1. SEE Testing

1.1 SEE Test Procedure

Testing was done at Texas A&M University on July 18-21, 2000. The Cyclotron facility at Texas A&M University was used to provide the heavy ions. The facility, coupled to a K500 superconducting cyclotron is capable of providing a wide range of test ions and energies for advanced radiation testing.

The instrumentation used to command and monitor the HS-4080AEH while it was under test consisted of the following:

- Digital Voltage Meter (DVM)
- Two regulated power supplies (20V and 80V)
- DC current meter
- Dual channel storage oscilloscope
- Two High Speed Counters

The DVM monitored the regulated power supply voltage before and after exposure. The DC current meter monitored the current drawn by the device under test. In addition to supplying power to the device (normal and boot voltages), the regulated power supply also supplied the input bias conditions. The oscilloscope constantly monitored the two outputs during exposure, triggering on a transient and storing the output. Transients were then observed by setting the oscilloscope's persistence to infinity so any transient would be captured and stored. The counters were also connected to the two outputs and counted transients that were of sufficient magnitude to be recognized as a change in logic state.

1.2 Test Devices and Setup

Seven fully functional parts were packaged in 24-pin DIPs, with taped on lids to facilitate testing. The parts, bonded out as shown in Figure 1, were biased with 10V between VCC/VDD (pins 17 and 19) and GND (pin 4), with the DC current meter monitoring the current between VDD and GND. 10K resistors were placed from HDEL (pin 9) and LDEL (pin 11) to GND. Toggle switches were used to control the bias conditions on HEN (pin 2) and DIS (pin 3). The outputs were ALO (pin 15), AHO (pin 13), BLO (pin 21), and BHO (pin 24). BHS (pin 23), BLS (pin 18), ALS (pin 16), and AHS (pin 14) were tied to GND. AHB (pin 12) and BHB (pin 1) were tied to a separate supply that could be set to 10V to 20V for normal testing and to 80V for high voltage testing.

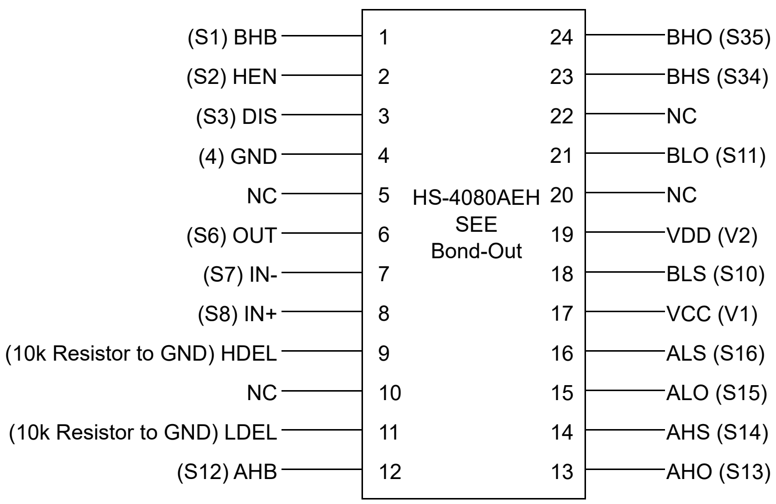

Figure 1. HS-4080AEH SEE Test Bond-Out
(Text in parentheses indicate switch or voltage supply connection)

The truth table for the HS-4080AEH is shown in Table 1. When V_{DD} is less than 8V, the Low Voltage Lockout (LVLO) circuitry ensures that the part is disabled and all four outputs are held low. When V_{DD} is greater than 9V and DIS is LOW and HEN is HIGH, the part is enabled and the outputs are controlled by IN+ and IN-. When DIS is LOW and HEN is LOW the high side outputs (AHO and BHO) are held LOW. When DIS is HIGH the part is disabled and all four outputs are held LOW. The HS4080ARH was not tested for SET with V_{DD} less than 8V.

Table 1. HS-4080AEH Truth Table

V_{DD}	Input			Output			
	IN+>IN-	HEN	DIS	ALO	AHO	BLO	BHO
>9V	HIGH	HIGH	LOW	LOW	HIGH	HIGH	LOW
>9V	LOW	HIGH	LOW	HIGH	LOW	LOW	HIGH
>9V	HIGH	LOW	LOW	LOW	LOW	HIGH	LOW
>9V	LOW	LOW	LOW	HIGH	LOW	LOW	LOW

Because of the nature of its use as a Full Bridge Driver, the transitions of interest would be the outputs inadvertently changing from a LOW to a HIGH during exposure. This condition causes both N-Channel MOSFETs on the same side of the Full Bridge configuration to conduct at once, risking burnout. Therefore, four SEU conditions were tested, all at V_{DD} > 9V.

- DIS LOW/HEN HIGH/IN+ > IN- – Check to see if ALO or BHO go from LOW to HIGH during exposure.
- DIS LOW/HEN HIGH/IN- > IN+ – Check to see if AHO or BLO go HIGH during exposure.
- DIS LOW/HEN LOW/IN+ > IN- – Check to see if BHO goes from LOW to HIGH during exposure.
- DIS LOW/HEN LOW/IN- > IN+ – Check to see if AHO goes from LOW to HIGH during exposure.

Toggle switches provided the appropriate levels on IN+, IN-, HEN, and DIS. The outputs (ALO, AHO, BLO, and BHO) were connected through scope probe connectors to oscilloscopes and through BNC connectors to pulse counters.

1.3 Test Procedure

To determine latch-up or burnout sensitivity, several devices were first exposed to Au ions at an incident angle of 60 degrees and temperatures of approximately 27°C and 125°C, at maximum supply voltage and under dynamic operating conditions. During and after exposure, the devices were monitored for excessive current with the DVM.

Then, while maintaining the appropriate static input conditions from Table 1, additional devices were exposed to Kr ions at an incident angle of 60 degrees and temperatures of approximately 27°C and 125°C and minimum supply voltage (and one at maximum voltage) to determine single event upset and/or transient behavior. During and after exposure, the devices were monitored for excessive current with the DVM and for upset with the Oscilloscope.

2. Results

No latch-up or burnout was observed on three parts tested dynamically at 27°C and one part at 125°C at maximum supply voltages (V_{DD} = 20V, V_{BOOT} = 80V) using 1353MeV Au ions (LET = 90.9MeV-cm^2/mg) at 60° incidence from perpendicular (representing an effective LET of 181.8MeV-cm^2/mg as compared to testing with normal incidence). However, Unit 13 showed unacceptable overlapping of the outputs (scope traces are shown in Figure 2 and Figure 3). All exposures were run to a fluence of 1×10^7ions/cm^2/sec. The flux was greater than or equal to 6×10^4. Parts were toggled at 1Khz and 20KHz, 50% duty cycle. Supply current was measured pre-rad and post-rad and the results are shown in Table 2. There was little or no difference in the pre-rad and post-rad currents. The accumulated total dose for these parts was about 1.0×10^4rad(Si).

Table 2. HS-4080AEH Dynamic SEE Latch-Up/Burnout Test Results

Unit	Current		Conditions and Comments
	Pre (mA)	Post (mA)	V_{CC} = 20V; V_{BOOT} = 80V Temp = 27°C and 125°C; Ion = Au Fluence = 1×10^{7}ions/cm^2; Flux = 6.5×10^{4}ions/cm^2/sec Angle = 60°; LET_{eff} = 181.8MeV-cm^2/mg Total Accumulated Dose = 1.4×10^{4}rad(Si)
13	12.5	12.5	20kHz - No latch-up or Burnout - BHO goes High While BLO is High
13	13.4	13.4	Temp = 125°C - 20 kHz - BHO goes High While BLO is High - No latch-up or Burnout
14	12.6	12.6	1kHz - No latch-up or Burnout - BHO goes High While BLO is High
15	13.1	13.1	1kHz - No latch-up or Burnout

After changing the ion species to 2100MeV Kr (LET = 35.5MeV-cm^2/mg) at 60-degree incidence from the perpendicular (an effective LET of 71.0MeV-cm^2/mg), one part was tested statically, and two parts were tested dynamically for single event transients per Table 1. For these exposures, V_{DD} was set to 10V and V_{BOOT} was set to GND. All exposures were run to a fluence of 2×10^{6}ions/cm^2 and a flux of greater than or equal to 9×10^{4}ions/cm^2/sec. The results are shown in Table 3. The static conditions for the INPUT STATES and corresponding OUTPUT STATES are given. The pre-rad and post-rad currents were not recorded as there were no significant differences between the two.

Table 3. HS-4080AEH Single Event Transient Test Results

Unit	Input States			Output States				Conditions and Comments
	IN+ > IN-	HEN	DIS	ALO	AHO	BLO	BHO	V_{CC} = 20V; V_{BOOT} = 0V Temp = 27°C; Ion = Krypton Fluence = 2×10^{6}ions/cm^2; Flux = 9×10^{4}ions/cm^2/sec Angle = 60°; LET_{eff} = 71MeV-cm^2/mg Total Accumulated Dose = 1.5×10^{3}rad(Si)
11	H	H	L	L	H	H	L	Static test - 7 volt transient on AHO, 5 volt transient on BHO
	L	H	L	H	L	L	H	No transients
	H	L	L	L	L	H	L	No transients
	L	L	L	H	L	L	L	No transients
2	H	H	L	L	H	H	L	Dynamic test – 5µs period – 2 High to Low transients on AHO
	H	H	L	H	L	L	H	Retested - No transients
	H	L	L	L	L	H	L	No transients
	L	L	L	H	L	L	L	No transients
10	H	H	L	L	H	H	L	Dynamic test – Outputs were jittery but no transients were observed
	L	H	L	H	L	L	H	No transients
	H	L	L	L	L	H	L	No transients
	L	L	L	H	L	L	L	No transients

No Low to High transients were observed during exposure to Kr, however, as can be seen in Figure 4, some non-fatal High to Low transients were seen in the static mode. The Low to High glitches are noise. Two parts were then exposed dynamically. The first part had a couple of transients on AHO. However, when it was exposed again, they did not reappear. The second part did not have any transients. The scope traces from that exposure are shown in Figure 5.

Based on these results a conservative transient cross-section and minimum LET can be estimated. At a fluence of 1×10^6 ions/cm^2, and assuming 100 transients per output (the approximate number seen with Au), the saturated cross-section would be 1×10^{-4} cm^2. Because only a couple of transients were seen in the static mode and no transients were seen in the dynamic mode when using Kr at 60 degrees, the minimum LET threshold can be estimated to be just less than 70MeV-cm^2/mg.

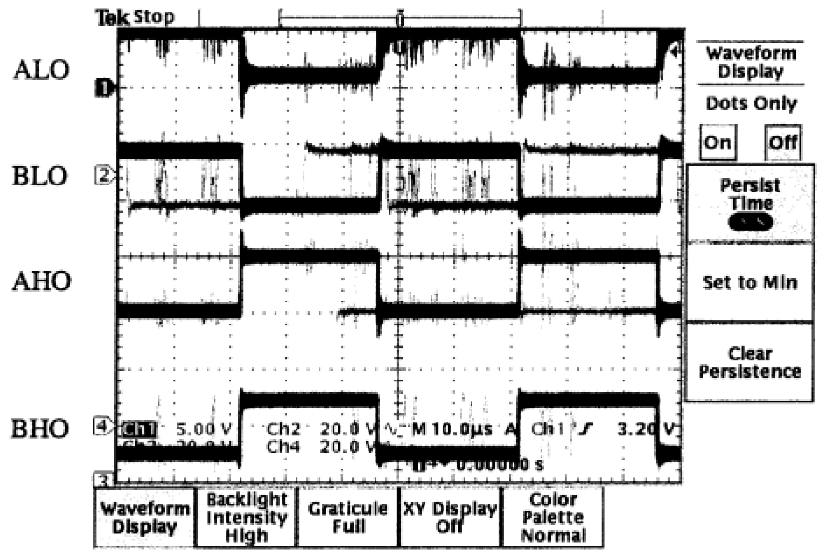

Figure 2. HS-4080AEH Scope Traces During 125°C Dynamic Exposure to Au ions
Note High/High Overlaps of BLO/BHO (Unit 13)

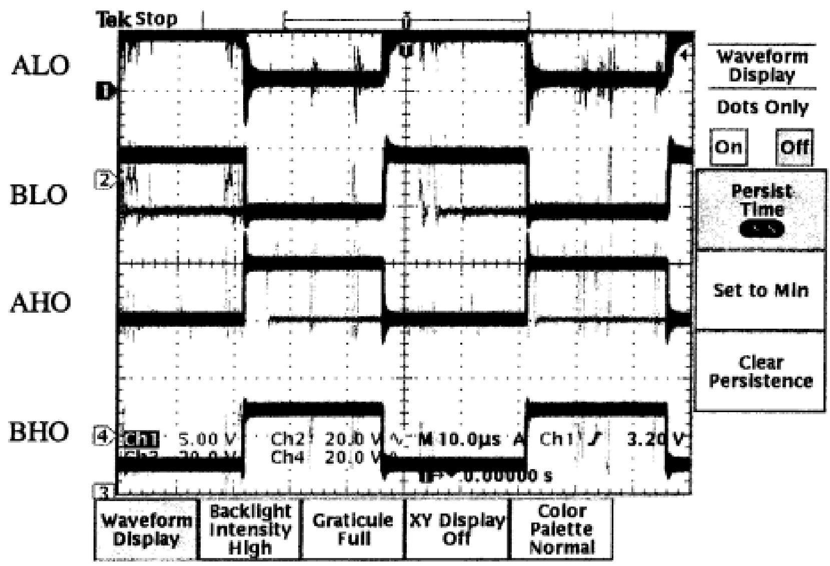

Figure 3. HS-4080AEH Scope Traces During 27°C Dynamic Exposure to Au Ions
Note the presence of a couple of unacceptable High to Low transients in BLO and BHO (Unit 13)

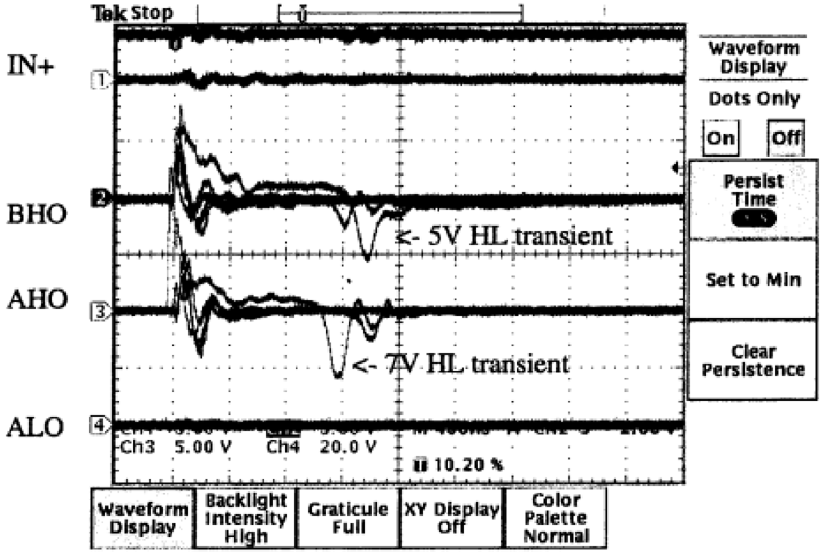

Figure 4. HS-4080AEH Scope Traces During 27°C Static Exposure to Krypton Ions
Note 5V and 7V High to Low Transients on BHO and AHO (Unit 11)

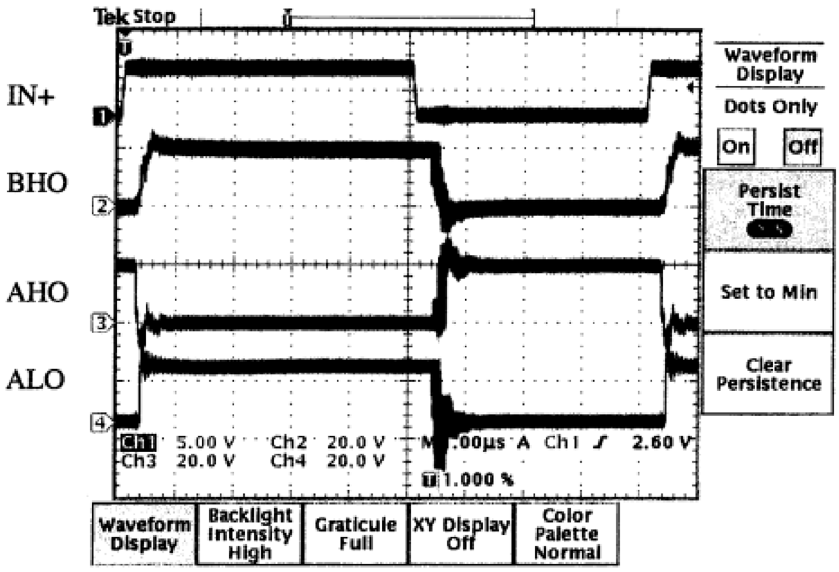

Figure 5. HS-4080AEH Scope Traces During 27°C Dynamic Exposure to Krypton Ions
No transients (Unit 10)

3. Conclusion

As expected, SEE testing of the HS-4080AEH did not produce any latch-up or other destructive effects at a high LET of 90.9MeV-cm^2/mg. Additionally, no potentially destructive (at the system level) low-to-high (LH) transients were observed up to an estimated LET of 70MeV-cm^2/mg.

4. Revision History

Revision	Date	Description
1.00	Nov 13, 2024	Initial release.

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