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Subcontract NP-1

WANL-TME-1944

8 August 1969

Westinghouse Astronuclear Laboratory

FLASH X-RAY TESTING OF INTEGRATED CIRCUIT

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INTRODUCTION

In May of 1969, a series of flash x-ray tests on integrated circuits were conducted at Westinghouse Astronuclear Laboratory's Flash X-ray Facility. The purpose of the test program was to investigate transient x-ray effects on sense amplifier (MC1440G) and read-write register (S8828A) integrated circuits associated with magnetic core memory systems. Although some experimental test data were available on these specific integrated circuits, the ionizing radiation transient response of these devices was unknown.

The integrated circuits were subjected to a flux of 10^6 R/sec to 5×10^9 R/sec. The duration of the induced photo voltage pulses was approximately 2 milliseconds and increased with increasing radiation rate. Radiation levels from 10^6 R/sec to 5×10^8 R/sec did not alter the read-write register operation; however, at a level of 10^9 R/sec, the circuit operation became erratic for periods up to 100 μ sec. No latch-up or permanent damage was noted after exposure to levels of 5×10^9 R/sec.

EQUIPMENT

A Field Emission Corporation Model 706 Febetron with a Type 5510 electron tube was used as a flash x-ray source. An external 8-mil thick tungsten target was placed over the aperture of the electron tube to convert the electron beam to a bremsstrahlung x-ray source. The x-ray pulse was observed using a Field Emission Corporation Model 3060 pulse radiation detector and a Tektronix Model 519 oscilloscope. The x-ray pulses were introduced through a copper screen into a shielded room where the target circuits were positioned. Provisions were made to operate the readout electronics in the screen room if necessary during the operation of the flash x-ray generator by using the portable lead personnel shield illustrated in Figure 1. Remote triggering of the oscilloscopes eliminated the need for personnel in the screen room during x-ray exposure.

X-RAY PULSE MEASUREMENTS

The flash x-ray machine was fired ten times for calibration purposes. A series of photographs were taken of the output of the Model 3060 pulse radiation detector with the Tektronix 519 oscilloscope to determine the uniformity of the x-ray pulses. Figure 2 shows a

Figure 1. Test Setup

Horizontal Scale: 5 n sec/div

Figure 2. Typical Detected X-Ray Pulse

typical detected x-ray pulse with a risetime of approximately 1 n sec and a duration (FWHM) of approximately 3 n sec. In order to calibrate the x-ray pulse magnitude, a number of lithium fluoride (LiF) thermoluminescent microrods* were placed at specific distances from the tungsten target. For accuracy purposes, ten shots from the flash x-ray generator were used to obtain an averaged accumulated dose per pulse. Figure 3 describes the dose and peak dose rate per pulse versus distance as determined from the LiF dosimetry.

TEST CIRCUITS

Figure 4 illustrates the two types of integrated circuits (sense amplifier and read-write register) that were selected for evaluation in the x-ray environment. The circuits were electrically mated. Each circuit had its own power supply. In case of latch-up, the current-limited power supply would prevent damage to the integrated circuits. Provisions were made so that either of the above circuits could be shielded or exposed to the x-ray pulse while still connected in the operational circuit arrangement shown in Figure 4.

In the test, three radiation response parameters of the integrated circuits were evaluated. The first was the magnitude of x-ray induced photocurrent pulse as a function of dose. The second response parameter was the decay time of the induced photocurrent. Third was the recovery time of the integrated circuit to normal operation as a function of the dose in the event that the integrated circuits should become momentarily disabled. Since the x-ray pulse is only a few nanoseconds wide, the effects observed are more properly correlated to total dose per pulse rather than peak dose rate.

Sense Amplifier

The sense amplifier evaluated was a Motorola MC1440G integrated circuit. The Motorola MC1550 is the military specification version of the MC1440 series. The sense amplifier was first subjected to the x-ray environment with no input signal. In Figure 4, the differential input leads have two 100 Ω carbon resistors connected to ground. The pulse transformer and signal cables were disconnected from the sense amplifier so that any induced signal on the input coaxial cable could not generate a transient effect that may not be

*Isotopes Inc. Type 167106

Figure 3. Dose and Peak Dose Rate Per Pulse vs Distance From Target

LAMP VISUAL AID

Figure 4. Test Circuits

associated directly with the sense amplifier. The sense amplifier was placed at specific distances from the tungsten target to allow observation of the induced photo voltages at various doses per pulse. Figure 5 shows induced photo voltage vs dose per pulse on two sense amplifiers that were tested with no input signal. Figure 6 illustrates a typical induced pulse at the output terminals with the circuit 6 inches from the target (1 R/pulse). Referring to Figure 3, this represents a peak dose rate of approximately 10^8 R/sec. The photo voltage increased with increasing radiation levels until about 3 inches from the target (3×10^8 R/sec). The induced voltage then decreased as the sense amplifier was moved inward from 3 inches to 1/2 inch from the tungsten target ($> 3 \times 10^8$ R/sec). This effect may be due to the various PN junctions in the sense amplifier beginning to saturate during exposure to the flash x-ray pulse thereby causing a loading effect on the photovoltage output.

The sense amplifiers were next subjected to the flash x-ray pulse with an input signal rate of 100 kHz (1 μ sec wide pulses). With the threshold input set at -6 Vdc, the input sensitivity was measured. The input sensitivity was ± 20 MV which conformed to the manufacturer's specification. The signal level at the differential input was set at 40 MV which should approximate a typical memory core pulse output. The sense amplifier was positioned at specific distances from the tungsten target to achieve dose rates from 10^7 to 3×10^9 R/sec. The circuit remained operational for all peak dose rates to 10^9 R/sec; however, a level shift occurred on the output. This is illustrated in Figure 7. It was also observed that the induced photo voltage decreased as the sense amplifier was moved inward from 3 inches to 1/2 inch from the tungsten target with an input signal present. The sense amplifier continued to operate during this time.

Read-Write Register

The read-write register was a Signetics S8828A 14 pin in-line cased integrated circuit. The prefix S denotes that this is a military specification unit. The S8828A was wired so that the output signal from the sense amplifier drives the set input. The $\bar{Q}$ output was tied back to the data input terminal to make the S8828A perform as a flip-flop circuit. The output of the flip-flop was loaded with a typical output impedance as shown in Figure 4. The lamp served as a visual indicator to determine when the flip-flop changed states. The

Figure 5. Induced Photo Voltage versus Dose per Pulse

Horizontal Scale: 2 m sec/div
Vertical Scale: 0.1 V/div
Peak Dose Rate: 7×10^6 R/sec

Figure 6. Typical Induced Photo Pulse

Horizontal Scale: $10 \mu \text{ sec/div}$
Vertical Scale: 5 V/div
Peak Dose Rate: 10^9 R/sec
Input Signal: 100 k Hz

Figure 7. Sense Amplifier DC Output Shift

flip-flop was tested with no input signal from the sense amplifier and preset in either of its two states: "1" or "0". Figure 8 shows the induced photo voltage vs dose for two flip-flops and the level of the minimum pulse which caused a change of state. The flip-flop was also tested with a 100 kHz input to the sense amplifier at various distances from the tungsten target. The operation of the flip-flop remained normal until a peak dose rate of approximately 10^9 R/sec was reached. At this level, the flip-flop became inoperative for time periods of about 100 μ sec. Figure 9 is an oscilloscope photograph showing the erratic flip-flop operation while positioned 1/2 inch from the target (2.5×10^9 R/sec).

CONCLUSIONS

The sense amplifier was tested at peak pulse radiation levels from 10^6 R/sec to 5×10^9 R/sec with and without an input signal. In both cases, the sense amplifier performed satisfactorily except for an induced voltage transient. The induced voltage at 5×10^6 R/sec was 1 volt peak with a decay time of 2 m sec. The decay time constant appeared to be independent of the dose rate.

The read-write register was also tested at radiation levels from 10^6 R/sec to 5×10^9 R/sec with and without an input signal. In both cases, the register performed satisfactorily up to radiation levels of approximately 10^9 R/sec. Erratic operation or cessation of operation for periods of time up to about 100 μ sec was observed above 10^9 R/sec.

The sense amplifier and read-write register did not latch-up for a radiation level of approximately 10^9 R/sec. The maximum corresponding dose was approximately 10 R. Since the duration of the radiation pulse was 3 n sec, the effects noted are more properly related to total dose per pulse rather than dose rate. No permanent damage occurred in either of the test circuits at a dose of 10 R. Thus, the sense amplifier and read-write registers tested have been shown to perform satisfactorily in a moderately severe transient radiation environment.

Figure 8. Induced Photo Voltage versus Dose per Pulse

Horizontal Scale: $10 \mu \text{ sec/div}$
Vertical Scale: 5 V/div
Peak Dose Rate: $2.5 \times 10^9 \text{ R/sec}$

Figure 9. Erratic Flip-Flop Operation