UNBIASED-D** | | |
| NUMBER | 5 | 5 |
| INITIAL MEAN | 0.666E-03 | 0.867E+04 |
| AVERAGE CHANGE | -0.130E-02 | 0.780E+02 |
| STD OF MEAN | 0.114E-03 | 0.791E+03 |
| AVE PER CENT CHANGE | -0.195E+03 | 0.845E+00 |
| INTERVAL ESTIMATE | -0.216E+03 | -0.104E+02 |
| AS PER CENT | -0.173E+03 | 0.122E+02 |
| PER CENT AVE CHANGE | -0.195E+03 | 0.899E+00 |
| **1.5 MEV BIASED-E** | | |
| NUMBER | 10 | 10 |
| INITIAL MEAN | 0.568E-03 | 0.939E+04 |
| AVERAGE CHANGE | -0.117E-02 | 0.351E+03 |
| STD OF MEAN | 0.326E-03 | 0.277E+02 |
| AVE PER CENT CHANGE | -0.217E+03 | 0.374E+01 |
| INTERVAL ESTIMATE | -0.247E+03 | 0.353E+01 |
| AS PER CENT | -0.165E+03 | 0.395E+01 |
| PER CENT AVE CHANGE | -0.206E+03 | 0.374E+01 |

FAIRCHILD A709

| | CMRR | RESISTANCE |
|---|---|---|
| **1.5 MEV UNBIASED-F** | | |
| NUMBER | 5 | 5 |
| INITIAL MEAN | 0.588E-03 | 0.867E+04 |
| AVERAGE CHANGE | -0.834E-03 | 0.264E+03 |
| STD OF MEAN | 0.385E-03 | 0.422E+02 |
| AVE PER CENT CHANGE | -0.165E+03 | 0.304E+01 |
| INTERVAL ESTIMATE | -0.223E+03 | 0.244E+01 |
| AS PER CENT | -0.606E+02 | 0.365E+01 |
| PER CENT AVE CHANGE | -0.142E+03 | 0.305E+01 |
| **CONTROL-G** | | |
| NUMBER | 5 | 5 |
| INITIAL MEAN | 0.656E-03 | 0.100E+05 |
| AVERAGE CHANGE | -0.138E-02 | 0.760E+02 |
| STD OF MEAN | 0.293E-03 | 0.378E+02 |
| AVE PER CENT CHANGE | -0.211E+03 | 0.810E+00 |
| INTERVAL ESTIMATE | -0.266E+03 | 0.291E+00 |
| AS PER CENT | -0.155E+03 | 0.123E+01 |
| PER CENT AVE CHANGE | -0.211E+03 | 0.760E+00 |
| **F-TESTS** | | |
| GROUPS A-B-G | 0.133E+01 | 0.323E+01 |
| GROUPS C-D-G | 0.947E+00 | 0.170E+01 |
| GROUPS F-F-G | 0.346E+01 | 0.109E+03 |
| GROUPS A-C-E-G | 0.632E+00 | 0.489E+01 |
| GROUPS B-D-F-G | 0.232E+01 | 0.247E+00 |
| GROUPS ALL | 0.136E+01 | 0.204E+01 |
| **T-TESTS** | | |
| GROUPS A-B | -0.869E+00 | -0.105E+01 |
| GROUPS C-D | 0.808E+00 | 0.132E+01 |
| GROUPS F-F | -0.179E+01 | 0.484E+01 |
| GROUPS A-G | 0.130E+01 | 0.197E+01 |
| GROUPS B-G | 0.131E+01 | 0.219E+01 |
| GROUPS C-G | 0.116E+01 | 0.191E+01 |
| GROUPS D-G | 0.612E+00 | 0.565E-02 |
| GROUPS F-G | 0.121E+01 | 0.161E+02 |
| GROUPS F-G | 0.254E+01 | 0.742E+01 |
| GROUPS A-C | -0.319E+00 | -0.253E+01 |
| GROUPS A-E | -0.161E+00 | -0.187E+02 |
| GROUPS C-E | 0.165E+00 | 0.103E+01 |
| GROUPS B-D | 0.111E+01 | 0.147E+00 |
| GROUPS B-F | -0.605E+00 | -0.515E+01 |
| GROUPS D-F | -0.257E+01 | -0.525E+00 |

Amelco 807BE



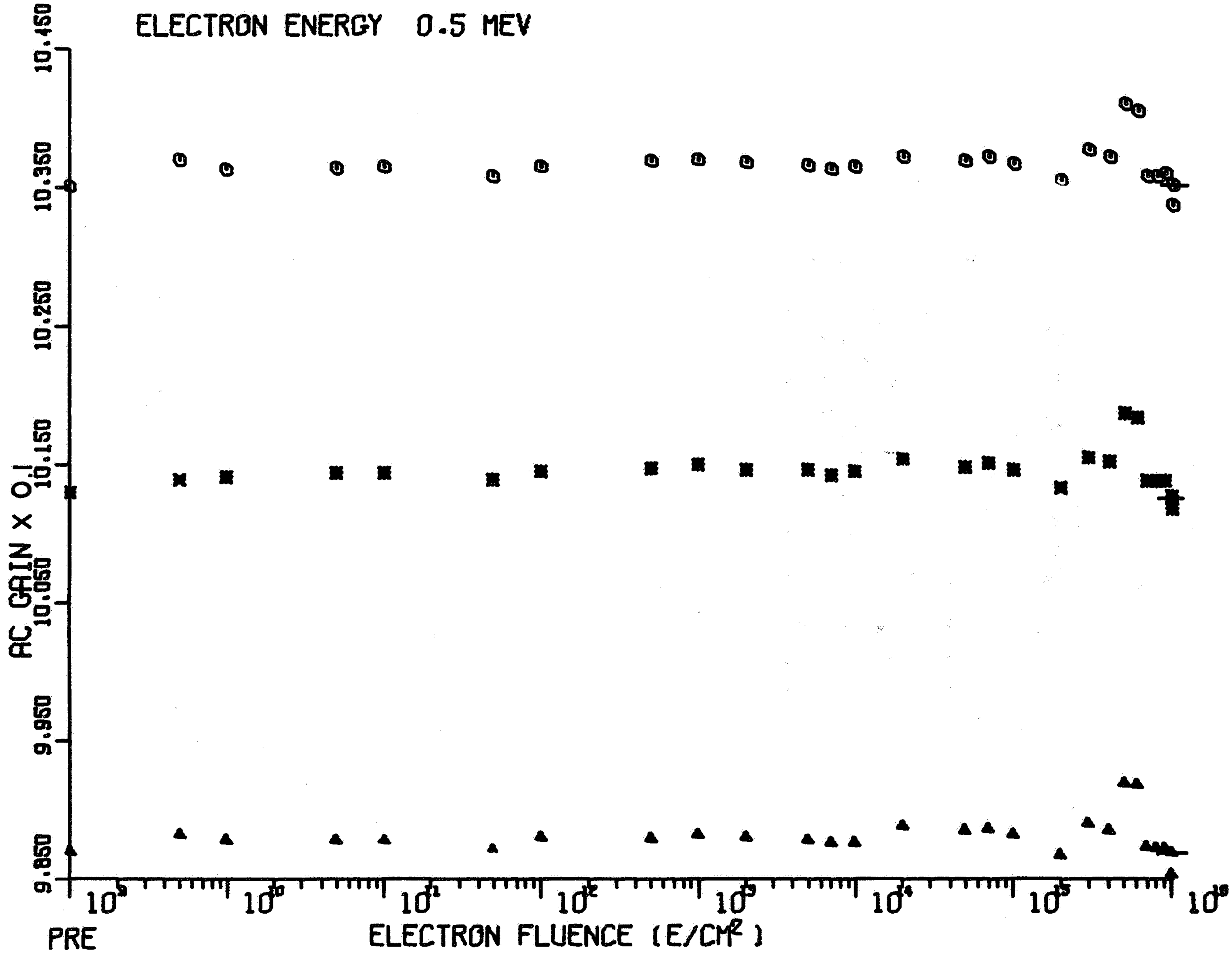

TEST CONDITIONS:

1. Pin 5, -12 volts.
2. Pin 10,+12 volts.
3. Temperature 25 C.

TEST PARAMETERS:

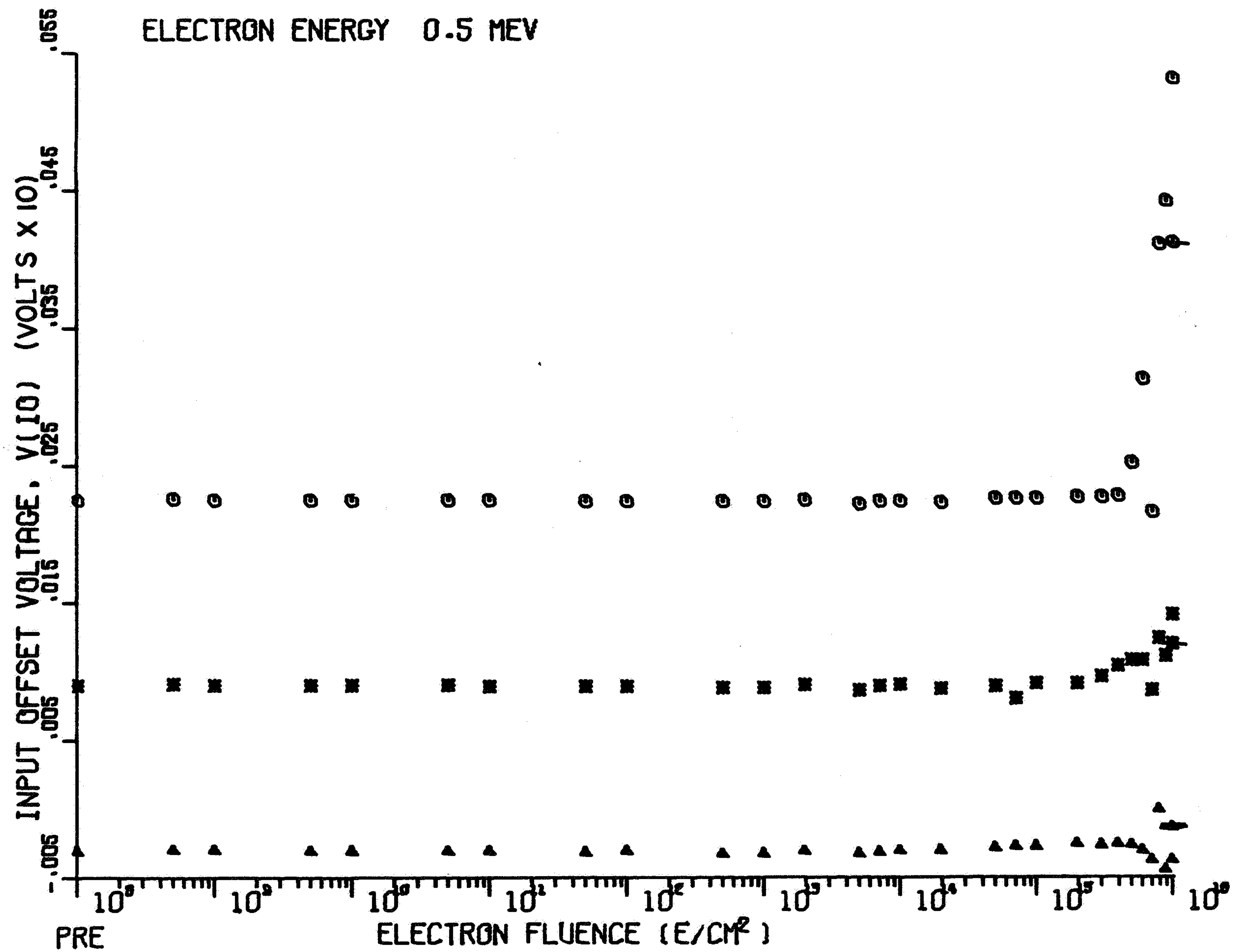
1. Open-loop gain.
2. Closed-loop gain.
3. Input offset voltage.
4. + Saturation voltage.
5. - Saturation voltage.
6. Input bias current.
7. Input offset current.
8. Common mode rejection.
9. Resistance.

FIGURE 44. TEST PLAN FOR 807BE AMPLIFIER




STATIC AC GAIN RADIATION RESPONSE FOR 807BE AMPLIFIERS.

FIGURE 45




STATIC INPUT OFFSET VOLTAGE RADIATION RESPONSE FOR 807BE AMPLIFIERS.

FIGURE 46

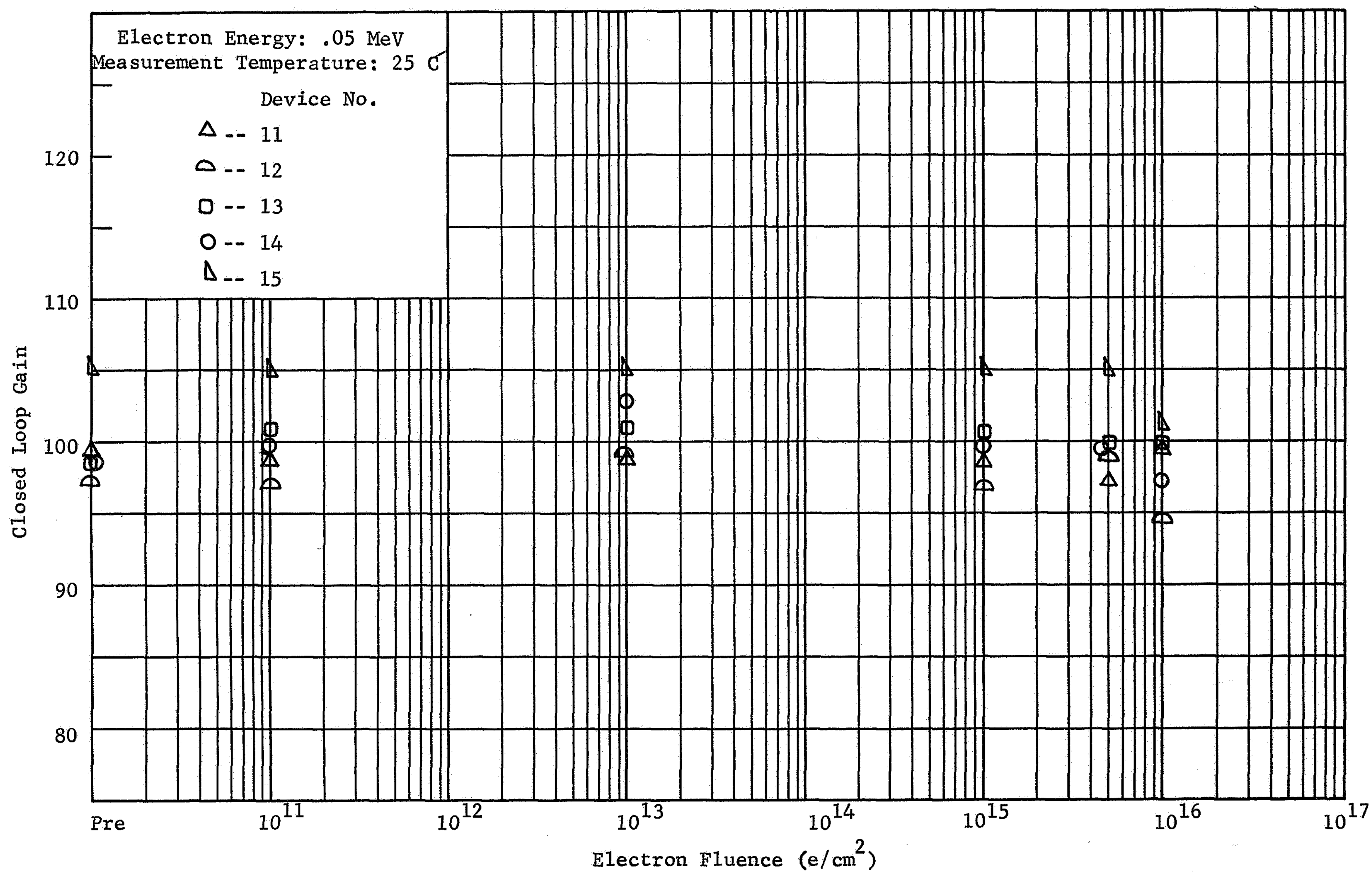
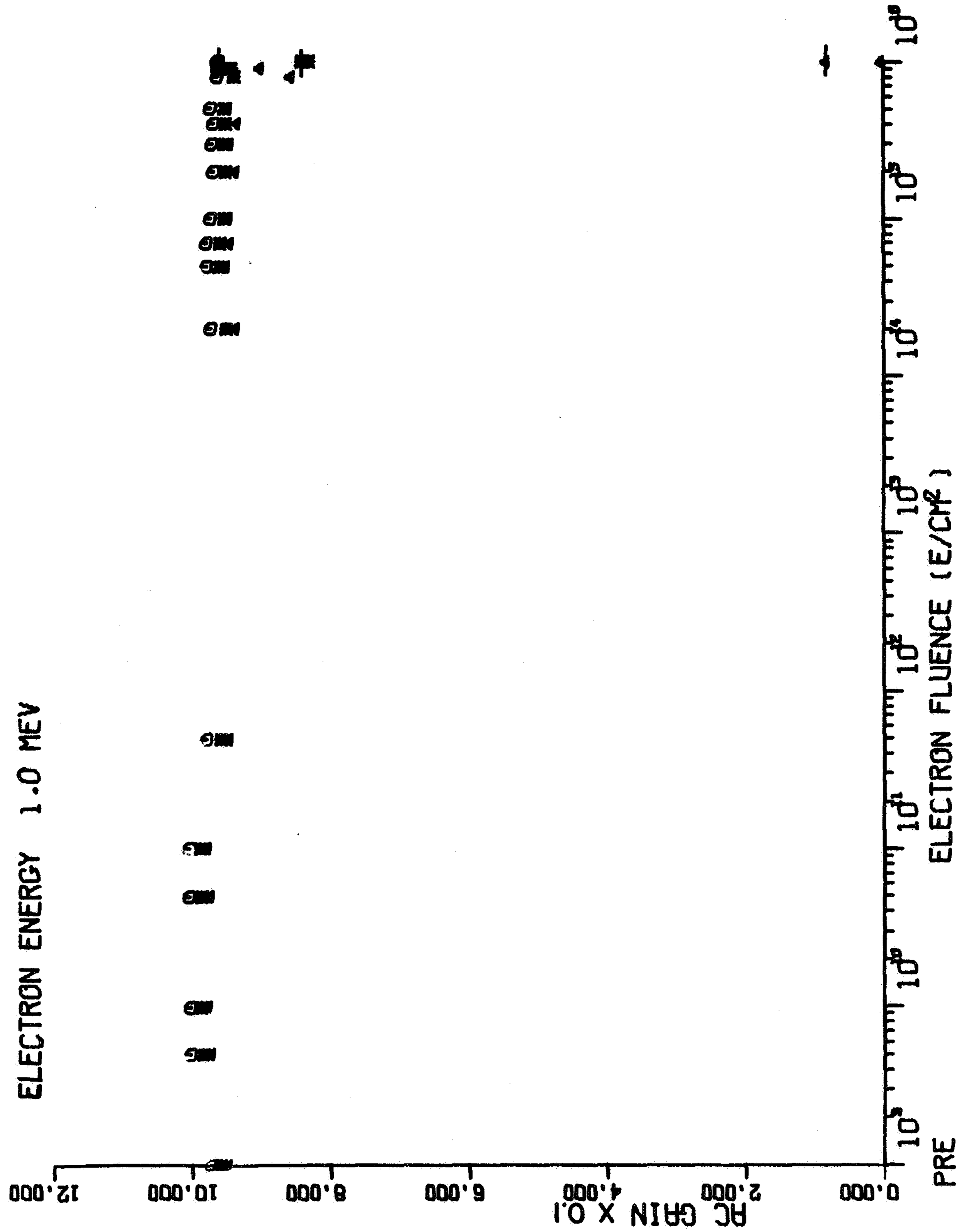
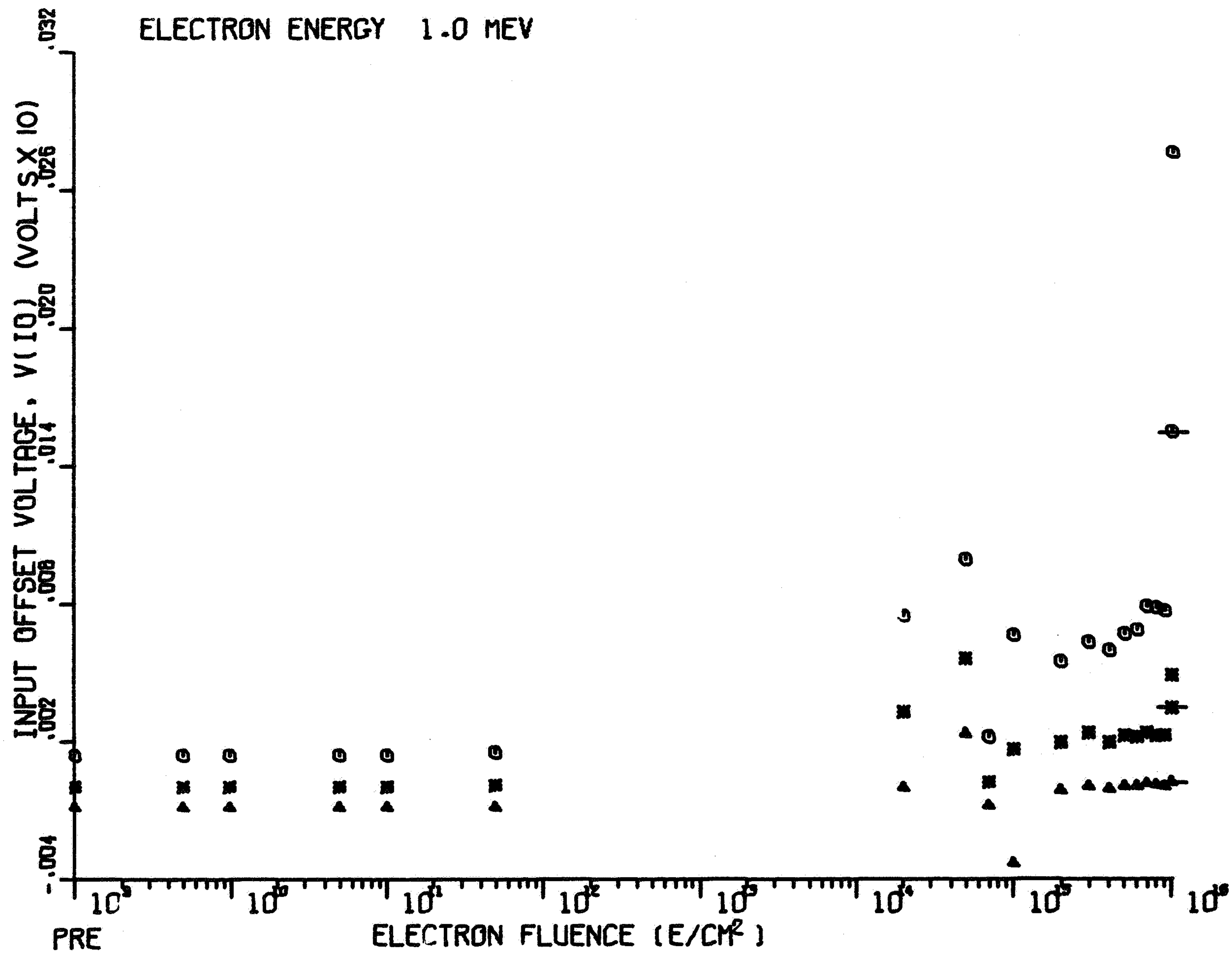



FIGURE 47. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF 807 BE AMPLIFIERS.



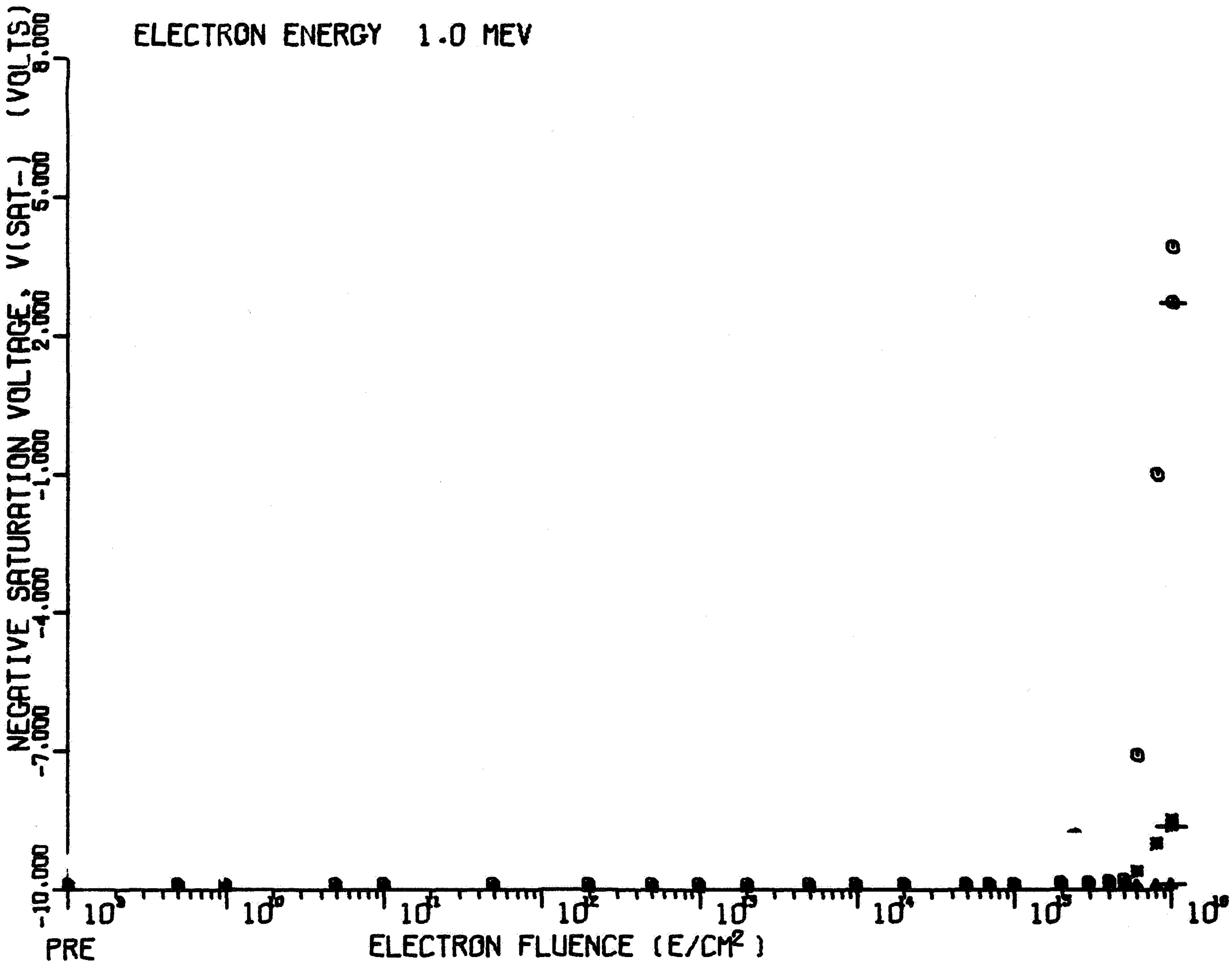

STATIC AC GAIN RADIATION RESPONSE FOR 807BE AMPLIFIERS.

FIGURE 48




STATIC INPUT OFFSET VOLTAGE RADIATION RESPONSE FOR 807BE AMPLIFIERS.

FIGURE 49




STATIC NEGATIVE SATURATION VOLTAGE RADIATION RESPONSE FOR 807BE AMPLIFIERS.

FIGURE 50

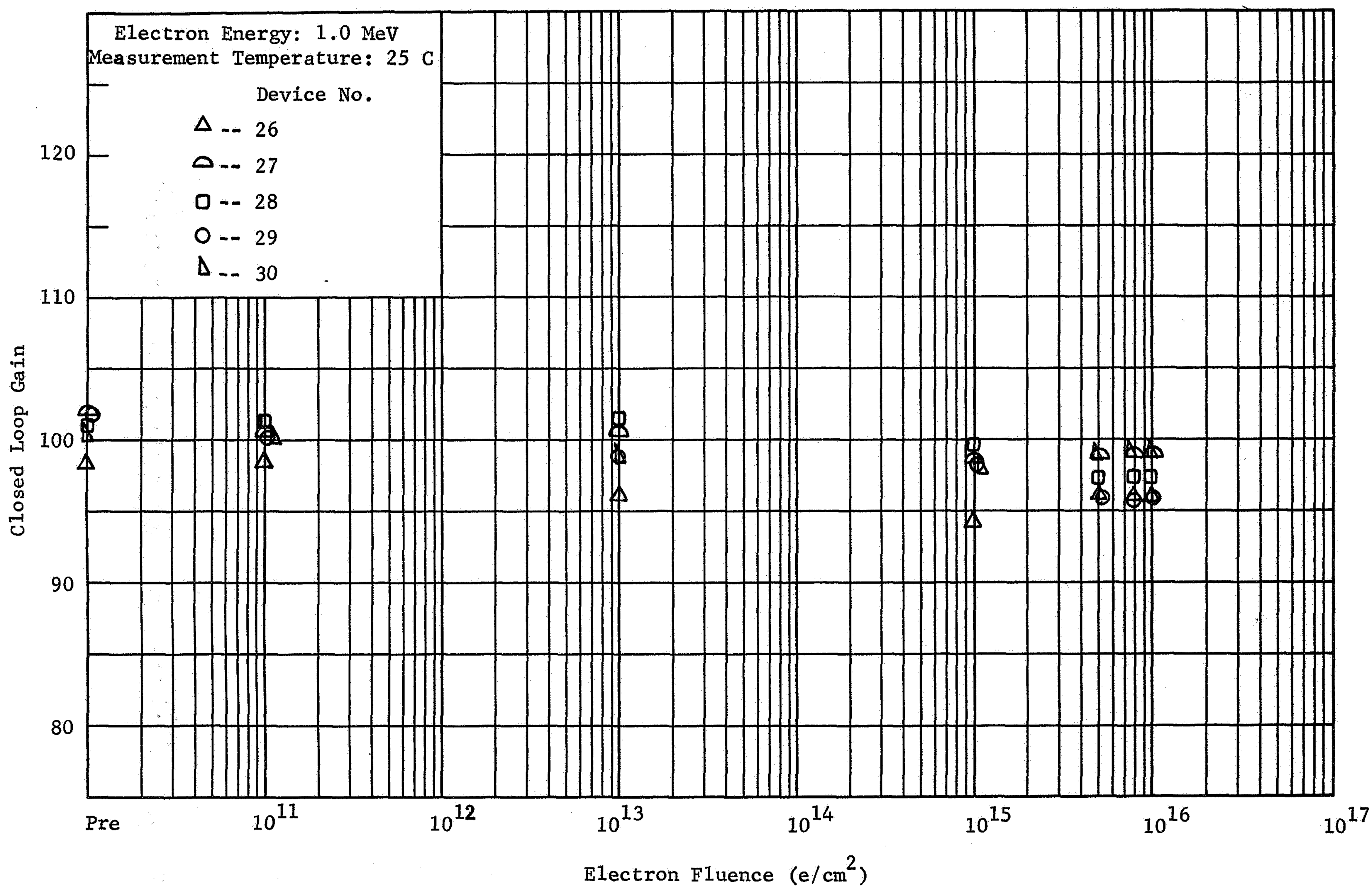



FIGURE 51. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF 807 BE AMPLIFIERS.

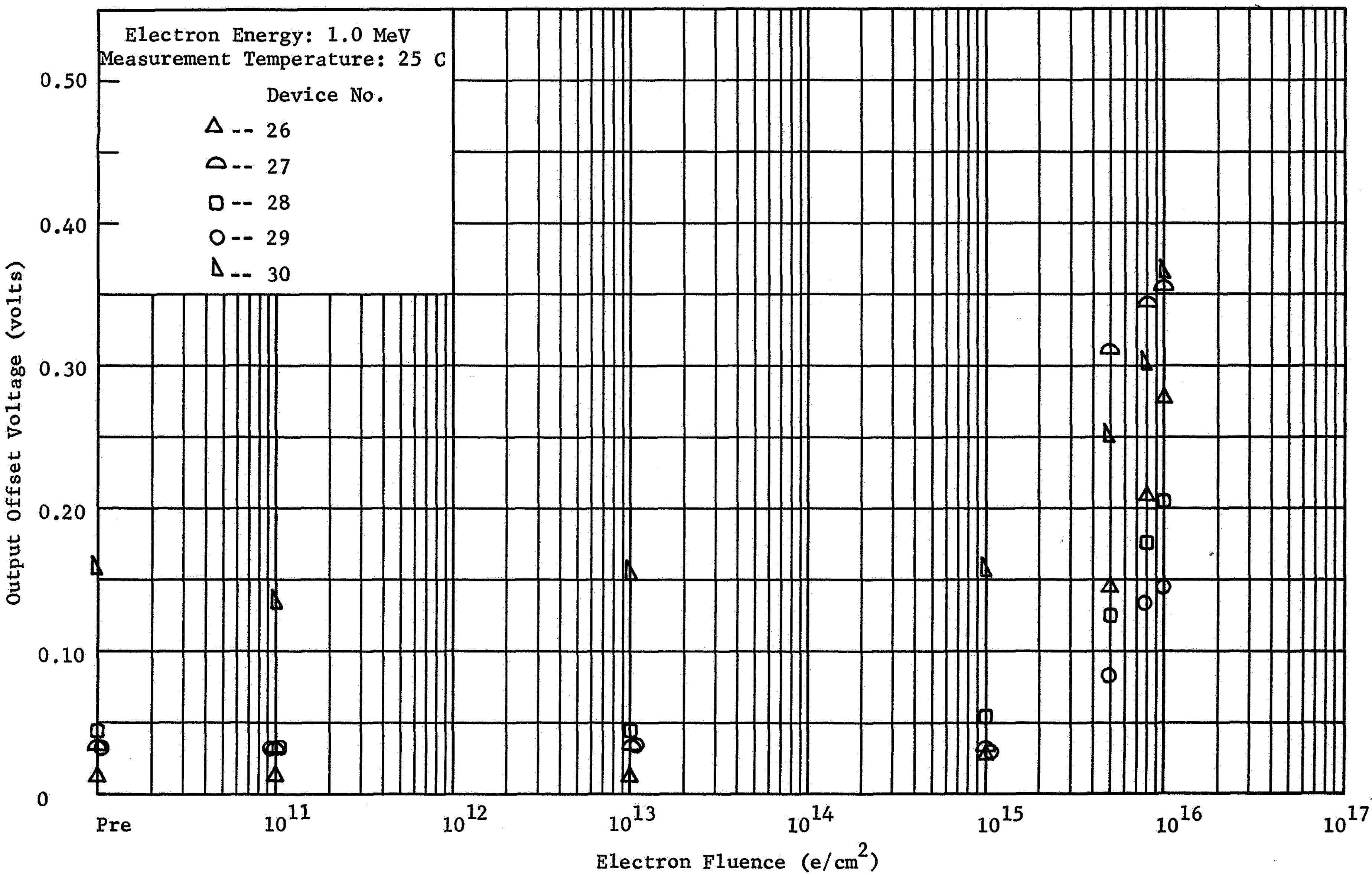
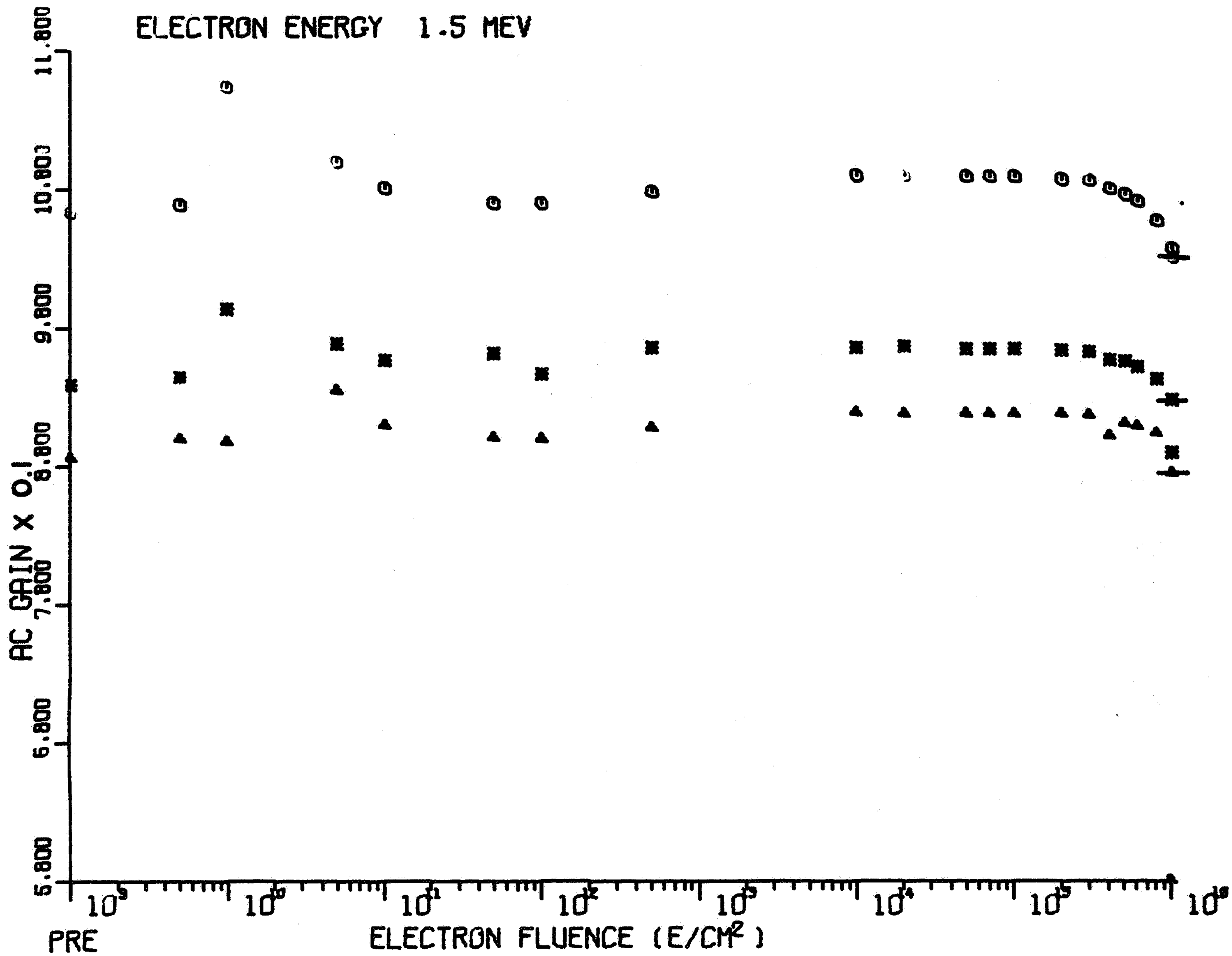
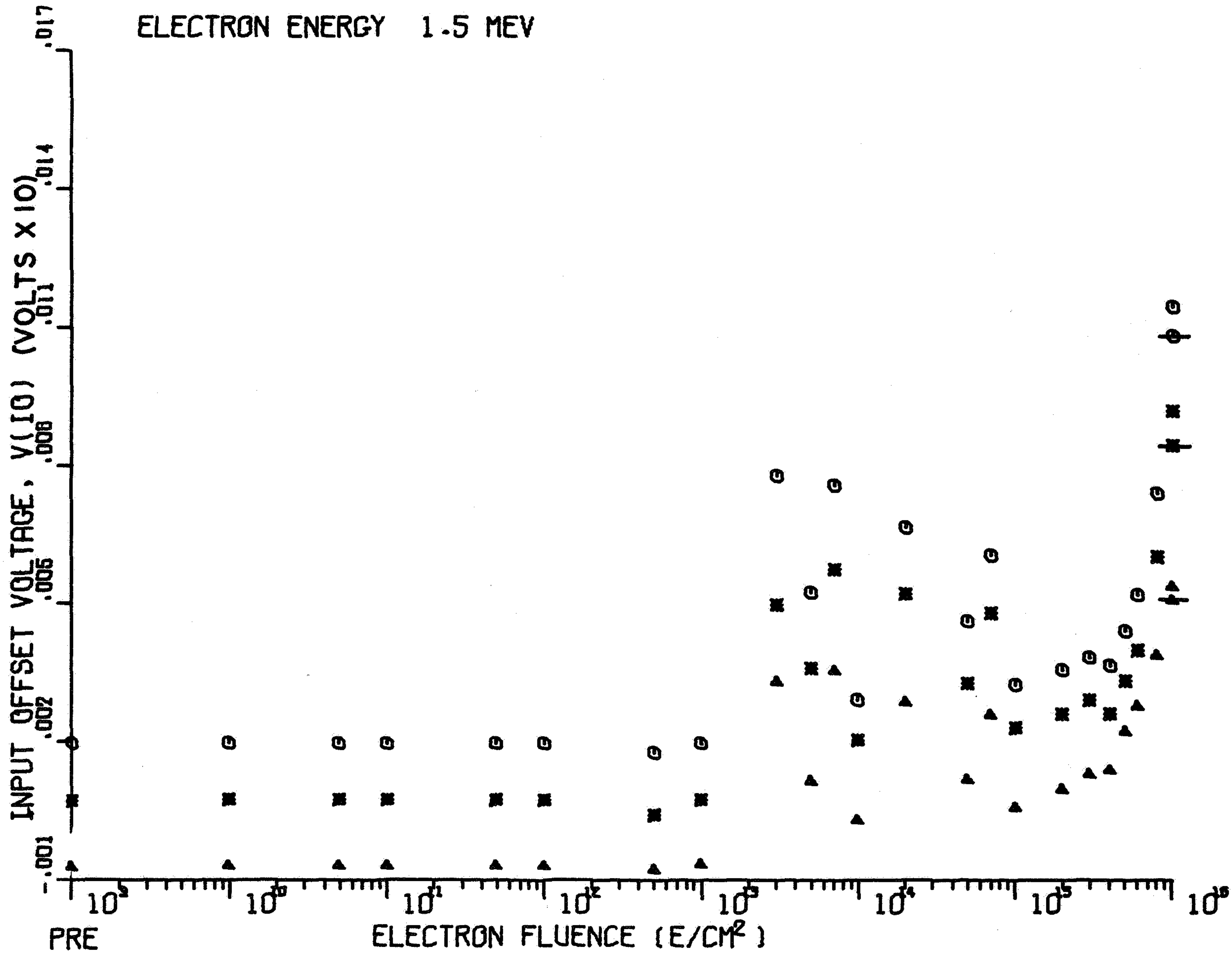



FIGURE 52. PULSED OUTPUT OFFSET VOLTAGE RESPONSE OF 807 BE AMPLIFIERS.



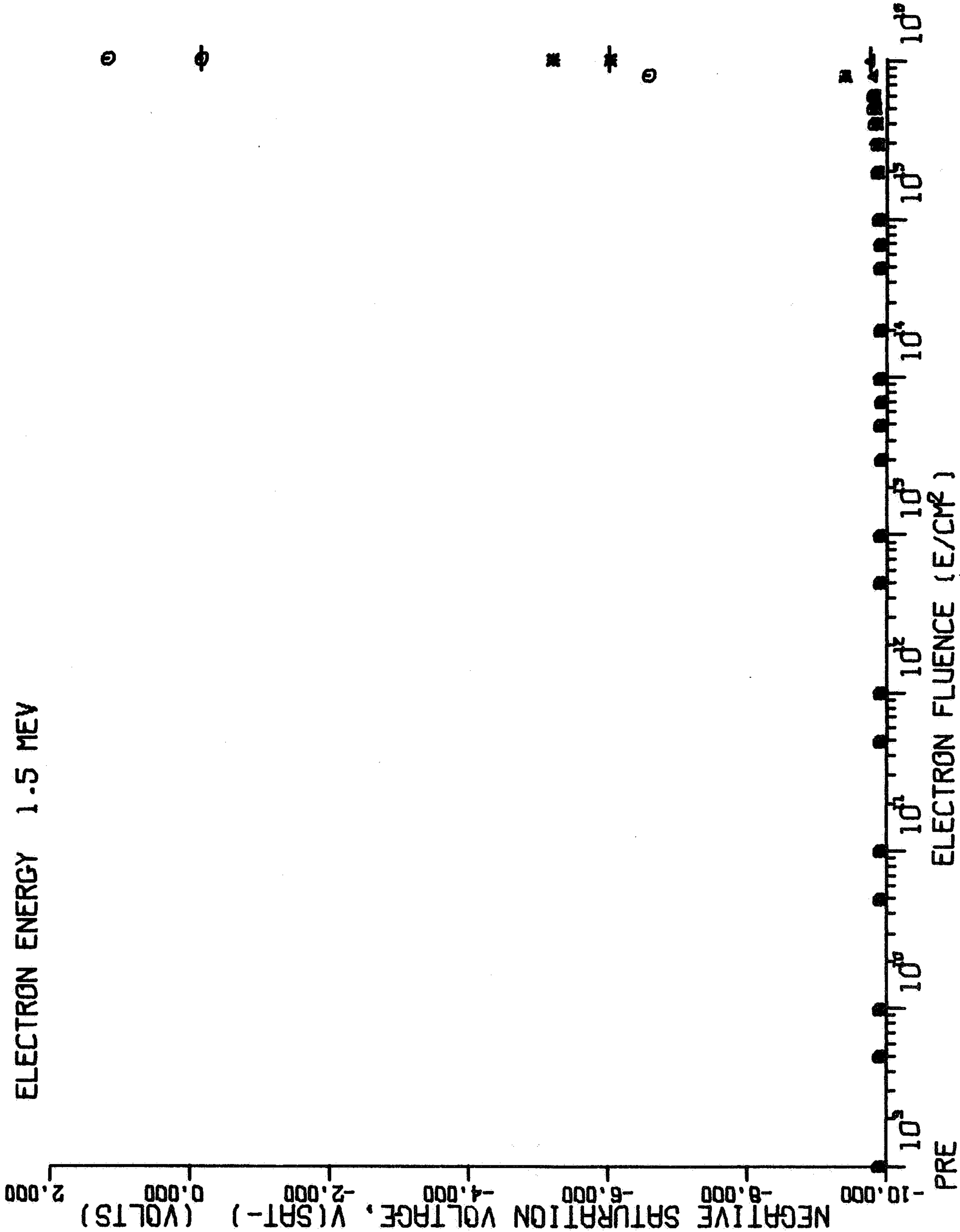

STATIC AC GAIN RADIATION RESPONSE FOR 807BE AMPLIFIERS.

FIGURE 53




STATIC INPUT OFFSET VOLTAGE RADIATION RESPONSE FOR 807BE AMPLIFIERS.

FIGURE 54




STATIC NEGATIVE SATURATION VOLTAGE RADIATION RESPONSE FOR 807BE AMPLIFIERS.

FIGURE 55

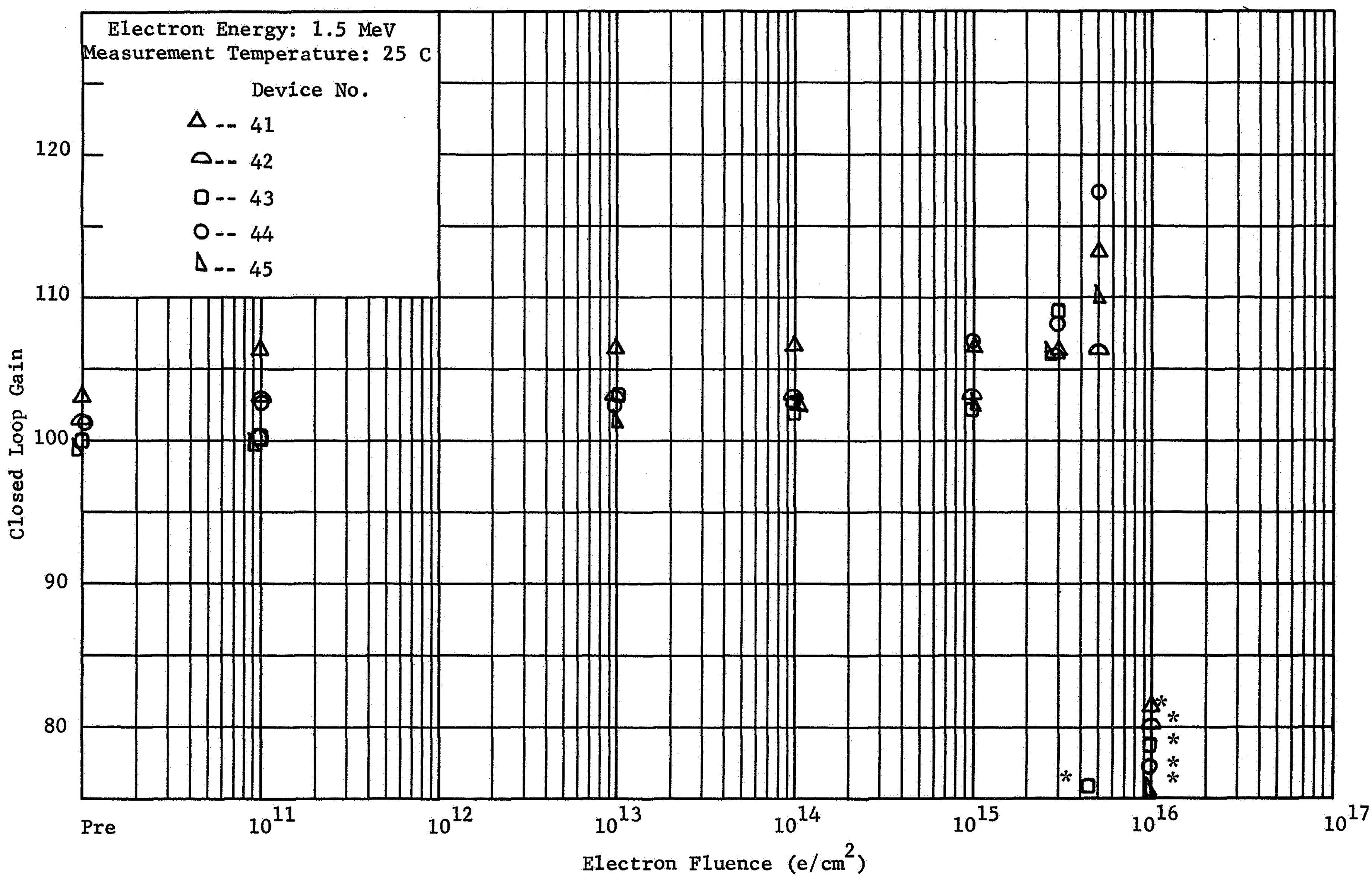



FIGURE 56. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF 807 BE AMPLIFIERS.

* Device in saturation for all input voltages.

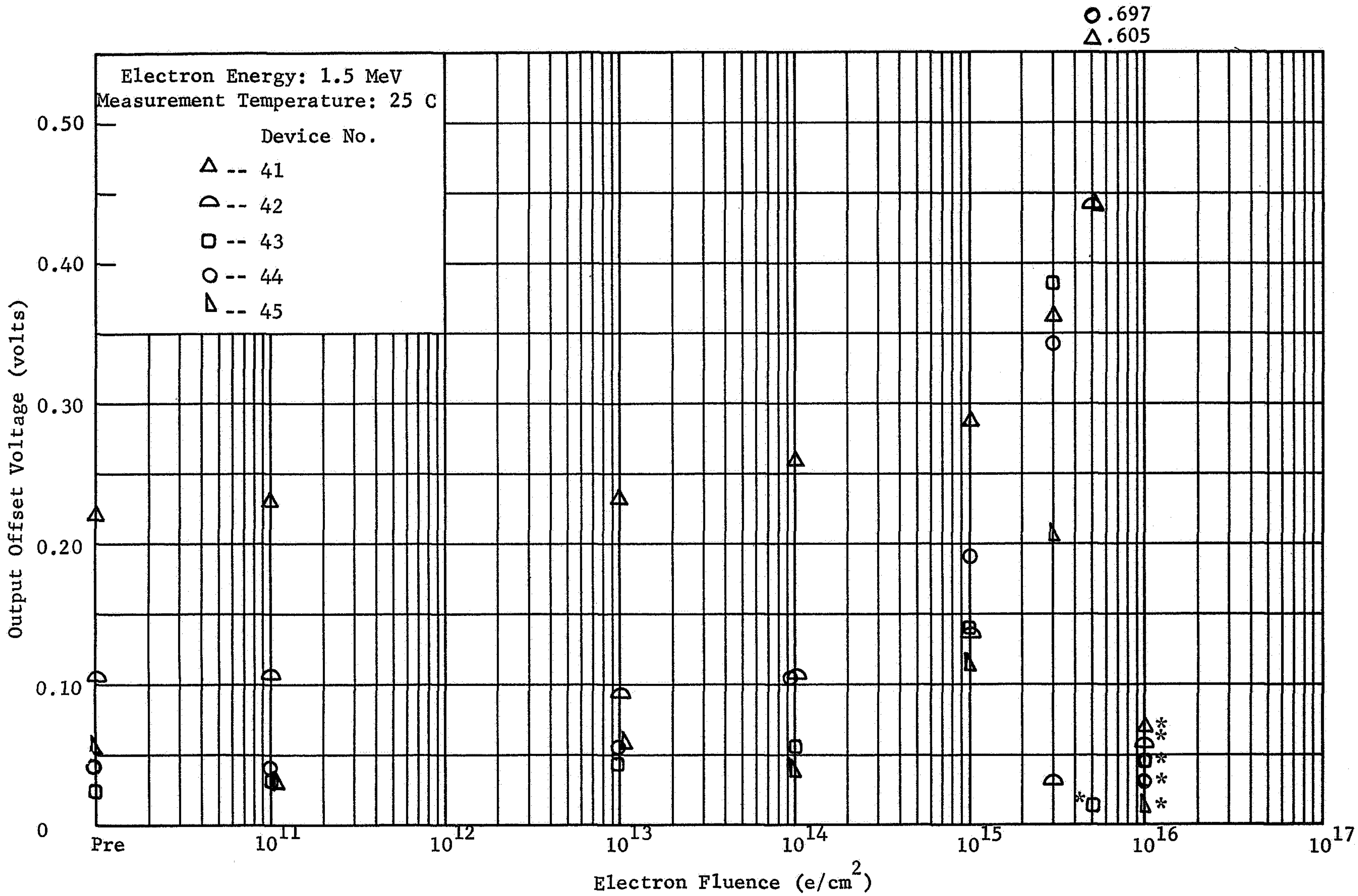



FIGURE 57. PULSED OUTPUT OFFSET VOLTAGE RESPONSE OF 807 BE AMPLIFIERS.

* Device in saturation for all input voltages.

AMELCO 807BE

| | I O.S. | V SAT - | V SAT + | GAIN C.L. | V O.S. | I BIAS | CMRR |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | -0.140E-08 | -0.101E+02 | 0.104E+02 | 0.100E+03 | 0.874E-03 | 0.426E-06 | 0.514E-03 |
| AVERAGE CHANGE | 0.702E-08 | -0.100E-02 | 0.300E-01 | 0. | 0.603E-04 | 0.130E-06 | 0.100E-04 |
| STD OF MEAN | 0.660E-08 | 0.876E-02 | 0.816E-02 | 0. | 0.291E-04 | 0.677E-07 | 0.327E-04 |
| AVE PER CENT CHANGE | 0.206E+04 | 0.100E-01 | 0.289E+00 | 0. | 0.259E+02 | 0.320E+02 | 0.203E+01 |
| INTERVAL ESTIMATE | -0.164E+03 | 0.722E-01 | 0.233E+00 | 0. | 0.452E+01 | 0.193E+02 | -0.260E+01 |
| AS PER CENT | -0.839E+03 | -0.523E-01 | 0.346E+00 | 0. | 0.928E+01 | 0.420E+02 | 0.649E+01 |
| PER CENT AVE CHANGE | -0.501E+03 | 0.994E-02 | 0.289E+00 | 0. | 0.690E+01 | 0.306E+02 | 0.195E+01 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.980E-09 | -0.100E+02 | 0.104E+02 | 0.100E+03 | -0.121E-03 | 0.494E-06 | 0.608E-03 |
| AVERAGE CHANGE | 0.368E-08 | -0.120E-01 | 0.400E-01 | 0. | 0.719E-03 | 0.266E-06 | -0.200E-04 |
| STD OF MEAN | 0.623E-08 | 0.447E-02 | 0.100E-01 | 0. | 0.162E-02 | 0.391E-07 | 0.141E-04 |
| AVE PER CENT CHANGE | -0.835E+02 | 0.119E+00 | 0.386E+00 | 0. | -0.425E+02 | 0.543E+02 | -0.326E+01 |
| INTERVAL ESTIMATE | -0.414E+03 | 0.175E+00 | 0.266E+00 | 0. | 0.106E+04 | 0.440E+02 | -0.618E+01 |
| AS PER CENT | 0.116E+04 | 0.642E-01 | 0.505E+00 | 0. | -0.225E+04 | 0.637E+02 | -0.402E+00 |
| PER CENT AVE CHANGE | 0.376E+03 | 0.119E+00 | 0.386E+00 | 0. | -0.593E+03 | 0.538E+02 | -0.329E+01 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.980E-08 | -0.101E+02 | 0.104E+02 | 0.100E+03 | -0.178E-03 | 0.521E-06 | 0.632E-03 |
| AVERAGE CHANGE | -0.860E-08 | 0.780E+00 | -0.680E-01 | -0.200E+00 | 0.184E-02 | 0.238E-05 | 0.180E-04 |
| STD OF MEAN | 0.585E-07 | 0.230E+01 | 0.187E+00 | 0.632E+00 | 0.164E-02 | 0.111E-05 | 0.634E-04 |
| AVE PER CENT CHANGE | -0.251E+03 | -0.777E+01 | -0.630E+00 | -0.200E+00 | -0.195E+04 | 0.444E+03 | 0.334E+01 |
| INTERVAL ESTIMATE | -0.515E+03 | 0.862E+01 | -0.194E+01 | -0.652E+00 | -0.379E+03 | 0.304E+03 | -0.433E+01 |
| AS PER CENT | 0.339E+03 | -0.241E+02 | 0.635E+00 | 0.252E+00 | -0.170E+04 | 0.609E+03 | 0.100E+02 |
| PER CENT AVE CHANGE | -0.878E+02 | -0.776E+01 | -0.653E+00 | -0.200E+00 | -0.104E+04 | 0.457E+03 | 0.285E+01 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | -0.290E-08 | -0.101E+02 | 0.104E+02 | 0.100E+03 | 0.815E-03 | 0.372E-06 | 0.536E-03 |
| AVERAGE CHANGE | -0.370E-07 | 0.116E+00 | 0.200E-02 | 0. | 0.939E-03 | 0.249E-05 | -0.160E-04 |
| STD OF MEAN | 0.101E-07 | 0.321E-01 | 0.837E-02 | 0. | 0.418E-03 | 0.244E-06 | 0.297E-04 |
| AVE PER CENT CHANGE | 0.674E+03 | -0.115E+01 | 0.192E-01 | 0. | 0.123E+04 | 0.644E+03 | -0.400E+01 |
| INTERVAL ESTIMATE | 0.171E+04 | -0.757E+00 | -0.809E-01 | 0. | 0.515E+02 | 0.561E+03 | -0.986E+01 |
| AS PER CENT | 0.843E+03 | -0.155E+01 | 0.119E+00 | 0. | 0.179E+03 | 0.723E+03 | 0.389E+01 |
| PER CENT AVE CHANGE | 0.127E+04 | -0.115E+01 | 0.193E-01 | 0. | 0.115E+03 | 0.642E+03 | -0.299E+01 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 9 | 10 | 10 | 9 | 9 | 10 | 10 |
| INITIAL MEAN | 0.643E-08 | -0.100E+02 | 0.104E+02 | 0.100E+03 | 0.656E-03 | 0.513E-06 | 0.599E-03 |
| AVERAGE CHANGE | -0.436E-07 | 0.302E+01 | -0.720E-01 | -0.267E+01 | 0.593E-02 | 0.615E-05 | 0.271E-03 |
| STD OF MEAN | 0.590E-07 | 0.624E+01 | 0.391E-01 | 0.283E+01 | 0.164E-02 | 0.865E-06 | 0.519E-03 |
| AVE PER CENT CHANGE | -0.237E+03 | -0.300E+02 | -0.694E+00 | -0.267E+01 | -0.359E+03 | 0.125E+04 | 0.472E+02 |
| INTERVAL ESTIMATE | -0.138E+04 | 0.144E+02 | -0.964E+00 | -0.484E+01 | 0.712E+03 | 0.108E+04 | -0.168E+02 |
| AS PER CENT | 0.278E+02 | -0.745E+02 | -0.425E+00 | -0.493E+00 | 0.110E+04 | 0.132E+04 | 0.107E+03 |
| PER CENT AVE CHANGE | -0.677E+03 | -0.300E+02 | -0.694E+00 | -0.267E+01 | 0.904E+03 | 0.120E+04 | 0.453E+02 |

AMELCO 807BE

| | I O.S. | V SAT - | V SAT + | GAIN C.L. | V O.S. | I BIAS | CMRR |
|---|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | | |
| NUMBER | 3 | 5 | 5 | 3 | 3 | 5 | 5 |
| INITIAL MEAN | -0.760E-09 | -0.101E+02 | 0.104E+02 | 0.100E+03 | 0.718E-03 | 0.676E-06 | 0.624E-03 |
| AVERAGE CHANGE | -0.147E-06 | 0.110E+02 | -0.164E+00 | -0.433E+01 | 0.801E-02 | 0.706E-05 | 0.536E-03 |
| STD OF MEAN | 0.275E-07 | 0.663E+01 | 0.114E+00 | 0.577E+00 | 0.476E-03 | 0.657E-06 | 0.614E-03 |
| AVE PER CENT CHANGE | -0.784E+03 | -0.109E+03 | -0.158E+01 | -0.433E+01 | 0.135E+04 | 0.105E+04 | 0.907E+02 |
| INTERVAL ESTIMATE | 0.283E+05 | -0.273E+02 | -0.295E+01 | -0.577E+01 | 0.950E+03 | 0.924E+03 | -0.363E+02 |
| AS PER CENT | 0.103E+05 | -0.191E+03 | -0.215E+00 | -0.290E+01 | 0.128E+04 | 0.117E+04 | 0.208E+03 |
| PER CENT AVE CHANGE | 0.193E+05 | -0.109E+03 | -0.158E+01 | -0.433E+01 | 0.112E+04 | 0.104E+04 | 0.859E+02 |
| **CONTROL-G** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.364E-08 | -0.101E+02 | 0.104E+02 | 0.100E+03 | 0.390E-03 | 0.496E-06 | 0.626E-03 |
| AVERAGE CHANGE | -0.348E-08 | 0.200E-02 | 0.340E-01 | 0. | -0.200E-05 | 0.300E-07 | 0.600E-05 |
| STD OF MEAN | 0.103E-07 | 0.295E-01 | 0.305E-01 | 0. | 0.164E-04 | 0.112E-06 | 0.365E-04 |
| AVE PER CENT CHANGE | -0.291E+03 | -0.193E-01 | 0.328E+00 | 0. | -0.397E+01 | 0.345E+01 | 0.742E+00 |
| INTERVAL ESTIMATE | -0.447E+03 | 0.344E+00 | -0.372E-01 | 0. | -0.574E+01 | -0.220E+02 | -0.627E+01 |
| AS PER CENT | 0.256E+03 | -0.383E+00 | 0.692E+00 | 0. | 0.472E+01 | 0.341E+02 | 0.819E+01 |
| PER CENT AVE CHANGE | -0.956E+02 | -0.198E-01 | 0.327E+00 | 0. | -0.513E+00 | 0.605E+01 | 0.958E+00 |
| **F-TESTS** | | | | | | | |
| GROUPS A-B-G | 0.321E+01 | 0.114E+01 | 0.603E+00 | IIIII | 0.142E+01 | 0.123E+02 | 0.170E+01 |
| GROUPS C-D-G | 0.934E+00 | 0.469E+00 | 0.105E+01 | 0.472E+00 | 0.400E+01 | 0.155E+02 | 0.728E+00 |
| GROUPS E-F-G | 0.922E+01 | 0.536E+01 | 0.120E+02 | 0.431E+01 | 0.499E+02 | 0.157E+03 | 0.152E+01 |
| GROUPS A-C-E-G | 0.219E+01 | 0.145E+01 | 0.273E+01 | 0.659E+01 | 0.430E+02 | 0.127E+03 | 0.199E+01 |
| GROUPS B-D-F-G | 0.931E+02 | 0.136E+02 | 0.131E+02 | 0.329E+03 | 0.569E+02 | 0.421E+03 | 0.393E+01 |
| GROUPS ALL | 0.727E+01 | 0.656E+01 | 0.385E+01 | 0.663E+01 | 0.369E+02 | 0.125E+03 | 0.262E+01 |
| **T-TESTS** | | | | | | | |
| GROUPS A-B | 0.939E+00 | 0.261E+01 | -0.208E+01 | IIIII | -0.134E+01 | -0.410E+01 | 0.194E+01 |
| GROUPS C-D | 0.106E+01 | 0.633E+00 | -0.819E+00 | -0.694E+00 | 0.120E+01 | -0.156E-01 | 0.112E+01 |
| GROUPS E-F | 0.286E+01 | -0.228E+01 | 0.236E+01 | 0.983E+00 | -0.210E+01 | -0.207E+01 | -0.879E+00 |
| GROUPS A-G | 0.242E+01 | -0.306E+00 | -0.401E+00 | IIIII | 0.440E+01 | 0.219E+01 | 0.216E+00 |
| GROUPS B-G | 0.133E+01 | -0.105E+01 | 0.418E+00 | IIIII | 0.998E+00 | 0.445E+01 | -0.149E+01 |
| GROUPS C-G | -0.191E+00 | 0.742E+00 | -0.119E+01 | -0.694E+00 | 0.247E+01 | 0.463E+01 | 0.388E+00 |
| GROUPS D-G | -0.519E+01 | 0.585E+01 | -0.226E+01 | IIIII | 0.503E+01 | 0.197E+02 | -0.105E+01 |
| GROUPS E-G | -0.148E+01 | 0.106E+01 | -0.528E+01 | -0.207E+01 | 0.794E+01 | 0.155E+02 | 0.112E+01 |
| GROUPS F-G | -0.109E+02 | 0.370E+01 | -0.375E+01 | -0.178E+02 | 0.398E+02 | 0.236E+02 | 0.193E+01 |
| GROUPS A-C | 0.839E+00 | -0.107E+01 | 0.165E+01 | 0.100E+01 | -0.344E+01 | -0.640E+01 | -0.355E+00 |
| GROUPS A-E | 0.270E+01 | -0.153E+01 | 0.808E+01 | 0.299E+01 | -0.114E+02 | -0.219E+02 | -0.159E+01 |
| GROUPS C-E | 0.130E+01 | -0.106E+01 | 0.661E-01 | 0.269E+01 | -0.543E+01 | -0.846E+01 | -0.153E+01 |
| GROUPS B-D | 0.767E+01 | -0.883E+01 | 0.652E+01 | IIIII | -0.294E+00 | -0.102E+02 | -0.272E+00 |
| GROUPS B-F | 0.123E+02 | -0.371E+01 | 0.398E+01 | 0.178E+02 | -0.740E+01 | -0.231E+02 | -0.202E+01 |
| GROUPS D-F | 0.840E+01 | -0.366E+01 | 0.324E+01 | 0.178E+02 | -0.221E+02 | -0.149E+02 | -0.201E+01 |

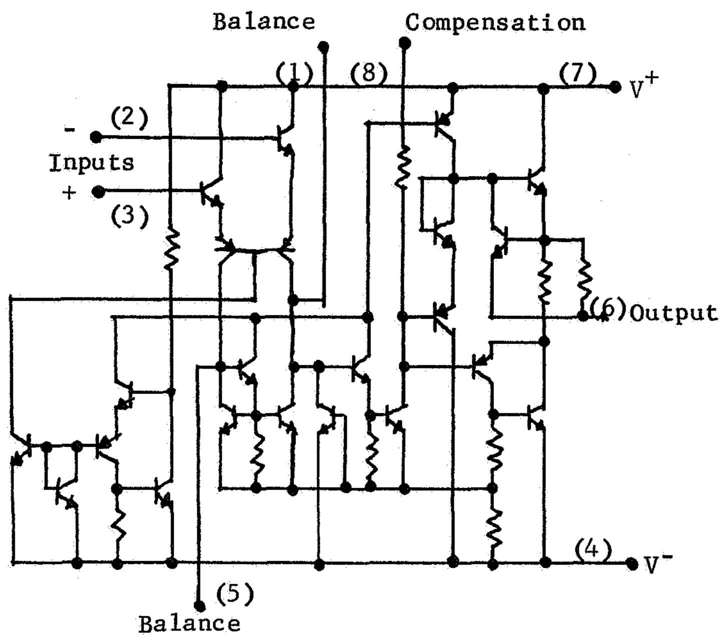
AMELCO 807HE

| | GAIN O.L. |
|---|---|
| **0.5 MEV BIASED-A** | |
| NUMBER | 10 |
| INITIAL MEAN | 0.692E+05 |
| AVERAGE CHANGE | -0.251E+04 |
| STD OF MEAN | 0.943E+04 |
| AVE PER CENT CHANGE | -0.341E+01 |
| INTERVAL ESTIMATE | -0.134E+02 |
| AS PER CENT | 0.613E+01 |
| PER CENT AVE CHANGE | -0.363E+01 |
| **0.5 MEV UNBIASED-B** | |
| NUMBER | 5 |
| INITIAL MEAN | 0.653E+05 |
| AVERAGE CHANGE | -0.958E+04 |
| STD OF MEAN | 0.335E+04 |
| AVE PER CENT CHANGE | -0.146E+02 |
| INTERVAL ESTIMATE | -0.210E+02 |
| AS PER CENT | -0.830E+01 |
| PER CENT AVE CHANGE | -0.147E+02 |
| **1.0 MEV BIASED-C** | |
| NUMBER | 10 |
| INITIAL MEAN | 0.658E+05 |
| AVERAGE CHANGE | -0.517E+05 |
| STD OF MEAN | 0.134E+05 |
| AVE PER CENT CHANGE | -0.789E+02 |
| INTERVAL ESTIMATE | -0.932E+02 |
| AS PER CENT | -0.641E+02 |
| PER CENT AVE CHANGE | -0.786E+02 |
| **1.0 MEV UNBIASED-D** | |
| NUMBER | 5 |
| INITIAL MEAN | 0.719E+05 |
| AVERAGE CHANGE | -0.588E+05 |
| STD OF MEAN | 0.264E+04 |
| AVE PER CENT CHANGE | -0.818E+02 |
| INTERVAL ESTIMATE | -0.863E+02 |
| AS PER CENT | -0.772E+02 |
| PER CENT AVE CHANGE | -0.818E+02 |
| **1.5 MEV BIASED-E** | |
| NUMBER | 9 |
| INITIAL MEAN | 0.673E+05 |
| AVERAGE CHANGE | -0.647E+05 |
| STD OF MEAN | 0.139E+05 |
| AVE PER CENT CHANGE | -0.949E+02 |
| INTERVAL ESTIMATE | -0.112E+03 |
| AS PER CENT | -0.803E+02 |
| PER CENT AVE CHANGE | -0.962E+02 |

AMELCO 807BE

| | GAIN O.L. |
|---|---|
| **1.5 MEV UNBIASED-F** | |
| NUMBER | 3 |
| INITIAL MEAN | 0.601E+05 |
| AVERAGE CHANGE | -0.607E+05 |
| STD OF MEAN | 0.613E+04 |
| AVE PER CENT CHANGE | -0.978E+02 |
| INTERVAL ESTIMATE | -0.126E+03 |
| AS PER CENT | -0.756E+02 |
| PER CENT AVE CHANGE | -0.101E+03 |
| **CONTROL-G** | |
| NUMBER | 5 |
| INITIAL MEAN | 0.687E+05 |
| AVERAGE CHANGE | 0.500E+03 |
| STD OF MEAN | 0.112E+04 |
| AVE PER CENT CHANGE | 0.685E+00 |
| INTERVAL ESTIMATE | -0.129E+01 |
| AS PER CENT | 0.275E+01 |
| PER CENT AVE CHANGE | 0.728E+00 |
| **F-TESTS** | |
| GROUPS A-B-G | 0.274E+01 |
| GROUPS C-D-G | 0.588E+02 |
| GROUPS E-F-G | 0.627E+02 |
| GROUPS A-C-E-G | 0.694E+02 |
| GROUPS B-D-F-G | 0.418E+03 |
| GROUPS ALL | 0.578E+02 |
| **T-TESTS** | |
| GROUPS A-B | 0.160E+01 |
| GROUPS C-D | 0.115E+01 |
| GROUPS E-F | -0.473E+00 |
| GROUPS A-G | -0.698E+00 |
| GROUPS B-G | -0.638E+01 |
| GROUPS C-G | -0.856E+01 |
| GROUPS D-G | -0.462E+02 |
| GROUPS E-G | -0.103E+02 |
| GROUPS F-G | -0.229E+02 |
| GROUPS A-C | 0.952E+01 |
| GROUPS A-E | 0.115E+02 |
| GROUPS C-E | 0.208E+01 |
| GROUPS B-D | 0.258E+02 |
| GROUPS B-F | 0.156E+02 |
| GROUPS D-F | 0.638E+00 |

National Semiconductor LM101



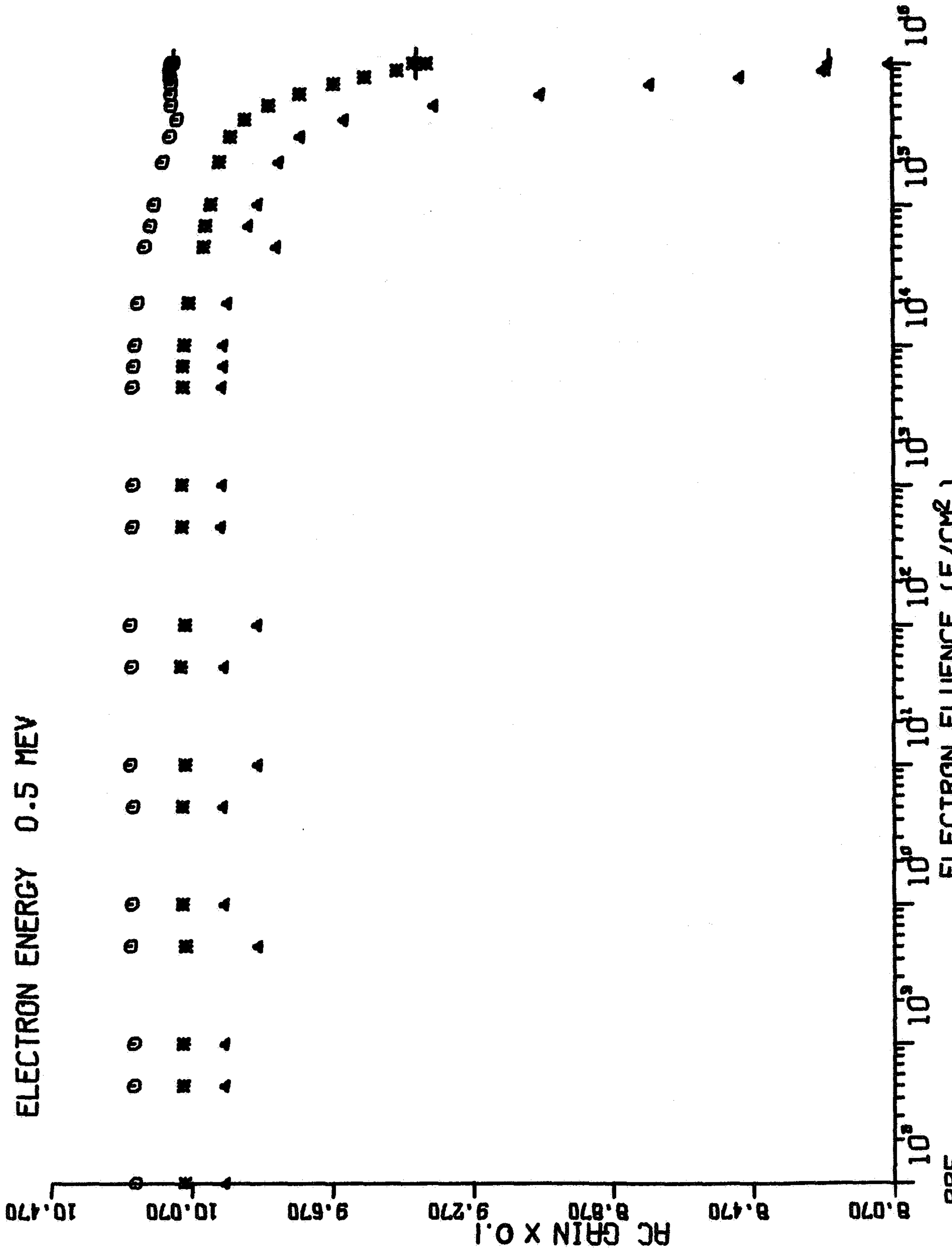

TEST CONDITIONS:

1. Pin 4, -12 volts, -5 volts.
2. Pin 7, +12 volts, +5 volts.
3. Temperature 25 C.

TEST PARAMETERS:

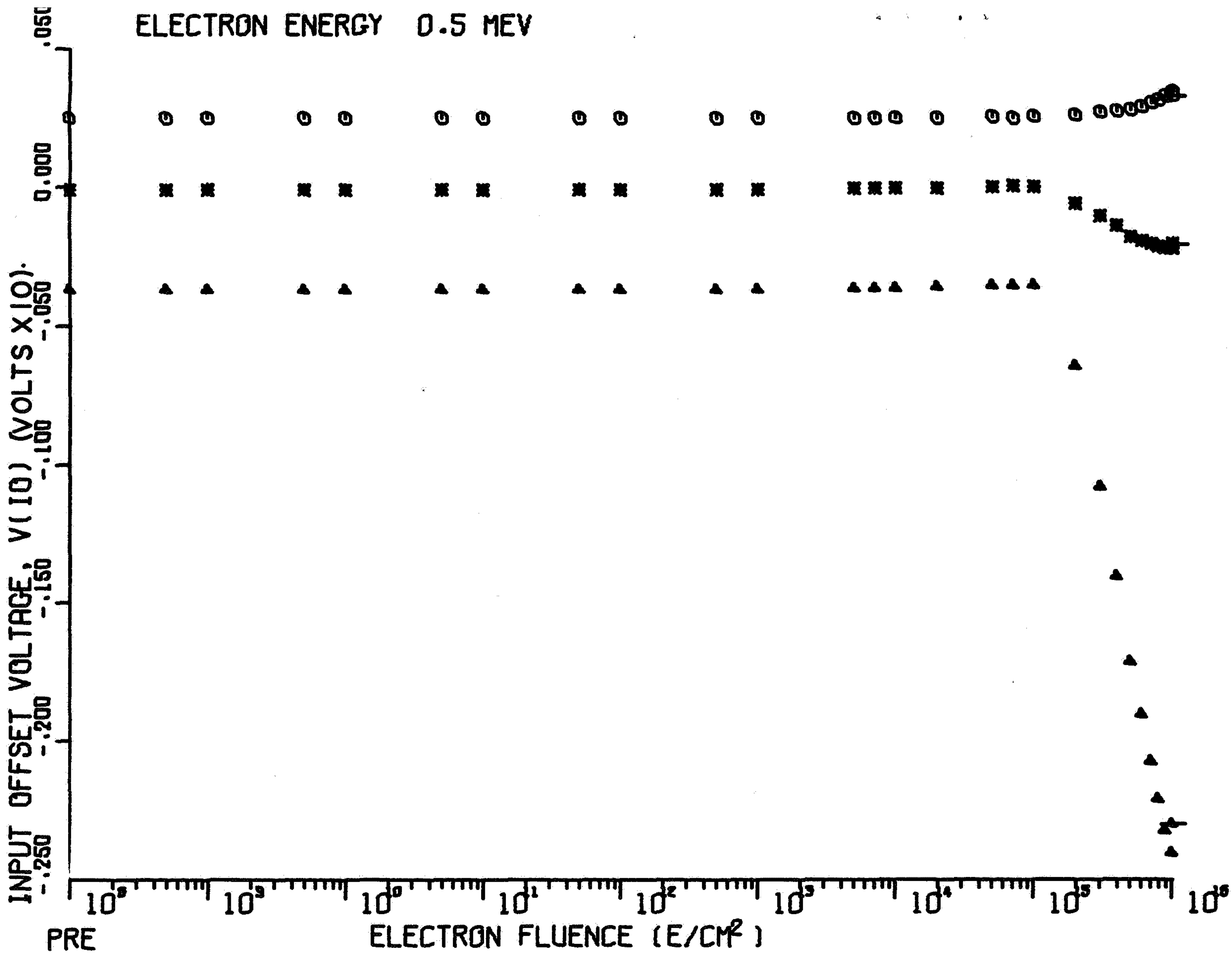
1. Open-loop gain.
2. Open-loop gain (at $V_{CC}$ = +5 volts and $V_{BB}$ = -5 volts).
3. Closed-loop gain.
4. Input offset voltage.
5. Input offset voltage (at $V_{CC}$ = +5 volts and $V_{BB}$ = -5 volts).
6. Input bias current.
7. + Saturation voltage.
8. - Saturation voltage.
9. Common mode rejection ratio.
10. Input offset current.
11. Power supply current.

FIGURE 58. TEST PLAN FOR LM101 AMPLIFIER




STATIC AC GAIN RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 59




STATIC INPUT OFFSET VOLTAGE RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 60

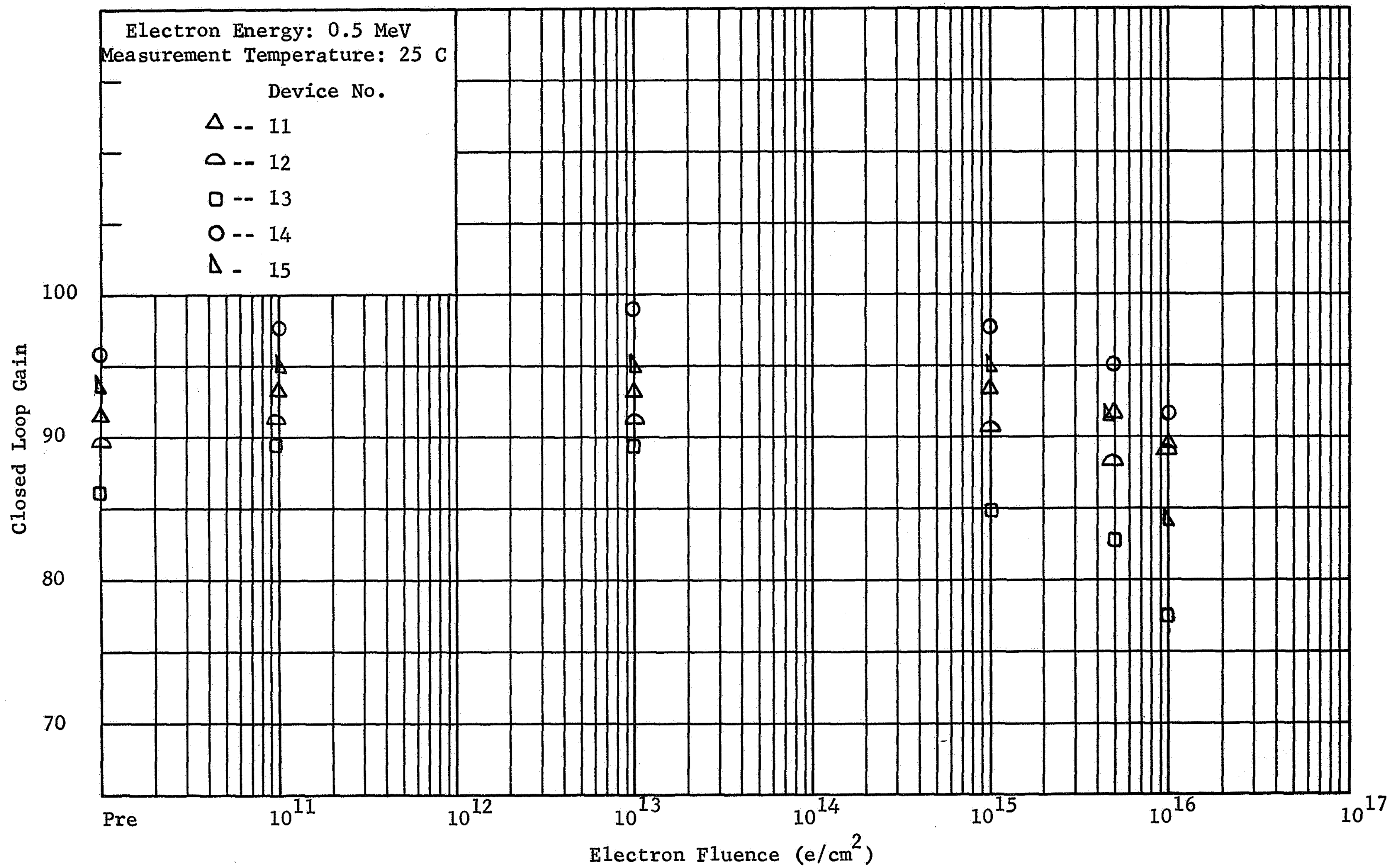
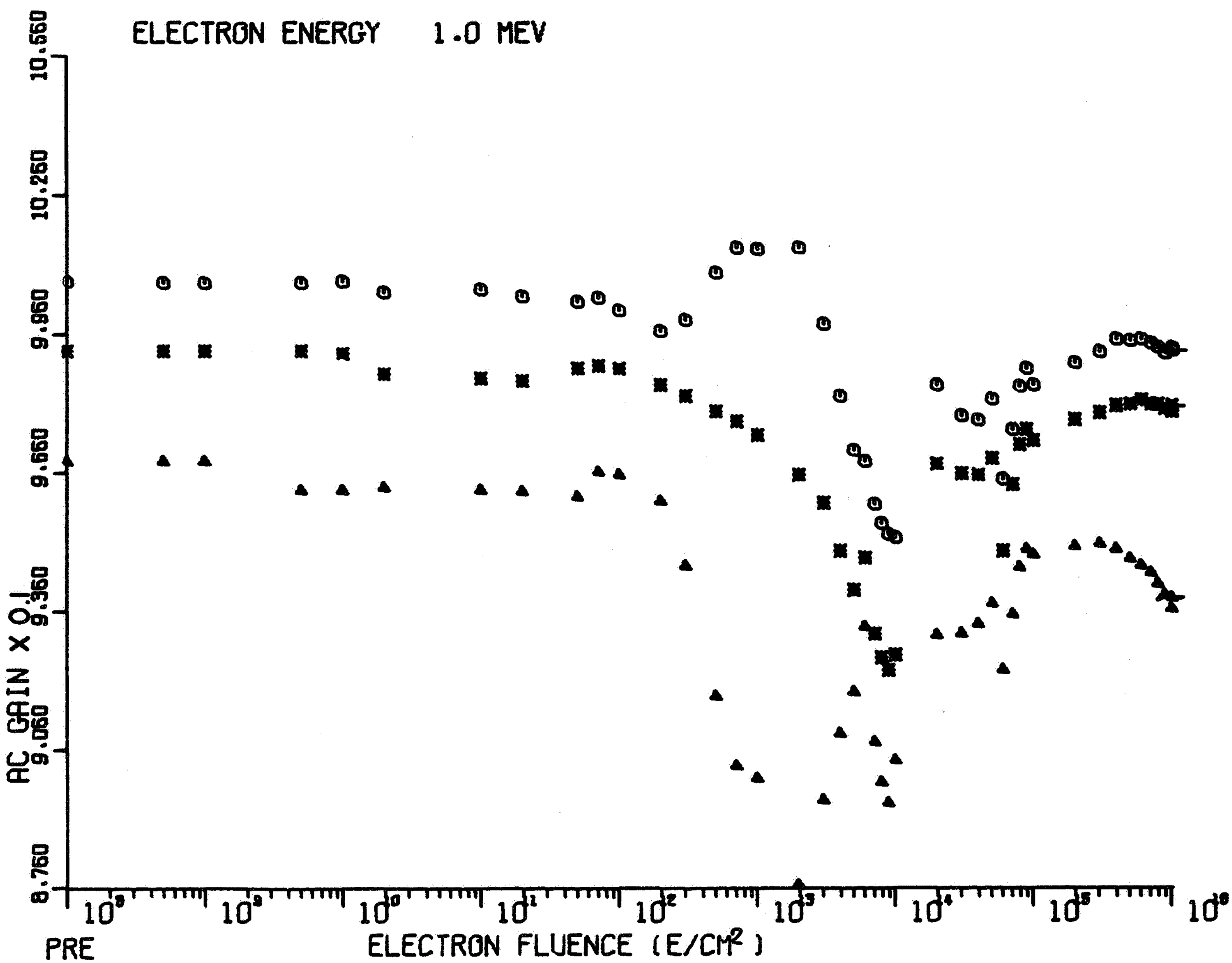
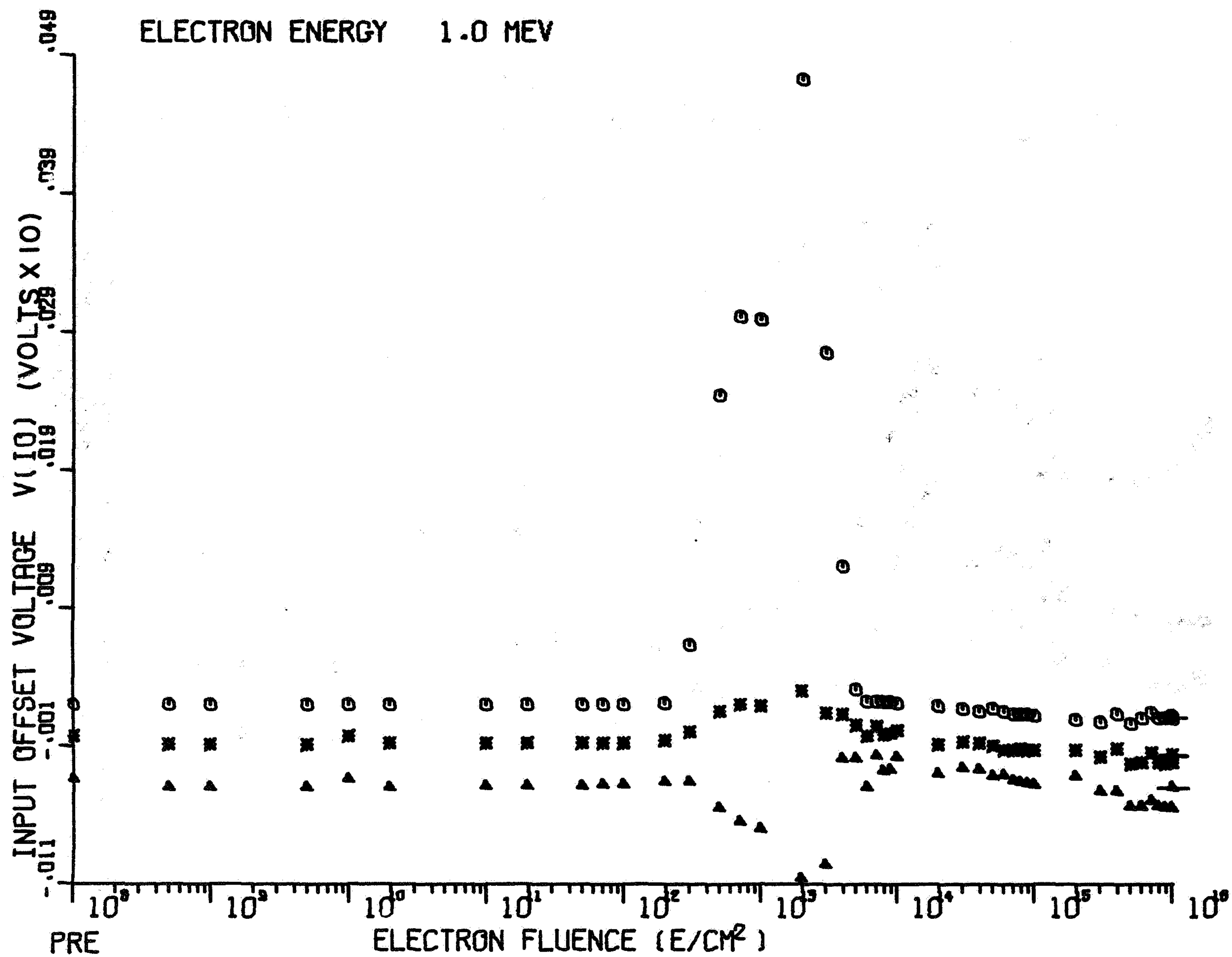



FIGURE 61. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF LM 101 AMPLIFIERS.



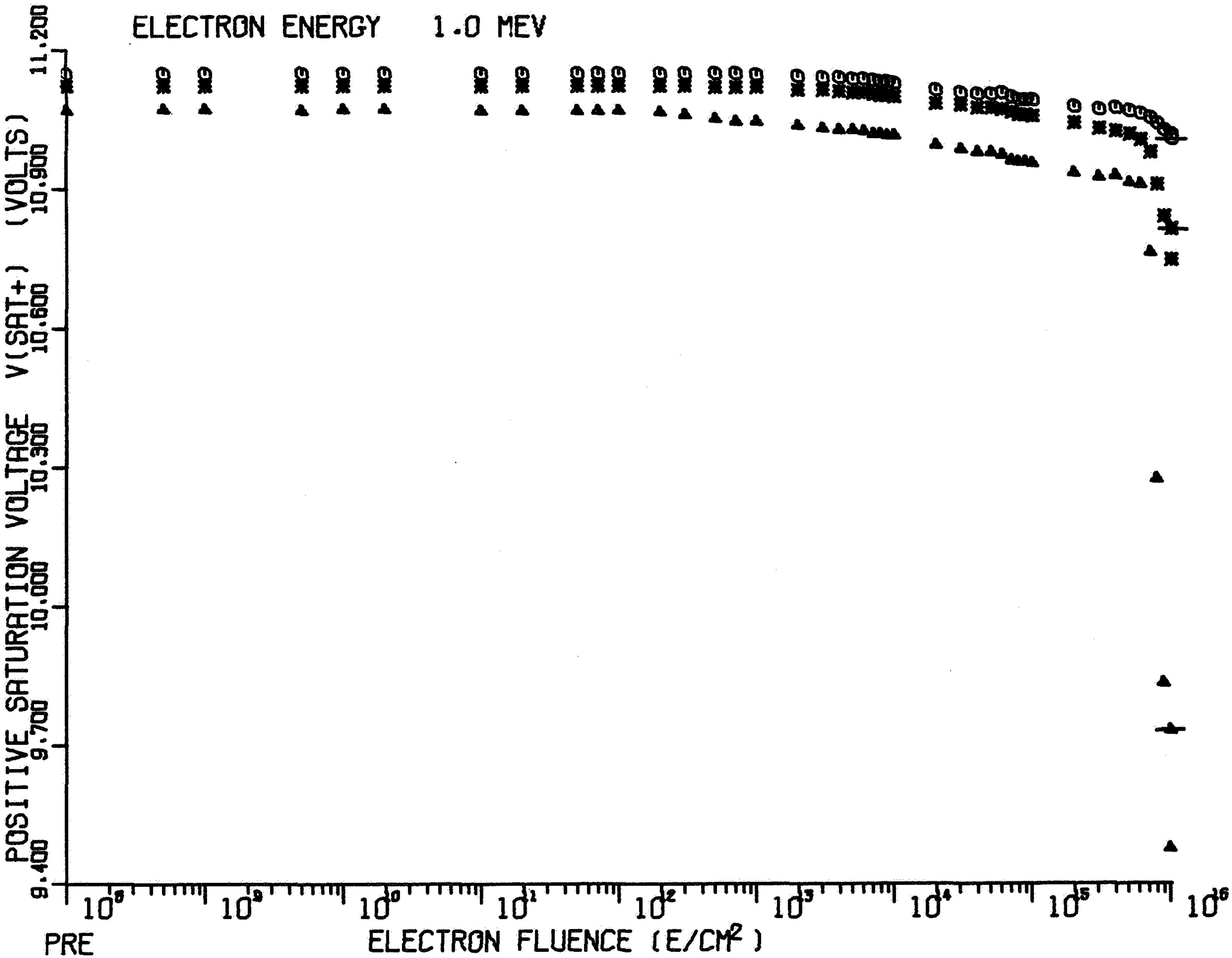

STATIC AC GAIN RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 62



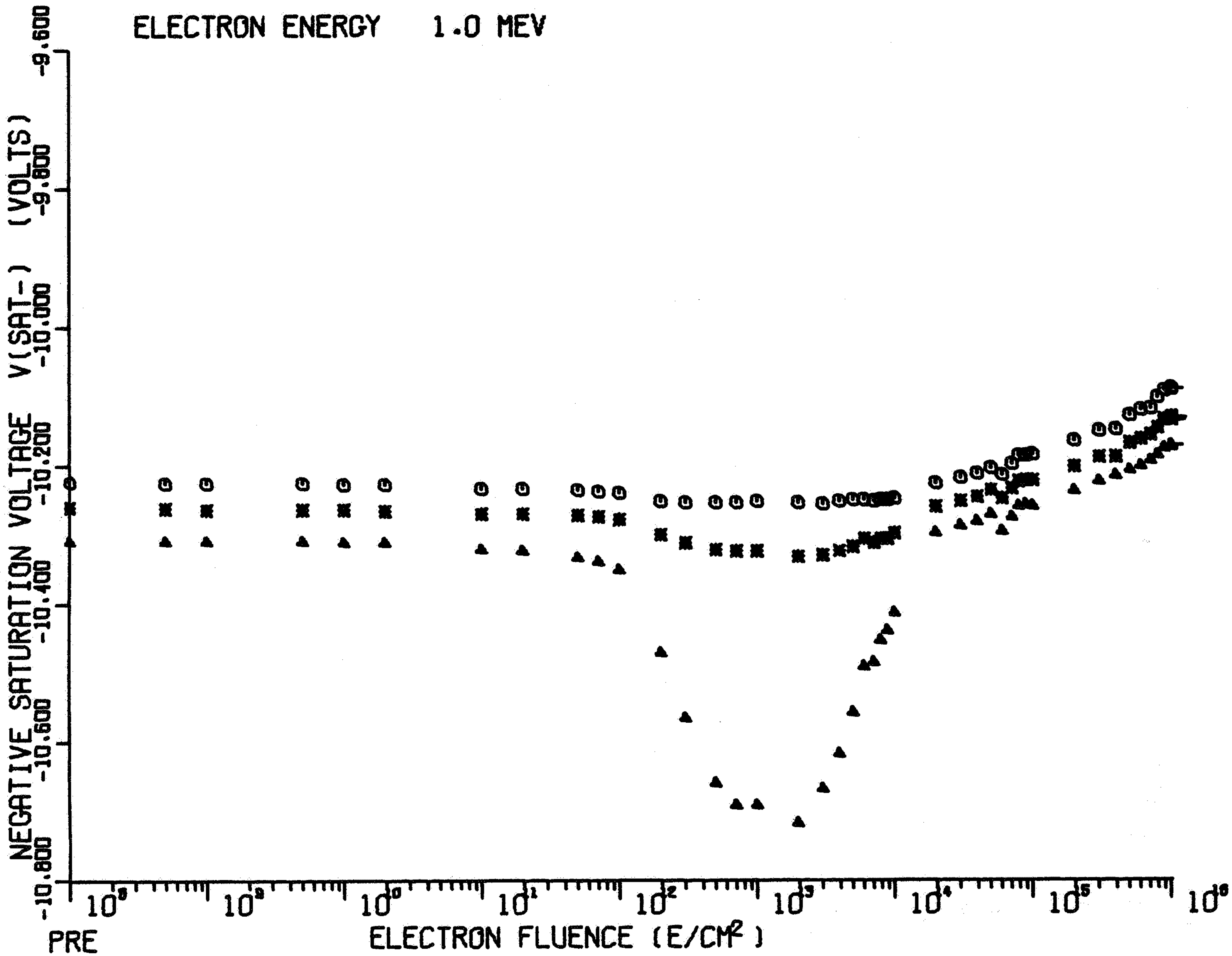

STATIC INPUT OFFSET VOLTAGE RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 63




STATIC POSITIVE SATURATION VOLTAGE RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 64




STATIC NEGATIVE SATURATION VOLTAGE RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 65

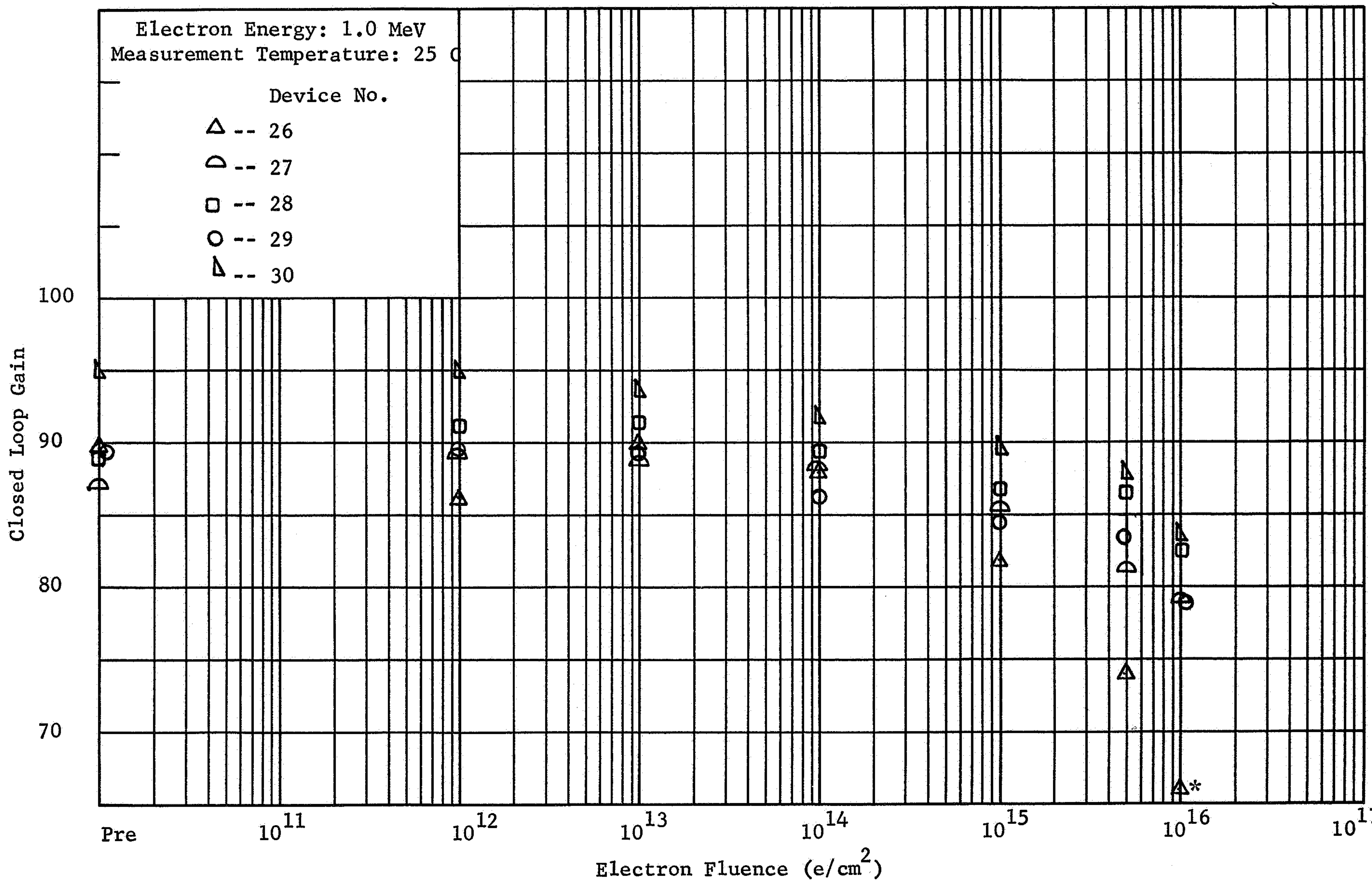



FIGURE 66. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF LM 101 AMPLIFIERS

* Device in saturation for all input voltages

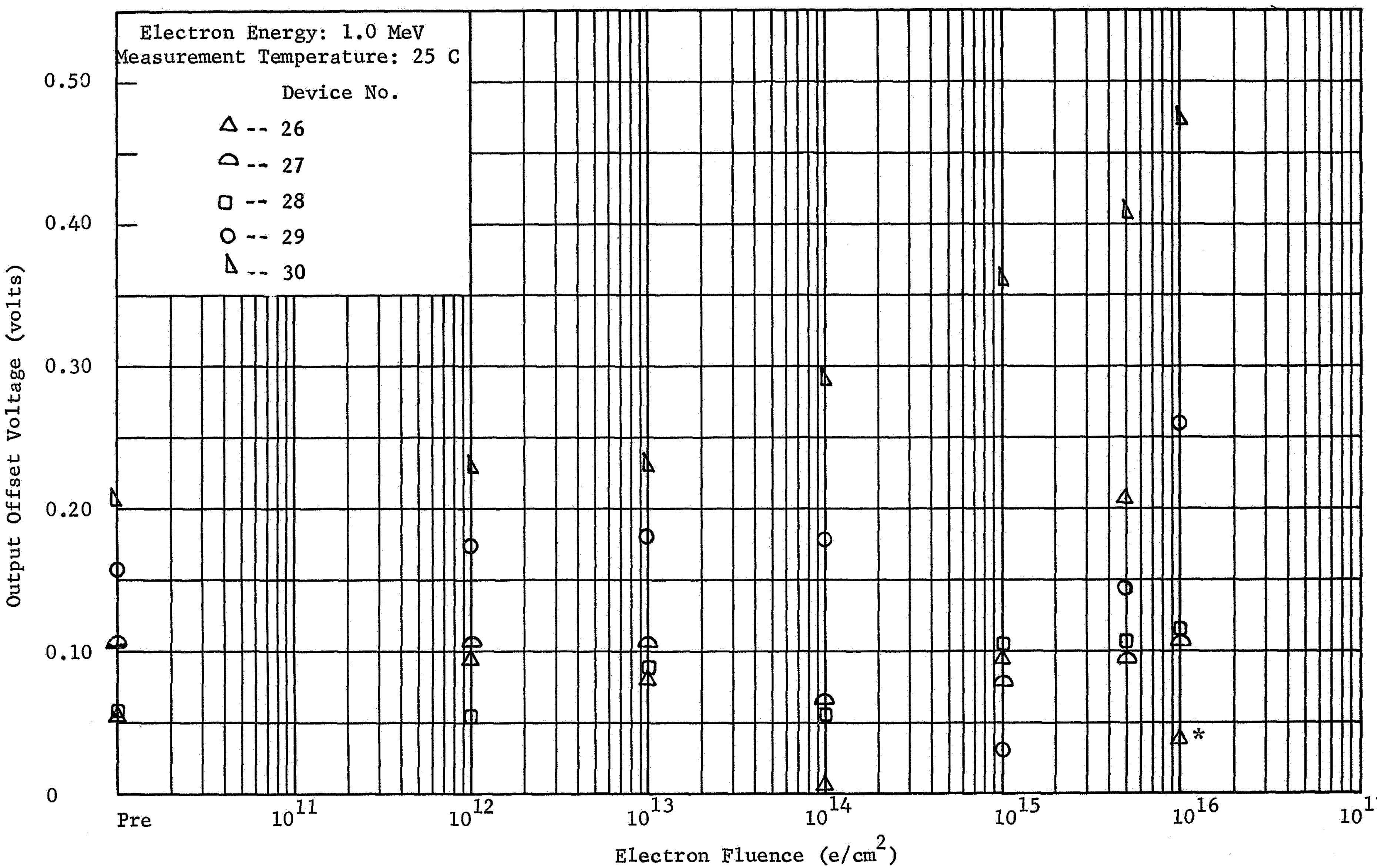
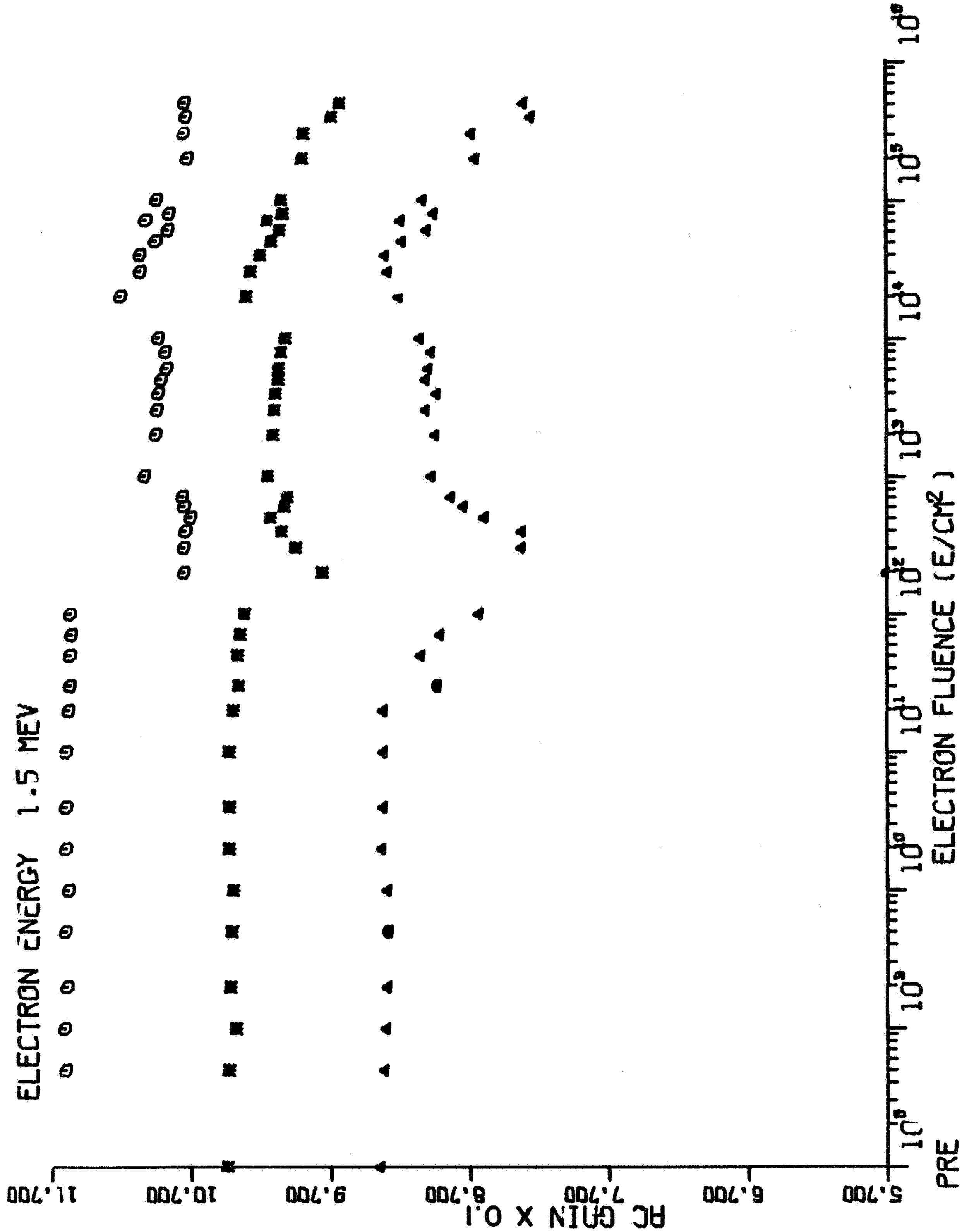


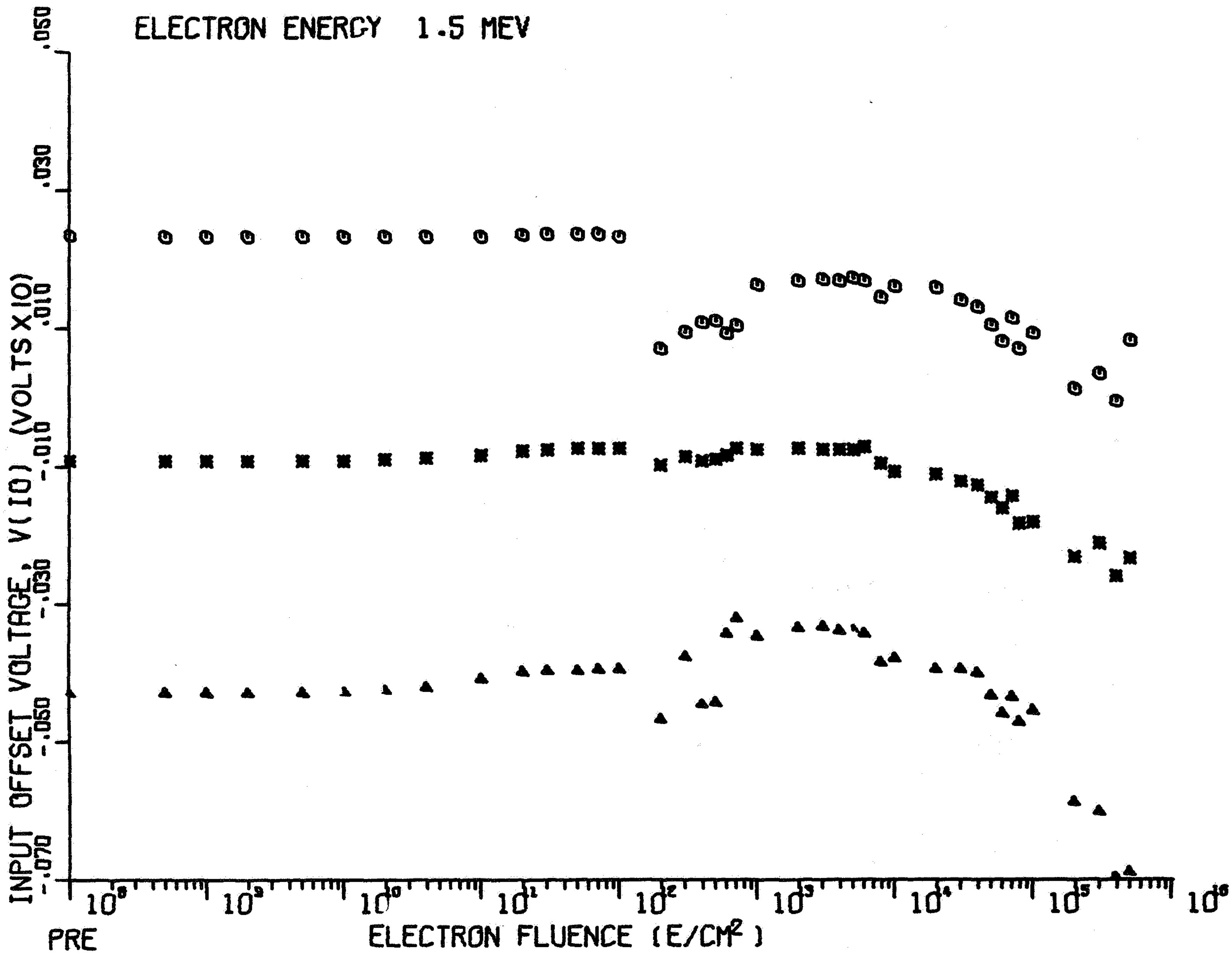

FIGURE 67. PULSED OUTPUT OFFSET VOLTAGE RESPONSE FOR LM 101 AMPLIFIERS.

* Device in saturation for all input voltages.



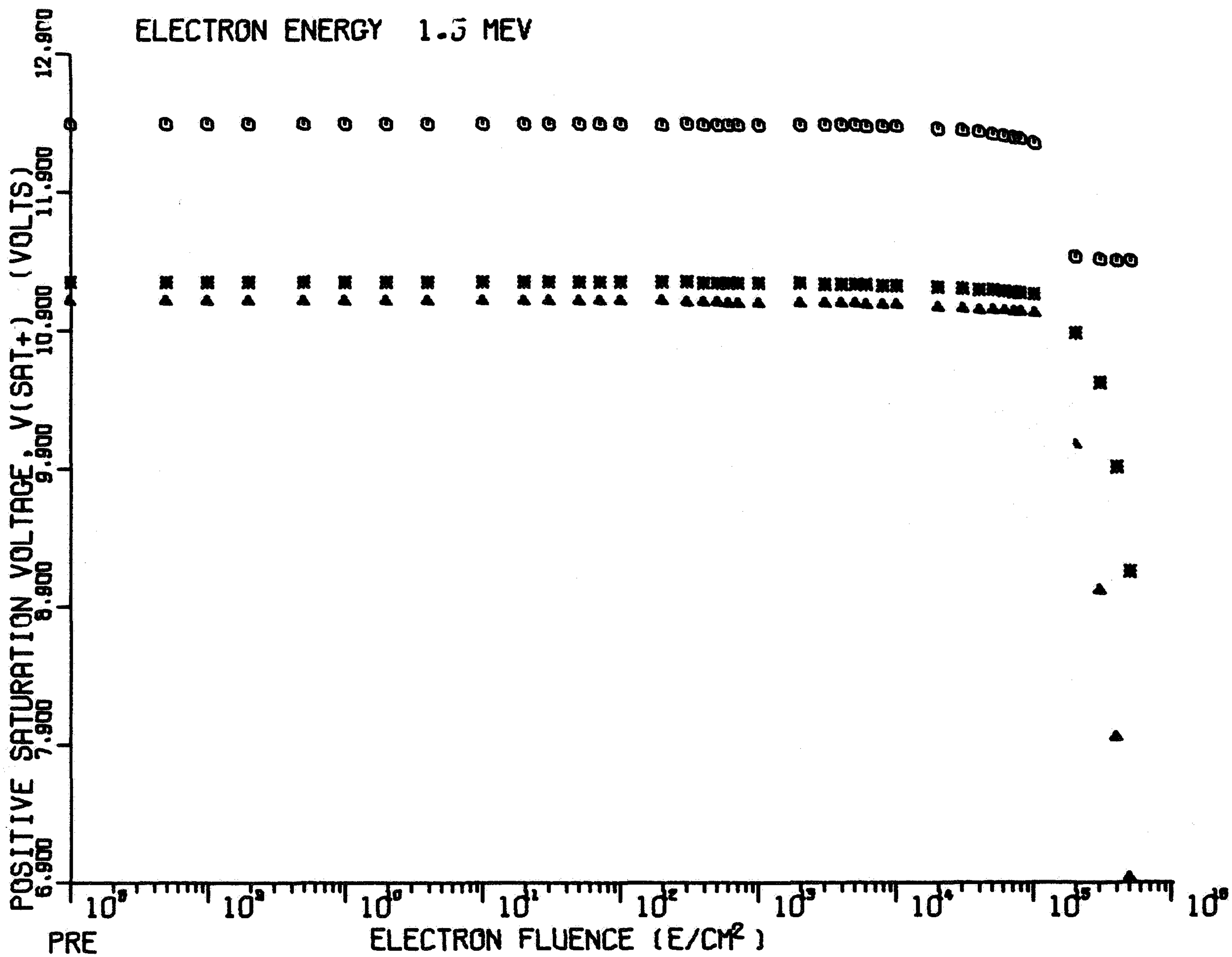

STATIC AC GAIN RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 68



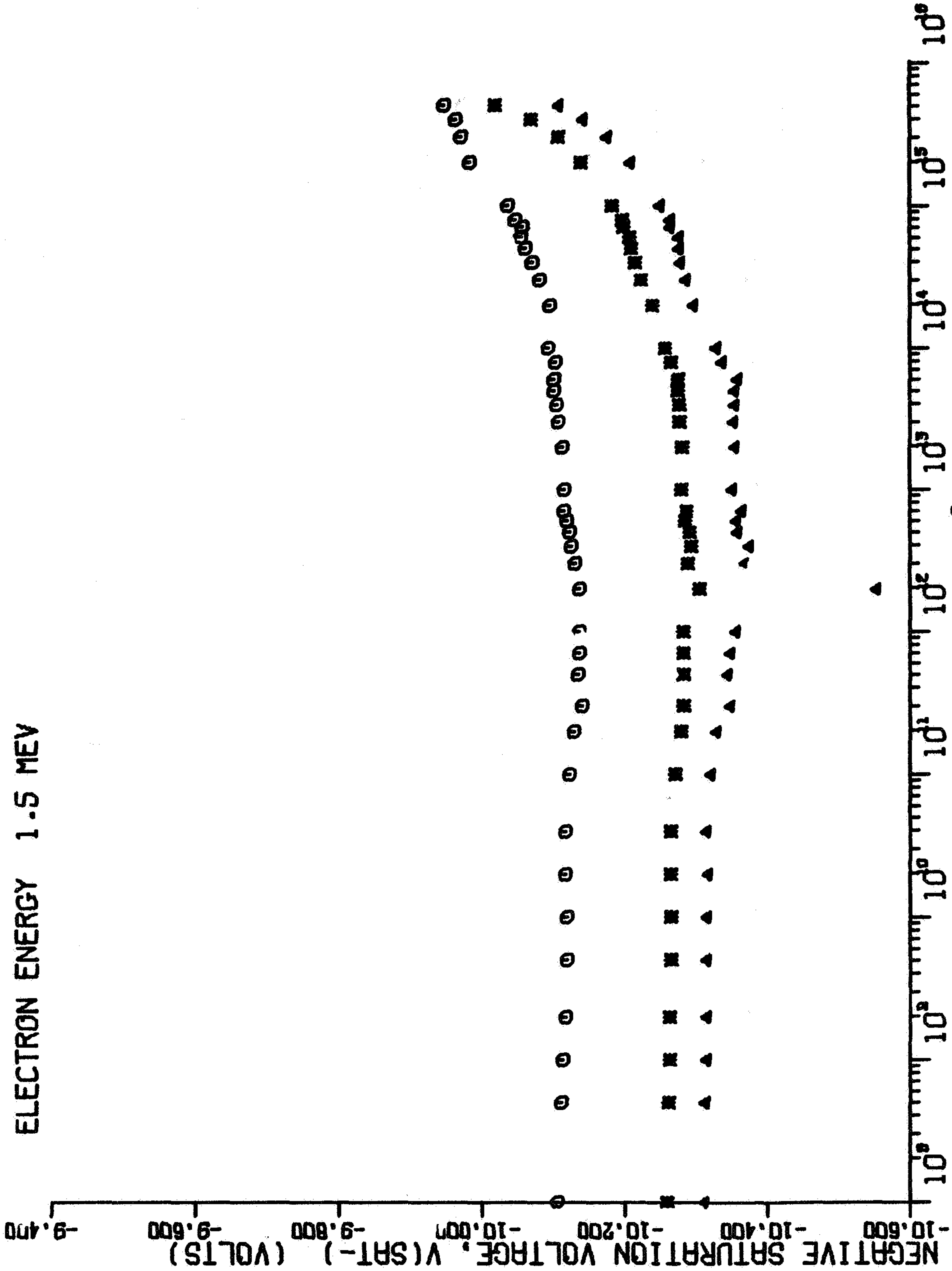

STATIC INPUT OFFSET VOLTAGE RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 69




STATIC POSITIVE SATURATION VOLTAGE RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 70




STATIC NEGATIVE SATURATION VOLTAGE RADIATION RESPONSE FOR LM101 AMPLIFIERS.

FIGURE 71

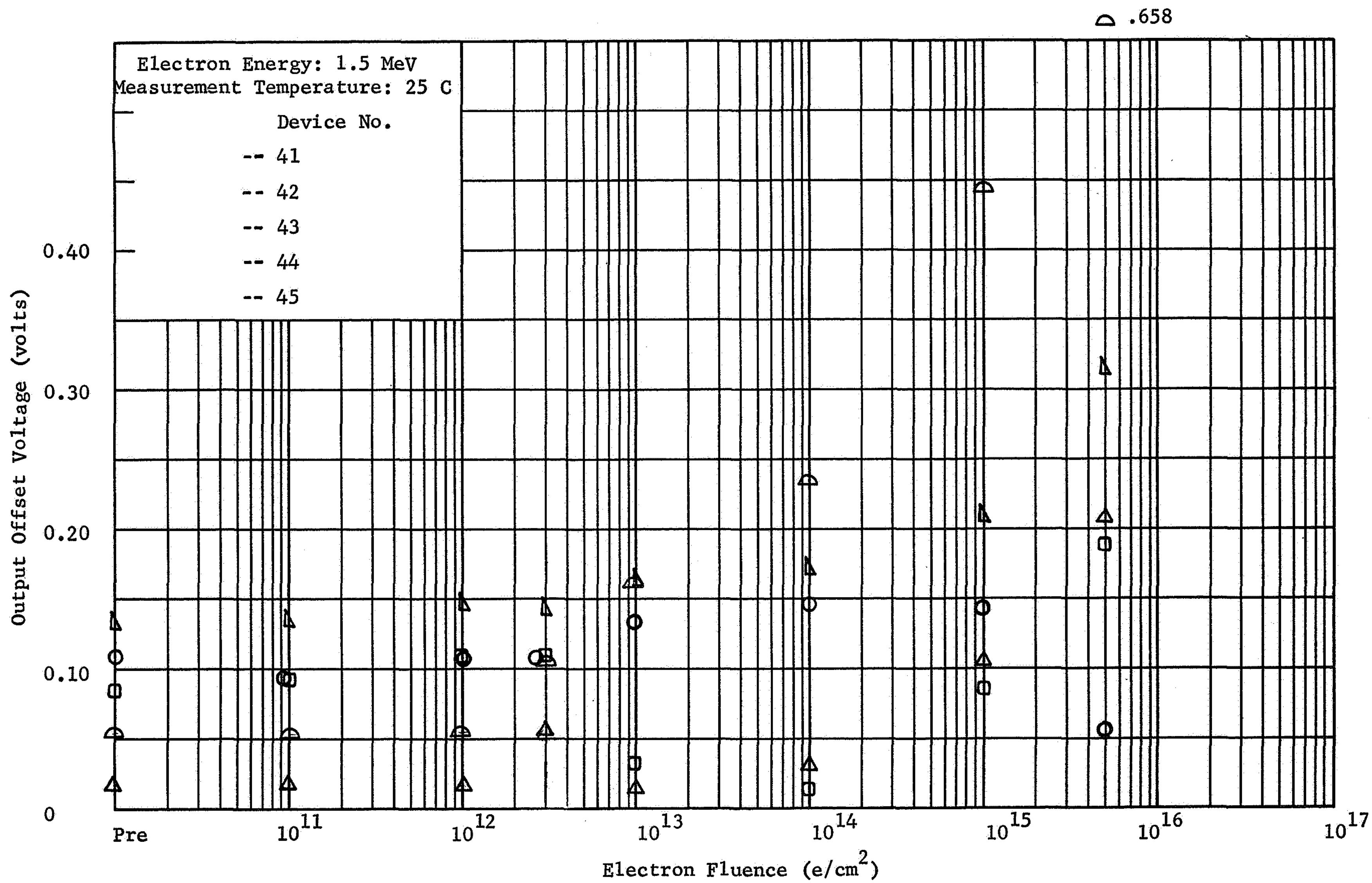



FIGURE 72. PULSED OUTPUT OFFSET VOLTAGE RESPONSE FOR LM 101 AMPLIFIERS.

NATIONAL SEMICONDUCTOR LM101

| | GAIN O.L. | G(OL 5) | GAIN C.L. | V SAT + | V SAT - | V O.S. | V(O.S. 5) |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.752E+05 | 0.438E+05 | 0.100E+03 | 0.112E+02 | -0.104E+02 | -0.141E-03 | -0.157E-03 |
| AVERAGE CHANGE | -0.448E+05 | -0.313E+05 | -0.520E+01 | 0.190E-01 | 0.580E-01 | 0.324E-03 | 0.826E-03 |
| STD OF MEAN | 0.897E+04 | 0.658E+04 | 0.274E+01 | 0.738E-02 | 0.503E-01 | 0.464E-03 | 0.838E-03 |
| AVE PER CENT CHANGE | -0.596E+02 | -0.714E+02 | -0.520E+01 | 0.170E+00 | -0.556E+00 | -0.429E+02 | -0.785E+02 |
| INTERVAL ESTIMATE | -0.682E+02 | -0.823E+02 | -0.716E+01 | 0.123E+00 | -0.211E+00 | 0.569E+01 | -0.144E+03 |
| AS PER CENT | -0.511E+02 | -0.608E+02 | -0.324E+01 | 0.218E+00 | -0.901E+00 | -0.466E+03 | -0.906E+03 |
| PER CENT AVE CHANGE | -0.597E+02 | -0.716E+02 | -0.520E+01 | 0.170E+00 | -0.556E+00 | -0.230E+03 | -0.525E+03 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.752E+05 | 0.349E+05 | 0.996E+02 | 0.111E+02 | -0.104E+02 | 0.760E-03 | 0.901E-03 |
| AVERAGE CHANGE | -0.303E+05 | -0.134E+05 | -0.400E+00 | 0.100E-01 | 0.110E+00 | 0.190E-03 | 0.279E-03 |
| STD OF MEAN | 0.129E+05 | 0.958E+04 | 0.548E+00 | 0.707E-02 | 0.474E-01 | 0.786E-03 | 0.780E-03 |
| AVE PER CENT CHANGE | -0.391E+02 | -0.353E+02 | -0.404E+00 | 0.897E-01 | -0.105E+01 | 0.130E+02 | 0.198E+02 |
| INTERVAL ESTIMATE | -0.617E+02 | -0.725E+02 | -0.108E+01 | 0.110E-01 | -0.489E+00 | -0.103E+03 | -0.765E+02 |
| AS PER CENT | -0.190E+02 | -0.444E+01 | 0.281E+00 | 0.168E+00 | -0.162E+01 | 0.153E+03 | 0.138E+03 |
| PER CENT AVE CHANGE | -0.404E+02 | -0.385E+02 | -0.402E+00 | 0.897E-01 | -0.105E+01 | 0.250E+02 | 0.310E+02 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.753E+05 | 0.458E+05 | 0.100E+03 | 0.112E+02 | -0.104E+02 | -0.885E-03 | -0.755E-03 |
| AVERAGE CHANGE | -0.504E+05 | -0.342E+05 | -0.500E+00 | -0.197E+00 | 0.214E+00 | -0.216E-02 | -0.123E-02 |
| STD OF MEAN | 0.171E+05 | 0.631E+04 | 0.707E+00 | 0.239E+00 | 0.295E-01 | 0.146E-02 | 0.228E-02 |
| AVE PER CENT CHANGE | -0.649E+02 | -0.745E+02 | -0.500E+00 | -0.177E+01 | -0.205E+01 | 0.408E+02 | -0.807E+01 |
| INTERVAL ESTIMATE | -0.832E+02 | -0.846E+02 | -0.101E+01 | -0.330E+01 | -0.185E+01 | 0.362E+03 | 0.379E+03 |
| AS PER CENT | -0.508E+02 | -0.648E+02 | 0.580E-02 | -0.231E+00 | -0.226E+01 | 0.127E+03 | -0.531E+02 |
| PER CENT AVE CHANGE | -0.670E+02 | -0.747E+02 | -0.500E+00 | -0.177E+01 | -0.205E+01 | 0.245E+03 | 0.163E+03 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.823E+05 | 0.420E+05 | 0.100E+03 | 0.112E+02 | -0.104E+02 | 0.139E-03 | 0.832E-04 |
| AVERAGE CHANGE | -0.617E+05 | -0.326E+05 | -0.180E+01 | -0.332E+01 | 0.204E+00 | -0.253E-03 | 0.457E-03 |
| STD OF MEAN | 0.210E+05 | 0.100E+05 | 0.447E+00 | 0.250E+01 | 0.635E-01 | 0.107E-02 | 0.122E-02 |
| AVE PER CENT CHANGE | -0.734E+02 | -0.765E+02 | -0.180E+01 | -0.298E+02 | -0.195E+01 | 0.276E+02 | 0.773E+02 |
| INTERVAL ESTIMATE | -0.107E+03 | -0.107E+03 | -0.236E+01 | -0.575E+02 | -0.120E+01 | -0.114E+04 | -0.127E+04 |
| AS PER CENT | -0.434E+02 | -0.478E+02 | -0.124E+01 | -0.197E+01 | -0.271E+01 | 0.773E+03 | 0.237E+04 |
| PER CENT AVE CHANGE | -0.750E+02 | -0.775E+02 | -0.180E+01 | -0.298E+02 | -0.195E+01 | -0.182E+03 | 0.549E+03 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.741E+05 | 0.428E+05 | 0.100E+03 | 0.112E+02 | -0.104E+02 | -0.649E-03 | -0.496E-03 |
| AVERAGE CHANGE | -0.586E+05 | -0.356E+05 | -0.330E+01 | -0.116E+01 | 0.170E+00 | -0.334E-02 | -0.242E-02 |
| STD OF MEAN | 0.978E+04 | 0.695E+04 | 0.823E+00 | 0.794E+00 | 0.300E+00 | 0.177E-02 | 0.213E-02 |
| AVE PER CENT CHANGE | -0.790E+02 | -0.829E+02 | -0.330E+01 | -0.104E+02 | -0.163E+01 | -0.448E+03 | -0.294E+03 |
| INTERVAL ESTIMATE | -0.885E+02 | -0.947E+02 | -0.389E+01 | -0.155E+02 | 0.425E+00 | 0.709E+03 | 0.794E+03 |
| AS PER CENT | -0.696E+02 | -0.715E+02 | -0.271E+01 | -0.532E+01 | -0.369E+01 | 0.320E+03 | 0.180E+03 |
| PER CENT AVE CHANGE | -0.790E+02 | -0.831E+02 | -0.330E+01 | -0.104E+02 | -0.163E+01 | 0.515E+03 | 0.487E+03 |

NATIONAL SEMICONDUCTOR LM101

| | GAIN O.L. | G(OL 5) | GAIN C.L. | V SAT + | V SAT - | V O.S. | V(O.S. 5) |
|---|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.716E+05 | 0.345E+05 | 0.988E+02 | 0.112E+02 | -0.104E+02 | -0.732E-03 | -0.731E-03 |
| AVERAGE CHANGE | -0.541E+05 | -0.279E+05 | -0.500E+01 | -0.465E+01 | 0.280E+00 | 0.164E-03 | 0.108E-02 |
| STD OF MEAN | 0.136E+05 | 0.128E+05 | 0.620E+01 | 0.215E+01 | 0.515E-01 | 0.226E-02 | 0.248E-02 |
| AVE PER CENT CHANGE | -0.758E+02 | -0.788E+02 | -0.508E+01 | -0.417E+02 | -0.269E+01 | 0.208E+03 | 0.137E+03 |
| INTERVAL ESTIMATE | -0.991E+02 | -0.127E+03 | -0.129E+02 | -0.656E+02 | -0.207E+01 | 0.337E+03 | 0.274E+03 |
| AS PER CENT | -0.519E+02 | -0.346E+02 | 0.274E+01 | -0.178E+02 | -0.330E+01 | -0.379E+03 | -0.568E+03 |
| PER CENT AVE CHANGE | -0.755E+02 | -0.808E+02 | -0.506E+01 | -0.417E+02 | -0.269E+01 | -0.210E+02 | -0.147E+03 |
| **CONTROL-G** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.792E+05 | 0.430E+05 | 0.100E+03 | 0.112E+02 | -0.104E+02 | 0.770E-03 | 0.862E-03 |
| AVERAGE CHANGE | -0.112E+04 | 0.108E+04 | -0.800E+00 | 0.260E-01 | -0.800E-02 | -0.300E-05 | 0.600E-05 |
| STD OF MEAN | 0.489E+04 | 0.261E+04 | 0.837E+00 | 0.548E-02 | 0.837E-02 | 0.433E-04 | 0.678E-04 |
| AVE PER CENT CHANGE | -0.126E+01 | 0.254E+01 | -0.800E+00 | 0.233E+00 | 0.769E-01 | 0.287E+01 | 0.548E+01 |
| INTERVAL ESTIMATE | -0.909E+01 | -0.504E+01 | -0.184E+01 | 0.172E+00 | 0.177E+00 | -0.818E+01 | -0.907E+01 |
| AS PER CENT | 0.626E+01 | 0.101E+02 | 0.239E+00 | 0.294E+00 | -0.229E-01 | 0.740E+01 | 0.105E+02 |
| PER CENT AVE CHANGE | -0.141E+01 | 0.251E+01 | -0.800E+00 | 0.233E+00 | 0.769E-01 | -0.390E+00 | 0.696E+00 |
| **F-TESTS** | | | | | | | |
| GROUPS A-B-G | 0.364E+02 | 0.400E+02 | 0.126E+02 | 0.677E+01 | 0.930E+01 | 0.690E+00 | 0.245E+01 |
| GROUPS C-D-G | 0.209E+02 | 0.488E+02 | 0.598E+01 | 0.129E+02 | 0.630E+02 | 0.748E+01 | 0.180E+01 |
| GROUPS E-F-G | 0.591E+02 | 0.345E+02 | 0.234E+01 | 0.216E+02 | 0.221E+01 | 0.103E+02 | 0.604E+01 |
| GROUPS A-C-E-G | 0.282E+02 | 0.451E+02 | 0.169E+02 | 0.148E+02 | 0.287E+01 | 0.174E+02 | 0.634E+01 |
| GROUPS B-D-F-G | 0.183E+02 | 0.127E+02 | 0.219E+01 | 0.104E+02 | 0.343E+02 | 0.121E+00 | 0.498E+00 |
| GROUPS ALL | 0.140E+02 | 0.175E+02 | 0.572E+01 | 0.174E+02 | 0.296E+01 | 0.101E+02 | 0.453E+01 |
| **T-TESTS** | | | | | | | |
| GROUPS A-B | -0.256E+01 | -0.428E+01 | -0.381E+01 | 0.226E+01 | -0.192E+01 | 0.420E+00 | 0.122E+01 |
| GROUPS C-D | 0.112E+01 | -0.386E+00 | 0.372E+01 | 0.407E+01 | 0.425E+00 | -0.256E+01 | -0.153E+01 |
| GROUPS E-F | -0.739E+00 | -0.153E+01 | 0.884E+00 | 0.467E+01 | -0.800E+00 | -0.332E+01 | -0.284E+01 |
| GROUPS A-G | -0.101E+02 | -0.104E+02 | -0.345E+01 | -0.187E+01 | 0.286E+01 | 0.154E+01 | 0.215E+01 |
| GROUPS B-G | -0.473E+01 | -0.327E+01 | 0.894E+00 | -0.400E+01 | 0.548E+01 | 0.548E+00 | 0.779E+00 |
| GROUPS C-G | -0.623E+01 | -0.118E+02 | 0.731E+00 | -0.204E+01 | 0.162E+02 | -0.325E+01 | -0.119E+01 |
| GROUPS D-G | -0.630E+01 | -0.725E+01 | -0.236E+01 | -0.300E+01 | 0.740E+01 | -0.522E+00 | 0.623E+00 |
| GROUPS E-G | -0.122E+02 | -0.112E+02 | -0.552E+01 | -0.328E+01 | 0.130E+01 | -0.415E+01 | -0.249E+01 |
| GROUPS F-G | -0.818E+01 | -0.494E+01 | -0.150E+01 | -0.466E+01 | 0.123E+02 | 0.166E+00 | 0.964E+00 |
| GROUPS A-C | 0.919E+00 | 0.991E+00 | -0.525E+01 | 0.285E+01 | -0.846E+01 | 0.514E+01 | 0.268E+01 |
| GROUPS A-E | 0.327E+01 | 0.140E+01 | -0.210E+01 | 0.470E+01 | -0.117E+01 | 0.635E+01 | 0.448E+01 |
| GROUPS C-E | 0.130E+01 | 0.468E+00 | 0.816E+01 | 0.368E+01 | 0.462E+00 | 0.162E+01 | 0.120E+01 |
| GROUPS B-D | 0.285E+01 | 0.308E+01 | 0.443E+01 | 0.298E+01 | -0.265E+01 | 0.746E+00 | -0.274E+00 |
| GROUPS B-F | 0.282E+01 | 0.202E+01 | 0.165E+01 | 0.485E+01 | -0.543E+01 | 0.240E-01 | -0.685E+00 |
| GROUPS D-F | -0.687E+00 | -0.644E+00 | 0.115E+01 | 0.903E+00 | -0.208E+01 | -0.374E+00 | -0.590E+00 |

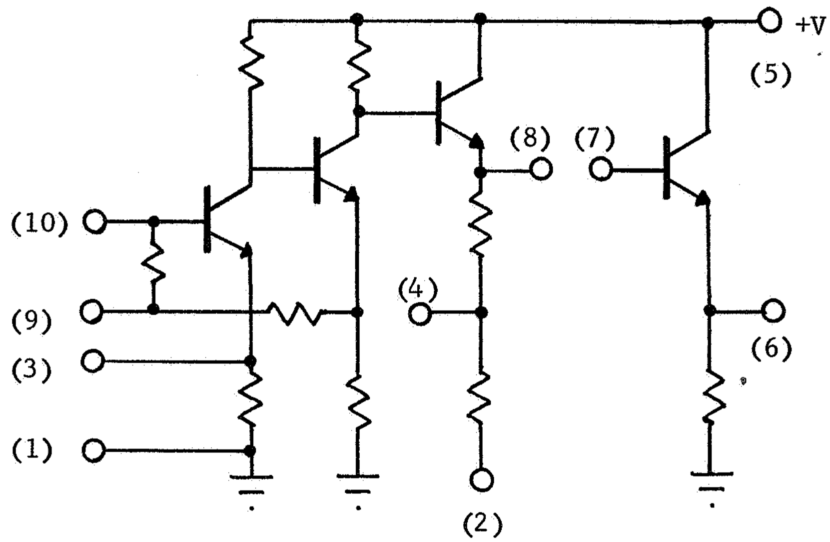
NATIONAL SEMICONDUCTOR LM101

| | I(CC) | I BIAS | I O.S. |
|---|---|---|---|
| 0.5 MEV BIASED-A | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.177E-02 | 0.275E-06 | -0.298E-09 |
| AVERAGE CHANGE | -0.411E-03 | -0.440E-07 | 0.249E-08 |
| STD OF MEAN | 0.742E-04 | 0.345E-07 | 0.613E-08 |
| AVE PER CENT CHANGE | -0.230E+02 | -0.159E+02 | 0.298E+04 |
| INTERVAL ESTIMATE | -0.262E+02 | -0.250E+02 | 0.637E+03 |
| AS PER CENT | -0.202E+02 | -0.701E+01 | -0.231E+04 |
| PER CENT AVE CHANGE | -0.232E+02 | -0.160E+02 | -0.835E+03 |
| 0.5 MEV UNBIASED-B | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.141E-02 | 0.278E-06 | -0.320E-08 |
| AVERAGE CHANGE | -0.334E-03 | 0.278E-06 | -0.260E-08 |
| STD OF MEAN | 0.123E-03 | 0.726E-07 | 0.483E-08 |
| AVE PER CENT CHANGE | -0.239E+02 | 0.101E+03 | 0.138E+02 |
| INTERVAL ESTIMATE | -0.345E+02 | 0.676E+02 | 0.269E+03 |
| AS PER CENT | -0.129E+02 | 0.132E+03 | -0.106E+03 |
| PER CENT AVE CHANGE | -0.237E+02 | 0.100E+03 | 0.813E+02 |
| 1.0 MEV BIASED-C | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.167E-02 | 0.261E-06 | 0.701E-09 |
| AVERAGE CHANGE | -0.105E-02 | 0.140E-05 | -0.202E-07 |
| STD OF MEAN | 0.186E-03 | 0.129E-06 | 0.312E-07 |
| AVE PER CENT CHANGE | -0.626E+02 | 0.548E+03 | 0.333E+04 |
| INTERVAL ESTIMATE | -0.710E+02 | 0.502E+03 | -0.607E+04 |
| AS PER CENT | -0.551E+02 | 0.572E+03 | 0.302E+03 |
| PER CENT AVE CHANGE | -0.630E+02 | 0.537E+03 | -0.288E+04 |
| 1.0 MEV UNBIASED-D | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.182E-02 | 0.259E-06 | 0.740E-08 |
| AVERAGE CHANGE | -0.123E-02 | 0.172E-05 | 0.109E-07 |
| STD OF MEAN | 0.261E-03 | 0.150E-06 | 0.379E-07 |
| AVE PER CENT CHANGE | -0.675E+02 | 0.673E+03 | 0.173E+03 |
| INTERVAL ESTIMATE | -0.857E+02 | 0.593E+03 | -0.488E+03 |
| AS PER CENT | -0.500E+02 | 0.736E+03 | 0.783E+03 |
| PER CENT AVE CHANGE | -0.678E+02 | 0.664E+03 | 0.148E+03 |
| 1.5 MEV BIASED-E | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.172E-02 | 0.261E-06 | 0.950E-08 |
| AVERAGE CHANGE | -0.121E-02 | 0.155E-05 | -0.584E-07 |
| STD OF MEAN | 0.149E-03 | 0.207E-06 | 0.676E-07 |
| AVE PER CENT CHANGE | -0.705E+02 | 0.596E+03 | -0.436E+03 |
| INTERVAL ESTIMATE | -0.768E+02 | 0.535E+03 | -0.112E+04 |
| AS PER CENT | -0.645E+02 | 0.649E+03 | -0.106E+03 |
| PER CENT AVE CHANGE | -0.706E+02 | 0.592E+03 | -0.615E+03 |

NATIONAL SEMICONDUCTOR LM101

| | I(CC) | I BIAS | I O.S. |
|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.169E-02 | 0.272E-06 | -0.138E-07 |
| AVERAGE CHANGE | -0.126E-02 | 0.165E-05 | -0.356E-08 |
| STD OF MEAN | 0.206E-03 | 0.179E-06 | 0.418E-07 |
| AVE PER CENT CHANGE | -0.744E+02 | 0.629E+03 | 0.100E+06 |
| INTERVAL ESTIMATE | -0.899E+02 | 0.526E+03 | 0.402E+03 |
| AS PER CENT | -0.596E+02 | 0.689E+03 | -0.350E+03 |
| PER CENT AVE CHANGE | -0.748E+02 | 0.607E+03 | 0.258E+02 |
| **CONTROL-G** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.181E-02 | 0.294E-06 | 0.840E-08 |
| AVERAGE CHANGE | 0.260E-05 | 0.200E-07 | 0.780E-10 |
| STD OF MEAN | 0.518E-05 | 0.215E-07 | 0.178E-08 |
| AVE PER CENT CHANGE | 0.148E+00 | 0.651E+01 | 0.953E+01 |
| INTERVAL ESTIMATE | -0.211E+00 | -0.228E+01 | -0.253E+02 |
| AS PER CENT | 0.498E+00 | 0.159E+02 | 0.272E+02 |
| PER CENT AVE CHANGE | 0.143E+00 | 0.680E+01 | 0.929E+00 |
| **F-TESTS** | | | |
| GROUPS A-B-G | 0.452E+02 | 0.890E+02 | 0.169E+01 |
| GROUPS C-D-G | 0.695E+02 | 0.305E+03 | 0.211E+01 |
| GROUPS E-F-G | 0.132E+03 | 0.151E+03 | 0.284E+01 |
| GROUPS A-C-E-G | 0.130E+03 | 0.364E+03 | 0.447E+01 |
| GROUPS B-D-F-G | 0.651E+02 | 0.265E+03 | 0.276E+00 |
| GROUPS ALL | 0.686E+02 | 0.250E+03 | 0.319E+01 |
| **T-TESTS** | | | |
| GROUPS A-B | -0.154E+01 | -0.119E+02 | 0.161E+01 |
| GROUPS C-D | 0.154E+01 | -0.426E+01 | -0.170E+01 |
| GROUPS E-F | 0.525E+00 | -0.974E+00 | -0.165E+01 |
| GROUPS A-G | -0.122E+02 | -0.375E+01 | 0.847E+00 |
| GROUPS B-G | -0.612E+01 | 0.762E+01 | -0.116E+01 |
| GROUPS C-G | -0.125E+02 | 0.234E+02 | -0.143E+01 |
| GROUPS D-G | -0.106E+02 | 0.251E+02 | 0.639E+00 |
| GROUPS E-G | -0.179E+02 | 0.161E+02 | -0.190E+01 |
| GROUPS F-G | -0.137E+02 | 0.202E+02 | -0.194E+00 |
| GROUPS A-C | 0.102E+02 | -0.343E+02 | 0.226E+01 |
| GROUPS A-E | 0.153E+02 | -0.239E+02 | 0.284E+01 |
| GROUPS C-E | 0.211E+01 | -0.183E+01 | 0.162E+01 |
| GROUPS B-D | 0.697E+01 | -0.194E+02 | -0.792E+00 |
| GROUPS B-F | 0.867E+01 | -0.159E+02 | 0.511E-01 |
| GROUPS D-F | 0.191E+00 | 0.661E+00 | 0.574E+00 |

Signetics SE501G



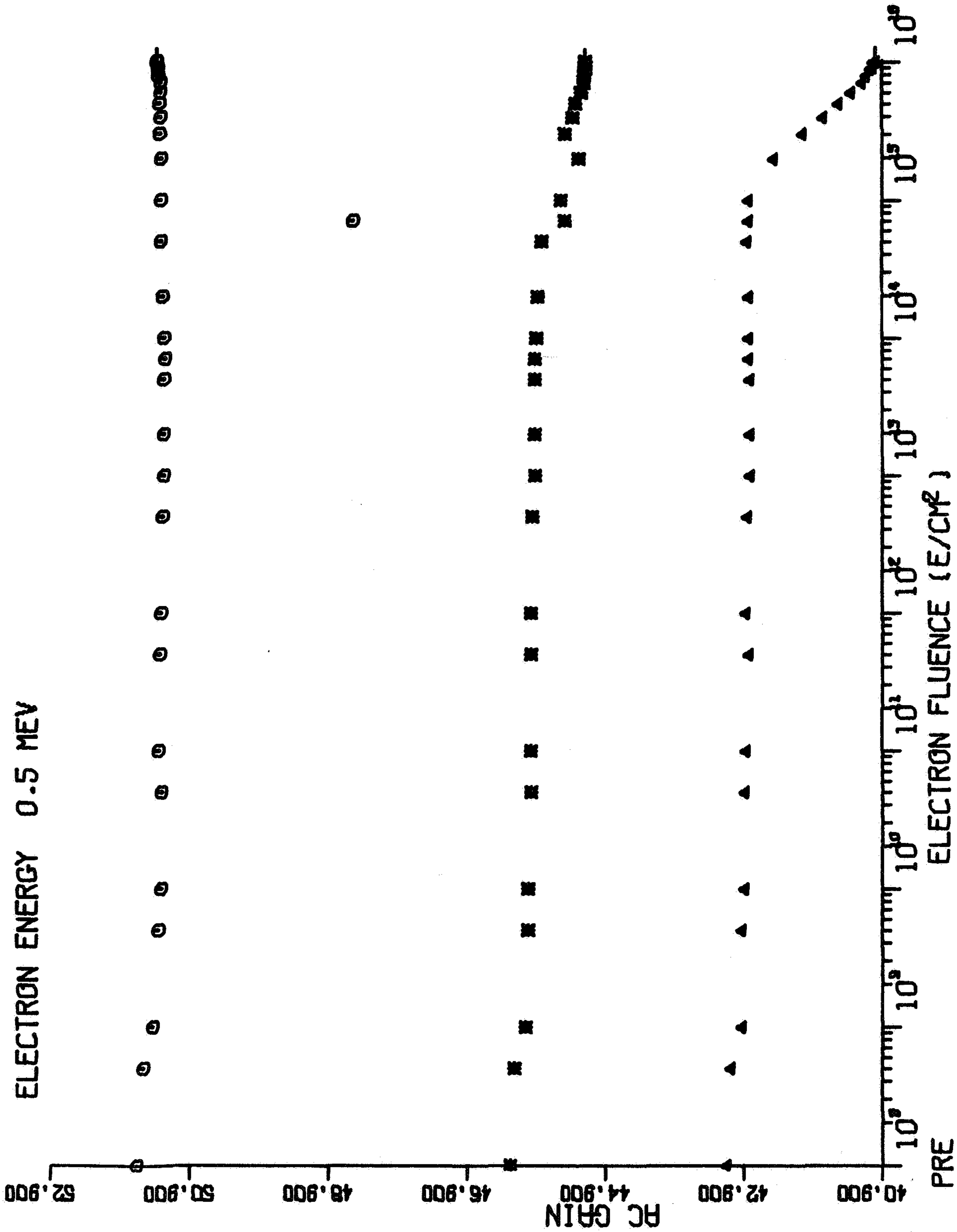

TEST CONDITIONS:

1. Pin 5,+6 volts.
2. Temperature 25 C.

TEST PARAMETERS:

1. Voltage gain.
2. Dc output level.
3. Dc input level.
4. ± Saturation voltage.
5. Resistance.
6. Transistor leakage current.
7. Transistor gain 50 μA, 10 mA.
8. Transistor base-to-emitter voltage 50 μA, 10 mA.
9. Gain ratio.

FIGURE 73. TEST PLAN FOR SE501G AMPLIFIER




STATIC AC GAIN RADIATION RESPONSE FOR SE501G AMPLIFIERS.

FIGURE 74

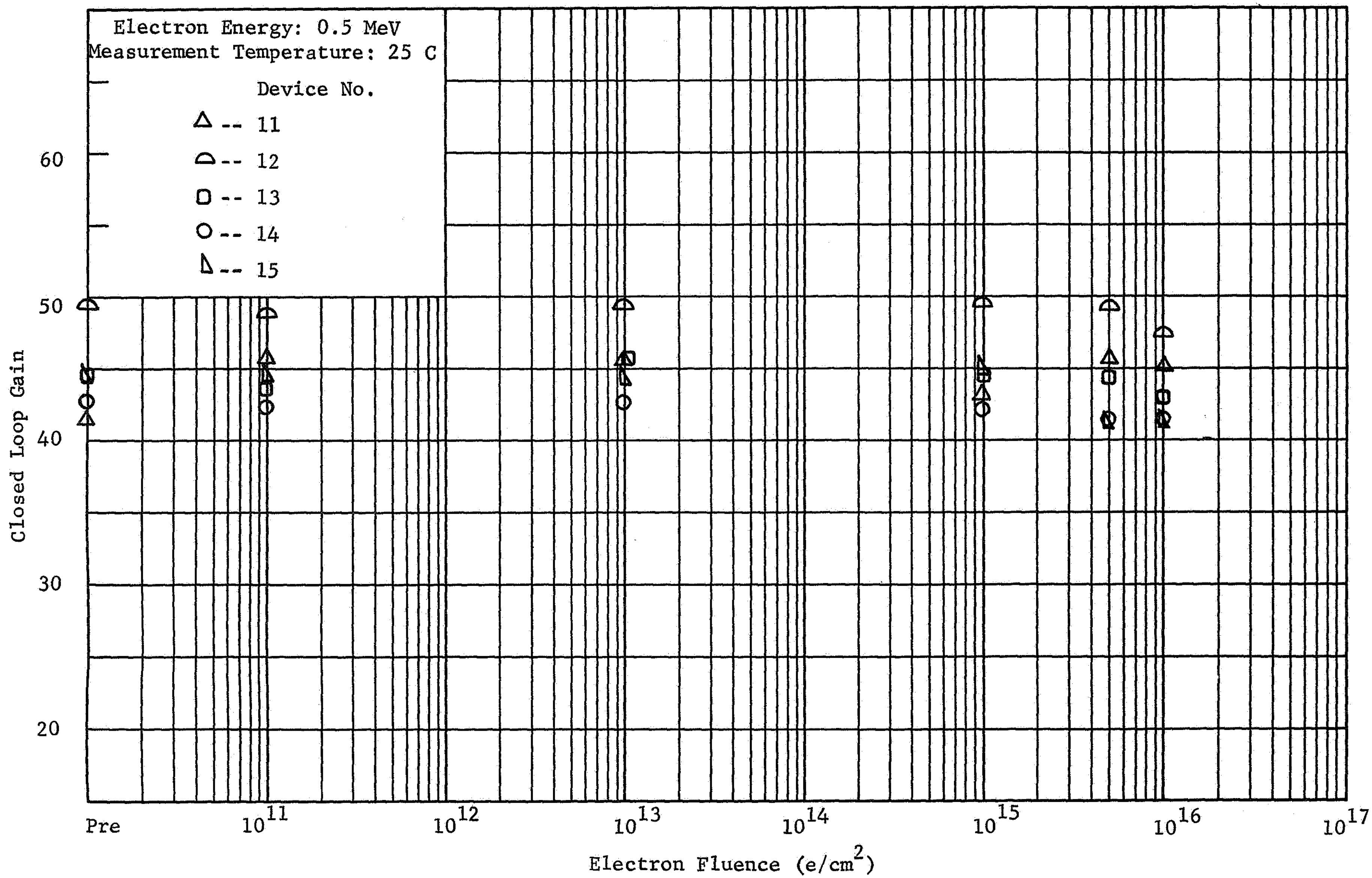
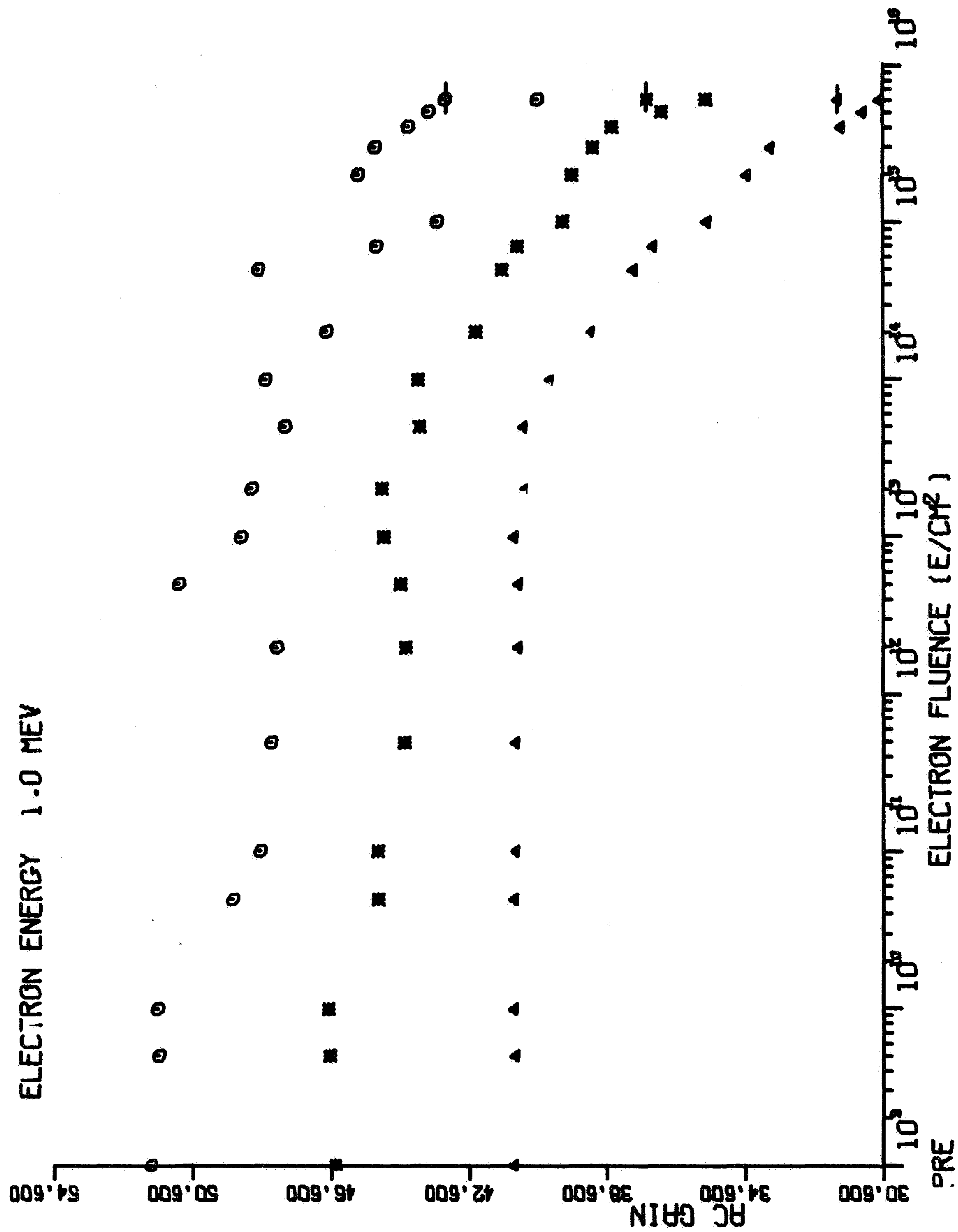
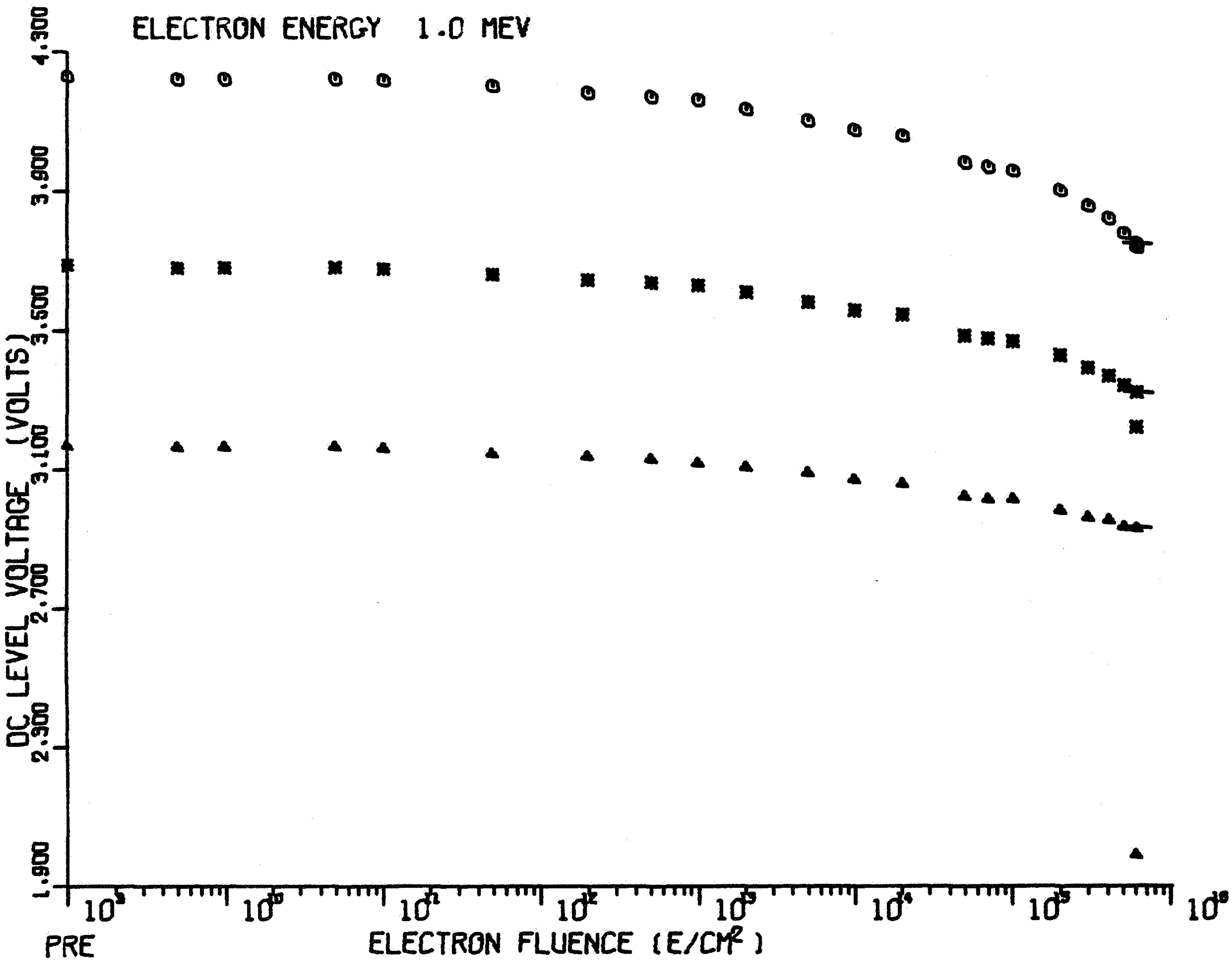



FIGURE 75. PULSED CLOSED LOOP GAIN RAIDATION RESPONSE OF SE 501 G AMPLIFIERS.




STATIC AC GAIN RADIATION RESPONSE FOR SE501G AMPLIFIERS.

FIGURE 76




STATIC DC LEVEL VOLTAGE RADIATION RESPONSE FOR SE501G AMPLIFIERS.

FIGURE 77

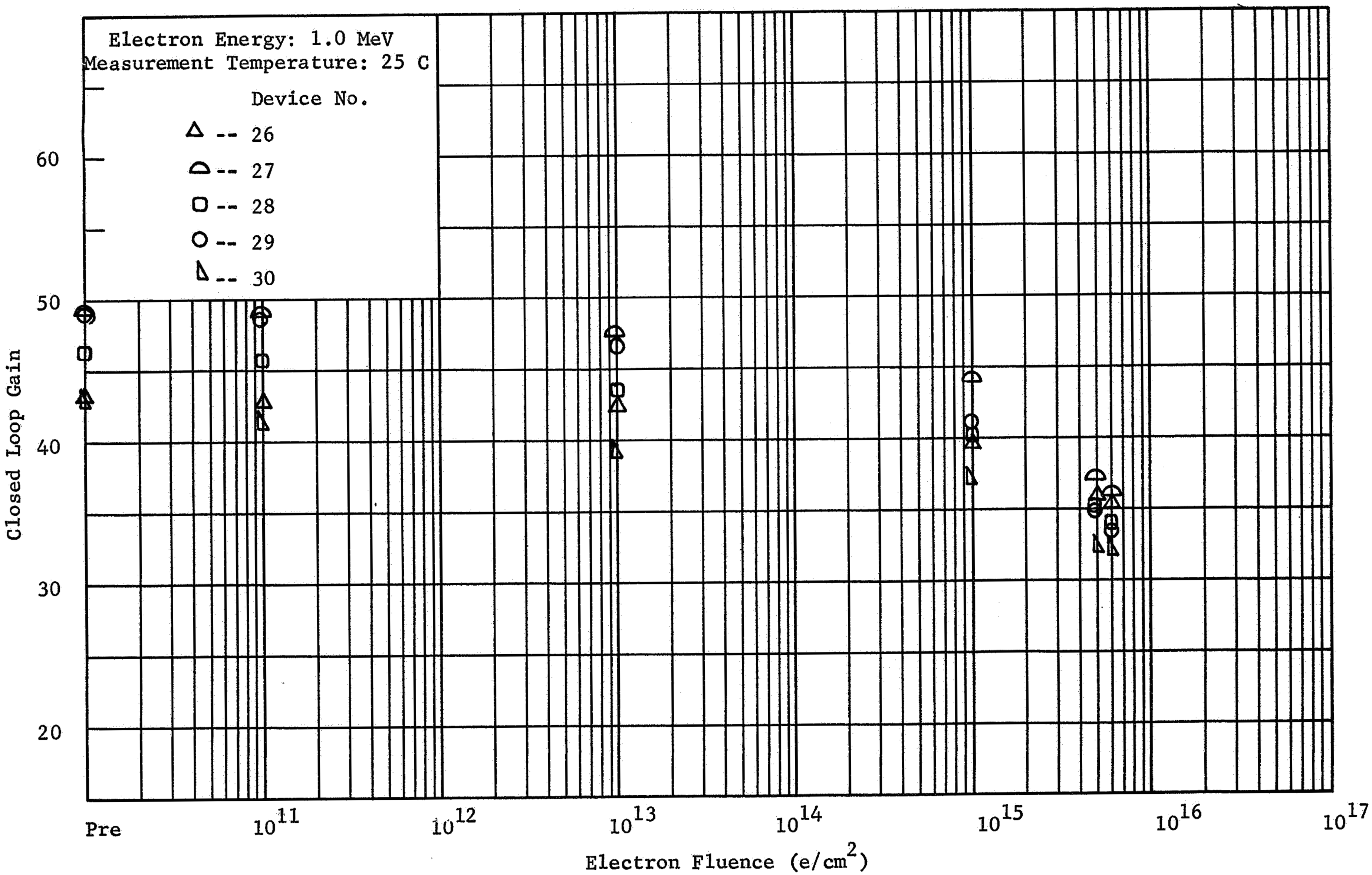
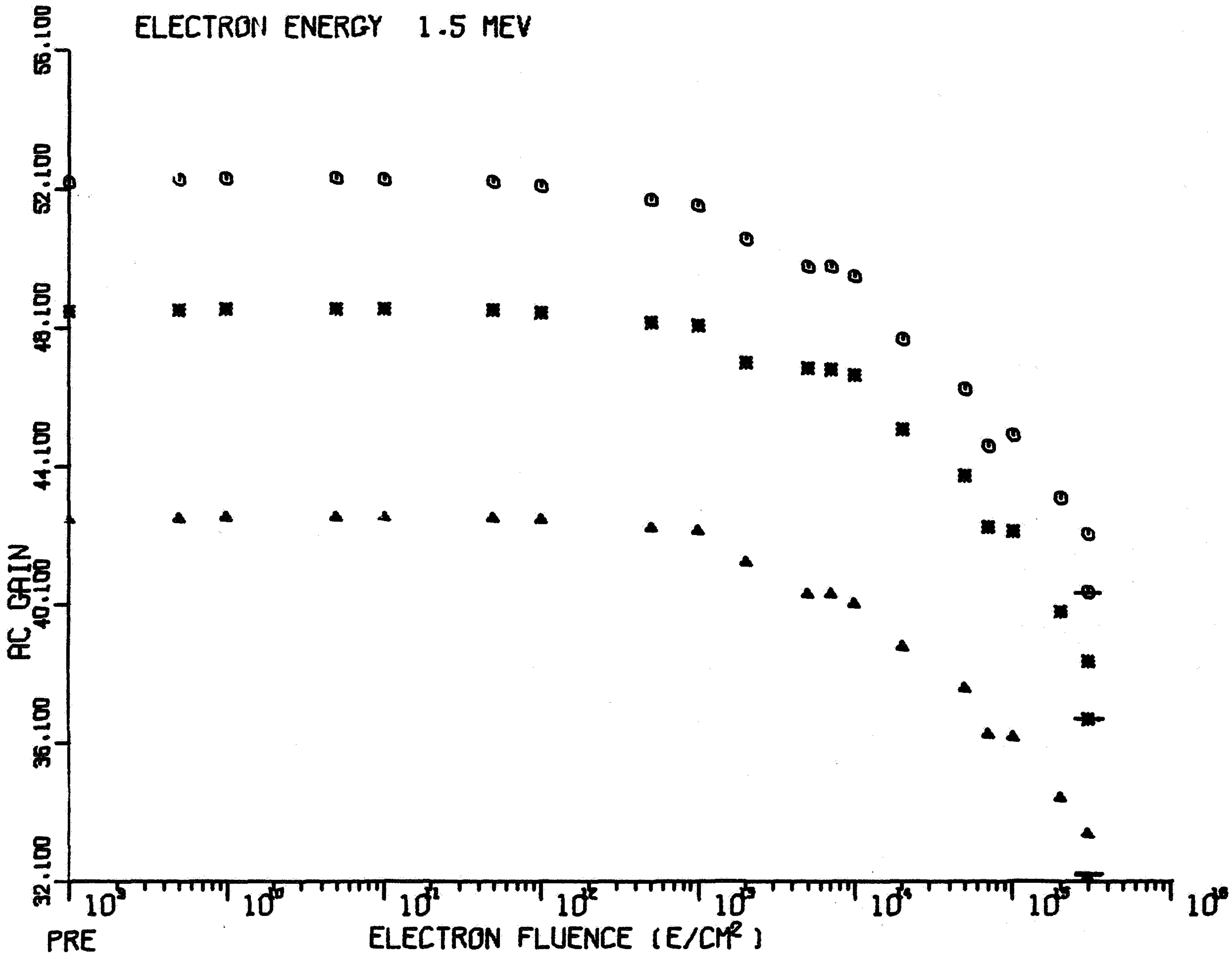
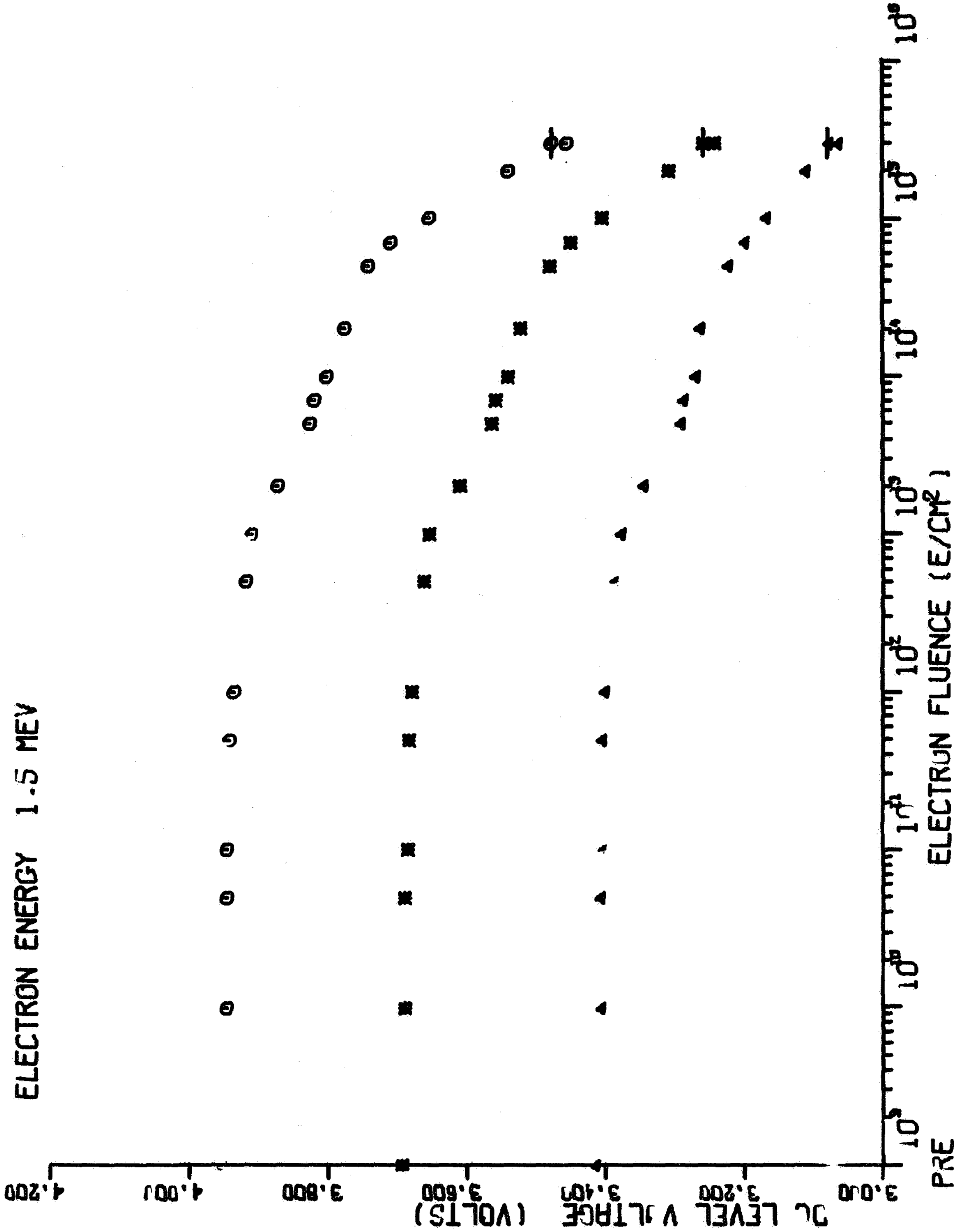



FIGURE 78. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF SE 501 G AMPLIFIERS.




STATIC AC GAIN RADIATION RESPONSE FOR SE501G AMPLIFIERS.

FIGURE 79




STATIC DC LEVEL VOLTAGE RADIATION RESPONSE FOR SE501G AMPLIFIERS.

FIGURE 80

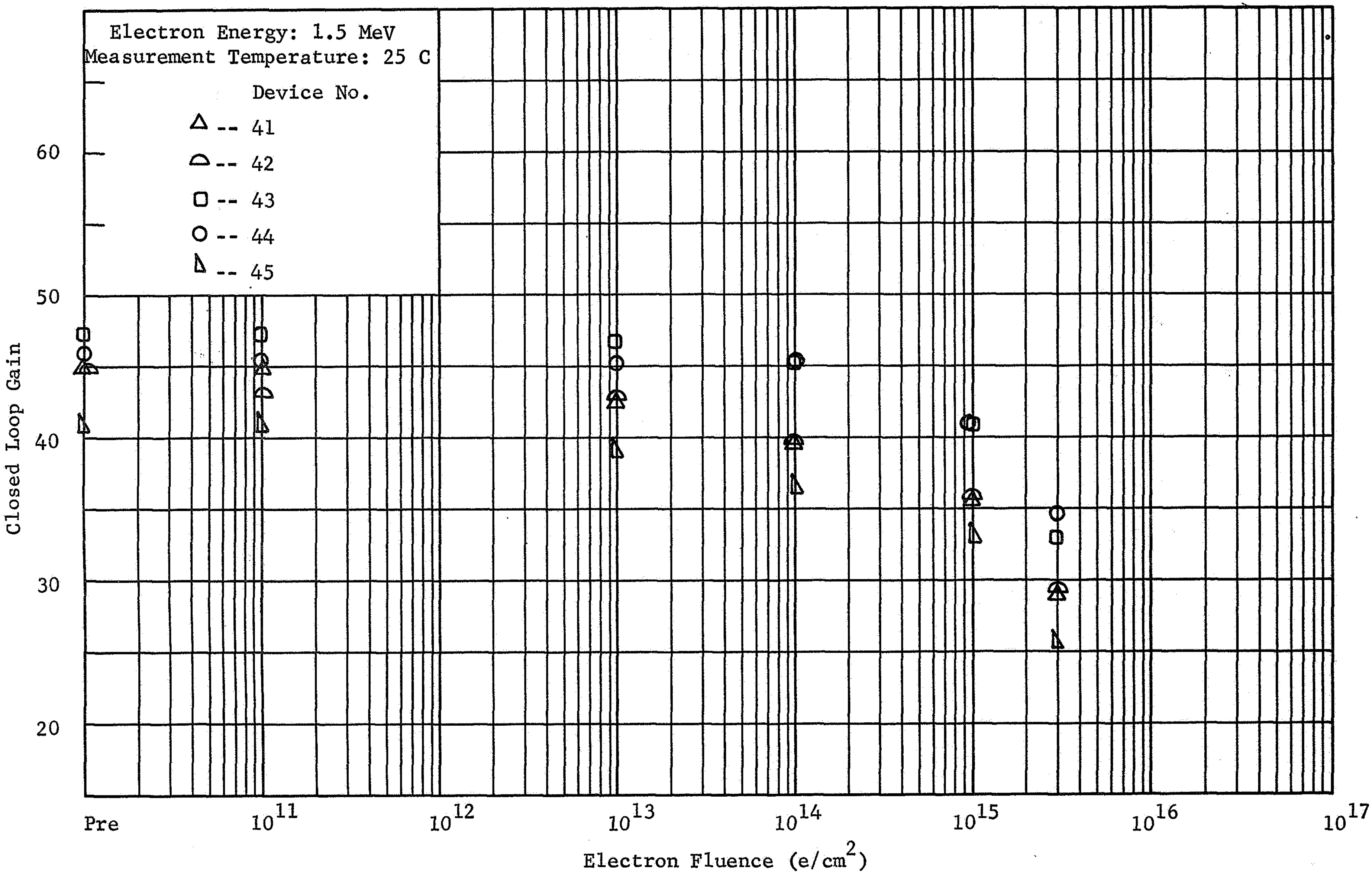



FIGURE 81. PULSED CLOSED LOOP GAIN RADIATION RESPONSE OF SE 501 G AMPLIFIERS.

SIGNETICS SE501

| | V SAT - | V SAT + | GAIN C.L. | V(D.C. IN) | V(D.C.OUT) | RESISTANCE | I(CBO) |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.198E+01 | 0.514E+01 | 0.463E+02 | 0.809E+00 | 0.373E+01 | 0.457E+04 | 0.210E-08 |
| AVERAGE CHANGE | 0.160E-01 | 0.290E-01 | -0.200E-01 | -0.280E-02 | -0.280E-01 | 0.930E+02 | 0.380E-06 |
| STD OF MEAN | 0.516E-02 | 0.738E-02 | 0.121E+01 | 0.257E-02 | 0.559E-01 | 0.457E+02 | 0.120E-05 |
| AVE PER CENT CHANGE | 0.809E+00 | 0.564E+00 | -0.105E+00 | -0.346E+00 | -0.762E+00 | 0.206E+01 | 0.141E+06 |
| INTERVAL ESTIMATE | 0.620E+00 | 0.462E+00 | -0.192E+01 | -0.573E+00 | -0.183E+01 | 0.132E+01 | -0.228E+05 |
| AS PER CENT | 0.993E+00 | 0.667E+00 | 0.183E+01 | -0.119E+00 | 0.322E+00 | 0.275E+01 | 0.589E+05 |
| PER CENT AVE CHANGE | 0.806E+00 | 0.564E+00 | -0.432E-01 | -0.346E+00 | -0.751E+00 | 0.203E+01 | 0.181E+05 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.193E+01 | 0.518E+01 | 0.444E+02 | 0.816E+00 | 0.370E+01 | 0.425E+04 | 0.362E-06 |
| AVERAGE CHANGE | 0.120E-01 | -0.140E-01 | -0.400E-01 | -0.360E-02 | -0.120E-01 | 0.680E+02 | 0.160E-06 |
| STD OF MEAN | 0.447E-02 | 0.114E-01 | 0.568E+00 | 0.321E-02 | 0.390E-01 | 0.409E+02 | 0.358E-06 |
| AVE PER CENT CHANGE | 0.619E+00 | -0.270E+00 | -0.464E-01 | -0.442E+00 | -0.322E+00 | 0.160E+01 | 0.260E+02 |
| INTERVAL ESTIMATE | 0.333E+00 | -0.544E+00 | -0.168E+01 | -0.930E+00 | -0.163E+01 | 0.406E+00 | -0.784E+02 |
| AS PER CENT | 0.908E+00 | 0.299E-02 | 0.150E+01 | 0.471E-01 | 0.983E+00 | 0.279E+01 | 0.167E+03 |
| PER CENT AVE CHANGE | 0.620E+00 | -0.270E+00 | -0.901E-01 | -0.441E+00 | -0.324E+00 | 0.160E+01 | 0.443E+02 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.192E+01 | 0.522E+01 | 0.473E+02 | 0.812E+00 | 0.374E+01 | 0.445E+04 | 0.935E-08 |
| AVERAGE CHANGE | 0.400E-02 | -0.130E+00 | -0.998E+01 | -0.990E-02 | -0.354E+00 | 0.620E+02 | -0.938E-09 |
| STD OF MEAN | 0.699E-02 | 0.141E-01 | 0.190E+01 | 0.160E-02 | 0.406E-01 | 0.107E+03 | 0.106E-07 |
| AVE PER CENT CHANGE | 0.211E+00 | -0.249E+01 | -0.212E+02 | -0.122E+01 | -0.947E+01 | 0.139E+01 | 0.404E+02 |
| INTERVAL ESTIMATE | -0.522E-01 | -0.269E+01 | -0.240E+02 | -0.136E+01 | -0.102E+02 | -0.326E+00 | -0.908E+02 |
| AS PER CENT | 0.470E+00 | -0.230E+01 | -0.182E+02 | -0.108E+01 | -0.868E+01 | 0.311E+01 | 0.708E+02 |
| PER CENT AVE CHANGE | 0.209E+00 | -0.249E+01 | -0.211E+02 | -0.122E+01 | -0.945E+01 | 0.139E+01 | -0.100E+02 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.191E+01 | 0.517E+01 | 0.470E+02 | 0.812E+00 | 0.371E+01 | 0.445E+04 | 0.367E-06 |
| AVERAGE CHANGE | 0.200E-02 | -0.148E+00 | -0.145E+02 | -0.168E-01 | -0.474E+00 | 0.700E+02 | 0.166E-09 |
| STD OF MEAN | 0.447E-02 | 0.192E-01 | 0.272E+01 | 0.295E-02 | 0.627E-01 | 0.579E+02 | 0.343E-08 |
| AVE PER CENT CHANGE | 0.107E+00 | -0.286E+01 | -0.307E+02 | -0.207E+01 | -0.128E+02 | 0.156E+01 | 0.360E+02 |
| INTERVAL ESTIMATE | -0.186E+00 | -0.332E+01 | -0.380E+02 | -0.252E+01 | -0.149E+02 | -0.416E-01 | -0.112E+01 |
| AS PER CENT | 0.395E+00 | -0.240E+01 | -0.237E+02 | -0.162E+01 | -0.107E+02 | 0.318E+01 | 0.121E+01 |
| PER CENT AVE CHANGE | 0.105E+00 | -0.286E+01 | -0.309E+02 | -0.207E+01 | -0.128E+02 | 0.157E+01 | 0.453E-01 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.191E+01 | 0.517E+01 | 0.482E+02 | 0.807E+00 | 0.373E+01 | 0.452E+04 | 0.964E-08 |
| AVERAGE CHANGE | 0.800E-02 | -0.900E-01 | -0.120E+02 | -0.118E-01 | -0.385E+00 | 0.860E+02 | 0.125E-09 |
| STD OF MEAN | 0.789E-02 | 0.163E-01 | 0.163E+01 | 0.187E-02 | 0.528E-01 | 0.458E+02 | 0.223E-08 |
| AVE PER CENT CHANGE | 0.415E+00 | -0.174E+01 | -0.249E+02 | -0.146E+01 | -0.103E+02 | 0.191E+01 | 0.429E+02 |
| INTERVAL ESTIMATE | 0.123E+00 | -0.197E+01 | -0.273E+02 | -0.163E+01 | -0.113E+02 | 0.118E+01 | -0.152E+02 |
| AS PER CENT | 0.714E+00 | -0.151E+01 | -0.225E+02 | -0.130E+01 | -0.931E+01 | 0.262E+01 | 0.178E+02 |
| PER CENT AVE CHANGE | 0.419E+00 | -0.174E+01 | -0.249E+02 | -0.146E+01 | -0.103E+02 | 0.190E+01 | 0.130E+01 |

SIGNETICS SE501

| | V SAT - | V SAT + | GAIN C.L. | V(D.C. IN) | V(D.C.OUT) | RESISTANCE | I(CBO) |
|---|---|---|---|---|---|---|---|
| 1.5 MEV UNBIASED-F | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.190E+01 | 0.517E+01 | 0.457E+02 | 0.811E+00 | 0.365E+01 | 0.446E+04 | 0.630E-08 |
| AVERAGE CHANGE | 0. | -0.166E+00 | -0.169E+02 | -0.186E-01 | -0.518E+00 | 0.880E+02 | 0.429E-09 |
| STD OF MEAN | 0. | 0.321E-01 | 0.182E+01 | 0.404E-02 | 0.572E-01 | 0.268E+02 | 0.344E-09 |
| AVE PER CENT CHANGE | 0. | -0.322E+01 | -0.372E+02 | -0.229E+01 | -0.142E+02 | 0.197E+01 | 0.604E+02 |
| INTERVAL ESTIMATE | 0. | -0.398E+01 | -0.420E+02 | -0.291E+01 | -0.161E+02 | 0.123E+01 | 0.180E-01 |
| AS PER CENT | 0. | -0.244E+01 | -0.321E+02 | -0.168E+01 | -0.122E+02 | 0.272E+01 | 0.136E+02 |
| PER CENT AVE CHANGE | 0. | -0.321E+01 | -0.370E+02 | -0.229E+01 | -0.142E+02 | 0.197E+01 | 0.680E+01 |
| CONTROL-G | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.196E+01 | 0.516E+01 | 0.464E+02 | 0.813E+00 | 0.379E+01 | 0.443E+04 | 0.304E-08 |
| AVERAGE CHANGE | 0.100E-01 | 0.340E-01 | 0.700E+00 | -0.140E-02 | 0.340E-01 | 0.440E+02 | -0.164E-09 |
| STD OF MEAN | 0.707E-02 | 0.548E-02 | 0.274E+00 | 0.548E-03 | 0.391E-01 | 0.103E+03 | 0.469E-09 |
| AVE PER CENT CHANGE | 0.509E+00 | 0.660E+00 | 0.152E+01 | -0.172E+00 | 0.911E+00 | 0.117E+01 | 0.131E+02 |
| INTERVAL ESTIMATE | 0.622E-01 | 0.528E+00 | 0.776E+00 | -0.256E+00 | -0.385E+00 | -0.189E+01 | -0.246E+02 |
| AS PER CENT | 0.956E+00 | 0.791E+00 | 0.224E+01 | -0.886E-01 | 0.218E+01 | 0.387E+01 | 0.138E+02 |
| PER CENT AVE CHANGE | 0.509E+00 | 0.659E+00 | 0.151E+01 | -0.172E+00 | 0.898E+00 | 0.992E+00 | -0.540E+01 |
| F-TESTS | | | | | | | |
| GROUPS A-B-G | 0.221E+01 | 0.569E+02 | 0.114E+01 | 0.105E+01 | 0.272E+01 | 0.104E+01 | 0.323E+00 |
| GROUPS C-D-G | 0.212E+01 | 0.274E+03 | 0.855E+02 | 0.860E+02 | 0.170E+03 | 0.972E-01 | 0.379E-01 |
| GROUPS E-F-G | 0.330E+01 | 0.132E+03 | 0.194E+03 | 0.656E+02 | 0.166E+03 | 0.908E+00 | 0.162E+00 |
| GROUPS A-C-E-G | 0.537E+01 | 0.382E+03 | 0.163E+03 | 0.579E+02 | 0.159E+03 | 0.618E+00 | 0.821E+00 |
| GROUPS B-D-F-G | 0.770E+01 | 0.125E+03 | 0.157E+03 | 0.440E+02 | 0.169E+03 | 0.400E+00 | 0.100E+01 |
| GROUPS ALL | 0.627E+01 | 0.186E+03 | 0.134E+03 | 0.467E+02 | 0.137E+03 | 0.423E+00 | 0.610E+00 |
| T-TESTS | | | | | | | |
| GROUPS A-B | 0.147E+01 | 0.891E+01 | 0.346E-01 | 0.525E+00 | -0.569E+00 | 0.103E+01 | 0.393E+00 |
| GROUPS C-D | 0.577E+00 | 0.207E+01 | 0.378E+01 | 0.598E+01 | 0.452E+01 | -0.154E+00 | -0.224E+00 |
| GROUPS E-F | 0.223E+01 | 0.620E+01 | 0.532E+01 | 0.455E+01 | 0.448E+01 | -0.893E-01 | -0.297E+00 |
| GROUPS A-G | 0.188E+01 | -0.133E+01 | -0.129E+01 | -0.118E+01 | -0.220E+01 | 0.130E+01 | 0.694E+00 |
| GROUPS B-G | 0.535E+00 | -0.849E+01 | -0.262E+01 | -0.151E+01 | -0.186E+01 | 0.485E+00 | 0.100E+01 |
| GROUPS C-G | -0.156E+01 | -0.246E+02 | -0.123E+02 | -0.114E+02 | -0.176E+02 | 0.311E+00 | -0.161E+00 |
| GROUPS D-G | -0.214E+01 | -0.203E+02 | -0.125E+02 | -0.115E+02 | -0.154E+02 | 0.493E+00 | 0.213E+00 |
| GROUPS E-G | -0.478E+00 | -0.163E+02 | -0.170E+02 | -0.120E+02 | -0.156E+02 | 0.112E+01 | 0.282E+00 |
| GROUPS F-G | -0.316E+01 | -0.137E+02 | -0.214E+02 | -0.944E+01 | -0.178E+02 | 0.926E+00 | 0.228E+01 |
| GROUPS A-C | 0.437E+01 | 0.315E+02 | 0.140E+02 | 0.742E+01 | 0.149E+02 | 0.843E+00 | 0.100E+01 |
| GROUPS A-E | 0.268E+01 | 0.210E+02 | 0.187E+02 | 0.894E+01 | 0.147E+02 | 0.342E+00 | 0.999E+00 |
| GROUPS C-E | -0.120E+01 | -0.586E+01 | 0.257E+01 | 0.244E+01 | 0.147E+01 | -0.652E+00 | -0.312E+00 |
| GROUPS B-D | 0.354E+01 | 0.134E+02 | 0.117E+02 | 0.677E+01 | 0.140E+02 | -0.631E-01 | 0.100E+01 |
| GROUPS B-F | 0.600E+01 | 0.998E+01 | 0.198E+02 | 0.650E+01 | 0.163E+02 | -0.915E+00 | 0.100E+01 |
| GROUPS D-F | 0.100E+01 | 0.108E+01 | 0.167E+01 | 0.805E+00 | 0.116E+01 | -0.631E+00 | -0.170E+00 |

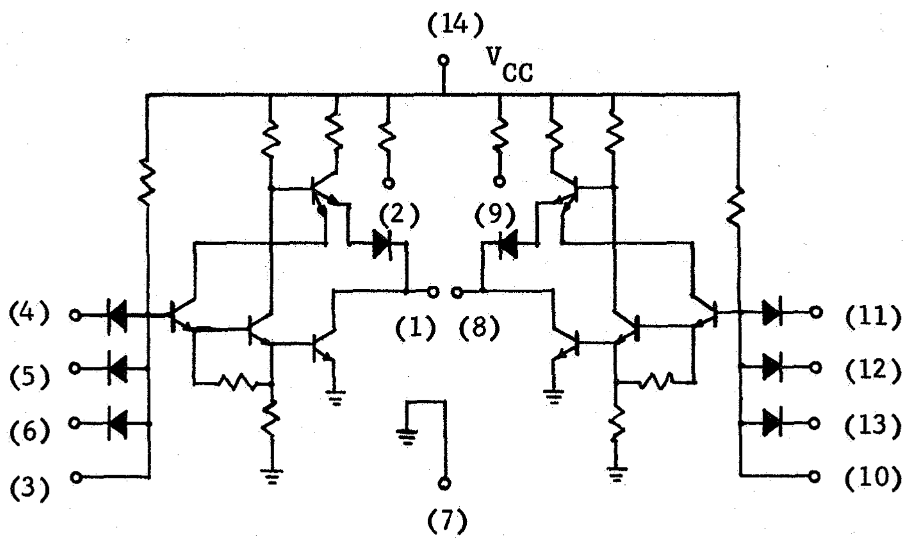
SIGNETICS SE501

| | V(BE) LOW | H(FE) LOW | GAIN RATIO | V(BE) HIGH | H(FE) HIGH |
|---|---|---|---|---|---|
| 0.5 MEV BIASED-A | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.658E+00 | 0.340E+02 | 0.152E+01 | 0.818E+00 | 0.514E+02 |
| AVERAGE CHANGE | 0.100E-03 | -0.172E+02 | 0.671E+01 | 0.390E-02 | -0.128E+02 |
| STD OF MEAN | 0.256E-02 | 0.114E+02 | 0.187E+02 | 0.412E-02 | 0.983E+01 |
| AVE PER CENT CHANGE | 0.152E-01 | -0.470E+02 | 0.432E+03 | 0.475E+00 | -0.249E+02 |
| INTERVAL ESTIMATE | -0.263E+00 | -0.745E+02 | -0.439E+03 | 0.116E+00 | -0.386E+02 |
| AS PER CENT | 0.293E+00 | -0.264E+02 | 0.132E+04 | 0.837E+00 | -0.112E+02 |
| PER CENT AVE CHANGE | 0.152E-01 | -0.504E+02 | 0.441E+03 | 0.477E+00 | -0.249E+02 |
| 0.5 MEV UNBIASED-B | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.660E+00 | 0.251E+02 | 0.185E+01 | 0.822E+00 | 0.412E+02 |
| AVERAGE CHANGE | 0.400E-03 | -0.112E+02 | 0.924E+00 | 0.200E-03 | -0.522E+01 |
| STD OF MEAN | 0.152E-02 | 0.722E+01 | 0.324E+00 | 0.239E-02 | 0.480E+01 |
| AVE PER CENT CHANGE | 0.594E-01 | -0.409E+02 | 0.535E+02 | 0.238E-01 | -0.113E+02 |
| INTERVAL ESTIMATE | -0.225E+00 | -0.801E+02 | 0.282E+02 | -0.336E+00 | -0.271E+02 |
| AS PER CENT | 0.345E+00 | -0.875E+01 | 0.716E+02 | 0.385E+00 | 0.178E+01 |
| PER CENT AVE CHANGE | 0.606E-01 | -0.444E+02 | 0.499E+02 | 0.243E-01 | -0.127E+02 |
| 1.0 MEV BIASED-C | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.660E+00 | 0.247E+02 | 0.168E+01 | 0.819E+00 | 0.449E+02 |
| AVERAGE CHANGE | -0.100E-02 | -0.180E+02 | 0.476E+00 | 0.299E-01 | -0.293E+02 |
| STD OF MEAN | 0.594E-02 | 0.599E+01 | 0.499E+00 | 0.461E-02 | 0.794E+01 |
| AVE PER CENT CHANGE | -0.148E+00 | -0.715E+02 | 0.303E+02 | 0.365E+01 | -0.650E+02 |
| INTERVAL ESTIMATE | -0.796E+00 | -0.904E+02 | 0.631E+01 | 0.325E+01 | -0.779E+02 |
| AS PER CENT | 0.493E+00 | -0.557E+02 | 0.442E+02 | 0.405E+01 | -0.526E+02 |
| PER CENT AVE CHANGE | -0.152E+00 | -0.731E+02 | 0.253E+02 | 0.365E+01 | -0.652E+02 |
| 1.0 MEV UNBIASED-D | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.661E+00 | 0.252E+02 | 0.173E+01 | 0.822E+00 | 0.427E+02 |
| AVERAGE CHANGE | 0.800E-03 | -0.189E+02 | 0.472E+00 | 0.322E-01 | -0.289E+02 |
| STD OF MEAN | 0.837E-03 | 0.408E+01 | 0.367E+00 | 0.396E-02 | 0.474E+01 |
| AVE PER CENT CHANGE | 0.121E+00 | -0.743E+02 | 0.311E+02 | 0.392E+01 | -0.674E+02 |
| INTERVAL ESTIMATE | -0.361E-01 | -0.951E+02 | 0.917E+00 | 0.332E+01 | -0.814E+02 |
| AS PER CENT | 0.278E+00 | -0.549E+02 | 0.538E+02 | 0.452E+01 | -0.539E+02 |
| PER CENT AVE CHANGE | 0.121E+00 | -0.750E+02 | 0.273E+02 | 0.392E+01 | -0.676E+02 |
| 1.5 MEV BIASED-E | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.657E+00 | 0.301E+02 | 0.169E+01 | 0.817E+00 | 0.492E+02 |
| AVERAGE CHANGE | 0.300E-03 | -0.238E+02 | 0.819E+00 | 0.299E-01 | -0.336E+02 |
| STD OF MEAN | 0.149E-02 | 0.991E+01 | 0.178E+00 | 0.387E-02 | 0.121E+02 |
| AVE PER CENT CHANGE | 0.465E-01 | -0.782E+02 | 0.498E+02 | 0.366E+01 | -0.675E+02 |
| INTERVAL ESTIMATE | -0.117E+00 | -0.102E+03 | 0.409E+02 | 0.332E+01 | -0.858E+02 |
| AS PER CENT | 0.208E+00 | -0.553E+02 | 0.559E+02 | 0.400E+01 | -0.507E+02 |
| PER CENT AVE CHANGE | 0.457E-01 | -0.789E+02 | 0.484E+02 | 0.366E+01 | -0.683E+02 |

SIGNETICS SE501

| | V(BE) LOW | H(FE) LOW | GAIN RATIO | V(BE) HIGH | H(FE) HIGH |
|---|---|---|---|---|---|
| 1.5 MEV UNBIASED-F | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.663E+00 | 0.261E+02 | 0.168E+01 | 0.825E+00 | 0.414E+02 |
| AVERAGE CHANGE | -0.120E-02 | -0.205E+02 | 0.548E+00 | 0.384E-01 | -0.292E+02 |
| STD OF MEAN | 0.447E-03 | 0.121E+02 | 0.279E+00 | 0.122E-01 | 0.160E+02 |
| AVE PER CENT CHANGE | -0.181E+00 | -0.767E+02 | 0.370E+02 | 0.467E+01 | -0.689E+02 |
| INTERVAL ESTIMATE | -0.265E+00 | -0.136E+03 | 0.120E+02 | 0.282E+01 | -0.118E+03 |
| AS PER CENT | -0.973E-01 | -0.210E+02 | 0.532E+02 | 0.649E+01 | -0.226E+02 |
| PER CENT AVE CHANGE | -0.181E+00 | -0.787E+02 | 0.326E+02 | 0.466E+01 | -0.705E+02 |
| CONTROL-G | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.655E+00 | 0.346E+02 | 0.164E+01 | 0.815E+00 | 0.567E+02 |
| AVERAGE CHANGE | -0.380E-02 | -0.340E+00 | 0.520E-01 | -0.180E-02 | 0.158E+01 |
| STD OF MEAN | 0.447E-03 | 0.270E+00 | 0.746E-01 | 0.356E-02 | 0.377E+01 |
| AVE PER CENT CHANGE | -0.580E+00 | -0.963E+00 | 0.310E+01 | -0.225E+00 | 0.186E+01 |
| INTERVAL ESTIMATE | -0.665E+00 | -0.195E+01 | -0.248E+01 | -0.764E+00 | -0.548E+01 |
| AS PER CENT | -0.495E+00 | -0.132E-01 | 0.882E+01 | 0.322E+00 | 0.111E+02 |
| PER CENT AVE CHANGE | -0.580E+00 | -0.983E+00 | 0.317E+01 | -0.221E+00 | 0.279E+01 |
| F-TESTS | | | | | |
| GROUPS A-B-G | 0.744E+01 | 0.579E+01 | 0.527E+00 | 0.452E+01 | 0.598E+01 |
| GROUPS C-D-G | 0.143E+01 | 0.265E+02 | 0.203E+01 | 0.111E+03 | 0.422E+02 |
| GROUPS E-F-G | 0.220E+02 | 0.110E+02 | 0.269E+02 | 0.513E+02 | 0.154E+02 |
| GROUPS A-C-E-G | 0.170E+01 | 0.804E+01 | 0.900E+00 | 0.132E+03 | 0.203E+02 |
| GROUPS B-D-F-G | 0.256E+02 | 0.788E+01 | 0.790E+01 | 0.483E+02 | 0.162E+02 |
| GROUPS ALL | 0.143E+01 | 0.465E+01 | 0.690E+00 | 0.670E+02 | 0.132E+02 |
| T-TESTS | | | | | |
| GROUPS A-B | -0.239E+00 | -0.106E+01 | 0.678E+00 | 0.184E+01 | -0.161E+01 |
| GROUPS C-D | -0.662E+00 | 0.284E+00 | 0.158E-01 | -0.951E+00 | -0.108E+00 |
| GROUPS E-F | 0.216E+01 | -0.555E+00 | 0.231E+01 | -0.207E+01 | -0.605E+00 |
| GROUPS A-G | 0.332E+01 | -0.323E+01 | 0.780E+00 | 0.263E+01 | -0.311E+01 |
| GROUPS B-G | 0.594E+01 | -0.335E+01 | 0.587E+01 | 0.104E+01 | -0.249E+01 |
| GROUPS C-G | 0.103E+01 | -0.648E+01 | 0.185E+01 | 0.134E+02 | -0.814E+01 |
| GROUPS D-G | 0.108E+02 | -0.102E+02 | 0.250E+01 | 0.143E+02 | -0.112E+02 |
| GROUPS E-G | 0.590E+01 | -0.518E+01 | 0.909E+01 | 0.153E+02 | -0.626E+01 |
| GROUPS F-G | 0.919E+01 | -0.373E+01 | 0.384E+01 | 0.707E+01 | -0.419E+01 |
| GROUPS A-C | 0.538E+00 | 0.217E+00 | 0.105E+01 | -0.133E+02 | 0.414E+01 |
| GROUPS A-E | -0.213E+00 | 0.138E+01 | 0.995E+00 | -0.145E+02 | 0.423E+01 |
| GROUPS C-E | -0.671E+00 | 0.156E+01 | -0.205E+01 | 0.934E-12 | 0.942E+00 |
| GROUPS B-D | -0.516E+00 | 0.209E+01 | 0.206E+01 | -0.155E+02 | 0.785E+01 |
| GROUPS B-F | -0.226E+01 | 0.148E+01 | 0.197E+01 | -0.687E+01 | 0.321E+01 |
| GROUPS D-F | 0.471E+01 | 0.284E+00 | -0.368E+00 | -0.108E+01 | 0.379E-01 |

Fairchild LPDTμL9042



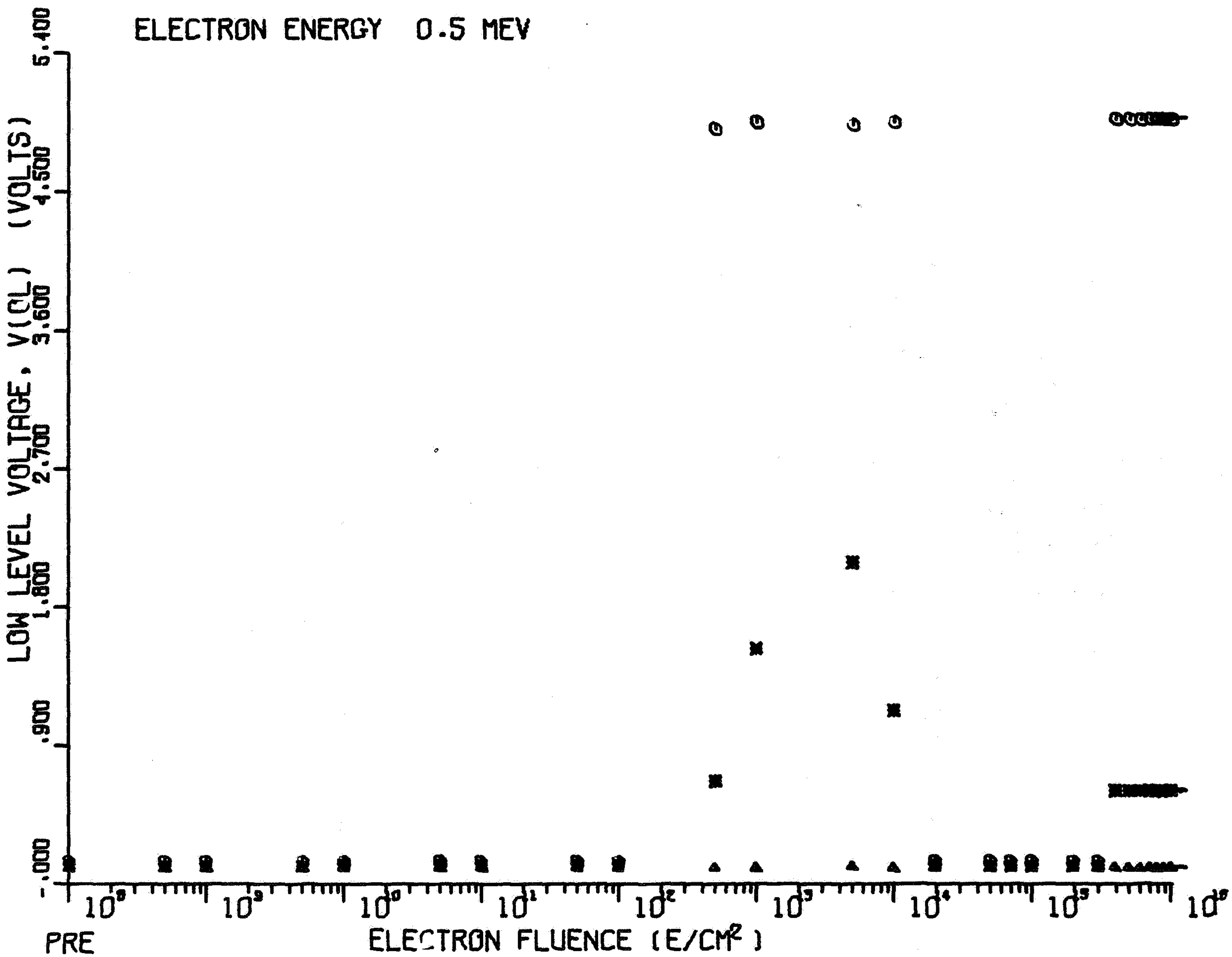

TEST CONDITIONS:

1. Pin 14, 5.0 volts.
2. Pin 7, ground.
3. Temperature 25 C.

TEST PARAMETERS:

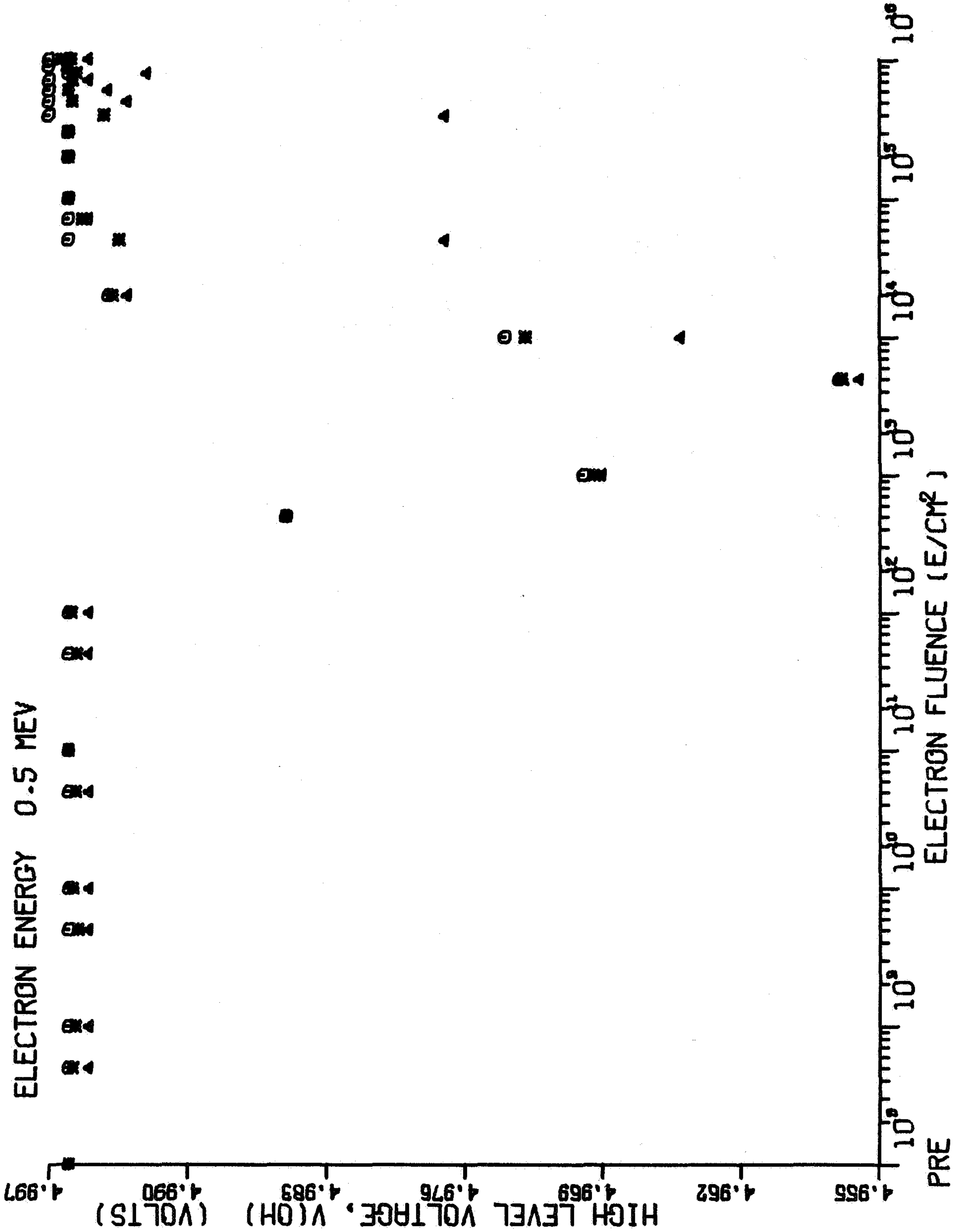
1. Output-voltage levels ($V_{OH}$, $V_{OL}$).
2. Input-voltage levels ($V_{IH}$, $V_{IL}$).
3. Input leakage current.
4. Input-diode forward voltage.
5. Input drive current.
6. Resistance.
7. Propagation delay.
8. Circuit gain.

FIGURE 82. TEST PLAN FOR LPDTμL9042 GATES




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L9042 GATES.

FIGURE 83




STATIC HIGH LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L9042 GATES.

FIGURE 84

STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPOT L9042 GATES.
LOW LEVEL VOLTAGE, V(OL) (VOLTS)
ELECTRON ENERGY 0.5 MEV

| FLUENCE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0. | .119310 | .120620 | .117920 | .121170 | .132880 | .147460 | .135090 | .126240 | .099570 | .104240 |
| 0.5E+09 | .118130 | .119500 | .116760 | .120030 | .131740 | .146300 | .133940 | .125100 | .098440 | .103110 |
| 0.1E+10 | .118170 | .119560 | .116800 | .120060 | .131760 | .146320 | .133950 | .125110 | .098450 | .103120 |
| 0.5E+10 | .118150 | .119540 | .116790 | .120030 | .131750 | .146320 | .133940 | .125100 | .098430 | .103090 |
| 0.1E+11 | .119580 | .120940 | .118200 | .121480 | .133180 | .147750 | .135400 | .126560 | .098890 | .104560 |
| 0.5E+11 | 0.000000 | .120760 | .118030 | .121300 | .133000 | .147570 | .135210 | .126360 | .099710 | .104370 |
| 0.1E+12 | .119360 | .120740 | .117990 | .121250 | .132950 | .147530 | .135190 | .126350 | .099690 | .104350 |
| 0.5E+12 | .118990 | .120370 | .117670 | .120870 | .132590 | .147220 | .134820 | .125990 | .098350 | .103970 |
| 0.1E+13 | .119030 | .120420 | .117720 | .120920 | .132670 | .147530 | .134910 | .126050 | .099370 | .103990 |
| 0.5E+13 | .122730 | .120260 | .119060 | .127630 | .811100 | 4.909000 | .141790 | .127590 | .100510 | .105740 |
| 0.1E*14 | .125260 | .122660 | .121270 | .131260 | 4.949000 | 4.949000 | 4.540000 | .130280 | .101780 | .106460 |
| 0.5E+14 | .124610 | .124650 | 4.880000 | .125350 | 4.936000 | 4.936000 | 4.936000 | .637000 | .104530 | .108300 |
| 0.1E+15 | .121630 | .122720 | .123330 | .124300 | 4.947000 | 4.912000 | .554700 | .129520 | .101800 | .106500 |
| 0.2E+15 | .118350 | .119840 | .116910 | .120500 | .135250 | .147110 | .134190 | .125030 | .098480 | .103460 |
| 0.5E+15 | .118230 | .119770 | .116690 | .120490 | .131920 | .146300 | .134050 | .125040 | .098320 | .102240 |
| 0.7E+15 | .117970 | .119410 | .116300 | .120240 | .131630 | .145960 | .133750 | .124700 | .097970 | .102890 |
| 0.1E+16 | .118090 | .119810 | .116550 | .121460 | .131910 | .146210 | .134060 | .124920 | .098160 | .103280 |
| 0.2E+16 | .117600 | .119590 | .116080 | .121000 | .131530 | .145640 | .133770 | .124410 | .097570 | .102490 |
| 0.3E+16 | .116910 | .119050 | .115500 | .120900 | .130950 | .145210 | .133240 | .123680 | .096880 | .102130 |
| 0.4E+16 | 4.966000 | .118750 | .114950 | .120360 | .130730 | .144930 | .133040 | .123410 | .096510 | .101830 |
| 0.5E+16 | 4.966000 | .118860 | .114880 | .120730 | .130750 | .144900 | .132980 | .123360 | .096440 | .102110 |
| 0.6E+16 | 4.966000 | .119280 | .115290 | .120950 | .131130 | .145210 | .133580 | .123700 | .096700 | .102060 |
| 0.7E+16 | 4.966000 | .119170 | .115060 | .121240 | .130970 | .145070 | .133420 | .123520 | .096540 | .102060 |
| 0.8E+16 | 4.966000 | .119000 | .114780 | .121250 | .130920 | .145000 | .133370 | .123540 | .096360 | .101060 |
| 0.9E+16 | 4.967000 | .119980 | .115740 | .121500 | .131820 | .145890 | .134310 | .124420 | .097230 | .102960 |
| 0.1E+17 | 4.967000 | .119840 | .115550 | .121480 | .131560 | .145520 | .133970 | .123990 | .096980 | .101730 |
| 0.1E+17 | 4.967000 | .119900 | .115650 | .121500 | .131660 | .145710 | .134350 | .124170 | .097050 | .101950 |

STATIC HIGH LEVEL OUTPUT RADIATION RESPONSE FOR LPDT L9042 GATES.
HIGH LEVEL VOLTAGE, V(OH) (VOLTS)
ELECTRON ENERGY 0.5 MEV

| FLUENCE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0. | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.5E+09 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.1E+10 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.995000 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.996000 |
| 0.5E+10 | 4.996000 | 4.996000 | 4.995000 | 4.995000 | 4.995000 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.995000 |
| 0.1E+11 | 4.995000 | 4.996000 | 4.996000 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.5E+11 | 4.995000 | 4.996000 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.996000 |
| 0.1E+12 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.5E+12 | 4.995000 | 4.996000 | 4.996000 | 4.996000 | 4.995000 | 4.996000 | 4.995000 | 4.996000 | 4.996000 | 4.995000 |
| 0.1E+13 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.995000 |
| 0.5E+13 | 4.985000 | 4.985000 | 4.985000 | 4.985000 | 4.985000 | 4.985000 | 4.985000 | 4.985000 | 4.985000 | 4.985000 |
| 0.1E+14 | 4.970000 | 4.969000 | 4.970000 | 4.970000 | 4.969000 | 4.969000 | 4.969000 | 4.970000 | 4.969000 | 4.969000 |
| 0.5E+14 | 4.957000 | 4.957000 | 4.957000 | 4.957000 | 4.957000 | 4.957000 | 4.956000 | 4.957000 | 4.957000 | 4.957000 |
| 0.1E+15 | 4.974000 | 4.974000 | 4.974000 | 4.974000 | 4.973000 | 4.965000 | 4.974000 | 4.974000 | 4.973000 | 4.974000 |
| 0.2E+15 | 4.994000 | 4.994000 | 4.994000 | 4.993000 | 4.994000 | 4.994000 | 4.993000 | 4.994000 | 4.994000 | 4.994000 |
| 0.5E+15 | 4.995000 | 4.996000 | 4.995000 | 4.995000 | 4.995000 | 4.996000 | 4.995000 | 4.995000 | 4.995000 | 4.977000 |
| 0.7E+15 | 4.995000 | 4.995000 | 4.996000 | 4.995000 | 4.995000 | 4.995000 | 4.996000 | 4.996000 | 4.995000 | 4.995000 |
| 0.1E+16 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.2E+16 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.3E+16 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.4E+16 | 4.996000 | 4.996000 | 4.997000 | 4.977000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.5E+16 | 4.996000 | 4.996000 | 4.997000 | 4.993000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 |
| 0.6E+16 | 4.996000 | 4.997000 | 4.996000 | 4.994000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.997000 | 4.996000 |
| 0.7E+16 | 4.996000 | 4.996000 | 4.997000 | 4.996000 | 4.996000 | 4.995000 | 4.995000 | 4.995000 | 4.996000 | 4.996000 |
| 0.8E+16 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.992000 |
| 0.9E+16 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.997000 | 4.996000 | 4.996000 |
| 0.1E+17 | 4.997000 | 4.997000 | 4.997000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.997000 |
| 0.1E+17 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.996000 | 4.995000 |

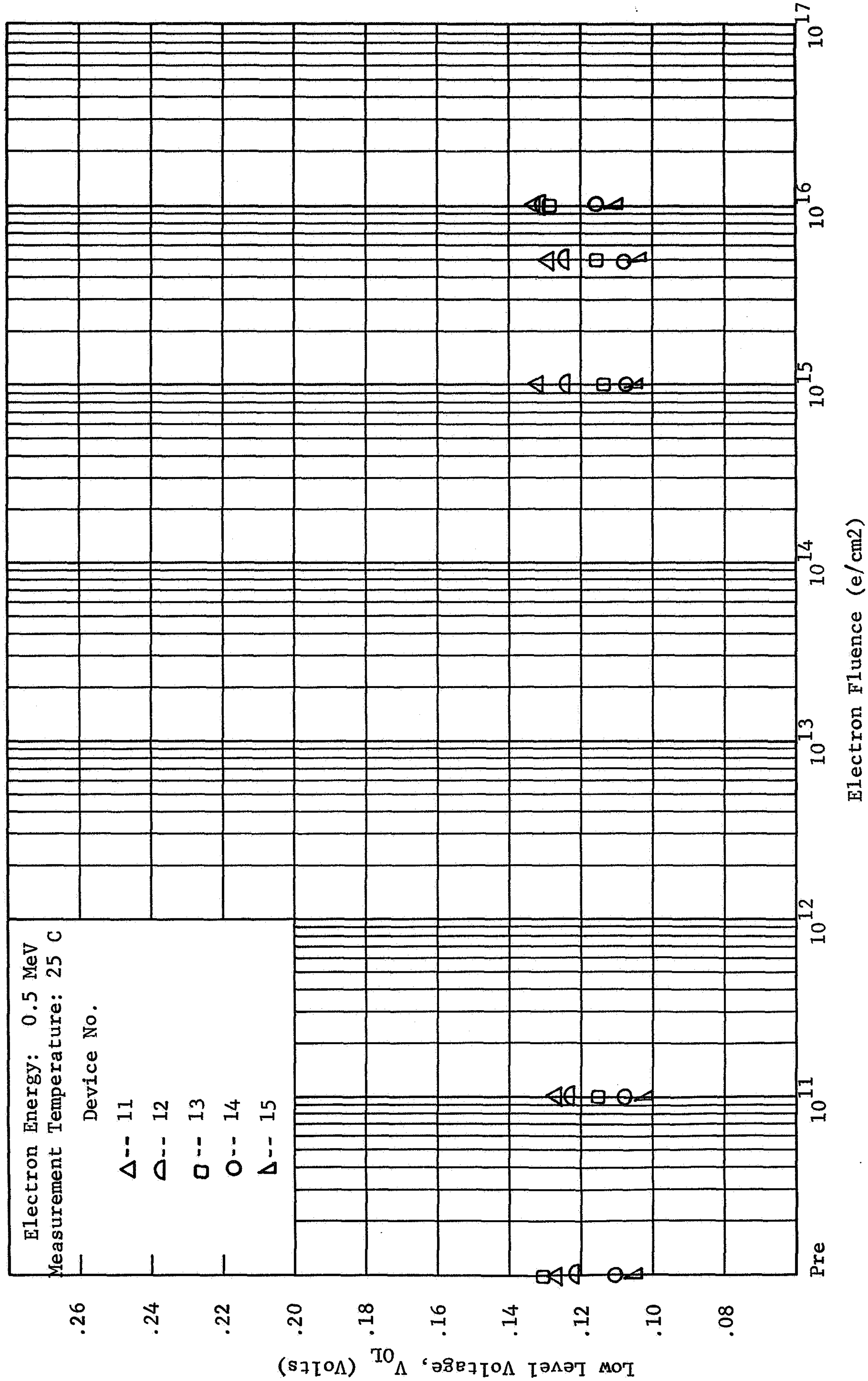
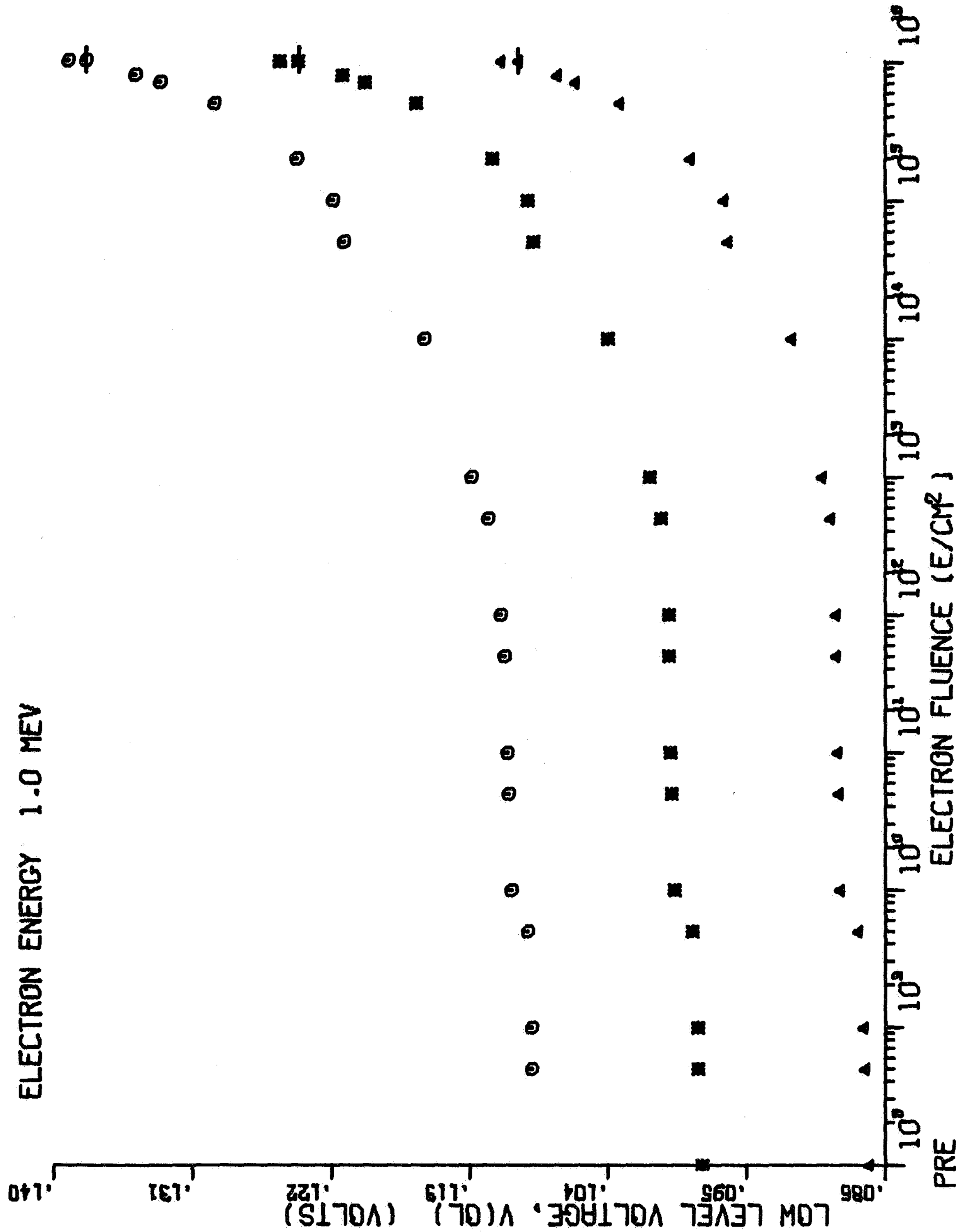



FIGURE 85. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDTμL 9042 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L9042 GATES.

FIGURE 86

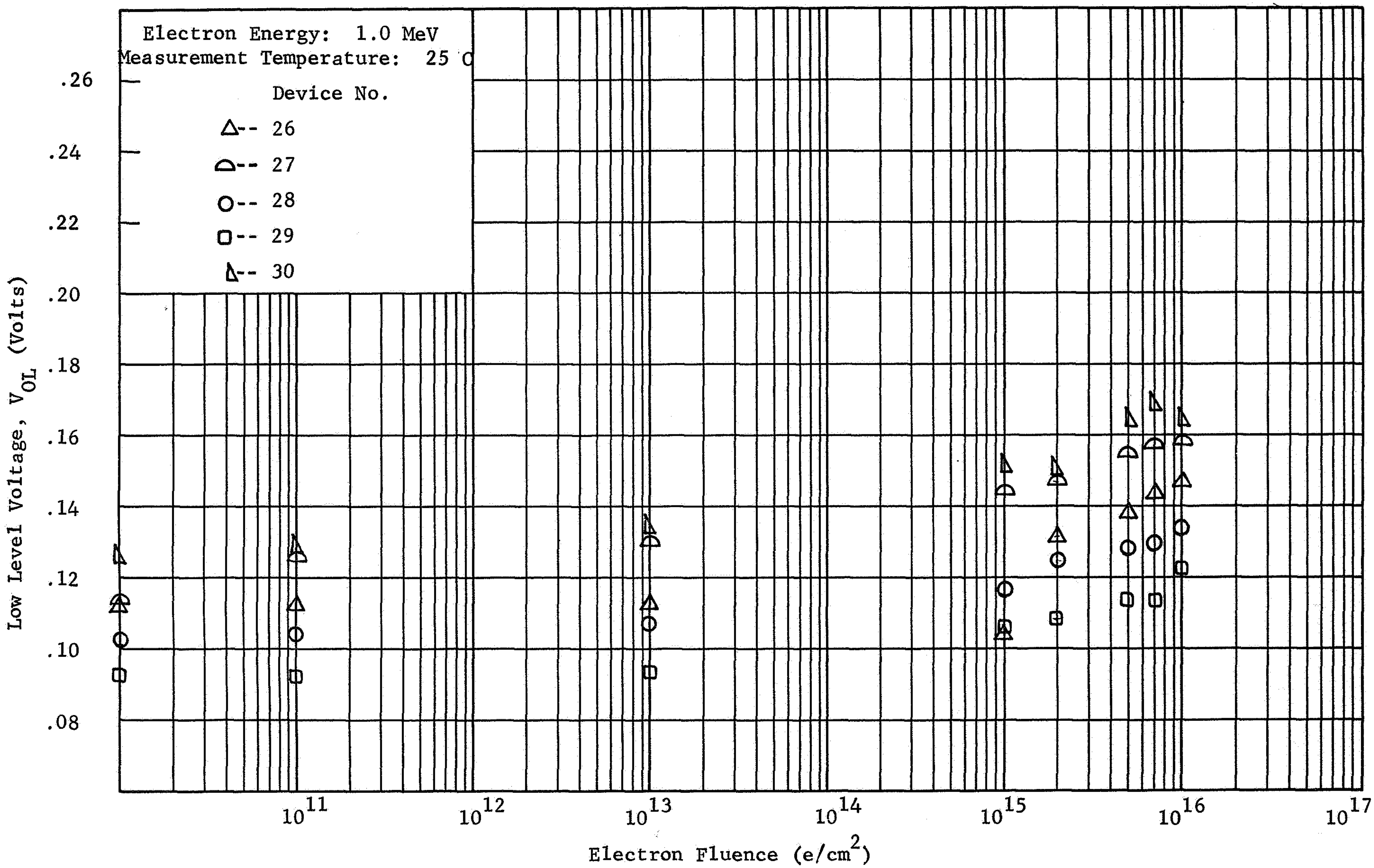
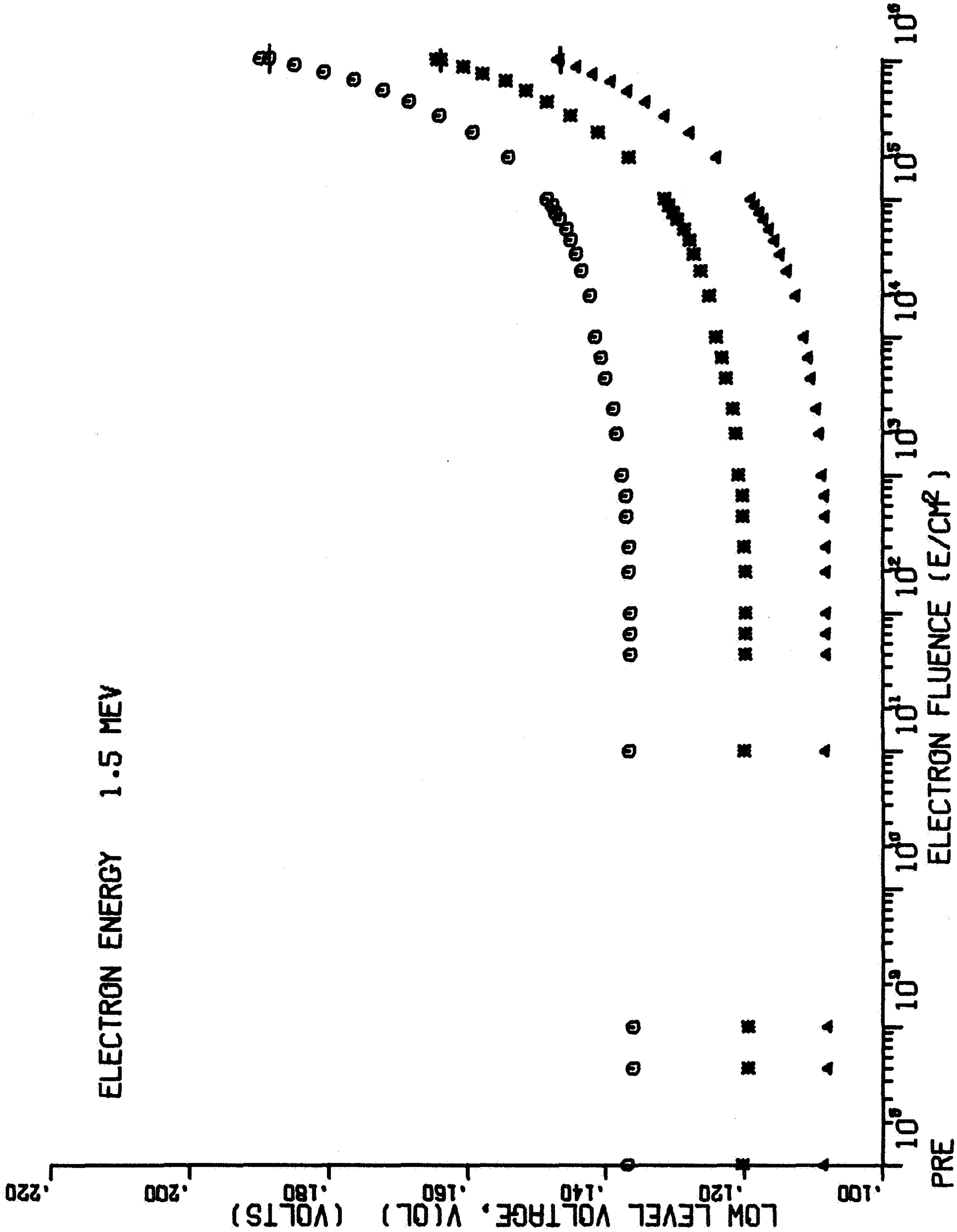
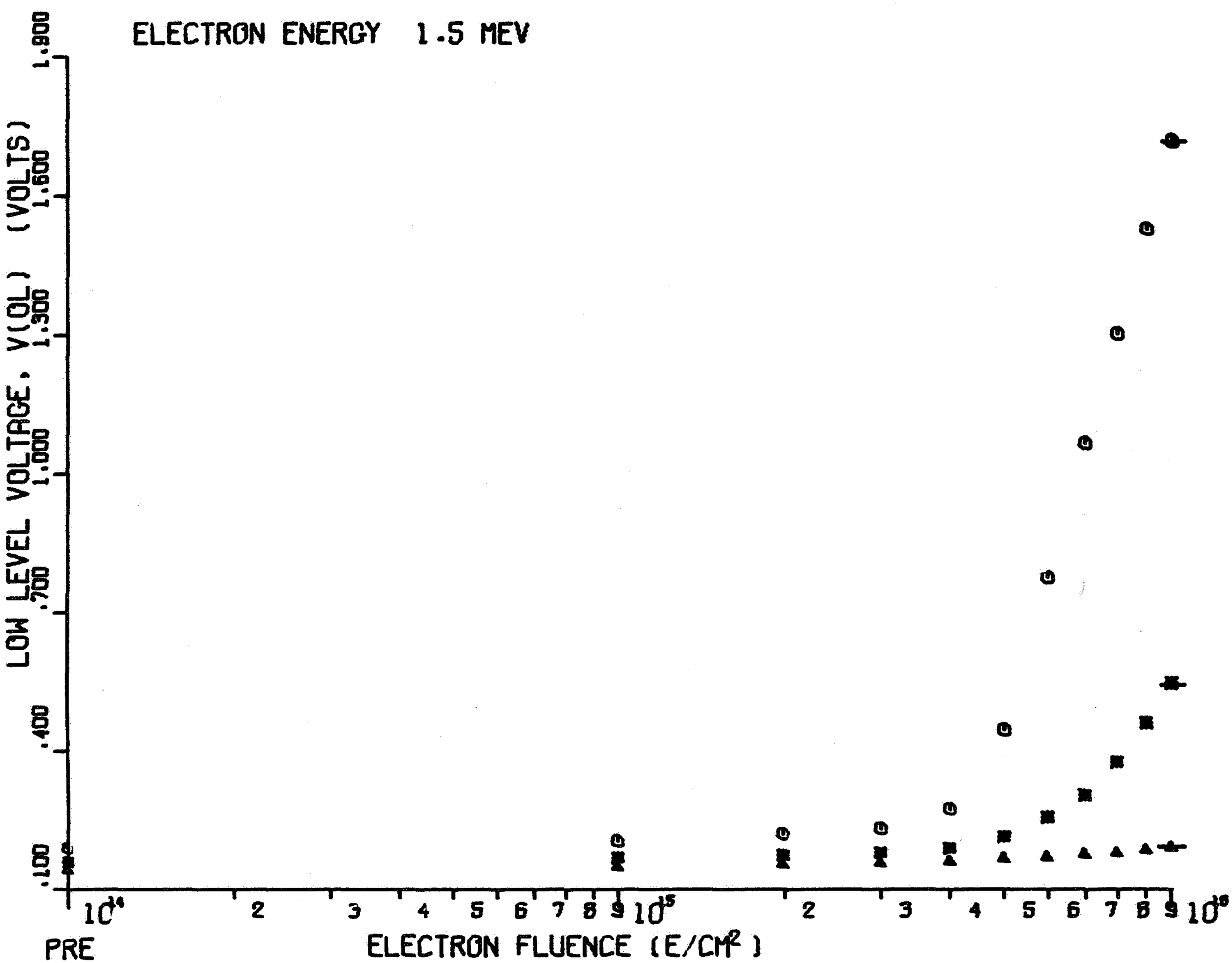



FIGURE 87. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L 9042 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L9042 GATES.

FIGURE 88




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L9042 GATES.

FIGURE 89

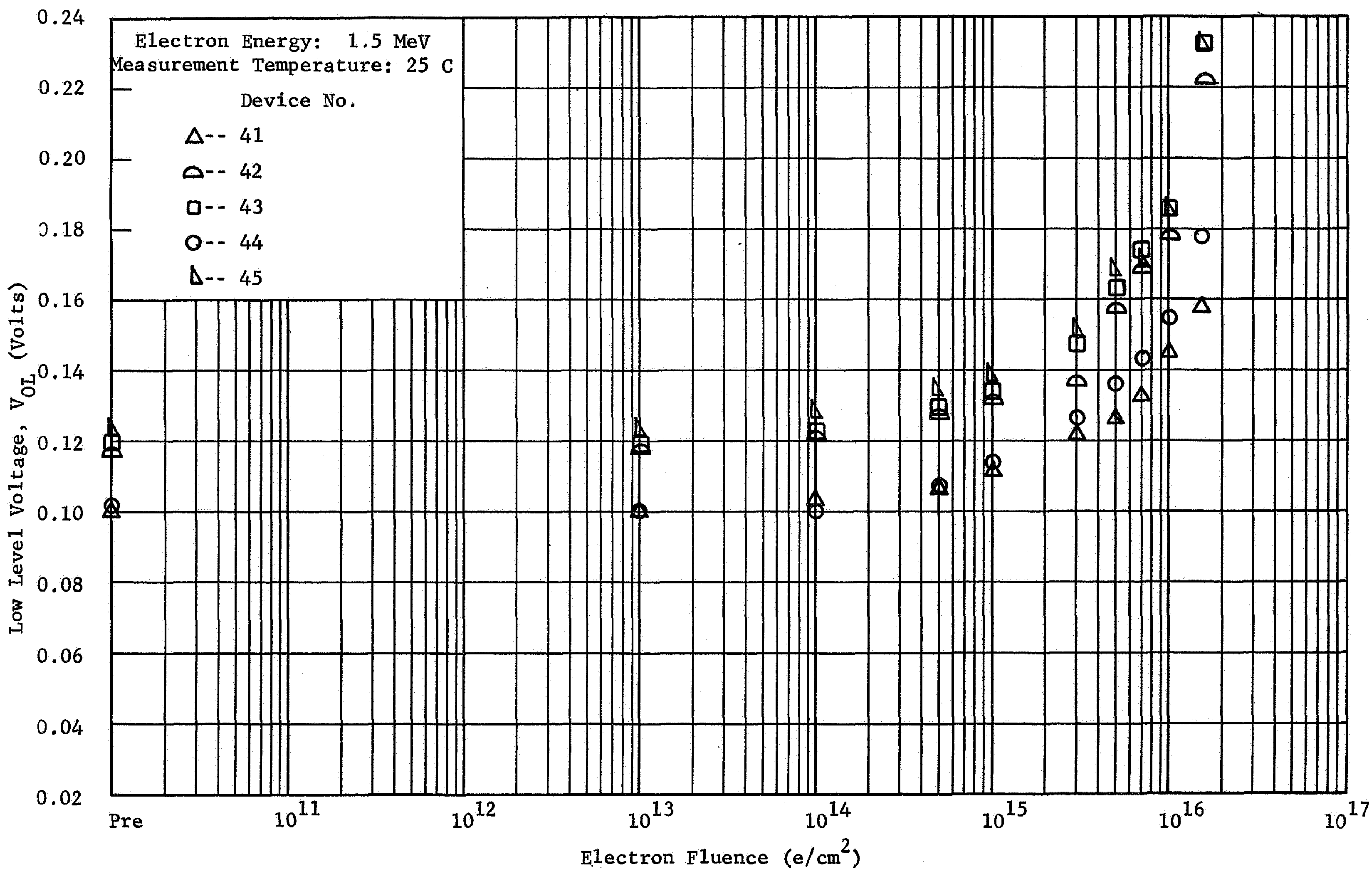



FIGURE 90. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L 9042 GATES.

FAIRCHILD LPDT L9042

| | V(OH) | V(OL) | V(IL) | V(IH) | V(DF) | I DRIVE | RESISTANCE |
|---|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.104E+00 | 0.136E+01 | 0.142E+01 | 0.644E+00 | 0.115E-03 | 0.371E+05 |
| AVERAGE CHANGE | 0. | 0.136E+00 | -0.300E-02 | 0.574E-01 | -0.124E-01 | -0.300E-05 | 0.207E+04 |
| STD OF MEAN | 0. | 0.588E-01 | 0.465E-01 | 0.580E-01 | 0.379E-02 | 0.707E-06 | 0.589E+03 |
| AVE PER CENT CHANGE | 0. | 0.128E+03 | -0.243E+00 | 0.403E+01 | -0.192E+01 | -0.263E+01 | 0.565E+01 |
| INTERVAL ESTIMATE | 0. | 0.605E+02 | -0.446E+01 | -0.103E+01 | -0.265E+01 | -0.337E+01 | 0.362E+01 |
| AS PER CENT | 0. | 0.201E+03 | 0.402E+01 | 0.910E+01 | -0.119E+01 | -0.185E+01 | 0.756E+01 |
| PER CENT AVE CHANGE | 0. | 0.131E+03 | -0.221E+00 | 0.403E+01 | -0.192E+01 | -0.261E+01 | 0.559E+01 |
| **CONTROL-G** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.116E+00 | 0.137E+01 | 0.145E+01 | 0.646E+00 | 0.112E-03 | 0.380E+05 |
| AVERAGE CHANGE | 0. | 0.980E-03 | -0.780E-02 | -0.130E-01 | -0.400E-04 | -0.400E-06 | 0.908E+03 |
| STD OF MEAN | 0. | 0.719E-03 | 0.904E-02 | 0.321E-01 | 0.680E-03 | 0.251E-05 | 0.379E+03 |
| AVE PER CENT CHANGE | 0. | 0.836E+00 | -0.567E+00 | -0.910E+00 | -0.674E-02 | -0.331E+00 | 0.241E+01 |
| INTERVAL ESTIMATE | 0. | 0.756E-01 | -0.139E+01 | -0.365E+01 | -0.137E+00 | -0.313E+01 | 0.115E+01 |
| AS PER CENT | 0. | 0.162E+01 | 0.249E+00 | 0.185E+01 | 0.125E+00 | 0.242E+01 | 0.363E+01 |
| PER CENT AVE CHANGE | 0. | 0.848E+00 | -0.568E+00 | -0.898E+00 | -0.619E-02 | -0.357E+00 | 0.239E+01 |
| **F-TESTS** | | | | | | | |
| GROUPS A-B-G | IIIII | 0.652E+00 | 0.408E+00 | 0.356E+01 | 0.354E-01 | 0.495E-01 | 0.213E-01 |
| GROUPS C-D-G | 0.103E+02 | 0.527E+01 | 0.120E+02 | 0.880E+00 | 0.128E+02 | 0.264E+01 | 0.233E+01 |
| GROUPS E-F-G | IIIII | 0.221E+01 | 0.914E+00 | 0.557E+01 | 0.448E+02 | 0.141E+02 | 0.107E+02 |
| GROUPS A-C-E-G | 0.820E+00 | 0.471E+01 | 0.216E+01 | 0.141E+02 | 0.203E+02 | 0.136E+01 | 0.116E+01 |
| GROUPS B-D-F-G | 0.160E+02 | 0.234E+02 | 0.522E+00 | 0.797E+01 | 0.293E+02 | 0.274E+01 | 0.756E+01 |
| GROUPS ALL | 0.118E+02 | 0.363E+01 | 0.953E+00 | 0.122E+02 | 0.171E+02 | 0.106E+01 | 0.966E+00 |
| **T-TESTS** | | | | | | | |
| GROUPS A-B | IIIII | 0.650E+00 | 0.377E+00 | 0.150E+01 | 0.231E+00 | 0.206E+00 | 0.952E-01 |
| GROUPS C-D | 0.353E+01 | 0.357E+00 | -0.833E+00 | -0.140E+01 | -0.172E-01 | 0.444E+00 | 0.384E+00 |
| GROUPS E-F | IIIII | 0.106E+01 | -0.112E+01 | -0.221E+01 | 0.624E+00 | -0.339E+01 | 0.123E+01 |
| GROUPS A-G | IIIII | 0.929E+00 | -0.525E+00 | -0.172E+01 | 0.112E+00 | 0.244E+00 | 0.177E+00 |
| GROUPS B-G | IIIII | 0.355E+01 | -0.193E+01 | -0.222E+01 | -0.375E+00 | 0.126E+00 | 0.500E+00 |
| GROUPS C-G | -0.694E+00 | 0.280E+01 | -0.423E+01 | -0.102E+01 | -0.490E+01 | -0.149E+01 | 0.189E+01 |
| GROUPS D-G | -0.400E+01 | 0.136E+02 | -0.290E+01 | 0.123E-01 | -0.517E+01 | -0.152E+01 | 0.199E+01 |
| GROUPS E-G | IIIII | 0.178E+01 | -0.376E+01 | 0.254E+01 | -0.118E+02 | -0.479E+01 | 0.451E+01 |
| GROUPS F-G | IIIII | 0.512E+01 | 0.227E+00 | 0.237E+01 | -0.716E+01 | -0.223E+01 | 0.372E+01 |
| GROUPS A-C | 0.100E+01 | -0.298E+01 | 0.133E+01 | -0.126E+01 | 0.258E+01 | 0.798E+00 | -0.127E+00 |
| GROUPS A-E | IIIII | -0.239E+01 | 0.973E+00 | -0.752E+01 | 0.578E+01 | 0.149E+01 | -0.117E+01 |
| GROUPS C-E | -0.100E+01 | -0.232E+01 | -0.173E+01 | -0.629E+01 | 0.680E+01 | 0.671E+01 | -0.437E+01 |
| GROUPS B-D | 0.400E+01 | -0.130E+02 | 0.199E+01 | -0.347E+01 | 0.369E+01 | 0.170E+01 | -0.103E+01 |
| GROUPS B-F | IIIII | -0.507E+01 | -0.633E+00 | -0.394E+01 | 0.632E+01 | 0.242E+01 | -0.308E+01 |
| GROUPS D-F | -0.400E+01 | -0.407E+01 | -0.808E+00 | -0.259E+01 | 0.386E+01 | 0.163E+01 | -0.301E+01 |

FAIRCHILD LPDT L9042

| | V(OH) | V(OL) | V(IL) | V(IH) | V(DF) | I DRIVE | RESISTANCE |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 9 | 9 | 9 | 10 | 9 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.116E+00 | 0.137E+01 | 0.144E+01 | 0.644E+00 | 0.110E-03 | 0.381E+05 |
| AVERAGE CHANGE | 0. | 0.571E-02 | -0.128E-01 | -0.349E-01 | 0.270E-03 | 0.889E-06 | 0.120E+04 |
| STD OF MEAN | 0. | 0.112E-01 | 0.198E-01 | 0.163E-01 | 0.605E-02 | 0.115E-04 | 0.358E+04 |
| AVE PER CENT CHANGE | 0. | 0.513E+01 | -0.920E+00 | -0.242E+01 | 0.449E-01 | 0.139E+01 | 0.355E+01 |
| INTERVAL ESTIMATE | 0. | -0.248E+01 | -0.204E+01 | -0.330E+01 | -0.630E+00 | -0.717E+01 | -0.358E+01 |
| AS PER CENT | 0. | 0.123E+02 | 0.178E+00 | -0.156E+01 | 0.714E+00 | 0.878E+01 | 0.966E+01 |
| PER CENT AVE CHANGE | 0. | 0.492E+01 | -0.930E+00 | -0.243E+01 | 0.419E-01 | 0.805E+00 | 0.314E+01 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.112E+00 | 0.138E+01 | 0.144E+01 | 0.644E+00 | 0.121E-03 | 0.350E+05 |
| AVERAGE CHANGE | 0. | 0.240E-02 | -0.162E-01 | -0.482E-01 | -0.380E-03 | -0.200E-06 | 0.104E+04 |
| STD OF MEAN | 0. | 0.534E-03 | 0.356E-02 | 0.150E-01 | 0.191E-02 | 0.249E-05 | 0.464E+03 |
| AVE PER CENT CHANGE | 0. | 0.216E+01 | -0.118E+01 | -0.333E+01 | -0.601E-01 | 0.848E-01 | 0.302E+01 |
| INTERVAL ESTIMATE | 0. | 0.155E+01 | -0.150E+01 | -0.463E+01 | -0.426E+00 | -0.273E+01 | 0.133E+01 |
| AS PER CENT | 0. | 0.274E+01 | -0.856E+00 | -0.205E+01 | 0.308E+00 | 0.240E+01 | 0.463E+01 |
| PER CENT AVE CHANGE | 0. | 0.215E+01 | -0.118E+01 | -0.334E+01 | -0.590E-01 | -0.166E+00 | 0.298E+01 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.896E-01 | 0.136E+01 | 0.143E+01 | 0.643E+00 | 0.115E-03 | 0.372E+05 |
| AVERAGE CHANGE | -0.100E-03 | 0.324E-01 | -0.212E-01 | -0.255E-01 | -0.498E-02 | -0.200E-05 | 0.134E+04 |
| STD OF MEAN | 0.316E-03 | 0.246E-01 | 0.346E-02 | 0.162E-01 | 0.217E-02 | 0.816E-06 | 0.438E+03 |
| AVE PER CENT CHANGE | -0.200E-02 | 0.171E+03 | -0.156E+01 | -0.178E+01 | -0.775E+00 | -0.174E+01 | 0.361E+01 |
| INTERVAL ESTIMATE | -0.653E-02 | 0.164E+02 | -0.175E+01 | -0.259E+01 | -0.102E+01 | -0.225E+01 | 0.277E+01 |
| AS PER CENT | 0.252E-02 | 0.557E+02 | -0.138E+01 | -0.971E+00 | -0.533E+00 | -0.123E+01 | 0.445E+01 |
| PER CENT AVE CHANGE | -0.200E-02 | 0.361E+02 | -0.156E+01 | -0.178E+01 | -0.775E+00 | -0.174E+01 | 0.361E+01 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.109E+00 | 0.136E+01 | 0.145E+01 | 0.646E+00 | 0.115E-03 | 0.377E+05 |
| AVERAGE CHANGE | -0.800E-03 | 0.283E-01 | -0.198E-01 | -0.128E-01 | -0.496E-02 | -0.220E-05 | 0.126E+04 |
| STD OF MEAN | 0.447E-03 | 0.442E-02 | 0.192E-02 | 0.172E-01 | 0.202E-02 | 0.837E-06 | 0.128E+03 |
| AVE PER CENT CHANGE | -0.160E-01 | 0.260E+02 | -0.145E+01 | -0.879E+00 | -0.769E+00 | -0.190E+01 | 0.337E+01 |
| INTERVAL ESTIMATE | -0.271E-01 | 0.209E+02 | -0.163E+01 | -0.235E+01 | -0.116E+01 | -0.282E+01 | 0.293E+01 |
| AS PER CENT | -0.490E-02 | 0.310E+02 | -0.128E+01 | 0.588E+00 | -0.380E+00 | -0.101E+01 | 0.377E+01 |
| PER CENT AVE CHANGE | -0.160E-01 | 0.260E+02 | -0.145E+01 | -0.881E+00 | -0.767E+00 | -0.191E+01 | 0.335E+01 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.115E+00 | 0.137E+01 | 0.145E+01 | 0.641E+00 | 0.116E-03 | 0.370E+05 |
| AVERAGE CHANGE | 0. | 0.338E+00 | -0.189E-01 | 0.162E-01 | -0.114E-01 | -0.450E-05 | 0.255E+04 |
| STD OF MEAN | 0. | 0.417E+00 | 0.238E-02 | 0.133E-01 | 0.208E-02 | 0.850E-06 | 0.760E+03 |
| AVE PER CENT CHANGE | 0. | 0.276E+03 | -0.138E+01 | 0.112E+01 | -0.178E+01 | -0.392E+01 | 0.685E+01 |
| INTERVAL ESTIMATE | 0. | 0.352E+02 | -0.150E+01 | 0.460E+00 | -0.201E+01 | -0.440E+01 | 0.544E+01 |
| AS PER CENT | 0. | 0.554E+03 | -0.125E+01 | 0.177E+01 | -0.155E+01 | -0.335E+01 | 0.838E+01 |
| PER CENT AVE CHANGE | 0. | 0.295E+03 | -0.138E+01 | 0.111E+01 | -0.176E+01 | -0.387E+01 | 0.691E+01 |

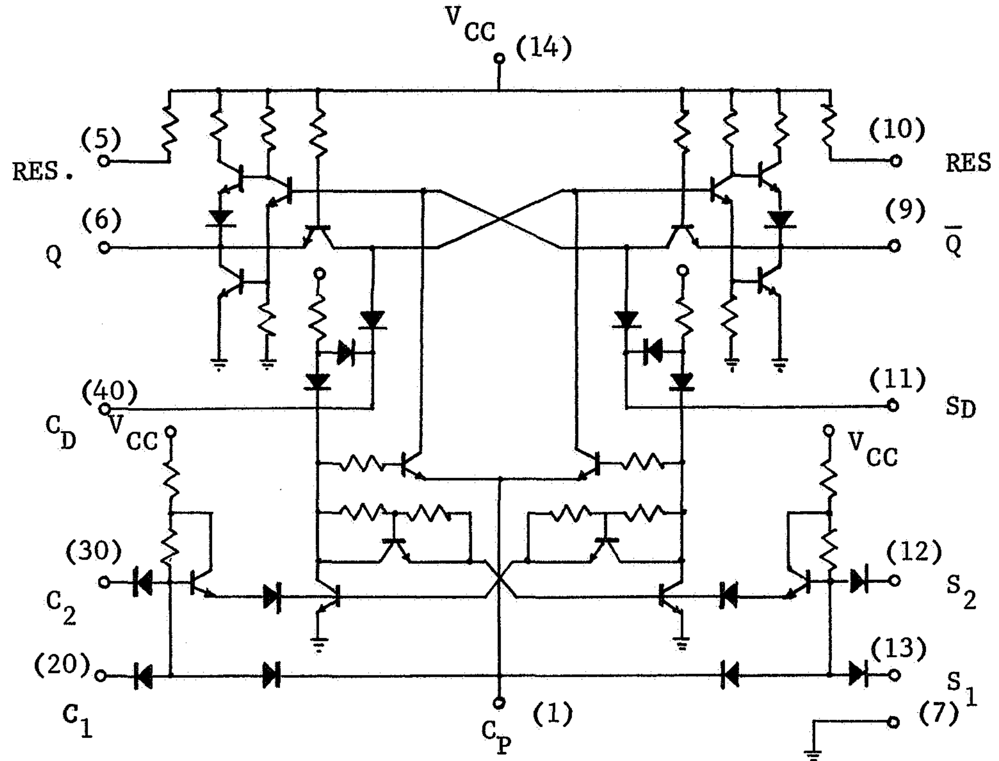
FAIRCHILD LPDT L9042

| | I LEAKAGE | T(DR) | T(DF) |
|---|---|---|---|
| **0.5 MEV BIASED-A** | | | |
| NUMBER | 10 | 7 | 7 |
| INITIAL MEAN | 0.469E-08 | 0.217E-07 | 0.455E-07 |
| AVERAGE CHANGE | -0.348E-08 | 0.214E-09 | 0.149E-07 |
| STD OF MEAN | 0.117E-07 | 0.344E-08 | 0.962E-08 |
| AVE PER CENT CHANGE | 0.165E+02 | -0.121E-01 | 0.333E+02 |
| INTERVAL ESTIMATE | -0.253E+03 | -0.137E+02 | 0.132E+02 |
| AS PER CENT | 0.104E+03 | 0.156E+02 | 0.523E+02 |
| PER CENT AVE CHANGE | -0.742E+02 | 0.987E+00 | 0.328E+02 |
| **0.5 MEV UNBIASED-B** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.722E-09 | 0.208E-07 | 0.486E-07 |
| AVERAGE CHANGE | 0.148E-09 | 0.160E-09 | 0.720E-08 |
| STD OF MEAN | 0.476E-10 | 0.393E-08 | 0.110E-08 |
| AVE PER CENT CHANGE | 0.205E+02 | -0.651E+00 | 0.149E+02 |
| INTERVAL ESTIMATE | 0.123E+02 | -0.226E+02 | 0.120E+02 |
| AS PER CENT | 0.287E+02 | 0.242E+02 | 0.176E+02 |
| PER CENT AVE CHANGE | 0.205E+02 | 0.768E+00 | 0.148E+02 |
| **1.0 MEV BIASED-C** | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.813E-09 | 0.212E-07 | 0.503E-07 |
| AVERAGE CHANGE | 0.228E-09 | 0.470E-08 | 0.300E-08 |
| STD OF MEAN | 0.545E-09 | 0.287E-08 | 0.163E-08 |
| AVE PER CENT CHANGE | 0.475E+02 | 0.213E+02 | 0.607E+01 |
| INTERVAL ESTIMATE | -0.199E+02 | 0.125E+02 | 0.364E+01 |
| AS PER CENT | 0.760E+02 | 0.319E+02 | 0.829E+01 |
| PER CENT AVE CHANGE | 0.280E+02 | 0.222E+02 | 0.596E+01 |
| **1.0 MEV UNBIASED-D** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.852E-09 | 0.255E-07 | 0.498E-07 |
| AVERAGE CHANGE | 0.284E-08 | 0.630E-08 | 0.200E-08 |
| STD OF MEAN | 0.491E-08 | 0.517E-08 | 0.235E-08 |
| AVE PER CENT CHANGE | 0.461E+03 | 0.238E+02 | 0.404E+01 |
| INTERVAL ESTIMATE | -0.382E+03 | -0.451E+00 | -0.183E+01 |
| AS PER CENT | 0.105E+04 | 0.499E+02 | 0.986E+01 |
| PER CENT AVE CHANGE | 0.334E+03 | 0.247E+02 | 0.402E+01 |
| **1.5 MEV BIASED-E** | | | |
| NUMBER | 9 | 10 | 10 |
| INITIAL MEAN | 0.848E-09 | 0.195E-07 | 0.469E-07 |
| AVERAGE CHANGE | 0.307E-09 | 0.416E-07 | -0.190E-08 |
| STD OF MEAN | 0.449E-09 | 0.124E-07 | 0.570E-08 |
| AVE PER CENT CHANGE | 0.297E+02 | 0.215E+03 | -0.349E+01 |
| INTERVAL ESTIMATE | -0.450E+01 | 0.168E+03 | -0.128E+02 |
| AS PER CENT | 0.768E+02 | 0.259E+03 | 0.465E+01 |
| PER CENT AVE CHANGE | 0.362E+02 | 0.214E+03 | -0.405E+01 |

## FAIRCHILD LPDT L9042

| | I LEAKAGE | T(DR) | T(DF) |
|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.806E-09 | 0.292E-07 | 0.516E-07 |
| AVERAGE CHANGE | 0.214E-09 | 0.314E-07 | -0.760E-08 |
| STD OF MEAN | 0.684E-10 | 0.184E-07 | 0.321E-08 |
| AVE PER CENT CHANGE | 0.287E+02 | 0.117E+03 | -0.145E+02 |
| INTERVAL ESTIMATE | 0.160E+02 | 0.291E+02 | -0.225E+02 |
| AS PER CENT | 0.371E+02 | 0.186E+03 | -0.701E+01 |
| PER CENT AVE CHANGE | 0.266E+02 | 0.108E+03 | -0.147E+02 |
| **CONTROL-G** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.778E-09 | 0.214E-07 | 0.472E-07 |
| AVERAGE CHANGE | 0.110E-09 | -0.160E-08 | 0.220E-08 |
| STD OF MEAN | 0.548E-10 | 0.631E-08 | 0.837E-09 |
| AVE PER CENT CHANGE | 0.149E+02 | -0.524E+01 | 0.457E+01 |
| INTERVAL ESTIMATE | 0.540E+01 | -0.441E+02 | 0.246E+01 |
| AS PER CENT | 0.229E+02 | 0.291E+02 | 0.686E+01 |
| PER CENT AVE CHANGE | 0.141E+02 | -0.748E+01 | 0.466E+01 |
| **F-TESTS** | | | |
| GROUPS A-B-G | 0.450E+00 | 0.272E+00 | 0.614E+01 |
| GROUPS C-D-G | 0.227E+01 | 0.459E+01 | 0.723E+00 |
| GROUPS E-F-G | 0.615E+00 | 0.184E+02 | 0.614E+01 |
| GROUPS A-C-E-G | 0.789E+00 | 0.609E+02 | 0.129E+02 |
| GROUPS B-D-F-G | 0.150E+01 | 0.110E+02 | 0.433E+02 |
| GROUPS ALL | 0.839E+00 | 0.286E+02 | 0.134E+02 |
| **T-TESTS** | | | |
| GROUPS A-B | -0.681E+00 | 0.255E-01 | 0.176E+01 |
| GROUPS C-D | -0.173E+01 | -0.783E+00 | 0.971E+00 |
| GROUPS E-F | 0.451E+00 | 0.128E+01 | 0.205E+01 |
| GROUPS A-G | -0.674E+00 | 0.646E+00 | 0.291E+01 |
| GROUPS B-G | 0.117E+01 | 0.529E+00 | 0.811E+01 |
| GROUPS C-G | 0.474E+00 | 0.272E+01 | 0.102E+01 |
| GROUPS D-G | 0.124E+01 | 0.217E+01 | -0.180E+00 |
| GROUPS E-G | 0.959E+00 | 0.723E+01 | -0.157E+01 |
| GROUPS F-G | 0.265E+01 | 0.378E+01 | -0.661E+01 |
| GROUPS A-C | -0.100E+01 | -0.293E+01 | 0.390E+01 |
| GROUPS A-E | -0.968E+00 | -0.852E+01 | 0.454E+01 |
| GROUPS C-E | -0.341E+00 | -0.916E+01 | 0.261E+01 |
| GROUPS B-D | -0.123E+01 | -0.211E+01 | 0.449E+01 |
| GROUPS B-F | -0.177E+01 | -0.370E+01 | 0.976E+01 |
| GROUPS D-F | 0.120E+01 | -0.293E+01 | 0.540E+01 |

Fairchild LPDTμL9040




TEST CONDITIONS:

1. Pin 14, 5.00 volts.

2. Pin 7, ground.

3. Pin 11, open.

4. Temperature 25 C.

TEST PARAMETERS:

1. Output-voltage levels ($Q$, $\bar{Q}$) both $V_H$ $V_L$.

2. Leakage current at $C_D$.

3. Input currents.

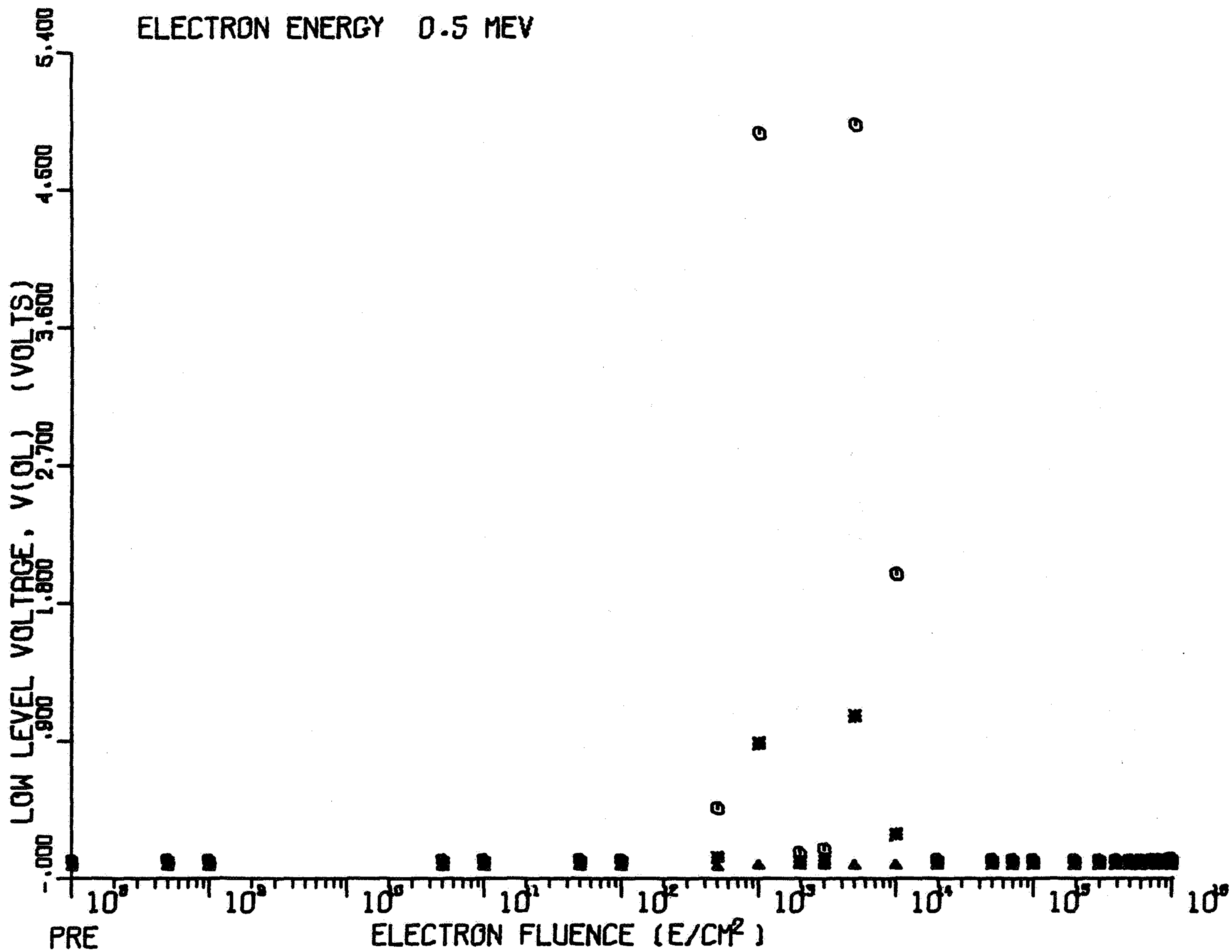
4. Resistance (15 KΩ).

5. Propagation delay.

6. Minimum clock amplitude.

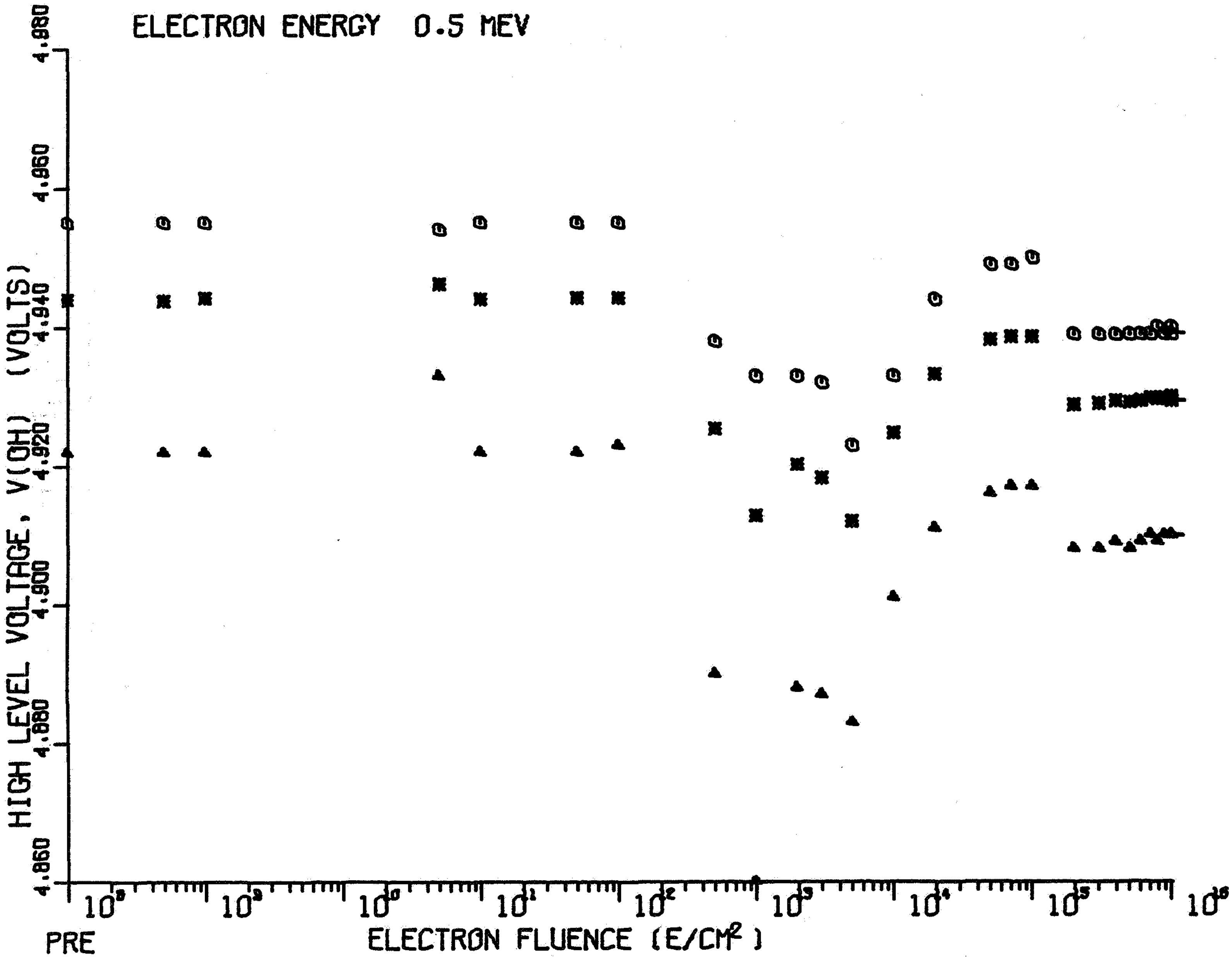
7. Minimum input one voltage.

FIGURE 91. TEST PLAN FOR LPDTμL9040




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDTμL9040 FLIP-FLOPS.

FIGURE 92




STATIC HIGH LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L9040 FLIP-FLOPS.

FIGURE 93

STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT L9040 FLIP-FLOPS.
LOW LEVEL VOLTAGE, V(OL) (VOLTS)
ELECTRON ENERGY 0.5 MEV

| FLUENCE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0. | .117920 | .096940 | .079230 | .094700 | .075670 | .116290 | .112540 | .108410 | .091080 | .085650 |
| 0.5E+09 | .117550 | .096470 | .078820 | .094390 | .075240 | .116070 | .112350 | .108060 | .090710 | .085310 |
| 0.1E+10 | .117480 | .096430 | .078750 | .094310 | .075180 | .116000 | .112280 | .108000 | .090640 | .085230 |
| 0.5E+11 | .117030 | .096110 | .078400 | .094010 | .074840 | .115660 | .111950 | .107570 | .090290 | .084890 |
| 0.1E+12 | .117170 | .096120 | .078360 | .093950 | .074790 | .115620 | .111870 | .107630 | .090240 | .084830 |
| 0.5E+12 | .116610 | .095560 | .077820 | .093490 | .074330 | .115140 | .110990 | .106710 | .089360 | .084010 |
| 0.1E+13 | .116190 | .095170 | .077460 | .092920 | .073780 | .115000 | .111370 | .106710 | .089620 | .083830 |
| 0.5E+13 | .118450 | .097380 | .081970 | .095240 | .076110 | .121660 | .456400 | .110520 | .098140 | .086230 |
| 0.1E+14 | .119050 | .097970 | .077330 | .095710 | .076600 | 3.069000 | 4.864000 | .112520 | .258070 | .089050 |
| 0.2E+14 | .124440 | .103510 | .077290 | .101220 | .082100 | .120180 | .162980 | .120220 | .095600 | .092180 |
| 0.3E+14 | .124780 | .103890 | .080810 | .101570 | .082460 | .192930 | .126200 | .122620 | .132030 | .093650 |
| 0.5E+14 | .124770 | .103890 | .084080 | .101700 | .082530 | 4.900000 | .133500 | .121070 | 4.917000 | .094050 |
| 0.1E+15 | .123110 | .102340 | .084290 | .099970 | .080790 | .114180 | .121340 | .115840 | 1.985000 | .094590 |
| 0.2E+15 | .121380 | .100710 | .082750 | .098350 | .079170 | .117220 | .116340 | .111900 | .091240 | .089400 |
| 0.5E+15 | .120690 | .100250 | .082160 | .097790 | .078530 | .119250 | .115970 | .111300 | .094000 | .088830 |
| 0.7E+15 | .120720 | .100490 | .082080 | .097690 | .078380 | .119070 | .115900 | .111200 | .093710 | .088750 |
| 0.1E+16 | .120650 | .100620 | .082180 | .097740 | .078410 | .119070 | .116060 | .111240 | .093720 | .088810 |
| 0.2E+16 | .120580 | .101030 | .082490 | .097860 | .078640 | .119140 | .116410 | .111470 | .093650 | .089060 |
| 0.3E+16 | .120450 | .101260 | .082700 | .097970 | .078750 | .119150 | .116640 | .111620 | .093910 | .089190 |
| 0.4E+16 | .120350 | .101370 | .082760 | .097940 | .078800 | .119030 | .116670 | .111640 | .093870 | .089230 |
| 0.5E+16 | .120750 | .101950 | .083280 | .098440 | .079310 | .119450 | .117250 | .112160 | .094300 | .089750 |
| 0.6E+16 | .121040 | .102200 | .083600 | .098660 | .079530 | .119630 | .117460 | .112410 | .094510 | .090030 |
| 0.7E+16 | .120870 | .102100 | .083510 | .098520 | .079400 | .119450 | .117330 | .112300 | .094370 | .089920 |
| 0.8E+16 | .120800 | .102090 | .083570 | .098550 | .079450 | .119450 | .117380 | .112340 | .094480 | .089940 |
| 0.9E+16 | .120760 | .102110 | .083550 | .098450 | .079420 | .119350 | .117190 | .112270 | .094420 | .089950 |
| 0.1E+17 | .120570 | .101970 | .083400 | .098300 | .079280 | .119150 | .117180 | .112150 | .094240 | .089820 |
| 0.1E+17 | .122190 | .103590 | .084980 | .099990 | .080980 | .120840 | .119860 | .115040 | .097150 | .092700 |

STATIC HIGH LEVEL OUTPUT RADIATION RESPONSE FOR LPDT L9040 FLIP-FLOPS.
HIGH LEVEL VOLTAGE, V(OH) (VOLTS)
ELECTRON ENERGY 0.5 MEV

| FLUENCE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0. | 4.955000 | 4.948000 | 4.922000 | 4.943000 | 4.934000 | 4.953000 | 4.952000 | 4.950000 | 4.944000 | 4.940000 |
| 0.5E+09 | 4.955000 | 4.948000 | 4.922000 | 4.943000 | 4.933000 | 4.953000 | 4.952000 | 4.950000 | 4.943000 | 4.940000 |
| 0.1E+10 | 4.955000 | 4.948000 | 4.922000 | 4.944000 | 4.934000 | 4.953000 | 4.952000 | 4.950000 | 4.944000 | 4.940000 |
| 0.5E+11 | 4.954000 | 0.000000 | 0.000000 | 4.944000 | 4.933000 | 4.953000 | 4.953000 | 4.950000 | 4.943000 | 4.939000 |
| 0.1E+12 | 4.955000 | 4.948000 | 4.922000 | 4.944000 | 4.933000 | 4.953000 | 4.952000 | 4.950000 | 4.944000 | 4.940000 |
| 0.5E+12 | 4.955000 | 4.948000 | 4.922000 | 4.944000 | 4.934000 | 4.953000 | 4.952000 | 4.951000 | 4.944000 | 4.940000 |
| 0.1E+13 | 4.955000 | 4.948000 | 4.923000 | 4.943000 | 4.934000 | 4.953000 | 4.953000 | 4.950000 | 4.943000 | 4.940000 |
| 0.5E+13 | 4.938000 | 4.931000 | 4.890000 | 4.927000 | 4.917000 | 4.935000 | 4.937000 | 4.929000 | 4.926000 | 4.925000 |
| 0.1E+14 | 4.933000 | 4.926000 | 4.884000 | 4.922000 | 4.911000 | 4.860000 | 4.912000 | 4.925000 | 4.930000 | 4.925000 |
| 0.2E+14 | 0.000000 | 4.926000 | 4.888000 | 4.921000 | 4.911000 | 4.932000 | 4.933000 | 4.927000 | 4.926000 | 4.918000 |
| 0.3E+14 | 4.927000 | 4.921000 | 4.887000 | 4.916000 | 4.906000 | 4.932000 | 4.929000 | 4.924000 | 4.924000 | 4.917000 |
| 0.5E+14 | 4.919000 | 4.913000 | 4.883000 | 4.908000 | 4.898000 | 4.923000 | 4.923000 | 4.918000 | 4.921000 | 4.914000 |
| 0.1E+15 | 4.933000 | 4.926000 | 4.901000 | 4.923000 | 4.912000 | 4.933000 | 4.933000 | 4.927000 | 4.933000 | 4.928000 |
| 0.2E+15 | 4.944000 | 4.936000 | 4.911000 | 4.933000 | 4.923000 | 4.941000 | 4.942000 | 4.939000 | 4.935000 | 4.929000 |
| 0.5E+15 | 4.949000 | 4.942000 | 4.916000 | 4.937000 | 4.928000 | 4.947000 | 4.947000 | 4.944000 | 4.938000 | 4.934000 |
| 0.7E+15 | 4.949000 | 4.942000 | 4.917000 | 4.938000 | 4.928000 | 4.948000 | 4.947000 | 4.945000 | 4.936000 | 4.934000 |
| 0.1E+16 | 4.950000 | 4.943000 | 4.917000 | 4.938000 | 4.928000 | 4.947000 | 4.947000 | 4.945000 | 4.936000 | 4.934000 |
| 0.2E+16 | 4.939000 | 4.933000 | 4.908000 | 4.928000 | 4.919000 | 4.937000 | 4.937000 | 4.935000 | 4.928000 | 4.925000 |
| 0.3E+16 | 4.939000 | 4.933000 | 4.908000 | 4.929000 | 4.919000 | 4.937000 | 4.938000 | 4.934000 | 4.929000 | 4.926000 |
| 0.4E+16 | 4.939000 | 4.933000 | 4.909000 | 4.929000 | 4.920000 | 4.938000 | 4.937000 | 4.935000 | 4.929000 | 4.925000 |
| 0.5E+16 | 4.939000 | 4.933000 | 4.908000 | 4.929000 | 4.920000 | 4.938000 | 4.937000 | 4.935000 | 4.928000 | 4.925000 |
| 0.6E+16 | 4.939000 | 4.933000 | 4.909000 | 4.929000 | 4.920000 | 4.938000 | 4.937000 | 4.935000 | 4.929000 | 4.926000 |
| 0.7E+16 | 4.939000 | 4.934000 | 4.910000 | 4.929000 | 4.920000 | 4.938000 | 4.938000 | 4.936000 | 4.929000 | 4.926000 |
| 0.8E+16 | 4.940000 | 4.933000 | 4.909000 | 4.929000 | 4.920000 | 4.938000 | 4.938000 | 4.935000 | 4.929000 | 4.926000 |
| 0.9E+16 | 4.939000 | 4.934000 | 4.910000 | 4.929000 | 4.920000 | 4.938000 | 4.938000 | 4.936000 | 4.929000 | 4.926000 |
| 0.1E+17 | 4.940000 | 4.934000 | 4.910000 | 4.929000 | 4.921000 | 4.938000 | 4.938000 | 4.936000 | 4.929000 | 4.926000 |
| 0.1E+17 | 4.939000 | 4.933000 | 4.910000 | 4.929000 | 4.921000 | 4.938000 | 4.937000 | 4.935000 | 4.928000 | 4.925000 |

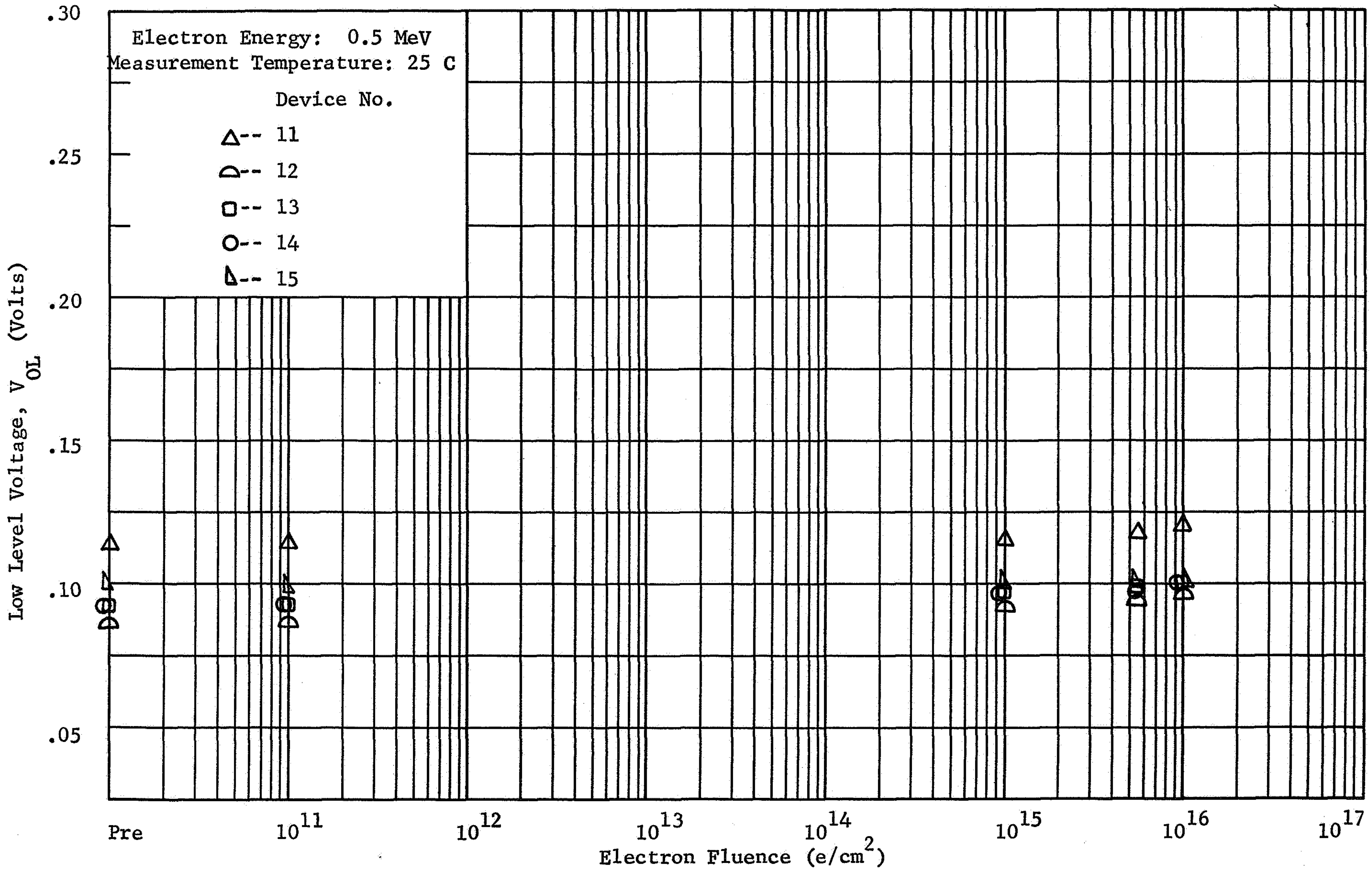
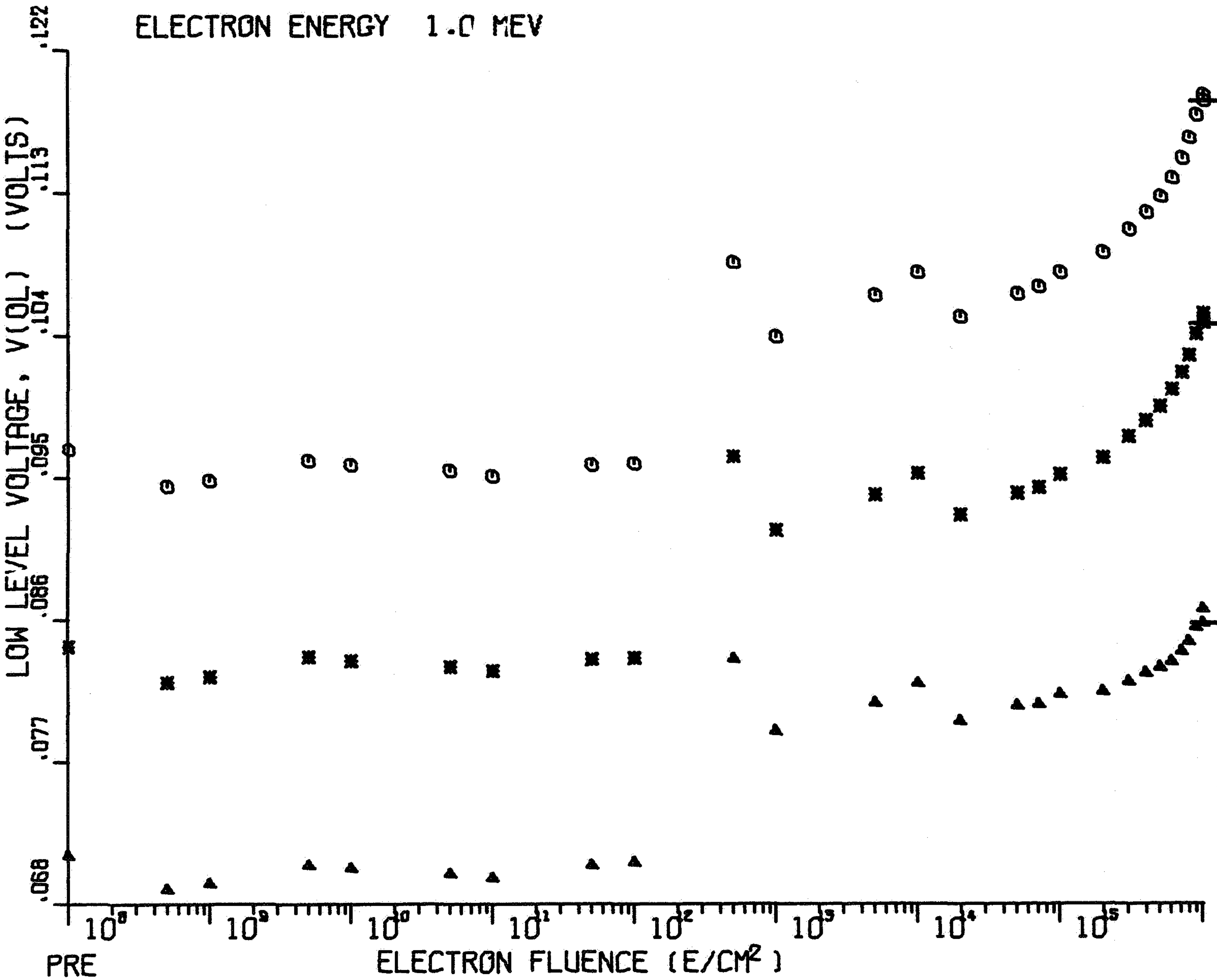



FIGURE 94. **PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L 9040 FLIP-FLOPS.**




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDTμL9040 FLIP-FLOPS.

FIGURE 95

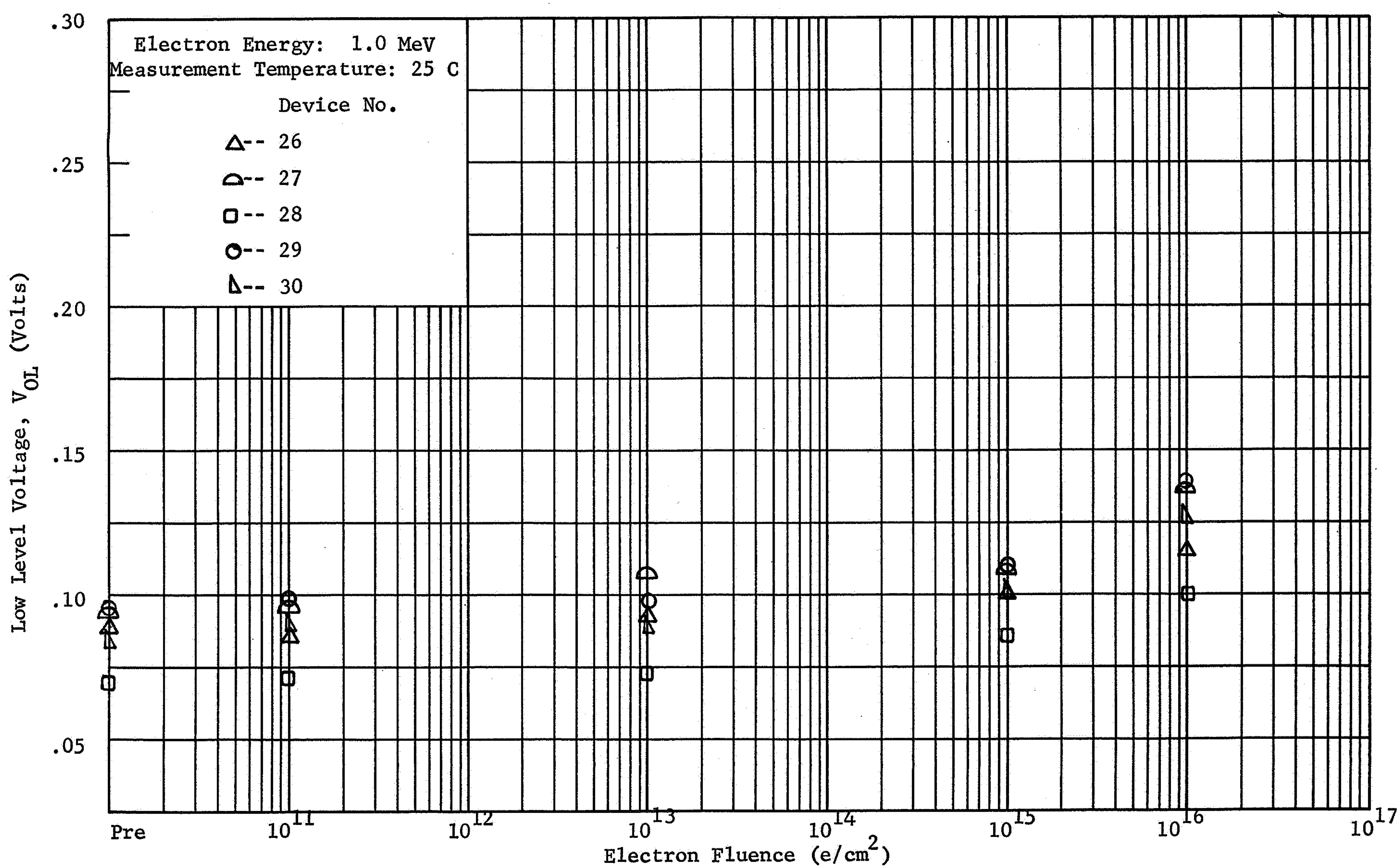
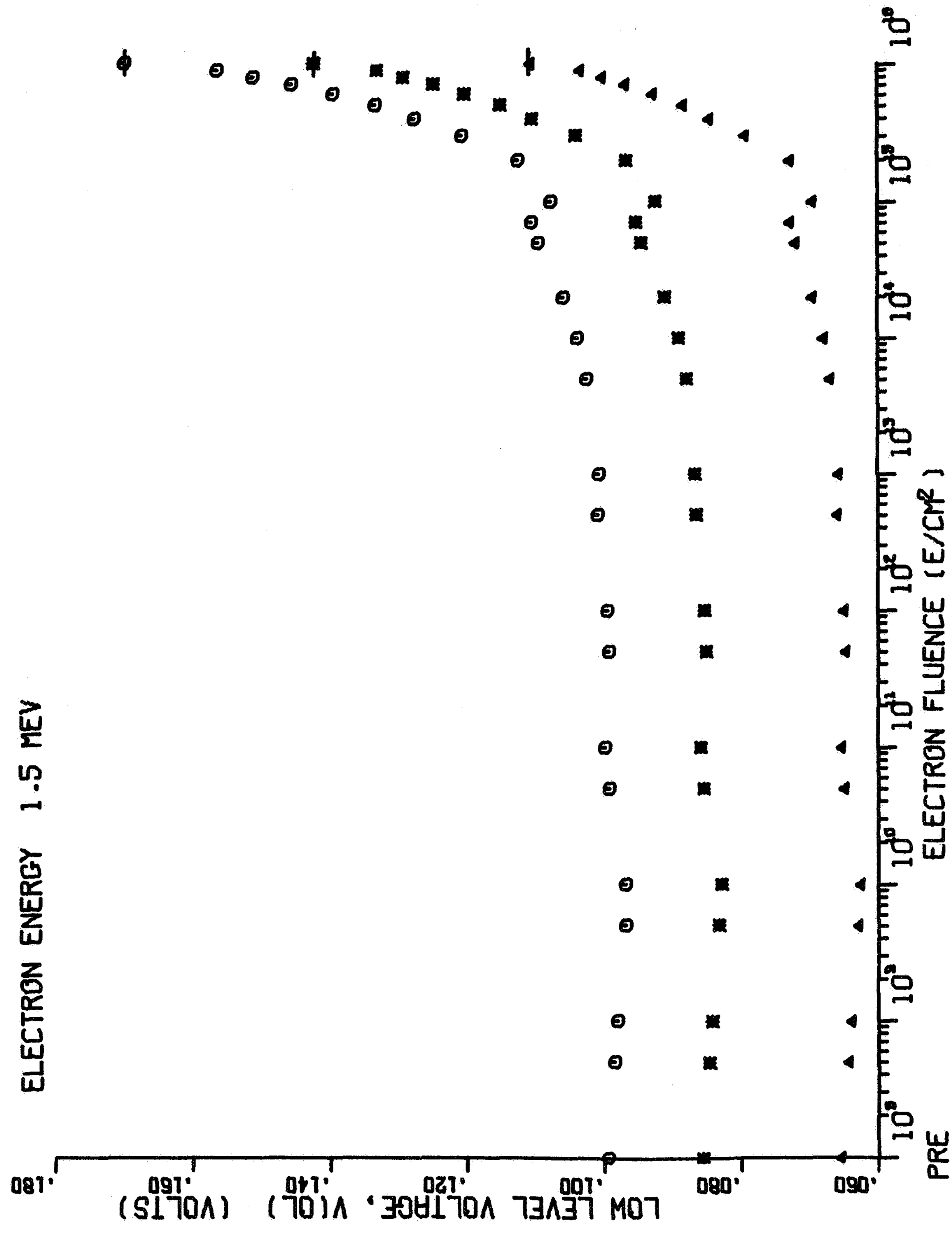



FIGURE 96. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L 9040 FLIP-FLOPS.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L9040 FLIP-FLOPS.

FIGURE 97

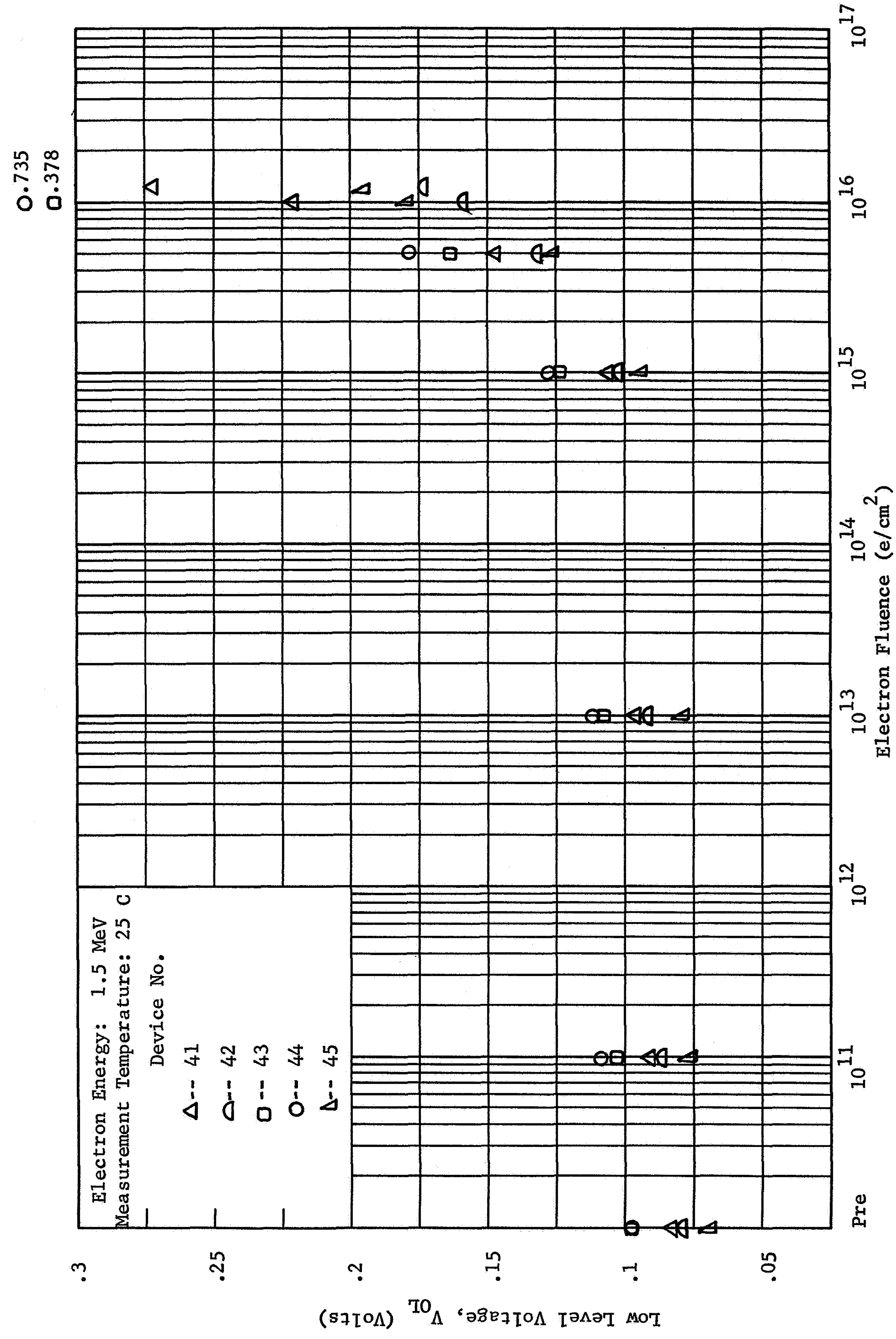



FIGURE 98. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR LPDT$\mu$L 9040 FLIP-FLOPS.

FAIRCHILD LPOT L9040

| | V(QL) | V(QH) | V(BAR Q H) | V(BAR Q L) | I(IN CD) | I(IN SD) | I(IN CP) |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.950E-01 | 0.498E+01 | 0.498E+01 | 0.957E-01 | 0.135E-03 | 0.136E-03 | 0.206E-03 |
| AVERAGE CHANGE | 0.293E-02 | 0.390E-02 | 0.182E-01 | 0.299E-02 | -0.300E-06 | -0.290E-05 | -0.330E-05 |
| STD OF MEAN | 0.846E-03 | 0.120E-02 | 0.107E-01 | 0.749E-03 | 0.823E-06 | 0.264E-05 | 0.347E-05 |
| AVE PER CENT CHANGE | 0.322E+01 | 0.783E-01 | 0.366E+00 | 0.321E+01 | -0.207E+00 | -0.218E+01 | -0.161E+01 |
| INTERVAL ESTIMATE | 0.245E+01 | 0.611E-01 | 0.212E+00 | 0.256E+01 | -0.657E+00 | -0.353E+01 | -0.281E+01 |
| AS PER CENT | 0.372E+01 | 0.955E-01 | 0.518E+00 | 0.368E+01 | 0.214E+00 | -0.744E+00 | -0.399E+00 |
| PER CENT AVE CHANGE | 0.308E+01 | 0.783E-01 | 0.365E+00 | 0.312E+01 | -0.222E+00 | -0.214E+01 | -0.160E+01 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.946E-01 | 0.498E+01 | 0.499E+01 | 0.944E-01 | 0.139E-03 | 0.139E-03 | 0.212E-03 |
| AVERAGE CHANGE | 0.314E-02 | 0.380E-02 | 0.162E-01 | 0.188E-02 | 0. | 0.122E-04 | -0.460E-05 |
| STD OF MEAN | 0.140E-02 | 0.130E-02 | 0.415E-02 | 0.274E-02 | 0.707E-06 | 0.307E-04 | 0.313E-05 |
| AVE PER CENT CHANGE | 0.330E+01 | 0.762E-01 | 0.325E+00 | 0.219E+01 | -0.500E-02 | 0.749E+01 | -0.210E+01 |
| INTERVAL ESTIMATE | 0.148E+01 | 0.438E-01 | 0.222E+00 | -0.162E+01 | -0.630E+00 | -0.186E+02 | -0.400E+01 |
| AS PER CENT | 0.516E+01 | 0.109E+00 | 0.428E+00 | 0.560E+01 | 0.630E+00 | 0.361E+02 | -0.336E+00 |
| PER CENT AVE CHANGE | 0.332E+01 | 0.762E-01 | 0.325E+00 | 0.199E+01 | 0. | 0.876E+01 | -0.217E+01 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.932E-01 | 0.498E+01 | 0.498E+01 | 0.932E-01 | 0.133E-03 | 0.131E-03 | 0.201E-03 |
| AVERAGE CHANGE | 0.244E-01 | 0.680E-02 | 0.172E-01 | 0.212E-01 | 0.290E-05 | 0.170E-05 | 0.270E-05 |
| STD OF MEAN | 0.271E-02 | 0.155E-02 | 0.623E-02 | 0.235E-02 | 0.160E-05 | 0.643E-05 | 0.125E-05 |
| AVE PER CENT CHANGE | 0.263E+02 | 0.136E+00 | 0.345E+00 | 0.227E+02 | 0.212E+01 | 0.146E+01 | 0.136E+01 |
| INTERVAL ESTIMATE | 0.241E+02 | 0.114E+00 | 0.256E+00 | 0.209E+02 | 0.132E+01 | -0.221E+01 | 0.899E+00 |
| AS PER CENT | 0.283E+02 | 0.159E+00 | 0.435E+00 | 0.245E+02 | 0.303E+01 | 0.481E+01 | 0.179E+01 |
| PER CENT AVE CHANGE | 0.262E+02 | 0.136E+00 | 0.345E+00 | 0.227E+02 | 0.218E+01 | 0.130E+01 | 0.135E+01 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.827E-01 | 0.498E+01 | 0.498E+01 | 0.819E-01 | 0.132E-03 | 0.131E-03 | 0.203E-03 |
| AVERAGE CHANGE | 0.269E-01 | 0.900E-02 | 0.252E-01 | 0.277E-01 | 0.300E-05 | 0.100E-05 | 0.480E-05 |
| STD OF MEAN | 0.615E-02 | 0.245E-02 | 0.947E-02 | 0.596E-02 | 0.187E-05 | 0.255E-05 | 0.466E-05 |
| AVE PER CENT CHANGE | 0.325E+02 | 0.181E+00 | 0.507E+00 | 0.338E+02 | 0.231E+01 | 0.828E+00 | 0.233E+01 |
| INTERVAL ESTIMATE | 0.233E+02 | 0.120E+00 | 0.270E+00 | 0.248E+02 | 0.513E+00 | -0.165E+01 | -0.484E+00 |
| AS PER CENT | 0.418E+02 | 0.242E+00 | 0.743E+00 | 0.429E+02 | 0.403E+01 | 0.317E+01 | 0.521E+01 |
| PER CENT AVE CHANGE | 0.325E+02 | 0.181E+00 | 0.506E+00 | 0.339E+02 | 0.227E+01 | 0.761E+00 | 0.236E+01 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.897E-01 | 0.498E+01 | 0.498E+01 | 0.909E-01 | 0.137E-03 | 0.131E-03 | 0.205E-03 |
| AVERAGE CHANGE | 0.109E+00 | 0.114E-01 | 0.182E-01 | 0.619E-01 | 0.810E-05 | 0.960E-05 | 0.135E-04 |
| STD OF MEAN | 0.103E+00 | 0.462E-02 | 0.873E-02 | 0.845E-02 | 0.373E-05 | 0.138E-04 | 0.242E-05 |
| AVE PER CENT CHANGE | 0.117E+03 | 0.229E+00 | 0.365E+00 | 0.685E+02 | 0.602E+01 | 0.864E+01 | 0.664E+01 |
| INTERVAL ESTIMATE | 0.397E+02 | 0.162E+00 | 0.240E+00 | 0.615E+02 | 0.398E+01 | -0.209E+00 | 0.573E+01 |
| AS PER CENT | 0.204E+03 | 0.295E+00 | 0.491E+00 | 0.748E+02 | 0.788E+01 | 0.149E+02 | 0.742E+01 |
| PER CENT AVE CHANGE | 0.122E+03 | 0.229E+00 | 0.365E+00 | 0.682E+02 | 0.593E+01 | 0.735E+01 | 0.658E+01 |

FAIRCHILD LPDT L9040

| | V(QL) | V(QH) | V(BAR Q H) | V(BAR Q L) | I(IN CD) | I(IN SD) | I(IN CP) |
|---|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.867E-01 | 0.498E+01 | 0.498E+01 | 0.867E-01 | 0.124E-03 | 0.125E-03 | 0.192E-03 |
| AVERAGE CHANGE | 0.152E+00 | 0.150E-01 | 0.242E-01 | 0.182E+00 | 0.116E-04 | 0.640E-05 | 0.174E-04 |
| STD OF MEAN | 0.112E+00 | 0.587E-02 | 0.108E-01 | 0.175E+00 | 0.391E-05 | 0.230E-05 | 0.241E-05 |
| AVE PER CENT CHANGE | 0.168E+03 | 0.302E+00 | 0.487E+00 | 0.199E+03 | 0.995E+01 | 0.535E+01 | 0.926E+01 |
| INTERVAL ESTIMATE | 0.152E+02 | 0.155E+00 | 0.218E+00 | -0.401E+02 | 0.544E+01 | 0.283E+01 | 0.751E+01 |
| AS PER CENT | 0.337E+03 | 0.448E+00 | 0.754E+00 | 0.460E+03 | 0.133E+02 | 0.739E+01 | 0.106E+02 |
| PER CENT AVE CHANGE | 0.176E+03 | 0.301E+00 | 0.486E+00 | 0.210E+03 | 0.935E+01 | 0.511E+01 | 0.907E+01 |
| **CONTROL-G** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.841E-01 | 0.497E+01 | 0.497E+01 | 0.856E-01 | 0.126E-03 | 0.128E-03 | 0.197E-03 |
| AVERAGE CHANGE | 0.360E-03 | 0.320E-02 | 0.286E-01 | 0.420E-03 | -0.400E-06 | -0.420E-05 | -0.420E-05 |
| STD OF MEAN | 0.321E-03 | 0.837E-03 | 0.150E-01 | 0.148E-03 | 0.548E-06 | 0.581E-05 | 0.497E-05 |
| AVE PER CENT CHANGE | 0.380E+00 | 0.643E-01 | 0.576E+00 | 0.478E+00 | -0.366E+00 | -0.377E+01 | -0.194E+01 |
| INTERVAL ESTIMATE | -0.457E-01 | 0.434E-01 | 0.201E+00 | 0.276E+00 | -0.854E+00 | -0.888E+01 | -0.527E+01 |
| AS PER CENT | 0.902E+00 | 0.852E-01 | 0.949E+00 | 0.706E+00 | 0.222E+00 | 0.234E+01 | 0.100E+01 |
| PER CENT AVE CHANGE | 0.428E+00 | 0.643E-01 | 0.575E+00 | 0.491E+00 | -0.316E+00 | -0.327E+01 | -0.214E+01 |
| **F-TESTS** | | | | | | | |
| GROUPS A-B-G | 0.152E+02 | 0.642E+00 | 0.202E+01 | 0.537E+01 | 0.411E+00 | 0.195E+01 | 0.223E+00 |
| GROUPS C-D-G | 0.914E+02 | 0.152E+02 | 0.264E+01 | 0.936E+02 | 0.930E+01 | 0.195E+01 | 0.985E+01 |
| GROUPS F-F-G | 0.368E+01 | 0.955E+01 | 0.160E+01 | 0.601E+01 | 0.178E+02 | 0.292E+01 | 0.684E+02 |
| GROUPS A-C-E-G | 0.777E+01 | 0.162E+02 | 0.175E+01 | 0.321E+03 | 0.284E+02 | 0.457E+01 | 0.665E+02 |
| GROUPS B-D-F-G | 0.825E+01 | 0.141E+02 | 0.123E+01 | 0.495E+01 | 0.317E+02 | 0.101E+01 | 0.344E+02 |
| GROUPS ALL | 0.692E+01 | 0.133E+02 | 0.150E+01 | 0.809E+01 | 0.255E+02 | 0.183E+01 | 0.519E+02 |
| **T-TESTS** | | | | | | | |
| GROUPS A-B | -0.366E+00 | 0.148E+00 | 0.398E+00 | 0.123E+01 | -0.694E+00 | -0.161E+01 | 0.705E+00 |
| GROUPS C-D | -0.111E+01 | -0.214E+01 | -0.198E+01 | -0.311E+01 | -0.108E+00 | 0.231E+00 | -0.138E+01 |
| GROUPS E-F | -0.740E+00 | -0.130E+01 | -0.117E+01 | -0.226E+01 | -0.169E+01 | 0.506E+00 | -0.295E+01 |
| GROUPS A-G | 0.646E+01 | 0.116E+01 | -0.156E+01 | 0.746E+01 | 0.244E+00 | 0.609E+00 | 0.412E+00 |
| GROUPS B-G | 0.432E+01 | 0.866E+00 | -0.178E+01 | 0.119E+01 | 0.100E+01 | 0.117E+01 | -0.152E+00 |
| GROUPS C-G | 0.194E+02 | 0.480E+01 | -0.212E+01 | 0.194E+02 | 0.443E+01 | 0.173E+01 | 0.427E+01 |
| GROUPS D-G | 0.964E+01 | 0.501E+01 | -0.429E+00 | 0.102E+02 | 0.390E+01 | 0.183E+01 | 0.295E+01 |
| GROUPS F-G | 0.232E+01 | 0.386E+01 | -0.172E+01 | 0.160E+02 | 0.498E+01 | 0.211E+01 | 0.947E+01 |
| GROUPS F-G | 0.303E+01 | 0.445E+01 | -0.533E+00 | 0.233E+01 | 0.679E+01 | 0.380E+01 | 0.875E+01 |
| GROUPS A-C | -0.239E+02 | -0.468E+01 | 0.256E+00 | -0.233E+02 | -0.564E+01 | -0.209E+01 | -0.515E+01 |
| GROUPS A-E | -0.326E+01 | -0.497E+01 | 0.662E-12 | -0.220E+02 | -0.696E+01 | -0.281E+01 | -0.126E+02 |
| GROUPS C-E | -0.260E+01 | -0.298E+01 | -0.295E+00 | -0.147E+02 | -0.406E+01 | -0.164E+01 | -0.126E+02 |
| GROUPS B-D | -0.843E+01 | -0.419E+01 | -0.195E+01 | -0.880E+01 | -0.335E+01 | 0.813E+00 | -0.375E+01 |
| GROUPS B-F | -0.298E+01 | -0.416E+01 | -0.155E+01 | -0.231E+01 | -0.653E+01 | 0.421E+00 | -0.125E+02 |
| GROUPS D-F | -0.250E+01 | -0.211E+01 | 0.156E+00 | -0.198E+01 | -0.444E+01 | -0.352E+01 | -0.537E+01 |

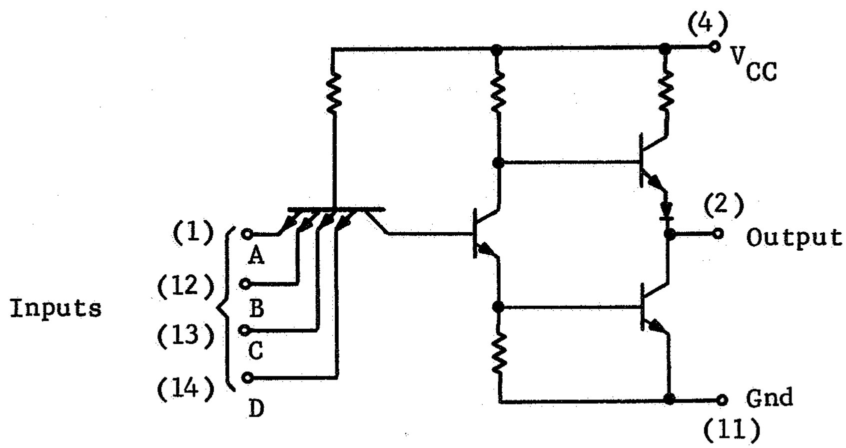
FAIRCHILD LPDT L9040

| | RESISTANCE | MIN CP AMP | MIN V(CI) | T(DR) | T(DF) | I(L CD) |
|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.140E+05 | 0.133E+01 | 0.123E+01 | 0.835E-07 | 0.162E-06 | 0.939E-09 |
| AVERAGE CHANGE | 0.196E+03 | 0.370E-01 | 0.124E+00 | 0.290E-08 | 0.700E-08 | 0.186E-09 |
| STD OF MEAN | 0.169E+03 | 0.245E-01 | 0.188E-01 | 0.269E-08 | 0.167E-07 | 0.249E-09 |
| AVE PER CENT CHANGE | 0.144E+01 | 0.280E+01 | 0.101E+02 | 0.353E+01 | 0.485E+01 | 0.224E+02 |
| INTERVAL ESTIMATE | 0.536E+00 | 0.146E+01 | 0.901E+01 | 0.117E+01 | -0.304E+01 | 0.819E+00 |
| AS PER CENT | 0.227E+01 | 0.409E+01 | 0.112E+02 | 0.577E+01 | 0.117E+02 | 0.388E+02 |
| PER CENT AVE CHANGE | 0.140E+01 | 0.277E+01 | 0.101E+02 | 0.347E+01 | 0.433E+01 | 0.198E+02 |
| **0.5 MEV UNBIASED-B** | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.137E+05 | 0.133E+01 | 0.124E+01 | 0.796E-07 | 0.160E-06 | 0.840E-09 |
| AVERAGE CHANGE | 0.124E+03 | 0.460E-01 | 0.128E+00 | 0.200E-08 | 0.660E-08 | 0.208E-09 |
| STD OF MEAN | 0.211E+03 | 0.451E-01 | 0.493E-02 | 0.141E-08 | 0.313E-08 | 0.105E-09 |
| AVE PER CENT CHANGE | 0.949E+00 | 0.351E+01 | 0.103E+02 | 0.247E+01 | 0.409E+01 | 0.246E+02 |
| INTERVAL ESTIMATE | -0.101E+01 | -0.748E+00 | 0.985E+01 | 0.307E+00 | 0.169E+01 | 0.896E+01 |
| AS PER CENT | 0.283E+01 | 0.768E+01 | 0.108E+02 | 0.472E+01 | 0.655E+01 | 0.394E+02 |
| PER CENT AVE CHANGE | 0.908E+00 | 0.346E+01 | 0.103E+02 | 0.251E+01 | 0.412E+01 | 0.242E+02 |
| **1.0 MEV BIASED-C** | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.144E+05 | 0.130E+01 | 0.122E+01 | 0.808E-07 | 0.151E-06 | 0.839E-09 |
| AVERAGE CHANGE | 0.250E+03 | 0.480E-01 | 0.135E+00 | 0.160E-08 | 0.106E-07 | 0.297E-09 |
| STD OF MEAN | 0.878E+02 | 0.274E-01 | 0.547E-02 | 0.158E-08 | 0.217E-08 | 0.138E-09 |
| AVE PER CENT CHANGE | 0.174E+01 | 0.374E+01 | 0.111E+02 | 0.208E+01 | 0.705E+01 | 0.369E+02 |
| INTERVAL ESTIMATE | 0.130E+01 | 0.218E+01 | 0.107E+02 | 0.584E+00 | 0.598E+01 | 0.236E+02 |
| AS PER CENT | 0.218E+01 | 0.519E+01 | 0.114E+02 | 0.338E+01 | 0.804E+01 | 0.472E+02 |
| PER CENT AVE CHANGE | 0.174E+01 | 0.369E+01 | 0.111E+02 | 0.198E+01 | 0.701E+01 | 0.354E+02 |
| **1.0 MEV UNBIASED-D** | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.144E+05 | 0.128E+01 | 0.120E+01 | 0.700E-07 | 0.123E-06 | 0.104E-08 |
| AVERAGE CHANGE | 0.172E+03 | 0.520E-01 | 0.132E+00 | 0.118E-07 | 0.364E-07 | 0.960E-10 |
| STD OF MEAN | 0.265E+03 | 0.522E-01 | 0.841E-02 | 0.141E-07 | 0.417E-07 | 0.131E-09 |
| AVE PER CENT CHANGE | 0.120E+01 | 0.418E+01 | 0.110E+02 | 0.196E+02 | 0.403E+02 | 0.969E+01 |
| INTERVAL ESTIMATE | -0.109E+01 | -0.996E+00 | 0.101E+02 | -0.824E+01 | -0.124E+02 | -0.649E+01 |
| AS PER CENT | 0.348E+01 | 0.912E+01 | 0.119E+02 | 0.420E+02 | 0.715E+02 | 0.250E+02 |
| PER CENT AVE CHANGE | 0.119E+01 | 0.406E+01 | 0.110E+02 | 0.169E+02 | 0.295E+02 | 0.927E+01 |
| **1.5 MEV BIASED-E** | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.139E+05 | 0.127E+01 | 0.122E+01 | 0.806E-07 | 0.156E-06 | 0.105E-08 |
| AVERAGE CHANGE | 0.326E+03 | 0.910E-01 | 0.141E+00 | -0.440E-08 | 0.206E-07 | 0.540E-10 |
| STD OF MEAN | 0.125E+03 | 0.692E-01 | 0.875E-02 | 0.460E-08 | 0.645E-08 | 0.199E-09 |
| AVE PER CENT CHANGE | 0.237E+01 | 0.747E+01 | 0.115E+02 | -0.558E+01 | 0.133E+02 | 0.927E+01 |
| INTERVAL ESTIMATE | 0.170E+01 | 0.328E+01 | 0.110E+02 | -0.954E+01 | 0.103E+02 | -0.839E+01 |
| AS PER CENT | 0.299E+01 | 0.111E+02 | 0.120E+02 | -0.138E+01 | 0.162E+02 | 0.186E+02 |
| PER CENT AVE CHANGE | 0.234E+01 | 0.718E+01 | 0.115E+02 | -0.546E+01 | 0.132E+02 | 0.513E+01 |

FAIRCHILD LPDT L9040

| | RESISTANCE | MIN CP AMP | MIN V(C1) | T(OR) | T(OF) | I(L CO) |
|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.146E+05 | 0.133E+01 | 0.121E+01 | 0.856E-07 | 0.164E-06 | 0.738E-09 |
| AVERAGE CHANGE | 0.246E+03 | 0.200E-02 | 0.135E+00 | -0.960E-08 | -0.184E-07 | 0.196E-09 |
| STD OF MEAN | 0.853E+02 | 0.110E-01 | 0.103E-01 | 0.713E-08 | 0.328E-07 | 0.650E-10 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.160E+00 | 0.111E+02 | -0.114E+02 | -0.122E+02 | 0.279E+02 |
| INTERVAL ESTIMATE | 0.956E+00 | -0.872E+00 | 0.101E+02 | -0.216E+02 | -0.360E+02 | 0.156E+02 |
| AS PER CENT | 0.240E+01 | 0.117E+01 | 0.122E+02 | -0.878E+00 | 0.136E+02 | 0.375E+02 |
| PER CENT AVE CHANGE | 0.168E+01 | 0.150E+00 | 0.111E+02 | -0.112E+02 | -0.112E+02 | 0.266E+02 |
| **CONTROL-G** | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.143E+05 | 0.129E+01 | 0.120E+01 | 0.978E-07 | 0.160E-06 | 0.826E-09 |
| AVERAGE CHANGE | -0.100E+02 | 0.260E-01 | 0.121E+00 | 0.440E-08 | 0.108E-07 | 0.280E-10 |
| STD OF MEAN | 0.110E+03 | 0.329E-01 | 0.300E-02 | 0.270E-08 | 0.226E-07 | 0.782E-10 |
| AVE PER CENT CHANGE | -0.373E-01 | 0.208E+01 | 0.101E+02 | 0.434E+01 | 0.538E+01 | 0.368E+01 |
| INTERVAL ESTIMATE | -0.102E+01 | -0.114E+01 | 0.980E+01 | 0.107E+01 | -0.107E+02 | -0.837E+01 |
| AS PER CENT | 0.880E+00 | 0.516E+01 | 0.104E+02 | 0.793E+01 | 0.242E+02 | 0.151E+02 |
| PER CENT AVE CHANGE | -0.698E-01 | 0.201E+01 | 0.101E+02 | 0.450E+01 | 0.673E+01 | 0.339E+01 |
| **F-TESTS** | | | | | | |
| GROUPS A-B-G | 0.249E+01 | 0.479E+00 | 0.352E+00 | 0.124E+01 | 0.109E+00 | 0.141E+01 |
| GROUPS C-D-G | 0.481E+01 | 0.811E+00 | 0.966E+01 | 0.347E+01 | 0.234E+01 | 0.921E+01 |
| GROUPS E-F-G | 0.148E+02 | 0.552E+01 | 0.982E+01 | 0.102E+02 | 0.647E+01 | 0.187E+01 |
| GROUPS A-C-E-G | 0.783E+01 | 0.362E+01 | 0.511E+01 | 0.130E+02 | 0.211E+01 | 0.366E+01 |
| GROUPS B-D-F-G | 0.173E+01 | 0.172E+01 | 0.349E+01 | 0.605E+01 | 0.302E+01 | 0.378E+01 |
| GROUPS ALL | 0.317E+01 | 0.297E+01 | 0.314E+01 | 0.836E+01 | 0.385E+01 | 0.249E+01 |
| **T-TESTS** | | | | | | |
| GROUPS A-B | 0.718E+00 | -0.509E+00 | -0.460E+00 | 0.694E+00 | 0.523E-01 | -0.186E+00 |
| GROUPS C-D | 0.867E+00 | -0.198E+00 | 0.981E+00 | -0.234E+01 | -0.203E+01 | 0.269E+01 |
| GROUPS E-F | 0.127E+01 | 0.281E+01 | 0.113E+01 | 0.173E+01 | 0.376E+01 | -0.153E+01 |
| GROUPS A-G | 0.245E+01 | 0.734E+00 | 0.394E+00 | -0.102E+01 | -0.371E+00 | 0.136E+01 |
| GROUPS B-G | 0.126E+01 | 0.802E+00 | 0.287E+01 | -0.176E+01 | -0.412E+00 | 0.307E+01 |
| GROUPS C-G | 0.500E+01 | 0.138E+01 | 0.532E+01 | -0.257E+01 | -0.289E-01 | 0.399E+01 |
| GROUPS D-G | 0.142E+01 | 0.943E+00 | 0.265E+01 | 0.115E+01 | 0.121E+01 | 0.994E+00 |
| GROUPS E-G | 0.508E+01 | 0.197E+01 | 0.487E+01 | -0.391E+01 | 0.131E+01 | 0.277E+00 |
| GROUPS F-G | 0.412E+01 | -0.155E+01 | 0.297E+01 | -0.411E+01 | -0.164E+01 | 0.369E+01 |
| GROUPS A-C | -0.896E+00 | -0.946E+00 | -0.173E+01 | 0.132E+01 | -0.678E+00 | -0.123E+01 |
| GROUPS A-E | -0.195E+01 | -0.233E+01 | -0.251E+01 | 0.433E+01 | -0.241E+01 | 0.131E+01 |
| GROUPS C-E | -0.157E+01 | -0.183E+01 | -0.178E+01 | 0.390E+01 | -0.465E+01 | 0.317E+01 |
| GROUPS B-D | -0.317E+00 | -0.195E+00 | -0.734E+00 | -0.154E+01 | -0.159E+01 | 0.149E+01 |
| GROUPS B-F | -0.120E+01 | 0.212E+01 | -0.134E+01 | 0.357E+01 | 0.170E+01 | 0.217E+00 |
| GROUPS D-F | -0.594E+00 | 0.210E+01 | -0.607E+00 | 0.302E+01 | 0.231E+01 | -0.152E+01 |

Texas Instruments SN54L20



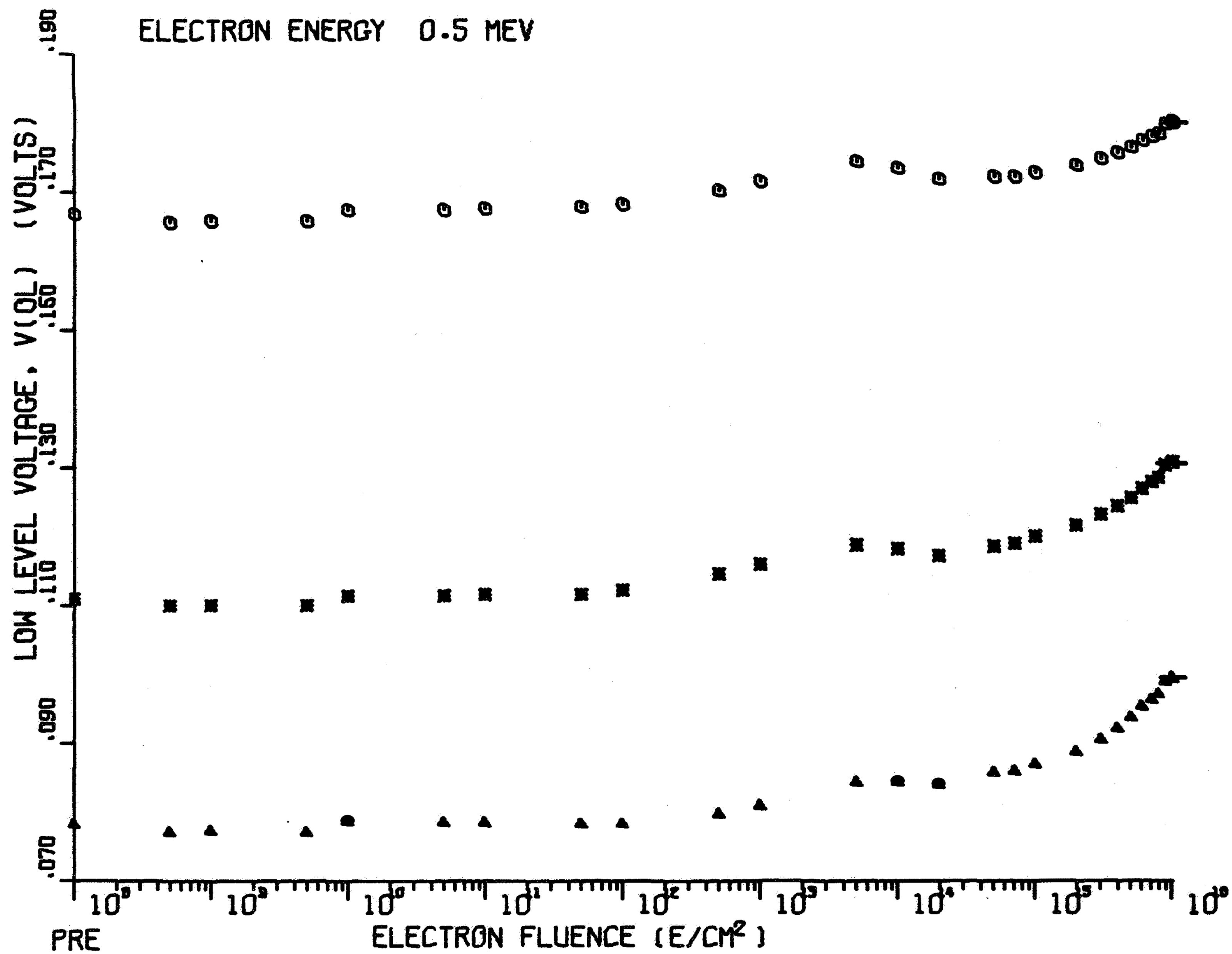

TEST CONDITIONS:

1. Pin 4, 5.0 volts.
2. Pin 11, ground.
3. Temperature 25 C.

TEST PARAMETERS:

1. Output-voltage levels ($V_{OH}$, $V_{OL}$).
2. Input-voltage levels ($V_{IH}$, $V_{IL}$).
3. Input leakage current.
4. Input drive current.
5. Power supply current.
6. Propagation delay.

FIGURE 99. TEST PLAN FOR SN54L20




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN54L20 GATES.

FIGURE 100

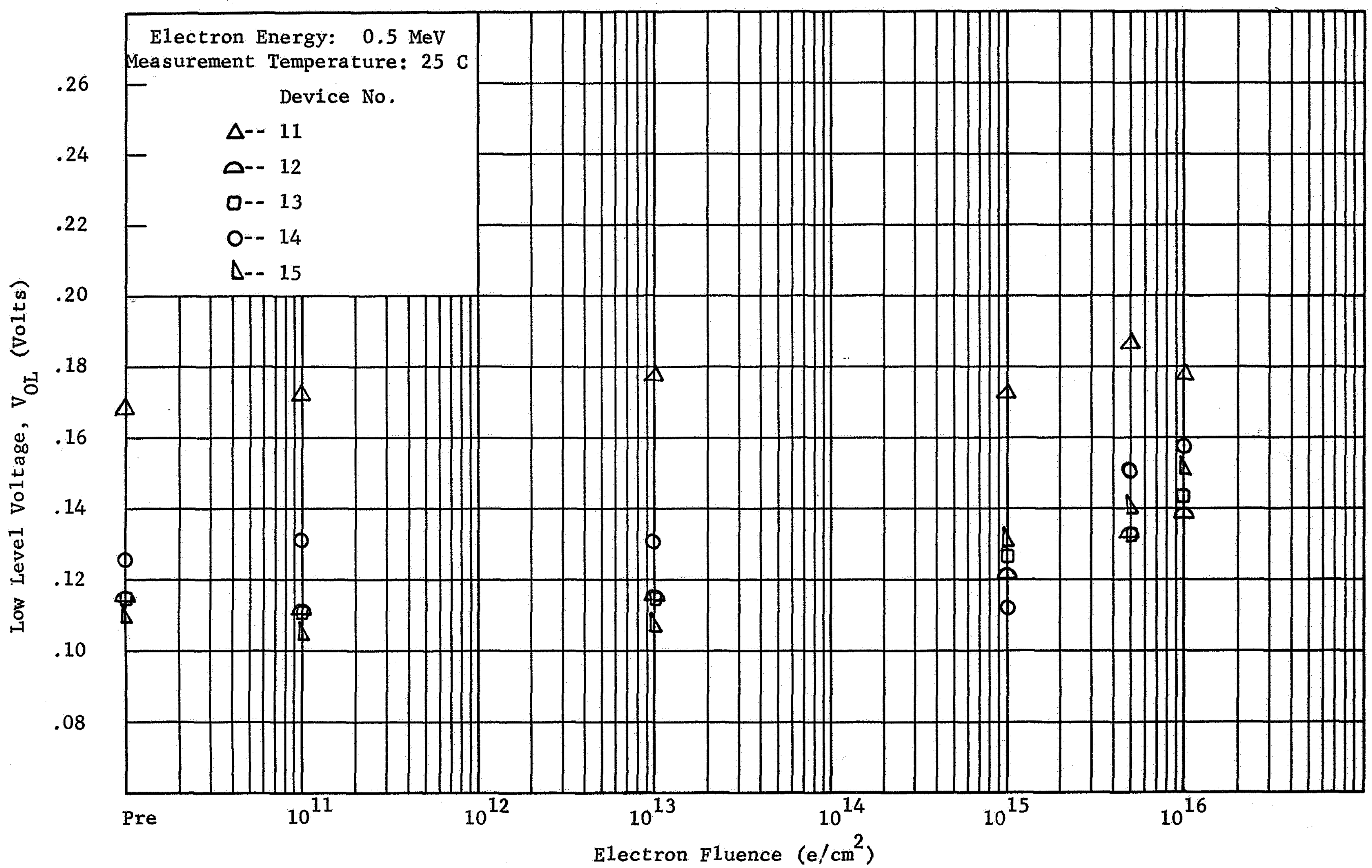
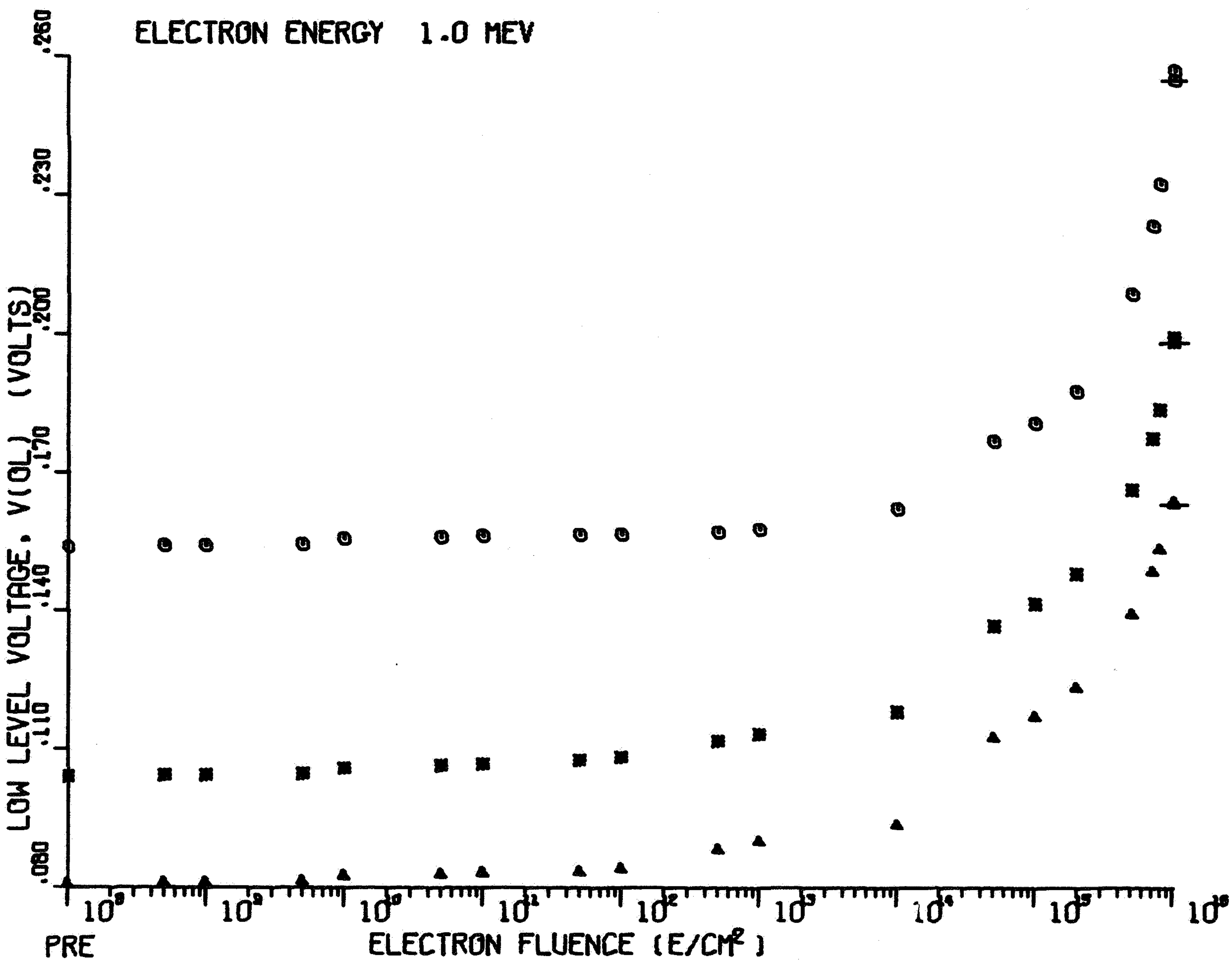



FIGURE 101. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN 54L20 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN54L20 GATES.

FIGURE 102

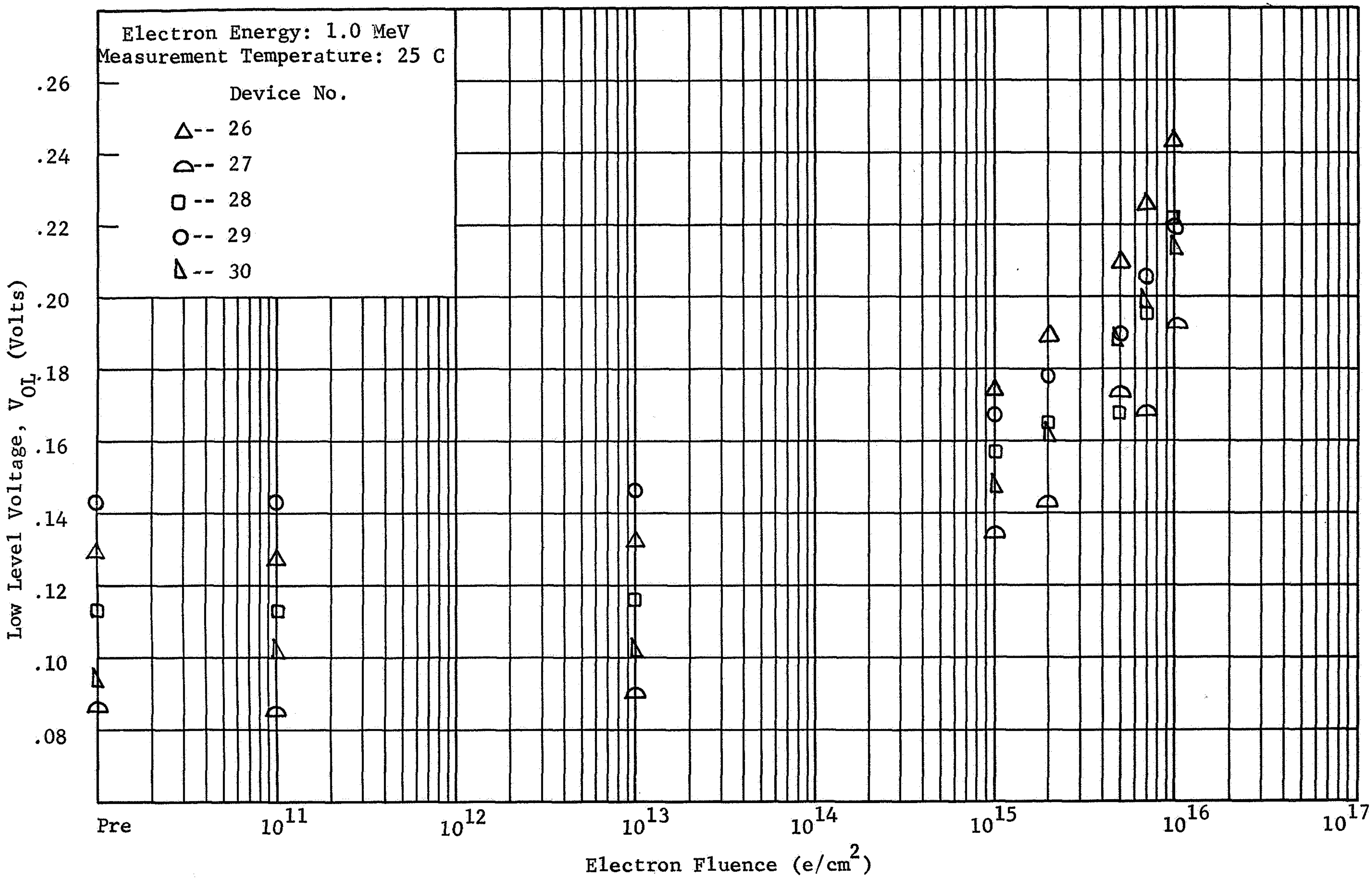
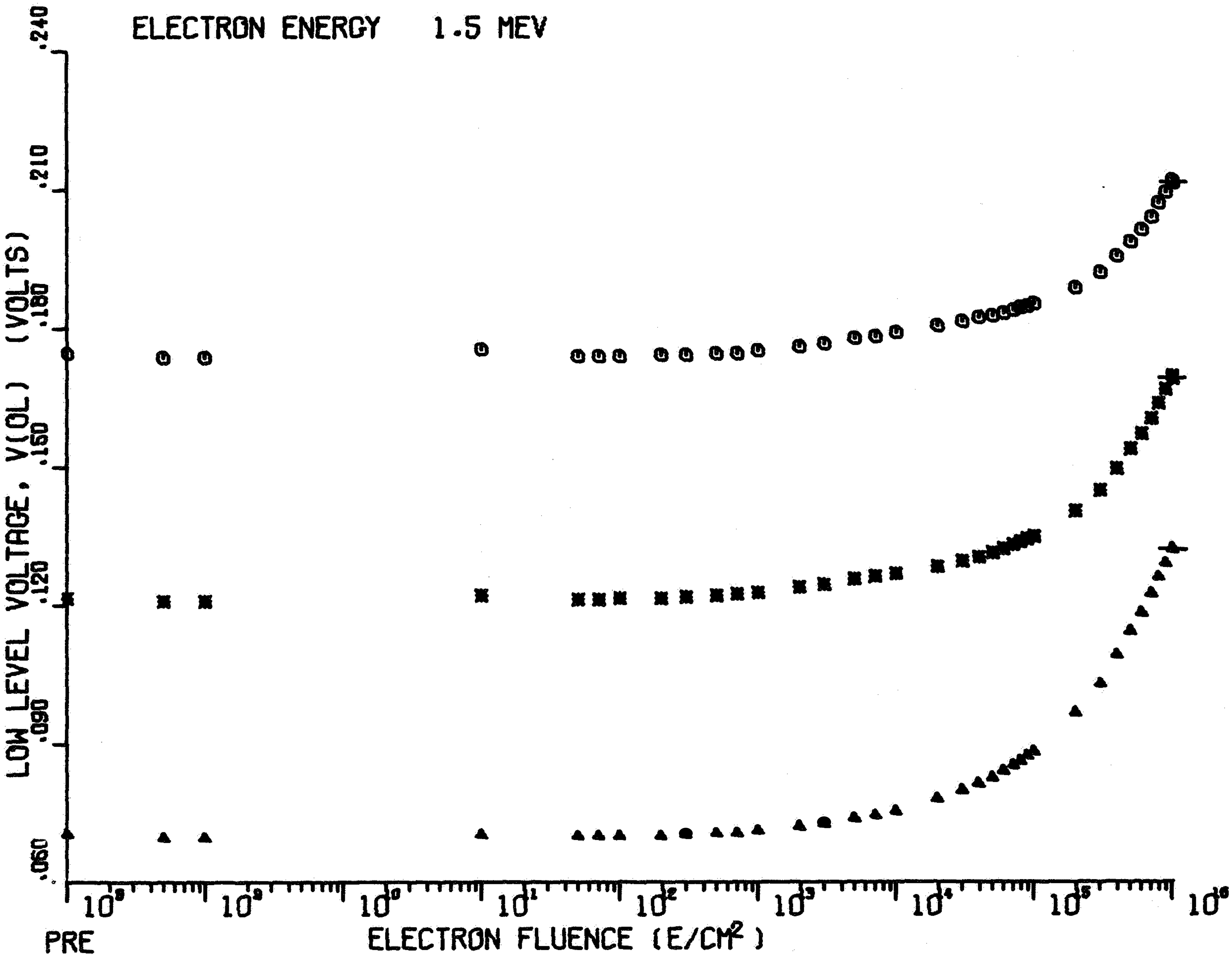
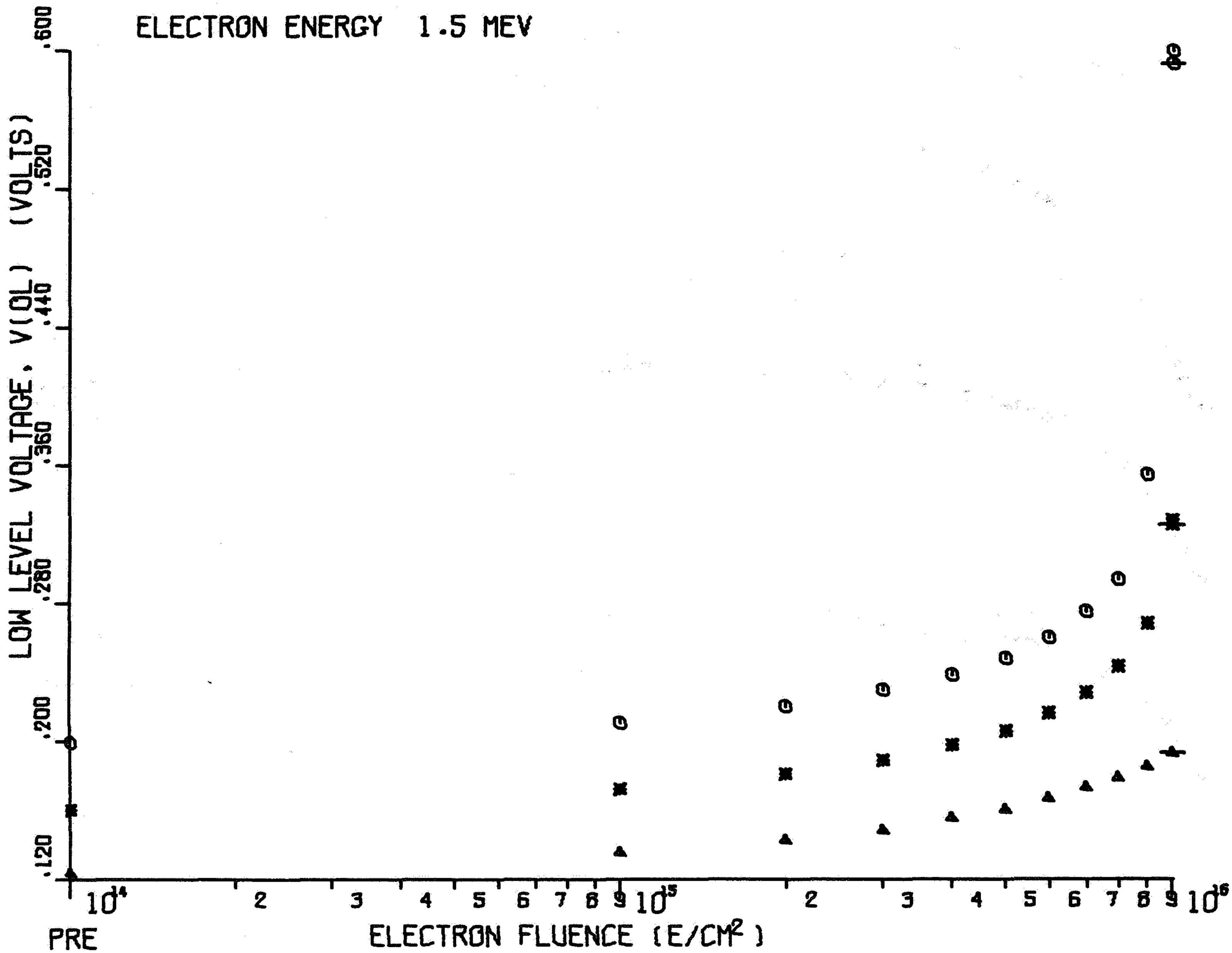



FIGURE 103. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN 54L20 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN54L20 GATES.

FIGURE 104




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN54L20 GATES.

FIGURE 105

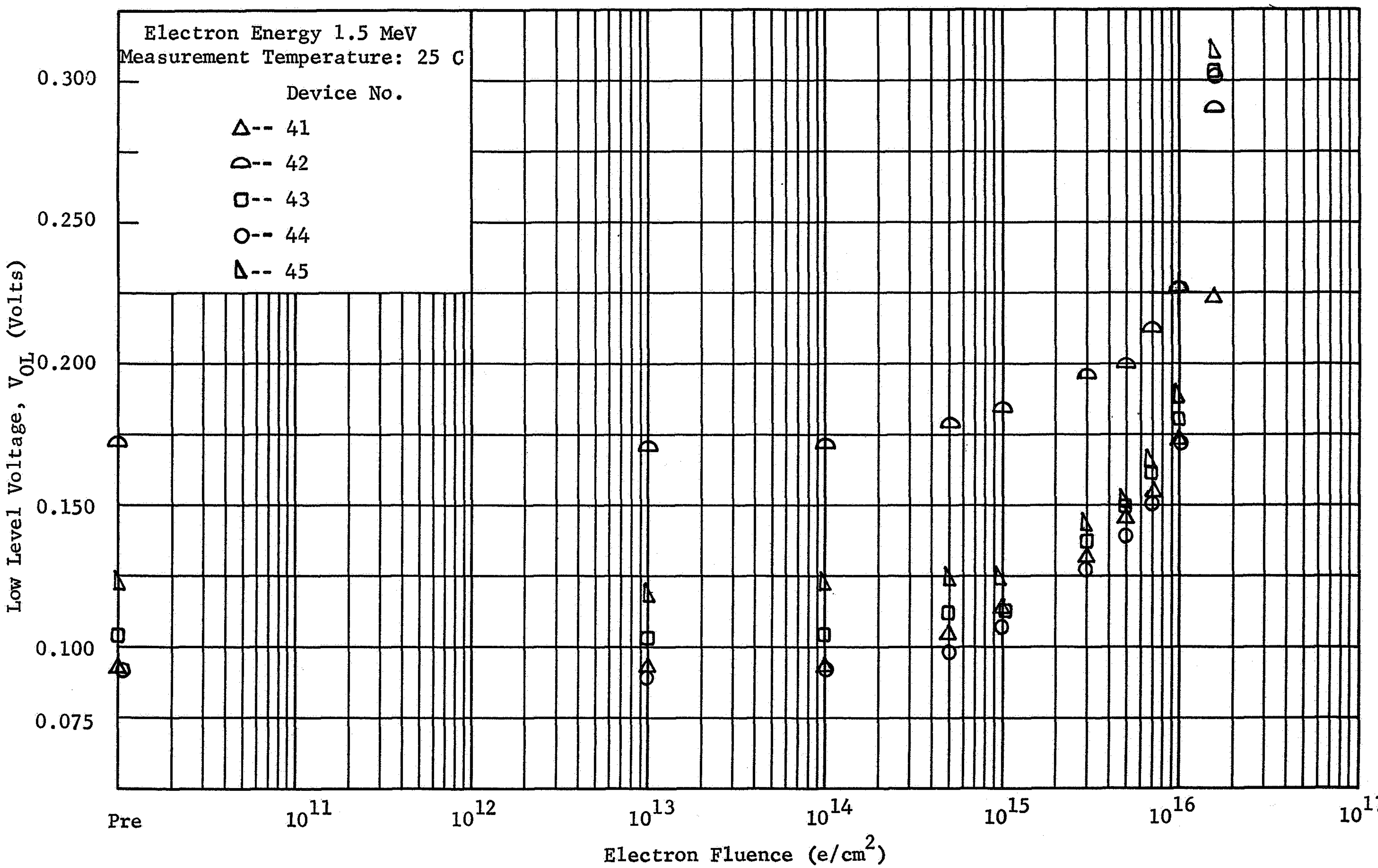



FIGURE 106. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN 54L20 GATES.

TEXAS INSTRUMENT SN54L20

| | V(OL) | V(OH) | V(IH) | V(IL) | I DRIVE | I(CC1) | I(CC0) |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.106E+00 | 0.500E+01 | 0.138E+01 | 0.128E+01 | 0.987E-04 | 0.368E-03 | 0.532E-03 |
| AVERAGE CHANGE | 0.217E-01 | -0.400E-03 | -0.439E-01 | -0.313E-01 | -0.710E-05 | -0.120E-05 | -0.720E-05 |
| STD OF MEAN | 0.401E-02 | 0.966E-03 | 0.110E-01 | 0.131E-01 | 0.213E-05 | 0.451E-04 | 0.475E-04 |
| AVE PER CENT CHANGE | 0.228E+02 | -0.800E-02 | -0.317E+01 | -0.244E+01 | -0.721E+01 | -0.264E+00 | -0.132E+01 |
| INTERVAL ESTIMATE | 0.178E+02 | -0.218E-01 | -0.374E+01 | -0.317E+01 | -0.874E+01 | -0.909E+01 | -0.774E+01 |
| AS PER CENT | 0.233E+02 | 0.582E-02 | -0.260E+01 | -0.171E+01 | -0.565E+01 | 0.844E+01 | 0.503E+01 |
| PER CENT AVE CHANGE | 0.206E+02 | -0.800E-02 | -0.317E+01 | -0.244E+01 | -0.719E+01 | -0.326E+00 | -0.135E+01 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.122E+00 | 0.500E+01 | 0.138E+01 | 0.127E+01 | 0.103E-03 | 0.380E-03 | 0.552E-03 |
| AVERAGE CHANGE | 0.178E-01 | -0.800E-03 | -0.470E-01 | -0.284E-01 | 0.598E-04 | 0.660E-05 | -0.740E-05 |
| STD OF MEAN | 0.999E-02 | 0.447E-03 | 0.187E-01 | 0.213E-01 | 0.148E-03 | 0.423E-04 | 0.241E-04 |
| AVE PER CENT CHANGE | 0.162E+02 | -0.160E-01 | -0.342E+01 | -0.225E+01 | 0.574E+02 | 0.181E+01 | -0.128E+01 |
| INTERVAL ESTIMATE | 0.445E+01 | -0.271E-01 | -0.509E+01 | -0.431E+01 | -0.120E+03 | -0.121E+02 | -0.677E+01 |
| AS PER CENT | 0.248E+02 | -0.490E-02 | -0.173E+01 | -0.152E+00 | 0.236E+03 | 0.156E+02 | 0.409E+01 |
| PER CENT AVE CHANGE | 0.146E+02 | -0.160E-01 | -0.341E+01 | -0.223E+01 | 0.579E+02 | 0.174E+01 | -0.134E+01 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.104E+00 | 0.500E+01 | 0.139E+01 | 0.128E+01 | 0.102E-03 | 0.375E-03 | 0.546E-03 |
| AVERAGE CHANGE | 0.932E-01 | -0.600E-03 | -0.294E-01 | -0.110E-02 | -0.101E-04 | 0.881E-04 | 0.667E-04 |
| STD OF MEAN | 0.231E-01 | 0.516E-03 | 0.122E+00 | 0.122E+00 | 0.311E-05 | 0.376E-03 | 0.376E-03 |
| AVE PER CENT CHANGE | 0.915E+02 | -0.120E-01 | -0.216E+01 | -0.130E+00 | -0.982E+01 | 0.223E+02 | 0.117E+02 |
| INTERVAL ESTIMATE | 0.737E+02 | -0.194E-01 | -0.843E+01 | -0.690E+01 | -0.120E+02 | -0.432E+02 | -0.371E+02 |
| AS PER CENT | 0.105E+03 | -0.461E-02 | 0.419E+01 | 0.672E+01 | -0.769E+01 | 0.952E+02 | 0.615E+02 |
| PER CENT AVE CHANGE | 0.896E+02 | -0.120E-01 | -0.212E+01 | -0.859E-01 | -0.986E+01 | 0.235E+02 | 0.122E+02 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.109E+00 | 0.500E+01 | 0.138E+01 | 0.128E+01 | 0.106E-03 | 0.393E-03 | 0.569E-03 |
| AVERAGE CHANGE | 0.955E-01 | -0.600E-03 | -0.632E-01 | -0.374E-01 | 0.138E-04 | -0.256E-04 | -0.356E-04 |
| STD OF MEAN | 0.146E-01 | 0.548E-03 | 0.841E-02 | 0.105E-01 | 0.426E-04 | 0.336E-05 | 0.207E-05 |
| AVE PER CENT CHANGE | 0.915E+02 | -0.120E-01 | -0.456E+01 | -0.291E+01 | 0.125E+02 | -0.652E+01 | -0.628E+01 |
| INTERVAL ESTIMATE | 0.709E+02 | -0.256E-01 | -0.532E+01 | -0.394E+01 | -0.370E+02 | -0.757E+01 | -0.671E+01 |
| AS PER CENT | 0.104E+03 | 0.160E-02 | -0.381E+01 | -0.190E+01 | 0.631E+02 | -0.545E+01 | -0.580E+01 |
| PER CENT AVE CHANGE | 0.876E+02 | -0.120E-01 | -0.457E+01 | -0.292E+01 | 0.130E+02 | -0.651E+01 | -0.626E+01 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.116E+00 | 0.497E+01 | 0.137E+01 | 0.127E+01 | 0.998E-04 | 0.376E-03 | 0.539E-03 |
| AVERAGE CHANGE | 0.248E+00 | 0.280E-02 | -0.727E-01 | -0.451E-01 | -0.105E-04 | -0.374E-04 | -0.534E-04 |
| STD OF MEAN | 0.155E+00 | 0.127E-01 | 0.167E-01 | 0.174E-01 | 0.207E-05 | 0.570E-05 | 0.863E-05 |
| AVE PER CENT CHANGE | 0.228E+03 | 0.600E-01 | -0.527E+01 | -0.352E+01 | -0.105E+02 | -0.993E+01 | -0.930E+01 |
| INTERVAL ESTIMATE | 0.118E+03 | -0.126E+00 | -0.616E+01 | -0.452E+01 | -0.120E+02 | -0.110E+02 | -0.110E+02 |
| AS PER CENT | 0.309E+03 | 0.239E+00 | -0.442E+01 | -0.257E+01 | -0.904E+01 | -0.885E+01 | -0.876E+01 |
| PER CENT AVE CHANGE | 0.213E+03 | 0.563E-01 | -0.529E+01 | -0.355E+01 | -0.105E+02 | -0.993E+01 | -0.990E+01 |

TEXAS INSTRUMENT SN54L20

| | V(OL) | V(OH) | V(IH) | V(IL) | I DRIVE | I(CC1) | I(CC0) |
|---|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.115E+00 | 0.500E+01 | 0.137E+01 | 0.126E+01 | 0.984E-04 | 0.366E-03 | 0.533E-03 |
| AVERAGE CHANGE | 0.925E+00 | -0.240E-02 | -0.606E-01 | -0.268E-01 | -0.800E-05 | -0.314E-04 | -0.456E-04 |
| STD OF MEAN | 0.336E+00 | 0.594E-02 | 0.223E-01 | 0.329E-01 | 0.200E-05 | 0.297E-05 | 0.365E-05 |
| AVE PER CENT CHANGE | 0.491E+03 | -0.481E-01 | -0.436E+01 | -0.207E+01 | -0.810E+01 | -0.857E+01 | -0.855E+01 |
| INTERVAL ESTIMATE | 0.927E+02 | -0.996E-01 | -0.644E+01 | -0.536E+01 | -0.107E+02 | -0.958E+01 | -0.940E+01 |
| AS PER CENT | 0.817E+03 | 0.196E+00 | -0.240E+01 | 0.111E+01 | -0.561E+01 | -0.757E+01 | -0.770E+01 |
| PER CENT AVE CHANGE | 0.455E+03 | 0.480E-01 | -0.442E+01 | -0.212E+01 | -0.813E+01 | -0.857E+01 | -0.855E+01 |
| **CONTROL-G** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.125E+00 | 0.500E+01 | 0.137E+01 | 0.127E+01 | 0.988E-04 | 0.368E-03 | 0.534E-03 |
| AVERAGE CHANGE | 0.880E-03 | -0.800E-03 | -0.166E-01 | -0.840E-02 | 0.800E-06 | -0.160E-05 | -0.240E-05 |
| STD OF MEAN | 0.356E-03 | 0.447E-03 | 0.351E-02 | 0.378E-02 | 0.837E-06 | 0.385E-05 | 0.404E-05 |
| AVE PER CENT CHANGE | 0.684E+00 | -0.160E-01 | -0.121E+01 | -0.662E+00 | 0.805E+00 | -0.427E+00 | -0.446E+00 |
| INTERVAL ESTIMATE | 0.351E+00 | -0.271E-01 | -0.153E+01 | -0.103E+01 | -0.242E+00 | -0.173E+01 | -0.139E+01 |
| AS PER CENT | 0.106E+01 | -0.490E-02 | -0.896E+00 | -0.293E+00 | 0.186E+01 | 0.843E+00 | 0.489E+00 |
| PER CENT AVE CHANGE | 0.706E+00 | -0.160E-01 | -0.122E+01 | -0.664E+00 | 0.810E+00 | -0.435E+00 | -0.449E+00 |
| **F-TESTS** | | | | | | | |
| GROUPS A-B-G | 0.232E+02 | 0.680E+00 | 0.102E+02 | 0.455E+01 | 0.152E+01 | 0.787E-01 | 0.333E-01 |
| GROUPS C-D-G | 0.490E+02 | 0.290E+00 | 0.377E+00 | 0.283E+00 | 0.223E+01 | 0.356E+00 | 0.264E+00 |
| GROUPS E-F-G | 0.872E+01 | 0.244E+00 | 0.199E+02 | 0.554E+01 | 0.640E+02 | 0.968E+02 | 0.958E+02 |
| GROUPS A-C-E-G | 0.153E+02 | 0.576E+00 | 0.106E+01 | 0.855E+00 | 0.306E+02 | 0.681E+00 | 0.587E+00 |
| GROUPS B-D-F-G | 0.107E+02 | 0.137E+01 | 0.984E+01 | 0.178E+01 | 0.764E+00 | 0.370E+01 | 0.145E+02 |
| GROUPS ALL | 0.127E+02 | 0.508E+00 | 0.840E+00 | 0.611E+00 | 0.163E+01 | 0.547E+00 | 0.483E+00 |
| **T-TESTS** | | | | | | | |
| GROUPS A-B | 0.111E+01 | 0.868E+00 | 0.410E+00 | -0.329E+00 | -0.148E+01 | -0.322E+00 | 0.875E-02 |
| GROUPS C-D | -0.202E+00 | 0. | 0.606E+00 | 0.652E+00 | -0.183E+01 | 0.664E+00 | 0.597E+00 |
| GROUPS E-F | -0.223E+01 | 0.661E-01 | -0.119E+01 | -0.144E+01 | -0.223E+01 | -0.218E+01 | -0.191E+01 |
| GROUPS A-G | 0.114E+02 | 0.868E+00 | -0.534E+01 | -0.376E+01 | -0.787E+01 | 0.194E-01 | -0.221E+00 |
| GROUPS B-G | 0.379E+01 | 0. | -0.358E+01 | -0.207E+01 | 0.890E+00 | 0.432E+00 | -0.457E+00 |
| GROUPS C-G | 0.879E+01 | 0.736E+00 | -0.230E+00 | 0.131E+00 | -0.758E+01 | 0.524E+00 | 0.403E+00 |
| GROUPS D-G | 0.145E+02 | 0.632E+00 | -0.114E+02 | -0.579E+01 | 0.681E+00 | -0.105E+02 | -0.164E+02 |
| GROUPS E-G | 0.349E+01 | 0.623E+00 | -0.729E+01 | -0.459E+01 | -0.116E+02 | -0.126E+02 | -0.124E+02 |
| GROUPS F-G | 0.348E+01 | 0.120E+01 | -0.436E+01 | -0.124E+01 | -0.908E+01 | -0.137E+02 | -0.178E+02 |
| GROUPS A-C | -0.966E+01 | 0.577E+00 | -0.374E+00 | -0.779E+00 | 0.252E+01 | -0.746E+00 | -0.616E+00 |
| GROUPS A-E | -0.460E+01 | -0.796E+00 | 0.455E+01 | 0.201E+01 | 0.362E+01 | 0.252E+01 | 0.302E+01 |
| GROUPS C-E | -0.311E+01 | -0.848E+00 | 0.111E+01 | 0.113E+01 | 0.339E+00 | 0.106E+01 | 0.101E+01 |
| GROUPS B-D | -0.980E+01 | -0.632E+00 | 0.177E+01 | 0.846E+00 | 0.667E+00 | 0.170E+01 | 0.260E+01 |
| GROUPS B-F | -0.337E+01 | -0.120E+01 | 0.105E+01 | -0.913E-01 | 0.102E+01 | 0.201E+01 | 0.350E+01 |
| GROUPS D-F | -0.285E+01 | -0.112E+01 | -0.244E+00 | -0.686E+00 | 0.114E+01 | 0.289E+01 | 0.533E+01 |

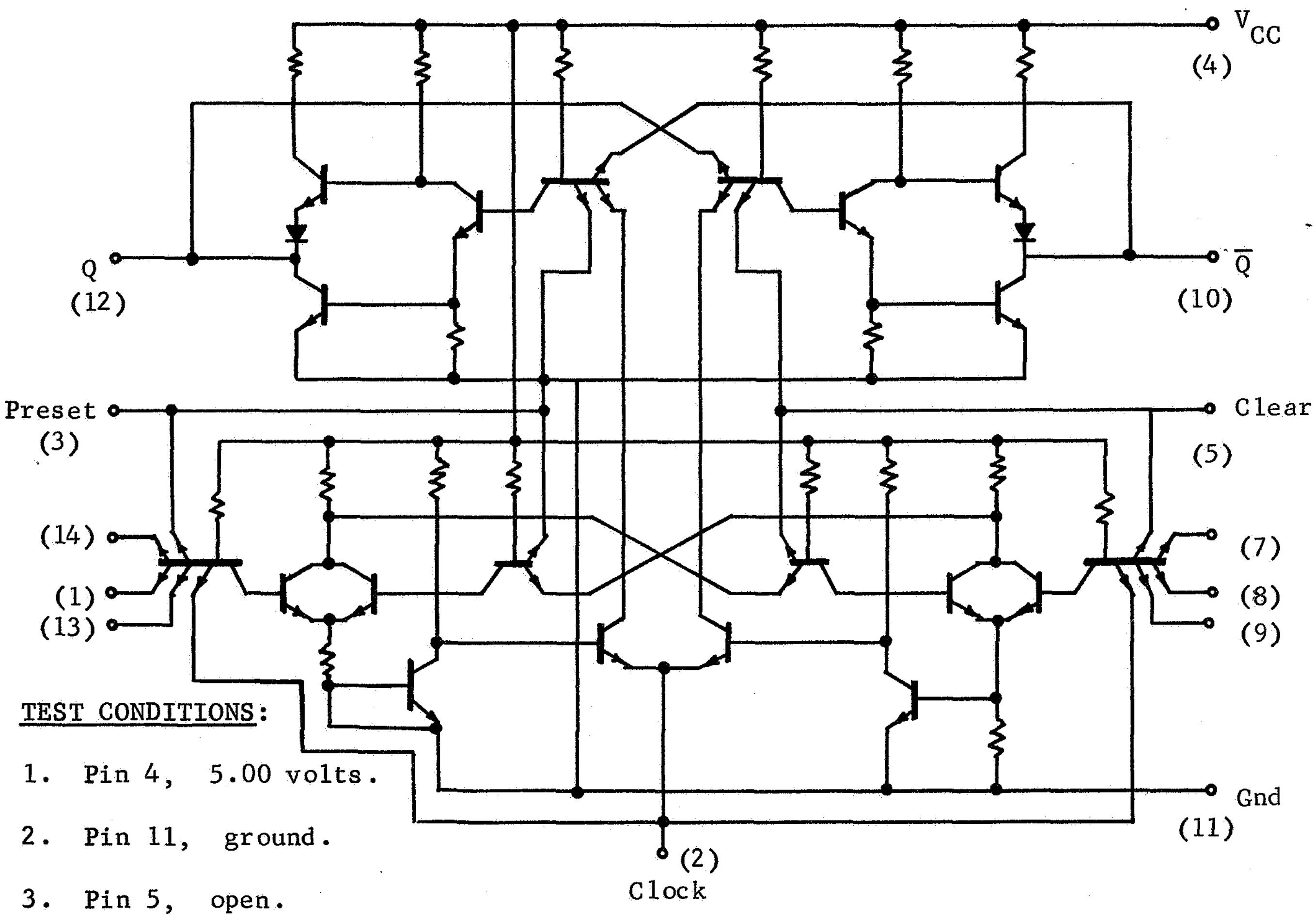
TEXAS INSTRUMENT SN54L20

| | I LEAKAGE | T(DR) | T(DF) |
|---|---|---|---|
| **0.5 MEV BIASED-A** | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.105E-05 | 0.257E-07 | 0.244E-07 |
| AVERAGE CHANGE | -0.314E-06 | 0.940E-08 | 0.253E-08 |
| STD OF MEAN | 0.406E-06 | 0.329E-08 | 0.246E-08 |
| AVE PER CENT CHANGE | -0.117E+02 | 0.383E+02 | 0.116E+02 |
| INTERVAL ESTIMATE | -0.578E+02 | 0.274E+02 | 0.316E+01 |
| AS PER CENT | -0.229E+01 | 0.457E+02 | 0.176E+02 |
| PER CENT AVE CHANGE | -0.300E+02 | 0.366E+02 | 0.104E+02 |
| **0.5 MEV UNBIASED-B** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.620E-06 | 0.236E-07 | 0.215E-07 |
| AVERAGE CHANGE | -0.144E-06 | 0.480E-08 | 0.330E-08 |
| STD OF MEAN | 0.159E-06 | 0.673E-08 | 0.160E-08 |
| AVE PER CENT CHANGE | -0.280E+02 | 0.169E+02 | 0.160E+02 |
| INTERVAL ESTIMATE | -0.549E+02 | -0.151E+02 | 0.608E+01 |
| AS PER CENT | 0.859E+01 | 0.558E+02 | 0.246E+02 |
| PER CENT AVE CHANGE | -0.232E+02 | 0.203E+02 | 0.153E+02 |
| **1.0 MEV BIASED-C** | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.888E-06 | 0.257E-07 | 0.232E-07 |
| AVERAGE CHANGE | -0.521E-06 | 0.180E-07 | 0.254E-08 |
| STD OF MEAN | 0.444E-06 | 0.399E-08 | 0.273E-08 |
| AVE PER CENT CHANGE | -0.278E+02 | 0.731E+02 | 0.122E+02 |
| INTERVAL ESTIMATE | -0.944E+02 | 0.588E+02 | 0.254E+01 |
| AS PER CENT | -0.229E+02 | 0.809E+02 | 0.194E+02 |
| PER CENT AVE CHANGE | -0.587E+02 | 0.698E+02 | 0.110E+02 |
| **1.0 MEV UNBIASED-D** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.729E-06 | 0.226E-07 | 0.231E-07 |
| AVERAGE CHANGE | -0.441E-06 | 0.188E-07 | 0.152E-08 |
| STD OF MEAN | 0.281E-06 | 0.221E-08 | 0.255E-08 |
| AVE PER CENT CHANGE | -0.550E+02 | 0.840E+02 | 0.820E+01 |
| INTERVAL ESTIMATE | -0.108E+03 | 0.708E+02 | -0.714E+01 |
| AS PER CENT | -0.126E+02 | 0.950E+02 | 0.203E+02 |
| PER CENT AVE CHANGE | -0.604E+02 | 0.829E+02 | 0.659E+01 |
| **1.5 MEV BIASED-E** | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.996E-06 | 0.252E-07 | 0.242E-07 |
| AVERAGE CHANGE | -0.709E-06 | 0.264E-07 | 0.148E-07 |
| STD OF MEAN | 0.932E-06 | 0.701E-08 | 0.495E-08 |
| AVE PER CENT CHANGE | -0.557E+02 | 0.116E+03 | 0.657E+02 |
| INTERVAL ESTIMATE | -0.138E+03 | 0.852E+02 | 0.465E+02 |
| AS PER CENT | -0.431E+01 | 0.125E+03 | 0.757E+02 |
| PER CENT AVE CHANGE | -0.712E+02 | 0.105E+03 | 0.611E+02 |

TEXAS INSTRUMENT SN54L20

| | I LEAKAGE | T(DR) | T(DF) |
|---|---|---|---|
| 1.5 MEV UNBIASED-F | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.689E-06 | 0.263E-07 | 0.231E-07 |
| AVERAGE CHANGE | -0.524E-06 | 0.343E-07 | 0.109E-07 |
| STD OF MEAN | 0.282E-06 | 0.667E-08 | 0.744E-08 |
| AVE PER CENT CHANGE | -0.708E+02 | 0.134E+03 | 0.511E+02 |
| INTERVAL ESTIMATE | -0.127E+03 | 0.992E+02 | 0.701E+01 |
| AS PER CENT | -0.253E+02 | 0.162E+03 | 0.869E+02 |
| PER CENT AVE CHANGE | -0.761E+02 | 0.131E+03 | 0.469E+02 |
| CONTROL-G | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.105E-05 | 0.257E-07 | 0.232E-07 |
| AVERAGE CHANGE | -0.725E-06 | -0.240E-08 | 0.166E-08 |
| STD OF MEAN | 0.164E-05 | 0.485E-08 | 0.550E-09 |
| AVE PER CENT CHANGE | -0.119E+02 | -0.637E+01 | 0.716E+01 |
| INTERVAL ESTIMATE | -0.262E+03 | -0.328E+02 | 0.420E+01 |
| AS PER CENT | 0.125E+03 | 0.141E+02 | 0.101E+02 |
| PER CENT AVE CHANGE | -0.688E+02 | -0.934E+01 | 0.714E+01 |
| F-TESTS | | | |
| GROUPS A-B-G | 0.631E+00 | 0.106E+02 | 0.868E+00 |
| GROUPS C-D-G | 0.146E+00 | 0.529E+02 | 0.411E+00 |
| GROUPS E-F-G | 0.614E-01 | 0.467E+02 | 0.110E+02 |
| GROUPS A-C-E-G | 0.459E+00 | 0.429E+02 | 0.333E+02 |
| GROUPS B-D-F-G | 0.405E+00 | 0.445E+02 | 0.605E+01 |
| GROUPS ALL | 0.538E+00 | 0.347E+02 | 0.162E+02 |
| T-TESTS | | | |
| GROUPS A-B | -0.892E+00 | 0.181E+01 | -0.630E+00 |
| GROUPS C-D | -0.365E+00 | -0.408E+00 | 0.696E+00 |
| GROUPS E-F | -0.427E+00 | -0.209E+01 | 0.123E+01 |
| GROUPS A-G | 0.773E+00 | 0.561E+01 | 0.768E+00 |
| GROUPS B-G | 0.788E+00 | 0.194E+01 | 0.216E+01 |
| GROUPS C-G | 0.379E+00 | 0.871E+01 | 0.701E+00 |
| GROUPS D-G | 0.382E+00 | 0.888E+01 | -0.120E+00 |
| GROUPS E-G | 0.238E-01 | 0.820E+01 | 0.580E+01 |
| GROUPS F-G | 0.269E+00 | 0.996E+01 | 0.276E+01 |
| GROUPS A-C | 0.109E+01 | -0.524E+01 | -0.861E-02 |
| GROUPS A-E | 0.123E+01 | -0.696E+01 | -0.701E+01 |
| GROUPS C-E | 0.578E+00 | -0.332E+01 | -0.685E+01 |
| GROUPS B-D | 0.206E+01 | -0.441E+01 | 0.132E+01 |
| GROUPS B-F | 0.263E+01 | -0.697E+01 | -0.222E+01 |
| GROUPS D-F | 0.470E+00 | -0.496E+01 | -0.265E+01 |

Texas Instruments SN54L71



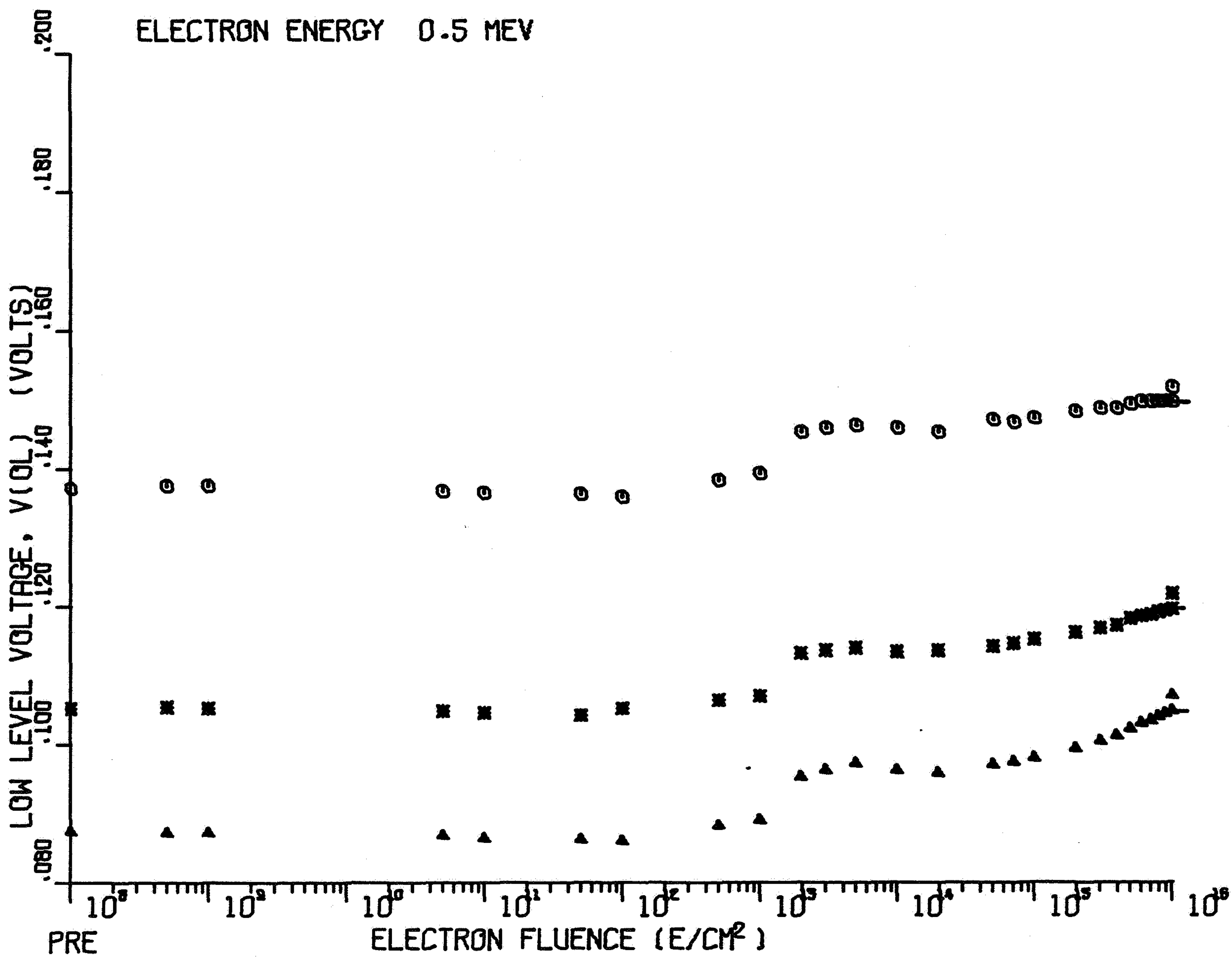

TEST CONDITIONS:

1. Pin 4, 5.00 volts.
2. Pin 11, ground.
3. Pin 5, open.
4. Temperature 25 C.

TEST PARAMETERS:

1. Output-voltage levels (Q $\overline{Q}$ both $V_H$, $V_L$).
2. Leakage current (PRESET and $R_1$).
3. Input currents.
4. Power supply current.
5. Propagation delay.
6. Minimum clock amplitude.
7. Minimum input one voltage.

FIGURE 107. TEST PLAN FOR SN54L71 FLIP-FLOPS




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN54L71 FLIP-FLOPS.

FIGURE 108

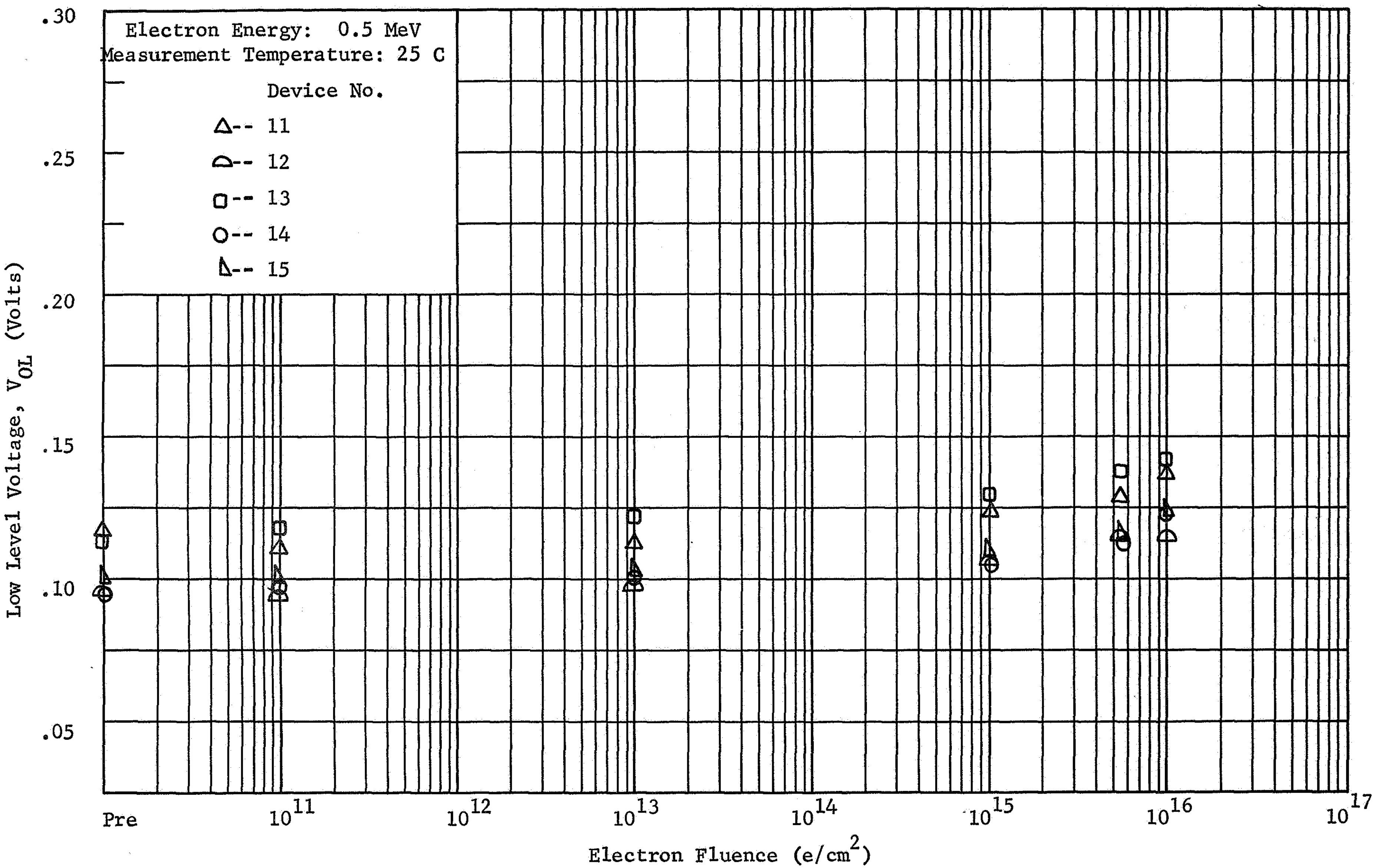
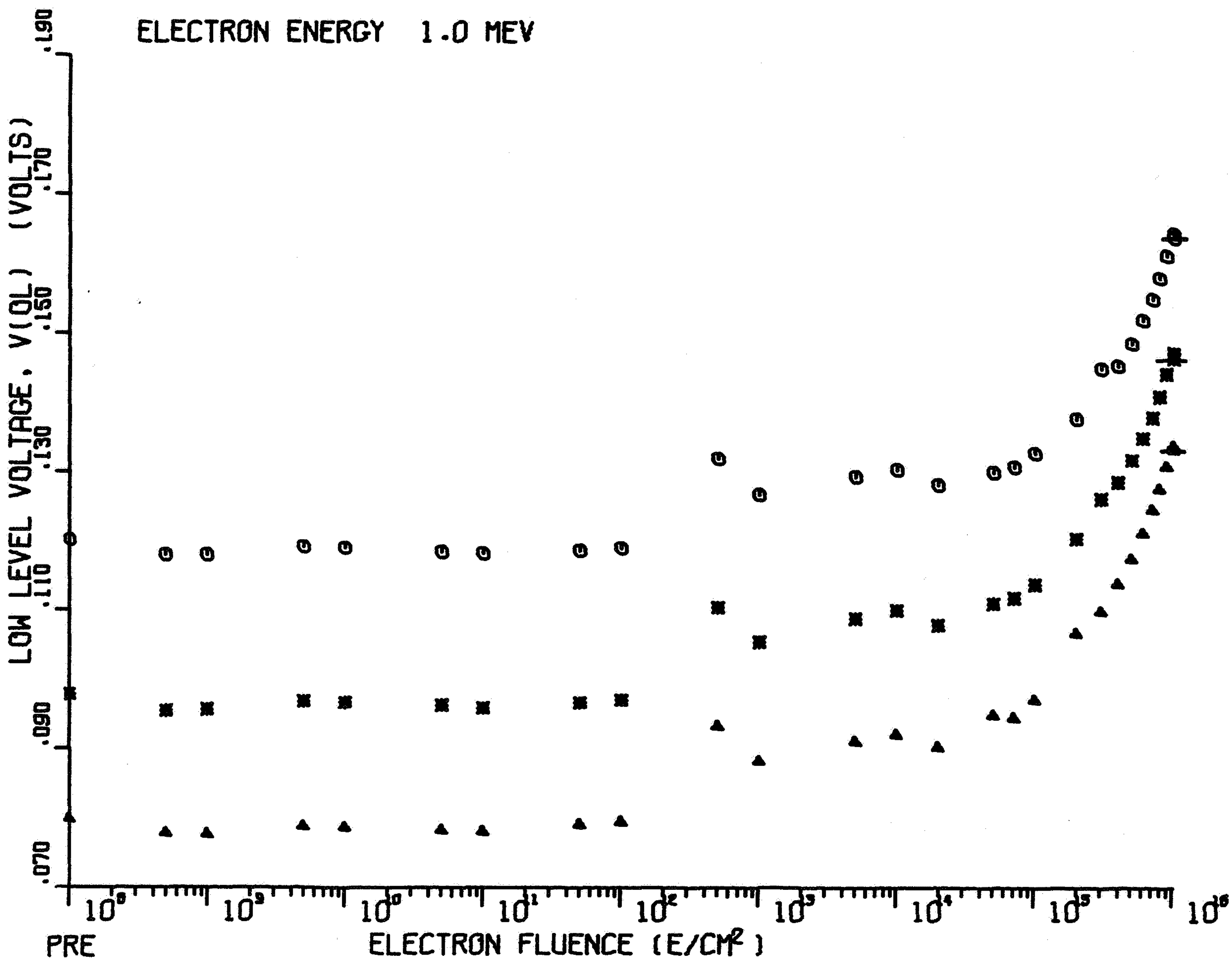



FIGURE 109. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN 54L71 FLIP-FLOPS.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN54L71 FLIP-FLOPS.

FIGURE 110

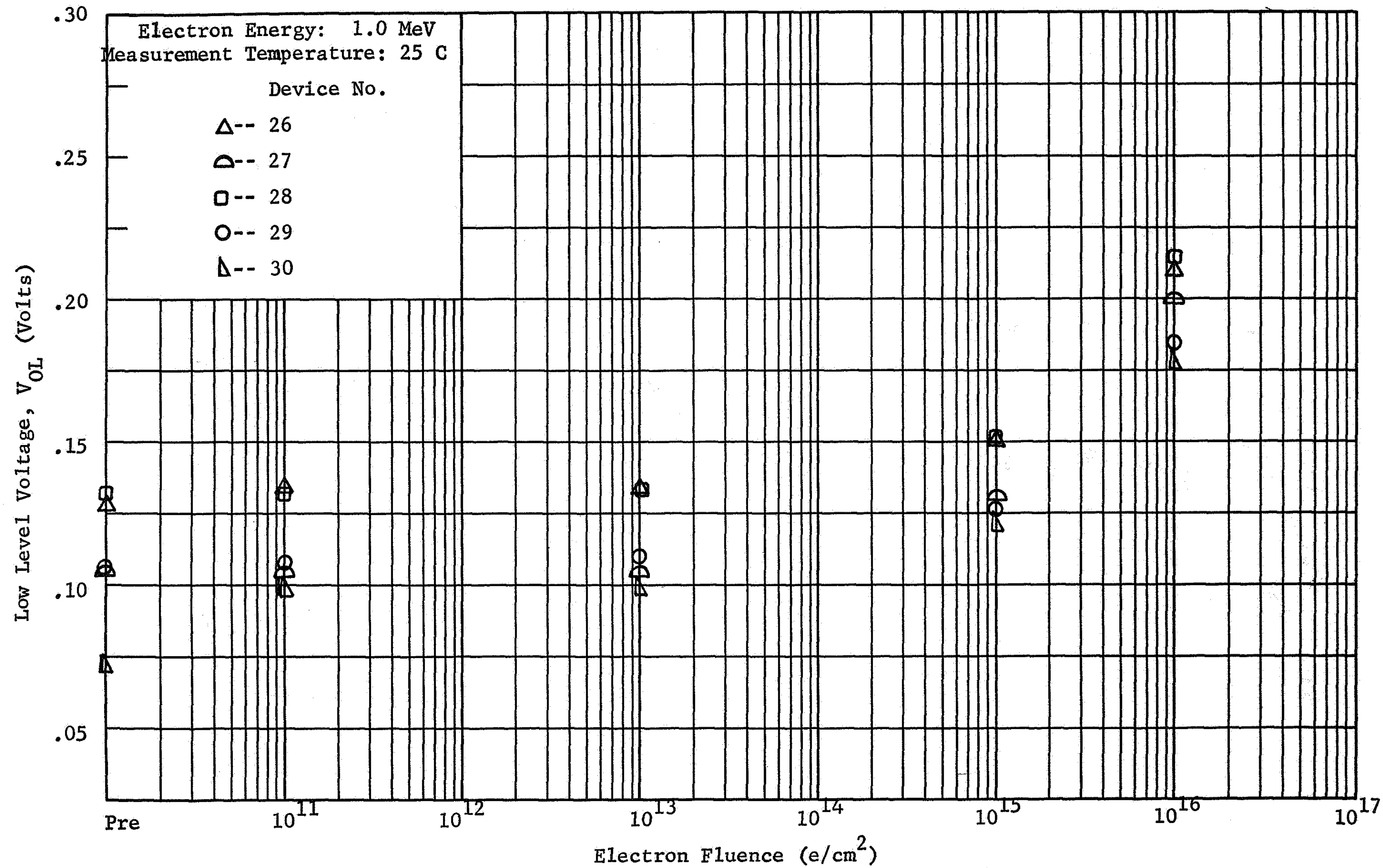
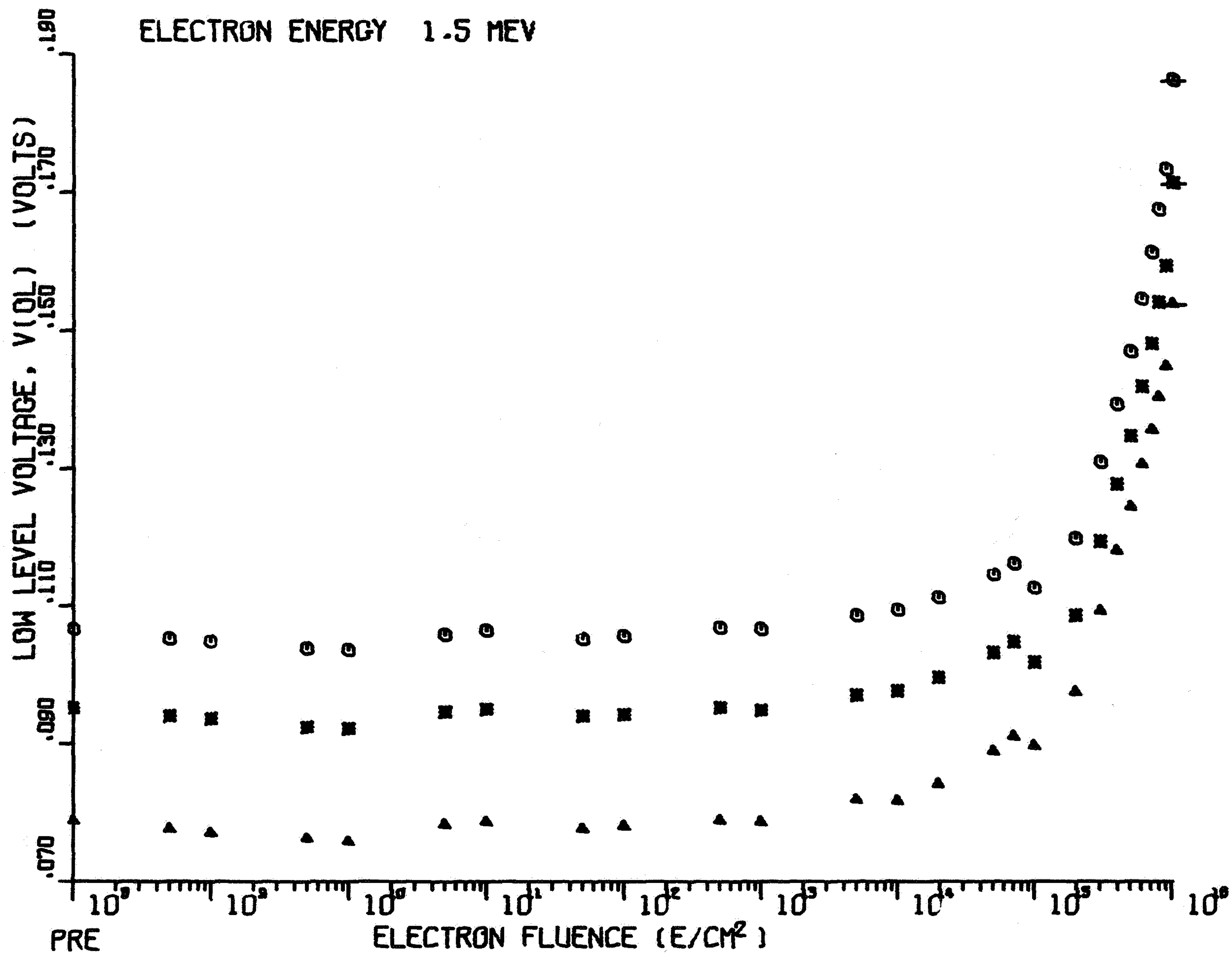
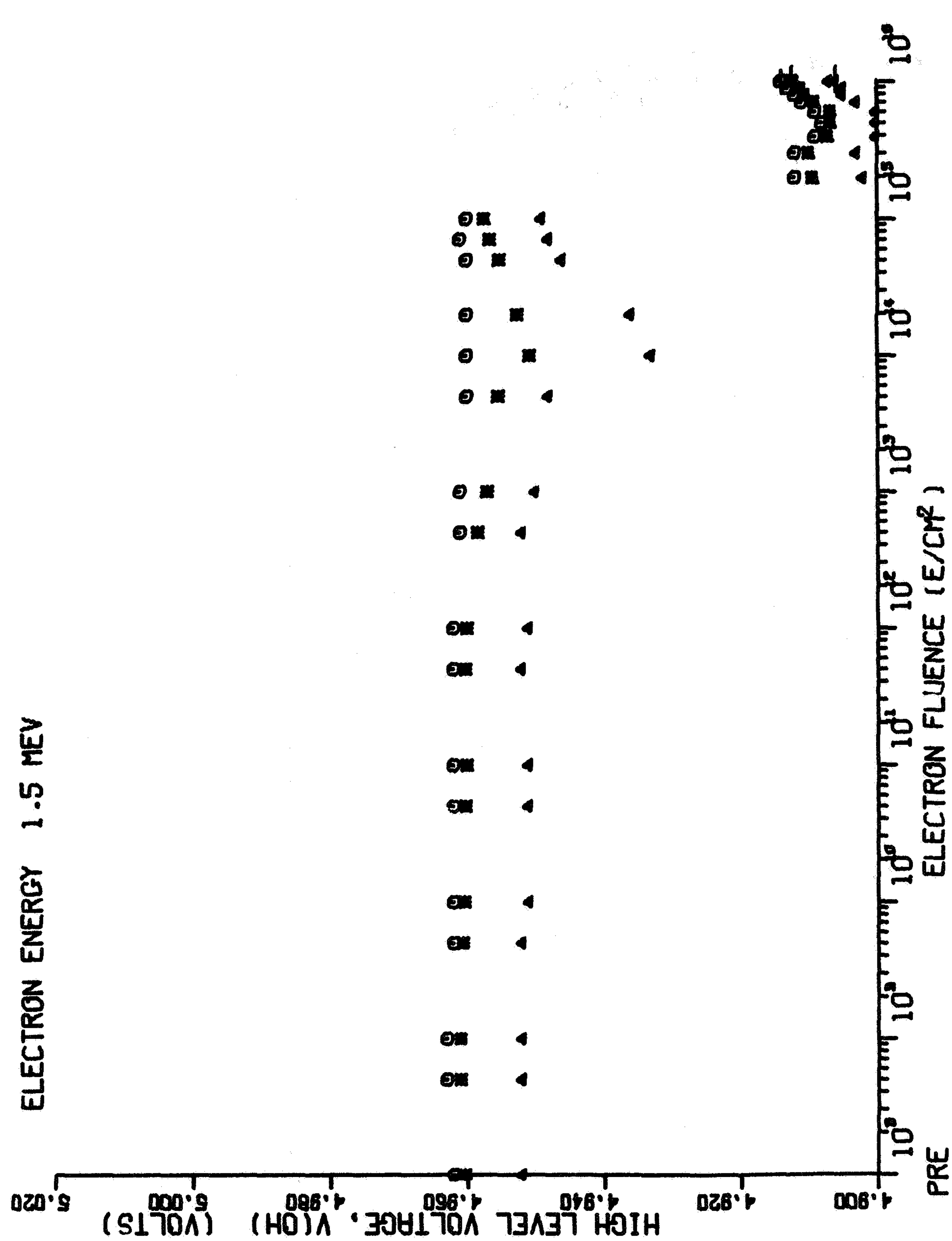



FIGURE 111. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN 54L71 FLIP-FLOPS.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN54L71 FLIP-FLOPS.

FIGURE 112




STATIC HIGH LEVEL OUTPUT RADIATION RESPONSE FOR SN54L71 FLIP-FLOPS.

FIGURE 113

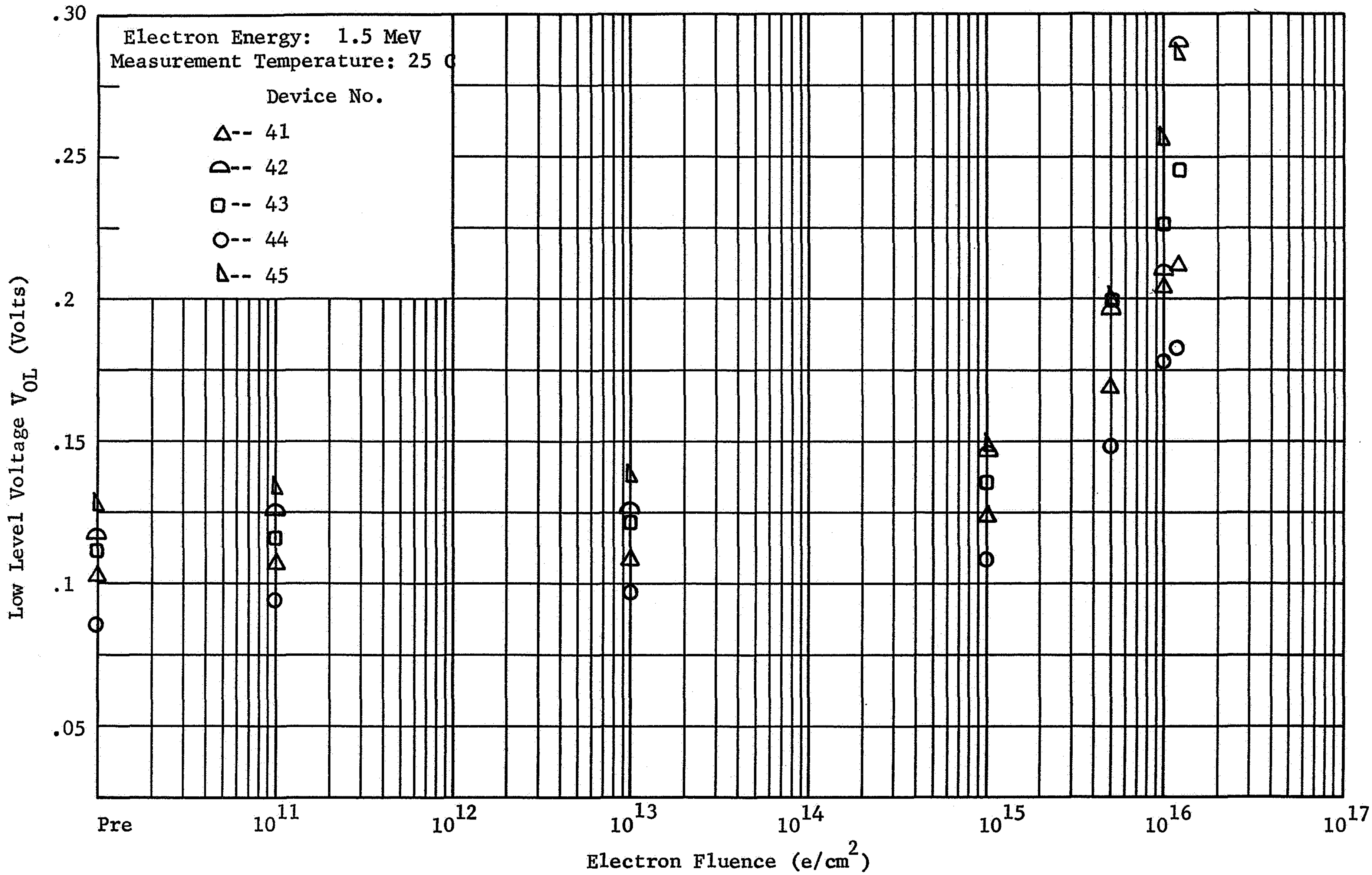



FIGURE 114. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR SN 54L71 FLIP-FLOPS.

TEXAS INSTRUMENT SN54L71

| | V(QL) | V(BAR Q L) | V(QH) | V(BAR Q H) | I(LRI) | I(L PSET) | I(IN PSET) |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 9 | 10 | 10 | 10 | 9 | 9 | 9 |
| INITIAL MEAN | 0.103E+00 | 0.102E+00 | 0.499E+01 | 0.499E+01 | 0.881E-06 | 0.146E-05 | 0.163E-03 |
| AVERAGE CHANGE | 0.179E-01 | 0.131E-01 | 0.500E-03 | -0.200E-02 | 0.364E-06 | 0.698E-06 | -0.322E-05 |
| STD OF MEAN | 0.365E-02 | 0.305E-02 | 0.465E-02 | 0.205E-02 | 0.809E-06 | 0.111E-05 | 0.199E-05 |
| AVE PER CENT CHANGE | 0.182E+02 | 0.135E+02 | 0.100E-01 | -0.401E-01 | 0.483E+02 | 0.620E+02 | -0.199E+01 |
| INTERVAL ESTIMATE | 0.146E+02 | 0.107E+02 | -0.566E-01 | -0.695E-01 | -0.293E+02 | -0.108E+02 | -0.291E+01 |
| AS PER CENT | 0.201E+02 | 0.150E+02 | 0.767E-01 | -0.106E-01 | 0.112E+03 | 0.107E+03 | -0.104E+01 |
| PER CENT AVE CHANGE | 0.174E+02 | 0.129E+02 | 0.100E-01 | -0.401E-01 | 0.413E+02 | 0.479E+02 | -0.197E+01 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.101E+00 | 0.101E+00 | 0.499E+01 | 0.499E+01 | 0.987E-06 | 0.164E-05 | 0.151E-03 |
| AVERAGE CHANGE | 0.174E-01 | 0.168E-01 | 0.160E-02 | 0.100E-02 | -0.204E-07 | 0.232E-06 | -0.180E-05 |
| STD OF MEAN | 0.200E-02 | 0.156E-02 | 0.114E-02 | 0.453E-02 | 0.278E-06 | 0.673E-06 | 0.130E-05 |
| AVE PER CENT CHANGE | 0.175E+02 | 0.169E+02 | 0.321E-01 | 0.200E-01 | 0.633E+01 | 0.179E+02 | -0.122E+01 |
| INTERVAL ESTIMATE | 0.147E+02 | 0.148E+02 | 0.370E-02 | -0.926E-01 | -0.371E+02 | -0.368E+02 | -0.227E+01 |
| AS PER CENT | 0.196E+02 | 0.186E+02 | 0.604E-01 | 0.133E+00 | 0.329E+02 | 0.651E+02 | -0.120E+00 |
| PER CENT AVE CHANGE | 0.172E+02 | 0.167E+02 | 0.321E-01 | 0.200E-01 | -0.207E+01 | 0.141E+02 | -0.119E+01 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.107E+00 | 0.105E+00 | 0.499E+01 | 0.499E+01 | 0.782E-06 | 0.140E-05 | 0.152E-03 |
| AVERAGE CHANGE | 0.592E-01 | 0.493E-01 | 0.900E-03 | -0.500E-03 | -0.290E-06 | -0.318E-06 | 0.260E-05 |
| STD OF MEAN | 0.651E-02 | 0.431E-02 | 0.328E-02 | 0.707E-03 | 0.314E-06 | 0.405E-06 | 0.395E-05 |
| AVE PER CENT CHANGE | 0.563E+02 | 0.476E+02 | 0.180E-01 | -0.100E-01 | -0.291E+02 | -0.169E+02 | 0.191E+01 |
| INTERVAL ESTIMATE | 0.512E+02 | 0.439E+02 | -0.290E-01 | -0.202E-01 | -0.657E+02 | -0.433E+02 | -0.148E+00 |
| AS PER CENT | 0.599E+02 | 0.498E+02 | 0.651E-01 | 0.116E-03 | -0.836E+01 | -0.205E+01 | 0.356E+01 |
| PER CENT AVE CHANGE | 0.556E+02 | 0.469E+02 | 0.180E-01 | -0.100E-01 | -0.371E+02 | -0.227E+02 | 0.171E+01 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.108E+00 | 0.107E+00 | 0.499E+01 | 0.499E+01 | 0.768E-06 | 0.124E-05 | 0.166E-03 |
| AVERAGE CHANGE | 0.640E-01 | 0.658E-01 | 0.340E-02 | 0.568E-14 | -0.355E-06 | -0.436E-06 | 0.389E-05 |
| STD OF MEAN | 0.446E-02 | 0.613E-02 | 0.152E-02 | 0.173E-02 | 0.258E-06 | 0.360E-06 | 0.228E-05 |
| AVE PER CENT CHANGE | 0.599E+02 | 0.629E+02 | 0.681E-01 | 0.642E-05 | -0.412E+02 | -0.295E+02 | 0.239E+01 |
| INTERVAL ESTIMATE | 0.539E+02 | 0.546E+02 | 0.304E-01 | -0.431E-01 | -0.878E+02 | -0.711E+02 | 0.582E+00 |
| AS PER CENT | 0.641E+02 | 0.688E+02 | 0.106E+00 | 0.431E-01 | -0.450E+01 | 0.848E+00 | 0.398E+01 |
| PER CENT AVE CHANGE | 0.590E+02 | 0.617E+02 | 0.681E-01 | 0.114E-12 | -0.462E+02 | -0.351E+02 | 0.228E+01 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | .10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.100E+00 | 0.984E-01 | 0.499E+01 | 0.499E+01 | 0.956E-06 | 0.156E-05 | 0.156E-03 |
| AVERAGE CHANGE | 0.111E+00 | 0.816E-01 | 0.320E-02 | -0.500E-03 | -0.484E-06 | -0.571E-06 | 0.580E-05 |
| STD OF MEAN | 0.169E-01 | 0.105E-01 | 0.641E-02 | 0.255E-02 | 0.428E-06 | 0.645E-06 | 0.339E-05 |
| AVE PER CENT CHANGE | 0.112E+03 | 0.842E+02 | 0.642E-01 | -0.100E-01 | -0.423E+02 | -0.281E+02 | 0.380E+01 |
| INTERVAL ESTIMATE | 0.986E+02 | 0.753E+02 | -0.277E-01 | -0.466E-01 | -0.827E+02 | -0.661E+02 | 0.217E+01 |
| AS PER CENT | 0.123E+03 | 0.906E+02 | 0.156E+00 | 0.265E-01 | -0.186E+02 | -0.701E+01 | 0.529E+01 |
| PER CENT AVE CHANGE | 0.111E+03 | 0.829E+02 | 0.641E-01 | -0.100E-01 | -0.506E+02 | -0.365E+02 | 0.373E+01 |

TEXAS INSTRUMENT SN54L71

| | V(QL) | V(BAR Q L) | V(QH) | V(BAR Q H) | I(LR1) | I(L PSET) | I(IN PSET) |
|---|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.107E+00 | 0.106E+00 | 0.498E+01 | 0.499E+01 | 0.865E-06 | 0.160E-05 | 0.157E-03 |
| AVERAGE CHANGE | 0.100E+00 | 0.103E+00 | 0.108E-01 | -0.100E-02 | -0.470E-06 | -0.250E-06 | 0.920E-05 |
| STD OF MEAN | 0.230E-01 | 0.230E-01 | 0.169E-01 | 0.707E-03 | 0.252E-06 | 0.378E-06 | 0.804E-05 |
| AVE PER CENT CHANGE | 0.936E+02 | 0.963E+02 | 0.217E+00 | -0.200E-01 | -0.546E+02 | -0.267E+02 | 0.611E+01 |
| INTERVAL ESTIMATE | 0.673E+02 | 0.698E+02 | -0.204E+00 | -0.376E-01 | -0.906E+02 | -0.451E+02 | -0.502E+00 |
| AS PER CENT | 0.121E+03 | 0.124E+03 | 0.637E+00 | -0.245E-02 | -0.182E+02 | 0.137E+02 | 0.123E+02 |
| PER CENT AVE CHANGE | 0.940E+02 | 0.967E+02 | 0.217E+00 | -0.200E-01 | -0.544E+02 | -0.157E+02 | 0.587E+01 |
| **CONTROL-G** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.991E-01 | 0.990E-01 | 0.499E+01 | 0.499E+01 | 0.103E-05 | 0.175E-05 | 0.154E-03 |
| AVERAGE CHANGE | -0.100E-03 | 0.200E-04 | 0.260E-02 | 0. | -0.524E-07 | -0.820E-08 | -0.100E-05 |
| STD OF MEAN | 0.579E-03 | 0.447E-04 | 0.114E-02 | 0.122E-02 | 0.875E-07 | 0.808E-07 | 0.707E-06 |
| AVE PER CENT CHANGE | -0.177E+00 | 0.196E-01 | 0.521E-01 | -0.241E-05 | -0.527E+01 | -0.816E+00 | -0.653E+00 |
| INTERVAL ESTIMATE | -0.826E+00 | -0.359E-01 | 0.237E-01 | -0.305E-01 | -0.156E+02 | -0.622E+01 | -0.122E+01 |
| AS PER CENT | 0.624E+00 | 0.763E-01 | 0.805E-01 | 0.305E-01 | 0.545E+01 | 0.528E+01 | -0.794E-01 |
| PER CENT AVE CHANGE | -0.101E+00 | 0.202E-01 | 0.521E-01 | 0. | -0.508E+01 | -0.470E+00 | -0.650E+00 |
| **F-TESTS** | | | | | | | |
| GROUPS A-B-G | 0.752E+02 | 0.740E+02 | 0.635E+00 | 0.228E+01 | 0.109E+01 | 0.121E+01 | 0.344E+01 |
| GROUPS C-D-G | 0.257E+03 | 0.325E+03 | 0.181E+01 | 0.472E+00 | 0.191E+01 | 0.212E+01 | 0.338E+01 |
| GROUPS E-F-G | 0.795E+02 | 0.845E+02 | 0.129E+01 | 0.320E+00 | 0.300E+01 | 0.220E+01 | 0.640E+01 |
| GROUPS A-C-E-G | 0.194E+03 | 0.276E+03 | 0.734E+00 | 0.186E+01 | 0.478E+01 | 0.557E+01 | 0.155E+02 |
| GROUPS B-D-F-G | 0.749E+02 | 0.771E+02 | 0.122E+01 | 0.523E+00 | 0.460E+01 | 0.230E+01 | 0.715E+01 |
| GROUPS ALL | 0.102E+03 | 0.115E+03 | 0.165E+01 | 0.131E+01 | 0.364E+01 | 0.376E+01 | 0.974E+01 |
| **T-TESTS** | | | | | | | |
| GROUPS A-B | 0.284E+00 | -0.254E+01 | -0.512E+00 | -0.180E+01 | 0.101E+01 | 0.845E+00 | -0.143E+01 |
| GROUPS C-D | -0.145E+01 | -0.610E+01 | -0.160E+01 | -0.810E+00 | 0.398E+00 | 0.548E+00 | -0.622E+00 |
| GROUPS E-F | 0.104E+01 | -0.251E+01 | -0.129E+01 | 0.423E+00 | -0.672E-01 | -0.102E+01 | -0.118E+01 |
| GROUPS A-G | 0.107E+02 | 0.939E+01 | -0.978E+00 | -0.198E+01 | 0.113E+01 | 0.139E+01 | -0.238E+01 |
| GROUPS B-G | 0.187E+02 | 0.241E+02 | -0.139E+01 | 0.477E+00 | 0.245E+00 | 0.792E+00 | -0.121E+01 |
| GROUPS C-G | 0.200E+02 | 0.250E+02 | -0.111E+01 | -0.102E+01 | -0.163E+01 | -0.167E+01 | 0.199E+01 |
| GROUPS D-G | 0.318E+02 | 0.240E+02 | 0.943E+00 | 0.599E-11 | -0.248E+01 | -0.259E+01 | 0.450E+01 |
| GROUPS E-G | 0.144E+02 | 0.170E+02 | 0.204E+00 | -0.410E+00 | -0.219E+01 | -0.191E+01 | 0.436E+01 |
| GROUPS F-G | 0.976E+01 | 0.999E+01 | 0.108E+01 | -0.158E+01 | -0.350E+01 | -0.140E+01 | 0.282E+01 |
| GROUPS A-C | -0.168E+02 | -0.217E+02 | -0.222E+00 | -0.218E+01 | 0.237E+01 | 0.270E+01 | -0.398E+01 |
| GROUPS A-E | -0.162E+02 | -0.198E+02 | -0.108E+01 | -0.145E+01 | 0.290E+01 | 0.308E+01 | -0.696E+01 |
| GROUPS C-E | -0.906E+01 | -0.900E+01 | -0.101E+01 | -0.340E-11 | 0.116E+01 | 0.105E+01 | -0.194E+01 |
| GROUPS B-D | -0.213E+02 | -0.173E+02 | -0.212E+01 | 0.461E+00 | 0.197E+01 | 0.196E+01 | -0.477E+01 |
| GROUPS B-F | -0.804E+01 | -0.834E+01 | -0.122E+01 | 0.976E+00 | 0.268E+01 | 0.140E+01 | -0.302E+01 |
| GROUPS D-F | -0.347E+01 | -0.348E+01 | -0.976E+00 | 0.120E+01 | 0.716E+00 | -0.794E+00 | -0.144E+01 |

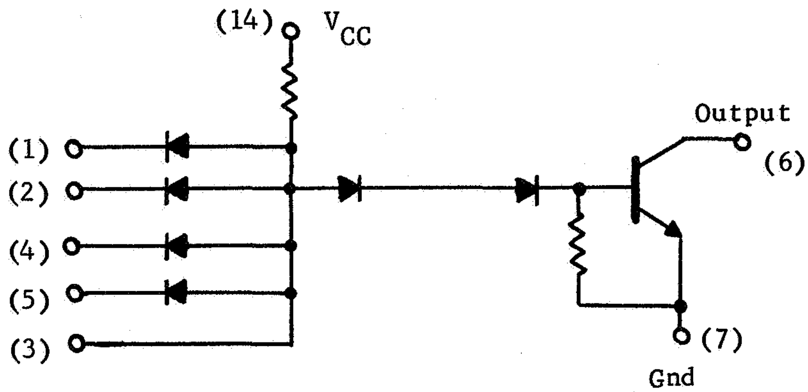
TEXAS INSTRUMENT SN54L71

| | I(IN R1) | I(CC) | MIN CP AMP | MIN V(S1) | T(DR) | T(OF) |
|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | |
| NUMBER | 9 | 9 | 10 | 9 | 10 | 10 |
| INITIAL MEAN | 0.389E+04 | 0.823E-03 | 0.129E+01 | 0.130E+01 | 0.231E-07 | 0.540E-07 |
| AVERAGE CHANGE | -0.122E-05 | -0.303E-04 | -0.210E-01 | -0.131E-01 | 0.280E-08 | 0.174E-07 |
| STD OF MEAN | 0.833E-06 | 0.292E-05 | 0.173E-01 | 0.138E-01 | 0.140E-08 | 0.272E-08 |
| AVE PER CENT CHANGE | -0.315E+01 | -0.375E+01 | -0.161E+01 | -0.100E+01 | 0.123E+02 | 0.324E+02 |
| INTERVAL ESTIMATE | -0.479E+01 | -0.396E+01 | -0.258E+01 | -0.182E+01 | 0.779E+01 | 0.286E+02 |
| AS PER CENT | -0.150E+01 | -0.341E+01 | -0.667E+00 | -0.194E+00 | 0.165E+02 | 0.358E+02 |
| PER CENT AVE CHANGE | -0.314E+01 | -0.369E+01 | -0.162E+01 | -0.101E+01 | 0.121E+02 | 0.322E+02 |
| **0.5 MEV UNBIASED-B** | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.358E-04 | 0.752E-03 | 0.129E+01 | 0.129E+01 | 0.240E-07 | 0.582E-07 |
| AVERAGE CHANGE | -0.140E-05 | -0.280E-04 | -0.160E-01 | -0.124E-01 | 0.260E-08 | 0.132E-07 |
| STD OF MEAN | 0.548E-06 | 0.412E-05 | 0.182E-01 | 0.699E-02 | 0.114E-08 | 0.239E-08 |
| AVE PER CENT CHANGE | -0.390E+01 | -0.372E+01 | -0.123E+01 | -0.956E+00 | 0.109E+02 | 0.226E+02 |
| INTERVAL ESTIMATE | -0.581E+01 | -0.441E+01 | -0.300E+01 | -0.163E+01 | 0.494E+01 | 0.176E+02 |
| AS PER CENT | -0.201E+01 | -0.304E+01 | 0.510E+00 | -0.289E+00 | 0.167E+02 | 0.278E+02 |
| PER CENT AVE CHANGE | -0.391E+01 | -0.373E+01 | -0.124E+01 | -0.961E+00 | 0.108E+02 | 0.227E+02 |
| **1.0 MEV BIASED-C** | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.361E-04 | 0.768E-03 | 0.129E+01 | 0.129E+01 | 0.237E-07 | 0.583E-07 |
| AVERAGE CHANGE | -0.160E-05 | -0.430E-04 | -0.240E-01 | -0.183E-01 | 0.550E-08 | 0.201E-07 |
| STD OF MEAN | 0.843E-06 | 0.298E-05 | 0.107E-01 | 0.383E-01 | 0.165E-08 | 0.420E-08 |
| AVE PER CENT CHANGE | -0.439E+01 | -0.561E+01 | -0.185E+01 | -0.133E+01 | 0.234E+02 | 0.351E+02 |
| INTERVAL ESTIMATE | -0.610E+01 | -0.588E+01 | -0.245E+01 | -0.355E+01 | 0.182E+02 | 0.293E+02 |
| AS PER CENT | -0.276E+01 | -0.532E+01 | -0.126E+01 | 0.707E+00 | 0.282E+02 | 0.396E+02 |
| PER CENT AVE CHANGE | -0.443E+01 | -0.560E+01 | -0.186E+01 | -0.142E+01 | 0.232E+02 | 0.345E+02 |
| **1.0 MEV UNBIASED-D** | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.388E-04 | 0.827E-03 | 0.125E+01 | 0.129E+01 | 0.222E-07 | 0.506E-07 |
| AVERAGE CHANGE | -0.800E-06 | -0.400E-04 | 0.140E-01 | -0.182E-01 | 0.660E-08 | 0.168E-07 |
| STD OF MEAN | 0.447E-06 | 0.187E-05 | 0.894E-02 | 0.476E-02 | 0.152E-08 | 0.363E-08 |
| AVE PER CENT CHANGE | -0.212E+01 | -0.485E+01 | 0.112E+01 | -0.141E+01 | 0.302E+02 | 0.344E+02 |
| INTERVAL ESTIMATE | -0.349E+01 | -0.512E+01 | 0.232E+00 | -0.186E+01 | 0.212E+02 | 0.243E+02 |
| AS PER CENT | -0.631E+00 | -0.455E+01 | 0.201E+01 | -0.949E+00 | 0.382E+02 | 0.421E+02 |
| PER CENT AVE CHANGE | -0.206E+01 | -0.483E+01 | 0.112E+01 | -0.141E+01 | 0.297E+02 | 0.332E+02 |
| **1.5 MEV BIASED-E** | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.370E-04 | 0.795E-03 | 0.126E+01 | 0.130E+01 | 0.240E-07 | 0.583E-07 |
| AVERAGE CHANGE | -0.900E-06 | -0.558E-04 | -0.800E-02 | -0.371E-01 | -0.500E-08 | -0.278E-07 |
| STD OF MEAN | 0.160E-05 | 0.329E-05 | 0.244E-01 | 0.745E-02 | 0.302E-08 | 0.498E-08 |
| AVE PER CENT CHANGE | -0.239E+01 | -0.702E+01 | -0.600E+00 | -0.285E+01 | -0.206E+02 | -0.443E+02 |
| INTERVAL ESTIMATE | -0.552E+01 | -0.731E+01 | -0.201E+01 | -0.327E+01 | -0.118E+02 | -0.416E+02 |
| AS PER CENT | 0.651E+00 | -0.672E+01 | 0.748E+00 | -0.245E+01 | 0.298E+02 | 0.538E+02 |
| PER CENT AVE CHANGE | -0.243E+01 | -0.701E+01 | -0.632E+00 | -0.286E+01 | 0.208E+02 | 0.477E+02 |

TEXAS INSTRUMENT SN54L71

| | I(IN R1) | I(CC) | MIN CP AMP | MIN V(S1) | T(DR) | T(DF) |
|---|---|---|---|---|---|---|
| 1.5 MEV UNBIASED-F | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.370E-04 | 0.804E-03 | 0.126E+01 | 0.129E+01 | 0.238E-07 | 0.588E-07 |
| AVERAGE CHANGE | -0.140E-05 | -0.476E-04 | 0.200E-02 | -0.262E-01 | 0.840E-08 | 0.184E-07 |
| STD OF MEAN | 0.548E-06 | 0.422E-05 | 0.110E-01 | 0.383E-02 | 0.114E-08 | 0.773E-08 |
| AVE PER CENT CHANGE | -0.373E+01 | -0.592E+01 | 0.164E+00 | -0.204E+01 | 0.355E+02 | 0.329E+02 |
| INTERVAL ESTIMATE | -0.562E+01 | -0.657E+01 | -0.924E+00 | -0.240E+01 | 0.293E+02 | 0.150E+02 |
| AS PER CENT | -0.195E+01 | -0.527E+01 | 0.124E+01 | -0.167E+01 | 0.412E+02 | 0.470E+02 |
| PER CENT AVE CHANGE | -0.378E+01 | -0.592E+01 | 0.159E+00 | -0.204E+01 | 0.353E+02 | 0.313E+02 |
| CONTROL-G | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.336E-04 | 0.111E-02 | 0.126E+01 | 0.129E+01 | 0.246E-07 | 0.570E-07 |
| AVERAGE CHANGE | 0.600E-06 | -0.800E-06 | -0.400E-02 | -0.154E-01 | -0.160E-08 | 0.240E-08 |
| STD OF MEAN | 0.195E-05 | 0.110E-05 | 0.152E-01 | 0.106E-01 | 0.270E-08 | 0.148E-08 |
| AVE PER CENT CHANGE | 0.327E+01 | -0.122E+00 | -0.305E+00 | -0.119E+01 | -0.706E+01 | 0.537E+01 |
| INTERVAL ESTIMATE | -0.542E+01 | -0.194E+00 | -0.181E+01 | -0.221E+01 | -0.201E+02 | 0.168E+01 |
| AS PER CENT | 0.899E+01 | 0.502E-01 | 0.118E+01 | -0.176E+00 | 0.713E+01 | 0.814E+01 |
| PER CENT AVE CHANGE | 0.179E+01 | -0.718E-01 | -0.317E+00 | -0.119E+01 | -0.650E+01 | 0.491E+01 |
| F-TESTS | | | | | | |
| GROUPS A-B-G | 0.481E+01 | 0.173E+03 | 0.166E+01 | 0.943E-01 | 0.115E+02 | 0.618E+02 |
| GROUPS C-D-G | 0.613E+01 | 0.550E+03 | 0.187E+02 | 0.191E-01 | 0.288E+02 | 0.393E+02 |
| GROUPS E-F-G | 0.243E+01 | 0.513E+03 | 0.421E+00 | 0.137E+02 | 0.192E+02 | 0.376E+02 |
| GROUPS A-C-E-G | 0.338E+01 | 0.433E+03 | 0.232E+01 | 0.214E+01 | 0.133E+02 | 0.490E+02 |
| GROUPS B-D-F-G | 0.387E+01 | 0.213E+03 | 0.411E+01 | 0.355E+01 | 0.325E+02 | 0.122E+02 |
| GROUPS ALL | 0.245E+01 | 0.205E+03 | 0.421E+01 | 0.172E+01 | 0.141E+02 | 0.212E+02 |
| T-TESTS | | | | | | |
| GROUPS A-B | 0.425E+00 | -0.124E+01 | -0.520E+00 | -0.107E+00 | 0.276E+00 | 0.293E+01 |
| GROUPS C-D | -0.196E+01 | -0.204E+01 | -0.678E+01 | -0.571E-02 | -0.125E+01 | 0.149E+01 |
| GROUPS E-F | 0.670E+00 | -0.415E+01 | -0.861E+00 | -0.304E+01 | -0.240E+01 | 0.288E+01 |
| GROUPS A-G | -0.248E+01 | -0.215E+02 | -0.186E+01 | 0.321E+00 | 0.423E+01 | 0.111E+02 |
| GROUPS B-G | -0.221E+01 | -0.143E+02 | -0.113E+01 | 0.529E+00 | 0.320E+01 | 0.827E+01 |
| GROUPS C-G | -0.312E+01 | -0.302E+02 | -0.297E+01 | -0.163E+00 | 0.638E+01 | 0.879E+01 |
| GROUPS D-G | -0.157E+01 | -0.404E+02 | 0.229E+01 | -0.540E+00 | 0.592E+01 | 0.798E+01 |
| GROUPS E-G | -0.160E+01 | -0.358E+02 | -0.332E+00 | -0.464E+01 | 0.412E+01 | 0.108E+02 |
| GROUPS F-G | -0.221E+01 | -0.240E+02 | 0.717E+00 | -0.215E+01 | 0.762E+01 | 0.443E+01 |
| GROUPS A-C | 0.980E+00 | 0.934E+01 | 0.466E+00 | 0.384E+00 | -0.395E+01 | -0.171E+01 |
| GROUPS A-E | -0.542E+00 | 0.178E+02 | -0.137E+01 | 0.479E+01 | -0.209E+01 | -0.579E+01 |
| GROUPS C-E | -0.123E+01 | 0.911E+01 | -0.190E+01 | 0.152E+01 | 0.460E+00 | -0.374E+01 |
| GROUPS B-D | -0.190E+01 | 0.593E+01 | -0.331E+01 | 0.153E+01 | -0.471E+01 | -0.185E+01 |
| GROUPS B-F | 0. | 0.743E+01 | -0.190E+01 | 0.387E+01 | -0.804E+01 | -0.144E+01 |
| GROUPS D-F | 0.190E+01 | 0.368E+01 | 0.190E+01 | 0.293E+01 | -0.212E+01 | -0.419E+00 |

Radiation, Inc. RD310



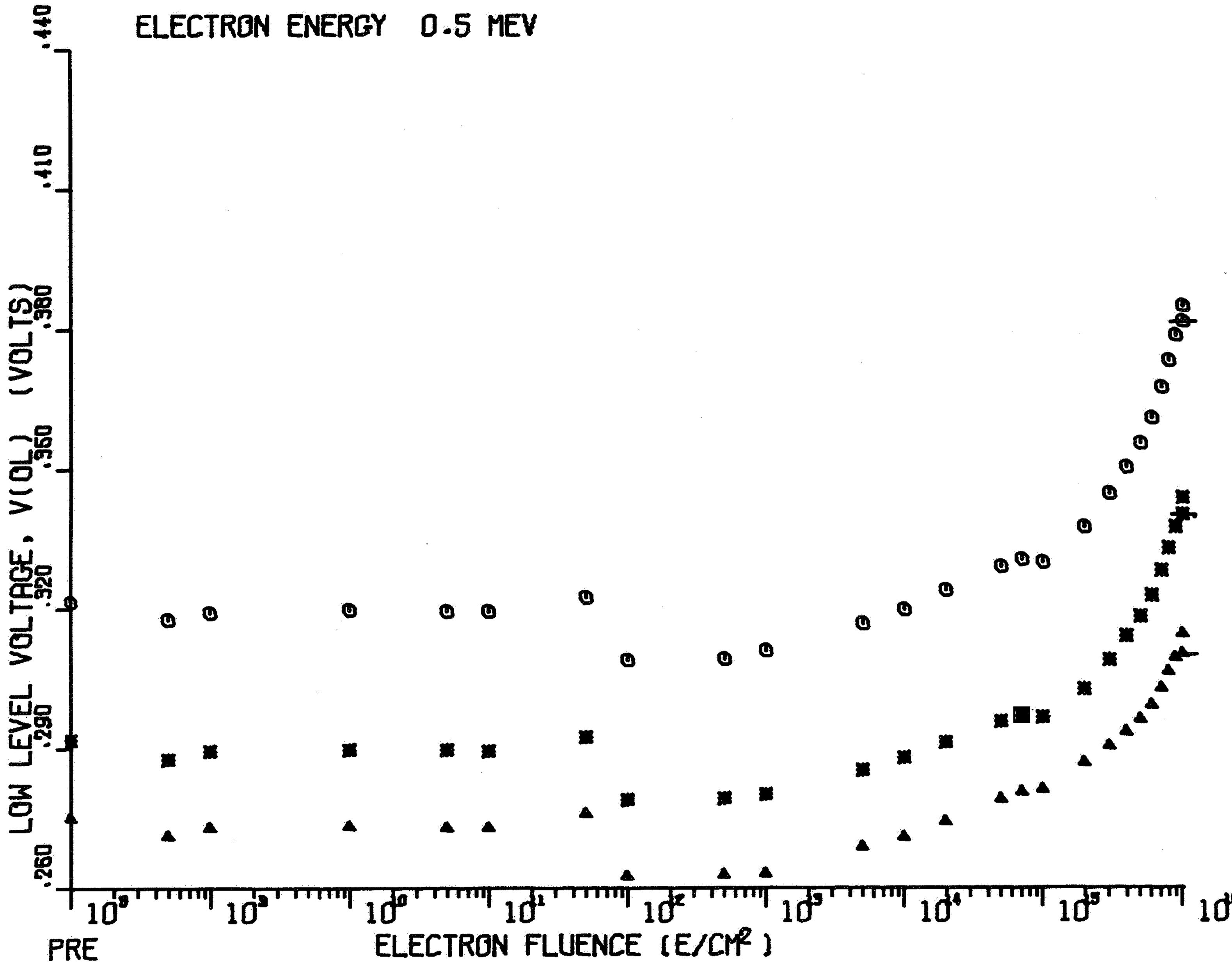

TEST CONDITIONS:

1. Pin 14, 5.0 volts.
2. Pin 7, ground.
3. Temperature 25 C.

TEST PARAMETERS:

1. Output-voltage levels ($V_{OH}$, $V_{OL}$).
2. Input-voltage levels ($V_{IH}$, $V_{IL}$).
3. Input leakage current.
4. Input drive current.
5. Diode forward voltage.
6. Resistance.
7. Propagation delay.

FIGURE 115. TEST PLAN FOR RD310 GATES




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD310 GATES.

FIGURE 116

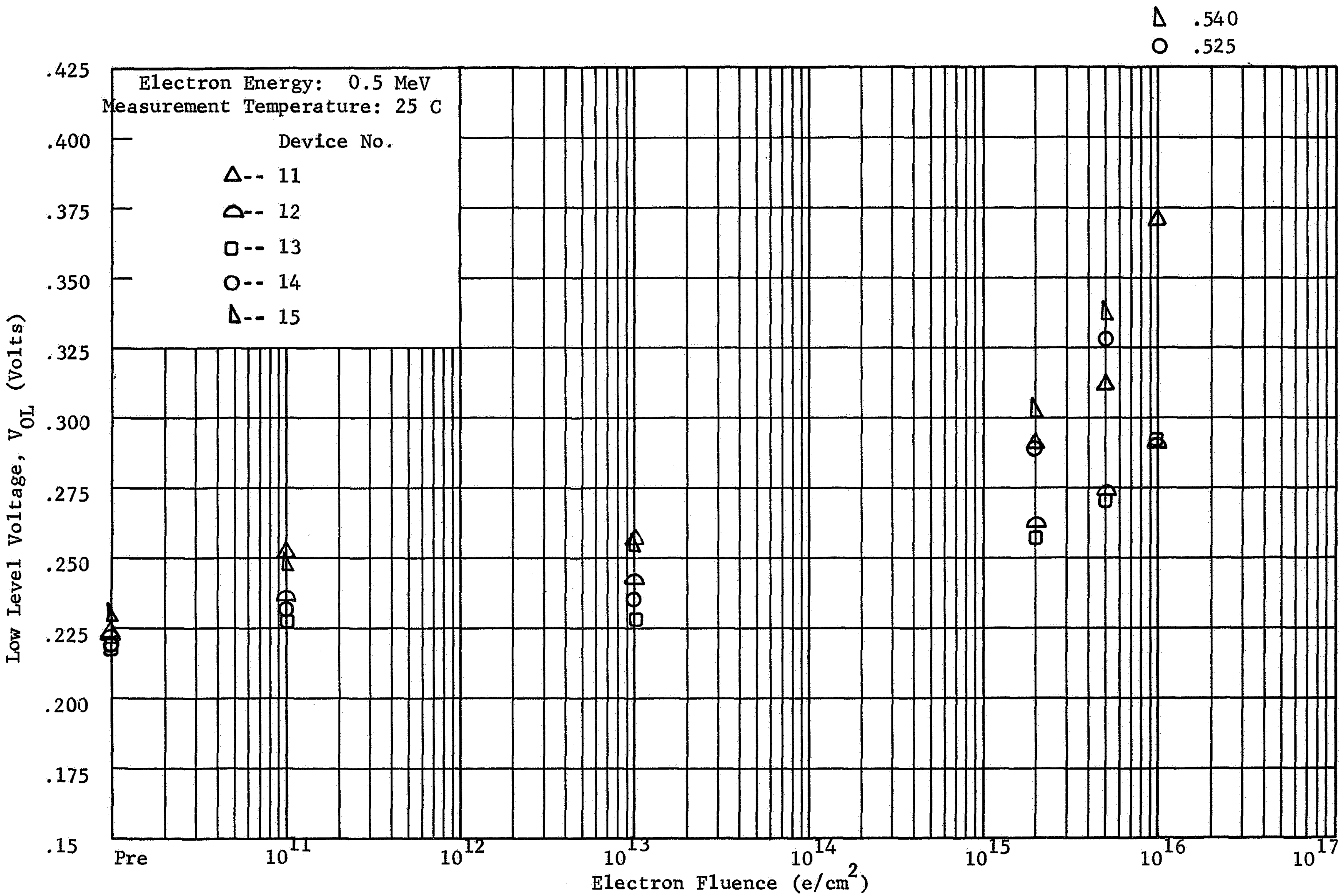
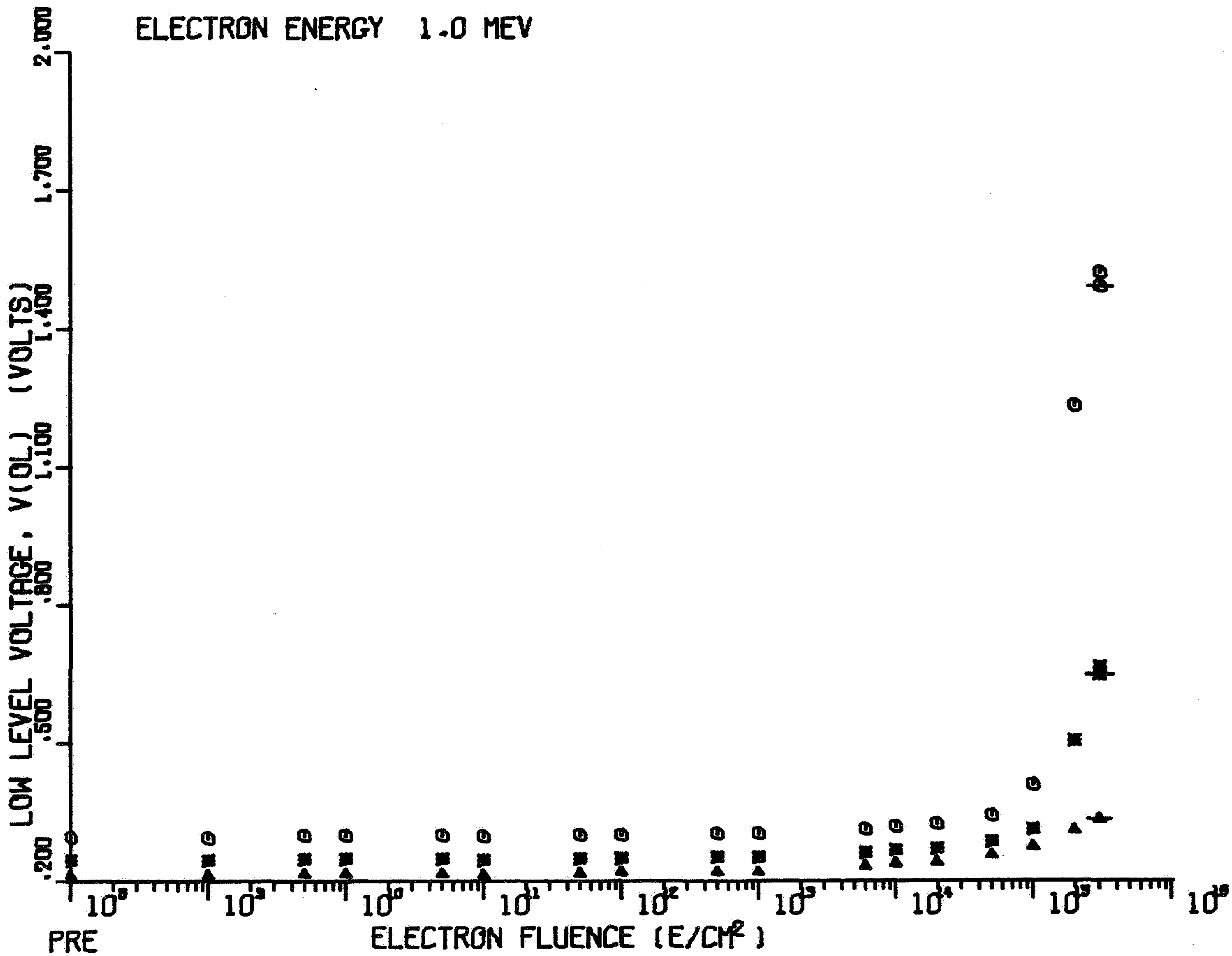



FIGURE 117. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD 310 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD310 GATES.

FIGURE 118

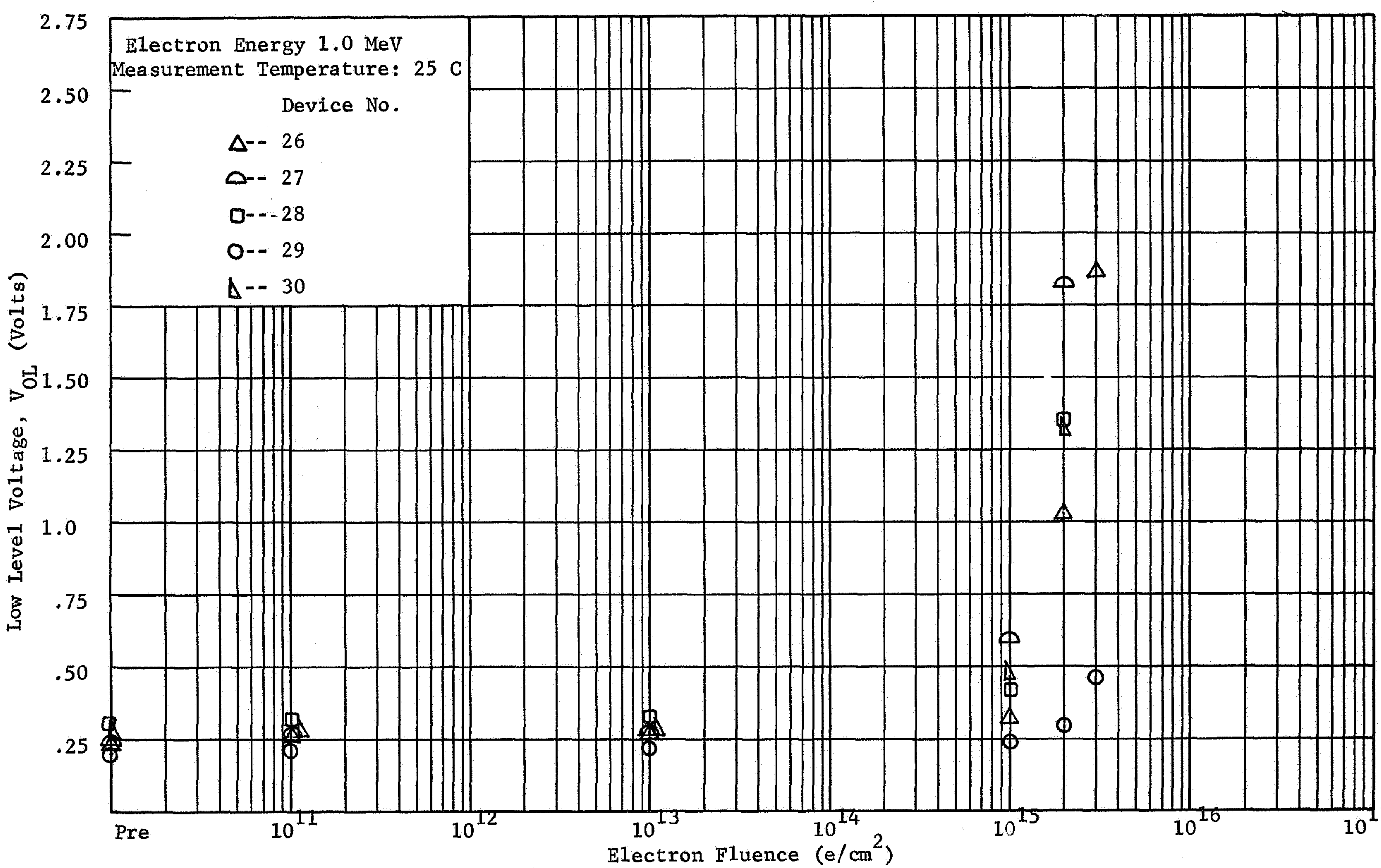
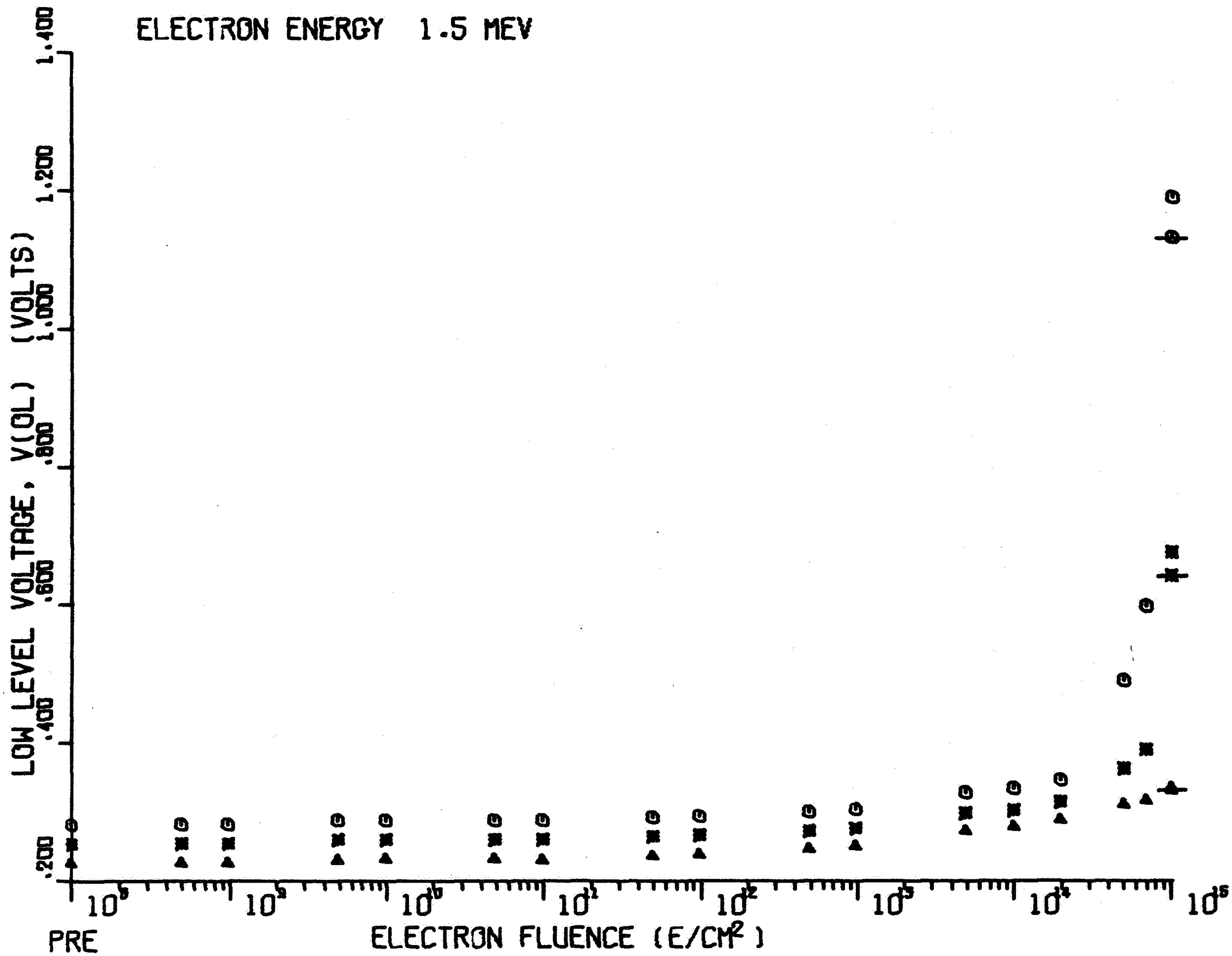



FIGURE 119. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD 310 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD310 GATES.

FIGURE 120

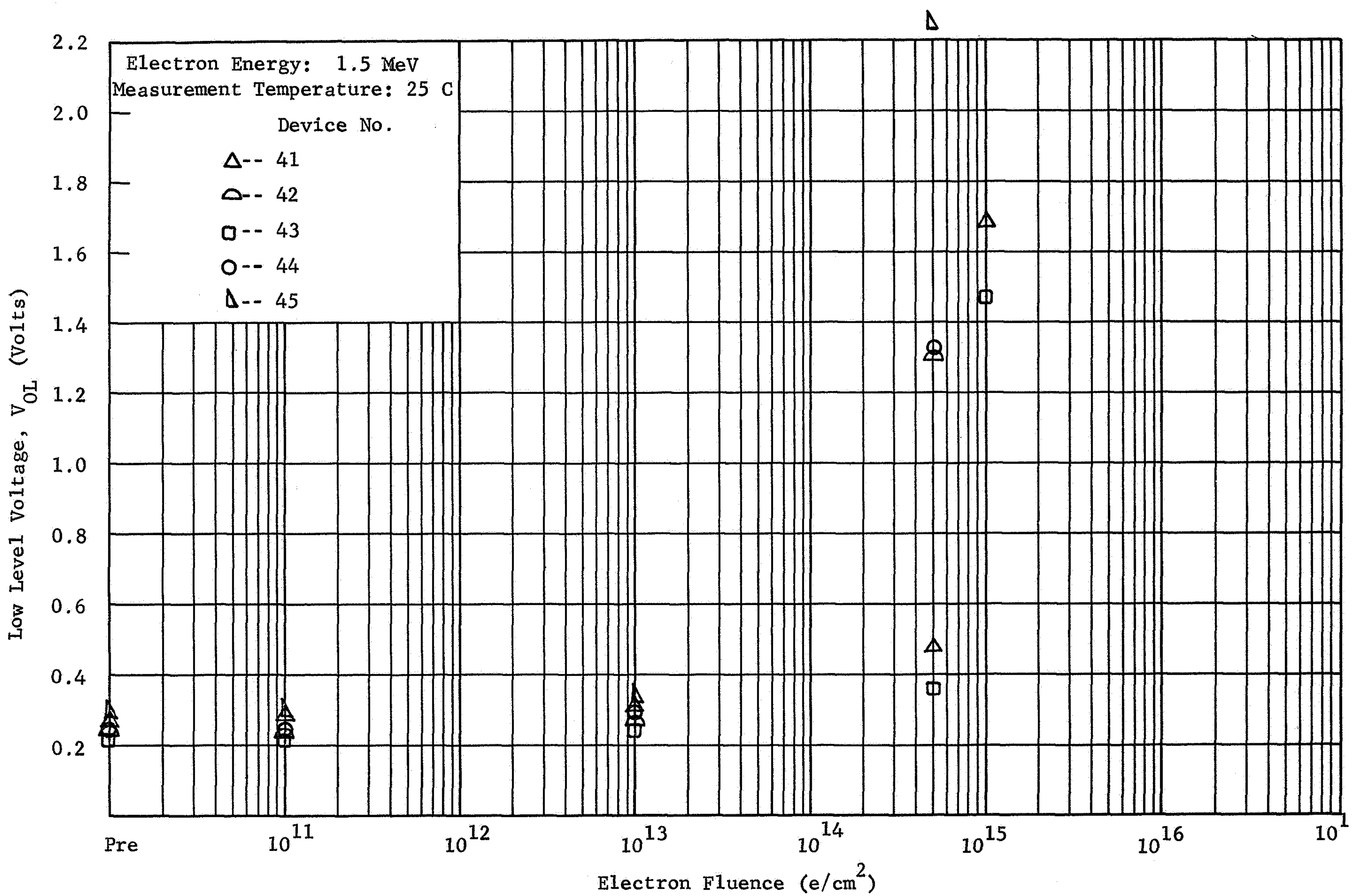



FIGURE 121. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD 310 GATES.

RADIATION RD310

| | V(OH) | V(OL) | V(IL) | V(IH) | I DRIVE | V(DF) | RESISTANCE |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.243E+00 | 0.138E+01 | 0.144E+01 | 0.216E-02 | 0.778E+00 | 0.190E+04 |
| AVERAGE CHANGE | 0.200E-03 | 0.607E-01 | -0.344E-01 | -0.474E-01 | -0.390E-04 | 0.457E-02 | 0.408E+02 |
| STD OF MEAN | 0.103E-02 | 0.901E-02 | 0.138E-01 | 0.114E-01 | 0.953E-05 | 0.730E-03 | 0.294E+02 |
| AVE PER CENT CHANGE | 0.400E-02 | 0.250E+02 | -0.248E+01 | -0.329E+01 | -0.180E+01 | 0.587E+00 | 0.209E+01 |
| INTERVAL ESTIMATE | -0.108E-01 | 0.223E+02 | -0.320E+01 | -0.387E+01 | -0.212E+01 | 0.520E+00 | 0.104E+01 |
| AS PER CENT | 0.188E-01 | 0.276E+02 | -0.178E+01 | -0.273E+01 | -0.149E+01 | 0.654E+00 | 0.326E+01 |
| PER CENT AVE CHANGE | 0.400E-02 | 0.250E+02 | -0.249E+01 | -0.330E+01 | -0.181E+01 | 0.587E+00 | 0.215E+01 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.221E+00 | 0.138E+01 | 0.144E+01 | 0.213E-02 | 0.777E+00 | 0.193E+04 |
| AVERAGE CHANGE | 0.200E-03 | 0.693E-01 | -0.446E-01 | -0.562E-01 | -0.262E-04 | 0.606E-02 | 0.234E+02 |
| STD OF MEAN | 0.447E-03 | 0.275E-01 | 0.658E-02 | 0.657E-02 | 0.904E-05 | 0.124E-02 | 0.345E+02 |
| AVE PER CENT CHANGE | 0.400E-02 | 0.310E+02 | -0.322E+01 | -0.390E+01 | -0.123E+01 | 0.779E+00 | 0.114E+01 |
| INTERVAL ESTIMATE | -0.710E-02 | 0.159E+02 | -0.381E+01 | -0.447E+01 | -0.176E+01 | 0.581E+00 | -0.101E+01 |
| AS PER CENT | 0.151E-01 | 0.467E+02 | -0.263E+01 | -0.334E+01 | -0.705E+00 | 0.978E+00 | 0.342E+01 |
| PER CENT AVE CHANGE | 0.400E-02 | 0.313E+02 | -0.322E+01 | -0.390E+01 | -0.123E+01 | 0.780E+00 | 0.121E+01 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.223E+00 | 0.139E+01 | 0.144E+01 | 0.211E-02 | 0.771E+00 | 0.195E+04 |
| AVERAGE CHANGE | 0.200E-03 | 0.435E+00 | -0.703E-01 | -0.745E-01 | -0.381E-04 | 0.133E-01 | 0.227E+02 |
| STD OF MEAN | 0.422E-03 | 0.365E+00 | 0.835E-02 | 0.881E-02 | 0.606E-05 | 0.992E-03 | 0.241E+02 |
| AVE PER CENT CHANGE | 0.400E-02 | 0.187E+03 | -0.507E+01 | -0.516E+01 | -0.182E+01 | 0.173E+01 | 0.111E+01 |
| INTERVAL ESTIMATE | -0.203E-02 | 0.777E+02 | -0.550E+01 | -0.559E+01 | -0.201E+01 | 0.163E+01 | 0.281E+00 |
| AS PER CENT | 0.100E-01 | 0.312E+03 | -0.464E+01 | -0.472E+01 | -0.160E+01 | 0.182E+01 | 0.204E+01 |
| PER CENT AVE CHANGE | 0.400E-02 | 0.195E+03 | -0.507E+01 | -0.516E+01 | -0.180E+01 | 0.173E+01 | 0.116E+01 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.231E+00 | 0.138E+01 | 0.144E+01 | 0.218E-02 | 0.776E+00 | 0.188E+04 |
| AVERAGE CHANGE | 0. | 0.100E+01 | -0.668E-01 | -0.664E-01 | -0.368E-04 | 0.149E-01 | 0.234E+02 |
| STD OF MEAN | 0. | 0.536E+00 | 0.120E-01 | 0.151E-01 | 0.769E-05 | 0.957E-03 | 0.358E+02 |
| AVE PER CENT CHANGE | 0. | 0.426E+03 | -0.482E+01 | -0.460E+01 | -0.171E+01 | 0.192E+01 | 0.114E+01 |
| INTERVAL ESTIMATE | 0. | 0.145E+03 | -0.591E+01 | -0.591E+01 | -0.213E+01 | 0.177E+01 | -0.112E+01 |
| AS PER CENT | 0. | 0.722E+03 | -0.375E+01 | -0.331E+01 | -0.125E+01 | 0.207E+01 | 0.360E+01 |
| PER CENT AVE CHANGE | 0. | 0.434E+03 | -0.483E+01 | -0.461E+01 | -0.169E+01 | 0.192E+01 | 0.124E+01 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.229E+00 | 0.139E+01 | 0.145E+01 | 0.223E-02 | 0.773E+00 | 0.182E+04 |
| AVERAGE CHANGE | 0. | 0.400E+00 | -0.655E-01 | -0.711E-01 | -0.296E-04 | 0.121E-01 | 0.341E+02 |
| STD OF MEAN | 0. | 0.322E+00 | 0.187E-01 | 0.204E-01 | 0.768E-05 | 0.163E-02 | 0.237E+02 |
| AVE PER CENT CHANGE | 0. | 0.174E+03 | -0.471E+01 | -0.490E+01 | -0.133E+01 | 0.157E+01 | 0.182E+01 |
| INTERVAL ESTIMATE | 0. | 0.740E+02 | -0.569E+01 | -0.593E+01 | -0.157E+01 | 0.142E+01 | 0.941E+00 |
| AS PER CENT | 0. | 0.275E+03 | -0.376E+01 | -0.391E+01 | -0.108E+01 | 0.172E+01 | 0.280E+01 |
| PER CENT AVE CHANGE | 0. | 0.175E+03 | -0.472E+01 | -0.492E+01 | -0.133E+01 | 0.157E+01 | 0.187E+01 |

RADIATION RD310

| | V(OH) | V(OL) | V(IL) | V(IH) | I DRIVE | V(OF) | RESISTANCE |
|---|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.217E+00 | 0.138E+01 | 0.144E+01 | 0.196E-02 | 0.774E+00 | 0.208E+04 |
| AVERAGE CHANGE | 0. | 0.135E+01 | -0.706E-01 | -0.702E-01 | -0.296E-04 | 0.185E-01 | 0.396E+02 |
| STD OF MEAN | 0. | 0.563E+00 | 0.184E-01 | 0.276E-01 | 0.913E-05 | 0.160E-02 | 0.141E+02 |
| AVE PER CENT CHANGE | 0. | 0.623E+03 | -0.510E+01 | -0.485E+01 | -0.151E+01 | 0.239E+01 | 0.183E+01 |
| INTERVAL ESTIMATE | 0. | 0.301E+03 | -0.675E+01 | -0.723E+01 | -0.209E+01 | 0.215E+01 | 0.102E+01 |
| AS PER CENT | 0. | 0.944E+03 | -0.346E+01 | -0.249E+01 | -0.931E+00 | 0.263E+01 | 0.270E+01 |
| PER CENT AVE CHANGE | 0. | 0.623E+03 | -0.510E+01 | -0.486E+01 | -0.151E+01 | 0.239E+01 | 0.166E+01 |
| **CONTROL-G** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.224E+00 | 0.138E+01 | 0.144E+01 | 0.192E-02 | 0.775E+00 | 0.211E+04 |
| AVERAGE CHANGE | 0. | -0.340E-03 | -0.320E-02 | -0.194E-01 | -0.100E-05 | 0.200E-03 | 0.144E+02 |
| STD OF MEAN | 0.707E-03 | 0.110E-02 | 0.563E-02 | 0.472E-02 | 0.100E-05 | 0.442E-03 | 0.129E+02 |
| AVE PER CENT CHANGE | 0.800E-06 | -0.147E+00 | -0.232E+00 | -0.134E+01 | -0.519E-01 | 0.256E-01 | 0.679E+00 |
| INTERVAL ESTIMATE | -0.176E-01 | -0.758E+00 | -0.738E+00 | -0.175E+01 | -0.117E+00 | -0.449E-01 | -0.773E-01 |
| AS PER CENT | 0.176E-01 | 0.455E+00 | 0.274E+00 | -0.939E+00 | 0.126E-01 | 0.966E-01 | 0.144E+01 |
| PER CENT AVE CHANGE | 0. | -0.152E+00 | -0.232E+00 | -0.135E+01 | -0.521E-01 | 0.258E-01 | 0.681E+00 |
| **F-TESTS** | | | | | | | |
| GROUPS A-B-G | 0.103E+00 | 0.352E+02 | 0.204E+02 | 0.227E+02 | 0.356E+02 | 0.697E+02 | 0.168E+01 |
| GROUPS C-D-G | 0.472E+00 | 0.913E+01 | 0.104E+03 | 0.525E+02 | 0.750E+02 | 0.451E+03 | 0.212E+00 |
| GROUPS F-F-G | 0. | 0.191E+02 | 0.283E+02 | 0.123E+02 | 0.301E+02 | 0.221E+03 | 0.228E+01 |
| GROUPS A-C-E-G | 0.268E+00 | 0.598E+01 | 0.365E+02 | 0.236E+02 | 0.347E+02 | 0.232E+03 | 0.170E+01 |
| GROUPS B-D-F-G | 0.286E+00 | 0.151E+02 | 0.345E+02 | 0.102E+02 | 0.215E+02 | 0.283E+03 | 0.711E+00 |
| GROUPS ALL | 0.256E+00 | 0.139E+02 | 0.216E+02 | 0.102E+02 | 0.165E+02 | 0.186E+03 | 0.946E+00 |
| **T-TESTS** | | | | | | | |
| GROUPS A-B | 0. | -0.917E+00 | 0.155E+01 | 0.158E+01 | -0.249E+01 | -0.296E+01 | 0.102E+01 |
| GROUPS C-D | 0.104E+01 | -0.243E+01 | -0.664E+00 | -0.133E+01 | -0.359E+00 | -0.298E+01 | -0.454E-01 |
| GROUPS F-F | IIIII | -0.423E+01 | 0.500E+00 | -0.719E-01 | 0. | -0.732E+01 | -0.387E+00 |
| GROUPS A-G | 0.387E+00 | 0.148E+02 | -0.479E+01 | -0.518E+01 | -0.872E+01 | 0.122E+02 | 0.189E+01 |
| GROUPS B-G | 0.535E+00 | 0.566E+01 | -0.107E+02 | -0.102E+02 | -0.620E+01 | 0.905E+01 | 0.546E+00 |
| GROUPS C-G | 0.694E+00 | 0.261E+01 | -0.161E+02 | -0.129E+02 | -0.133E+02 | 0.278E+02 | 0.713E+00 |
| GROUPS D-G | 0. | 0.417E+01 | -0.107E+02 | -0.664E+01 | -0.103E+02 | 0.312E+02 | 0.529E+00 |
| GROUPS F-G | 0. | 0.273E+01 | -0.715E+01 | -0.551E+01 | -0.814E+01 | 0.158E+02 | 0.171E+01 |
| GROUPS F-G | 0. | 0.537E+01 | -0.785E+01 | -0.405E+01 | -0.697E+01 | 0.261E+02 | 0.283E+01 |
| GROUPS A-C | 0. | -0.324E+01 | 0.704E+01 | 0.593E+01 | -0.252E+00 | -0.224E+02 | 0.151E+01 |
| GROUPS A-E | 0.612E+00 | -0.333E+01 | 0.423E+01 | 0.321E+01 | -0.243E+01 | -0.134E+02 | 0.561E+00 |
| GROUPS C-F | 0.150E+01 | 0.225E+00 | -0.740E+00 | -0.485E+00 | -0.275E+01 | 0.105E+01 | -0.107E+01 |
| GROUPS B-D | 0.100E+01 | -0.388E+01 | 0.363E+01 | 0.138E+01 | 0.200E+01 | -0.126E+02 | 0. |
| GROUPS B-F | 0.100E+01 | -0.509E+01 | 0.298E+01 | 0.110E+01 | 0.592E+00 | -0.143E+02 | -0.911E+00 |
| GROUPS D-F | IIIII | -0.101E+01 | 0.388E+00 | 0.270E+00 | -0.135E+01 | -0.452E+01 | -0.884E+00 |

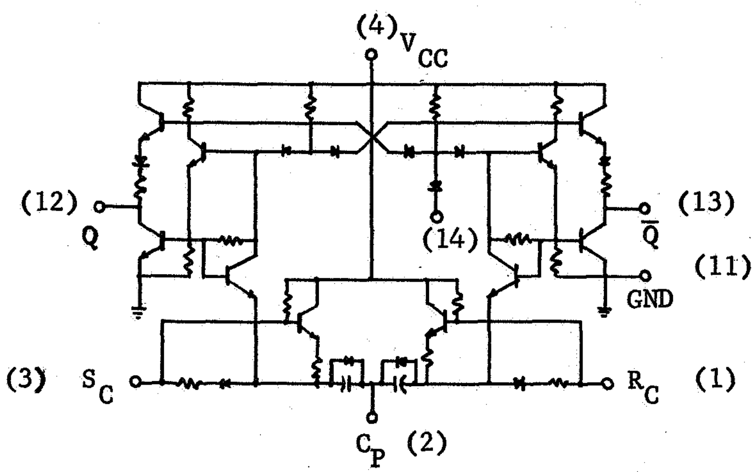
RADIATION RD310

| | T(DR) | T(DF) | I LEAKAGE |
|---|---|---|---|
| **0.5 MEV BIASED-A** | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.790E-08 | 0.133E-07 | 0.405E-09 |
| AVERAGE CHANGE | 0.155E-08 | -0.520E-08 | -0.190E-10 |
| STD OF MEAN | 0.100E-08 | 0.494E-08 | 0.101E-09 |
| AVE PER CENT CHANGE | 0.204E+02 | -0.311E+02 | 0.605E+01 |
| INTERVAL ESTIMATE | 0.106E+02 | -0.654E+02 | -0.225E+02 |
| AS PER CENT | 0.287E+02 | -0.125E+02 | 0.131E+02 |
| PER CENT AVE CHANGE | 0.196E+02 | -0.390E+02 | -0.469E+01 |
| **0.5 MEV UNBIASED-B** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.782E-08 | 0.136E-07 | 0.372E-09 |
| AVERAGE CHANGE | 0.158E-08 | -0.582E-08 | 0.122E-09 |
| STD OF MEAN | 0.169E-08 | 0.410E-08 | 0.151E-09 |
| AVE PER CENT CHANGE | 0.213E+02 | -0.375E+02 | 0.513E+02 |
| INTERVAL ESTIMATE | -0.656E+01 | -0.801E+02 | -0.177E+02 |
| AS PER CENT | 0.470E+02 | -0.532E+01 | 0.833E+02 |
| PER CENT AVE CHANGE | 0.202E+02 | -0.427E+02 | 0.328E+02 |
| **1.0 MEV BIASED-C** | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.806E-08 | 0.129E-07 | 0.606E-09 |
| AVERAGE CHANGE | 0.240E-09 | -0.408E-08 | 0.161E-09 |
| STD OF MEAN | 0.124E-08 | 0.797E-08 | 0.234E-09 |
| AVE PER CENT CHANGE | 0.438E+01 | -0.778E+01 | 0.870E+02 |
| INTERVAL ESTIMATE | -0.806E+01 | -0.759E+02 | -0.107E+01 |
| AS PER CENT | 0.140E+02 | 0.126E+02 | 0.542E+02 |
| PER CENT AVE CHANGE | 0.298E+01 | -0.317E+02 | 0.266E+02 |
| **1.0 MEV UNBIASED-D** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.794E-08 | 0.113E-07 | 0.101E-08 |
| AVERAGE CHANGE | 0.600E-10 | -0.240E-08 | 0.185E-08 |
| STD OF MEAN | 0.106E-08 | 0.670E-08 | 0.336E-08 |
| AVE PER CENT CHANGE | 0.176E+01 | -0.115E+01 | 0.399E+03 |
| INTERVAL ESTIMATE | -0.159E+02 | -0.949E+02 | -0.231E+03 |
| AS PER CENT | 0.174E+02 | 0.524E+02 | 0.599E+03 |
| PER CENT AVE CHANGE | 0.756E+00 | -0.212E+02 | 0.184E+03 |
| **1.5 MEV BIASED-E** | | | |
| NUMBER | 10 | 10 | 10 |
| INITIAL MEAN | 0.768E-08 | 0.162E-07 | 0.460E-09 |
| AVERAGE CHANGE | 0.820E-09 | -0.808E-08 | 0.212E-09 |
| STD OF MEAN | 0.114E-08 | 0.545E-08 | 0.107E-09 |
| AVE PER CENT CHANGE | 0.112E+02 | -0.416E+02 | 0.948E+02 |
| INTERVAL ESTIMATE | 0.867E-01 | -0.738E+02 | 0.294E+02 |
| AS PER CENT | 0.213E+02 | -0.258E+02 | 0.628E+02 |
| PER CENT AVE CHANGE | 0.107E+02 | -0.498E+02 | 0.461E+02 |

RADIATION RD310

| | T(DR) | T(DF) | I LEAKAGE |
|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.818E-08 | 0.129E-07 | 0.779E-09 |
| AVERAGE CHANGE | -0.180E-09 | -0.378E-08 | 0.495E-09 |
| STD OF MEAN | 0.303E-09 | 0.557E-08 | 0.220E-09 |
| AVE PER CENT CHANGE | -0.220E+01 | -0.181E+02 | 0.154E+03 |
| INTERVAL ESTIMATE | -0.680E+01 | -0.831E+02 | 0.284E+02 |
| AS PER CENT | 0.240E+01 | 0.244E+02 | 0.986E+02 |
| PER CENT AVE CHANGE | -0.220E+01 | -0.293E+02 | 0.635E+02 |
| **CONTROL-G** | | | |
| NUMBER | 5 | 5 | 5 |
| INITIAL MEAN | 0.888E-08 | 0.132E-07 | 0.420E-09 |
| AVERAGE CHANGE | 0.522E-08 | -0.470E-08 | -0.400E-10 |
| STD OF MEAN | 0.591E-08 | 0.475E-08 | 0.453E-10 |
| AVE PER CENT CHANGE | 0.616E+02 | -0.275E+02 | -0.761E+01 |
| INTERVAL ESTIMATE | -0.238E+02 | -0.803E+02 | -0.229E+02 |
| AS PER CENT | 0.141E+03 | 0.908E+01 | 0.386E+01 |
| PER CENT AVE CHANGE | 0.588E+02 | -0.356E+02 | -0.952E+01 |
| **F-TESTS** | | | |
| GROUPS A-B-G | 0.267E+01 | 0.711E-01 | 0.371E+01 |
| GROUPS C-D-G | 0.513E+01 | 0.148E+00 | 0.218E+01 |
| GROUPS E-F-G | 0.490E+01 | 0.134E+01 | 0.199E+02 |
| GROUPS A-C-E-G | 0.532E+01 | 0.812E+00 | 0.595E+01 |
| GROUPS B-D-F-G | 0.319E+01 | 0.363E+00 | 0.130E+01 |
| GROUPS ALL | 0.412E+01 | 0.697E+00 | 0.221E+01 |
| **T-TESTS** | | | |
| GROUPS A-B | -0.438E-01 | 0.241E+00 | -0.217E+01 |
| GROUPS C-D | 0.276E+00 | -0.404E+00 | -0.165E+01 |
| GROUPS E-F | 0.190E+01 | -0.143E+01 | -0.341E+01 |
| GROUPS A-G | -0.198E+01 | -0.187E+00 | 0.437E+00 |
| GROUPS B-G | -0.132E+01 | -0.399E+00 | 0.229E+01 |
| GROUPS C-G | -0.265E+01 | 0.159E+00 | 0.187E+01 |
| GROUPS D-G | -0.192E+01 | 0.626E+00 | 0.126E+01 |
| GROUPS E-G | -0.236E+01 | -0.118E+01 | 0.495E+01 |
| GROUPS F-G | -0.204E+01 | 0.281E+00 | 0.532E+01 |
| GROUPS A-C | 0.260E+01 | -0.378E+00 | -0.223E+01 |
| GROUPS A-E | 0.152E+01 | 0.124E+01 | -0.495E+01 |
| GROUPS C-E | -0.109E+01 | 0.131E+01 | -0.626E+00 |
| GROUPS B-D | 0.170E+01 | -0.973E+00 | -0.115E+01 |
| GROUPS B-F | 0.230E+01 | -0.659E+00 | -0.312E+01 |
| GROUPS D-F | 0.485E+00 | 0.354E+00 | 0.902E+00 |

Radiation, Inc. RD321



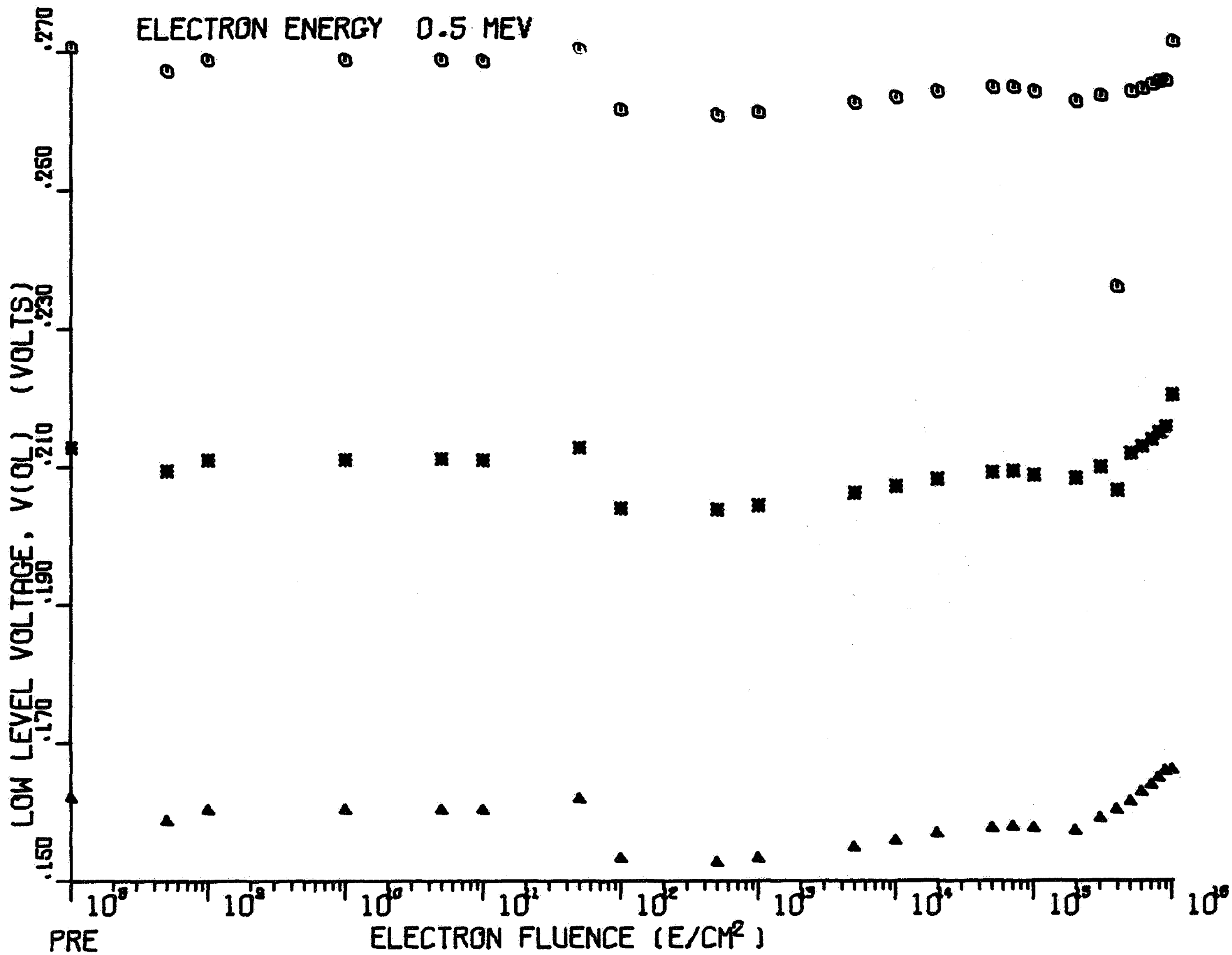

TEST CONDITIONS:

1. Pin 4, 5.0 volts.
2. Pin 11, ground.
3. Pin 14, open.
4. Temperature 25 C.

TEST PARAMETERS:

1. Output-voltage levels ($Q$, $\overline{Q}$) $V_H$, $V_L$.
2. Leakage current at $R_D$.
3. Input current at $R_D$, $R_C$, $C_P$.
4. Resistance.
5. Propagation delay.
6. Minimum clock amplitude.

FIGURE 122. TEST PLAN FOR RD321 FLIP-FLOP




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD321 FLIP-FLOPS.

FIGURE 123

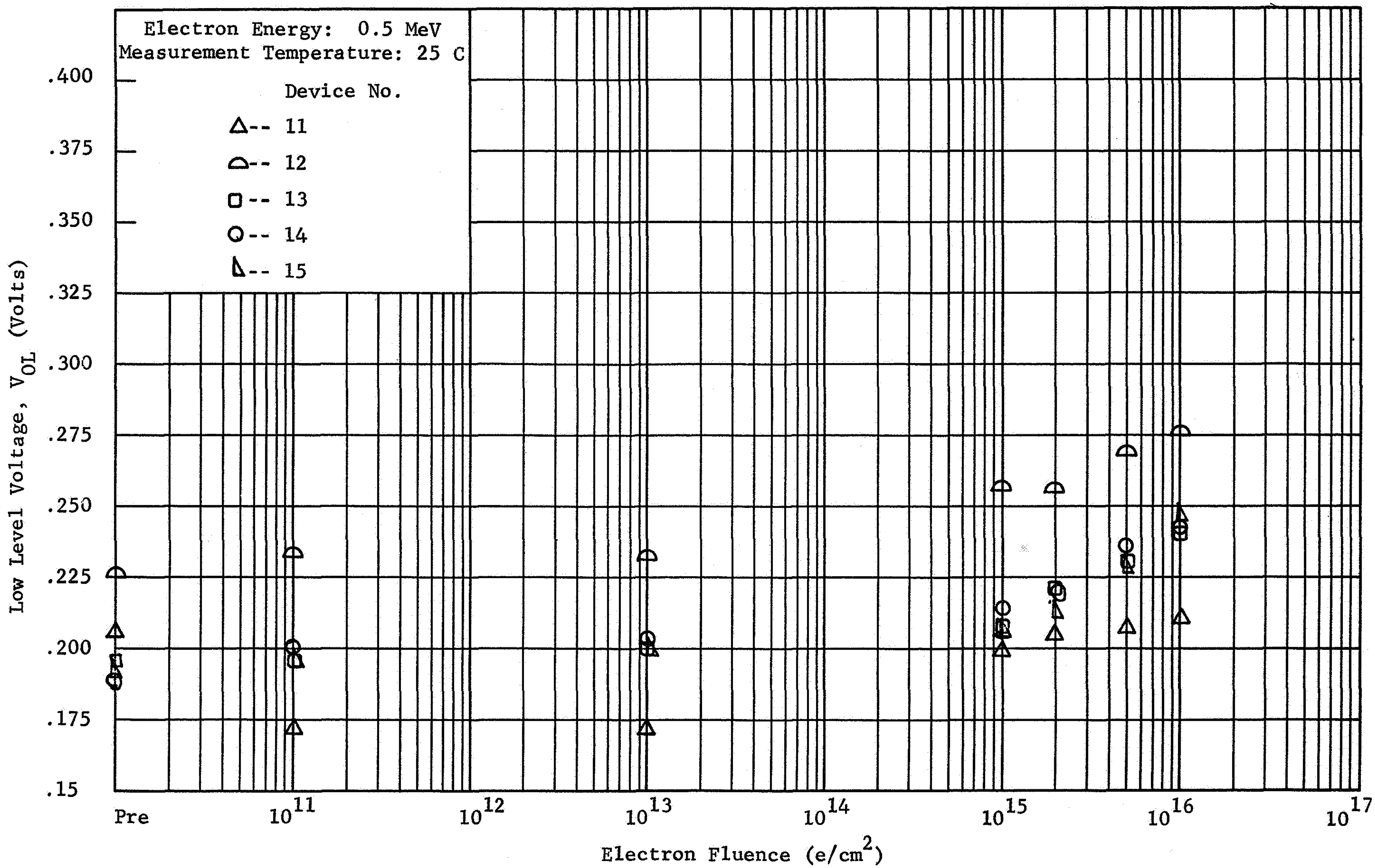
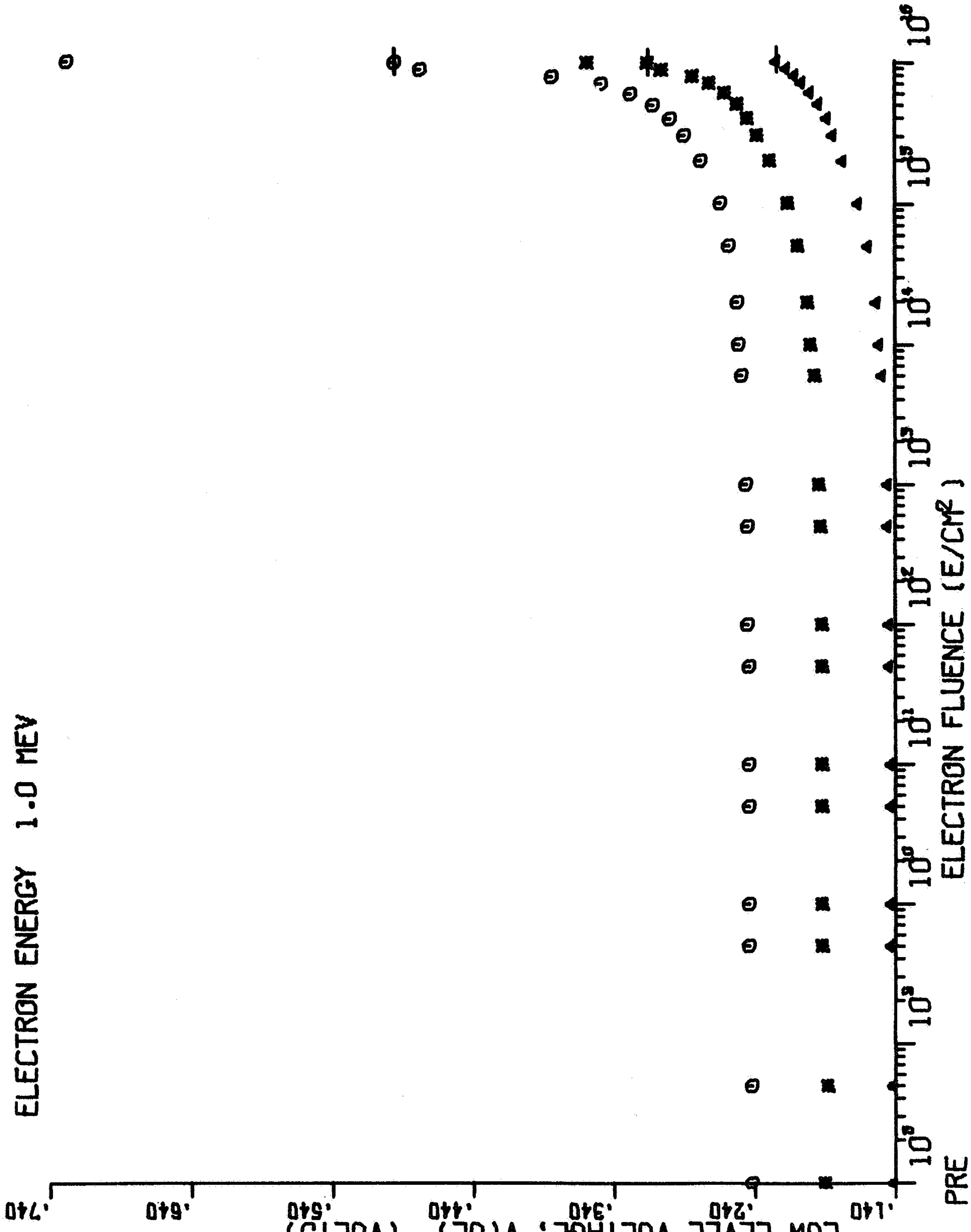



FIGURE 124. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD 321 FLIP-FLOPS.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD321 FLIP-FLOPS.

FIGURE 125

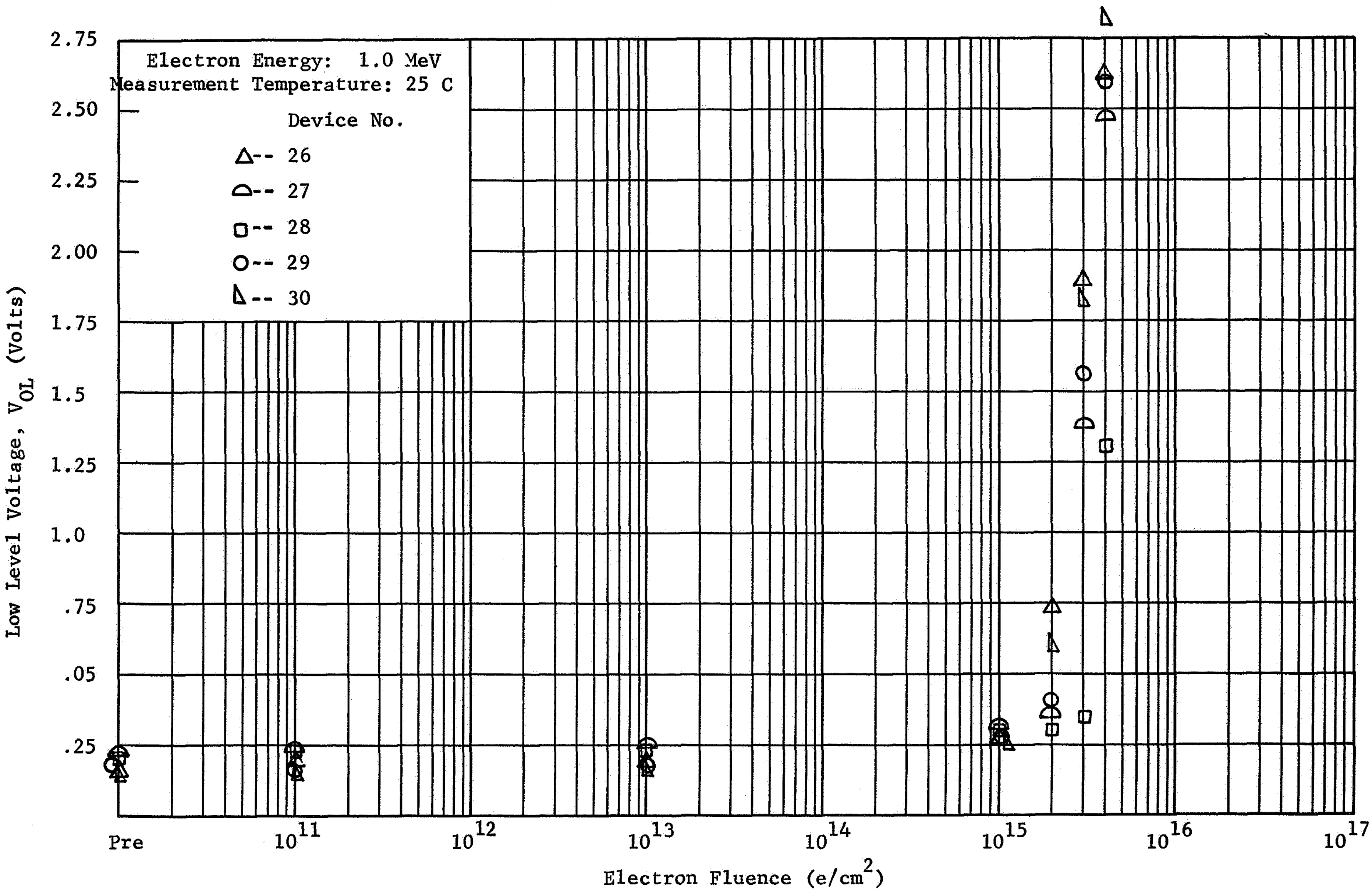
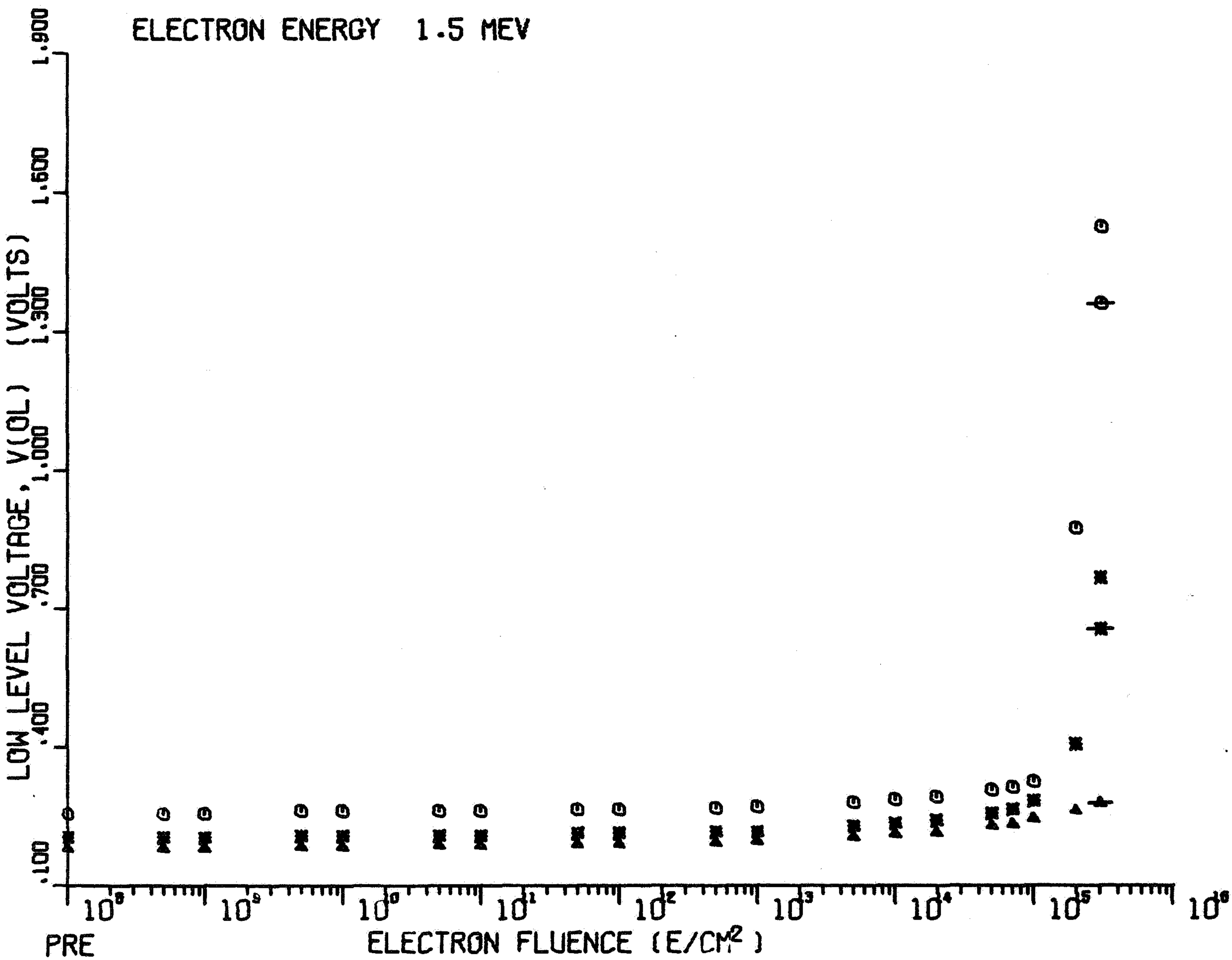
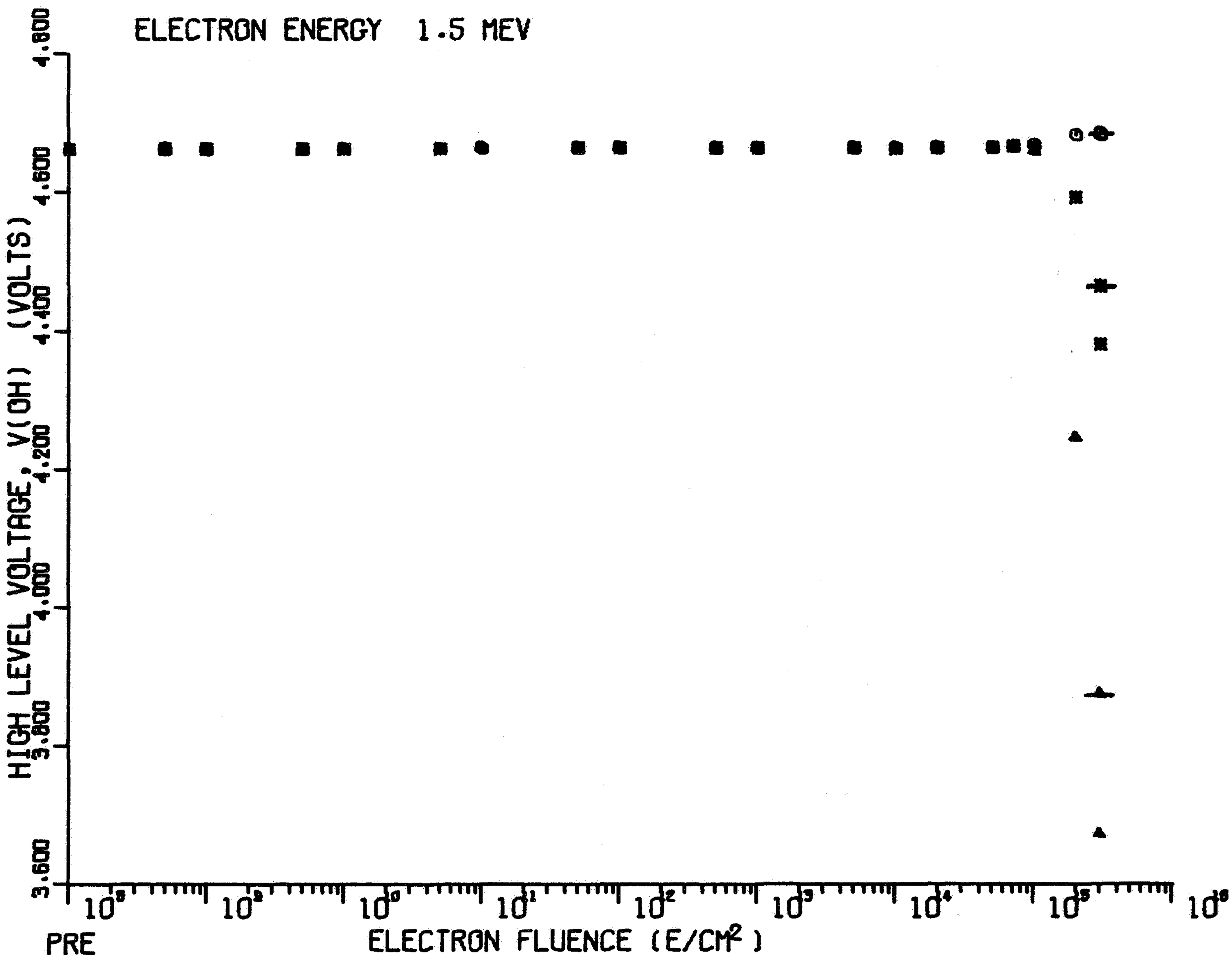



FIGURE 126. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD 321 FLIP-FLOPS.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD321 FLIP-FLOPS.

FIGURE 127




STATIC HIGH LEVEL OUTPUT RADIATION RESPONSE FOR RD321 FLIP-FLOPS.

FIGURE 128

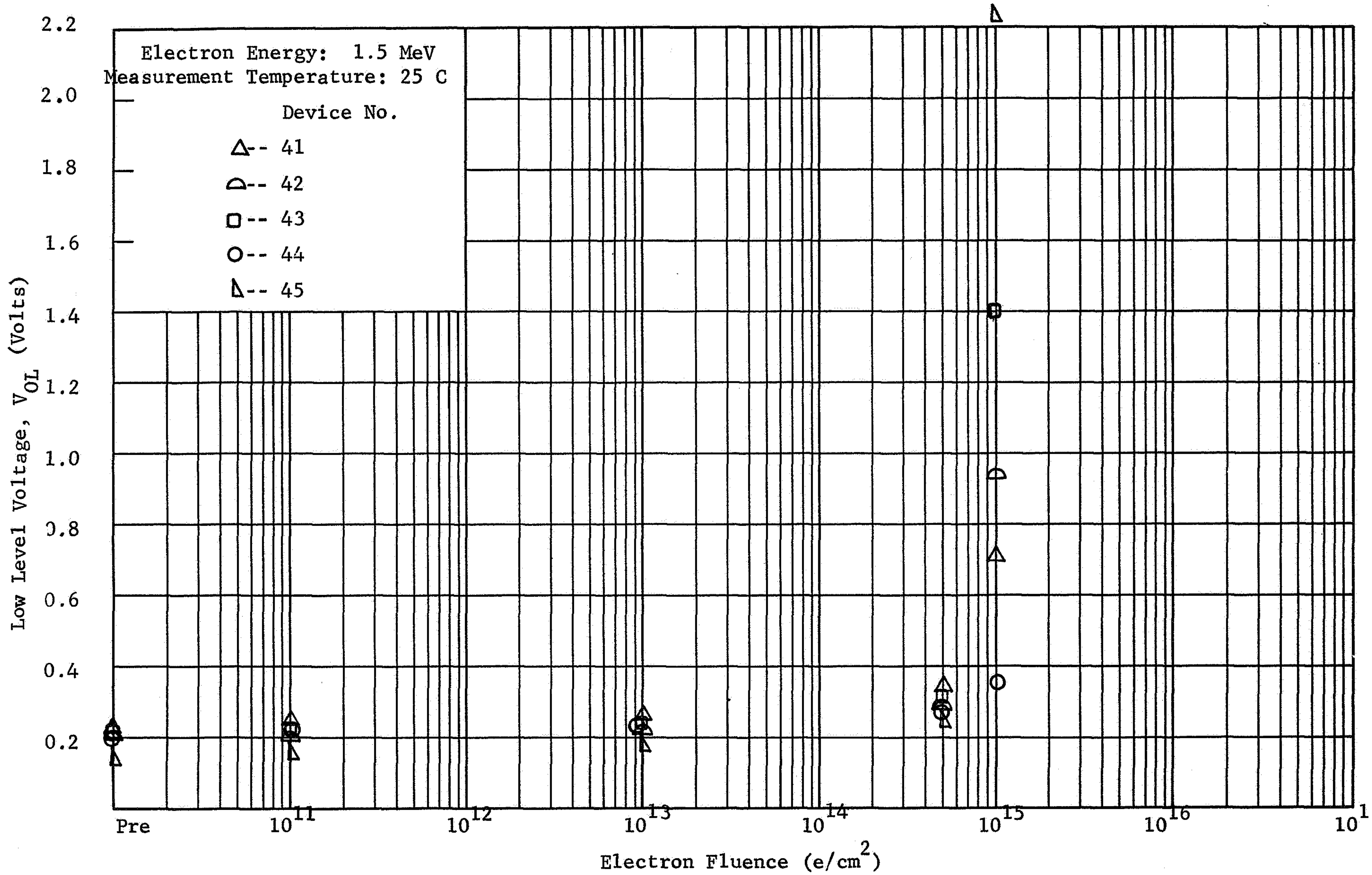



FIGURE 129. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD 321 FLIP-FLOPS.

RADIATION RD321

| | V(BAR Q L) | V(QH) | V(QL) | V(BAR Q H) | I(IN RC) | I(IN RD) | I(IN CP) |
|---|---|---|---|---|---|---|---|
| **0.5 MEV BIASED-A** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.191E+00 | 0.499E+01 | 0.183E+00 | 0.499E+01 | 0.781E-03 | 0.122E-02 | 0.883E-03 |
| AVERAGE CHANGE | 0.222E-01 | 0.490E-02 | 0.164E-01 | 0.690E-02 | -0.128E-04 | -0.262E-04 | -0.406E-04 |
| STD OF MEAN | 0.337E-02 | 0.316E-03 | 0.303E-02 | 0.568E-03 | 0.196E-04 | 0.113E-04 | 0.842E-05 |
| AVE PER CENT CHANGE | 0.120E+02 | 0.981E-01 | 0.930E+01 | 0.138E+00 | -0.169E+01 | -0.215E+01 | -0.465E+01 |
| INTERVAL ESTIMATE | 0.104E+02 | 0.936E-01 | 0.776E+01 | 0.130E+00 | -0.344E+01 | -0.282E+01 | -0.528E+01 |
| AS PER CENT | 0.129E+02 | 0.103E+00 | 0.101E+02 | 0.146E+00 | 0.159E+00 | -0.149E+01 | -0.391E+01 |
| PER CENT AVE CHANGE | 0.116E+02 | 0.981E-01 | 0.895E+01 | 0.138E+00 | -0.164E+01 | -0.215E+01 | -0.460E+01 |
| **0.5 MEV UNBIASED-B** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.186E+00 | 0.499E+01 | 0.178E+00 | 0.499E+01 | 0.787E-03 | 0.120E-02 | 0.871E-03 |
| AVERAGE CHANGE | 0.293E-01 | 0.480E-02 | 0.280E-01 | 0.680E-02 | -0.176E-04 | -0.270E-04 | -0.510E-04 |
| STD OF MEAN | 0.247E-02 | 0.447E-03 | 0.297E-02 | 0.447E-03 | 0.119E-04 | 0.696E-05 | 0.145E-04 |
| AVE PER CENT CHANGE | 0.159E+02 | 0.961E-01 | 0.159E+02 | 0.136E+00 | -0.250E+01 | -0.223E+01 | -0.576E+01 |
| INTERVAL ESTIMATE | 0.141E+02 | 0.850E-01 | 0.137E+02 | 0.125E+00 | -0.411E+01 | -0.298E+01 | -0.792E+01 |
| AS PER CENT | 0.174E+02 | 0.107E+00 | 0.179E+02 | 0.147E+00 | -0.361E+00 | -0.154E+01 | -0.379E+01 |
| PER CENT AVE CHANGE | 0.158E+02 | 0.961E-01 | 0.158E+02 | 0.136E+00 | -0.224E+01 | -0.226E+01 | -0.586E+01 |
| **1.0 MEV BIASED-C** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.175E+00 | 0.499E+01 | 0.166E+00 | 0.499E+01 | 0.748E-03 | 0.113E-02 | 0.832E-03 |
| AVERAGE CHANGE | 0.559E+00 | -0.960E+00 | 0.121E+00 | -0.200E-02 | -0.346E-04 | -0.410E-04 | -0.117E-03 |
| STD OF MEAN | 0.483E+00 | 0.910E+00 | 0.392E-01 | 0.294E-02 | 0.107E-04 | 0.629E-05 | 0.231E-04 |
| AVE PER CENT CHANGE | 0.290E+03 | -0.192E+02 | 0.720E+02 | -0.401E-01 | -0.482E+01 | -0.363E+01 | -0.140E+02 |
| INTERVAL ESTIMATE | 0.122E+03 | -0.323E+02 | 0.559E+02 | -0.822E-01 | -0.565E+01 | -0.403E+01 | -0.161E+02 |
| AS PER CENT | 0.517E+03 | -0.620E+01 | 0.896E+02 | 0.212E-02 | -0.360E+01 | -0.323E+01 | -0.121E+02 |
| PER CENT AVE CHANGE | 0.319E+03 | -0.192E+02 | 0.727E+02 | -0.401E-01 | -0.463E+01 | -0.363E+01 | -0.141E+02 |
| **1.0 MEV UNBIASED-D** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.187E+00 | 0.499E+01 | 0.181E+00 | 0.499E+01 | 0.786E-03 | 0.120E-02 | 0.870E-03 |
| AVERAGE CHANGE | 0.291E+01 | -0.141E+01 | 0.262E+01 | -0.122E+01 | -0.314E-04 | -0.538E-04 | -0.223E-03 |
| STD OF MEAN | 0.834E+00 | 0.260E+00 | 0.904E+00 | 0.641E+00 | 0.770E-05 | 0.126E-04 | 0.502E-04 |
| AVE PER CENT CHANGE | 0.159E+04 | -0.282E+02 | 0.148E+04 | -0.245E+02 | -0.406E+01 | -0.445E+01 | -0.254E+02 |
| INTERVAL ESTIMATE | 0.100E+04 | -0.347E+02 | 0.831E+03 | -0.405E+02 | -0.521E+01 | -0.581E+01 | -0.328E+02 |
| AS PER CENT | 0.211E+04 | -0.218E+02 | 0.207E+04 | -0.860E+01 | -0.278E+01 | -0.319E+01 | -0.185E+02 |
| PER CENT AVE CHANGE | 0.155E+04 | -0.282E+02 | 0.145E+04 | -0.245E+02 | -0.399E+01 | -0.450E+01 | -0.256E+02 |
| **1.5 MEV BIASED-E** | | | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.188E+00 | 0.499E+01 | 0.181E+00 | 0.499E+01 | 0.784E-03 | 0.119E-02 | 0.872E-03 |
| AVERAGE CHANGE | 0.113E+01 | -0.172E+01 | 0.230E+00 | -0.684E-01 | -0.222E-04 | -0.427E-04 | -0.140E-03 |
| STD OF MEAN | 0.616E+00 | 0.926E+00 | 0.218E+00 | 0.110E+00 | 0.676E-05 | 0.613E-05 | 0.214E-04 |
| AVE PER CENT CHANGE | 0.610E+03 | -0.344E+02 | 0.126E+03 | -0.137E+01 | -0.287E+01 | -0.358E+01 | -0.160E+02 |
| INTERVAL ESTIMATE | 0.366E+03 | -0.476E+02 | 0.405E+02 | -0.295E+01 | -0.345E+01 | -0.396E+01 | -0.178E+02 |
| AS PER CENT | 0.835E+03 | -0.211E+02 | 0.213E+03 | 0.211E+00 | -0.222E+01 | -0.322E+01 | -0.143E+02 |
| PER CENT AVE CHANGE | 0.601E+03 | -0.344E+02 | 0.127E+03 | -0.137E+01 | -0.283E+01 | -0.359E+01 | -0.160E+02 |

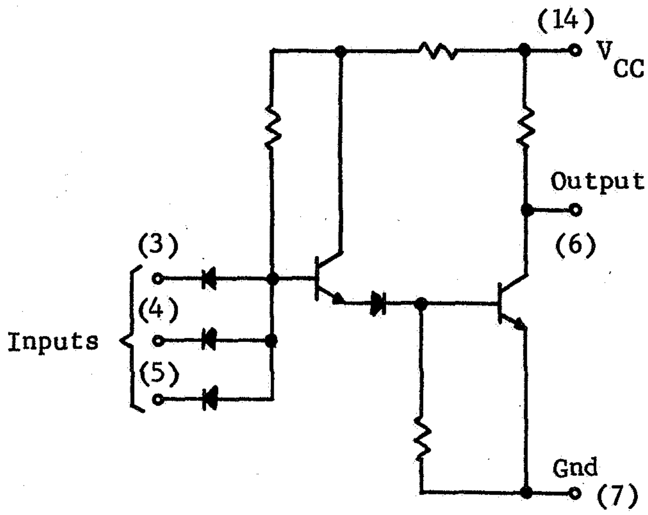
RADIATION RD321

| | V(BAR Q L) | V(QH) | V(QL) | V(BAR Q H) | I(IN RC) | I(IN RD) | I(IN CP) |
|---|---|---|---|---|---|---|---|
| **1.5 MEV UNBIASED-F** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.184E+00 | 0.499E+01 | 0.177E+00 | 0.499E+01 | 0.809E-03 | 0.123E-02 | 0.905E-03 |
| AVERAGE CHANGE | 0.133E+01 | -0.175E+01 | 0.106E+01 | -0.818E+00 | -0.294E-04 | -0.440E-04 | -0.179E-03 |
| STD OF MEAN | 0.781E+00 | 0.101E+01 | 0.681E+00 | 0.778E+00 | 0.961E-05 | 0.587E-05 | 0.335E-04 |
| AVE PER CENT CHANGE | 0.752E+03 | -0.350E+02 | 0.614E+03 | -0.164E+02 | -0.365E+01 | -0.356E+01 | -0.197E+02 |
| INTERVAL ESTIMATE | 0.197E+03 | -0.602E+02 | 0.121E+03 | -0.357E+02 | -0.511E+01 | -0.416E+01 | -0.243E+02 |
| AS PER CENT | 0.125E+04 | -0.983E+01 | 0.108E+04 | 0.297E+01 | -0.216E+01 | -0.297E+01 | -0.151E+02 |
| PER CENT AVE CHANGE | 0.724E+03 | -0.350E+02 | 0.599E+03 | -0.164E+02 | -0.363E+01 | -0.357E+01 | -0.197E+02 |
| **CONTROL-G** | | | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.205E+00 | 0.499E+01 | 0.197E+00 | 0.499E+01 | 0.749E-03 | 0.112E-02 | 0.822E-03 |
| AVERAGE CHANGE | 0.262E-02 | 0.460E-02 | 0.196E-02 | 0.680E-02 | -0.166E-04 | -0.540E-05 | 0.694E-18 |
| STD OF MEAN | 0.884E-03 | 0.548E-03 | 0.182E-03 | 0.447E-03 | 0.238E-04 | 0.865E-05 | 0.187E-05 |
| AVE PER CENT CHANGE | 0.130E+01 | 0.921E-01 | 0.100E+01 | 0.136E+00 | -0.253E+01 | -0.380E+00 | 0.138E-01 |
| INTERVAL ESTIMATE | 0.744E+00 | 0.785E-01 | 0.880E+00 | 0.125E+00 | -0.617E+01 | -0.144E+01 | -0.282E+00 |
| AS PER CENT | 0.182E+01 | 0.106E+00 | 0.111E+01 | 0.147E+00 | 0.174E+01 | 0.475E+00 | 0.282E+00 |
| PER CENT AVE CHANGE | 0.128E+01 | 0.921E-01 | 0.995E+00 | 0.136E+00 | -0.222E+01 | -0.481E+00 | 0.844E-13 |
| **F-TESTS** | | | | | | | |
| GROUPS A-B-G | 0.130E+03 | 0.879E+00 | 0.123E+03 | 0.944E-01 | 0.128E+00 | 0.864E+01 | 0.435E+02 |
| GROUPS C-D-G | 0.439E+02 | 0.587E+01 | 0.628E+02 | 0.292E+02 | 0.266E+01 | 0.429E+02 | 0.710E+02 |
| GROUPS E-F-G | 0.795E+01 | 0.810E+01 | 0.121E+02 | 0.762E+01 | 0.115E+01 | 0.586E+02 | 0.910E+02 |
| GROUPS A-C-E-G | 0.141E+02 | 0.125E+02 | 0.675E+01 | 0.351E+01 | 0.371E+01 | 0.282E+02 | 0.104E+03 |
| GROUPS B-D-F-G | 0.290E+02 | 0.156E+02 | 0.237E+02 | 0.748E+01 | 0.139E+01 | 0.284E+02 | 0.571E+02 |
| GROUPS ALL | 0.250E+02 | 0.102E+02 | 0.396E+02 | 0.147E+02 | 0.282E+01 | 0.198E+02 | 0.635E+02 |
| **T-TESTS** | | | | | | | |
| GROUPS A-B | -0.417E+01 | 0.505E+00 | -0.707E+01 | 0.342E+00 | 0.497E+00 | 0.144E+00 | 0.178E+01 |
| GROUPS C-D | -0.701E+01 | 0.107E+01 | -0.909E+01 | 0.628E+01 | -0.592E+00 | 0.268E+01 | 0.570E+01 |
| GROUPS E-F | -0.550E+00 | 0.600E-01 | -0.362E+01 | 0.310E+01 | 0.170E+01 | 0.392E+00 | 0.277E+01 |
| GROUPS A-G | 0.126E+02 | 0.136E+01 | 0.104E+02 | 0.342E+00 | 0.330E+00 | -0.360E+01 | -0.105E+02 |
| GROUPS B-G | 0.228E+02 | 0.632E+00 | 0.196E+02 | 0. | -0.839E-01 | -0.435E+01 | -0.780E+01 |
| GROUPS C-G | 0.253E+01 | -0.233E+01 | 0.666E+01 | -0.653E+01 | -0.206E+01 | -0.916E+01 | -0.111E+02 |
| GROUPS D-G | 0.780E+01 | -0.122E+02 | 0.648E+01 | -0.430E+01 | -0.132E+01 | -0.708E+01 | -0.993E+01 |
| GROUPS E-G | 0.401E+01 | -0.408E+01 | 0.229E+01 | -0.150E+01 | -0.711E+00 | -0.973E+01 | -0.143E+02 |
| GROUPS F-G | 0.380E+01 | -0.387E+01 | 0.347E+01 | -0.237E+01 | -0.111E+01 | -0.826E+01 | -0.119E+02 |
| GROUPS A-C | -0.351E+01 | 0.335E+01 | -0.841E+01 | 0.939E+01 | 0.308E+01 | 0.362E+01 | 0.985E+01 |
| GROUPS A-E | -0.568E+01 | 0.588E+01 | -0.309E+01 | 0.216E+01 | 0.143E+01 | 0.406E+01 | 0.136E+02 |
| GROUPS C-E | -0.231E+01 | 0.184E+01 | -0.155E+01 | 0.190E+01 | -0.310E+01 | 0.612E+00 | 0.224E+01 |
| GROUPS B-D | -0.773E+01 | 0.122E+02 | -0.642E+01 | 0.430E+01 | 0.218E+01 | 0.416E+01 | 0.736E+01 |
| GROUPS B-F | -0.373E+01 | 0.387E+01 | -0.339E+01 | 0.237E+01 | 0.173E+01 | 0.417E+01 | 0.781E+01 |
| GROUPS D-F | 0.309E+01 | 0.723E+00 | 0.309E+01 | -0.904E+00 | -0.363E+00 | -0.158E+01 | -0.165E+01 |

| | RESISTANCE | RADIATION RD321 I(LRU) |
|---|---|---|
| 0.5 MEV BIASED-A | | |
| NUMBER | 10 | 10 |
| INITIAL MEAN | 0.643E+04 | 0.315E-08 |
| AVERAGE CHANGE | 0.489E+02 | 0.186E-09 |
| STD OF MEAN | 0.634E+02 | 0.326E-09 |
| AVE PER CENT CHANGE | 0.705E+00 | 0.549E+01 |
| INTERVAL ESTIMATE | 0.557E-01 | -0.150E+01 |
| AS PER CENT | 0.146E+01 | 0.133E+02 |
| PER CENT AVE CHANGE | 0.760E+00 | 0.591E+01 |
| 0.5 MEV UNBIASED-B | | |
| NUMBER | 5 | 5 |
| INITIAL MEAN | 0.662E+04 | 0.154E-08 |
| AVERAGE CHANGE | 0.754E+02 | -0.540E-10 |
| STD OF MEAN | 0.706E+02 | 0.186E-09 |
| AVE PER CENT CHANGE | 0.115E+01 | -0.133E+02 |
| INTERVAL ESTIMATE | -0.185E+00 | -0.184E+02 |
| AS PER CENT | 0.246E+01 | 0.115E+02 |
| PER CENT AVE CHANGE | 0.114E+01 | -0.350E+01 |
| 1.0 MEV BIASED-C | | |
| NUMBER | 10 | 10 |
| INITIAL MEAN | 0.692E+04 | 0.141E-08 |
| AVERAGE CHANGE | 0.111E+03 | 0.150E-08 |
| STD OF MEAN | 0.830E+02 | 0.705E-09 |
| AVE PER CENT CHANGE | 0.149E+01 | 0.124E+03 |
| INTERVAL ESTIMATE | 0.748E+00 | 0.707E+02 |
| AS PER CENT | 0.246E+01 | 0.142E+03 |
| PER CENT AVE CHANGE | 0.161E+01 | 0.106E+03 |
| 1.0 MEV UNBIASED-D | | |
| NUMBER | 5 | 5 |
| INITIAL MEAN | 0.637E+04 | 0.168E-08 |
| AVERAGE CHANGE | 0.121E+03 | 0.138E-08 |
| STD OF MEAN | 0.600E+02 | 0.303E-09 |
| AVE PER CENT CHANGE | 0.189E+01 | 0.108E+03 |
| INTERVAL ESTIMATE | 0.734E+00 | 0.594E+02 |
| AS PER CENT | 0.307E+01 | 0.104E+03 |
| PER CENT AVE CHANGE | 0.190E+01 | 0.817E+02 |
| 1.5 MEV BIASED-E | | |
| NUMBER | 10 | 10 |
| INITIAL MEAN | 0.641E+04 | 0.183E-08 |
| AVERAGE CHANGE | 0.107E+03 | 0.225E-08 |
| STD OF MEAN | 0.759E+02 | 0.289E-08 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.289E+03 |
| INTERVAL ESTIMATE | 0.830E+00 | 0.103E+02 |
| AS PER CENT | 0.252E+01 | 0.237E+03 |
| PER CENT AVE CHANGE | 0.168E+01 | 0.123E+03 |

| | RESISTANCE | RADIATION RD321 I(LRD) |
|---|---|---|
| 1.5 MEV UNBIASED-F | | |
| NUMBER | 5 | 5 |
| INITIAL MEAN | 0.623E+04 | 0.141E-08 |
| AVERAGE CHANGE | 0.111E+03 | 0.149E-08 |
| STD OF MEAN | 0.869E+02 | 0.671E-09 |
| AVE PER CENT CHANGE | 0.174E+01 | 0.116E+03 |
| INTERVAL ESTIMATE | 0.534E-01 | 0.466E+02 |
| AS PER CENT | 0.351E+01 | 0.165E+03 |
| PER CENT AVE CHANGE | 0.178E+01 | 0.106E+03 |
| CONTROL-G | | |
| NUMBER | 5 | 5 |
| INITIAL MEAN | 0.685E+04 | 0.867E-08 |
| AVERAGE CHANGE | -0.680E+01 | -0.204E-08 |
| STD OF MEAN | 0.358E+02 | 0.459E-08 |
| AVE PER CENT CHANGE | -0.135E+00 | -0.175E+02 |
| INTERVAL ESTIMATE | -0.749E+00 | -0.892E+02 |
| AS PER CENT | 0.550E+00 | 0.422E+02 |
| PER CENT AVE CHANGE | -0.993E-01 | -0.235E+02 |
| F-TESTS | | |
| GROUPS A-B-G | 0.249E+01 | 0.174E+01 |
| GROUPS C-D-G | 0.579E+01 | 0.439E+01 |
| GROUPS E-F-G | 0.488E+01 | 0.333E+01 |
| GROUPS A-C-E-G | 0.426E+01 | 0.440E+01 |
| GROUPS B-D-F-G | 0.388E+01 | 0.250E+01 |
| GROUPS ALL | 0.253E+01 | 0.333E+01 |
| T-TESTS | | |
| GROUPS A-B | -0.737E+00 | 0.151E+01 |
| GROUPS C-D | -0.238E+00 | 0.380E+00 |
| GROUPS E-F | -0.850E-01 | 0.574E+00 |
| GROUPS A-G | 0.181E+01 | 0.159E+01 |
| GROUPS B-G | 0.232E+01 | 0.967E+00 |
| GROUPS C-G | 0.300E+01 | 0.248E+01 |
| GROUPS D-G | 0.410E+01 | 0.166E+01 |
| GROUPS E-G | 0.315E+01 | 0.224E+01 |
| GROUPS F-G | 0.281E+01 | 0.170E+01 |
| GROUPS A-C | -0.189E+01 | -0.536E+01 |
| GROUPS A-E | -0.187E+01 | -0.225E+01 |
| GROUPS C-E | 0.104E+00 | -0.799E+00 |
| GROUPS B-D | -0.111E+01 | -0.899E+01 |
| GROUPS B-F | -0.715E+00 | -0.496E+01 |
| GROUPS D-F | 0.212E+00 | -0.346E+00 |

## Equivalent 962 Circuits




CIRCUIT TYPES TESTED:

Fairchild DTµL962 Gates
Radiation 242 Gates
Philco PL962 Gates
Motorola SC1253 Gates
Motorola MC962 Gates
Motorola Dielectrically Isolated Gates
Texas Instrument SN15962 Gates

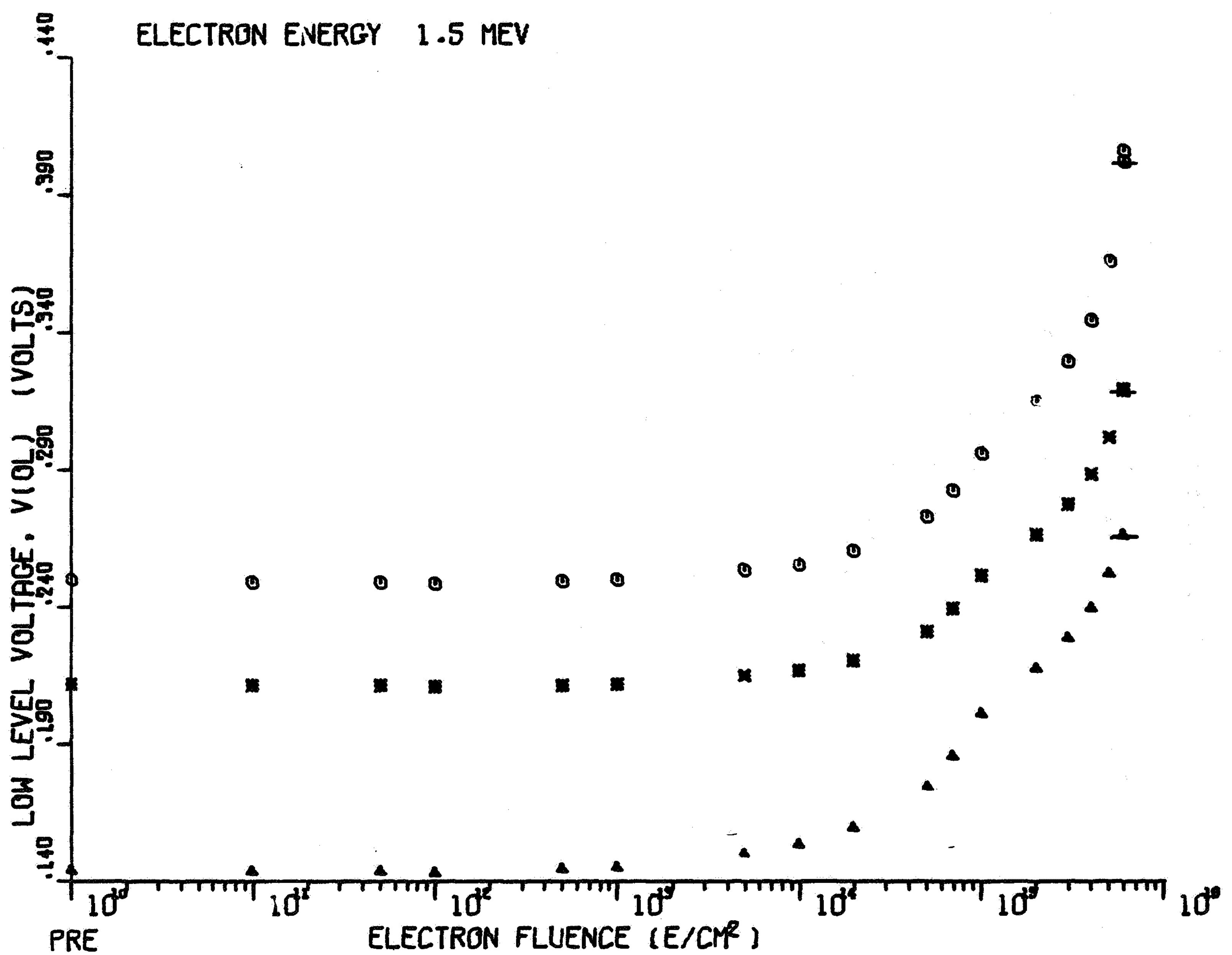
TEST CONDITIONS:

1. Pin 14, 5.0 volts.
2. Pin 7, ground.
3. Temperature 25 C.

TEST PARAMETERS:

1. Output-voltage levels.
2. Input-voltage levels.
3. Input leakage current.
4. Input drive current.
5. Resistance.
6. Propagation delay.

FIGURE 130. TEST PLAN FOR EQUIVALENT-CIRCUIT STUDY




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR FAIRCHILD 962 GATES.

FIGURE 131

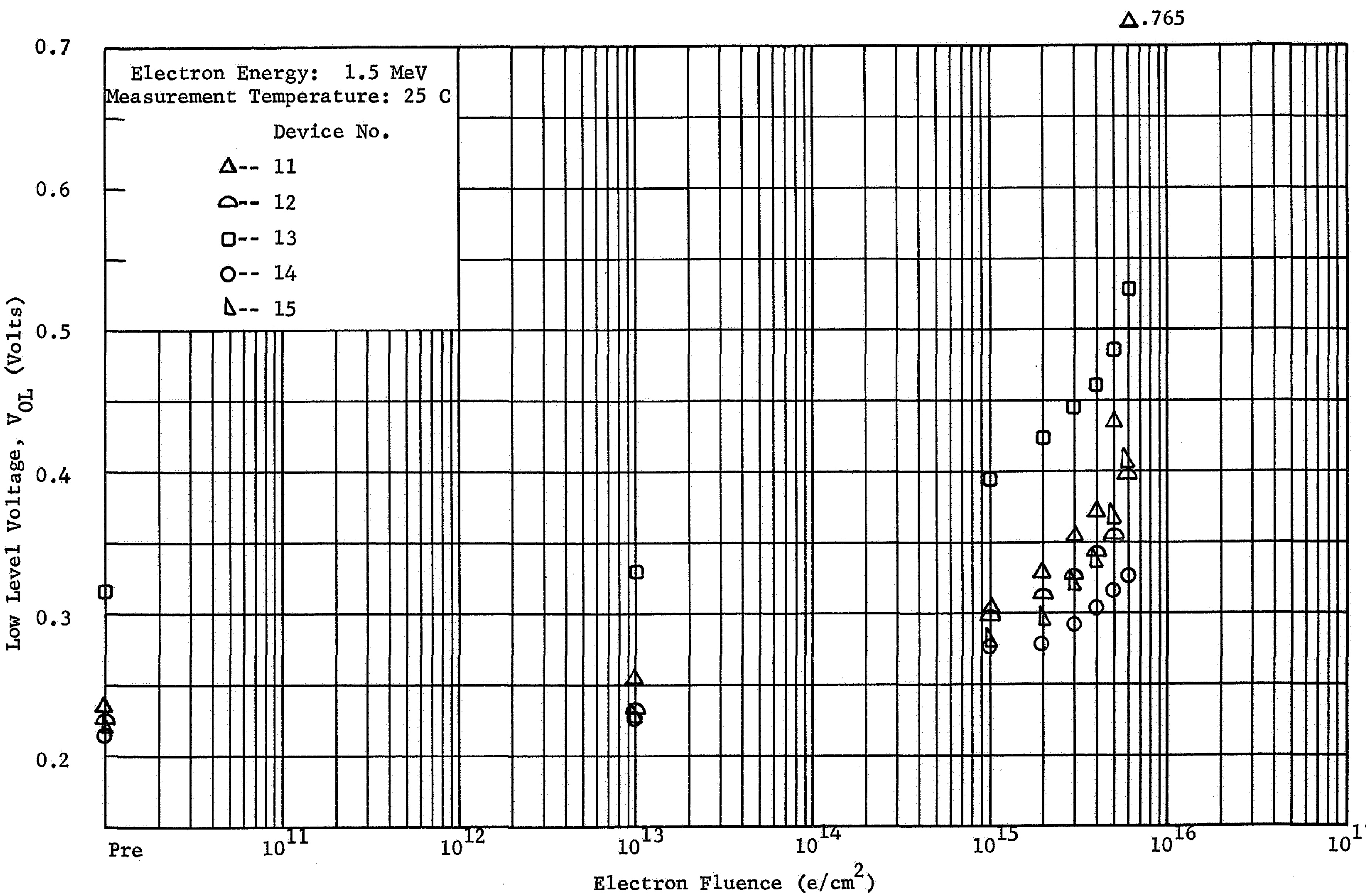
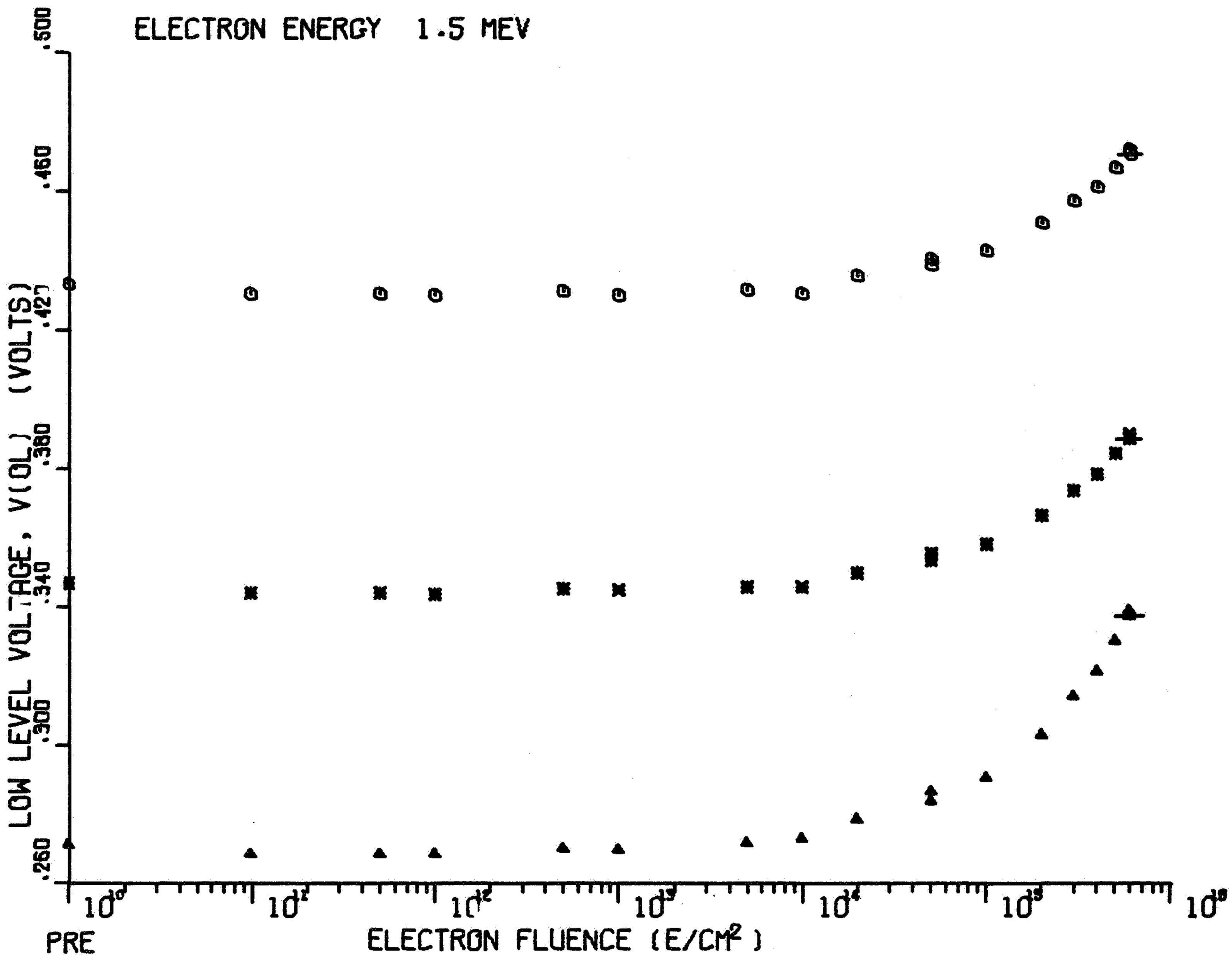



FIGURE 132. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR FAIRCHILD DTμL 962 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR MOTOROLA D962 GATES.

FIGURE 133

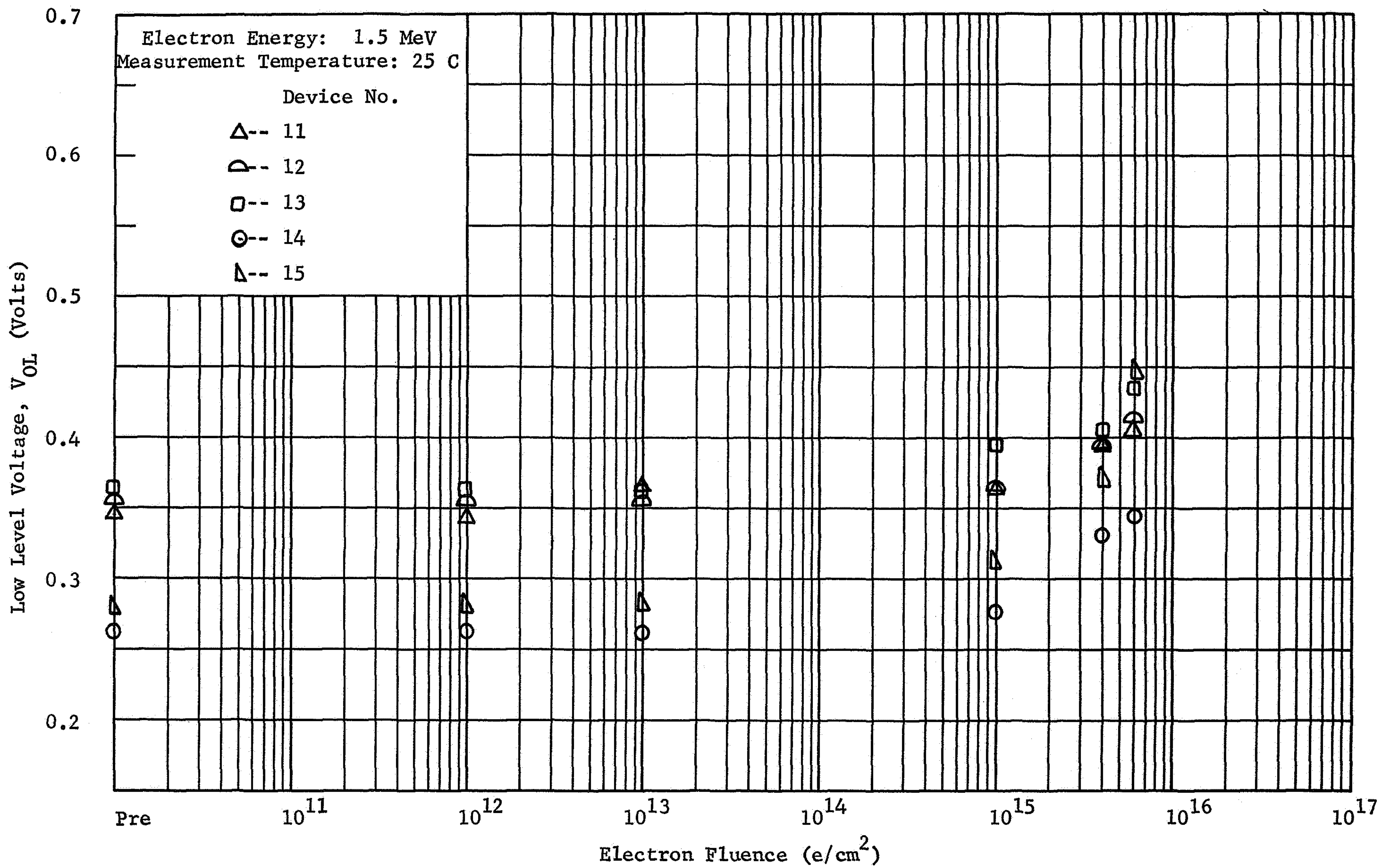
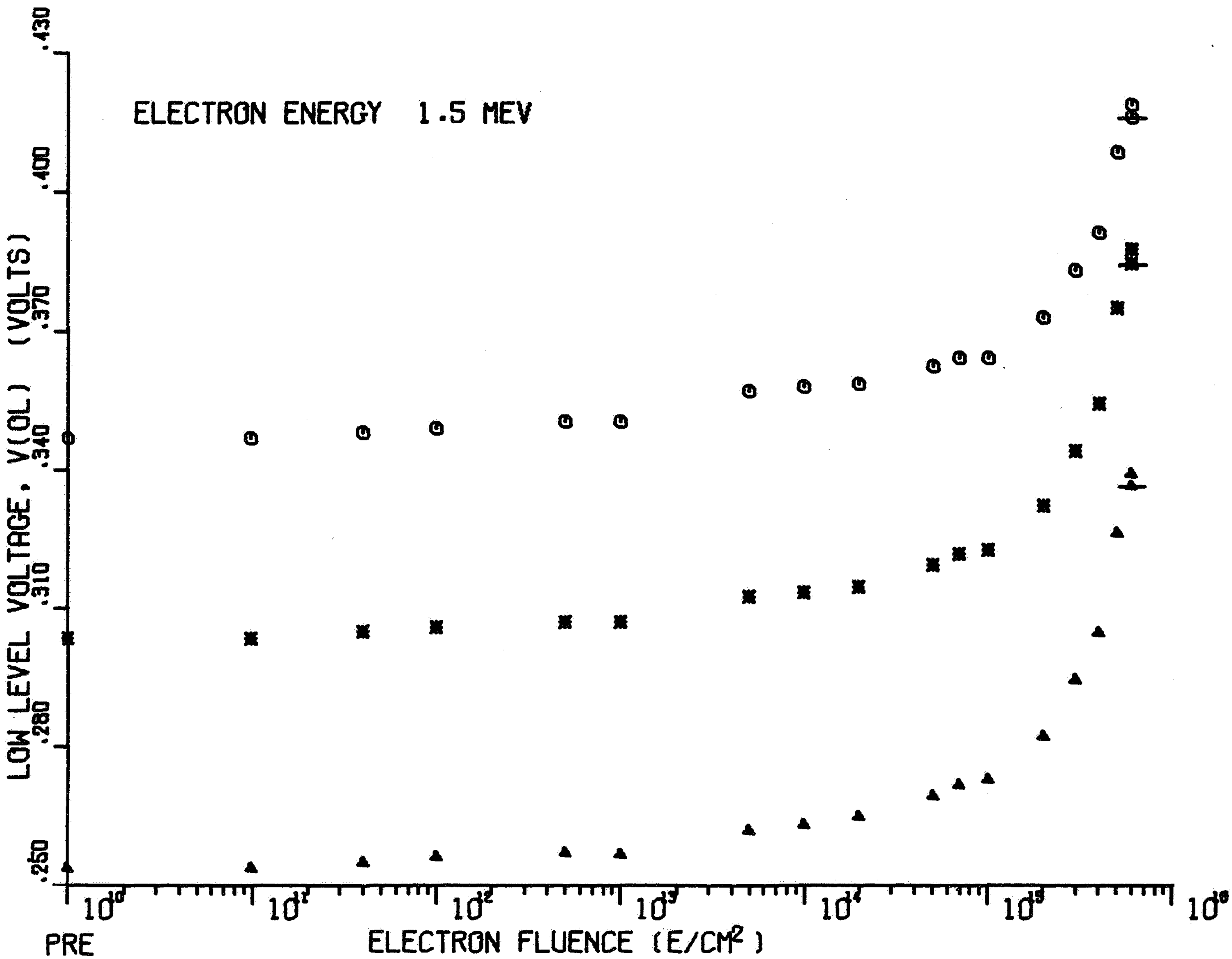



FIGURE 134. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR MOTOROLA DIELECTRICALLY ISOLATED GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR PHILCO 962 GATES.

FIGURE 135

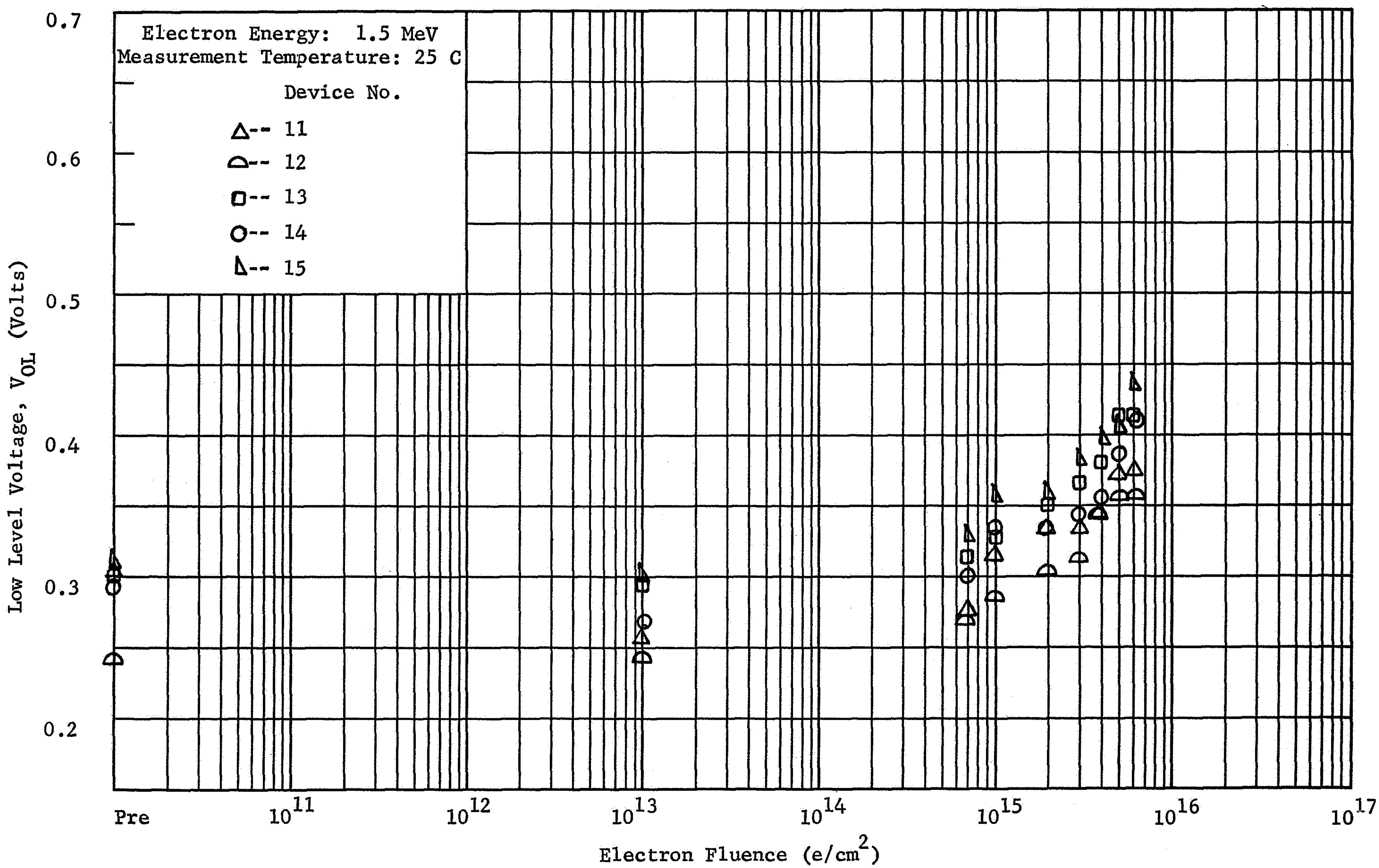
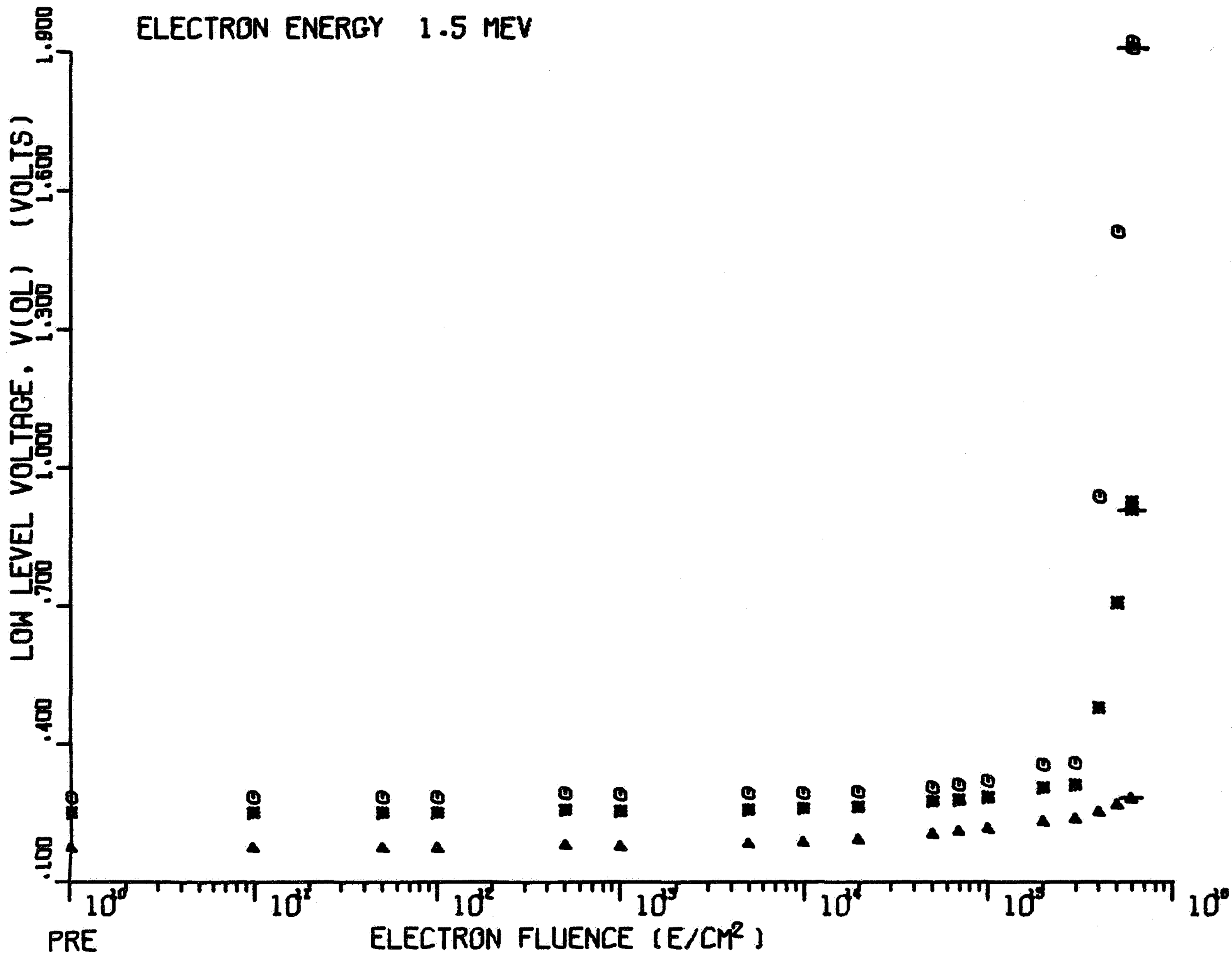



FIGURE 136. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR PHILCO PL 962 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD242 GATES.

FIGURE 137

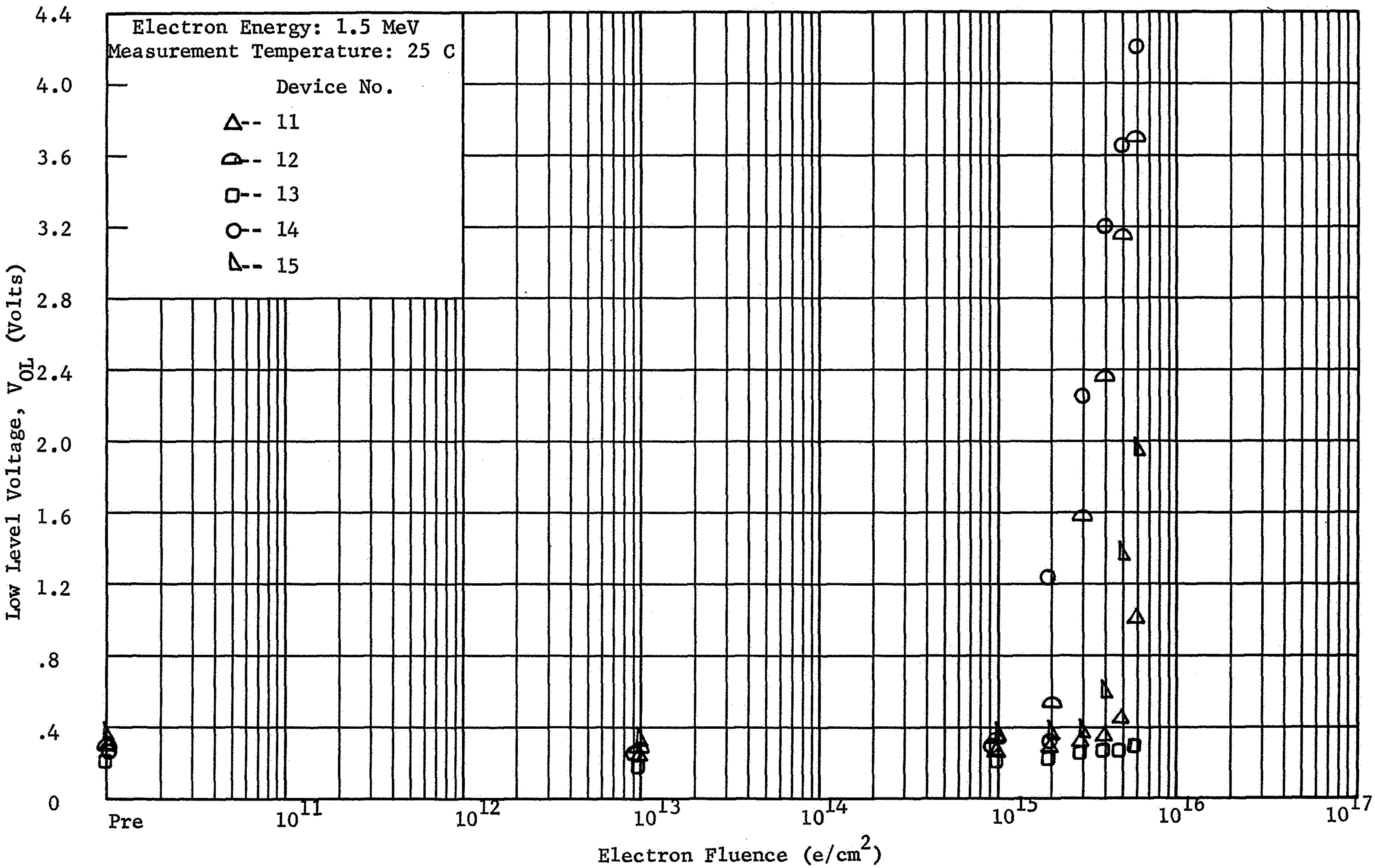
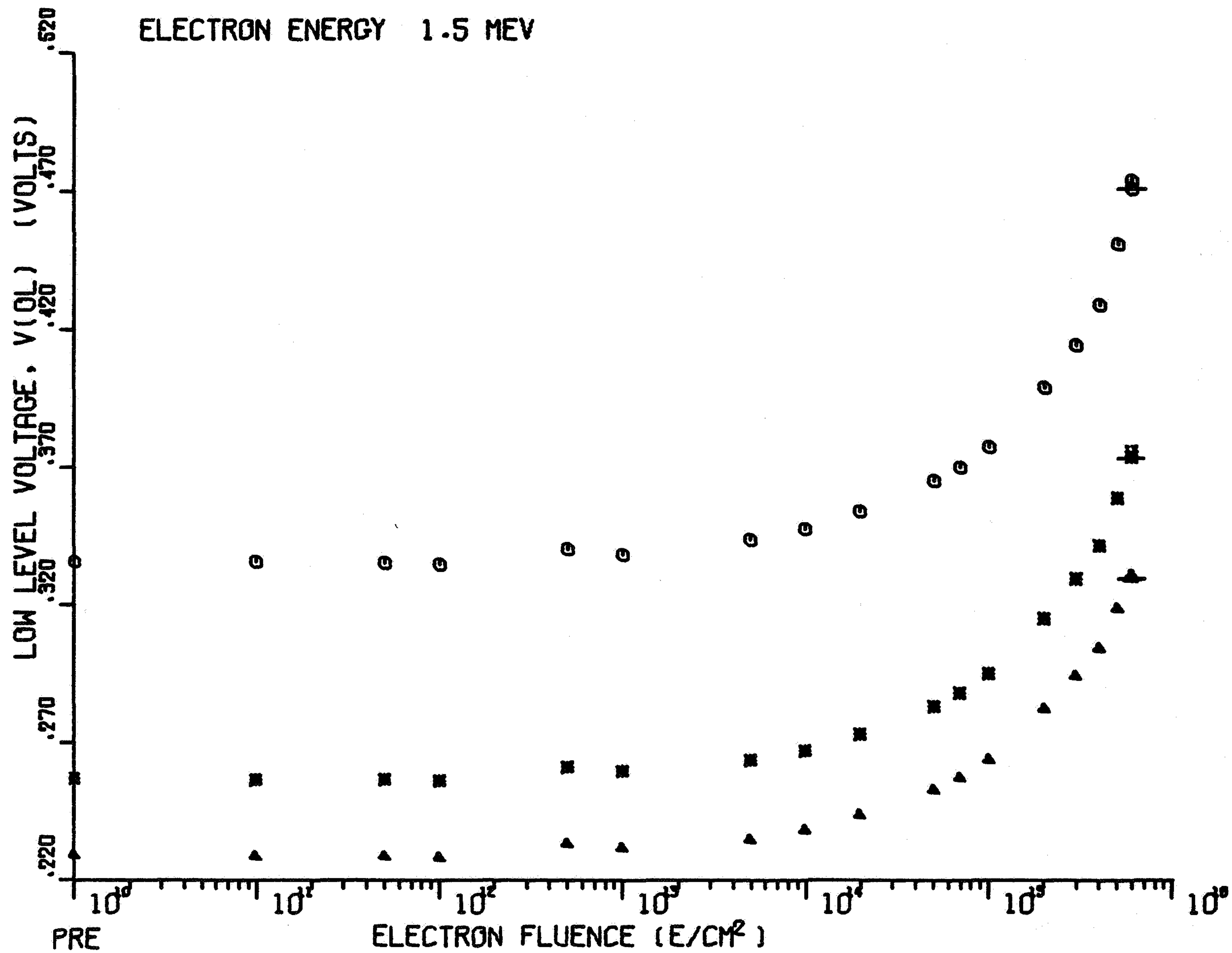



FIGURE 138. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR RD 242 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR TI962 GATES.

FIGURE 139

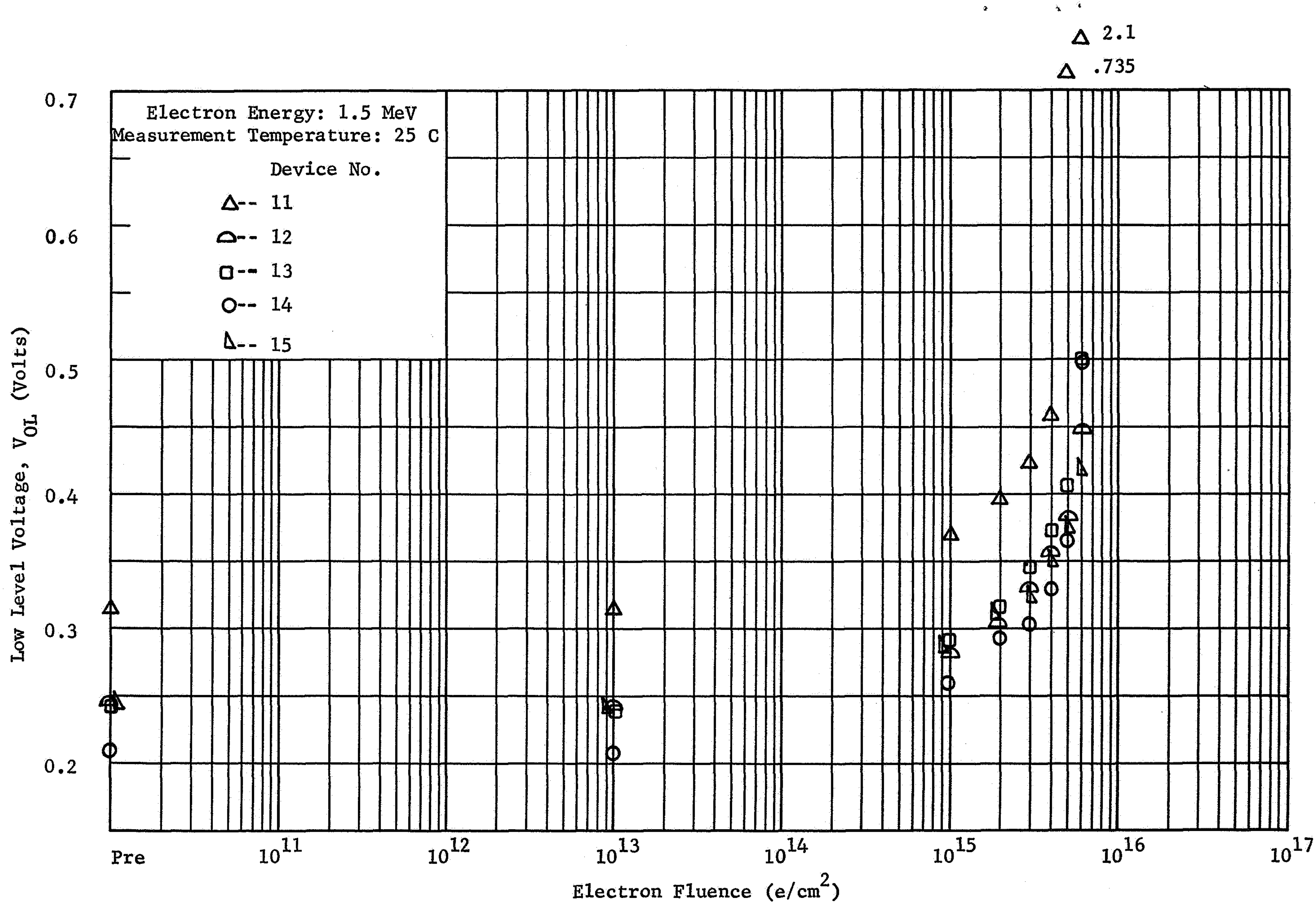
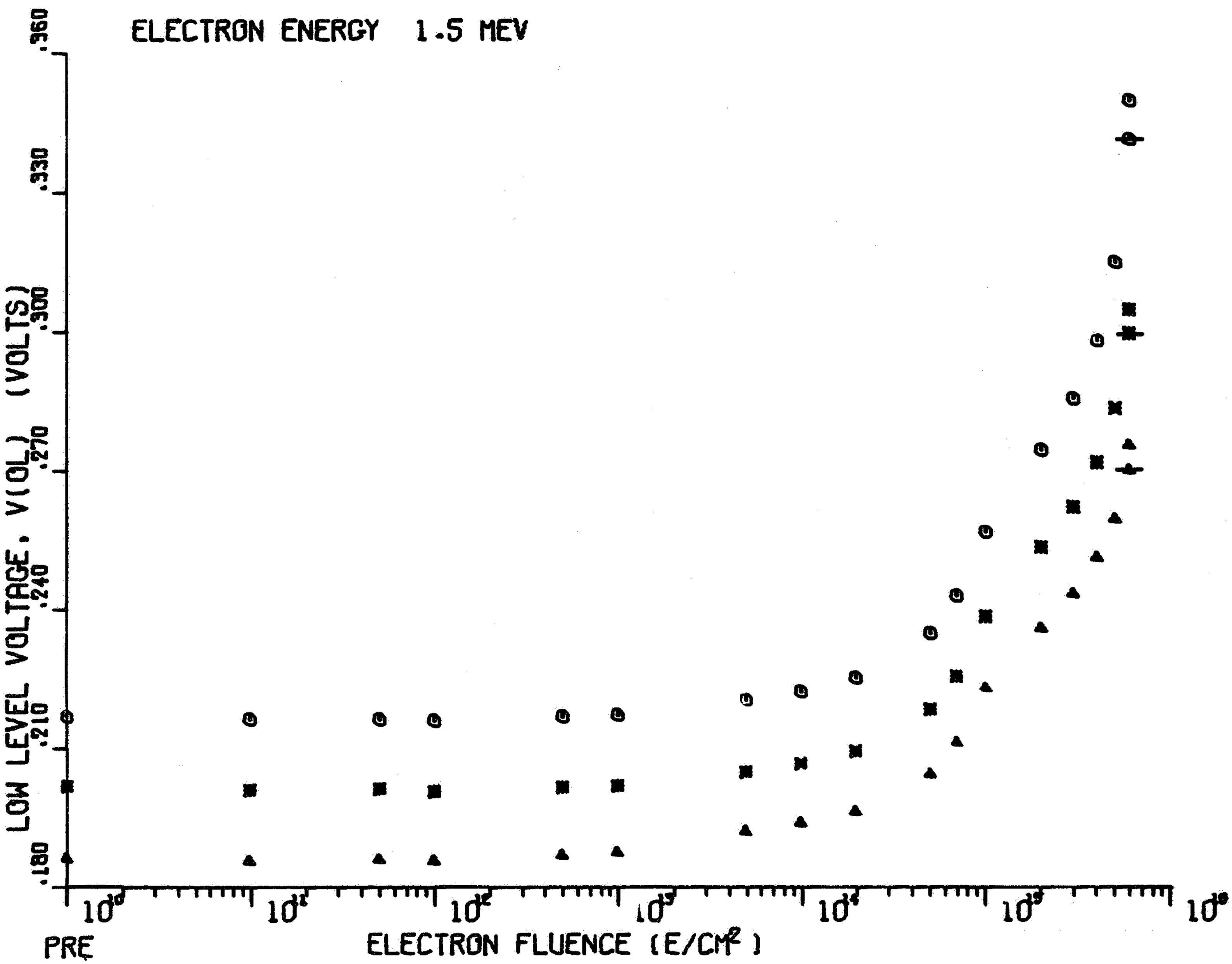



FIGURE 140. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR TEXAS INSTRUMENT SN 15962 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR MOTOROLA 962 GATES.

FIGURE 141

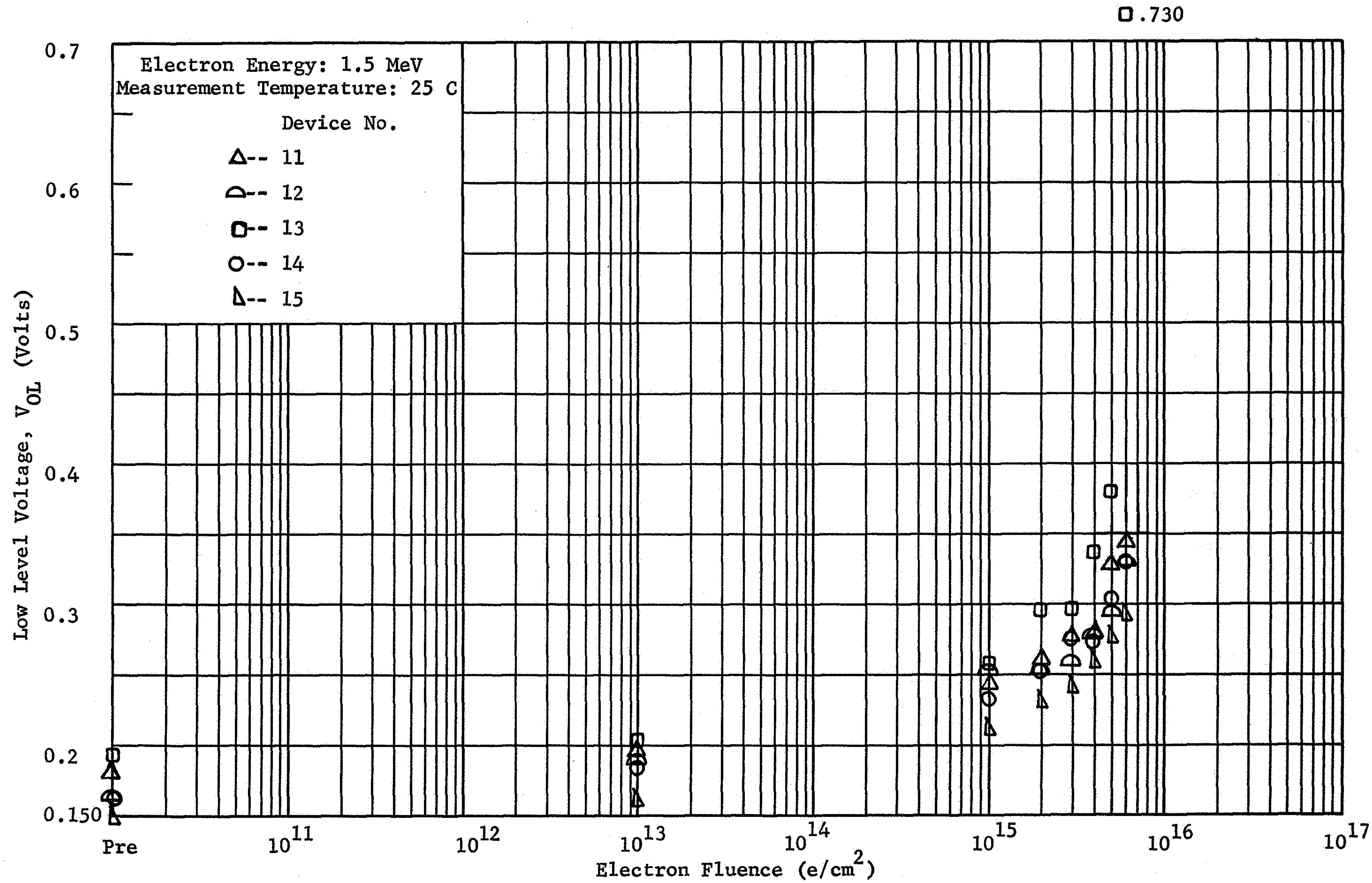
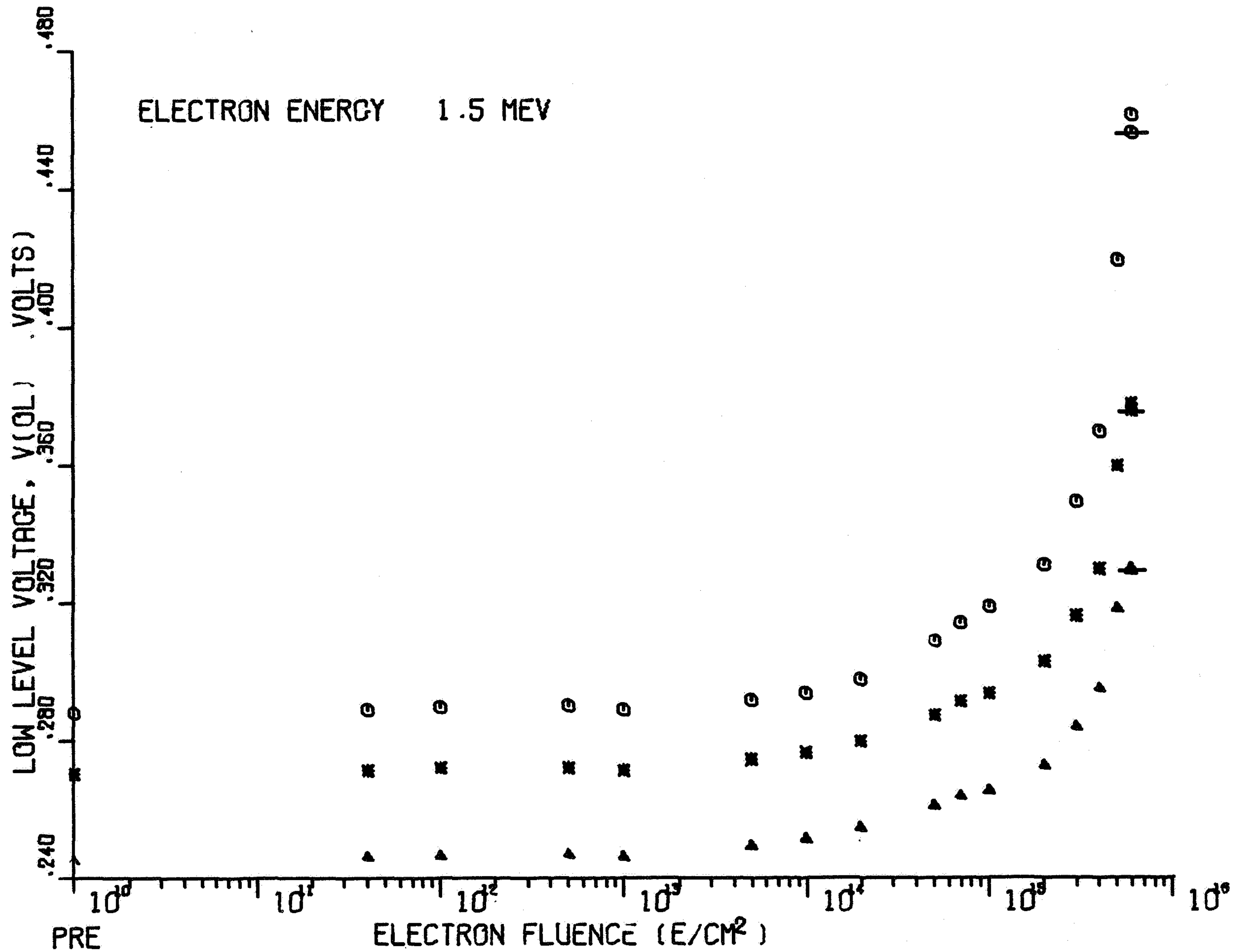



FIGURE 142. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR MOTOROLA MC 962 GATES.




STATIC LOW LEVEL OUTPUT RADIATION RESPONSE FOR SC1253 GATES.

FIGURE 143

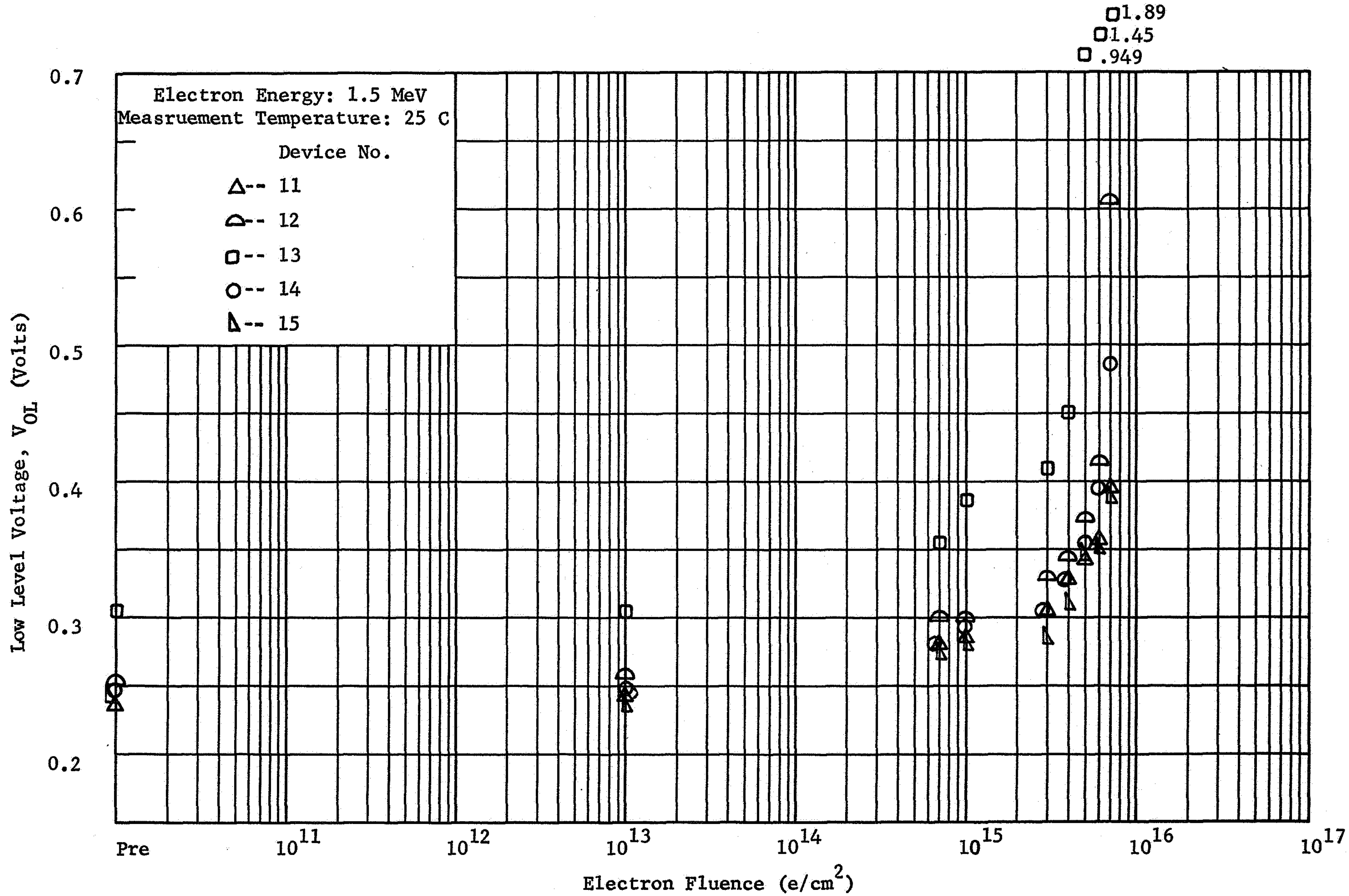



FIGURE 144. PULSED LOW LEVEL OUTPUT RADIATION RESPONSE FOR MOTOROLA SC 1253 GATES.

FAIRCHILD DT L962

| | V(OH) | V(OL) | V(IH) | V(IL) | I DRIVE |
|---|---|---|---|---|---|
| **BIASED-A** | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.189E+00 | 0.136E+01 | 0.134E+01 | 0.124E-02 |
| AVERAGE CHANGE | 0.110E-02 | 0.104E+00 | -0.260E-02 | 0.110E-02 | -0.240E-04 |
| STD OF MEAN | 0.316E-03 | 0.171E-01 | 0.119E-01 | 0.110E-01 | 0.516E-05 |
| AVE PER CENT CHANGE | 0.220E-01 | 0.568E+02 | -0.196E+00 | 0.841E-01 | -0.195E+01 |
| INTERVAL ESTIMATE | 0.175E-01 | 0.486E+02 | -0.817E+00 | -0.508E+00 | -0.224E+01 |
| AS PER CENT | 0.265E-01 | 0.615E+02 | 0.435E+00 | 0.672E+00 | -0.164E+01 |
| PER CENT AVE CHANGE | 0.220E-01 | 0.551E+02 | -0.191E+00 | 0.823E-01 | -0.194E+01 |
| **UNBIASED-B** | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.235E+00 | 0.131E+01 | 0.129E+01 | 0.122E-02 |
| AVERAGE CHANGE | 0.180E-02 | 0.123E+00 | 0.820E-02 | -0.220E-02 | -0.240E-04 |
| STD OF MEAN | 0.192E-02 | 0.212E-01 | 0.572E-02 | 0.277E-02 | 0.894E-05 |
| AVE PER CENT CHANGE | 0.360E-01 | 0.524E+02 | 0.629E+00 | -0.172E+00 | -0.193E+01 |
| INTERVAL ESTIMATE | -0.118E-01 | 0.410E+02 | 0.842E-01 | -0.439E+00 | -0.298E+01 |
| AS PER CENT | 0.837E-01 | 0.634E+02 | 0.117E+01 | 0.968E-01 | -0.106E+01 |
| PER CENT AVE CHANGE | 0.360E-01 | 0.522E+02 | 0.627E+00 | -0.171E+00 | -0.197E+01 |
| **CONTROLS-C** | | | | | |
| NUMBER | 16 | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.500E+01 | 0.204E+00 | 0.135E+01 | 0.133E+01 | 0.124E-02 |
| AVERAGE CHANGE | 0.425E-02 | 0.244E-02 | -0.421E-01 | -0.281E-01 | -0.206E-04 |
| STD OF MEAN | 0.950E-02 | 0.234E-02 | 0.248E-01 | 0.293E-01 | 0.298E-04 |
| AVE PER CENT CHANGE | 0.852E-01 | 0.119E+01 | -0.312E+01 | -0.211E+01 | -0.155E+01 |
| INTERVAL ESTIMATE | -0.163E-01 | 0.587E+00 | -0.410E+01 | -0.329E+01 | -0.295E+01 |
| AS PER CENT | 0.186E+00 | 0.181E+01 | -0.214E+01 | -0.937E+00 | -0.385E+00 |
| PER CENT AVE CHANGE | 0.850E-01 | 0.120E+01 | -0.312E+01 | -0.211E+01 | -0.166E+01 |
| **F-TEST** | | | | | |
| GROUPS A-B-C | 0.689E+00 | 0.285E+03 | 0.194E+02 | 0.613E+01 | 0.891E-01 |
| **T-TESTS** | | | | | |
| GROUPS A-B | -0.116E+01 | -0.185E+01 | -0.189E+01 | 0.648E+00 | 0.784E-12 |
| GROUPS A-C | -0.104E+01 | 0.238E+02 | 0.468E+01 | 0.300E+01 | -0.353E+00 |
| GROUPS B-C | -0.563E+00 | 0.236E+02 | 0.442E+01 | 0.194E+01 | -0.246E+00 |

FAIRCHILD DT L962

| | I LEAKAGE | RESISTANCE | T(DF) | T(DR) |
|---|---|---|---|---|
| BIASED-A | | | | |
| NUMBER | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.409E-07 | 0.615E+04 | 0.361E-07 | 0.876E-08 |
| AVERAGE CHANGE | 0.199E-07 | 0.117E+03 | -0.250E-07 | 0.110E-09 |
| STD OF MEAN | 0.192E-07 | 0.654E+02 | 0.154E-07 | 0.218E-09 |
| AVE PER CENT CHANGE | 0.615E+02 | 0.190E+01 | -0.666E+02 | 0.134E+01 |
| INTERVAL ESTIMATE | 0.150E+02 | 0.114E+01 | -0.998E+02 | -0.527E+00 |
| AS PER CENT | 0.821E+02 | 0.266E+01 | -0.387E+02 | 0.304E+01 |
| PER CENT AVE CHANGE | 0.485E+02 | 0.190E+01 | -0.692E+02 | 0.126E+01 |
| UNBIASED-B | | | | |
| NUMBER | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.584E-07 | 0.616E+04 | 0.261E-07 | 0.864E-08 |
| AVERAGE CHANGE | 0.500E-07 | 0.123E+03 | -0.163E-07 | 0.660E-09 |
| STD OF MEAN | 0.873E-07 | 0.107E+03 | 0.285E-08 | 0.351E-09 |
| AVE PER CENT CHANGE | 0.308E+03 | 0.195E+01 | -0.622E+02 | 0.743E+01 |
| INTERVAL ESTIMATE | -0.100E+03 | -0.171E+00 | -0.760E+02 | 0.260E+01 |
| AS PER CENT | 0.271E+03 | 0.415E+01 | -0.489E+02 | 0.127E+02 |
| PER CENT AVE CHANGE | 0.856E+02 | 0.199E+01 | -0.624E+02 | 0.764E+01 |
| CONTROLS-C | | | | |
| NUMBER | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.410E-07 | 0.594E+04 | 0.233E-07 | 0.819E-08 |
| AVERAGE CHANGE | 0.246E-08 | 0.160E+02 | 0.423E-08 | -0.300E-09 |
| STD OF MEAN | 0.612E-08 | 0.558E+02 | 0.857E-08 | 0.213E-09 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.259E+00 | 0.579E+02 | -0.363E+01 |
| INTERVAL ESTIMATE | -0.196E+01 | -0.231E+00 | -0.143E+01 | -0.505E+01 |
| AS PER CENT | 0.139E+02 | 0.770E+00 | 0.377E+02 | -0.228E+01 |
| PER CENT AVE CHANGE | 0.599E+01 | 0.270E+00 | 0.181E+02 | -0.366E+01 |
| F-TEST | | | | |
| GROUPS A-B-C | 0.361E+01 | 0.874E+01 | 0.240E+02 | 0.327E+02 |
| T-TESTS | | | | |
| GROUPS A-B | -0.108E+01 | -0.129E+00 | -0.123E+01 | -0.377E+01 |
| GROUPS A-C | 0.340E+01 | 0.420E+01 | -0.624E+01 | 0.473E+01 |
| GROUPS B-C | 0.229E+01 | 0.298E+01 | -0.518E+01 | 0.754E+01 |

MOTOROLA DIELECT. ISOLATED CTS

| | V(OH) | V(OL) | V(IH) | V(IL) | I DRIVE |
|---|---|---|---|---|---|
| BIASED-A | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.311E+00 | 0.135E+01 | 0.132E+01 | 0.125E-02 |
| AVERAGE CHANGE | -0.100E-02 | 0.540E-01 | -0.414E-01 | -0.412E-01 | -0.520E-04 |
| STD OF MEAN | 0.816E-03 | 0.832E-02 | 0.108E-01 | 0.873E-02 | 0.132E-04 |
| AVE PER CENT CHANGE | -0.200E-01 | 0.180E+02 | -0.307E+01 | -0.311E+01 | -0.417E+01 |
| INTERVAL ESTIMATE | -0.317E-01 | 0.154E+02 | -0.365E+01 | -0.358E+01 | -0.493E+01 |
| AS PER CENT | -0.832E-02 | 0.193E+02 | -0.250E+01 | -0.264E+01 | -0.342E+01 |
| PER CENT AVE CHANGE | -0.200E-01 | 0.174E+02 | -0.307E+01 | -0.311E+01 | -0.417E+01 |
| UNBIASED-B | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.302E+00 | 0.136E+01 | 0.134E+01 | 0.123E-02 |
| AVERAGE CHANGE | -0.100E-02 | 0.700E-01 | -0.456E-01 | -0.546E-01 | -0.152E-03 |
| STD OF MEAN | 0.104E-09 | 0.251E-01 | 0.829E-02 | 0.124E-01 | 0.228E-03 |
| AVE PER CENT CHANGE | -0.200E-01 | 0.248E+02 | -0.334E+01 | -0.406E+01 | -0.102E+02 |
| INTERVAL ESTIMATE | -0.200E-01 | 0.129E+02 | -0.410E+01 | -0.521E+01 | -0.353E+02 |
| AS PER CENT | -0.200E-01 | 0.335E+02 | -0.259E+01 | -0.292E+01 | 0.107E+02 |
| PER CENT AVE CHANGE | -0.200E-01 | 0.232E+02 | -0.335E+01 | -0.407E+01 | -0.123E+02 |
| CONTROLS-C | | | | | |
| NUMBER | 16 | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.500E+01 | 0.204E+00 | 0.135E+01 | 0.133E+01 | 0.124E-02 |
| AVERAGE CHANGE | 0.425E-02 | 0.244E-02 | -0.421E-01 | -0.281E-01 | -0.206E-04 |
| STD OF MEAN | 0.950E-02 | 0.234E-02 | 0.248E-01 | 0.293E-01 | 0.298E-04 |
| AVE PER CENT CHANGE | 0.852E-01 | 0.119E+01 | -0.312E+01 | -0.211E+01 | -0.155E+01 |
| INTERVAL ESTIMATE | -0.163E-01 | 0.587E+00 | -0.410E+01 | -0.329E+01 | -0.295E+01 |
| AS PER CENT | 0.186E+00 | 0.181E+01 | -0.214E+01 | -0.937E+00 | -0.385E+00 |
| PER CENT AVE CHANGE | 0.850E-01 | 0.120E+01 | -0.312E+01 | -0.211E+01 | -0.166E+01 |
| F-TEST | | | | | |
| GROUPS A-B-C | 0.220E+01 | 0.113E+03 | 0.837E-01 | 0.296E+01 | 0.412E+01 |
| T-TESTS | | | | | |
| GROUPS A-B | -0.765E-11 | -0.189E+01 | 0.758E+00 | 0.245E+01 | 0.144E+01 |
| GROUPS A-C | -0.173E+01 | 0.236E+02 | 0.794E-01 | -0.137E+01 | -0.313E+01 |
| GROUPS B-C | -0.121E+01 | 0.113E+02 | -0.309E+00 | -0.194E+01 | -0.237E+01 |

MOTOROLA DIELECT. ISOLATED CTS

| | I LEAKAGE | RESISTANCE | T(DF) | T(DR) |
|---|---|---|---|---|
| BIASED-A | | | | |
| NUMBER | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.109E-07 | 0.547E+04 | 0.428E-07 | 0.692E-08 |
| AVERAGE CHANGE | 0.760E-09 | -0.427E+02 | -0.280E-07 | 0.100E-09 |
| STD OF MEAN | 0.103E-08 | 0.931E+02 | 0.433E-08 | 0.291E-09 |
| AVE PER CENT CHANGE | 0.774E+01 | -0.800E+00 | -0.652E+02 | 0.166E+01 |
| INTERVAL ESTIMATE | 0.200E+00 | -0.200E+01 | -0.726E+02 | -0.156E+01 |
| AS PER CENT | 0.137E+02 | 0.436E+00 | -0.581E+02 | 0.445E+01 |
| PER CENT AVE CHANGE | 0.695E+01 | -0.780E+00 | -0.653E+02 | 0.145E+01 |
| UNBIASED-B | | | | |
| NUMBER | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.790E-08 | 0.633E+04 | 0.376E-07 | 0.690E-08 |
| AVERAGE CHANGE | 0.115E-07 | -0.152E+02 | -0.253E-07 | 0.460E-09 |
| STD OF MEAN | 0.210E-07 | 0.119E+03 | 0.511E-08 | 0.365E-09 |
| AVE PER CENT CHANGE | 0.365E+03 | -0.560E+00 | -0.674E+02 | 0.675E+01 |
| INTERVAL ESTIMATE | -0.185E+03 | -0.258E+01 | -0.843E+02 | 0.105E+00 |
| AS PER CENT | 0.476E+03 | 0.210E+01 | -0.506E+02 | 0.132E+02 |
| PER CENT AVE CHANGE | 0.146E+03 | -0.240E+00 | -0.674E+02 | 0.667E+01 |
| CONTROLS-C | | | | |
| NUMBER | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.410E-07 | 0.594E+04 | 0.233E-07 | 0.819E-08 |
| AVERAGE CHANGE | 0.246E-08 | 0.160E+02 | 0.423E-08 | -0.300E-09 |
| STD OF MEAN | 0.612E-08 | 0.558E+02 | 0.857E-08 | 0.213E-09 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.259E+00 | 0.579E+02 | -0.363E+01 |
| INTERVAL ESTIMATE | -0.196E+01 | -0.231E+00 | -0.143E+01 | -0.505E+01 |
| AS PER CENT | 0.139E+02 | 0.770E+00 | 0.377E+02 | -0.228E+01 |
| PER CENT AVE CHANGE | 0.599E+01 | 0.270E+00 | 0.181E+02 | -0.366E+01 |
| F-TEST | | | | |
| GROUPS A-B-C | 0.247E+01 | 0.166E+01 | 0.776E+02 | 0.179E+02 |
| T-TESTS | | | | |
| GROUPS A-B | -0.168E+01 | -0.493E+00 | -0.104E+01 | -0.208E+01 |
| GROUPS A-C | -0.862E+00 | -0.202E+01 | -0.110E+02 | 0.405E+01 |
| GROUPS B-C | 0.159E+01 | -0.825E+00 | -0.725E+01 | 0.587E+01 |

PHILCO PL962

| | V(OH) | V(OL) | V(IH) | V(IL) | I DRIVE |
|---|---|---|---|---|---|
| BIASED-A | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.499E+01 | 0.256E+00 | 0.134E+01 | 0.133E+01 | 0.111E-02 |
| AVERAGE CHANGE | 0.180E-01 | 0.911E-01 | -0.530E-02 | -0.840E-02 | -0.290E-04 |
| STD OF MEAN | 0.189E-02 | 0.774E-02 | 0.960E-02 | 0.331E-02 | 0.876E-05 |
| AVE PER CENT CHANGE | 0.361E+00 | 0.361E+02 | -0.394E+00 | -0.632E+00 | -0.261E+01 |
| INTERVAL ESTIMATE | 0.334E+00 | 0.335E+02 | -0.905E+00 | -0.810E+00 | -0.317E+01 |
| AS PER CENT | 0.388E+00 | 0.378E+02 | 0.117E+00 | -0.454E+00 | -0.205E+01 |
| PER CENT AVE CHANGE | 0.361E+00 | 0.357E+02 | -0.394E+00 | -0.632E+00 | -0.261E+01 |
| UNBIASED-B | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.499E+01 | 0.244E+00 | 0.135E+01 | 0.134E+01 | 0.114E-02 |
| AVERAGE CHANGE | 0.180E-01 | 0.111E+00 | 0.720E-02 | -0.116E-01 | -0.220E-04 |
| STD OF MEAN | 0.236E-08 | 0.673E-02 | 0.729E-02 | 0.114E-02 | 0.447E-05 |
| AVE PER CENT CHANGE | 0.361E+00 | 0.458E+02 | 0.537E+00 | -0.868E+00 | -0.193E+01 |
| INTERVAL ESTIMATE | 0.361E+00 | 0.423E+02 | -0.138E+00 | -0.974E+00 | -0.241E+01 |
| AS PER CENT | 0.361E+00 | 0.492E+02 | 0.121E+01 | -0.762E+00 | -0.144E+01 |
| PER CENT AVE CHANGE | 0.361E+00 | 0.457E+02 | 0.534E+00 | -0.868E+00 | -0.193E+01 |
| CONTROLS-C | | | | | |
| NUMBER | 16 | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.500E+01 | 0.204E+00 | 0.135E+01 | 0.133E+01 | 0.124E-02 |
| AVERAGE CHANGE | 0.425E-02 | 0.244E-02 | -0.421E-01 | -0.281E-01 | -0.206E-04 |
| STD OF MEAN | 0.950E-02 | 0.234E-02 | 0.248E-01 | 0.293E-01 | 0.298E-04 |
| AVE PER CENT CHANGE | 0.852E-01 | 0.119E+01 | -0.312E+01 | -0.211E+01 | -0.155E+01 |
| INTERVAL ESTIMATE | -0.163E-01 | 0.587E+00 | -0.410E+01 | -0.329E+01 | -0.295E+01 |
| AS PER CENT | 0.186E+00 | 0.181E+01 | -0.214E+01 | -0.937E+00 | -0.385E+00 |
| PER CENT AVE CHANGE | 0.850E-01 | 0.120E+01 | -0.312E+01 | -0.211E+01 | -0.166E+01 |
| F-TEST | | | | | |
| GROUPS A-B-C | 0.148E+02 | 0.125E+04 | 0.184E+02 | 0.292E+01 | 0.444E+00 |
| T-TESTS | | | | | |
| GROUPS A-B | 0. | -0.496E+01 | -0.255E+01 | 0.207E+01 | -0.166E+01 |
| GROUPS A-C | 0.449E+01 | 0.432E+02 | 0.446E+01 | 0.210E+01 | -0.841E+00 |
| GROUPS B-C | 0.318E+01 | 0.571E+02 | 0.432E+01 | 0.123E+01 | -0.101E+00 |

PHILCO PL962

| | I LEAKAGE | RESISTANCE | T(OF) | T(OR) |
|---|---|---|---|---|
| BIASED-A | | | | |
| NUMBER | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.228E-06 | 0.628E+04 | 0.223E-07 | 0.647E-08 |
| AVERAGE CHANGE | -0.590E-08 | 0.113E+03 | -0.123E-07 | 0.720E-09 |
| STD OF MEAN | 0.177E-07 | 0.132E+03 | 0.129E-08 | 0.305E-09 |
| AVE PER CENT CHANGE | -0.426E+01 | 0.184E+01 | -0.550E+02 | 0.111E+02 |
| INTERVAL ESTIMATE | -0.816E+01 | 0.291E+00 | -0.592E+02 | 0.776E+01 |
| AS PER CENT | 0.298E+01 | 0.329E+01 | -0.509E+02 | 0.145E+02 |
| PER CENT AVE CHANGE | -0.259E+01 | 0.179E+01 | -0.551E+02 | 0.111E+02 |
| UNBIASED-B | | | | |
| NUMBER | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.806E-07 | 0.631E+04 | 0.222E-07 | 0.638E-08 |
| AVERAGE CHANGE | 0.130E-07 | 0.908E+02 | -0.132E-07 | 0.820E-09 |
| STD OF MEAN | 0.106E-07 | 0.592E+02 | 0.227E-08 | 0.164E-09 |
| AVE PER CENT CHANGE | 0.230E+02 | 0.146E+01 | -0.588E+02 | 0.129E+02 |
| INTERVAL ESTIMATE | -0.135E+00 | 0.275E+00 | -0.718E+02 | 0.966E+01 |
| AS PER CENT | 0.324E+02 | 0.260E+01 | -0.465E+02 | 0.161E+02 |
| PER CENT AVE CHANGE | 0.161E+02 | 0.144E+01 | -0.592E+02 | 0.129E+02 |
| CONTROLS-C | | | | |
| NUMBER | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.410E-07 | 0.594E+04 | 0.233E-07 | 0.819E-08 |
| AVERAGE CHANGE | 0.246E-08 | 0.160E+02 | 0.423E-08 | -0.300E-09 |
| STD OF MEAN | 0.612E-08 | 0.558E+02 | 0.857E-08 | 0.213E-09 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.259E+00 | 0.579E+02 | -0.363E+01 |
| INTERVAL ESTIMATE | -0.196E+01 | -0.231E+00 | -0.143E+01 | -0.505E+01 |
| AS PER CENT | 0.139E+02 | 0.770E+00 | 0.377E+02 | -0.228E+01 |
| PER CENT AVE CHANGE | 0.599E+01 | 0.270E+00 | 0.181E+02 | -0.366E+01 |
| F-TEST | | | | |
| GROUPS A-B-C | 0.447E+01 | 0.409E+01 | 0.269E+02 | 0.743E+02 |
| T-TESTS | | | | |
| GROUPS A-B | -0.217E+01 | 0.348E+00 | 0.993E+00 | -0.678E+00 |
| GROUPS A-C | -0.174E+01 | 0.261E+01 | -0.600E+01 | 0.101E+02 |
| GROUPS B-C | 0.283E+01 | 0.258E+01 | -0.442E+01 | 0.107E+02 |

RADIATION RD242

| | V(OH) | V(OL) | V(IH) | V(IL) | I DRIVE |
|---|---|---|---|---|---|
| **BIASED-A** | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.499E+01 | 0.203E+00 | 0.130E+01 | 0.129E+01 | 0.111E-02 |
| AVERAGE CHANGE | -0.260E-02 | 0.414E+00 | -0.360E-02 | -0.230E-01 | -0.300E-05 |
| STD OF MEAN | 0.303E-02 | 0.483E+00 | 0.148E-01 | 0.254E-01 | 0.483E-05 |
| AVE PER CENT CHANGE | -0.520E-01 | 0.193E+03 | -0.288E+00 | -0.174E+01 | -0.271E+00 |
| INTERVAL ESTIMATE | -0.954E-01 | 0.334E+02 | -0.109E+01 | -0.320E+01 | -0.579E+00 |
| AS PER CENT | -0.872E-02 | 0.374E+03 | 0.538E+00 | -0.376E+00 | 0.408E-01 |
| PER CENT AVE CHANGE | -0.521E-01 | 0.204E+03 | -0.278E+00 | -0.179E+01 | -0.269E+00 |
| **UNBIASED-B** | | | | | |
| NUMBER | 5 | 4 | 4 | 4 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.214E+00 | 0.130E+01 | 0.127E+01 | 0.119E-02 |
| AVERAGE CHANGE | -0.540E-02 | 0.126E+01 | 0.500E-03 | -0.900E-02 | -0.140E-04 |
| STD OF MEAN | 0.472E-02 | 0.123E+01 | 0.228E-01 | 0.163E-01 | 0.114E-04 |
| AVE PER CENT CHANGE | -0.108E+00 | 0.584E+03 | 0.219E-01 | -0.713E+00 | -0.119E+01 |
| INTERVAL ESTIMATE | -0.225E+00 | -0.327E+03 | -0.276E+01 | -0.275E+01 | -0.236E+01 |
| AS PER CENT | 0.926E-02 | 0.151E+04 | 0.283E+01 | 0.133E+01 | 0.130E-01 |
| PER CENT AVE CHANGE | -0.108E+00 | 0.589E+03 | 0.384E-01 | -0.707E+00 | -0.117E+01 |
| **CONTROLS-C** | | | | | |
| NUMBER | 16 | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.500E+01 | 0.204E+00 | 0.135E+01 | 0.133E+01 | 0.124E-02 |
| AVERAGE CHANGE | 0.425E-02 | 0.244E-02 | -0.421E-01 | -0.281E-01 | -0.206E-04 |
| STD OF MEAN | 0.950E-02 | 0.234E-02 | 0.248E-01 | 0.293E-01 | 0.298E-04 |
| AVE PER CENT CHANGE | 0.852E-01 | 0.119E+01 | -0.312E+01 | -0.211E+01 | -0.155E+01 |
| INTERVAL ESTIMATE | -0.163E-01 | 0.587E+00 | -0.410E+01 | -0.329E+01 | -0.295E+01 |
| AS PER CENT | 0.186E+00 | 0.181E+01 | -0.214E+01 | -0.937E+00 | -0.385E+00 |
| PER CENT AVE CHANGE | 0.850E-01 | 0.120E+01 | -0.312E+01 | -0.211E+01 | -0.166E+01 |
| **F-TEST** | | | | | |
| GROUPS A-B-C | 0.454E+01 | 0.106E+02 | 0.125E+02 | 0.813E+00 | 0.191E+01 |
| **T-TESTS** | | | | | |
| GROUPS A-B | 0.141E+01 | -0.192E+01 | -0.404E+00 | -0.101E+01 | 0.268E+01 |
| GROUPS A-C | -0.220E+01 | 0.345E+01 | 0.442E+01 | 0.450E+00 | 0.184E+01 |
| GROUPS B-C | -0.216E+01 | 0.447E+01 | 0.311E+01 | 0.124E+01 | 0.480E+00 |

# RADIATION RD242

| | I LEAKAGE | RESISTANCE | T(DF) | T(DR) |
|---|---|---|---|---|
| BIASED-A | | | | |
| NUMBER | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.325E-08 | 0.591E+04 | 0.592E-07 | 0.844E-08 |
| AVERAGE CHANGE | 0.105E-07 | 0.567E+02 | -0.475E-07 | 0.260E-09 |
| STD OF MEAN | 0.119E-07 | 0.497E+02 | 0.440E-07 | 0.783E-09 |
| AVE PER CENT CHANGE | 0.601E+03 | 0.969E+00 | -0.710E+02 | 0.319E+01 |
| INTERVAL ESTIMATE | 0.599E+02 | 0.359E+00 | -0.133E+03 | -0.356E+01 |
| AS PER CENT | 0.585E+03 | 0.156E+01 | -0.272E+02 | 0.972E+01 |
| PER CENT AVE CHANGE | 0.322E+03 | 0.960E+00 | -0.803E+02 | 0.308E+01 |
| UNBIASED-B | | | | |
| NUMBER | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.336E-08 | 0.541E+04 | 0.298E-07 | 0.856E-08 |
| AVERAGE CHANGE | 0.592E-07 | 0.700E+02 | -0.184E-07 | 0.114E-08 |
| STD OF MEAN | 0.110E-06 | 0.407E+02 | 0.618E-08 | 0.145E-08 |
| AVE PER CENT CHANGE | 0.159E+04 | 0.130E+01 | -0.607E+02 | 0.119E+02 |
| INTERVAL ESTIMATE | -0.230E+04 | 0.359E+00 | -0.875E+02 | -0.769E+01 |
| AS PER CENT | 0.583E+04 | 0.223E+01 | -0.360E+02 | 0.343E+02 |
| PER CENT AVE CHANGE | 0.177E+04 | 0.129E+01 | -0.617E+02 | 0.133E+02 |
| CONTROLS-C | | | | |
| NUMBER | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.410E-07 | 0.594E+04 | 0.233E-07 | 0.819E-08 |
| AVERAGE CHANGE | 0.246E-08 | 0.160E+02 | 0.423E-08 | -0.300E-09 |
| STD OF MEAN | 0.612E-08 | 0.558E+02 | 0.857E-08 | 0.213E-09 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.259E+00 | 0.579E+02 | -0.363E+01 |
| INTERVAL ESTIMATE | -0.196E+01 | -0.231E+00 | -0.143E+01 | -0.505E+01 |
| AS PER CENT | 0.139E+02 | 0.770E+00 | 0.377E+02 | -0.228E+01 |
| PER CENT AVE CHANGE | 0.599E+01 | 0.270E+00 | 0.181E+02 | -0.366E+01 |
| F-TEST | | | | |
| GROUPS A-B-C | 0.349E+01 | 0.303E+01 | 0.124E+02 | 0.788E+01 |
| T-TESTS | | | | |
| GROUPS A-B | -0.144E+01 | -0.516E+00 | -0.145E+01 | -0.155E+01 |
| GROUPS A-C | 0.227E+01 | 0.188E+01 | -0.463E+01 | 0.273E+01 |
| GROUPS B-C | 0.219E+01 | 0.199E+01 | -0.544E+01 | 0.407E+01 |

TEXAS INSTRUMENT SN15962

| | V(OH) | V(OL) | V(IH) | V(IL) | I DRIVE |
|---|---|---|---|---|---|
| BIASED-A | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 9 |
| INITIAL MEAN | 0.501E+01 | 0.223E+00 | 0.133E+01 | 0.131E+01 | 0.117E-02 |
| AVERAGE CHANGE | 0.700E-03 | 0.122E+00 | 0.151E-01 | 0.790E-02 | -0.211E-04 |
| STD OF MEAN | 0.211E-02 | 0.121E-01 | 0.642E-02 | 0.404E-02 | 0.333E-05 |
| AVE PER CENT CHANGE | 0.140E-01 | 0.550E+02 | 0.113E+01 | 0.603E+00 | -0.180E+01 |
| INTERVAL ESTIMATE | -0.182E-01 | 0.507E+02 | 0.788E+00 | 0.383E+00 | -0.203E+01 |
| AS PER CENT | 0.442E-01 | 0.584E+02 | 0.148E+01 | 0.825E+00 | -0.159E+01 |
| PER CENT AVE CHANGE | 0.140E-01 | 0.545E+02 | 0.113E+01 | 0.604E+00 | -0.181E+01 |
| UNBIASED-B | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.501E+01 | 0.233E+00 | 0.134E+01 | 0.133E+01 | 0.126E-02 |
| AVERAGE CHANGE | 0.600E-03 | 0.190E+00 | 0.274E-01 | 0.720E-02 | -0.240E-04 |
| STD OF MEAN | 0.548E-03 | 0.726E-01 | 0.541E-02 | 0.268E-02 | 0.548E-05 |
| AVE PER CENT CHANGE | 0.120E-01 | 0.798E+02 | 0.204E+01 | 0.543E+00 | -0.190E+01 |
| INTERVAL ESTIMATE | -0.160E-02 | 0.428E+02 | 0.154E+01 | 0.292E+00 | -0.245E+01 |
| AS PER CENT | 0.256E-01 | 0.120E+03 | 0.254E+01 | 0.795E+00 | -0.137E+01 |
| PER CENT AVE CHANGE | 0.120E-01 | 0.815E+02 | 0.204E+01 | 0.543E+00 | -0.191E+01 |
| CONTROLS-C | | | | | |
| NUMBER | 16 | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.500E+01 | 0.204E+00 | 0.135E+01 | 0.133E+01 | 0.124E-02 |
| AVERAGE CHANGE | 0.425E-02 | 0.244E-02 | -0.421E-01 | -0.281E-01 | -0.206E-04 |
| STD OF MEAN | 0.950E-02 | 0.234E-02 | 0.248E-01 | 0.243E-01 | 0.298E-04 |
| AVE PER CENT CHANGE | 0.852E-01 | 0.119E+01 | -0.312E+01 | -0.211E+01 | -0.155E+01 |
| INTERVAL ESTIMATE | -0.163E-01 | 0.587E+00 | -0.410E+01 | -0.329E+01 | -0.295E+01 |
| AS PER CENT | 0.186E+00 | 0.181E+01 | -0.214E+01 | -0.937E+00 | -0.385E+00 |
| PER CENT AVE CHANGE | 0.850E-01 | 0.120E+01 | -0.312E+01 | -0.211E+01 | -0.166E+01 |
| F-TEST | | | | | |
| GROUPS A-B-C | 0.997E+00 | 0.107E+03 | 0.427E+02 | 0.106E+02 | 0.440E-01 |
| T-TESTS | | | | | |
| GROUPS A-B | 0.102E+00 | -0.299E+01 | -0.366E+01 | 0.348E+00 | 0.124E+01 |
| GROUPS A-C | -0.116E+01 | 0.388E+02 | 0.710E+01 | 0.383E+01 | -0.484E-01 |
| GROUPS B-C | -0.843E+00 | 0.110E+02 | 0.612E+01 | 0.264E+01 | -0.248E+00 |

TEXAS INSTRUMENT SN15962

| | I LEAKAGE | RESISTANCE | T(DF) | T(DR) |
|---|---|---|---|---|
| BIASED-A | | | | |
| NUMBER | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.495E-08 | 0.602E+04 | 0.383E-07 | 0.112E-07 |
| AVERAGE CHANGE | 0.289E-08 | 0.817E+02 | -0.278E-07 | 0.141E-08 |
| STD OF MEAN | 0.119E-08 | 0.906E+02 | 0.478E-08 | 0.409E-09 |
| AVE PER CENT CHANGE | 0.900E+02 | 0.138E+01 | -0.723E+02 | 0.126E+02 |
| INTERVAL ESTIMATE | 0.411E+02 | 0.281E+00 | -0.816E+02 | 0.994E+01 |
| AS PER CENT | 0.756E+02 | 0.243E+01 | -0.638E+02 | 0.152E+02 |
| PER CENT AVE CHANGE | 0.584E+02 | 0.136E+01 | -0.727E+02 | 0.125E+02 |
| UNBIASED-B | | | | |
| NUMBER | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.788E-08 | 0.561E+04 | 0.343E-07 | 0.112E-07 |
| AVERAGE CHANGE | 0.870E-08 | 0.838E+02 | -0.253E-07 | 0.158E-08 |
| STD OF MEAN | 0.230E-08 | 0.791E+02 | 0.692E-08 | 0.540E-09 |
| AVE PER CENT CHANGE | 0.155E+03 | 0.152E+01 | -0.729E+02 | 0.140E+02 |
| INTERVAL ESTIMATE | 0.741E+02 | -0.256E+00 | -0.988E+02 | 0.810E+01 |
| AS PER CENT | 0.147E+03 | 0.325E+01 | -0.488E+02 | 0.201E+02 |
| PER CENT AVE CHANGE | 0.110E+03 | 0.149E+01 | -0.738E+02 | 0.141E+02 |
| CONTROLS-C | | | | |
| NUMBER | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.410E-07 | 0.594E+04 | 0.233E-07 | 0.819E-08 |
| AVERAGE CHANGE | 0.246E-08 | 0.160E+02 | 0.423E-08 | -0.300E-09 |
| STD OF MEAN | 0.612E-08 | 0.558E+02 | 0.857E-08 | 0.213E-09 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.259E+00 | 0.579E+02 | -0.363E+01 |
| INTERVAL ESTIMATE | -0.196E+01 | -0.231E+00 | -0.143E+01 | -0.505E+01 |
| AS PER CENT | 0.139E+02 | 0.770E+00 | 0.377E+02 | -0.228E+01 |
| PER CENT AVE CHANGE | 0.599E+01 | 0.270E+00 | 0.181E+02 | -0.366E+01 |
| F-TEST | | | | |
| GROUPS A-B-C | 0.367E+01 | 0.329E+01 | 0.708E+02 | 0.101E+03 |
| T-TESTS | | | | |
| GROUPS A-B | -0.656E+01 | -0.440E-01 | -0.829E+00 | -0.684E+00 |
| GROUPS A-C | 0.220E+00 | 0.230E+01 | -0.108E+02 | 0.140E+02 |
| GROUPS B-C | 0.220E+01 | 0.215E+01 | -0.700E+01 | 0.118E+02 |

MOTOROLA MC962

| | V(OH) | V(OL) | V(IH) | V(IL) | I DRIVE |
|---|---|---|---|---|---|
| BIASED-A | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.166E+00 | 0.138E+01 | 0.136E+01 | 0.134E-02 |
| AVERAGE CHANGE | -0.300E-03 | 0.102E+00 | 0.880E-02 | -0.360E-02 | -0.103E-03 |
| STD OF MEAN | 0.483E-03 | 0.845E-02 | 0.163E-01 | 0.106E-01 | 0.170E-04 |
| AVE PER CENT CHANGE | -0.600E-02 | 0.612E+02 | 0.634E+00 | -0.269E+00 | -0.749E+01 |
| INTERVAL ESTIMATE | -0.129E-01 | 0.576E+02 | -0.206E+00 | -0.823E+00 | -0.862E+01 |
| AS PER CENT | 0.910E-03 | 0.649E+02 | 0.148E+01 | 0.292E+00 | -0.680E+01 |
| PER CENT AVE CHANGE | -0.600E-02 | 0.612E+02 | 0.639E+00 | -0.266E+00 | -0.771E+01 |
| UNBIASED-B | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.162E+00 | 0.138E+01 | 0.136E+01 | 0.133E-02 |
| AVERAGE CHANGE | -0.100E-02 | 0.124E+00 | 0.120E-01 | -0.440E-02 | -0.106E-03 |
| STD OF MEAN | 0.104E-09 | 0.249E-01 | 0.469E-02 | 0.740E-02 | 0.114E-04 |
| AVE PER CENT CHANGE | -0.200E-01 | 0.764E+02 | 0.868E+00 | -0.326E+00 | -0.796E+01 |
| INTERVAL ESTIMATE | -0.200E-01 | 0.576E+02 | 0.448E+00 | -0.100E+01 | -0.903E+01 |
| AS PER CENT | -0.200E-01 | 0.958E+02 | 0.129E+01 | 0.352E+00 | -0.691E+01 |
| PER CENT AVE CHANGE | -0.200E-01 | 0.767E+02 | 0.870E+00 | -0.324E+00 | -0.797E+01 |
| CONTROLS-C | | | | | |
| NUMBER | 16 | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.500E+01 | 0.204E+00 | 0.135E+01 | 0.133E+01 | 0.124E-02 |
| AVERAGE CHANGE | 0.425E-02 | 0.244E-02 | -0.421E-01 | -0.281E-01 | -0.206E-04 |
| STD OF MEAN | 0.950E-02 | 0.234E-02 | 0.248E-01 | 0.293E-01 | 0.298E-04 |
| AVE PER CENT CHANGE | 0.852E-01 | 0.119E+01 | -0.312E+01 | -0.211E+01 | -0.155E+01 |
| INTERVAL ESTIMATE | -0.163E-01 | 0.587E+00 | -0.410E+01 | -0.329E+01 | -0.295E+01 |
| AS PER CENT | 0.186E+00 | 0.181E+01 | -0.214E+01 | -0.937E+00 | -0.385E+00 |
| PER CENT AVE CHANGE | 0.850E-01 | 0.120E+01 | -0.312E+01 | -0.211E+01 | -0.166E+01 |
| F-TEST | | | | | |
| GROUPS A-B-C | 0.184E+01 | 0.391E+03 | 0.251E+02 | 0.450E+01 | 0.459E+02 |
| T-TESTS | | | | | |
| GROUPS A-B | 0.318E+01 | -0.266E+01 | -0.424E+00 | 0.151E+00 | 0.353E+00 |
| GROUPS A-C | -0.150E+01 | 0.447E+02 | 0.574E+01 | 0.252E+01 | -0.794E+01 |
| GROUPS B-C | -0.121E+01 | 0.204E+02 | 0.477E+01 | 0.176E+01 | -0.618E+01 |

MOTOROLA MC962

| | I LEAKAGE | RESISTANCE | T(DF) | T(DR) |
|---|---|---|---|---|
| BIASED-A | | | | |
| NUMBER | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.518E-07 | 0.592E+04 | 0.757E-08 | 0.752E-08 |
| AVERAGE CHANGE | -0.277E-08 | 0.821E+02 | 0.580E-09 | 0.430E-09 |
| STD OF MEAN | 0.574E-08 | 0.750E+02 | 0.732E-09 | 0.365E-09 |
| AVE PER CENT CHANGE | 0.511E+01 | 0.139E+01 | 0.760E+01 | 0.581E+01 |
| INTERVAL ESTIMATE | -0.133E+02 | 0.480E+00 | 0.750E+00 | 0.224E+01 |
| AS PER CENT | 0.257E+01 | 0.229E+01 | 0.146E+02 | 0.919E+01 |
| PER CENT AVE CHANGE | -0.535E+01 | 0.139E+01 | 0.766E+01 | 0.572E+01 |
| UNBIASED-B | | | | |
| NUMBER | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.295E-07 | 0.593E+04 | 0.734E-08 | 0.744E-08 |
| AVERAGE CHANGE | 0.193E-08 | 0.100E+02 | 0.260E-09 | 0.660E-09 |
| STD OF MEAN | 0.264E-08 | 0.497E+02 | 0.619E-09 | 0.152E-09 |
| AVE PER CENT CHANGE | 0.313E+02 | 0.162E+00 | 0.332E+01 | 0.891E+01 |
| INTERVAL ESTIMATE | -0.456E+01 | -0.872E+00 | -0.693E+01 | 0.634E+01 |
| AS PER CENT | 0.177E+02 | 0.121E+01 | 0.140E+02 | 0.114E+02 |
| PER CENT AVE CHANGE | 0.656E+01 | 0.169E+00 | 0.354E+01 | 0.887E+01 |
| CONTROLS-C | | | | |
| NUMBER | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.410E-07 | 0.594E+04 | 0.233E-07 | 0.819E-08 |
| AVERAGE CHANGE | 0.246E-08 | 0.160E+02 | 0.423E-08 | -0.300E-09 |
| STD OF MEAN | 0.612E-08 | 0.558E+02 | 0.857E-08 | 0.213E-09 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.259E+00 | 0.579E+02 | -0.363E+01 |
| INTERVAL ESTIMATE | -0.196E+01 | -0.231E+00 | -0.143E+01 | -0.505E+01 |
| AS PER CENT | 0.139E+02 | 0.770E+00 | 0.377E+02 | -0.228E+01 |
| PER CENT AVE CHANGE | 0.599E+01 | 0.270E+00 | 0.181E+02 | -0.366E+01 |
| F-TEST | | | | |
| GROUPS A-B-C | 0.280E+01 | 0.405E+01 | 0.139E+01 | 0.370E+02 |
| T-TESTS | | | | |
| GROUPS A-B | -0.172E+01 | 0.193E+01 | 0.836E+00 | -0.133E+01 |
| GROUPS A-C | -0.217E+01 | 0.257E+01 | -0.133E+01 | 0.647E+01 |
| GROUPS B-C | -0.183E+00 | -0.215E+00 | -0.102E+01 | 0.930E+01 |

MOTOROLA SC1253

| | V(OH) | V(OL) | V(IH) | V(IL) | I DRIVE |
|---|---|---|---|---|---|
| BIASED-A | | | | | |
| NUMBER | 10 | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.500E+01 | 0.231E+00 | 0.139E+01 | 0.138E+01 | 0.100E-02 |
| AVERAGE CHANGE | -0.250E-02 | 0.109E+00 | -0.409E-01 | -0.605E-01 | -0.420E-04 |
| STD OF MEAN | 0.472E-02 | 0.259E-01 | 0.307E-02 | 0.465E-02 | 0.215E-04 |
| AVE PER CENT CHANGE | -0.500E-01 | 0.472E+02 | -0.294E+01 | -0.439E+01 | -0.412E+01 |
| INTERVAL ESTIMATE | -0.117E+00 | 0.393E+02 | -0.310E+01 | -0.464E+01 | -0.574E+01 |
| AS PER CENT | 0.175E-01 | 0.553E+02 | -0.278E+01 | -0.415E+01 | -0.266E+01 |
| PER CENT AVE CHANGE | -0.500E-01 | 0.473E+02 | -0.294E+01 | -0.440E+01 | -0.420E+01 |
| UNBIASED-B | | | | | |
| NUMBER | 5 | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.500E+01 | 0.235E+00 | 0.139E+01 | 0.138E+01 | 0.101E-02 |
| AVERAGE CHANGE | -0.100E-02 | 0.221E+00 | -0.490E-01 | -0.710E-01 | -0.500E-04 |
| STD OF MEAN | 0.707E-03 | 0.219E+00 | 0.791E-02 | 0.771E-02 | 0.707E-05 |
| AVE PER CENT CHANGE | -0.200E-01 | 0.883E+02 | -0.351E+01 | -0.514E+01 | -0.499E+01 |
| INTERVAL ESTIMATE | -0.375E-01 | -0.216E+02 | -0.422E+01 | -0.584E+01 | -0.584E+01 |
| AS PER CENT | -0.244E-02 | 0.210E+03 | -0.281E+01 | -0.445E+01 | -0.410E+01 |
| PER CENT AVE CHANGE | -0.200E-01 | 0.942E+02 | -0.351E+01 | -0.515E+01 | -0.497E+01 |
| CONTROLS-C | | | | | |
| NUMBER | 16 | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.500E+01 | 0.204E+00 | 0.135E+01 | 0.133E+01 | 0.124E-02 |
| AVERAGE CHANGE | 0.425E-02 | 0.244E-02 | -0.421E-01 | -0.281E-01 | -0.206E-04 |
| STD OF MEAN | 0.950E-02 | 0.234E-02 | 0.248E-01 | 0.293E-01 | 0.298E-04 |
| AVE PER CENT CHANGE | 0.852E-01 | 0.119E+01 | -0.312E+01 | -0.211E+01 | -0.155E+01 |
| INTERVAL ESTIMATE | -0.163E-01 | 0.587E+00 | -0.410E+01 | -0.329E+01 | -0.295E+01 |
| AS PER CENT | 0.186E+00 | 0.181E+01 | -0.214E+01 | -0.937E+00 | -0.385E+00 |
| PER CENT AVE CHANGE | 0.850E-01 | 0.120E+01 | -0.312E+01 | -0.211E+01 | -0.166E+01 |
| F-TEST | | | | | |
| GROUPS A-B-C | 0.279E+01 | 0.143E+02 | 0.347E+00 | 0.109E+02 | 0.372E+01 |
| T-TESTS | | | | | |
| GROUPS A-B | -0.694E+00 | -0.166E+01 | 0.291E+01 | 0.332E+01 | 0.798E+00 |
| GROUPS A-C | -0.208E+01 | 0.166E+02 | 0.146E+00 | -0.345E+01 | -0.197E+01 |
| GROUPS B-C | -0.121E+01 | 0.425E+01 | -0.607E+00 | -0.319E+01 | -0.215E+01 |

MOTOROLA SC1253

| | I LEAKAGE | RESISTANCE | T(DF) | T(DR) |
|---|---|---|---|---|
| **BIASED-A** | | | | |
| NUMBER | 10 | 10 | 10 | 10 |
| INITIAL MEAN | 0.796E-08 | 0.697E+04 | 0.289E-07 | 0.620E-08 |
| AVERAGE CHANGE | -0.351E-08 | -0.200E+01 | -0.203E-07 | 0.860E-09 |
| STD OF MEAN | 0.972E-08 | 0.705E+02 | 0.467E-08 | 0.227E-09 |
| AVE PER CENT CHANGE | 0.674E+01 | -0.604E-01 | -0.697E+02 | 0.139E+02 |
| INTERVAL ESTIMATE | -0.131E+03 | -0.752E+00 | -0.819E+02 | 0.113E+02 |
| AS PER CENT | 0.432E+02 | 0.695E+00 | -0.588E+02 | 0.165E+02 |
| PER CENT AVE CHANGE | -0.441E+02 | -0.287E-01 | -0.703E+02 | 0.139E+02 |
| **UNBIASED-B** | | | | |
| NUMBER | 5 | 5 | 5 | 5 |
| INITIAL MEAN | 0.362E-08 | 0.716E+04 | 0.281E-07 | 0.648E-08 |
| AVERAGE CHANGE | 0.302E-08 | -0.147E+04 | -0.200E-07 | 0.820E-09 |
| STD OF MEAN | 0.421E-09 | 0.308E+04 | 0.224E-08 | 0.409E-09 |
| AVE PER CENT CHANGE | 0.864E+02 | -0.211E+02 | -0.710E+02 | 0.124E+02 |
| INTERVAL ESTIMATE | 0.690E+02 | -0.739E+02 | -0.811E+02 | 0.483E+01 |
| AS PER CENT | 0.979E+02 | 0.329E+02 | -0.613E+02 | 0.205E+02 |
| PER CENT AVE CHANGE | 0.834E+02 | -0.205E+02 | -0.712E+02 | 0.127E+02 |
| **CONTROLS-C** | | | | |
| NUMBER | 16 | 16 | 16 | 16 |
| INITIAL MEAN | 0.410E-07 | 0.594E+04 | 0.233E-07 | 0.819E-08 |
| AVERAGE CHANGE | 0.246E-08 | 0.160E+02 | 0.423E-08 | -0.300E-09 |
| STD OF MEAN | 0.612E-08 | 0.558E+02 | 0.857E-08 | 0.213E-09 |
| AVE PER CENT CHANGE | 0.168E+01 | 0.259E+00 | 0.579E+02 | -0.363E+01 |
| INTERVAL ESTIMATE | -0.196E+01 | -0.231E+00 | -0.143E+01 | -0.505E+01 |
| AS PER CENT | 0.139E+02 | 0.770E+00 | 0.377E+02 | -0.228E+01 |
| PER CENT AVE CHANGE | 0.599E+01 | 0.270E+00 | 0.181E+02 | -0.366E+01 |
| **F-TEST** | | | | |
| GROUPS A-B-C | 0.251E+01 | 0.337E+01 | 0.491E+02 | 0.787E+02 |
| **T-TESTS** | | | | |
| GROUPS A-B | -0.147E+01 | 0.157E+01 | -0.134E+00 | 0.247E+00 |
| GROUPS A-C | -0.193E+01 | -0.723E+00 | -0.828E+01 | 0.132E+02 |
| GROUPS B-C | 0.202E+00 | -0.205E+01 | -0.616E+01 | 0.821E+01 |

CORRELATION BETWEEN CIRCUIT TYPES

| | V(OH) | V(OL) | V(IH) | V(IL) | I DRIVE |
|---|---|---|---|---|---|
| F-TEST | | | | | |
| ALL CIRCUIT TYPES | 0.408E+02 | 0.136E+02 | 0.550E+02 | 0.407E+02 | 0.103E+02 |
| T-TESTS COMPARING BIASED CIRCUIT TYPES | | | | | |
| CIRCUITS 1-2 | 0.758E+01 | 0.838E+01 | 0.762E+01 | 0.952E+01 | 0.626E+01 |
| CIRCUITS 1-3 | -0.280E+02 | 0.222E+01 | 0.558E+00 | 0.261E+01 | 0.156E+01 |
| CIRCUITS 1-4 | 0.385E+01 | -0.202E+01 | 0.166E+00 | 0.275E+01 | -0.939E+01 |
| CIRCUITS 1-5 | 0.593E+00 | -0.264E+01 | -0.413E+01 | -0.183E+01 | -0.143E+01 |
| CIRCUITS 1-6 | 0.767E+01 | 0.452E+00 | -0.179E+01 | 0.974E+00 | 0.140E+02 |
| CIRCUITS 1-7 | 0.241E+01 | -0.511E+00 | 0.984E+01 | 0.163E+02 | 0.257E+01 |
| CIRCUITS 2-3 | -0.292E+02 | -0.103E+02 | -0.789E+01 | -0.111E+02 | -0.460E+01 |
| CIRCUITS 2-4 | 0.161E+01 | -0.235E+01 | -0.652E+01 | -0.214E+01 | -0.110E+02 |
| CIRCUITS 2-5 | -0.238E+01 | -0.146E+02 | -0.142E+02 | -0.161E+02 | -0.683E+01 |
| CIRCUITS 2-6 | -0.233E+01 | -0.127E+02 | -0.813E+01 | -0.868E+01 | 0.749E+01 |
| CIRCUITS 2-7 | 0.990E+00 | -0.642E+01 | -0.141E+00 | 0.617E+01 | -0.125E+01 |
| CIRCUITS 3-4 | 0.183E+02 | -0.211E+01 | -0.305E+00 | 0.180E+01 | -0.822E+01 |
| CIRCUITS 3-5 | 0.193E+02 | -0.675E+01 | -0.558E+01 | -0.987E+01 | -0.254E+01 |
| CIRCUITS 3-6 | 0.297E+02 | -0.287E+01 | -0.236E+01 | -0.137E+01 | 0.122E+02 |
| CIRCUITS 3-7 | 0.128E+02 | -0.212E+01 | 0.112E+02 | 0.289E+02 | 0.177E+01 |
| CIRCUITS 4-5 | -0.283E+01 | 0.191E+01 | -0.367E+01 | -0.380E+01 | 0.940E+01 |
| CIRCUITS 4-6 | -0.237E+01 | 0.204E+01 | -0.178E+01 | -0.223E+01 | 0.179E+02 |
| CIRCUITS 4-7 | -0.564E-01 | 0.199E+01 | 0.781E+01 | 0.460E+01 | 0.560E+01 |
| CIRCUITS 5-6 | 0.146E+01 | 0.433E+01 | 0.114E+01 | 0.322E+01 | 0.141E+02 |
| CIRCUITS 5-7 | 0.196E+01 | 0.138E+01 | 0.249E+02 | 0.351E+02 | 0.288E+01 |
| CIRCUITS 6-7 | 0.147E+01 | -0.897E+00 | 0.950E+01 | 0.156E+02 | -0.703E+01 |
| T-TESTS COMPARING UNBIASED CIRCUIT TYPES | | | | | |
| CIRCUITS 1-2 | 0.325E+01 | 0.361E+01 | 0.119E+02 | 0.922E+01 | 0.125E+01 |
| CIRCUITS 1-3 | -0.188E+02 | 0.117E+01 | 0.241E+00 | 0.701E+01 | -0.447E+00 |
| CIRCUITS 1-4 | 0.316E+01 | -0.210E+01 | 0.737E+00 | 0.932E+00 | -0.154E+01 |
| CIRCUITS 1-5 | 0.134E+01 | -0.197E+01 | -0.545E+01 | -0.545E+01 | -0.601E-12 |
| CIRCUITS 1-6 | 0.325E+01 | -0.819E-01 | -0.115E+01 | 0.622E+00 | 0.127E+02 |
| CIRCUITS 1-7 | 0.306E+01 | -0.998E+00 | 0.131E+02 | 0.188E+02 | 0.510E+01 |
| CIRCUITS 2-3 | -0.228E+08 | -0.356E+01 | -0.107E+02 | -0.772E+01 | -0.127E+01 |
| CIRCUITS 2-4 | 0.208E+01 | -0.220E+01 | -0.424E+01 | -0.478E+01 | -0.135E+01 |
| CIRCUITS 2-5 | -0.653E+01 | -0.348E+01 | -0.165E+02 | -0.109E+02 | -0.125E+01 |
| CIRCUITS 2-6 | -0.437E-03 | -0.342E+01 | -0.135E+02 | -0.777E+01 | -0.450E+00 |
| CIRCUITS 2-7 | 0.180E-10 | -0.153E+01 | 0.663E+00 | 0.251E+01 | -0.999E+00 |
| CIRCUITS 3-4 | 0.111E+02 | -0.212E+01 | 0.627E+00 | -0.362E+00 | -0.146E+01 |
| CIRCUITS 3-5 | 0.710E+02 | -0.240E+01 | -0.497E+01 | -0.144E+02 | 0.632E+00 |
| CIRCUITS 3-6 | 0.228E+08 | -0.111E+01 | -0.124E+01 | -0.215E+01 | 0.153E+02 |
| CIRCUITS 3-7 | 0.601E+02 | -0.112E+01 | 0.117E+02 | 0.170E+02 | 0.748E+01 |
| CIRCUITS 4-5 | -0.282E+01 | 0.197E+01 | -0.259E+01 | -0.222E+01 | 0.177E+01 |
| CIRCUITS 4-6 | -0.208E+01 | 0.210E+01 | -0.112E+01 | -0.569E+00 | 0.128E+02 |
| CIRCUITS 4-7 | -0.206E+01 | 0.188E+01 | 0.458E+01 | 0.760E+01 | 0.600E+01 |
| CIRCUITS 5-6 | 0.653E+01 | 0.191E+01 | 0.481E+01 | 0.329E+01 | 0.145E+02 |
| CIRCUITS 5-7 | 0.400E+01 | -0.304E+00 | 0.178E+02 | 0.214E+02 | 0.650E+01 |
| CIRCUITS 6-7 | 0.899E-10 | -0.984E+00 | 0.148E+02 | 0.139E+02 | -0.933E+01 |

# CORRELATION BETWEEN CIRCUIT TYPES

| | I LEAKAGE | RESISTANCE | T(DF) | T(DR) |
|---|---|---|---|---|
| F-TEST | | | | |
| ALL CIRCUIT TYPES | 0.497E+01 | 0.446E+01 | 0.176E+02 | 0.219E+02 |
| T-TESTS COMPARING BIASED CIRCUIT TYPES | | | | |
| CIRCUITS 1-2 | 0.314E+01 | 0.444E+01 | 0.591E+00 | 0.870E-01 |
| CIRCUITS 1-3 | 0.312E+01 | 0.924E-01 | -0.260E+01 | -0.515E+01 |
| CIRCUITS 1-4 | 0.131E+01 | 0.232E+01 | 0.153E+01 | -0.583E+00 |
| CIRCUITS 1-5 | 0.279E+01 | 0.996E+00 | 0.565E+00 | -0.886E+01 |
| CIRCUITS 1-6 | 0.357E+01 | 0.111E+01 | -0.524E+01 | -0.238E+01 |
| CIRCUITS 1-7 | 0.344E+01 | 0.391E+01 | -0.918E+00 | -0.753E+01 |
| CIRCUITS 2-3 | 0.119E+01 | -0.304E+01 | -0.110E+02 | -0.466E+01 |
| CIRCUITS 2-4 | -0.257E+01 | -0.298E+01 | 0.140E+01 | -0.606E+00 |
| CIRCUITS 2-5 | -0.427E+01 | -0.303E+01 | -0.539E-01 | -0.825E+01 |
| CIRCUITS 2-6 | 0.192E+01 | -0.330E+01 | -0.205E+02 | -0.224E+01 |
| CIRCUITS 2-7 | 0.138E+01 | -0.110E+01 | -0.380E+01 | -0.652E+01 |
| CIRCUITS 3-4 | -0.243E+01 | 0.125E+01 | 0.254E+01 | 0.173E+01 |
| CIRCUITS 3-5 | -0.156E+01 | 0.611E+00 | 0.996E+01 | -0.427E+01 |
| CIRCUITS 3-6 | -0.531E+00 | 0.636E+00 | -0.273E+02 | 0.193E+01 |
| CIRCUITS 3-7 | -0.374E+00 | 0.242E+01 | 0.525E+01 | -0.116E+01 |
| CIRCUITS 4-5 | 0.200E+01 | -0.765E+00 | -0.141E+01 | -0.411E+01 |
| CIRCUITS 4-6 | 0.317E+01 | -0.893E+00 | -0.346E+01 | -0.622E+00 |
| CIRCUITS 4-7 | 0.288E+01 | 0.215E+01 | -0.195E+01 | -0.233E+01 |
| CIRCUITS 5-6 | 0.305E+01 | -0.108E-01 | -0.186E+02 | 0.565E+01 |
| CIRCUITS 5-7 | 0.207E+01 | 0.231E+01 | -0.357E+01 | 0.371E+01 |
| CIRCUITS 6-7 | 0.207E+00 | 0.258E+01 | 0.140E+02 | -0.316E+01 |
| T-TESTS COMPARING UNBIASED CIRCUIT TYPES | | | | |
| CIRCUITS 1-2 | 0.958E+00 | 0.192E+01 | 0.346E+01 | 0.884E+00 |
| CIRCUITS 1-3 | 0.940E+00 | 0.581E+00 | -0.192E+01 | -0.924E+00 |
| CIRCUITS 1-4 | -0.147E+00 | 0.103E+01 | 0.697E+00 | -0.720E+00 |
| CIRCUITS 1-5 | 0.106E+01 | 0.651E+00 | 0.271E+01 | -0.319E+01 |
| CIRCUITS 1-6 | 0.123E+01 | 0.213E+01 | -0.127E+02 | -0.581E-13 |
| CIRCUITS 1-7 | 0.120E+01 | 0.115E+01 | 0.230E+01 | -0.664E+00 |
| CIRCUITS 2-3 | -0.143E+00 | -0.178E+01 | -0.487E+01 | -0.201E+01 |
| CIRCUITS 2-4 | -0.955E+00 | -0.151E+01 | -0.194E+01 | -0.102E+01 |
| CIRCUITS 2-5 | 0.296E+00 | -0.155E+01 | 0. | -0.384E+01 |
| CIRCUITS 2-6 | 0.101E+01 | -0.436E+00 | -0.111E+02 | -0.113E+01 |
| CIRCUITS 2-7 | 0.902E+00 | 0.105E+01 | -0.214E+01 | -0.147E+01 |
| CIRCUITS 3-4 | -0.937E+00 | 0.647E+00 | 0.178E+01 | -0.491E+00 |
| CIRCUITS 3-5 | 0.890E+00 | 0.158E+00 | 0.374E+01 | -0.301E+01 |
| CIRCUITS 3-6 | 0.227E+01 | 0.234E+01 | -0.128E+02 | 0.160E+01 |
| CIRCUITS 3-7 | 0.211E+01 | 0.113E+01 | 0.480E+01 | 0.168E-13 |
| CIRCUITS 4-5 | 0.103E+01 | -0.347E+00 | 0.167E+01 | -0.636E+00 |
| CIRCUITS 4-6 | 0.117E+01 | 0.209E+01 | -0.672E+01 | 0.737E+00 |
| CIRCUITS 4-7 | 0.114E+01 | 0.112E+01 | 0.544E+00 | 0.475E+00 |
| CIRCUITS 5-6 | 0.432E+01 | 0.177E+01 | -0.824E+01 | 0.367E+01 |
| CIRCUITS 5-7 | 0.542E+01 | 0.113E+01 | -0.164E+01 | 0.251E+01 |
| CIRCUITS 6-7 | -0.908E+00 | 0.107E+01 | 0.195E+02 | -0.821E+00 |

## CONCLUSIONS

The research described in this report has extended the knowledge of the effects of space radiation on current types of analog and digital microcircuits. The performance information generated under this program has provided a means to identify current silicon integrated microcircuits that have demonstrated resistance to space radiation based on their response to electron exposures. In addition, the information presented should be usable for selection of components and design decisions for systems programmed for space missions.

Several significant conclusions are warranted by the research results. These are:

(1) The degradations of circuit parameters which were permanent in nature were found to increase with electron energy. These results are similar to, and consistent with, results obtained for individual transistors.

(2) The conclusions of Phase I and Phase II of this program are reaffirmed; i.e., the point of failure of all the microcircuits studied centered around the transistors. The radiation resistance of present silicon integrated circuits depends on the stability of the gain of the active elements and the tolerance of the circuit design with respect to gain degradation.

(3) In addition, to permanent degradation, temporary changes in output parameters were observed as a result of irradiation. Since these changes were not observed in all the circuits studied, it is concluded that failure modes are possible which are related not only to the degradation of the individual active elements but also to the fabrication of the integrated circuit.

(4) The evidence indicates that the temporary effects were, at least, initiated by surface damage. Since these changes occurred rapidly and at different exposure rates, the nature of the monitoring measurements did not preclude the possibility that exposure rate could be a significant factor contributing to the effect.

(5) In general, the degradation among the passively irradiated circuits was more severe than among the powered circuits, especially for the 1.5 MeV irradiation.

(6) The useful life of microcircuits under a steady-state electron environment can be increased by operating amplifiers at low closed-loop gains and by decreasing the permissible fan-out of the digital circuits.

(7) The overall radiation responses of the electrically equivalent 962 circuits were similar, but significant differences were observed in the magnitude of parameter changes. No correlation was found between the radiation response of these circuits and the circuit topology or the method of isolation. The observed differences in parameter changes are attributed to differences in processing techniques used during device fabrication.

The research has also raised questions that remain unanswered at this point. The temporary effect observed as a result of the irradiation is a good example. The implication of this effect leaves some uncertainty in the design of systems which must function during as well as after radiation exposure. It is not clear whether these effects would be observed under the low radiation rate characteristic of the space environment. Since surface damage seems to be responsible for these temporary changes, a method should be established by which surface degradation in integrated circuits can be identified and measured.

Since no model exists which may be used to explain the temporary effects observed, a detailed failure analysis is needed for a limited number of devices. The objective of this analysis would be to isolate the problem and generate a model that explains the observed behavior.

A reduction in fan-out has been shown to be conservative design practice for a radiation environment. Analytical methods are needed to extend the existing data to determine the extent to which this practice is helpful in increasing the radiation longevity of the circuits. In the same light, these analytical methods can be utilized to extend the radiation-effects data obtained on a particular device type to electrically similar circuits; i.e., often existing circuit designs are modified slightly to improve the electrical performance resulting in a "second generation" circuit that is structurally similar to the predecessor.

## NEW TECHNOLOGY

This section is not applicable.