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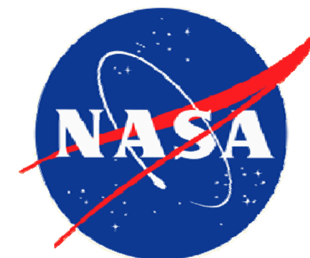

Total Dose Effects on Single Event Transients in Digital CMOS and Linear Bipolar Circuits

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Presented by S. Buchner at SEE Symposium,
San Diego, CA, April 2009

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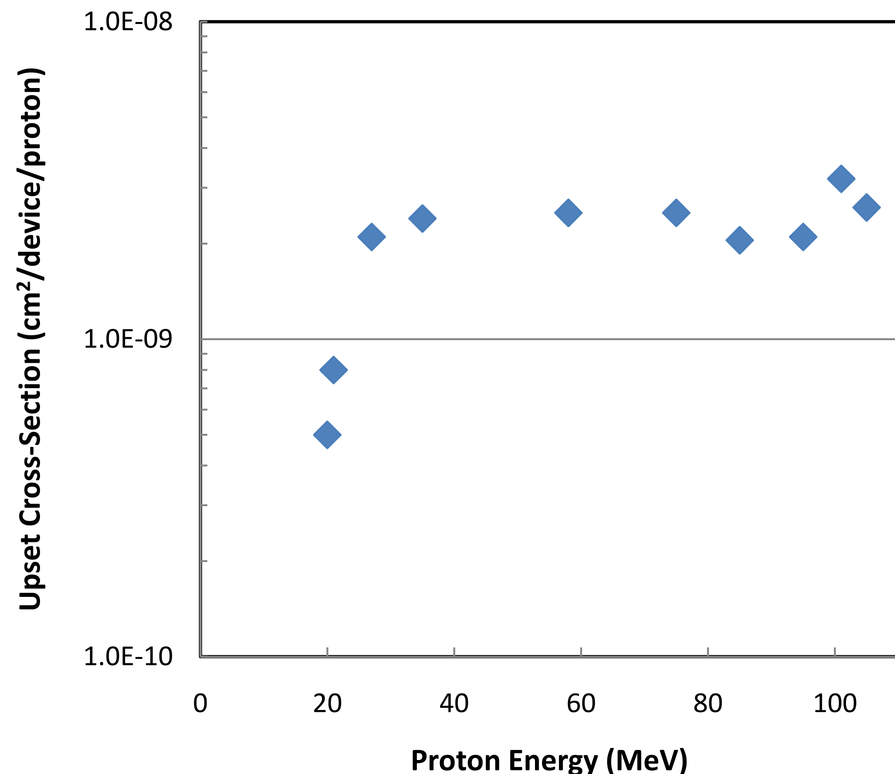
Introduction

- Exposure of ICs to ionizing radiation changes electrical parameters.
- TID effect observed in both CMOS and bipolar circuits:
  - In bipolar circuits, transistors exhibit **gain degradation**
  - In CMOS circuits, transistors exhibit **threshold voltage shifts**
- Changes in electrical parameters can cause changes in SEU/SET rates. Depending on effect, rates may increase or decrease.
- Therefore, measures taken for SEU/SET mitigation might work at the beginning of a mission but not at the end following TID exposure.

Introduction

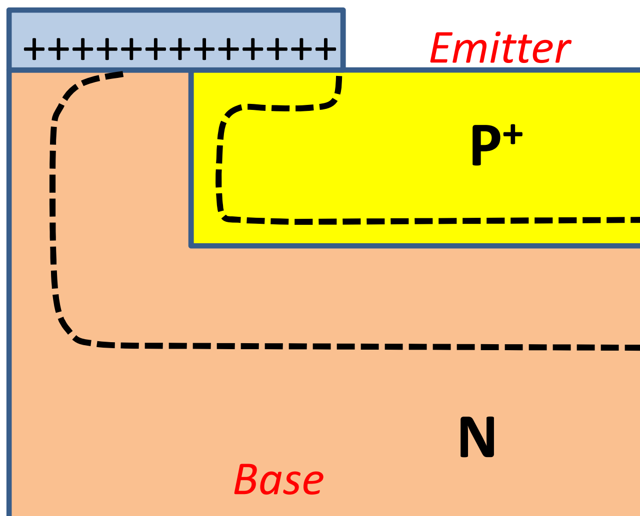
TID concerns arise during proton testing of circuits with small SEU cross-sections

- At 60 MeV, a fluence of 7×10^{11} p/cm^2 gives a TID of 100 krad(Si).
- For 10% statistics require 100 upsets or 3×10^{11} p/cm^2.
- Assume 50% charge yield in presence of electric field.
- Equivalent TID(e$^-$) = 20 krad.
- If part has a hardness of 50 krad, can measure 2 points before electrical parameters exceed manufacturer's specifications and part must be changed.
- Schwank et al have investigated proton-induced TID effects in SRAMs (2004)

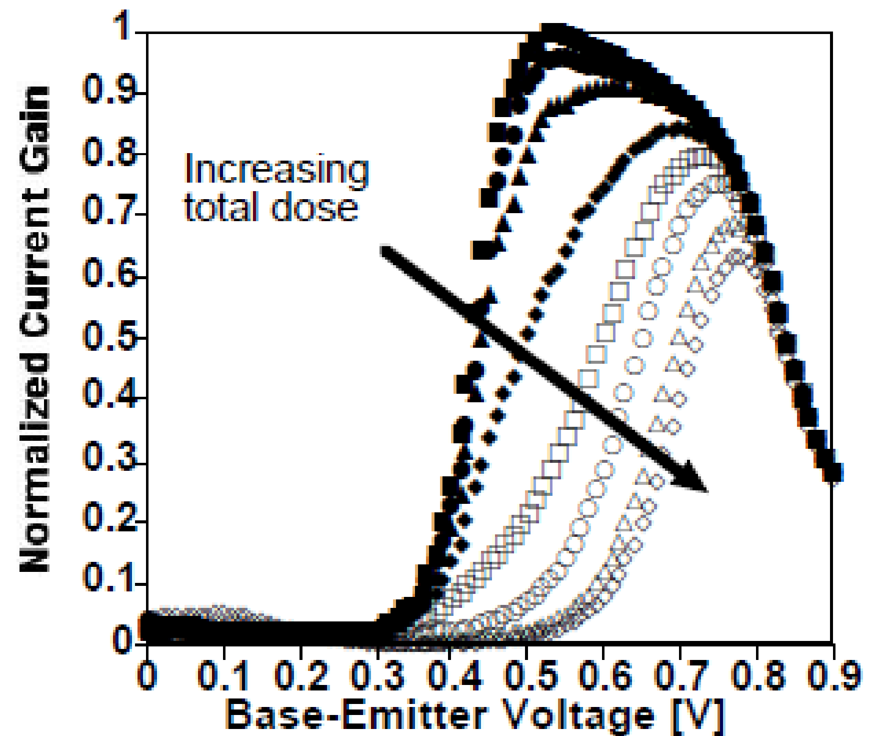


Introduction – Bipolar Transistors

TID causes charge buildup that distorts emitter/base junction field and degrades gain.



Schmidt et al, IEEE TNS 1996

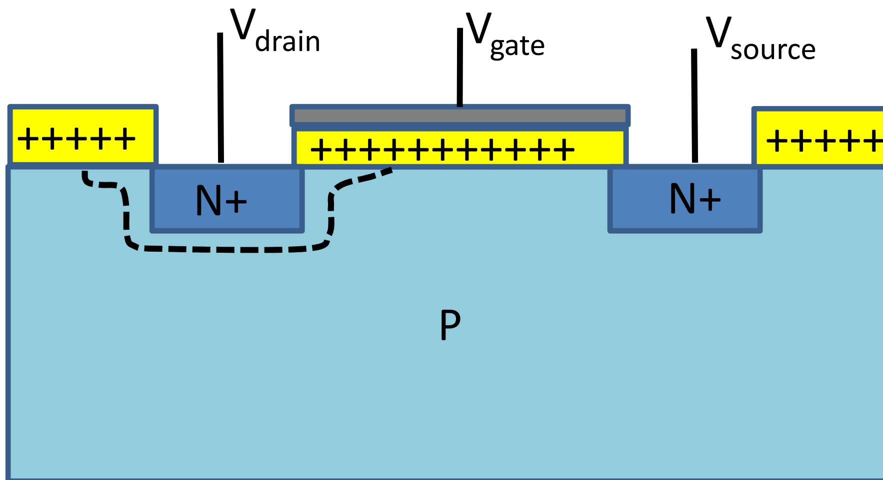


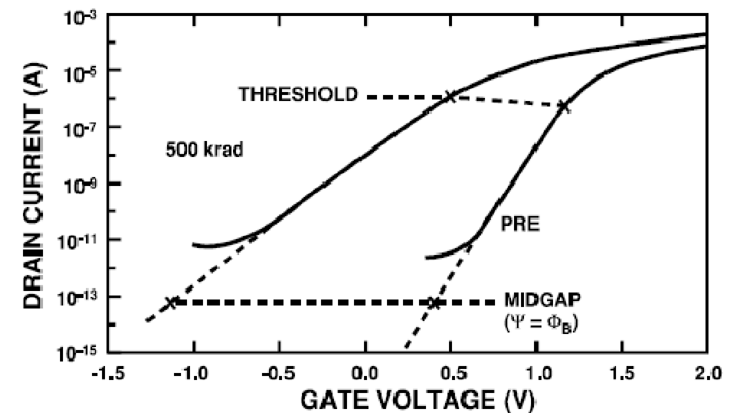
Schrimpf, NSREC 2001 Short Course

Introduction – MOS transistors

TID causes charge buildup that shifts threshold Voltage and increases leakage currents.

N-channel MOSFET





J. Schwank, NSREC Short Course 2002

LINEAR BIPOLAR CIRCUIT

VOLTAGE COMPARATOR – LM139

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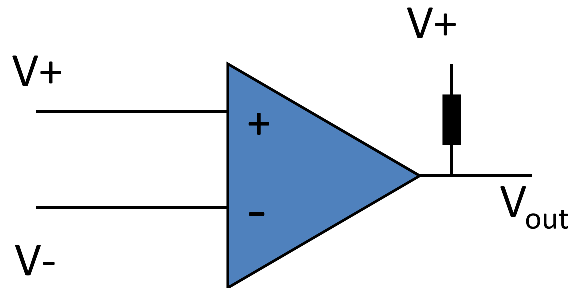
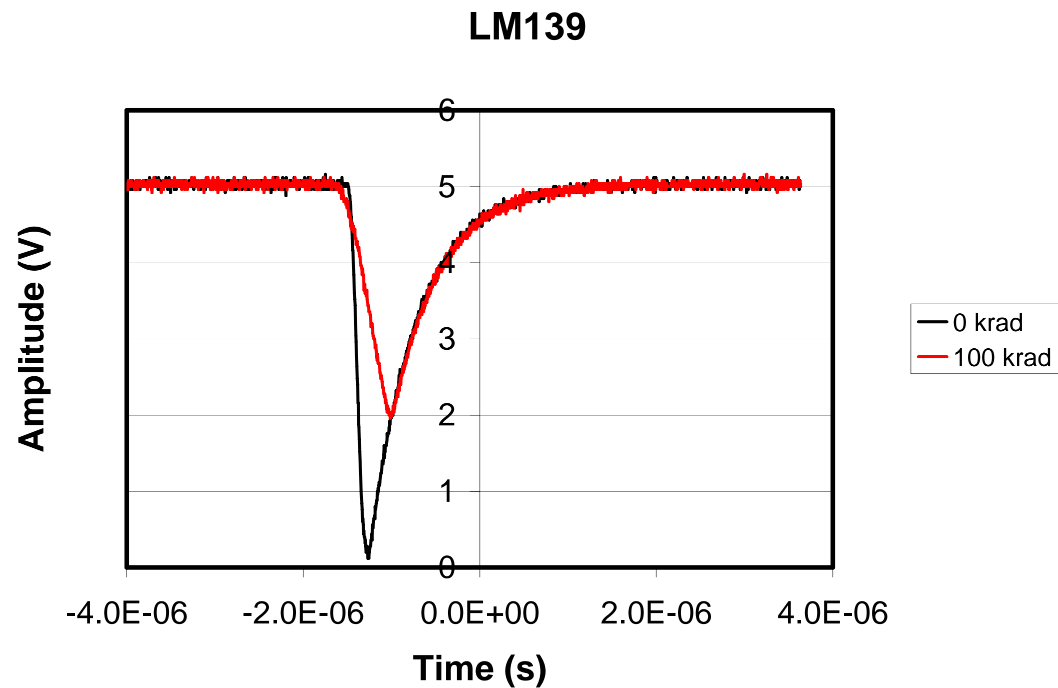
Voltage Comparator – LM139

- **LM139 -** SETs become smaller with TID





LINEAR BIPOLAR CIRCUIT

Operational Amplifier – LM124

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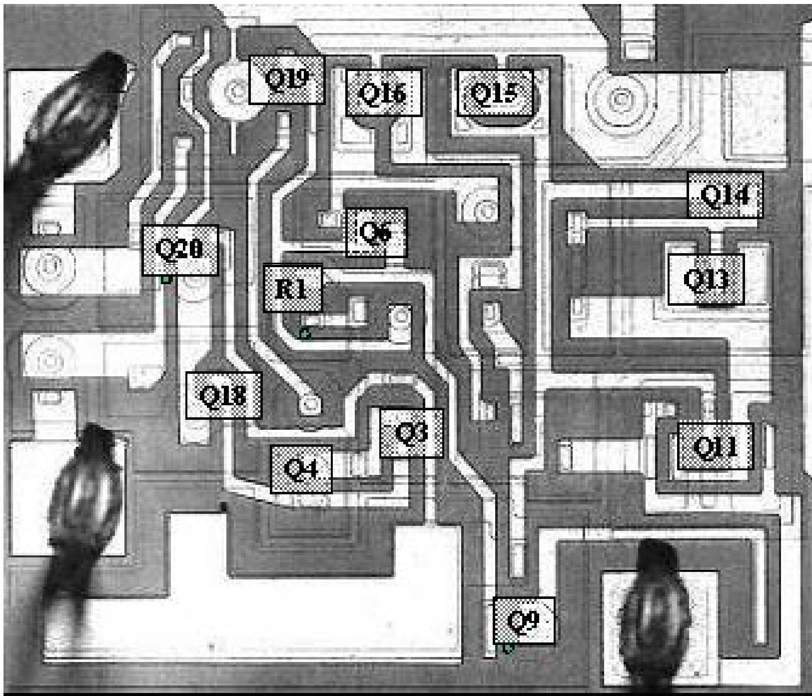
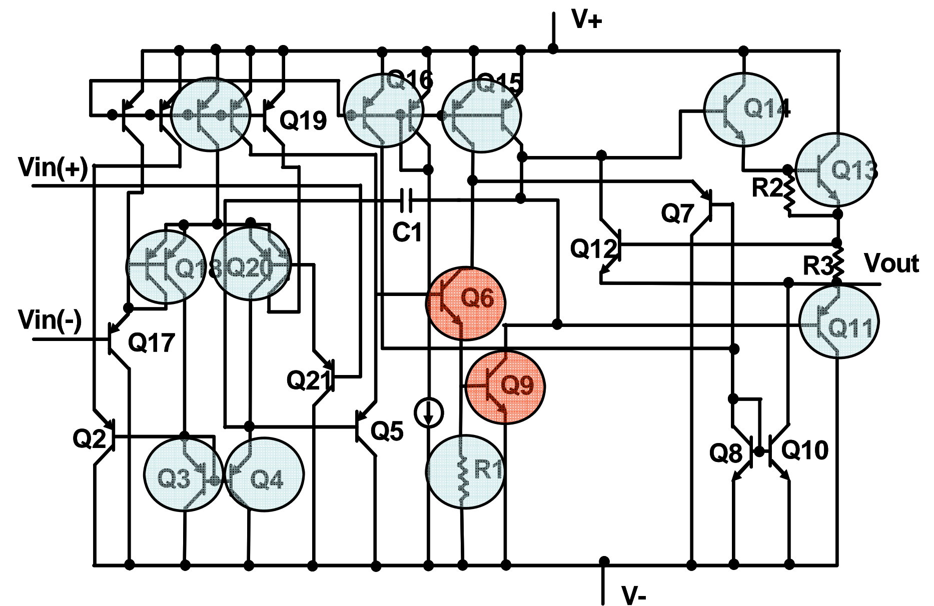
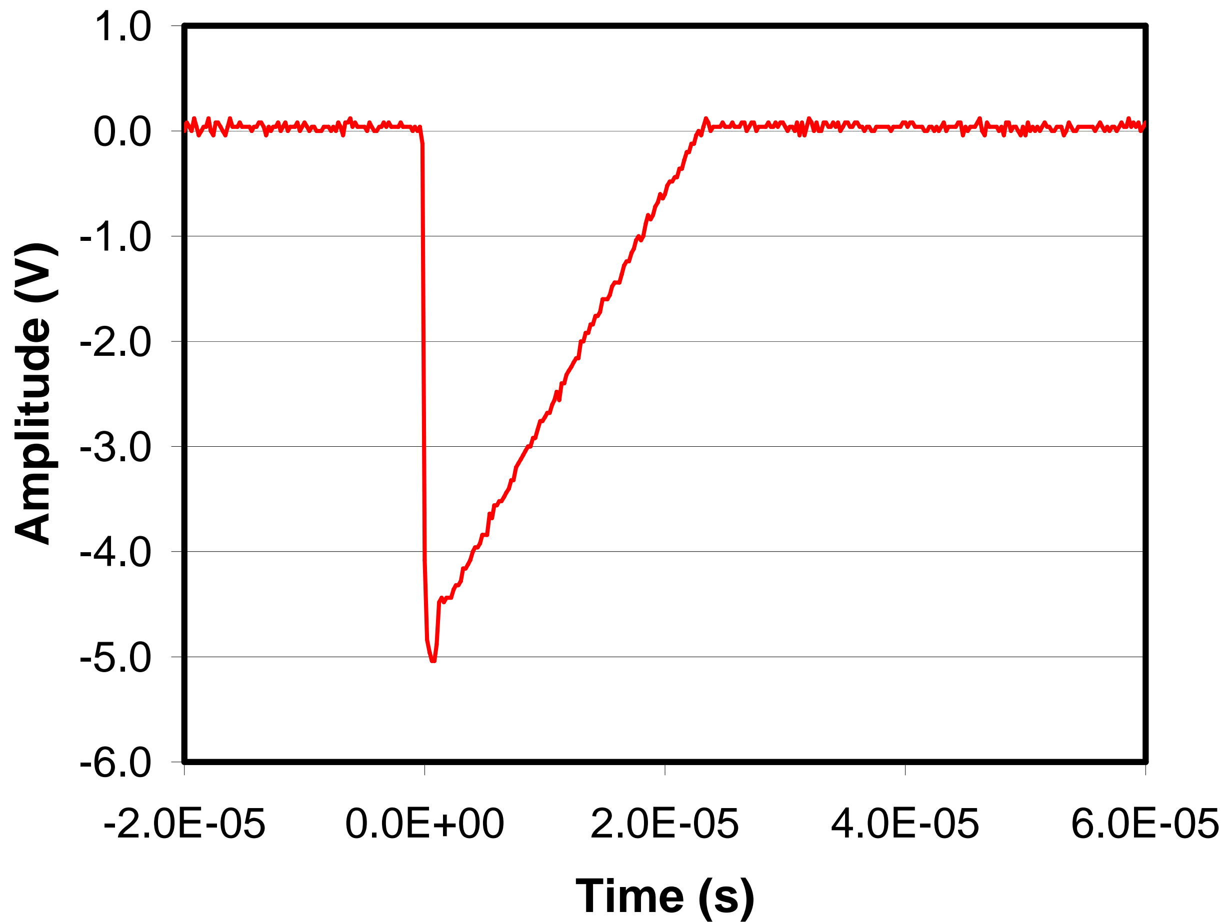
Operational Amplifier – LM124

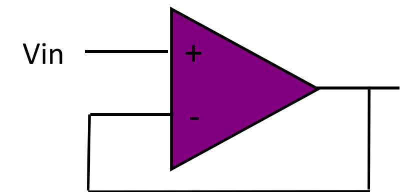
- Used focused pulsed laser to inject charge into Q9 and R.





LM124 – Q9 VF





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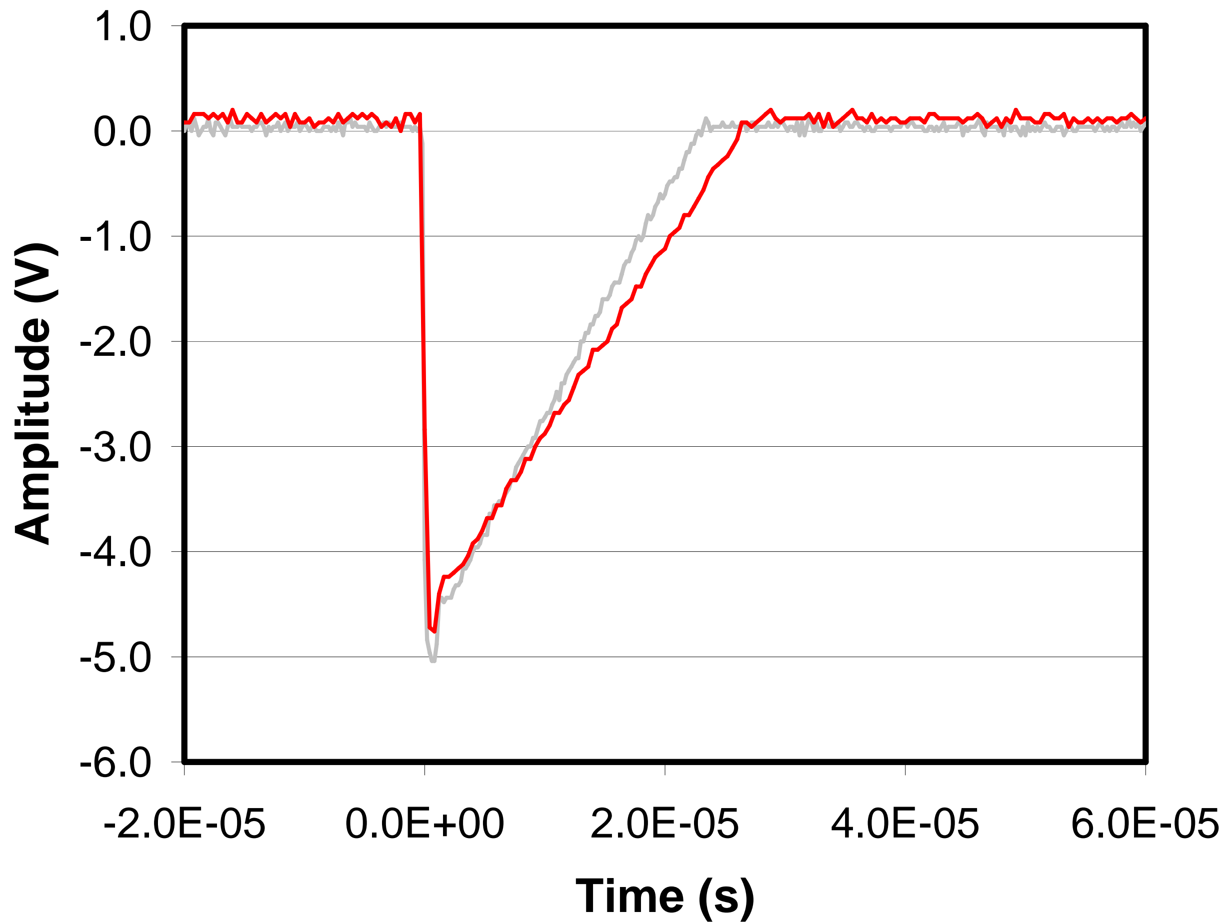
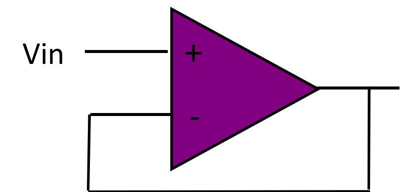
LM124 – Q9 VF





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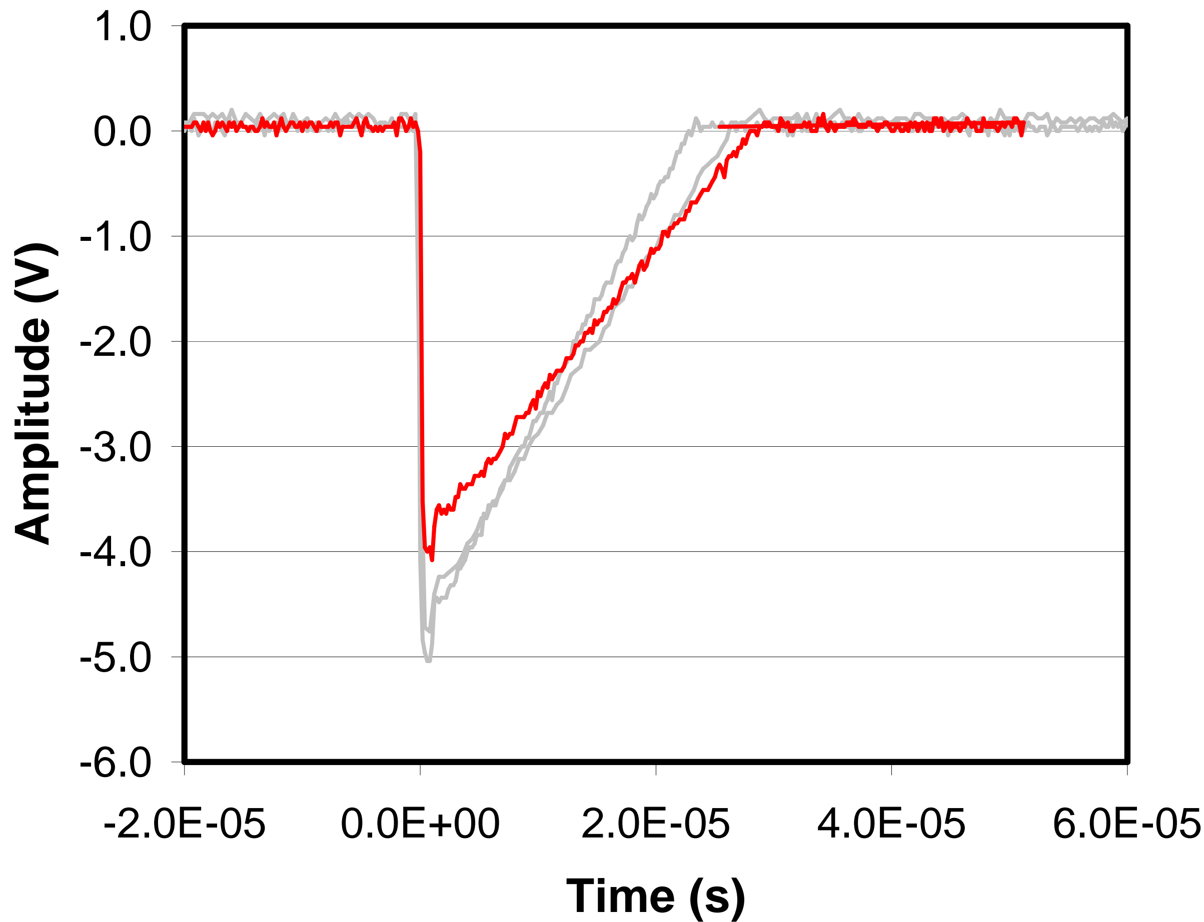
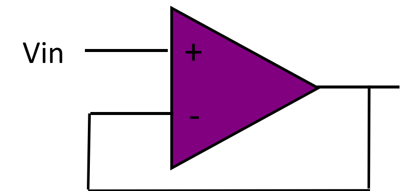
LM124 – Q9 VF





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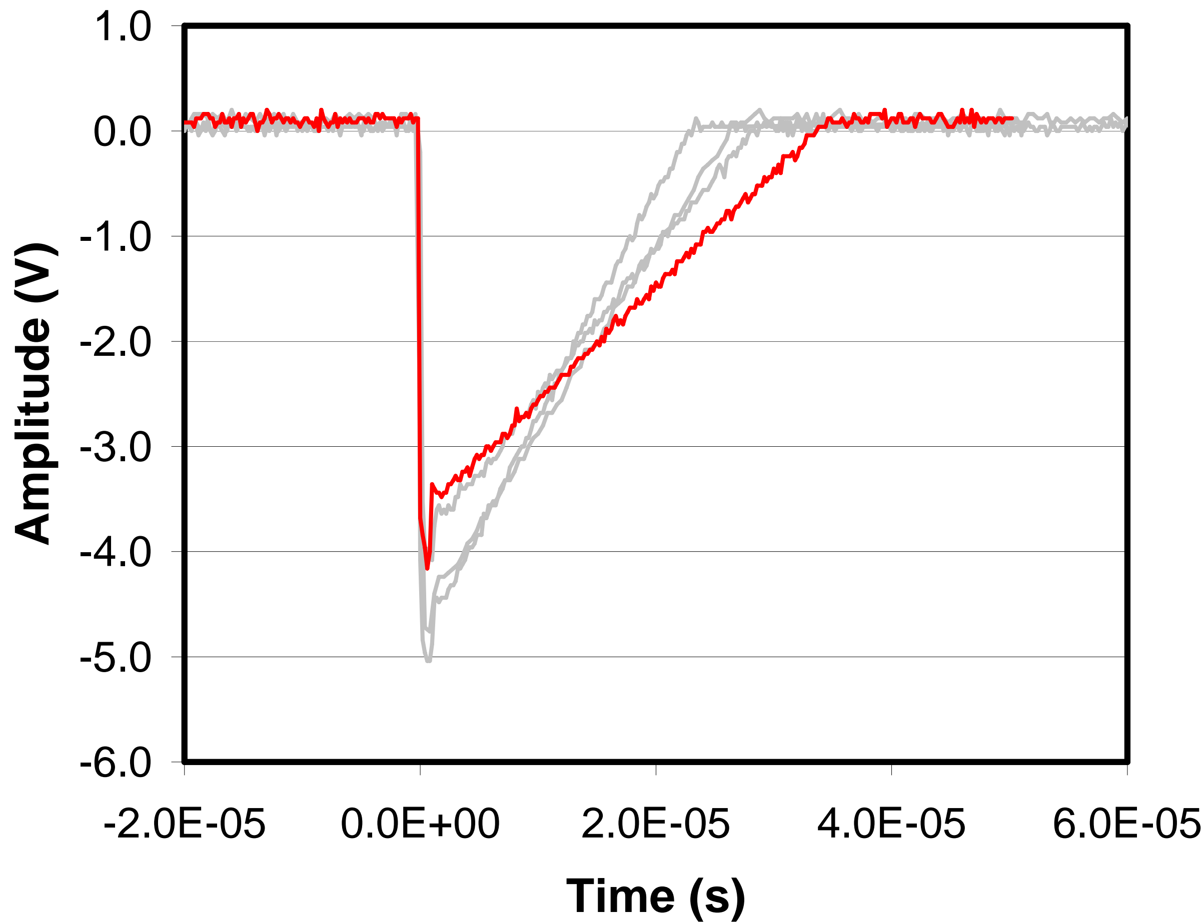

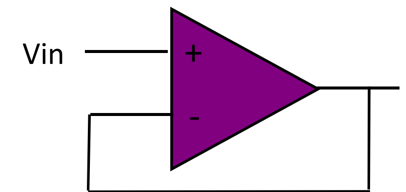

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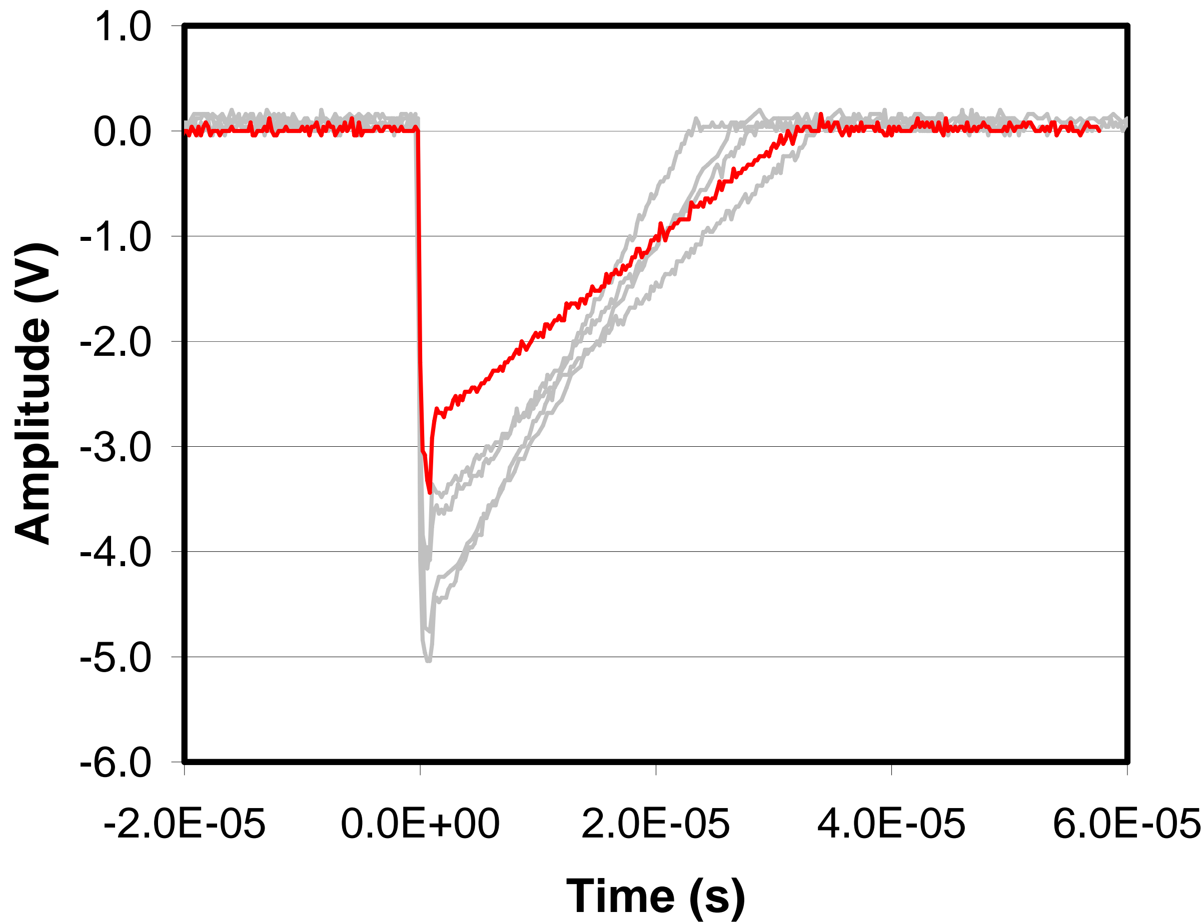
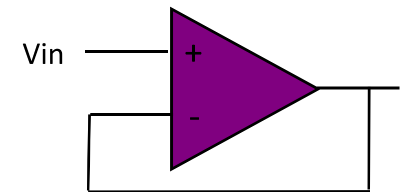
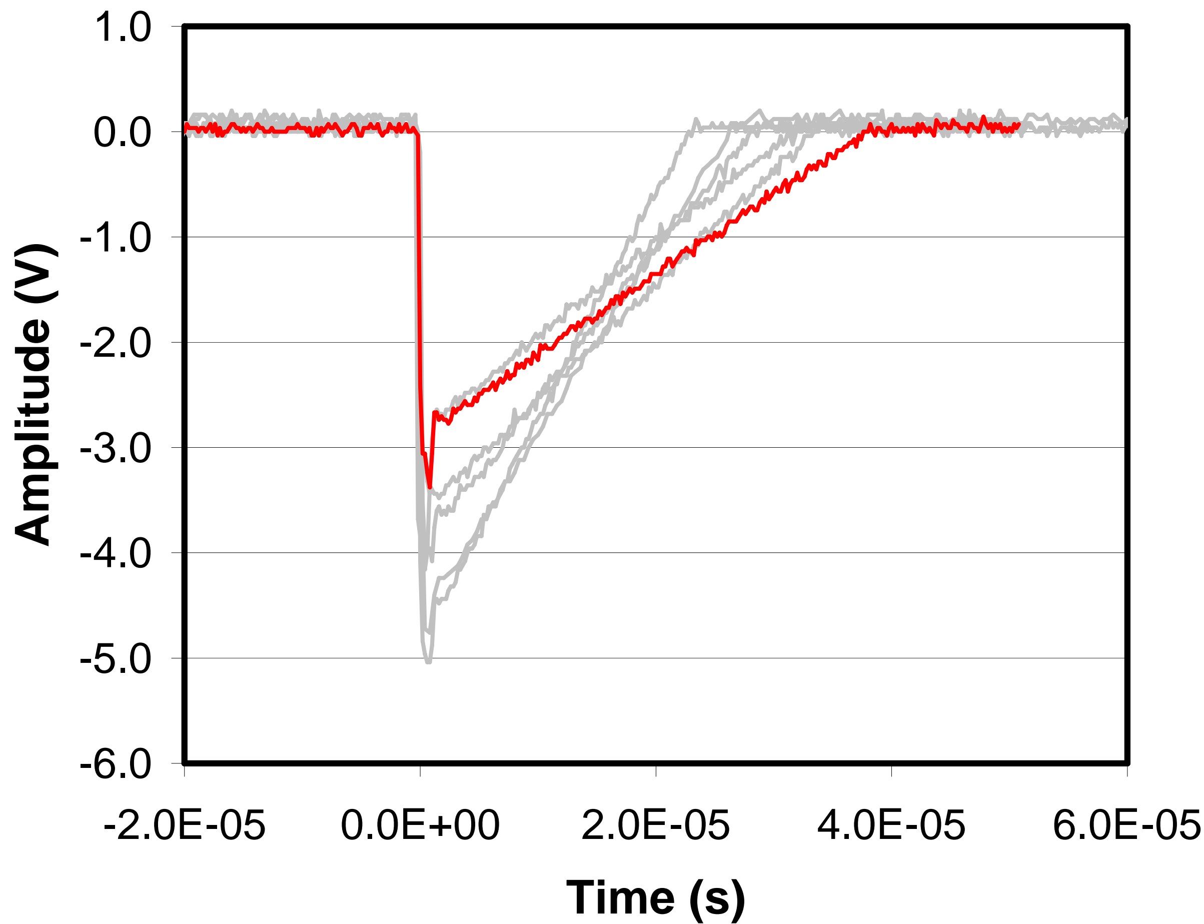
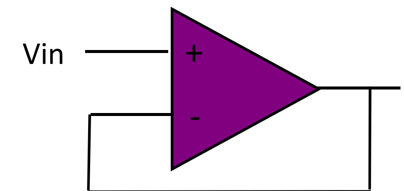




LM124 – Q9 VF





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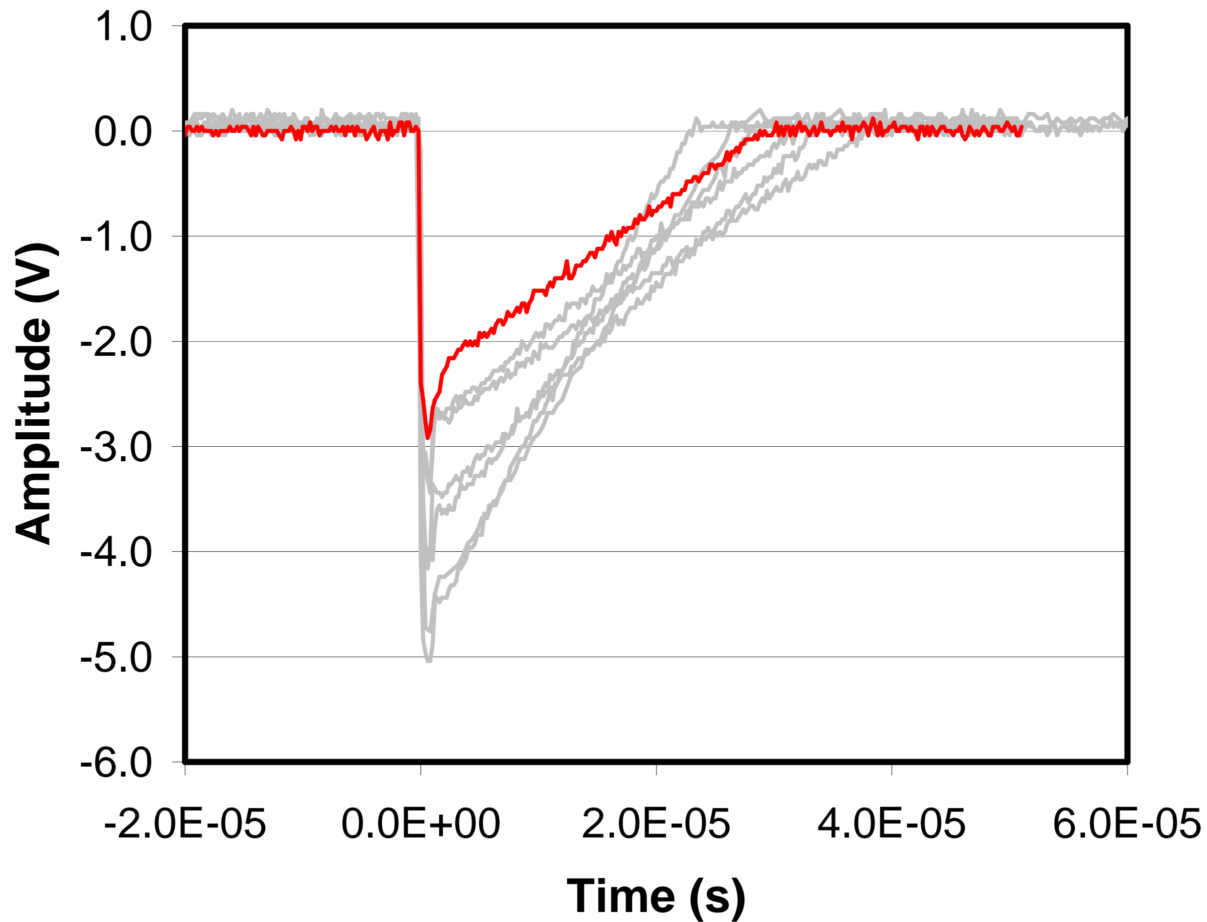

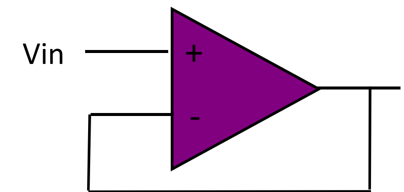

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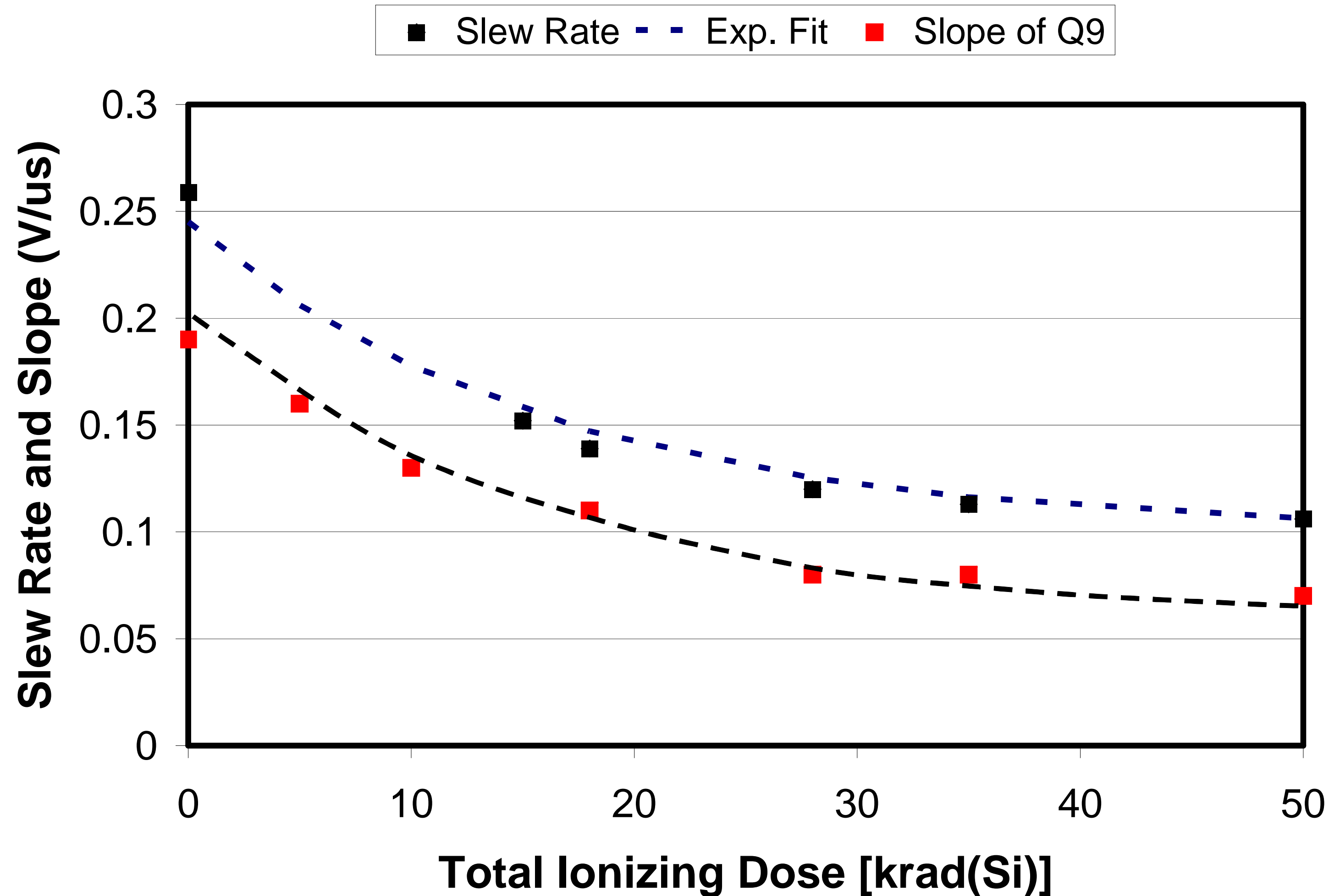
LM124 – Slew Rate



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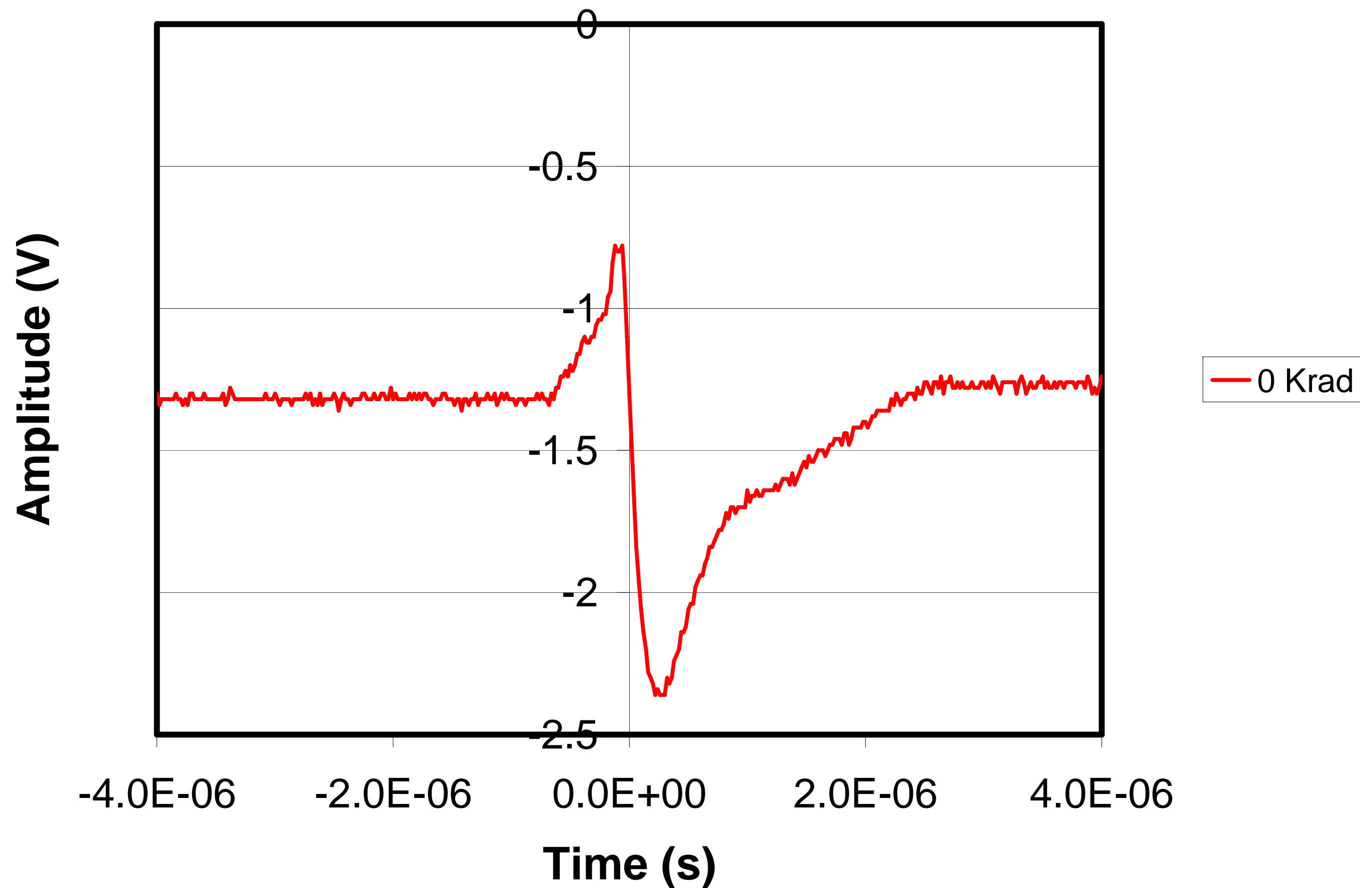
LM124 – R1 (Inverter Mode)



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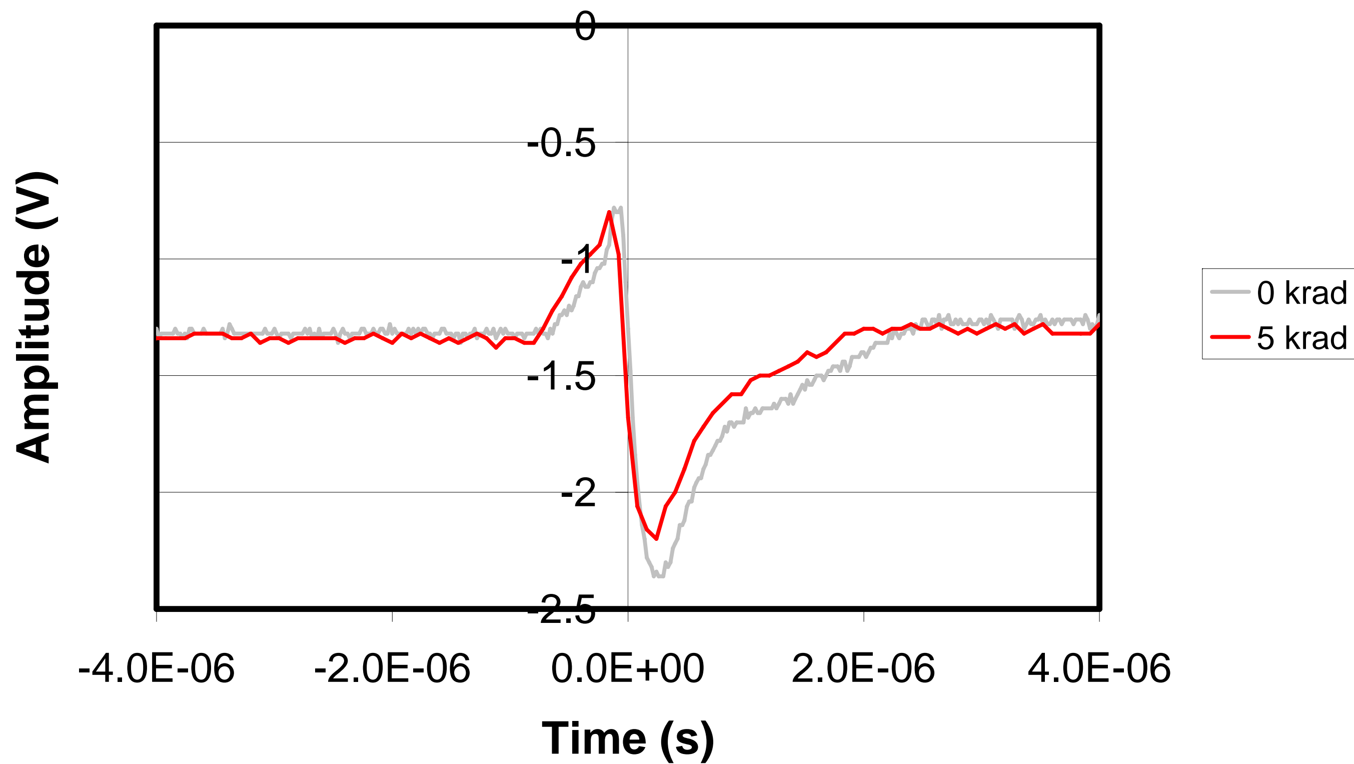

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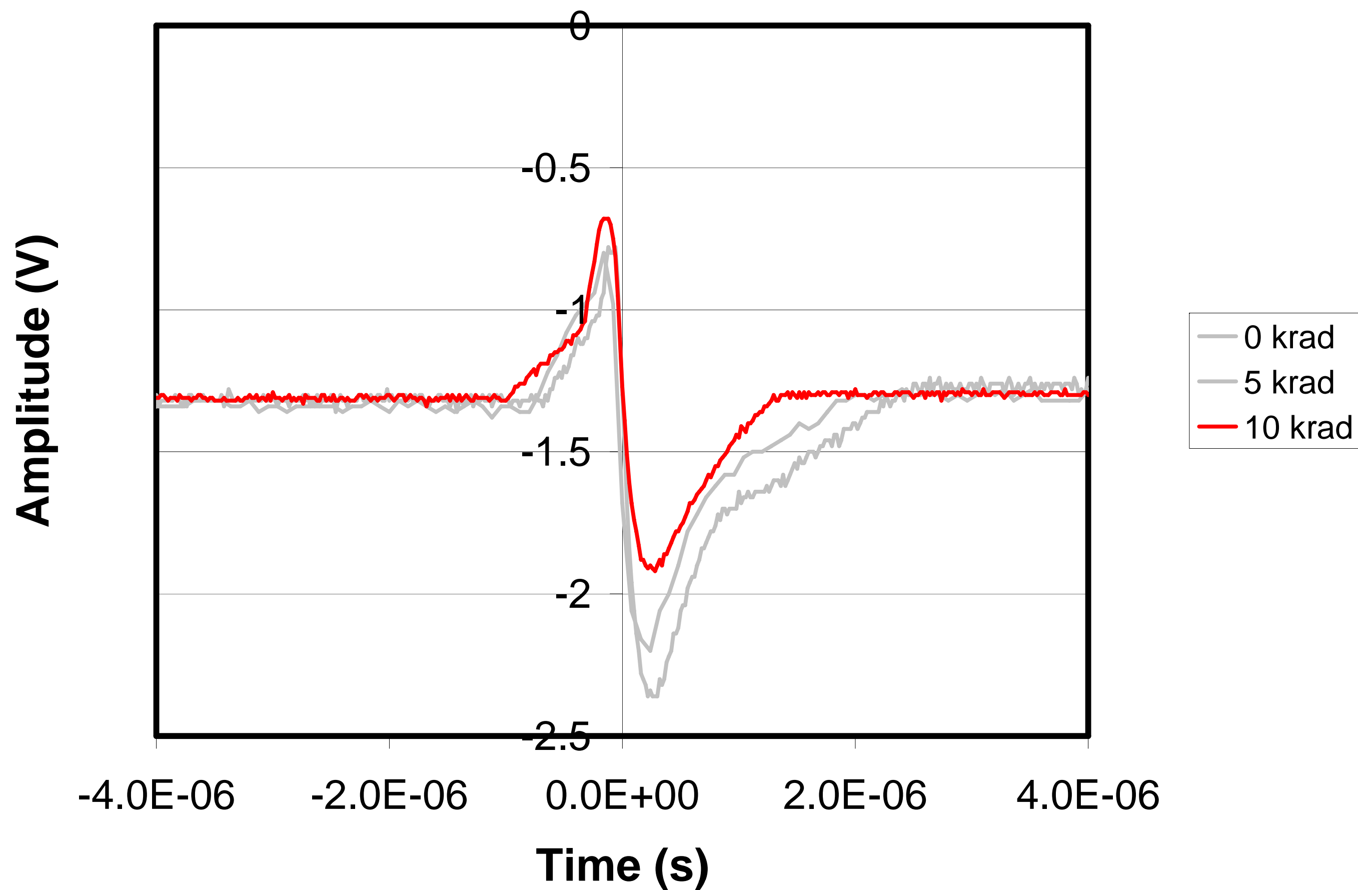

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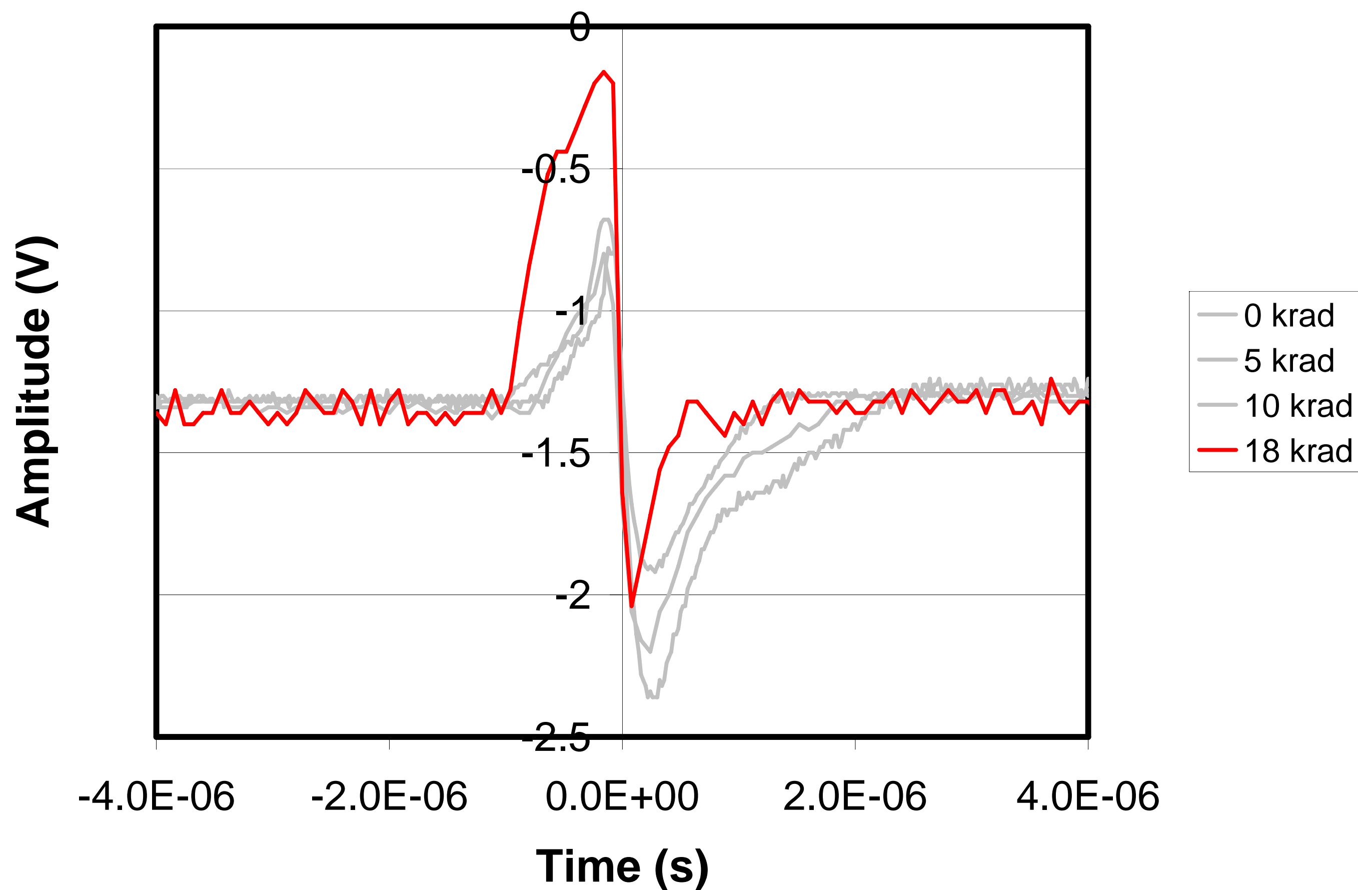

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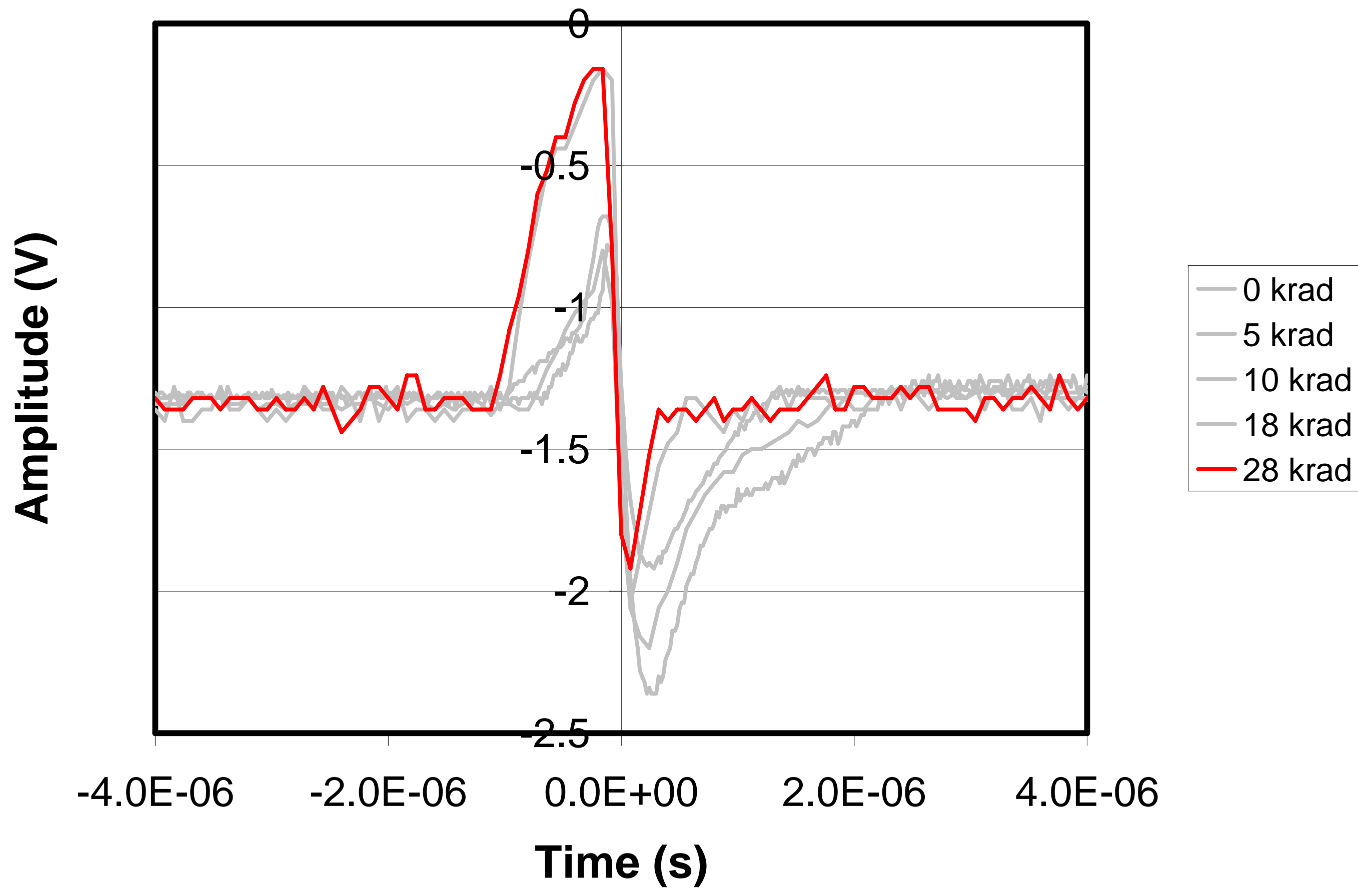

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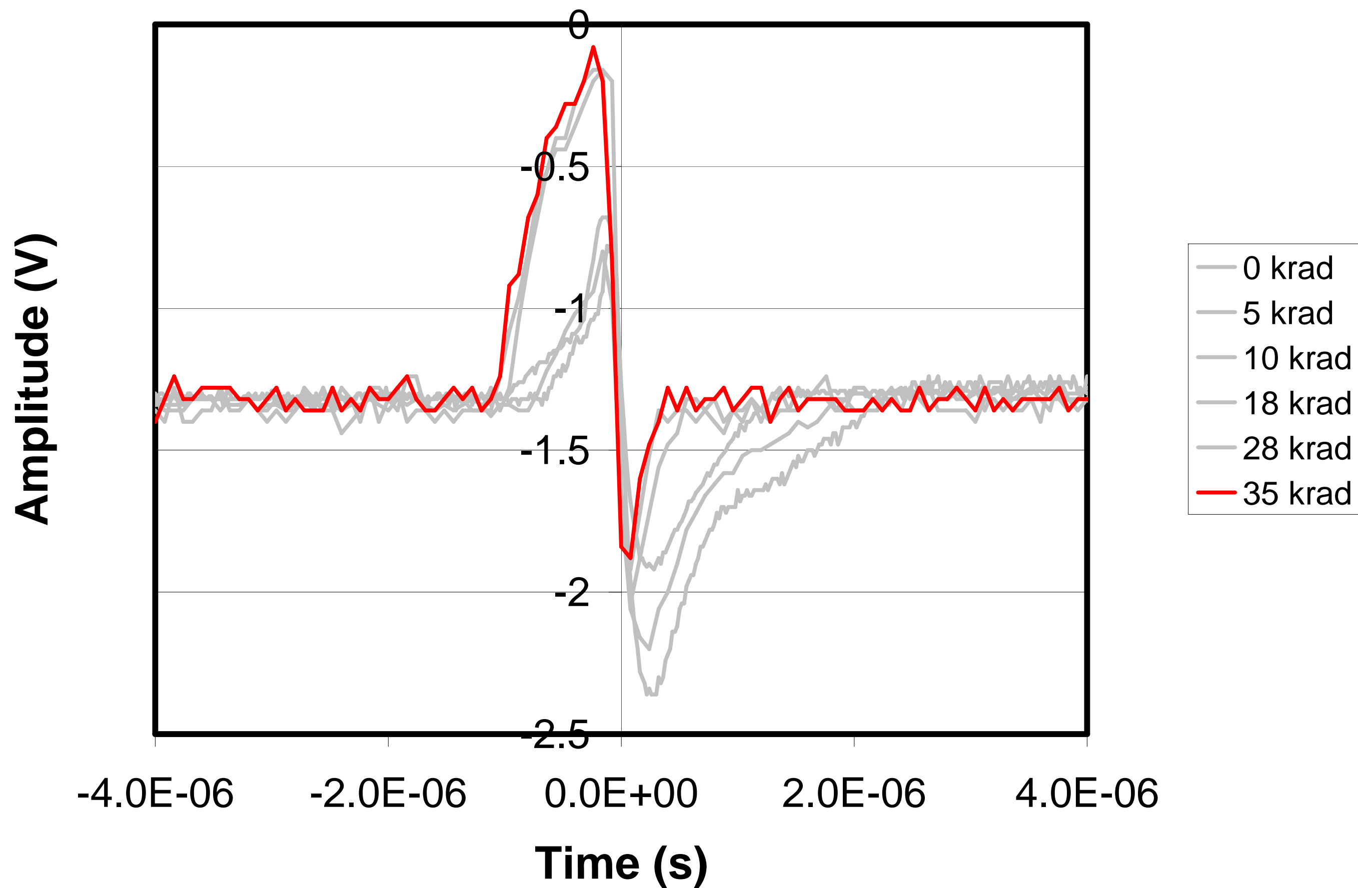

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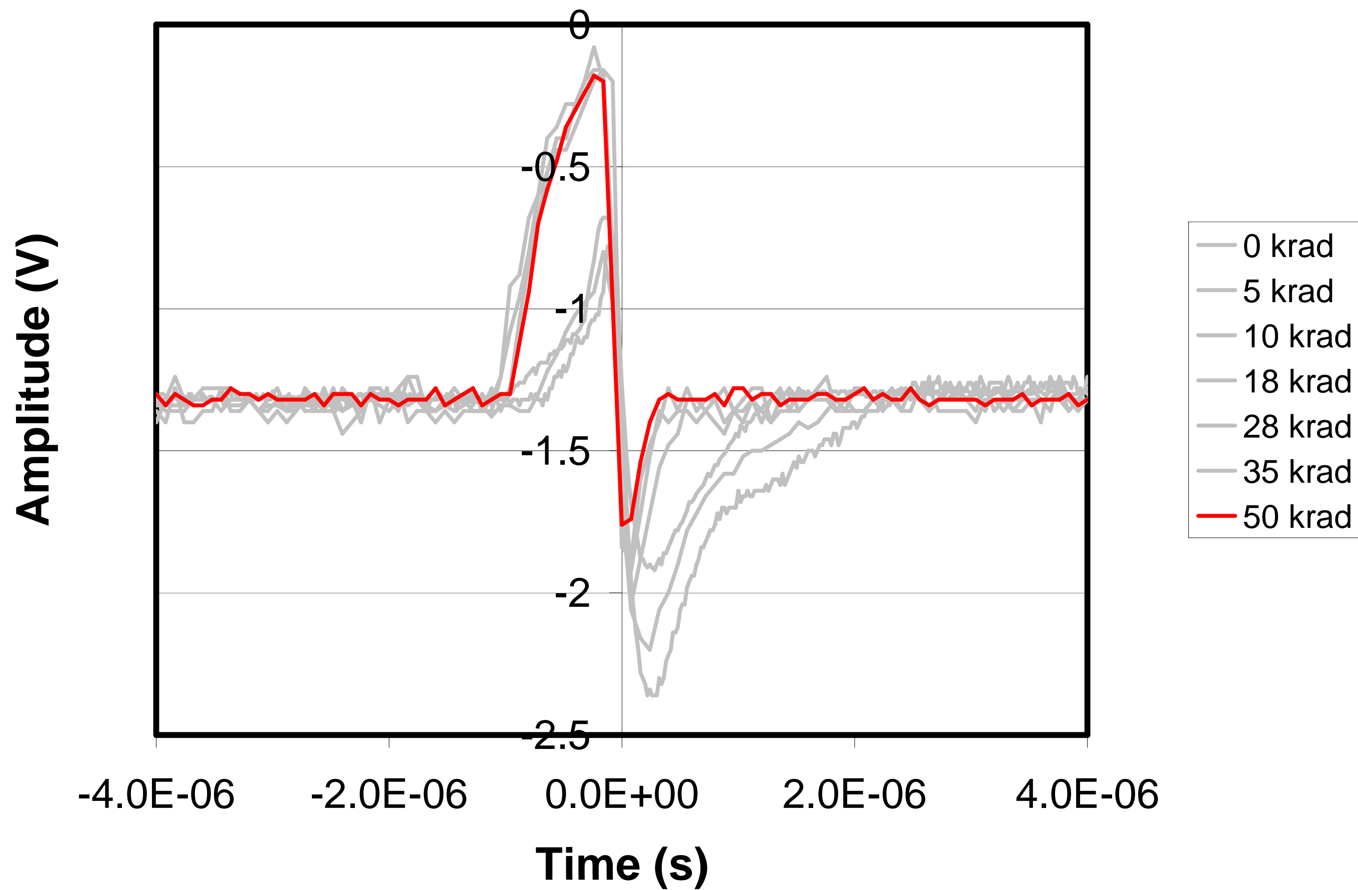

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DIGITAL CMOS CIRCUIT

Test Circuit from Micro-RDC

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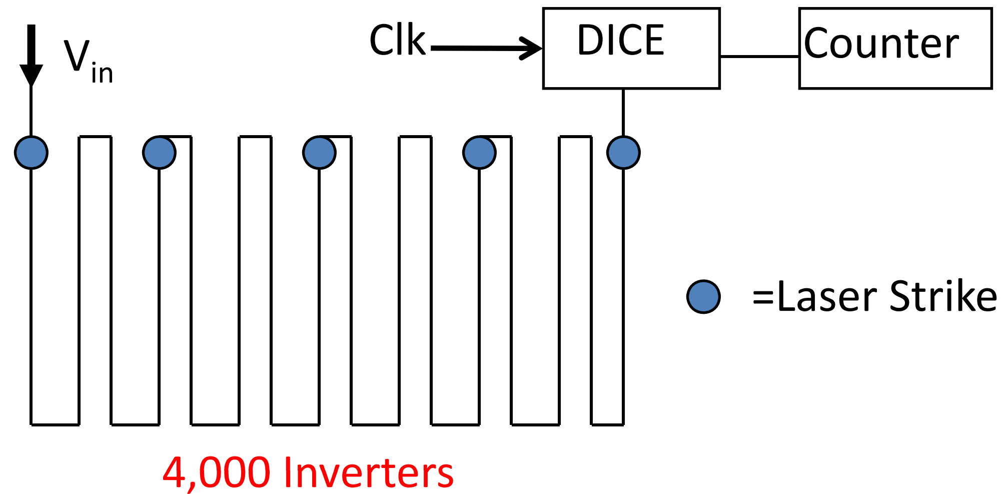
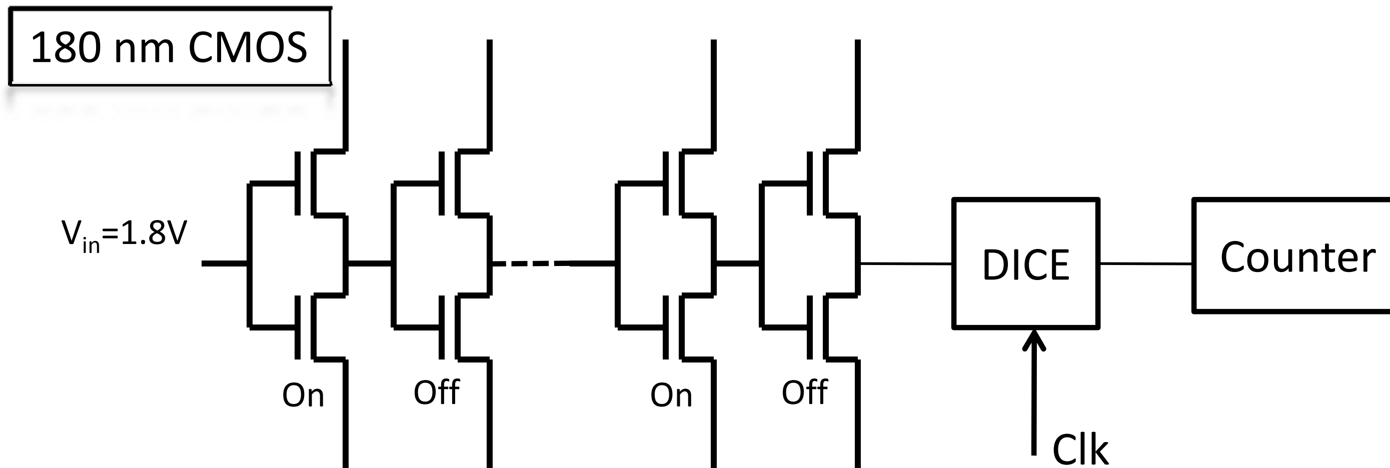
Digital Test Circuit

- Use pulsed laser to measure transient width

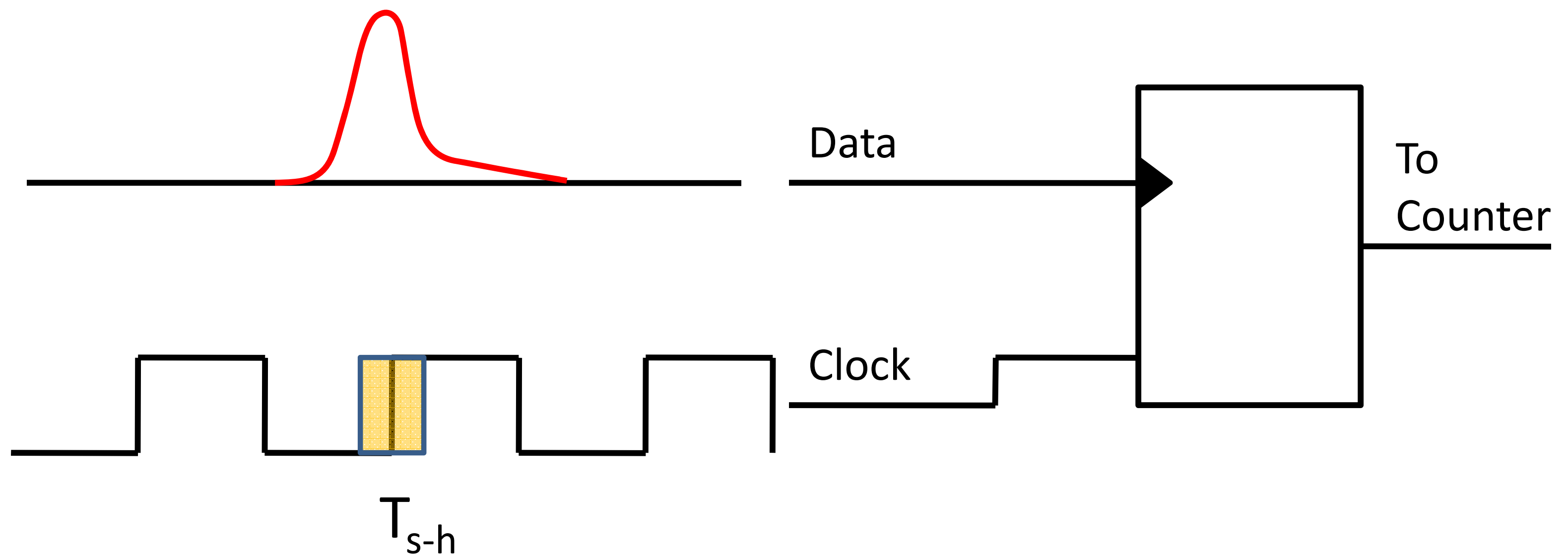




Digital Test Circuit

$$R = (\tau_{pw} - T_{s\text{-}h}) \bullet f_{clk} \bullet f_{laser}$$

$$\text{Pulse-width} = \tau_{pw} = T_{s\text{-}h} + \frac{R}{f_{clk} \bullet f_{laser}}$$



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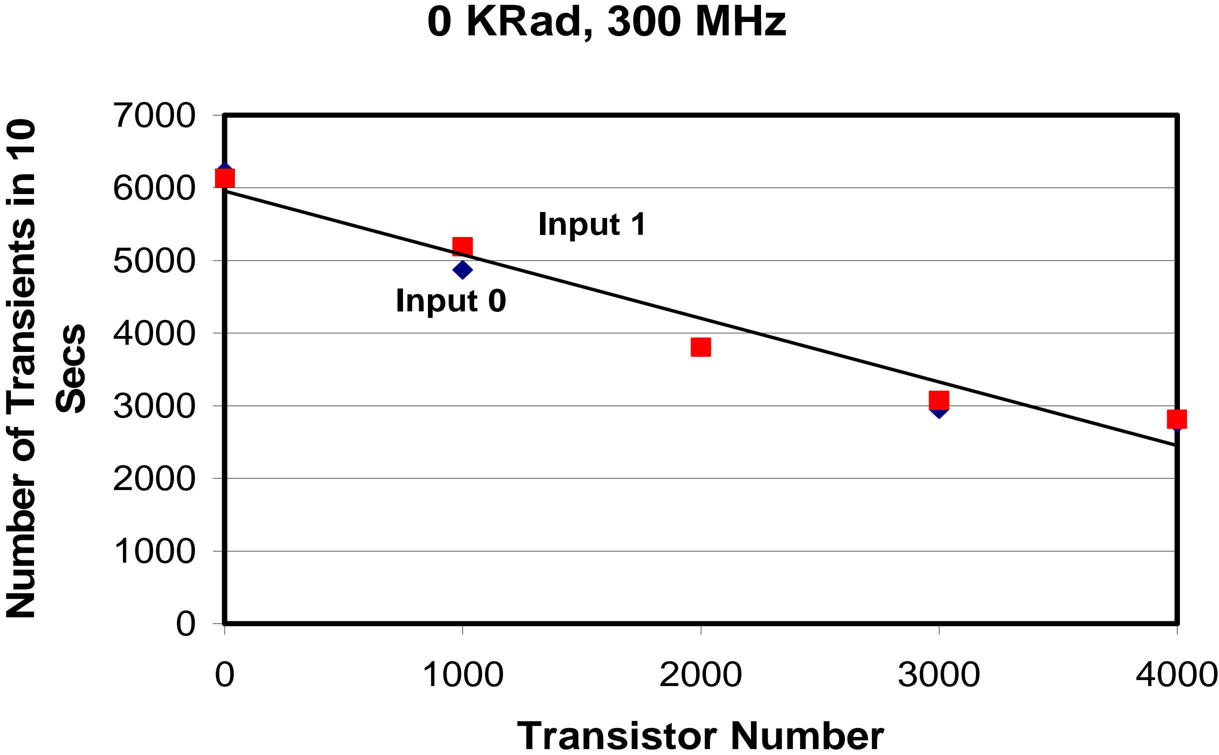
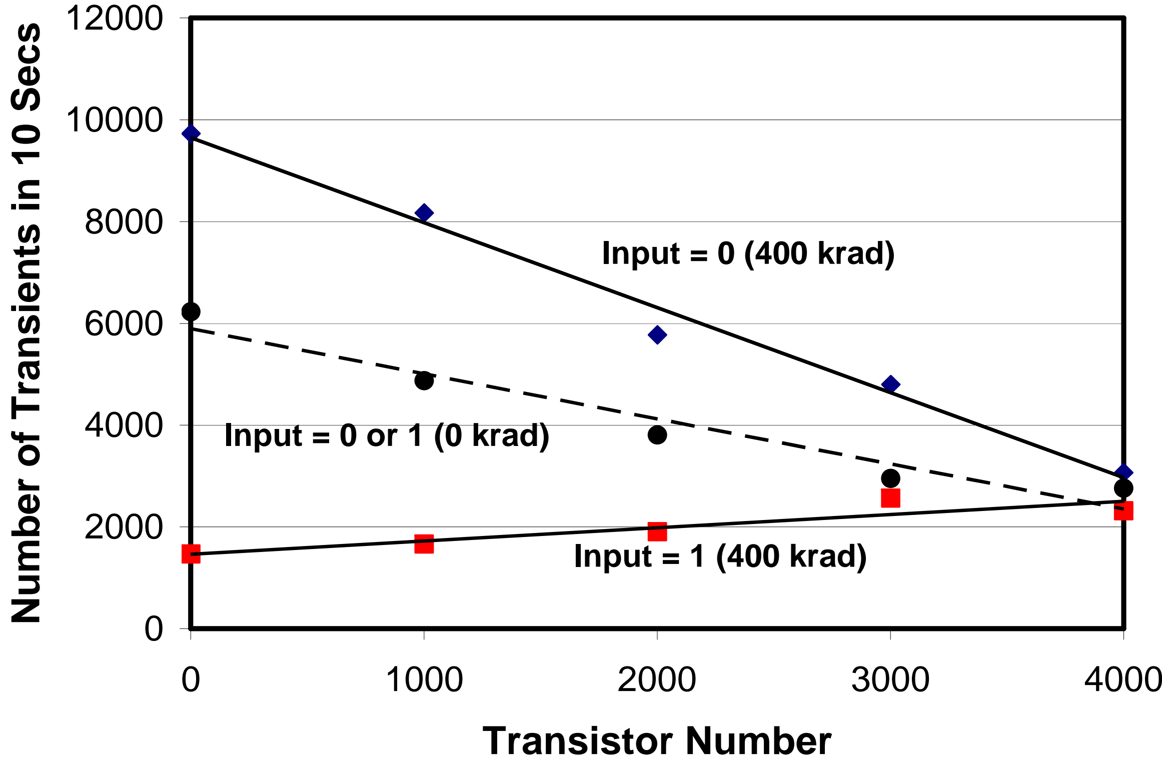
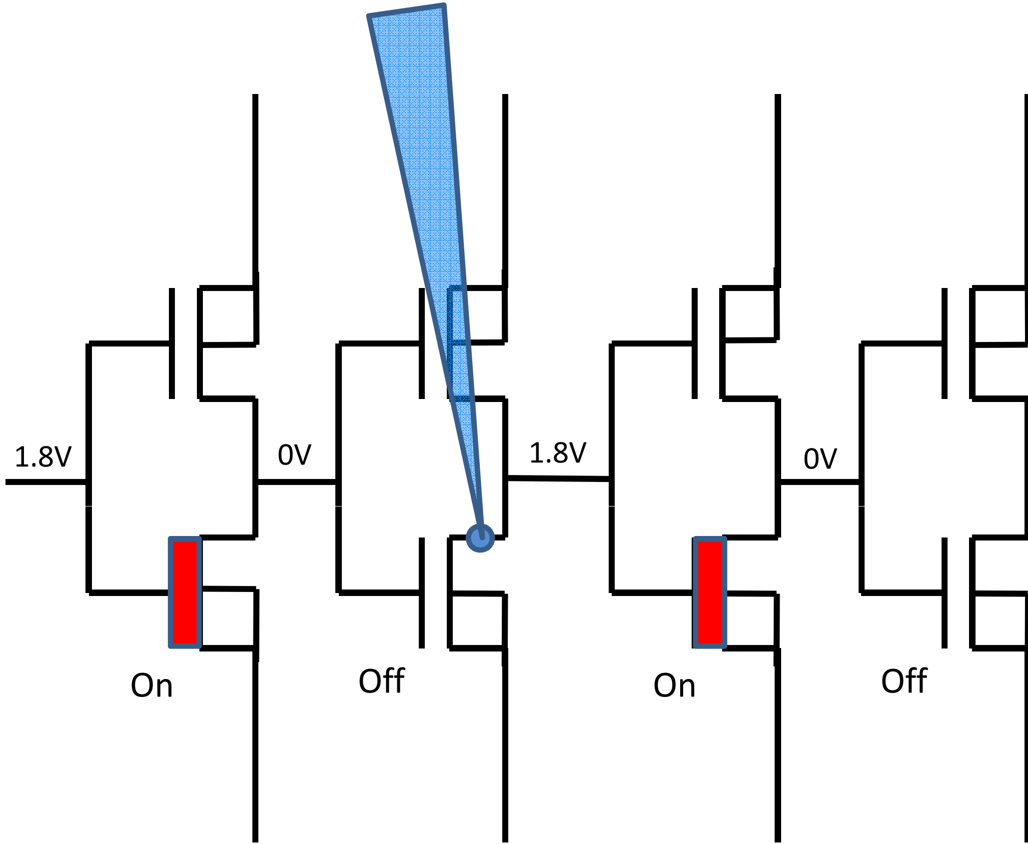
Test Results



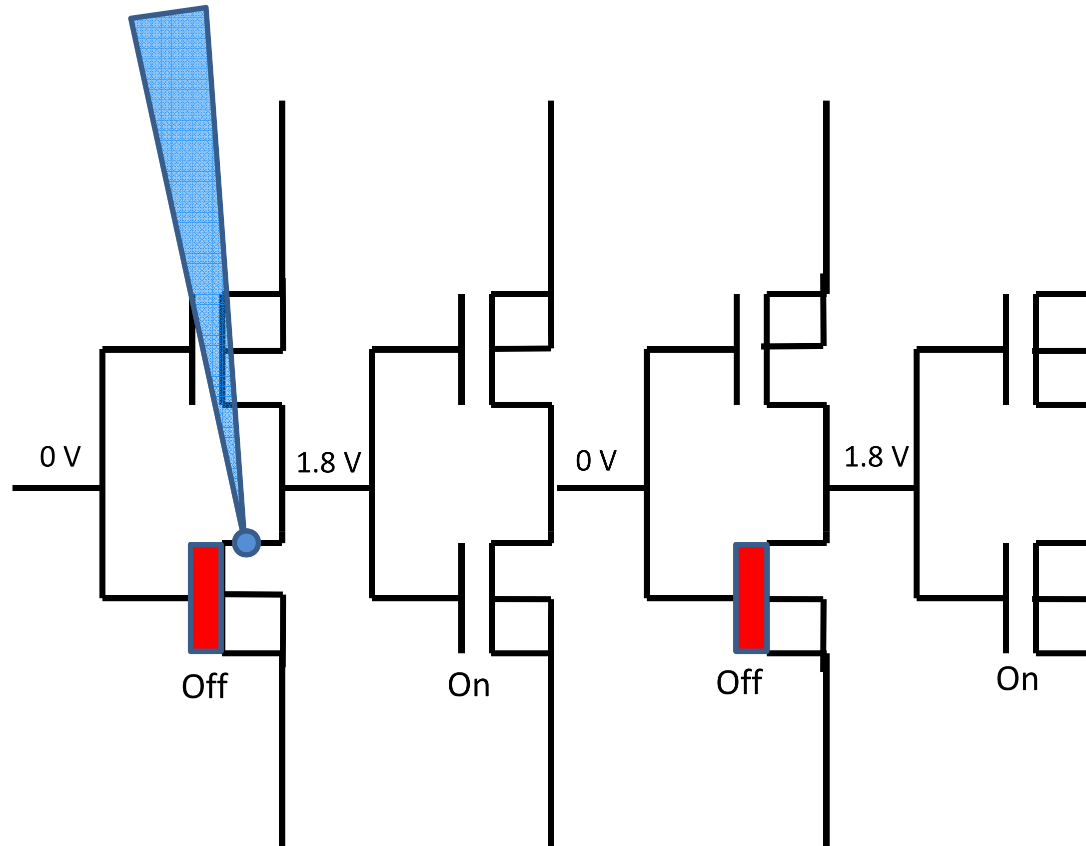
Test Results



Explanation



Explanation



Summary

- Exposure of ICs to ionizing radiation alters their electrical parameters and therefore their SET shapes and sensitivities.
- The effect occurs in both CMOS and bipolar circuits.
- Depending on effect, rates may increase or decrease.
- Effect of TID on SET rates should be considered if SETs cannot be tolerated.
- This work is being extended to other ICs such as a phase locked loop and memories.