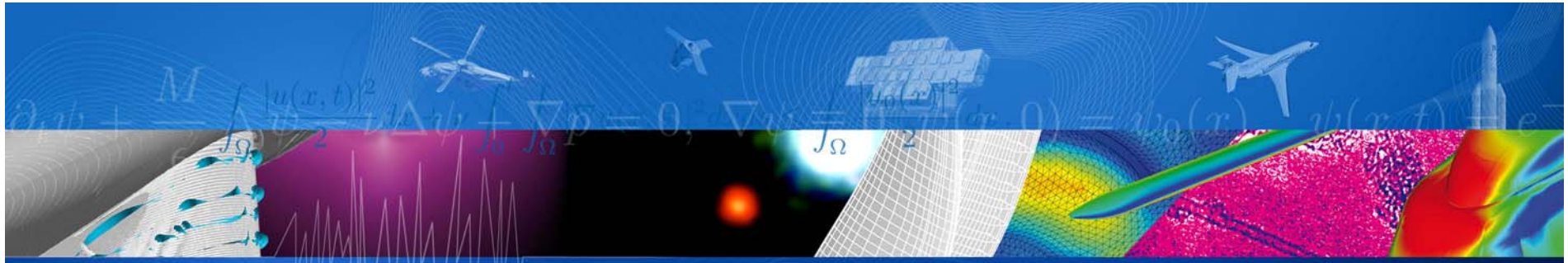

Study on Low Dose Rate Dependency Effect of Radiation

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Contract #11407/95/NL COO10
ESA Report No: ESA_QCA0822S_C
ESA Technical Officer: M. Poizat

ONERA
THE FRENCH AEROSPACE LAB

return on innovation

Objectives and motivations

Many bipolar linear parts exhibit Enhanced Low Dose Rate Sensitivity (ELDRS) effect

The standard and guidelines does not appropriately describe an ELDRS test method (standard dose rate)

- defining an appropriate test approach for highlighting ELDRS effects on bipolar based technologies
- comparing 36rad(Si)/h (LDR) with 360rad(Si)/h (HDR) in terms of component degradation
- is the component degradation exacerbated at extremely low dose rates (<36rad(Si)/h, ELDR)?

ELDRS: preliminary

- Degradation ↔ Qot, Nit
- Low Dose Rate → Qot annealing (long) // degradation
  Qot, Nit : higher yield
- Bias effect (bipolar)
  - ✓ Active zones: frindging fields, OFF WC for degradation
  - ✓ Passive zones: can be opposite
  - ✓ Mostly low E field in oxides => ELDRS / Qot-Nit

Experimental details

- Set of 9 device types
- 10 parts irradiated per dose rate, 5 biased / 5 unbiased (1 ref)

- irradiation steps: 5, 10, 15, 20, 30, 50, 70, 100krad
- annealing : 1 week/25°, 1 week/100°

  Help for interprating results

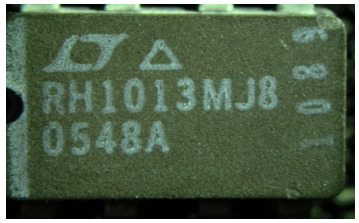
- ESTEC gamma facility
  - 360rad(Si)/h: May 2010 (HDR)
  - 36rad(Si)/h: June-October 2010 (LDR)
  - ➢ Comparison of LDR with HDR in terms of component degradation

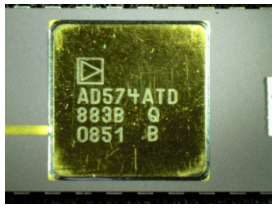
- ONERA bunker (ELDR) : *planned for 2nd term 2011 (≤10 rad(Si)/h)*

Samples (1)

2x Operational amplifiers and 1x comparator

OP15AZ	AD	Precision J-FET input Op. Amp.	QMLV	DIL8
LM111	TI	Precision voltage comparator	883B	DIL8
RH1013MJ8	LTC	Dual precision Op. Amp.	Radhard	DIL8





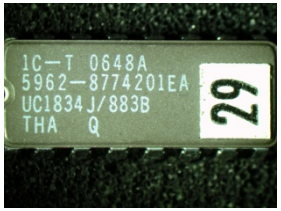
1x A/D converter and 1x PWM

AD574ATD	AD	12-b A/D converter	883B	DIL28
UCC1806J (BiCMOS)	TI	Low-power dual-output current-mode PWM controller	883B (one single diffusion lot)	DIL16

Samples (2)

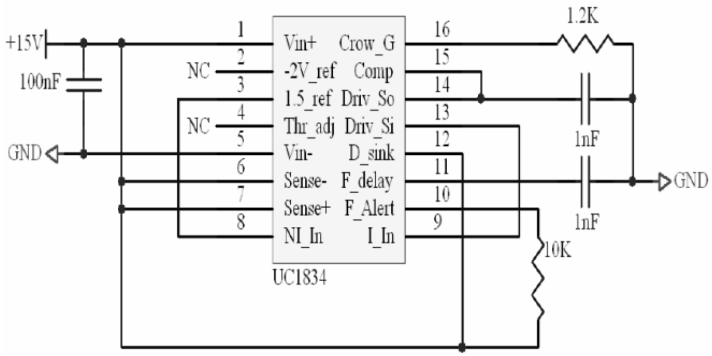
2x Precision references and 2x regulators

AD584SH	AD	Pin programmable precision voltage ref.	883B	Can8
RH1021CMH	LTC	Precision 5V ref.	Radhard	TO5
UC1834J	TI	High efficiency linear regulator	883B (one single diffusion lot)	DIL16
JL117BXA	NSC	Voltage regulator	883B	TO39

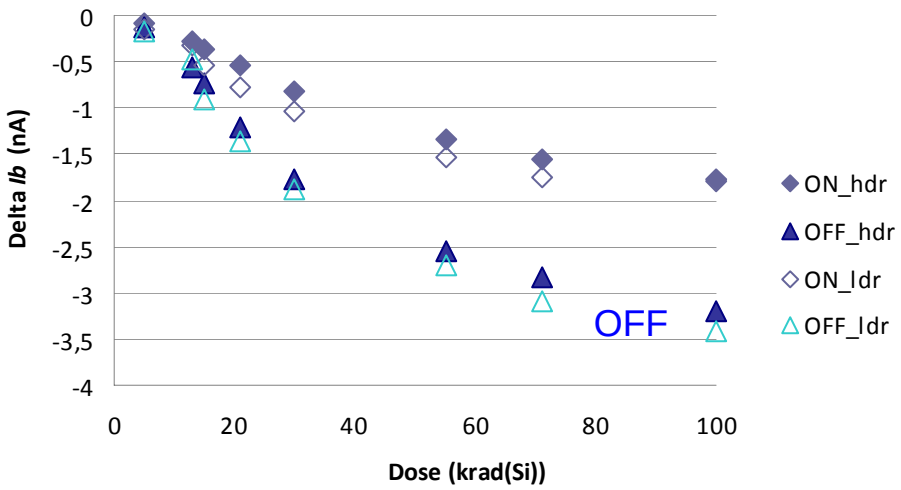


UC1834 results

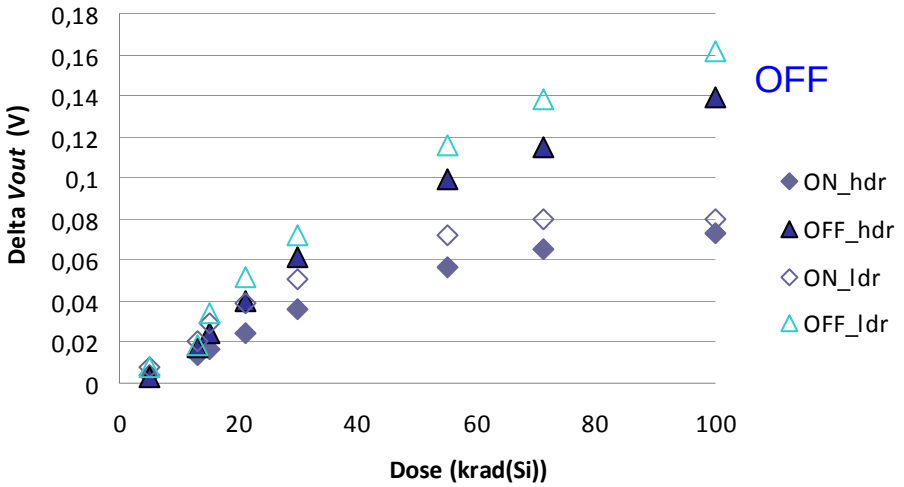
slight DR effect … not significant
bias predominant (OFF = wc)
Out of spec. > 10-20 krad(Si) (Vout)
!!! Marginal parts (ex. Istb)



Input Bias Current (Vcm=1.5V)



Output Voltage Reference (-2.0V)

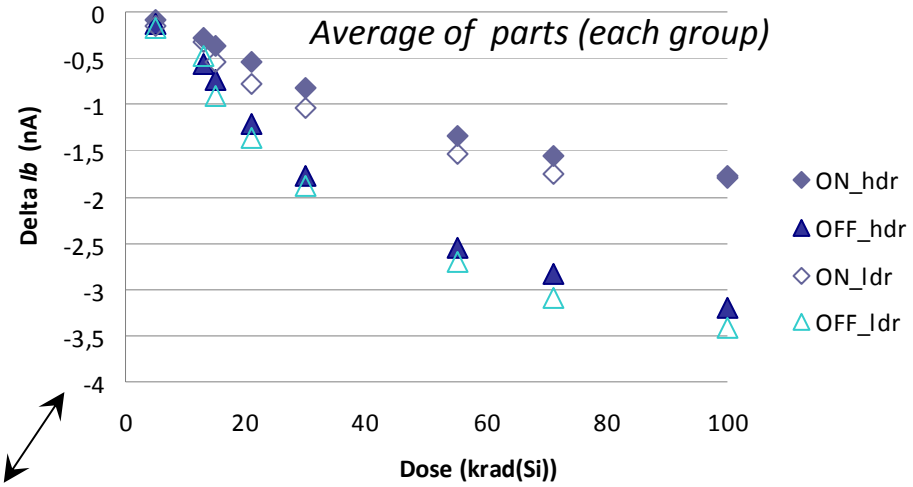


Average of parts (each group)

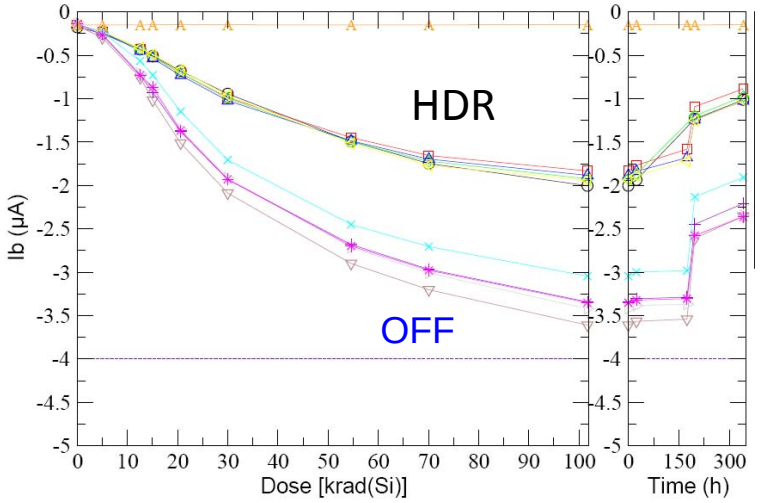
UC1834 results

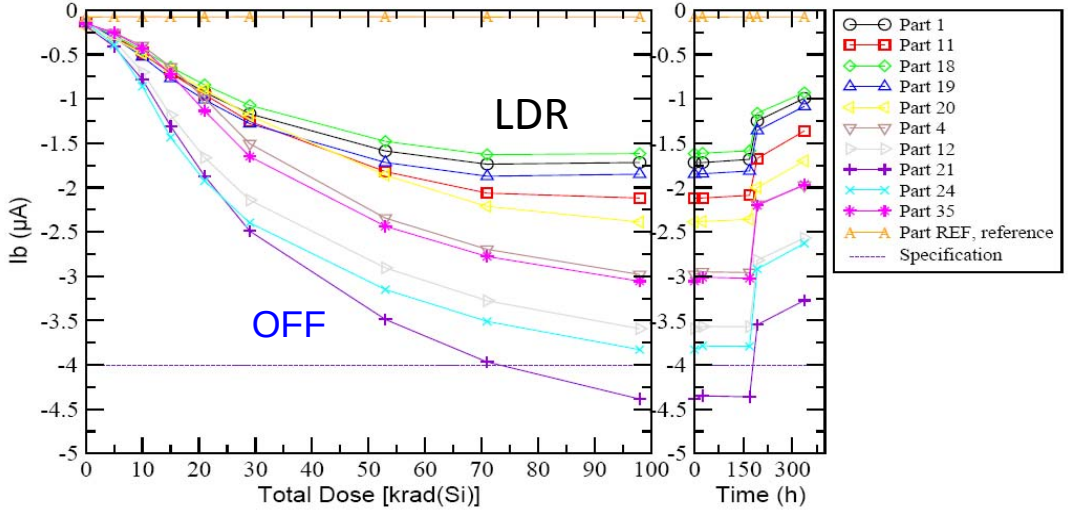
LDR enhancement factor not significant …
but spec. exceeded for LDR (not HDR)
and ELDR expected WC

"Annealing": 0 at ambiant, partial at 100°C



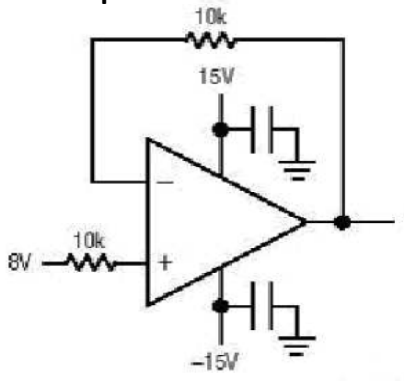
Input Bias Current (Vcm=1.5V)



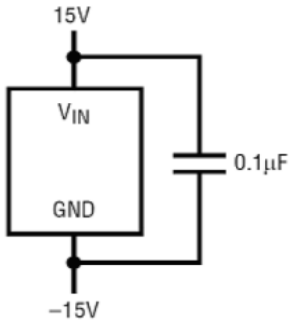


RH1013 and RH1021 results

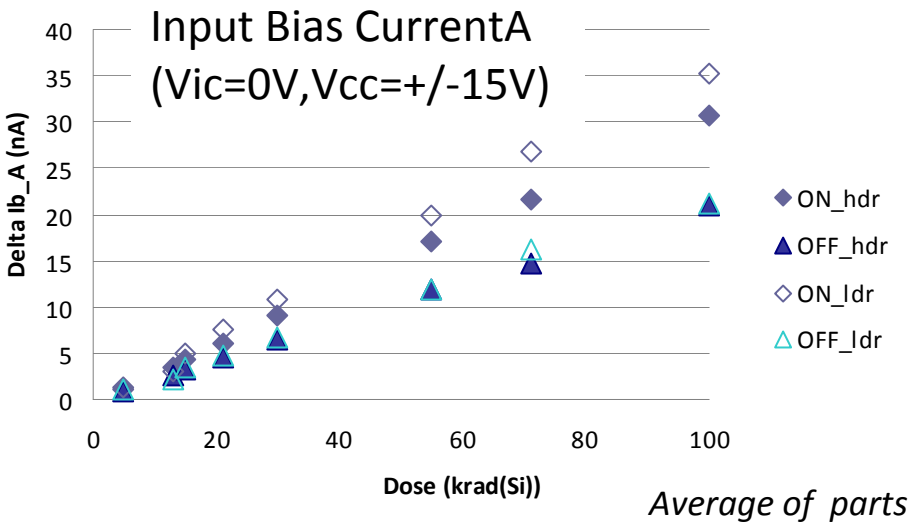
Bias effect: ON = wc
Ib out of spec. at 50krad hdr, 70krad ldr

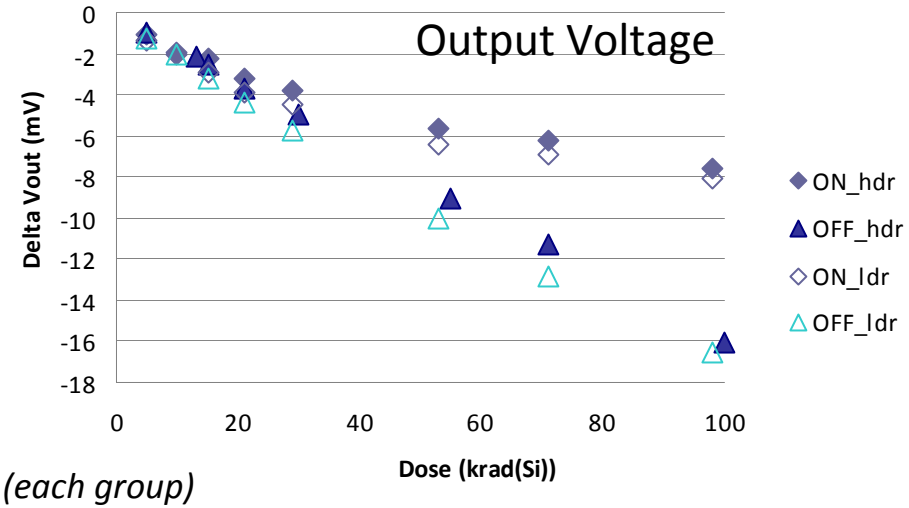


Bias effect : OFF = wc
LineReg & Vout out of spec. at 10-30krad



Bias predominant, LDR enhancement not significant





Average of parts (each group)

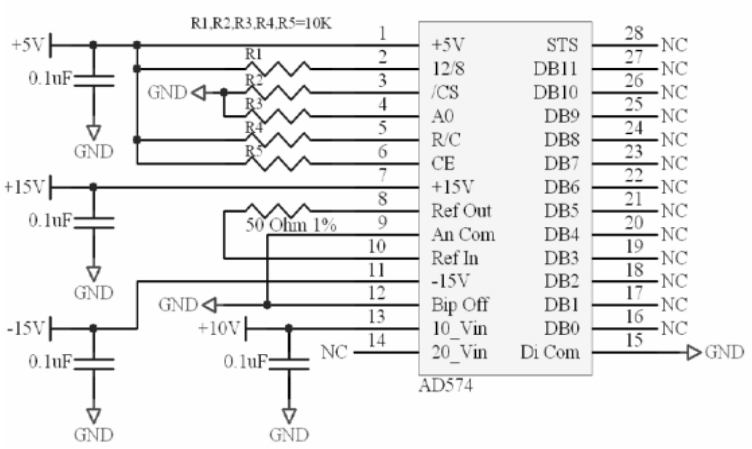
AD574 results

Complex DR & bias responses (parameter dependant)

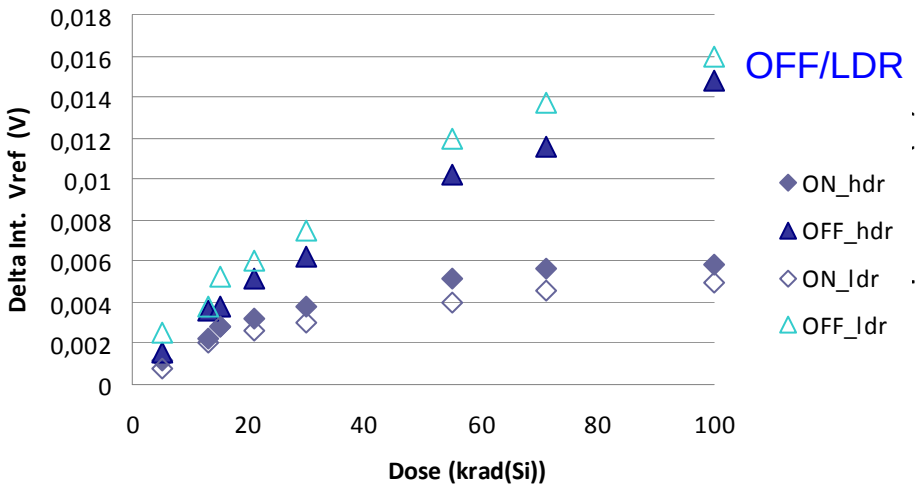
Partial to complete annealing (parameter dependant)

Pass 100krad

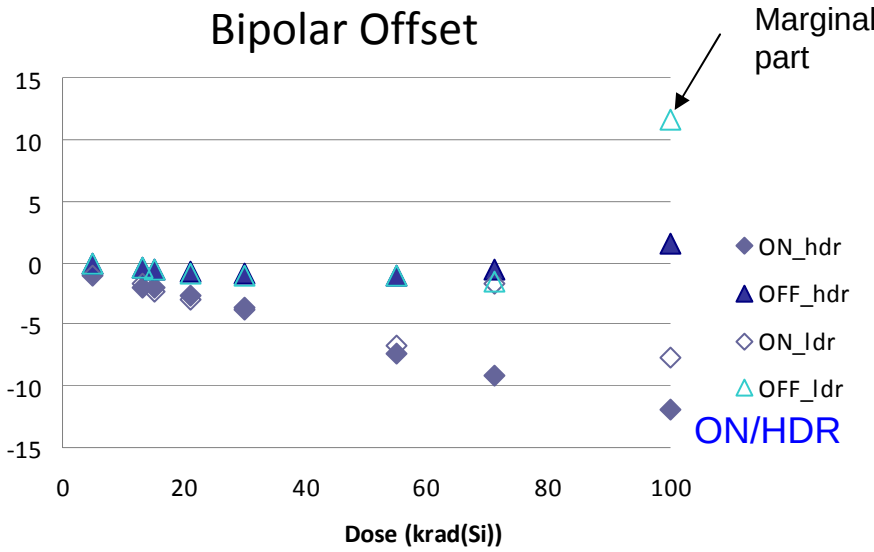
Out of spec. 20 krad (bip. offset)



Internal reference Voltage (Iout=1.5mA)



Bipolar Offset



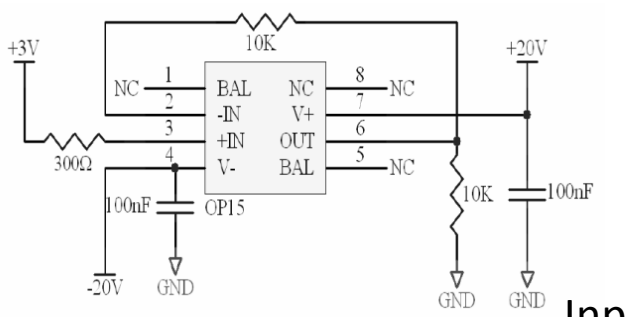
Average of parts (each group)

OP15 results

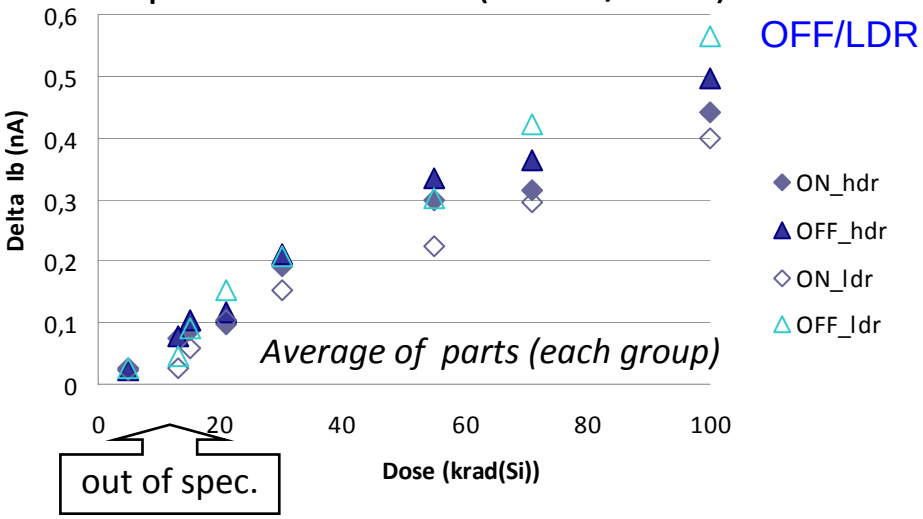
Complex DR and bias effect

- enhancement factor: param. dependant (Vos WC), HDR WC for Is, Ios
- ON/OFF WC : param. dependant

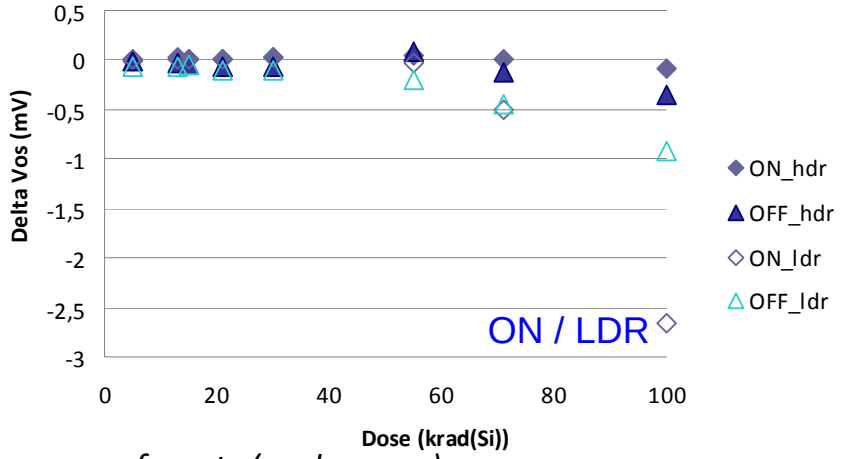
Rebound effect! (HDR & LDR)



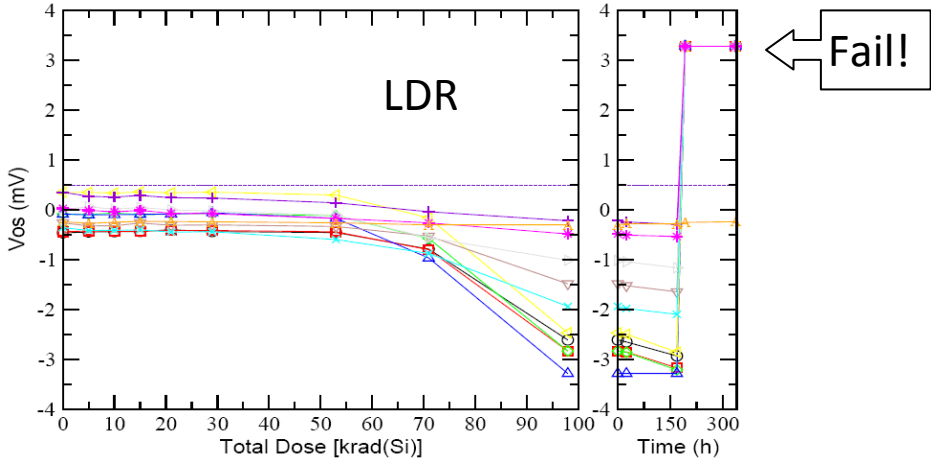
Input Bias Current (Vcc=+/-15V)



Input Offset Voltage (Vcc=+/-15V)

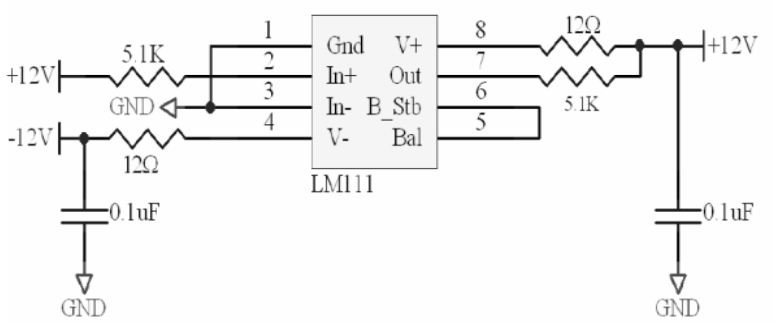


Average of parts (each group)

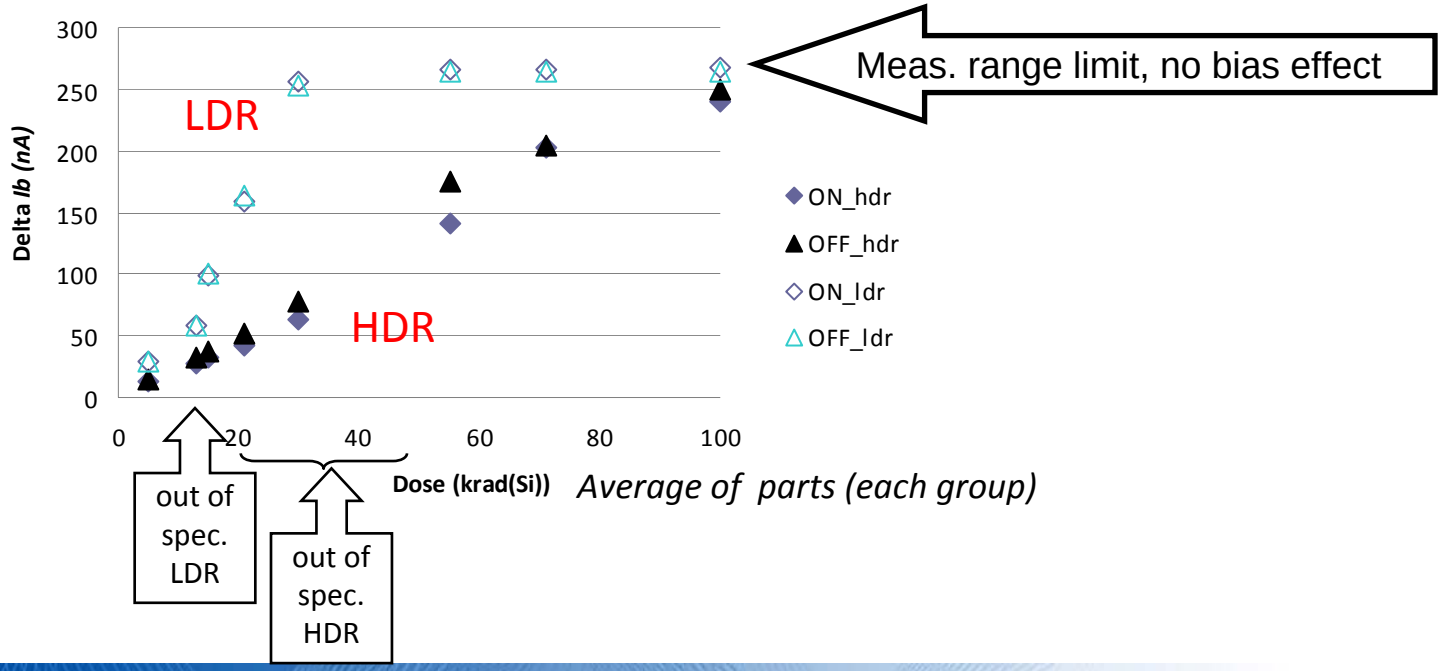


LM111 results

Complex DR effect (LDR or HDR)
enhancement factor: WC for Ib at LDR (out of spec. at 20-50 krad HDR, 10-15 krad LDR)
Bias effect : par. dependant (ON WC if any)



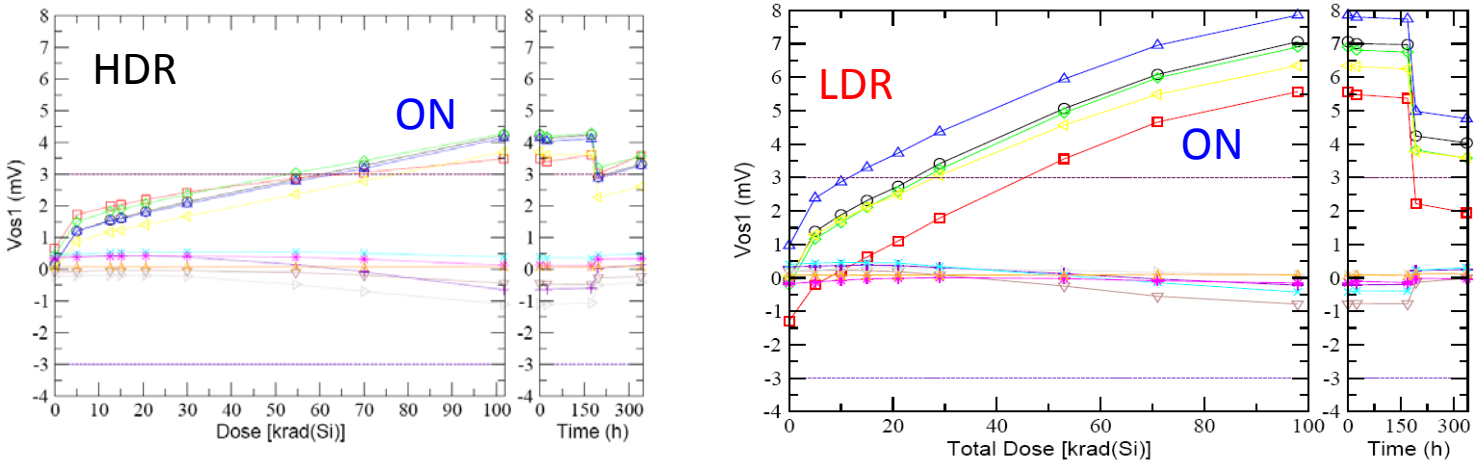
Positive Input Bias Current (Vsupply=+/-15V, Vout=0V)



LM111 results

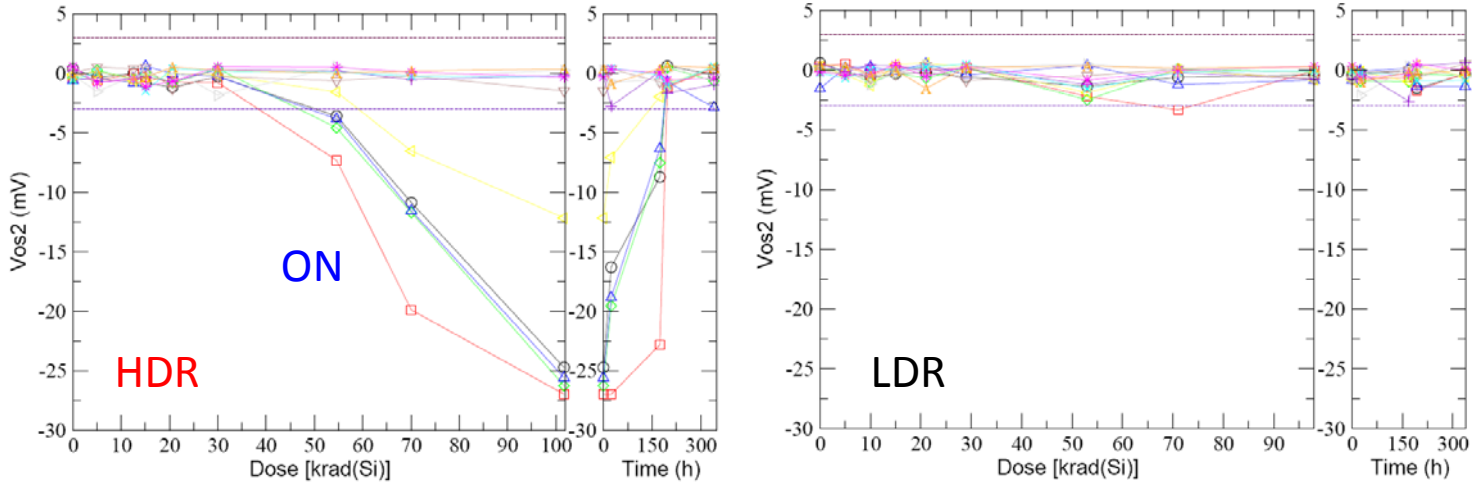
Input Offset Voltage (Vic=0V,Vcc=+/-15V)

partial annealing



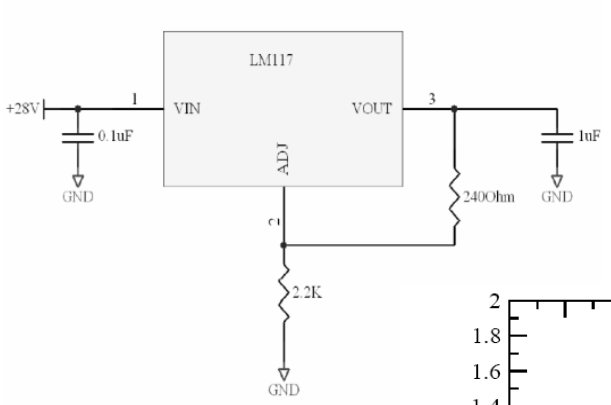
Input Offset Voltage (Vic=13V,Vcc=+/-15V)

complete annealing

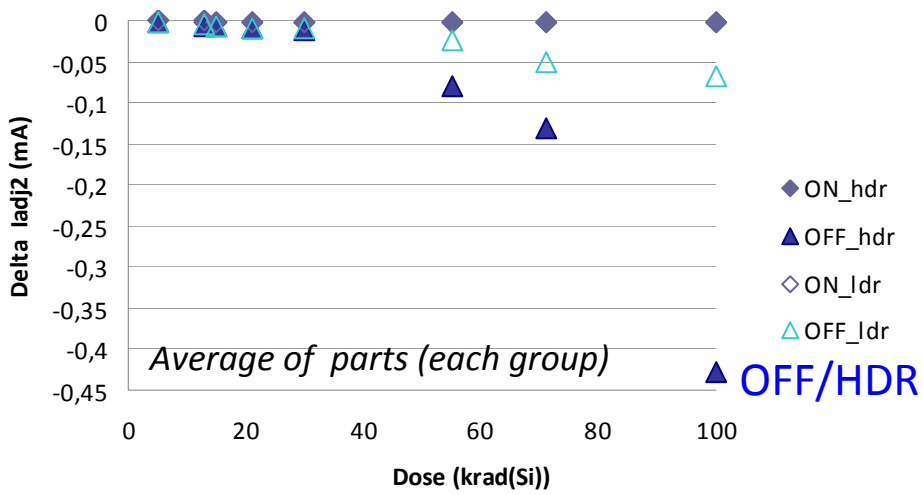


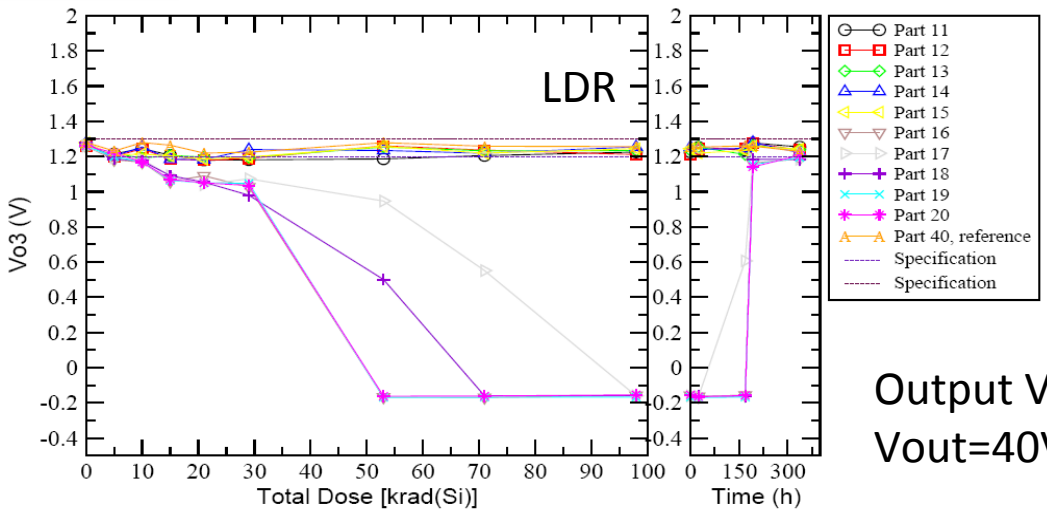
JL117 results

"CMOS-like" device : HDR WC + annealing
Bias effect : OFF = wc
Out of spec. at 10krad (Vout)



Adjust Pin Current (Vin=41.25V,Iout=5mA)





Output Voltage (Vin-Vout=40V, Iout=10mA)

Summary of results

DR effect (LDR wc) *Enhanc. factor* + ↑ ..... ≤1.6 -	Complex DR effect (LDR or HDR) enhancement factor: WC for Ib /LDR	ELDR required	Bias effect: param. dependant (ON WC)	LM111
	Complex DR effect enhancement : param. depend. (Vos wc) HDR WC for Is, Ios Rebound		bias effect: param.dependant (ON/OFF)	OP15
	Complex DR (LDR or HDR) & bias effect (param. dependant). Pass 100krad			AD574
	Bias predominant, LDR enhancement not significant		OFF WC	AD584 UC1834
			ON WC OFF WC	RH1013 RH1021
CMOS-like	HDR WC (end of ir. at 30krad)	ELDR not required	ON WC Partial/complete annealing (par. dep.)	UCC1806
	HDR WC (out of spec. at 10krad)		OFF WC Complete annealing	JL117

Conclusions

- Comparison of 36rad(Si)/h (LDR) with 360rad(Si)/h (HDR) in terms of component degradation
- Set of 9 Bipolar / BiCMOS devices

- ❑ All device types exhibit DR effects with varying enhancement factor
- ❑ 3x more sensitive with LDR + 4x not significant => ELDR required for investigating WC degradation

  Rem: 360rad/h too low (comp. to 36rad/h) as HDR to determine ELDRS
- ❑ 2x « CMOS-like »: ELDR not required
- ❑ bias effect : device and parameter –dependant

- ❖ *Importance of performing xDR testing with ≠bias to approach an upper bound, or worst case, for device parameter performance*

- ❖ ELDR testing (*2nd term 2011, ≤10 rad(Si)/h)) : DR for bounding degradation (device dependent)? …. the lowest possible with a reduced total dose….*