JUNE 2023

TEXAS
The University of Texas at Austin

COMBINED RADIATION ENVIRONMENT DAMAGE IN ELECTRONIC DEVICES

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Motivation

- Current practice of evaluating radiation damage in electronics generally assumes that the effect from different stresses in a combined environment are independent
  - and can be summed linearly
  - this limitation is because there are few facilities that can examine these stresses in a combined or ordered manner
- Damage to electronics in combined ionization damage (photon/electron) and displacement damage (neutron/ion) environments could be higher than the sum of the two environments if there is a synergistic effect
- Better understanding can help improve survivability of space-based electronics especially when subject to solar events

Previous Work

- Recent work by Yan et al. (NIMA, Vol. 831, pp. 334-338, 2016) suggested that a synergistic effect might occur in OP07 operational amplifiers
- However, the dosimetry methods used in this work were questionable making it difficult to draw conclusions
- Thus, in our work, we developed a methodology that could be used to study combined environment effects using a research reactor and pure TID system with detailed dosimetry measures

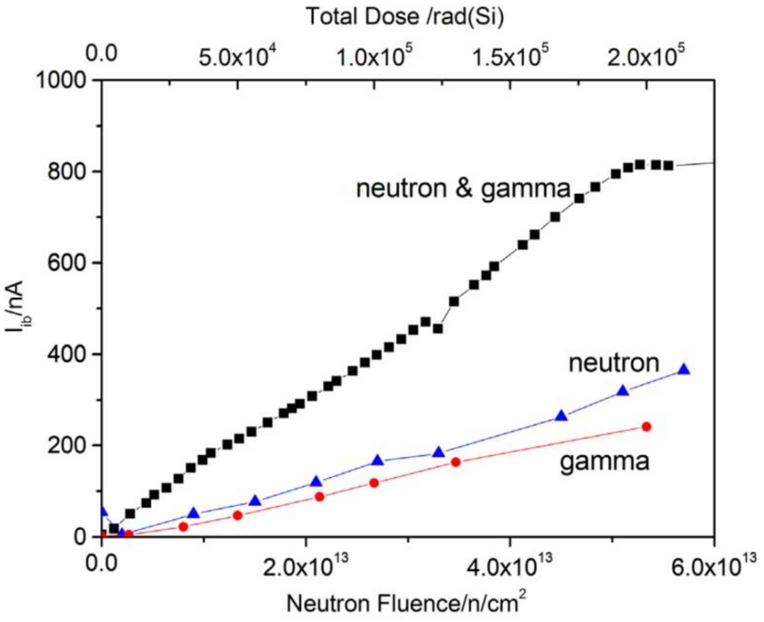
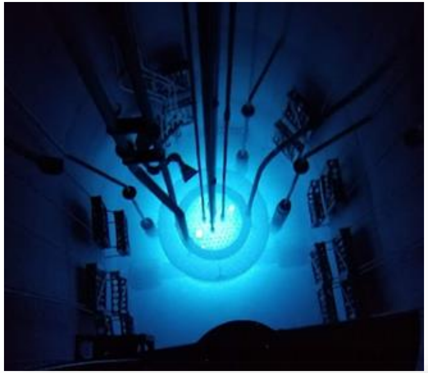
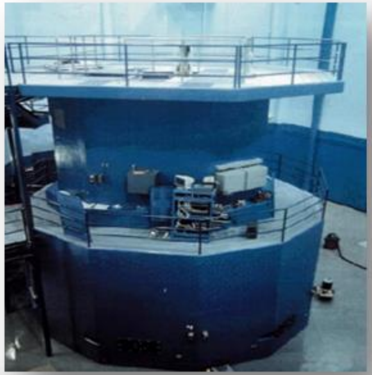


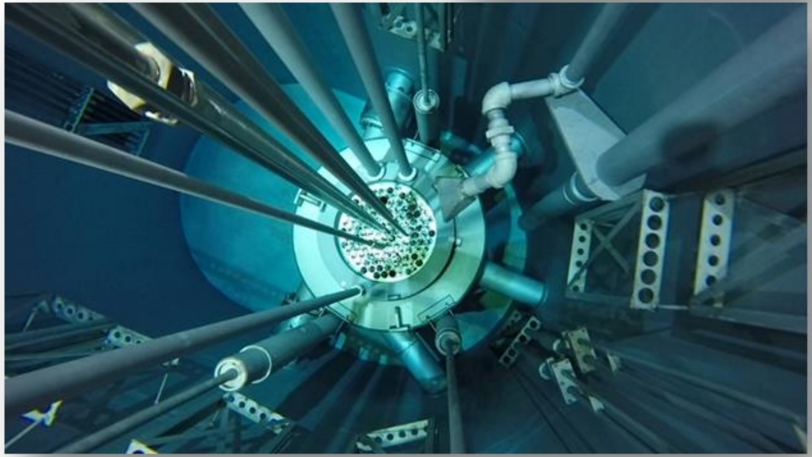
Fig. 5. Response of the input bias current I_{ib} under the three radiation environments.

UT-NETL Reactor

- The University of Texas at Austin (UT-Austin) Nuclear Engineering Teaching Laboratory (NETL) is home to a 1.1 MW TRIGA Mark II reactor
- Initial criticality in 1992
- Reactor is principally designed as a neutron beam facility but include numerous in-core irradiation facilities

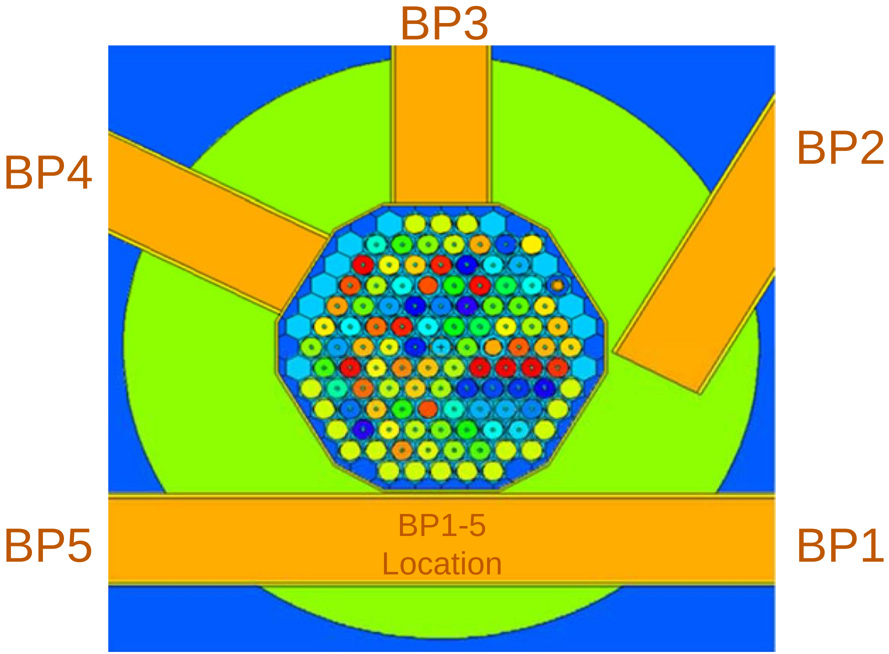






Neutron Irradiation

- Neutron irradiations were performed using the beam port 1-5 position at the UT-NETL 1.1 MW TRIGA Mark II reactor
  - This position is directly adjacent to the reactor core and allows for a dry irradiation port with active cabling for devices
  - This delivers to the sample a 1-MeV (Si) Eq. fluence of 2.10E12 n/cm^2 per MJ of reactor energy

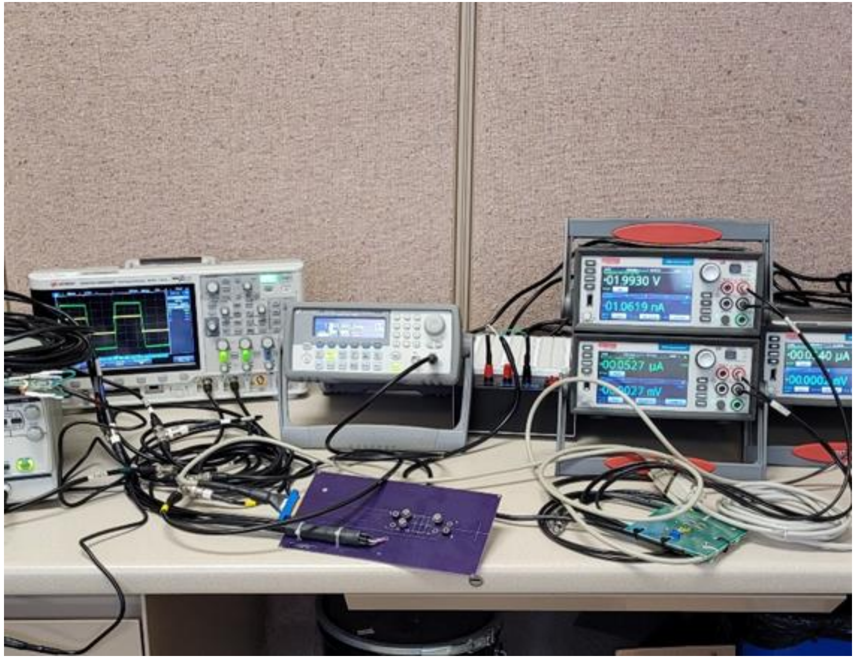


Neutron Irradiation (continued)

- Significant gamma flux is present from the reactor in the BP 1-5 position
  - A one-inch-thick cylindrical lead filter is used to reduce gamma dose to 3 krad per MJ of reactor energy

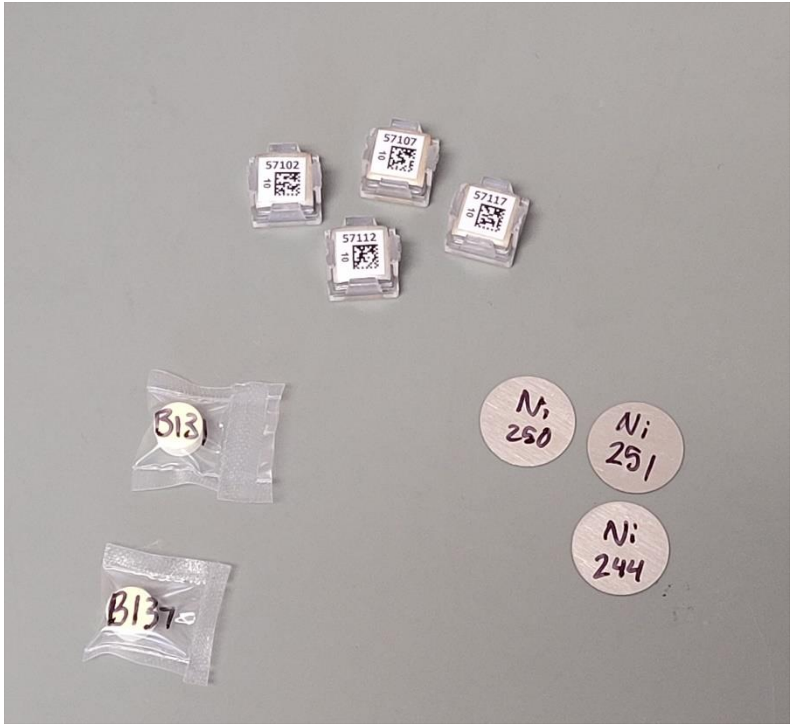
Testing Boards

- Circuit boards were developed to mount LM741 opamps during irradiation
- The electronics measured inverting and non-inverting input bias current and slew rate before, during, and after irradiation



Dosimetry

- The reactor position used in these irradiations was well characterized using multiple foil irradiations to unfold a detailed flux spectrum
  - During irradiations, nickel foils and sulfur pellets were used to measure the 1 MeV (Si) Eq. neutron fluence in reactor irradiations
- TLD-400s were used in all irradiations to measure the gamma dose provided to samples

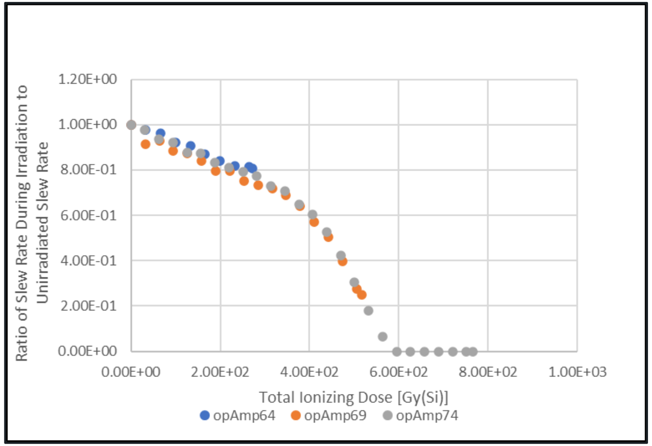


Photon Irradiation

- Photon irradiation was done using the MultiRad 350 at UT-Austin’s Dell Medical School
- The MultiRad is calibrated to measure dose to tissue and the team used TLD-400s read out by the RML at SNL to measure the appropriate dose to silicon

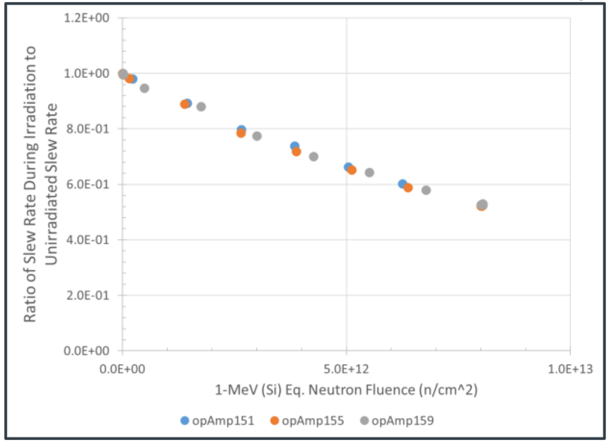
Slew Rate

- Slew rate is the maximum rate of change of an opamp's output voltage
  - It is a measure of performance of the output signal for an opamp
- Across multiple photon-only irradiations the slew rate degradation showed similar degradation
  - If the opamp did not fail, it had the opportunity to recover after the irradiation
- Growth in slew rate immediately following irradiation was not seen in neutron only irradiation



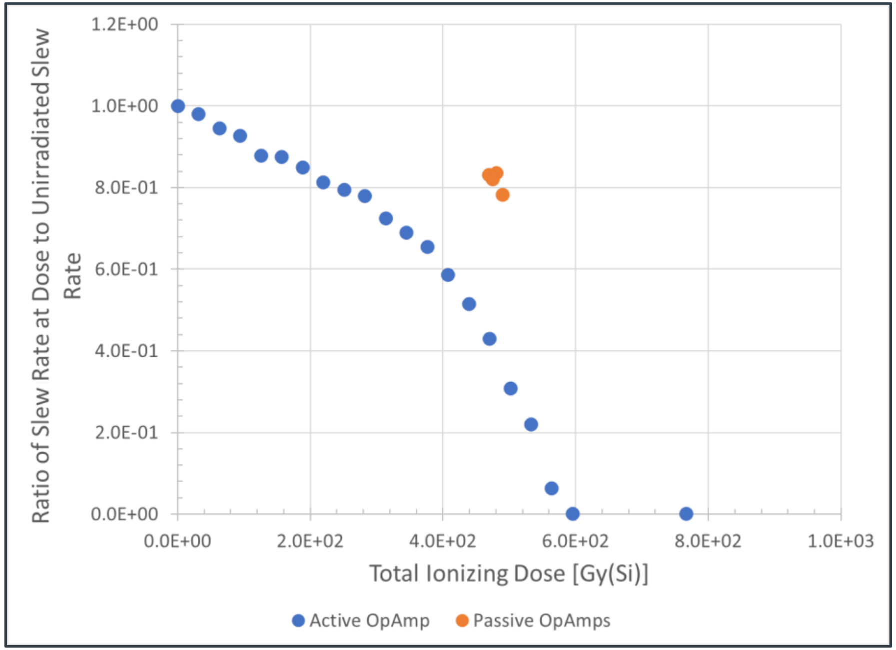
Photon-only

Reactor-only



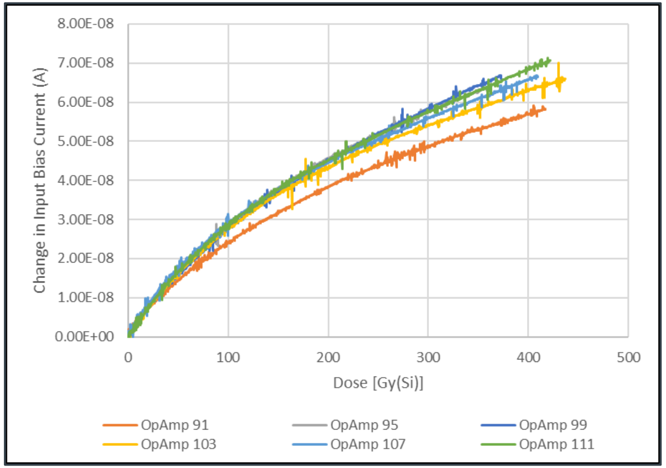
Passive Slew Rate

- Measurements were made both actively and passively
  - Active measurements show results as current passes through it
  - Passive measurements allow for analysis of op amps when current is not running through it
- Significant differences are seen between passive and active measurements
  - Potentially due to time or current annealing effects

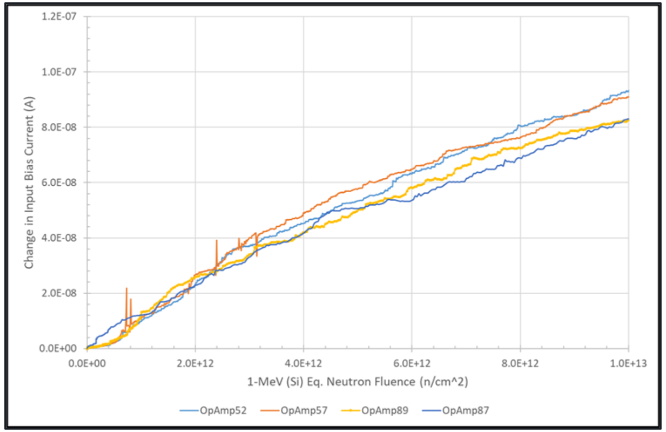


Input Bias Current

- Input bias current is the current drawn by the input terminals of the opamp
  - It is a measure of the performance of the input stage of the device
- The change in input bias current was shown to increase with respect to radiation dose



Photon-only



Reactor-only

Challenges

- Reactor environment contains both neutron and gamma fluxes
  - While gamma dose in reactor environment is small compared to gamma irradiator it is not insignifcant and must be accounted for
- Due to radioactivation, current test setup results in delay between neutron and photon irradiations
- Currently effects are measured as a function of cumulative dose
  - However, dose rate effects likely play a part in damage to the device

Future Work

- Future work will irradiate circuit boards with both photons and neutrons
- Photons will continue to be produced by the MultiRad 350 and neutrons by the NETL reactor
- There will be a time delay between irradiations due to instruments being at different facilities and the necessity to allow for decay of neutron irradiated devices
  - Currently using a 7-day delay between irradiations
- In an ideal setup, a TID irradiation facility would be built in the reactor facility such that a shorter time delay could occur between TID and displacement damage stresses to devices

Acknowledgements

- Sandia National Laboratories
  - This work is funded under PO 2049205 by Sandia National Laboratories
- Dave Vehar and the Radiation Metrology Laboratory at Sandia
  - provided all the TLD measurements for this work