Single-Event Testing of the AD8151 Digital Crosspoint Switch

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Abstract – We present data on the SEE sensitivity of the AD8151 Digital Crosspoint Switch to heavy-ion irradiation at the Texas A&M University Cyclotron Facility. Data was taken under a variety of conditions including data rate, number of connected paths and ion LET. The results show the presence of both temporary losses of data transmission resulting in bursts of errors as well as a complete cessation of data transmission.

I. INTRODUCTION

The AD8151 Digital Crosspoint Switch manufactured by Analog Devices is capable of switching 33 inputs to any (or many) of 17 outputs with a maximum throughput of 3.2 Gbps per port. Because of its low power and high speed, it has potential applications in space for optical network switching or for a Giga-bit Ethernet.

Ionizing radiation in space can affect the part's reliability either by upsetting the data contained in the registers specifying which of the switches are on and which are off or, through direct strikes to the switches themselves, momentarily turning them on or off. The first case represents a loss or redirection of data transmission. To restart transmission, the data must first be reloaded into the configuration registers. The second case results in a temporary loss or redirection of data transmission.

The goal of this experiment was to measure the bit-error rate as a function of ion LET, data rate and number of switch connections through which the data passes and to characterize the nature of the errors, i.e., the length of a burst.

II. PART OPERATION

The switch is a fully differential non-blocking array, which requires two lines for each input and output. The signals are routed internally from inputs to outputs by connecting or disconnecting a matrix of switches. The state of each switch, whether "on" or "off", is programmed into the device. The first step is to load sequentially the data specifying the state of each switch into a "first rank" latch. Once all the data have been stored in the "first rank" latch, they are strobed into the "second rank" latch. The outputs of the second rank latch are decoded to select which of the switches in the 33x17-switch matrix are on and which are off.

The parts are packaged in plastic 184 lead LQFP (leaded quad flat pack). To allow the heavy ions with their limited range in matter to reach the chip, the plastic encapsulant was removed by acid etching. The part itself sustained no damage as a result of the etching. An evaluation board provided by Analog Devices Inc was used for testing.

III. TEST TECHNIQUES

SEE testing was carried out at the Texas A&M University Cyclotron Facility. Table 1 shows the heavy ions used for testing.

Table 1. Ions used for testing together with their LETs and angles of incidence.

Ion	LET ($MeV.cm^2/mg$)	Angles (Degrees)
Ne	2.86	0,45,60
Ar	8.96	0,45,60
Kr	30	0,60

The part was mounted in air on a stage that made it possible to change the angle of incidence, thereby increasing the effective ion LET. A Bit Error-Rate Tester (BERT) was used to provide a serial stream of data ("1s" and "0s") to the input of the AD8151. The signals supplied by the BERT were a standard, pseudo-random 127-bit repeating sequence pattern having a value of – 0.75 V_{dc} with 1.5 V peak-to-peak differential. After passing through the switch, the signals were fed back into the BERT for comparison with the expected signal. High performance cables (18 GHz) were used for all RF signals. Two configurations were tested to evaluate how the BER depended on the number of switches through which the signal passed. In the first configuration a single input was connected through the switch matrix to a single output, i.e., BERT(out) →In(10)→Out(0)→BERT(in). In the second configuration the signal from the BERT passed through the switch five times, i.e., BERT(out)→In(10)→ Out(0)→In(13)→Out(2)→In(8)→Out(6)→In(28)→Out (16)→In(18)→Out(10)→BERT(in). The BERT compared the actual output with the expected output to check for any changes in data. That information was stored for later analysis. During the actual runs, the part was started before the beam was switched on. The beam was switched off either after a fixed fluence or immediately following a cessation of transmission, which was heralded by the BERT as a loss of synchronization (LOS). To calculate the bit error rate (BER) the total number of bits transmitted during the exposure time must be known as well as the total number of errors. The total number of transmitted bits was obtained from the product of the data rate and the time the beam was on.

IV. RESULTS

The set of errors obtained from each run was analyzed according to whether they were "non-burst" (single-bit errors) or "burst" errors (a stream of errors). A single burst consists of more than one sequential error and is termed a "burst event." An "non-burst" event contains a single error. The total number of events is the sum of the burst events and the non-burst events.

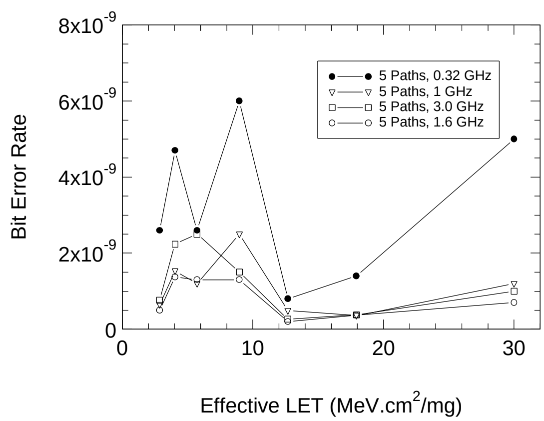

Fig. 1. Total event BER for 5 paths through the switch for different data rates. The event BER consists of both burst and non-burst events.

Fig. 1 shows the dependence of the event BER on the ion LET and on the data rate for 5 passes through the switch. For all LETs, the BER for the lowest data rate exceeds the BER for all other data rates. Generally, the high the data rate, the lower is the BER. There appears to be a peak in the BER at a LET of 7 MeV.cm^2/mg and then a stead increase with LET at higher LETs. The generally higher bit error rate at the lower LETs is most likely due to the fact that at low LETs most of the errors are non-burst errors, consisting of single bit upsets. At higher LETs most of the events consist of long bursts of errors. Many more non-burst errors (that dominate at low LETs) can be recorded during a fixed time interval than burst errors (that dominate at high LETs).

Fig. 2 shows the dependence of the event BER on the ion LET and on the data rate for a single pass through the switch. Again, the event BER can be quite high at low LETs where it is dominated by non-burst errors. There are large variations in the event BER with LET for the same frequency.

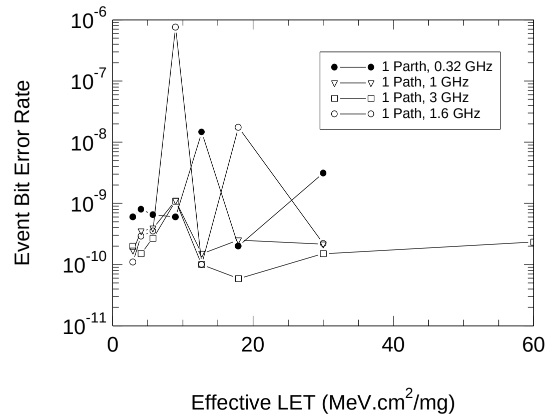

Fig. 2. Event BER as a function of ion LET for 1 pass through the switch.

The average number of data bits in each burst was calculated as a function of LET and data rate. Figure 3 shows that at low LETs the average number of errors in a burst is quite small (<5), but that between 6 MeV.cm^2/mg and 10 MeV.cm^2/mg there is a sudden large increase in the length of the bursts. The data indicates that at the highest LETs there is no clear dependence of burst length on data rate.

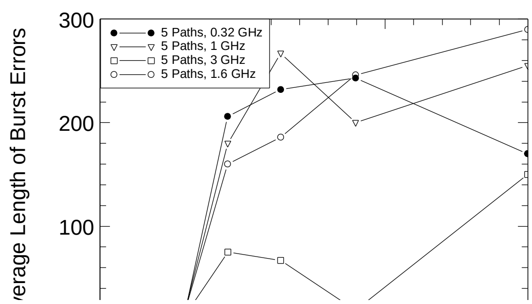

Fig. 3. Average length of burst errors as a function of ion LET and data transmission rate for 5 passes through the switch.

Figure 4 shows that the situation is the similar for the case of 1 pass through the switch, i.e., at low LETs the bursts are short but between 5 MeV.cm^2/mg and 10

MeV.cm^2/mg there is a dramatic increase in the average number of bits in a burst. The curves in figures 3 and 4 all show a peak at a LET of about 10 MeV.cm2/mg followed by an increase at higher LETs.

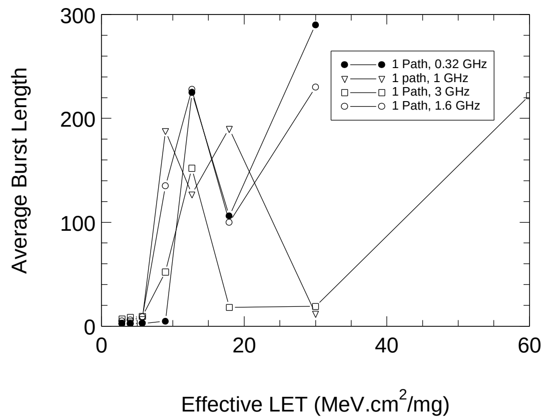

Fig. 4. Average number of bits in a burst as a function of ion LET for different data rates and for a single pass through the switch.

The other effect observed was a LOS by the BERT, indicating a cessation of data transmission. Figure 5 shows the LOS cross-section as a function of effective LET. There is a threshold at about 9 MeV.cm^2/mg, below which no LOSs were observed. The LOS cross-section increases with increasing LET, but there is no obvious dependence on data rate.

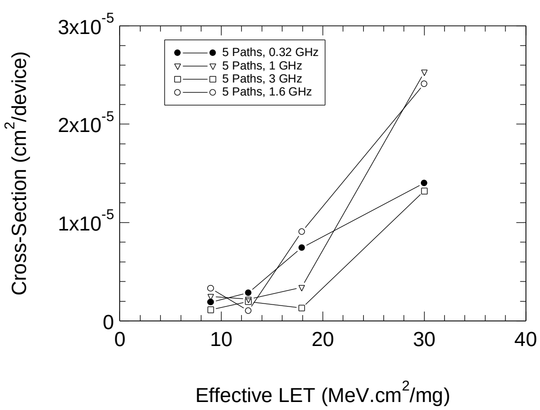

Fig. 5. Loss-of-Synchronization cross-section as a function of ion LET for different data rates for 5 passes through the switch.

Figure 6 shows the LOS cross-section as a function of effective LET for the case of a single pass through the switch. It seems obvious that for this configuration the cross-section should be about one fifth that of the configuration where the signal makes five passes through the switch. As a result the statistics are poor and it is difficult to discern any clear trends in the data.

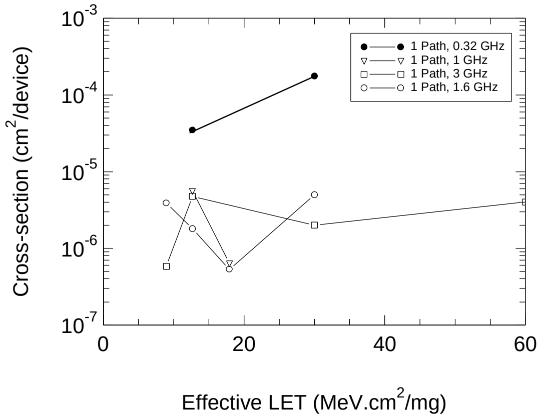

Fig. 6. Loss-of-synchronization cross-section as a function of ion effective LET for different data rates and for a single pass through the switch.

During the test no latchups were observed up to an effective LET of 60 MeV.cm^2/mg, and no changes in supply current were observed up to a dose of 14 krad(Si).

V. CONCLUSIONS

The AD8151 Cross Point Switch exhibits two types of single-event effects. The first consists of a temporary loss of transmission caused by heavy ion strikes to the switches themselves and resulting in bursts of errors whose length depends on ion LET. The second consists of a complete cessation of transmission caused by heavy ion strikes to the registers containing the data specifying the switch configuration. Only by rewriting the data to the registers can data transmission be restarted. The part is latchup-free to a LET of 60 MeV.cm^2/mg and shows no changes in supply current up to a TID of 14 krad(Si).