A Self-compensated Preamplifier Survived up to 0.6 Mrad of Total Ionizing Dose based on GBW Compensation

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I. INTRODUCTION

- The proposed variable size MOSFET and Radiation hardening Layout provides radiation hardening operational amplifier.

- MPFD(Micro-Pocket Fission Detectors) developed at INL
- Same concept as coaxial fission chamber filled argon gas
- Miniature fission chamber for Neutron detection in reactor core

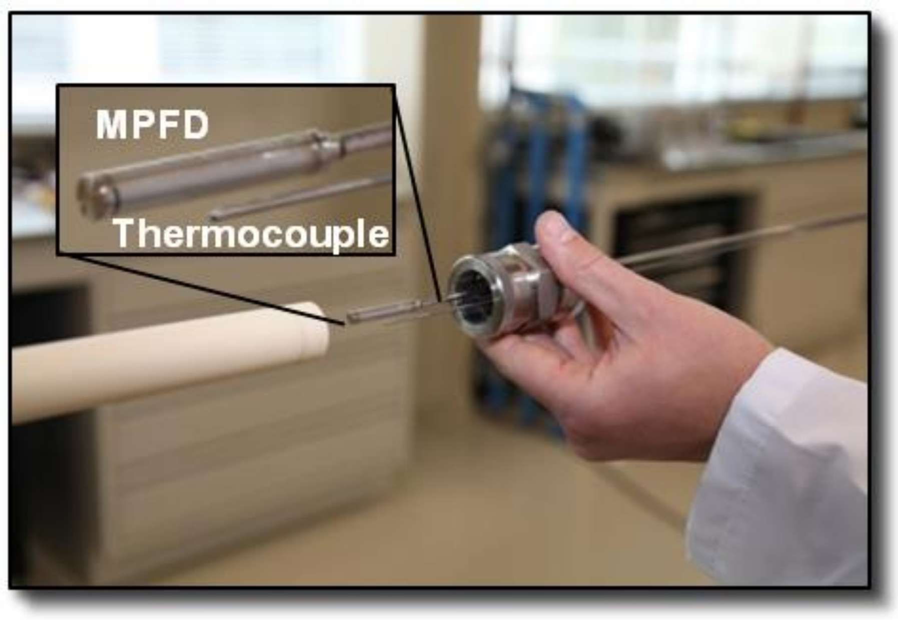

Fig. 1. Behaviors of the MPFD as target detector

II. Performance degradation of a Preamplifier

- *Gain degradation of BJT due to reduction of carrier life-time [2]*

$$\beta_F = \frac{I_C}{I_B} = \frac{1}{\frac{W_B{}^2}{2\tau_b D_n} + \frac{D_p W_B N_A}{D_n L_p N_D}} \quad (1)$$

- W_B is the width of the base region, D_n is the diffusion coefficient of electron and the N_A/N_D is the relative doping ratio of the base region and the emitter region.

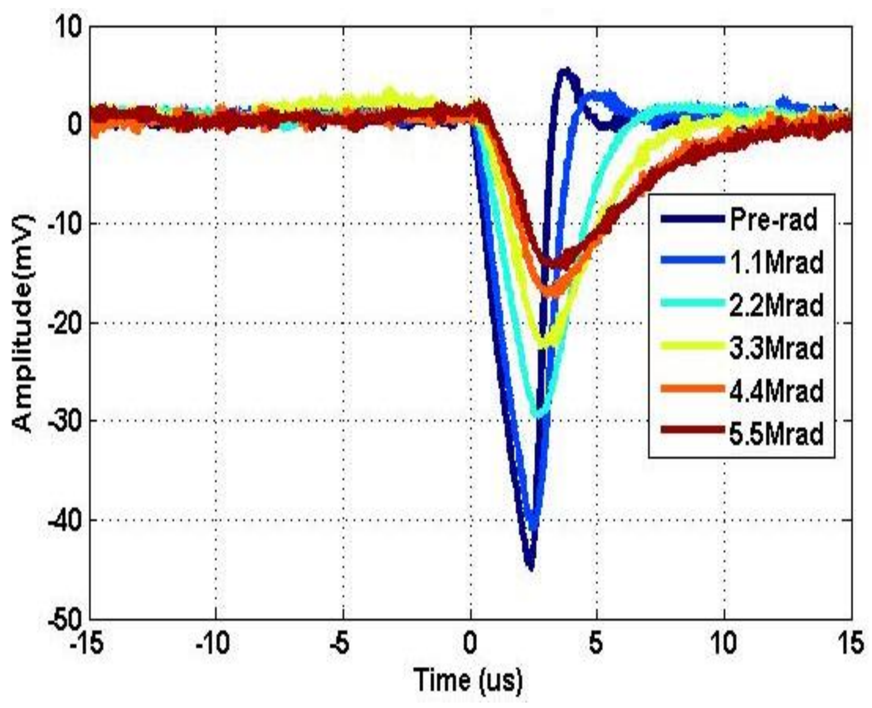

Fig. 2. During the irradiation test with Cobalt-60 γ-ray exposure up to 5.5 Mrad were plotted for amplitude variation

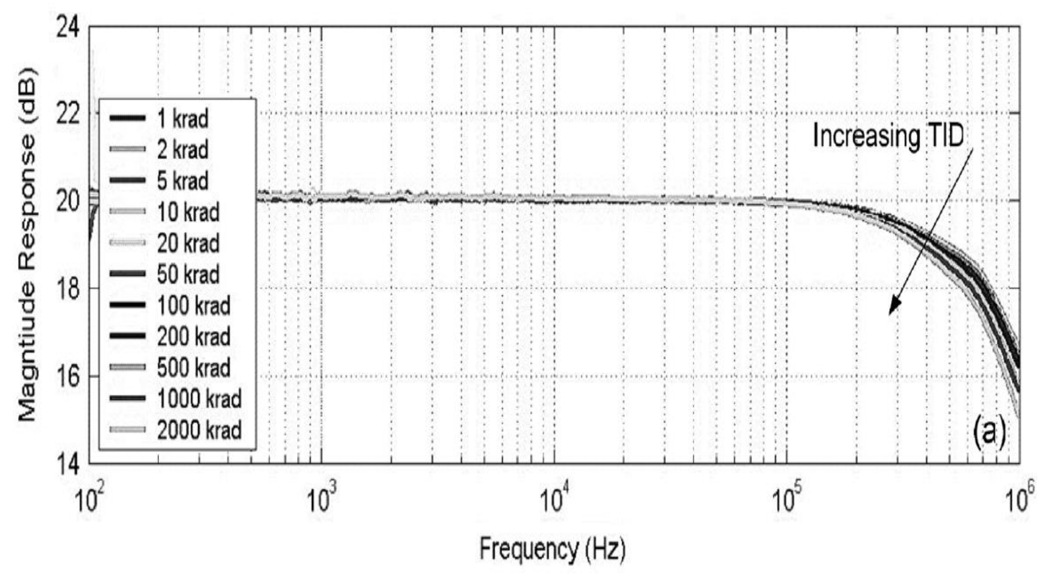

Fig. 3. Gain bandwidth product results during the irradiation test with Cobalt-60 γ-ray exposure up to 2 Mrad [3]

- *Gain bandwidth product (GBWP) reduction*

$$\text{GBWP} = \frac{g_m}{C_c} \quad (2)$$

- g_m is the trans-conductance of differential input stage and C_c is the Miller capacitor

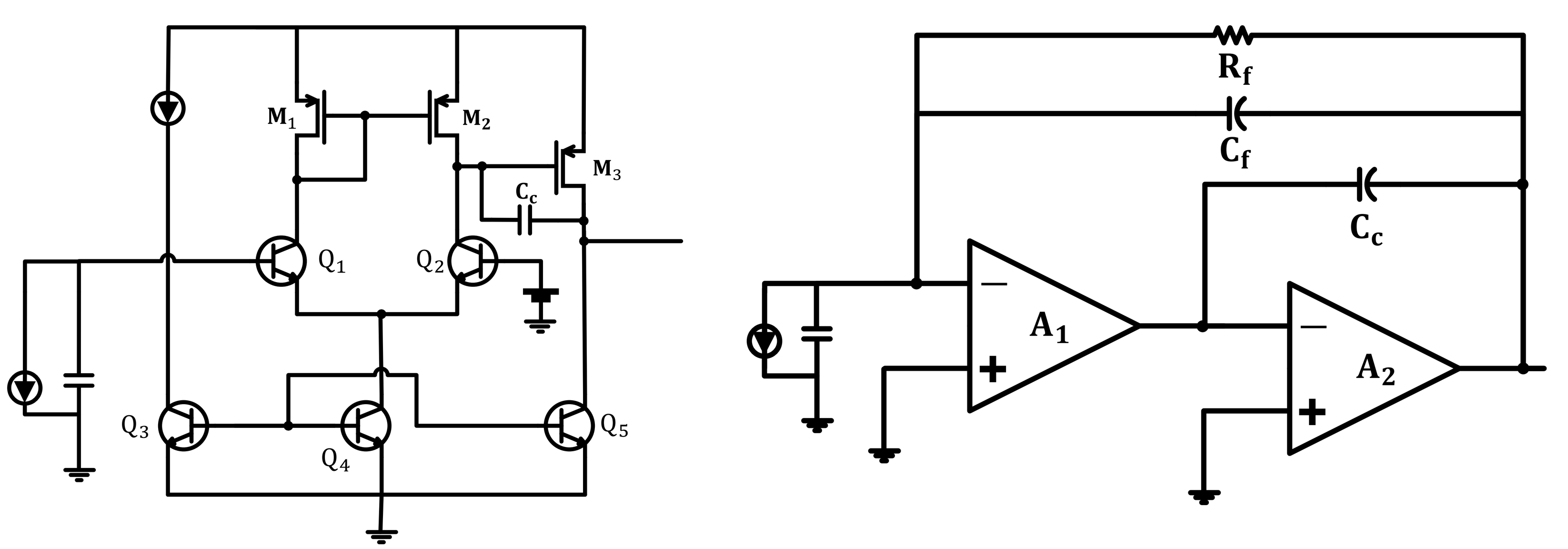

Fig. 4. Schematic of a charge-sensitive amplifier consisted of BiCMOS with feedback resistor, feedback capacitor and Miller capacitor

III. Self-compensated CSA for radiation hardness

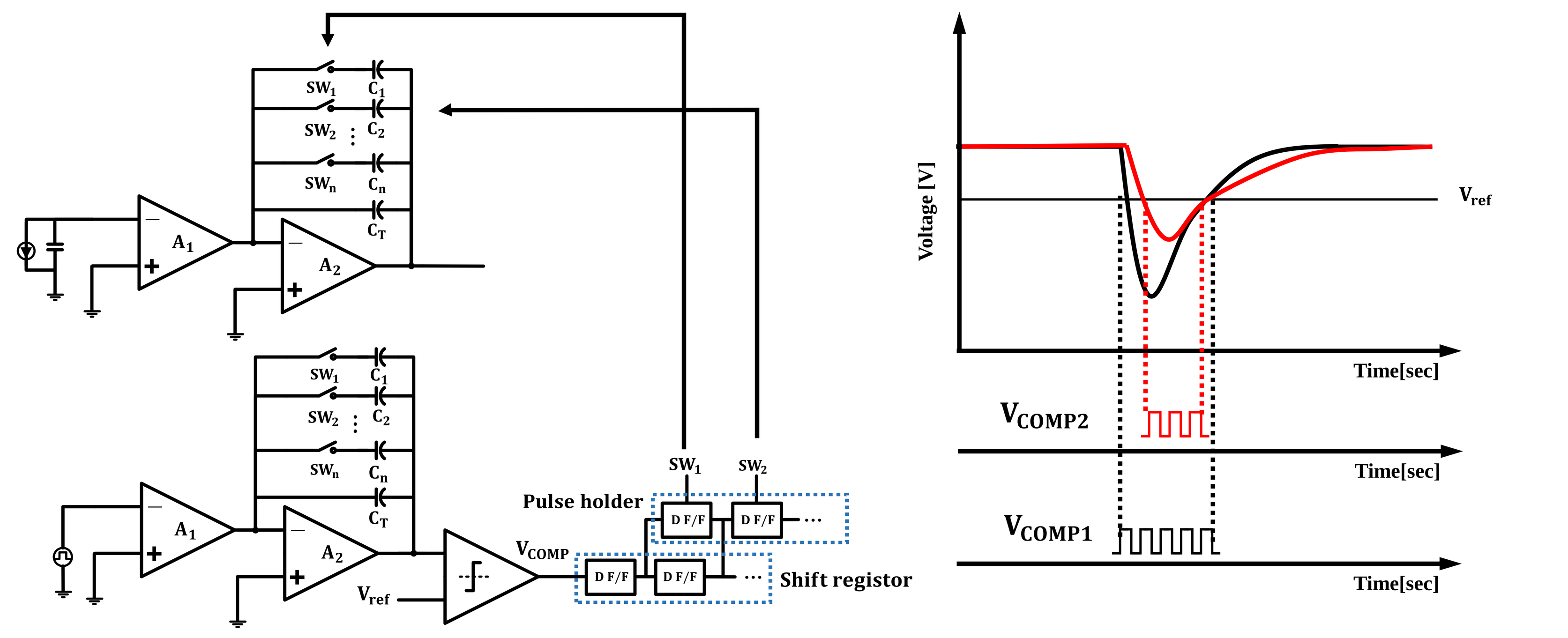

Fig. 5. A proposed CSA configuration for GBWP compensation by using measurement on amplitude degradation of replicated CSA and then by controlling the number of Miller capacitors.

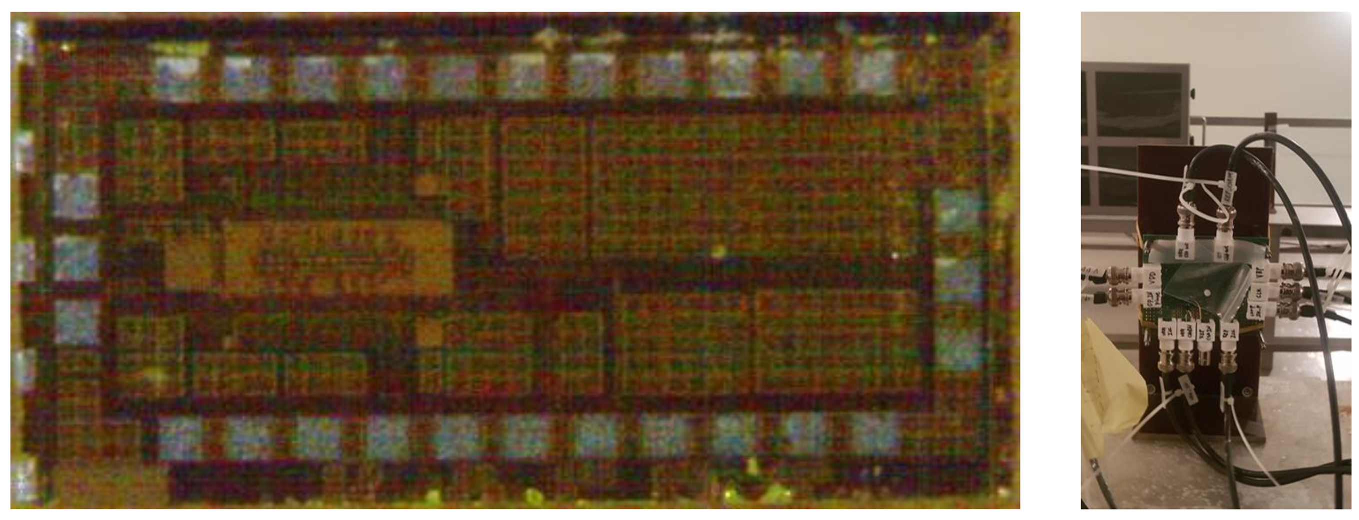

Fig. 6. Preamplifier layout with variable size and proposed radiation hardening layout

IV. RESULTS & CONCLUSION

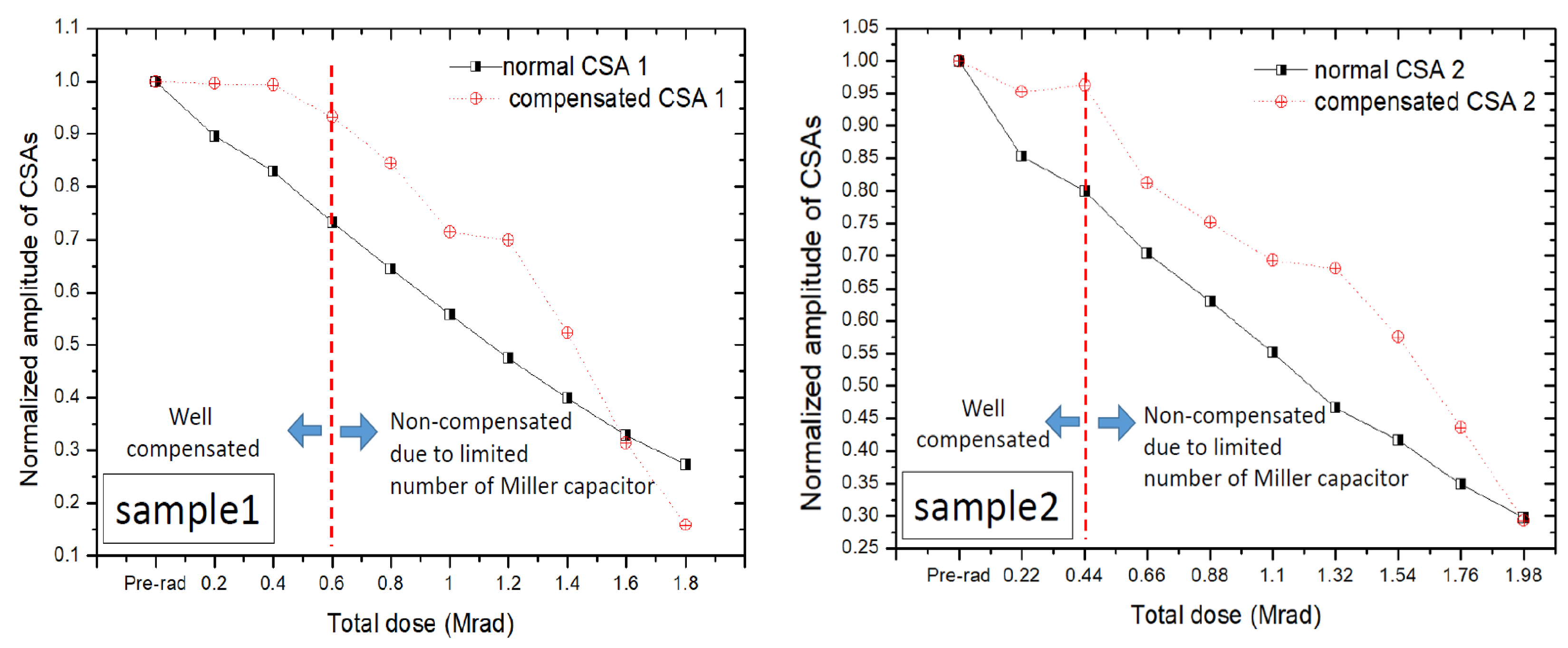

Fig. 7. During the irradiation test with Cobalt-60 γ-ray exposure up to 1.8 Mrad, output signals of self-compensated CSA were measured.

- **Irradiation test results**

The proposed self-compensated CSA for robustness to radiation are presented up to 0.6 Mrad. The circuit provides less amplitude variation by using changeable eight Miller capacitors for the compensation. The radiation hardening ability could be expandable with wider range of Miller capacitance that can covers higher radiation dose level.

References

[1] D.S. McGregor, M.F. Ohmes, R.E. Ortiz, A.S.M. Sabbir Ahmed, J. Kenneth Shultis, Micro-pocket fission detectors (MPFD) for in-core neutron flux monitoring, Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip. 554 (2005) 494–499. doi:10.1016/j.nima.2005.06.086.
[2] A. S. Sedra and K. C. Smith, Microelectronics Circuits. 2004.
[3]B. Mossawir et al., "A TID and SEE radiation-hardened, wideband, low-noise amplifier," in IEEE Transactions on Nuclear Science, 2006.