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SANDIA CORPORATION
SANDIA BASE, ALBUQUERQUE, N. M.

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Capt. Kenneth L. Gilbert
Ballistics System Division
Norton Air Force Base
California

Dear Capt. Gilbert:

This letter records the information concerning the redesign of the Minuteman A Read Amplifier which was given to Messrs. F. E. Shaw, R. T. Matsumoto, and H. A. Schweitzer of Autonetics on November 12 and 13, 1963 as well as recent information sent to Mr. Shaw. Although the redesign of the amplifier is not complete, and probably will not be completed for sometime, we though it advisable to keep you appraised of our progress, approach to the problem, experimental data and recommendations regarding the redesign.

The data we made available to the Autonetics' personnel during their visit are as follows:

1. The Autonetics' personnel inspected the original read amplifier data and we explained the amplitude response and pulse duration of the amplifier as a function of radiation. Our estimates of the probability of system malfunctions contained in our report on the Minuteman system are based upon this data.

2. They also saw the read amplifier data which we obtained after the transistors normally used in the read amplifier were replaced with Type 107M transistors. The 107M is the transistor, as we understand the situation, suggested by Dr. Keister as a replacement which would harden the circuit. Based on our measurements of this transistor we expected only slight circuit improvement and the circuit response data which we obtained by irradiating the circuit verified our expectations. The difference in peak amplitude response of the circuit with the 107M transistor was about 20%, i.e., a 20% improvement. Because the time constants of this particular circuit essentially determine the pulse duration of the radiation induced response, substitution of the 107M transistor made a negligible change in the duration of the response. These experimental data indicate that significant improvements cannot be attained by the simple expediency of substituting transistors into the existing read amplifier circuit.

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3. We also made available to the Autonetics' personnel our measurements of primary and secondary photocurrents for eight or nine codes of the most modern switching-transistors. Of the transistors tested, the 2N2369 and 2N709 codes had the minimum radiation-induced transient response.

4. Because of the data in Items 1, 2, and 3, we believe that it will not be possible to meet the radiation requirements using currently available transistors if the amplifier does not have a balanced or differential configuration, i.e., it is necessary that radiation-induced transistor response in one part of the amplifier cancel the transistor response in another part of the amplifier and thereby reduce the output transient signal level.

5. A copy of the circuit diagram and our experimental data for a three-transistor amplifier was given to the Autonetics' personnel. This amplifier had the proper gain for use in the read amplifier circuit and had a response at an exposure of 1.5 rads of less than 0.7 volts. (An output signal less than about 0.7 volts gives a zero probability of failure for the amplifier at the corresponding radiation level.) It may not be desirable to use this amplifier because of the difficulty of determining the requirements a transistor must meet to guarantee that the response of one transistor cancels the transient response of another transistor. Although proper cancellation was obtained experimentally in our laboratories, we recommended that the Autonetics' personnel investigate the circuit analytically if they were interested in pursuing its use.

6. We gave the Autonetics' personnel copies of a schematic and our experimental data for a differential amplifier which looks promising. This differential amplifier could be used as the first stage in the pre-amplifier. Although additional stages of gain must be added, it appears possible to obtain the required gain and transient response (0.7 volts output at 1.5 rads). This circuit has a disadvantage of requiring a balanced termination to simulate the read head.

7. While the Autonetics' personnel were here we obtained transient data using our flash X-ray machine on a grounded-base differential-amplifier which they suggested during the course of our conversations. The data on this amplifier indicate that it would require very careful balancing and selection of transistors to obtain the necessary performance.

8. We discussed our theoretical calculations and substantiating experimental data which indicate the optimum circuit design for the first stages of a radiation-hardened linear amplifier. If properly used by Autonetics', the design approach indicated by these calculations should make it possible to design an optimum hardened amplifier.

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Attached is our letter to Mr. F. E. Shaw at Autonetics confirming a telephone conversation with him on November 21 wherein we gave him a circuit configuration reflecting some of our thoughts in regard to utilizing differential amplifiers and the information contained in Item 8 above. Although the letter is self-explanatory, it should be noted that this amplifier configuration meets the radiation requirements.

The test information contained in the letter indicates the transient response of the amplifier at doses of 1.5 rads is well within the 0.7 volt requirement. Autonetics will furnish a circuit to Sandia Corporation which incorporates our suggestions regarding the use of balanced configurations. We expect to test and determine its response at our flash X-ray machine and may make further suggestions for improving it.

Because the effort to harden the Read Amplifier is a continuing one, you may expect additional letters of this nature to appraise you of our participation and progress in this hardening effort.

Most sincerely,

S. C. Rogers
Division 5321

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Enc: Ltr. to F. E. Shaw, dtd 12/13/63

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