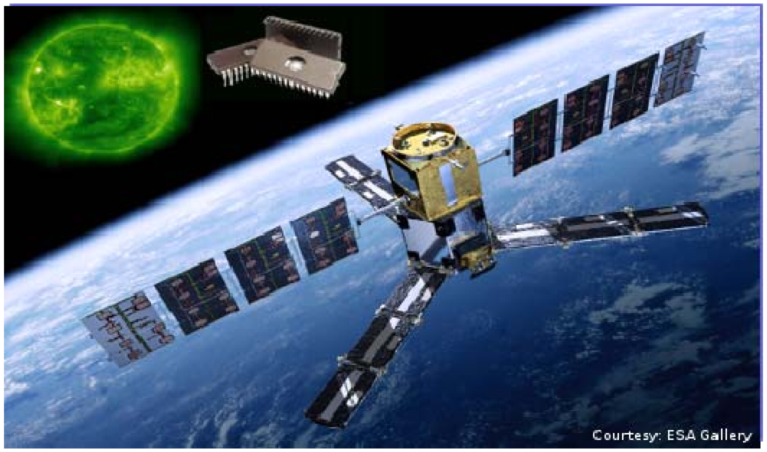
ELDRS - Verification of Enhanced Low Dose Rate Sensitivity Accelerated Test Method

ESTEC - Contract No. 22051/NL/PA



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- Proposed Parts List
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- Preliminary Test Results
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- ELDRS Website eldrs.net

ELDRS Test Method

Motivation

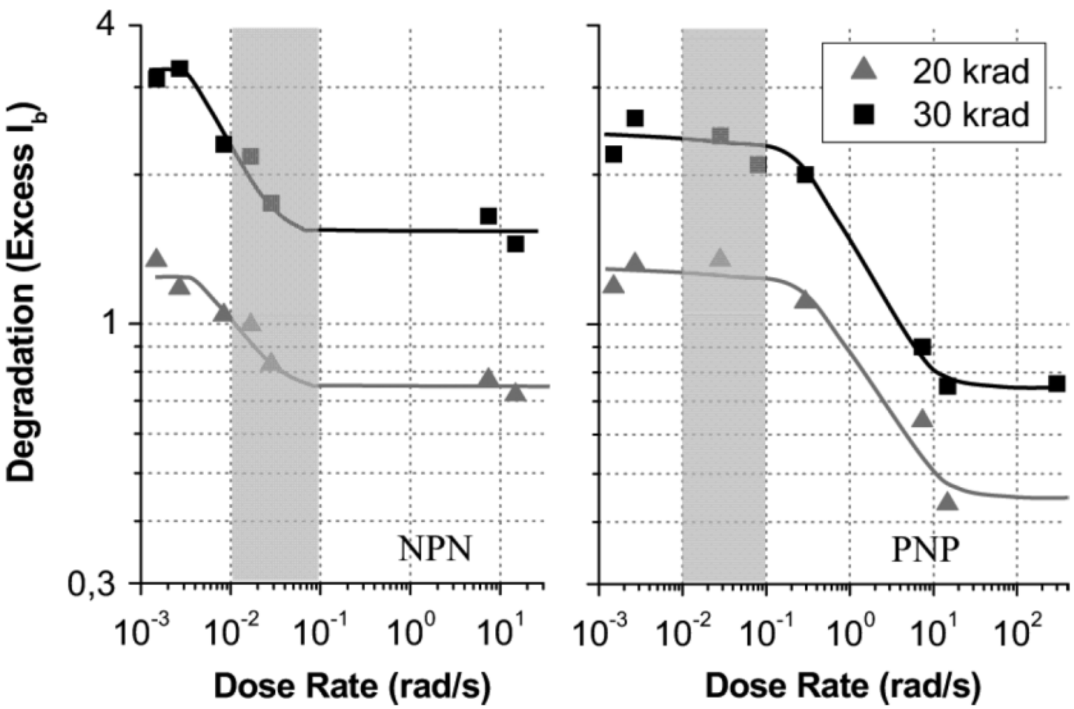
- Concern for **bipolar technology** used in space

- Low dose rate testing is **time consuming** !
- e.g. 100krad:
  10 mrad/sec → 4 months
- 1 mrad/sec → ~3.5 years

- **Accelerated switching dose rate method** proposed by UM2

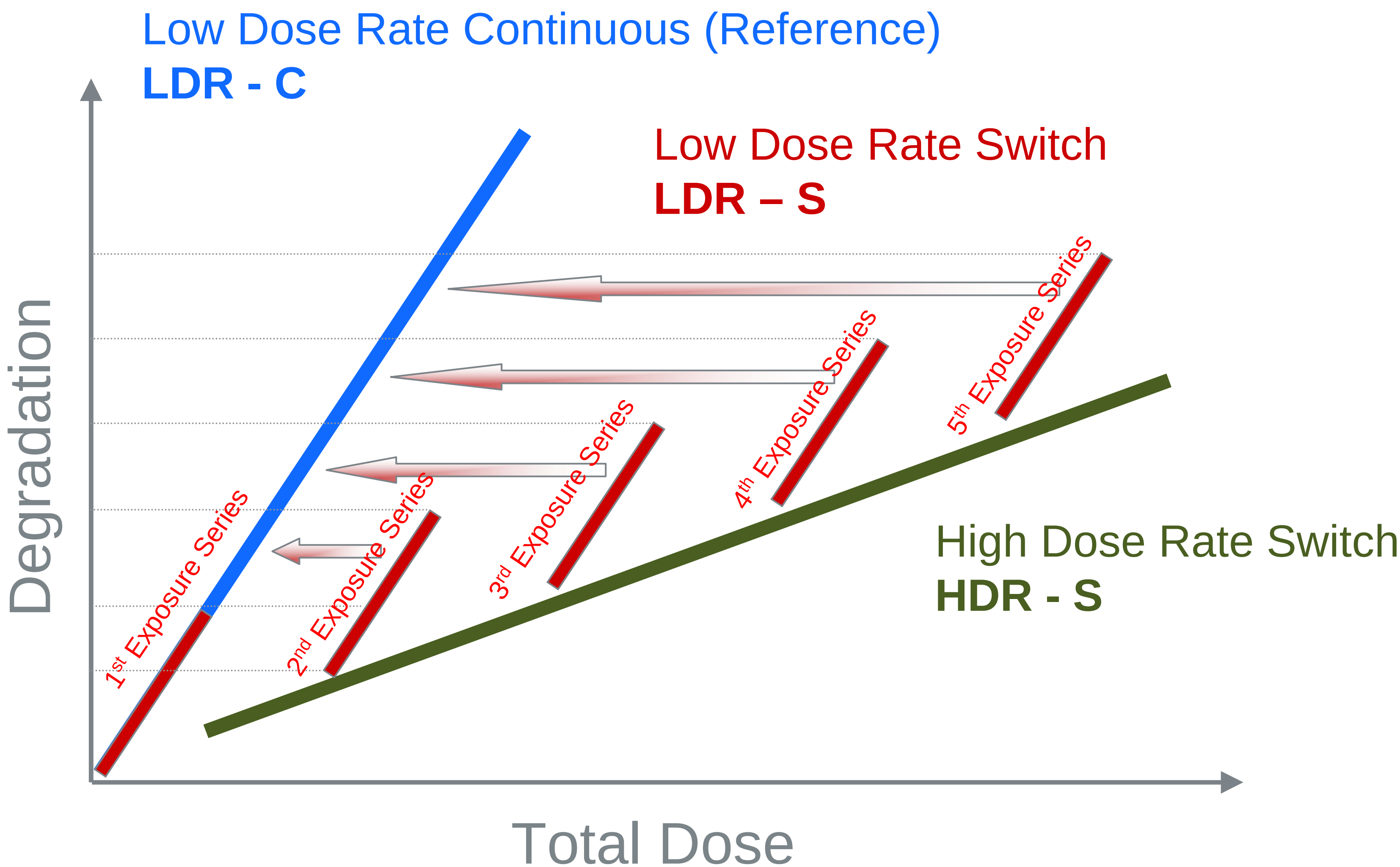
- ELDRS project checks the **applicability** of UM2 test method

Degradation of the base current, I_b for NPN and PNP transistors
Total dose: 20 and 30 krad (SiO_2)



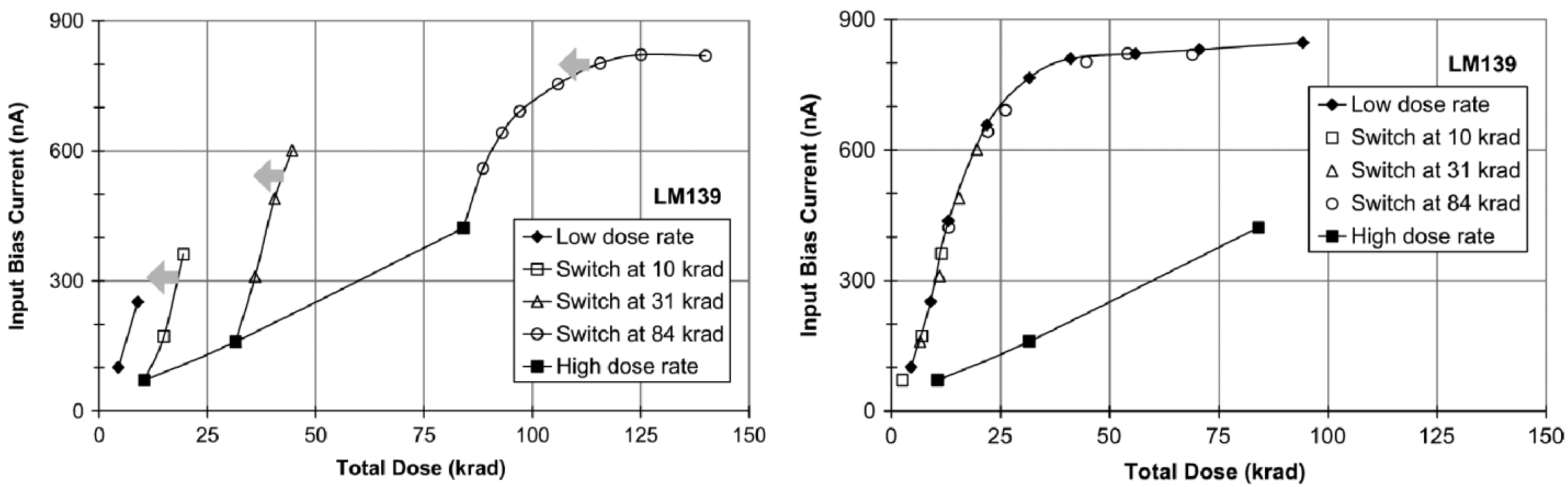
Reference: J. Boch, et.al., „Physical model for low dose rate effect in bipolar devices", IEEE-TNS, vol. 53, p. 3655, December 2006

The Accelerated Switching Test Method



Example: ELDRS Effect for LM139

Accelerated switching test for input bias current of LM139



Ref: .J. Boch, et.al., „The Use of a Dose –Rate Switching Technique to CharacterizeBipolar Devices“, IEEE-TNS, vol. 56 (6), p. 3347, December 2006

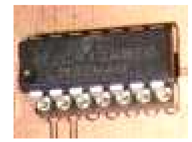
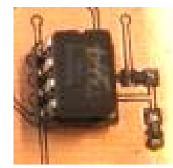
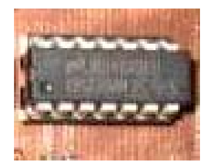
Proposed Parts List

Selection of parts for the experiments

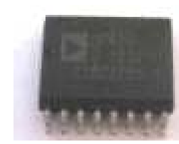
- **Basis**: Approved component list by ESA CTB radiation working group
- **Selection Parameter**:
  - **E (0,1)**: ELDRS sensitivity (literature)[1)]
  - **I (0,1)**: pnp Input stage[1)]
  - **S (0,1)**: availability of 70 units from one wafer lot (SLDC)
  - **P(0,0.5,1)**: Price < 5000 Euro for 70 units
- **Selection Formula:** **S = E • I • S • P**[1)]
- **Selection Criteria:**
  - S ≥ 0.5

1) If ELDRS sensitivity is not known from literature information about “pnp stage” is considered to be sufficient.

Part Types used for 1st Measurement Campaign

Part Type	Description	Manufacturer	Picture
LM324AN	Operational Amplifier	National Semiconductor	
LM158AJ	Operational Amplifier	National Semiconductor	
LM311N	Comparator	National Semiconductor	
LM339AN	Comparator	National Semiconductor	
HS9-OP470ARH	Radiation Hard Operational Amplifier	Intersil	

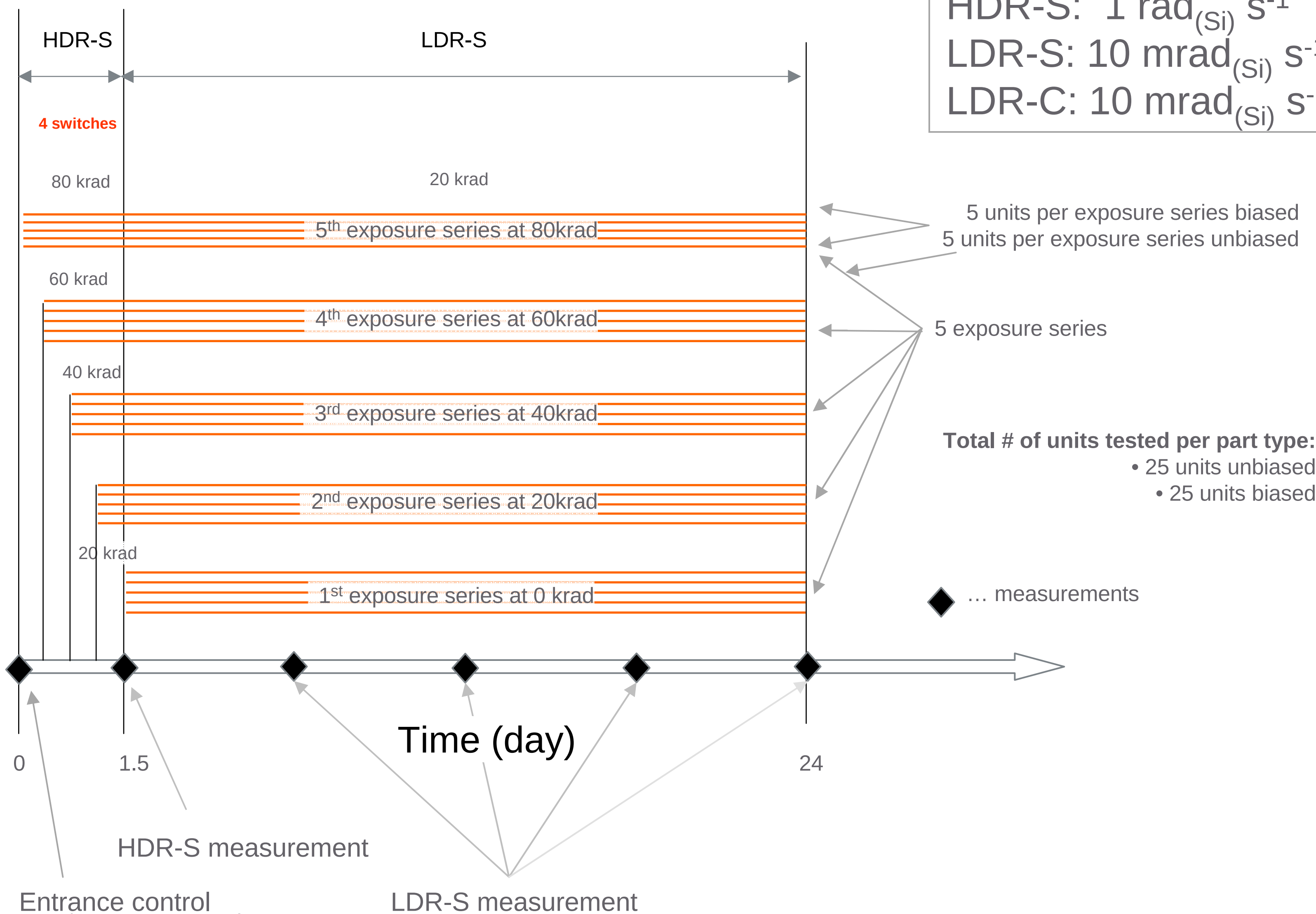
Part Types used for 2nd Measurement Campaign

Part Type	Description	Manufacturer	Picture
HS9-139RH	Radiation Hard Comparator	Intersil	
OP470	Operational Amplifier	Analog Devices	
OP177	Operational Amplifier	Analog Devices	
LM336-2.5	Reference Diode	National Semiconductor	
LM317	Voltage Reference	National Semiconductor	

Verification Test Plan

Irradiation Plan

HDR-S: 1 rad$_{(Si)}$ s^{-1}
LDR-S: 10 mrad$_{(Si)}$ s^{-1}
LDR-C: 10 mrad$_{(Si)}$ s^{-1}

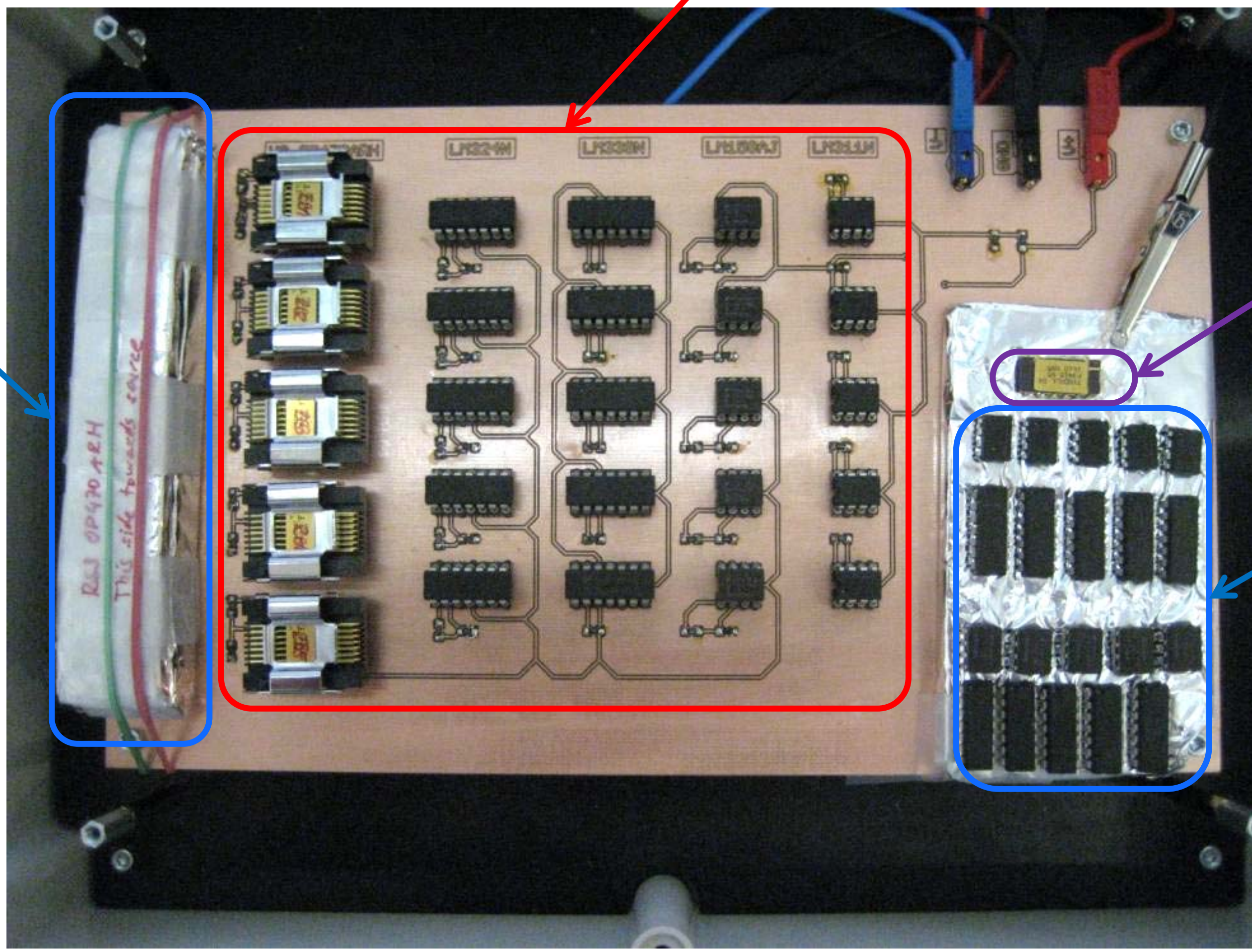


Total # of units tested per part type:
- 25 units unbiased
- 25 units biased

Irradiation Board

Biased Units

Unbiased Units

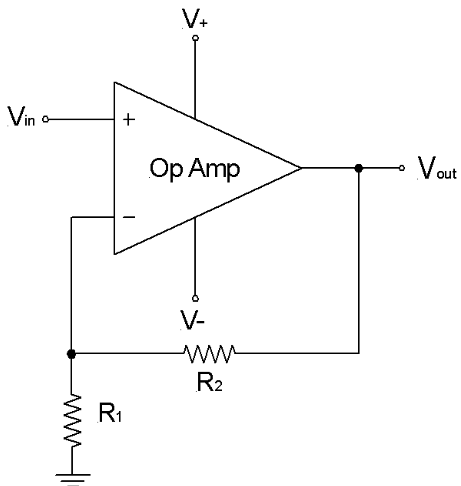


RADFET Dosemeter

Unbiased Units

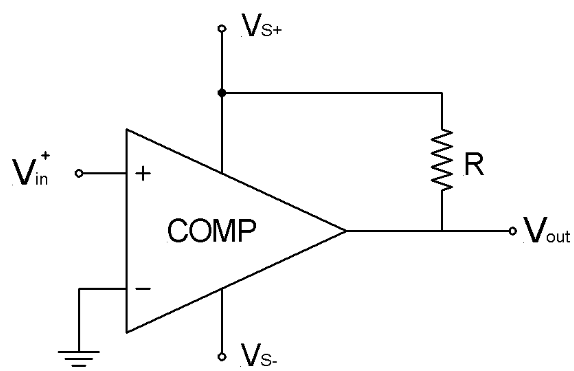
Biasing Conditions During Exposure

Operational Amplifier



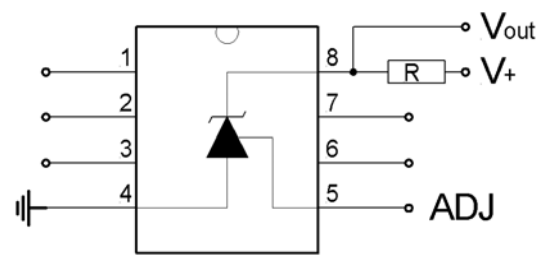
$V_+ = +15V$; $V_- = -15V$
$V_{in} = \sim 0.5V$; $V_{out} = \sim 5V$
$R_1 = 1k\Omega$; $R_2 = 10k\Omega$; f = 11

Comparator



$V_+ = +15V$; $V_- = -15V$
$V_{in} = \sim 0.5V$; $V_{out} = V_{OS+}$
$R = 15k\Omega$

Voltage Reference



$V_{in} = +5V$
$R = 2.5\ k\Omega$

Note: Unbiased configuration is achieved by mounting DUTs in antistatic IC Foam that is enwrapped in Aluminium foil.

Parameters for Investigation of Degradation

Operational Amplifiers and Comparators

Parameter	Symbol
Offset Voltage	V_{OS}
Quiecent Current	$+I_S$ / $-I_S$
Bias Currents	I_{b+} / I_{b-}
Open Loop Gain	A_{VO}
Common Mode Rejection Ratio	CMRR
Slew Rate	SR
Power Supply Rejection Ratio	PSRR
Output Voltage Swing	$+V_0$ / $-V_0$
Short Circuit Current	I_{SC}

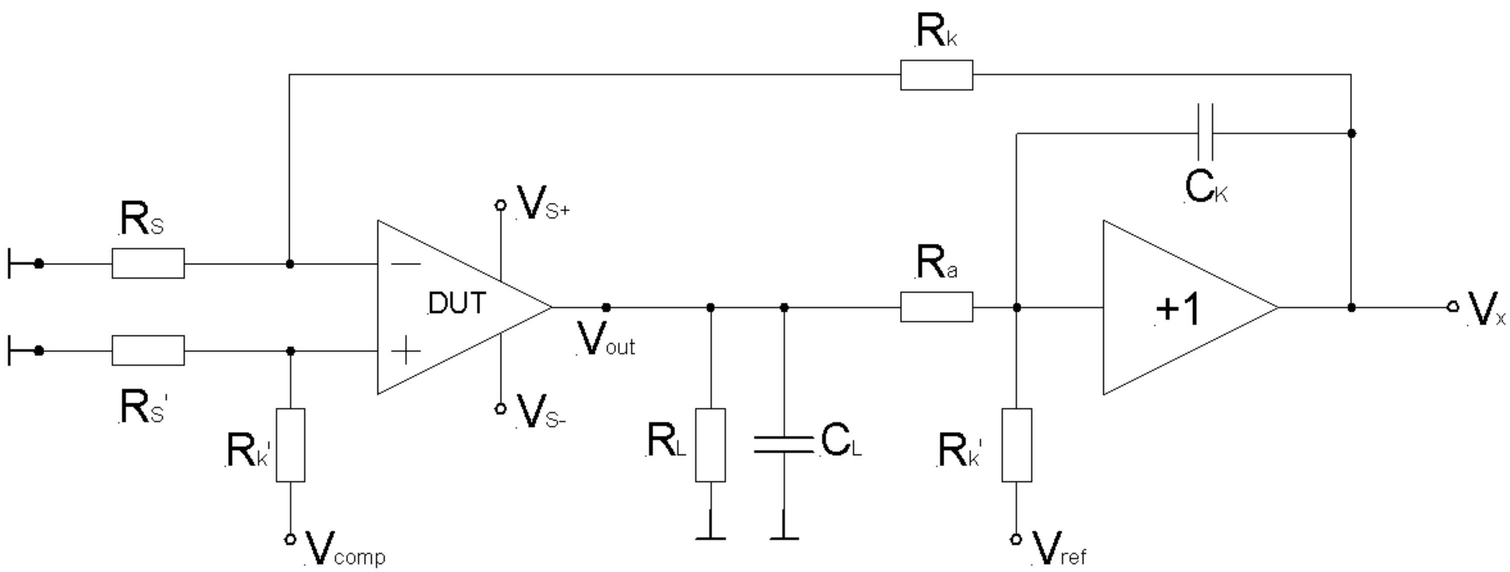
Voltage Regulator

Parameter	Symbol
Output Voltage	V_0
Line Regulation	RegLine
Load Regulation	RegLoad
Quiescent Current	I_q
Drop Out Voltage	D_{OV}

Voltage Reference

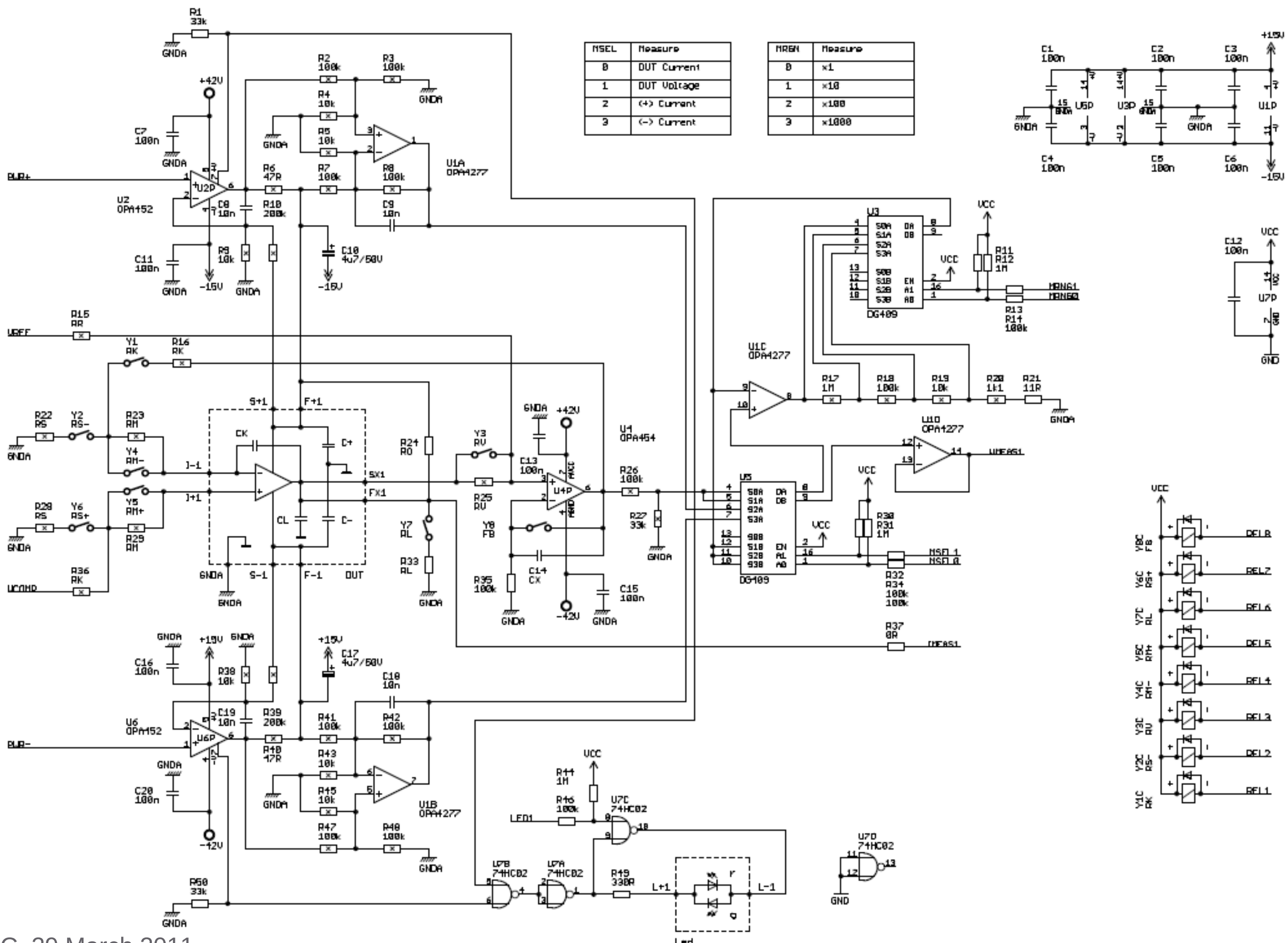
Parameter	Symbol
Output Voltage	V_0

Example: Test Circuitry for Open-Loop-Gain, A_{VO}

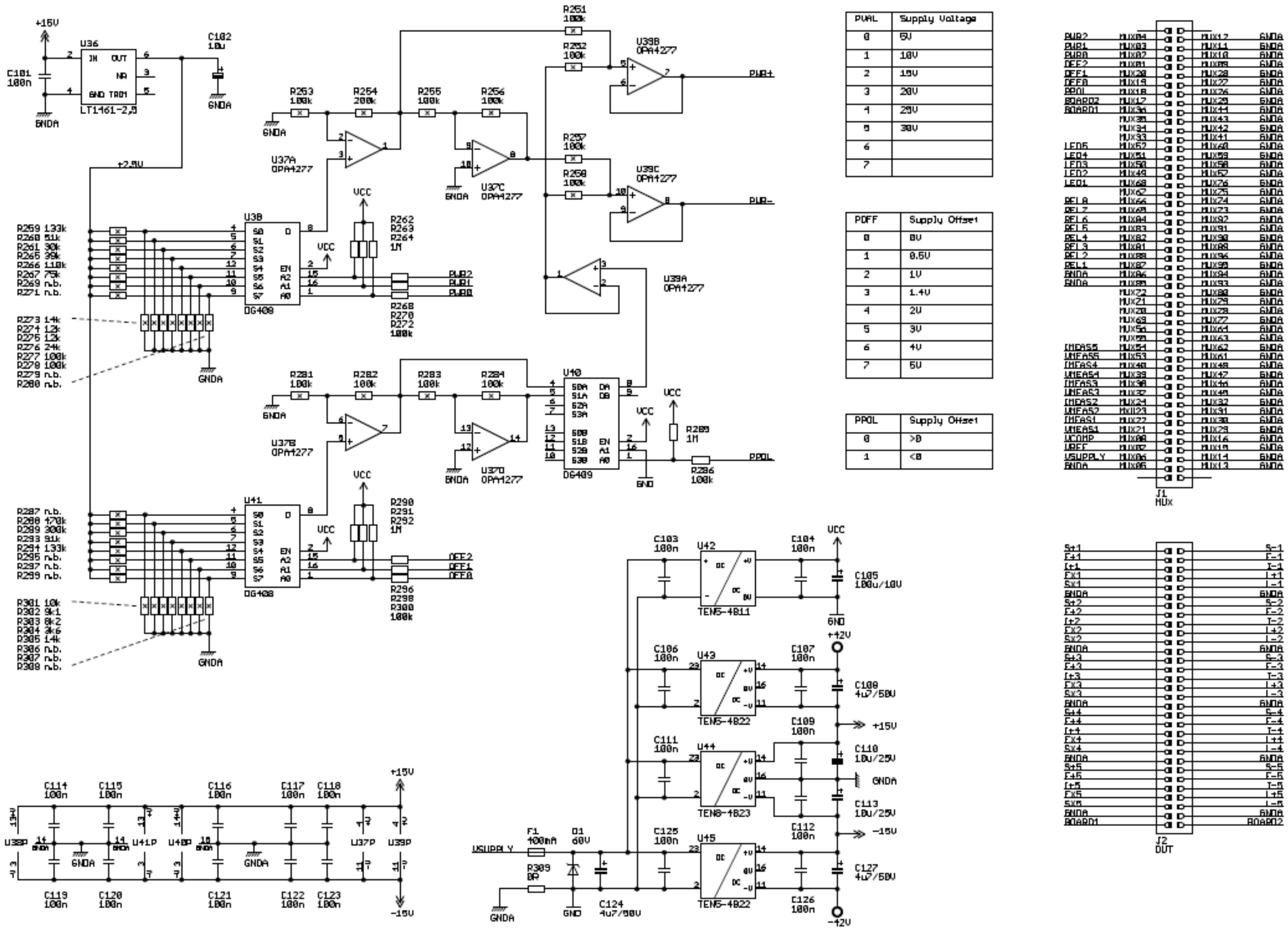


- DUT is operated in a feed back loop
- e.g. Measurement of Open Loop Gain
  - Certain Output Voltage is forced → ΔV_{in} is measured
  - A_{VO} is determined

Test Circuitry for Test board - Part 1



Test Circuitry for Test board – Part 2



PVAL	Supply Voltage
0	5V
1	10V
2	15V
3	20V
4	25V
5	30V
6	
7	

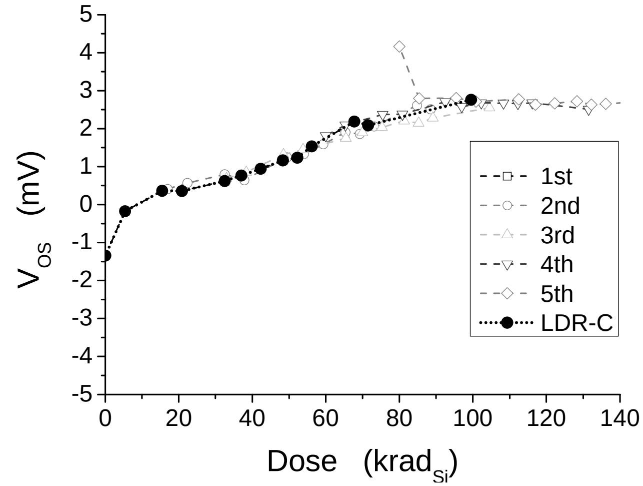
POFF	Supply Offset
0	0V
1	0.5V
2	1V
3	1.4V
4	2V
5	3V
6	4V
7	5V

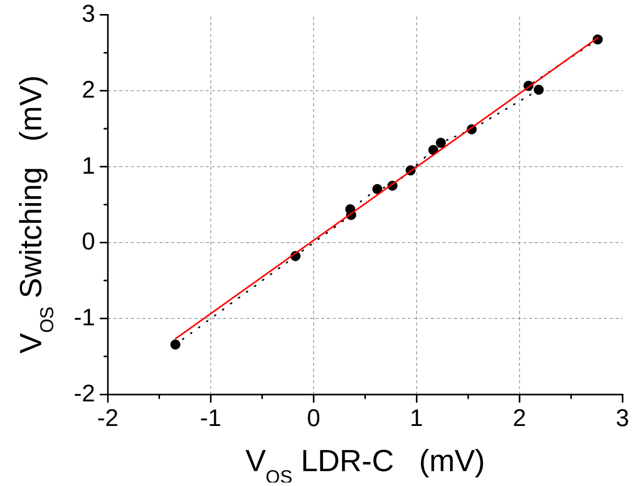
PPOL	Supply Offset
0	>0
1	<0

Preliminary Test Results

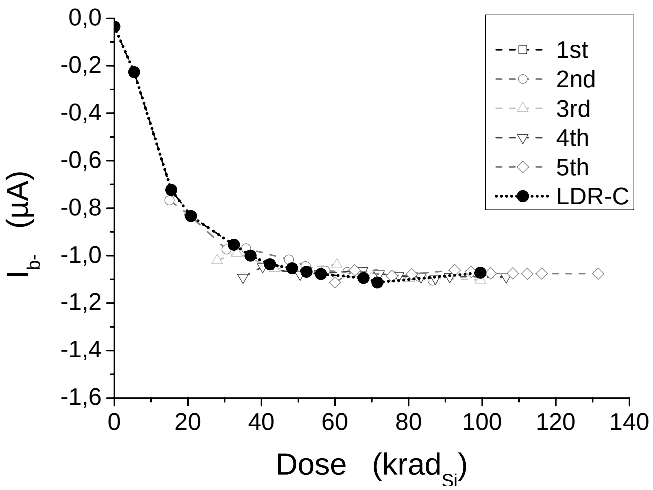
LM339AN: Unbiased

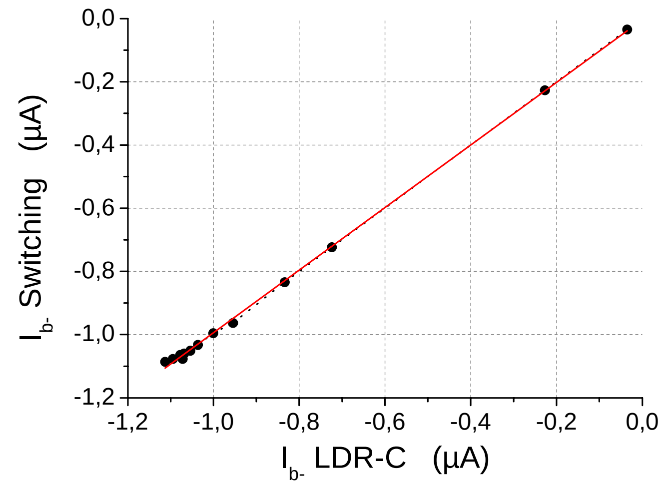
Offset Voltage, V_{os}





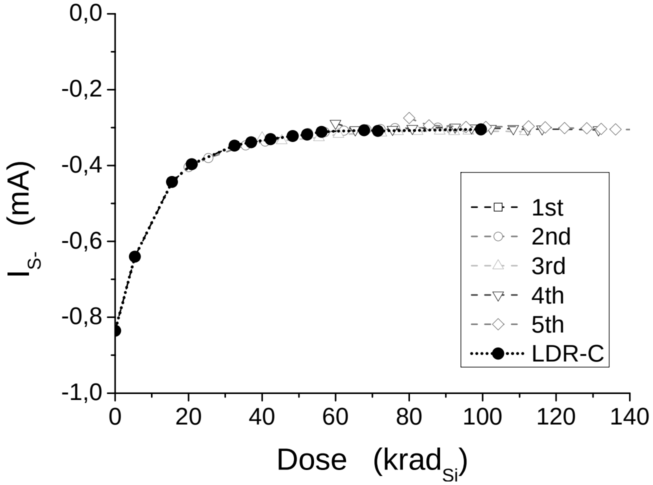
Negative input bias current, I_b

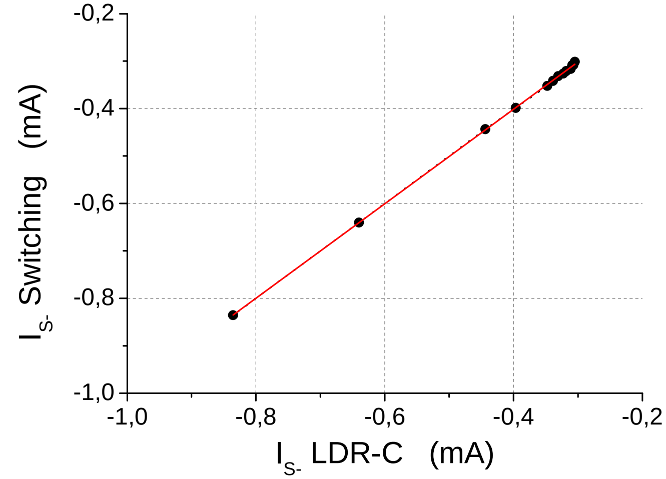




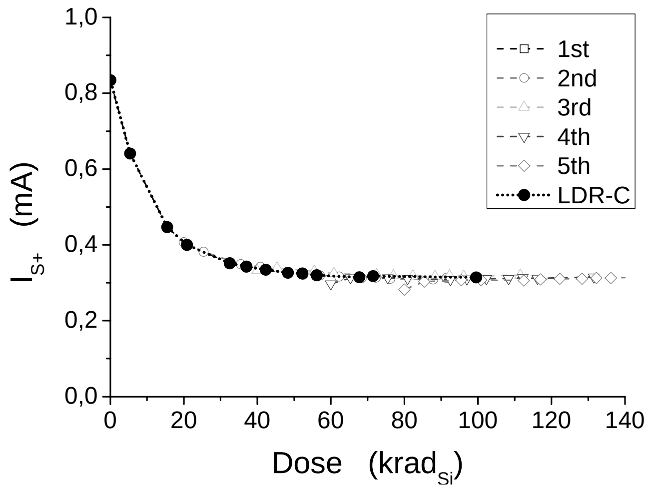
LM339AN: Unbiased

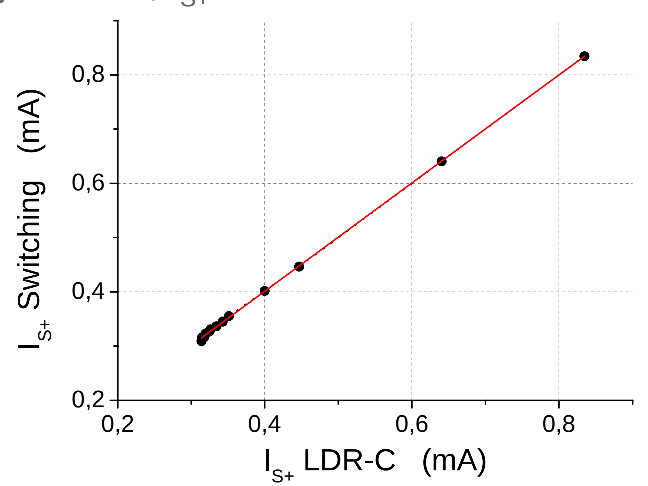
Negative Supply Current, I_{S-}





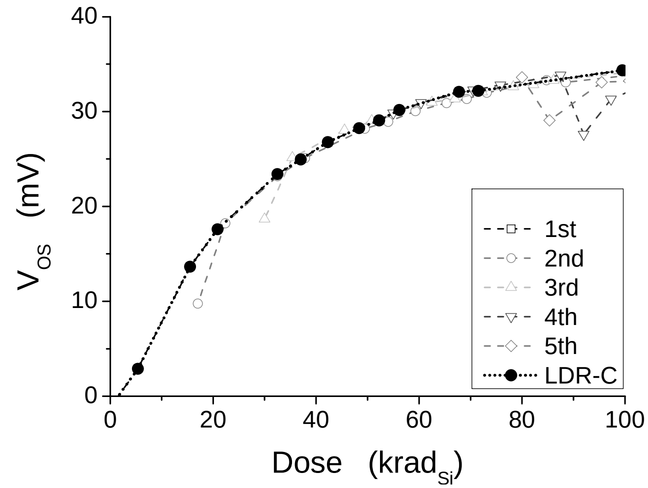
Positive Supply Current, I_{S+}

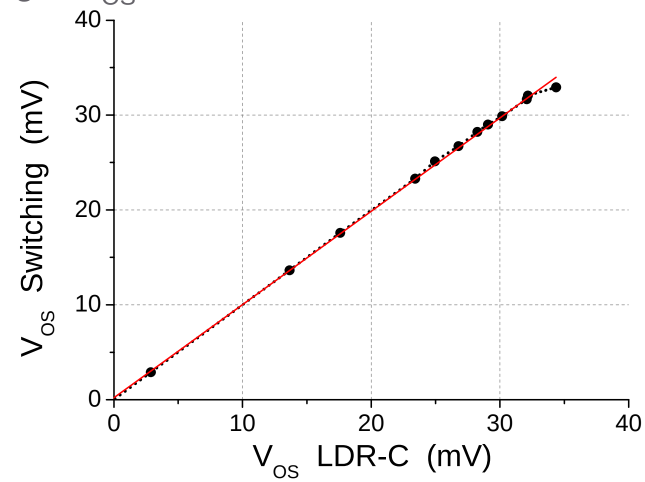




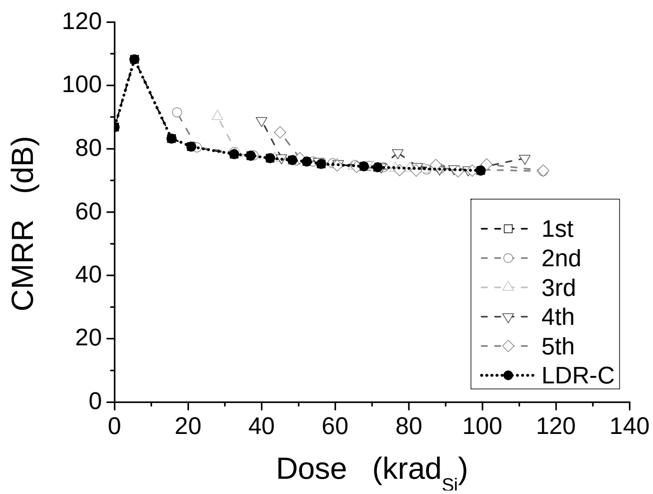
LM339AN: Biased

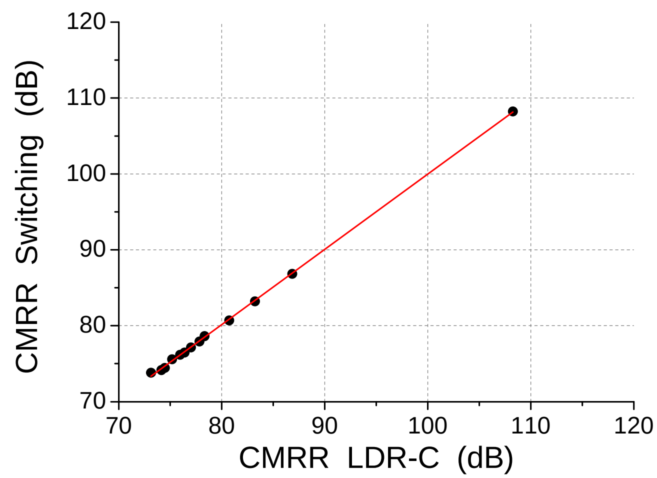
Offset Voltage, V_{OS}





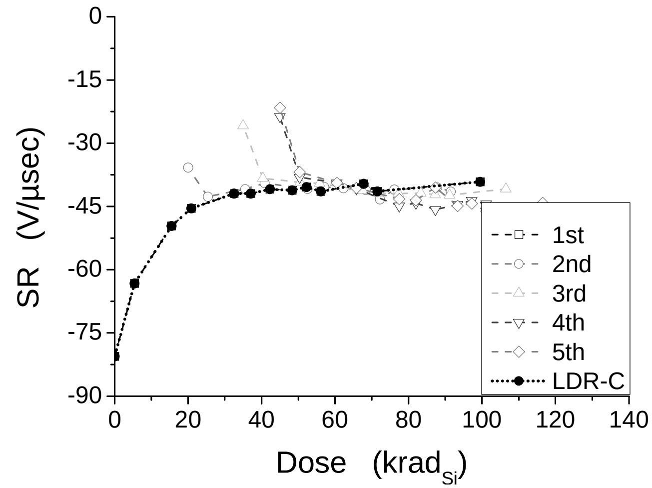
Common Mode Rejection Ratio, CMRR

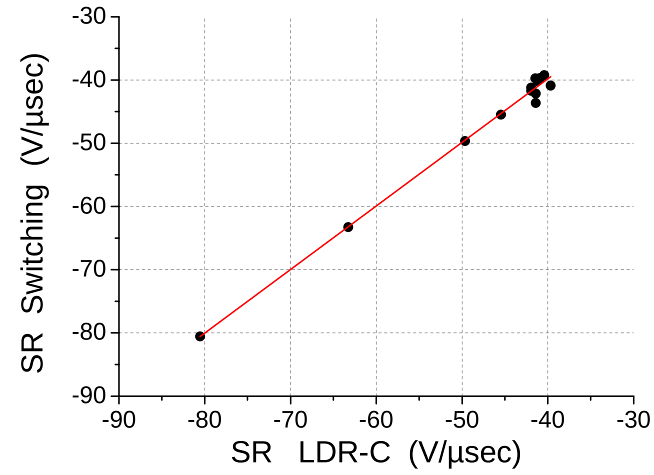




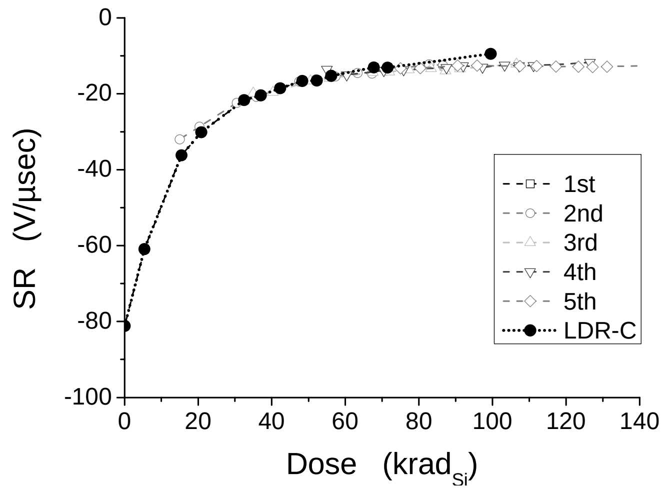
LM339AN: Slew Rate SR

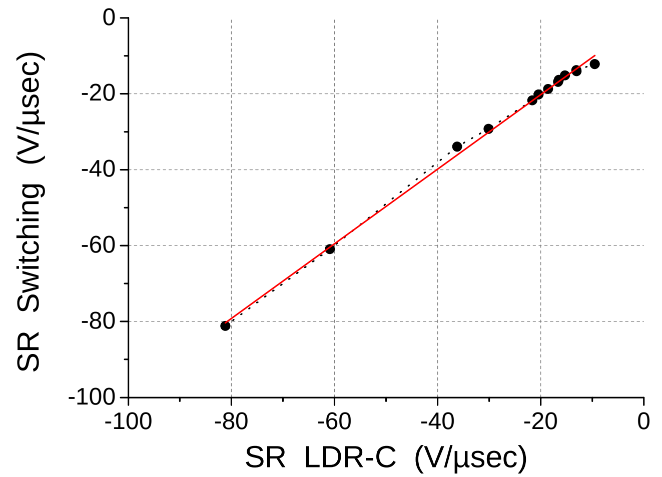
Biased





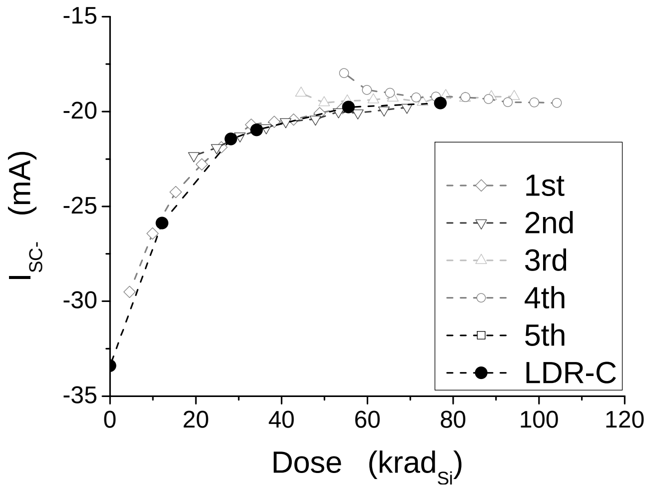
Unbiased

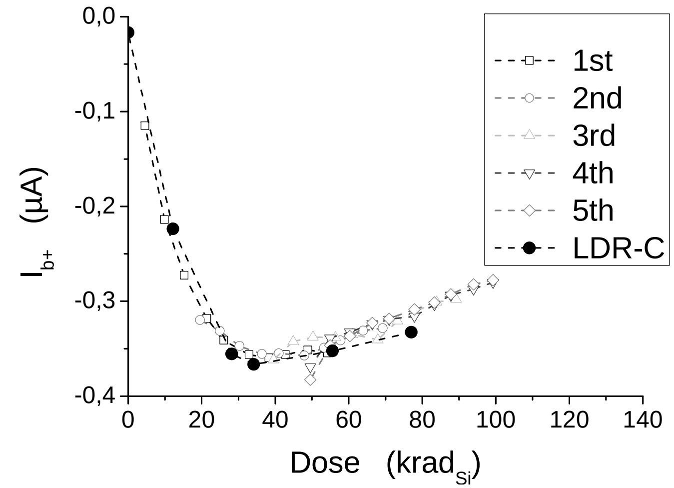




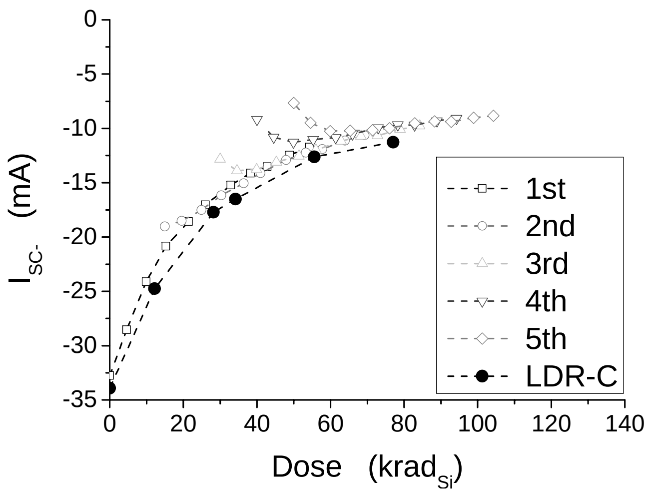
LM324AN: Short Circuit Current I_{SC-}, Positive Input Bias Current, I_{b+}

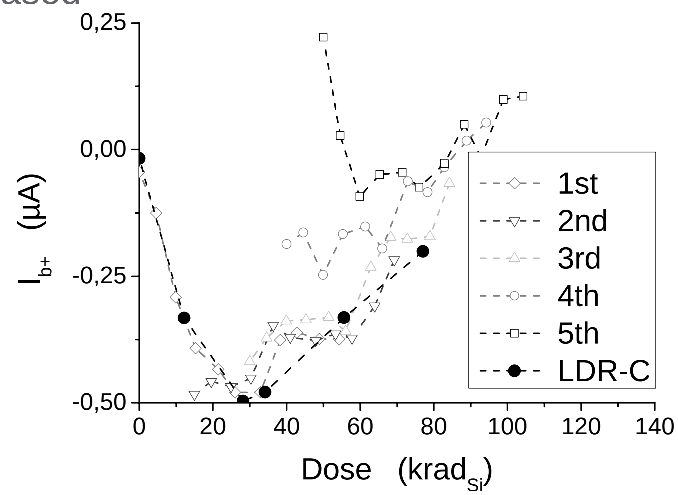
Biased





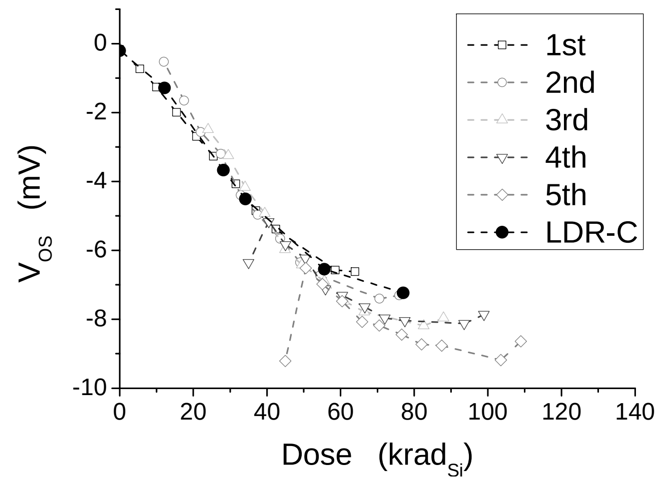
Unbiased

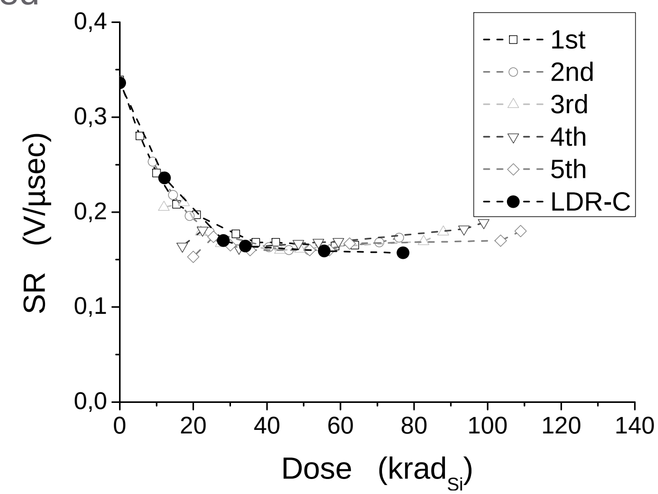




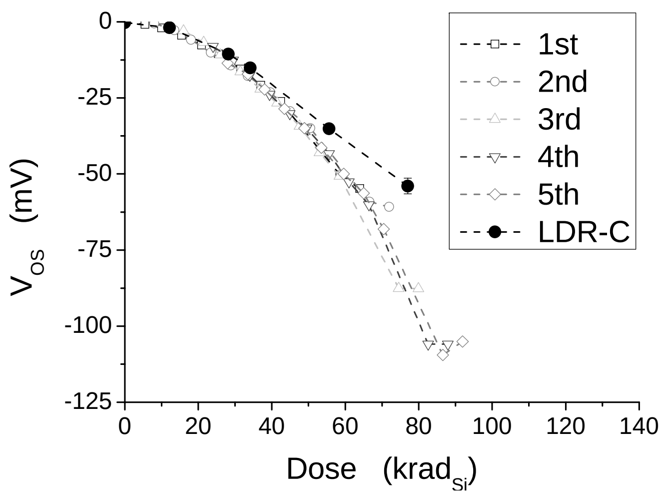
LM158AJ: Offest Voltage, V_{OS}, Slew Rate SR

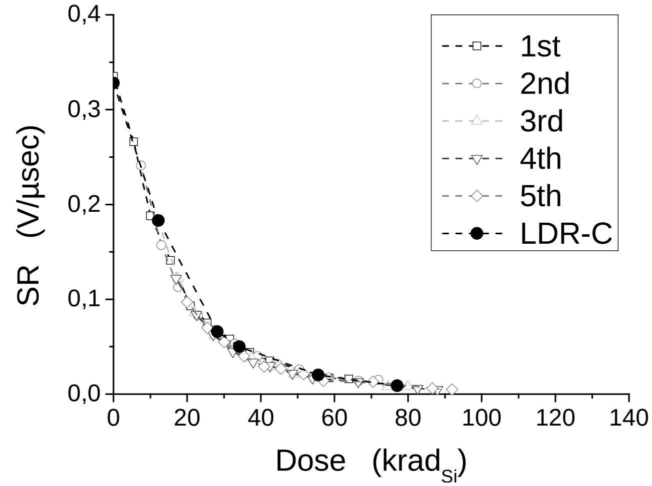
Biased





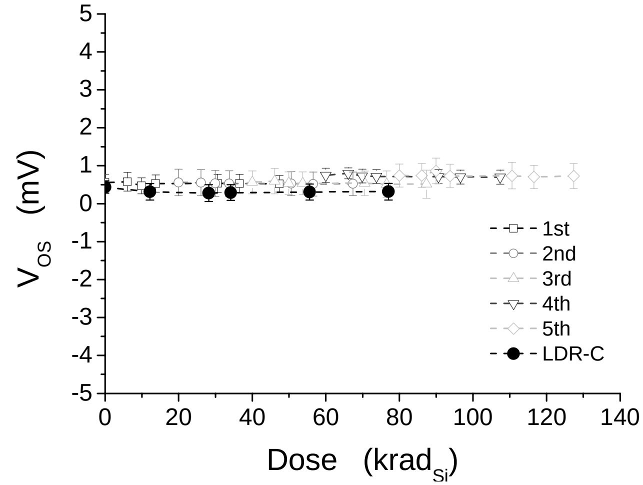
Unbiased

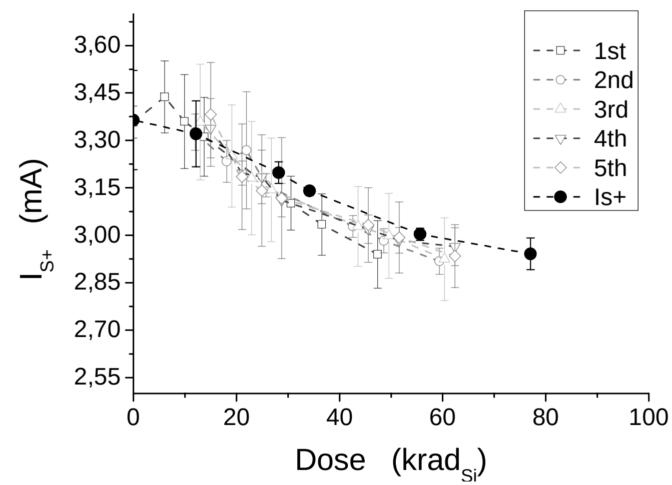




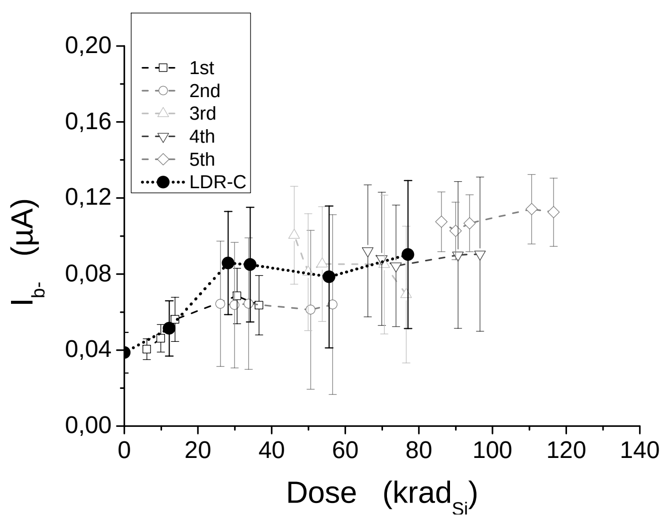
HS9-OP470ARH (radiation hard): V_{OS}, I_{b-}, I_{S+}, SR

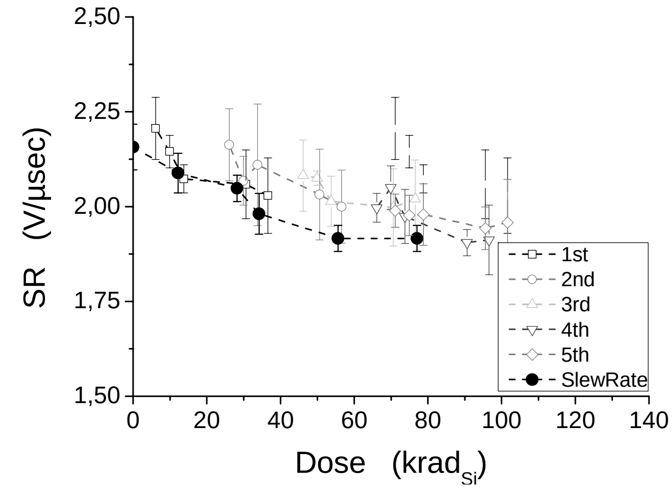
Biased



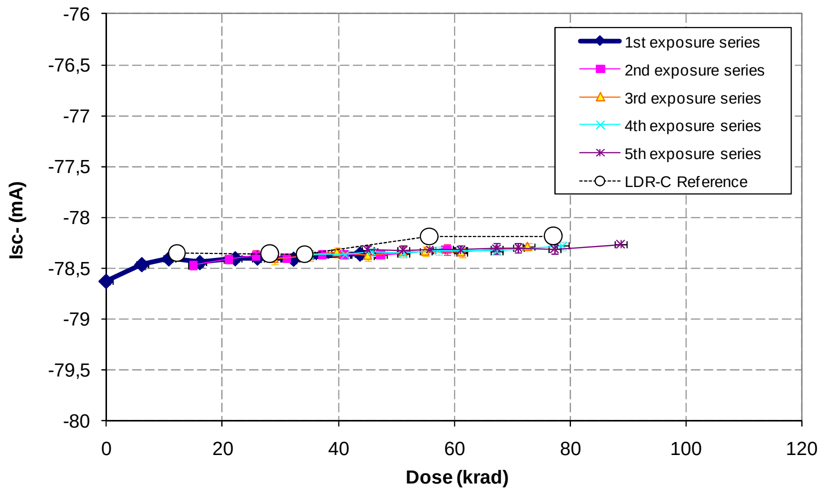


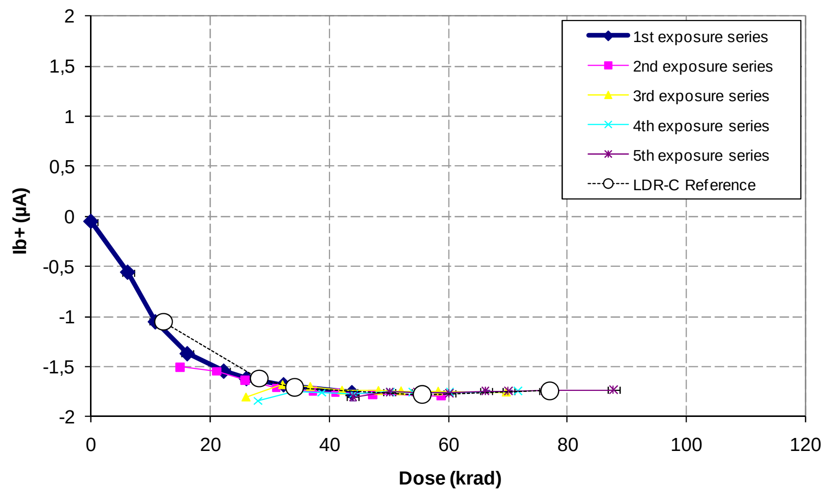
Unbiased

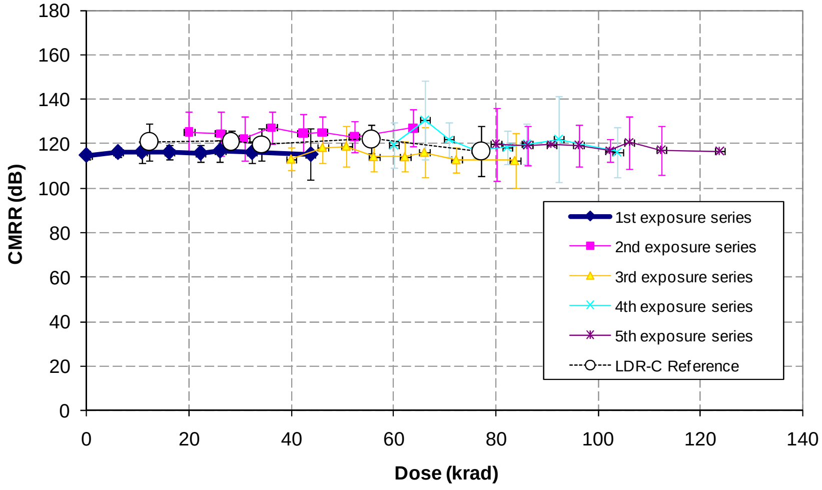


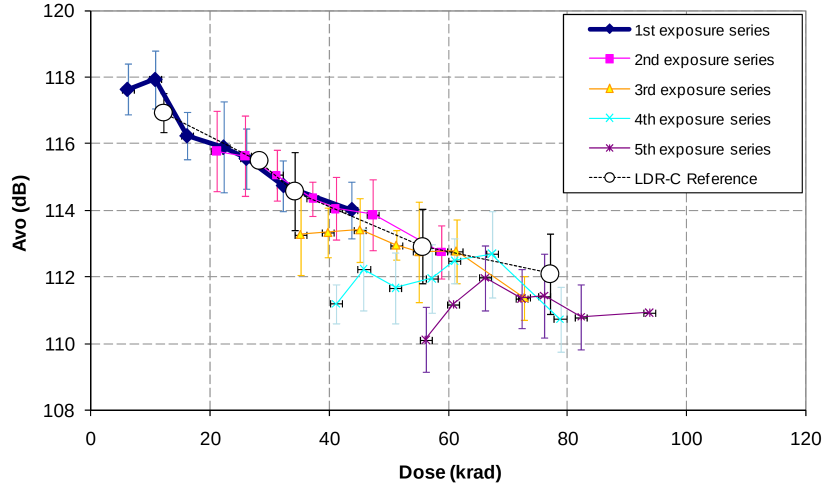


LM311N: Unbiased, I_{SC-}, I_{b+}, CMRR, A_{VO}





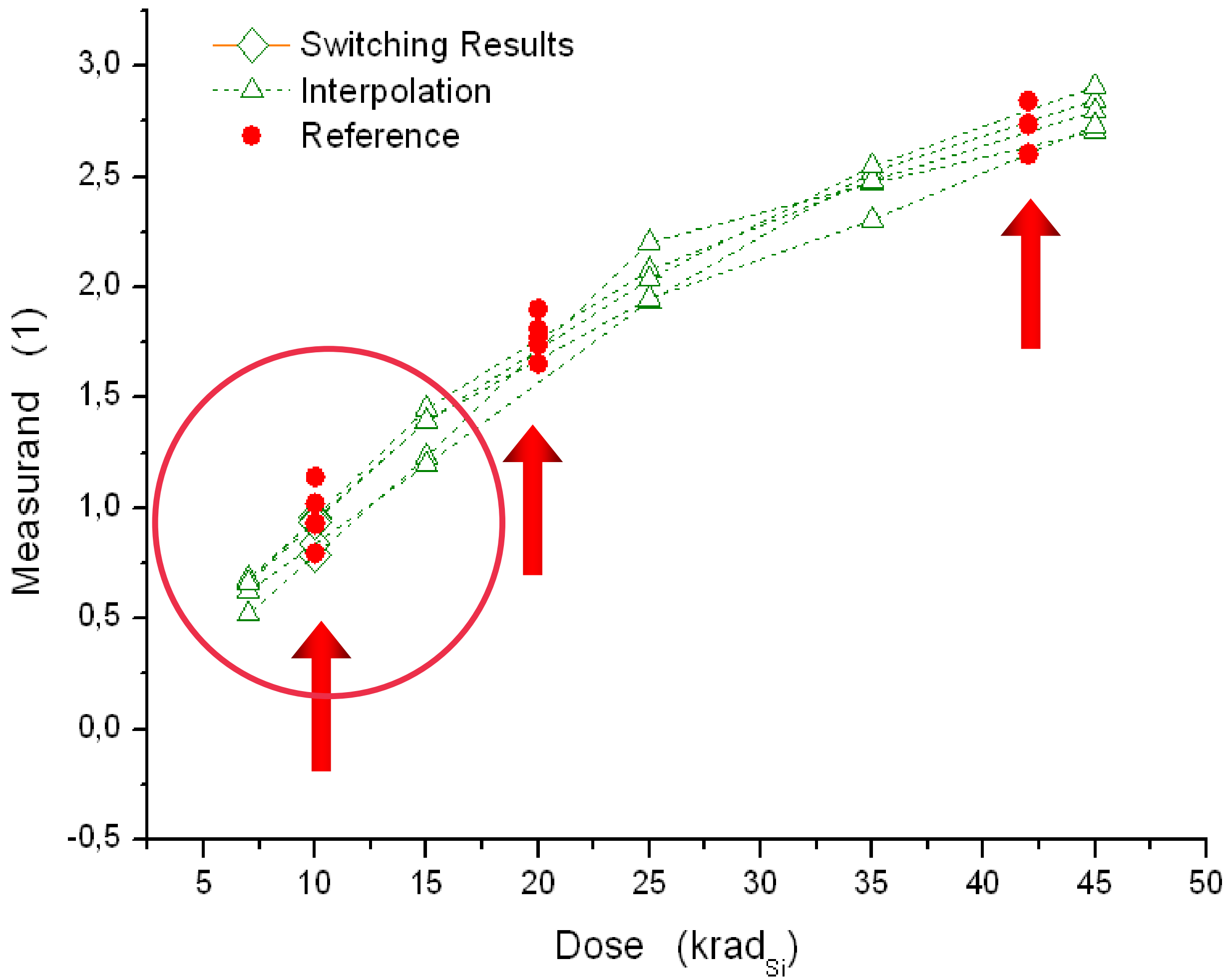




Statistical Analysis with ANOVA

MW1

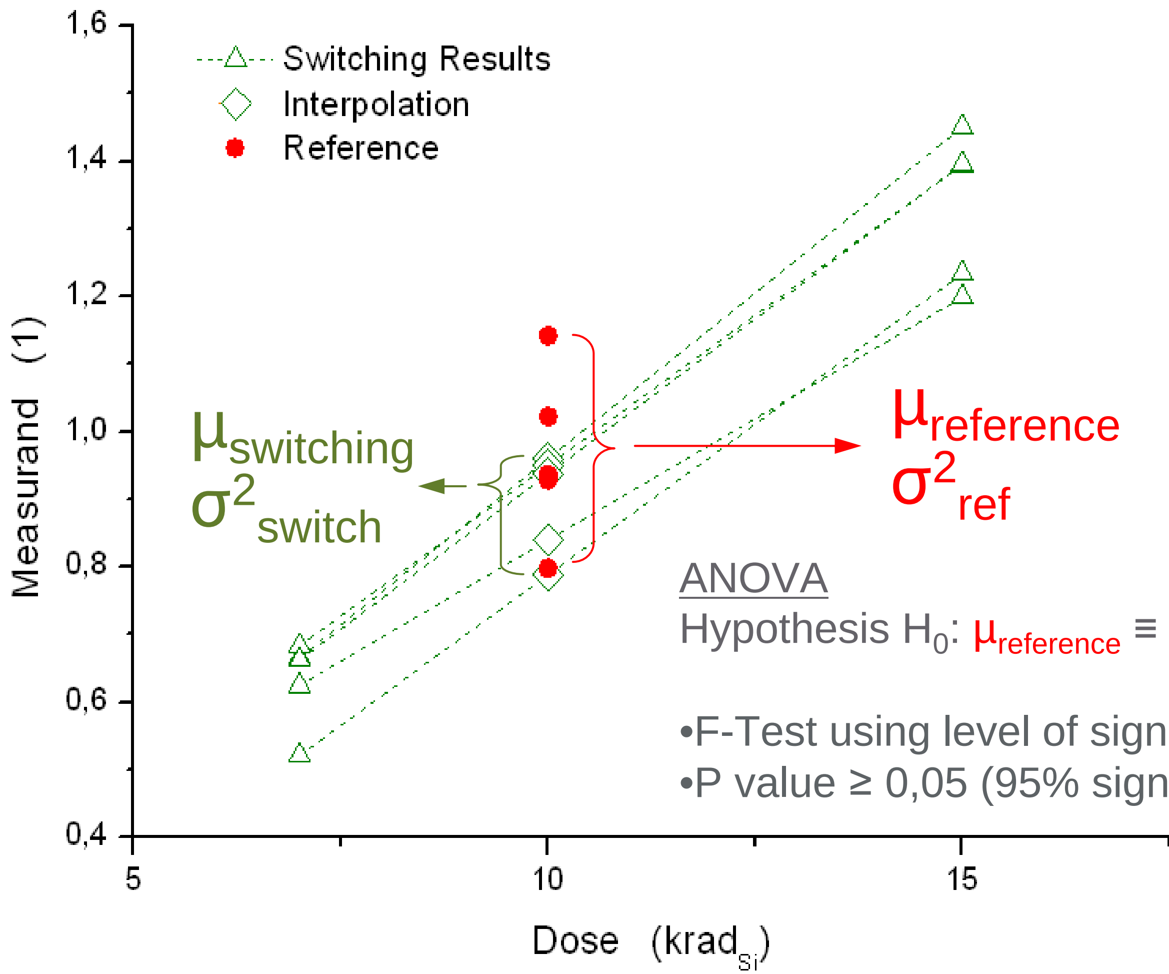
Statistical Analysis of Results



Slide 33

MW1 Update Legende
WindM, 27/03/2011

Statistical Analysis of Results

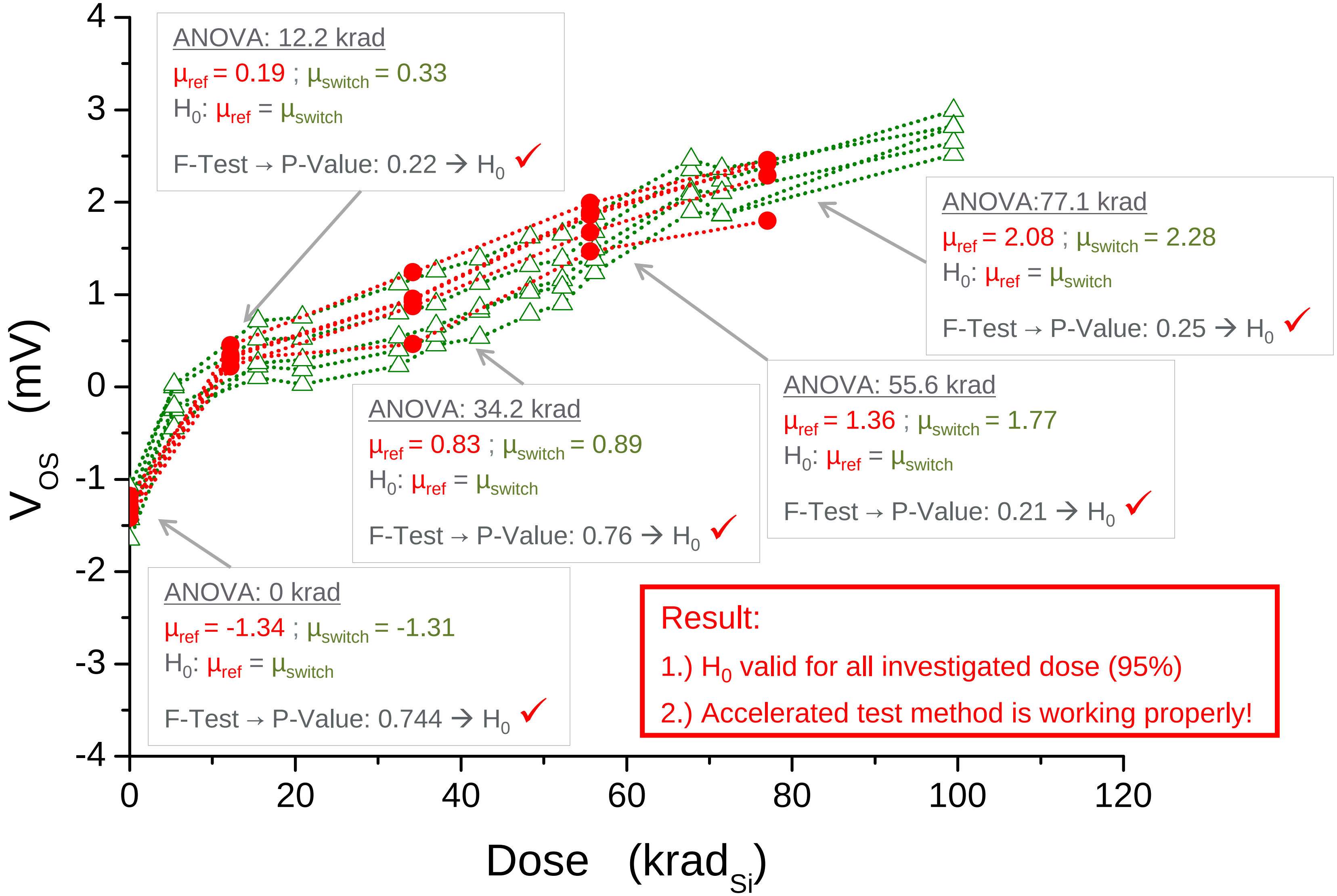


ANOVA

Hypothesis H_0: $\mu_{reference} \equiv \mu_{switching}$

- F-Test using level of significance α
- P value $\geq$ 0,05 (95% significance level)

Example: Offset Voltage, V_{OS} for LM339AN

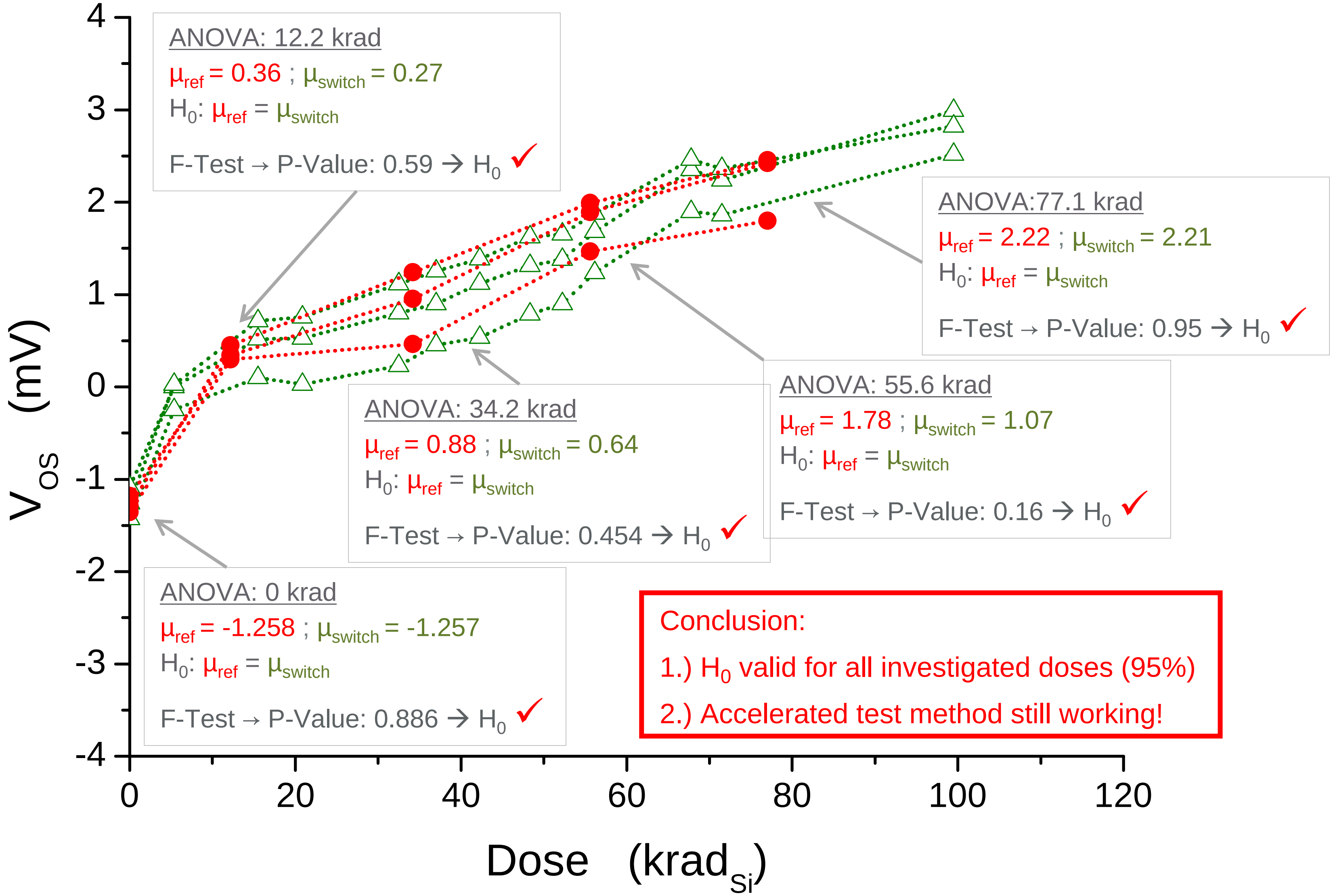


Result:

1.) H_0 valid for all investigated dose (95%)

2.) Accelerated test method is working properly!

Reduction of Sample Size from 5 → 3



Conclusion:

1.) H_0 valid for all investigated doses (95%)

2.) Accelerated test method still working!

Conclusion and Outlook

- **10 different part types** selected for tests with **operational amplifiers, comparators, voltage regulator** and **voltage reference**
- **700 units** investigated on ELDRS for a wide range of parameters
- In general the **accelerated switching test method worked very well** for all degraded parameters for all part types
- The **variance of a parameter** might be a limiting quantity for the method
- Preliminary results for **LM324AN**, **LM339N**, **LM158AJ** indicate good comparison of **accelerated switching test method** with the **reference exposure**
- For **LM311N** the variance of the CMRR is larger than the degradation (**weak-degraded)**
- **HS9-OP470ARH** (radiation hard) show **weak-degraded** and **degraded parameters**
- For **weak-degraded** parameters further analysis is needed
- Statistical analysis with **ANOVA** looks promising
- ANOVA will be used to investigate **reduction of sample size**
- Continue and complete **irradiation measurements** and **data analysis**
- Project will be finished in **Summer 2011**

ELDRS Website: eldrs.net


Austrian Institute Of Techn...

eldrs.net/index.php

ELDRS

ELDRS Project

Menu

- ELDRS project
- Project overview
- The ELDRS effects
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Traditionally, Total Ionising Dose (TID) characterisation of bipolar based EEE components is performed at high dose rates reducing test time at irradiation facilities and hence costs. The dose rates employed are usually significantly higher than those experienced by components in-flight. Over the last decade Enhanced Low Dose Rate Sensitivity (ELDRS) has been observed and reported in the literature and considered to be of serious concern, demonstrating the need for radiation testing performed at low dose rate. The ELDRS effect is manifested as increased component degradation with decreasing TID dose rate. ELDRS affects bipolar technologies.

Today, ELDRS testing of components is comprised at low dose rates, representing a significant cost item and complicating project schedule depending on project TID requirements. This is in particular true for high TID level projects such as telecommunication and navigation. To address some of these issues a number of accelerated ELDRS test methods have been proposed. One of them, the so-called accelerated switching test method, is investigated within the scope of this project. This test method has been shown to reduce low dose rate testing time significantly for selected part types and electric parameters. Its general applicability on a comprehensive set of electric parameters will be investigated using a large set of different part types.

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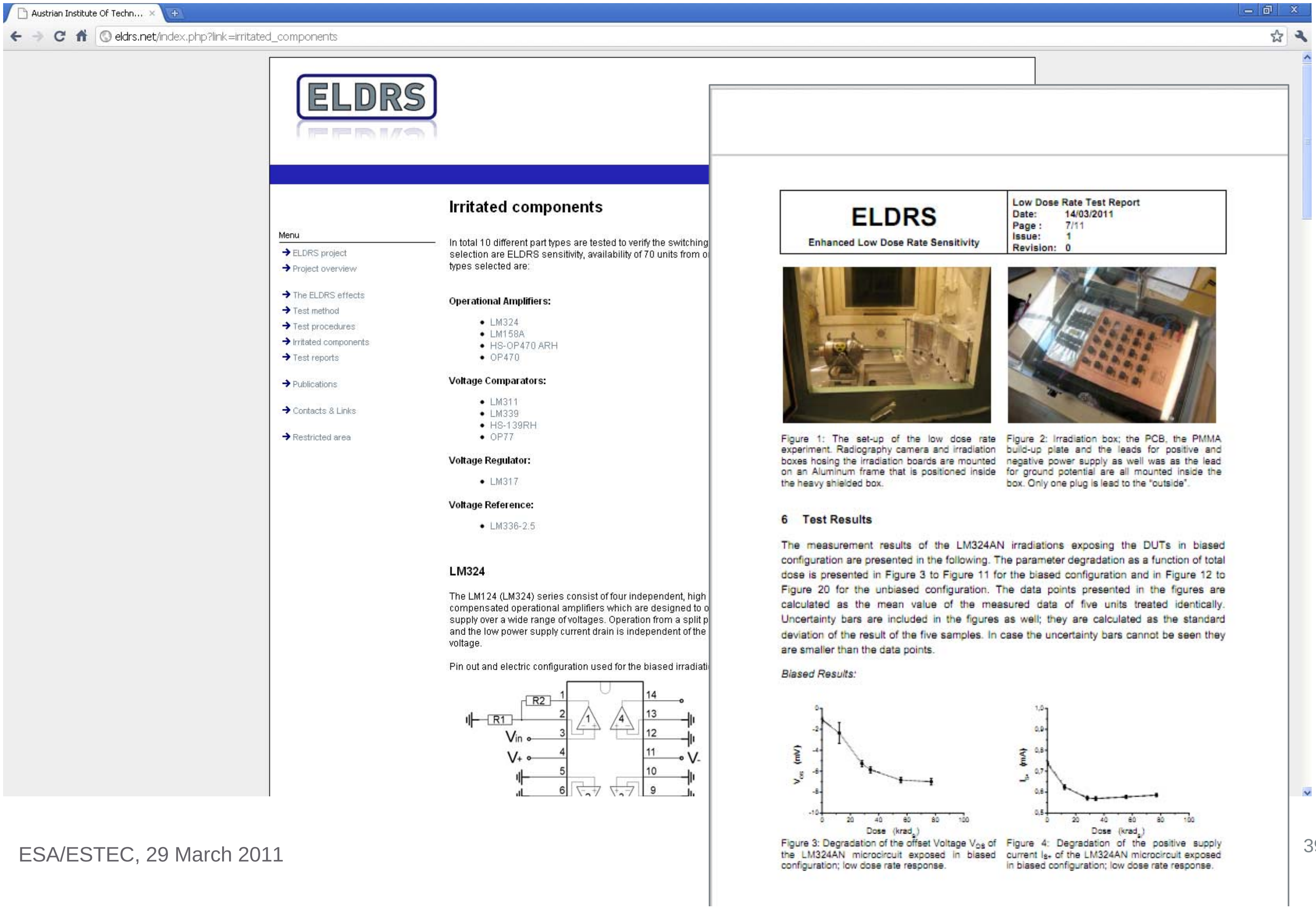
Imprint Disclaimer

Status: ELDRS Website – Irradiated Components



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Acknowledgments

- The support by **National Semiconductor** (Kirby Kruckmeyer)and **Intersil** (Nick van Vonno) with part types for testing is acknowledged!
- The support by **Tyndall** (Aleksander Jaksic) with RADFETS for reference measurements is acknowledged!
- The project is contracted by the **European Space Agency (ESA)** under Contract No. 22051/NL/PA (GSTP) and supported by the **Austrian Federal Ministry for Transport, Innovation and Technology**. National coordination is done by the **Austrian Promotion Agency FFG**.

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