IDEC Chip Design Contest

A TID and SEE Radiation-Hardened-by-Design Receiver

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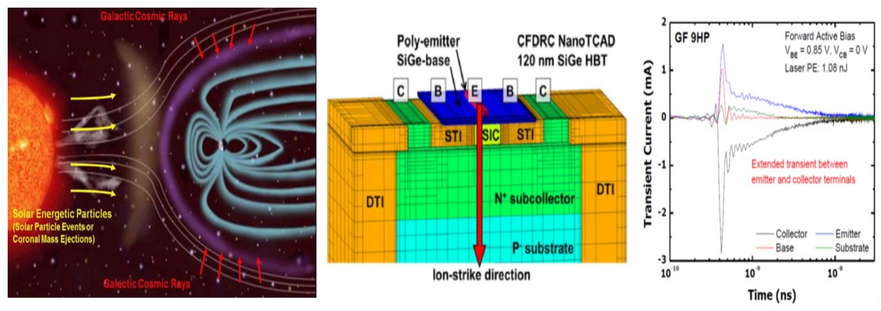
Abstract

- In extreme environments such as space, radiation can damage device with TID and SEE effect so that alter the overall performance of the transceiver system from its originally intended specifications.
- SEE occurs when a high-energy particle strikes a circuit, generating a large number of electron-hole pairs within a short duration
- TID leads to the accumulation of charge traps in insulating materials, which can increase leakage currents, alter threshold voltages, and degrade key performance metrics, such as gain and noise figure (NF) in amplifiers
- To minimize the effects of radiation, capacitors and resistors are added to the most radiation-sensitive parts of the LNA and VCO.



(Left) Space radiation environment, (center) simulation of SEE generation, (right) SEE transient current in a transistor

Solution

◆ RHBD LNA with a Feedback Amplifier

- Compensating the performance and transconductance degradation caused by TID
- The negative feedback reduces the sensitivity to parameter variations or degradation, which helps increase the reliability against the effect of TID
- Enhancing the receiving signals of the RF system

◆ Quadrature Voltage-Controlled Oscillator (VCO)

- SEE events can disrupt the bias voltage, compromising the proper operation of the circuit.
- The quadratic structure used in this design is inherently tolerant to TID effects, ensuring reliable operation in radiation environments

◆ Radiation hardened biasing circuit in VCO

- In a VCO, one of the sensitive devices to SEE is the tail transistor, which generates bias current of the branch
- There are two ways to reduce SEE on biasing circuits
  - ➔To mitigate this, increasing the time constant (τ = R x C) is an effective method
    Increase the effective capacitance by inserting a shunting capacitor
  - ➔ Utilize a structure that decouples the fluctuations of bias circuit from the main path in the circuit
- This technique can be applied to various circuits and works by delaying the disturbance between the differential pair and the bias circuit, absorbing some of the voltage drop caused by SEE

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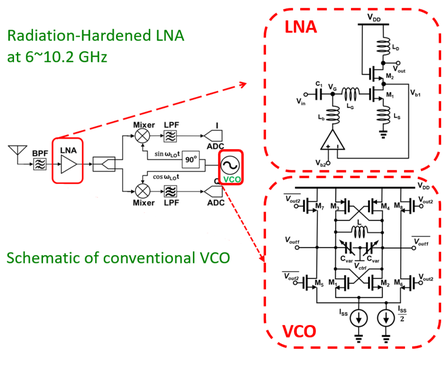
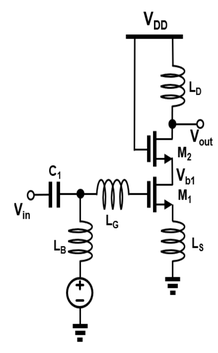
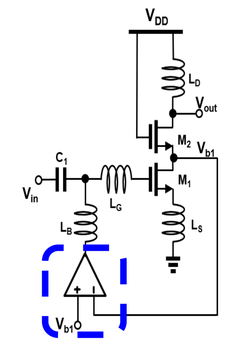


Overall transceiver structure

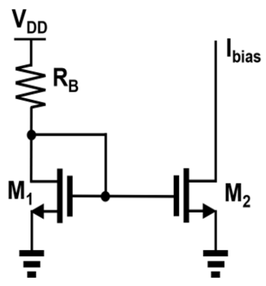


(a) Conventional LNA

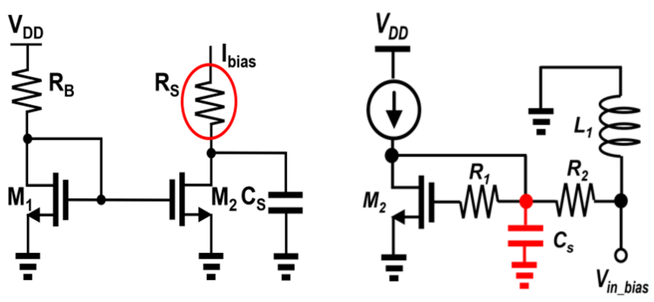


(b) Proposed LNA

❖Schematic of LNA



(a) Conventional biasing circuit



(b) Two proposed biasing circuits

Simulation Results

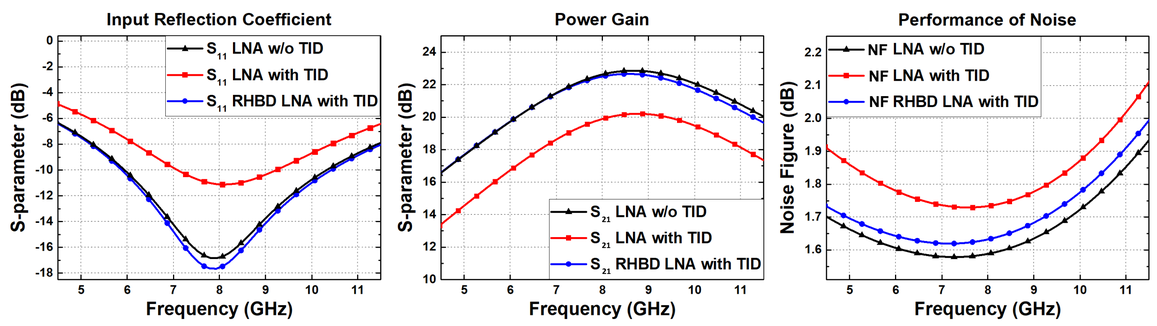
◆ Simulation Results of LNA

- We compare the proposed LNA with the conventional LNA
- The comparison characteristics are S_{11}, S_{12} and Noise Figure
- The proposed LNA shows the performance degradation under 10%

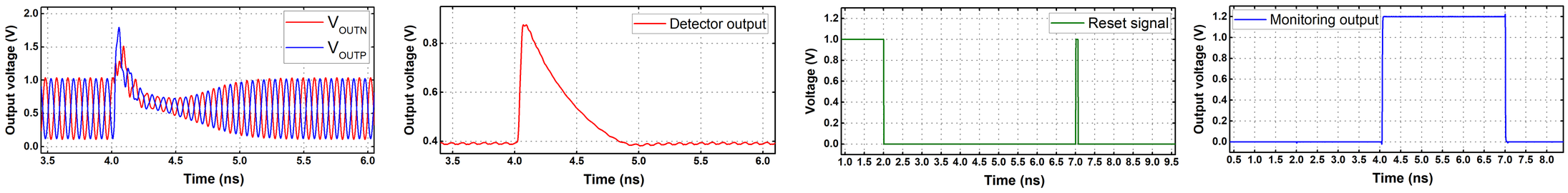
◆ Simulation Results of VCO

- SEE is checked by checking the output of SEE detector of VCO
- When the Reset signal becomes 1V, the output of SEE detector of VCO becomes 0V

❖Simulation Result of Proposed LNA



❖Simulation Result of SEE Detector of VCO



(a) Output of VCO under SEEs (b) Output of RF detector under SEEs (c) Input Reset Signal of Storage circuit in transient (d) Output of SEE Detector of VCO in transient

Conclusion

1. The proposed LNA maintain the transistors' performance degradation under 5% in Radiation environment
2. This solution prolongs the life of system and maintains stable operation
3. It is possible to improve the performance by mitigating the radiation effects at the circuit level with maintaining the traditional technology
4. It can prevent the performance degradation of High-speed communication and radar system
5. It is necessary at the field of space, military, medical radiation, and especially high precision system