

Advancements in 28nm CMOS Radiation Hardened IP for Particle Physics Experiments

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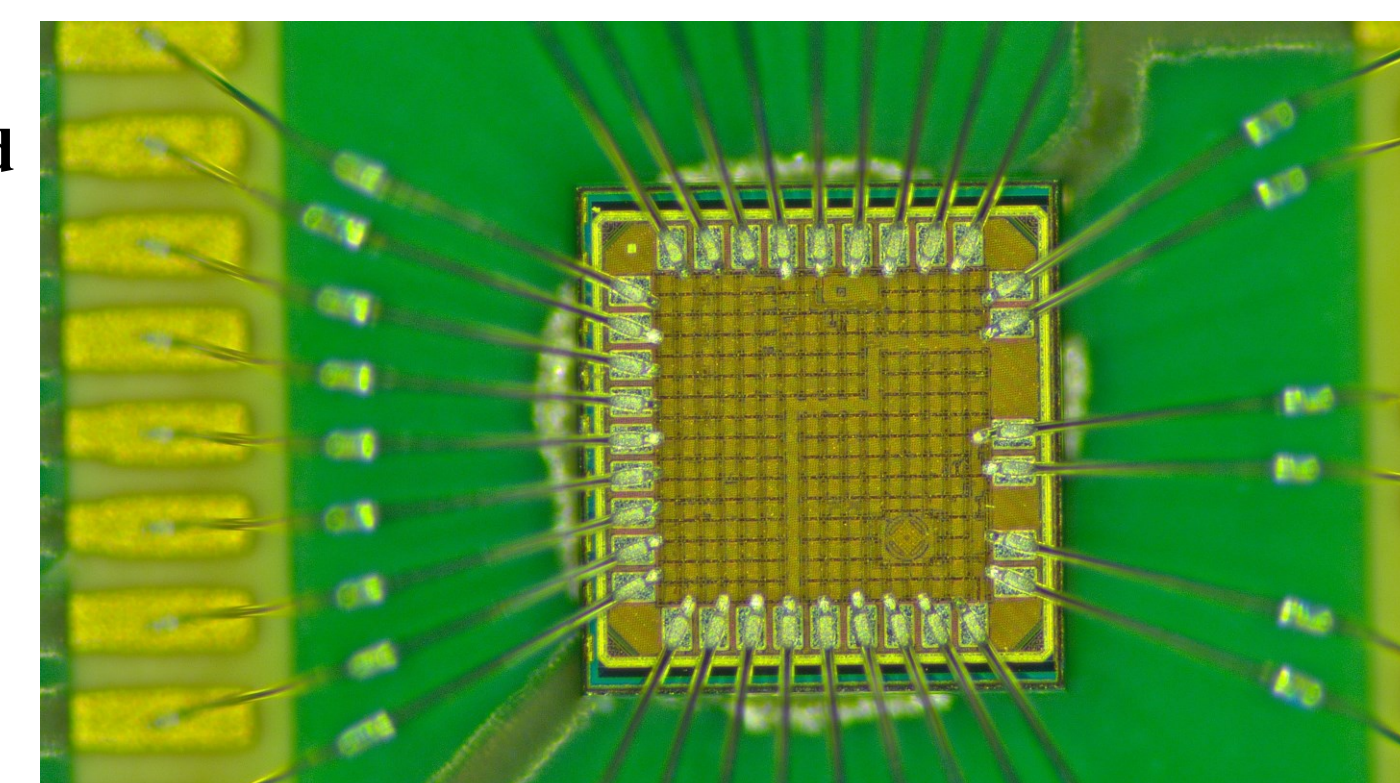
Quality analogue radiation-hardened design in 28nm CMOS is an iterative process best achieved through IP development. Rutherford Appleton Laboratory (RAL) ASIC Design Group has implemented two test-structure ASICs, PURNIX and YELNIX, to validate the performance of circuits up to 1GRAD TID. PURNIX includes essential building-block radiation-hardened IP, while YELNIX includes a prototype LGAD preamplifier and TDC sub-circuit options. Irradiated performance will be evaluated in collaboration with the universities of Birmingham and Oxford. In parallel, we continue our developments with an improved low-voltage amplifier architecture, low-profile 8bit-ADC, <20ps TDC and 25Gbps readout circuits.

Progress

- ❑ PURNIX & YELNIX radiation-hardened 28nm test-structure ASICs fabricated
- ❑ Pre-radiation results show very good matching to simulation data
- ❑ Radiation test board in layout phase for up-to-1GRAD irradiation at Birmingham and Oxford University facilities
- ❑ Test structure FURNIX to be fabricated in Q2 2025 featuring newly developed IP

Future Plans

- ❑ Silicon-proven building block IP successfully demonstrated
 - ❑ Pending irradiation tests
- ❑ Focus now shifting to develop more complex radhard IP
 - ❑ Novel sub-20ps TDC - (not a vernier delay line)
 - ❑ 25Gbps Serializer – 12.5GHz LC A-PLL
 - ❑ High performance low-voltage amplifiers
 - ❑ Internal self-calibration circuitry

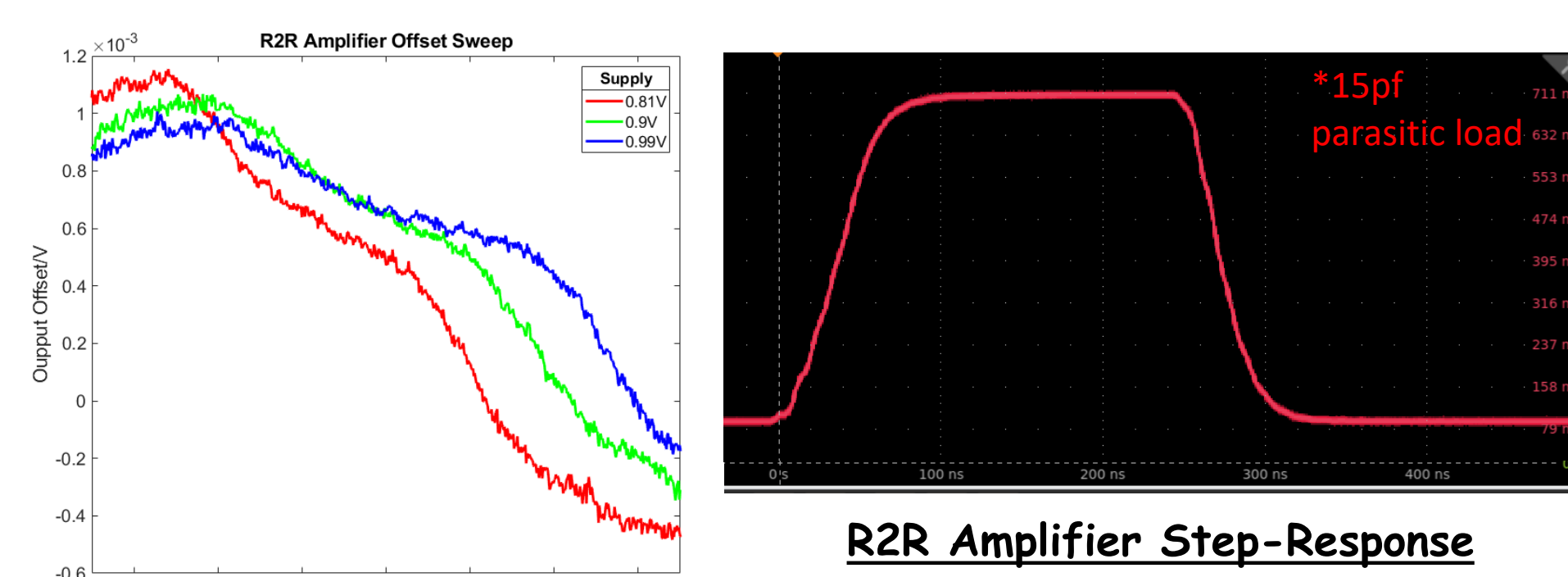


PURNIX ASIC

Pre-irradiation Results

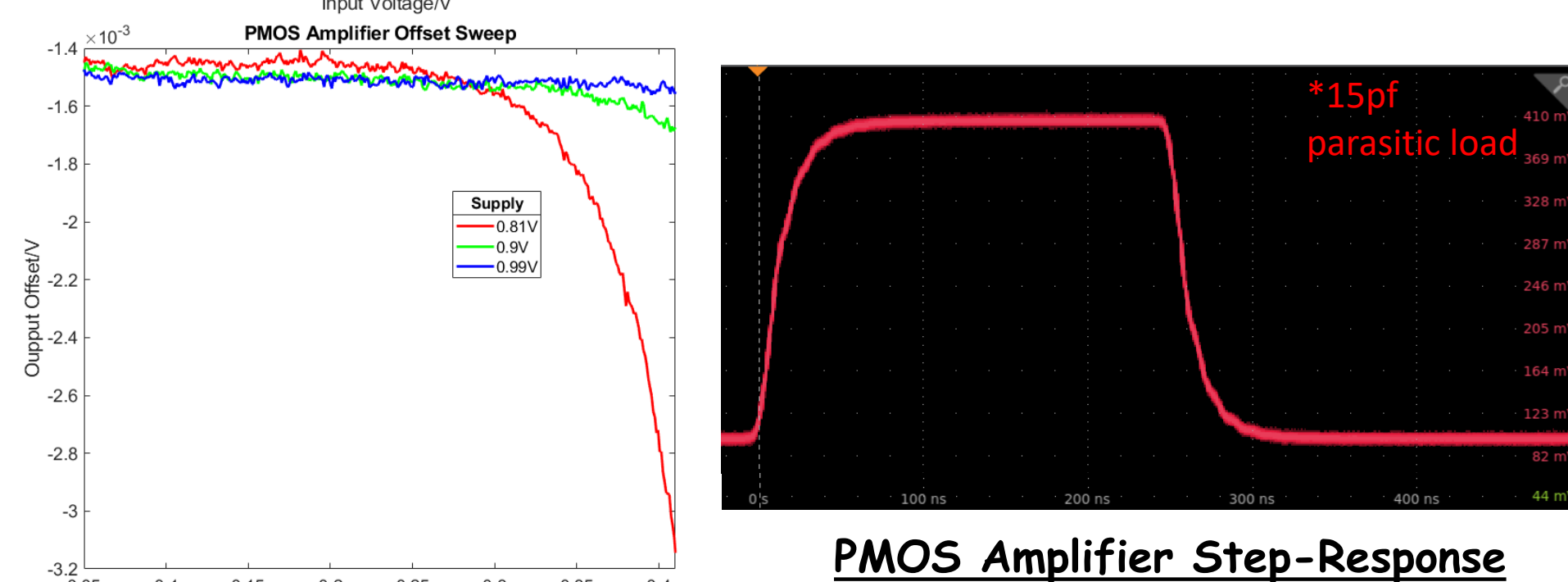
Rail-to-Rail Amplifier

- ❑ <800μW power consumption
- ❑ 70x42μm²
- ❑ Input range of 100-700mV
- ❑ Bandwidth 30MHz at 1pF load
- ❑ Output offset 1.4mV std.



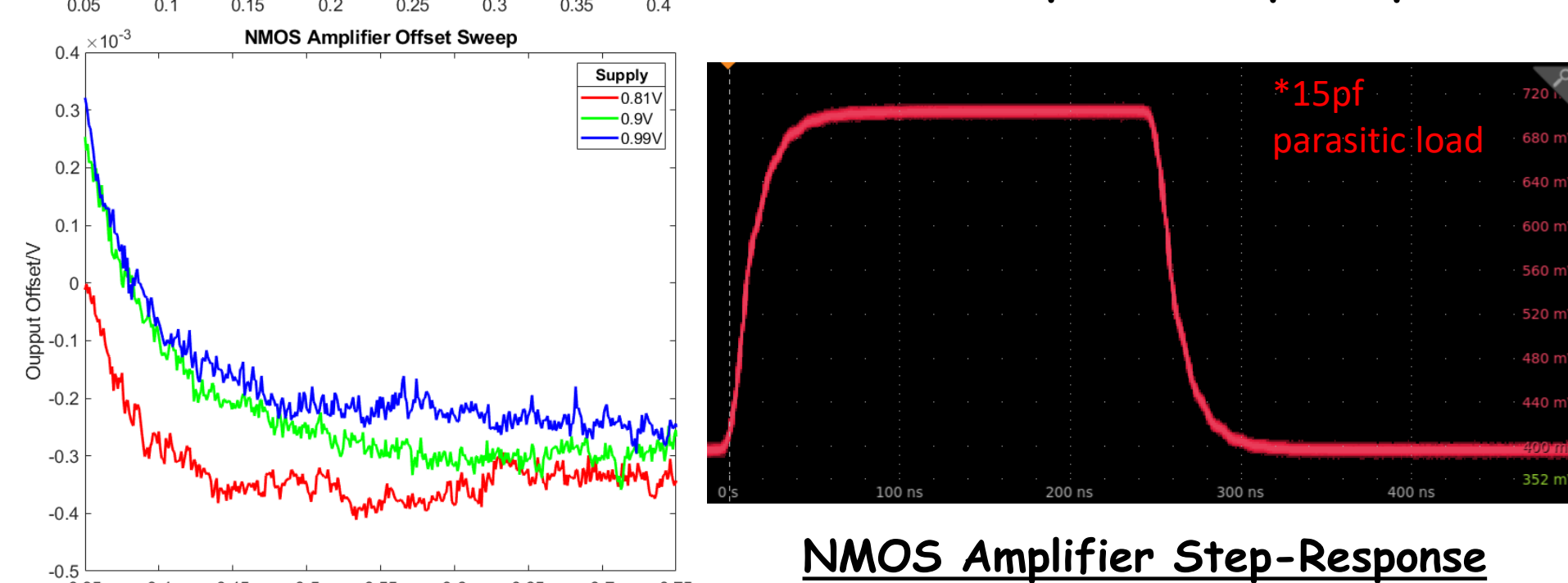
PMOS Reference Amplifier

- ❑ <711μW power consumption
- ❑ 63x53μm²
- ❑ Input range of 100-410mV
- ❑ Bandwidth 100MHz at 1pF load
- ❑ Output offset 1.3mV std.



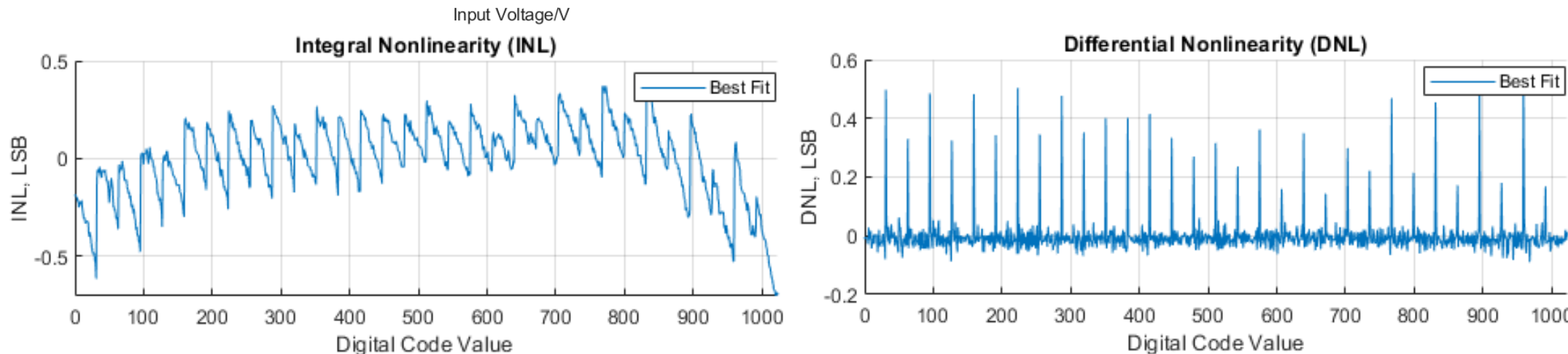
NMOS Reference Amplifier

- ❑ <700μW power consumption
- ❑ 60x40μm²
- ❑ Input range of 390-700mV
- ❑ Bandwidth 100MHz at 1pF load
- ❑ Output offset 1.5mV std.



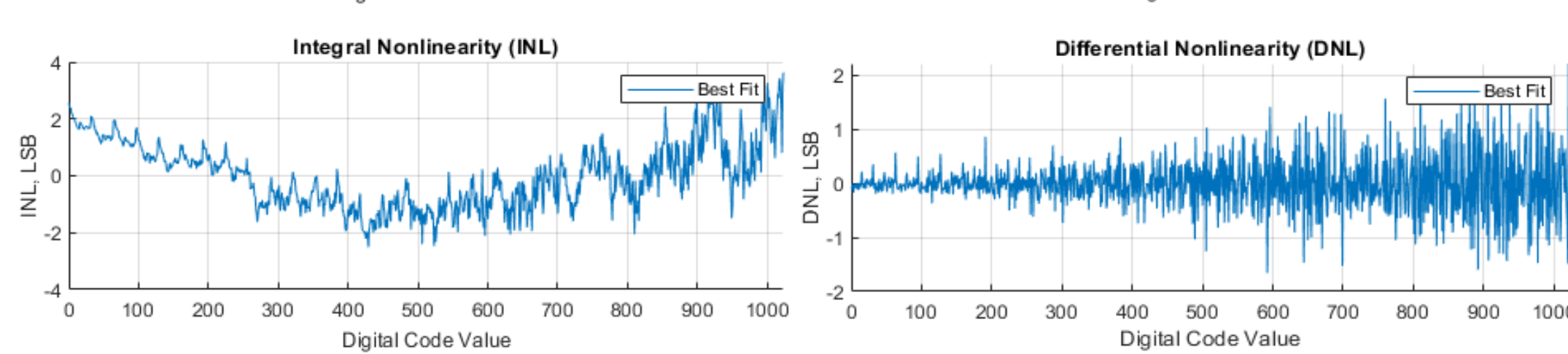
10-Bit VDAC

- ❑ 80x80μm²
- ❑ Output voltage 100-700mV
- ❑ 1-bit INL/DNL



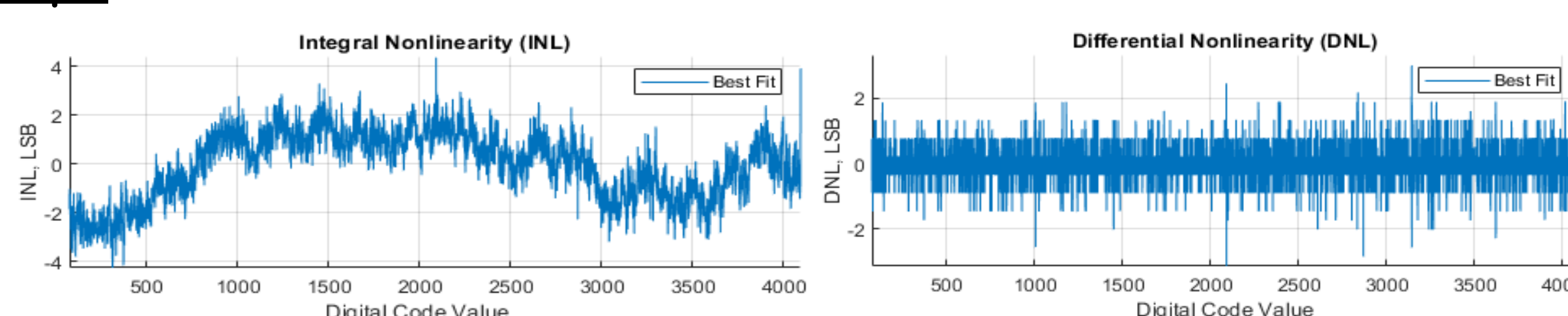
10-Bit IDAC

- ❑ 130x170μm²
- ❑ Max output Range: 200μA
- ❑ <4-bit INL/DNL



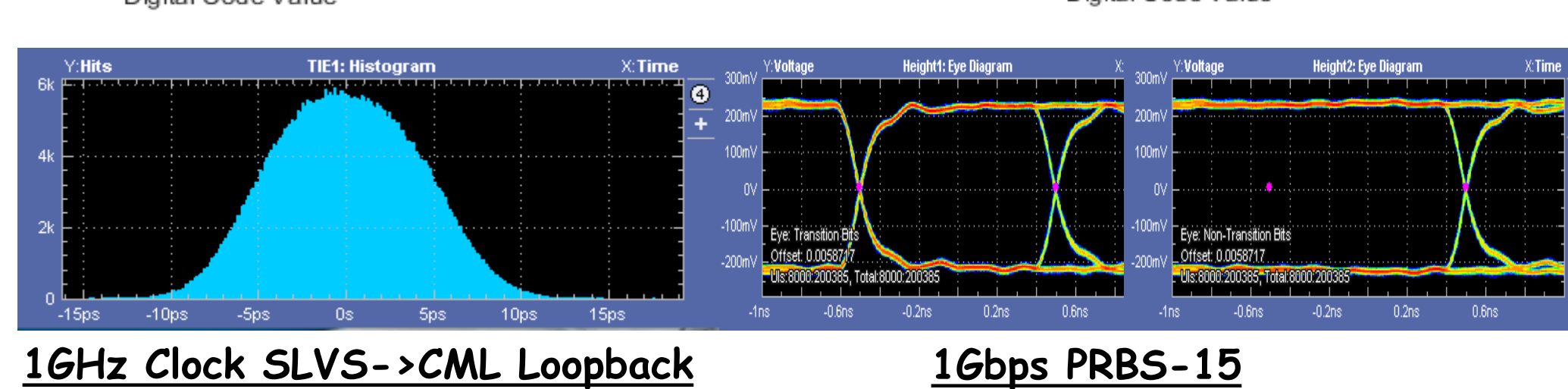
12-Bit Compact Slope Monitor ADC

- ❑ 230x220μm²
- ❑ 100Ksps
- ❑ Full range ADC



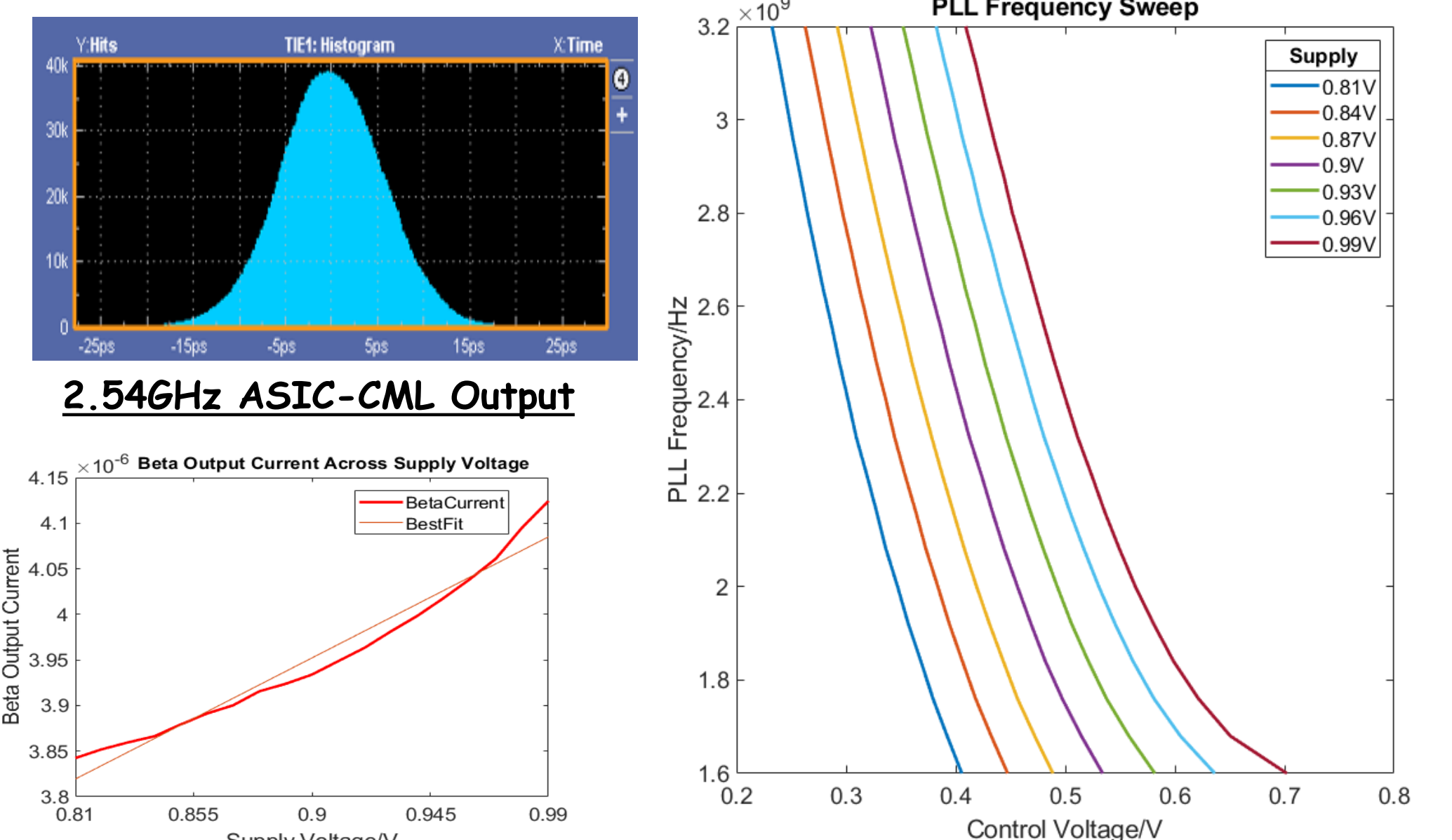
1GHz SLVS/CML I/O

- ❑ 1+ GHz SLVS Clock RX
- ❑ 3+ GHz CML TX
- ❑ SLVS: 60x33μm²
- ❑ CML: 100x36μm²



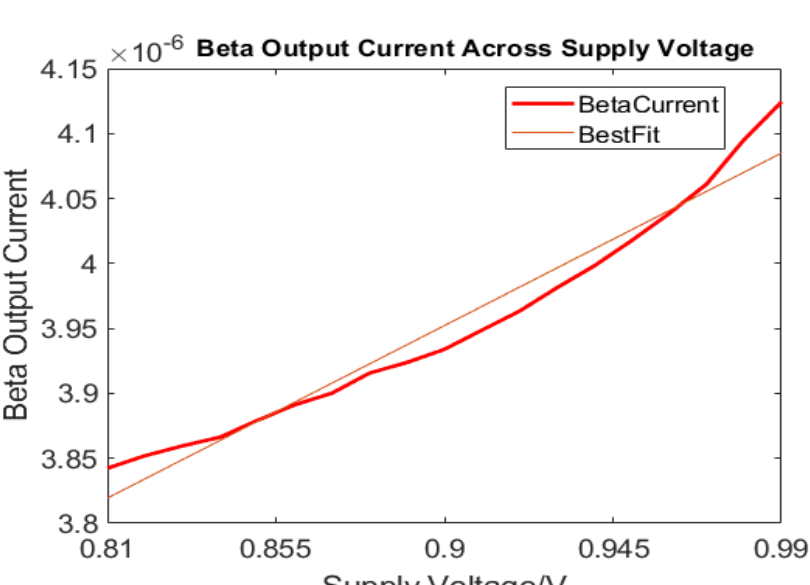
2.54GHz A-PLL

- ❑ 12-Stage Ring Oscillator
- ❑ 12 × 33ps Phased clock outputs
- ❑ 260x320μm²



Beta Multiplier

- ❑ 4μA output current
- ❑ 45x32μm²
- ❑ Sensitivity: 14nA/°C

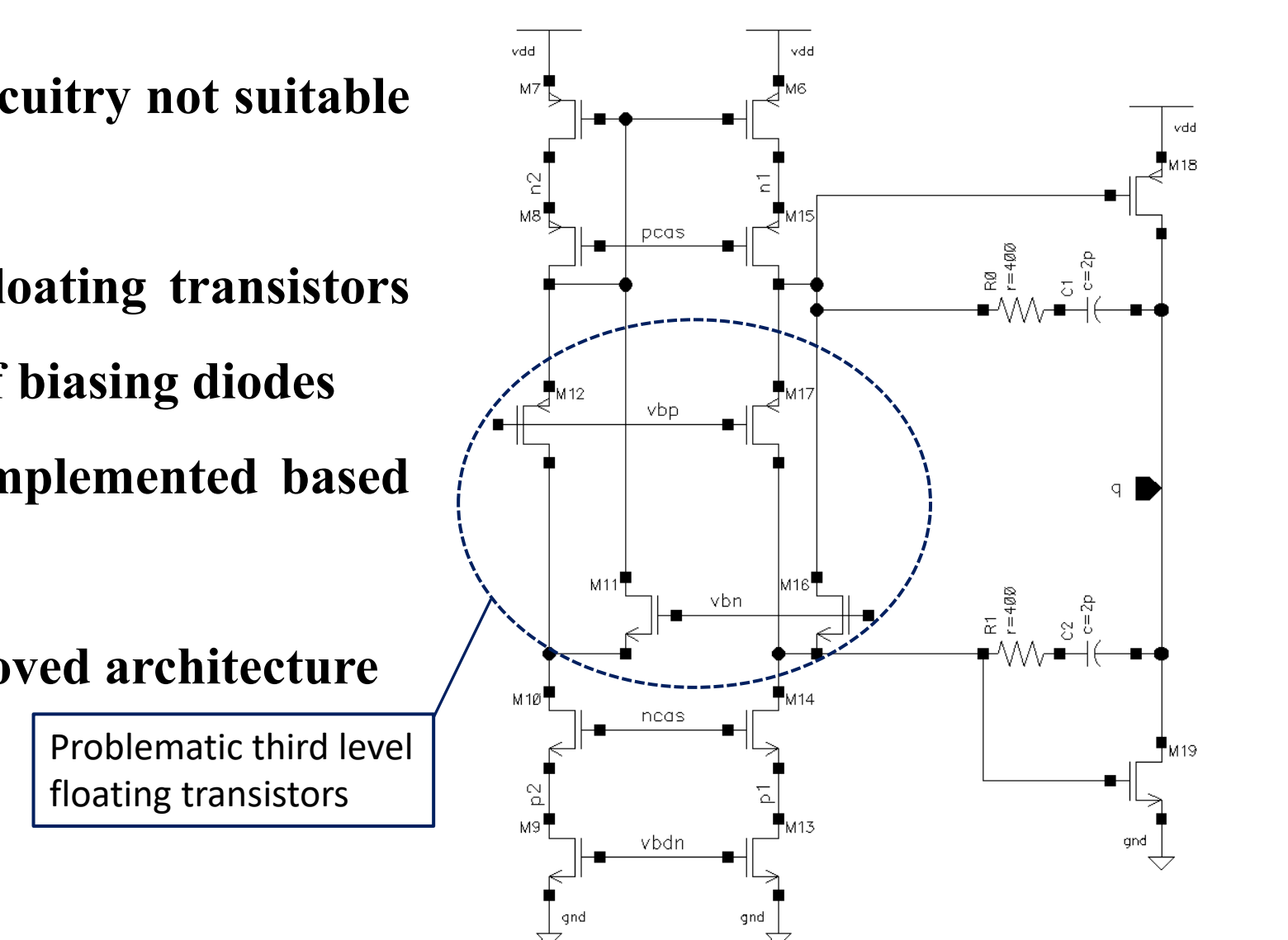


Irradiation Plans

- ❑ Up-to-1GRAD TID damage effects
 - ❑ Proton irradiations at the MC40 Cyclotron Facility in Birmingham University
 - ❑ X-ray irradiations at the Oxford Physics Microstructure Detector (OPMD) laboratory
- ❑ SEU effects on triplicated high-speed digital processing circuits, slow memory circuits and PLL RO circuits

Improved Low-Voltage Folded Cascode Amplifier Architecture

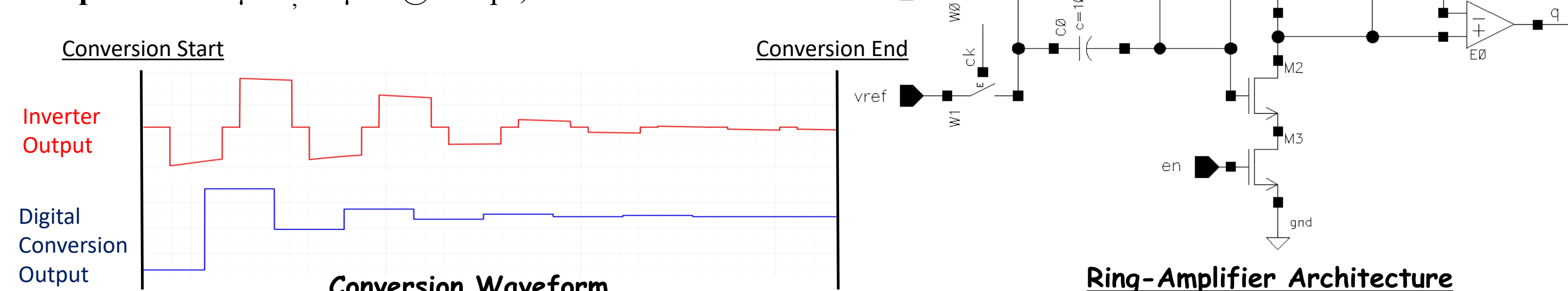
- ❑ Traditional 5 transistor stacked class AB biasing circuitry not suitable for low voltage supplies
- ❑ The improved architecture works by having the floating transistors set at the cascode level thereby removing one level of biasing diodes
- ❑ Improved Rail-2-Rail (R2R) Amplifier has been implemented based on the fabricated R2R present in the results section
 - ❑ PMOS/NMOS reference amplifiers use the improved architecture
- ❑ Specs
 - ❑ <800μW power consumption
 - ❑ 87x64μm²
 - ❑ Input range of 100-700mV
 - ❑ Input offset <0.8mV Std.



Original second-stage Folded Cascode Architecture

8bit Compact Ring-Amplifier ADC

- ❑ Successive approximation ring-amplifier architecture implemented
- ❑ Very low power and area
- ❑ Self-contained, no external requirements – internal clock generator
- ❑ Ideal for self-calibration applications
- ❑ Specs: 80x80μm², 5.4μW @ 1Ksps, <1-bit INL/DNL



Bandgap

- ❑ 220x210μm²
- ❑ Output voltages 100mV, 700mV
- ❑ Temperature sensitivity ~1.96uV/°C

